Intrusion of Abiotic Domain and Atrophy of Aquatic Biodiversity in Chilika Lake

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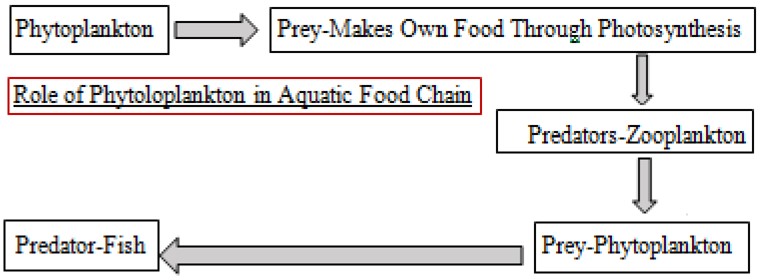
Abstract: ***This paper reviews the quintessential and contemporary conditions of the Chilika Lagoon, accentuating the adverse effects on abiotic species leading to decline of biotic species. The largest biodiversity hotspot on eastern coast of India.Chilika is the largest brackish water lake in Asia which presents an attractive and unparalleled fusion of marine, river, and estuarine habitat that supports unique conglomeration of marine, brackish water and freshwater microbes. Abiotic effects of siltation and salinity, has led to parallel loss of biotic species due to the changes in microbial community of phytoplankton, and abasement of lake ecosystem owing to the freshwater invasive species thereby declining the overall fertility of the aquatic biodiversity.***

Keywords: Biodiversity, Biotic, Abiotic, Phytoplankton, Siltation, Salinity

1. Introduction

The alarming depletion of the aquatic biodiversity of Chilika Lake scrutinized considering the impact of abiotic domain over the biotic domain.The Chilika Lagoon is the second largest brackish water lake in the world, situated in humid tropical climatic coastal zone of Odisha (former Orissa), India, declared as a Ramsar site (listed as a wetland for intensive conservation and management by the ministry of Environment and Forests, Government of India) under the convention on 'Wetlands of international importance'. The biodiversity hotspot comprises of diverse biotic anatomy with phytoplankton, algae, zooplankton, Protozoa, porifera, fishes and multifarious abiotic anatomy comprising of landmass with brackish water and freshwater.



Bacterial assimilation of methane, methanol and methylamine is crucial in the detritus food chain. Methane produced at the bottom of our lakes provides nutrition for microorganisms and eventually becomes an indirect food source for fish.

Methane is an organic compound containing the fundamental building block of nearly all living material: carbon. It provides an important source of energy and nutrients for bacteria. Methane is produced in oxygen-free environments and is found in abundance at the bottom of lakes.

Methane is taken up by methane oxidizing bacteria, which in turn are eaten by zooplankton and other aquatic organisms. These organisms eventually end up in fish stomachs, meaning that food webs not only feed off organic carbon from plants in the lake or from the surrounding land; but also from deep-lying and oxygen-free, yet carbon-rich, sediment stores where methane is formed. Methylotrophs are globally distributed and phylogenetically dispersed.There is extensive authentication for the striving methanotrophs in various regions including the saline and alkaline aquatic environments of Chilika.

