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Viewpoint

Benthic indicators: From subjectivity to objectivity – Where is the line?

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ABSTRACT

Over the last few years, the interest in using benthic indicators to assess marine environments has increased dramatically after a rather long period of relative stagnation, mostly due to the need to assess the status of coastal marine waters required by North American and European regulations. Numerous papers on this topic have been published in the domain of ecology, using a variety of different terms to refer to two categories of information: benthic species and the status of benthic communities. Nowadays, the abundant literature on these two categories makes it possible to comment on (1) the definition of the different terms used by benthic researchers, (2) the current increase of papers of rising complexity about benthic indicators, and (3) the subjectivity and objectivity involved in using benthic indicators. Faced with the increase in the number of methods, we recommend pragmatism and thus the transfer of simple methods to the research consultancies that are responsible for assessing benthic quality in numerous impact studies. Using certain procedures, such as the "sentinel species", the best professional judgement (BPJ) and taxonomic sufficiency (TS), should clearly be encouraged.

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1. Introduction

Managing the quality of estuarine and coastal waters is a challenge for western countries, such as those in North America and Europe. The United States' Clean Water Act (CWA), published in 1972 as part of the Federal Water Pollution Control Amendments, and the European Union's Water Framework Directive (WFD), published in 2000, both defined clearly the objectives of these legislations. They notably encourage the improvement of water quality in the future to insure both the use of coastal waters for recreative activities and for the harvest and/or cultivation of seafood, such as mussels, oysters and clams. Water quality can be determined by analysing the chemicals present in the water (e.g., oxygen content, metallic and organic pollutants, nutrients) or using biological indicators (also called bio-indicators) as surrogates to indicate the quality of the water in which they are present.

Among these bio-indicators, there are five biological compartments retained in the WFD: phytoplankton, macroalgae, angiosperms, macrozoobenthos and fish (Leonardsson et al., 2009; Rosenberg et al., 2004). However, surprisingly, some biological components were not selected for the WFD (e.g., zooplankton) in spite of their abundance in the water column. Zooplankton is a good indicator of the evolution of the sea surface temperature. For example, over the three last decades, the North Atlantic has experienced a northern migration of warm temperate species into the North Sea and a migration of boreal species into the Arctic (Beaugrand, 2003). The plankton as a whole is seriously affected in confined areas, such as harbours (Patriti, 1984). In the open sea, even in areas that are severely impacted by industrial or domestic effluents, the plankton progressively return to a more normal composition as they get farther away from the disturbance (Patriti, 1982, 1984). Equally surprising was the exclusion of certain meiobenthic groups (e.g., foraminifera, harpacticoid copepods or nematodes), known to indicate changes in salinity and climate clearly. Due to the sensibility of copepods and foraminifera to oil spills, these are a good choice as bio-indicators for pollution of the marine environment (Mojtahid et al., 2008; Raffaelli and Mason, 1981).

The study of the Los Angeles and Long Beach harbours five decades ago was based on the benthic populations in these harbours and is generally considered as a cornerstone for the use of biological indicators and animal communities to describe polluted marine environments (Reish, 1959). Over the last few years, the interest in using benthic indicators to assess marine environments has increased dramatically after a rather long period of relative stagnation, although paradoxically there is now a lack of qualified systematists needed to acquire the necessary knowledge to build and validate these indicators and indices. This increasing interest is mostly due to the need for new tools for assessing the status of marine waters, which is required by regulations like the CWA and the WFD.

In this context, a certain number of new indicators and indices have been proposed. Most of the pollution indices have been created based on "subjective" or "objective" biological indicators.

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This has led the European scientific community to see the advantages of developing biological indicators and indices based on the macrobenthos compartment. Still, the first interest in the macrobenthic organisms as indicator species dates back several decades for the North American and European scientific communities. It is no longer contested that macrobenthic organisms as indicators have many advantages: they are relatively non-mobile and therefore useful for studying the local effects of physical and chemical perturbations; some of these species are long-lived; their taxonomy and their quantitative sampling is relatively easy; and there is extensive literature on their distribution in specific environments and on the effect of the various stresses that these organisms could encounter (Borja et al., 2008).

