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

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Introduction

Wetlands are often regarded as natural "filters" for nutrients from external sources such as agricultural fertilizers, animal manure, and domestic sewage. Once in a wetland, these nutrients can be taken by primary producers, thereby stimulating their growth (e.g., Murkin *et al.* 1994). The nature of the competition for nutrients between macroscopic plants (macrophytes) and the various algal assemblages that occur in wetlands is not well known, largely because the significance of algae to total wetland primary production is poorly documented.

In a previous manipulation experiment in Delta Marsh, we found that periphytic and metaphytic algae flourished after pulse and press additions of inorganic N and P but macrophytes and phytoplankton were unaffected (McDougal and Goldsborough 1995). We suspect the lack of response by phytoplankton, which we hypothesized would thrive on nutrients added to the water column, occurred because the study site was sufficiently shallow that profuse macrophytes provided ample colonization substrata for epiphyton and ultimately for metaphyton, all of which outcompeted phytoplankton for nutrients. If so, we hypothesized that macrophyte removal, along with added nutrients, would lead to phytoplankton proliferation. We tested this hypothesis in a follow-up experiment conducted in 1995.

Methods

Experimental enclosures

Ten floating enclosures (5 x 5 m) were installed in the center of Blind Channel on 23 May 1995. Water depth at the time of the study ranged from 100 to 120 cm. Six enclosures, chosen randomly from among the ten enclosures available, were used in this experiment (Fig. 1). 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. Sixty-four cylindrical acrylic rods (0.64 cm diameter, 90 cm length; Goldsborough *et al.* 1986) were positioned vertically in each enclosure in an 8 by 8 grid. The rods were pushed 30 cm into the sediments leaving the uppermost 60 cm of each rod available for periphytic algal colonization. We attempted to exclude fish from the enclosures by placing minnow traps in each enclosure, which were emptied on a daily basis throughout the experiment.

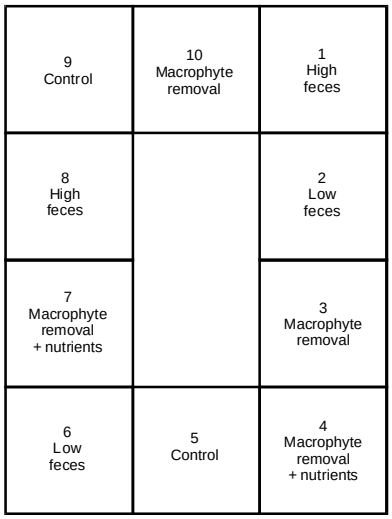

Figure 1. Schematic diagram of 5 x 5 m enclosures used in Blind Channel during 1995. Enclosures 1, 2, 6 and 8 were used in concurrent experiments (Purcell and Goldsborough, this volume; Pettigrew and Hann, this volume).

Experimental treatments

The experiment began on 26 June, designated as week 1, and continued until 31 August (week 10). During the four weeks prior to the onset of experimental treatments, the enclosures were allowed to recover from the disturbance caused by installation of the curtains. This period allowed time for macrophyte and algal growth.

Enclosures were assigned randomly to one of the following three treatments, with two replicate enclosures per treatment: (1) continual macrophyte removal; (2) continual macrophyte removal plus thrice-weekly additions of inorganic N and P; and (3) control (no

manipulation). Macrophyte removal and nutrient additions commenced on 26 June and 28 June, respectively, and continued to the week of 28 August. Inorganic N and P was added every Monday, Wednesday and Friday from 28 June to 28 August (Table 1).

Macrophyte removal was achieved by clipping the macrophytes at the sediment/water interface using long-handled grass clippers. A long-handled rake and a sieve were used to remove the clipped macrophytes from the enclosures. These macrophytes were dried at 104°C and weighed. Continual removal of macrophytes was the goal of this treatment but, despite regular harvesting, it was difficult to keep pace with macrophyte regrowth during mid-summer. As a result, there was always a short "shrubby" mat of macrophytes in the bottom of the harvested enclosures.

Sampling and analyses

Water samples were collected twice weekly for chemical analysis. Vertical changes in dissolved oxygen and photosynthetically active radiation were recorded twice weekly (data not reported here). Samples of epipelon, epiphyton (on macrophytes), periphyton (on rods), phytoplankton, metaphyton and macrophytes were collected weekly throughout the experiment.

