The Palaeobotanist 57(2008) : 503-509
0031-0174/2008 $2.00

Palynological records of mangrove degradation around Chilka Lake, Orissa, India

ASHA KHANDELWAL

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

(Received 18 July, 2007; revised version accepted 23 June, 2008)

ABSTRACT

Khandelwal A 2008. Palynological records of mangrove degradation around Chilka Lake, Orissa, India. The Palaeobotanist 57(3): 503-509.

The pear shaped Chilka Lake lying along the eastern coast of Orissa State, is one of the ecological and socio-economical important wetlands of India. This open lagoon is identified as a nationally important and internationally renowned ecosystem, which harbours a range of marine, brackish and fresh water biodiversity. Palynological syntheses based on the results of investigated mid-late Holocene profiles (Balugaon, Rambha, Nalabana, Dangmal, Solari, Chandrapur, Geokhala, Bhowania) are compared with the upper part of core CHI-9 encompassing period of 13,000 years. It has been observed from the pollen record that tropical dense mangrove forest thriving luxuriantly during early Holocene has decreased considerably with the passage of time.

The present mangrove ecosystem, though more restricted, is fairly stable with maintenance of conserved mangrove forests in protected prograding bays in Mahanadi delta and in estuaries kept open by adequate river flow. However, siltation, eutrophication and industrial development are major threatening factors affecting the sensitivity of lake resulting in shrinkage and total disappearance of surrounding vegetation. It has been indicated that certain metals, such as Co, Cr, Cu, Ni, V, Zn As, Pb, Cd are responsible for the environmental stress of the ecosystem which are continuously incorporated by the use of fertilizers and pesticides in agriculture. There should be an appeal and educational effort to stop the destruction and fragmentation of mangroves. The planned eco-friendly rehabilitation of mangroves, along with harmonious urban development and industrialization is required in order to restore the past glory of Chilka Lake.

Key-words—Palynostratigraphy, Mangroves, Chilka Lake, Orissa, India.

भारत में उड़ीसा की चिल्का झील के आस-पास मैंग्रोव निम्नीकरण के परागाणविक अभिलेख

आशा खंडेलवाल

सारांश

उड़ीसा राज्य के पूर्वी तट पर स्थित नाशपाती-नुमा चिल्का झील भारत की एक पारिस्थितिक एवं सामाजिक-आर्थिक महत्वपूर्ण आर्द्र-भूमि है। यह खुला लैगून राष्ट्रीय रूप से महत्वपूर्ण एवं अंतर्राष्ट्रीय रूप से प्रतिष्ठित पारिस्थितिक तंत्र के रूप में विख्यात है, जो कि समुद्री, नुनखरा एवं अलवण जल जैवविविधता को एक क्रमबद्ध आश्रय देता है। बहुत-सी अनुसंधानित मध्य-अंतिम परिच्छेदिकाओं (बालुगाँव, रांभा, नालाबना, डंगमल, सोलारी, चन्द्रपुर, जियोखाला, भौवनिया) के परागाणविक परिणामों के आधार पर क्रोड सी एच आई-9 से तुलना की गई है जिसने 13,000 वर्षों की अवधि परिवेष्टित की। पराग अभिलेख से प्रेक्षित किया गया है कि प्रारंभिक होलोसीन के दौरान विपुलता से फलते-फुलते उष्णकटिबंध्धीय संघन मैंग्रोव वन समय के गमन के साथ विचारणीय रूप से कम हो गए हैं।

मौजूदा पारिस्थितिक तंत्र हाँलाकि ज्यादा सीमित है, महानदी डेल्टा में रक्षित पुरःक्रमणी खाड़ियों में संरक्षित मैंग्रोव जंगलों के रख-रखाव के साथ स्पष्टतः स्थायी है तथा ज्वारनदमुखों में पर्याप्त नदी प्रवाह से खुला रहा। फिर भी, गादीकरण, सुपोषण एवं औद्योगिक विकास बड़े खतरे से पूर्ण कारक हैं व झील की सुग्राहिता, इसके संकुचन तथा आस-पास की वनस्पति के लोप का प्रभावित कर रहे हैं। यह इंगित किया गया है कि पारिस्थितिक तंत्र के पर्यावरणीय दबाव हेतु कुछेक धातुएं जैसे- Co, Cr, Cu, Ni, V, Zn, As, Pb, Cd उत्तरदायी हैं जो कि कृषि में उर्वरकों एवं कीटनाशकों के प्रयोग में सतत रूप से समाविष्ट हैं प्रकृति संरक्षण के रूप में मैग्रोवों को बचाने की जरूरत ज्यादा है। मैंग्रोवों के विनाश एवं विखंडन को रोकने हेतु अपील और शैक्षणिक प्रयास होने चाहिए। चिल्का झील क अतीत गौरव के पुनरुद्धार हेतु सुव्यवस्थित शहरी विकास एवं औद्योगिकीकरण के साथ मैंगोवों के योजनाबद्ध परिवेश-अनूकूल पुनर्वास सुझावित है।

