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Impacts of Mechanical Macrophyte Removal Devices on Sediment Scouring in Littoral Habitats: II. Experimental Operation in the Littoral Zone of Eau Galle Reservoir, Wisconsin

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PURPOSE: Research experimentally evaluated the impacts of a mechanical macrophyte removal device on changes in sediment bed elevation and water quality in the littoral zone of a shallow embayment located in Eau Galle Reservoir, Wisconsin.

BACKGROUND: Mechanical macrophyte removal devices are an attractive, low-cost means of removing macrophytes in specific areas without herbicides or repeated mechanical harvesting. However, commercially available mechanical macrophyte removal devices that employ a submerged roller arm and paddle design to entangle and uproot macrophytes may have indirect negative impacts to littoral habitat by resuspending and scouring sediment and associated nutrients. Excavation and alteration of sediment substrate (see James et al. (2004)) can have an impact on invertebrate and fish habitat and lead to enhanced nutrient recycling, depending on the density of use in relation to lake shoreline size.

The objective of this study was to experimentally quantify sediment displacement and changes in water quality associated with resuspension during operation of mechanical macrophyte removal devices employing a submerged roller arm and paddle design.

METHODS: The impacts of mechanical macrophyte removal devices on sediment characteristics and water quality were evaluated in the Lousy Creek embayment of Eau Galle Reservoir, Wisconsin (see Barko et al. (1990) for a description of the lake). The embayment is shallow (less than 1 m average depth) and typically exhibits high macrophyte biomass during the summer months (more than 100 g/m^2 as loss on ignition biomass) consisting of *Ceratophyllum demersum, Potamogeton nodosus* and *P pectinatus*, *Najas flexilis*, *Elodea canadensis*, and *Heteranthera dubia* (Godshalk and Barko 1988). Sediments in the embayment are nutrient rich (total nitrogen = 4.713 mg/g; phosphorus = 0.966 mg/g), dominated by silt fractions (57 to 92 percent), and exhibit a variable texture (moisture content range = 32 to 75 percent).

One reference and two treated sites were established within an approximately 1000-m^2 area near the shoreline in the embayment. Water depth at these locations ranged between approximately 35 and 75 cm. At the two treated sites, Weed Rollers® (Crary WeedRoller®, TarraMarc Industries, West Fargo, North Dakota, USA) were installed, using manufacturer's instructions, on wooden docks that were secured with stanchions. The Weed Rollers consisted of a roller arm with fin-like projections that was attached to a pivot arm and motor. The arm is slowly rolled along the bottom of an area (up to a 270-deg arc) and reverses direction at the end of each arc. The fin-like paddles churn up the sediment, loosen macrophyte roots, and sweep them to each side clearing the area. Weed Roller® operations were initiated on 25 May 1999, at one treated site (WR-May; Weed Roller® catalog # 51067) and on 26 July 1999, at the other treated site (WR-July; Weed Roller® catalog # 51285). WR-May represented control of macrophytes at the beginning of the growing season while WR-July represented control of macrophytes at peak biomass. The roller arm lengths of Weed Rollers® deployed at the WR-May and WR-July site were 30 and 28 ft, respectively. Because electrical service was not available at the Lousy Creek site, gasoline-powered generators were used to run the Weed Rollers® during the summer.

The approximately 270-deg arc created by movement of the Weed Roller® roller arm was divided by three equally spaced transects for sediment coring purposes (Figure 1). At each of three stations along the transects, three replicate intact sediment cores were collected for examination of physical characteristics and one sediment core was collected for chemical analysis of nitrogen (N) and phosphorus (P). In the laboratory, sediment cores were carefully sectioned at 10-cm intervals. All sediment core sections were dried at 105 ^{o}C to a constant weight to determine moisture content and sediment bulk density. Total N and P on sediment sections were determined using automated chemistry (Lachat QuikChem Analyzer; Hach Company, Loveland, Colorado) after digestion with red mercuric oxide (Plumb 1981).