Water samples were analyzed for pH, ammonia, soluble reactive P (SRP), and silicon, according (methods of Stainton *et al.* 1977), nitrate (APHA 1992), and alkalinity (APHA 1992). Additional water samples were analyzed weekly for inorganic N and P by Norwest Labs (Winnipeg) for comparison and calibration purposes. The total P content of periphyton, phytoplankton (seston), macrophytes, invertebrates, sediment, and water was measured using an ignition method (Andersen 1976). Only data for inorganic N and P levels in the water column are reported here.

Phytoplankton, epipelon, and periphyton productivity was measured weekly using the ^{14}C fixation method described by Goldsborough (1994) and Goldsborough *et al*. (1986). Algal chlorophyll *a* was measured via spectrophotometric analysis of 90% methanol extracts, with concentration determined using formulae of Marker *et al*. (1980).

Macrophyte subsamples were measured (leaf, stem and flower length and width), dried for 24 hours at 105°C and weighed. By comparing the ratio of the dry weight of the measured portion to the dry weight of the remainder of the sample, we could estimate the surface area of macrophytes in the entire sample, which corresponded to a known surface area of the enclosure bottom. Assuming even macrophyte coverage over the bottom area of the enclosure (25 m^2), we could then calculate the surface area of macrophytes available for colonization per square meter of enclosure bottom.

Weekly sampling of metaphyton began when it appeared in an enclosure. A 15 by 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 104°C and weighed. A weighed subsample of each dried metaphyton sample was analyzed for P content.

Table 1. Quantities of phosphorus (as $NaH_2PO_4 \cdot 2H_2O$) and nitrogen (as $NaNO_3$) added to each nutrient-pressed enclosure (4 and 7) over a 10-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 7:1.

Nutrient	Chemical /addition (g/encl)	N or P /addition (g/encl)	Total additions (/encl)	Total (g/encl)
Nitrogen	60.678	9.71	27	262.17
Phosphorus	6.715	1.34	27	36.18

Results

The levels of nitrate and SRP in the water column of the control and macrophyte removal enclosures were low and remained relatively constant over the experimental period (Fig. 2). In the nutrient addition enclosures, N and P began to rise slightly by the week of 9 July. By the end of July and throughout most of August, inorganic nutrient levels (including ammonia) increased steadily in the nutrient addition enclosures. Around 20 August, SRP and nitrate levels began to drop off while ammonia continued to increase.

Phytoplankton chlorophyll concentration and productivity did not vary among treatments (Fig. 3). There is a sharp decrease in both parameters in mid-June after which they remained low throughout July and August. A short-lived film of algae developed on the water surface in enclosures with added nutrients in mid-July

Periphyton production was low in all treatments throughout the experiment, except for one date in mid-July (Fig. 4). There were slight differences in chlorophyll concentration among the treatments; chlorophyll concentration in the macrophyte removal treatment increased slightly during the experiment. Corresponding

