Available online at www.sciencedirect.com
ScienceDirect
Marine Pollution Bulletin 55 (2007) 215–224
MARINE POLLUTION BULLETIN
www.elsevier.com/locate/marpolbul

Polychaete/amphipod ratio revisited

J.C. Dauvin *, T. Ruellet

Station Marine de Wimereux, Université des Sciences et Technologies de Lille, FRE CNRS 2816 ELICO, 28 Avenue Foch, BP 80, 62930 Wimereux, France
GIP Seine-Aval, 12 Avenue Aristide Briand, 76000 Rouen, France

Abstract

In this paper, we reexamine the opportunistic polychaete/amphipod ratio, modifying it to allow estuarine and coastal communities to be divided into the five classes suggested by the European Water Framework Directive (WFD). The resulting biological index, called the BOPA index, considers the total number of individuals collected in the samples, the frequency of opportunistic polychaetes, and the frequency of amphipods (except the genus *Jassa*). After comparing this new index to AMBI and BENTIX, two other indices that have been proposed in the literature, we tested it in two situations involving soft-bottom communities in the English Channel (Bay of Morlaix and Bay of Seine). Our results show that the BOPA index is simple to use. Amphipods and opportunistic polychaetes (21 species, nine genus and two families from the AZTI list for a total of 3459 taxa) are easy to identify, providing that both the number of these organisms in a sample and the total number of individuals collected (independent of the sampling surface) is known. The BOPA is appropriate for use in the poorest communities whose total number of individuals exceeds 20 individuals.

Keywords: Benthic indicators; Opportunistic polychaetes; Amphipods; BOPA index; AMBI; BENTIX; English Channel

1. Introduction

The implementation of the European Water Framework Directive (WFD, 2000/06/EC) has provoked a huge debate about the use of benthic bio-indicators and indices to determine the quality of European coastal and estuarine (transitional) water masses, according to Ecological Quality Status (EcoQ) (see Borja et al., 2000, 2003, 2004a,b; Borja and Heinrich, 2005; Simboura and Zenetos, 2002; Simboura, 2004; Simboura et al., 2005). Two of the more recent quality indices—AMBI (AZTI, Borja et al., 2000) and BENTIX (Simboura and Zenetos, 2002)—require classifying soft benthic species into previously defined ecological groups (see Pearson and Rosenberg, 1978; Grall and Glémarec, 1997) as well as knowing the respective proportion of these different groups in the communities (or samples). In fact, all of the recent indices require knowledge of the relative abundances of sensitive species faced with increased organic sedimentary matter and those of the non-sensitive opportunistic species—resistant, indifferent or favored—that proliferate in such organically enriched sedimentary matter. Among the sensitive species, crustaceans, especially amphipods, form a particularly sensitive zoological group, not only to significant increases in organic matter but also to increases in other kinds of pollution including metals and hydrocarbons (Dauvin, 1987, 1998). Several families, such as Ampeliscidae, Pontoporeidae, Melitidae and Gammaridae, are greatly affected by hydrocarbons and can disappear completely given a large oil spill, for example (Dauvin, 1987, 1998, 2000).

In an earlier paper, Gomez Gesteira and Dauvin (2000) tested a variety of species ratios (polychaetes/crustaceans, opportunistic polychaetes/crustaceans, and opportunistic polychaetes/amphipods) in an effort to identify the most efficient abundances ratio for determining the impact of oil spills on soft-bottom communities. According to their results, the most efficient ratio was $\log[(\text{opportunistic polychaetes}/(\text{amphipods}+1))+1]$, which varied from $\leqslant 1$, given a relative absence of pollution, to >1 in stations

* Corresponding author.
E-mail address: jean-claude.dauvin@univ-lille1.fr (J.C. Dauvin).

0025-326X/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2006.08.045

subjected to high levels of pollution, where the amphipods disappeared completely. Similar research has been done to identify the effects of pollution on the meiobenthos, with Raffaelli and Mason (1981) suggesting the use of a nematode/copepod ratio (N/C ratio).

Nikitik and Robinson (2003) used the opportunistic polychaete/amphipod ratio as an indicator when studying the effects of the 'Sea Empress' oil spill in the Milford Haven waterway (UK). However, they used the formula log[opportunistic polychaetes/(amphipods + 1)], without the additional +1 in the calculation of the ratio. Therefore, the ratio sometimes produces negative values. This variation was probably due to a certain ambiguity in the original publication (Gomez Gesteira and Dauvin, 2000) with regard to the +1 used to prevent a total absence of amphipods and the other +1 used to prevent a total absence of opportunistic polychaetes. This opportunistic polychaete/amphipod ratio produces results that vary between a minimum value of 0 and a maximum value that can exceed 10.

