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Limno-Chemical Characteristics of a Scroll Meander Depression in Comparison with Other Sectors of a Floodplain Wetland of Assam, India

RANJAN K. MANNA[1,*], MD. AFTABUDDIN[1], MD. ABUL HASSAN[2] and ALOK SARKAR[1]
[1]Regional Centre, Central Inland Fisheries Research Institute (ICAR)
HOUSEFED Complex, Dispur, Guwahati - 781 006, India
[2]Central Inland Fisheries Research Institute (ICAR)
Barrackpore, Kolkata - 700120, India

Abstract

Floodplain wetlands (beel) in Assam constitute a major fishery resource of the region. Spatio-temporal variability of six common limno-chemical parameters viz. water temperature, pH, dissolved oxygen, free carbon dioxide, specific conductivity and total alkalinity were determined monthly during 2001-02 at surface and bottom of deep scroll meander in comparison with those at shallow areas of Samaguri beel, Nagaon, Assam, India. Shallow zone was infested with submerged macrophytes throughout the year, whereas deep zone was devoid of them. All the parameters varied widely across the zones especially bottom of scroll meander depression, which behave differently as compared to all other sectors. Trophogenic activity in surface of shallow zone and tropholytic activity in bottom of deep zone controlled the limno-chemical parameters. Establishment of riverine connectivity in monsoon played a major role in controlling those parameters especially in bottom of the deep zone by enhanced mineralization of bottom organic matter as evidenced by sharp increase of sp. conductivity. Meander depression is characterized with lower temperature, acidic pH, anoxic water, higher sp. conductivity, higher free CO_2 concentration and higher total alkalinity. Surface of the deep zone with low variability of the parameters may provide better limno-chemical environment for fishes as compared to all other sectors for survival and growth.

Introduction

The state of Assam, a northeastern state of India is dotted with numerous hilly tributaries of the Brahmaputra River in the north and Barak River in the south. Meandering behaviour of these hilly streams produced a large number of ox-bow lakes out of cut-off meanders with a total area of approximately 1 lakh ha. Those lakes are

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* Corresponding author. Tel: +91 361 2228486
E-mail address: rkmanna@yahoo.com

called as floodplain wetlands (locally known as beel) as they establish the connectivity with the parent river during monsoon causing flushing of them by floodwaters. Increased human intervention through embankment, sluice gate etc. at the connecting channel caused adverse impact on overall ecology of many such wetlands with increased organic matter accumulation, aquatic macrophyte infestation etc (Manna & Aftabuddin 2007a). Understanding their high fisheries production potential, these wetlands attracted the interest of researchers and the attention of policy makers in the recent past (Sugunan & Bhattacharjya 2000). Limno-chemical study can reveal the ecological status of a wetland describing its physical, chemical and biological components important from fisheries point of view. Earlier studies were mainly from a selected area of such wetlands which could not give the overall picture of the ecosystem (Yadava et al. 1987; Acharjee et al. 1999). The seasonally connected wetlands are unique in character in two ways. Firstly, floodplain wetlands with seasonal connectivity remained lentic for 7-8 months and lotic for rest of the year. Secondly, wetlands with meander depression has two different ecosystems - submerged macrophyte infested shallow zone (1-3 m deep) and weed-free deep scroll meander depression zone (6-8 m deep). Samaguri beel located in Samaguri of Nagaon district of Assam has both of those characteristics. Limno-chemical study was performed in this beel by selecting two sampling centres - one in shallow zone and other in deep zone. Surface and bottom layer are considered for sampling as it is assumed that bottom of these two sectors should behave differently. The objective of this study was i) how shallow zone behaved as compared to deep zone, ii) what was the impact of river connectivity on common limno-chemical parameters.

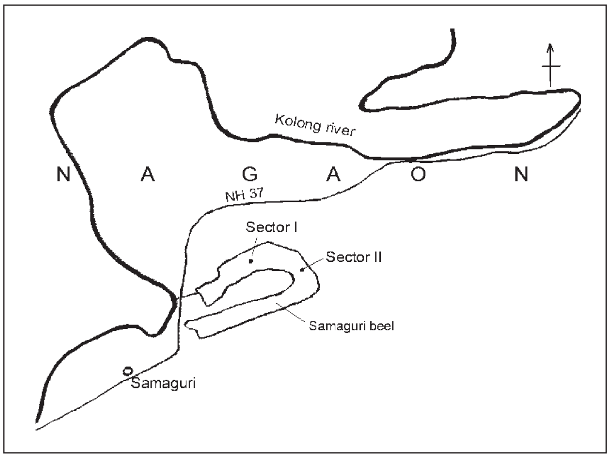

Figure 1. Site map of Samaguri beel (Samaguri, Nagaon, Assam, India)