Most of the studies have been done on soft-bottom communities; however, some researchers have used the hard-bottom epifauna, and some progress has recently been made in the use of hard-bottom fauna, especially vagile fauna, as indicators of water quality (Bevilacqua et al., 2009), following precursor studies in the 1960s and 1970s (see Bellan-Santini, 1969, 1980). Most of the authors in the literature have developed water quality indicator/s and index/indices to indicate the responses of the fauna to a pollution gradient, with the disappearance of sensitive species in polluted area, the increase in the abundance of certain resistant species in moderately polluted areas, and the survival and even the proliferation of opportunistic species in the more polluted zones. In the most polluted zone, no macrofauna resists.

The above developments were greatly inspired by the idea of macrobenthos succession (Pearson and Rosenberg, 1978) with respect to organic enrichment and pollution of the marine environment. Pearson and Rosenberg's paper is probably the most cited by the scientists working on benthos (>14,000 citations; R. Rosenberg, personal communication). In fact, it was the source of most of the discussions and the proposed indicators and indices used in soft-bottom macrobenthic communities. The success of Pearson & Rosenberg's idea is also certainly due to the fact that, during the decades preceding their paper, a real corpus of knowledge and basic data had been acquired, particularly in Europe, corpus to which Pearson and Rosenberg referred in their paper.

The objective of this *Viewpoint* is to provide our take on (1) the definition of the different terms used by benthic researchers, (2) the current increase of papers of rising complexity about benthic indicators, and (3) the subjectivity and objectivity involved in using benthic indicators. In this paper, we comment mostly on the coastal soft-bottom communities, and we do not discuss the reference status for benthic communities.

2. Definition of terms used in publications

Many papers have been published in the domain of ecology using different terms for qualifying benthic species and the status of benthic communities [mainly "Ecological Quality Status" (EcoQS)].

2.1. Terms used to qualify benthic species

- A "*sensitive species*" is a species that can only survive within a narrow range of environmental conditions and disappear from polluted areas and zones undergoing environmental change (i.e., climate or habitat changes).
- A "*tolerant species*" means a species that is not sensitive to a particular stress and/or pollution.
- An "*opportunistic species*" is a species that can quickly exploit new resources or ecological niches as they become available. For example, the species can rapidly colonize a new environment. These species are characterised by early reproduction, high reproduction rates, rapid development, small body size and an uncertain adult survival rate.
- A "*characteristic species*" means a species linked to a particular biocenotic structure referred to as a "community", a "biotic assemblage" or a "biocenosis".
- A "*sentinel species*" is a particular species which by its presence or its relative abundance "warns" an observer about possible imbalances in the surrounding environment and/or alterations of the community functions.
- An "*indicative species*", or an "*indicator species*" (in our opinion, the nearest equivalent term), will signal the presence of a particular factor, either biotic or more often abiotic, within a given environment. These "*indicative species*" intervene in a community's functions rather than in its structure. For example, a species may indicate an environmental condition, such as a pollution, species competition or climate change. "*Indicative species*" or "*indicator species*" are among the most sensitive species in a region and sometimes act as an early warning system for monitoring biologists. Sometimes, the term "*pollution indicator species*" is used for species that increase with the amount of organic matter.
- An "*indifferent species*" is a species with no real affinity for any particular community and which shows no response to pollution. In fact, based on the personal observations of one of the authors of this *Viewpoint* (Gérard Bellan), "*indifferent species*" are rarely found in the most polluted or the most degraded areas, where only the opportunistic polychaetes *Capitella capitata* and *Scolelepis fuliginosa* survive. Though, according to the purists, "*indifferent species*" do not form a real community, but rather a gathering of a given species. These species are not necessarily rare, and they have frequently been considered to have a "*large ecological valence*".