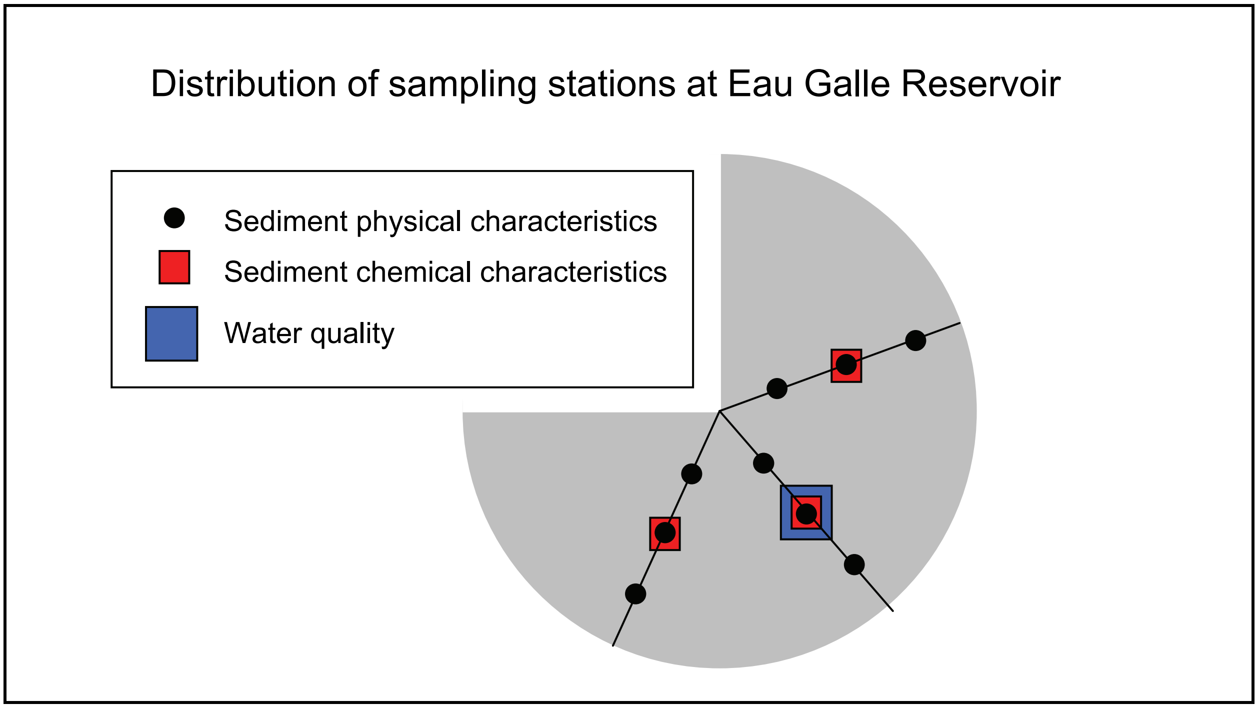

Figure 1. Sampling scenarios for the examination of sediment physical and chemical characteristics and water quality. Shaded area represents the region impacted by mechanical rolling arm operation

Changes in bed elevation were examined at the reference and two treated sites in conjunction with Weed Roller® operation. Rope, marked at 5-ft intervals, was attached to poles driven into the sediment and stretched across the three sites along the same transects used for sediment coring (Figure 1). At 2- to 10-ft intervals along the rope transect, water column depth was measured to the nearest 1 cm using a depth chain. Depth measurements were collected in the area impacted by Weed Roller® operations and in regions immediately beyond the furthest extent of the roller arm. All depth measurements were corrected for variations in pool elevation, which were monitored with a staff gauge deployed in the embayment. Depth measurements were obtained before and after initiation of Weed Roller® operations at both treated sites. They were also measured in the reference site for comparison with those measured in treated sites. Changes in bed elevation were calculated as the difference between the initial water column depth (i.e., before Weed Roller® operation) and the water column depth after Weed Roller® operation.