Materials and methods

Samaguri beel, a horse-shoe shaped floodplain wetland (26°25′35"N, 92°51′45"E) in Samaguri, Nagaon, Assam was generated from river Kolong, a southern tributary of river Brahmaputra (Fig. 1). The wetland was connected with the parent river by a channel through a culvert under national highway 37. Connectivity was established with the

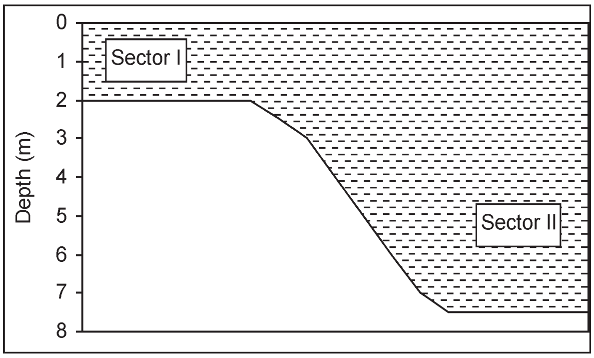

Figure 2. Average depth of shallow region (Sector I) and meander scroll depression (Sect

main river during June-July in monsoon facilitating intrusion of turbid floodwater in the wetland. Two sampling centres were selected in the beel - sector I at shallow area with average depth of 2 m and sector II at meander scroll with average depth of 7.5 m (Fig. 2). Both surface and bottom water were collected with the help of water sampler and six common limno-chemical parameters viz. water temperature, pH, dissolved oxygen, free carbon dioxide, specific conductivity and total alkalinity were measured during daytime with regular time interval of 6 hrs viz. 06:00 h, 12:00 h and 18:00 h. The study was performed from April, 2001 to February, 2002. Data of water pH, free CO_2, sp. conductivity and total alkalinity were not recorded during April. The limno-chemical parameters were measured following standard methods.

Results and Discussion

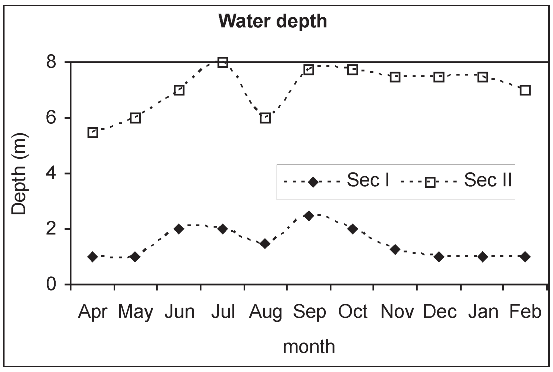

Figure 3. Seasonal variation of water depth

Shallow area near the connecting channel was designated as Sector I and deep area at meander depression as sector II. Sector I remained infested with submerged and floating aquatic macrophytes like *Najas*, *Ceratophylum*, *Vallisneria*, *Hydrilla* and water hyacinth throughout the year. Sector II is devoid of any submerged macro phytes as the area is deep enough not to allow their establishment. Only constructed brush parks made of water hyacinth used as fish aggregating device were there in sector II. Similar brush parks and their impact on common limnochemical parameters were reported by Manna and Aftabuddin (2008). Turbid floodwater intrusion was observed in June-July and in September in the wetland through connecting channel from river Kolong. Water level increased by 1.0-1.5 m during monsoon raising water depth up to 2.5 m in sector I (Fig. 3). Submerged macrophytes tolerated this increase in water depth and survived unlike in Morakolong beel where sudden increase in water level with turbid monsoon inflow caused mass mortality of submerged macrophytes (Manna & Aftabuddin 2007a). Decrease of water depth in August is due to outflow of water from the wetland to the main river through the same channel.

Water temperature

Water temperature controls metabolic activity of aquatic organism and thereby their growth, reproductive behaviour etc. Temperature is one of the major contributing factors behind the distribution of aquatic macrophytes (Dale 1986). Seasonal variation of biomass of submerged macrophytes was observed to be influenced by temperature along with solar radiation (Rooney and Kalff 2000). Growth of fishes is strongly influenced by water temperature. Carps grow better in the temperature range of 20-30°C, whereas moderate growth is observed at a temperature range of 13-20°C. For reproduction, carps need a temperature greater than 18°C.