In this paper, we propose to reexamine the opportunistic polychaete/amphipod ratio, modifying it so that it can be used to assign estuarine and coastal communities to the five EcoQ (ECOlogical Quality Status) classes suggested by the WFD: *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. We compared this modified ratio, called the benthic opportunistic polychaetes amphipods index (BOPA), to the recently proposed AMBI (Borja et al., 2000) and BENTIX (Simboura and Zenetos, 2002) indices, which are based on a theoretical model of successive species, ranked according to their sensitivity to a gradient of organic pollution. The ecological status of an area is not only lied at the organic matter content. We then tested our BOPA index by studying the ecological quality of several soft-bottom communities in the English Channel, one of which had been subjected to hydrocarbon pollution, while others had been subjected heavy river discharge.

2. Materials and methods

2.1. Indices used

The proportions of the five ecological groups (EG) provided by the AZTI laboratory's regularly updated list (October 2005; www.azti.es) were used to calculate the AMBI index (Borja et al., 2000; Borja and Muxika, 2005):

$$\mathrm{AMBI} = 0\mathrm{EG}_1 + 1.5\mathrm{EG}_2 + 3\mathrm{EG}_3 + 4.5\mathrm{EG}_4 + 6\mathrm{EG}_5$$

These EG are ranked according to their sensitivity to an increasing stress gradient: EG_1 (species very sensitive to organic matter enrichment), EG_2 (species indifferent to enrichment), EG_3 (species tolerant to excess organic matter enrichment), EG_4 (second-order opportunistic species favored by excess organic matter enrichment) and EG_5 (first-order opportunistic species favored by excess organic enrichment). The results of the AMBI calculation can vary between 0 (high ecological status) and 7 (bad ecological status) (Borja et al., 2003).

To calculate the BENTIX index (Simboura and Zenetos, 2002), the same groups were used, but were proportioned differently. EG_1 and EG_2 were placed in one group G_I, and EG_3, EG_4, and EG_5 were placed in a second group G_{II}, and the calculation was $\mathrm{BENTIX} = 6G_I + 2G_{II}$. The results for the BENTIX index can either be equal to 0 (bad ecological status) or can vary between 2 (poor ecological status) and 6 (high ecological status).

Both the AMBI and BENTIX indices require a major taxonomic classification effort, which is contrary to the principle of "taxonomic sufficiency" (Ellis, 1985; Dauvin et al., 2003) that recommends reducing the classification effort by considering only those taxonomic categories higher than species when appropriate. Clearly, identifying amphipods to the species level is not necessary when calculating AMBI or BENTIX since all of these organisms have the same sensitivity to increased organic matter, with the exception of one genus (*Jassa*). In fact, excepting *Jassa*, all amphipods belong to AZTI's EG_1 group, and all opportunistic polychaetes belong to the groups EG_4 and EG_5 (see www.azti.es). Thus, in accordance with the taxonomic sufficiency principle, we propose to exploit the opportunistic polychaete/amphipod ratio to determine ecological quality, using relative frequencies ([0; 1]) rather than abundances ([0; +∞[) in order to define the limits of the index.

Our new index, the *benthic opportunistic polychaetes amphipods index* is written:

$$\text{BOPA index} = \log\left(\frac{f_P}{f_A + 1} + 1\right),$$

where f_P is the opportunistic polychaete frequency (ratio of the total number of opportunistic polychaete individuals to the total number of individuals in the sample); f_A, the amphipod frequency (ratio of the total number of amphipod individuals excluding the opportunistic *Jassa* amphipods to the total number of individuals in the sample); and $f_P + f_A \leqslant 1$. The two "+1" terms (without unit) in the equation are needed in order (1) to allow the division operation to be completed even when f_A is null, and (2) to prevent the eventuality that a log of zero (which does not exist) would need to be calculated if f_P is null. The BOPA index is null only when there are no opportunistic polychaetes, indicating an area with a very low amount of organic matter. The index is low when the environment is good, with few opportunistic species; and it increases as increasing organic matter degrades the environment. Its value can vary between 0 (when $f_P = 0$) and log 2 (ca. 0.30103, when $f_A = 0$) because:

$$f_P = [0;1] \quad \text{and} \quad f_A = [0;1]$$
$$(f_A + 1) = [1;2]$$
$$\frac{f_P}{f_A + 1} = [0;1]$$
$$\left(\frac{f_P}{f_A + 1} + 1\right) = [1;2]$$
$$\text{BOPA index} = [0; \log 2]$$