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Original Research Paper

Sanative Role of Macrophytes in Aquatic Ecosystems

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ABSTRACT

Five common aquatic macrophytes (*Phragmites communis, Typha angustata, Ceratophyllum demersum, Lemna* sp. and *Salvinia natans*) were planted and grown in different fibre glass tanks containing lake sediment and water, with an aim to study the changes brought about by these macrophytes in aquatic ecosystems. The study revealed that aquatic macrophytes in freshwater environment provide important ecosystem functions: (i) increase pH, creating conditions for volatilization of NH_4-N, precipitation of phosphorus and $CaCO_3$ (ii) enhancement of dissolved oxygen on account of high productivity creating drop in conductivity and making most cations and anions non-available in the ambient water (iii) prevent resuspension of sediment into water column and (iv) uptake of nitrogen and phosphorus, thereby improving overall quality of water.

INTRODUCTION

The aquatic environment is vastly different from the terrestrial environment with which we are more familiar. Compared to air, water is a more viscous medium, a better solvent and more stable thermally, but it also transposes more force and reduces diffusion rates. These properties of the aqueous environment have a direct and indirect effect on aquatic macrophytes. Conversely, aquatic macrophytes modify the aquatic environment through their development and metabolic activity (Madsen et al. 2001), have curative effect resulting in reduction of some chemical pollutants like nitrates and ammonia (Ratushnyak 2008) and can directly mobilize nutrients such as nitrogen and phosphorus from the sediments via root uptake, incorporation into tissue and subsequent senescence. They can also indirectly recycle nutrients from the sediment by increasing pH in the water column through photosynthetic activities (Barko & Smart 1980, Carpenter 1980, Landers 1982, Smith & Adams 1986, Drake & Heaney 1987 and Barko & James 1998).

The aim of this study is to evaluate and analyse water quality changes by submerged, emergent and free floating macrophytes, and to highlight the importance of these undermined macrophytes to water quality as they are important in many aspects of restoration not only when removed but also when retained.

MATERIALS AND METHODS

The present research work was conducted in the field under simulated conditions, within the Nishat basin of the Dal lake during the year March 2000 (spring season) to January 2002 (winter season). A set of five fibre glass tanks (in duplicates) of 3’ × 2’ × 4’ size, were placed within the lake in shallow region close to the shore. All the tanks were filled with lake sediments (6-12 inches) and lake water (approx. 3/4th of the tank size). Mono-specific strands of selected macrophytes were grown in the enclosed chambers with *Phragmites communis* in tank 1, *Typha angustata* in tank 2, *Ceratophyllum* *demersum* in tank 3, *Lemna* sp. in tank 4 and *Salvinia natans* in tank 5. A suitable aliquot from water was analysed at the start of the experiment and has been categorized as initial reading. Water samples from each tank were analysed on routine basis usually after an interval of five days and one day after, in case of any downpour. Surface water samples were taken from all the tanks using Ruttner sampler. The water temperature was recorded by digital thermometer while the pH and specific conductivity were measured using ELE (England) pH and conductivity meters. Oxygen concentration was determined by Winkler's modified method and fixation of the samples was done in the field. For rest of the parameters, methods given in APHA (1997) and Golterman & Clymo (1969) were followed using DR4000 UV- spectrophotometer (HATCH, USA). All statistical analysis and graphics were done with programme CSS. STATISTICA 7.0 (Statsoft Inc. 2004).

RESULTS

The initial, minimum and maximum values of physico-chemical characteristics recorded in five tanks containing different macrophytes during the two years are shown in Fig. 1. The annual cycle of the water temperature in the present study go more or less hand in hand to that of air temperature in all the experimental tanks beset with different macrophytes. The temperature records show gradual increase from spring to a summer high, till minimum values were recorded in winter. One way analysis of variance (ANOVA) showed no significant variation between different tanks during the study period as $F_{cal} < f_{crit}$.

Tanks with emergent macrophytes recorded maximum values in specific conductivity during summer and minimum in autumn while tank with submersed vegetation recorded the reverse. ANOVA showed significant variations between different tanks during the study period as $F_{cal} > f_{crit}$.