Data collected in Samaguri beel revealed that suitable water temperature (18.4-34.4°C) has helped in continuous flourishing of submerged macrophyte in sector I. Highest temperature (34.4°C) was recorded in May in sector I surface and lowest (18.4°C) in January in sector II bottom. During morning (6:00 h), all other zones have comparable water temperature except Sector II bottom, temperature of which was lower in most of the cases with higher difference of 9.5C than that of surface water in July (Fig. 4-6). However, during August cold rain water and outflow of bottom water disturbed the thermocline in sector II with reduced gap of water temperature between surface and bottom. Though in the morning, surface and bottom water of sector I were of almost same temperature, noon and evening sampling recorded thermocline in shallow sector I also with lower bottom temperature. The highest temperature difference (4.3°C) between surface and bottom in sector I was noted in the month of December during noon hours despite only 1 m water depth. Hindered water circulation by near-surface dense canopy of submerged macrophtes in December caused such high difference. Similar observation with much hot surface water (by 5.9-6.3°C) at submerged macrophyte zone was reported by us in Puthimari beel of Barpeta district of Assam where dense canopy of *Ceratophylum* sp. was responsible for the hotter surface water (Manna and Aftabuddin 2007b). Surface water of sector I observed higher increase of temperature from morning to noon than any other sector due to shallow water depth as well as hindered water circulation by thick submerged macrophytes. For example, during April in sector I surface water temperature increased from 27°C in the morning to 32.2°C at noon, bottom water temperature of the same place increased only from 27.1°C to 28.6°C at the same time. Similar phenomenon was observed in May, October, December and February. Thermocline in sector II was less prominent during winter months with less difference of temperature between surface and bottom. As surface of submerged macrophyte zone observed much higher water temperature, care must be taken to measure this important water parameter.

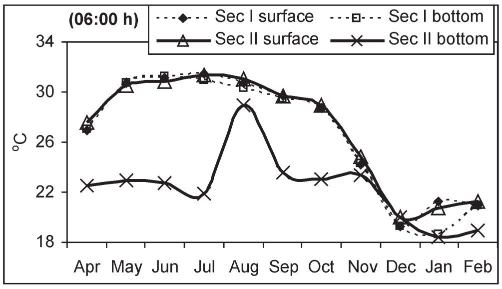

Figure 4. Seasonal variation of temperature (06:00 h)

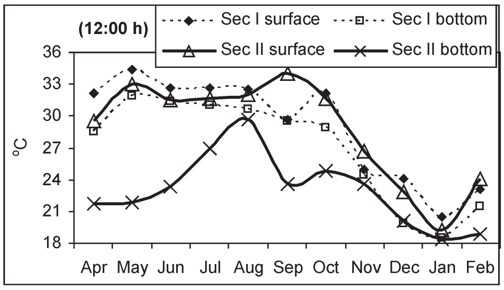

Figure 5. Seasonal variation of temperature (12:00 h)

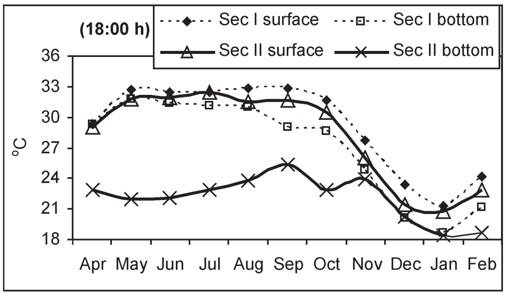

Figure 6. Seasonal variation of temperature (18:00 h)

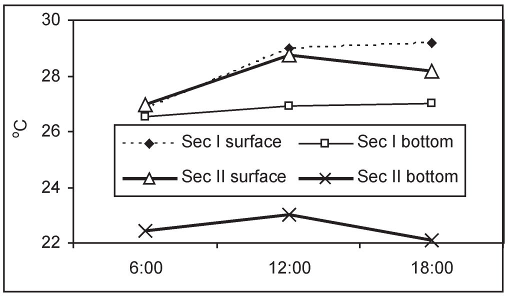

Figure 7. Average diurnal variation of temperature

Water pH

Water pH is considered as one of the most fundamental limno-chemical parameters controlling metabolic activity of aquatic organisms. Water pH was observed to control the types of aquatic macrophytes (Vestergaard & Sand-Jensen 2000). Water pH in a eutrophic system was observed to be strongly controlled by photosynthesis and respiration. Photosynthetic autotrophs used free CO_2 to increase the pH, whereas respiratory release of CO_2 decreases the pH of the system. The more the photosynthesis, the higher will be the increase in pH. Organic acids (humic acid, fulvic acid etc) produced by microbial decomposition may also contribute to low pH especially at the bottom.

