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Eco-biology of a Precambrian intertidal benthic brachiopod, *Lingula anatina* from the confluence of Subarnarekha estuary with Bay of Bengal, India

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Original Article

Abstract

Three different morphotypes of an intertidal macro-benthic brachiopod, *Lingula anatina* have been found to inhabit in three contrasting intertidal mudflats (based on different soil textures and vegetations) in an ecotone, the confluence of Subarnarekha estuary (21°35'48" Northern Latitude and 87°27'17" Eastern Longitude) with the Bay of Bengal, India. The species under study is very unique in respect of size, shape, texture and colour of shell and possesses longer lophophoral cavities, shorter ventral canals, long pedicle, well-developed posterior adductor muscles etc., showing phyllogenetic relationship with mesozoic lingulids. Gut content analysis and assessment of bioturbatory activities have established the roles of the studied species towards ecosystem functioning which also displayed distinct seasonal fluctuation of population density (0 - 2986±123.12 Nom^{-2}), biomass (0-1287.88±93.69 gm^{-2} and size class (0 -13.32 cm) in relation to the prime physicochemical parameters such as salinity, pH, temperature, nutrients etc. of both soil and interstitial water during the period of July 2009 to June 2011. Different statistical tools such as ANOVA, Duncan's Test, Regression and Correlation analyses have revealed the impact of tidal inundation and exposure along with other ecological variables in determining the occurrence, distribution and population fluctuation of this faunal component.

Keywords: *Lingula anatina, Subarnarekha estuary, ecological variables, population.*

Introduction

Estuary representing an ecologically important coastal environments, is located between fresh water rivers and the sea, characterized by highly varying physicochemical, morphological and hydrological conditions (Carter, 1988 and Ysebaert *et al*., 2002), which exhibits some of the most biologically productive habitats on earth (Kennish, 2002 and McLusky and Elliott, 2004). Estuarine food webs are often complex, largely because of high diversity of both producers and consumers inhabiting such ecosystem experiencing extreme and variable environmental conditions (Chakraborty, 2010). Midnapore (East) coastal belt in West

Bengal, India, just on the southern part of Sundarban Mangrove Estuary, encompasses a diversified habitats and niches which accommodate a good number of faunal components in the form of pelagic and benthic forms. Among these, lophophorate benthic inarticulate brachiopod, *Lingula anatina* has been reported from an ecotone at the confluence of Subarnarekha estuary with the Bay of Bengal, West Bengal- Orissa coastal belt, India (Samanta *et al.*, 2014). *L. anatina* being a gonochoristic sessile benthic suspension feeder is endowed with two slightly dissimilar valves like molluscan bivalves and a pedicle as long extention of ventral valves which act as an anchoring device. Although several studies have already been conducted on macrobenthic fauna in the present study site at the confluence of Subarnarekha estuary (Khalua *et al.*, 2003; Annon, 2005; Chatterjee *et al.*, 2008; Chandra *et al.*, 2008 and Chakraborty, 2010), no investigation on eco-biology of *L. anatina* in and around this estuarine complex have been made. The present paper has attempted to focus on the population dynamics and distribution of *L. anatina*, an intertidal benthic fauna in respect of biological and physicochemical attributes of this estuarine- marine ecotone of India.

Material and methods

Physiography of the study sites

Three ecologically contrasting sites (viz. S-I, S-II and S-III) from the estuarine- mangrove ecosystem near Subarnarekha estuary (Longitude 87°5'E to 88°5'E and Latitude 20°30'N to 22°2'N) have been selected for the present study during July, 2009 to June, 2011.

Procedure for biological samplings

Random samplings of three different morphotypes of *L. anatina*, were made from three study sites through twelve months and six seasons in two consecutive years during low tide level. For quantitative estimation, five quadrates having an area of $1m^2$ were placed randomly and bottom dwelling faunal components especially the brachiopods were unearthed, counted and expressed as Nom^{-2}. Mean biomass was estimated by taking the weight of the collected species inhabiting in each quadrate in the field with the help of a digital balance (Model no. D S 252, Essae- Teraoka Limited) and has been expressed as gm^{-2}. Collected specimens were grouped into different size classes (0-5 cm, 6-10 cm, 11-15 cm and 16-20 cm) and their mean size classes (lengths) were recorded with the help of slide calipers and with a plastic scale.

