The effect of macrophyte exclusion and inorganic nutrient addition on the algal communities in a prairie wetland

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Introduction

The presence of submerged, emergent and floating leaf macrophytes in wetlands increases the complexity of nutrient cycling, competition for nutrients and light, and algal community structure. Submerged macrophytes are limited by growth habit and by the light environment to a narrow range of water depths and therefore their abundance changes as water levels in a wetland fluctuate. Cultural eutrophication has also been shown to promote reductions in macrophyte abundance (Phillips *et al.* 1978, Sand-Jensen and Borum 1991) and prairie wetlands are quite vulnerable to such increased nutrient loading, being situated in a zone of intensive agricultural activity. To examine the effects of macrophytes and external nutrient loading on algal communities, we manipulated macrophyte abundance and inorganic nitrogen (N) and phosphorus (P) levels in a series of enclosures in the Blind Channel of Delta Marsh.

We had manipulated submerged macrophyte abundance in a previous experiment by clipping the plants off at the sediment water interface (McDougal and Goldsborough 1995). However, this method resulted in incomplete macrophyte removal, as the clipped plants remained metabolically active and continued to grow and take up nutrients. In the present study, we achieved a more effective macrophyte manipulation by using a black polypropylene weed barrier cloth to exclude macrophytes.

We hypothesize that phytoplankton will flourish in the enclosures where macrophytes are excluded, particularly in the ones with added nutrients. In the enclosures where nutrient is added and macrophytes remain, we hypothesize that metaphyton will develop. Epiphyton will dominate in unmanipulated controls.

Methods

Experimental enclosures and treatments

Twelve floating enclosures (5 x 5 m) were installed in the Blind Channel on 11 June 1996. Water depth at the time of the study ranged from 80 to 100 cm. A translucent plastic curtain was secured to the inside of each enclosure and embedded into the sediments with metal rebar, enclosing a total water volume of about 20,000 L each. Nine of the enclosures were chosen to maximize interspersion of four replicated treatments: (1) addition of inorganic N and P thrice weekly; (2) exclusion of macrophytes; (3) exclusion of macrophytes plus addition of N and P thrice weekly; and (4) unmanipulated controls (three replicates) (Fig. 1). Porous black polypropylene fabric (Dewitt Pro-5 Weed Barrier) was anchored over the sediment in the four enclosures (#3, 6, 10, 12) where macrophytes were to be excluded. This fabric was perforated to facilitate gas and nutrient exchange at the sediment water interface. Forty-two cylindrical acrylic rods (0.64 cm diameter, 90 cm length; Goldsborough *et al.* 1986) were positioned

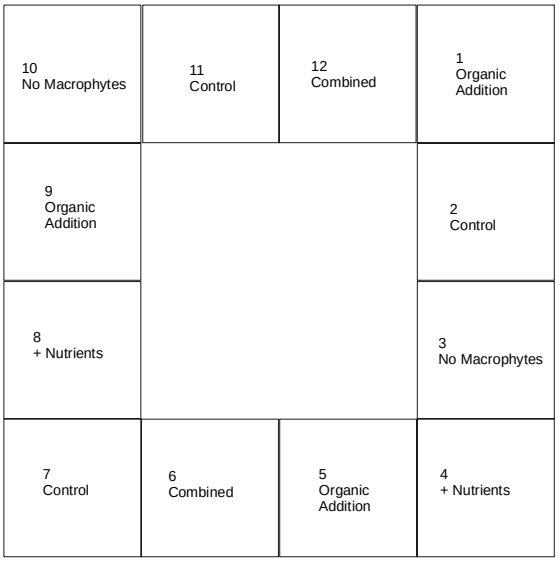

Figure 1. Schematic diagram of 5 x 5 m enclosures used in 1996. Enclosures used in this experiment were 3 and 10: No Macrophytes (macrophyte exclusion), 4 and 8: + Nutrients (nutrient addition), 6 and 12: Combined (nutrient addition plus macrophyte exclusion), and 2, 7 and 11: Control (unmanipulated). Enclosures 1, 5, and 9 were used in concurrent experiments (Purcell and Goldsborough, this volume.)

vertically in each enclosure in a 6 x 7 grid. The uppermost 60 cm of each rod was available for periphytic algal colonization while the lower 30 cm was pushed firmly into the sediments.

