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Dinoflagellate diversity and distribution in Chilika Lagoon with description of new records

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The study deals with the diversity and spatial distribution of the dinoflagellate class Dinophyceae in Chilika lagoon, north east coast of India. Thirty-eight species of dinoflagellates belonging to eight families were recorded, of which twelve are new reports to the lagoon. Of the twenty-six species recorded earlier, *Neoceratium furca*, *Neoceratium fusus*, *Dinophysis caudata* and *Noctiluca scintillans* were common among most of the earlier studies. Current study recorded presence of *Dinophysis miles,* which has not been encountered ever since it was first reported from the lagoon six decades ago. An updated checklist of dinoflagellates indicated presence of 68 species in the lagoon. The outer channel of the lagoon differed from southern and central sectors in distribution of dinoflagellates under the influence of salinity regime.

[**Keywords:** Dinoflagellates, Chilika lagoon, *Dinophysis miles*, *Neoceratium*, *Amphisolenia*]

Introduction

The dinoflagellates (Class Dinophyceae) are an important group of phytoplankton in marine and freshwaters and the largest phytoplankton group of marine ecosystems[1]. These flagellates range from non-motile symbionts to free swimming cells; their motion stimulated by various environmental clues like chemicals, light, gravity, etc.[2]. Due to the presence of various photosynthetic pigments, around 50% of the dinoflagellates show autotrophic behaviour[1]. The other half, that lack the plastids, have flexible naked cell wall and thus show heterotrophic behaviour[3, 4, 5]. Autotrophic dinoflagellates are an integral part of the lowest aquatic food chain and the heterotrophic dinoflagellates channelize energy into planktonic food webs through microbial loop. Dinoflagellates are considered as one of the considerable components of microplankton and also significantly contribute to the diet of meso and meta zooplankton[6]. They are cosmopolitan in distribution[7, 8] and have been acknowledged for their importance, both in temperate and tropical waters. Dinoflagellates are also well known as toxin producing phytoplankton[9] and causative organisms of ‘red tides’[10]. Harmful plankton blooms on aquatic animals and human beings have also been witnessed worldwide[11, 12, 13, 14, 15, 16]. India being a peninsular country has not been spared from the same[14, 15, 16] causing impetus to study the dinoflagellate groups in all possible waters to ensure environmental safety.

Chilika, a coastal lagoon is situated along the northern Bay of Bengal, in coastal Odisha. Sea water exchange through two channels and influx of freshwater through rivers largely influence and determine the hydrodynamics of the lagoon[17]. Distinct salinity gradient due to the water exchange produces pronounced effect on the spatial and temporal distribution as well as diversity of phytoplankton species in the lagoon[18]. Planktonic group ‘dinoflagellates’, as primary producers in marine food web are important to the trophic cycle of the lagoon; at the same time some of them being toxin producing, might also be potentially harmful to the biota of the lagoon if blooms occur. Studies [19, 20, 21, 22] have been carried out on the phytoplankton population of Chilika lagoon, indicting presence and absence of certain species dinoflagellates and their group abundance. However detailed taxonomy of the group from the lagoon is limited to few studies[23, 24]. Hence it is important to study the diversity, distribution and factors influencing their distribution in the lagoon, which is attempted through this study.

Materials and Methods

'Chilika' is Asia's largest brackish water lagoon and a declared Ramsar site since 1981. The lagoon has a water spread of 1165 km^2. This lagoon is shallow with water depth ranging between 0.38 and 4.2 m. Lake is situated in Odisha, along the east coast of India, between Latitude 19° 28'-19° 54' N and Longitude 85° 06'-85° 35' E. Spatial and temporal changes in salinity gradients, due to the freshwater flow from the riverine system and seawater influx from Bay of Bengal through two openings, gives Chilika lagoon characteristics of marine, estuarine and freshwater ecosystems (Fig. 1). Based on the salinity gradient, the lagoon has been classified into four broad ecological sectors; they being, the southern sector (saline), central sector (brackish), northern sector (fresh water) and the outer channel (saline). Samples were collected from twelve stations located across the four sectors of the lagoon as indicated in Fig. 1. Station 1, 2 and 3 situated in the southern sector of the lagoon; station 1 is connected to the sea through Palur canal and thus has continuous seawater influx. Station 4, 5, 6 and 10 are located in the central sector, which has lesser saline influence. Stations 7, 8 and 9 are located in the outer channel closer to sea mouth and hence remain saline most part of the year. Station 11 and 12 are in the northern sector, where station 12 is mainly freshwater in nature due to influx from rivers.