Identification of collected specimen

L. anatina after collection from different tidal levels at different study sites were identified following standard literature of Emig (1984).

Soil texture analysis

Textural compositions of soil were estimated by means of mechanical analysis following international pipette method as illustrated by Banerjee and Chattopadhay (1980).

Morphoanatomy

Study of morphoanatomy has been carried out with the help of dissecting pan and dissecting microscope in the laboratory (Rupert *et al.*, 2004).

Analysis of physicochemical parameters

Monthly sampling of soil and interstitial water was carried out from different tidal levels of three study sites for estimating physicochemical parameters (Water Temperature, pH, Salinity, Dissolved Oxygen, Turbidity, Conductivity, Nitrogen, Phosphorous and Potassium; Soil Temperature, pH, Organic carbon, Salinity, Nitrogen, Phosphorous, Potassium and Texture) following standard methods (Strickland and Parsons, 1968;Jackson, 1973;FAO, 1976 and APHA, 2005) and with the help of Water Quality Checker (TOA, Model No-WQC22A, Japan).

Determination of bioturbatory activities

Burrow morphology have been determined at different distances from the lowest tidal levels by pouring and excavating casts of plaster of Paris within and from the burrow. Bioturbatory scores were determined following the literature of Swift (1993) and biovolumes were estimated following the literature of Vincent *et al.* (2009).

Dispersion

Standard literature of Battista, 2003 was followed for determination of microdistribution pattern of *L. anatina*,

where : $\frac{S^2}{\overline{X}} = 1$ Random pattern, : $\frac{S^2}{\overline{X}} > 1$ Contagious or clumped pattern and : $\frac{S^2}{\overline{X}} < 1$ Uniform or negatively contagious pattern. Fisher's Coefficient of Dispersion or $CD = \frac{\sum(X - \overline{X})^2}{\overline{X}(N-1)}$ was simply $\frac{S^2}{\overline{X}}$ ratio. Significant departure from unity was adjusted using't' test. 't' value was calculated using the formula $t = 2 \times \sqrt{\frac{2N}{(N-1)^2}}$.

Length-weight relationship

The length- weight relationship was estimated following the standard literatures of Samanta *et al.*(2014) and Dubey *et al.* (2014).

Statistical analysis

Different statistical analyses were done by following standard books (Zar, 1999) and utilizing 'STATISTICA' (STATSOFT, 2001), 'SPSS (10.0)', Statisti XL statistical power for MS Excel and Q1Macros, 2014 software package with the help of a P-4 computer.

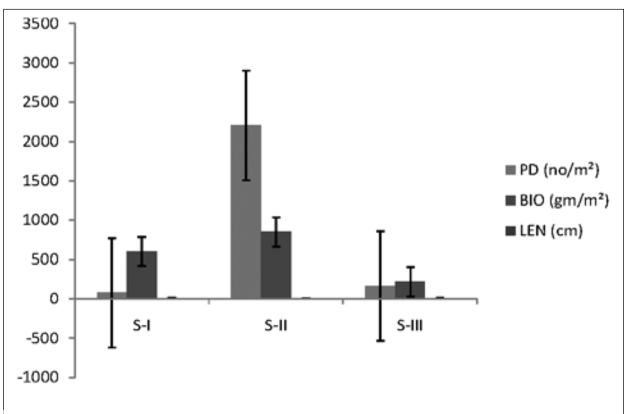
Results

Diversity and density of L. anatina

Based on the pilot survey on different intertidal belts of Midnapore, East (West Bengal) - Balasore (Odisha) coastal tract during the study period, three different morphotypes of *L. anatina* belonging to Lingulidae (inarticulata) family have been recorded.

