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Checklist of intertidal benthic macrofauna of a brackish water coastal lagoon on east coast of India: The Chilika lake

Debasish Mahapatro[1], R.C. Panigrahy, S. Panda[2] and R.K. Mishra[3]
1. Department of Marine Science, Berhampur University, Berhampur, Ganjam Odisha, India
2. Department of Forest and Environment, Bhubaneswar, Odisha, India
3. National Centre for Antarctic and Ocean Research (NCAOR), MoES, Goa- 403 804 India
Corresponding author email: dsmahapatro@gmail.com
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Abstract During the present inventory study related to benthic macrofaunal assemblage in the intertidal region of outer channel area, Chilika lake encompassing the period from 2007 to 2010, recorded a total of 135 species from 8 phyla. The phylum annelid became the major group having 46 species followed by mollusca with 41 species. The class polychaeta emerged as the dominant group with 39 species followed by the class bivalve having 21 species. Some of the taxa substantiated during the study period were those of *Spongilla alba*, *Membranipora bengalensis*, *Capitella capitata*, *Minuspio cirrifera*, *Heromastus filliformis*, *Grandidierella taihuensis*, *Niphargus chilkensis*, *Quadrimaera incerta*, *Ampithoe ramondi*, *Mesopodopsis orientalis*, *Ctenapseudes chilkensis*, *Alpheus edwardsii*, *Uca* sp., *Diogenes custos*, *Remipes* sp., *Amphibalanus Amphitrite*, *Chironomus*, *Lepas (Anatifa) anatifera*, *Meretrix meretrix*, *Mactra stultorum*, *Brachidontes striatulus*, *Solen annandalei*, *Crassostrea cuttackensis*, *Bufonaria echinata*, *Epitonium clathrus Nassarious stolatus*, *Umbonium vestiarium*, *Astropecten bengalensis*, *Ichthyocampus carce etc.* One rare species of the family syngnathidae namely *Hippocampus fuscus* was recorded during the present study from the sea grass meadows. From the correlation matrix it was revealed that the environmental parameters like salinity and chlorophyll *a* appeared as the major factor controlling the intertidal macrobenthos of outer channel area. Strong seasonal heterogeneity was also observed in the environmental parameters like salinity, DO along with the number of macrobenthos taxa. Higher number of benthic taxa in summer as compared to monsoon in both years of study was also evidenced. Since many of the newly occurring taxa in the lagoon premises were of typical marine forms observed during 2009-10 study year, therefore the positive impact of a new lagoon inlet on benthic macrofaunal assemblage in the intertidal region is highly corroborated.
Keywords Outer channel area; Chilika lake; Intertidal region; Benthic macrofauna

Introduction

Coastal lagoons are usually shallow brackish water ecosystem, highly productive and dynamic in nature. They are found in the transitional zone between continental land mass & oceanic milieu (Anthony et al., 2009; Mohapatro *et al.*, 2013). According to Kjerfve (1994), coastal lagoons are defined as "*an inland water body, usually oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by one or more restricted inlets, and having depths which seldom exceed a couple of meter*". The intertidal zones of such shallow coastal lagoons are positioned high among the most productive marine ecosystems in the world (Alongi 1990; Heip et al., 1995; Panigrahy 2000; Anthony et al., 2009; Mohapatro et al., 2013). In general, the benthic communities of such intertidal region are considered as the pioneer components of coastal and marine ecosystem process (Lu, 2005). Factors affecting significantly on intertidal macrobenthos are those of frequent tidal incursion, sharp declination in salinity and seasonal variation of different abiotic parameters (Alongi, 1990; Ysebaert et al., 2002). The sediment composition is also considered as one of the important parameter to the intertidal organisms which determines larval recruitment and settlement followed by species composition (Sanders, 1958, Gray, 1974, Warwick et al., 1990). It has been well documented by Herman et al. (1999) and Riisgård & Kamermans (2001) that the macrobenthos community is mostly feed up on microphytobenthos or phytoplankton whereas some of them also use detritus materials such as the debris of sea weeds, sea grass and other macrophyte vegetation as their chief source of food (Créach et al., 1997). Thus intertidal zones become the most suitable region for many of the fishes, shellfishes, shorebirds and benthic macroinvertebrates to colonies for feeding and breeding process (Alongi, 1990, Ysebaert et al., 2002; Elias et al., 2005). Impact of natural and anthropogenic stress on intertidal macrobenthos might be drastic. According to Alongi (1990), any alteration in the species composition of intertidal macrobenthic community due to natural event and/or anthropogenic stress have deleterious effect on species composition and abundance of tertiary consumers of higher trophic strata like fishes, migratory birds, even for dolphins with respect to time and space. Thus intertidal benthos plays a critical role in coastal biodiversity. It also decipher immense ecological functioning such as variation in the physical and chemical composition of sediment (Gaudencio and Cabral, 2007; Shou et al., 2009), recycling of nutrients, metabolism of different pollutants and secondary production (Snelgrove, 1998). Some of the sessile intertidal organisms are the best source of bioactive compounds; even few of them are also used in the ecotoxicological studies such as heavy metal, PCB, PHC. Because of their sessile mode of life style and capability to withstand under environmental extreme conditions, these are often used as the suitable indicators of pollution or environmental stress (Dauer, 1993). With these facts and information, the present study is basically designed for the documentation of intertidal macrobenthos and other megabenthic organism in the outer channel area of Chilika lake.

Chilika lake is the largest brackish water coastal ecosystem in Asia and second largest in the world, enriched with biodiversity and a rich source of large scale exploitable fishery resources. It appeared as the largest habitat for migratory bird species and Irrawaddy dolphin (Panigrahy, 2000; Panda et al., 2009). Research on biodiversity aspect of Chilika lake has been started since a century ago which has been evidenced by the perusal of literature such as Preston (1915), Annandale (1915), Annandale and Kemp (1915), Sewell and Annandale (1922). They reported details of the macrobenthic community distribution and species composition. Later Rajan (1965), Patnaik (1971), Sarma et al. (1981) and ZSI (1995) have furnished good amount of information related to the various aspects of bottom fauna of Chilika. Besides this, there are hundreds of literature available related to biodiversity, fisheries, hydrography, change in geomorphology, pollution aspects etc. But there is no literature available to enumerate the intertidal benthic fauna of Chilika lake. Therefore, to fill this gap of information, the present study is designed (i) to develop a comprehensive checklist of macrobenthic community of Chilika lake residing in the Outer channel area including mega-benthic fauna, (ii) to compare the environmental data and no. of macrobenthos taxa between two periods i.e. before the opening of natural inlet during 2007-08 (one inlet) with the data of the year 2009-10 (two inlet), (iii) to find out the correlation between different environmental parameter with number of macrobenthic taxa recorded during the study period.