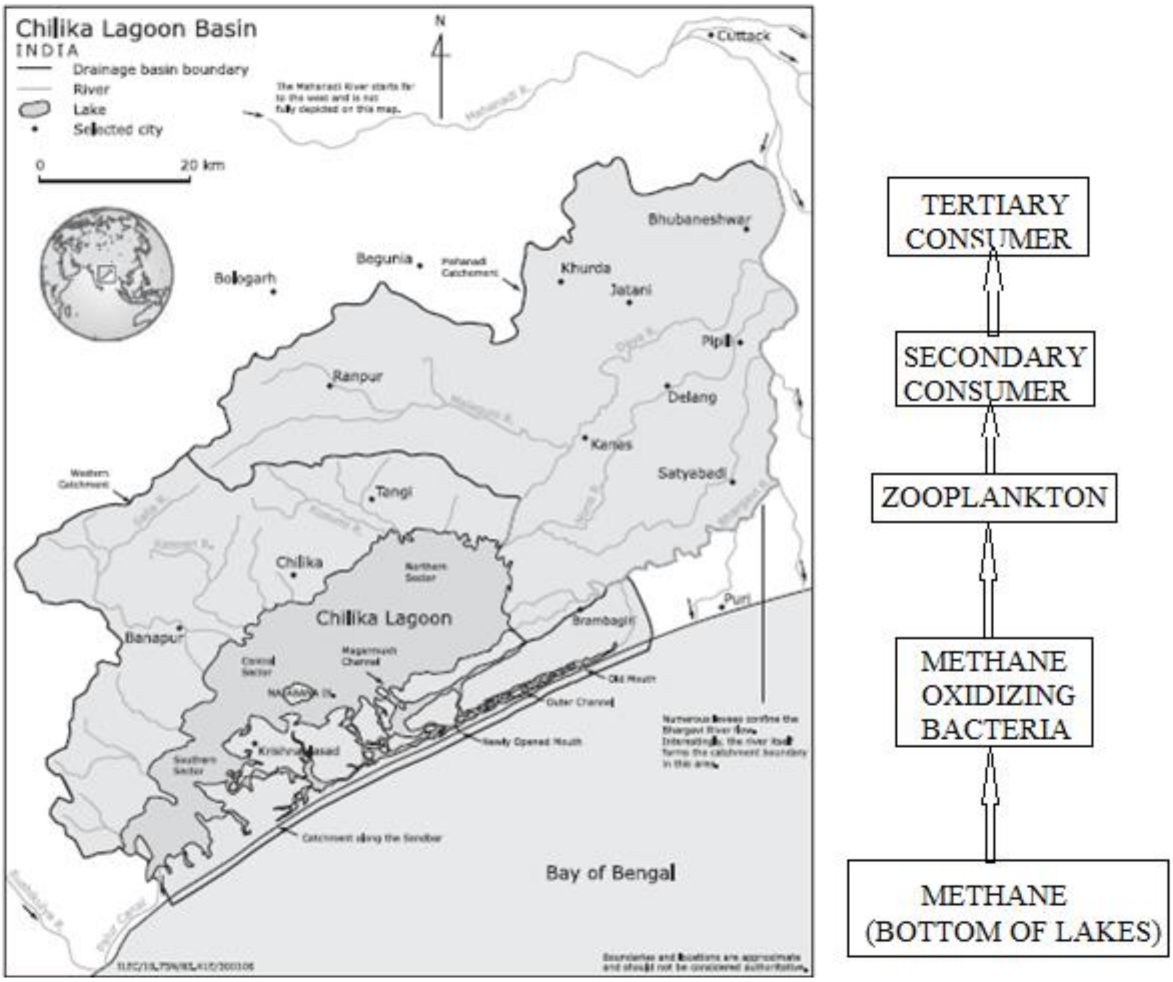


Image 1: Source: 2006 Blackwell Publishing Asia Pty Ltd

2. Erstwhile Utopian Scenario of Chilika

The quintessential conditions of the lake included interflow of gradient of freshwater and saltwater. Chilika is separated from the Bay of Bengal by a sandbar whose width varies between 100 and 1.5km, a long outer channel connects the main lagoon with the Bay of Bengal near the village of Arakhukuda.The pear shaped lagoon has a maximum linear axis of 64.3 km, with an average mean width of 20.1 km.The lagoon is spread over three coastal districts of the state: Puri, Khurda and Ganjam.The lagoon area is reported to have varied between 1165 sq.km. in the monsoon and 906 sq.km. in the summer, intervention of human settlements, aquaculture and agriculture along the sediment inflows from the catchment have reduced the average lagoon area to 760 sq.km.

Hydrologically, Chilika is influenced by three sub-systems, including the Mahanadi river system, rivers flowing in the lagoon from the western catchment and the Bay of Bengal. The lagoon receives freshwater from a series of 52channels.The spatial and temporal salinity gradients, as a result of freshwaterflows from the riverine system and seasonal seawater influx, have given Chilika unique characteristics of an estuarine ecosystem and exercised a continuous, selective influence on the biota.