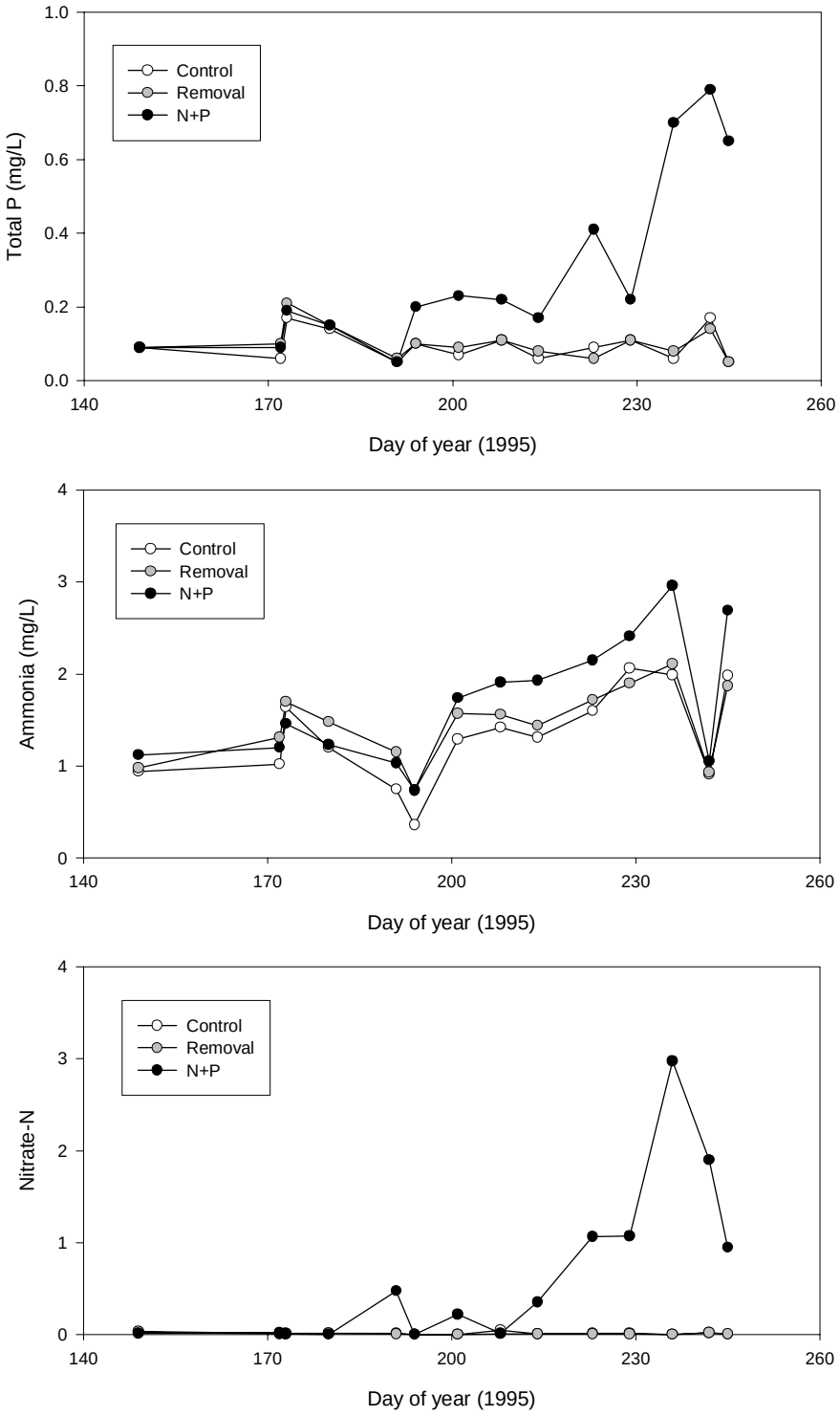

Figure 2. Total phosphorus, nitrate+nitrite-N, and ammonium-N levels in control, macrophyte removal, and macrophyte removal plus nutrient addition (N+P) enclosures over a 13-week period in Delta Marsh. Nutrient addition and macrophyte removal commenced on 28 June. (Note changes in scale on vertical axis.)

