Waterfowl feces as a source of nutrients to planktonic and benthic algae in Delta Marsh

Sara L. Purcell and L. Gordon Goldsborough
Department of Botany, University of Manitoba
Winnipeg, Manitoba R3T 2N2

Introduction

The role that waterfowl play in regulating wetland algae may be two-fold: they can affect the magnitude of algal substratum, competition and herbivory by consuming macrophytes and invertebrates (Bazely and Jeffries 1989; Gere and Andrikovics 1992; Hanson and Butler 1990, 1994; Hargeby *et al*. 1994) and they can affect the wetland nutrient regime through their feces and decaying carcasses (Gere and Andrikovics 1992; Manny *et al*. 1994; Parmenter and Lamarra 1991).

The objective of this study was to determine the response of planktonic and benthic algae in Delta Marsh to experimental additions of waterfowl feces. We hypothesized, based on the results of previous experiments in which inorganic nutrient additions stimulated algal assemblages (McDougal and Goldsborough 1995), that inorganic nutrients liberated from fresh feces of mallard ducks (*Anas platyrhynchos*) and Canada geese (*Branta canadensis*) would increase the biomass (chlorophyll content) and primary productivity (carbon fixation rate) of algae (and possibly macrophytes) in treated *in situ* enclosures. We also hypothesized that phytoplankton in the water column (in close proximity to added feces) would be the primary beneficiary of the increased supply of nutrients, so their importance would increase in this normally epiphyton-dominated ecosystem (Goldsborough and Robinson 1996).

Materials and Methods

Enclosures were deployed in Blind Channel, near the University Field Station (Delta Marsh), to examine the response by enclosed algae to feces additions. Each enclosure, 5 m x 5 m in size, consisted of a square frame supported by foam blocks from which was suspended a translucent plastic curtain. A metal bar sewn into the lower edge of the curtain was embedded into the sediments to anchor the curtains and prevent lateral flow between the enclosure and the surrounding marsh. Each enclosure contained approximately 20,000 L of water. Twelve enclosures were anchored on 11 June 1996 in a water depth of about 1 m (Fig. 1). Following enclosure deployment, fish (primarily fathead minnows and sticklebacks) were removed using a seine net. Gee-type minnow traps were then placed in each enclosure for the duration of the experiment to monitor the presence of these consumers.

Cumulative feces additions (12.2 kg fresh feces per enclosure) approximated the same load as added to the "high" treatment enclosures during the first year of this study (Purcell and Goldsborough 1996). Feces from Canada geese and mallard ducks were collected in 1995 and July 1996 from wild flocks at the Delta Waterfowl and Wetlands Research Station. All feces were stored at -30°C until required for additions, at which time they were thawed, mixed with carbon-filtered water, and sprinkled on the water surface of the target enclosure. Three of the six experimental enclosures received weekly additions of 1.5 kg fresh feces each between 5 July and 23 August (8 weeks). Three randomly selected

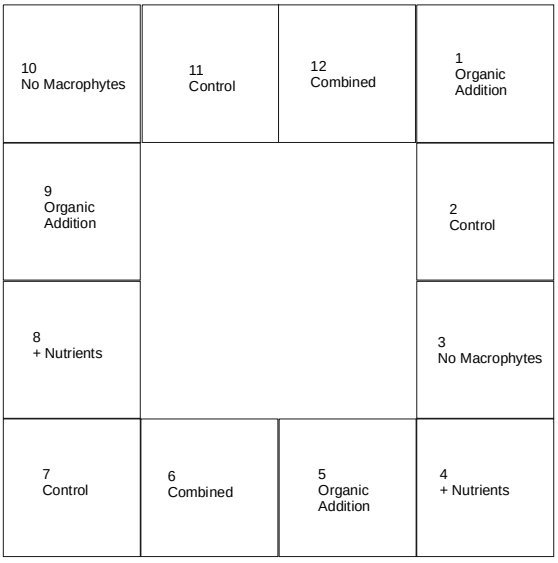

Figure 1. Schematic diagram of 5 x 5 m enclosures used in 1996. Enclosures 1, 5 and 9 received feces additions while enclosures 2, 7 and 11 were unmanipulated controls. Remaining enclosures were used in concurrent experiments (McDougal and Goldsborough, this volume.)

enclosures served as controls that received no feces additions throughout the experiment. The experiment additions in 1996 consisted primarily of mallard duckling feces that had a total P content of 17.4 mg/g dry weight, a total N content of 52.3 mg/g dry weight and a moisture content of 77%. The estimated N and P loadings during each feces addition were 0.240 g/m^2 P and 0.722 g/m^2 N.

