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Are lagoon characteristics lost due to freshwater intake? A preliminary micro ecosystem study in Malala Lagoon, Bundala National Park, Sri Lanka

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Abstract
Malala Lagoon is the largest water body (600 ha) in Bundala National Park, which is Sri Lanka's first Ramsar wetland. Malala borders sea by a sand barrier on south and adjoins Embillakala lagoon (mean salinity 0.04± 0.005 g/l). Main objectives of this study were to investigate physico-chemical parameters, variation of biological component due to freshwater input and to find out biological indicators contributing to the status of Malala Lagoon. Studies were carried out along a 3000 m transect from land end to sand barrier. Mean depth of the lagoon was 125.4 ± 4.2 cm and salinity varied from 1.6 ± 0.03 to 0.08 ± 0.005 g/l dictating freshwater dominance although separated by a sand bar adjoining to the sea. Freshwater rotifer (*Brachionus plictalis)* was non-detectable towards land-side. However, *Brachionus plictalis* showed a significant increase towards sand barrier (14 rotifers/l) indicative of freshwater influence. Eutrophic conditions were evident from increased micronutrient levels towards sand barrier such as Phosphate levels from 75.0 ± 2.3 to 121.3 ± 28 µg/l and Nitrate levels from 160.2 ± 2 .8 to 174.7 ± 2.4 µg/l. Flora and fauna (fishes, birds and benthos) showed a marked variation towards the sand barrier indicating gradual increase of freshwater conditions. A freshwater bivalve *Psidium conventus,* which is considered as an important micro-zooplankton, was abundant towards the sand barrier. Findings showed influence of freshwater intake to Malala Lagoon has created dynamic microecosystem characteristics on different segments of the aquatic ecosystem. Such mixing of high amount of freshwater with brackish/saline water may facilitate damage of already established niches. Therefore, proper management of Malala water body is preferred.

Introduction

Wetlands are diverse ecosystems, which have different degrees of functional variations (Hunter, 1998). Functional importance of the wetlands has been given serious attention in the recent past since wetlands are important to regulate water levels within water sheds, improve water quality, reduce flood and storm damage, provide important fish and wild life habitat and many other uses to humans as well (Richardson, 1994). However, most important feature of a wetland is its role of maintaining biodiversity. Not only for fish and wild life it also provides very important habitat for aquatic and semi aquatic vegetation as well and vegetation is a very conspicuous feature of wetlands (Verhoeven 1992). Man made hydrologic alterations such as freshwater input and drainage were found as the major deteriorating factors of lagoons causing habitat changes (Maltby *èt al.* 1992, USEPA 1994b).

The study site of the present investigation, Bundala National Park, is situated in the southern part Sri Lanka. It is known as the first Ramsar wetland of the country (CEA 1993).

