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First report of a rare bloom of *Ornithocercus magnificus*, Stein 1883 along the coastal waters of Kochi; A possible indicator of increasing sea surface temperature

Lavanya Ratheesh*, Reena V. Joseph, Parvathy Rajeev, Shelton Padua, D. Prema, V. Kripa and P. Kaladharan

ICAR- Central Marine Fisheries Research Institute, P. B. No. 1603, Kochi- 682 018, India.

*Correspondence e-mail: lavanyacmfri2010@gmail.com

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Original Article

Abstract

A bloom of the planktonic dinoflagellate, *Ornithocercus magnificus* was reported for the first time in the surface waters of the off Kochi coastal region with an evidently higher density of 1.7 x 10^6 cells L^{-1} on 18.12.2019. No conspicuous colouration of the surface waters was noticed even with the higher abundance of (1.7 x 10^6 cells L^{-1}) observed near the barmouth area (6-7 m). The tracking on the occurrence of this genus in this region from 2013 to 2019 revealed their occurrence only during three times over the six years, *i.e.* the post monsoon season of 2013 and 2014 and during pre-monsoon of 2016. The SST of the three stations of the post monsoon season was compared for the last three years from 2017 to 2019, and an evident variation in the SST distribution was noticed in this region. The SST in 2019 was 2.1°C higher than that observed during 2017. The occurrence of *Ornithocercus magnificus* showed a positive correlation with SST ($r_s = 0.425$, $p < 0.05$). It was also noted that the occurrence of this species was observed during the El Nino years. The Oceanic Niño Index (ONI) also positively correlated with the SST during the period ($r_s = 0.432$, $p < 0.05$). The higher abundance of this species in 2019 when warmer SST was observed and their positive correlation with SST indicates the preferences of *O.magnificus* to warmer waters. The Shannon and Weiner diversity index (H') ranged from 2.87-3.29 and the water quality index (WQI) remained good during the bloom. As *Ornithocercus magnificus* did occur during higher SST, this genus can be used as a proxy of climate change and hence has a strong potential to be used as indicator species of higher SST variation if found in novel environments.

Keywords: *Sea Surface Temperature (SST), off Kochi, climate change, Ornithocercus magnificus, seasonal bloom, indicator species*

Introduction

Micro algal blooms commonly observed along the west coast of India, although are caused by dinoflagellates, diatom blooms commonly prevail along the east coast of India (D'Silva *et al.*, 2012; Subramanian, 1958, 1968; Kaladharan and Asokan, 2012). Of the 39 bloom forming species reported, *Noctiluca scintillans* and *Trichodesmium erythraeum* blooms are observed to be the recurrent ones. The blooms of these species mostly occurs with the withdrawal of the south-west monsoon and during the pre-monsoon period. Though occurrence of algal blooms are natural phenomenon and have been observed throughout the recorded history, recent studies around the globe indicates an

increase in the frequency of occurrence and wide geographical spread over the last few decades. Exceptional bloom forming species contribute only 5.5-6.7% of the total phytoplankton flora of the world's oceans (Soumia, 1995).

Ornithocercus, a genus of planktonic dinoflagellates are known for their complex morphology and widespread occurrence in the tropical oceans (Syed *et al*., 2008). As they reportedly occur mostly in the warmer waters, this genus could be used as a proxy for increasing SST and as a potential indicator species of environmental change if found in novel environments (Kim *et al.,* 2013). Bloom reports of this genus along the coastal waters of India are so scarce that the first report on the bloom of this species from the Indian waters was from the west coast of India in 2015 (Karthik *et al*., 2017). As this species have a preference for warmer waters, they are mostly observed during the pre-monsoon and post monsoon periods along the west coast of India.

Most of the studies hitherto conducted on the phytoplankton blooms along the tropical waters, have given focus to the hydrographic and environmental parameters and their influence on the bloom occurrence only after their visible developments. However, the present study being part of the regular environmental monitoring programme of the coastal waters of off Kochi, the contributing factors behind the manifestation of the bloom could be envisaged clearly. The present study reports the occurrence of the bloom of *Ornithocercus magnificus* for the first time during the post monsoon period of 2019 along the inshore waters of Kochi in south west coast of India.

