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LUNAR RHYTHM IN THE PLANKTONIC BIOMASS OF BAY OF BENGAL AT DIGHA-ON-SEA (W. B.)

PUSPALATA MOHARANA[a1] AND A. K. PATRA[b]

[ab]Fishery Science Research Laboratory P.G. Department of Zoology, Utkal University, Bhubaneswar, Odisha, India

ABSTRACT

The lunar cycle imparts certain stimulating effects on the rhythmic behaviour of plankton and their life processes by which they actively migrate to the sea surface and gradually sink as the moon fades, This may result in morphological changes in Organisms, such as Lorica which becomes smaller towards the full moon night by changing the size of postero lateral spines and surface area. In addition Cyclo-morphic forms have been observed in zooplankton, that seems to be a suitable achievement for reproductive purposes such as swarming and for the differentiation of sex by secondary sexual character. Lunar rhytham in plankton appears to be governed by an internal clock, otherwise called as the "Biological Clock". The plankton (Phyto-zoo plankton) exhibiting their numerical rhythms in response to lunar cycle have become evident from this study (i.e. 2013). On the full moon light the total planktonic Biomass was highest in comparison to the other phases of lunar cycle. The physico-chemical parameters which showed certain positive effect on the lunar cycle caused congenial condition. In relation to lunar advancement certain morphological changes (Cyclomorphosis) of forms were reported in some Rotifera, Cladocera and Copepoda.

KEYWORDS : Lunar rhythm, plankton Bay of Bengal, Digha

It is the nature, the organisms irrespective of their body size and habitat should follow the principles of nature. Nature maintains the shape of the biotic community and develops the behavioral attitudes in them, that passed from generation to generation. The behavioral in life histories help to analyse the activities of animals in terms of innate and learned behavior and the neural mechanisms also/play a pivotal role in this activity. In the Universe, all phenomena are relative and cyclic. The movement of moon on its orbit around the earth produces two rhythms i.e. (i) tidal that flows twice a day and (ii) rhythmic variation of the height of the tides, which are of the considerable importance on animals and plants. The environmental rhythm of recurring ulteration of illumination and darkness in the earth's natural photoperiod, and same has played a vital role in biological history of all living organisms, be they plants or animals. The present investigation has been carried out for an entire lunar period i.e. from (new moon light) 7, November to 6 ,December, 2013 (day before next new moon night) at a specific site S-2 (Digha Sea beach) and time (2000h) to observe its periodic effect on the ethology and standing stock of rheoplankton communities. This lunar cycle has been divided into four periods (phases) (i) new moon phase, (ii) full moon phase, (iii) post full moon phase and (iv) full dark phase. (Samples were collected in triplicate in plastic container during evening hours (2000h) and were analysed in the laboratory).

MATERIALS AND METHODS

Planktonic sampling in triplicate was made from the littoral and limentic zones (within 50 cm depth) of the Bay of Bengal during lunar cycle i.e. 7th November 2013 to 6th December, from S_2 study site (Old Digha). Collection were made from 100 liters of water sample by a plastic buckets of 10 liters capacity and from transferring through a plankton collecting net of No, 25 nylon bolting silk (mesh size 0.03-0.04 mm), Collected planktonic sample was reduced to 30cc of concentrated sample after filtration through the plankton net, It was preserved in 4 % formaline and brought to the libratory for analysis. During study a sub sample of one cc from the stock was taken into the Sedegewick Rafter types plankton Counting cell (1 cc, capacity) for the qualitative and quantitative estimation as per ward and Wipple, 1959. All organism encountered were represented in absolute number. Spices wise counting and collection (nL^{-1}) was made using the formula suggested by Trivedi and Goel, 1986 Observation were also made regarding vertical migration. behavioral pattern, Swarming, Cyclomorphosis and population density of plankton.

RESULTS

Physicochemical Rhythm

Certain physico-chemical parameters of the Sea at Digha during the whole lunar period of the year 2013 in winter season at S_2 were analysed and shown in table 1.