The pH values of experimental tanks containing different macrophytes displayed significant variation on monthly and on seasonal basis. Maximum values were recorded usually during summer while minimum during winter. pH varied significantly between different experimental tanks as $F_{cal} > f_{crit}$.

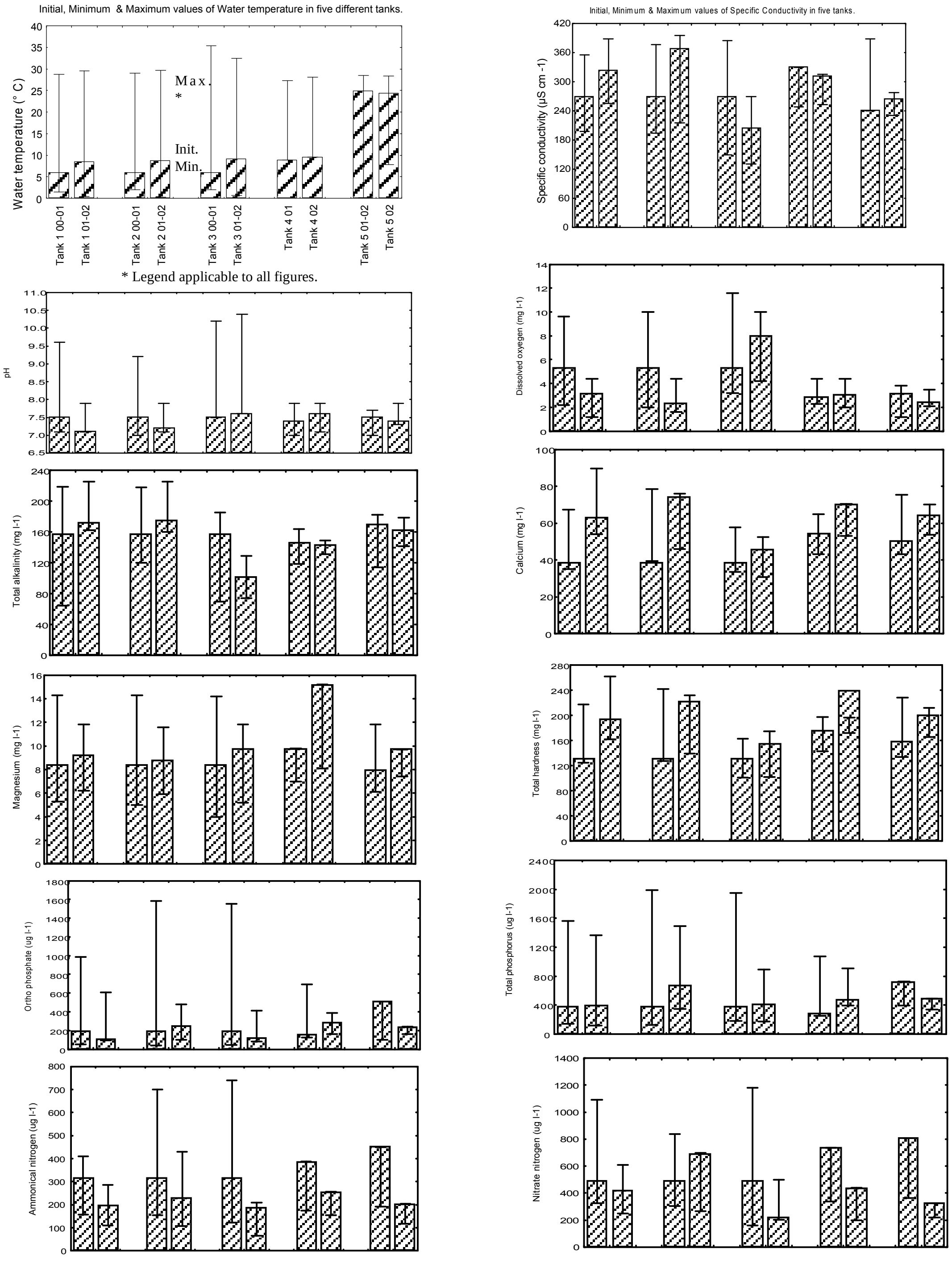
The dissolved oxygen values estimated in experimental tanks containing different macrophytes recorded significant variations. The DO content was much higher during spring-summer in tank containing submersed vegetation, while minimum value was recorded in tanks with free floating vegetation.