During July 1999, a centrally located station was established in each site for water sampling purposes (Figure 1). In situ turbidity was monitored at reference and treated sites during Weed Roller® operation using a logging data sonde and turbidity sensor (YSI 6000; Yellow Springs Instruments, Yellow Springs, Ohio). Prior to deployment of the data sondes, the turbidity sensor was calibrated using known turbidity standards. Data sondes were deployed approximately 25-30 cm above the sediment surface in each site by attaching them to one of the central line transects located above the water surface. The data sondes recorded turbidity at 2-min intervals. At 5- to 60-min intervals during the same period in July, the upper 0.3 m of the water column was sampled using an integrated sampler as described in Barko et al. (1984). For total suspended solids (TSS), suspended material retained on a precombusted glass fiber filter (Gelman (A/E) was dried to a constant weight at 105 ^{o}C for dry mass determination (American Public Health Association (APHA) 1992). Samples for total phosphorus were predigested with potassium persulfate according to Ameel et al. (1993) before colorimetric analysis using automated analyzer techniques (Lachat QuikChem autoanalyzer, Hach Company, Loveland, CO; Method 10-115-01-1-A). Water samples for analysis of soluble reactive phosphorus were filtered through a 0.45-µm filter (Gelman Metricel) prior to analysis using automated techniques.

RESULTS: The Weed Roller® was operated at the two treated sites in late May 1999 (i.e., WR-May), and late July 1999 (i.e., WR- July; Figure 2). WR-May ran for 2 to 3 hr a day for several days in late May to clear macrophytes. Thereafter, operation of WR-May occurred once in June and approximately weekly in July through early September to maintain macrophyte control. Hours of operation of WR-May during July through early September ranged between 2 and more than 8 hr. WR-July, started in late July near the time of peak macrophyte biomass, was operated for 4 to 6 hr during consecutive days initially to clear macrophyte growth. Operation thereafter occurred for 4- to 6-hr periods approximately weekly in August through early September.