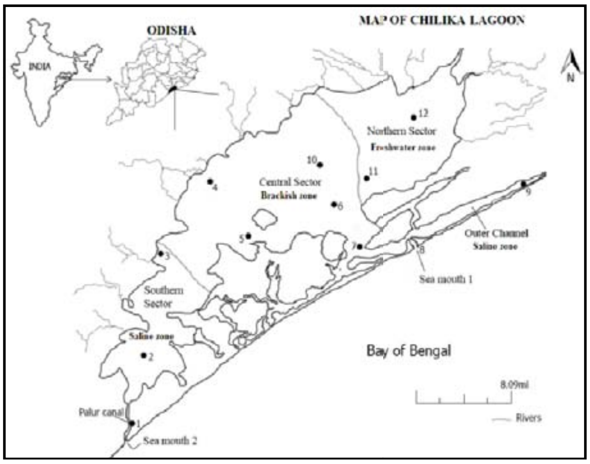

Figure 1. Study area with 12 sampling stations indicated

Plankton samples were collected from October 2012 to August 2014 using plankton net of 20 to 74 μ mesh. Post collection, the samples were preserved in 4% formalin and brought to laboratory for further analysis. The samples were viewed and images were captured under 10x, 40x and 60x magnification, using a Nikon Eclipse 50i microscope having image processing features. The identification of taxonomic characters like body length, width, horn length, foot, hypotheca and epitheca were measured and recorded for all size ranges, wherever necessary, using image processing software NIS elements D inbuilt with the microscope. Samples were identified using standard identification keys[25, 26, 27] and the nomenclature followed was the International Code of Botanical Nomenclature (ICBN). The valid and updated names of the species were followed using WoRMS[28]. Cluster analysis was performed based on Bray-Curtis similarity using PRIMER V6 software to assess the distribution pattern in various stations of the lagoon. Physico-chemical parameters like pH, salinity, water temperature, depth, transparency, DO, BOD, phosphate, nitrate and silicate were measured following APHA[29]. Statistical analysis was based on 99 samples of each 9 families of dinoflagellates and 10 physico-chemical parameters as mentioned above. Data were analyzed using Principal Component Analysis (PCA) with the CANOCO 5 software[30, 31].

Result

Thirty eight species of dinoflagellates belonging to 9 families under 5 orders were identified; of which 12 are new records to the lagoon. Fourteen species belonged to the family Gonyaulacaceae; 11 species under Ceratiaceae; three species under Dinophyceae; four species under Prorocentraceae; two species were under Pyrophacaceae and one species each under Amphisoleniaceae, Noctilucaceae Polykrikaceae and Gymnodiniaceae. Gonyaulacaceae not only remained the most dominant group but also the most diverse with five species of *Protoperidinium*, four species of *Alexandrium*, two species of *Gonyaulax*, one species each of *Lingulodinium* and *Protoceratium*. The second dominant family was Ceratiaceae that comprised of twelve species of genus *Neoceratium*. Two species of *Dinophysis* and one species of *Ornithocercus* were recorded under the family Dinophyceae.

The average water temperature of the lagoon ranged from 25.7 °C during winter and 33.4 °C during summer; salinity ranged from freshwater (0 ppt) to saline (34ppt) throughout the study period across the lagoon. The newly recorded dinoflagellate species, as shown in Table 1, were mostly prevalent in the outer channel followed by southern sector and central sectors. The northern sector had the least number of dinoflagellates and none were recorded from station 12. Cluster analysis based on the station wise distribution of these dinoflagellates in the lagoon showed Southern sector and central sector as more similar and differing from the outer channel and station 11 in Northern sector (Fig. 4) in presence of dinoflagellate species.

Description of newly recorded dinoflagellates

The description of the newly recorded species, based on their diagnostic characters along with their observed measurements from the lagoon are given in the following section.

