Ecological Indicators 12 (2012) 143–153

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

# Response of different benthic indices to diverse human pressures

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ARTICLE INFO

*Keywords:*
Benthic indicators
Soft-bottom communities
Subjectivity
Objectivity
Human pressures
Site comparison

ABSTRACT

The interest in benthic indicators for soft-bottom marine communities has dramatically increased after a rather long period of relative stagnation due to the need for new tools to assess the status of marine waters, called for by the Clean Water Act and the Water Framework Directive. Our expertise on benthic communities has permitted us to gather a vast amount of data from diverse water bodies under unpolluted and polluted conditions (e.g., accidental oil spill, sewage, long-term anthropogenic estuarine constraints) in tidal estuaries, harbours, and on the coastal shelf from Atlantic Ocean and Mediterranean Sea. We compared the results of four biotic indices on the various available datasets: Shannon-Wiener $H'$ diversity, AMBI and BO2A, which divide the species into Ecological Groups, and ITI, which divides the species into trophic groups, and the agreement of Best Professional Judgement (BPJ) on the assessment of ecological conditions. Benthic indicators as "*sentinel species*", which is a particular species that by its presence or its relative abundance warns of possible unbalances in the surrounding environment or distortions in community functions, was also tested. Indicators, BPJ and opportunist sentinel species gave similar ECoQS for the different sampling sites. We discuss the use of Biological Indicators as 'objective' or 'subjective' alternatives for assessing soft-bottom communities, and propose to employ simple methods such as BPJ and taxonomy sufficiency in such diagnostic approaches.



## 1. Introduction

Since the publication of the Water Framework Directive in 2000 (WFD, 2000/60/EC), the search for more effective indicators to assess the quality of the water in water bodies has generated a dramatic increase in the number of papers published. In addition, several workshops, conferences and colloquiums have been specifically organised on this topic and special sessions in other international forums participated in this debate. This abundance of research has produced a profusion of new tools (see Devlin et al., 2007; ICES, 2008; Pinto et al., 2009; Borja et al., in press). In some specific cases, such as for transitional waters and for estuaries [due to the "Paradox of estuarine quality" (Dauvin, 2007; Elliott and Quintino, 2007)], this dramatic increase appeared necessary. Consequently, complicated indices continue to be proposed and published (see Dauvin et al., 2010).

Benthic invertebrate fauna was one of the most developed indicators among the biological compartments selected by the WFD (phytoplankton, macroalgae, angiosperms, benthic invertebrate fauna and fish). These organisms in this compartment presents a lot of advantages for assessing ecological quality: (1) they are relatively sedentary; (2) they have relatively long life-spans; (3) they comprise diverse species that exhibit different sensitivities or tolerances to stress; and (4) they play an important role in cycling nutrients and materials between the underlying sediments and the overlying water column (Dauvin, 2007; Bellan, 2008; Borja et al., 2008).

Nevertheless, Rakocinski and Zapfe (2005) have underlined several disadvantages of the existing benthic indices based on benthic organisms: (1) they represent a static expression of an ecological condition, (2) they are not explicitly linked to changes in ecological function, (3) they may not be specific with respect to different kinds of stressors, (4) they are subject to underlying taxonomic changes across estuarine gradients, (5) their use can be labour intensive, and (6) they are not applied consistently across bio-geographic provinces. This last point was recently underlined by Grémare et al.

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doi:10.1016/j.ecolind.2011.03.019

(2009) when these authors compared the efficiency of two indices – AMBI and BQI – at a European scale.

Despite these disadvantages, the use of benthic invertebrate fauna as biological indicators had begun several years ago before the WFD. One of the foundation studies was conducted by Reish five decades ago (1959) on the Los Angeles and Long Beach harbours. The concept of macrobenthic sensitivity or resistance was inspired by the paradigm of macrobenthos succession in terms of organic enrichment and pollution of the marine environment (Pearson and Rosenberg, 1978). The paper written by Pearson and Rosenberg (1978) caused numerous discussions about the conception of indicators and indices used in soft-bottom macrobenthic communities, as well as these developed in the WFD. However, the increase of organic matter was not the only source of pollution in the sediment; other sources (e.g., metals, hydrocarbons, dredging deposits) can also affect the structure and functioning of benthic communities. This is the limitation of Pearson and Rosenberg's concept. Indicators, as AMBI (Borja et al., 2000) or BENTIX (Simboura and Zenetos, 2002), group the species into several ecological groups, ranging from the more sensitive species to the more tolerant species with respect to increases in organic matter. In addition, these ecological groups are based in part on subjective or objective expertise. But, this reality does not discourage people from developing, adapting and creating new indices, especially since the beginning of the year 2000, in spite of their tautology, as Diaz et al. (2004) pointed out. Other indices are based on functional groups as Infaunal Trophic Index (Mearns and Word, 1982). ITI draws on the premise that the community structure can be evaluated according with the feeding behaviour of the benthic invertebrates as a response to the organic matter content (Pinto et al., 2009).

In reality, two main questions raised: (1) is it necessary to use complicated indices to assess the quality of benthos? and (2) what are the respective parts of subjectivity and objectivity in the assessment of benthic quality status? Nowadays, several papers encourage facilitating the benthic index approach, taking into account taxonomy sufficiency (Dauvin et al., 2009; Dauvin and Ruellet, 2009) or expert judgement (Weisberg et al., 2008; Teixeira et al., 2010).

Our expertise on benthic communities has permitted us to gather a vast amount of data from diverse water bodies under unpolluted and polluted conditions in various environments, from tidal estuaries and harbours to the coastal shelf of the Atlantic Ocean and the Mediterranean Sea. After selecting a dataset that permitted us to visualize several shallow water sites and harbours, in unpolluted or polluted conditions, we aim in this paper to compare the agreement of several kinds of benthic indicators (i.e., '*sentinel species*', Shannon $H'$ diversity, AMBI, BO2A and ITI) and Best Professional Judgement (BPJ), and discuss their subjectivity and objectivity on the assessment of ecological conditions.

## 2. Materials and methods

### 2.1. Sampling sites

A total of 124 sites were gathered from tidal estuaries and harbours to the coastal shelf of the Atlantic Ocean and the Mediterranean Sea (Fig. 1), affected by several sources of pollution (e.g., accidental oil spills, sewage, long-term anthropogenic estuarine constraints and their local or regional adaptations including the special environment in transitional water bodies).

As Dauvin and Ruellet (2007) have suggested previously, the sites with a number of individuals <20 should be excluded in the assessment. There were three sites excluded: two from the navigational channel of the Seine estuary and one in the Marseilles harbour where *Capitella capitata* was the only species sampled, with six specimens. Consequently, the total numbers of sites considered in our statistical analyses were 121 of the total 124.

Table 1 resumes the main characteristics of the eight sampling sites. For supplementary details on the composition of the benthic communities and human pressures see:

- Dauvin et al. (2007) for the Bay of Seine (Northeast France);
- Dauvin (1998, 2000) for the Bay of Morlaix (Southwest France);
- Gomez Gesteira and Dauvin (2005) for the Ares-Betanzos Ria in Galicia (Northwest Spain);
- De-la-Ossa-Carretero et al. (2008, 2009, 2010) for the Castellon coast (Mediterranean, Northeast Spain);
- Bellan (1967a,b) for the Marseilles harbour and Bellan et al. (1999) for the Cortiou discharge in the Marseilles region (Mediterranean, Southwest France);
- and Bakalem (2008) and Bakalem et al. (2009) for the fine sand communities and METAP (1993, 1994), Grimes (2003, 2010), Grimes et al. (2010) for harbours along the Algerian coast (Mediterranean, Northern Algeria).

