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Full Length Research Paper

Distribution and succession of aquatic macrophytes in Chilka Lake - India

M. Jaikumar[1]*, D.Chellaiyan[2], L.Kanagu[3], P. Senthil Kumar[3] and C. Stella[3]

[1]Aquaculture Foundation of India 4/04, Kabaleswarar Nagar, Neelankarai, Chennai 115, India.
[2]Department of Animal Science ,Bharathidasan University, Tiruchirappalli-24, India.
[3]Department of Oceanography and Coastal Area Studies, School of Marine Sciences, Alagappa University Thondi Campus, Thondi, Tamilnadu, India.

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Chilka is the largest brackish water lake in Asia and also the second largest lake in the world. It is situated between 19°28' and 19°54' North latitude and 85°05' and 85° 38' East longitude. A mix of estuarine, marine and freshwater ecosystem is observed here and the lagoon has a long history of sustainable fishing. In September 2000 as a part of its management endeavour, the local authority had opened a new mouth at Satpada to facilitate efficient tidal mixing between the lake and the sea. Prior to this (1996 to 1997) salinity in the lake was low, which favoured intense growth of (invasive) macrophytic vegetation (e.g. Potamogeton, Halophila, Gracilaria, Ruppia etc.) and the effect is the greatest in the northern most part of the lake with intense (freshwater) weeds mainly Eichornia, Hydrilla, Chara, etc. Aquatic macrophytes are important in the functioning of the water body. They offer food and shelter for many organisms and promote habitat diversity. The paper seeks to isolate and describe weedy and non weedy zones inside the lake using grid sampling by Gramin® GPS.

Key words: Chilka Lake, macrophyte, weeded and nonweeded, global positioning system (GPS), salinity.

INTRODUCTION

Chilka Lake is the largest in Asia and unique for its magnificent biological diversity, ecological complexity and sustainability. Lagoons are highly productive and used for raising selected species of prawn and fish species. In general, coastal lagoons trap inorganic sediments and organic matter filters. The understanding of physical dynamics of a lagoon is important for planning and implementation of management strategies. Coastal lakes and lagoons are unique and different from estuaries, fjords, bay, tidal rivers and sea straits, thus require separate attention. They are important features of many coastlines and are among the world's most productive marine environments (Odum, 1971). Chilka was included in the Montreux Record – a threatened list of Ramsar site – in 1993, as reduction in weeded area, and rise in salinity, flushing rate and seagrass cover, etc. Not only information on ecological amplitude of algae and seagrasses, or of aquatic macrophytes but also of the terrestrial plant communities living in the stressed environment of the islands and the shores and their role in this ecosystem are wanting.

Bandhyapadhya and Gopal (1991) suggested that the hydrographical regime of a lagoon is largely determined by the relationships between the fresh and saline water inputs into the system and rate of evaporation, which develops a "two layer" (estuarine) circulation pattern with surface out flowing water of low salinity and a tide-induced subsurface in flowing sea water (Mee, 1978). This vast water body spreading over an area of 1100 sq. km. is a biodiversity hot-spot for rare, vulnerable and endangered aquatic flora and fauna, such as the Irrawaddy dolphin; and harbours more than 800 species of animals (Ghosh, 1995), about 225 species of fish and

*Corresponding author. E-mail: jaikumarmarine@gmail.com. Tel: +91-9941563955.

