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The role of Pondweed (*Potamogeton spp*) beds as an important micro-ecosystem in Embillakala lagoon of Bundala National Park; A Ramsar wetland in Sri Lanka

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Abstract
The present study focused on the ecological role of aquatic macrophytes on micro-ecosystem diversity of pondweed beds in Embillakala lagoon of Bundala National Park. The taxonomic investigation indicates that pondweed beds of Embillakala lagoon may comprise of a hybrid of *Potamogeton crispus* (Linnaeus, 1753) and *Potamogeton nodosus* (Poiret, 1788). The study compared the physico-chemical parameters and biological parameters between the pondweed beds and non-weedy localities of the lagoon. Mean dissolved oxygen level and the BOD_5 were respectively significantly higher in pondweed beds (8.92±0.1mg/l; 1.7±0.3mg/l) in contrast to non-weedy localities (5.35±0.3mg/l; 1.3±0.1mg/l) and the mean nitrate concentration was also significantly higher in pondweed beds (1671.16±606.2µg/l) when compared with non-weedy localities (133.14±22.5µg/l). Mean suspended solids were comparatively lower in pondweed beds (193.24±116.4mg/l) than in non-weedy localities (222.6±156.5mg/l). Means of dissolved phosphate level (78.1±35.0µg/l), gross primary productivity (0.56±0.1mg/l/h), salinity (2.57±0.28ppt), alkalinity (3.5±1.2mmol/l) and suspended solids were not significantly different between pondweed beds and non-weedy localities. Results showed a significantly ($p<0.01$) higher abundance of microcrustaceans (*Phyllodiapotomus annendalai*, *Cyclops minutus*, *Cypridiopsis* sp), prawn larvae and insect larvae in pondweed beds in contrast with non-weedy localities indicating the value of the pondweed beds as a larval feeding ground. Benthic mollusc species *Phos senticosus* and *Bithynia tentaculata* were also abundant in pondweed beds. As shown by the present study, pondweed beds exhibit a specific ecological identity. Further studies on pondweed beds and non-weedy localities are encouraged as a useful indicator to understand the micro-ecosystem dynamics and diversity in Bundala water bodies. Regulation of the growth of pondweed beds in Embillakala lagoon may be a useful management tool.

Introduction

Studies of wetland vegetation have a long tradition in phyto-sociology and consequently there are many highly detailed descriptions of the composition of wetland plant

communities and their environmental affinities (Miranda and Hodges 2000; Willby *et al.* 2001).

Wetland plant communities add physical stability while enhancing the habitat heterogeneity, which is very important to accommodate more species (Rorslett 1987, Hiromi *et al.* 2003). Another ecological significance includes their utilization as spawning and sheltering habitats for eggs and larvae of fishes and aquatic insects and as a cover for waterfowls and small fishes. This implies that aquatic macrophytes hold importance not only as a biotic component but also an abiotic component of aquatic and wetland ecosystem (Cook 1996).