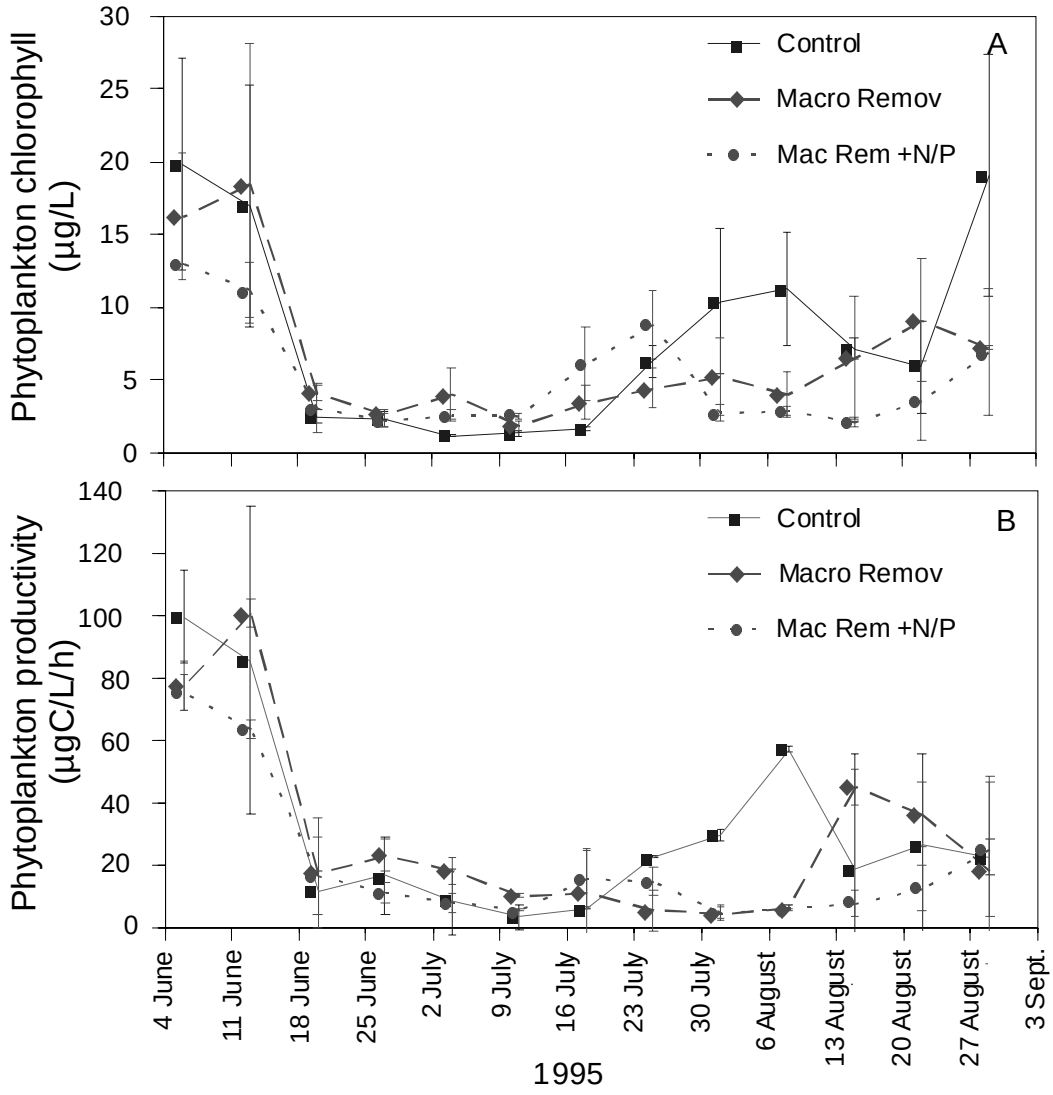

Figure 3. Changes in phytoplankton chlorophyll concentration (A) and phytoplankton photosynthetic productivity (B) over 13 weeks in control, macrophyte removal, and macrophyte removal plus nutrient addition (N+P) enclosures at Delta Marsh. Nutrient addition and macrophyte removal commenced on 28 June. (Note changes in scale.)

values in the macrophyte removal plus nutrient addition treatment increased to the beginning of July, then decreased throughout the rest of the experiment. Levels in the control were consistently low.

Epipelon chlorophyll concentration and productivity decreased slightly from mid-June to the beginning of July but values were generally low throughout the experiment with no differences among treatments (Fig. 5).

Metaphyton occurred only in the enclosures from which macrophyte were removed and nutrients were added; it was first observed during the first week of August. Metaphyton biomass peaked around mid-August and declined thereafter (data not shown).

Discussion

Phytoplankton production responded neither to macrophyte removal nor to macrophyte removal plus nutrient addition. The decline in phytoplankton biomass in mid-June was probably due to reduced water column turbulence after the installation of the enclosure curtains, coupled with high grazing pressure by cladocerans (Sandilands and Hann 1996).

Periphyton biomass, sampled from acrylic rods, increased in both macrophyte removal treatments over the controls but there was no indication that periphyton responded to added N and P. The difference in trends in periphyton biomass between macrophyte removal and removal plus nutrient addition treatments can be