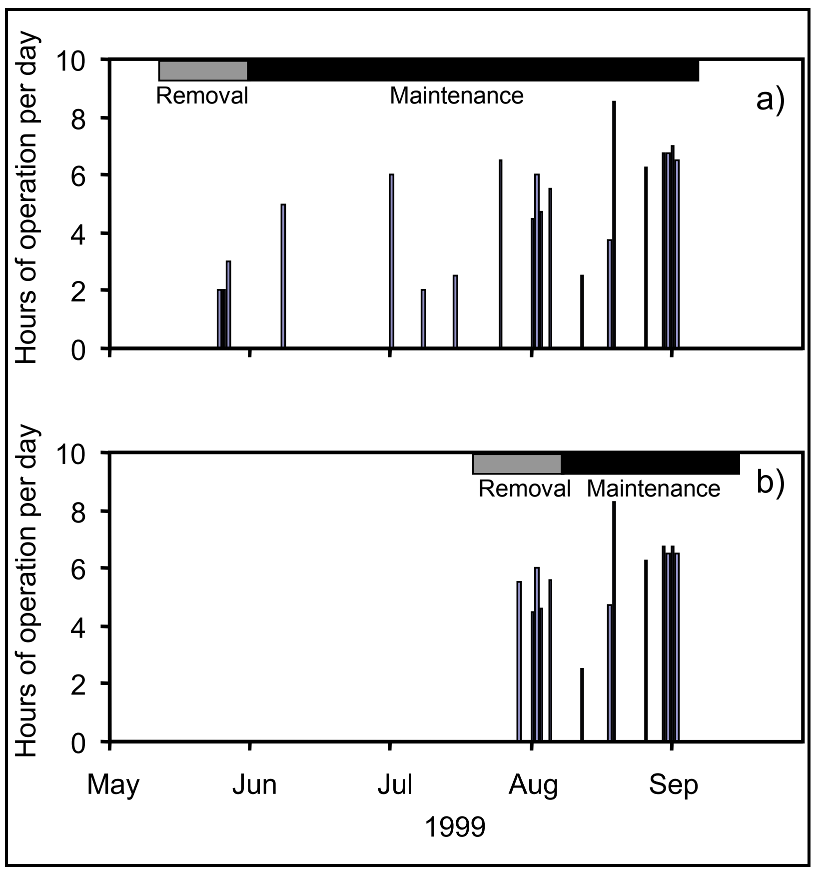

Figure 2. Seasonal variations in the hours of operation for the two treated sites: a) operations initiated in May, and b) operations initiated in July

Overall, WR-May was operated for approximately 98 hr while WR-July was operated for approximately 74 hr.

After 98 hr of Weed Roller® operation, net sediment losses from the treated area were observed on 7 September at the WR-May site between the 5- and 15-ft (1.5- and 4.6-m) interval along all transects while net sediment gains were observed between 25 and 35 ft (7.6- and 10.7-m) (Figure 3). Net sediment gains exceeded 15 cm near the motor; however, they declined with increasing distance along all transects. These patterns were attributed to differences in the buoyancy and vertical position of the roller arm along its axis during operation, which caused it to slant upward, resulting in greatest sediment excavation near the motor. Sediment gains occurring between 30 and 35 ft (9.1 and 10.7 m) along all transects were due to piling up of sediment that was pushed out of the region impacted by the roller arm. Within the impacted area, an overall average loss of 6.3 cm of sediment was observed in the WR-May site.

After 74 hr of Weed Roller® operation at the WR-July site, net sediment losses were observed over the 5- to 25- to 30-ft (7.5- to 7.6- to 9.1-m) interval along all transects (Figure 3). These losses ranged between 1 and 7 cm. Beyond the extent of the roller arm (i.e., approximately 30 ft (9.1 m)), net sediment gains were observed, particularly along the north and west transects, indicating piling up of the sediment that was moved out of the region impacted by Weed Roller® operation. Within the impacted area, an overall average loss of 2.7 cm of sediment was observed in the WR-July site. Minimal net changes in bed sediment elevation occurred in the reference site.

Physical characteristics (moisture content and sediment bulk density) of the surface sediments (i.e., upper 10 cm) at centrally located stations did not change appreciably as a result of Weed Roller® operation (not shown). Although sediment cores collected in the reference, WR-May, and WR-July had a distinct sediment sublayer, it was generally located 25 to 35 cm below the sediment surface. Based on earlier research on Eau Galle Reservoir by Barko et al. (1990), this sublayer was identified as preimpoundment soils, and exhibited a much lower mean moisture content and a higher sediment bulk density. Sediments located above this sublayer were more homogeneous with respect to sediment moisture content. Since the depth of this subsurface sediment layer was located below the depth of maximum excavation via Weed Rollers® observed from examination of changes in bed elevation along transects, the Weed Roller® arm probably did not penetrate to this sublayer. As a result, no differences were observed in mean moisture content and sediment bulk density between Weed Roller® and reference sites in Eau Galle Reservoir, even though net sediment loss was observed in the WR-May and WR-July site. These patterns contrasted with the often marked differences observed for these variables in the surface layer of other Weed Roller® and reference sites located in Minnesota (James et al. 2004). Due to the vertical homogeneity of the surface sediment layer over the 25- to 30-cm depth, mean sediment total N and P concentrations were also similar between the WR-May and WR-July sites, relative to the reference site.

Variations in turbidity, TSS, and P concentrations during Weed Roller® operation are shown in Figure 4 for a 2-hr run (0900 - 1100 hr) at the WR-May site on 9 July. Submersed macrophyte coverage was nearly 100 percent in the reference site. In the WR-May site, macrophyte coverage was nearly zero in most areas affected by Weed Roller® operation. However, there were some sparse areas of macrophyte growth in the WR-May site, primarily in locations where apparent gaps between rollers resulted in failure to dislodge the plants.