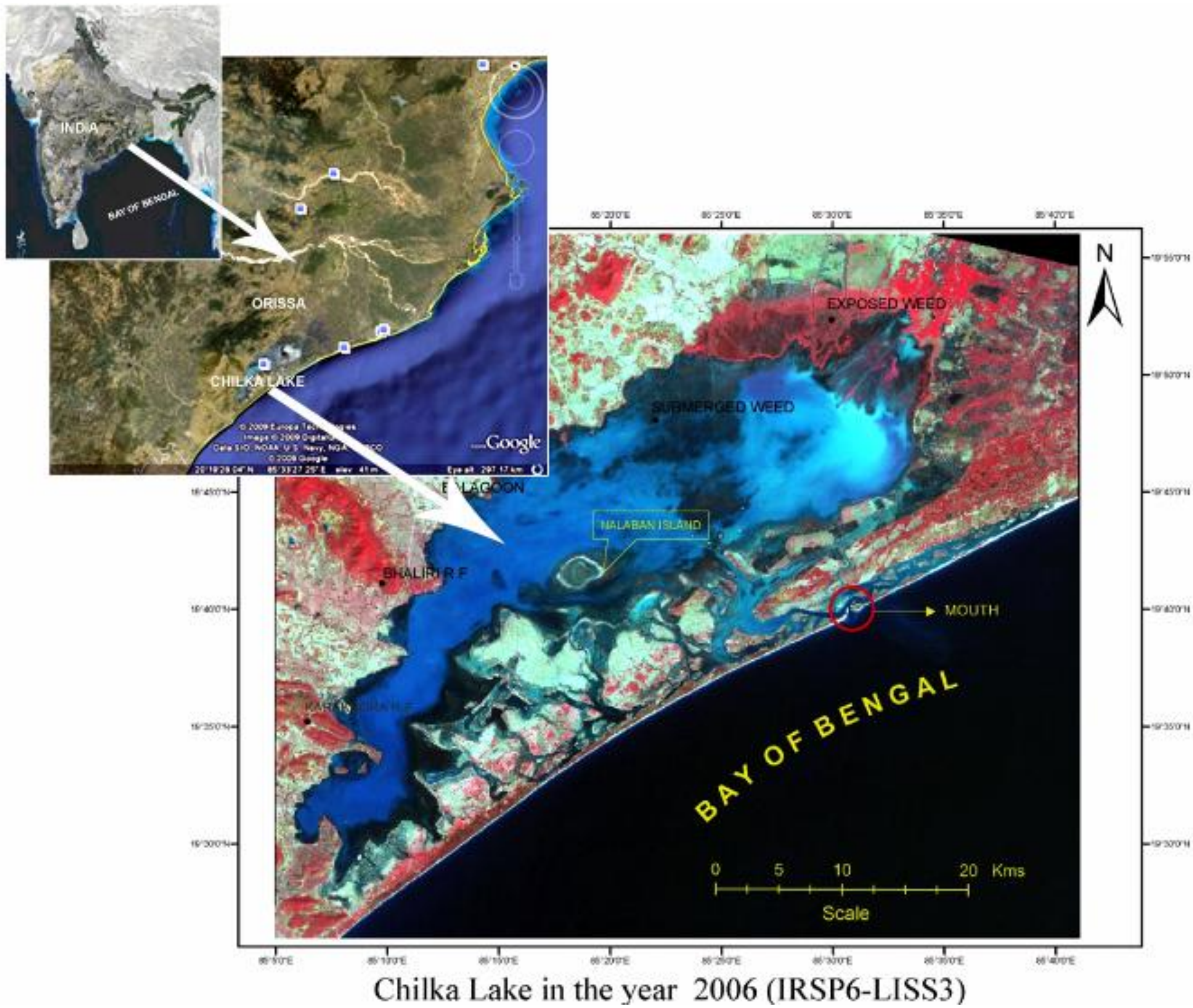

Figure 1. Study area map.

159 species/subspecies of migratory birds (Dev, 1997). It is also a highly productive ecosystem with rich fishery resources providing food and livelihood support for over 64000 fisher families comprising a population of over 2 lakh fishers and 0.2 million local fisherfolk, despite the ecodegradation being experienced (Mohapatro et al., 2007). Though much information regarding ecological and environmental status of the lake exist, particularly in terms of crustaceans, fisheries and phytoplankton, little is known of the weed/macrophyte taxonomy, their distributional patterns, quantitative ecological status and their role in the food chains of different fishes and birds, as well as in protecting soil erosion and purifying the water.

Study area

Site description

Chilka Lake, a shallow (2 m) brackish water lagoon on the east coast of India, about 350 km south of Kolkata (Figure 1) (Gupta et al., 2008). The lake is pearshaped and covers a total area of about 1,000 km^2 during