### 2.2. Quality status assessment

#### 2.2.1. Benthic indicators

The benthic indicators assessed in this paper can be divided into three categories:

1. *Indicators strictly based on ecological groups*: Developed by Borja et al. (2000), the AMBI (AZTI Marine Biotic Index) analyzes the proportions of five ecological groups (using the species list published on the AZTI website in February 2010) according to a gradient of organic matter enrichment (Pearson and Rosenberg, 1978); it was calculated according to the guidelines of Borja and Muxika (2005). The BO2A (Benthic Opportunistic Annelida Amphipods index) was also calculated; this indicator respects the principle of taxonomic sufficiency and uses only two well-known zoological groups as indicator species, consequently limiting the misclassification of taxa caused by too many ecological groups (Dauvin and Ruellet, 2007, 2009; De-la-Ossa-Carretero and Dauvin, 2010).
2. *Indicators strictly based on trophic groups*: The primary indicator in this group is the ITI (Infaunal Trophic Index; Mearns and Word, 1982), which holds that the ecological quality of the community increases with the dominance of suspension feeders and decreases with the dominance of subsurface deposit feeders.
3. *Indicators strictly based on diversity*: The main indicator in this category is $H'$ (the Shannon Index with $\log_2$) proposed by Shannon (1948). It was used based on the theory of information, as proposed in the original text.

The five ECOlogical Quality Status (EcoQS) classes suggested by the WFD were used in this study: *high* (in blue) for unpolluted sites, *good* (in green) for slightly polluted sites, *moderate* (in yellow) for moderately polluted sites, *poor* (in orange) for heavily polluted sites, and *bad* (in red) for extremely polluted or azoic sites. The thresholds are reported in Table 2 (Ruellet and Dauvin, 2007) [i.e. those defined by Borja et al. (2000) for AMBI, Vincent et al. (2002) for $H'$ indicator and De-la-Ossa-Carretero and Dauvin (2010) for the BO2A]. For the ITI, only three EcoQSs were used: *degraded* for sites with a dominance of subsurface deposit feeders, *perturbed* for sites showing miscellaneous trophic groups (e.g., subsurface deposit feeders, deposit feeders and suspension feeders), and *normal* for sites with a dominance of suspension feeders.

**Table 1**
Main characteristics of the benthic communities and the human pressures in the eight sampling sites. Information's on the sampling design are also indicated for each sampling stations.

| Location of the sites | Date | Sampling's season | Number of sampling stations | Number of observations | Depth (m) | Sampling | Number of replicates | Communities sampled | Human pressure |
|---|---|---|---|---|---|---|---|---|---|
| Bay of Seine (Eastern English Channel, France) | 2008 | Summer (September) | 11 | 9 (2 azoic sites) | 5–20 | Van Veen grab | 5 | *Abra alba-Pectinaria koreni* muddy sand community and *Macoma balthica* community in the Seine estuary | Multiple anthropogenic perturbations: urbanization, dykes, navigation, organic (HAPs, PCBs) and metallic contaminants |
| Bay of Morlaix (Western English Channel, France) | 1977–1983 | Winter (February) and summer (August) | 2: Pierre Noire (PN) and Rivière de Morlaix (RM) | 24 | 17 (for PN) to 10 (for RM) | Smith McIntyre grab | 10 | *Abra alba-Aponuphis bilineata* fine sand community (PN) *Abra alba-Melinna palmata* muddy sand community (RM) | Hydrocarbons from the *Amoco Cadiz* wreck (April 1978) |
| Galicia (Ares-Betanzos Ria, Atlantic Ocean, Northwest Spain) | 2002–2006 | Winter (March–April) and summer (July–August) | 2: X and Z | 20: 10 at each station | 10–15 | 1/127 $m^{-2}$ Box Corer | 3 | Ecotone between the *Abra alba* and the *Venus gallina* communities | Hydrocarbons from the *Aegean Sea* wreck (December 1992) |
| Castellón coast (Mediterranean Sea, Northeast Spain) | 2006 | Summer (July) | 5:<br>Vinaroz<br>Benicarló<br>Peñíscola<br>Alcossebre<br>Torreblanca | 15<br>(3)<br>(3)<br>(3)<br>(3)<br>(3) | 14.8 (mean depth) | Van Veen grab (400 $cm^2$) | 3 | *Spisula subtruncata* fine sand communities | Sewage outfalls along 40 km of the coast |
| Marseille Harbour (Mediterranean Sea, Southwest France) | 1965 and 1966 | Summer | 12 along a polluted-unpolluted gradient | 12 (1 azoic) | <15 (for polluted sites) and >15 (for unpolluted site) | Size-one orange-peel bucket grab 5 $dm^3$ | 1 | <15 m oligospecific communities with *Capitella capitata*; >15 more species with *Corbula gibba*, *Thysasira flexuosa*, *Lumbrineris latreilli* | Several sources of contaminants: hydrocarbons, plants, sewage, etc. |
| Cortiou discharge (Mediterranean Sea, Southwest France) | 1965–2001 | Summer | 5<br>St 4<br>St I7<br>St F2<br>St E6<br>St D2 | 12 | 35–86 | Size-one orange-peel bucket grab modified 5 $dm^3$ | 5 to 8 (pooled) | Similar than Marseille harbour, according depth and distance from sea-outlet of sewage outfall. Fast and important recovery after 1986 | Before 1986, 4-6 $m^3\,s^{-1}$ of raw domestic water from City sewer. After 1986, physical treatment plant reducing pollutants |
| Algerian coast (Mediterranean Sea, Northern Algeria) | 1980s and 1990s | Summer | 7<br>Fetzara<br>Jijel<br>Bejaia<br>Bou Ismail<br>Arzew<br>Oran Bay<br>Algier Bay | 16<br>2<br>2<br>2<br>2<br>2<br>2<br>4 | 9–40 | 0.1 $m^{-2}$ Van Veen grab (for Algiers and Jijel) and 0.1 $m^{-2}$ and Smith McIntyre grab in other sites | ? | Fine sand communities with *Spisula subtruncata*, *Venus gallina*, *Owenia fusiformis*, *Ampelisca brevicornis* | Sewage, urbanization (Fetzara, Jijel, Oran Bay, Bou Ismail). Hydrocarbons, sewage, heavy metal, urbanization (Arzew, Bejaia, Algier Bay) |
| Algerian Harbours (Mediterranean Sea, Northern Algeria) | 1995–2001 | Summer (June–August) | 5<br>Annaba<br>Algier<br>Bejaia<br>Ghazaouet<br>Oran | 14<br>4<br>4<br>2<br>2<br>2 | 3–35 | 0.25 $m^{-2}$ Van Veen grab | 2 | From oligospecific mud community with *Capitella capitata*; and *Corbula gibba* to muddy fine sand *Abra alba* community | Heavy metal pollution, maritime traffic, harbour activity, urban discharges, etc. |