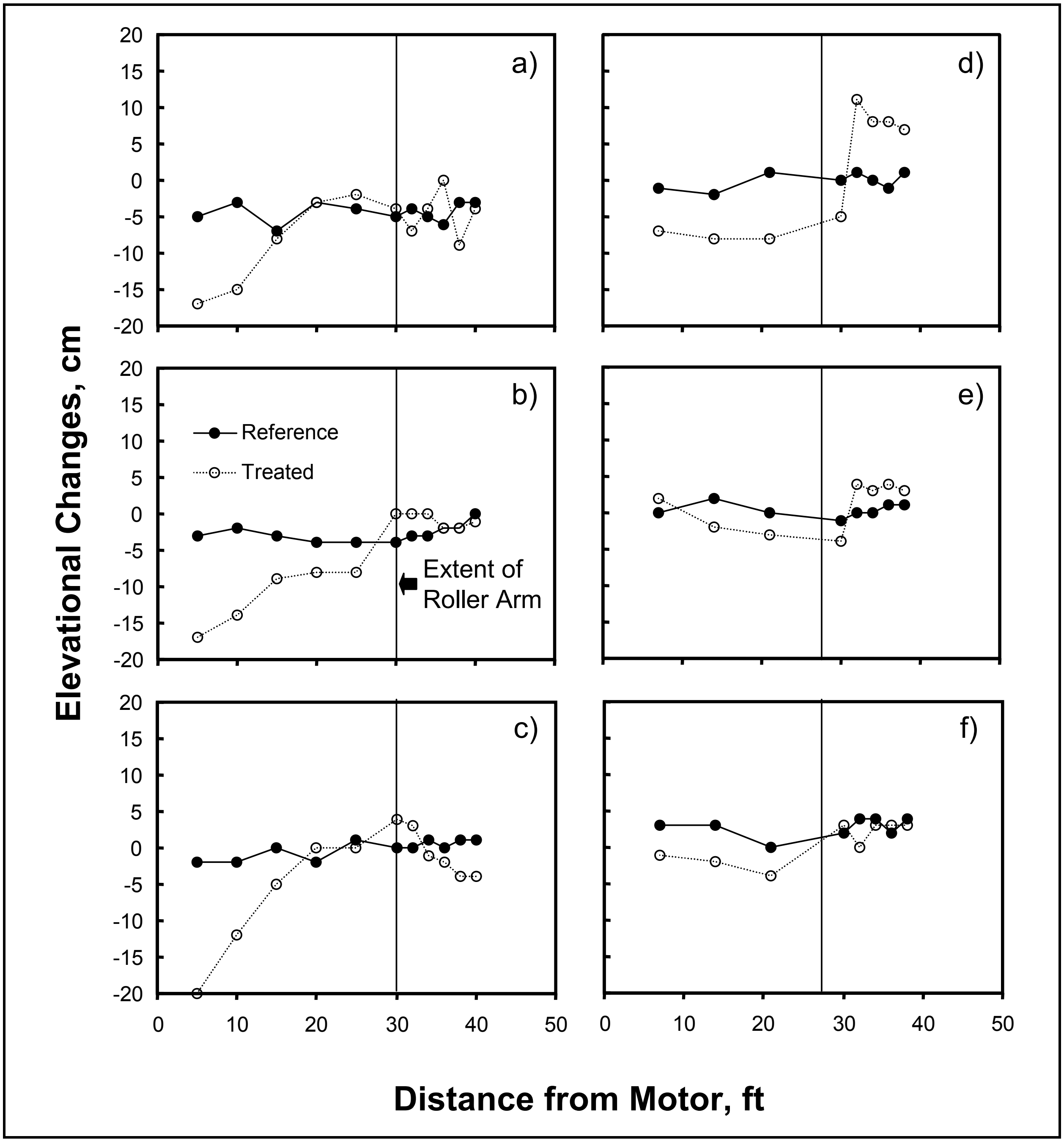

Figure 3. Sediment bed changes as a result of Weed Roller® operation. Values were calculated as the difference between initial (i.e., before operation) and final (i.e., after operation over a summer period) sediment bed elevation. Negative values represent net sediment loss and positive values represent sediment gains. Panels a-c show sediment bed changes for the three transects after 98 hr of operation between May and September. Panels d-f show changes that occurred after 74 hr of operation between July and September 1999

Before initiation of Weed Roller® operations (i.e., prior to 0900 hr), turbidity was near detection limits in both reference and WR-May sites (Figure 4a). During operation of the Weed Roller®, turbidity in the WR-May site was elevated relative to reference values and exhibited periodic peaks in NTU that were associated with movement of the roller arm under the turbidity sensor. During periods when the roller arm was not in the vicinity of the turbidity sensor, values declined in the WR-May site, suggesting some redeposition and/or movement of suspended particles out of the area. With the exception of three peaks in NTU in the reference site, turbidity was near detection throughout the study period. Since TSS and P were low throughout the study (see below) and resuspension was not apparent at the reference site, these peaks in turbidity were probably associated with localized influences such as zooplankton. Shortly after stopping Weed Roller® operations at 1100 hr, turbidity in the WR-May site declined rapidly and approached detection limits.