2.2. Terms used to qualify the EcoQS of benthic communities

"*Index/Indices*" is a generic term used in a very large range of scientific domains, from marine biology to sociology to economics. It corresponds mainly to a numerical scale used to compare one variable to another or to a reference number, a value or a ratio (a value on a measurement scale) derived from a series of observed facts. It can reveal relative changes over time.

"*Biotic Index/Indices*" is a term used to give a status report about a particular environment by indicating the types of organisms that are in it. It is often used to assess the quality of an environment. It generally ranges from a minimum value to a maximum value and permits to classify the status of an environment compared to a reference status.

The term '*Indicator*' is used often in ecology and environmental planning but also in a large variety of other domains ranging from economics to sociology and political science. Although it is often used ambiguously and in different contexts, a systematic overview of the existing definitions of the term has not yet been compiled. Recently, Heink and Kowarik (2010) reviewed the different uses and definitions of the term "*indicator*" in ecology and environmental planning. These authors differentiate three categories used to define indicators, "*namely measures* (e.g., *species richness*)*, components* (e.g., *a certain taxon*)*, and values and measurement results* (e.g., *a vegetation cover of 50% in the understorey*)." Furthermore, they make a distinction between descriptive and normative indicators, with hybrid indicators being those that can be used both descriptively and normatively. They also proposed to retain the OECD definition (2003): "*an indicator in ecology is a component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals. Environmentally relevant phenomena are pressures, states, and responses*".

"*Biological indicators*", or "*bio-indicators*", are detectors that reveal the existence of complex conditions resulting from a group of biotic and abiotic factors that are difficult to measure individually. Bio-indicators can range from the infra-cellular level to the level of communities and/or ecosystems. Their levels must be carefully qualified. A biological indicator should quantify the information available, be scientifically credible and explain temporal and/or spatial changes using data that can be collected within realistic temporal and spatial limits. These bio-indicators are limited in number and can be adapted to future developments (Bellan, 2008).

"*Ecological indicators*" are used to communicate information about ecosystems and the impact that human activity has on these ecosystems to diverse groups of people (e.g., the general public or government policy makers). Ecosystems are complex, and ecological indicators can help describe them in simpler terms that can be understood and used by non-scientists to make management decisions. The terms "*ecological indicator*" and "*environmental indicator*" are often used interchangeably. However, "*ecological indicators*" are actually a sub-set of "*environmental indicators*". Generally, "*environmental indicators*" provide information about the pressures exerted on the environment, environmental and social conditions and society's responses to these conditions. "*Ecological indicators*" refer only to ecological processes (Girardin et al., 1999; Kurtz et al., 2001).

2.3. The use of these terms in the literature

Table 1 gives the number of papers in which the terms mentioned above were used, respectively, in all Elsevier publications and Marine Pollution Bulletin (MPB) (obtained via Science Direct on the 3rd of February 2010). Apart the term "index/indices" and "indicator/s", used in many papers that are not necessarily related to biology or ecology, the other terms are used regularly in the papers published by Elsevier about ecological and biological assessment. For some of the terms remaining (i.e., "*biotic index/indices*", "*opportunistic species*", "*sentinel species*"), MPB accounts for a mere 10% of the papers published by Elsevier. The terms "*indicative species*", "*indifferent species*", "*pollution indicator species*" and "*characteristic species*" are used rarely in MPB papers. Neither is "*Sentinel species*" used much in MPB. However, according to the MPB/Elsevier ratio, the term "*pollution indicator species*" was used more frequently.

In order to avoid the problems related to different understandings of these terms and to maintain integrity of their use, we feel it would be better to provide a clear definition of the meaning of the terms used in the literature, as recommended by Heink and Kowarik (2010).

Table 1
Numbers of papers using different terms in all journals published by Elsevier and in the journal, Marine Pollution Bulletin [Science direct website consulted on 3rd February 2010, with the terms in quotation marks (" ")].