1 Material and Methods

Study area-Chilika lake which is also regarded as a coastal lagoon, located between 19^{O}28’and 19^{O} 54’N and 85^{O} 05’and 85^{O} 38’E (Figure 1). It is the largest brackish water coastal ecosystem in Asia and situated on the east coast of India. The pear-shaped water body of Chilika lake measure about 64.5 km long and width varies from 5 km to18 km where as the water spread area has been estimated from 906 sq. km in summer to 1165 in monsoon seasons (Panda et al., 2009). Ecologically, the lagoon can be divided in to four sub-ecosystems such as Northern sector (fresh water), Central sector (Brackish water), Southern sector (Brackish-cum-marine water) and outer channel area having the marine characteristics (Panda et al., 2009).

The outer channel is 32 kilometer long channel connects the lagoon with the Bay of Bengal through couple on inlets (“Shipakuda inlet” and “Gobakunda inlet”). Another man made channel of 16 kilometers long called “Palur Canal” is connected with the lake at the southern tip. This channel is started from the Rushikulya estuary and brings sea water from Bay of Bengal under the influence of tidal rhythm towards the southern sector of the lake. Salinity becomes the main guiding parameter and thus strongly determines the distribution of flora and fauna of it. The Nalabana Is. of Chilika lake is the shallow area with exposed soft sediment. During winters it become the major feeding, breeding and nesting ground of migratory and residential birds. It provides homage to 0.1 million of population of wintering birds every year. Furthermore, the lake is also acts as an ideal habitat for Irrawaddy dolphins. More than 10,000 mt of fisheries output per annum is reported from Chilika lake. Thus, it provides livelihood support to 0.2 million of fisher folk. Like other coastal ecosystems, Chilika lake ecosystem also faced sever environmental degradation due to closing of a lagoon inlet during the last decade of 20th century. As a consequence of such event, the lagoon-sea interaction had been cut off completely. Salinity followed by fisheries output in the lake was dropdown drastically. This had not only created a major a concern about the socioeconomics of the local people but also a eutrophic condition was developed.

In order to develop the previous pristine brackish water characteristics of the lake by increasing the salinity level *vis-a-vis* fisheries output, a dredged mouth was opened during 23rd September 2000 which was named as "Shipakuda inlet". After two years of opening of this dredged inlet, the fisheries output was increased up to 7 folds where as the desired salinity level was maintained (Mohapatra et al., 2007; Panda et al., 2009). After 8 years of this hydrological intervention, another mouth was opened by natural process (1 km northeast of the dredged mouth) during the year 2008. This natural inlet was termed as "Gobakunda inlet" (CDA, 2010). Both these inlets put major role in the sediment & water exchange between the lagoon and sea. However, very less study was carried out regarding this to explain the change in water quality and biodiversity.

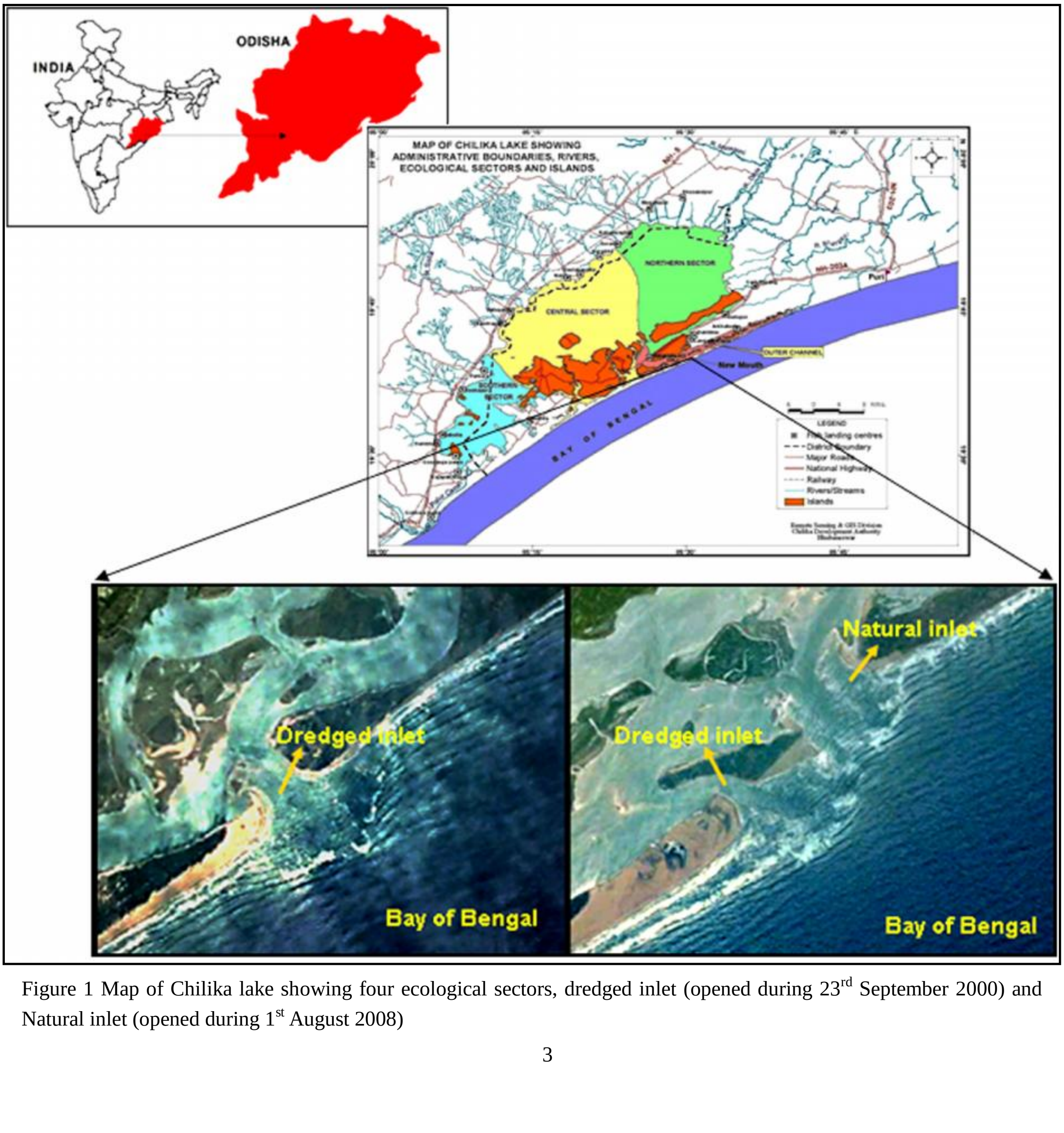

Figure 1 Map of Chilika lake showing four ecological sectors, dredged inlet (opened during 23rd September 2000) and Natural inlet (opened during 1st August 2008)