Order- Gonyaulacales

Family- Gonyaulacaceae

Alexandrium ostenfeldii, (Paulsen) Balech and Tangen, 1985

A single or two celled colonial form, with large and spherical cells ranging between 40-56 μ in length and 40-50 μ in trans-diameter width (Balech 1995). Distinguished with a large ventral pore on the first apical plate; the apical pore plate with a large comma-shaped foramen and a thin theca. Epitheca and hypotheca are of equal height (Fig. 2a). Recorded during pre-monsoon and prevalent in station 7 (30.5ppt) and station 8 (33.10 ppt).

Lingulodinium polyedrum, (F. Stein) J. D. Dodge, 1989

Posses pentagon or polyhedral shaped cells with thick, coarsely aerolated theca plates, ranging from 40 to 54 μ in length and 37 to 53 μ in width. Apical horn or ant-apical spines absent. The polyhedral body is formed by ridges along the plate sutures [22, 26]. The specimen from Chilika measured 38.52 μ in length and 34 μ in width (Fig. 2b). The species was recorded during pre-monsoon from station 7 (33.6 ppt), station 8 (34 ppt) and station 9 (30.7 ppt).

Protoperidinium pellucidum, Bergh, 1881

Body shape of the species is quadrangular with short apex; paired ant-apical spines, which are slightly distant; apical spines shorter and closer. Hypothecal pore is situated beside the cingulum. The specimen measured 19.93- 91.41 μ in length and 15.37- 70.89 μ in width (Fig. 2c). A marine species, recorded during pre-monsoon from both station 3 (22.6 ppt) in southern sector and station 8 (34 ppt) and station 9 (30.7 ppt) in outer channel of the lagoon.

Protoperidinium elegans, (Cleve) Balech, 1974

Compressed large sized dinoflagellate with long apical and ant-apical horns**.** Right horn slightly forward to the left. Apical horn is centrally located whereas the straight ant-apical horn is slightly divergent (Fig. 2d). The total length of the specimen measured 57.54 μ, and the central flat area measured 4.44 μ. The right and left horn measured 22.51 μ and 23.27 μ, whereas the apical horn measured 22.32 μ. The species was recorded from station 7 (33.6 ppt) and station 11 (33.1 ppt).

Protoceratium reticulatum, (Claparède and Lachmann) Butschli, 1885

The occasionally polygonal, otherwise oval shaped dinoflagellate, has large hypotheca than epitheca due to the circumferential shift of cingulum. A ventral pore present on the left side of apical plate. The cell has numerous brown chloroplasts. As the name suggests, the body surface is highly reticulated, that distinguishes the species from its related ones. The length of the specimen was 45.88 μ and width 12.89 μ (Fig 2e). The hypotheca remained larger (27 μ) than epitheca (12.89 μ). Being a marine species, showed less tolerance to change in salinity and thus was mostly confined to the outer channel region of the lagoon in a salinity range of 22.2 to 33.1 ppt.

Family- Ceratiaceae

Neoceratium breve var. *curvulum*, Jörgensen, 1911

Neoceratium breve possess large cells, distinguished by variation in the curvature of the posterior horns. The variation is in the right horn, which is tightly curved towards the body. The length of the specimen was 270 μ and the width was 75.75 μ. The left horn was 127.76 μ and the right curved horn was 94.85 μ long. The distance of right horn from body was 35.15 μ but the curved horn was 26.47 μ (Fig 2f). Recorded from the outer channel in station 8 (30.20 ppt) during pre monsoon.

Neoceratium dens, (Ostenfeld and Schmidt) F. Gomez, D. Moreira and P. Lopez-Garcia, 2010

The species has large cells with straight apical horn, slightly tilted to the left. The cells are distinguished with the 3-4 times shorter bluntly acute left ant-apical horn when compared to right. A stack of two to four cells were often observed. The length of the specimen ranged from 159 to 173 µ and the width 67 to 74.7 µ. The larger horn measured 104.75-110.13 µ and the smaller one was 5 times smaller (20.68- 26.94 µ) (Fig 2g). Recorded from station 8 (30.2) of outer channel during pre- monsoon period.

Neoceratium falcatum, (Kofoid) F. Gomez, D. Moreira and P. Lopez-Garcia, 2010

The species has elongated, fusiform body with longer epitheca (with horn) and shorter hypotheca (with horn). The apical horn is straight while the antapical horn has a sharp bend at its distal end. The longer epitheca has a junction at its apical horn. The specimen has the longer ant-apical horn measuring 240.84 µ and at its maximum width at the junction was 21.64 µ. The junction spine measured 40.81 µ (Fig 2h). A marine species,recorded only from station 8 (30.2) of outer channel during pre-monsoon period.