Terms	Elsevier	Marine Pollution Bulletin	MPB/Elsevier (%)
"Indices/index"	1,725,527	1909	0.11
"Indicator"	654,219	2733	0.42
"Biological indicator"	6333	500	7.90
"Sensitive species"	5284	215	4.07
"Indicator species"	4258	263	6.18
"Tolerant species"	4109	131	3.19
"Bioindicator"	3568	342	9.58
"Ecological indicator"	2410	131	5.43
"Characteristics species"	1957	24	1.24
"Opportunistic species"	1506	180	11.95
"Sentinel species"	791	81	10.24
"Biotic indices/index"	788	124	15.74
"Indifferent species"	206	9	4.37
"Indicative species"	97	5	5.15
"Pollution indicator species"	61	21	34.42

3. Assessment of the benthic communities using a characteristic species, a univariate index or a multi-metric index

The main reason for the actual development of research on the benthos (mainly the macrobenthos communities) is the benthic quality assessment required by the different marine environmental protection policies, especially the WFD (Europe) and the CWA (USA). The advantages of using macro-invertebrates to assess ecological quality are multiple: (1) these organisms are relatively sedentary, meaning that they cannot avoid deteriorating water/sediment quality conditions; (2) they have relatively long life-spans; (3) they include diverse species that exhibit different tolerances to stress; and (4) they play an important role in cycling nutrients and materials between the underlying sediment and the overlying water column. Among the disadvantages, we could mention that (1) they may not be specific enough in terms of the different kinds of stress, (2) they are subject to underlying taxonomic changes across the estuarine gradients, (3) their use can be labour intensive, and (4) they are not applied consistently across bio-geographic regions (Borja et al., in press).

In fact, benthic communities can be assessed at three structural and/or functional levels for ecosystem integration, using (1) a characteristic species, (2) a univariate index or (3) a multi-metric index.

3.1. Using a characteristic species

Species, especially characteristic and indicative species, can provide information (e.g., species richness and composition) about benthic environmental conditions (e.g., sediment type, hydrodynamics) but also about the perturbations affecting a community indicated by the presence of different species categories (i.e., sentinel, tolerant or opportunistic species).

Species can be classified in five Ecological Groups (EG) in terms of their response to organic enrichment: EG-I (species very sensitive to organic enrichment), EG-II (species indifferent to enrichment), EG-III (species tolerant of excessive organic enrichment), EG-IV (second-order opportunistic species) and EG-V (first-order opportunistic species). When it was developed, this classification was established specifically for the domestic and/or industrial pollution that led to this organic enrichment. It has been validated for a large set of impact sources, but it still needs to be validated for a very large set of other less "conventional" impact sources, such as drill cutting discharges, harbour and dyke construction, engineering works, dredging processes, mud disposal, sand extraction and/or large artificial inputs of fresh water (Bellan, 2008; Borja et al., 2008).

Nevertheless, benthic organic enrichment is not the only cause of disturbance in the benthic biotic composition. Consequently, the indices, which were created to indicate the benthic response to increasing organic matter, are too greatly influenced by the zones polluted by organic matter to distinguish them from those polluted by other contaminants, such as industrial waste, thermal discharges or natural factors (e.g., hydrodynamics or salinity gradients like those in transitional water bodies). These indices evaluate these transitional water bodies (e.g., estuaries and lagoons) badly since the "good" indicators are absent or under-represented (Bellan, 2008; Dauvin, 2007).

As suggested by Mearns and Word (1982), species can also be classified in trophic groups, which often simplify the food types in four main trophic groups (TG): TG-1 – suspension feeders, TG-2 – carrion feeders (e.g., carnivorous, omnivorous and necrophagous species), TG-3 – surface deposit feeders and those species that are both suspension feeders and surface deposit feeders, and TG-4 – subsurface deposit feeders that feed on sedimentary detritus and bacteria.

Species can be also classified with their biological traits, such as longevity, type of reproduction or mobility. Nowadays, Biological Traits Analysis (BTA) has attracted much interest because it takes functional diversity into account (see Bremner et al., 2003a, b). BTA is primarily used to assess marine benthic ecosystems.