Material and methods

The bloom of *Ornithocercus magnificus* was observed serendipitously on 18-12-2019 during the regular environmental monitoring programme of coastal waters of off Kochi on board MT *Krish II*. Because of the absence of conspicuous coloration of the surface waters subsequent to the bloom formation, the occurrence of bloom was observed only during the phytoplankton analysis of the samples collected during the cruise.

Study area

Seawater, phytoplankton, zooplankton and sediment samples were collected from 3 stations as shown in Fig. 1, during the morning hours. The stations included the barmouth area (9°58'10.23"N; 76°14'26.79"E; 6-7 m depth) and two near-shore locations, one at 10 m depth (9°55'7.82"N; 76°11'3.74"E; 10m S) and the third one at 20 m depth (9°52'59.29"N; 76° 6'20.69"E; 20 m S). Stations 10 m S and 20 m S located away from the port channel are prominent fishing zones along the off Kochi coastal waters.

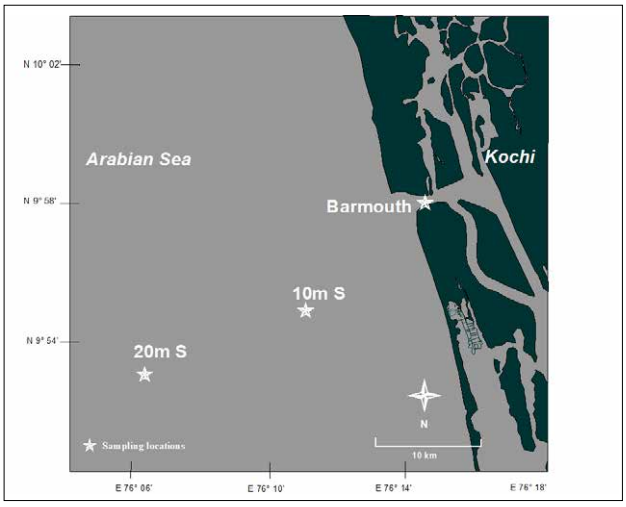

Fig.1. Map showing the sampling locations where the bloom of *Ornithocercus magnificus* as observed along the near shore waters of Kochi.

Sample collection and data analysis

Seawater samples from surface were collected and analysed for the physico-chemical parameters as per the standard methods (APHA, 1998). Water quality indices (WQI) were also evaluated, as per the selected environmental indicators of USEPA (2006). Phytoplankton samples were collected by horizontal hauling of a standard plankton net (IIOE Std) with mesh size of 20 μm and 1m^2 mouth diameter at a speed of 2 knots for 10 minutes. Enumeration and identification of the phytoplankton samples were carried out following the standard phytoplankton identification manuals (Subrahmanyan, 1958; 1968). The Shannon and Weiner index was estimated to assess the phytoplankton species diversity of the bloom (Shannon and Weaver, 1949) using the statistical software PRIMER (Ver.6). Spearman correlation analysis (2-tailed) was also carried out using SPSS software (SPSS Statistics 23) to find out any correlation between the hydrological parameters and the abundance of *O. magnificus*. Oceanic Niño Index (ONI) developed by the National Oceanic and Atmospheric Administration (NOAA) being the standard for identification of El Niño and La Niña events in the tropical Pacific was also taken for the period from 2013-2019 and used for finding out any relationship between increased SST and the occurrence of blooming of *Ornithocercus magnificus*.

Results and discussion

Ornithocercus magnificus-Systematics and general characteristics

Ornithocercus is a genus of thecate dinoflagellate belonging to the family Dinophysaceae, limited to the warmer waters of the tropical and subtropical oceans. They are commonly observed in oceanic waters, with many species having distribution below

the euphotic zone. The species range in length between 40-170 μm and hence comes under the microplankton category. Though, *Ornithocercus* is not as diverse as *Peridinium, Ceratium, Dinophysis* and other dinoflagellate genera, but is represented by only 15 species globally (Gomez, 2005). Three species of *Ornithocercus* were reported from the northern Arabian Sea (Kuzmenko, 1975) and nine species from the Indian Ocean (Taylor, 1976). In a study conducted by Syed *et al.* (2008), it is known that *O. magnificus* has been found to be the most frequently observed, among the four species of *Ornithocercus* in the shelf waters of North Arabian Sea shelf off Pakistan. Another study from the Brazilian coast in the South Atlantic Ocean (Eveline *et al.*, 2014) observed that like any other dinoflagellate genera, *Ornithocercus* also have phased cell division with cell division of *O. magnificus* occurring with the day's first sunlight. In the present study, the species was identified to be *O. magnificus* as specified by Taylor (1976) and the body length ranged from 63-90μm (Fig. 2).