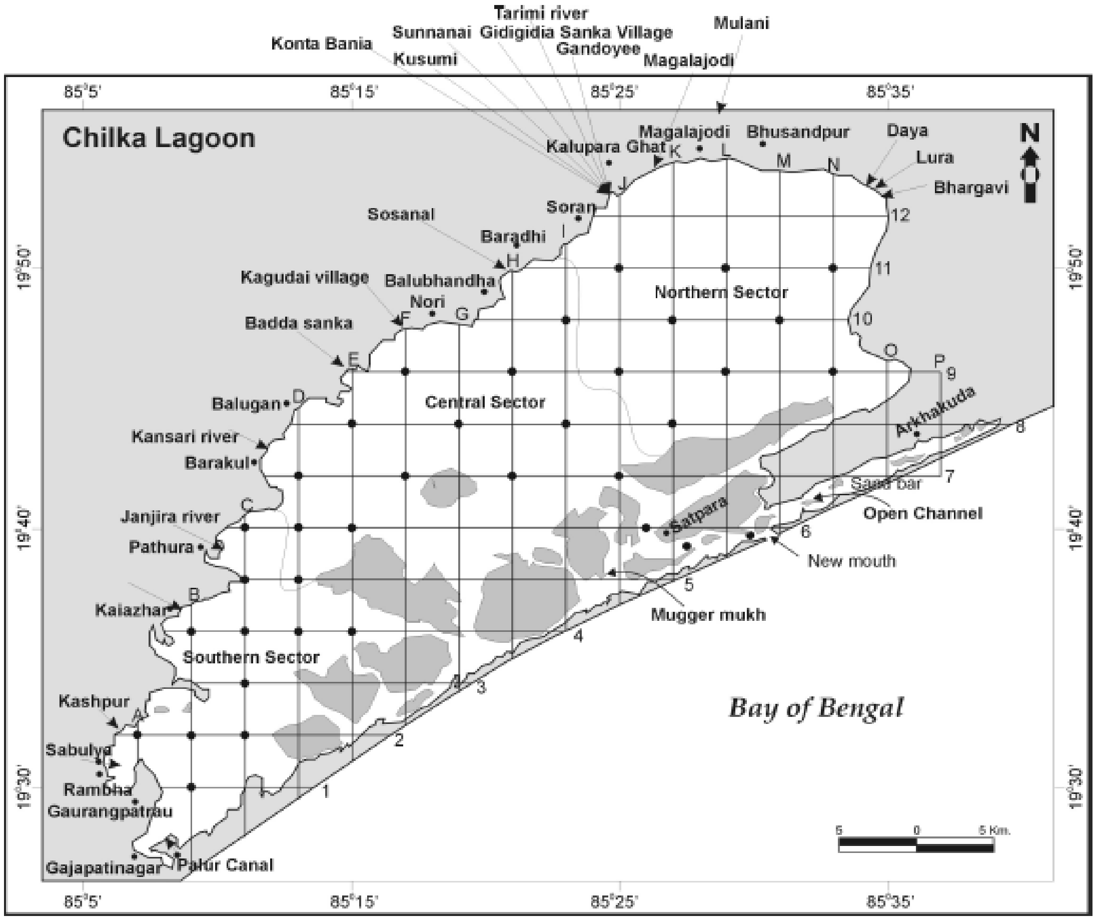

Figure 2. Fresh water inlets of Chilka Lake.

monsoon (August to October), which is reduced, during pre-monsoon (April to May) when evaporation far exceeds precipitation, by nearly 60%. Topographically, Chilka Lake is divided into south (also known as Rambha Bay), central and north sectors, and a connection to the sea – the 32 km long narrow channel, Bay of Bengal (Satyanarayana, 1999). Recent estimates by the Chilka Development Authority (CDA.2000), reveal that 365,500 tonnes of sediment are discharged into the lagoon during monsoon, the rivers/streams from the western catchment contribute 25% (90,203 tonnes) of silt load (Figure 2), while the distributaries of the Mahanadi contribute as much as 75% (275,297 tonnes) into the Lake. It is apparent that the high sediment loads contributed by the distributaries of Mahanadi are creating rapid sedimentation in the north western part of the lagoon and the inlet channel.

MATERIALS AND METHODS

During this study, two observations were made in May and January 2007, in an attempt to examine the influence of seasonal monsoons and accretion/erosion phenomena (characteristic of this area) on weeded and non weeded areas in the Chilka under tropical conditions. Weeds were collected in 124 stations latitude and longitude distribution inside Chilka Lagoon (Figure 2), from four different sectors earlier mentioned. Cholornity was estimated by Knudsen's titration method (Barnes, 1959) for the entire year (May 2006 to January 2007) to know the salinity distribution in Chilka Lake regarding aquatic weed. The precipitable halide ions in 10 ml volume of sea water sample were determined by titration with (standardized) silver nitrate (alpha(1989) value, -0.150 to +0.145) (standardized against standard sea water obtained from the National Institute of Oceanography, Goa) solution from a burette using potassium chromate as an indicator (Grasshoff et al., 1999). The volume of silver nitrate utilized was almost equal to salinity and the final value was obtained using the following formula and expressed as PSU (Practical Salinity Units):

Salinity (PSU) = B8*N0.03545*1.80655*1000/ml of the sample.

Where B is burette reading or volume of silver nitrate used and N, the normality of Silver nitrate.The sampling stations/grids were established using GARMIN® 45 GPS (Global Positioning System), USA. A country boat fitted with an outboard motor was employed for movement.