1.1 Outer channel- general information

Outer channel is the marine influenced region of Chilika lake having the length of 18 km and width varies from 200 m to 2 km. This is the deeper region of Chilika lake having observed depth more than 3 m while during monsoon its depth is significantly high due to massive ingress of fresh water from the northern and western catchment. The sediment texture of this region is varied from coarse sand to fine sand while many patches of soft bottom sediment were also seen. Some areas those are called as intertidal mudflats usually located at the sheltered region of the new inlet channels. The Shipakuda region of outer channel area is covered with artificially implanted mangrove vegetation. The flank areas are occupied with shoreline vegetation such as *Casuarina* plantation, halophytes and grasses where as the bottom of the intertidal sediment is dominated with the occurrence of sea grass meadows and sea weeds. Five species of sea grass were observed in the outer channel region such as *Halophila ovalis*, *Halophila ovata*, *Halophila beccari*, *Halodule pinnifolia* and *Halodule uninervis*. This can be visualised in a better manner during the low tide periods. Besides these many brackish water macrophyte are reported from outer channel area such as *Ruppia maritima*, *Potamogetone pectinatus* etc. Among sea weeds *Chaetomorpha linum*, *Enetromorpha* sp., *Ulva* sp. etc become conspicuous. Large bed of bivalve community belonging to *Crassostrea cuttackensis* and *Meretrix* sp., are frequently observed in the low tide periods nearer to the “*Manikpatana*”, “*Arakhkuda*”, “*Gobakunda*” and “*Shipakuda*” region of outer channel area. During winter season, the shoreline areas are often covered with shore birds. A major portion of them are migratory in nature. They usually feed on the macrobenthic organisms like polychaetes, amphipods and gastropods. The location of the inlet channel favoured the lagoon-sea interaction, as well as the entry of anadromous fishes those are frequently invade the lagoon area for breeding purposes. In addition this, many of the larval stages of fishes, shellfishes and the juvenile of fish, prawn and crab are seen. It is a major tourist destination in India. From these above descriptions, it is understood that the outer channel area of Chilika lake is one of the most diversity rich areas of in India which provides an ideal habitat for flora and fauna.

1.2 Sample collection and analysis

With the intention to evaluate the impact of opening a natural inlet upon macrobenthic species composition and water quality parameters, special attention had been paid to compare the data of 2007-08 (single inlet) to that of 2009-10 (two inlets) of outer channel area. In order to get the water samples and sediment for macrobenthic community analysis, random sampling procedure was adopted during 2007 to 2010 on seasonal basis. Water quality parameters such as water temperature, salinity, pH, were measured by using a standardised water quality checker of (TOA DKK, Made in Japan). The dissolved oxygen was analysed by using the Winkler’s method whereas Chlorophyll *a* of water was measured by adopting the procedure prescribed by Strickland and Parson (1972). The sediment samples were taken in replicate during the low tide period by using a Van Veen grab sampler (0.04 m^2). After collection, the sediment samples were washed through the sieve having mesh size of 500 micron. Then after the large bodied organisms were photographed immediately and preserved. After a cursory survey, the macrobenthos samples were kept in labelled jar and preserved in the 10% neutralised formalin and stained through Rose Bengal solution. Later, all those samples were transferred into the laboratory, where the specimen samples were washed once again and steps had been adopted for identification up to species level. Specimen those were not identified up to species level confined to genus level only. Identification process was made by adopting the standard literature (Fauvel, 1953; Gosner, 1971; Subba Rao, 1992; 2003). A nylon scoop net was deployed to collect the megabenthos organisms (size more than 500 micron) most of them belonged to fishes, crab and prawns from the bottom sediment. For identification of fishes and shell fishes FAO species identification sheets were used available in the website FAO. org followed by the website of Fish base.

2 Results

2.1 Environmental parameters

Environmental parameters of outer channel area of Chilika lake can be observed from table 1. From which it was observed that the salinity level was high during summer season of 2009-10 as compared to 2007-08 where as lower values were seen in monsoon season winter have moderate values. The water temperature in both the years observed with little difference. However the winter season of 2009-10 recorded higher values as compared to the winter of the previous study year. The dissolved oxygen content of 2009-10 was found less as compared to 2007-08. Lower DO in monsoon and higher value in winter was reported. During the entire study period the pH level was found alkaline (i.e. pH above 8) whereas monsoon season of 2007-08 and summer season 2009-10 the pH value was low i.e. 7.9 and 7.8 respectively, higher values were seen in winter of 2009-10. The concentration of chlorophyll *a* was high in premonsoon season of 2009-10 as compared to 2007-08. Higher values found in summer season where as lower concentration were associated with monsoon season observed in both the years of study (Table 1).

The number of macrobenthos taxa can be revealed from the same table from which it was observed that summer season of 2009-10 had more number of macrobenthic taxa i.e.131 no. of species as compared to monsoon season of 2007-08 having 80 no. only. Monsoon season of both the study year exhibited lower values of macrobenthos taxa as compared to summer season while winter season have shown moderate values. From Table 2 the results of correlation matrix can be viewed from which it was observed that the number of macrobenthic taxa have significant positive correlation with salinity ($r = 0.948$, $p<0.001$) and chlorophyll *a* ($r = 0.760$, $p<0.001$). Salinity and water temperature had shown negative correlation with DO and pH.