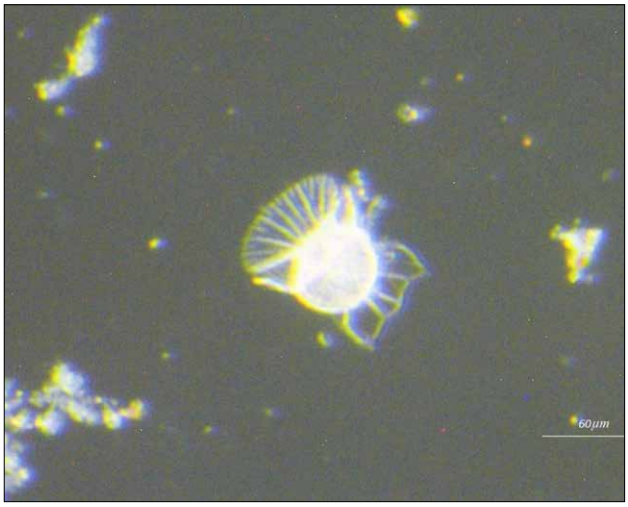

Fig. 2. Enlarged view of the dinoflagellate, *Ornithocercus magnificus*

Bloom characteristics

This is for the first time a bloom of *Ornithocercus magnificus* (Fig. 3) is reported along the coastal waters off Kochi. The bloom occurred during the post monsoon period and more specifically on 18.12.2019. Evidently higher density of this species was observed with a cell count of 1.7 x 10^6 cells L^{-1} in the barmouth region and with a decreasing trend towards the offshore waters (Fig. 4). No conspicuous colouration of the surface waters was noticed during the cruise as the red tides observed during the bloom of *N. scintillans* and brownish colouration during the bloom of *Trichodesmium* sp. However, Subrahmayan (1958) had mentioned that at certain times, this species also cause discolouration of seawater at higher densities. There were no signs or evidences of fish mortality in the bloom affected region. The sightings of the Humpback dolphins and marine birds such

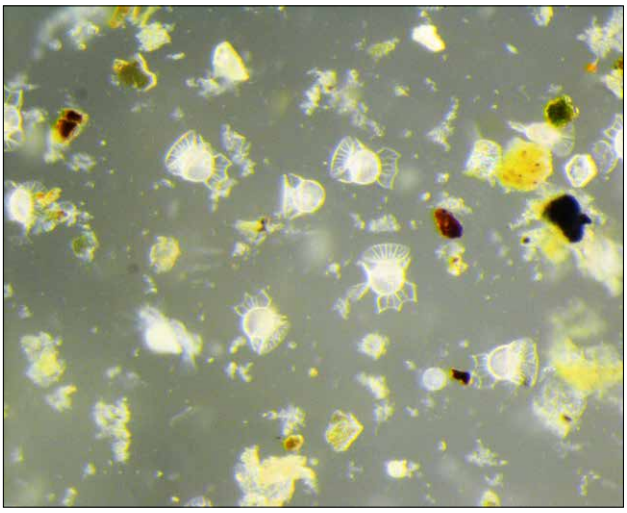

Fig. 3. Image of bloom of *Ornithocercus magnificus* along the off Kochi coastal waters

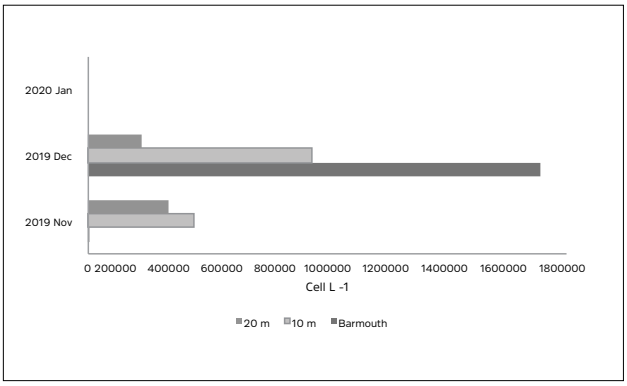

Fig. 4. *Ornithocercus magnificus* abundance along the three sampling locations during the months of November& December 2019 and January 2020

as the seagulls and terns in the nearshore waters during this period indicated increased fish availability even during the bloom incident. During the post monsoon period of 2011 an intense "green tide" due to *Chattonella marina* (Subramanyan) Hara and Chihara (1982) was noticed along the Calicut coast which lasted for a month and was associated with large scale mortality of fish and bivalves (Kaladharan and Asokan, 2012).