मुख्य शब्द—परागाणुस्तरक्रमविज्ञान, मैंग्रोव, चिल्काझील, उड़ीसा।

Changing Scenario in Palaeobotany and Allied Subjects
Editor : J.S. Guleria

INTRODUCTION

CHILKA Lake is one of the ecological and socio-economical important wetlands of India. This open lagoon is identified as a nationally important and internationally renowned ecosystem, which harbours a range of marine, brackish and fresh water biodiversity. This wetland ecosystem is presently under threat mainly by anthropogenic pressure. The changes in salinity concentration, eutrophication, siltation, decrease in aquatic flora and fauna, changes in species composition of migratory birds, extraction of bioresources are the major factors resulting in loss of biodiversity. Due to an overall loss of the biodiversity Chilka Lake was added to the List of Ramsar sites in danger in 1993 (Sekhar, 2004). Over the last few decades, Chilka has attracted the attention of biologists, fishery scientists, geologists, oceanographers, planners, administrators, ecologists, naturalists and conservationists.

The pear shaped Chilka Lake (19º45' N: 85º25' E) is situated on the southern part of the Mahanadi delta-complex along the eastern coast of Orissa State. It is situated south-west of Puri and measures approx. 65 km NE-SW and 20 km EW at its widest point. It belongs to Tropical/Subtropical zone where temperature ranges between 15°C in months of December and January and 45°C in the hottest month of May. The lake is cut off from the Bay of Bengal by a continuous sandy barrier-spit measuring ca. 60 km in length and 150 m in width where backshore dunes are developed in the southern half of the spit in two or three parallel groups. The lagoonal inlet opening into the Bay of Bengal is ca. 300 m wide. Optically stimulated luminescence dating (OSL) determined the age of the barrier spit spanning between 350 years near the level of beach up to 40 years near the top of the barrier (Murray & Mohanti, 2004).

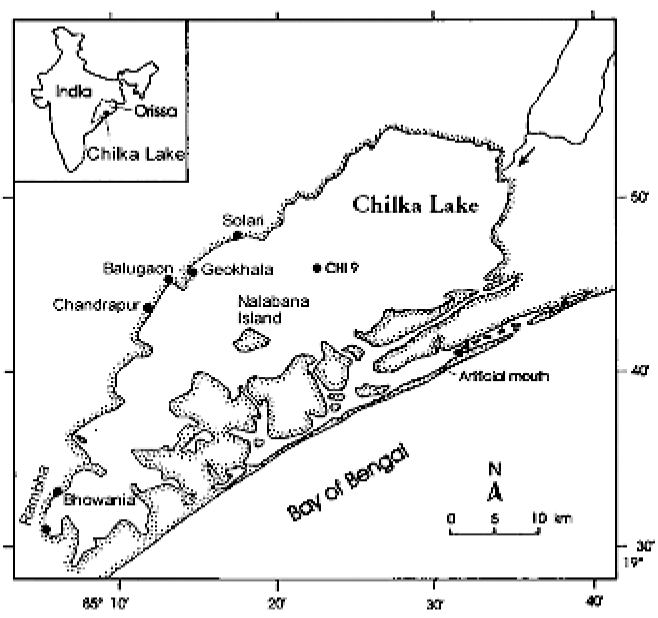

Fig. 1—Showing location of investigated sites in and around Chilka Lake, Orissa, India.