Macrophytes vegetation

The detailed survey and studies on the plant resources of the islands and the surrounding lake, (Tables 2 and 3) it is hoped, will give very important information on the present status and monitoring the changes, if any, over time. The vegetation of the lake ecosystem is broadly classified into aquatic and terrestrial Island vegetation. The aquatic vegetation being algal and macrophytic. The macrophytes were classified, according to their zonation along the lake salinity gradient, into submerged (*Holodule universis*, *Holophila* sp.), free floating (freshwater aquatic weeds), floating-leaved, emergent and wet meadow types. Until the late 1960s (Kachroo, 1956), Hogeweg and Brenkert (1969) who extensively surveyed the Indian vegetation in a variety of habitats, for the first time applied the growth form system proposed by Hartog and Segal (1964) with some modifications. The growth forms are plants of comparable structure and similar relations to their physical environment. They recognized 23 growth forms among Indian aquatic vegetation but the system suffers from the problem of how to define an aquatic plant. For example, plants such as Sagittaria, Butomus, Eichhornia, and Scirpus were excluded from their classification. The immense phenotypic plasticity and adaptability to the ever-changing environment under the monsoonic climate result in great modification of phenophases under diverse ecophases, and this in turn renders the growth-form system inapplicable to Indian aquatic vegetation (Gopal et al., 1978; Gopal, 1990).

Although several earlier studies recognized associations of two or more species (Mirashi, 1954; Vyas, 1964), Zutshi (1975) for the first time used the Braun-Blanquet's phytosociological approach to identify 26 associations, based on growth form spectrum and ecological affinities, in the aquatic vegetation of Kashmir. The ordination method of classifying vegetation has not yet been employed in India. By grid sampling inside the Chilka Lake will clearly show the weeded and non weeded area (Figure 3). Phytoplankton and seaweed community is under the algal vegetation. Seaweed community is distributed only in brackish and marine water zones. Aquatic macrophytes are of the Pleustophyte, Epihydate, Vittate, Rosette and Helophytic types. The terrestrial island vegetation is the formation of typical coastal scrubs. A total of 8 genera of seaweeds had been collected from different sectors of the lake at different seasons. This large-scale diversity has a key role in the food chain and act as a spawning ground in the Lake Ecosystem.

A total number of 12 species of seaweeds under Chlorophyceae and Rhodophyceae are only distributed in marine and brackish water zone. It is now established that the origin of the plant is in the Chilka lake and rivers. The macrophytes form an important ecological component of the lake ecosystem. They provide anchorage for Zooplankton and Phytoplankton, which constitute food for fish. They provide breeding shelter for the breeding fish; improve oxygen conditions in water and form hiding places (refugia) for fish. The wetland system is also important as a refuge for fish species that have gone extinct in the main lakes including Lake Victoria and Lake Kyoga (Information Sheet on Ramsar Wetlands). Out of several wetlands in India, Chilka Lake in the state of Orissa was designated as Ramsar site in 1991 as an internationally important waterfowl habitat.

RESULTS

Over 200 km^2 of the lagoon area in the northern sector is infested with Nalagrass which is of high fibre content and bamboo like, and could serve as raw material for production of paper and card boards. Allocation of seaweeds varied depending on several factors like season, tidal amplitude, salinity, availability or quality of substrate, etc. The landmass of this lake is classified into mainly three categories - namely 1) Island 2) Shoreline or 3) Spit adjoining areas or bank sites. According to different topographic patterns the islands can be divided into four major types on the basis of major edaphic conditions such as i) Rocky islands, ii) Sand mixed rocky islands, iii) Sand-clay mixed rocky island and iv) Sandy islands. During post monsoon (November to March), the freshwater flow into the lagoon is almost nil. Northerly winds facilitate the tidal water entry into the lagoon through the outer channel, increasing the salinity. The salinity gradually rise in all the sectors, ranging from 2 to 6 PSU (Northern sector), 8 to 13 PSU (Central sector) and 9 to 15 PSU(Southern sector) and in the outer channel the rise in the salinity level is rather high and reaches almost sea level. During the summer, evaporation and prevailing southern winds cause greater salinity all over the lagoon.

The Northern and Central sectors turn mesohaline (medium range of salinity), with salinity ranging from 5.5 to 22 PSU and 7.5 to 27 PSU, respectively. The Southern sector shows a slight increase (10 to 11 PSU) (Ramanathan et al., 1964). The outer channel is practically like seawater at this point, with salinity at 34 to 35 PSU (Mohanty, 1975) due to increased silt load, narrowing of the lagoon mouth and other factors. Evaporation causes a slight increase in salinity in the Northern sector (1.8 to 4.5 PSU) and the Central sector during the post-monsoon period (October to December). The Southern sector shows a slight decrease in salinity (7 to 8 PSU) due to slow mixing with the rest of the lagoon (Ramanathan et al., 1964). The outer channel remains almost fresh during the monsoon due to the unidirectional flow of freshwater from the lagoon. Overall average salinity for the whole lake was observed to have dropped from 22.31 (PSU) in 1957 to 1958 to 13.2 PSU in 1960 to 1961 and 9.14 to 11.83 PSU between 1961 and 1964, but appears to have stabilized after the rapid drop. Such a decrease in salinity had a great adverse impact on the biodiversity as well as fisheries of Chilka.