The presence or absence of a species in a sample, such as a first-order opportunistic species or a sentinel species, can be enough to indicate degradation or the effect of pollution on a benthic community. The presence of the opportunistic polychaetes *C. capitata* complex or *S. fuliginosa* indicates a high concentration of organic matter. In addition, if these species have high abundances (>1000 ind. m^{-2} or more) with low species richness, it is certain that the community is highly polluted. Some other opportunistic species can also be a good indicator of pollution (see Bellan, 2008).

3.2. Using a univariate index

Benthic or biotic indices can be classified into three categories (see Diaz et al., 2004; ICES, 2008; Pinto et al., 2009). They can generally be calculated using only the values for species richness and abundance, but some of them also require the biomass. The three categories are: (i) based on diversity – Margalef index, J' Pielou evenness index, H' Shannon-Wiener index, Simpson's Index, Benthic Quality Index (BQI), for example; (ii) based on ecological groups – AMBI and its reciprocal 1/AMBI, Ecological Quality Ratio (EQR), BENTIX, BOPA, for example; and (iii) based on trophic groups – ITI.

Most of the more recently developed indices in the second category have been based on dividing macrobenthic species into previously defined ecological groups (EG) and then determining the respective proportion of the different groups in the benthic communities. These second-category indices provide information about the relative abundances of the sensitive species faced with increasing organic matter in the sediment and the relative abundances of the species that are resistant or indifferent to such increases or, according to Pearson and Rosenberg, even favoured by such conditions (e.g., the opportunistic species that proliferate when the sediment is rich in organic matter, while the sensitive species disappear). For most of these benthic/biotic indices, there are high biases when an EcoQS is calculated for samples with low number of species and individuals. Discarding samples with low numbers of individuals (i.e., 10 or, even better, 20 individuals) seems to be more efficient. Some replicates can be agglomerated to reach these minimal abundances.

3.3. Using a multi-metric index

Similar to the univariate indices, functional indices and multi-metric indices have been developed. These are integrative tools and methods for assessing the ecological integrity of benthic systems (see Borja et al., 2008: Chapman, 2009; Diaz et al., 2004; ICES, 2008; Pinto et al., 2009). These multi-criteria or multi-metric indices include primary and derived community indices (e.g., based on species richness, abundance, diversity) as well as the percentage abundance of different functional and trophic groups. For example, the MISS index (Macrobenthic Index for Semi-sheltered Systems) (Lavesque et al., 2009) takes into account the natural variability of a set of variables when describing the biological integrity of the reference conditions. These reference conditions are divided into three groups: community structure (i.e., A, B, species number, H', J'); trophic composition (i.e., grazer, selective deposit feeder, non-selective deposit feeder, suspension feeder and carrion feeder); and pollution indicators (i.e., AMBI, BOPA, W statistic, abundance of the sensitive, tolerant and opportunistic species). Most researchers agree about the need to assess "ecological status at the ecosystem level" rather than at the species level or the chemical level (Chapman, 2009).

4. Subjective versus objective assessment

From the outset, we would like to state that we consider the notions of subjectivity and objectivity to be one of those "false problems" about which scientists are so fond of arguing. Using investigative tools were available to them a century ago, marine biologists observed the presence of species that were gathered in certain habitats; depending on the specific ecological condition in these habitats, these species groups were mutually exclusive. This was the first step in the development of a sociology of living beings that gradually led to the description of animal and plant communities and, ultimately, to the description of biocenoses. At the same time, these old-time marine biologists found that these groups or communities were related to environmental factors, most often abiotic. It was sometimes possible to measure these environmental factors or even to predict what would be the factor (or combination of factors) encouraging a particular group of species or excluding it.

One of the authors of this *Viewpoint* (Denise Bellan-Santini) observed in the early 1960s the gradual disappearance in the Gulf of Marseilles, in the discharge area of the main domestic sewer of Marseilles (*Calanque de Cortiou*), of an alga Phaeophycae *Cystoseira stricta* (now *Cystoseira amentacea* var. *stricta*), one of the "flagship" species in a community established on a rocky coastline subject to strong hydrodynamics (Bellan-Santini, 1969). At the time, she thought that the localized disappearance of *C. stricta* could be linked locally to the progressive abandonment of traditional soap and its almost total replacement by anionic detergents, newly issued from the petroleum-chemistry, which were released into the sea at an estimated at 4–5 tons per day.