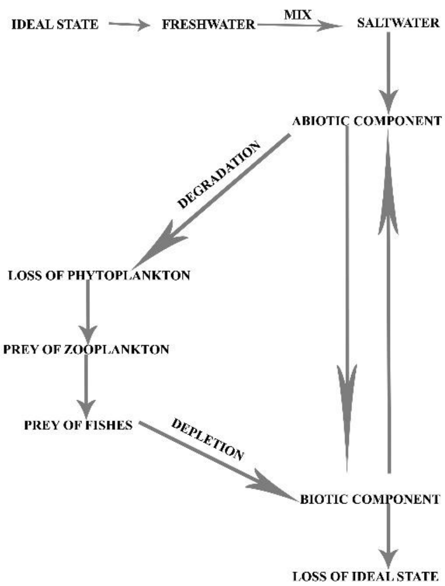


Image 2: Loss of Ideal State

3. Present Scenario of Atrophy of Biodiversity

The blocked mouth as a result of siltation has led to reduced amount of interflow of freshwater and saltwater.This has led to the loss of ideal lake conditions.Hence, the effects on abiotic domain have direct Interrelation with biotic domain leading to the loss of aquatic biodiversity. At least three species of brackish water Proifera, and a number of crustaceans (Brachyura Decapods), have disappeared over the past 60 years. Of the 74 species of molluscs, at least 50 species could not be traced. Of the 65 fish species noted in the lagoon during 1980's, 24 species were found to be freshwater fishes. The decline in total fish diversity from the earlier recorded 217 species to 69 is startling. In the Chilika lagoon 30 species of crustaceans and 60 species of molluscs were first discovered. (Annadale 1924)

The floral diversity provides 72 phytoplankton genera and eight seaweed genera from different sectors of lagoon in different seasons, which plays a key role in the food chain of this lagoon ecosystem. Methanol-oxidizing bacteria play significant role in biogeochemical carbon cycling by facilitating incorporation of C_1 derivatives into biomass using methanol as the sole carbon and energy source. Cyto- and bio-chemical properties, such as, synthesis of osmoprotectants, accumulation of potassium ions, formation of glycoprotein S-layers on the outer cell wall surface, and modification of the chemical composition of their membranes, allow these specialized group (haloalkaliphilic methanotrophs) to adapt to saline and alkaline habitats.

Table 1

Type	Annadale(1915-1924)	Ghosh(1995)	Comments
Protozoa	Few	61	
Porifera	7	2	As a result of decline in salinity
Colenterate	6	7	
Nematods	4	37	Five new species
Molluscs	74	87	Type of locality for 60 species,3 freshwater molluscs not present in 1995 due to decline in salinity
Reptila	22	23	Eight species of 1915-1924 not found in 1995
Birds	NA	156	
Mammals	18	18	Five new entrants in place of five earlier records
Pisces	217	69	24 freshwater species
Source:	Annadale(1915-1924 and Ghosh(1995)		

4. Enumerating Abiotic Components

The dependence of biotic factors over the abiotic factors in maintaining the ideal state of lake is the preliminary requirement for regaining the depleted aquatic biodiversity and the original characteristics of the lake.

The abiotic factor includes water and sediment parameters of the lake whereas the biotic factor includes flora and fauna present in the lake. The physical and chemical parameters have significant effect on the biological parameters in the lake ecosystem. The correlation exists between the physico-chemical parameters with flora and fauna of the lake can able to provide necessary information on the lake ecosystem. The growth and development of flora and fauna is mainly governed by the physico-chemical parameters of water and sediment.

The physical factor includes, water color, turbidity, depth, transparency, current, tidal wave and total suspended solids etc. Besides these, there are some important factors, such as weather, rainfall and atmospheric temperature which have also direct effect on Lake Ecosystem.