Water pH varied in the range of 6.2-8.2 i.e. 100 times change of acid concentration was observed during study period. As expected, highest pH (8.2) was recorded in surface water of Sector I during October-November caused by photosynthesis of thick submerged macrophytes. Bottom water of sector II was of acidic nature in most cases, which is due to, accumulated CO_2 released from decomposition of bottom organic matter. Both surface and bottom water of sector I showed almost the same pH in the morning throughout the year. However rapid increase of pH was observed in surface water of sector I as days passed by. Bottom water of the same zone showed unimpressive change during same period. This may be due to the balancing act of microbial respiration generated CO_2 and photosynthetically consumed CO_2. Highest change of pH from 6.8 in morning to 8.2 in noon hours during October-November was observed in surface water of sector I, where thick infestation of submerged macrophyte existed. Similar high pH up to 9.2 at early afternoon from 6.1 in the morning in submerged macrophyte zone was observed in Puthimari beel (Manna and Aftabuddin 2007b). It may be mentioned here that constant pH in the environment is better than regular variation of pH for survival of aquatic organism. Water pH in the range of 7.0-8.0 is known to be ideal for fish growth. Low pH caused acid stress, respiratory problem and mucus secretion on gills of fishes. On the other hand, higher pH damages gill, eye lens, cornea and disturbs acid-base balance of blood of fishes. Water pH is often used to understand fisheries ecology of a water body. In the wetland studied pH varied significantly across sector, within a day and throughout the year, pH of such wetlands may be mentioned along with these environmental factors for better understanding of ecosystem health.

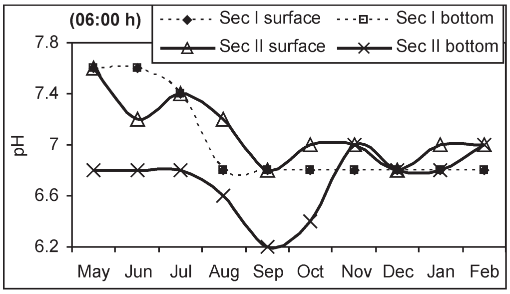

Figure 8. Seasonal variation of water pH (06:00 h)

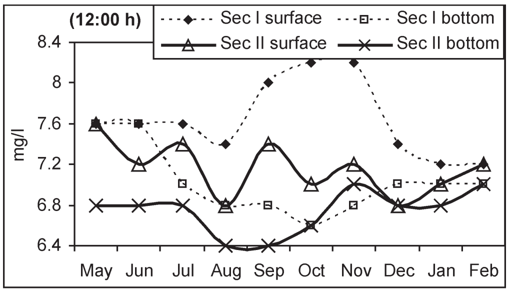

Figure 9. Seasonal variation of water pH (12:00 h)

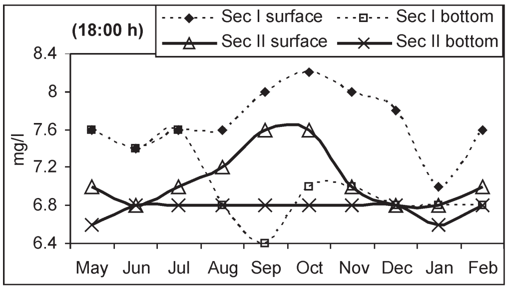

Figure 10. Seasonal variation of water pH (18:00 h)

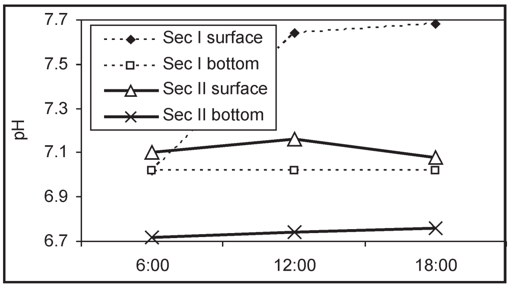

Figure 11. Average diurnal variation of pH (12:00 h)

Specific conductivity

Specific conductivity of water reflects the total ion concentration and thereby nutrient status of a water body. Specific conductivity was mentioned as one of the major environmental factors for controlling aquatic macrophyte distribution, richness and composition in wetlands (Crowder et al. 1977; Rolon & Maltchik 2005).