The experiment began on 2 July, designated as week 1, and continued until 29 August (week 9). During the three weeks prior to the onset of experimental treatments, the enclosures were allowed to recover from the disturbance caused by installation of the curtains and the black polypropylene fabric. This period allowed time for macrophyte and algal growth. Inorganic N and P were added every Monday, Wednesday and Friday, commencing 03 July, to 28 August (Table 1).

Sampling and analyses

Water samples were collected twice weekly and analyzed for pH, ammonia, soluble reactive P (SRP), and silicon (Stainton *et al.* 1977), nitrate and alkalinity (APHA 1992). Additional water samples were analyzed weekly for inorganic N and P by Norwest Labs (Winnipeg) for comparison and calibration purposes. Samples of epiphyton (on macrophytes), periphyton (on rods), phytoplankton, metaphyton and macrophytes were collected weekly throughout the experiment. Algal chlorophyll *a* was extracted in 90% methanol and analyzed spectrophotometrically using formulae of Marker *et al.* (1980). Phytoplankton and periphyton productivity was measured weekly using the ^{14}C fixation method described by Goldsborough (1994) and Goldsborough et al. (1986).

Macrophyte subsamples were measured (leaf, stem and flower length and width), dried for 24 hours at 105°C and weighed. The surface area of macrophytes available for colonization per square meter of bottom was calculated from these measurements and from an empirical formula developed previously between dry weight and surface area.

Weekly sampling of metaphyton began when it appeared in an enclosure. A 15 x 15 cm square of polystyrene foam was placed under the metaphyton mat and slowly moved up through the water column until it was floating at the surface with the metaphyton supported on top. A small copper tube (2.0 cm^2 inner area), sharpened at one end was used to cut through the mat. One set of samples was analyzed for chlorophyll *a*, while a second set of samples was dried to constant weight at 105°C and weighed.

Table 1. Quantities of phosphorus (as $NaH_2PO_4 \cdot 2H_2O$) and nitrogen (as $NaNO_3$) added to each nutrient addition enclosure (#4, 6, 8, 12) over a nine week period. The total load reflects the proportion of the inorganic chemical that was elemental N or P. The ratio of total N to total P was approximately 7:1.

Nutrient	Chemical per add (g/encl)	N or P per add (g/encl)	Total additions (/encl)	Total N or P (g/encl)
Nitrogen	125.00	20.6	25	515.0
Phosphorus	13.83	2.7	25	67.5

Results

Levels of SRP and Nitrate+Nitrite-N began to increase in the water column from the time of first nutrient addition on 03 July in both the nutrient addition and the combined treatments (Fig. 2). From mid-July on, levels of SRP and Nitrate+Nitrite-N were lower in combined nutrient addition plus macrophyte exclusion enclosures than in enclosures receiving nutrient addition alone. Ammonium-N levels were low in all treatments until early August, when there was a slight increase in ammonium-N in the nutrient addition treatment.