A few years later, when the methodology of detergent titration for seawater had been developed, a good relationship was found between the disappearance or the progressive reduction of the community and the rates of anionic detergents in superficial seawater (Arnoux and Bellan-Santini, 1972). This conclusion was based both on a thorough knowledge of the settlement itself and of the environment in the broadest sense. More recently, Weisberg et al. (2008), based on their personal experiences in 50 years of working along the Californian coast, demonstrated that their interpretation of benthic data is often subjective but it is also based on their best professional judgment, which could lead to a viable evaluation benchmark. The fundamental reason is probably due to the fact that, for them, the species was, as D.J. Reish observed, like an "old good friend".

Hereafter, we will use the above examples for illustrate the conclusions of Weisberg et al. and Reish more thoroughly. For the assessing quality status of benthic habitats, the panoply of tools and methods is extensive, and the number of new indices continues to increase dramatically in the scientific literature. Furthermore, there is a broad range of sophistication/complexity in the methods used. Nowadays, the methods proposed vary from the simplest index used to assess species richness to the most complex metrics that require the use of multi-metric analysis. To explain the explosion in the number of tools, the most frequently-evoked reason is that it is necessary to adapt the existing index or metric to local or regional conditions or to a particular area or system: for example, the coastal indices have been adapted for use in the WFD's transitional waters.

Some years ago, Diaz et al. (2004) denounced "*the tautological development of new indices which appears to be endemic, self-propagating and rarely justified*". They observed that so many indices have emerged over the last 20 years that environmental managers or scientists have hard time accepting any given metric. These authors explored the properties of 64 indices and concluded "*that there was a tendency for investigators to embrace broadly similar goals and exploit comparable methods of metric assembly, irrespective of local or national interests, and that this was evidence for the duplication of methods available in the published literature, rather than the independent alternative indices*".

The questions arising from this conclusion are: "Do all these tools and methods have different objectives?" and "Are complicated tools necessary to provide appropriate information about the quality status of a benthic community?

Assessment approaches mainly measure the environmental variables that "objectively" define the characteristics of a supposed quality status or of the resources used directly and profitably by humans. These approaches all have their proponents and their detractors (Bellan, 2008). In the early 1980s, a theoretical study about biotic indices called into doubt the relevance of these approaches for characterising the quality of ecosystems (Bellan, 2008). The indicative species approaches were believed to depend on the skill of the operator, who applies an expeditious judgment. In spite of the expressed criticism, the interest shown by scientists has not diminished, and these approaches have provided significant results. Each species in a community integrates the relatively distant history of its environment, and this is the reason that the indicative species and biotic indices correlate.

In addition, to be effective, many of the methods or tools require users to have optimal knowledge of systematics and great expertise in the ecology and ethology of the chosen species. But, as underlined in several recent papers (Boero, 2010), the number of taxonomists has decreased dramatically, and in the future, it will no doubt be difficult to correctly denominate all the species found in macrobenthic communities. Furthermore, environmental impact assessments are often conducted by research consultancies operated by generalists who do not have sufficient species expertise to correctly identify the fauna in the study sites or to re-establish the synonymy of the species names found in the literature. Nonetheless, they continue to establish extensive lists of species for those paying for the study.

Dauvin (2005) underlined the difficulties caused by an evolving field of knowledge and the complexity of identifying each macrobenthic species, and proposed that the taxonomic identification for environmental impact assessments be done at levels higher than the species (e.g., at the genus or family levels), according to the Taxonomic Sufficiency (TS) concept introduced 25 years ago by Ellis (1985). However, despite numerous publications showing that TS methods can be used to identify major changes in marine populations following disturbances (Bevilacqua et al., 2009; Dauvin et al., 2003, 2009), such methods are rarely applied in environmental impact assessments. It is surprising that so few people performing environmental impact assessments employ these methods, preferring instead to compile species lists, despite the fact that they are riddled with taxonomic errors. The result is errors in the assignment of ecological quality status, especially if EG are used, as in AMBI. The reason for this apparent mistrust is probably the continual evolution of current classifications above the species level (i.e., genus and family) that prevent authors from routinely using them.

