ARTICLE IN PRESS
MPB-07985; No of Pages 10
Marine Pollution Bulletin xxx (2016) xxx–xxx
Contents lists available at ScienceDirect
Marine Pollution Bulletin
journal homepage: www.elsevier.com/locate/marpolbul

Bioindicator role of tintinnid (Protozoa: Ciliophora) for water quality monitoring in Kalpakkam, Tamil Nadu, south east coast of India

Dibyendu Rakshit [a], Gouri Sahu [b], Ajit Kumar Mohanty [b], Kamala Kanta Satpathy [b], M.P. Jonathan [c], K. Murugan [d], Santosh Kumar Sarkar [a,*]

[a] Department of Marine Science, University of Calcutta, 35 Ballygunge Circular Road, Calcutta 700019, India
[b] Indira Gandhi Centre for Atomic Research, Environment and Safety Division, Kalpakkam, Tamil Nadu 603 102, India
[c] Centro Interdisciplinario de Investigaciones y Estudios sobre Medio Ambiente y Desarrollo (CIIEMAD), Instituto Politécnico Nacional (IPN), Calle 30 de Junio de 1520, Barrio la Laguna Ticomán, Del. Gustavo A. Madero, C.P.07340, México DF, Mexico
[d] Thiruvalluvar University, Sekkadu, Vellore, Tamil Nadu 632 115, India

ARTICLE INFO

Article history:
Received 18 July 2016
Received in revised form 23 August 2016
Accepted 24 August 2016
Available online xxxx

Keywords:
Bioindicator
Tintinnid
Species diversity
Water quality
Bay of Bengal

ABSTRACT

The feasibility of a potential bioindicator based on functional groups of microzooplankton tintinnids for bioassessments of water quality status was studied during southwest monsoon (June to September) along the coastal waters of Kalpakkam, India during 2012–2015. The work highlights the following features (1) tintinnid community composed of 28 species belonging to 11 genera and 9 families, revealed significant differences among the four study sites (2) maximum numerical abundance (2224 ± 90 ind. l^{-1}) and species diversity ($H' = 2.66$) of tintinnid were recorded towards Bay of Bengal whereas minimum abundance (720 ± 35 ind. l^{-1}) and diversity ($H' = 1.74$) were encountered in the backwater sites, (3) multivariate analyses [RELATE, Biota-environment (BIOENV) and canonical analysis of principal coordinates (CAP)] reveal that chl *a*, nitrate and phosphate were the potential causative factors for tintinnid distribution. Based on the results, we suggest that tintinnids may be used as a potential bioindicator of water quality status in marine ecosystem.

1. Introduction

Tintinnids are ubiquitous and significant components of microzooplankton communities in the ocean and play a crucial role in microbial food webs (Wang et al., 2014). They have a substantial trophic impact in planktonic food webs because tintinnid can graze 4% to 60% of net annual production, and they contribute significantly to heterotrophic biomass and production in the aquatic ecosystems. By virtue of their rapid growth rate and sensitive reaction to environmental changes, they have been considered as effective bioindicators of water quality and environmental contamination (Kim et al., 2012). Tintinnids have many advantages as a favourable bioindicator to evaluate environmental stress and anthropogenic impact in aquatic ecosystems (Jiang et al., 2011a, 2011b, 2013a, 2013b; Xu et al., 2011a, 2011b, 2011c, 2014). With their short life cycle and delicate pellicles, they may response more quickly to environmental changes than any metazoa (Coppellotti and Matarazzo, 2000; Ismael and Dorgham, 2003). Many ciliated microbiota can tolerate extremes of environmental conditions as compared to macrofauna (Xu et al., 2011a, 2011b). Thus, tintinnids have been used as favourable bio-indicators of water quality in many aquatic environments (e.g., Jiang et al., 2011a, 2011b, 2013a, 2013b; Xu et al. 2011a, 2014; Rakshit et al. 2016a). These loricate ciliates are important components of the aquatic ecosystem and play a crucial role in transferring elements and energy from low trophic levels (e.g., pico- and nano-phytoplankton) to high trophic levels (e.g., copepods) (Corliss 2002). There have been several studies of marine planktonic tintinnid assemblages (Jiang et al. 2011a; Zhang and Wang 2000; Dolan et al. 2012, 2013). As regard to their relationships with marine water quality, however, little information has been documented (Zhang and Wang 2000, 2001). Although there have been a number of recent investigations on bio-assessment using ciliated protozoa, the ability of marine tintinnids for discriminating water quality status is yet to be studied (Jiang et al. 2011a; Xu et al. 2011a, 2014). Hence the work has been undertaken with the following objectives: (1) to assess the impact of south-west monsoon on tintinnid community structure for 4 consecutive years (2012–2015) in Kalpakkam coastal waters; (2) to investigate the relationships among tintinnid communities and environmental variables by using multivariate statistical analyses and (3) to ascertain the applicability of tintinnid communities as a bioindicator for water quality assessment.

* Corresponding author at: Department of Marine Science, University of Calcutta, 35, Ballygunge Circular Road, Calcutta 700019, India.
E-mail address: cusarkar@gmail.com (S.K. Sarkar).

http://dx.doi.org/10.1016/j.marpolbul.2016.08.058
0025-326X/

2. Materials and methods

2.1. Study area and data collection

Kalpakkam coast (12°33′ N latitude and 80°11′ E longitude) is situated about 80 km south of Chennai megacity, south-eastern part of India (Fig. 1). The average rainfall at Kalpakkam is ~1200 mm. This part (Tamil Nadu) of the peninsular India receives bulk of its rainfall (~60%) from NE monsoon (Satpathy et al. 2010a). The Edaiyur and Sadras backwater systems are important features of this coast. These backwaters are connected to the Buckingham canal, which run parallel to the coast. During the period of NE monsoon and seldom during SW monsoon, these two backwaters get opened to the coast discharging considerable amount of freshwater to the coastal milieu for a period of 2 to 3 months. However, with the stoppage of monsoon, a sandbar is formed between the backwaters and sea due to the littoral drift, which is a prominent phenomenon in the east coast of India, resulting in a situation wherein the inflow of low saline water from the backwaters to sea is stopped.