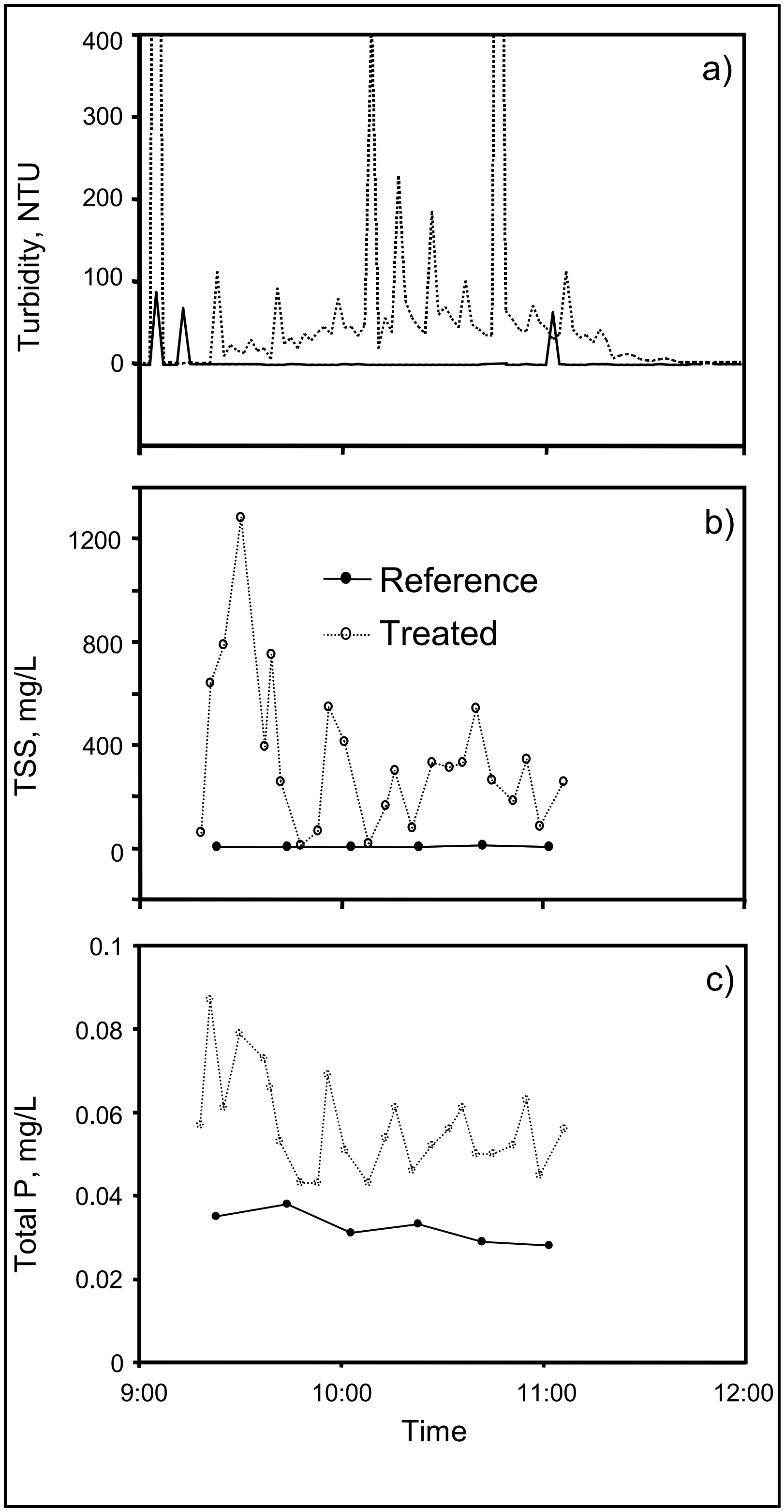

Figure 4. Variations in a) turbidity, b) total suspended solids (TSS), and c) total phosphorus (P) in the reference and treated site during 2 hr of operation on 9 July 1999

Like turbidity, TSS exhibited marked peaks in concentration in the WR-May site during Weed Roller® operations between 0900 and 1100 hr on 9 July (Figure 4b). These peaks were associated with periods when the Weed Roller® arm passed through the sampling station. TSS exceeded 50 mg/L on these occasions and exhibited a maximum value of nearly 1300 mg/L at 0930. In contrast, the reference site exhibited very low TSS throughout the study. During periods when the Weed Roller® arm was not in the vicinity of the sampling station, concentrations declined. Total P was also elevated in the WR-May site during Weed Roller® operations, relative to concentrations observed in the reference site (Figure 4c). Concentrations of total P ranged from 0.043 mg/L to 0.087 mg/L in the WR-May site while they were much lower in the reference site, ranging from 0.028 mg/L to 0.038 mg/L. SRP was generally <0.01 in the reference and WR-May sites during the study period (not shown), indicating that most of the resuspended P was in the particulate form during Weed Roller® operation. However, SRP was higher in the WR-May than in the reference site during operation, suggesting some entrainment of soluble P into the water column or desorption due to equilibrium processes.

