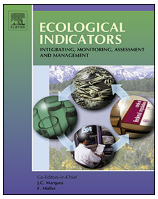
Ecological Indicators 91 (2018) 679–688

Contents lists available at ScienceDirect

Ecological Indicators

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



Original Articles

Assessing benthic ecological status under impoverished faunal situations: A case study from the southern Gulf of Mexico

Norma A. Santibañez-Aguascalientes[a,*], Ángel Borja[b], J. Gabriel Kuk-Dzul[a], Jorge L. Montero-Muñoz[a], Pedro-Luis Ardisson[a]

[a] *Departamento de Recursos del Mar, Cinvestav, Carretera antigua a Progreso, km 6, Apdo, Postal 73-Cordemex, 97310 Mérida, Yucatán, Mexico*
[b] *AZTI, Marine Research Division, Herrera Kaia Portualdea s/n, 20110 Pasaia, Spain*

ARTICLE INFO

Keywords:
AMBI
M-AMBI
Contaminants
Defaunation
Ecological status
Macroinfauna

ABSTRACT

Biological indices such as AZTI's Marine Biotic Index (AMBI) and multivariate AMBI (M-AMBI) have been used in monitoring programs worldwide to assess the benthic ecological status (ES) of transitional and coastal waters. However, their reliability is reduced under faunal impoverishment and defaunation, low abundance/number of taxa, and/or high percentage of taxa not assigned or mis-assigned to ecological group, which imply removing these data from the analysis. In order to avoid loss of robustness when these situations are met, here we propose an approach based on decision criteria that utilize these indices together with environmental and contaminants data. Our area of study is the southern Gulf of Mexico seafloor, where a survey was carried out during the rainy season across a sampling grid of 75 sites. To achieve this, we first distinguished homogeneous groups of sites and then defined states ('good', 'fair', and 'bad') from three sediment quality elements: benthic indices, environmental data by quartile values, and contaminant concentrations in the context of sediment quality guidelines. Overall, 69% of sampling sites showed low abundance and defaunation, mainly at sites located on the continental shelf, where most of them ranged from 'moderate' to 'poor' ES, principally by 'fair' environmental data and secondly, oil-related disturbance. Conversely, sites located near the mouths of rivers and coastal lagoons recorded the highest abundance and showed diverse sensitivity levels, ranging from 'high' to 'bad' ES. In conclusion, the use of this states-based approach allowed us to support and interpret the results of AMBI and M-AMBI, since their values were related to environmental and contaminants data. This approach may be useful in many contexts to avoid the loss of data when assessing the ES of the seafloor under defaunation or low abundance conditions.

1. Introduction

Macroinfauna species are often used as bioindicators of natural disturbance and anthropogenic pollution of aquatic systems (Borja et al., 2000). These organisms are used in monitoring programs because they are relatively sedentary, they have relatively long life-spans and they participate in cycling nutrients and transference of energy to top trophic levels (Pearson and Rosenberg, 1978; Rosenberg, 2001). Their ecological responses allow them to be classified in a range from sensitive to opportunistic species, and their abundances have been used in marine biotic indices aimed at assessing benthic community health. For example, one application is the Marine Biotic Index (AMBI) developed by AZTI (Borja et al., 2000) along with the multivariate AMBI application (M-AMBI) (Borja et al., 2004b; Muxika et al., 2007).

The European Water Framework Directive (WFD) includes AMBI and M-AMBI methodologies to assess the ecological status of macroinvertebrates in transitional and coastal waters, as well as other biological (e.g. phytoplankton, macroalgae, fishes), physicochemical (e.g. salinity, temperature, nutrients, dissolved oxygen, contaminants) and hydrodynamic (e.g. waves, tides) elements (Borja et al., 2009). Among the biological elements, macroinfauna is of major importance. If for example, macroinfauna has a 'moderate' status and the remainder of the elements have a 'high' status, the ecological status should be 'moderate', after the 'one out, all out' principle (Borja et al., 2003, 2004b). Part of this approach is used by Borja et al. (2009) as a decision-tree to integrate different elements into a unified ecological status assessment.

AMBI and M-AMBI are sensitive and representative indices (Borja et al., 2015), but their reliability is reduced under faunal impoverishment and defaunation situations, i.e. sediment samples with low abundance/number of taxa (1–3) and/or a high percentage of taxa not assigned (> 20%) or mis-assigned to an ecological group, which imply

---

[*] Corresponding author.
E-mail address: norma.santibanez@cinvestav.mx (N.A. Santibañez-Aguascalientes).

https://doi.org/10.1016/j.ecolind.2018.04.048
Received 21 November 2017; Received in revised form 9 March 2018; Accepted 20 April 2018

that sites with these characteristics must be removed from the analyses (Borja et al., 2004a; Borja and Muxika, 2005; Checon et al., 2018).

In some benthic areas that are naturally impoverished (i.e. coastal lagoons, dynamic beaches, oligohaline stretches), some authors (e.g. Dauvin, 2007; Munari and Mistri, 2008) have cautioned against the use of benthic indices, and alternate indices based on higher taxa have been proposed for use in such environments (Munari et al., 2009).

AMBI and M-AMBI have been considered as the most suitable biotic indices to assess ecological status, both in the southern (Granados-Barba et al., 2009; Domínguez-Castanedo, 2012) as in the northern Gulf of Mexico (Gillett et al., 2015; Pelletier et al., 2018). However, some areas have faunal impoverishment and even defaunation, which reduce the reliability of these indices. In order to avoid loss of data when calculating ecological status under these circumstances, the objective of this study was to develop an approach based on decision criteria considering benthic indices, environmental and contaminant data in a case study from the southern Gulf of Mexico (sGM).