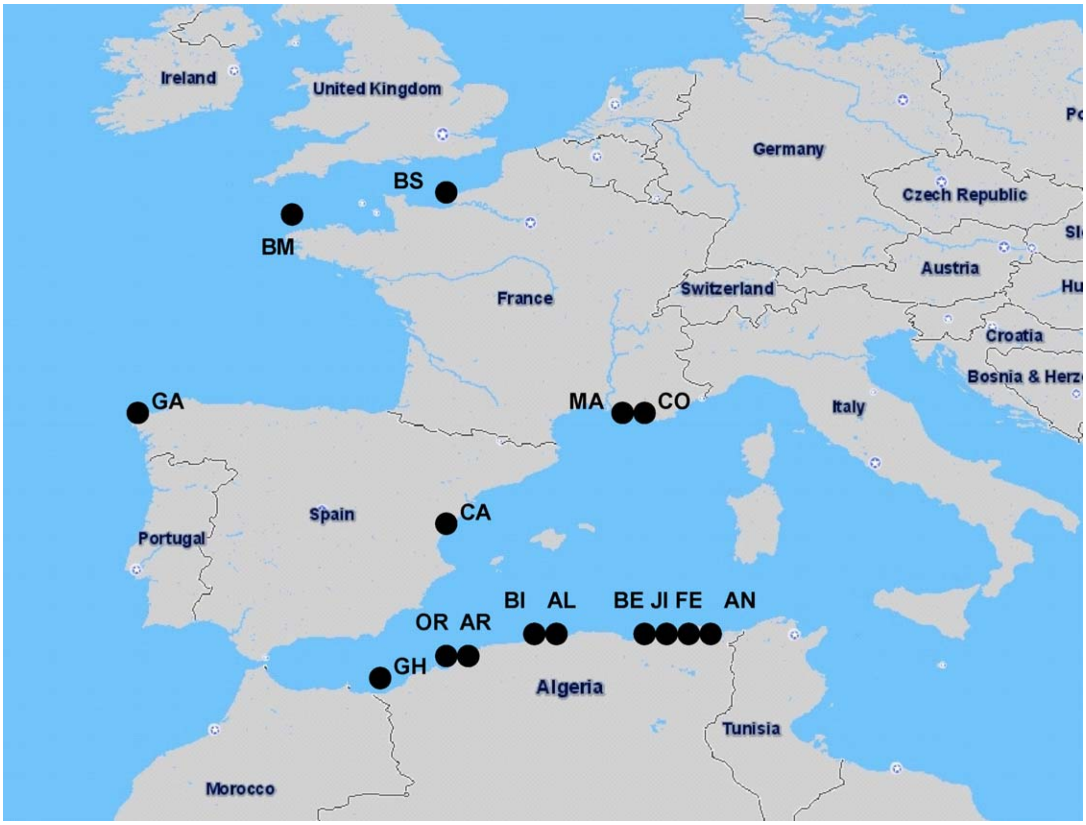


**Fig. 1.** Locations of the sampling sites in the North-eastern Atlantic Ocean and western part of the Mediterranean Sea (BS: Bay of Seine; BM: Bay of Morlaix; GA: Galicia, CA: Castellon coast; MA: Marseilles harbour; CO: Cortiou emissary; GH: Ghazaouet; OR: Oran; AR: Arzew; BI: Bou Ismail; AL: Algiers; BE: Bejaia; JI: Jijel; FE: Fetzara; AN: Annaba).

### 2.2.2. *Best professional judgement*

Recent assessments of benthic macrofauna community conditions using 'best professional judgement' (BPJ) (Weisberg et al., 2008; Teixeira et al., 2010) have revealed that experts, based on their experience, are able to evaluate the quality status of benthic samples using four categories with a high degree of agreement. They also able to rank samples from best to worst condition (Teixeira et al., 2010) with a good degree of agreement, though the agreement was better for samples at the extremes of the disturbance gradient.

Four experts (AB, GB, JCD, and SG), who have experience in benthic monitoring ranging from 15 to 50 years, assigned a blind score to each of the 124 sites. This score was composed of one of the four condition categories based on narrative description, as suggested in Teixeira et al. (2010): (1) unaffected community (high and good states of the WFD), (2) marginal deviation from unaffected (moderate status of the WFD), (3) affected (poor status of the WFD), and (4) very affected (bad of the WFD). For this score, they were given only the lists of species with the number of individuals of each species, without any other information about the sample locations, sediment type and polluted or unpolluted conditions. The four experts were also asked to identify the criteria used in their judgement as (1) very important, (2) important but secondary, (3) marginally important, and (4) useful, but only to interpret other criteria. The seven criteria used by these experts to categorize samples were: (1) presence of opportunistic species, (2) presence of tolerant species, (3) presence of sensitive species, (4) number of taxa present in the sample, (5) total abundance in the sample, (6) abundance dominance patterns by opportunistic species, and (7) abundance dominance pattern by sentinel species.

### 2.2.3. *Sentinel species and other species categories*

Dauvin et al. (2010) have recently reviewed the definition of different terms used to characterize the species in the field of benthic indicators: *sensitive species*, *tolerant species*, *opportunistic species*, *indifferent species*, *indicative species*, *indicator species*, *pollution indicator species*, and *sentinel species*. Since experts ranked (see Section 3) presence of opportunistic and sentinel species as the more important criteria in BPJ, both aspects are analysed. The term, *sentinel species*, was established as a particular species that by its presence or its relative abundance 'warns' an observer about possible imbalances in the surrounding environment and/or alterations of the community functions. In this study, we take into account two kinds of sentinel species: those that indicate an increase in organic

**Table 2**
Threshold values between the five ecological statuses considered for the selected benthic indicators: AMBI, BO2A, $H'$, and ITI (see text for definitions and references for the threshold levels).

| | AMBI | BO2A | $H'$ | | ITI |
|---|---|---|---|---|---|
| High | 0–1.2 | 0.00000–0.01950 | $+\infty$–4.00 | | |
| Good | 1.2–3.3 | 0.01951–0.13100 | 4.00–3.00 | Normal | 60–100 |
| Moderate | 3.3–4.3 | 0.13101–0.19804 | 3.00–2.00 | Perturbed | 30–60 |
| Poor | 4.3–5.5 | 0.19804–0.26155 | 2.00–1.00 | Degraded | 0–30 |
| Bad | 5.5–7.0 | 0.26155–0.30103 | 1.00–0.00 | | |

matter, considered opportunistic (e.g., *Capitella capitata* complex, *Malacoceros* (*Scolelepis*) *fuliginosa*, *Neanthes* (*Nereis*) *caudata* complex, *Cirriformia* (*Audouinia*) *tentaculata*, *Schistomeringos* (*Dorvillea*, *Staurocephalus*) *rudolphi* among the polychaetes and *Corbula gibba* among the bivalves), and those that are known to be very sensitive to disturbance (i.e., the amphipods *Ampelisca*) (see Bellan, 2008; Bakalem, 2008; Grimes, 2010).

*2.2.4. Statistical analysis*

A Mann–Whitney–Wilcoxon (MWW) non-parametric test was used for assessing whether two series of diagnoses have equal values. In other words, there were no significant differences between the assessments (EcoQS) (Scherrer, 1984). MWM tests were performed between the benthic indicator assessments (e.g., $H'$ versus AMBI) for paired samples and between the diagnoses of the four experts ($p$ level <0.1%) for independent samples. The Pearson's correlation coefficient $r$ with $p$-value was also used between different applied indices and between sentinel species and different applied indices.