During the study, salinity in the lagoon ranged from 0.06 PSU (northern Sector, fresh water zone, monsoon 2) to 36 PSU (northern, pre monsoon) (Table 1). Salinity during (monsoon 1) ranged from 0.13 PSU (Stn. 33, northern sector) to 28.53 PSU (Stn. 36, outer channel). Salinity during post monsoon ranged from 1.02 PSU (Stn. 30, northern sector) to 27.1 PSU (Stn. 36, outer channel). Salinity during pre monsoon ranged from 0.12 PSU (Stn. 33, northern sector) to 36 PSU (Stn. 28, northern sector). Salinity during monsoon 2 ranged from 0.06 PSU (Stn. 30, northern sector) to 13.7 PSU (Stn. 2, southern sector). Seawater exchange takes place predominantly

Table 1. Salinity during the study period [range and (mean±s.d)].

Season	Monsoon 1	Post Monsoon	Pre Monsoon	Monsoon 2
Salinity (PSU)	0.13 - 28.53 (11.08±9.36)	1.02 - 27.1 (11.49±7.07)	0.12 - 36.00 (21.43±8.98)	0.06 - 13.70 (4.76±3.94)
Zones	Southern sector	Central sector	Northern Sector	Outer Channel
Salinity (PSU)	4.41 - 29.4 (15.99±5.95)	0.11 - 30.80 (9.84±8.59)	0.06 - 36.00 (5.84±9.56)	0.18 - 33.79 (16.20±13.41)

Table 2. Algae and macrophyte distribution pattern in Chilka May 2006.

Sample	Latitude	Longitude	Algae	Major weeds	Minor weeds
1	19.51791	85.16799	S.G	*Holophila* sp.	*Cheatomorpha*
1A	19.52194	85.1778	S.G	*Holodule* sp.	-
1B	19.51054	85.14988	S.G	*cheatomorpha*	*Holodule* sp.
1C	19.51636	85.14306	S.G	*Holodule* sp.	-
2A	19.55921	85.15422	S.G	*Holodule universis*	*Holophila* sp.
4A	19.55926	85.18053	S.G	*H. universis*	*Holophila* sp.
4B	19.54867	85.18092	S.G	*H. universis*	*Holophila* sp.
4	19.53351	85.1832	S.G	*H. universis*	*Holophila* sp.
5A	19.58887	85.1804	S.G	*Holophila* sp.	-
5B	19.56684	85.18331	S.G	*Holophila* sp.	-
6A	19.60539	85.14326	S.G	*H. universis*	-
6B	19.61263	85.14983	S.G	*H. universis*	-
6C	19.62348	85.16744	S.G	*H. universis*	-
7A	19.60045	85.19576	S.G	*Holophila* sp.	-
7B	19.59756	85.19023	S.G	*Holophila* sp.	-
8B	19.60317	85.2083	S.G	*H. universis*	*Holophila* sp.
8B	19.60317	85.2083	S.G	*Holophila* sp.	-
8B	19.60594	85.21647	S.G	*H. universis*	-
10	19.63768	85.18375	S.G	*H. universis*	-
10A	19.63408	85.17974	S.G	*H. universis*	-
10B	19.63731	85.18414	S.G	*H. universis*	*Enteromorpho* sp.
11	19.63726	85.23438	S.G	*Holophila sp.*	*Gracillaria* sp.
11A	19.62941	85.21352	S.G	*H. universis*	-
11b1	19.61988	85.21622	S.G	*H. universis*	-
12A	19.67195	85.1845	S.G	*H. universis*	-
13A	19.68028	85.19872	S.G	*H. universis*	-
13B	19.6665	85.2157	S.G	*H. universis*	-
14	19.66514	85.24432	S.G	*H. universis*	-
14A	19.65749	85.24061	S.G	*H. universis*	-
14B	19.65324	85.23438	S.G	*Holophila* sp.	-
15	19.70177	85.2187	S.G	*H. universis*	-
15 1-2	19.68658	85.20734	M.A	*Gracillaria* sp.	-
15 2-2	19.6996	85.199118	S.G	*Holophila* sp.	-
16A	19.69153	85.34074	S.G	*H. universis*	-
16C	19.68274	85.32191	S.G	*H. universis*	-
16D	19.67657	85.29609	S.G	*H. universis*	-

Table 2. Contd.