The chemical parameters includes pH, Conductivity, Alkalinity, Acidity, Salinity. The major element includes Calcium, Iron, Chloride, fluoride and Sulphate which showed substantial role in the water quality ecosystem. The minor elements includes Ammonia, Nitrite, Nitrate, Organic nitrogen, Inorganic phosphate, Total phosphate, Reactive silica and Total silica.

Aquatic macrophyte, algae and Phytoplankton require nutrients and light to grow. These factors modify the composition of plant community, species composition of fish, prawn, crab and other aquatic fauna of the lake. Environmental factors interact with one another in the same ecosystem, where it is extremely difficult to analyze the effect of any one factor on any component of the ecosystem. It is possible to deduce the general principles which assist in understanding responses of plants to various factors in the environment.

Table 2: Source: Qualitative and Quantitative Composition-P.K.Pattanaik

Months		Transperancy(cm)	Air Temp.	Water Temp.	Ph	Salinity(%)	Dissolved Oxygen	Alkalinity	Phosphate	Nitrite	Silicate
January		77	22	25.5	8.44	9.99	6.55	123	2.80	0.04	32.3
February		75.8	24	26	8.60	10.68	7.50	120	1.04	2.00	50.00
March		75.8	26	28	8.66	10.68	5.38	120	0.08	0.50	50.00
April		63	26	27.5	8.25	10.03	4.98	106	0.13	0.26	56.2
May		72	29	31	8.54	10.72	4.03	110	0.17	0.34	56.3
June		92.5	29.5	30.5	8.53	12.61	5.21	106	0.88	0.29	69.8
July		87.8	26	27.5	8.54	14.96	4.59	103	3.50	0.27	56.2
August		69	27	28	8.58	16.67	4.48	98	0.50	0.40	30.8
September		80	28	29	8.81	12.79	5.60	97	0.25	0.15	50
October		91	25	27	8.41	12.34	7.22	102	0.45	0.20	50
November		86	21	25	8.18	12.61	4.87	106	1.75	0.06	49
December		85	20	24	8.6	13.24	4.98	109	1.45	0.07	37.5
Source:	Qualitative and Quantitative Composition-P.K.Pattnaik										

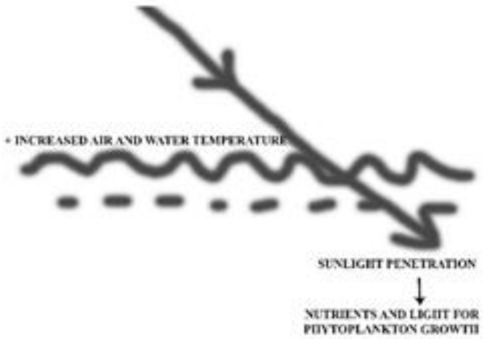
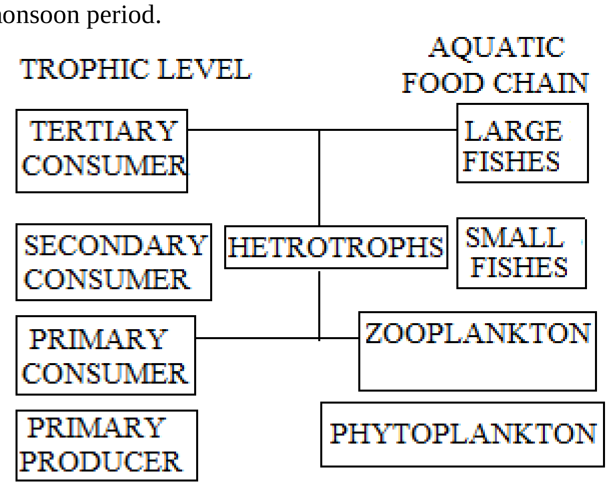


Image 3

According to the above table,when the temperature is maximum the transperancy of water is maximum leading to penetration of light which provides nutrients for the growth of phytoplankton.Hence, increasing the salinity Level to maintain the freshwater saltwater gradient.