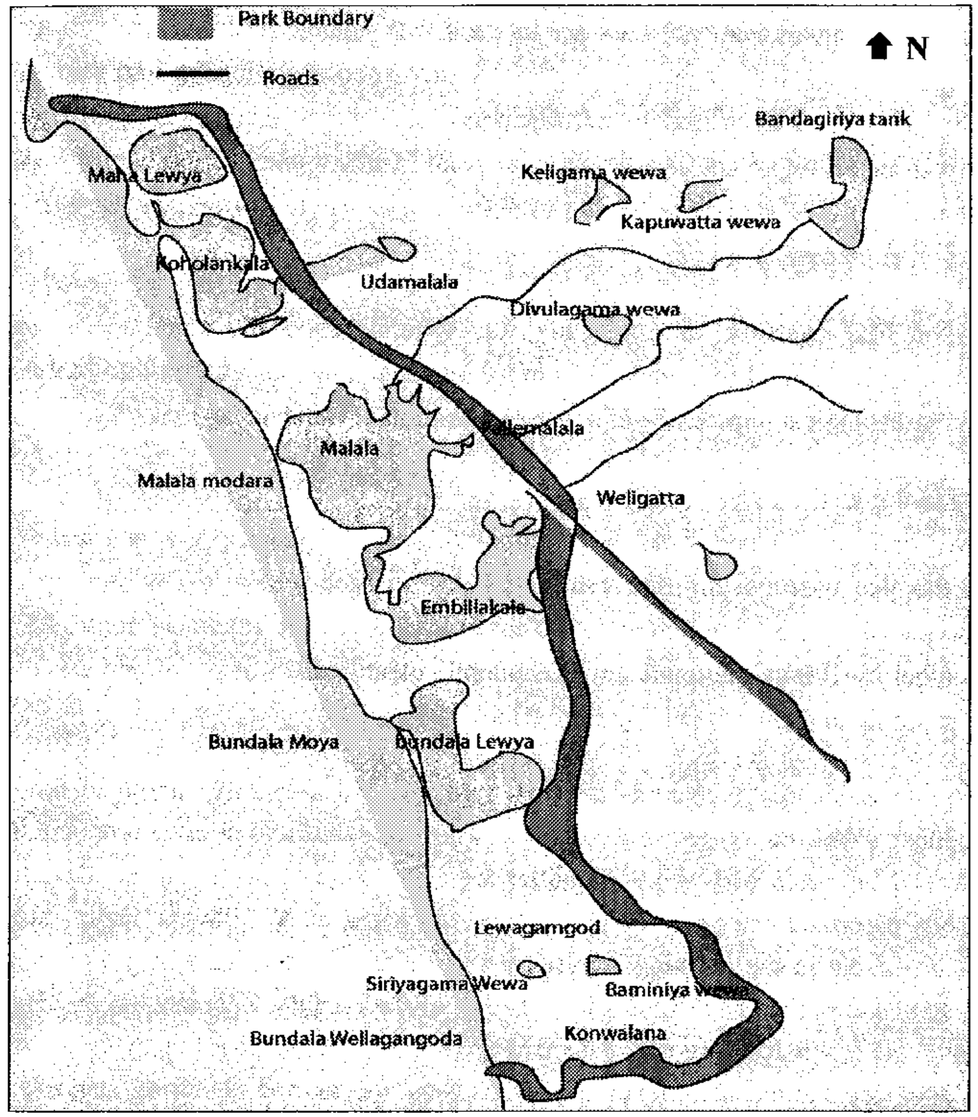

Figure 1: A schematic diagram indicating important water bodies of Bundala National Park and its surroundings. (Modified after Benthem *et al.* 1993)

The intensification of anthropogenic eutrophic processes in lakes and reservoirs aggravate the quality of water and change the hydrochemical indexes (Ricardo 1998). Aquatic vegetation acquires in those cases an important significance as natural bio-filter and as participant of circulation of substances in aquatic ecosystems (Hiromi *et al.* 2003). Bundala National Park (BNP) is the first Ramsar wetland in Sri Lanka (Ramsar Convention Bureau 1997). Koholankala (390 ha), Malala (650 ha), Embillakala (430 ha) and Bundala (520 ha) are shallow brackish water lagoons in BNP (Figure 1). Lagoons of BNP create complex wetland systems that accommodate a rich bird life and other important fresh and brackish water organisms including fishes, reptilians and mammals etc.

Lagoons of Bundala National Park are infested with aquatic macrophytes with varying densities spatially and temporally. Especially the Embillakala lagoon harbored several macrophyte assemblages predominated by pondweeds. Pondweed genera *Potamogeton* is known to be an important aquatic vascular plant in many parts of the world (Fant and Preston 2004). The studies pertaining to aquatic macrophyte in Bundala National Park, however, are meager.

Therefore the objective of this study was to understand the important ecological characteristics of pondweed beds in Embillakala lagoon and also to offer an initiative to study the ecological importance of aquatic vegetation in Bundala lagoons.

Methodology

Heavily infested 20 pondweed beds (approximately 40 plants per 1 m^2) and twenty localities that were not infested with any weeds in Embillakala lagoon were selected. These patches were approximately 100 m^2 in area and were relatively separated from each other by 100 m approximately. Taxonomic identification of pondweed was carried out according to the botanical literature (Cook 1974, 1996).