28A	19.77441	85.27137	S.G	*H. universis*	-
28B	19.77985	85.27456	S.G	*H. universis*	-
28C	19.786	85.28793	S.G	*Gracillaria* sp.	*H. universis* *Chara, R. reparium*
28H	19.80261	85.35048	S.G	*H. universis*	-
28F	19.79439	85.32418	S.G	*H. universis*	-
29A	19.80043	85.41113	S.G	*H. universis*	-
29C	19.80451	85.43005	S.G	*H. universis*	-
31	19.83281	85.417134	S.G	*H. universis*	-
31A	19.79811	85.33186	S.G	*H. universis*	-
31B	19.81953	85.35683	S.G	*H. universis*	*Gracillaraia* sp.
31	19.82144	85.36686			
32	19.83363	85.48347	A.W	*Najas* sp.	*H. universis*
32C	19.83215	85.49652	A.W	*Potomotogan*	*Hydra,Certophyllum*
32C	19.82909	85.50275	M.A	*Gracillaria* sp.	-
32C	19.82909	85.50275	S.G	*H. universis*	-
33	19.7396	85.22189	A.W	*Hydra*	-

S.G.= Sea grass, M.A= macro algae, A.W= aquatic weeds; Southern sector = stations 1-14; Central sector = stations 15 - 17, 23 – 28; Northern sector = stations 29 – 33.

Table 3. Algae and macrophyte distribution pattern in Chilka January 2007.

Sample	Latitude	Longitude	Algae	Major weeds	Minor weeds
1	19.51086	85.15538	S.G	*Holodule universis*	*Holophila ovalis*
1A	19.51448	85.15965	S.G	*H. universis*	*0*
1 B	19.51611	85.1424	S.G	*H. universis*	*0*
2A	19.55989	85.15346	S.G	*H. universis*	*0*
2B	19.55147	85.14808	S.G	*H. universis*	*0*
4	19.53326	85.18314	S.G	*H. universis*	*0*
4A	19.52996	85.17336	S.G	*H. universis*	*Holophila ovalis*
4B	19.54445	85.18224	S.G	*H. universis*	*0*
5A	19.58678	85.18009		*Gracillaria* sp.	*H.U.; Holophila ovalis*
5B	19.56772	85.18282	S.G	*H. universis*	*Holophila ovalis*
6A	19.60537	85.14297	S.G	*H. universis*	*Holophilla ovalis*
6B	19.61256	85.14915	S.G	*H. universis*	
6B1	19.6098	85.14533	S.G	*H. universis*	*0*
6C	19.62361	85.16698	S.G	*H. universis*	*0*
7A	19.5949	85.19032	S.G	*H. universis*	*0*
7B	19.59165	85.18467	S.G	*H. universis*	*0*
8A	19.6061	85.21658		*Gracillaria* sp.	*0*
10	19.63634	85.18356	S.G	*H. universis*	*0*
10A	19.63754	85.18404	S.G	*H. universis*	*Ceramium, Gracillaria* sp.
10 B	19.64781	85.17062	S.G	*Najas sp.*	*0*
11	19.6374	85.21587	S.G	*H. universis*	*Ceramium,Gracillaria* sp.
11A	19.6289	85.21352		*Gracillaria* sp.	*0*
11B	19.6199	85.21652		*Gracillaria* sp.	*0*
12A	19.67384	85.18388	S.G	*H. universis*	*Gracillaria* sp.
12B	19.66663	85.17324	S.G,A.W	*H. universis*	*Gracilliria* sp. , *Vallisneria* sp.
12C	19.76938	85.19035		*Ceramium* sp.	*H.U.,Gracellaria* sp.

Table 3. Contd.