The lagoon has an average area of 868 sq km and the average annual rainfall in the Chilka has been estimated to be 1766 mm. The lagoon is fed by a number of rivers, streams and streamlets and it conveys the runoff into sea through a narrow water channel which constantly shifts northwards and is getting narrower. The Mahanadi deltaic distributaries contribute 51% of the total inflow into the lagoon whereas the western catchments account for 39% and the direct precipitation 10%. The maximum sediment load comes to the lagoon during the monsoonal months of July-September. The geology, geomorphology, vegetation and ecozones of Chilka and the surrounding area is given in detail elsewhere (Gupta & Khandelwal, 1990; Khandelwal, 1992). In addition, Mohanti (1993) dealt with the overall geological, environmental aspects focussing on the degradation of the Chilka Lake at present.

Mangroves are tropical trees and shrubs that grow in intertidal areas. They play a significant role in coastal stabilization and promoting land accretion, fixation of mud banks, dissipation of winds, tidal and wave energy. Traditionally, people have used mangroves for the benefit of the local community, but increasing populations have led to an increasing non-sustainable abuse of the resources. A wide range of human activities, such as charcoal and firewood utilization, expansion of agricultural areas, aquaculture, urban and industrial development, harbour construction, mining, and housing projects, have put mangroves at risk. Presently, the mangroves are totally lacking around Chilka Lake owing to the excessive biotic pressure which was otherwise festooned by the mangrove forest in the near past. Nevertheless, a few remnants of mangroves, albeit in degraded form, such as *Avicennia* sp., *Acanthus ilicifolius*, *Excoecaria agallocha* are often found growing along the lagoon.

Chilka is a very rich preserve of ecological biodiversity th brackish and freshwater species, including several dangered, threatened, and vulnerable species. The socio-onomic exploitation of mangroves has resulted in complete termination of vegetation from the landscape except a few otected pockets and conserved forest in Mahanadi Delta, issa. With this backdrop of highly diversified possible root uses, it is important to study this wetland more closely, with view to its conservation. The major root causes of odiversity loss are population dynamics, globalization, uaculture technology, forest degradation and other ological changes. In view of the above, Chilka is chosen to derstand precisely the palaeoenvironmental scenario in time d space and to suggest measures to restituate the vironment of recent past.

Several sediment profiles were collected ranging in depth tween 3-5 m, one each from Balugaon (Gupta & Khandelwal, 90; Khandelwal & Gupta, 1994), Solari, Chandrapur and eokhala (Kohli, 1996) from the western flank, Rambha handelwal & Gupta, 1993) from the southern flank, Bhowania (Khandelwal & Gupta, 1999) from the north-eastern flank, Dangmal (Khandelwal & Gupta, 2000) from within Bhitarkanika wildlife sanctuary in District Cuttack. Nalabana (Gupta & Khandelwal, 1992) was collected from an island and CHI-9 from within the lake, over the water (Fig.1). Litho-bio-and chronostratigraphic methods have been applied to unveil the nature of depositional environment, Holocene evolution of mangrove vegetation with the events of marine transgression and regression. The chief objective of present study is to understand precisely the palaeoenvironmental scenario in time and space and to suggest measures to restitute the environment from further degradation.

RESULT

The salient features of palynological studies of each investigated site in and around Chilka Lake are presented below:

Balugaon

Based on pollen statistics of a 5.50 m deep vertical sediment profile from Balugaon covering a time span of about 4000 years B.P., a pollen diagram has been prepared and relative frequencies of each pollen/spore have been plotted in order to reconstruct the palaeofloristics (Gupta & Khandelwal, 1990). Organodebris analysis helped in assessment of depositional environment of Balugaon (Khandelwal & Gupta, 1994). The pollen diagram had been classified in five pollen assemblage zones in ascending chronological order prefixed with their site initials, e.g. B-I to B-V. Pollen zones B-I and B-II enjoyed a luxuriant growth of core mangrove taxa, such as Rhizophoraceae, *Avicennia*, *Heritiera*, *Excoecaria*, *Sonneratia*, *Acanthus ilicifolius* and *Acrostichum aureum*. Thereafter, the core mangroves lost the consistency and continued in degraded form till 400 years B.P. and thereafter vanished from the landscape. However, peripheral mangroves, such as *Pandanus*, *Borassus*, *Cocos*, *Lumnitzera*, *Terminalia*, etc. were insignificant till 1500 years B.P. but gained later coinciding with the downfall of the core-mangroves. The peripheral mangroves too disappeared from the scene around 300 years B.P. This changing pattern of vegetation could be abused in the hands of man.