Light extinction was measured biweekly on bright, sunny days with a Li-Cor LI-185 meter and a LI-192SA submersible quantum sensor. Turbidity was measured weekly using a Hach Model 2100B turbidimeter. Dissolved oxygen was measured weekly at 10 and 50 cm depths in the evening using a YSI Model 51B meter. Water samples were collected about 15 cm below the water surface and analyzed weekly for soluble reactive phosphorus (SRP), ammonia-N, and nitrate-N (Stainton *et al.* 1977; APHA 1992).

Methods used for measuring algal chlorophyll and photosynthesis were the same as used in 1995 (Purcell and Goldsborough 1996). Phytoplankton chlorophyll (µg/L), photosynthesis (µg/L/h), and particulate P (µg/L) were monitored weekly, starting on 18 June. Periphyton was monitored in each enclosure from weekly samples of 42 acrylic rods that had been positioned in the enclosures on 13 June. The rods were not sampled for two weeks following deployment to allow time for algal colonization. Three rods were randomly sampled from each enclosure each week, starting on 27 June, for measurement of chlorophyll (µg/cm^2), photosynthesis (µg/cm^2/h), and particulate P (µg/cm^2). Epipelon chlorophyll (µg/cm^2) and productivity (µg/cm^2/h) were measured at three randomly selected sites in each enclosure at biweekly intervals beginning on 24 June.

Submersed macrophytes were sampled weekly at two randomly selected positions in each enclosure, starting on 26 June, using a Downing Box Sampler (Downing 1984). The sampler consisted of a hinged, clear acrylic box (30.5 cm x 11 cm x 19 cm) that was submersed below the water surface and closed around a sample of macrophytes. Following collection, macrophytes were rinsed of phytophilous invertebrates using a recorded amount of carbon-filtered water (500 ml or 250 ml depending on the amount of macrophyte collected from the Downing Box), placed into a glass jar and shaken vigorously to dislodge epiphytes. Contents of the jar were poured through a 53 µm steel sieve into a basin to collect dislodged epiphytes. A measured amount of carbon-filtered water (500 ml or 250 ml) was used to rinse the macrophytes, the jar and the basin. The total volume of water used was recorded and subsample was retained for analysis of epiphyton biomass (total chlorophyll). The cleaned macrophyte samples were bagged and returned to the lab where the surface area (length and diameter of stems and leaves) of a representative sub-sample was measured. Plants were then dried at 100°C for 24 hours and weighed. A sub-sample of the dry macrophyte tissue was placed in pre-weighed glass vials for total P analysis (µg/g). Macrophyte biomass (g/m^2) in the enclosures was measured four times during the sampling period (17 June, 15 July, 12 August and 27 August) using a open-ended PVC cylinder. The sampler enclosed all macrophytes contained in 0.45 m^2 of the enclosure bottom. Collected macrophytes were dried at 100°C for 24 hours and weighed.

The statistical analysis for all parameters in both years was performed using a one-way analysis of variance (ANOVA) to distinguish treatment differences which may have occurred on the days sampled. The null hypothesis was rejected when $p \leq 0.05$ and the treatments were said to be significantly different. Analyses were performed using the Data Analysis Toolpak of Microsoft Excel Version 5.0a.

Results

Enclosure water was turbid (> 2 NTU) at the beginning of the experiment (Fig. 2), prior to feces additions, for two reasons. First, the enclosure curtains provided protection against the effects of wind and fish on the resuspension of bottom sediments. Second, as the experiment progressed, the roots of growing macrophytes reduced sediment resuspension. Turbidity decreased with time and there was no difference between controls and feces treatments ($p > 0.05$). The light extinction coefficient (Fig. 3) decreased during the experiment in the feces treatments and controls, coinciding with increased biomass of submersed macrophytes (Fig. 4). However, none of these parameters was affected significantly ($p > 0.05$) by feces treatments.