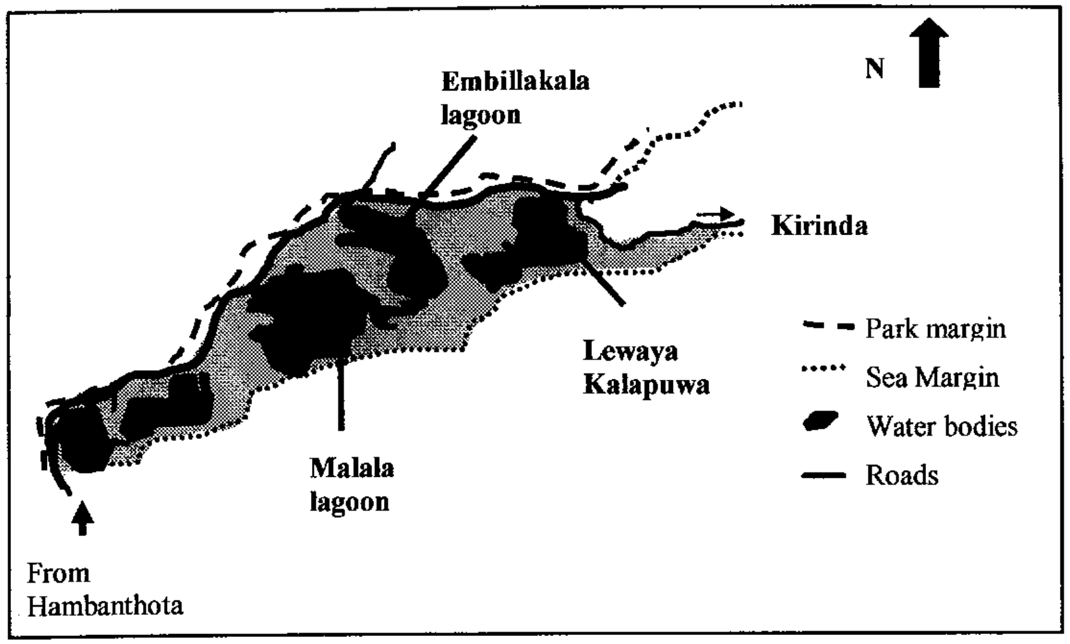

Figure 1: Schematic diagram of major water bodies of Bundala National Park.

It is reputed for its rich biological diversity and as a habitat for many resident and migratory birds. Especially, importance of saline water bodies for migratory wading birds has been stressed elsewhere (Sadoul *et al.* 1998). Freshwater influence might cause habitat changes, which is unfavorable for aquatic associated birds. Bundala National Park consists of several temporary and permanent aquatic bodies, which is known to have a rich species composition. Especially the coastal lagoons Malala, Embillakala, Bundala Lewaya and Koholankala Lewaya are important due to relatively large sizes. Malala Lagoon opens to the sea by 20 m length and 8 m wide sand bar. Opposite end is demarcated by human settlements in Weligaththa region. Malala Lagoon receives freshwater indirectly from Embillakala lagoon and directly from the Malala Oya (CEA 1993).

Our main objectives of this study were to investigate status of physico-chemical and biological properties of Malala Lagoon due to freshwater input and to find out biological indicators dictating the status of the lagoon.

Methodology

Sampling criteria was designed based on preliminary investigations carried out in the Malala Lagoon. The sampling locations were selected to find out variations in the species associations based on the water quality. The hypothesis to be tested was variations in the salinity towards the sand bar due to freshwater intrusion.

Selection of a transects

A transect was selected North to Malala Lagoon and towards sand bar (Figure 2) that runs 3000 m in length. All sampling sites were selected in every 200 m of the transect. In each sampling location, water quality, trophic analysis, physical measurements and fish sampling were carried out. The study was carried out from December 2000-April 2001.