The basic water quality parameters (pH, salinity, total alkalinity, dissolved nitrate & phosphate, dissolved oxygen level, BOD_5, suspended solids and primary productivity) of pondweed beds and non-weedy localities were investigated according to the standard methods described elsewhere (Wilson 1973, Mackeret, *et al.* 1989). Usually sampling was carried out in the morning between 9 to 11 a.m. Six samples were taken from the surface of the randomly selected sites in each of the locality. Zooplankton and Benthic invertebrate community were investigated according to the standard methods (Gibson *et al.* 2000). Taxonomic identification of organisms was carried out using standard keys (Keerthisinghe 1978, Pennack 1989, Fernando 1990). Abundance of target organisms was enumerated as individuals per litre of water or mud.

The data collected in non-weedy localities and pondweed beds were statistically compared. T statistics was applied to compare the results using SPSS 95 statistical package.

Results

Potamogeton spp. was a submersed perennial with reddish-green leaves. It has submerged leaves with wavy edges and floating leaves with non-wavy edges. Stems are slightly compressed (1.2 mm thick), usually branching and mostly 4 - 8 cm long. Leaves are sessile, slightly clasping, linear-oblong to linear-oblanceolate or oblong to oblanceolate, 3.8 cm long, 3 - 10 mm wide, 3 - 5 nerved, rounded at the tip, narrowed at the base, margin usually undulate-crisped, finely serrate or not.

Major planktonic organisms encountered in pondweed beds were Calanoid copepods (*Phyllodiaptomus annendalai*, *Acartiella minor*, *Helidiaptomus vididus*), Cyclopoid copepods (*Cyclops minutus*), Cladocerans (*Diphanosoma* sp., *Polysoma* sp.), Ostracods (*Cypriodopsis* sp.), prawn larvae and fish larvae.

Mean densities of Calanoid Copepods, Cyclopoid Copepods, Cladocerans, Ostracods, prawn larvae and fish larvae differed significantly in pondweed beds when compared to non-weedy localities ($p \leq 0.05, 0.01$) (See Table 1).

Table 1: Comparison of key planktonic organisms between pondweed beds and non–weedy localities

Faunal group	Pondweed beds (Number per liter)	Non infested localities (Number per liter)
Calanoid copepods (1)	8.21 ± 0.1*	2.13 ± 0.01
Cyclopoid copepods (2)	3 ± 0.05*	0
Cladocerans (3)	3 ± 0.02**	1 ± 0.001
Ostracods (4)	2.3 ± 0.04*	0.8 ± 0.001
Prawn larvae	5.32 ± 0.3**	0.1 ± 0.002
Fish larvae	2.1 ± 0.03*	0.2 ± 0.001

***Mean comparison; levels of significance *t = 0.05, **t = 0.01**

(1) *Phyllodiaptomus annendalai*, *Acartiella minor* and *Helidiaptomus vididus* **(2)** *Cyclops minutus* **(3)** *Diphanosoma* sp. and *Polysoma* sp. **(4)** *Cypriodopsis* sp.

Mean dissolved oxygen level was significantly higher (8.92 ± 0.1 mg/l, $p<0.001$) in pondweed beds than in non-weedy localities (5.35 ± 0.3 mg/l). Mean Biological Oxygen Demand (BOD_5) was significantly higher (1.7 ± 0.3 mg/l, $p<0.01$) in pondweed beds than in non-weedy localities (1.3 ± 0.1 mg/l). Mean nitrate level was significantly higher

(1671.16 ± 606.2 µg/l) in pondweed beds and was 133.14 ± 22.5 µg/l in non-weedy localities. Mean suspended solid value was 193.24 ± 116.4 mg/l in pondweed beds while it was 222.6 ± 156.5 mg/l in non-weedy localities. Mean salinity was 2.57 ± 0.28 ppt in pondweed beds and that was 2.58 ± 0.26 ppt in non-weedy localities. Mean dissolved phosphate concentration was 78.1 ± 35.0 µg/l in pondweed beds and it was 61.1 ± 30.28 µg/l in non-weedy localities. Mean total alkalinity was 3.5 ± 1.2mmol/l in pondweed beds and it was 3.1 ± 0.5mmol/l in non-weedy localities. Mean Gross Primary Productivity (GPP) was 0.56 ± 0.1 mg/l/h in pondweed beds while it was 0.48 ± 0.1 mg/l/h in non-weedy localities. Mean values of the physico-chemical parameters and the range of the values recorded in pondweed beds and non-weedy localities are given in table 2.