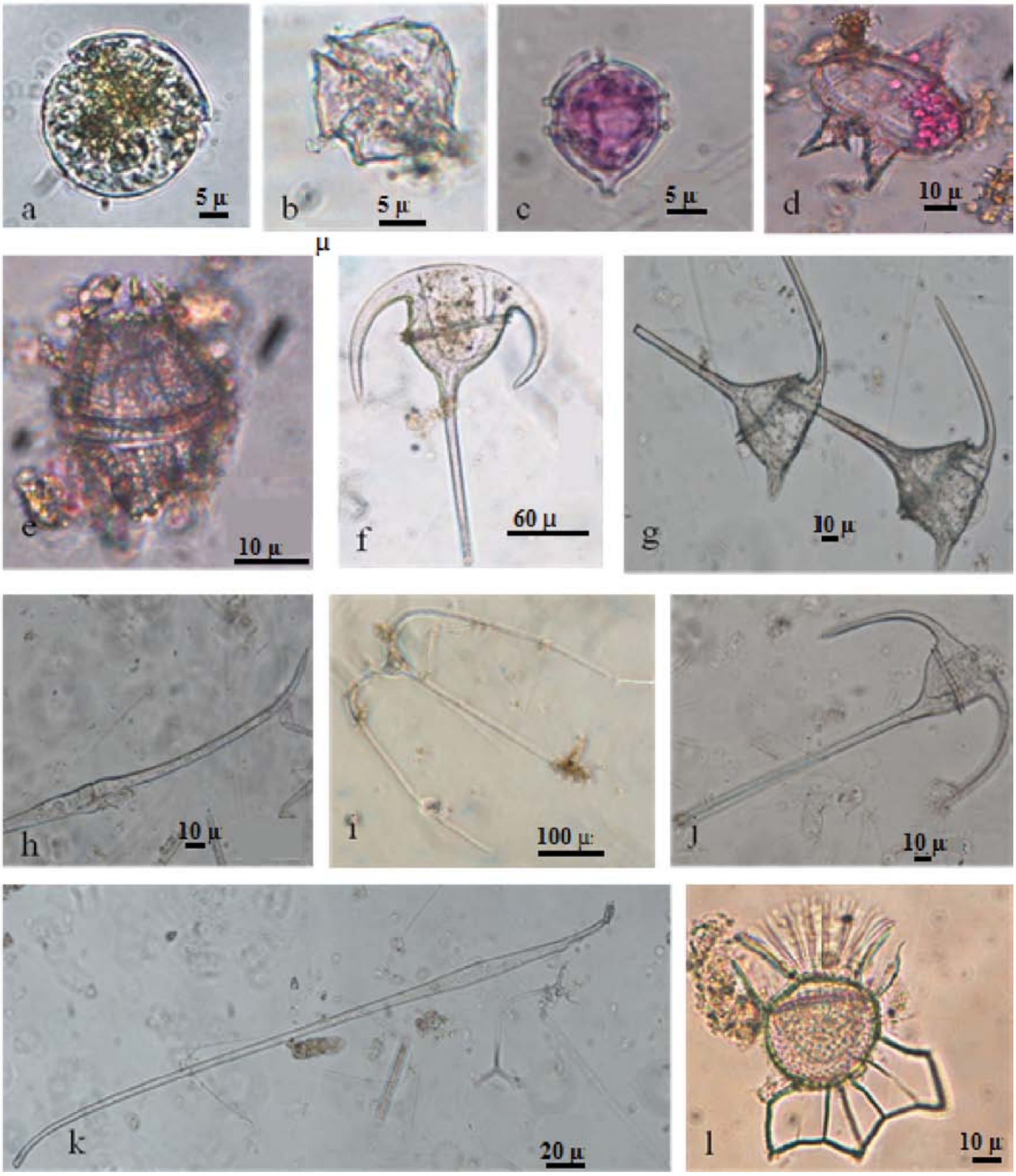

Figure 2. Dinoflagellate species newly recorded from the lagoon. (a) *Alexandrium ostenfeldii*, (b) *Lingulodinium polyedrum*, (c) *Protoperidinium pellucidum*, (d) *Protoperidinium elegans* (e) *Protoceratium reticulatum*, (f) *Neoceratium breve* var. *curvulum*, (g) *Neoceratium dens*, (h) *Neoceratium falcatum*, (i) *Neoceratium macroceros*, (j) *Neoceratium tripos* var. *atlanticum*, (k) *Amphisolenia astragalus*, (l) *Ornithocercus magnificus*