2. Material and methods

2.1. Study area and sampling design

The study was carried out in the sGM between 18°9′29.99″–22°45′ N and 96°00′–88°00′ W (Fig. 1). The oceanographic features of this region are regulated by: (i) surface runoff into the southwestern Gulf of Mexico and ground water discharges in the Yucatan Peninsula area influence; (ii) the circulation pattern, which is dominated by wind conditions—during spring and summer the Lazo Current reaches maximum speed in a south to south-west direction, and during autumn and winter the flow reverts to a west-east direction; (iii) coastal upwelling from east of the Yucatan Peninsula, which is more intense during spring; and (iv) the sedimentological transition from calcareous to terrigenous sediments (Yáñez-Arancibia and Sánchez-Gil, 1983; Carranza-Edwards et al., 1993; Salas-de-León et al., 2008). The study area has rich primary productivity ($> 40.4\,\mathrm{mg\,C\,m^{-2}\,d^{-1}}$), high biodiversity and supports coastal resources valuable to fishing, tourism, and industrial and commercial activities, which are also the primary anthropogenic pressures. In fact, this region includes the largest oil fields in Mexico since the late 1970s, which cover an 8000 km^2 area from nearshore to offshore (García-Cuellar et al., 2004; Soto et al., 2014).

Data were collected during the Oceanographic Campaign 2012, conducted onboard the R/V Justo Sierra by PEMEX Exploración y Producción, Regiones Marinas and Cinvestav Unidad Mérida. A grid of 75 sampling sites was sampled from July to October 2012 (the rainy season) at a water depth ranging from 2 to 200 m (Fig. 1). Sediment samples were collected using a Hessler-Sandia box corer (40 × 40 × 60 cm) and a Smith-McIntyre grab (36 × 30.5 × 20 cm) depending on depth and sediment type. A single sampling unit was successfully obtained from each site via a sediment sampler descending vertically and penetrating deeply into the seabed. To analyze macroinfauna, the sediment content of the device was sub-sampled with the aid of three PVC cores, 10 cm in diameter and 5 cm long (0.0236 m^2). To analyze sediment characteristics (texture, redox potential and organic carbon) and contaminants (lead and hydrocarbons), sediment subsamples were collected directly from the surface (5 cm) via the box corer sediment column. The redox potential was recorded *in situ* by platinum electrodes and a potentiometer, while sediment samples for texture, organic carbon and contaminants were placed in high-density polythene (HDPE) bags and kept at 4 °C. Organisms were relaxed with 10% $MgCl_2$ and fixed with 4% formalin.

2.2. Laboratory analyses

Sediment texture (sand, clay, silt and carbonates) was analyzed by the hydrometer and pipette method (Buchanan, 1984). The organic carbon content was quantified onboard by wet oxidation with dicromate/H_2SO_4 and back titration of the excess with Fe SO_4^{11} (Buchanan, 1984). Hydrocarbon sediment samples were separated and quantified by gas chromatography with alum oxide and silica gel in a Hewlett Packard 3365 Series II chromatograph after Wade et al. (1993). Four hydrocarbon fractions were measured: total hydrocarbons (TH), polycyclic aromatic hydrocarbons (PAHs), low molecular weight polycyclic aromatic hydrocarbons (LMW PAHs) and high molecular weight polycyclic aromatic hydrocarbons (HMW PAHs); and two priority HMW PAHs: benzo[*a*]anthracene (BaA) and dibenzo[*a,h*]anthracene (DBA). Lead (Pb) sediment samples were extracted by centrifuges and filters systems following the APHA technique (American Public Health Association, 1985) and were quantified by atomic absorption spectrophotometer (Perkin Elmer TM SIMAA 6100).

Sediment samples with macroinfauna were passed through a

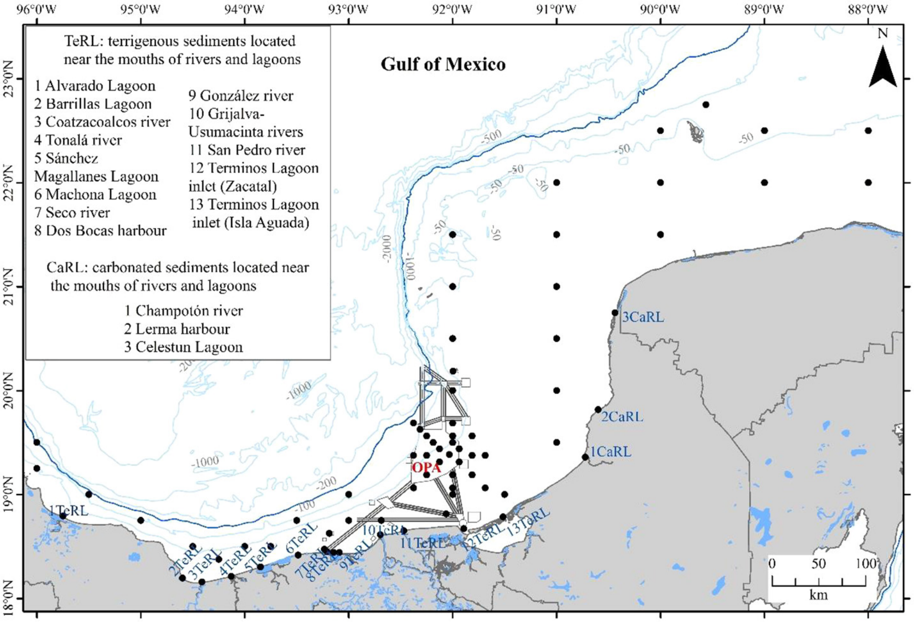


Fig. 1. Sampling sites in the southern Gulf of Mexico. The coastal sites represent the principal river discharges and lagoons of the region (oil production area, OPA; bold blue line shows 200 m isobath). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)