

Do Benthic Indicator Tools Respond to All Impact Sources? The Case of AMBI (AZTI Marine Biotic Index)

Á. Borja* and I. Muxika

AZTI Foundation; Marine Environment Unit, Herrera Kaia, Portualdea s/n; 20110 Pasaia, Spain

*E-mail: aborja@pas.azti.es

Key words: benthic indicators, AMBI, opportunistic species, sensitive species, environmental impact.

In the last years the interest on benthic indicators has increased dramatically, with a long list of new indicators proposed (see Diaz *et al.*, 2004, for a revision). One of them, the AMBI, was designed to establish the ecological quality of European coasts, investigating the response of soft-bottom communities to natural and man-induced changes in water quality (Borja *et al.*, 2000, 2003a). Hence, the AMBI offers a ‘pollution classification’ of a particular site, representing the benthic community ‘health’ (sensu Grall and Glémarec, 1997). The AMBI is based upon ecological models, such as those of Glémarec & Hily (1981) and Hily (1984). The theoretical basis is that of the ecological adaptative strategies of the r, k and T (McArthur & Wilson, 1967; Pianka, 1970; and Gray, 1979) and the progressive steps in stressed environments (Bellan, 1967; Pearson & Rosenberg, 1978; and Salen-Picard, 1983). Most of the concepts developed within the AMBI are based upon previous proposals, for example: (i) the species should be classified into five ecological groups (following several authors, such as Leppäkoski (1975), Glémarec & Hily (1981), and Grall & Glémarec (1997)); and (ii) with a scale introduced, from 0 to 7, based upon Hily (1984), Hily *et al.* (1986) and Majeed (1987).

However, the most novel contribution of the AMBI was the formula permitting the derivation of a series of continuous values (Borja *et al.*, 2000). Hence, taking into account the final objective of the proposal, several thresholds in the scale of the AMBI were established; those were based upon the proportions amongst the five ecological groups (see Fig. 2, in Borja *et al.*, 2000). These thresholds are coincident with the benthic community health proposed by Grall & Glémarec (1997) (see Table 1, in Borja *et al.*, 2000), whose sources can be found in Reish (1959), Bellan (1967) and Pearson & Rosenberg (1976). Further, the AMBI has been applied in the assessment of the ‘Ecological Status’, under the European Water Framework Directive (see Borja *et al.*, 2003b; 2004a; 2004b). In this particular case, these authors recommend the use of AMBI only as a part of a set of measures and indices (a multimetric approach), such as diversity, richness, etc., in order to minimize misclassification problems.

The AMBI has been verified successfully in relation to a very large set of environmental impact sources, including drill cutting discharges, submarine outfalls, harbour and dyke construction, heavy metal inputs, eutrophic processes, engineering works, diffuse pollutant inputs, recovery in polluted systems under the impact of sewerage schemes, dredging processes, mud disposal, sand extraction, oil spills, fish farming, etc. (see Table 1). On the other hand, the geographical areas where it has been applied extend over the Atlantic Sea, Baltic Sea, Mediterranean Sea, North Sea, Norwegian Sea, all in Europe, but also in Hong Kong, Uruguay and Brazil (see Table 1).

Table 1. *Different impact sources and geographical areas for which AMBI has been applied in recent years. Key: p.c. = personal communication.*