During the study period, specific conductivity of water of Samaguri beel varied from 68.5 µS.cm^{-1} (Sector II surface, September) to 246.0 µS.cm^{-1} (Sector II bottom, October). Other studies in wetlands of Assam indicated that arrival of monsoon was accompanied by decrease of sp. conductivity mainly due to dilution. Interestingly, all the sectors in our study followed those observations except bottom of sector II. With monsoon rain and inflow, sp. conductivity of the bottom water of sector II increased sharply and that trend continued up to October i.e. end of monsoon (Fig. 12-14). Cold oxygenated rainwater and river inflow in monsoon probably accelerated microbial decomposition of bottom organic matter resulting in release of CO_2 increasing total alkalinity and decreasing pH. H^+ ion from increased carbonic acid and other released nutrients may be responsible for the higher values of sp. conductivity in bottom water of sector II during monsoon months. Sp. conductivity data showed high positive correlation with total alkalinity ($p < 0.001$). High correlation of seasonal conductivity and total alkalinity was observed by Mortimer (1971) in his studies in Esthwarte water, England. Sp. conductivity of bottom water is more than surface water in most of the months in both the sectors, which may be due to higher H^+ released from dissociated carbonic acid generated from accumulated CO_2. Bottom of sector II behaved differently than other three sectors in case of diurnal changes (Fig. 15). Sp. conductivity increased from morning to noon and then decreased in all other sectors except bottom of sector II. Probably, two opposing factors played the key role in sp. conductivity changes. H^+ ion from increased carbonic acid due to bacterial decomposition increased sp. conductivity, whereas assimilation of CO_2 by photosynthetic autotrophs utilizing dissolved CO_2 and HCO_3^- released OH^-, which neutralize H^+ causing decrease in sp. conductivity. Light dependent intensive nitrogen fixation by cyanobacteria in anaerobic condition at bottom also may have a role behind decrease of sp. conductivity.

Dissolved oxygen (DO)

Dissolved oxygen in water is the prime requisite for metabolism of all aerobic aquatic organisms. Oxygen controls strongly the availability of many inorganic nutrients and thereby regulates the growth of aquatic plant communities. Oxygen content in water is increased by photosynthesis and decreased by respiration of all aquatic organisms including microbes. Microbial decomposition is one of the major oxygen consumption factors in the wetland studied.

DO showed wide variability ranging from 0-18.9 $mg.l^{-1}$ during the entire study period. Deposited organic matter at sediment-water interface i.e. tropholytic zone utilized all oxygen of bottom water converting near sediment zone anoxic in many occasions. Bottom of sector II is more affected due to more water depth showing anoxic character in most of the months with little oxic during post-monsoon period. Bottom of sector I was also anoxic in many cases especially during higher water depth in monsoon when photosynthetically produced oxygen didnít counterbalance the bottom demand for oxygen and during late winter when reduced water depth helped better decomposition at bottom with more oxygen consumption. Surface of sector II observed less variability of DO, as low-density phytoplankton was the sole contributor. Very high variability of DO with supersaturation was observed in surface of sector I, the trophogenically most active zone infested with submerged macrophytes. A change of 4-6 mg.l^{-1} DO is not very uncommon in eutrophic lakes (Lingeman et al. 1975). Interestingly, very high DO of surface of sector I was unable to influence the bottom water despite the shallow nature of that zone. Near-surface dense canopy of submerged macrophytes may have hindered vertical water mixing as observed in case of temperature also. Lake with multiple depressions was reported to show very different oxygen concentration in different areas (Lind 1987; Wetzel 2001). As expected, bottom of both the sectors did not exhibit appreciable change in diurnal variation, surface of sector I showed sharp increase from morning to evening and surface of sector II observed major increase till noon and then remain steady up to evening (Fig. 19). During winter months also, sufficiently high DO during noon and evening especially in sector I surface was a clear indication of high photosynthetic activity taking place in winter season also. As oxygen concentration is often used to describe wetland health, care should be taken during sampling as different regions of beels with different depths and plant communities may contain totally different oxygen concentration.