Water quality

During the bloom occurrence, the SST, pH, salinity and dissolved oxygen at the surface were 30° C, 8.3$\pm$0.4, 33 ppt and 7.4$\pm$0.2 mgL^{-1} respectively (Fig. 5a, b). The WQI revealed 'good' in all the stations indicating that the bloom did not exert any prominent impact on the water quality. However the nutrient analysis revealed near zero inorganic phosphate concentration which prompted us for the qualitative investigation of the phytoplankton samples. The inorganic nitrate (0.01 mgL^{-1}) and chlorophyll *a* (0.47$\pm$0.44 mg/m^3) concentrations were also on the lower side.

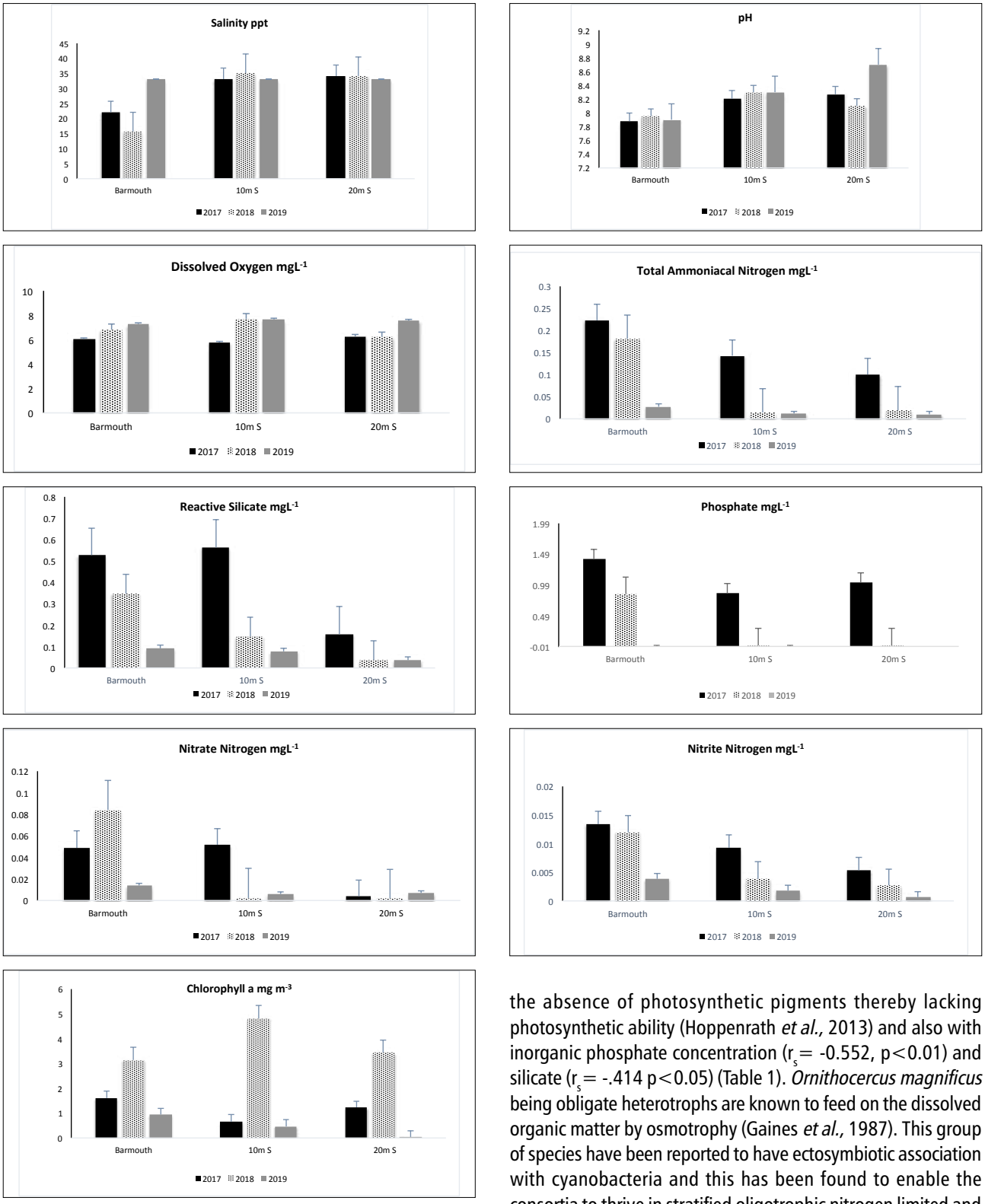

Fig.5.a. Station wise variations in the physiochemical parameters of the coastal waters Of Kochi during PoM from 2017-2019

Ornithocercus magnificus showed a significant negative correlation with chlorophyll (r_s=-0.568, $p<0.01$) due to the absence of photosynthetic pigments thereby lacking photosynthetic ability (Hoppenrath *et al.,* 2013) and also with inorganic phosphate concentration (r_s= -0.552, $p<0.01$) and silicate (r_s= -.414 $p<0.05$) (Table 1). *Ornithocercus magnificus* being obligate heterotrophs are known to feed on the dissolved organic matter by osmotrophy (Gaines *et al.,* 1987). This group of species have been reported to have ectosymbiotic association with cyanobacteria and this has been found to enable the consortia to thrive in stratified oligotrophic nitrogen limited and low nutrient waters (Gordon *et al.,* 1994; Tarangkoon *et al.*, 2010). Hence it is attributed to the alleviated concentrations of inorganic phosphate and silicate observed. Tarangkoon *et al.*, 2010, observed highest abundance of ectosymbiont-bearing