The species was found to inhabit at 3 different intertidal flats viz. S-I, S-II and S-III, having contrasting sediment characteristics. However, patchy and restricted densities have been recorded on those mudflats that experienced partial exposure during mid tide level and total exposure during extreme low tide level.

Like other macrobenthic fauna (Chakraborty and Choudhury, 1992), *L. anatina* also displayed distinct zonation pattern reflecting their adaptation to different degrees of tidal exposure and inundation. No individuals have been encountered during high tide level (HTL). Among the three study sites, maximum population density was recorded from S-II followed by S-III and S-I.



D- population Density, BIO-Biomass, LEN-Length

Fig. 1.Variation of biological parameters.

The morphotype-I (M-I) was collected from S-I whereas morphotype-II (M-II) was found from S-II and morphotype-III (M-III) was recorded from S-III. The different mean values with respective standard deviation at all study sites have been presented in the Fig.1.

Total population density (Nom^{-2}) of *L. anatina* was found to be 77.83±17.13Nom^{-2} at S-I, 2205.83±561.38 Nom^{-2} at S-II and 164.95±32.00 Nom^{-2} at S-III during the study period (Fig.1). Total biomass (gm^{-2}, Fig. 1) of studied species at S-I was 603.34±147.36 gm^{-2} which were 848.74±280.24 gm^{-2} at S-II and 215.81±38.72 gm^{-2} at S-III. The different values pertaining to size classes and lengths (cm), of *L. anatina* were recorded as 12.66±0.86 at S-I, 8.17±0.62 at S-II and 11.64±0.45 at S-III (Fig.1).

Morphoanatomy

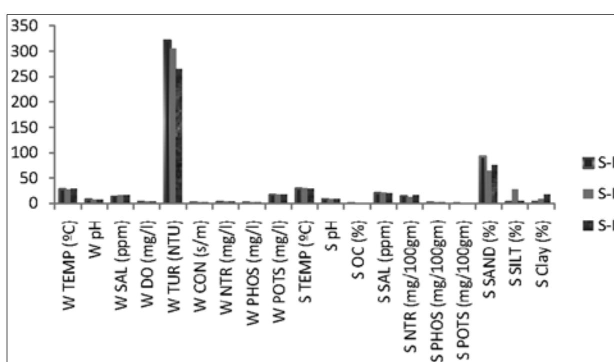
Three different morphotypes of *L. anatina* have been documented from three distinct mudflats (S-I, S-II and S-III) representing different shell and pedicle colours (brownish, blackish brown or greenish and grayish or whitish), lengths (shell-1-6cm and pedicle- 5 -35 cm), shapes and sizes. The studied species was observed to possess three pairs of oblique muscles, one pair of posterior adductor muscle, one pair of anterior adductor muscle, mantle membrane, a pair of lophophores- present on both sides of the mouth convoluted digestive system with digestive glands, one pair of nephridium and pale yellowish (Male) or deep yellowish (Female) gonads. No external manifestation to distinguish male and female has been detected during the present study (Samanta *et al.*, 2014).

Feeding habit

The results of gut content analysis revealed the presence of fragmented mangrove leaves, planktonic materials and detritus inside the gut which indicated their suspension feeding habits.

Physicochemical factors

Seasonal fluctuation of noted physicochemical factors as estimated during present study have been presented in the Fig. 2. Different water quality parameters recorded at



W- water, S- soil, TEMP- temperature, SAL- salinity, DO- Dissolved oxygen, TUR- turbidity, CON- conductivity, NTR- nitrogen, PHOS- phosphorous, POTS- potassium, OC- organic carbon.

