

Limnological Characterization of the Tristate Oxbow Wetland (Ohio, Indiana)¹

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ABSTRACT. We conducted a limnological study in bodies of water (Oxbow Lake, North Pond, Great Miami River, Ohio River) comprising the Tristate Oxbow Wetland region of southwestern Ohio and southeastern Indiana. This wetland, an extensive and important wildlife habitat located at the confluence of the Great Miami River and the Ohio River, is a region that has been and may in the future be impacted by industrial and commercial development. The present data suggest that Oxbow Lake and North Pond are strongly influenced by seasonal flooding patterns and resultant nutrient loading from the Great Miami River and the Ohio River. On the basis of physico-chemical and biological parameters, Oxbow Lake can be classified as a eutrophic to hypereutrophic system, while North Pond is mesotrophic to eutrophic.

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INTRODUCTION

During the past 200 years, approximately 90% of the original wetland acreage present in Ohio has been lost to agricultural, residential, and commercial development; similar loss rates have occurred in Indiana (World Resources Institute 1992). Wetlands are important landscape units in terms of biological productivity, wildlife habitat, and flood control (Mitsch and Gosselink 1993). Oxbow lakes and associated riverine floodplain habitats are common features of large, meandering rivers, and represent important wetland resources.

The majority of modern limnological data on oxbow lake formations has been produced in studies from the southeastern United States (Joo and Ward 1990a,b). Although meanders in the Ohio River and Great Miami River have produced numerous oxbow lakes, we are aware of no published limnological data on these systems or similar systems in the Midwest.

The Tristate Oxbow Wetland, located at the confluence of the Great Miami River and the Ohio River in southwestern Ohio and southeastern Indiana, encompasses a large wetland area long recognized for its biological diversity and importance as a breeding ground for resident and migratory waterfowl. Oxbow, Incorporated, a private conservation group, has worked in tandem with governmental entities and private landowners to establish and implement a highly successful conservation plan for this wetland. The potential ecological impact of riverboat gambling facilities to be sited on the Ohio River in close proximity to the Oxbow Wetland has focused renewed media and scientific attention on these conservation efforts.

In 1991 and 1992, we undertook a limnological study of water bodies within the Tristate Oxbow Wetland aimed at providing baseline data for future conservation efforts. General findings of this study and their potential impact on conservation planning have been

reported previously (Joo and Francko 1992, Francko and Joo 1994). Here we present and analyze comprehensive data sets on limnological variables of central importance to phytoplanktonic productivity and water quality.

MATERIALS AND METHODS

Study Area

The Tristate Oxbow Wetland is located at the confluence of the Great Miami River and the Ohio River (39° 05' N, 84° 45' W). The total area of the wetland is about 3,000 acres (12.14 km²). Approximately 40% of the Oxbow lies in Ohio, with 60% in Indiana (Fig. 1). The

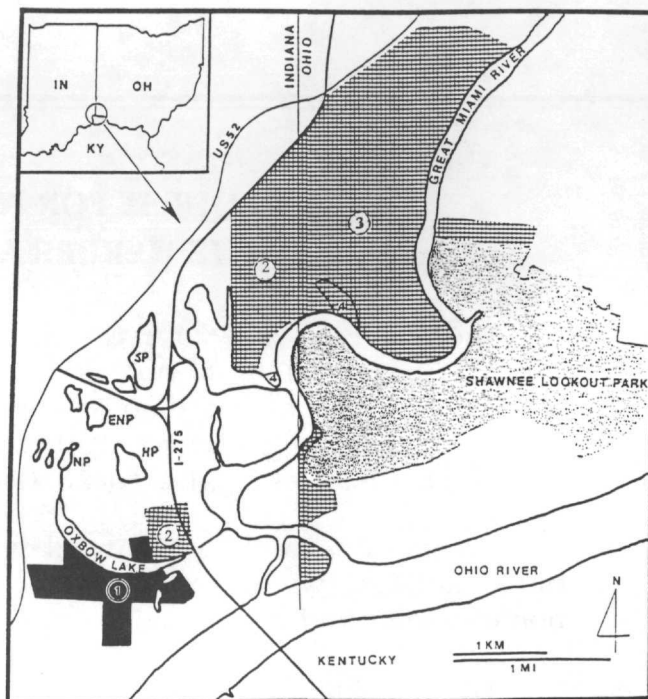


FIGURE 1. The Oxbow Wetland in Tristate area (Ohio, Indiana, Kentucky). Numbers denote land status as of period of study: 1) Oxbow, Inc. ownership; 2) Oxbow, Inc. conservation easement; 3) Hamilton County Park District (OH) conservation easement; 4) Indiana Department of Natural Resources and Ohio Department of Natural Resources ownership. "NP" denotes North Pond.