Table 1. Correlation matrix for the physico - chemical parameters influencing the bloom of *O. magnificus*

		AT	SST	Salinity	pH	DO	CHLa	TAN	Phosphate	Silicate	Nitrite	Nitrate	Diatoms	Dinoflagellates	Total phyto	*O.magnificus*	ONI index
Diatoms	Correlation Coefficient	.033	-.169	-.219	-.322	-.033	-.299	-.536**	-.133	-.035	-.269	-.402*	1.000	.202	.623**	.000	.014
	Sig. (2-tailed)	.875	.418	.293	.116	.875	.146	.006	.527	.868	.193	.046		.333	.001	.998	.947
	N	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Dinoflagellates	Correlation Coefficient	-.009	.415*	.156	.090	.503*	-.304	-.384	-.411*	-.419*	-.407*	-.180	.202	1.000	.742**	.715**	-.019
	Sig. (2-tailed)	.968	.039	.457	.667	.010	.139	.058	.041	.037	.043	.389	.333		.000	.000	.928
	N	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Total phytoplankton	Correlation Coefficient	.056	.268	.087	-.099	.361	-.317	-.465*	-.358	-.297	-.361	-.245	.623**	.742**	1.000	.559**	-.040
	Sig. (2-tailed)	.790	.196	.679	.637	.076	.123	.019	.079	.150	.076	.237	.001	.000		.004	.850
	N	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
O. magnificus	Correlation Coefficient	.032	.425*	.152	.068	.504*	-.568**	-.249	-.552**	-.414*	-.369	-.069	.000	.715**	.559**	1.000	-.216
	Sig. (2-tailed)	.878	.034	.467	.745	.010	.003	.230	.004	.040	.070	.744	.998	.000	.004		.300
	N	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
ONI index	Correlation Coefficient	.762**	.432*	-.017	.246	-.156	.461*	-.151	-.212	-.337	-.202	.063	.014	-.019	-.040	-.216	1.000
	Sig. (2-tailed)	.000	.031	.937	.237	.457	.020	.473	.309	.100	.334	.767	.947	.928	.850	.300	
	N	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