For the BPJ, a weighted Kappa analysis (Cohen, 1960; Landis and Kosch, 1977) was used to analyse the agreement among all the experts and mean assessed condition with respect to each expert. Kappa analysis was also applied among EcoQS obtained by three of the indices (AMBI, BO2A and $H'$) and BPJ at each area and for the total of the sites. The Kappa analysis methodology proposed by Borja et al. (2007) was employed. The equivalence table from Monserud and Leemans (1992) was used to establish the level of agreement. In addition, since the importance of misclassification is not the same between close categories (e.g., unaffected and affected) as between distant categories (e.g., between unaffected and severely affected), we chose to apply Fleiss–Cohen weights (Fleiss and Cohen, 1973) to the analysis to decrease the importance of misclassification between close categories and increase the importance between distant categories.

## 3. Results

*3.1. General pattern of the dataset*

The specific richness (SR) and number of collected specimens varied greatly for the 124 selected samples (Appendix A; Fig. 2a). In fact, the SR varied from 0 in the navigational channel of the Seine estuary in an azoic zone due to the continuous dredging to allow access to Rouen harbour, located at 120 km from the sea, to 133 in August 1980 and August 1982 at the Pierre Noire site (Bay of Morlaix). The SR displayed a Gaussian form, and most of the samples showed an intermediate SR ranging between 30 and 60 (Fig. 2a). The number of individuals also varies from 0, in the same site in the Seine estuary as the SR, to 37,658 in August 1977 at the Pierre Noire site (Fig. 2b). The samples showed two maximums according their abundances: about 30% of the samples with a number of individuals ranging between 100 and 500 and about 30% of the samples with a number of individuals ranging between 1000 and 5000 (Fig. 2b).

*3.2. Assessment using benthic indicators*

Fig. 3 shows the number of samples corresponding to the five EcoQS given by $H'$, AMBI, BO2A and ITI. They were mainly classified as High and Good status (more than >50%), Poor and Bad Status were less represented: they were mostly located in Marseilles harbour, the Cortiou outfall and the Algerian harbours (Appendix A; Fig. 3). $H'$ appears to be the most optimistic index, followed by AMBI and BO2A. BO2A gave more Poor and Bad statuses than AMBI. For the ITI, 93 samples showed an intermediate perturbed status (76.8%),

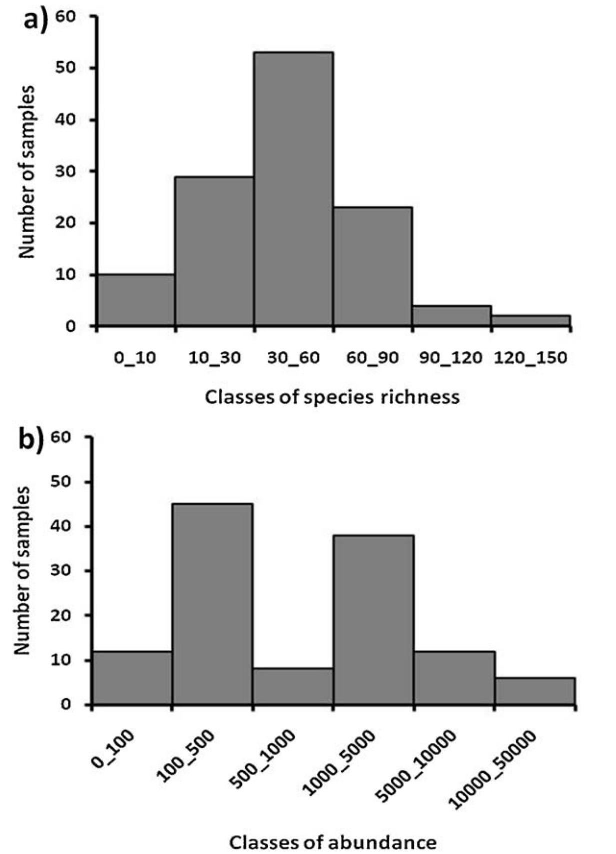


**Fig. 2.** Distribution of the 124 selected samples (a) according to the species richness and (b) according to the number of individuals.

20 samples showed a normal status (16.6%), and only eight (6.6%) corresponded to degraded samples.

If the five EcoQS are taken into consideration, the MWW tests for paired samples showed that there were no significant differences between the assessment given by $H'$, AMBI and BO2A, meaning that there was a good concordance among the three indicators. In order to compare these results with the ITI results, the High and Good status (corresponding to the Normal status of ITI), and the Poor and Bad status (corresponding to the Degraded status of ITI) were pooled; the Moderate status was not changed and corresponded to the Perturbed status of ITI. The MWW tests for paired samples showed that only $H'$ and BO2A gave similar statuses (i.e., there was no significant difference between their assessments), while all comparisons gave significantly different assessments. Fig. 3 illustrates the divergence of diagnoses among these indicators. Nevertheless, in the case of samples collected in some sites (e.g., in Spain), the three indicators ($H'$, AMBI and BO2A) gave very similar diagnoses, despite the Aegean oil spill in Galicia and despite the presence of sewage pollution along the Castellon coast. The diagnoses were more divergent for polluted sites: in the Bay of Morlaix with the Amoco Cadiz oil spill, in the Marseilles harbour and the Cortiou canal, and in the Algerian harbours with accumulation of organic matter.

Clearly, the ITI based on the trophic groups of species with only three status was more divergent that the other indicators for assessing the EcoQS (Fig. 3). This divergence was also related to the fact that this index produced most of the perturbed status (mean).

Species Richness was significantly correlated with the abundance, $H'$ and AMBI, while $H'$ was significantly correlated with AMBI and BO2A. AMBI and BO2A were highly correlated (Table 3). ITI was significantly correlated only with the abundance (Table 3).

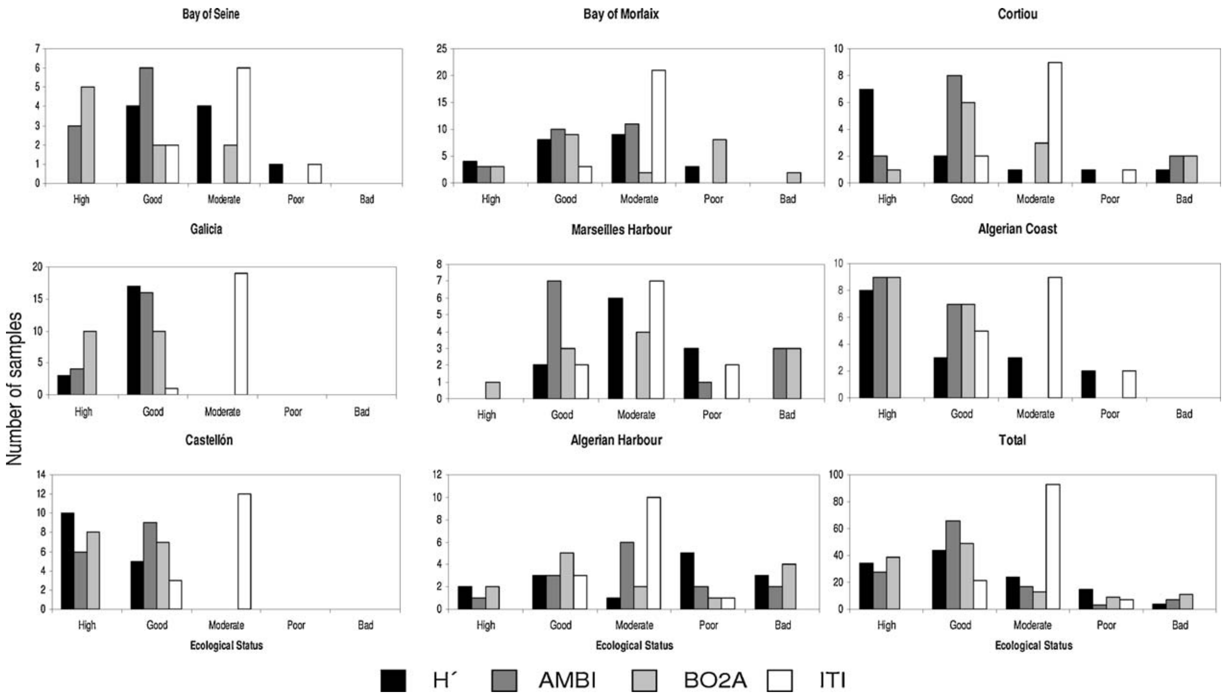


**Fig. 3.** Number of samples corresponding to the five EcoQS produced by $H'$, AMBI, BO2A, and ITI, for each of the eight sites and for all 121 samples.