Table 1 Seasonal comparison of environmental data between the year 2007-08(single inlet) with the year 2009-10 (double inlet) in the outer channel area of Chilika lake

	2007-08 (one inlet)			2009-10 (two inlet)		
Environmental parameter	Summer	Monsoon	Winter	Summer	Monsoon	Winter
Salinity(ppt)	30.98±2.19	6.87±2.09	15.17±5.69	32.01±1.17	10.85±5.56	17.76±7.38
Water temp.(^{o}C)	30.16±0.35	30.03±1.02	24.53±0.44	30.77±0.38	30.56±0.35	26.80±0.31
Dissolved oxygen (mg/l)	7.32±0.52	8.77±0.15	8.77±0.15	6.98±0.16	8.41±0.36	9.03±0.54
pH	8.14±0.09	7.94±0.09	8.34±0.21	7.88±0.05	8.02±0.06	8.41±0.24
Chl. a (mg/m^3)	7.82±3.10	3.10±0.74	5.19±0.11	8.51±2.40	2.90±1.00	6.24±1.20
Macrobenthic taxa (no.)	109	80	95	131	92	118

Table 2 Correlation matrix between the environmental data with no. of macrobenthos taxa observed during the entire study period

	Salinity	*WT*	*DO*	*pH*	*Chl. a*	*Macrobenthic taxa*
Salinity	1					
WT	0.216	1				
DO	−0.876	−0.661	1			
pH	−0.119	−0.995	0.583	1		
Chl. a	0.928	0.565	−0.993	−0.481	1	
Macrobenthic taxa	0.948	−0.106	−0.676	0.204	0.760	1

2.2 Species composition

A total 135 no. of species belonging to 8 phylum, 19 classes, 52 orders and 102 families were documented (Table 3). Phylum annelid exhibited highest contribution with 46 species in which class polychaetes alone contributed 39 species. Phylum mollusca appeared as the second most dominant group contributed with 41 species belonging to three classes i.e. bivalve 21 species, gastropoda19 sp. and polyplacophora 1 sp. Twenty nine species of arthropoda were reported. Order amphipoda was major having 11 species where as lecosiidae and isopoda having two species each. Representation of orders like mysida, stomatopoda, diptera, sessilia, lepadiformes had one species each. The phylum coelenterate comprised with 6 species whereas chordate included with 5 species. Phylum porifera with 4 species and echinodermata contributed with 3 species observed from the sandy sediment of the study area (Table 3 and Figure 2). Many species were reported during the present study as first record from this lagoon ecosystem.

3 Discussion

In general, tropical intertidal habitats differ greatly from temperate areas in relation to macrofaunal community composition (Alongi 1990). Sandy beaches and intertidal sand flats of tropical region are usually occupied with amphipods, crabs and bivalve molluscs while intertidal mud flat is often dominated with polychaetes and gastropod (Alongi 1990). These observations are in congruence with the present findings made during 2007-2010. The macrobenthos community of tropical region reacts negatively with fresh water influx during monsoon season. It is because of (i) sudden reduction in salinity, (ii) sediment re-suspension and (iii) low dissolved oxygen content. However, the disturbed macrobenthic community recolonise immediately after the end of the flood season by forming small, surface deposit and suspension feeding polychaetes and bivalves (Alongi 1990). Similar observations were gathered in the recent study. The number macrobenthic species taxa was found low during monsoon where higher values were associated with summer season (Table 2). This directly supports the contemplation of Alongi (1990) and Gaonkar et al. (2013). Complete impoverishment of taxa or defunation during monsoonal periods, is a common phenomenon in different coastal ecosystems of Indian subcontinent. But, similar observations were not observed during the study period in Chilika lake (Table 2). However, rather the case of defaunation during monsoon, many of the small bodied polychaetes organisms, amphipods and bivalves were frequently observed in the bottom sediment of outer channel area. Similar kind of observation was not reported in the contemporary literature over this aspect. The reason of non-defaunation during monsoon might be the case of quick adaptation of benthic organisms in respect to changing seasonal climatic conditions. Larval recruitment under environmental extreme is a physiological adaptation of many of the marine organisms. Moreover, this becomes a method of their survival (Kinne, 1977). Under such circumstances, species documented during the monsoon season were those of *Capitella capitata*, *Aricidea* sp., *Chone fauvelli*, *Paraprionospio pinnata*, *Heteromastus* sp., *Mediomastus* sp.,etc. Among bivalves, *Brachidontes striatulus* , sp., *Theora opalina* etc and one tanaidacea *Ctenapseudes chilkensis* and among isopod *Cirolana fluviatilis* found conspicuous.

3.1 Species composition

Porifera - In the present study, the species composition of porifera was not found similar with the findings of ZSI (1995). One brackish water species namely *Spongilla alba* was observed significantly in the bottom of the outer channel area observed during the winter and summer months where as *Pione vastifica* Hancock,1849 is a shell boring poriferan species mostly seen in associated with large bodied mollusc such as *Telescopium telescopium*, *Meretrix* sp., *Crassostrea* and *Saccostrea* species, *Indothais* sp., etc. Among new occurrence, species like *Haliclona indistincta* Bowerbank, 1866 was conspicuously observed which was often colonized on hard surfaces.

Coelenterates – Two species namely *Halecium tenellum* Hincks, 1861 and *Actinia equina* Linnaeus 1758 were reported first time where as *Nevadne glauca* is still endemic to Chilika lake only where as *Edwardsia jonesii* Seshaiya & Cuttress 1969 observed from the lake premises. This is earlier reported by ZSI (1995). However, the beadlet sea anemone *Actinia equina* was evidenced from the hard rocky surfaces with exposed tentacles in outer channel. It is a common intertidal anthozoan of east coast and west coast of India having sessile mode of life style. It can tolerate higher fluctuations of salinity, temperature and desiccation.

Bryozoa- The species composition of this group is represented by a single species namely *Membranipora (Electra) bengalensis* Stoliczka, 1869. This species is not reported earlier from Chilika lake ecosystem as evidenced from ZSI report (1995). It is already reported from Vishakhapatnam harbor, Sunderban and Cochin back water region of India.