Rambha

One 4.30 m deep vertical sediment profile, covering a time span of about 4000 years B.P., has been palynologically investigated and a pollen diagram has been prepared incorporating the relative values of all the taxa encountered (Khandelwal & Gupta, 1993). Two major pollen assemblage zones have been recognised in ascending chronological order prefixed with the site initial, viz. R-I and R-II. This has been done to express biostratigraphic units in terms of palaeovegetation and to translate them in relation to the significant events and episodes which had occurred during the course of sediment deposition on the southern flank of Chilka.

Lithostratigraphically, the sediments could be broadly classified as sticky grey clay with silt and sand in different denominations and having black organic thin streaks between 4.30 to 2.00 m depth. Thereafter, sediments were composed of blackish organic mud with abundance of shell fragments and fish scales. Pollen zone R-I (4.30-2.20 m) records splendid growth of core mangroves. This period signifies high values of Rhizophoraceous taxa, like *Rhizophora*, *Ceriops* and *Bruguiera* followed by *Aegialitis*, *Avicennia*, *Heritiera* and *Excoecaria* whereas peripheral mangroves and midland taxa were present in low number. Chenopodiaceae, an inhabitant of salt marshes, was also present in high values. This set-up of vegetation on the southern bank of Chilka suggests the prevailing marine environment with minor fluctuations between 4000-1500 years B.P. Pollen zone R-II encompassing a time period of 1500 years before present was characterized by the steep fall in the core mangroves all through out. Rhizophoraceae reduced to fraction. *Aegialitis*, *Sonneratia* and *Heritiera* disappeared from the landscape. However, *Avicennia*, *Excoecaria* and *Lumnitzera* continued in good values. Chenopodiaceae also maintained good values throughout. It is thus, envisaged that between 4000-1500 years B.P. typical marine milieu prevailed encouraging the establishment and development of core mangroves. Thereafter, degradation of mangroves began leading to the formation of salt marshes.

Nalabana Island

One 3.75 m deep vertical sediment profile has been palynologically investigated (Gupta & Khandelwal, 1992). The sediments laid down at Nalabana were more or less similar throughout and identified as clayey sand in different denomination. However, organic matter was present in considerably low quantity and hence no radiocarbon date could be obtained. Nevertheless, lithology of Nalabana profile suggests that the sediments were laid down at a faster rate and therefore, age extrapolation of 3.75 m deep Nalabana profile does not go beyond 2000 years B.P. The overall picture permeated out of this investigation revealed that the core and peripheral mangroves were recorded in degraded form but salt marsh vegetation, predominated mostly by Chenopodiaceae, sedges and marine grass (*Porteratia coarctata*), were recorded. Between 2000-1800 years B.P., the mangorves were sporadic but sedges, grasses and Chenopodiaceae colonized the island far and wide. Thereafter, between 1800-1600 years B.P. Rhizophoraceae vanished and other mangroves reduced to fraction. But between 1600-1200 B.P., the mangroves reappeared in moderate values whereas halophytes reduced proportionately indicating the frequent inundation of the area by sea water. The period between 1200 to 500 years B.P. recorded an evident depression amongst the arboreal components in general and mangroves in particular except for *Acanthus ilicifolius* which experienced sizeable improvement. However,