### *3.3. Best Professional Judgement (BPJ)*

Table 4 gives the four categories assigned by the four benthic experts to each of the 124 samples selected in the dataset: 1 – unaffected (green); 2 – marginal deviation from unaffected (yellow); 3 – affected (orange) and 4 – severely affected (red). The experts were in a perfect agreement for 51 samples (41%), and only one expert differed from the three others for 46 (37%) other samples, so there was good agreement between experts in more than three cases out of four. The results of the MWW tests for independent samples showed that there were no significant differences between the assessments given by the four experts, which mean that there was a high level of agreement among the experts. Similarly, the results of Kappa agreement analysis (Table 5) indicated a high level of agreement among experts. The experts had a "very good" level of agreement, and this agreement was "almost perfect" comparing each expert assessment with the mean assessed condition.

Table 6 gives the rank of the criteria used by the four experts. All the experts thought the presence of opportunistic species was very important (1), and found the total abundance in the samples only useful (4). They thought that the presence of sensitive species was very important or important. Three of the experts judged the dominance by opportunistic species to be very important, and the presence of tolerant species as important. For the other criteria, the experts had more divergent opinions.

### *3.4. Agreement among indices and Best Professional Judgement*

Kappa agreement analysis (Table 7) indicated a high level of agreement (Good and Very Good) between indices, i.e. AMBI and BO2A, AMBI and $H'$ and BO2A when all the data were considered. BPJ showed a Moderate agreement with the three indices for all data. Nevertheless, the agreement analyses made site per site showed a large range of percentage of mismatch. There were Null to Very Low agreements in the Bay of Seine, Galicia, Castellon and Algerian harbours, while the were a high level of agreement in other sites for the indices but low agreement with BPJ except at Cortiou where the agreement between BPJ and indices was Moderate to Good.

### *3.5. Sentinel species*

The percentages of two kinds of sentinel species are taken into account according to the five EcoQS produced by the three other indices $H'$, AMBI and BO2A (only the percentages >1% were taken

**Table 3**
Pearson coefficient values ($R$) and significance level ($p$) between different applied indices. SR: species richness, N: abundance, $H'$ Shannon diversity, *Ampelisca*: % of *Ampelisca* and Opportunistic species: % of opportunistic species in the samples.

| *p* | *R* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | SR | *N* | $H'$ | AMBI | BO2A | ITI | *Ampelisca* | Opportunistic species |
| SR | – | 0.500 | 0.432 | −0.281 | −0.151 | 0.093 | 0.166 | −0.607 |
| N | **<0.0001** | – | | 0.008 | 0.141 | 0.193 | 0.341 | −0.236 |
| $H'$ | **<0.0001** | 0.092 | – | −0.625 | −0.547 | 0.004 | −0.142 | −0.639 |
| AMBI | **0.002** | 0.927 | **<0.0001** | – | 0.837 | −0.108 | −0.414 | 0.790 |
| BO2A | 0.094 | 0.118 | **<0.0001** | **<0.0001** | – | −0.120 | −0.265 | 0.567 |
| ITI | 0.305 | **0.032** | 0.969 | 0.233 | 0.184 | – | 0.341 | 0.197 |
| *Ampelisca* | 0.176 | **0.004** | 0.249 | **0.000** | 0.029 | **0.004** | – | – |
| Opportunistic species | **<0.0001** | **0.035** | **<0.0001** | **<0.0001** | **<0.0001** | 0.080 | – | – |

**Table 4**
Condition categories assigned by the four experts (A1, A2, A3 and A4) to each of the 124 samples selected in the dataset. 1: unaffected (green); 2: marginal deviation from unaffected (yellow); 3: affected (orange) and 4: severely affected (red). BS: Bay of Seine; RM: *Rivière de Morlaix*, Bay of Morlaix; PN: Pierre Noire, Bay of Morlaix; X and Z, Galicia, 02, February...; /77, 1977...; Castellon coast, Vinaroz (VIN), Benicarló (BEN), Peñíscola (BEN), Alcossebre (ALC) and Torreblanca (TOR), V1, near the emissary, N1, 200 m from the emissary, N2, 1000 m from the emissary; C, Cortiou; II, II/III, III < 15, III > 15, Marseilles harbour; ALG, Algiers; ARZ, Arzew; BEJ, Bejaia; FET, Fetzara; JIJ, Jijel; OR, Oran; HALG, Algiers harbour; HAN, Annaba harbour; HBEJ, Bejaia harbour; HGZ Ghazaouet harbour; HORA, Oran harbour.