Table 2: Variation of some physico-chemical parameters in pondweed beds and non-weedy localities

Parameter	Pondweed beds	Non-weedy localities	t-statistics (two tail)
Dissolved Oxygen (mg/l)	8.92 ± 0.1 (8.7-9.3)	5.35 ± 0.3 (5.2-5.8)	0.001*
BOD$_5$ (mg/l)	1.7 ± 0.3 (1.6-1.9)	1.3±0.1 (1.2-1.4)	0.01*
Suspended solids (mg/l)	193.24 ± 116.4 (68.4-320.6)	222.6 ± 156.5(76.4-412.5)	0.1
Salinity (ppt)	2.57 ± 0.28 (1.9-2.8)	2.58 ± 0.26 (2.2-2.9)	0.95
PH	9.5 ± 0.15 (9.3-9.6).	9.2 ± 0.5 (8.6-9.8)	0.1
Dissolved phosphate (µg/l)	78.1 ± 35.0 (42.3-122.6)	61.1± 30.28 (54.3-102.5)	0.3
Nitrate (µg/l)	1671.16 ± 606.2 (800.56-2800.98)	133.14 ± 22.5 (98.54-155.32)	*0.001
Gross Primary Productivity (mg/l/h)	0.56 ± 0.1 (0.2-0.9)	0.48± 0.1 (0.3-0.9)	0.2
Total alkalinity (mmol/l)	3.5± 1.2 (2.7-5.1)	3.1 ± 0.5 (2.3-5.6)	0.2

However dissolved phosphate level, GPP, salinity, alkalinity and suspended solids were not significantly different between the pondweed beds and the non-weedy localities. *Phos senticosus*, *Gyroscala perplexa*, *Planorbarius corneus*, *Bithynia tentaculata* and insect larval stages were the key benthic organisms recorded in pondweed beds and non-weedy localities. Mean densities of *Phos senticosus* in pondweed beds and non-weedy localities were 159.5 ± 54.6 (per 1kg mud) and 103.4 ± 35.4 (per 1kg mud), respectively. The mean density of *Phos senticosus* was significantly higher ($p<0.05$) in pondweed beds when compared with non-weedy localities. Mean densities of *Gyroscala perplexa*, *Planorbarius corneus* and *Bithynia tentaculata* were not significantly different ($p>0.05$) between pondweed beds and non-weedy localities. Mean insect larval density (May fly nymph and Chironomid larvae) was 6.01 ± 1.2 (per 1kg mud) in pondweed beds and it

was 1.2 ± 0.01 (per 1kg mud) in non-weedy localities. Thus the insect larval density was significantly higher ($p<0.01$) in pondweed beds (See Table 3).

Table 3: Variation of key benthic organisms in pondweed beds and non-weedy localities

	Infested regions with pondweed	Non infested regions	t-statistics 2 tail significance
Phos senticosus (Linnaeus, 1758)	159.5 ± 54.6	103.4 ± 35.4	*0.04
Gyroscala perplexa (Pease, 1860)	31.5 ± 12.9	40.5 ± 22.7	0.4
Planorbarius corneus (Linnaeus, 1758)	4.0 ± 2.9	6.4 ± 8.9	0.5
Bithynia tentaculata (Linnaeus, 1758)	693.4 ± 221	336.1 ± 96.2	0.4
Insect larvae	6.01 ± 1.2	1.2 ± 0.01	**0.01

* denotes the level of significance

Correlation Coefficients

There was no significant correlation between Gross primary productivity, Dissolved Oxygen level and Calanoid copepod density at studied pondweed beds. Although the soluble Nitrate level and Calanoid copepod densities were significantly correlated ($r=0.7$, $p=0.02$) at studied pondweed beds, those factors were not significantly correlated at non-weedy localities ($r=0.45$, $p= 0.085$).

Discussion

The prevalence of inter-specific hybrids of *Potamogeton spp* was evident (Fant and Preston 2004). According to taxonomic investigation, the studied pondweed beds in Embillakala lagoon may comprise of a hybrid of *Potamogeton* spp. It may be a close relative of *Potamogeton crispus*, Linnaeus 1753 or *Potamogeton nodosus*, Poiret 1788. Further research is required to identify the true taxonomic status of this pondweed species.