In the more restricted field of monitoring the positive or negative evolution of assemblages affected by man-made disturbances, the use of biological indicators and biotic indices seems to be an effective alternative. "Objective" or "subjective", the procedures for selecting sensitive species able to indicate changes in communities due to disturbances are not simply interesting; they may, in fact, be full of potential. The problem is again a question of the methodological appropriateness of biotic indices with respect to the level of complexity and the structure of communities observed in a given place. In the 1980s, several specialists considered the methods for differentiating biological indicators to be too "subjective" and didn't resonate clearly with recent advances in theoretical ecology (Bellan, 2008). Based on observations that tolerant species were predominantly found in disturbed environments, meaning they mainly occur in zones with a small number of species, and sensitive species are present in zones with no disturbances or only minor ones, several authors tried to obtain more "objective" indicators.

On the AZTI list (<http://www.azti.es>), Borja and his collaborators proposed a classification of near 5900 macrobenthic species in five ecological groups (EG) (as defined above). Three main problems remain within this essential, very informative tool for benthologists working on benthic indicators: (1) the origins of the data sources are not given, (2) the use of a single universal sensitivity/tolerance list for different geographical areas appears inappropriate for benthic species that are able to adapt their behaviour to local or regional environmental conditions (Grémare et al., 2009), and (3) the absence of previous versions of the list, which need to be archived in a publicly accessible place so that results can be compared according to the list used. In fact, when the list was revised in July 2006, the new list comprised significant modifications, which resulted, for reasons that are not clear to us, in the moving of *Pectinaria* (*Lagis*) *koreni* from group EG-I to group EG-IV, for example.

If the AZTI list is not set down definitively, the EcoQ of a sample could still change, even once the indicator thresholds are set. Creating a definitive version of the list is the only possible way to obtain an objective tool, minimizing the variability of the subjective expert judgement. Most benthologists would agree that "*sensitive species*" should be classified in EG-I and "*first-order opportunistic species*" in EG-V. The species classifications for other EG are more subjective, especially for the "*tolerant species*" and the "*indifferent species*".

However, the AZTI method has yielded good results in the more specific field of species protection, with the Red List of endangered species or national heritage lists. Such lists [e.g., European Register of Marine Species (ERMS)] are established and revised periodically by an official panel of experts. This has the advantage of insuring, when benthic monitoring is outsourced in application of the various Conventions and Directives, the data acquired will retain their overall consistency and coherency in terms of comprehension and consensus, if not on the international level, at least on the level of the maritime basins and/or bio-geographic regions. The question of whether or not, in the future, species can be classified in different EG according to their sensitive/tolerant reaction to local environmental conditions is open to debate.

Recent assessments of benthic macrofauna community conditions using "best professional judgement" (BPJ) (Teixeira et al., 2010; Weisberg et al., 2008) has revealed that experts, based on their experience, are able to rank samples from best to worst condition and to classify samples into four categories with a high degree of agreement (Teixeira et al., 2010). There is also good agreement on the condition category, though the agreement was better for samples at the extremes of the disturbance gradient. The absence of regional bias (i.e., the west coast versus the east coast in the United States, or the Atlantic coast versus the Mediterranean coast in Europe) suggests that expert judgment is a viable means for establishing a uniform scale to calibrate indices consistently across geographic regions.