[1]Corresponding author

Biological Rhythm

The plankton (phyto-zooplanton) performed their numerical rhythms in response to lunar cycle (table 1). Seven species of Chlorophyceae, two species of Cyanophyceae and four species of Bacillariophyceae were reported (table 2) forming 32.36 % to 36.02% of total planktonic stock. The zooplankton group was comprised of five species of Protozoa, six species of Rotifera, five species of Cladocera and three species of Copepoda (table 3) forming 64.08% to 67.78% of the total planktonic biomass Among the zooplankton, *Mesocyclops leuckartii*, *Diaptonus wierzerskii* and *Heliodiaptomus viddus* from Copepods, *Diaphanosoma exisum* Macrothrix species and *Moina micrura* from Cladocera, *Keratella tropica* from Rotifera and *Difflugia corona* from Protozoa and in phytoplanktons *Volvox* Globator(L) *Ehrenb* and *Euglena* species *Ehrenb* from *Chlorophyceae*, *Pinnularia Viridis Ehrenb*, *Nitzschia closterium* and *Gomphonema lanceolatum Ehrenb* from *Bracillariophyceae* and *Oscillatoria simplicissima* from Cyanophyceae were the dominant species. The number of zooplankton was observed to be increased gradually at the pelagic level from new moon night 7 November, 2013 reaching their population maxima on full moon night on 21 November, 2013. Then they showed a decreasing trend towards the post full moon phase and found to be minimum on the previous night of new moon in (i.e. full dark night : 6 December, 2013). The phytoplankton population were also followed the same behavioural trend of increase and decrease during the lunar rhythm alike zooplankton, resulting minimum (93 nL^{-1}) on 6 December, 2013 and maximum (191 nL^{-1}) on 21 November, 2013. However, the phytoplankton population did not show such sharp fluctuation like the zooplankton.

DISCUSSION

Physicochemical Rhythm

The physico-chemical parameters studied during a lunar cycle in winter 2013 follow the same trend as seasonal changes in the marine ecosystem. The content of the factors may vary as in vast aquatic medium like sea, big lakes during different phases of lunar period (Pati, 1981). In the present investigation as it is a sea where water surface area is unlimited and vast, so a direct corrclation between the physico-chemical parameters and lunar effect do not exist.

Several investigators (Parker, 1902; Hurkat and Mathur, 1977; Aldredge and King, 1980; Nayak and Patra, 1982; Yousuf and Qadri, 1985; Patra et al., 1986; Gauda and Panigrahi, 1989; Nayak and Gochhait, 1990; Choudhury et al., 1991, 1992; Singh and Srivastava, 1993 and Yousuf and Mir., 1994) have reported different rhythmicity in fresh water organisms of both lentic and lotic ecosystems and correlated it with the variations in light intensity, temperature, transparency and feeding spectrums. The favourable physicochemical parameters of the sea during

Table 1 : Certain Physicochemical Parameters of the Sea at Digha Sea Shore During a Lunar Cycle (S_2) 2013

Parameters	Lunar Period			
	New Moon Phase 7Nov-13 Nov.	Full Moon Phase 14 Nov-21 Nov	Post Full Moon Phase 22 Nov -28 Nov	Full Dark Phase 29-Nov-6 Dec
Weather Condition	Bright	Bright	Bright	Bright
Water Depth (cm)	60 ± 1.5	80 ± 2.0	63 ± 1.6	60 ± 1.5
Rate of Water Flow (cm/mt)	100 ± 5	120 ± 3	115 ± 3	110 ± 4
Water Temp(^{0}C)	20.5 ± 0.568	18.5 ± 0.402	18.7 ± 0.502	17.9 ± 0.468
pH	8.3 ± 0.232	8.6 ± 0.354	8.4 ± 0.345	8.1 ± 0.348
Dissolved Oxygen (mgL^{-1})	8.5 ± 0.24	8.2 ± 0.16	8.6 ± 0.21	8.1 ± 0.28
Free Carbon Dioxide (mgL^{-1})	3.8 ± 0.12	3.1 ± 0.21	3.4 ± 0.18	3.6 ± 0.14
Total Alkalinity (mgL^{-1})	56 ± 1.6	75 ± 1.9	73 ± 2.2	71 ± 2.0
Chloride (mgL^{-1})	33.0 ± 0.05	32.0 ± 0.06	31.5 ± 0.08	33.6 ± 0.06
Silicate (mgL^{-1})	6.5 ± 0.08	5.5 ± 0.12	5.3 ± 0.07	5.1 ± 0.05
Inorganic Phosphate (mgL^{-1})	0.016 ± 0.001	0.016 ± 0.002	0.013 ± 0.001	0.010 ± 0.002
Sulphate (mgL^{-1})	10.5 ± 0.016	9.7 ± 0.12	8.5 ± 0.08	7.6 ± 0.16
Total Nitrogen (mgL^{-1})	0.095 ± 0.002	0.102 ± 0.003	0.104 ± 0.003	0.126 ± 0.002