4.1 Analyzing Abiotic Parameters

Watertemperature, salinity, dissolved oxygen, pH, alkalinity, phosphate-phosphorus, nitrate-nitrite, silicate, silicon and light penetration (transparency) in Rambha Bay (Table 2). The Bay experiences little salinity fluctuations due to, isolated and restricted nature of the area as it is surrounded by islands and also it is far away from the lagoonal mouth. The summer evaporation plays a vital role in raising the salinity in general. The water temperature is not much affected either by sea discharge or river, since it is far away from river entrance and the lagoonal mouth. The pH of water remains alkaline throughout. The total alkalinity records higher values during pre and post monsoonal months. The phosphate values were on ascent during the monsoon seasons and declined during the rest of the period. Nitrate and nitrite values were generally low during post and pre-monsoon period whilst the values were higher during the monsoon. The silicate values were low during the late pre-monsoon and monsoon periods and high during the post-monsoon period.



5. Discerning the disruption

Inorder to regain the original state of lake ecosystem,the abiotic factors need to be monitored and procured to its ideal state leading to retrieving the biotic factors. The seawater inflow in the lagoon reduced due to choked sea inlets with silt leading to quantitative reduction of the Methylotrophs. The Methylotrophs are distributed in diverse environments from freshwater Lake, deep-sea sediments, hyper saline lake, chlorinated environments, plant phyllosphere to hot water effluent, suggesting their ubiquity. The aerobic methylotrophs covered 1,100 km^2 of the Chilika Lake sediments through established molecular markers (such as the functional gene *mxaF* and phylogenetic 16S rRNA gene probes) which demonstrated the presence of phylogenetically diverse aerobic methylotrophs. The total viable counts were relatively higher in sediments near the sea mouth. (Panaspada, Joshi et al.)

International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

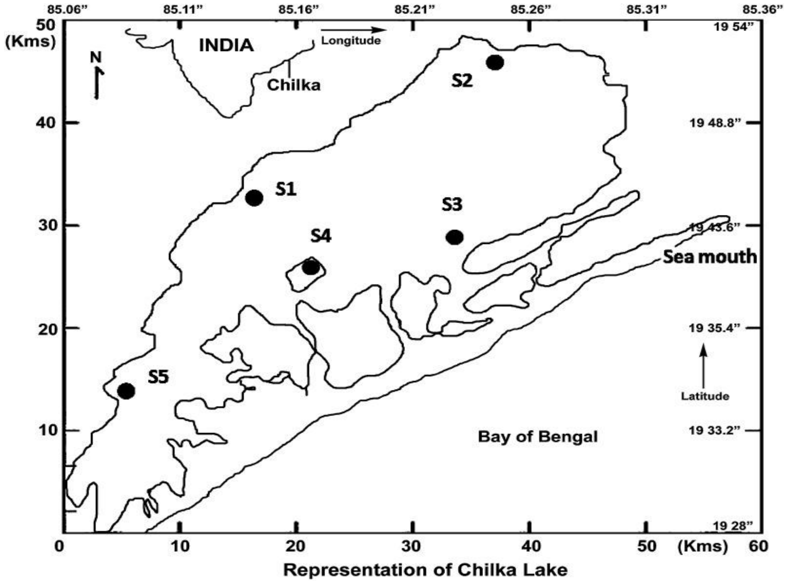


Image 4: Source:Phylogenetic Study-Kamlesh K. Meena

Table 3: Source-Phylogentic study of methanol oxidizers from chilika;Kamlesh K. Meena

Sample point	Location	Salinity, NaCl (mm)	pH	% Organic carbon	Log CFUs	*mxaF* gene copies (per gram sediment)
S1	Balugaon	80.0 ± 1.5	8.1 ± 0.2	0.8 ± 0.03	5.477 ± 0.35	4.9×10^6
S2	Bhusandapur	90.0 ± 1.6	7.8 ± 0.2	0.5 ± 0.02	5.792 ± 0.45	1.60×10^6
S3	Panaspada	100.0 ± 1.7	8.2 ± 0.3	1.5 ± 0.05	6.484 ± 0.51	1.25×10^7
S4	Nalaban	85.0 ± 1.1	8.1 ± 0.1	1.1 ± 0.03	5.991 ± 0.50	1.21×10^6
S5	Breakfast island	85.0 ± 0.9	8.8 ± 0.4	1.1 ± 0.04	6.305 ± 0.53	1.20×10^6