| Samples | A1 | A2 | A3 | A4 | Samples | A1 | A2 | A3 | A4 | Samples | A1 | A2 | A3 | A4 | Samples | A1 | A2 | A3 | A4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BS2 | 2 | 1 | 3 | 2 | PN08/81 | 2 | 1 | 1 | 1 | PEN.S1 | 1 | 1 | 2 | 1 | III>15 | 2 | 2 | 2 | 3 |
| BS7 | 2 | 2 | 3 | 2 | PN03/82 | 2 | 1 | 1 | 1 | PEN.S2 | 2 | 1 | 2 | 2 | ALG1 | 1 | 1 | 2 | 1 |
| BS10 | 1 | 1 | 2 | 1 | PN08/82 | 2 | 2 | 2 | 2 | ALC.V1 | 1 | 1 | 1 | 1 | ALG2 | 1 | 1 | 1 | 1 |
| BS11 | 2 | 1 | 2 | 1 | PN03/83 | 1 | 1 | 1 | 1 | ALC.N1 | 2 | 1 | 2 | 2 | ALG3 | 1 | 1 | 2 | 2 |
| BS15 | 2 | 1 | 1 | 1 | X12/92 | 1 | 1 | 1 | 1 | ALC.N2 | 1 | 1 | 1 | 1 | ALG4 | 2 | 2 | 2 | 2 |
| BS24 | 3 | 3 | 3 | 3 | X03/93 | 2 | 1 | 3 | 2 | TOR.V1 | 1 | 1 | 1 | 1 | ARZ1 | 1 | 1 | 1 | 2 |
| BS28 | 2 | 2 | 2 | 2 | X08/93 | 1 | 1 | 1 | 1 | TOR.N1 | 1 | 1 | 2 | 1 | ARZ2 | 2 | 1 | 1 | 2 |
| BS40 | 2 | 1 | 2 | 2 | X03/94 | 2 | 1 | 2 | 1 | TOR.N2 | 2 | 1 | 2 | 2 | BEJ1 | 1 | 1 | 2 | 1 |
| BS55 | 4 | 4 | 4 | 4 | X09/94 | 1 | 1 | 1 | 1 | C65C6 | 4 | 4 | 4 | 4 | BEJ2 | 1 | 1 | 1 | 1 |
| BS56 | 3 | 1 | 3 | 3 | X04/95 | 1 | 1 | 1 | 1 | C89I7e | 4 | 4 | 4 | 4 | BOU1 | 2 | 1 | 1 | 1 |
| BS58 | 3 | 1 | 3 | 3 | X08/95 | 1 | 1 | 1 | 1 | C94I7e | 2 | 1 | 2 | 3 | BOU2 | 1 | 1 | 1 | 2 |
| RM08/77 | 3 | 3 | 3 | 2 | X04/96 | 1 | 1 | 1 | 1 | C95I7e | 3 | 3 | 2 | 3 | FET1 | 1 | 1 | 1 | 1 |
| RM02/78 | 2 | 2 | 2 | 2 | X07/96 | 1 | 1 | 1 | 1 | C96I7e | 3 | 1 | 3 | 3 | FET2 | 2 | 1 | 2 | 2 |
| RM08/78 | 3 | 3 | 3 | 3 | X11/96 | 1 | 1 | 1 | 1 | C01I7e | 4 | 1 | 2 | 3 | JIJ1 | 1 | 1 | 1 | 1 |
| RM02/78 | 3 | 2 | 2 | 2 | Z11/92 | 1 | 1 | 1 | 1 | C76F2 | 3 | 2 | 3 | 3 | JIJ2 | 2 | 1 | 3 | 1 |
| RM08/79 | 3 | 2 | 2 | 2 | Z03/93 | 2 | 1 | 2 | 2 | C76E6 | 2 | 1 | 1 | 2 | ORA1 | 2 | 1 | 2 | 3 |
| RM02/80 | 3 | 2 | 2 | 2 | Z08/93 | 1 | 1 | 2 | 1 | C76D2 | 1 | 1 | 3 | 3 | ORA2 | 1 | 1 | 3 | 1 |
| RM08/80 | 3 | 3 | 3 | 3 | Z03/94 | 2 | 1 | 1 | 1 | C94F2 | 1 | 1 | 2 | 2 | HALG1 | 3 | 3 | 3 | 3 |
| RM02/81 | 3 | 3 | 2 | 3 | Z09/94 | 2 | 1 | 2 | 1 | C94E6 | 1 | 1 | 1 | 3 | HALG2 | 2 | 2 | 2 | 2 |
| RM08/81 | 3 | 3 | 3 | 3 | Z04/95 | 1 | 1 | 1 | 1 | C94D2 | 2 | 1 | 2 | 2 | HALG3 | 3 | 3 | 4 | 4 |
| RM03/82 | 3 | 2 | 2 | 2 | Z08/95 | 1 | 1 | 1 | 1 | II | 4 | 4 | 4 | 4 | HALG4 | 3 | 3 | 3 | 3 |
| RM08/82 | 3 | 2 | 3 | 2 | Z04/96 | 1 | 1 | 1 | 1 | II | 4 | 4 | 4 | 4 | HAN1 | 4 | 4 | 4 | 4 |
| RM03/83 | 2 | 2 | 1 | 2 | Z07/06 | 1 | 1 | 1 | 1 | II | 4 | 4 | 4 | 4 | HAN2 | 4 | 3 | 4 | 3 |
| PN08/77 | 1 | 1 | 1 | 1 | Z11/06 | 1 | 1 | 1 | 1 | II/III | 4 | 4 | 4 | 4 | HAN3 | 3 | 3 | 3 | 3 |
| PN03/78 | 1 | 1 | 2 | 1 | VIN.V1 | 2 | 1 | 2 | 2 | II/III | 3 | 4 | 4 | 4 | HAN4 | 3 | 3 | 4 | 3 |
| PN08/78 | 2 | 2 | 2 | 2 | VIN.N1 | 2 | 1 | 1 | 1 | II/III | 3 | 4 | 3 | 3 | HBEJ1 | 3 | 3 | 4 | 3 |
| PN03/79 | 2 | 2 | 2 | 1 | VIN.N2 | 1 | 1 | 1 | 1 | III<15 | 3 | 3 | 3 | 3 | HBEJ2 | 2 | 2 | 2 | 3 |
| PN08/79 | 2 | 2 | 2 | 2 | BEN.V1 | 2 | 1 | 1 | 3 | III<15 | 3 | 2 | 2 | 3 | HGZ1 | 3 | 3 | 4 | 3 |
| PN03/80 | 2 | 2 | 1 | 2 | BEN.N1 | 1 | 1 | 1 | 1 | III<15 | 4 | 3 | 4 | 4 | HGZ2 | 4 | 3 | 4 | 3 |
| PN08/80 | 2 | 2 | 1 | 2 | BEN.N3 | 1 | 1 | 2 | 1 | III>15 | 2 | 1 | 3 | 3 | HORA1 | 4 | 4 | 4 | 4 |
| PN03/81 | 2 | 2 | 2 | 2 | PEN.V | 2 | 2 | 2 | 2 | III>15 | 3 | 1 | 3 | 3 | HORA2 | 3 | 2 | 2 | 3 |

into account in the figures, not shown in this paper, and for the Pearson coefficient values; see Appendix A for the raw data).

There was a general trend showing that low dominance of opportunistic species was associated mainly with High and Good EcoQS, while Poor and Bad EcoQS were associated with high dominance, probably indicating high level of organic matter in the sediment. This pattern was more accurate for AMBI than for $H'$ and BO2A.

Conversely, *Ampelisca* were mainly present in cases of High and Good EcoQS, except two samples from the Bay of Morlaix, which were taken after the Amoco Cadiz oil spill during post-spill colonisation of the *Ampelisca* and a summer proliferation of the tolerant polychaete species *Pseudopolydora pulchra* when while Poor or Bad EcoQS were identified by $H'$ and BO2A. AMBI showed more accurate relationship than both of the other indicators ($H'$ and BO2A).

The percentages of *Ampelisca* were significantly correlated with the abundance, AMBI, BO2A and ITI, while the percentages of opportunistic species were significantly correlated with all indices apart ITI (Table 3).

## 4. Discussion

Statistical tests showed that the three chosen indices – $H'$, AMBI and BO2A – gave similar EcoQS, with both AMBI and BO2A often giving the same assessment for many samples (Fig. 3; Tables 3 and 7; see also Appendix A). The ITI approach was based on different concepts, and used only three classes for assessing benthic EcoQS and accentuated the Moderate perturbed class even in areas (Galicia and Castellon) which were classified as High and Good by other indices (Fig. 3). Many papers (Labrune et al., 2006; Blanchet et al., 2008; Borja and Dauer, 2008; Borja et al., 2008; Bakalem et al., 2009;

**Table 5**
Kappa values with agreement levels in parentheses (lower left) for the condition category assignments, and the percentage of mismatch (upper right between expert and mean assessment) classification. (Level of agreement: AP – "Almost perfect"; VG – "Very Good"; G – "Good").

| | Percentage of mismatch | | | | |
|---|---|---|---|---|---|
| | A1 | A2 | A3 | A4 | Mean |
| A1 | – | 34.68 | 34.68 | 27.42 | 14.52 |
| A2 | 0.80 (VG) | – | 39.52 | 30.65 | 30.65 |
| A3 | 0.79 (VG) | 0.77 (VG) | – | 33.87 | 24.19 |
| A4 | 0.82 (VG) | 0.74 (VG) | 0.78 (VG) | – | 16.13 |
| Mean | 0.94 (AP) | 0.86 (VG) | 0.86 (AP) | 0.89 (AP) | – |