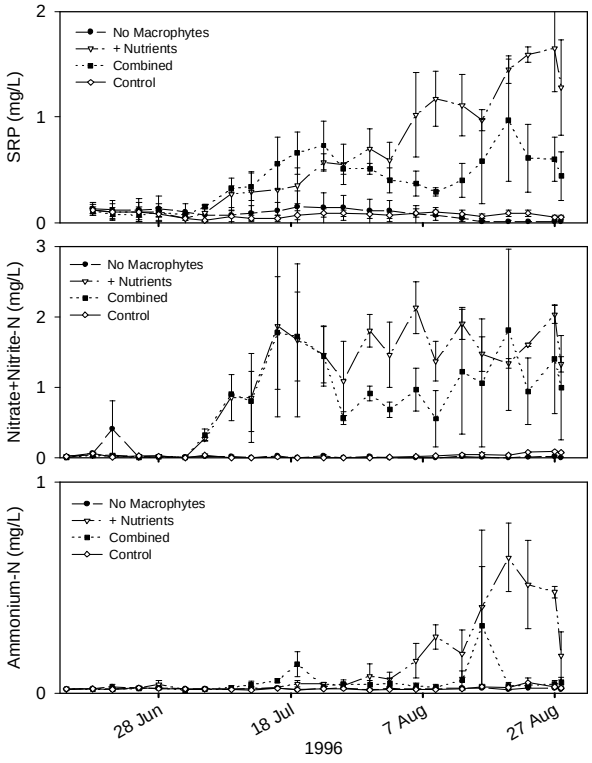

Figure 2. Soluble reactive phosphorus, nitrate+nitrite-N, and ammonium-N levels in macrophyte exclusion (No Macrophytes), nutrient addition (+ Nutrients), nutrient addition plus macrophyte exclusion (Combined), and unmanipulated (Control) enclosures in Delta Marsh. Macrophyte exclusion commenced on 12 June and nutrient addition commenced on 03 July, 1996.

Nutrient levels in the macrophyte exclusion treatment did not differ from nutrient levels in controls.

Phytoplankton biomass and productivity also began to increase from the time of first nutrient addition on 03 July in both the nutrient addition and the combined treatments (Fig. 3A and 3B). From mid-July to the end of August, phytoplankton biomass was five times higher in both nutrient addition and combined treatments than in controls. Towards the end of August, phytoplankton biomass in the combined treatment increased to about ten times the biomass in controls. Phytoplankton biomass in the macrophyte exclusion treatment did not differ substantially from that in controls.

Periphyton biomass and productivity showed a general increasing trend in all treatments over the course of the experiment (Fig. 4A and 4B). Periphyton biomass in the combined treatment showed the greatest increase compared with increases in biomass in other treatments from mid-July to the end of August.

Epiphyton biomass increased in the nutrient addition treatment, compared to epiphyton biomass in controls (Fig. 5A). By the end of August, epiphyton biomass was four times higher in nutrient addition enclosures than in controls. Metaphyton was present briefly in the macrophyte exclusion treatment, and from early July to the end of August in the combined treatment (Fig. 5B). After an early peak in metaphyton biomass in mid-July, metaphyton biomass was low over the rest of the season.

Macrophyte biomass was variable over the course of the season in control and nutrient addition treatments, but this variability was attributed to natural patchiness in macrophyte distribution rather than to any treatment effect (figure not shown).

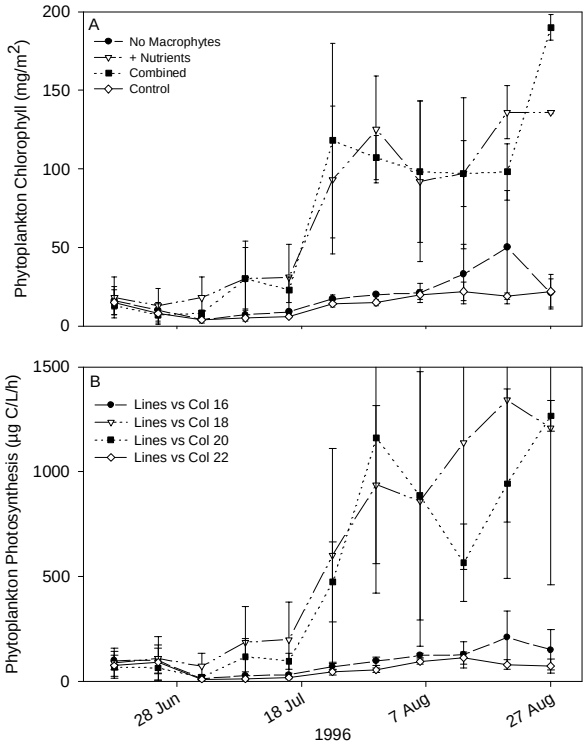

Figure 3. Changes in phytoplankton chlorophyll concentration (A) and phytoplankton photosynthetic productivity (B) over 11 weeks in macrophyte exclusion (No Macrophytes), nutrient addition (+ Nutrients), nutrient addition plus macrophyte exclusion (Combined), and unmanipulated (Control) enclosures in Delta Marsh. Macrophyte exclusion commenced on 12 June and nutrient addition commenced on 03 July, 1996. (Note changes in scale.)