Fig. 2.Variation of physicochemical parameters.

different study sites were as follows: temperature (ºC) - 23.52- 32.25, pH- 7.02- 8.50, salinity (ppm)- 8.42- 25.27, dissolved oxygen(mgl^{-1})- 3.23- 4.68, turbidity (NTU)- 230- 362.50, conductivity (s/m)- 1.77- 3.11, nitrogen (mgl^{-1})- 1.87- 5.75, phosphorous (mgl^{-1})- 1.25- 2.72 and potassium (mgl^{-1})- 15.54- 20.80 whereas soil parameters estimated from same site were as follows: temperature (ºC)- 25.37- 34.00, pH- 7.91- 9.22, organic carbon (%)- 0.34- 1.28, salinity (ppm)- 11.43- 32.62, nitrogen (mgl^{-1})- 6.51- 27.36, phosphorous (mgl^{-1})- 0.95- 3.70, potassium (mgl^{-1})- 0.20- 0.71, sand (%)- 61.70- 94.33, silt (%)- 2.98- 30.84 and clay (%)- 1.37- 21.22.

Bioturbatory structure

The burrow of *L. anatina* had two parts- the upper part was oval in shape and it measured about two- thirds of the total length of the burrow, in which shell was moved along a single plane and the lower portion was cylindrical in shape in which only the pedicle was moved. Burrow depths (as created by *L. anatina*) were recorded as 0.36- 0.45 m, major and minor burrow diameters were documented as 0.017- 0.020 m and 0.005- 0.006 m respectively and biovolumes (amount of soil excavated during burrowing) were estimated as 0.0010- 0.00486 m^3 during present investigation. Bioturbatory scores of studied fauna have also been presented here in the Table- 1. Coefficient of correlation analysis between burrow depth and biovolume revealed positive significant correlation at S-I and S-II and negative significant correlation at S-III. The 't' test analysis further strengthen the hypothesis that there was a significant effect of burrow depths, major diameter of burrow, minor diameter of burrow and population density on biovolume formation by the studied species.

Table1. Bioturbatory scores of studied species as observed during study period.

Study site	Mobility	Feeding	Burrowing	Total
S-I	3	2	1	6
S-II	0	2	1	3
S-III	1	2	1	4

Length-Weight relationship

Statistical analysis revealed that there were both significant positive and negative relationship between the length and weight of studied species. Coefficient of correlation analysis between length and weight of *L. anatina* showed significant negative relationship at S-I and S-III and positive relationship at S-II. The condition factor deducted based on these two biological characteristics were found to be 0.69 at S-I, 0.12 at S-II and 0.14 at S-III. Calculated results have expressed that the lengths (cm) and body weight (g) of studied animal at all study sites were almost constant throughout the study period.

Table 2. Fisher's coefficient of dispersion reflecting pattern of distribution.

Study sites	Computed CD	t value	Random	Clumped	Regular
S-I	4.35	1.38	1±1.38	›2.38	‹0.38
S-II	242.72	1.38	1±1.38	›2.38	‹0.38
S-III	8.43	1.38	1±1.38	›2.38	‹0.38

Dispersion

The calculated values of Coefficient of dispersion (CD) were always higher than (1+t) during present study indicating their distribution as clumped type as presented in the Table- 2.

Statistical results

ANOVA analysis revealed that main effect of years, seasons, tidal levels and physicochemical parameters at all study sites on population density, biomass and size class are found to be significant.

Duncan's test ($P<0.05$) with respect to the main effect of study sites showed that the mean population density (Nom^{-2}) of *L. anatina* displayed higher values at S-II than S-III and S-I. Biomass of the species exhibited higher values at S-II followed by S-I and S-III. However, size classes were shown to be significantly higher at S-I than S-III and S-II. The same test exhibited that the mean population density of *L. anatina* were higher during postmonsoon followed by pre-monsoon and monsoon. In contrast biomass (gm^{-2}) revealed significant higher results during pre-monsoon than post monsoon and monsoon. However, mean lengths of *L. anatina* were significantly higher during pre-monsoon period than other two seasons.

Coefficient of correlation analysis expressed that out of nine water quality parameters only three (pH, salinity and conductivity) showed significant positive correlations with density, biomass and size class of studied species. However out of nine soil parameters only two (salinity and silt content of soil) revealed significant positive correlations with three selected biological parameters.