3.2 Annelida

Polychaetes – In general polychaetes are the major macrobenthic group in the soft sediment of intertidal and subtidal region of east coast and west coast of India (Musale and Desai 2011). A total of 39 polychaetes species were reported from outer channel area in contrast of 31 species reported by ZSI (1995) from whole lake and 20 species of Southern (1921). About 85% percent of the polychaetes species observed by Southern (1921) are also reported during the present study. Few of the common species found during 1920 and in the present study are comprised of

Sigambra constricta, *Lumbrinereis*, *Polydora*, *Cossura sp.*, *Scoloplos sp.*, *Axiothella* sp.,*Euclymene* sp., *Myriochele* sp., *Polydora* sp., *Diopatra*, *Fabricia* sp., etc. The present list of polychaetes are well comparable with those of the findings documented by Gaonkar et al. (2013) while working on Mandovi & Zuary estuary, findings of Martin et al. (2011) studying on flow restricted estuarine system of cochin backwater, with Musale and Desai (2011) who reported 63 polychaetes species while working in south east and west coast of India and Pillai (2001) working on Cochin estuarine system. All these ecosystems are influenced with organic pollution load followed by environmental stress. Common dominated species in such ecosystem were *Capitella capitata* and *Minuspio cirrifera* species. Same composition of polychaeta species was also evidenced in this study. Similar findings were made by Mendez et al., (2010) while working on sandy beaches of Patagonia, Brazil. Besides this, certain species appeared in the outer channel area for the first time such as *Hydroides elegans* Haswell, 1883, *Pomatoceros caeruleus* Fauvel, 1933, *Amphictene auricoma* (O.F. Müller, 1776), *Pisione remota* Southern, 1914, *Hesione picta* Müller in Grube, 1858, *Eteone picta* Quatrefages, 1866 etc. The present observation is in resemblance with the findings of Vijayakumar et al. (1991) who worked upon Kakinada Bay, backwater and Murrugan and Ayyakkanu (1991) who studied the Cudalore- Uppanar backwater of south east coast of India. Polychaetes like *Hydroides elegans* Haswell, 1883, and *Pomatoceros caeruleus* Fauvel, 1933, are the two serpulid polychaetes usually seen in the hard substratum of coastal and estuarine ecosystem in the Indo-Pacific region. It is also observed on the surface of the bivalves like *Crassostrea cuttackensis*. Polychaete like *Fabricia spongicola* usually seen among the Poriferan species such as *Spongilla alba* (Southern, 1921). Polychaete species mostly observed in the intertidal mudflat were those of *Nephthys polybranchia*, *Euclymene annandalei*, *Sigambra constricta*, *Glycinde oligodon*, *Myriochele picta*. Some of the species found in the sand flats like *Lumbrinereis polydesma*, *Nereis chilkaënsis*, *Scoloplos marsupialis*, *Nereis reducta* were conspicuous. Polychaetes found in the bivalve community were those of *Perinereis* sp., *Polydora hornelli*. They bore in the thick shells of molluscs. Among sea grass meadows polychaetes like *Neanthes chilkaënsis*, *Fabricia spongicola* were predominant. A number of sand binding polychaetes were noticed during the present study. The species like *Diopatra neapolitana* was often observed inside the tube formed with large sized molluscan debris and sand particles. The species *Spiophanes bombyx* reported first time in this study area often forms tubes in the sand. Other members of this group were *Myriochele picta* and *Axiothella obockensis*. Three species were observed predominantly in all the season throughout the study period i.e. *Capitella capitata*, *Heteromastus filliformis* and *Minuspio cirrifera*. These findings are in well resemblance with Southern (1921) and ZSI (1995).

3.3 Sipunculid and Echiurid

Recent barcoding study of sipunculid and echuird confirmed that both these organisms are belonging to the phylum annelid (WoRMS). In the present inventory study, the species like S*ipunculus nudus* Linnaeus, 1766, *Apionsoma capitatum* Gerould, 1913 and the echiurid *Ochetostoma arkati* Prashad, 1935 were reported. All these species are not reported earlier from Chilika lake (ZSI, 1995). According to WoRMS (World Register of Marine Species), they are the typical marine forms dominating mostly in the sandy sediment.

Usually, sipunculids are the inhabitants of shallow intertidal sandy region areas while few of them were also observed on the large sized molluscan shells and in hermit crabs. They can burrow in the sandy sediment. Like sipunculids, the echiurids are also having the property of burrowing in the sandy or muddy sediment in the shallow intertidal and subtidal substratum. From Chilika Lake, available information regarding these kinds of annelids is much less. Thus it need more research attention.

Oligochaets – These are also belonging to the phylum annelid. Common representatives observed from outer channel such as *Limnodrilus* sp., and *Tubifex* sp. Mostly they were observed in the monsoon season when salinity becomes less. They are usually considered as the indicator species for pollution or stress. They can survive in low oxygen, and in deprived conditions of food availability. They became the major food stuff of different fishes, shell fishes and birds. Since they buried in the deep sediment hence, can accumulate many compounds and metals.

Table 3 Checklist of intertidal macrofauna in the outer channel area of Chilika lake

Phylum	**Class**	**Order**	**Family**		***Genus/species***
Porifera	Demospongiae	Haplosclerida	Spongillidae	1	*Spongilla alba* Carter, 1849
			Chalinidae	2	*Haliclona indistincta* Bowerbank, 1866
		Hadromerida	Clionaidae	3	*Pione vastifica* Hancock,1849*
			Suberitidae	4	*Protosuberites lacustris* Annandale 1915
Coelenterate	Hydrozoa	Leptothecata	Haleciidae	5	*Halecium tenellum* Hincks, 1861 *
	Anthozoa	Actiniaria	Nevadneidae	6	*Nevadne glauca* Annandale, 1915 *
			Actiniidae	7	*Actinia equine* Linnaeus 1758*
			Edwardsiidae	8	*Edwardsia jonesii* Seshaiya & Cuttress, 1969
				9	*Unidentified 1*
				10	*Unidentified 2*
Bryozoa	Gymnolaemata	Cheilostomida	Membraniporidae	11	*Membranipora bengalensis* Stoliczka, 1869
Annelida	Polychaeta	Phyllodocida	Nereididae	12	*Nereis reducta* Southern, 1921
				13	*Neanthes chilkensis* Southern, 1921
				14	*Neanthes glandicncta* Southern, 1921
				15	*Namalycastis indica* Southern, 1921
				16	*Perinereis nigropunctata* Horst 1889
			Nepthtyidae	17	*Bipalponephtys cornuta* Southern, 1921
				18	*Nephtys polybranchia* Southern, 1921
			Hesionidae	19	*Oxydromus fasciatus* Grube, 1855
				20	*Hesione picta* Müller in Grube, 1858
			Pilargidae	21	*Sigambra constricta* Southern 1921
			Phyllodocidae	22	*Eulalia viridis* Linnaeus, 1767
				23	*Eteone picta* Quatrefages, 1866
			Goniadidae	24	*Glycinde oligodon* Southern, 1921
				25	*Goniadopsis longicirrata* Arwindsson, 1899)
			Glyceridae	26	*Glycera alba* Southern, 1921
			Sigalionidae	27	*Pisione remota* Southern, 1914
		Sabellida	Maldanidae	28	*Euclymene annandalei*, Southern, 1921
				29	*Axiothella obockensis* Gravier, 1905
			Fabriciidae	30	*Fabricia spongicola*, Southern 1921
			Oweniidae	31	*Owenia fusiformis* Delle Chiaje, 1844
				32	*Myriochele picta* Southern 1921
			Sabellidae	33	*Chone fauveli* McIntosh, 1916
			Serpulidae	34	*Pomatoceros caeruleus* Fauvel, 1933
				35	*Hydroides elegans* Haswell, 1883
		not assigned	Capitellidae	36	*Capitella capitata* Fabricius,1780
				37	*Heteromastus filiformis* (Claparède, 1864)
				38	*Mediomastus sp.*, Hartman, 1969
			Cossurida	39	*Cossura coasta*
		Eunicida	Onuphidae	40	*Diopatra neapolitana* Delle Chiaje, 1844
			Lumbrineridae	41	*Lumbrineris polydesma*,Southern 1921
			Eunicidae	42	*Marphysa gravelyi* Southern 1921
		Spionida	Spionidae	43	*Paraprionospio pinnata* Ehlers, 1901
				44	*Minuspio cirrifera*
				45	*Spiophanes bombyx* (Claparède, 1870)
				46	*Polydora hornelli* Willey, 1905
		Scoleisida	Orbiniidae	47	*Scoloplos marsupialis* Southern, 1921
		Paraonida	Pilargidae	48	*Aricidea* (*Acmira*) *lopezi* Berkeley & Berkeley, 1956
		Terebellida	Pectinariidae	49	*Amphictene auricoma* (O.F. Müller, 1776)
		Eunicida	Onuphidae	50	*Onuphis eremita* Audouin & Milne Edwards, 1833
	Gephyrea	Sipunculoidea	Sipunculidae	51	*Sipunculus nudus* Linnaeus, 1766
				52	*Unidentified 1*
				53	*Unidentified 2*
	Phascolosomatidea	Phascolosomatida	Phascolosomatidae	54	*Apionsoma capitatum* Gerould, 1913
	Echiura	Echiuroidea	Echiuridae	55	*Ochetostoma arkati* (Prashad, 1935)
	Clitellata	Oligochaeta	Naididae	56	*Tubifex tubifex Lamarck, 1816*
		Haplotaxita	Tubificidae	57	*Limnodrilus hoffmeisteri* Claparède, 1862
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	58	*Ampelisca pusilla* Sars, 1895