post monsoon (winter months) provide a suitable back ground to enhance the planktonic population . Although the phytoplankton populations are numerically greater than zooplankton, they are found to be comparatively less in number due to their sinking behavior in the absence of solar energy. Moon light is most possibly the vital factor responsible for the vertical upward (Talseri, S_1) and down ward (Mohana S_3) movement of zooplankton. Further, this type of movement may also be associated with their negative geotactic nature (Pennak, 1944; Welch, 1962; Bohra, 1977; Jakher et al., 1982 and Patra et al., 1986) and suppressed by a negative phototaxis nature of zooplankton during day hours and expressed well at night (Parker, 1902; Vashisht and Sharma, 1980 and Yoh, 1982). It is also reported that zooplankton actively orients to a band of optimum light intensity and accordingly they adjust to the prevailing condition (Cushing, 1951 and Hardy and Bainbridge, 1954). Alldredge and King, 1980) has also stressed the effects of moon light on the vertical migration patterns of demersal zooplankton. It is reported that almost all the zooplanktons reach at the surface in new moon phase when the illumination and water temperature remain low. The maximum population density of Copepoda and Cladocera are observed during the full moon period. This may be refered to their more activeness and large population dynamics. In the full moon night they are abundant (46.59%) in comparison to the whole planktons stock. Thus, it is presumed that, the lunar cycle definitely imparts a stimulating effect on their life processes by which they actively migrate to the surface and then gradually decrease as the cycles of the moon decreases with the lunar advancement, various morphological changes of forms are also noticed in Rotifera, Cladocera and Copepoda. The Rotiferans like *Brachionus calcyflorus* Pallas, *Brachionus forficula Wierzeski* and *Keratella tropica Apstein* showed variations in the size of lorica, being smaller towards the full moon, changing the size of postero-lateral spines and surface area. Similarly the *Cladoceran* like *Moina micrura* and *Daphnia carinata* King and *Copepode* like *Mesocyclopes leuckartii* Claus are also exhibited variations in shape and size of their bodies and appendages. Among all, the *Mesocyclops* sp. Exhibited the maximum

Table 2 : Certain Qualitative & Quantitative (organism) nL^{-1} Analysis of Phytoplankton of the Sea at Digha Sea Shore During a Lunar Cycle (S_2) 2013

Parameters	Lunar Period			
	New Moon Phase 7Nov-13 Nov.	**Full Moon Phase 14 Nov-21 Nov**	**Post Full Moon Phase 22 Nov -28 Nov**	**Full Dark Phase 29-Nov-6 Dec**
Chlorophyceae				
Euglena spirogyra Eh.	4-20	18-38	20-15	18-7
Euglena viridis Eh.	6-11	9-21	10-9	7-5
Ulothrix zonakta Kutz.	3-26	5-15	8-6	5-11
Volovx globator (L) Eh.	3-21	18-33	18-13	12-5
Spirogyra SP	4-15	6-15	9-7	6-6
Pandorina morum Mull	3-9	4-12	8-6	5-1
Coxmarium bortytis Menegh (Letter Debary)	8-11	6-14	6-3	6-3
Total	21-89	62-133	79-55	56-36
Cyan Ophyceae				
Uivillaporia simplicissima	6-21	9-24	14-6	8-7
Microcystis aeruginose	2-11	10-5	6-8	8-3
Total	8-27	18-29	20-15	15-5
Bacillariophyceae				
Naviula cuspidata Eh.	0-9	18-16	10-8	6-8
Plannularia virids Eh.	16-26	20-38	30-3	18-8
Himphonema lanceolatum	3-16	9-25	12-6	7-6
Rhpalodio closterium	7-6	3-14	3-11	7-1
Total	34-61	48-101	69-60	44-27