| Impact Sources | Locations (Countries) | Seas | Author |
|--|----------------------------|-------------------|---|
| Various sources along UK | (United Kingdom) | Atlantic Ocean | A. Miles, A. Prior (p.c., 2003) |
| Outfall and harbour | Brittany (France) | | Borja <i>et al.</i> , 2003a |
| Engineering works (dyke) | Basque Country (Spain) | | Borja <i>et al.</i> , 2000, 2003a |
| Sewerage works | Basque Country (Spain) | | Borja <i>et al.</i> , 2000, 2003a; Gorostiaga <i>et al.</i> , 2004) |
| Harbour construction | Basque Country (Spain) | | Muxika <i>et al.</i> , 2005 |
| Submarine outfall | Basque Country (Spain) | | Borja <i>et al.</i> , 2000; 2003b |
| Harbour and river inputs | Basque Country (Spain) | | Muxika <i>et al.</i> , 2003 |
| Various sources | Tejo estuary (Portugal) | | M.J. Gaudencio (p.c., 2003) |
| Eutrophy | Mondego estuary (Portugal) | | Salas <i>et al.</i> , 2004 |
| River inputs | Guadalquivir (Spain) | | AZTI (unpublished data) |
| Heavy metals | Huelva (Spain) | | Borja <i>et al.</i> , 2003a |
| Estuarine inputs | Cádiz (Spain) | | A. Rodríguez-Martín (p.c., 2003) |
| Various sources | (Morocco) | | H. Bazairi (p.c., 2003) |
| Various sources | (Brazil, Uruguay) | | Muniz <i>et al.</i> , in press |
| Various sources | Latvia | Baltic Sea | V. Jermakovs (p.c., 2004) |
| Anoxia-hypoxia | Sweden | | Muxika <i>et al.</i> , 2005 |
| Dredging mud disposal | Sweden | | S. Smith (p.c., 2003) |
| Various sources along Sweden | Sweden | | M. Blomqvist (p.c., 2003) |
| Various sources in a lagoon | Smir (Morocco) | Mediterranean Sea | A. Chaouti (p.c., 2003) |
| Dredging in harbour | Ceuta (Spain) | | Muxika <i>et al.</i> , in press |
| Diffuse pollution (mines, agriculture,...) | Almeria and Murcia (Spain) | | Borja <i>et al.</i> , 2003a |
| Aquaculture cages | Murcia, Valencia (Spain) | | AZTI (unpublished data) |
| Mining debris | Mar Menor (Spain) | | L. Marín (p.c., 2004) |
| Submarine outfall | Catalonia (Spain) | | M.J. Cardell (p.c., 2003) |
| Marina | Catalonia (Spain) | | S. Pinedo (p.c., 2003) |
| Wastewater discharge in a lagoon | France | | G. Reimonenq (p.c., 2003) |
| Inputs to a coastal lagoon | Adriatic Sea (Italy) | | Caselli <i>et al.</i> , 2003 |
| Various sources | Adriatic Sea (Italy) | | Forni and Occhipinti Ambrogi, 2003 |
| Industrial and urban pollution | Port of Trieste (Italy) | | Solis-Weiss, <i>et al.</i> (in press) |
| Submarine outfall | Gulf of Trieste (Italy) | | Solis-Weiss (p.c., 2004) |
| Various sources | Adriatic Sea (Italy) | | R. Simonini (p.c., 2004) |
| Submarine outfall | Saronikos Gulf (Greece) | | Borja <i>et al.</i> , 2003a |
| Aquaculture cages | 3 locations (Greece) | | Muxika <i>et al.</i> , in press |
| River inputs | Thames (United Kingdom) | North Sea | M. Davison (p.c., 2002) |
| Oil-based drilling muds (oil platforms) | 11 locations (UK) | | Muxika <i>et al.</i> , 2005 |
| Impacts on sandy shores | (Netherlands) | | S. Mulder (p.c., 2003) |
| Dredged sediment dumping | (United Kingdom) | | H. Rees (p.c., 2004) |
| Ester-based drilling muds (oil platforms) | North Sea (Netherlands) | | Borja <i>et al.</i> , 2003a |
| Re-opening of brackish lake to sea | Veerse Meer (Netherlands) | | V. Escaravage (p.c., 2004) |
| Sand extraction | Belgium | | Bonne <i>et al.</i> , 2003; Muxika <i>et al.</i> , 2005 |
| Dredged sediment dumping | Hong-Kong (China) | | Nicholson and Hui, 2003 |