Total alkalinity values fluctuated vividly both on monthly and on annual basis. Tanks with emergent macrophytes recorded maximum values during summer, while minimum in spring. On the other hand tank with submersed vegetation depicted higher value in winter and lower during summer. Significant variations in alkalinity values were recorded between tanks containing different macrophytes as $F_{cal} > f_{crit}$.

Divalent ionic components (Ca^{2+}, Mg^{2+}) displayed large variations in all the tanks with no clear cut trend. Higher concentration of orthophosphate, total phosphorus, ammonia and nitrate were observed mostly during winter, while minimum values were recorded during autumn in almost all the experimental tanks.

DISCUSSION

Out of the physical factors water temperature recorded high values during summer months while low temperatures were observed during winter months. Tank containing submersed vegetation, viz.,



* Legend applicable to all figures.

Fig. 1: Initial, minimum and maximum values recorded in different tanks during two years.

Ceratophyllum demersum recorded higher water temperature in comparison to emergent and free floating vegetation. The reason being, that heat absorbed by submersed vegetation and its subsequent dissipation into surrounding water raises its temperature. Raspopov et al. (2002) while studying the influence of aquatic macrophytes on a littoral zone observed that physiology and morphology of higher aquatic macrophytes results in specific temperature regime in stands of these plants. Thus, the diurnal water temperature fluctuations in these stands are greater than those in open water. Temperature patterns the reverse of those in submerged macrophytes stands. In dense emergent halophyte stands due to the absorption of solar energy by emergent foliage during the day time and decrease of heat emission from water at night, generally the temperature regime in water is similar to that in open water.

Water temperature helped in mobilizing PO_4-P and total phosphorus, while it curtailed the value of dissolved oxygen. Tanks containing *Ceratophyllum demersum* and *Salvinia natans* recorded dependence of pH on water temperature thereby depicting that the photosynthesis of submersed macrophytes is responsible for changing pH as well as dissolved oxygen in ambient waters (Table 1). The fluctuation in pH has been related to photosynthetic activities and also with dissolved oxygen by many workers (Wanganeo 1984, Kundangar & Sarwar 1991 and Wanganeo & Wanganeo 1993).

With the advancement in seasons a corresponding enhancement in photosynthesis has resulted in a shift towards more alkaline type of waters in the tank containing submersed macrophyte. This results in increased pH, creating optimal conditions for volatilization of ammonia and chemical precipitation of phosphorus and $CaCO_3$. The results are in confirmation with the study of Kaul & Trisal (1984) and Brix (1993).

In general, higher conductivity values were recorded during winter-spring and lower in summer-autumn seasons in almost all the experimental tanks. However, tank containing submerged macrophytes recorded least conductivity values in comparison to other tanks. The drop of conductivity is due to the diminution in dissolved ions which is caused by the precipitation of calcium carbonate and other minerals. Such precipitation is carried out in high pH which is produced by high productivity. In this case, submersed macrophytes present caused diminution of dissolved ions, thus signifying that these macrophytes are responsible for reducing of conductivity on enhancement of dissolved oxygen levels.

Submersed vegetation (*Ceratophyllum demersum*) in comparison to free floating and emergent macrophytes has been found to be more efficient in reducing the calcium content in the ambient waters. The reason being that during high rate of photosynthesis, there is formation of $CaCO_3$ which gets precipitated thus reducing the calcium levels in ambient waters. This is in conformity with the findings of Kaul & Trisal (1984) who studied chemical characteristics of wetland waters of Kashmir and indicated decalcification under increased atmospheric temperature and attributed it to an increased biological activity and also to the formation of insoluble $CaCO_3$.

Submersed macrophytes have been found to lower the total hardness and total alkalinity values to a greater extent in comparison to free floating and emergent macrophytes. The high rate of photosynthesis has been found responsible for generating CO_3 alkalinity. The use of bicarbonate as a carbon source by plants particularly submerged angiosperms have been well established (Wetzel & Rich 1973, Kaul et al. 1978, Kaul & Trisal 1984 and Wanganeo & Wanganeo 1993).