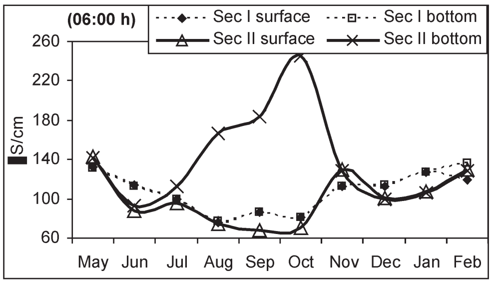

Figure 12. Seasonal changes of sp. conductivity (06:00 h)

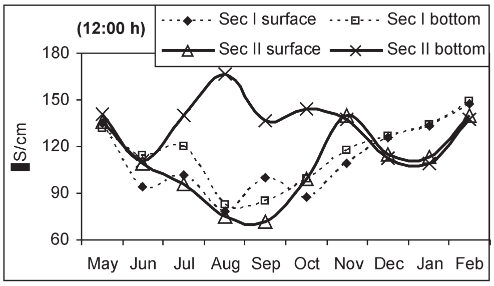

Figure 13. Seasonal changes of sp. conductivity (12:00 h)

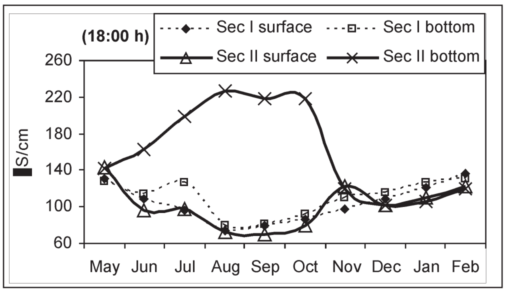

Figure 14. Seasonal changes of specific conductivity (18:00 h)

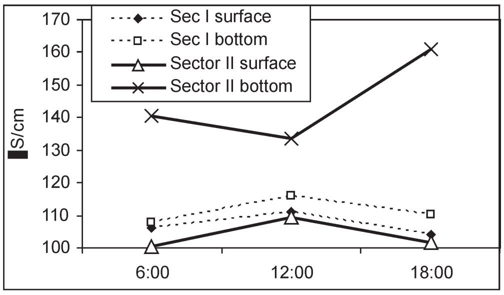

Figure 15. Average diurnal changes of specific conductivity

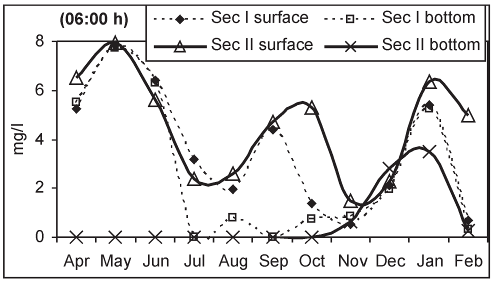

Figure 16. Seasonal variation of dissolved O_2 (06:00 h)

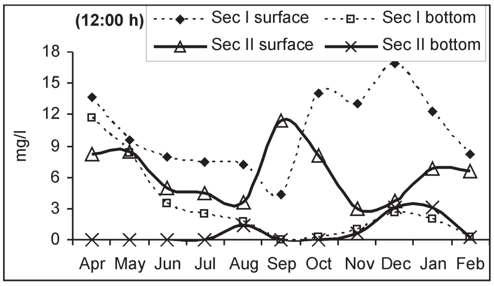

Figure 17. Seasonal variation of dissolved O_2 (12:00 h)

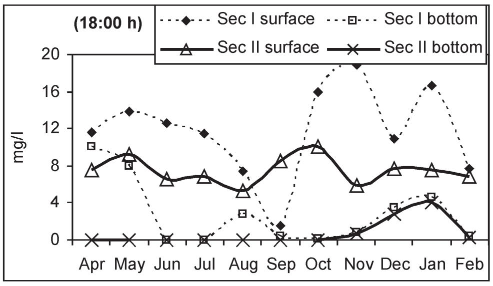

Figure 18. Seasonal variation of dissolved O_2 (18:00 h)

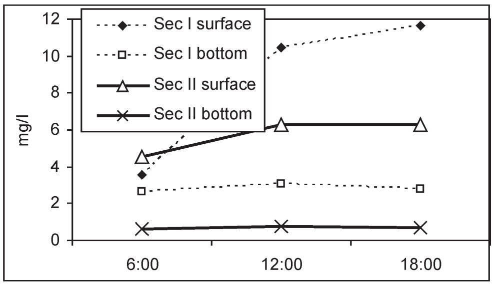

Figure 19. Average diurnal variation of dissolved O_2

Dissolved carbon dioxide

Dissolved inorganic carbon, carbon dioxide and bicarbonate are the sources of carbon for photosynthesis of submerged aquatic plants and hence they can directly control the growth of submerged macrophytes (Bowes & Salvucci 1989).