Dissolved oxygen concentrations (Figs. 5 and 6) varied during the experiment but they did not differ significantly between controls and feces treatments ($p > 0.05$). Oxygen concentration at 10 cm depth was consistently higher than at 50 cm.

Nitrate-N (NO_3-N) concentrations were always below the detection limit (< 0.05 mg/L) in both controls and feces treatments. Ammonia (NH_3-N) levels increased after the first feces addition, but they returned to control levels by the following week (Fig. 7). However, starting in late July, NH_3-N concentrations were consistently higher in feces treatments than in controls. Soluble reactive phosphorus (SRP) concentrations were always < 0.1 mg/L in the controls (Fig. 8). From mid-July onwards, SRP concentrations

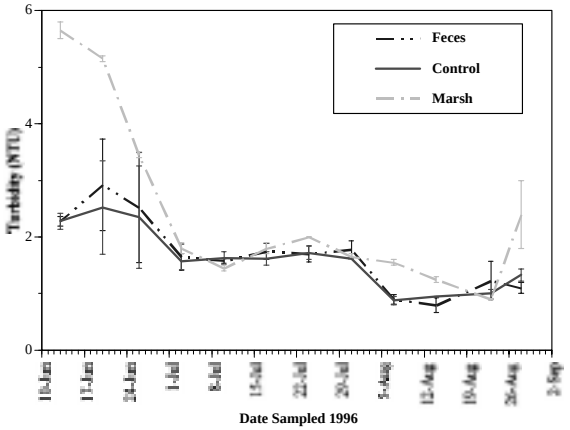

Figure 2. Changes in water column turbidity (NTU) in control and feces-enriched enclosures, as compared to values in the surrounding marsh. Thrice-weekly feces additions began on 5 July.

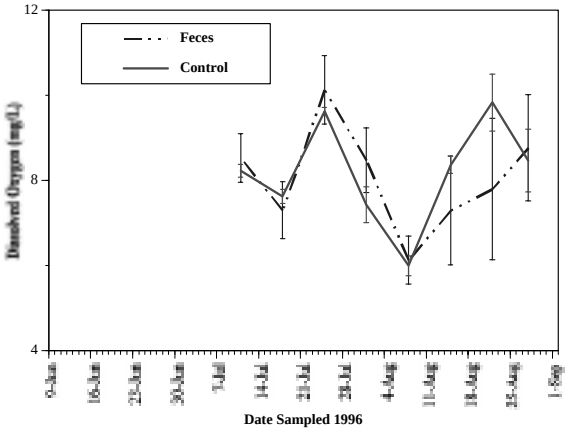

Figure 5. Changes in dissolved oxygen at 10 cm depth (mg/L) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

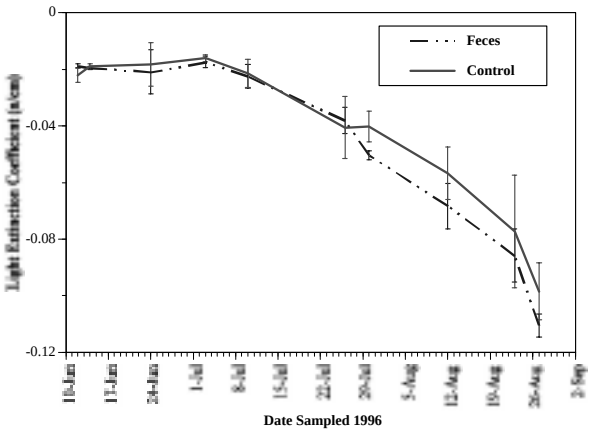

Figure 3. Changes in water column light extinction (n/cm) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

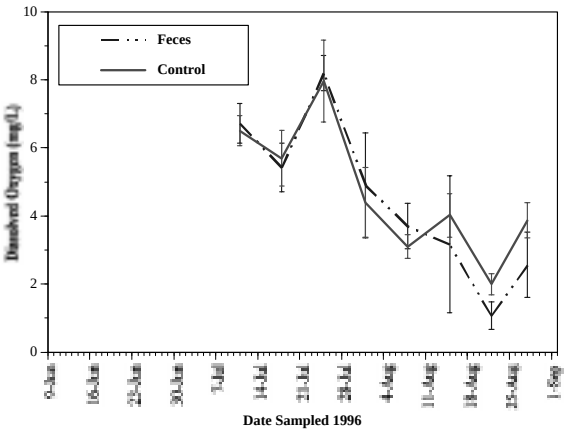

Figure 6. Changes in dissolved oxygen at 50 cm depth (mg/L) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