DISCUSSION: Similar to results obtained from lakes located in the Fergus Falls-Alexandria and Brainerd region of Minnesota (James et al. 2004), Weed Roller® operation resulted in removal of sediment in treated sites located in Eau Galle Reservoir. Although the hours of operation per summer (i.e., 78 hr for WR-May and 98 hr for WR-July) were low relative to the average of 400 hr of operation per summer recommended by the manufacturer (Crary WeedRoller®; Instructions and Parts Manual), sediment removal by Weed Rollers® was apparent in the Lousy Creek embayment. This pattern was attributed to the very flocculent silty delta deposits associated with the Lousy Creek sub-watershed, which require less energy for removal per hour of operation.

While the fate of sediment removed from Weed Roller® sites cannot be quantified with certainty, results suggested at least two removal mechanisms. The first removal mechanism is physical scraping and excavation of sediments by the roller arm to the sides of the impacted area. From examination of changes in bed elevation in Weed Roller® sites, regions immediately outside of the impacted area were found to exhibit net accumulation of sediment, suggesting piling up of sediment outside the impacted area via roller arm activity. The second mechanism of removal is resuspension of sediment into the water column and removal via hydraulic transport. Roller arm action substantially increased turbidity and TSS in the water column. Much of this resuspended sediment probably became redeposited in nearby shallow regions as suggested by declines in turbidity after passage of the roller arm and after shutdown of the machine. However, wind shear and circulation during Weed Roller® operation could result in transport of a portion of the resuspended sediment to other regions as well.