According to the results it was evident that the pondweed beds harbored more diversed population than non-weedy localities. This finding is in consistent with the previous work (Barbara *et al.* 2000, Katharina and Mark 2001). Insect larval aggregation was quite clearly evident in weed patches indicating it to be a larval insect feeding ground. This increased the biological diversity of the system, which may be very important for species sustenance such as bird and fishes. Nutrient availability and nutrient supply are key determinants of the composition, structure and productivity of wetland vegetation (Willby *et al.* 2001). Investigations have shown that *P. crispum* prefers alkaline and high nutrient waters (Riis and Sand-Jensen 2001). Studies have also shown that sediment nitrogen and phosphorous were the key factors controlling the growth of aquatic macrophytes (Madsen and Cedergreen 2002). Further research is required to understand the interaction between sediment nutrient content and aquatic macrophyte assemblages in Bundala lagoons.

Present study revealed that *Potamogeton* spp was the most dominating aquatic macrophyte in Embillakala lagoon. It may be ascribed to the high nutrient level and proper alkaline conditions required for the growth of *Potamogeton* spp. in Embillakala lagoon. The growth of *Potamogeton* spp. might also be facilitated by its ability to uptake nutrients sufficiently both via foliage and roots. Although it has been shown that *P. crispus* can uptake its nutritional requirements from water, it also has the ability to utilize sediment nutrients (Madsen and Cedergreen 2002) indicating a possible threat to water column characteristics at high densities. In Embillakala lagoon sediment phosphorous and nitrogen levels may be quite high since Lunugamvehera agricultural runoff usually brings lot of enriched sediments into the lagoon. Over 80% of fishermen fishing in Embillakala lagoon believed that pondweeds have been established after the diversion of Lunugamvehera agricultural water into Embillakala lagoon. Probably this may be due to the influx of nitrate rich water into the Embillakala lagoon via Lunugamvehera agricultural run off.

Malala lagoon also harbored a moderate density of pondweed beds during December 2000 and January 2001. But, with rising salinity levels, these pondweed beds disappeared. This observation highlights the specific water quality requirement for the growth and survival of the pondweed.

Dissolved oxygen level in pondweed beds was significantly higher when compared with non-weedy localities. Gross Primary Productivity between these two regions, however, was not significantly different. This can be attributed to the fact that there was no significant contribution of phytoplankton to the production of oxygen in pondweed beds. The higher oxygen level was solely due to the photosynthetic activity of the pondweeds. Miranda, *et al.*, (2000) discussed the importance of high oxygen levels in weed beds, which create microhabitats especially important for the sustenance of fishes. Nitrate level was significantly higher in pondweed beds. Since pondweed beds are inhabited by many organisms, excessive excretion of nitrogenous wastes might be the reason for higher nitrate levels.

Pondweeds could be managed as a tool to stabilize the water clarity. In shallow eutrophic lakes the clear water status is largely stabilized by increased submerged macrophyte

growth because of improved light availability (Ricardo, 1998). Submerged vegetation has a positive influence on water clarity through a number of mechanisms such as nutrient retention, improved possibilities for zooplankton to avoid fish predation hence resulting in increased zooplankton grazing on phytoplankton and decreased sediment suspension (Strand and Welsner, 2001). Suspended solid content did not significantly differ between pondweed beds and non-weedy localities. This was mainly due to the higher variation occurred between replicates. But mean values of suspended solids were quite high in non-weedy localities. Low phytoplankton production may be due to the increased grazing pressure exerted by higher zooplankton densities. The ecological role of pondweed beds with reference to plankton, fishes and birds may be useful titles for future studies (Strand and Welsner 2001).

This study did not focus on the diurnal changes of habitat parameters in the pondweed beds. Further studies regarding such changes may offer a clearer picture of the ecological role of pondweed beds.

No studies have yet been carried out in Bundala National Park water bodies pertaining to aquatic vegetation. Further research is urgently needed to identify the biology, dynamics and relationships of these aquatic macrophytes to other environmental factors, since that data may be very useful in the management of lagoon environment. Careful mitigation and regulations of the growth of pondweed beds based on research data may be a useful management tool.

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