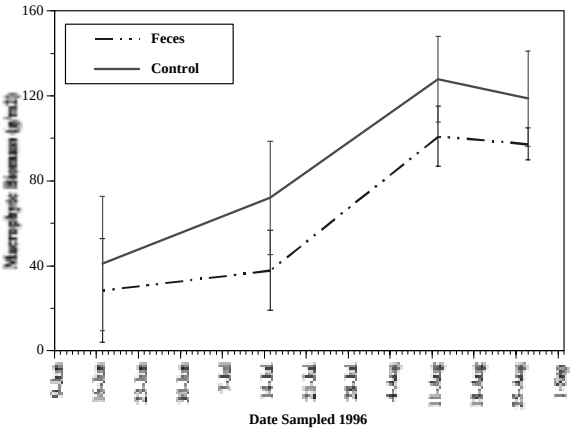

Figure 4. Changes in dry weight of submersed macrophyte (g/m^2) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

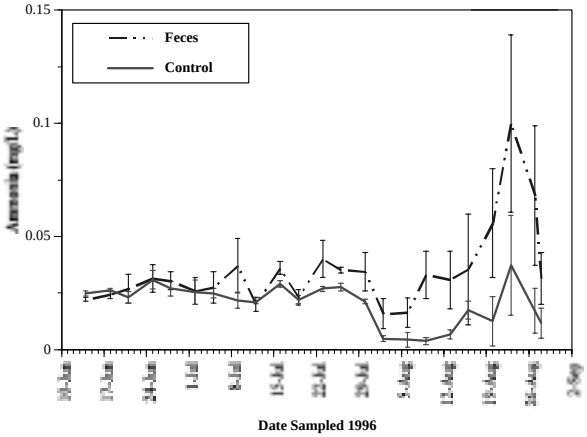

Figure 7. Changes in ammonia-N (mg/L) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

in the feces treatments were significantly higher than those in the controls ($p < 0.05$).

Phytoplankton chlorophyll content (Fig. 9) and photosynthetic rate (Fig. 10) varied over the course of the experiment. Highest values were generally observed in the controls but the differences were not significant ($p > 0.05$). Epiphyton chlorophyll content varied erratically over time with no significant difference between controls and treatments (Fig. 11). Likewise, periphyton chlorophyll content (Fig. 12) and photosynthetic rate (Fig. 13) showed no consistent response to feces additions. The same result was found for epipelon chlorophyll content (Fig. 14) and photosynthetic rate (Fig. 15). In summary, feces additions did not significantly affect the biomass or productivity of phytoplankton, epiphyton, periphyton, or epipelon.

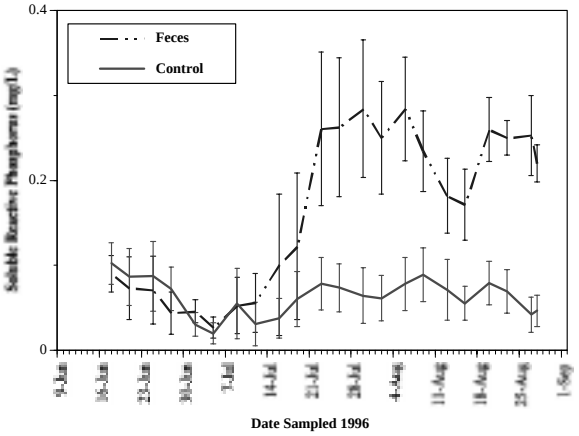

Figure 8. Changes in soluble reactive phosphorus (mg/L) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

Discussion

Natural waterfowl feces loading to Delta Marsh was calculated from measurements of bird density and defecation rates, and mass and chemical composition of the feces. There is approximately 1 bird per hectare of the marsh (B. Jones, Manitoba Natural Resources, pers. comm.) which is equivalent to 0.0001 bird per m^2. Manny *et al*. (1994) measured defecation rates of Canada geese on Wintergreen Lake, Michigan and determined that geese defecate 1.96 droppings/bird/h during the day and 0.37 droppings/bird/h at night. Therefore, assuming a 12 daylight period, the average goose will defecate about 28 times per day. The average dry weight of one goose dropping is about 1.2 g (Manny *et al*. 1994) and the water content of a fresh dropping is 81% (Purcell, unpublished data). Therefore, given these data, the daily loading rate is 0.0204 g wet weight per m^2 per day or 1 g/m^2 over an 8 week period. By comparison, the cumulative load of feces added to each manipulated enclosure over the 8 week experimental period was 489 g/m^2. Therefore, the level of feces loading used in this experiment greatly exceeded levels that may occur naturally in the marsh.

