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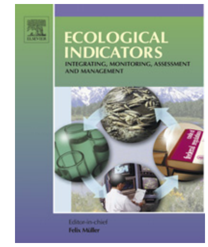

Assessing estuarine benthic quality conditions in Chesapeake Bay: A comparison of three indices

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ABSTRACT

Legislation in US and Europe has been adopted to determine the ecological integrity of estuarine and coastal waters, including, as one of the most relevant elements, the benthic macroinvertebrate communities. It has been recommended that greater emphasis should be placed on evaluating the suitability of existing indices prior to developing new ones. This study compares two widely used measures of ecological integrity, the Benthic Index of Biotic Integrity (B-IBI) developed in USA and the European AZTI's Marine Biotic Index (AMBI) and its multivariate extension, the M-AMBI. Specific objectives were to identify the frequency, magnitude, and nature of differences in assessment of Chesapeake Bay sites as 'degraded' or 'undegraded' by the indices. A dataset of 275 subtidal samples taken in 2003 from Chesapeake Bay were used in this comparison. Linear regression of B-IBI and AMBI, accounted for 24% of the variability; however, when evaluated by salinity regimes, the explained variability increased in polyhaline (38%), high mesohaline (38%), and low mesohaline (35%) habitats, remained similar in the tidal freshwater (25%), and decreased in oligohaline areas (17%). Using the M-AMBI, the explained variability increased to 43% for linear regression, and 54% for logarithmic regression. By salinity regime, the highest explained variability was found in high mesohaline and low polyhaline areas (53–63%), while the lowest explained variability was in the oligohaline and tidal freshwater areas (6–17%). The total disagreement between methods, in terms of degraded-undegraded classifications, was 28%, with high spatial levels of agreement. Our study suggests that different methodologies in assessing benthic quality can provide similar results even though these methods have been developed within different geographical areas.

1. Introduction

Assessment of the ecological integrity of benthic invertebrate communities in estuaries and coastal areas has progressed in recent years due in large part to legislation such as the 'Clean Water Act' in USA or the 'Water Framework Directive' (WFD) (Borja, 2005) and 'Marine Strategy Directive' (Borja, 2006) in Europe. Such policies, albeit broad in definition, explicitly recognize the link between fauna, flora and habitat, and require appropriate strategies for assessing the relative

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importance, status, or ecological integrity of water bodies. A plethora of tools and benthic indices have been developed for assessing such ecological integrity or status (see Díaz et al., 2004, for a review). The goal of all these indices is to reduce or summarize environmental conditions or quality to a number, which will form the basis for management decisions regarding environmental conditions.

The development of a benthic index should follow a logical path, similar to that of Weisberg et al. (1997): (i) defining criteria for degraded and undegraded sites based on non-biological measures such as bottom-water dissolved oxygen and sediment contaminant concentrations; (ii) identifying biological measures which respond to (and differ among) degraded and undegraded sites; (iii) adjusting these responses for habitat differences, if necessary; (iv) combining responsive measures into an index; and (v) validating the index using independent data. Indices formulated on ecological principles and properly validated will better communicate the complexity of ecological integrity. Benthic indices are especially relevant to management efforts because benthic invertebrates provide site-specific indicators of habitat conditions that integrate stress effects over time and over multiple types of stress (Gray, 1979), as highlighted by Ranasinghe et al. (2002).

Díaz et al. (2004) stated that there exists a tautological development of new indices, which appears to be endemic, self-propagating and rarely justified, and recommended that investigators place greater emphasis on evaluating the suitability of existing indices prior to developing new ones. A number of recent papers have compared different methodologies (Ranasinghe et al., 2002; Díaz et al., 2003; Reiss and Kröncke, 2005; Labrune et al., 2006; Quintino et al., 2006; Dauvin et al., 2007; Dauvin, 2007; Blanchet et al., 2008), but normally within the geographical area for which the indices were developed. There are also recent efforts to intercalibrate methodologies within the WFD, in order to obtain high levels of agreement in the final status classification (Reiss and Kröncke, 2005; Labrune et al., 2006; Borja et al., 2007). To our knowledge no comparison has been made between methods overseas. In this contribution we have selected for comparison two indices used within the geographical areas of Europe and USA. Of the indices studied by Díaz et al. (2004), 23% were European and 56% were developed for application in USA.