Investigated profiles	Depth	Age	Pollen zones (depth in metres)	Time span (in years)	Vegetation shifts
Balugaon (Gupta & Khandelwal, 1990)	5.50 m	3,100 ± 270 years B.P.	B- I (5.50-4.40)	700	Core mangroves flourished
			B-II (4.39-3.60)	500	Core & peripheral mangroves dominated
			B-III (3.59-2.40)	800	Intermixing of mangroves with fresh water taxa
			B-IV (2.39-1.35)	500	Intermixing of mangroves & fresh water taxa
			B-V (1.34-0.00)	700	**Mangroves disappeared**
Rambha (Khandelwal & Gupta, 1993)	4.30 m	3,470 ± 180 years B.P.	R-I a (4.30-3.75)	500	Core & peripheral mangroves flourished
			R-I b (3.74-3.20)	500	Core mangroves dominated
			R-I c (3.19-2.20)	900	Peripheral mangroves dominated & core mangroves declined
			R-II a (2.19-1.70)	400	Mangroves, hinterland taxa & Amaranth-chenopod prevailed
			R-II b (1.69-0.70)	300	Salt tolerant fresh water taxa prevailed
			R-II c (0.69-0.0)	700	**Mangroves degraded & formation of salt marshes**
Nalabana Island (Gupta & Khandelwal, 1992)	3.75 m	2,000 years B.P.	N-Ia (3.75 –3-50)	200	Mangroves sporadic
			N-I b (3.50-3.00)	200	Intermixing of mangroves with fresh water taxa
			N-I c (3.00-2.20)	400	Mangroves reappeared
			N-II a (2.20-1.40)	450	Mangroves with fresh & brackish water taxa
			N-II b (1.40-0.60)	250	Fresh water & brackish taxa dominated
			N-III (0.60–0.0)	500	**Mangroves replaced by grasses, sedges & Cheno/Amaranth**
Bhowania (Khandelwal & Gupta, 1999)	4.85 m	3,000 years B.P.	B-I (4.85-4.00)	600	Core & peripheral mangroves flourished
			B-II (4.01-3.40)	400	Core & peripheral mangroves declined
			B-III (3.41-2.40)	600	Core & peripheral mangroves sparsely represented
			B-IV (2.41-1.18)	900	Core & peripheral mangroves insignificant
			B-V (1.18-0.00)	500	**Mangroves feebly represented & establishment of salt marshes**
Solari (Kohli, 1996)	3 m	2,000 years B.P.	S-I (3.0-2.10)	500	Core mangroves & peripheral mangroves thrived well
			S-II (2.1 –1.6)	250	Core mangroves declined & peripheral ones continued
			S-III (1.6 - 0.0)	1000	**Core disappeared & peripheral Mangroves in very low percentage**
Chandrapur (Kohli, 1996)	3 m	2,000 years B.P.	C-I (3.0-2.7)	150	Core & peripheral mangroves flourished
			C-II (2.7-2.3)	200	Core & peripheral mangroves flourished
			C-III (2.3-1.7)	300	Core & peripheral mangroves with hinterland taxa
			C-IV (1.7-1.5)	100	Core & peripheral mangroves declined
			C-V (1.5-0.6)	450	Core & peripheral mangroves declined
			C-VI (0.6-0.0)	300	**Mangroves exterminated**
Geokhala (Kohli, 1996)	3 m	1,870 ± 300 years B.P.	G -I (3.0-2.0)	500	Core mangroves & peripheral mangroves flourished
			G -2 (2.0 -0.50)	750	Core mangroves & peripheral mangroves declined
			G -3 (0.50-0.00)	250	**Mangroves absent but abundance of Cheno/Amaranth**

Dangmal (Khandelwal and Gupta, 2000**)**	1.85 m	1,480 ± 210 years B.P.	D - I (1.85-1.65)	150	Core & peripheral mangroves sporadic
			D - II (1.65-1.05)	500	Core & peripheral mangroves sparsely represented
			D- III (1.05-0.50)	400	Intermixing of mangroves with fresh water taxa
			D- IV (0.50-0.00)	400	**Mangroves conserved**
CHI-9 (Khandelwal *et al.*, 2008)	7.8 m	13,000 years B.P.	CH-I (7.80-6.80)	13,000	Dominance of fresh water plants with initiation of brackish water conditions
			CH - II(6.80-3.20)	3000	Development and proliferation of mangroves
			CH -III(3.20-0.90)	4500	Peripheral mangroves & fresh water plants
			CH- IV(0.90-0.00)	2500	**Degraded mangroves and establishment of the present day condition**

Fig. 2—Summary of palynological investigation of sediment profiles in and around Chilka Lake.

grasses, sedges and Chenopodiaceae advanced considerably indicating the prevalence of salt marshes. This phase encompassing the period of past 500 years, may be correlated with the excessive human activities over the landscape preventing establishment of mangroves.

Bhowania

Based on palynoassemblage of 4.85 m deep vertical sediment profile from north-eastern flank of Chilka Lake, a pollen diagram has been prepared recording the relative values of all the taxa (Khandelwal & Gupta, 1999). The sediments were mostly comprised of black humified organic mud with silt and sand in different denominations. Although Bhowania profile has not been dated radiometrically but on the basis of correlation with other dated profiles, the base of the profile could be marked to ca. 3000 years B.P. In order to achieve precision in vegetation shift, five major pollen assemblage zones have been recognised and prefixed with site initials, viz. BH-1 to BH-V.