Neoceratium macroceros, (Ehrenberg) F. Gomez, D. Moreira and P. Lopez-Garcia, 2010

They are large cells with the apical horn slightly tilted to the right. The abruptly formed ant-apical horns initially extend equally but slightly beyond the posterior body before curving to run parallel to the apical horn; the left horn running slight anterior. The specimen measured 361.79 μ in length and 43.33 μ in breadth. The length of the apical horn was 478.70 μ and of the ant-apical horn was 245.18 μ (Fig 2i). Although a marine species, it showed a wide range of distribution in the lagoon. Recorded from both southern sector (8.9 ppt) in post- monsoon and from station 8 (33 ppt) and 9 (30.7 ppt) of outer channel. It was also recorded from station 11 (33.1 ppt) of Northern sector during pre- monsoon period.

Neoceratium tripos var. *atlanticum*, (Ostenfeld) Krakhmalny 2011

The length and width of the specimen from the lagoon was 274 μ and 53.29 μ, respectively. The slightly curved left horn measured 558 μ and the other one 529 μ (Fig 2j). The species is marine in habit[30] and was recorded only once from the outer channel of the lagoon at 33.6 ppt salinity.

Order- Dinophysiales

Family- Amphisoleniaceae

Amphisolenia astragalus, Kofoid and Michener, 1911

An elongated, fusiform dinoflagellate with head, neck, shoulder on a narrow body and an inflated mid region and a foot. The species is characterized with the presence of a broad, rounded heel on the foot without a heel spine. Presence of single ant-apical spine and absence of heel spine specifically differs the species from others within the family. The body length measured 374.58 μ, whereas the widest mid region of the body and the foot measured 11.64 μ and 71.53 μ, respectively (Fig 2k). A marine species recorded from station 8 (30.2 ppt) of outer channel during pre-monsoon.

Family- Dinophyceae

Ornithocercus magnificus, Stein, 1883

Small cell with well developed tri-lobed left sulcal list, one postero-ventral, one ant-apical and one postero-dorsal. The posterior part of the sulcal list has deeply arched area. Five ribs, supporting the three lobes of which, an accessory rib present on both side of the median lobe. Rib 1 is 'L' shaped and has spur (Fig. 2l). Total length of the species measured 95.64 μ and the widest body measured 41.74 μ. The upper flare measured 61.52 μ. Species was recorded from station 8 (34 ppt) and 9 (30.7 ppt) the outer channel during pre- monsoon period.

Figure 3. *Dinophysis miles* recorded from Chilika lagoon

Discussion

A number of studies have been carried out on dinoflagellates of Chilika lagoon. Patnaik[17] reported seven species of dinoflagellates (*Ceratium furca*, *C. tripos*, *C. fusus*, *C, longipes*, *Noctiluca scintillans*, *Dinophysis caudata* and *Peridinium diabolus*) and their distribution in the Chilika lagoon. Patnaik and Sarkar [20] added another species *Ceratium minutum* to the previous list from the central sector. Devasundaram and Roy[21] also reported seven species of dinoflagellates *viz*. *Dinophysis homunculus* (*Dinophysis caudata*), *D. miles*, *Peridinium* sp., *C. breve*, *C. furca* and *C. trichoceras* and a sub-species of *C. furca* '*engramma'*. Raman *et al*.[22] reported *Peridinium brevipes* (*Protoperidinium brevipes*) as the most dominant species in the lagoon. The species *Peridinium diabolus* (*Protoperidinium diabolum*) reported by Raman *et al*.[22] has not been recorded in the present study. Adhikary and Sahu[34] also reported the presence of *Ceratium furca (Neoceratium furca)*, *Noctiluca miliaris* (*Noctiluca scintillans*) and *Dinophysis caudata*. Panigrahi *et al*.[17] reported presence of 13 species of dinoflagellates discussing only six of them (*Ceratium lineatum*, *C. furca*, *C. tripos*, *Protoperidinium depressum*, *P. brevipes* and *Prorocentrum micans*); Rath and Adhikary [35] reported the presence of five species, adding *Gymnodinium heterostriatum* into the list of records. Panigrahi *et al*.[17] reported six species of dinoflagellates with *Protoperidinium depressum* and *Prorocentrum micans* as new additions. Jha *et al*.[23] reported presence of 29 species of dinoflagellates. The Chilika Development Authority[24] updated the number of species to 44. This list includes the species reported by Jha *et al*. [23] and an addition of 15 other species. Present study recorded *Dinophysis miles* (Fig. 3.) from station 8 in June 2013 at salinity of 34 ppt, which has never been reported after the species was first reported in 1954 by Roy[36] although a number of studies[17, 18, 19, 20, 21, 22, 23] have been carried out on the diversity of plankton in Chilika lagoon. Its availability in the lagoon appears to be very rare considering it being recorded only once from station 8 in June 2013 in the present study.