Discussion

Coastal zone represents the junction between the land and sea which supports a luxuriant growth of mangrove forests along with associated faunal component which are very rich in variety and abundance.

L. anatina (Brachiopoda) has been reported from Midnapore (East), West Bengal- Odisha coastal belt as a new record (Samanta *et al.*, 2014) which display their presence in higher densities at tidal belts of Talsari estuarine creeks. Tidal waves and water current are supposed to uproot these infaunal animals during monsoon period. Therefore their habitats undergoes alteration and reformation every year. As a result each new faunal colony has been developed accomodating the old and newer fauna leading to the formation of a mixed colony containing young, middle aged and aged individuals of *L. anatina*. Such kind of development of the population of this species has lead to form a metapopulation colony.

Three different morphotypes of studied species are presently distributed at 3 different intertidal flats viz. S-I, S-II and S-III having contrasting sediment characteristics. Biochemical analysis on their fatty acid composition established that they belong to same species level (Samanta *et al.*, 2014), yet morphological difference established them as cryptic species.

Dispersion greatly affects the interval, structure and other characteristics of the population. Individuals may be distributed randomly, uniformly or in clumps. The distribution is considered random if the position of each individual is independent of the others. Uniform distribution is the more even spacing of individuals than would occur by chance. The most common type of distribution is clumped, also called clustered, contagious and aggregated. This pattern of dispersion results from responses by plants and animals to habitat differences, daily and seasonal weather and environmental changes, reproductive patterns and social behavior (Smith, 1996).

During present study the values of CD with $1 \pm t$, was regarded as significant. The distribution was considered as random when $S^2/X=1$. Any deviation outside this range was regarded as non random and when it exceeded $(1+t)$, the distribution was clumped and if it was less than (1-t) it was regarded as regular distribution. The calculated values of CD were always higher than $(1+t)$ during present study. Hence, it inferred that the distribution type of studied species was clumped type.

From the evaluated result on seasonal abundance, it becomes apparent that total population density and biomass of *L. anatina* were higher at S-II followed by S-III and S-I. The nature of diversity and abundance of different species through different seasons is mainly due to a combination of various factors like marked salinity fluctuation, south west monsoon accompanied by heavy rains and also the structural modifications of sediments (Choudhuri and Choudhury, 1994). From the present investigation it is revealed that they are highly abundant species in all studied sites.

The sediment type results indicated that majority of *L. anatina* were found in sandy loam regions. The variance found in this study was in accordance with Worcester's 1969 observation. There is clear relationship between kinds of sediment texture and population density of studied species and sandy loam bottoms at S-II have high density of *L. anatina* which is also coincide with the findings of Keshavarz *et al.*, 2012.Variation of biomass was found to dependent on age groups and chance settlement of juveniles.

Bioturbatory structures formed by the different morphotypes of species have been encountered in this study and categorized as per the different scores put forward by Swift (1993). They could play a role in the redistribution of superficial sediment particles in intertidal regions and thereby influence fluxes of nutrients and contaminants across the sediment water interface. It seems that unique bioturbatory structures of different morphotypes have diverse functional role, but more intensive study is required to understand their functional as well as ecological significance.

The coefficient of correlation and 't'- test analysis have revealed that there existed significantly negative relationship between the lengths (cm) and weight (g) of *L. anatina* at S-I and s-III. Documented results have expressed that the lengths (cm) and weight (g) of studied animal at all three study sites were almost constant throughout the study period. The value Kn was less than 1 at all study sites and it was indicated that *L. anatina* used to live at these particular habitats where they were not in good condition.

Various statistical analyses had been computed in order to study the impact on the population dynamics (density and biomass) of different morphotypes of studied species of three study sites at different tidal levels with respect to physicochemical properties of water and soil. These analysis suggested that physicochemical parameters of both water and soil and sediment structure had a profound effect on *Lingula anatina*'s population density, biomass, size class bioturbatory activities and length- weight relationship.

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