**Table 6**
Criteria used by the four experts to rank and categorize species samples. (1 – very important; 2 – important but secondary; 3 – marginally important and 4 – useful, but only to interpret other criteria).

| Criteria | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| Presence of opportunistic species | 1 | 1 | 1 | 1 |
| Presence of tolerant species | 3 | 2 | 2 | 2 |
| Presence of sentinel species | 1 | 2 | 2 | 1 |
| Number of taxa present in the sample | 2 | 3 | 1 | 2 |
| Total abundance in the sample | 4 | 4 | 4 | 4 |
| Abundance dominance pattern of opportunistic species | 1 | 1 | 1 | 4 |
| Abundance dominance pattern of sentinel species | 1 | 2 | 2 | 3 |

Dauvin et al., 2009; Grémare et al., 2009; Ranasinghe et al., 2009) have highlighted the differences in assessments produced by the various benthic indicators. These differences are caused by several things, for example, the indicators do not use the same method for species classification (e.g., the AMBI classifies species into Ecological Groups following the Pearson and Rosenberg's concept; the BO2A takes into account only amphipod sensitive and polychaete opportunistic species; the ITI classifies species into Trophic Groups; or the $H'$ Shannon diversity index uses the numbers of species and individuals in a sample).

AMBI showed the highest correlation with sentinel species, i.e. dominance of opportunistic species and *Ampelisca*, than both other indicators ($H'$ and BO2A) showing that this index discriminate finely both groups of species (Table 3). However, the percentages of opportunistic species were highly significantly correlated (positive or negative correlations, see Table 3) with all indices except ITI. The dominance of sentinel species used in this study appears to be a good indicator of the ECoQS for the selected sampling sites. However, they must be accompanied by other indices for producing an accurate assessment of soft-bottom communities. Moreover, their presence and dominance was used by the experts for their Best Professional Judgement (Table 6). For the observer, sentinel species play an important 'warning' role with respect to possible imbalances in the surrounding environment or distortions in the functioning of a benthic community (Bellan, 2008). Under favourable conditions (i.e., an increase of organic matter), opportunistic species can rapidly increase their populations which suddenly aroused indicating polluted conditions; conversely, the presence and the dominance of the species sensitive to hydrocarbons and organic matter, such as amphipod *Ampelisca*, give information about the improved quality of benthic environment. However, their absence is not sufficient in and of itself to prove the community is affected. But their disappearance after an oil spill, when they were pre-spill observations, remained a remarkable indicator of sedi-

**Table 7**
Kappa values with agreement levels in parentheses (lower left) for the condition category assignments, and the percentage of mismatch (upper right AMBI, BO2A, $H'$ and expert and mean assessment) classification. (Level of agreement: AP – 'Almost perfect'; VG – 'Very Good'; G – 'Good'; M – 'Moderate'; L- 'Low'; VL – 'Very Low'; N: 'Null').

| | | Percentage of mismatch | | | |
|---|---|---|---|---|---|
| | | AMBI | BO2A | $H'$ | BPJ |
| Total | AMBI | – | 43.80 | 64.46 | 55.37 |
| | BO2A | 0.79(VG) | – | 66.12 | 53.72 |
| | $H'$ | 0.64 (G) | 0.56(G) | – | 59.50 |
| | BPJ | 0.52 (M) | 0.55(M) | 0.49(M) | – |
| Bay of Seine | AMBI | – | 44.44 | 66.66 | 77.77 |
| | BO2A | 0.19(VL) | – | 88.88 | 66.66 |
| | $H'$ | 0.00(N) | −0.38(N) | – | 88.89 |
| | BPJ | 0.00(N) | 0.05(N) | −0.23(N) | – |
| Bay of Morlaix | AMBI | – | 45.83 | 45.83 | 54.16 |
| | BO2A | 0.67(G) | – | 65 | 58.33 |
| | $H'$ | 0.64(G) | 0.64(G) | – | 62.5 |
| | BPJ | 0.17(VL) | 0.52(M) | 0.39(L) | – |
| Galicia | AMBI | – | 40.00 | 75.00 | 20.00 |
| | BO2A | 0.20(VL) | – | 55.00 | 20.00 |
| | $H'$ | −0.05(N) | −0.01(N) | – | 20.00 |
| | BPJ | 0.00(N) | 0.00(N) | 0.00(N) | – |
| Castellon | AMBI | – | 26.66 | 53.33 | 40.00 |
| | BO2A | 0.47(M) | – | 53.33 | 40.00 |
| | $H'$ | 0.00(N) | −0.09(N) | – | 40.00 |
| | BPJ | 0.00(N) | 0.00(N) | 0.00(N) | – |
| Cortiou | AMBI | – | 50.00 | 75.00 | 83.33 |
| | BO2A | 0.83 (VG) | – | 75.00 | 83.33 |
| | $H'$ | 0.92(AP) | 0.72(VG) | – | 91.67 |
| | BPJ | 0.49(M) | 0.59(G) | 0.48(M) | – |
| Marseilles harbour | AMBI | – | 45.45 | 81.81 | 72.72 |
| | BO2A | 0.81(VG) | – | | 72.72 |
| | $H'$ | 0.66(G) | 0.84(VG) | – | 100 |
| | BPJ | 0.38(L) | 0.33(L) | 0.29(L) | – |
| Algerian coast | AMBI | – | 37.5 | 56.25 | 43.75 |
| | BO2A | 0.24(L) | – | | 43.75 |
| | $H'$ | 0.00(N) | −0.12(N) | – | 50.00 |
| | BPJ | 0.00(N) | 0.00(N) | 0.22(L) | – |
| Algerian harbours | AMBI | – | 80.00 | 78.57 | 85.71 |
| | BO2A | 0.24(L) | – | | 71.42 |
| | $H'$ | 0.45(M) | 0.18(VL) | – | 64.25 |
| | BPJ | 0.34(L) | 0.27(L) | 0.14(VL) | – |

ment pollution (Dauvin, 1998, 2000; Gomez Gesteira and Dauvin, 2005).

The BPJ exercise performed for this study confirmed the previous studies of Weisberg et al. (2008) and Teixeira et al. (2010) on the pertinence and accuracy of such approach. This confirmation was probably due to similar professional knowledge of the benthic experts and their high level of appropriation of the Pearson and Rosenberg paradigm concerning the response of a benthic community to increases in organic matter. Nevertheless, the Kappa analysis showed poorly agreement between indices and BPJ when each site, was taken into account: very low to null agreement levels especially in the Bay of Seine, Galicia, Castellon and Algerian coats (Table 7). This was mainly due to the low number of stations in each site, and discordance between category assignments. For example, in the Castellon site BPJ classified six stations (on a total of 15) as Moderate while all applied indices classified the 15 stations as Good and High. When all the data were considered, the level of agreement increased to Moderate between BPJ and the three indices (Table 7).