During the period between 3000-2400 years B.P., the area was predominated by halophytes, such as Chenopodiaceae and Asteraceae. The mangrove taxa, like *Heritiera*, *Acanthus ilicifolius*, *Avicennia*, *Excoecaria*, *Xylocarpus*, *Terminalia*, Rhizophoraceae and Palmae were very insignificant. Thus, the vegetation scenario during this period envisages the development of salt marshes abutting sea shore wherein periodic marine influence could not be overruled. During the period between 2400-2000 years B.P. general uprise in the mangrove taxa has been recorded *vis-a-vis* halophytes which dwindled down. This type of vegetation composition is suggestive of frequent inundation of this area by sea water and thereby this could be termed as tidal phase. The period between 2000-1400 years B.P. was characterized by the replenishment of halophytes and subduction in mangrove taxa. This led to the development of salt marshes again and cessation in the influence of sea water.

The period between 1400-500 years B.P. is characterized by insurgence of grasses, sedges and ferns and there was general decline in the values of halophytes and mangroves which led to the hypohaline conditions encouraging the development of reed-swamps. However, the period since 500 years B.P. is marked by replenishment of halophytes wherein mangroves were feebly present yielding space for the establishment of salt marshes.

Solari

One 3 m deep vertical sediment profile covering a period of 2000 years B.P. from Solari Village was investigated and one pollen diagram has been constructed to exhibit the relative values of all the taxa encountered (Kohli, 1996). The sediments were largely comprised of humified dark black organic mud with traces of silt and fine sand. The pollen study has envisaged that the core mangroves, predominated by Rhizophoraceae thrived well till 1500 years B.P. and thereafter, disappeared from the landscape. Nevertheless, peripheral mangroves thrived all through till 300 years B.P. and disappeared later on.

Chandrapur

Based on the recovered palynoflora from 3 m deep vertical sediment profile, a pollen diagram has been prepared exhibiting the relative frequencies of all the taxa (Kohli, 1996). The sediments were largely comprised of silty clay. On the basis of vegetation development and its correlation with other well dated pollen diagram from Chilka Lake, it was assumed that the total sediment accretion would have taken a time span of 2000 years B.P. The study has revealed that the core and peripheral mangroves thrived well in and around Chandrapur till 1500 years B.P. Thereafter, they continued in degraded form and exterminated from the landscape around 300 years B.P.

Geokhala

The results of pollen analysis of a 3 m deep vertical sediment profile from Geokhala were presented in the form of pollen diagram for the better understanding of vegetation shifts since 1870 ± 300 years B.P. (Kohli, 1996)**.** The sediments were largely comprised of black organic mud with thin band of silt and sand between 0.25-0.5 m depths. Pollen study has reflected that both core and peripheral mangroves flourished in Pollen zone G-I and then declined in G-II and thereafter they were almost exterminated from the landscape. The mangrove taxa recognised during the early phase were Rhizophoraceae, *Avicennia, Excoecaria agallocha*, *Acanthus ilicifolius* and *Brownlowia.* Pollen zone-III exhibited the preponderance of Chenopodiaceae pollen. This feature of vegetation composition helps to deduce that it was an area conducive for the development of salt marshes which often develop on the sheltered landward side of spit.

Dangmal

Dangmal is situated on the bank of river Baitarni in Bhitarkanika wildlife sanctuary in District Cuttack which is not in very close proximity of Chilka Lake but known for ideal tidal swamp area of Mahanadi Delta colonised by both core and peripheral mangroves. One 1.85 m deep sediment profile dated back to 1,480 ± 210 years B.P. was collected from Dangmal, an area within Bhitarkanika wildlife sanctuary in District Cuttack. The sediments were black humified organic mud with moderate plant debris. The pollen diagram based on subtle changes in the vegetation development, has been divided into four pollen zones prefixed with site initials, viz. D-1 to D-IV (Khandelwal & Gupta, 2000). The bottom samples of profile exhibited rich occurrence of core mangrove taxa, such as *Rhizophora, Heritiera, Sonneratia, Avicennia, Excoecaria, Aegialitis,* etc. However, the frequency of both core and peripheral mangroves declined in the middle and further reduced in the upper part of the profile. It was recorded that there was comparatively low degree of mangal exploitation at Dangmal as compared to other investigated sites of Mahanadi Delta, Orissa.

