Ecological Indicators 67 (2016) 380–390

Contents lists available at ScienceDirect

Ecological Indicators

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

Benthic quality assessment in a naturally- and human-stressed tropical estuary

J. Feebarani [a], T.V. Joydas [b,*], R. Damodaran [a], A. Borja [c]

[a] Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, Cochin 16, Kerala, India
[b] Center for Environment and Water, Research Institute, King Fahd University of Petroleum and Minerals, P.B. No. 1995, Dhahran 31261, Saudi Arabia
[c] AZTI-Tecnalia, Marine Research Division, Herrera Kaia, Portualdea z/g, 20110 Pasaia, Spain

ARTICLE INFO

Article history:
Received 21 December 2015
Received in revised form 26 February 2016
Accepted 2 March 2016
Available online 25 April 2016

Keywords:
Benthic invertebrate community
Quality assessment
AMBI
M-AMBI
Cochin Estuary
Arabian Sea

ABSTRACT

Cochin estuary, one of the largest tropical estuaries of India, supports high levels of human pressure throughout the year and natural stress during monsoon season. Six stations were monitored between 2002 and 2004 covering the pre-monsoon, monsoon, and post-monsoon seasons. Ecological status of macrobenthos was assessed using the AZTI's Marine Biotic Index (AMBI) and the multivariate-AMBI (M-AMBI). The overall 'moderate' disturbance classification (according to AMBI) and 'moderate-poor' ecological status (according to M-AMBI) indicate that the macrobenthos in the estuary experiences stress. There was a gradient of increasing quality from the most degraded northern site to the main estuary, downstream. Monsoon caused further reductions in quality of macrobenthos in the main estuary, while the degraded northern station showed improvement in 2003, when the monsoon was strong. The assessment of the Cochin Estuary using AMBI and M-AMBI indicates where this water body stands in comparison to European and other water bodies, which may be useful for developing required protective measures in tropical systems and to design monitoring strategies.

1. Introduction

Estuaries are one of the most important transition systems on earth and provide a number of ecosystem services and social benefits (Elliott and Whitfield, 2011; Barbier et al., 2011; Pinto et al., 2014). They serve as significant reproductive and nursery grounds for a variety of organisms. The linkage and gateway function of estuaries between marine and freshwater systems is an essential feature in the life cycle of several invertebrates (Barbier et al., 2012). The estuaries have a variety of habitats available for use as nesting and feeding sites. These ecosystems also fulfill many other important ecological functions, including acting as filters for terrestrial pollutants and providing protection from flooding. Throughout the world, the main driving force of biota in estuaries is the salinity gradient.

Many tropical estuaries are zones of high productivity due to a combination of shallowness and high nutrient input from rivers. The vegetation of the tropical estuaries as well as those found in their vicinity, particularly mangroves, is a contributory factor. Most tropical estuaries in the developing countries face problems of increasing human pressures due to the rapid population growth, tourism, shipping activities and poor management (Lee, 2008; Lotze, 2010).

Cochin estuary, one of the largest tropical estuaries of India, has been experiencing high levels of human pressures such as the discharge of pollutants, and land reclamation, which consequently resulted in the shrinkage of the backwaters (Menon et al., 2000). Upstream to the north of the Cochin Estuary are major polluting industries (identified in Fig. 1 as 'industrial zone') including an oil refinery, a fertilizer plant, a rare-earth processing plant, a minerals and rutiles plant, and a zinc smelter plant (Menon et al., 2000). A number of chemicals including pesticides, trace metals, and radioactive nuclides are released into the water from these industries (Balachandran et al., 2005; Kumar, 2011; Martin et al., 2012; Manju and Sujatha, 2013; Akhil and Sujatha, 2014; Anu et al., 2014). The southern area has several paddy fields and the use of organochlorines like hexachlorocyclohexane (HCH) and its isomers, and Endosulfan; organophosphates like malathion and methyl parathion to raise high yielding paddy varieties, is common (Kurup, 1992; Menon et al., 2000). The construction of Thannirmukham Bund (a hydraulic barrier), on the southern area of the estuary, to prevent saline intrusion into the upstream

* Corresponding author. Tel.: +966 13 860 3229; fax: +966 13 860 1205.
E-mail address: tvjoydas@kfupm.edu.sa (T.V. Joydas).