Considering the earlier reports and the current study an updated checklist of dinoflagellate species in the lagoon has been prepared (Table 2), which indicated that the lagoon is dinoflagellate species rich and the distribution is more extensive than reported earlier. The total number of species recorded till date from Chilika lagoon stands at 68. Of this, *Protoperidinium brevipes* was recorded only by Panigrahi *et al*.[17], *Protoperidinium conicum, Peridinium cinctum, P. umbonatum, Goniodoma polyedricum, Dinophysis acuta, Hemidinium nasutum, Glenodinium kulczynskii* by CDA [24] and 12 new records in the current study. The rest are common to all the previous records. Of the 68 dinoflagellate species recorded from Chilika, 15 species *viz*. *Alexandrium minutum*, *A. ostenfeldii*, *A. tamarense*, *A.monilatum*, *Lingulodinium polyedrum*, *Gonyaulax polygramma*, *Dinophysis caudata*, *D. acuta*, *D. fortii*, *Prorocentrum minimum*, *P. micans*, *P. belizeanum*, *P. lima*, *Noctiluca scintillans* and *Gymnodinium catenatum* are reported as potentially toxin producing species [26].

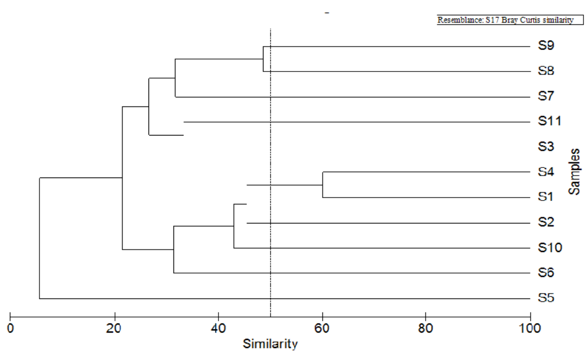

Figure 4. Bray-Curtis similarity of station wise dinoflagellate distribution in Chilika lagoon (S1 to S11 are stations).

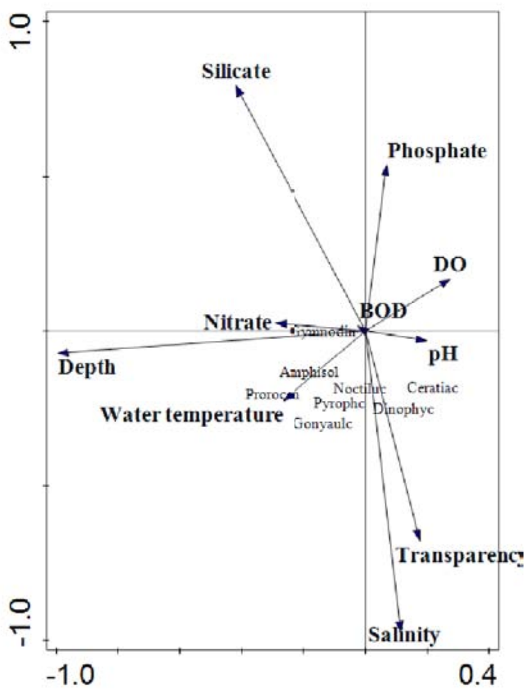

Figure 5. Ordination diagram based on PCA on dinoflagellate groups of Chilika with respect to environmental variables. Family names are represented by smaller font and environmental variables by arrows. Eigen values of the first two axes= 0.63 and 0.22.