Chi 9

A sediment core CHI 9 measuring 7.8 m long and covering a time span of about 13,000 years B.P. was palynologically investigated (Khandelwal *et al.,* 2008). The pollen diagram has been classified into 4 pollen zones in ascending chronological sequence prefixed with site initials, e.g. CH-I to CH-IV. In brief, Holocene environment and mangrove dynamics at CHI 9 exhibit dominance of fresh water plants in fresh to brackish water condition around 13,000 to 10,000 Yrs B.P. Transgression of the sea helped in proliferation of mangrove around 10,000 to 7,000 yrs B.P. The period 7,000 to 2,500 yrs B.P. recorded maximum sea level highstand around 6000 yrs. B.P. Later on recession in the tidal magnitude started and at the same time increase in the fresh water discharge affected colonization of core mangrove. In the last phase from 2500 yrs B.P. till today regression of the sea leading to degraded mangroves and establishment of the present day condition were encountered.

CONCLUSIONS

Lithofacies analysis, pollen assemblages and radiocarbon dates have been used to infer an evolutionary history for Late Quaternary vegetation succession and contemporary climatic changes through the analysis of sediment profiles from in and around Chilka Lake, Mahanadi Delta, Orissa (Fig. 2). The investigated core CHI 9 has been procured with the power operated piston corer and constituted a much deeper profile, in which radiocarbon dates covered almost entire Holocene. Thus, in totality CHI 9 profile can not be compared with the other investigated profiles in this area, such as Balugaon (Gupta & Khandelwal, 1990), Rambha (Khandelwal & Gupta, 1993), Nalabana (Gupta & Khandelwal, 1992) Solari, Chandrapur and Geokhala (Kohli, 1996).The other profiles were collected by manually operated Hiller's peat auger covering the history up to mid-late Holocene. However, it was envisaged that mangroves colonized in response to marine transgression in early and upper middle part of Holocene and established as *Rhizophora*-dominated mangroves. The other core and peripheral mangrove taxa were represented by *Sonneratia, Avicennia, Excoecaria, Heritiera, Acanthus, Acrostichum, Lumnitzera, Barringtonia, Pandanus, Cocos, Borassus, Phoenix, Terminalia,* Fabaceae, Meliaceae, etc. It has been observed from the pollen record that tropical dense mangrove forest thriving luxuriantly during early Holocene has decreased considerably with the passage of time. The upper parts of almost all profiles have exhibited either complete extermination of mangrove vegetation or they were recorded in degraded form. This phase, in the history of mangrove vegetation development, is important as it signifies degraded mangrove vegetation owing to human influences causing irreparable loss to the maritime forest. Palynological investigations from Kalibhanja Dian Island and Talchua Village of Brahmani Delta (Caratini *et al*., 1980) support the poor occurrence of mangroves in upper zones of investigated pollen sequences. Similar results are obtained from Sunderban-Gangetic plain of Bengal Basin (Vishnu-Mittre & Gupta, 1972; Gupta, 1981), Cauveri Delta, Tamilnadu (Tissot, 1980) and offshore Kerala and Karnataka (Van Campo, 1983). Degradation of mangroves in Paradip Island in Mahanadi Delta has been attributed to the construction of Paradip Port (Gupta & Yadav, 1990). It has also been reported that element concentrations of Chilka Lake are composed of anthropogenic and geogenic fractions in low range. However, Phosphates and some heavy elements (e.g. As, Cr, Cu) are enriched in the recent sediments. Thus, the environmental stress of the ecosystem is increased by the use of fertilizers and pesticides in agriculture (Wegele *et al.*, 2003). The lake is now being degraded with shallowing of the bottom due to heavy siltation, increasing freshwater influence, increased weed growth in which the submerged pond weed *Potamogeton* is very important. There is choking of the old mouth due to strong littoral drift of sands in the near shore region which arrests tidal inflow of saline waters into the lagoon. Due to enhance salinity a new mouth has been opened in approximately middle region of the long barrier-spit separating the lagoon from the open sea.

While summing up the results of pollen analytical investigations, one thing has come up in common that the mangrove vegetation flourished in recent past at different areas and thereafter, degradation of mangrove vegetation began slowly and gradually culminating around 500 years B.P. when the mangrove vegetation was ruthlessly exterminated from the landscape. The foremost cause of mangrove deterioration was the biotic influence followed by climatic and edaphic disturbances. For the restoration of the past glory of Chilka, the first and foremost step to be taken is to reduce excessive biotic pressure over the landscape and to put a check over the unplanned development. Ways and means are to be developed to regenerate the mangrove species in the areas which are now transformed into heath land and/or commercial exploitation with some plantation of exotic species. The slow but continuous process of plant succession has to pave the way for a thorough restitution of mangrove community which would re-act as buffer zone and in turn save the environment from degradation.