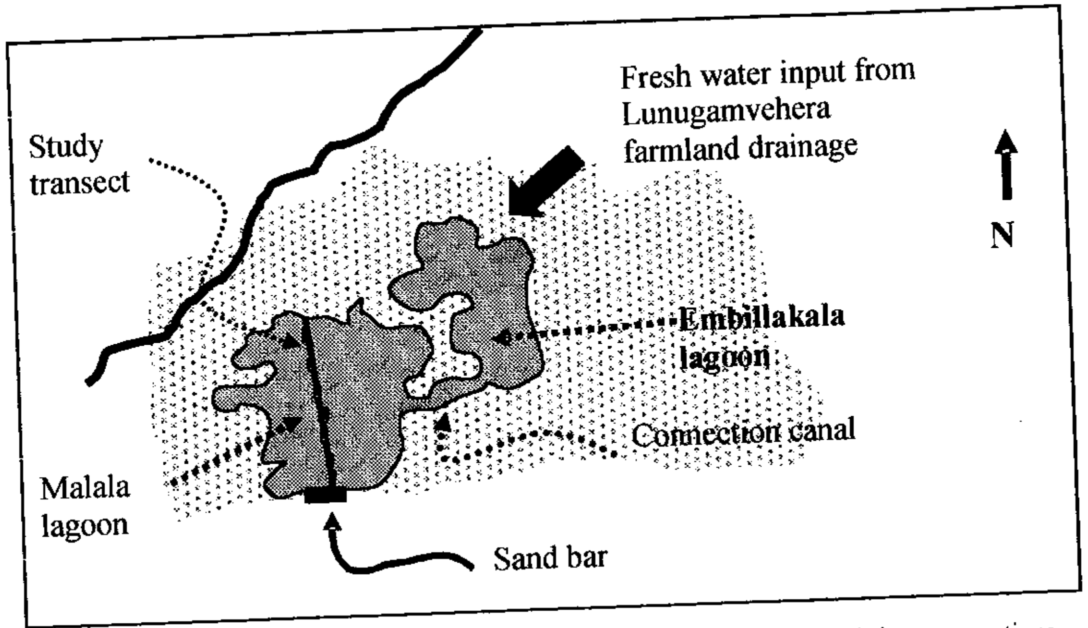

Figure 2. Diagrammatic presentation of Malala and Embillakala lagoons, their interconnections and sand bar to the sea.

Water quality and physical characters

Water quality assessments, and trophic system analysis were carried out using standard methods mentioned elsewhere (Wilson 1973). In brief dissolved oxygen and primary productivity of each site were determined by Winkler's method. Total alkalinity and salinity were measured using a titration method. Micronutrients namely PO_4^{-3} and NO_3^{-3} were measured using colorimetric method using spectrophotometer. Depth was measured by dipping a graduated bar through the water body along the predetermined transect only. Measurements were recorded *in situ*. Secchi depth was used to determine the light penetration ability. Temperature was measured using a thermometer. Sediment thickness was measured by dipping a graduated pole through sediments until the pole stops penetration. Suspended solids were measured by filtering samples through GFC filter papers and incubated the sample in incubating for 24 hours under 105 ^{0}C of temperature. Biological Oxygen Demand (BOD_5) was measured. Samples were analyzed in triplicates for each location.

Biological characters

Fish was caught using multi mesh (sizes vary from 7 mm-20 mm eye sizes, each eye size having total length of 10 m) gill net of 150 m length each. The nets were laid vertically over the sites perpendicular to the selected transect transversely early in the morning (07.00-08.30 hours) and fish catch was taken into account. Each sampling day three catches were taken. Number of fishe as total value as well as species composition were taken into account. Fishes were identified using standard taxonomic keys (Eddy 1969). Phytoplankton and zooplankton were sampled using plankton nets. Filtered zooplankton and phytoplankton were fixed with 70% alcohol and later taken for microscopic investigations. Identifications of phytoplankton and zooplankton were made using standard taxonomic keys (Pennack 1989, Fernando 1972). Benthic population was sampled using Eikmann grab (8x8x8 cm^3) and samples were fixed with 4% Formalin and

were analyzed in the laboratory within the next 48 hours. Microscopic and macroscopic identifications were made using standard taxonomic keys (Pennack 1989). Collected mud samples were weighed and number of organisms is given as individuals per 1 kg of mud. Bird counting was taken into account in regular intervals throughout the period. Bird counts were taken 2-3 times per week from 07.00-09.00 hours each day. The intervals were regular before and after sand bar opening. For bird counts two locations were selected. On the spot identifications were made using Binoculars with 10x50 field 5.7^0 100M at 1000M with the aid of standard picture guides (Harrison 1999).

Statistical analysis

Statistical analysis was carried out using SPSS. Each time mean value of each parameter has been taken into considerations. Mean comparisons were made in between transects. ANOVA was used to compare variations among sites for each parameter. Tukey's test was employed to distinguish differences between samples. At all times probability was taken $P<0.05$ level.