As the outer channel is distinct from the other sectors; and the southern and central sector are more similar with regard to occurrence of dinoflagellate species (Fig. 4), stations 7, 8 and 9 along the outer channel exhibited 50% similarity and stations of central and southern sectors showed 40-60% similarity. The dinoflagellate distribution in outer channel being distinct from the central and southern sectors it is explained based on the salinity difference amongst them. During the pre-monsoon period, salinity range of outer channel was 30-34 ppt, whereas the central sector had salinity at 21-33 ppt and that in the southern sector was 22-33 ppt. Therefore dinoflagellate species that prefer higher salinity was recorded from the outer channel, while the rest were distributed in all the other three sectors. Principal Component Analysis performed to summarize the effect of environmental parameters on the dinoflagellates has 85. 64% of explained variables with first two axis. Salinity followed by transparency were the most influencing parameters affecting the appearance and abundance of the dinoflagellates in the lagoon (Fig. 5). As indicated by D'Costa *et al*.[37], Alkawri and Ramaiah[38], environmental parameters like light, temperature and salinity have major influence on dinoflagellate distribution. The average temperature of the lagoon did not widely fluctuate during the study period, while the salinity across the sectors and seasons showed considerable variations suggesting salinity as the major influence on distribution of these dinoflagellate species in the lagoon. Unlike *Alexandrium minutum* and *A. tamarense,* that have been reported to tolerate salinity range of 5-37.5 ppt [39, 40], *A. ostenfeldii* in Chilika lagoon occurred only within the salinity range of 30.5 to 33.10 ppt. Species like *Amphisolenia astragalus*, *Neoceratium tripos* var. *atlanticum*, *N. dens*, *N. falcatum* and *N. breve* were mostly recorded from Station 8 during higher temperature and salinity. Species like *Neoceratium macroceros* and *Prorocentrum micans* were recorded from a range of salinity 8.9-33.1 ppt, indicating their tolerance to brackish zone as well. As salinity dependent distribution of the species is evident in the present study, salinity regime is important to maintain the dinoflagellate species diversity and abundance in the lagoon to avoid possible blooms and toxin formation. The strength of correlation among the dinoflagellate families was insignificant, the projection being very nearer to the coordinate origin (Fig. 5). Though not significant, a difference in correlation was observed in Gymnodiniaceae from all other groups which were positively correlated. Dinoflagellate abundance showed no significant positive correlation with nutrient parameters like nitrate and phosphate. However, the projection point of all the dinoflagellate groups lies in the opposite direction to the silicate, indicating strong negative correlation. Studies[42, 43] have suggested limitation of growth of diatoms and indirect proliferation of dinoflagellate with decreasing silicate level. This can be attributed to the utilization of similar nutrients for growth by both diatoms and dinoflagellates, except silica[41]. Thus the negative correlation of dinoflagellates to silicate in Fig. 5, is an indication of the dinoflagellates following similar phenomena in Chilika lagoon. Though the dinoflagellate population does not directly depend upon any of the nutrient parameters in the lagoon,

Table 1- Distribution of dinoflagellate species in Chilika lagoon.

Order	Family/ Species	Stations										
		1	2	3	4	5	6	7	8	9	10	11
	Gonyaulacaceae											
	Alexandrium minutum	+			+			+		+	+	
	*A. ostenfeldii**											
	A. tamarense		+		+					+		
	A. monilatum	+	+					+		+		
	*Lingulodinium polyedrum**							+	+	+		
	*Protoperidinium pellucidum**			+					+	+		+
	P. depressum								+			
	*P. elegans**							+				+
	P. oceanicum								+	+		
	P. steinii							+				+
	P. minimum							+				
	*Protoceratium reticulatum**			+					+			
Gonyaulacales	*Gonyaulax scrippsae*			+							+	
	G. spinifera		+								+	
	Ceratiaceae											
	Neoceratium breve								+			
	*Neoceratium breve var. curvulum**								+			
	*Neoceratium dens**								+			
	*Neoceratium falcatum**								+			
	N. furca var. furca			+				+	+	+		
	N. fusus	+	+	+	+		+		+	+	+	+
	N. longipes								+	+		
	*Neoceratium macroceros**	+	+						+	+		+
	N. trichoceros							+	+			
	N. tripos									+		
	*Neoceratium tripos var. atlanticum**								+			
	Pyrophacaceae											
Dinophysiales	*Pyrophacus horologium*								+			
	Pyrophacus steinii							+	+	+		