Continued Table 3

Phylum	Class	Order	Family		Genus/species
			Talitridae	59	*Orchestia aestuarensis* Wildish, 1987
			Melitidae	60	*Melita festiva* Chilton, 1885
			Niphargidae	61	*Niphargus chilkensis* Schiodte 1847
			Urothoidae	62	*Urothoe platydactyla* Rabindranath, 1971
			Corophiidae	63	*Americorophium triaeonyx Stebbing* 1904
			Aoridae	64	*Grandidierella taihuensis* Morino & Dai, 1990
			Eriopisidae	65	*Eriopisa chilkensis* Chilton, 1921
			Maeridae	66	*Quadrimaera incerta* (Chilton, 1883)
			Photidae	67	*Photis longicaudata* Bate & Westwood, 1862)
			Platyischnopidae	68	*Platyischnopus herdmani* Walker, 1904
			Ampithoidae	69	*Ampithoe ramondi* Audouin, 1826
			Gammaridae	70	*Gammarus annandalei* Monod, 1924
		Tanaidacea	Parapseudidae	71	*Ctenapseudes chilkensis Chilton, 1924*
		Isopoda	Cirolanidae	72	*Cirolana fluviatilis Leach, 1818*
			Sphaeromatidae	73	*Sphaeroma* sp. *Fabricius*, (*1787*)
		Mysida	Mysidae	74	*Mesopodopsis orientalis* W. Tattersall, 1908
		Stomatopoda	Squillidae	75	*Cloridopsis immaculata* (Kemp, 1913)
		Decapoda	Alpheidae	76	*Alpheus edwardsii* Audouin,1826*
			Ocypodidae	77	*Uca sp. Leach 1914* *
			Diogenidae	78	*Diogenes custos* Fabricious, 1798*
			Leucosiidae	79	*Philyra alcocki* Kemp, 1915*
				80	*Persephona lichtensteinii* Leach, 1817 *
			Hippidae	81	*Remipes* Latreille, 1804
			Matutidae	82	*Matuta planipes* Fabricius, 1798
			Leucosiidae	83	*Leucosia* anatum Herbst, 1783
	Maxillipoda	Sessilia	Balanidae	84	*Amphibalanus Amphitrite* Darwin, 1854
		Lepadiformes	Lepadidae	85	*Lepas (Anatifa) anatifera* Linnaeus, 1758
	Insecta	Diptera	Chironomidae	86	*Chironomus* Meigen, 1803
Mollusca	Bivalvia	Veneroida	Veneridae	87	*Meretrix meretrix* Linnaeus, 1758
				88	*Meretrix casta* Gmelin, 1791
				89	*Sunetta scripta* Linnaeus, 1758
				90	*Clementia papyracea* Gmelin, 1791
			Tellinidae	91	*Tellina tenuis* da Costa, 1778
			Donacidae	92	*Donax incarnatus* Gmelin 1791*
			Mactridae	93	*Mactra stultorum* Linnaeus, 1758
			Cyrenidae	94	*Corbicula fluminea* Müller, 1774
		Arcoida	Noetiidae	95	*Striarca lacteal* Linnaeus, 1758
		Mytiloida	Mytilidae	96	*Brachidontes striatulus* Hanley, 1843
				97	*Brachidontes undulates* Dunker, 1857
				98	*Modiolus modiolus* Linnaeus, 1758
				99	*Brachidontes modiolus* Linnaeus, 1767
				100	*Perna viridis* Linnaeus, 1758
				101	*Perna perna* Linnaeus, 1758
		Arcoidea	Arcidae	102	*Tegillarca granosa* Linnaeus, 1758
		Euheterodonta	Solenidae	103	*Solen annandalei* Preston, 1915
		Ostreoida	Ostreidae	104	*Crassostrea cuttackensis* (Newton & Smith, 1912)
				105	*Saccostrea cucullata* Born 1778
		Pectinoida	Anomiidae	106	*Anomia achaeus* Gray 1839
		Pectinoida	Placunidae	107	*Placuna placenta* Linnaeus, 1758
	Polyplacophora	Chitonida	Chitonidae	108	*Chiton (Chiton)* Linnaeus, 1758
	Gastropoda	Neogastropoda	Nassariidae	109	*Nassarious stolatus* Gmelin 1791
			Muricidae	110	*Indothais lacera* Born, 1778
			Cancellariidae	111	*Cancellaria elegans*
			Nassariidae	112	*Ilyanassa obsoleta* Say 1822
			Conidae	113	*Conus hyaena* Hwass in Bruguière, 1792
			Olividae	114	*Oliva oliva* Linnaeus, 1758
		Caenogastropoda	Potamididae	115	*Cerethideopsilla cingulata* Gmelin 1791
			Thiaridae	116	*Thiara scarba* Muller 1774
			Epitoniidae	117	*Epitonium clathrus* Linnaeus 1758