So, this study of several types of sites affected by different disturbances permitted to formulate some general comments:

- Indicators, BPJ and opportunist sentinel species gave similar ECoQS (Poor and Bad status, or affected or severely affected invertebrate fauna) in polluted harbours and large outfalls (e.g., the Cortiou outfall) (Fig. 3 and Table 4). This was probably related to the low hydrodynamism, the large discharge quantity and the storage of organic matter in the sediment of such environments. The response corresponded clearly to the Pearson and Rosenberg's concept (Pearson and Rosenberg, 1978); the assessment was objective and do not suffer of any doubt.
- Indicators and BPJ appeared not sufficiently sensitive to identify any disturbances in cases of low quantities of organic matter discharge or other sources of chronic sources of pollution (i.e., input of metals and organic contaminants) in coastal waters, for example, along the Castellon coast and in the Seine estuary where the benthos appeared in High or Good condition (Fig. 3) in spite of sewage outfalls (De-la-Ossa-Carretero et al., 2008, 2009, 2010) or a very highly contaminated environment (Dauvin et al., 2007). Only the zones in the navigational channel of the Seine estuary under dredging and low salinity conditions were identified as disturbed (see Appendix A).
- The Algerian coastal bays and gulfs appear to have a good ecological quality at the end of the 1980s and the beginning of the 1990s (High and Good ECoQS, Fig. 3), so the sampling sites from this period could be used later as reference sites as suggested by Bakalem et al. (2009) and Grimes et al. (2010).
- The presence of high abundances of tolerant species in estuarine conditions makes it difficult to differentiate polluted areas, like in the 'Rivière de Morlaix' site (Bay of Morlaix) where the polychaete *Chaetozone gibber*, dominant in 'normal conditions', hides the effect of the Amoco Cadiz oil spill (Dauvin, 2000). In fact, such transitional environments constitute variable ecosystems that are naturally organically rich (permanently Moderate to Poor ECoQS, see Appendix A), and thus the biota is similar to anthropogenically organically rich areas. This observation was the catalyst for the concept of 'estuarine quality paradox' (Dauvin, 2007; Elliott and Quintino, 2007): 'the dominant estuarine community is adapted to and reflects the high spatial and temporal variability of highly naturally-stressed areas. This community has features very similar to those found in anthropogenically stressed areas, thus making it difficult to detect anthropogenically induced stress in estuaries'. Because of this, there is a danger that any indicators based on these features and used to plan environmental improvements will be flawed.
- The existing indicators are not sensitive to identify the effects of oil spills on benthic communities. For example, all the temporal observations after the Aegean spill in Galicia were classified as High and Good (Fig. 3) in spite of hydrocarbons in the sediment (Gomez Gesteira and Dauvin, 2005). In both oil spills– the Amoco Cadiz off the northern coast of Brittany in France and the Aegean Sea off the Ares-Betanzos Ria in Galicia in northwest Spain – the main effects on soft-bottom fine muddy fine sand communities were the disappearance of the sensitive amphipod species, especially the species of the genus *Ampelisca*, due to hydrocarbon toxicity (Dauvin, 1998, 2000; Gomez Gesteira and Dauvin, 2005). Just after the spill, some *Ampelisca* specimens survived in the communities that had high species richness and abundance values (Dauvin, 2000). There were very limited increases in opportunistic species, except in the Bay of Morlaix, where the opportunistic polychaeta *Pseudopolydora pulchra* proliferated in 1982, four years after the spill. Moreover, this peak of abundance was identified only for a very short summer period, which demonstrated that surveys following oil spills must be designed with a suitably high yearly frequency (i.e., monthly or quarterly) and for a sufficiently long period of time after a spill. The recovery time of soft-bottom communities after an oil spill is about 7–10 years (Dauvin, 1998, 2010).
- Shannon $H'$ diversity index is not sensitive for detecting all stressed or polluted environments. In this study, it was too sensitive to species richness and to total abundances in the samples. In the case of the Pierre Noire site, $H'$ was relatively low before the spill (2.2–2.3, which corresponds to a Moderate status), increased just after the spill to reach 3.7–4.9, which corresponds Good and High status, and then decreased dramatically during the summer peak of the polychaete *Pseudopolydora pulchra* (1.13 in August 1982, Poor Status, Appendix A). At *Rivière de Morlaix*, $H'$ remained ineffective due to the dominance of the tolerant *Chaetozone gibber* species, while in the Ares-Betanzos Ria (Galicia in northwest Spain), $H'$ always had elevated values (3.8–5.4), which correspond to Good and High Status.

The question of the Ecological Quality Status of benthic communities has been associated to an Ecological Quality Ratio (i.e., the ratio between the quality observed in a site and a reference site). Discussed by Borja and Muxika (2005) and Muxika et al. (2007), these reference sites are not easy to determine, especially in stressed environments such as harbours and transitional waters. Often, the 'best' sample in terms of species richness and the Shannon $H'$ diversity index are selected as a reference (Grimes et al., 2010). It is unambiguous that observations before a stress, such as in the case of the Amoco Cadiz oil spill (Dauvin, 1998, 2000), permit the effect of a disturbance to be measured.

The accumulated data for along the North-Atlantic coast and along the Algerian coast in the western Mediterranean Sea (Bakalem et al., 2009; Grimes et al., 2010) guarantee the knowledge of the benthic status at a certain period but do not necessarily represent a reference status without human activities. In fact, most of the coastal and transitional waters have been subjected to anthropogenic influence for more than one century, and it is very difficult and probably impossible to find any marine coast that has not been influenced by man. Long-term survey of some benthic sites would also insure very interesting information about the resistance and resilience of communities and measurements of the range of the natural climatic fluctuations of coastal ecosystems. Such data are often necessary to measure precisely the impact of pollution (Dauvin, 2010).

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. Despite this lack of expertise, they continue to establish extensive lists of species for those paying for the study (Dauvin, 2005). Using the Taxonomic Sufficiency (TS) concept can reduce errors in assigning the EcoQS, especially if ecological groups are used, as in AMBI (Dauvin et al., 2010). Both BOPA and BO2A (Dauvin and Ruellet, 2007, 2009) use the TS concept and can be employed in coastal and estuarine environments with success. Using only the ratio between amphipods and opportunistic annelids, BO2A is a good alternative when the level of identification of the species is doubtful.

In conclusion, it appears that chosen biotic indices privilege the identification of species resistant and tolerant to anthropogenic disturbance and gave, apart ITI, similar ECoQS. They were good agreements and correlations between themselves, but also with the percentages of sentinel species and Best Professional Judgement. Whether developed 'objectively' or 'subjectively', the indices serve only to reinforce this disturbance phenomenon, which contributes to highlighting the species that resist the disturbances (Dauvin et al., 2010). The existing approaches to assess the EcoQS remained perfectible, including subjective ones. So, for the future, we encourage the research consultancies that are mostly responsible for assessing benthic quality in numerous impact studies to use simple pragmatic methods. When the EcoQS of a benthic community is assessed, the question is neither to identify the biodiversity of this community, nor to furnish elements about the benthic ecosystem functioning. Clearly, Best Professional Judgement and Taxonomic Sufficiency should be encouraged in such diagnostic approaches.

## Acknowledgments

The authors thank all the persons who participated in collecting and sorting benthic invertebrates, as well as Dr. Angel Borja (AZTI Tecnalia) for providing access to the Excel software sheet used to compute the Kappa analysis results. This research is a part of Jean-Claude Dauvin's contribution on the benthic indices for the BEEST LITEAU project, funded by the French Ministry of Ecology, Energy, Sustainable Development and Sea (MEEDDM) and the three regional Water Agencies: *Seine Normandie*, *Bretagne-Pays de Loire* and *Adour Garonne*. The authors thank the three reviewers for their very useful comments and suggestions on the first version of this paper.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ecolind.2011.03.019.

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