	Amphisoleniaceae											
	*Amphisolenia astragalus**								+			
	Dinophyceae											
	Dinophysis caudata								+			
	D. miles								+			
	*Ornithocercus magnificus**								+	+		
Prorocentrales	**Prorocentraceae**											
	Prorocentrum minimum						+		+			
	Prorocentrum micans					+		+	+			
	Prorocentrum belizeanum			+		+		+				
	Prorocentrum lima				+		+		+			
Noctilucales	**Noctilucaceae**											
	Noctiluca scintillans		+					+				
	Polykrikaceae											
Gymnodiniales	*Polykrikos schwarzii*			+				+				
	Gymnodiniaceae											
	Gymnodinium catenatum	+			+							

* indicates new records in present study; + indicate presence

diatom population and silicate level can be a limiting factor. The dinoflagellate group being species rich can contribute to the trophic cycle of the lagoon as important primary producers. Consecutively their wide distribution and range of salinity tolerance in the lagoon can be alarming. The lagoon being an open system with continuous nutrient influx from both rivers and openings to the seas, needs constant monitoring on the dinoflagellate diversity and abundance along with other related parameters to avoid any unwanted harmful bloom formations and for prior precautions.

Table 2- Checklist of dinoflagellate species recorded from Chilika lagoon.

Family/ Species	De54[21]	Pa73[19]	Pa76[20]	Ad92[34]	Ra05[18]	Pa09[17]	Jh09[23]	CDA14[24]	Present study
Gonyaulacaceae									
Alexandrium minutum							+	+	+
*A. ostenfeldii**									+
A. tamarense							+	+	+
A.monilatum							+	+	+
*Lingulodinium polyedrum**									+
*Protoperidinium pellucidum**									+
P. depressum						+		+	+
*P. elegans**									+
P. oceanicum							+	+	+
P. steinii								+	+
P. pedunculatum							+	+	
P. leonis							+	+	
P. divergens							+	+	
P. ovatum							+	+	
P. pallidum							+	+	
P. conicum								+	
Peridinium cinctum								+	
P. willei							+	+	
P. umbonatum								+	
P. diabolum		+	+						
P. brevipes						+			
*Protoceratium reticulatum**									+
Gonyaulax scrippsae								+	+
G. spinifera							+	+	+
G. polygramma								+	
Cladopyxidaceae									
Peridiniella cataneta							+	+	
Ceratiaceae									
Neoceratium breve	+	+	+						+
N. longipes		+	+		+				+

*N. breve var. curvulum**									+
N. contortum							+	+	
*N. dens**									+
*N. falcatum**									+
N. furca	+	+	+	+		+	+	+	+
N. furca var. furca									+
N. fusus		+	+				+	+	+
N. gibberum							+	+	
*N. macroceros**									+
N. minutum		+	+					+	
N. trichoceros	+								+
N. tripos					+	+	+	+	+
*N. tripos var. atlanticum**									+
N. lineatum					+	+			
Goniodomataceae									
Goniodoma polyedricum								+	
Pyrophacaceae									
Pyrophacus horlogium							+	+	+
P. stenii							+	+	+
Amphisoleniaceae									
*Amphisolenia astragalus**									+
Dinophyceae									
Dinophysis caudata	+	+	+	+	+				+
D. miles	+								+
D. acuta								+	
D. fortii							+	+	
*Ornithocercus magnificus**									+
Prorocentraceae									
Prorocentrum minimum							+	+	+
P. micans						+			+
P. belizeanum							+	+	+
P. lima							+	+	+
P. emerginatum								+	
P. maximum								+	
Noctilucaceae									
Noctiluca scintillans		+	+	+					+
Kofoidiniaceae									
Pomatodinium impatiens							+	+	
Polykrikaceae									
Polykrikos schwarzii							+	+	+
Gymnodiniaceae									
Gymnodinium catenatum							+	+	+
Gymnodinium heterostriatum					+				
Amphidinium poecilochroum								+	
Hemidiniaceae									
Hemidinium nasutum								+	
Peridiniaceae									
Peridiniopsis thompsonii							+	+	
Scrippsiella trochoidea							+	+	
Glenodiniaceae									
Glenodinium pulvisculus							+	+	
G. kulczynskii								+	

* indicate new records from present study; + indicates presence

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