Maximum methylotroph population was observed at relatively nearer to the sea mouth (at S3; Panaspada), followed by S5 (Breakfast island) down south, and minimum was in S1 (Balugaon), far away from sea mouth. All isolates were aerobic, catalase, urease positive and weakly oxidase positive.Methylobacteriumaerobically produces carotenoid pigment and bacteriochlorophyll, indicating that their ability to acquire ATP (adenosine and three phosphate) helps them to survive even in carbon deprivation. The mixing of the sea water in the lake might be a reason for the relatively high halotolerance. Surface sediment is aerobic, whereas the oxygen typically depleted within millimeters below possibly due to the oxygen diffusional limitation across the column coupled with the active aerobic respirers.

High organic matter including lipids imparts toxic effects on the thriving microbial communities. The study reports depict that a more diversified methylotrophs group from saline sediments, like Methylobacterium, Methyloversatilis, Pseudomonas, Hyphomicrobium and Mycobacterium. Methylophilus methylotrophus could be a crop plants growth promoter under nitrogen stress conditions as it produced significant amount of low-viscosity extracellular polysaccharides from methanol in a chemostat culture under nitrogen limiting condition.

Methylobacterium is a facultative methylotroph and cannot use methane, but is capable of utilizing methanol and some other C_1 compounds, as well as a wide range of multi-carbon substrates, as their sole carbon and energy source while Hyphomicrobium is a facultative methylotroph. The methylotrophic diversity of the Chilika Lake indicates the richness of the sediments in terms of microbial wealth.

Comparing the distribution and quantification of *mxaF* gene by qRT PCR method revealed higher methylotrophs population from S3 (Panaspada), suggesting a higher C_1utilization rate. (Kamlesh K.Meena).This explicates the presences of higher methanol oxidizing bacteria which are taken by the zooplanktons which are in turn taken by the fishes, balancing the aquatic biodiversity.

6. Cognition for detraction of phytoplankton community

Phytoplanktonare similar to terrestrial plants in that they contain chlorophyll and require sunlight in order to live and grow. Most phytoplankton are buoyant and float in the upper part of the ocean, where sunlight penetrates the water. Phytoplankton also require inorganic nutrients such as nitrates, phosphates, and sulfur which they convert into proteins, fats, and carbohydrates.Nutrient levels are important in controlling the abundance of many species of algae. The relative abundance of nitrogen and phosphorus can in effect determine which species of algae come to dominate.Algae are a very important source of food for aquatic life, but at the same time, if they become over-abundant, they can cause declines in fish when they decay.
Phytoplankton of Chilika Lagoon consisted of a mixture of marine, brackish-water and freshwater taxa, mainly represented by four groups of algae—diatoms (Bacillariophyceae), dinoflagellates (Pyrrophyceae and Dinophyceae), blue-green algae (cyanobacteria) and green

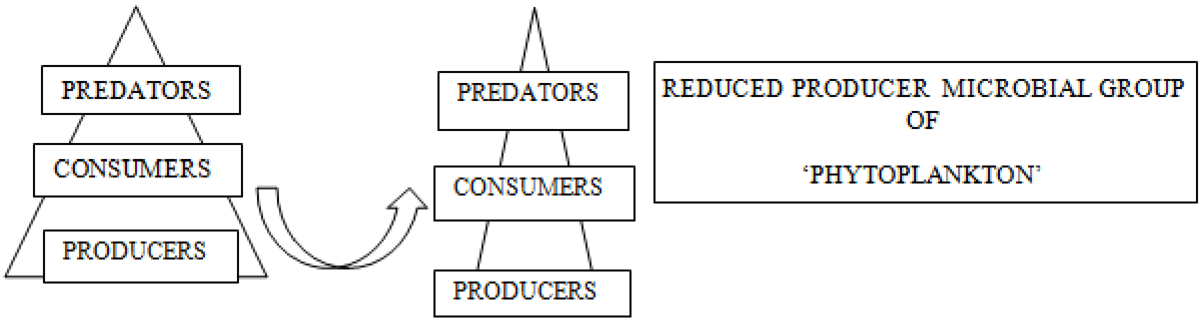
algae (Chlorophyceae). In total, 128 species of phytoplankton were identified. Diatoms were the dominant group and were represented by 79 species, (41 centrales and 38pennales). The dinoflagellate population was represented by13 species. Blue-green and green algae (with 9 familiesand15 genera) were represented by 18 species each. Some of the dominant taxa of phytoplankton, including those distributed throughout the lagoon as well as those in the more freshwater influenced northern sector and the saline water dominated outer channel area.(Satya Panigrahi-2008)