The Benthic Index of Biotic Integrity (B-IBI) developed in the USA by Weisberg et al. (1997) stratifies habitats based on benthic assemblage differences, identifies diagnostic metrics and thresholds based on the distribution of values at reference sites, and combines metrics into an index by a process that uses a simple scoring system that weights all measures equally. The B-IBI includes measures of species diversity, productivity, indicator species, and trophic composition. These measures vary with and are optimized for each habitat. The Shannon–Wiener index is the measure of diversity used, and both abundance and biomass are included in the productivity and indicator species measures. Similar measures have been successfully used in other benthic indices of biotic integrity in USA (e.g., Van Dolah et al., 1999; Llansó et al., 2002a,b).

In Europe, the AZTI's Marine Biotic Index (AMBI) developed by Borja et al. (2000) is based upon the proportion of species assigned to one of five levels of sensitivity to increasing levels of disturbance, from very sensitive to opportunist species. This index has been tested under different stress sources (e.g., Borja et al., 2003; Muxika et al., 2005) and has been applied not only in Europe, but also in Asia (Cai et al., 2003), northern Africa (Bazairi et al., 2005) and South America (Muniz et al., 2005). Although AMBI presents some weaknesses in the inner part of estuaries or when the number of species is very low (see Borja and Muxika, 2005), the recent addition of a multivariate species richness and Shannon diversity component to AMBI, called multivariate AMBI (M-AMBI; Muxika et al., 2007), has allowed for a broader application within the WFD. This method has been intercalibrated with other European methods (Borja et al., 2007).

The differences in approach and suites of measures included in different benthic indices leads to questions about whether the application of the various indices would yield different results (Ranasinghe et al., 2002). However, opportunities for comparison between indices are rare because it is unusual to have more than one benthic index available for any particular area. The availability of Chesapeake Bay (Fig. 1) benthic data used in the calculation of the B-IBI provided the opportunity to also apply and calculate AMBI for direct comparison of the two indices. Our specific objectives were to identify the frequency, magnitude, and nature of differences in assessment of Chesapeake Bay sites classified as 'degraded' or 'undegraded' by the B-IBI, AMBI, and M-AMBI.

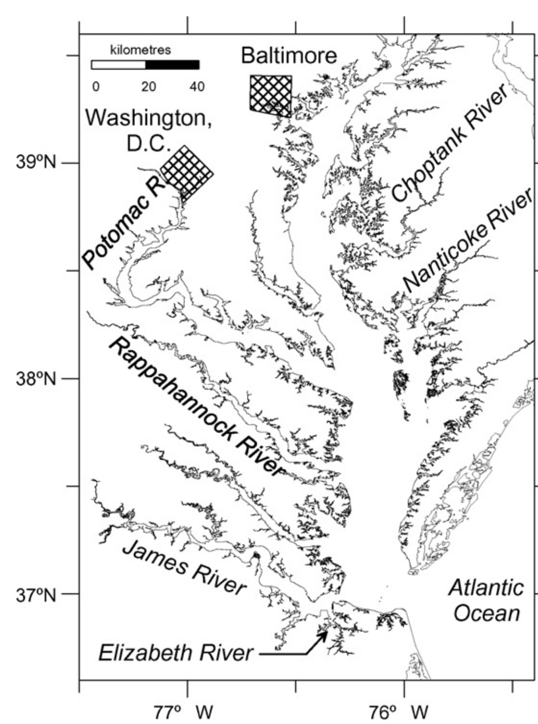

Fig. 1 – Study site in Chesapeake Bay, USA. Comparison among indices was made for 275 random sites sampled August–September 2003 by the Chesapeake Bay long-term benthic monitoring and the Elizabeth River biological monitoring programs.