As surface water i.e. trophogenic zone was involved with higher rate of photosynthesis, concentration of free CO_2 is less in surface of both the zones as compared to bottom, which being the tropholytic zone was the main source of free CO_2 (Fig. 21-23). Free CO_2 ranged from nil to as high as 157.68 mg.l^{-1} in sector II bottom at 18:00 h in October. Large biogenic accumulation of CO_2 in hypolimnion was observed in deep lakes with high organic load (Kling et al. 1992). Due to very high consumption rate of free CO_2 in surface of sector I, it is absent in most of the months especially during noon and evening sampling. Though the use of HCO_3^- is less efficient than free CO_2 use causing lower photosynthetic rate, absence of free CO_2 indicated possible HCO_3^- use for photosynthesis by macrophytes in sector I. (Prins & Elzenga 1989). Here, HCO_3^- is converted to CO_2 and OH^- between two cell layers of upper and lower epidermis of leaves. CO_2 is absorbed inside for photosynthesis releasing OH^- to the water causing increase in pH as observed. Free CO_2 was always present in bottom of sector II due to continuous microbial decomposition of sediment organic matter. Sharp increase in free

CO_2 in bottom of sector II during monsoon months may be due to increased aerobic microbial decomposition by cold oxygenated floodwater inflow and rain in addition to anaerobic decomposition. However, in bottom of sector II, CO_2 concentration decreased from morning to noon and then increased (Fig. 23). Utilization of CO_2 in upper photosynthetic zone and diffusion in atmosphere from upper surface due to increased temperature causing an upward diffusion of bottom accumulated CO_2 may be responsible for this diurnal changes.

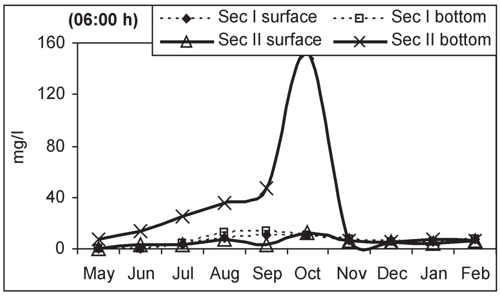

Figure 20. Seasonal changes of dissolved CO_2 (06:00 h)

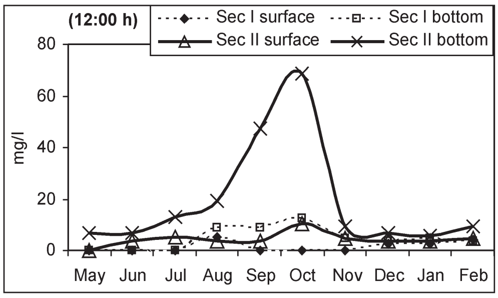

Figure 21. Seasonal changes of dissolved CO_2 (12:00 h)

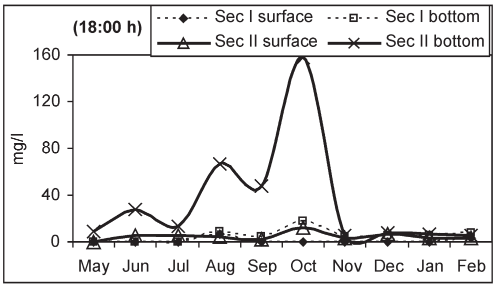

Figure 22. Seasonal changes of dissolved CO_2 (18:00 h)

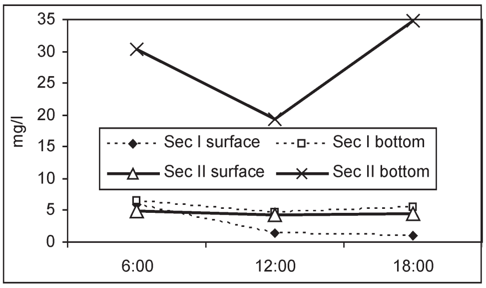

Figure 23. Average diurnal variation of dissolved CO_2

Total alkalinity (TA)

Alkalinity is measured as mg/l of $CaCO_3$ which assumes that alkalinity is due solely to carbonate and bicarbonate. With the increase in decomposition in the tropholytic zone and with increase of amount of CO_2, HCO_3^- concentration also increased near the sediment. Bacterial production of ammonium carbonate in the sediment is partly responsible for increase of HCO_3^- in bottom water.