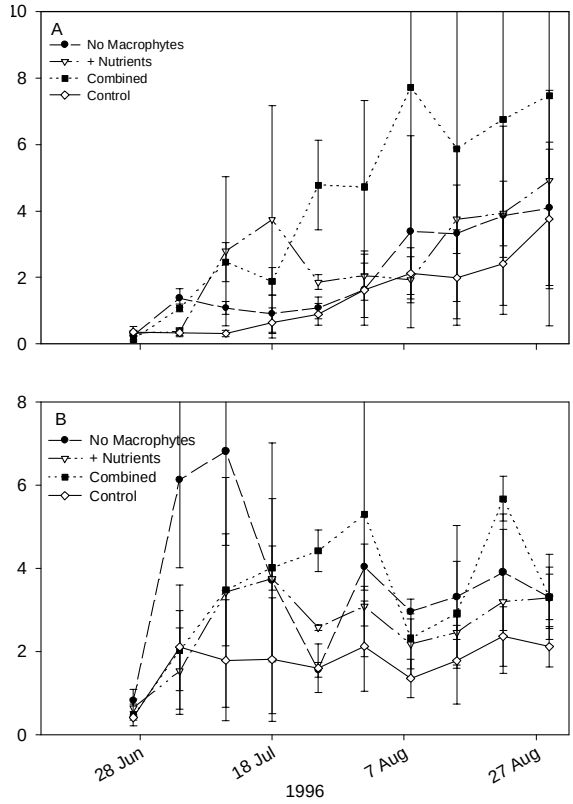

Figure 4. Changes in periphyton chlorophyll concentration (A) and periphyton photosynthetic productivity (B) over 11 weeks in macrophyte exclusion (No Macrophytes), nutrient addition (+ Nutrients), nutrient addition plus macrophyte exclusion (Combined), and unmanipulated (Control) enclosures in Delta Marsh. Macrophyte exclusion commenced on 12 June and nutrient addition commenced on 03 July, 1996. (Note changes in scale.)

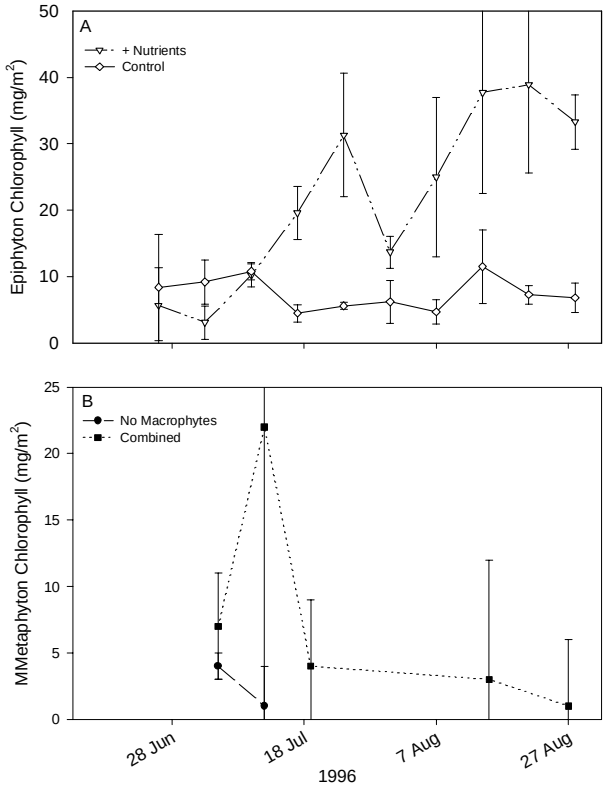

Figure 5. Changes in epiphyton chlorophyll concentration (A) and metaphyton chlorophyll concentration (B) over 11 weeks in macrophyte exclusion (No Macrophytes), nutrient addition (+ Nutrients), nutrient addition plus macrophyte exclusion (Combined), and unmanipulated (Control) enclosures in Delta Marsh. Macrophyte exclusion commenced on 12 June and nutrient addition commenced on 3 July 1996.

