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

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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 *et al.*, 2003a
Engineering works (dyke)	Basque Country (Spain)		Borja *et al.*, 2000, 2003a
Sewerage works	Basque Country (Spain)		Borja *et al.*, 2000, 2003a; Gorostiaga *et al.*, 2004)
Harbour construction	Basque Country (Spain)		Muxika *et al.*, 2005
Submarine outfall	Basque Country (Spain)		Borja *et al.*, 2000; 2003b
Harbour and river inputs	Basque Country (Spain)		Muxika *et al.*, 2003
Various sources	Tejo estuary (Portugal)		M.J. Gaudencio (p.c., 2003)
Eutrophy	Mondego estuary (Portugal)		Salas *et al.*, 2004
River inputs	Guadalquivir (Spain)		AZTI (unpublished data)
Heavy metals	Huelva (Spain)		Borja *et al.*, 2003a
Estuarine inputs	Cádiz (Spain)		A. Rodríguez-Martín (p.c., 2003)
Various sources	(Morocco)		H. Bazairi (p.c., 2003)
Various sources	(Brazil, Uruguay)		Muniz *et al.*, in press
Various sources	Latvia	Baltic Sea	V. Jermakovs (p.c., 2004)
Anoxia-hypoxia	Sweden		Muxika *et al.*, 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 *et al.*, in press
Diffuse pollution (mines, agriculture,...)	Almería and Murcia (Spain)		Borja *et al.*, 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 *et al.*, 2003
Various sources	Adriatic Sea (Italy)		Forni and Occhipinti Ambrogi, 2003
Industrial and urban pollution	Port of Trieste (Italy)		Solis-Weiss, *et al.* (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 *et al.*, 2003a
Aquaculture cages	3 locations (Greece)		Muxika *et al.*, in press
River inputs	Thames (United Kingdom)	North Sea	M. Davison (p.c., 2002)
Oil-based drilling muds (oil platforms)	11 locations (UK)		Muxika *et al.*, 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 *et al.*, 2003a
Re-opening of brackish lake to sea	Veerse Meer (Netherlands)		V. Escaravage (p.c., 2004)
Sand extraction	Belgium		Bonne *et al.*, 2003; Muxika *et al.*, 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.

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