Although the AMBI is particularly useful in detecting time and spatial impact gradient, its robustness could be reduced when only a very low number of taxa (1 to 3) and/or individuals are found in a sample. The same could occur when studying low-salinity locations (e.g. the very inner part of the estuaries), naturally-stressed locations (e.g. naturally organic matter enriched bottoms), or some particular impacts (e.g. sand extraction, some locations under dredged sediment dumping,

or physical impact). For problems associated with the use of AMBI, see Borja *et al.* (2004b), and the protocol for the use of AMBI contained in the free-ware software for its calculation (www.azti.es). In the above mentioned particular cases Borja *et al.* (2004b) recommend the use of AMBI, together with other metrics, in order to obtain a more comprehensive view of the benthic community, being also recommended a more detailed analysis and discussion of the results.

References

- Bellan, G., 1967. Pollution et peuplements benthiques sur substrat meuble dans la région de Marseille. 1 Partie. Le secteur de Cortiu. *Revue Internationale d'Océanographie Médicale*, VI-VII: 53-87.
- Bonne, W., Rekecki, A., Vincx, M., 2003. Chapter IV: Impact assessment of sand extraction on subtidal sandbanks using macrobenthos. In: *Benthic copepod communities in relation to natural and anthropogenic influences in the North Sea*. Ph.D. Thesis of W. Bonne, Ghent University, Biology Department, Marine Biology Section, Belgium, 207-226 p.
- Borja, A., Franco, J., Pérez, V., 2000. A Marine Biotic Index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. *Marine Pollution Bulletin*, **40**(12): 1100-1114.
- Borja, Á., Muxika, I., Franco, J., 2003a. The application of a Marine Biotic Index to different impact sources affecting soft-bottom benthic communities along European coasts. *Marine Pollution Bulletin*, **46**: 835-845.
- Borja, Á., Franco, J., Muxika, I., 2003b. Classification tools for marine ecological quality assessment: the usefulness of macrobenthic communities in an area affected by a submarine outfall. *ICES CM 2003/Session J-02*, Tallinn (Estonia), 24-28 September, 2003.
- Borja, Á., Franco, J., Valencia, V., Bald, J., Muxika, I., Belzunce, M.J., Solaun, O., 2004a. Implementation of the European water framework directive from the Basque country (northern Spain): a methodological approach. *Marine Pollution Bulletin*, **48**: 209-218.
- Borja, Á., Franco, J., Muxika, I., 2004b. The biotic indices and the Water Framework Directive: the required consensus in the new benthic monitoring tools. *Marine Pollution Bulletin*, **48**: 405-408.
- Casselli, C., Ponti, M., Abbiati, M., 2003. Valutazione della qualità ambientale della laguna costiera Pialassa Baiona attraverso lo studio dei suoi popolamenti bentonici. *XIII Congresso Società Italiana de Ecologia, Como, Villa Olmo, 8-10 Settembre 2003*, poster.
- Diaz, R.J., Solan, M., Valente, R.M., 2004. A review of approaches for classifying benthic habitats and evaluating habitat quality. *Journal of Environmental Management*, **73**: 165-181.
- Forni, G., Occhipinti Ambrogi, A., 2003. Applicazione del coefficiente biotico (Borja *et al.*, 2000) alla comunità macrobentonica del Nord Adriatico. Meeting of the Italian Society of Marine Biology, Tunisia, June 2003.
- Glémarec, M., Hily, C., 1981. Perturbations apportées à la macrofaune benthique de la baie de Concarneau par les effluents urbains et portuaires. *Acta Oecologica Oecologia Applicata*, **2**: 139-150.
- Gorostiaga, J.M., Borja, Á., Díez, I., Francés, G., Pagola-Carte, S., Sáiz-Salinas, J.I., 2004. Recovery of benthic communities in polluted systems. In: Á. Borja, M. Collins Eds. *Oceanography and Marine Environment of the Basque Country, Elsevier Oceanography Series*, Elsevier, Amsterdam **70**: 549-578.