Total alkalinity ranged from 28.56 $mg.l^{-1}$ at surface of sector I (most active trophogenic zone) in September to 137.09 $mg.l^{-1}$ at bottom of sector II (most active tropholytic zone) in October. Total alkalinity decreased sharply with arrival of monsoon in all the zones except bottom of sector II, which remained steady with much higher total alkalinity values as compared to other zones (Fig. 24-26). Establishment of river connection supplied oxygenated water to the bottom of sector II resulting in more efficient aerobic microbial decomposition at bottom along with anaerobic decomposition. End of river connectivity in post-monsoon brought back the high TA of sector II bottom to normal position indicating strong impact of river connectivity on this zone. Sector II bottom behaved differently with respect to other zones in diurnal behavior (Fig. 27). Sector II bottom showed decreasing trend in total alkalinity from morning to noon and then increased, whereas all other zones showed little increase from morning to noon and then decreased.

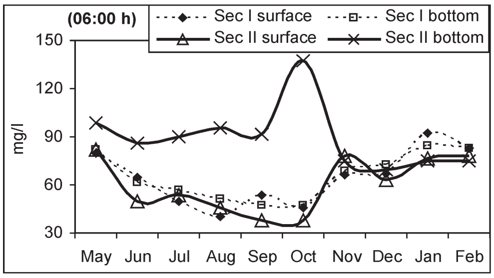

Figure 24. Seasonal changes of total alkalinity (06:00 h)

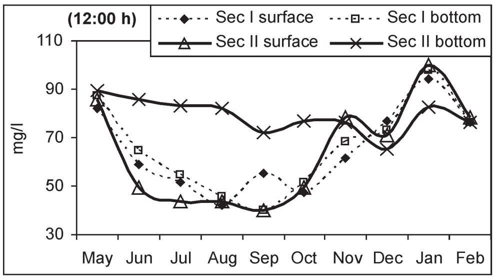

Figure 25. Seasonal changes of total alkalinity (12:00 h)

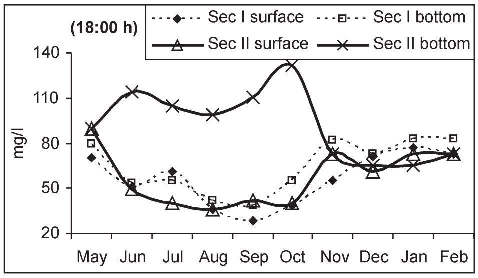

Figure 26. Seasonal changes of total alkalinity (18:00 h)

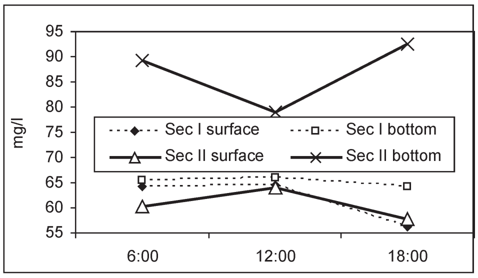

Figure 27. Average diurnal variation of total alkalinity

Conclusion

Present study in Samaguri beel clearly highlighted the fact that the shallow area with submerged macrophyte infestation behave differently as compared to the deep zone of scroll meander. Wide spatial and temporal variability of most common limno-chemical parameters were observed in this eutrophic ecosystem. Therefore, care should be taken in the measurement of common limnological parameters of fisheries interest in these types of floodplain wetlands. River connection brought desired efficient microbial decomposition of bottom organic matter in sector II. Analysis of bottom soil of these two sectors showed comparable organic carbon (unpublished results). So, establishment of river connectivity is a necessary measure for wetland habitat restoration.

Sector II bottom, being anoxic and very high concentration of CO_2 accumulation was not a suitable habitat for fishes. Wide diurnal variation of limno-chemical parameters in surface of sector I made this zone less suitable for fishes. Sector II surface with less variability of those parameters may provide better environment to fish fauna. As maximum area of the beel is shallow with thick submerged macrophyte infestation, some portion of this zone may be cleared of submerged macrophyte intermittently to provide better habitat for fishes (Hassan et al. 2006).

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