Table 3 : Qualitative & Quantitative (organism) nL^{-1} Analysis of Zooplanktons of the Sea at Digha Sea Shore During a Lunar Cycle (S_2) 2013

Species	Lunar Period			
	New Moon Phase 7Nov-13 Nov	**Full Moon Phase 14 Nov-21 Nov**	**Post Full Moon Phase 22 Nov -28 Nov**	**Full Dark Phase 29-Nov-6 Dec**
Protozoa				
Amoebaradiosa Eh.	0-7	2-9	2-9	2-6
Arcella vulgaris Eh.	6-7	5-17	13-9	3-9
Euglypha acanthophora Eh.	5-13	8-5	9-5	6-4
Diffugiacorena Wallich	3-12	12-27	18-13	5-2
Paramoecium Caudatum Eh.	6-14	6-18	8-6	2-5
Total	20-51	34-63	49-37	18-23
Rotifera				
Brachionus Calcyfloers Pallas	0-9	7-8	5-9	2-9
Brachionus Florus Wierzeski	4-7	8-13	13-5	3-7
Keratella tropica Apstein	5-13	12-23	11-8	10-6
Asplachna priodonata Mastax	2-21	5-9	7-21	14-6
Filina Longiseta Eh.	6-16	14-7	10-19	18-7
Rotaria vulgaris Richard	0-6	5-11	3-6	8-5
Total	15-63	52-69	48-59	63-38
Cladocera				
Simocephalus Vetulus Sch.	8-18	8-21	14-9	20-6
Diaphanosoma exisum Sars	16-38	24-46	32-26	14-23
Macrothrx Sp Baird	10-26	21-36	26-19	16-11
Daphnia Carinata King	6-16	9-18	10-7	2-3
Maina micrura Kutz	4-21	10-21	16-11	18-6
Total	44-111	75-135	98-67	56-26
Copepada				
Diaptomus wierzeskii Richard	19-18	15-34	18-13	16-9
Heliodiaptomus viddus Gurney	32-87	65-97	66-22	26-13
Mescocyclops leuckartii Claus	26-45	38-73	45-29	32-11
Total	67-148	117-201	113-61	27-45

cyclomorphosis with structural changes where four different forms were identified. These cyclomorphic forms may be the suitable achievement for reproductive purposes as swarming, may be a nuptial response. This suitable secondary sex differentiation in the body structure and nuptial response may fulfill their sexual goals. Mohan and Rao, 1983 have reported the increase in number of organisms expect copepode nauplii at the peek period of solar eclipse may be ascribed to the decrease in light intensity and the phenomenon of diurnal vertical migration as exhibited normally by these organisms under reduced light conditions and consequent physiological changes exhibited by the plankters. It is obvious that the planktonic organisms have keen sense of response to minute variations of light intensity. However, it can be finally concluded that the lunar rhythm acts on the ecophysiology of the plankton in marine ecosystems which ultimately might be governed by hormones of genetically based and accordingly guided

Table 4 : Lunar Rhythm in Average Standing Stock and % Distribution of Phytoplankton and Zooplankton at Sea Digha During 2013(7th November to 6th December, 2013)

Plankton (nL^{-1})	Lunar Period			
	New moon phase 7Nov - 13Nov	Full moon phase 14Nov-21Nov	Post full moon phase 22Nov- 28Nov	Full dark phase 29 Nov-6Dec
Total Plankton(nL^{-1})	37.5	559	417	251
Chlorophyceae(nL^{-1})	61	98	69	47
Cyanophyceae(nL^{-1})	19	25	21	11
Bacillariophyceae(nL^{-1})	48	73	65	36
Total Phytoplankton(nL^{-1})	123	191	149	93
Percentage(%)	32.24	34.04	35.58	36.0
Protozoa(nL^{-1})	33	49	41	19
Rotifera(nL^{-1})	39	62	53	48
Cadocera (nL^{-1})	78	104	83	42
Copepoda(nL^{-1})	109	161	96	58
Total zooplankton(nL^{-1})	256	369	271	161
Percentage(%)	67.74	65.95	64.42	64.0

by the internal clock, otherwise called as "Biological Clock" (Brown, 1962 and Bonning,1973).

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