12D	19.67741	85.18478		*Gracillaria* sp.	*H.U, Ceramium* sp.
12E	19.6664	85.17555	S.G	*H. universis*	*0*
13 A	19.6804	85.19869	S.G, M.A	*H. universis*	*Ceramium,Gracillaria*
13 B	19.66605	85.25574	S.G	*H. universis*	*0*
14	19.66596	85.24256	M.P	*Ceramium* sp.	*Gracillaria* sp.*, H.U*
14B	19.65341	85.23405		*Ceramium* sp.	*Gracillaria* sp.*, H.U*
14C	19.66357	85.27497	S.G	*H. universis*	*Gracillaria* sp.
14B1	19.66696	85.2623	S.G	*H. universis*	*Gracillaria*
14 E	19.66972	85.24772		*Gracillaria* sp.	*H. universis*
15 A	19.70021	85.19736	S.G	*H. universis*	*0*
15B	19.71085	85.19469	S.G	*H. universis*	*0*
15 C	19.71824	85.19765	M.P	*Ceramium*	*H. universis*
15 D	19.72738	85.20679	S.G	*H. universis*	*0*
16A	19.69205	85.28758		*H. universis*	*Gracillaria* sp.
16B	19.70772	85.30187		*H. universis*	*Gracillaria* sp.
16C	19.70821	85.31499		*Ceramium* sp.	*Gracillaria* sp.*, H.U*
17A	19.70356	85.33482		*Gracillaria* sp.	*H. universis*
17B	19.68277	85.3447	S.G	*H. universis*	*0*
17C	19.67176	85.32358	S.G	*H. universis*	*0*
17D	19.67377	85.29581	S.G	*H. universis*	*0*
17E	19.67205	85.27961	S.G	*H. universis*	*Gracillaria* sp.
23 A	19.74474	85.2184	S.G	*H. universis*	*0*
23 B	19.7497	85.24333	S.G	*H. universis*	*0*
23 C	19.764	85.25181	S.G	*H. universis*	*0*
25A	19.77283	85.41164	S.G	*H. universis*	
28 A	19.76926	85.2635	S.G	*H. universis*	0
28B	19.77983	85.26933	S.G	*H. universis*	0
28 C	19.78483	85.28313	S.G	*H. universis*	0
28C1	19.7863	85.28816	S.G	H. universis	0
28D	19.79109	85.29071	A.W	Chara..sp	0
28E	19.79222	85.31561	S.G	H. universis	0
28F	19.79605	85.32449	S.G	H. universis	0
28 G	19.80234	85.33675	S.G	H. universis	0
28H	19.80274	85.35062	S.G	*H. universis*	0
28I	19.80618	85.36752	S.G	*H. universis*	0
28	19.8	85.38342		*H. universis*	Ceramium
29A	19.80053	85.395.7	S.G	*H. universis*	0
29B	19.80025	85.41113	S.G	*H. universis*	0
31A	19.80151	85.34846	S.G	*H. universis*	0
31B	19.81953	85.35681	S.G	*H. universis*	*Ceramium* sp.
31C	19.82865	85.39721	S.G	*H. universis*	*Gracillaria* sp.
31	19.82849	85.42587	S.G	*H. universis*	0
32A	19.83039	85.44476	A.W	*Ceratophyllum* sp.	0
32B	19.83777	85.48249	A.W	*Hydrilla* sp.	0
32C	19.82675	85.50242	S.G, M.A	*Potomotogan* sp.	Rhizoclonium reparium.
33	19.81603	85.49841	A.W	*Hydrilla*	*Potomotogan* sp,Ceratophylum ,Salvinia

S.G.= Sea grass, M.A= macro algae, H.U= *Holodule universis*, H.O = *Holophila ovalis*, A.W = aquatic weeds. Southern sector = stations 1 to 14; Central sector = stations 15 to 17, 23 to 28; Northern sector = stations 29 to 33.

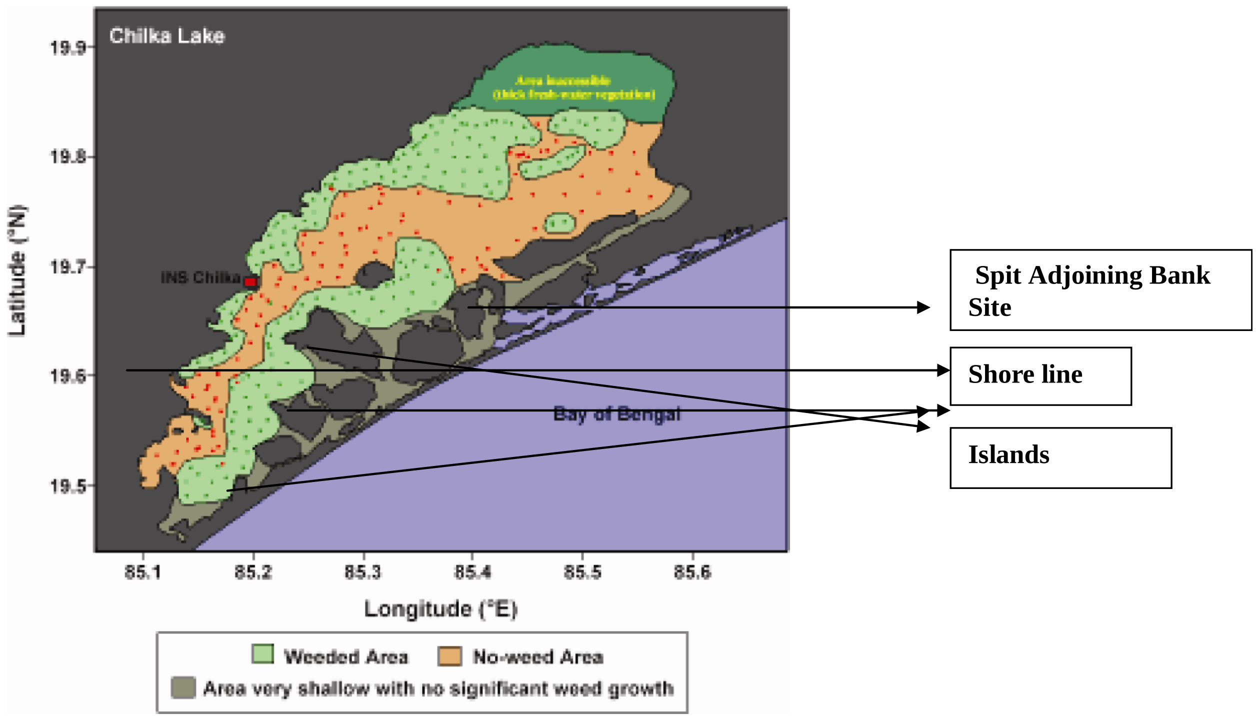

Figure 3. Weeded and non weeded area.