The Sadras backwater receives the domestic discharge of the Kalpakkam Township, whereas, Edaiyur backwater receives runoff from the nearby agricultural field. Edaiyur backwaters' mouth remains open throughout the year due to dredging activities. Madras Atomic Power Station (MAPS) located at Kalpakkam coast, uses seawater for cooling purposes at a rate of 35 $m^3\ sec^{-1}$ and the seawater is drawn through an intake structure located inside the sea at about 500 m away from shore. After extracting heat from the condenser, the heated seawater is discharged into the sea through an outfall canal. The thermal plume travels ~1.5 km to the northern side of MAPS during Feb/Mar to Sept/Oct, whereas it travels only up to ~0.5 km in southern side during Sept/Oct to Feb/Mar with the width of the plume approximately 200 m (Hussain et al. 2010). The Prototype Fast Breeder Reactor, which is yet to be commissioned, PFBR is located at about 680 m south of the MAPS.

According to the climatology of this area, the whole year has been divided into three seasons viz: (1) post-monsoon/summer (February–May), (2) pre-monsoon or SW monsoon (June–September), and (3) NE monsoon (October–January). The reversal of wind occurs during the transition period between the southwest (SW) and northeast (NE) monsoon. The transition between SW to NE monsoon takes place during September/October and the NE to SW transition occurs during February/March. The pole-ward current during SW monsoon changes to equator-ward during the SW to NE monsoon transition, whereas, a reverse current pattern is observed during the transition period between NE and SW monsoon (Varkey et al. 1996; Haugen et al. 2003). During SW monsoon (June–September), samples were collected for four consecutive years (2012–2015) from four sampling sites, namely: Edaiyur backwater (S_1); Sadras backwater (S_2); MAPS Jetty (S_3) and PFBR Jetty (S_4) as shown in (Fig. 1). The sites were fixed with the help of global

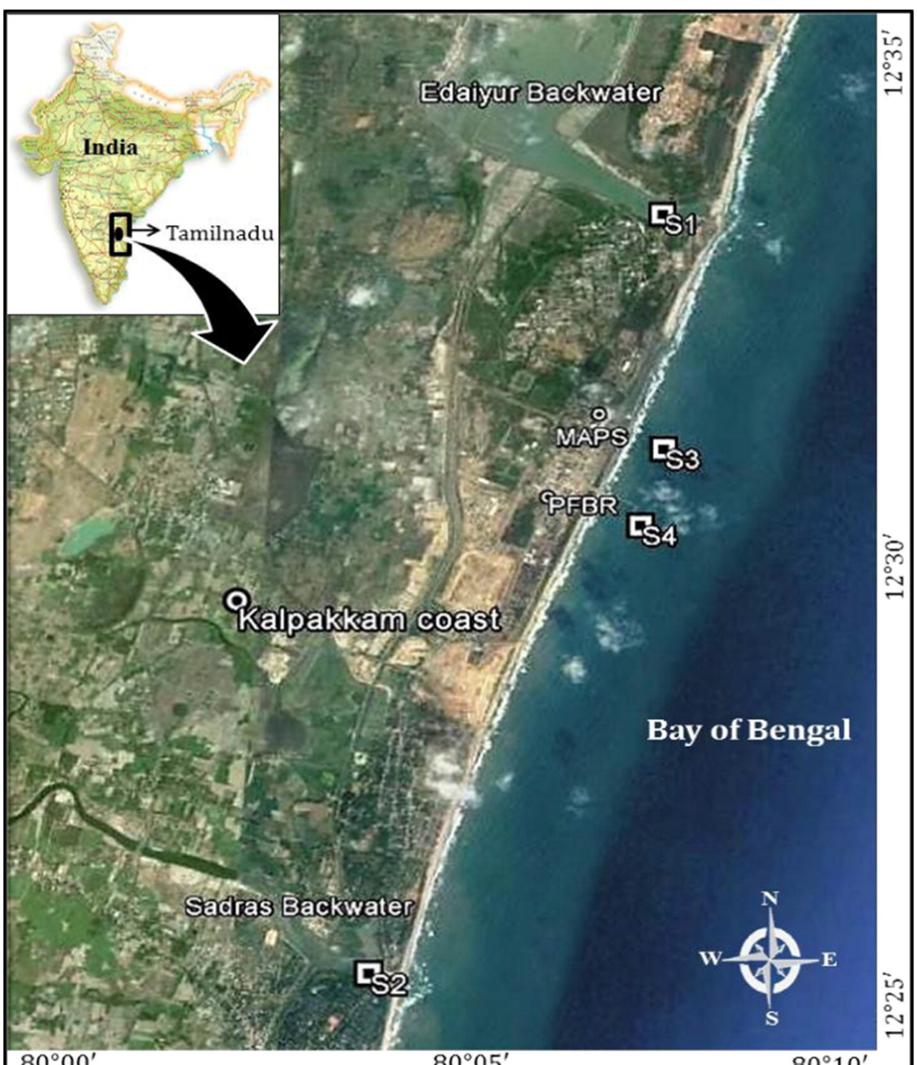

Fig. 1. Map showing the location of 4 sampling sites (S_1-S_4) along the Kalpakkam coast, Tamilnadu.