REFERENCES

Caratini C, Thanikaimoni G & Tissot C 1980. Mangroves of India : palynological study and recent history of the vegetation. Proceedings of VI International Palynological Conference, Birbal Sahni Institute of Palaeobotany, Lucknow (1976-1977) 3: 49-59.

Gupta HP 1981. Palaeoenvironments during Holocene time in Bengal Basin, India as reflected by palynostratigraphy. Palaeobotanist 27: 138-160.

Gupta HP & Khandelwal A 1990. Mangroves of India: history and palynostratigraphy of Chilka Lake, Orissa, India. *In*: Jain KP & Tiwari RS (Editors)—Proceedings of Symposium Vistas in Indian Palaeobotany. Palaeobotanist 38: 379-393.

Gupta HP & Yadav RR 1990. History of mangrove vegetation in Paradip and Jambnu Islands, Orissa for the past 500 years B.P: A palynological report. *In*: Jain KP & Tiwari RS (Editors)—Proceedings of Symposium Vistas in Indian Palaeobotany. Palaeobotanist 38: 359-369.

Gupta HP & Khandelwal A 1992. Mangrove development at Nalabana Island, Chilka Lake: A palynological interpretation. Geophytology 22: 235-238.

Khandelwal A 1992. Holocene history of mangrove vegetation in India: a palynological interpretation. Palaeobotanist 40: 383-392.

Khandelwal A & Gupta HP 1993. Palynological evidence of mangrove degradation during mid-late Holocene at Rambha, Chilka Lake, Orissa. Geophytology 23: 141-145.

Khandelwal A & Gupta HP 1994. Organodebris analysis of Chilka Lake, Orissa, India: An assessment of depositional environment. Palaeobotanist 42: 215-224.

Khandelwal A & Gupta HP 1999. Late Holocene climate and vegetation of Bhowania, Chilka Lake, Orissa. Gondwana Geological Magazine Special Volume 4: 301-306.

Khandelwal A & Gupta HP 2000. Mangrove history since 1,500 years B.P. at Dangmal, Baitarni-Brahmani Delta, Orissa, India. Palaeobotanist 49: 119-127.

Khandelwal A, Mohanti M , Scharf BW & García-Rodríguez F 2008. Vegetation history and sea level variations during the last 13,500 yrs inferred from a pollen record at Chilka Lake, Orissa, India, Vegetation History and Archaeobotany 17: 335-344.

Kohli D 1996. Palynostratigraphy and Palaeoenvironment of Mahanadi Delta, Orissa. Ph.D. Thesis, Lucknow University.

Mohanti Manmohan 1993. Chilka Lake-A case Study. 4th National Water Convention sponsored by Ministry of Water Resources, Govt. of India, Thiruvananthapuram 123-140.

Murray A & Mohanti M 2004. Recent development of the Chilka lagoon barrier spit on the Bay of Bengal, Orissa, eastern India: A chronology based on luminescence dating. Abstract Volume (edited by Thanawat Jarupongsakul & Yoshiki Saito), 5th International Conference on Asian Marine Geology (IGCP 475 Delta Map/APN Mega-Delta), Department of Geology, Chulalongkorn University, Bankok, Thailand.

Sekhar NU 2004. Fisheries in Chilka Lake: how community access and control impacts their management. Journal of Environment Management 73: 257-266.

Tissot C 1980. Palynologie et evolution recente de deux mangroves du Tamilnadu (Inde). Travaux et Documentaires Centres d 'Etude de Geographie Tropicale 39: 109-214.

Vishnu-Mittre & Gupta HP 1972. Pollen analytical study of Quaternary deposits in the Bengal Basin. Palaeobotanist 19: 297-306.

Wegele M, Zachmann DW, Garcia-Rodriguez F, Mohanti M & Scharf BW 2003. Distribution and speciation of heavy metals in recent and fossil sediments from Chilka Lagoon, India. 9th International Paleolimnology Symposium, Helsinki (Abstract).

Van Campo E 1983. Palaeoclimatologie des bordures de la mer d'Arbie depuis 150,000 ans. Analyse pollenique et stratigraphie isotopique. These, Montpellier 114 p.