Concentrations of SRP and NH_3-N in the water column increased in enclosures to which waterfowl feces were added, as compared to the controls, suggesting that inorganic nutrients were liberated from the feces. However, the magnitudes of the increases were less than was found to occur with additions of synthetic inorganic N and P (McDougal and Goldsborough 1995), even though the level of feces loading was calculated to include the same total P (based on analysis of total organic and inorganic P content of feces samples), suggesting that the nutrients were not fully mineralized from the feces.

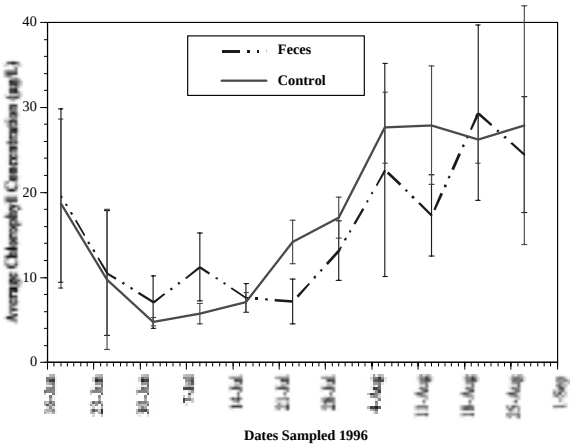

Figure 9. Changes in phytoplankton chlorophyll (µg/L) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

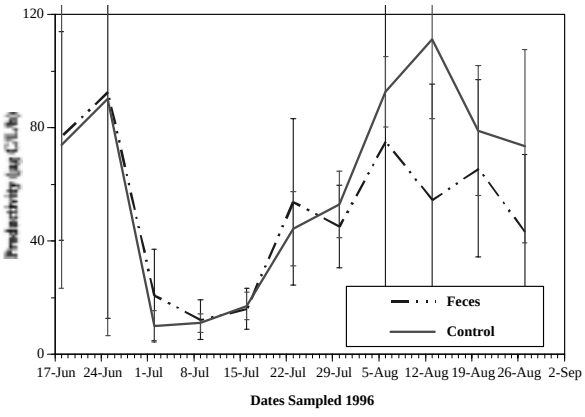

Figure 10. Changes in phytoplankton photosynthesis (µgC/L/h) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

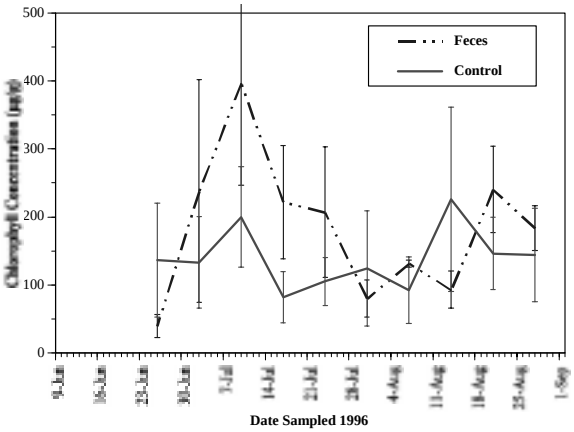

Figure 11. Changes in epiphyton chlorophyll (µg/g dry weight macrophyte) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