The spatial distributions of dissolved nutrients and salinity indicated that the phytoplankton proliferate in the areas of the lake that are influenced by the tributaries. The same is also true of the dense growth of macrophyte vegetation. Higher chlorophyll concentrations were less pronounced in the areas that were more influenced by water exchange with the sea, regardless of the nutrient concentrations. Spatial distributions of ammonia, nitrate and phosphate underwent significant changes during this time, which could be related to the phytoplankton uptake. The nutrient levels were lower during post-monsoon and summer and increased in the monsoon season. This variation leads to the following conceptual scheme: in 2001–2003, the plankton productivity/biomass was triggered by light availability, salinity changes and sustained by the pool of nutrients, which were supplied mostly through tributary discharges. The higher average population density of phytoplankton (higher chlorophyll a concentration) in summer can be linked to the lack of orthophosphate. This is probably due to the rapid uptake of phosphate by phytoplankton in summer, when there is a limited supply from the tributaries. This is supported by the fact that nutrient concentrations were lower in summer when the tributary discharges were negligible. (Satya Panigrahi-2008)

6.1 Role of Phytoplankton in Food Web

Phytoplankton are photosynthesizing microscopic organisms that inhabit the upper sunlit layer of almost all oceans and bodies of fresh water on Earth. They are agents for "primary production," the creation of organic compounds from carbon dioxidedissolved in the water, a process that sustains the aquatic web. They account for about half of all photosynthetic activity.Aquatic communities are often dominated byproducers that are smaller than the consumers that have high growth rates. Aquatic producers, such as planktonic algae or aquatic plants, lack the large accumulation of secondary growthas exists in the woody trees of terrestrial ecosystems. However, they are able to reproduce quickly enough to support a larger biomass of grazers. This inverts the pyramid. Primary consumers have longer lifespans and slower growth rates that accumulates more biomass than the producers they consume. Phytoplankton live just a few days, whereas the zooplankton eating the phytoplankton live for several weeks and the fish eating the zooplankton live for several consecutive years. Aquatic predators also tend to have a lower death rate than the smaller consumers, which contributes to the inverted pyramidal pattern. Population structure, migration rates, and environmental refuge for prey are other possible causes for pyramids with biomass inverted.

Proliferation of weeds to most parts of the lake because of silting and insufficient drainage aggravating the imbalance. The weeds proliferate in the rivers and get washed down to the lake during the monsoon. The weeds were kept in check in Chilika by the salt content of its water, but with a sharp drop in salinity -- from as much as 20 parts per thousand to near zero at some places -- there is nothing to prevent their rapid multiplication. The weeds, in turn, have increased silt deposit by choking the flow of water.



7. Remediation Process

A new mouth was dredge opened near Sipakuda to facilitate free water exchange between the lagoon and the sea in September 2000. Again in March 2008 a very wide natural new mouth opened near Gabakunda which facilitate the mixing of sea water with lake water, causing a wide variation in the physico chemical parameters of the lake. (A.P. Patra et al 2010)

There has been an overall rise in salinity levels in the Chilika Lagoon, in particular during the pre-monsoon period following the opening of the new mouth. This indicates that the tidal flux in the lagoon has increased and the associated circulation is effective in mixing the water masses. After the opening of the new mouth, weeds have reduced by a 172-km^2 area, in particular in the northeast part of the lagoon.