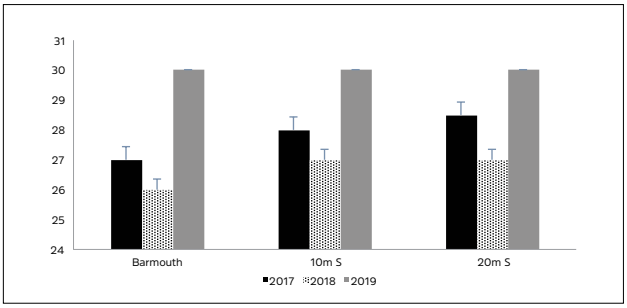

Fig. 5b. Variation in SST along the sampling locations during the post monsoon from 2017-2019

dinoflagellates especially *Ornithocercus magnificus* in certain euphotic zones in the Indian Ocean at low phosphate and chlorophyll a concentrations. In the present study the presence of ectosymbiotic cyanobacteria could not be ascertained as they were visible only in Transmission electron microscopy (TEM).

Temperature tolerance of Ornithocercus magnificus

The occurrence of this dinoflagellate species was found to be very rare along the south west coast especially in the coastal waters off Kochi except for the sporadic occurrences noticed during the post monsoon period of the years 2013 and 2014 and during the pre-monsoon season of 2016 (Fig. 4) concurrent to the conspicuously higher SST values observed. Interestingly, after 2016, this genus has been spotted only during 2019 (Fig. 5) that too at very higher density indicating the prominent changes occurring in the environment. The bloom was exclusively noted only during this season. The SST of the three stations of the post monsoon season was compared for the last three years from 2017 to 2019, and a conspicuous variation in the SST was noticed in this region. The SST in 2019 was 2.1° C higher than that observed during 2017 (Fig. 3b).

The occurrence of *Ornithocercus magnificus* showed a positive correlation with SST ($r_s = 0.425$, $p<0.05$) (Table 1). It was also noted that the occurrence of this species was observed during the El Nino years. The Oceanic Niño Index (ONI) was also correlated positively with the SST during the period ($r_s = 0.432$, $p<0.05$). The higher density of this species in 2019 when warmer SST was observed and their positive correlation with SST strongly indicates the preferences of *O.magnificus* to warmer waters. The year 2019 was also noted for its highest Indian Ocean Dipole (IOD) with the index value 2.0° C and above and was one of the strongest positive IOD. A study simulating the impact of a positive IOD event on Pacific surface wind and SST variations (Hameed *et al.*, 2018) showed that IOD-induced surface wind anomalies can produce El Nino-like SST anomalies, with the IOD's impact on SST being the strongest in the far-eastern Pacific. Thus warming up of the sea surface waters induced by

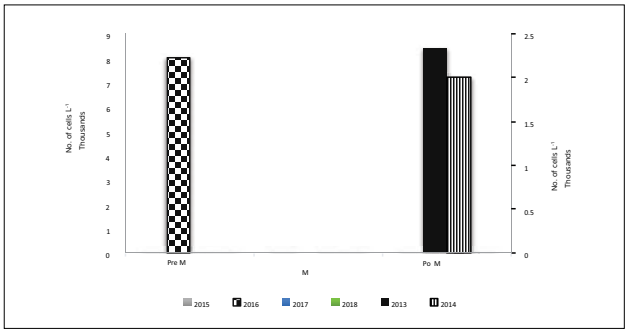

Fig.6. Seasonal occurrence of *Ornithocercus magnificus* in the coastal waters Off Kochi from 2013-2018

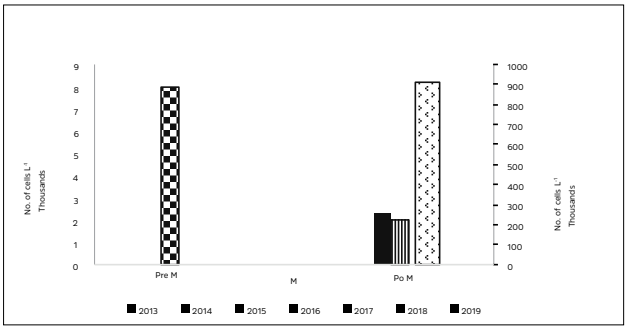

Fig.7. Occurrence of *Ornithocercus* sp in the coastal waters Off Kochi from 2013 -2019

El Nino effects and a strong positive IOD would have triggered the formation of the bloom of *O. magnificus* dominating the total phytoplankton abundance (<79-95%) .