In the last exercise (Teixeira et al., 2010), the 16 experts differed in the number of criteria they used for their assessments, and those using more criteria generally showed less directional deviation in their category assignments. Experts who attributed a greater importance to the dominance of tolerant species or the presence of sensitive species often rated sites more negatively than the average expert. On the contrary, those who tended to classify samples as being in a better condition than the average expert, in addition to using considerably fewer attributes, often disregarded the presence of tolerant species or sensitive species or both, or did not assign a great importance to any of these criteria. BPJ thus appears to be a viable solution for establishing a uniform benthic condition scale to calibrate assessment of benthic quality status consistently across geographic regions. The experience in benthic monitoring of the 16 experts who participated in this BJP exercise ranged from 16 to 38 years. So it appears, as Teixeira et al. (2010) have suggested, that objectivity may be combined with subjectivity based on expertise, know-how or skill.

Univariated indices based on diversity, including the Benthic Quality Index (BQI) (Rosenberg et al., 2004), are theoretically objective methods, but they all rely on the ability to identify all the species at the species level. This remains problematic as suggested above. One of the advantages of the benthic indices is their invariance with the sample size. However, diversity-based indices have the opposite problem: their dependence on the sampling effort (i.e., sampling area), not only for the species richness, which is the most sensitive to sample size, but also for the H' Shannon diversity and the BQI estimates, which can change with the total number of samples in an area.

If a relatively complex index were to be recommended by a Directive or a national assessment programme, another question arises: how would this index be selected? This is certainly the most difficult and controversial problem. It is necessary to use species that can be measured (i.e., counted). When several indices are used to interpret a phenomenon, they could be combined in the form of "biotic indices". Biological indicators and biotic indices should allow the status of an ecosystem to be characterised and its modifications, natural or anthropogenic, to be highlighted as early as possible.

The WFD proposes using five EcoQS (ECOlogical Quality Status) classes: *high* for unpolluted sites, *good* for slightly polluted sites, *moderate* for moderately polluted sites, *poor* for heavily polluted sites, and *bad* for extremely polluted or azoic sites. This EcoQS scheme requires that thresholds be established between the classes, which are often chosen subjectively. As suggested by Ruellet and Dauvin (2007), it will be also necessary to re-examine the threshold values between the five EcoQS so that they will have the same probability for each benthic indicator used by the EU Member States. These threshold values will certainly be established using the probability laws for distributing the index values and large datasets containing all the ecological situations encountered in Europe (from high EcoQS to bad EcoQS) but also for each type of benthic community. Still, some benthic communities will continue to appear more perturbed than the others if the current thresholds continue to be used.

In fact, it appears that, until recently, both biological indicators and biotic indices privileged the identification of species resistant to anthropogenic disturbance, which due to their low numbers and abundance values was the simplest identification method. Using species "*sensitive*" to these disturbances generally led to fewer consensuses or even to disagreement. Whether developed "objectively" or "subjectively", the indices that followed served only to reinforce this disturbance phenomenon, which contributed to highlighting the species that resisted the disturbances. Given that these disturbances are going to be reduced because of the implemented laws, it is essential to reconsider the relative importance of EG, for example, by giving a maximum weight to the species that are the most sensitive to the increasing man-made disturbances and a minimum weight to the species that are resistant or indifferent to such an increase. We must now consider that we have moved from a culture of fighting against anthropogenic impacts (i.e., pollution) to a culture of protection and restoration that leads to a reinterpretation of the data acquired in the field in order to reinstate them in a process that serves the dynamic of habitat or community restoration.

Nothing is perfect, but all approaches are perfectible, including subjective ones. We must remain pragmatic and transfer simple methods to the research consultancies that are responsible for assessing benthic quality in numerous impact studies. When using indicators and indices, investigators should be as realistic as possible, making these indicators and indices environmentally sustainable, economically viable, technologically feasible, socially desirable/tolerable, legally permissible and politically expedient (Borja et al., in press). Identification errors can lead to incorrect classifications and erroneous data interpretations, discrediting ecological studies, biotic indices and impact assessments. The question is not to identify the biodiversity of a site, nor to furnish elements on the benthic ecosystem functioning, but to give a diagnosis of the EcoQS. Clearly, the use of "*sentinel species*", best professional judgement and taxonomic sufficiency should be encouraged.

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