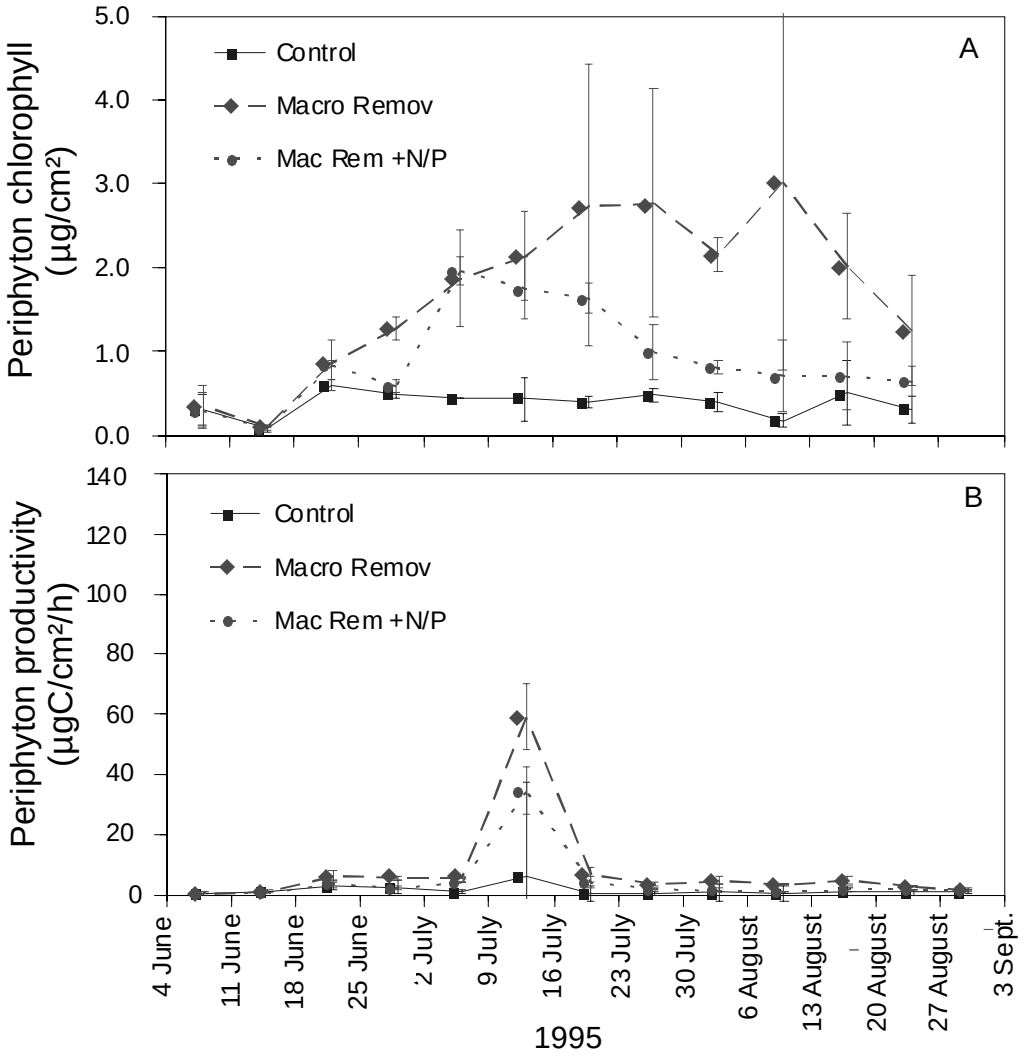

Figure 4. Changes in periphyton chlorophyll concentration (A) and periphyton photosynthetic productivity (B) over 13 weeks in control, macrophyte removal, and macrophyte removal plus nutrient addition (N+P) enclosures at Delta Marsh. Nutrient addition and macrophyte removal commenced on 28 June. (Note changes in scale.)

explained by differences in grazing pressure; cladocerans was relatively scarce in the macrophyte removal enclosures, allowing the periphyton biomass to increase. In the macrophyte removal plus nutrient addition enclosures, the decrease in periphyton biomass likely related to an increase in cladoceran grazers (Sandilands and Hann 1996). We attribute the anomalous high periphyton productivity value in mid-July to a mass of filamentous green algae (*Cladophora* sp.) that clung to the acrylic rod as it was sampled.

The clipping method for removing macrophytes from these enclosures was not entirely successful. Although clipping did reduce macrophyte surface area considerably, regrowth continued throughout the summer. Consequently, re-growing macrophytes continued to be a sink for nutrients added to the system. Macrophyte senescence began near the end of July, corresponding with the increase in nutrients observed in the water column of the nutrient addition enclosures. The "shrubby" macrophytes that remained in the removal treatment enclosures provided surface area for colonization by epiphytes and for subsequent development of metaphyton. Whereas epiphyton abundance was reduced because of the reduction in macrophyte surface area, the epiphyton community was an additional sink for added nutrients.