Discussion

Phytoplankton production responded to nutrient addition, but not to macrophyte exclusion as we had hypothesized. Phytoplankton response was similar in both treatments where nutrients were added (+ Nutrients and Combined), regardless of the presence or absence of macrophytes. In treatments which differed only in macrophyte abundance (Control vs. No Macrophytes) there were no differences in phytoplankton response. In previous enclosure experiments we were unable to detect a phytoplankton response to nutrient addition (McDougal and Goldsborough 1995, McDougal *et al.* 1997). In this experiment, while the N:P ratio remained the same, the total loading of N and P was doubled over loadings in previous experiments. It is possible that this higher nutrient load allowed phytoplankton production to outstrip grazing pressure, enabling us to detect a measurable response. Other studies have noted that their level of nutrient loading may have been too low to have a substantial impact on phytoplankton production (Murkin *et al.* 1994, Hecky pers. comm.).

The comparable response of phytoplankton to added nutrients in the two treatments, with or without macrophytes present, suggests that phytoplankton are better competitors than macrophytes for high levels of added nutrients. This is likely attributable to their faster growth rates, high surface/volume ratios, thinner diffusive boundary layers and their ability to position themselves favorably in the light environment (Sand-Jensen and Borum 1991). Grazing pressure was low in both treatments (Sandilands, personal communication) suggesting that differential grazing pressure was not a factor in the phytoplankton response.

The lower N and P concentrations in the water column of the combined treatment indicate that something other than phytoplankton was involved in uptake of the added nutrients. Periphyton biomass on acrylic rods was highest in the combined treatment, but the surface area provided by the rods for algal growth was limited. However, similar levels of periphyton biomass were likely present on the inner surfaces of the enclosure curtains and on the upper unshaded surface of the polypropylene fabric anchored at the sediment/water interface. Higher periphyton biomass on these surfaces in the combined treatment compared to the nutrient addition treatment could account for the lower nutrient concentrations in the water column in the combined treatment. Analysis of these data is currently in progress. Another possible explanation is that the absence of macrophytes in the water column of the combined treatment allowed for an increased rate of sedimentation, resulting in increased nutrient loss to the sediments. It is also possible that nutrients were being leached from senescing macrophytes in the nutrient addition treatment thus resulting in elevated nutrient levels in the water column (cf. Allen 1971, Wetzel and Penhale 1979). The slight increase in ammonia levels in the nutrient addition treatment in August corresponded with the onset of macrophyte senescence in these enclosures.

Epiphyton biomass also responded to nutrient addition, suggesting that both epiphyton and phytoplankton in the Blind Channel of Delta Marsh are nutrient-limited, rather than light limited. Metaphyton did not develop in the nutrient addition enclosures, possibly because it was outcompeted for nutrients by both phytoplankton and epiphyton. Metaphyton developed briefly in the macrophyte exclusion treatment, arising from attached algae on the acrylic rods. Small patches of metaphyton were present in the combined nutrient addition plus macrophyte exclusion treatment throughout most of the experiment. Many of these patches originated from attached algae on the rods. However, biomass of metaphyton was low compared to the biomass of phytoplankton.

Conclusions

The phytoplankton response was due to nutrient addition and not to the absence of macrophytes. Contrary to our hypothesis, metaphyton did not develop in the nutrient addition treatment where macrophytes remained. Instead, both phytoplankton and epiphyton blooms occurred in this treatment. Epiphyton and phytoplankton biomass were similar in unmanipulated controls.

It appears that when external nutrient loading is high, phytoplankton and, to a lesser extent, epiphyton are able to compete successfully for the added nutrients whether there are macrophytes present or not. It is likely that if macrophytes were to die back naturally because of flooding or because of shading by epiphytes and phytoplankton, the senescing plant matter would contribute a flush of nutrients to the water column, thus stimulating phytoplankton production as we achieved here by adding nutrients.

The response by both phytoplankton and epiphyton to nutrient loading provides important ecological information for conservation of wetland ecosystems. It has been shown that blooms of phytoplankton and epiphyton can shade submersed macrophytes to the point of decline (Phillips *et al*. 1978, Eminson and Phillips 1978). The decline of submersed macrophytes in a wetland would change the community structure of the ecosystem, reducing colonization surfaces for attached algae, reducing habitat and refugia for invertebrates and fish, and eliminating slow growing biomass that acts as long-term nutrient sinks. It is therefore very important to characterize ecosystem responses to nutrient loading.

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