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Oxbow region has been utilized by humans since pre-historic times and permanent settlement in the late 18th century has resulted in gradual conversion of bottom-land into agricultural land. Corn and soybeans are the major cash crops grown in the floodplain. In 1977, an interstate highway (I-275) and its interchanges were built through the heart of the wetland. During highway construction many gravel pits (3-11 m deep) were created. During periods of high water, almost all bodies of water are interconnected through pipes under the highway. Second-growth riparian and upland forest communities surround bodies of water on non-agricultural land.

Limnological Methods

Precipitation and temperature data (30-year monthly means and 1991-1992 data) were obtained from the Cincinnati-Northern Kentucky Airport Station, KY (National Oceanic and Atmospheric Administration; 16 km SE of the wetland). Water levels were measured at Oxbow Lake, and Ohio River water levels (approximately 40 km downstream of the study site) were obtained from the National Weather Service, Cincinnati, OH.

Physico-chemical parameters in Oxbow Lake, North Pond, and the Great Miami River were measured at two to three week intervals from April 1991 to April 1992. During flooding events, some parameters were measured weekly to monitor the duration and effect of flooding on water chemistry. Conductivity was measured using a Fisher conductivity meter. Alkalinity was measured using a titration method (0.02 N H_2SO_4 to an end point of pH 4.5). The Winkler method was used for the measurements of dissolved oxygen (Wetzel and Likens 1991) and an Orion Model 407A pH meter was used to measure pH. Nutrient concentrations (NO_3^- -N, NH_4^+ -N, and PO_4^{3-} -P) were determined by filtering (0.45 μm Whatman GF/F filters) water samples and freezing the filtrates, which were later analyzed with a QuickChem Automated Ion Analyzer (Lachat Instruments). Nitrate (QuickChem Method No. 10-107-04-1-B), ammonium (QuickChem Method No. 10-107-06-1-F), and soluble reactive phosphorus (SRP) (QuickChem Method No. 10-115-01-1-B) concentrations were determined on replicate filtered water samples. Detection limits of nutrients using these assays were approximately 1 $\mu g/l$ for nitrate-N, 5 $\mu g/l$ for ammonium-N, and 2 $\mu g/l$ for orthophosphate-P, with a standard deviation of ca. 12% over the concentration range used for standard curves (0-500 $\mu g/l$).

Water samples were also collected from the 0.1-m strata for determination of chlorophyll *a* concentrations. Samples (50-200 ml) were filtered through 0.45 μm cellulose acetate filters (Millipore) and stored frozen until analyzed. Chlorophyll *a* was determined spectrophotometrically using a monochromatic method (Wetzel and Likens 1991). Phytoplanktonic net primary productivity was measured *in situ* through an oxygen evolution method using replicate light bottles and a dark bottle control. Changes in dissolved oxygen in each bottle were measured using a previously described Winkler method (Wetzel and Likens 1991). Incubations of bottles at the surface of the lake were usually conducted from 11:00 AM to 1:00 PM.

RESULTS

Climatological data indicated that 1991-1992 mean monthly temperatures and precipitation were slightly above and below, respectively, 30-year monthly mean values. Despite somewhat lower than normal rainfall, annual water level changes in the Oxbow Wetland ranged over 3 m during the two-year observation (Fig. 2a). Water levels in Oxbow Lake generally rose and fell in concert with Ohio River levels. Most of the high water period occurred between December and April. Small changes in water level led to a large area of inundation, especially on the concave side of Oxbow Lake, which grades into an agricultural field with little topographic relief. The land between Oxbow Lake and the nearby gravel pit (North Pond) was also inundated during both spring seasons. By May of both 1991 and 1992, water within the floodplain had emptied into the confluence of Miami and Ohio River, primarily through a marsh and channel on the east side of Oxbow Lake (Fig. 1). Throughout the summer and fall of 1991 water levels in Oxbow Lake dropped continuously until late November, from a maximum depth of ca. 1 m in May to about 30 cm in November. North Pond has a maximum depth of ca. 6 m in late spring, but only about 4 m by late fall.