A similar observation on the temporal changes occurring in the dinoflagellate composition along the coastal waters off Korean Peninsula, at the Chagwi-Do, west-part of Jeju Island, was made by Kim *et al.* (2008) reporting the occurrence of 19 new dinoflagellate species which were previously not observed or found to be rare around this peninsula. Among the new species observed, *Ornithocercus* dominated with markedly higher abundance. The reason for their abundance was linked to the increasing SST happening subsequent to the global warming. A follow up study conducted in this same region in 2013 also confirmed the presence of numerous unreported tropical dinoflagellate species including many species of the genus, *Ornithocercus* (Kim *et al.,* 2013).

Phytoplankton composition

The phytoplankton community structure analysed during bloom at along the three sampling stations revealed the presence of 38 species under 28 genera among which the diatoms dominated with 23 species, followed by dinoflagellates with 14 species and one from Cyanophyceae. During the bloom, the total phytoplankton abundance was found to be 1.79 x 10^6 nos L^{-1} (Barmouth), 9.46 x10^5 (10m S) and 2.53x10^5 (20m S). The dinoflagellates contributed 83.3-96% of the total phytoplankton in all the stations, followed by diatoms ranging from 3.96 - 16.2%, lowest observed at the barmouth, while cyanophycea contributed only 0.3% and was present only at the 30 m S (Fig. 8). A change in the community structure of phytoplankton was also observed over the years from 2017 to 2019, during the PoM. It was observed that diatoms (74.08%) which once dominated the coastal waters off Kochi in 2017 and 2018, now has been dominated by dinoflagellates which was earlier found to be less conspicuous or subdominant (20.14%). Similar observation was made by Kim *et al.,* 2013 in the coastal waters Off Korea. The Shannon Weiner Diversity index (H') was recorded for the PoM season from 2017-2019, where the Barmouth station was observed to possess the highest (H' = 3.259) in 2019, while the lowest value was observed in 2017 at 20m S (H' = 2.537). During the bloom, among diatoms, *Coscinodiscus* sp dominated in all the stations, followed by *Chaetoceros affinis*, *Skeletonema costatum, Ditylum brightwellii, Odontella mobiliensis, Cerataulina* sp., *Rhizosolenia* sp., *Odontella sinensis* and among the dinoflagellates community, after the *Ornithocercus magnificus, Ceratium furca, Peridinium depressum, Dinophysis caudata* and *Prorocentrum gracile* were observed in all stations. No reports of fish mortality was observed during this period.

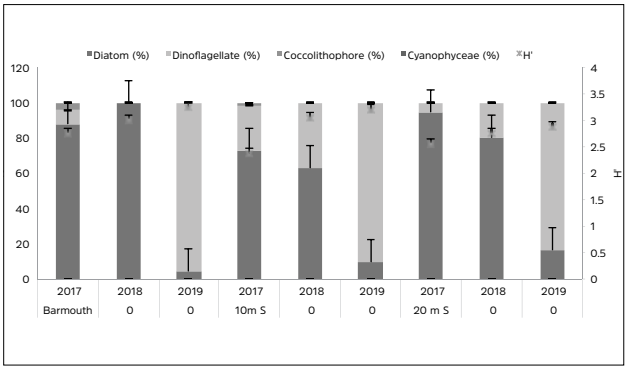

Fig.8. Variation in the percentage contribution of the phytoplankton taxa along with the variation in Shannon-Weiner Diversity Index (H') from 2017-19 during the PoM period in the off Kochi coastal waters

Ornithocercus magnificus bloom of this magnitude can be a warning sign on climate change impacts in the coastal waters of south west coast of India as the occurrence of this genus was hardly observed along this coast in the past. The SST in this region from the 2013 to 2019 positively correlated with the ONI revealing an increase in the average SST values indicating certain degree of impacts associated with climate change. The higher richness of this species in 2019 associated with higher SST and its occurrence during the El Nino years indicates the preferences of *O.magnificus* to warmer waters. The impact of the bloom of this genus on the fishery needs to be investigated in detail in the years to come. As opined by Dhulkhed *et al*., 1972,

the Indian oil sardine is occasionally known to forage heavily on *Ornithocercus*, especially in the demersal zone during the premonsoon season. The apparent shift in the predominance of dinoflagellates over diatoms as observed in 2019 indicates a change in the tropical waters off Kochi and needs to be monitored continuously.

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