http://dx.doi.org/10.1016/j.ecolind.2016.03.005
1470-160X/

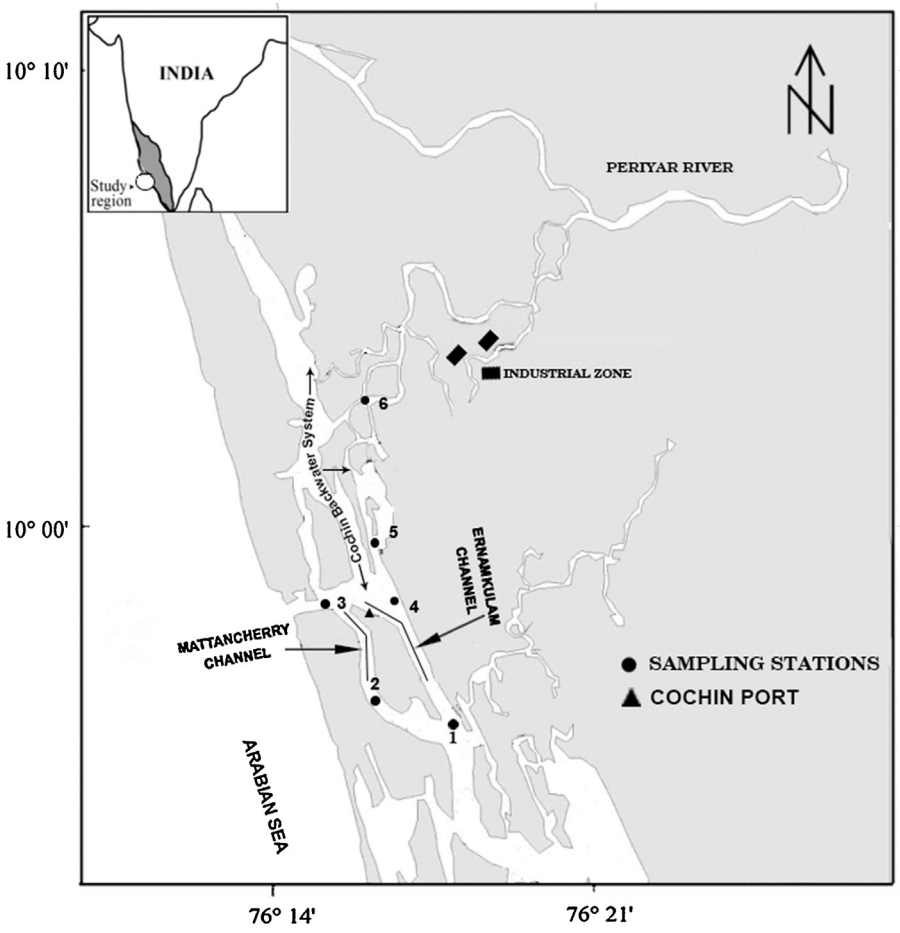

Fig. 1. Location of sampling stations in the Cochin estuary.

agricultural fields has imposed severe flow restrictions and an increased sedimentation rate in the estuary (Menon et al., 2000). The levels of various pollutants are only moderate in the central part of the estuary, although it receives domestic wastes and industrial effluents, particularly during the monsoon period (Martin et al., 2012). Intertidal land reclamations over the past several decades have resulted in 40–50% shrinkage of the Cochin Estuary (Gopalan et al., 1983; Asharaf, 1998). Maintenance dredging is being conducted every year in order to maintain the shipping channel at Cochin Port. The average amount of dredged material removed from the Mattancherry and Ernakulam Channels comes up to $3.61 \times 10^6\ m^3$ (Rasheed and Balchand, 1997) and around the same quantity ($3 \times 10^6\ m^3$) of material is dredged out of the approach channel also (Mathew and Chandramohan, 1993). Sediment accumulation rates in the estuarine and mangrove areas of the Cochin backwater are 3–6 times higher than that in the adjacent inner shelf area (Manjunatha et al., 1998).

In addition to these anthropogenic pressures, this estuary also experiences natural stress from the annual monsoonal rainfall regime. During the monsoon period (June–September) heavy rainfall results in higher river discharge, leading to freshwater condition in the estuary. Consequently the organisms of the estuary are adapted to large fluctuations in salinity.

Health assessment of the estuarine condition is important to undertake management measures. Benthic invertebrate community condition is used widely to assess the health of marine ecosystems due to their sedentary nature, longevity which leads to long-term exposure to toxic substances and the representation of diverse taxa which can respond to multiple types of stress (Jewett et al., 1999; Borja et al., 2000, 2003; Muxika et al., 2005; Gray and Elliot, 2009; Tataranni and Lardicci, 2010). Since relatively sessile, the status of the marine benthic communities can be used to determine the response to several kinds of environmental conditions, e.g., eutrophication, or effects of man-made perturbations (Pearson and Rosenberg, 1978; Guidetti et al., 2000; Hampel et al., 2009).

Since, 1960s, several benthic studies have been reported from the Cochin Estuary. Initial studies focused on the distribution of macrobenthic communities *vis-à-vis* seasonal changes in physico-chemical conditions of water and sediment (Desai and Krishnankutty, 1967; Devassy and Gopinathan, 1970; Kurian, 1972; Ansari, 1977; Pillai, 1977; Antony, 1979; Nair et al., 1983; Batcha, 1984; Gopalan et al., 1987; Rao and Balasubramanian, 1996; Sheeba, 2000). Stress on benthic communities due to pollution was reported, like the absence of benthic life in the industrial area in the northern limb of the estuary (Sarala devi, 1986) and invasion of opportunistic polychaetes (*Capitella capitata*) in Cochin estuary (Martin et al., 2011). However, so far, a comprehensive assessment of the health condition of the macrobenthic communities has not been undertaken in this estuary, and are poorly known in other tropical estuaries (Borja and Tunberg, 2011; Valença and Santos, 2012). Hence, the main objective of this study is to assess the ecological status of macrobenthic communities within the Cochin Estuary, taking into account both human pressures and natural variability, and their potential interactions. For this assessment, we have used benthic indices such as the AZTI's Marine Biotic Index (AMBI; Borja et al., 2000), and the multivariate-AMBI (M-AMBI; Muxika et al., 2007) to translate community composition into an ecological quality classification (Weisberg et al., 1997, 2008; Van