Thus, hydrologic data suggested that, during late winter-spring flood events, considerable exchange of

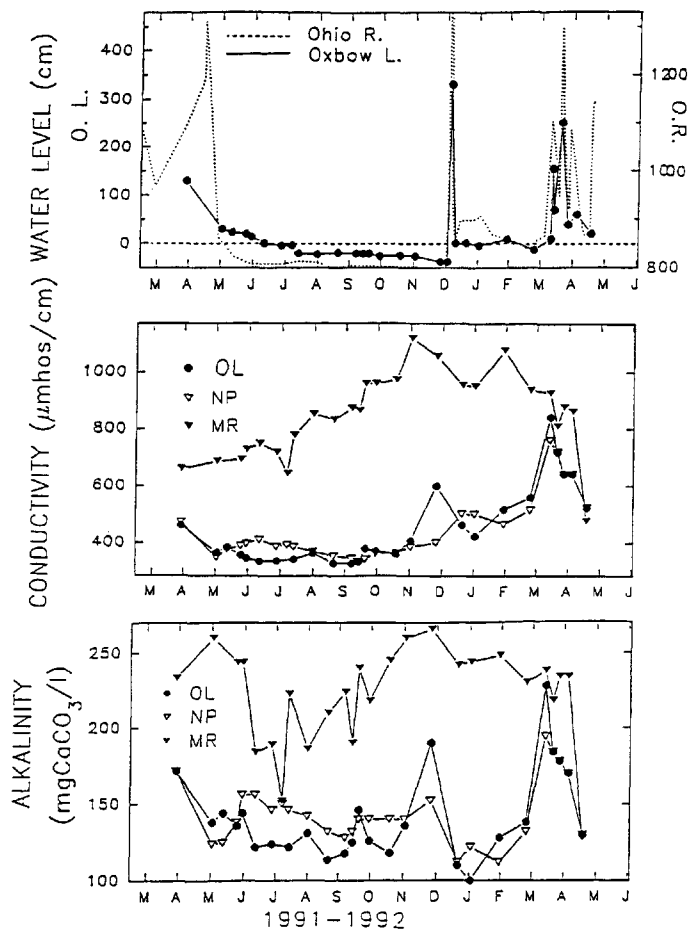


FIGURE 2. Seasonal changes in physico-chemical parameters in Oxbow Lake (OL), North Pond (NP), the Great Miami River (MR), and the Ohio River (OR). Top panel = water level, middle panel = conductivity, bottom panel = alkalinity.

water occurred between Oxbow Lake/North Pond and the Ohio River/Great Miami River confluence, whereas during the rest of the year the former water bodies were isolated from riverine water inputs. Water temperature measurements (data not shown) indicated that shallow Oxbow Lake did not undergo summer or winter thermal stratification. Weak summer thermal stratification and winter circulation above 4° C occurred in North Pond, consistent with its classification as a warm, monomictic lake type (Wetzel 1983).

A summary of 1991–1992 mean, standard deviation, and range values for physico-chemical and biological data from Oxbow Lake, North Pond, and the Great Miami River is shown in Table 1. Such summary data support the view that Miami River water contained more suspended solids and dissolved ions than either of the lakes within the Oxbow Wetland and that, with the exception of mean values for PO₄-P, NH₄-N, and chlorophyll *a*, North Pond and Oxbow Lake were similar systems.

However, cumulative mean values may mask trends evident during the course of the study period. Seasonal patterns in physico-chemical data appeared to support the hydrologic exchange model above. Conductivity in

Oxbow Lake and North Pond was much lower than the Miami River during the growing season (Fig. 2b); during flooding events in March and April 1992 conductivity in all three water bodies became similar. Similar seasonal patterns were noted in alkalinity values (Fig. 2c). The Great Miami River showed the highest alkalinity throughout the year, with Oxbow Lake and North Pond values increasing to levels similar to those of the Great Miami River during spring 1992 flooding. An increase in alkalinity at Oxbow Lake in December 1991 may also have resulted from floodwater influx.