Free floating macrophytes, especially *Salvinia natans* and *Lemna* sp., have been found to reduce NO_3-N, ammonical nitrogen and PO_4-P content in ambient waters followed by emergent macrophyte

Table 1. Correlation coefficient between different water quality parameters in five tanks.

		W.T	pH	D.O.	Cond-uctivity	T. alka-linity	T. Hard-ness	PO_4-P	T.P.	NH_4-N	NO_3-N
Tank 1~	Water temperature	1.00	-0.45	-0.60	-0.45	-0.10	-0.04	0.75	0.80	0.26	-0.03
	pH	~	1.00	0.91	-0.28	-0.58	-0.58	-0.06	-0.18	-0.60	0.08
	Dissolved oxygen	~	~	1.00	-0.40	-0.42	-0.54	-0.35	-0.45	-0.57	0.21
~Tank 2~	Water temperature	1.00	-0.31	-0.49	-0.72	-0.39	-0.15	0.67	0.70	0.24	-0.11
	pH	~	1.00	0.72	-0.12	-0.04	-0.36	-0.15	-0.07	-0.17	0.06
	Dissolved oxygen	~	~	1.00	-0.04	-0.01	-0.37	-0.12	-0.21	-0.01	-0.14
~Tank 3~	Water temperature	1.00	0.77	-0.36	-0.50	-0.50	-0.28	0.47	0.59	0.18	-0.04
	pH	~	1.00	0.66	-0.69	-0.05	-0.43	0.38	0.45	-0.17	0.06
	Dissolved oxygen	~	~	1.00	-0.69	-0.45	-0.55	-0.12	-0.29	-0.57	-0.52
~Tank 4~	Water temperature	1.00	-0.21	-0.32	-0.61	0.46	-0.57	0.69	0.67	0.39	-0.86
	pH	~	1.00	0.48	-0.13	-0.29	-0.60	-0.51	-0.52	-0.26	0.20
	Dissolved oxygen	~	~	1.00	-0.25	-0.82	-0.59	-0.73	-0.73	-0.23	0.05
~Tank 5~	Water temperature	1.00	-0.61	-0.37	-0.94	-0.82	-0.83	0.61	0.54	-0.24	0.02
	pH	~	1.00	0.61	-0.57	-0.16	-0.36	-0.81	-0.66	-0.22	0.49
	Dissolved oxygen	~	~	1.00	-0.36	-0.24	-0.37	-0.47	-0.54	-0.07	0.26

(*Phragmites communis*). Cedgreen & Madsen (2002) while studying nitrogen uptake by the floating macrophyte showed that *Lemna minor* has the capacity to take up significant amount of inorganic nitrogen through both roots and fronds; same results were obtained by Oron et al. (1988) that duckweed has high rate of nutrient uptake preferentially ammonium ions.

CONCLUSION

The macrophytes in the present study have been shown to stabilize the ambient environment and therefore play a sanative role in reducing the ion concentration and release of nutrients from the sediments under oxic conditions. It is also clear that the interaction between macrophytes vis-à-vis aquatic system is complex. Macrophytes have a direct and indirect effect on the physico-chemical environment and provide important ecosystem functions by creating conditions for volatilization of ammonia, precipitation of phosphorus and calcium carbonate; enhancement of dissolved oxygen and making most cation and anion non-available and improving water quality through uptake of nitrogen and phosphorus. The occurrence of macrophytes also coincides with high transparency. The establishment of submerged macrophyte stands is often considered to be crucial for restoration of shallow lakes but the effects of emergents are not so often recognized. On the contrary, emergent and floating life forms are often considered less significant in the lake restoration viewpoint, in fact they are often recommended to be harvested, to remove nutrients or to improve the recreational possibilities of the lake. This paper, however, highlighted the importance of these undermined macrophytes to water quality. They are important in many aspects of restoration not only when removed but also when retained. The data obtained suggest that during the active phase of vegetation (mid summer to mid autumn), auto-purification characteristics of water were more expressed and by the end of vegetation period (late autumn-winter), the sanative role of these macrophytes decreased. In general, the comprehensive function of macrophytes should be taken into more thorough account in lake restoration schemes; recreational expectations, and water quality aspects should be weighed and preferably combined. Thus, establishment and maintenance of aquatic macrophyte communities may be an effective management tool to be encouraged to improve overall quality of water.

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