Results

Malala Lagoon spreads over 650ha. Table 1 summarizes the water quality data. Water quality and related fauna and flora also showed several changes through the transect. Undoubtedly it is true to say when ecosystems are disturbed, potential changes in ecosystem structure and functions are expected, because it is generally known that stable ecosystems are functionally stable as well. Remarkable changes in the water quality could be detected towards the sand bar. Dissolved oxygen amount remained at high level indicating higher productivity. Net Primary Productivity was reducing (0.3 ± 0.01 –0.15 ± 0.01 mg/l/h) and Gross Primary Productivity was increasing (0.3 ± 0.04 –3.2 ± 0.8 mg/l/h) towards sand bar. This can be attributed to the fact that the high level of alkalinity which increases the availability of Carbon dioxide for photosynthesis. Salinity level was very low beyond brackish water conditions. Nitrate level was reducing towards sand bar and Phosphate level was increasing towards the sand bar. Mean depth of water through the selected transect was 121 cm. pH value was reducing towards sand bar, water was becoming acidic and total alkalinity remained approximately constant through the transect (Table 1).

Number of total zooplanktons varied in their population size through the transect. *Brachionus plicatilis* (Rotifera) and jellyfish were seen at higher levels. They seem reacting quickly due to water quality variations as a result of freshwater input. Densities of bivalve species and rotifer species increased gradually through the transect (Table 2). Therefore, results showed that there was an unseen relationship between saline tolerant species and water quality changes in the Malala Lagoon. It was also evident that a major macro zooplankton species showed spatial changes through the transect. *Diaptomus* species was predominant in every site, but showed a slight decline towards the sand bar. Other species were abundant in first few sites and population size reduced drastically towards the sand bar. Although not quantitatively presented in this paper, we observed a considerable species variation in phytoplankton community towards sand bar. Especially the unicellular algae component was significantly higher. In benthic environment Molluscan aggregation was evident. Bird population and aquatic vegetation densities were higher.

Table 1. Variation of physicochemical parameters of Malala Lagoon through the transect

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Distance from land	0	300	600	900	1200	1500	1800	2100	2400	2700
Salinity *	1.06 ±0.01	1.71±0.02	1.06±0.03	0.71±0.02	0.71±0.02	0.710.03±	0.71±0.02	0.71±0.04	0.71±0.02	0.71±0.1
Phosphate	75.0±2.6	76.3±3.2	79.6±2.8	81.2±4.1	93.2±2.6	93.2±2.5	93.3±1.6	98.3±3.6	119.3±3.2	121.3±2.5
Nitrate	174.7±3.2	178.2±2.7	189.4±2.4	172.2±2.8	162.8±4.2	142.3±4.3	147.0±3.8	148.7±3.8	154.4±2.9	160.2±3.2
Depth	82±1.6	92±1.6	79±2.5	135±3.8	140±4.3	140±3.2	152±4.1	168±2.9	128±3.2	95±2.8
DO	4±0.05	18.8±1.2	15.4±0.29	22.4±1.6	17.1±0.9	17.4±1.8	17.2±0.6	17.4±0.8	18.2±0.7	17.4±0.6
BOD	12.8±1.2	10.6±1.1	19.8±1.5	13.4±1.2	13.4±2.1	13.4±1.6	11.6±1.8	13.4±1.5	9.2±1.6	13±1.7
Alkalinity	4±0.3	4.4±0.9	4.2±0.8	4.2±1.2	4.2±1.2	5.6±1.3	4.4±0.9	4±0.8	4.4±1.2	4±1.2
pH	9.9±0.2	9±0.3	8.9±0.8	8.8±0.5	8.7±0.8	9.5±0.9	9.7±1.1	8.5±0.5	8.5±1.5	8.3±1.4
G.P.P	3.225±0.8	3.221±0.8	0.825±0.08	0.825±0.08	0.623±0.05	0.523±0.01	0.4125±0.05	0.425±0.02	0.421±0.05	0.321±0.04
N.P.P.	0.15±0.01	0.16±0.01	0.375±0.05	0.385±0.05	0.41±0.03	0.31±0.01	0.1125±0.01	0.41±0.02	0.42±0.01	0.31±0.01

Distance m; Salinity g/l; Phosphate µg/l; Nitrate µg/l; Depth cm; DO x10^3 g/l; BOD g/l per 5 days x10^3; Alkalinity mol/l; G.P.P mg/l /h; N.P.P mg/l /