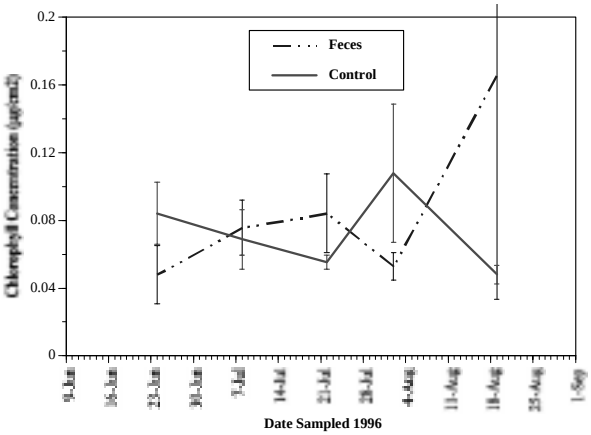

Figure 14. Changes in epipelon chlorophyll (µg/cm^2) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

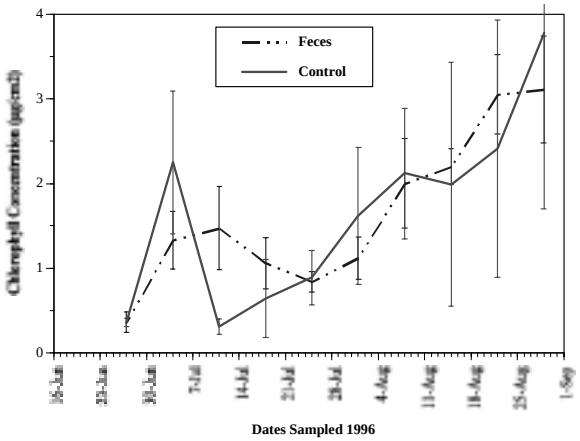

Figure 12. Changes in periphyton chlorophyll (µg/cm^2) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

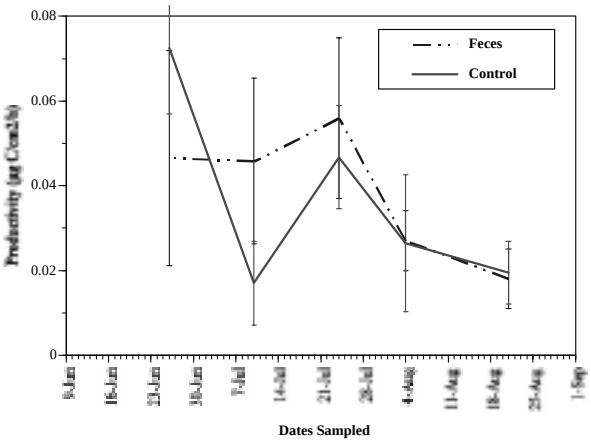

Figure 15. Changes in epipelon photosynthesis (µgC/cm^2/h) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

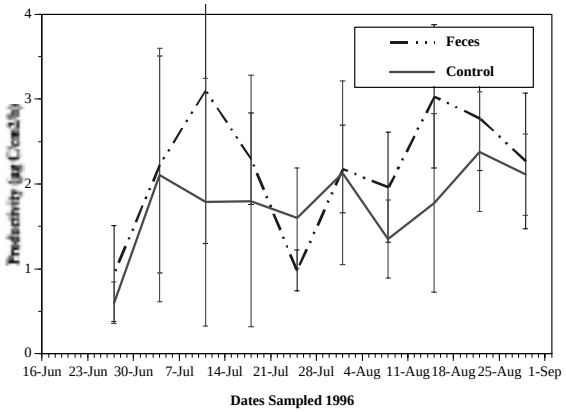

Figure 13. Changes in periphyton photosynthesis (µgC/cm^2/h) in control and feces-enriched enclosures. Thrice-weekly feces additions began on 5 July.

Contrary to the results of our previous experiments on the effects of nutrient enrichment in the marsh, and despite the availability of inorganic N and P in the water column resulting from weekly additions of water feces, none of the algal assemblages nor the submersed macrophytes responded positively. Changes in algal biomass and productivity appeared to reflect only natural seasonal variability. We are now evaluating several alternate hypotheses that may explain this result.

In conclusion, contrary to our hypothesis, additions of waterfowl feces in quantities far higher than those occurring naturally in Delta Marsh had no significant effect on the biomass and productivity of algae and submersed macrophytes. Consequently, we were unable to shift the system from the prevailing epiphyte-dominated state to a phytoplankton-dominated state. It appears likely that waterfowl feces are not significant

contributors to the marsh nutrient budget, at least over the duration of a single growing season.

Acknowledgments

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