Continued Table 3

Phylum	Class	Order	Family		*Genus/species*
		Littorinimorpha	Littorinidae	118	*Littorina littorea* Linnaeus, 1758
			Naticidae	119	*Natica tigrina* (Röding, 1798)
			Bursidae	120	*Bufonaria echinata* Link, 1807
			Cassidae	121	*Phalium areola Linnaeus 1758*
		Cycloneritimorpha	Neritidae	122	*Neritina smithii* Wood 1828
				123	*Nerita balteata* Reeve, 1855
		Neogastropoda	Nassariidae	124	*Bullia vittata* Linnaeus, 1767
		Anaspidea	Aplysiidae	125	*Aplysia sp.* Linnaeus, 1767*
		Not assigned	Trochidae	126	*Umbonium vestiarium Linnaeus, 1758*
		Not assigned	Solariellidae	127	*Solariella obscura* Couthouy, 1838
Echinodermata	Asteroidea	Paxillosida	Astropectinidae	128	*Astropecten indicus* Doderlein, 1888*
				129	*Astropecten bengalensis* Doderlein, 1888*
	Echinoidea	Camarodonta	Echinidae	130	*Clypeaster reticulatus* Linnaeus, 1758*
Chordata	Elasmobranchii	Myliobatiformes	Dasyatidae	131	*Himantura uarnak* Gmelin 1789*
		Rajiformes	Rajidae	132	*Raja torpedo* Linnaeus, 1758*
	Actinopterygii	Syngnathiformes	Syngnathidae	133	*Ichthyocampus carce* Hamilton, 1822
				134	*Hippocampus fuscus* Rüppell 1838*
		Pleuronectiforms	Cynoglossidae	135	*Cynoglossus cynoglossus* Hamilton 1822*

N.B. the * sign Indicated the species have rare occurrence in the study area

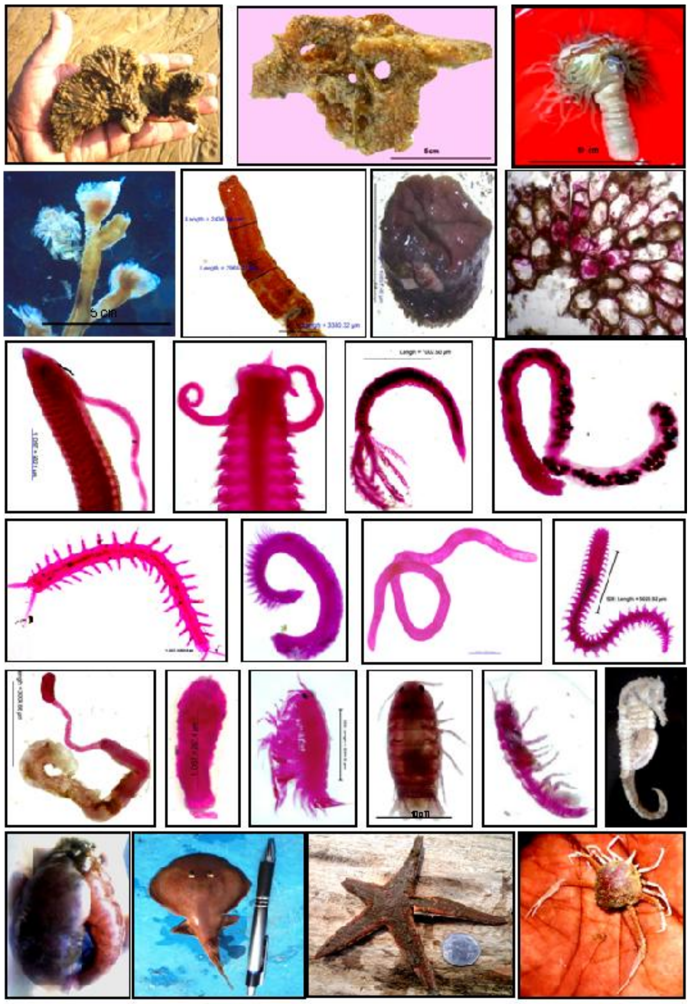

Figure 2 Images of benthic macrofauna- from left to right *Haliclona indistinct,Spongilla alba*, *Nevadne galuca*, *Halecium tenellum*, *Edwardsia jonesii*, *Actinia equina*, *Membranipora* (*Electra*) *bengalensis*, *Cossura coasta*, *Polydora hornelii*, *Chone fauveli*, *Mediomastus* sp., *Pisione* sp., *Minuspio cirrifera*, *Capitella capitata*, *Nepthys polybranchia*, *Sipunculus nudus* Linnaeus, 1766, *Ochetostoma arkati* (Prashad, 1935,) , *Urothoe* sp., *Cirolana fluviatilis*, *Ctenapseudes chilkensis*, *Hippocampus fuscus*, *Aplysia* sp., *Raja torpedo*, *Astropecten bengalnesis*, *Persephona lichtensteinii*

3.4 Arthropoda

Amphipoda- It is the major macrobenthic group observed in the present study. According to earlier records, Sewell and Annandale (1922) reported 17 amphipoda species from this lake while present study confirmed the occurrence of 11 species only. Some of the dominant species were *Niphargus*, *Quadrivisio* and *Grandidierella megnae, Eriopisa chilkensis* etc. Certain amphipods reported first time in this ecosystem are those of *Platyischnopus herdmani* Walker,1904, *Ampithoe ramondi* Audouin, 1826 and *Gammarus annandalei* Monod, 1924.

Decapoda- The pebble crab *Philyra alcocki* Kemp, 1915 was first reported by Sewell and Annandale (1922). This species was further reported during the present study. Similarly *Alpheus lobidens* De Haan, 1849 observed during the present study was also reported Sewell and Annandale (1922). Crabs like *Persephona lichtensteinii* Leach, 1817, *Leucosia anatum* Herbst, 1783 appeared in the lagoon system for the first time. Similarly the representatives of the order Sessilia and Lepadiformes like *Lepas* (*Anatifa*) *anatifera* Linnaeus, 1758 and *Amphibalanus amphitrite* are conspicuous as first time occurrence.