Metaphyton developed in early August in the enclosures with added nutrients when the increased levels of N and P occurred in the water column. Metaphyton biomass was less than that observed in a

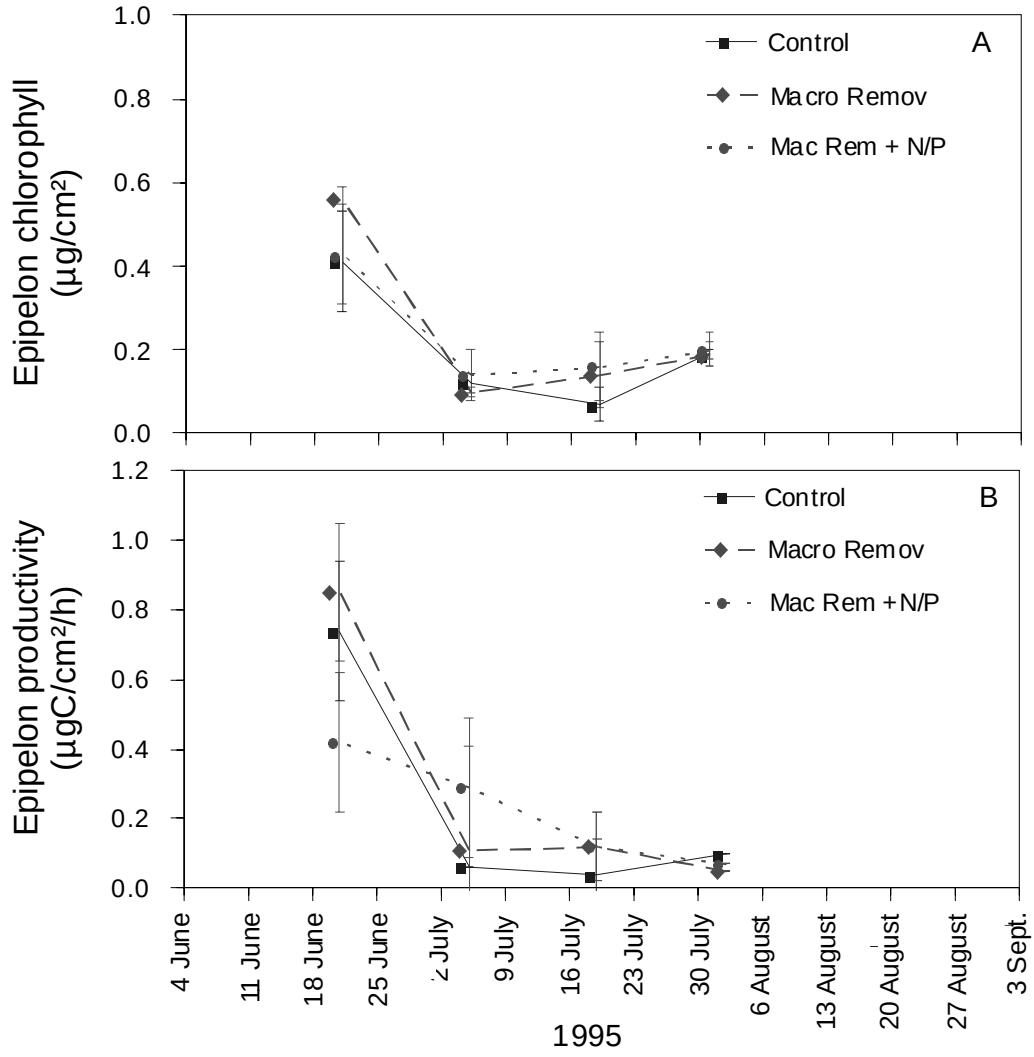

Figure 5. Changes in epipelon chlorophyll concentration (A) and epipelon photosynthetic productivity (B) over 13 weeks in control, macrophyte removal, and macrophyte removal plus nutrient addition (N+P) enclosures at Delta Marsh. Nutrient addition and macrophyte removal commenced on 28 June. (Note changes in scale.)

previous nutrient addition experiment (McDougal and Goldsborough 1995). This was probably because there was much less surface area of macrophytes from which the metaphyton could develop in the current experiment.

Conclusions

Contrary to our hypothesis, we were not able to shift the system from the prevailing epiphyton-dominated state to a phytoplankton-dominated state via the removal of submersed macrophytes and the addition of inorganic N and P. We suspect this was attributable to our inability to remove macrophytes completely from the system. The macrophytes remained a major nutrient sink as well as providing increased colonization surface area for epiphyton and metaphyton. A more effective technique for removing macrophytes will be investigated in an experiment planned for 1996.

Acknowledgements

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