Although hydrologic events also appeared to influence dissolved nutrient concentrations in Oxbow Lake and North Pond, seasonal correlations were less clear. Soluble reactive phosphorus (SRP) levels were generally high (range 10–2,900 µg/l) in both the lakes (Fig. 3a). During the growing season, Oxbow Lake maintained a relatively high SRP concentration. After the flooding events in December, SRP concentration declined sharply. Patterns of annual changes in SRP concentration at the North Pond were somewhat opposite of Oxbow Lake; growing season SRP concentrations varied between 10 and 20 µg/l, with elevated concentrations noted in

TABLE 1

Means, standard deviations, and ranges of limnological parameters in Oxbow Lake, North Pond, and the Great Miami River during 1991–1992.

	Unit	Oxbow Lake	North Pond	Miami River
Temperature	°C	14.8 ± 9.7 (2 - 29) n = 22	16.4 ± 9.8 (3 - 30) n = 22	nd
pH		8.27 ± 0.53 (7.1 - 9.3) n = 26	8.3 ± 0.56 (6.7 - 9.1) n = 27	8.52 ± 0.42 (7.8 - 9.2) n = 26
Conductivity	µmhos/cm	449 ± 139 (325 - 840) n = 26	446 ± 118 (331 - 760) n = 27	846 ± 149 (476 - 1118) n = 26
Alkalinity	mg CaCO ₃ /l	141 ± 29 (100 - 228) n = 26	144 ± 20 (112 - 194) n = 27	222 ± 33 (128 - 266) n = 26
Dissolved oxygen	mg/l	8.2 ± 4.2 (1.4 - 14.8) n = 19	10.8 ± 3.1 (3.6 - 14.8) n = 18	nd
Dissolved oxygen	% sat.	77 ± 35 (17 - 162) n = 19	113 ± 41 (27 - 187) n = 18	nd
PO ₄ -P	µg/l	50.2 ± 28.8 (4 - 96) n = 11	315 ± 906 (8 - 2895) n = 11	nd
NO ₃ -N	µg/l	411 ± 712 (0 - 2327) n = 11	437 ± 759 (7 - 2327) n = 11	nd
NH ₄ -N	µg/l	253 ± 602 (0 - 2041) n = 11	98 ± 160 (0 - 470) n = 11	nd
Chl <i>a</i>	µg/l	71 ± 80 (5 - 287) n = 23	13 ± 10 (1 - 47) n = 23	39 ± 30 (4 - 88) n = 20
Net Primary	mgC/m ³ /h	725 ± 729 (34 - 2459)	430 ± 429 (34 - 1488)	nd
Productivity		n = 14	n = 13	

n indicates sample size; nd = not determined.

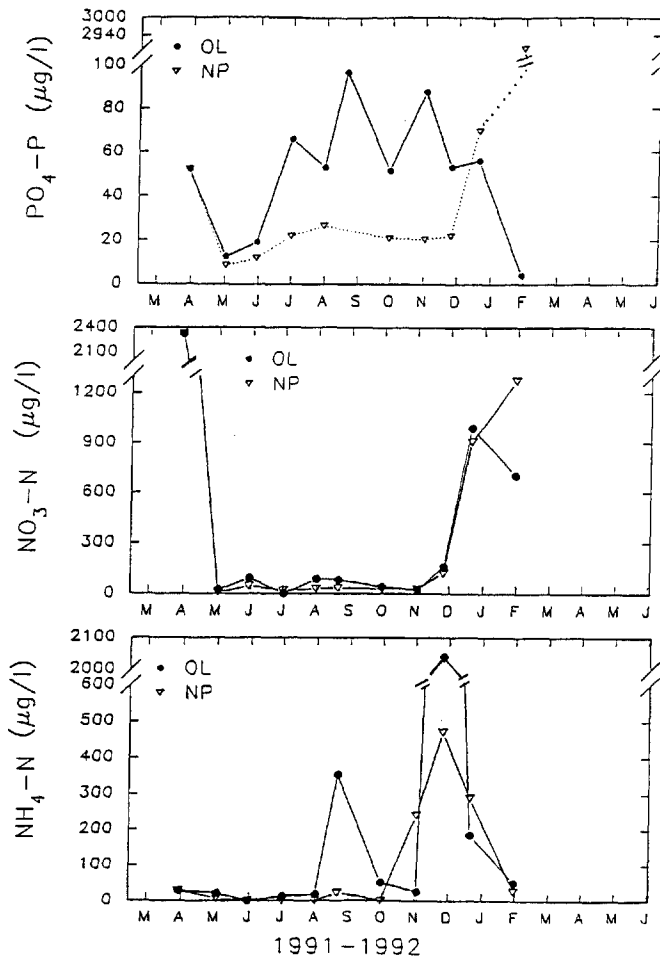


FIGURE 3. Seasonal changes in PO_4-P ($\mu g/l$; top panel), NO_3-N ($\mu g/l$; middle panel), and NH_4-N ($\mu g/l$; lower panel) in Oxbow Lake (OL) and North Pond (NP).

spring 1991 and following the December 1991 flood. Given that the December 1991 flood was a short-duration event, with water levels quickly dropping in January and February of 1992, the source of high SRP in February was not clear, but SRP washed into North Pond from the surrounding agricultural land may have remained in the water column during the winter months.