Tanaidacea- The tanaid crustacean *Ctenapseudes chilkensis* Chilton, 1924 is cosmopolitan in nature in the Chilika lake. It was reported in the outer channel area in all the season during this study. It becomes the important food item for many of the fishes, shell fishes and birds. Furthermore, it can be used as indicator species as it can sustain in all kind of environmental extremes.

3.5 Mollusca

Among the newly occurring species, a single representative of class polyplacophora of *Chiton* (*Chiton*) Linnaeus, 1758, was reported from a hard surface of outer channel area.

Bivalve- Newly occurring species recorded during the present study are *Perna perna* Linnaeus, 1758 *Brachidontes modiolus* Linnaeus, 1767 *Meretrix casta* Gmelin, 1791, However, most dominant species are those of *Perna viridis*, *Meretrix meretix*, *Crassostrea cuttackensis*, *Saccostrea cucculata* etc. A couple of species belonging to the genus *Brachiodontes* were observed in attached form from the sea grass meadows like *Halodule* and *Halophila* species and in the macrophyte *Potamogetone pectinatus*. The finding of present study is coinciding with ZSI (1995). The intertidal bed of outer channel is entirely composed of *Crassostrea cuttackensis, Saccostrea cucculata* and *Meretrix meretrix* species. A transparent bivalve called *Theora opalina* was also observed from this part of Chilika lake, where as a species of Razor shell named *Solen anndalei* was found significant during winter and summer season. This species *Solen anndalei was* earlier reported by Sewell and Annandale (1922).

Gastropod- The bottom sediment of outer channel area is composed with many of the dead shells of gastropods. They retain in the sediment for a longer period because of their hard shell. During the present study, many species occurred first time in the lake such as *Hyanassa obsoleta* Say 1822, *Conus hyaena* Hwass in Bruguière 1792, *Aplysia sp.* Linnaeus 1767 etc. The gastropod community of outer channel area is ranged from few mm of *Nassarious* species to *Telescopium* species which is as long as 10 cm or more. Dominant species of this region was comprised of *Oliva oliva, Cerethideopsilla cingulata, Epitonium clathrus, Indothais lacera, Cancellaria elegans, Littorina littorea, Natica tigrina, Bufonaria echinata, Nerita balteata, Neritina smithii, Bullia vittata and Umbonium vestiarium*. Species found in the sea grass bed were those of *Indothais lacera, Natica tigrina, Neritina smithii, Bullia vittata* etc. The intertidal bed of outer channel region is mostly composed of *Cerethideopsilla cingulata, Nassarious stolatus, Bullia vittata and Umbonium vestiarium* species.

Echinodermata- Two species of *Astropecten* such as *Astropecten indicus* Doderlein, 1888 and *Astropecten bengalensis* was first observed by Kohler 1910 and reported by (ZSI 1995). The present checklist again confirmed their presence in the shipakuda region of outer channel area. These were observed during the summer season of the year 2009-10 (photographs in Figure 2). However, another representative of echinoderm namely *Clypeaster reticulatus* Linnaeus, 1758 (sand dollar) was reported for the first time ever in this ecosystem from the same region. It is commonly seen in shallow intertidal region of other coastal region of Bay of Bengal. Being a typical marine form, its observation was found scanty during monsoon season where they again reappear in the late winter followed by summer season.

3.6 Chordata

Elasmobranchii- Two species are reported from the present inventory study namely *Himantura uarnak* Gmelin 1789 which is also reported by (ZSI 1995) where as *Raja torpedo* Linnaeus, 1758 is the first occurrence to the Chilika lake.

Actinopterygii- Two species of the family Syngnathidae such as *Hippocampus fuscus* Rüppell 1838 and *Ichthyocampus carce* Hamilton, 1822 has been confirmed from the lagoon system during the present study. The sea horse *Hippocampus fuscus* Rüppell 1838 was reported in the sea grass bed of *Halophila ovalis* located nearer to the Rambharatia region during 2009-10. Perusal of literature suggests that a species of sea horse named as *Hippocampus brachyrhynchus* Duncker 1914, later on synonym as *Hippocampus fuscus* Rüppell 1838 was reported from the southern sector of the lake area Choudhury (1916). But since then, no information regarding its ecology, diversity and distribution is available. However the image given by Choudhury (1916) and the morphometric characters furnished by him are seemed to be much similar with *Hippocampus kuda.* Thus, the identification of *Hippocampus brachyrhynchus* Duncker 1914 by Choudhury (1916) is still uncertain. Though this name *Hippocampus fuscus* Rüppell 1838 is highly popular as "Chilika sea horse". But, still concrete information is lacking. As a major breakthrough during the recent inventory, a complete organism of *H. fuscus* as was appeared in the lagoon. It's photograph was taken and given in figure 2 as evidence. This species is crucial, because in IUCN its status it is belonged to vulnerable but falls in data deficient category. Besides this, one species of Pleuronectiformes is also reported during the present study period namely *Cynoglossus cynoglossus* Hamilton 1822 (Sewell and Annandale, 1922).

The finding of the present study is in resemblance with the findings of Sewell and Annandale (1922), ZSI (1995) on Chilika lake, Sanjeeva Raj (2006) on Pulicate lake, Martine *et al.*, (2011) on Cochin backwater, Gaonkar et al. (2013) on Mandovi and zuari estuary and with Vishakhapatanam coast by Raut et al. (2005), Sarkar et al. (2005) etc.

In summary, it is noteworthy to mention that the intertidal macrobenthos of outer channel area is much diversified as it provides a suitable habitat to the wide range of organisms. Among environmental parameters salinity and Chlorophyll *a* are observed as major guiding factors for macrobenthos that determines seasonal distribution of taxa at outer channel area. Preponderance of higher number of macrobenthos taxa in the summer season in contrast to monsoon confirmed that the most of the macrobenthos species are belonging to marine habitat. The findings of the present study also supported the fact that opening of new lagoon inlet either due to natural process or by artificial means have substantial impact upon the macrobenthos of the intertidal region. The present study also provides a comprehensive checklist of benthic macrofaunal assemblage of outer channel of Chilika lake. The information gathered during the present study can be used as the baseline for future research. It will further helpful to develop a robust management strategy for the conservation of lake ecosystem.

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