- Grall, J., Glémarec, M., 1997. Using biotic indices to estimate macrobenthic community perturbations in the Bay of Brest. *Estuarine, Coastal and Shelf Science*, **44(suppl. A)**: 43-53.
- Gray, J.S., 1979. Pollution-induced changes in populations. *Philosophical Transactions of the Royal Society of London, Series B*, **286**: 545-561.
- Hily, C., 1984. *Variabilité de la macrofaune benthique dans les milieux hypertrophiques de la Rade de Brest*. Thèse de Doctorat d'Etat, Univ. Bretagne Occidentale. Vol. 1: 359 pp., Vol. 2: 337 pp.
- Hily, C., Le Bris, H., Glémarec, M., 1986. Impacts biologiques des émissaires urbains sur les écosystèmes benthiques. *Oceanis*, **12**: 419-426.
- Leppäkoski, E., 1975. Assessment of degree of pollution on the basis of macrozoobenthos in marine brackish-water environments. *Acta Academiae Aboensis, Ser. B*, **35(2)**: 1-96.
- Majeed, S.A., 1987. Organic matter and biotic indices on the beaches of North Brittany. *Marine Pollution Bulletin*, **18(9)**: 490-495.
- McArthur, R.H., Wilson, E.O., 1967. *The theory of island biogeography*. Princeton University Press, Princeton, USA.
- Muniz, P., Venturini, N., Pires-Vanin, A.M.S., Tommasi, L.R., Borja, A., in press. Testing the applicability of a Marine Biotic Index (AMBI) for assessing the ecological quality of soft-bottom benthic communities in the South America Atlantic region. *Marine Pollution Bulletin*.
- Muxika, I., Borja, Á., Franco, J., 2003. The use of a biotic index (AMBI) to identify spatial and temporal impact gradients on benthic communities in an estuarine area. *ICES CM 2003/Session J-01*, Tallinn (Estonia), 24-28 September, 2003.
- Muxika, I., Borja, Á., Bonne, W., 2005. The suitability of the marine biotic index (AMBI) to new impact sources along European coasts. *Ecological Indicators*, **5**: 19-31.
- Nicholson, S., Hui, Y.H., 2003. *Ecological monitoring for uncontaminated mud disposal investigation. First monitoring report, East of Ninepins*. Civil Engineering Department, Fill Management Division, The Government of Hong Kong Special Administrative Region, Mouchel Asia Environment, 34 pp. + annexes. Unpublished Report.
- Pearson, T., Rosenberg, R., 1976. A comparative study of the effects on the marine environment of wastes from cellulose industries in Scotland and Sweden. *Ambio*, **5**: 77-79.
- Pearson, T., Rosenberg, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Review*, **16**: 229-311.
- Pianka, E.R., 1970. On r- and K- selection. *American Naturalist*, **104(940)**: 592-597.
- Reish, D.J., 1959. An ecological study of pollution in Los Angeles-Long Beach harbors, California. *Allan Hancock Foundation Publications*, occasional paper, 22: 117 pp.
- Salas, F., Borja, A., Marques, J.C., 2004. Evaluation of the applicability of a marine biotic index to characterise the status of estuarine ecosystems: the case of Mondego estuary (Portugal). *Ecological Indicators*, **4**: 215-225.
- Salen-Picard, C., 1983. Schémas d'évolution d'une biocénose macrobenthique du substrat meuble. *Comptes Rendus de l'Académie des Sciences de Paris*, **296**: 587-590.
- Solís-Weiss, V., Aleffi, F., Bettoso, N., Rossin, P., Orel, G., Fonda-Umani, S., 2004. Effects of industrial and urban pollution on the benthic macrofauna in the Bay of Muggia (industrial port of Trieste, Italy). *Science of the Total Environment*, **328**: 247-263.