Nitrate concentrations in surface waters were near the limits of detection during much of the growing season (Fig. 3b). Flooding events in spring 1991 and December 1991 caused overall increases in nitrate concentration in both Oxbow Lake and North Pond. Ammonia concentrations were fairly low during summer, and sharply increased with the December 1991 flooding event, but not spring 1991 flooding (Fig. 3c). Late August 1991 water from Oxbow Lake, but not North Pond, was also high in ammonia. The source of this high ammonia and nitrate was likely the Ohio River and run-off from agricultural land within the floodplain. Similar nitrogen loading patterns phenomena have been observed in other oxbow lakes (Joo 1990).

The above nutrient data would classify Oxbow lake and North Pond as eutrophic and mesotrophic-eutrophic lake systems, respectively (Wetzel 1983). These trophic index values were also supported by data reflective of phytoplanktonic and bacterial metabolism. For example,

Oxbow Lake water contained consistently less oxygen (absolute and % saturation) than North Pond at mid-day during the growing season (Fig. 4a). However, during winter and spring flooding, oxygen levels at both sites increased and remained almost identical. Supersaturated oxygen levels in North Pond surface waters during the summer stratification period would likely have been caused by high photosynthetic activity in epilimnion (see Fig. 4c).

Algal biomass as estimated by seasonal change in phytoplankton chlorophyll *a* was high during the growing season in the Great Miami River and in Oxbow Lake (Fig 4b). Summer chlorophyll *a* concentrations in both systems would place them in the eutrophic to hypereutrophic range (Wetzel 1983). In North Pond, seasonal changes in chlorophyll *a* were less pronounced and growing season concentrations were consistent with a mesotrophic productivity status. Diatoms and euglenoids (especially the genera *Euglena*, *Trachelomonas*, and *Strombomonas*) were the dominant algal taxa throughout the year in both Oxbow Lake and North Pond. Diatoms dominated in the spring, but diatoms and euglenoids codominated throughout the rest of growing season.

Summer primary productivity values for both Oxbow Lake and North Pond would classify these systems