Table 2. Variation of zooplankton species (Number/l) through the transect

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Zooplankton Nauplii	8 ± 12	1.2 ± 0.1	1.6± 0.1	1.6±0.01	3.8±0.01	2.3±0.1	-	1.61±0.2	1.8±0.3	1.1±0.0
Diaptomus sp	32 ±10.6	1.6±0.03	3.2±0.2	12 ±0.01	10.7±2.5	8.1±3.1	-	2.7±0.03	1.2±0.04	1.1±0.0
Brachionus plicatilis (Rotifera)	0	0	0	0	0	5.7±1.2	5.7±1.2	5.8±1.3	14±1.2	131±13
Jelly fish	3 ± 0.5	1.3 ± 0.1	5.6±0.2	10. ±1.6	41.8±4.9	52. ±0.8	6.7±0.9	6.72±0.1	6±1.2	8.64±2.0
Psidium conventus(Bivalve)	5 ± 0.8	6 ±1.0	4.9±0.9	3.2±0.03	13.6±2.3	6.8±1.6	6.7±1.2	6.72±0.2	20±3.6	22±4.1

Total fish catch for the study time periods were relatively high including high species diversity. The mean total catch was 301 ± 25.36. Increased BOD level indicated that higher activity of microorganisms.

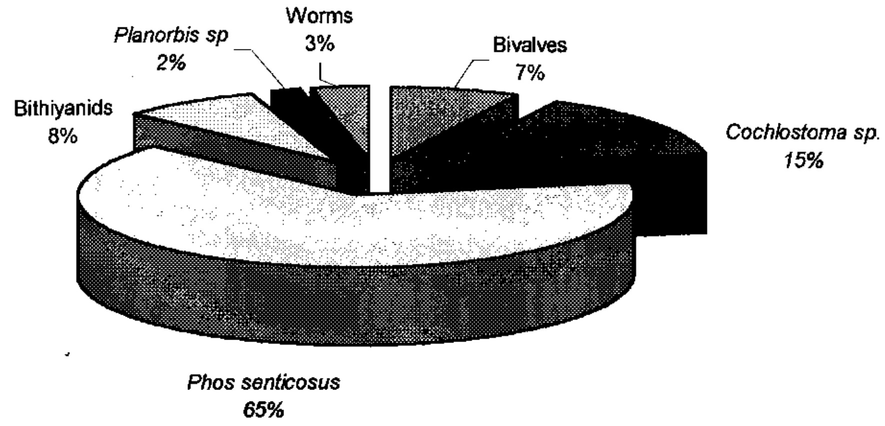

Figure 3. Proportionate abundance of recorded benthic organisms in the present

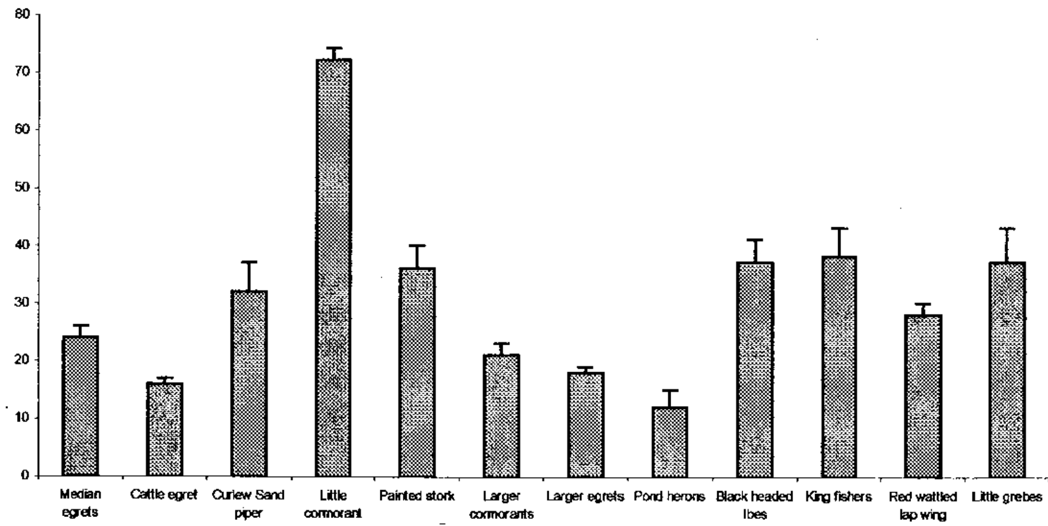

Figure 4. Variation (mean number/session count/study site) of key bird species recorded during field visits to Malala Lagoon study.

Discussion

Undoubtedly functioning of a sand bar to this ecosystem is highly important. Mainly sand bar functions as a barrier to salt water intrusion. Although the studied water body is a coastal water system, high salinity levels were not recorded. Because the main water input for the system was from a freshwater tank situated 30 km away. Results highlight the increase of gross primary production (GPP). Increase of GPP shows that the number of organisms has been increased and net primary production (NPP) shows that oxygen utilization by organisms was higher. Distribution pattern of organisms such as rotifers clearly indicates freshwater influence towards sand bar. Main reason for this freshwater influence was the freshwater input to North of Embillakala lagoon creating freshwater environment in Malala Lagoon through connection canal.

Nutrients such as nitrate and phosphate loading into the lagoon was much higher. It is possible to speculate that freshwater drainage from Lunugamwehera agricultural lands brings excess amounts of nutrients. Our studies in the freshwater input canal (which brings water from Lunugamwehera agricultural lands) indicated such phenomenon. Researchers argue that anthropogenic activities are also partly blamed for this effect (Mitsch and Gosslink 1986 and 1993). Recent investigations have shown that freshwater inputs into lagoon systems exerts detrimental effects leading to eutrophication, if