At treated sites, resuspension of sediment due to the sweeping action of the Weed Roller® arm led to localized increases of nutrient concentrations such as phosphorus in the water column. Resuspension of sediment and nutrients appeared to be the result of the roller arm stirring up sediment as it passed by the water sampling station. Resuspension of P into the water column may stimulate algal growth in localized areas treated by mechanical macrophyte removal devices. Although increases in soluble P were minor in treated sites, P mobilization from resuspended sediment in other aquatic systems will probably vary as a function of sorption kinetics (i.e., adsorption-desorption) between sediment particles and aqueous phases. For instance, in the shallow, wind-exposed Lake Arresø, Søndergaard et al. (1992) estimated that internal P loading via sediment resuspension and desorption was 60-70 mg m^{-2} d^{-1}, or 20 to 30 times greater than internal P loading from undisturbed sediments in the lake. More information is needed regarding resuspension by mechanical macrophyte removal devices as a function of sediment type (i.e., moisture content, sediment bulk density, particle size distribution) in order to predict resuspension potential, transport, and fate in aquatic systems.

Disturbance of sediment substrate, displacement to other regions, and resuspension by mechanical macrophyte removal devices need to be considered by lake managers in their aquatic plant control programs. High usage in the littoral zone could impact fish and invertebrate habitat and lead to enhanced resuspension and recycling of nutrients. Movement of this material to adjacent pelagic regions could stimulate algal growth and impair water clarity. These impacts need to be considered in relation to usage pressure and the area of the littoral zone.

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REFERENCES

Ameel, J. J., Axler, R. P., and Owen, C. J. (1993). "Persulfate digestion for determination of total nitrogen and phosphorus in low nutrient waters," *Amer. Environ. Lab.* (Oct. 1993), 8-10.

American Public Health Association (APHA). (1992) "Standard methods for the examination of water and wastewater,"18th ed.

Barko, J. W., Bates, D. J., Filbin, G. J., Hennington, S. M., and McFarland, D. G. (1984). "Seasonal growth and community composition of phytoplankton in a eutrophic Wisconsin impoundment," *J. Freshwat. Ecol.* 2, 519-533.

Barko, J. W., James, W. F., Taylor, W. D., and McFarland, D. G. (1990). "Effects of alum treatment on phosphorus and phytoplankton dynamics in Eau Galle Reservoir: A synopsis," *Lake Res. Manage.* 6, 1-8.

Godshalk, G. L., and Barko, J. W. (1988). "Effects of winter drawdown on submersed aquatics plants in Eau Galle Reservoir, Wisconsin," *Proceedings: 22nd Annual Plant Control Research Program 16-19 November, 1987, Portland, Oregon*. APCRP Miscellaneous Paper A-88-5, Vicksburg, MS.

James, W. F., Wright, D. I., Eakin, H. L., and Barko, J. W. (2004). "Impacts of mechanical macrophyte removal devices on sediment scouring in littoral habitats: I. Historical survey of operations in Minnesota Lakes," *APCRP Technical Notes Collection* (ERDC/TN APCRP-EA-08), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Plumb, R. H. (1981). "Procedures for handling and chemical analysis of sediment and water samples," Technical Report EPA/CE-81-1. U.S. Army Engineer, Waterways Experiment Station, Vicksburg, MS.

Søndergaard, M., Kristensen, P., and Jeppesen, E. (1992). "Phosphorus release from resuspended sediment in the shallow and wind-exposed Lake Arresø, Denmark," *Hydrobiologia* 228:91-99.

Statistical Analysis System (SAS). (1994). "SAS/STAT users guide, version 6, 4th edition," SAS Institute, Cary, NC.