Table 4: Source-A.P. Patra et al 2010

Parameters	Before opening of new mouth	After opening of new mouth
Ph	6.4-9.5	7.13-8.67
D.O.	3.9-12.4	1.63-10.32
B.O.D	0.25-9.56	0.22-6.01
Salinity	3.8-32	4.1-36.8
Nitrate	0.02-13.1	1.55-117.4
Phosphate	0.12-0.4	0.17-5.4
Silicate	0.21-0.45	3.55-156.25

Temp	Temp	ph	TDS	DO	BOD	COD	Chloride	Salinity	Nitrate	Phosphate	Silicate
	1										
ph	-0.16	1									
TDS	0.43	-0.03	1								
DO	-0.09	-0.15	-0.56	1							
BOD	0.01	-0.1	-0.34	0.78	1						
COD	-0.05	-0.33	-0.03	0.02	-0.22	1					
Chloride	0.47	0.02	0.87	-0.54	-0.31	-0.14	1				
Salinity	0.46	0.02	0.87	-0.56	-0.33	-0.13	1	1			
Nitrate	-0.11	-0.08	-0.25	0	-0.2	0.02	-0.14	-0.13	1		
Phosphate	-0.25	-0.13	-0.27	0.24	0.11	0.19	-0.39	-0.4	0.41	1	
Silicate	0.03	0	-0.37	0.2	0.13	-0.01	-0.49	-0.49	0.04	0.04	1

Source: A.P. Patra et al 2010

Low dissolved Oxygen in sea mouth area is due to less solubility of oxygen in salt saturated water that depends on water temperature, water movement and salinity. Less amount of DO found in the Lake after opening of new mouth at Gabakunda is due to ingress of sea water into the lake. Higher DO values often more than the saturation values were found mostly in the stations where more weeds are present and may be due to their photosynthetic activities. BOD is an indicator of organic load of water. Low B.O.D. in central sector in monsoon season is due to growth of phytoplankton and zooplankton. In pre monsoon season due to less depth of water BOD is less. The high BOD value was found at the place where the decomposition of the weeds occurs which is the indication of assimilation of organic load and occurrence of more microorganisms. (A.P. Patra et al 2010)

After opening of new mouth BOD is less than previous value. This may be due to less growth of microorganisms as the salinity of water increases. If C.O.D. /B.O.D. are greater than 2, then here is chemical pollution and biological treatment of material is needed. In the present study C.O.D /B.O.D. are less than 2, hence there is no chemical pollution in the lake water. In the present investigation the overall chloride content was found to be very high as well as the salinity of the water. This is due to high rate of evaporation and free ingress of seawater through newly created mouth near Gabakunda area. Mixing of seawater with lake water helps in increasing the nitrate content in the water than previous. The concentration of different forms of nitrogen give useful indication of level of micronutrients in the water and hence their ability to support plant growth. High nitrate content in water helps in growth of weeds in certain areas of the lake in turn lending towards combating the lost balance in the food web.The tributaries and the exchange of lagoon water with the Bay of Bengal most probably determine the water quality and the dynamics of the ecosystem. Hydrodynamics of the lagoon, weed coverage, input of urban sewage through tributaries and agricultural runoff are probably the key factors controlling the trophic conditions of the lagoon. An increase in salinity and total phosphorus was noted after the new mouth was opened, while the total suspended sediment load, the water column depth, and nitrogenous nutrients decreased. The new mouth opening also brought changes in the phytoplankton species composition.

8. Conclusions

1) Adoption of Physical Processes on land to reduce the siltation fosters the prerequisite for the survival of biotic components.
2) Restoration of Physical Properties comprising of reduced rate of siltation which avoids the choking of natural mouth of lake leads to restoration of chemical properties by modulating the lakes character from brackish to freshwater.
3) The revival of primary producers in form of phytoplankton aids in reviving the secondary producers in turn maintaining a balance in the food web circumventing the plummeting aquatic biodiversity.
4) Monitoring the adoption of physical processes on abiotic factors inorder to achieve the ideal lake conditions.

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