loaded in an unacceptable levels (USEPA 1994, USEPA 1993). High occupancy of rotifers was clearly evident towards sand bar. Rotifers are predominantly freshwater inhabitants but may occupy some brackish water systems (Wallace and Snell 1991). Rotifers are very important in the habitat because of their incredible reproductive rates, due to their high feeding and assimilation efficiencies. The rotifers play important roles in energy flow and nutrient cycling, accounting for more than 50% of the zooplankton production in some freshwater systems (Brinson 1993, Branco *et al.* 1998). Rotifers contribute to microbial loop and to higher tropic levels which is important for fish production (Boesch 1983, Bowers 1983, Farber and Constanza 1987, Dugan 1990, Daris 1993).

Excessive fertilizer usage of above paddy lands is a phenomenon common. Ultimately the nitrates and phosphates may drain with water and ends up in lagoon systems (Brinson 1993, Mitsch and Gosselink 1998, Weller 1981). This study therefore supports the view that freshwater input to the Malala Lagoon could show ecological importance. It is possible to believe that such water quality changes in Malala Lagoon environment brings the environment towards eutrophic conditions, thus jeopardizing its saline lagoon status. The study also has highlighted that by investigating faunal and floral dynamics water quality managers can make predictions of the condition of the lagoon system. For instance as a useful biological indicator of the system, some interpretations could be done using bird population estimations and species diversity. Birds are considered to be useful biological indicators due to the fact that they show some specific characters including the utilization of the higher level of food chain (US Council on environmental quality 1972, Furners *et al.* 1993, Schodde 1994). Therefore in future studies avifaunal statistics could be used in conjunction with micro ecosystem findings to come to proper conclusions. In mitigation and managing programs, these activities should be highly valued. In addition interaction of people and park authorities is a timely need with awareness programs for general public (Bernacsek 1988, Baldock *et al* 1984).

We can conclude that freshwater input from Lunugamvehera via Embillakala lagoon has a profound effect on lagoon ecosystem characteristics. Such defined mad made water dynamic alterations alarmingly affect lagoon health, causing loss of Ramsar wetland characteristics.

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