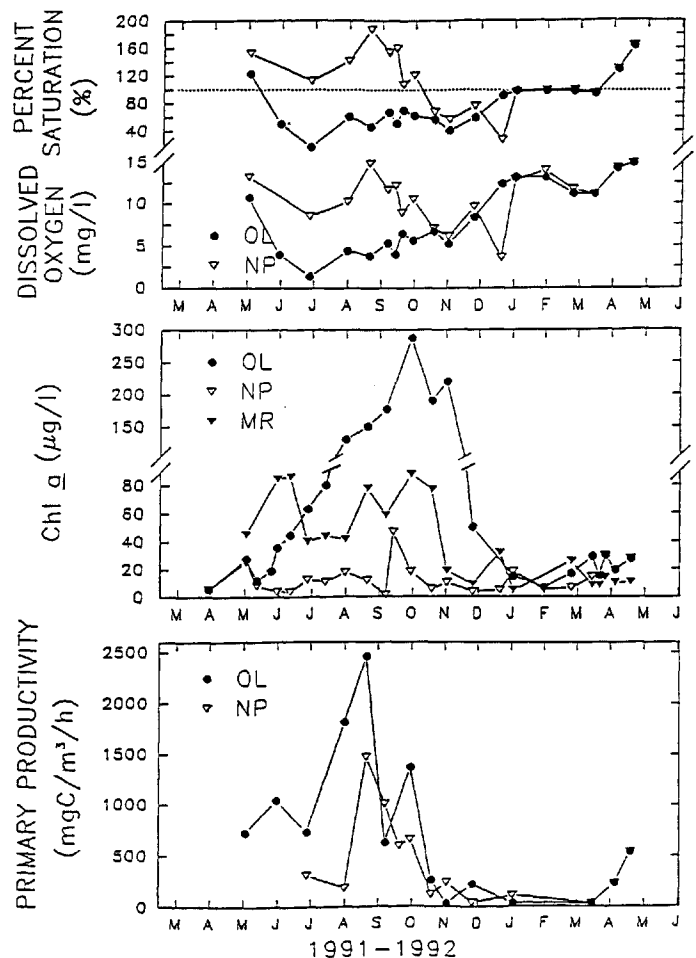


FIGURE 4. Seasonal changes in dissolved oxygen (top panel), chlorophyll *a* concentrations (middle panel), and primary productivity rates (lower panel) in Oxbow Lake (OL), North Pond (NP), and the Great Miami River (MR).

as eutrophic (Fig. 4c). In Oxbow Lake, seasonal productivity maxima occurred in the spring, summer, and fall, a pattern typical of temperate dimictic lakes, although this shallow system did not stratify and experience overturn events. A similar seasonal pattern was noted in North Pond, but overall productivity values were lower during the summer and fall seasons.

DISCUSSION

The limnological characteristics of Oxbow Lake and North Pond were influenced by yearly flooding events and patterns of run-off from agricultural lands, in a pattern similar to that noted in oxbow lakes of the southeastern U.S. (Joo and Ward 1990a,b). Ohio River and Great Miami River waters laden with agricultural run-off inundated the wetland during seasonal flooding, resulting in ionic and nutrient loading to Oxbow Lake and North Pond. During non-flooding periods, physico-chemical parameters in North Pond and Oxbow Lake differed from those of the adjacent river system, perhaps through that biotic utilization and abiotic mineralization processes.

Nutrient concentrations and various biological indicators support the view that Oxbow Lake represents a eutrophic to hypereutrophic system, whereas North Pond is mesotrophic to eutrophic. Data on mean nitrogen and phosphate concentrations (Table 1) reveal that, for the 1991–1992 sampling period as a whole, the N:P ratios in surface waters of both Oxbow Lake and North Pond were low (ca. 13:1 and 2:1, respectively). During the summer the N:P ratio was even lower (ca. 1:1). Such values are associated with nitrogen-limited systems (Wetzel 1983), suggesting that increased nitrogen loading from seasonal flood events could stimulate additional productivity.

Highly productive aquatic systems with euglenoid dominance are rarely reported except in well-developed oxbow lakes of the southeastern U.S. (Joo 1990). Conforti and Joo (1994) conducted a taxonomic and systematic study of phytoplankton in Oxbow Lake and three oxbow lake systems in Alabama. Of the 79 reported species of the Euglenophyte genera *Trachelomonas* and *Strombomonas*, 17 represented new taxa and 26 represented new records for the U.S. Oxbow Lake was by far the most diverse of the four oxbow lakes examined, with 73 of the 79 species present.

There are several possible mechanisms behind the success of diatom and euglenoid communities in the very shallow and turbid (Secchi depths <0.5 m; data not shown) Oxbow Wetland. Since Oxbow Lake is long and slender in shape, winds over the lake continuously create turbulence and supply silica from sediments. Thus, diatoms, which require high light levels and silica, could overcome light and silica limitation. Euglenoids with flagella can take advantage of their motility to move higher into the water column. In addition, they have

heterotrophic mode of organic food acquisition in organically-enriched environments.

The low levels of dissolved oxygen we noted during the non-flooding period in Oxbow Lake, despite high photosynthetic oxygen production rates noted at the same time, may have been caused by its shallowness and by high heterotrophic metabolism. As oxbow lake systems age, organic matter input and land-water interaction generally increase because of an increased area of surrounding wetland and vegetation (Joo 1990). Oxbow Lake is approximately 150 years old (Conforti and Joo 1994), very shallow, and has a thick organic sediment layer at the bottom, a combination of factors that would promote heterotrophic consumption of oxygen through the oxidation of organic matter, resulting in lower % oxygen saturation in surface waters than might be inferred from primary productivity values.

In summary, our data suggest that the functional ties between riverine and wetland systems in the Tristate Oxbow Wetland play a crucial role in regulating the physico-chemical and biological features of Oxbow Lake and North Pond, resulting in a wetland supporting a highly diverse Euglenophyte flora. Our data also suggest that future changes in riverine hydrology and/or nutrient loading processes could affect the productivity of both Oxbow Lake and North Pond.

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