through outer channel although there is a discrete connection (through Palur canal) further south in Rambha Bay. The main management problems of the lake include siltation, changes in salinity regime - in the northern, central and southern sectors; increase in invasive species, dense growth of Nalagrass (*Phragmatis karka*) in the northern sector of the lagoon, eutrophication, aquaculture activities, excessive extraction of bio-resources and an overall loss of biodiversity, leading to degradation of the lagoon's ecosystem.

DISCUSSION

Water level is closely related to light transmission, with deeper water hindering the processes of scattering and absorption (Wetzel, 1988). Submerged macrophytes usually extend into the depths in order to maximize their absorption of the light and CO_2 needed for photosynthesis; for example, *Hydrilla* spp. is very effective in elongating its shoots (Barko and Smart, 1981; Maberly and Madsen, 2002). In our monsoon time lake experiment, none of the plants survived when set at ground level. Maximum shoot lengths were achieved at 50 and 100 cm deep, but plants also elongated, to a lesser extent at 20 cm. During monsoon season, growth of the aquatic macrophytes was lower when compared to summer season in Chilka Lagoon. In monsoon, the range in daily air temperature fluctuated more than the daily water temperature. Therefore, moderately deep water may be beneficial for the survival and growth of weeds during monsoon (In Su et al., 2010).

Conclusion

Submersed macrophytes improve water quality in shallow eutrophic lakes through various mechanisms (Scheffer et al., 1993). They also greatly increase the colonization area in lakes for bacteria, cyanobacteria, algae and invertebrates. Epiphytes compete with macrophytes mainly for light and carbon, sometimes also for nutrients. Rooted submersed macrophytes retrieve nutrients mainly from the sediment (Best and Mantai, 1978; Carignan and Kalff, 1980), although significant uptake can also occur via shoots under eutrophic conditions (Ozimek et al., 1993). Generally, however, nutrient uptake of epiphytes is faster than that of macrophytes (Pelton et al., 1998). Light is generally considered to be the major limiting factor for both submerged macrophytes and epiphytes. Light attenuation increases with water depth, water turbidity and the thickness of the epiphyte layers (Sand-Jensen, 1990; Sand-Jensen and Borum, 1991). Especially epiphytes may cause the largest light attenuations for submerged macrophytes (Roberts et al., 2003). Optimal photosynthetic activity also depends on sufficient availability of carbon dioxide or bicarbonate. Often, light and carbon limitation of macrophytes co-occur, and interactive effects of light and carbon availability have been demonstrated experimentally (Madsen and Sand- Jensen, 1994).

Rapid growth of floating species is usually associated with an increase in water nutrients (Gopal, 1987) and in the Itaipu Reservoir the distribution of these species is positively related to N and P concentrations (Bini et al., 1999). The fast growth observed in our investigation was probably related to an increase in phosphorus concentration in the water after the water level recovery, derived from P release from re-flooded hydrosoils, and decomposition of terrestrial vegetation that had developed on the exposed sediments. For nearly 3 months (November 1999 to January 2000) the shoreline hydrosoils of the reservoir were exposed to air and terrestrial grasses grew over the exposed sediment. The flooding of these areas was followed by an increase in nutrients, especially phosphorus, the concentration of which increased. Despite the fast growth observed, the area colonized by floating species (ca. 0.2 km^2) represents less than 0.02% of Itaipu's total area.

In addition, growth of these plants was observed in only one arm and the reasons why they did not grow in other arms are not clear, given that the water level drawdown would have affected the entire reservoir simultaneously. This study was designed to get knowledge of weeded and non-weeded areas inside the Chilka Lagoon in four selected sectors to enhance its fishery potential. Due to low saline pattern in the northern sector observing the fresh water macrophytes and central sector observing the brackish water salinity is to enhance the fishery potential like prawn and crab . The rich and abundant macrophytes of Chilka Lake show potential for using this weed as raw material in paper making. A paper mill industry could be cited in the vicinity of Balugaon – on a pilot scale to begin with and scaled up in the future, if found economically viable. Environmental parameter and water quality inside the lake is more viable to start crab pen culture and seaweed culture this makes more benefit to the coastal villagers along the Chilka Lake .

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