Report for 2002IA9B: Evaluating the effectiveness of restored wetlands for reducing nutrient losses from agricultural watersheds

There are no reported publications resulting from this project.

Report Follows:

Nontechnical Summary

This study examined the effectiveness of recent wetland restorations and land use conversions for reducing nutrients in agricultural runoff in the Iowa Great Lakes watershed. It had two major research objectives: (1) to monitor nutrient concentrations in the inputs and outputs of restored wetlands to see how effective they are as nutrient sinks, and (2) to monitor nutrient concentrations in the outflow of subwatersheds differing in the extent of wetland restoration and set-aside acreage to determine if these differences have significantly reduced the levels of nutrients in subwatershed outflows. A review of available data on the 278 restored wetlands indicates that runoff from, at most, about 20% of the upland areas in the Iowa Great Lakes watershed passes through restored wetlands. In addition, the wetland restorations are located primarily in areas that are no longer cultivated, and, consequently, most of the wetlands do not receive significant agricultural runoff. Where they do receive agricultural drainage, the restored wetlands were effective sinks for total nitrogen (TN), but their effectiveness as sinks for total phosphorous (TP) is less clear. For subwatersheds, restoring wetlands and taking uplands out of crop production reduces the concentrations of total nitrogen in their outflows significantly, but effects on total phosphorus are unclear.

Project Goals and Objectives

Water quality data from the Iowa Great Lakes indicates that concentrations of nutrients in these lakes have not declined as a result of the restoration of hundreds of wetlands in the watershed. Why restoring wetlands has not lowered nutrient concentrations in the Iowa Great Lakes is the overarching goal of this study. This study investigated two possible reasons why restored wetlands may not be effective nutrient sinks: (1) Restored wetlands may not yet have the nutrient removal capacity of natural wetlands; and (2) the restored wetlands in the watershed may not intercept sufficient nutrient runoff to significantly impact overall nutrient inputs into the lakes.

The four specific objectives of the study were:

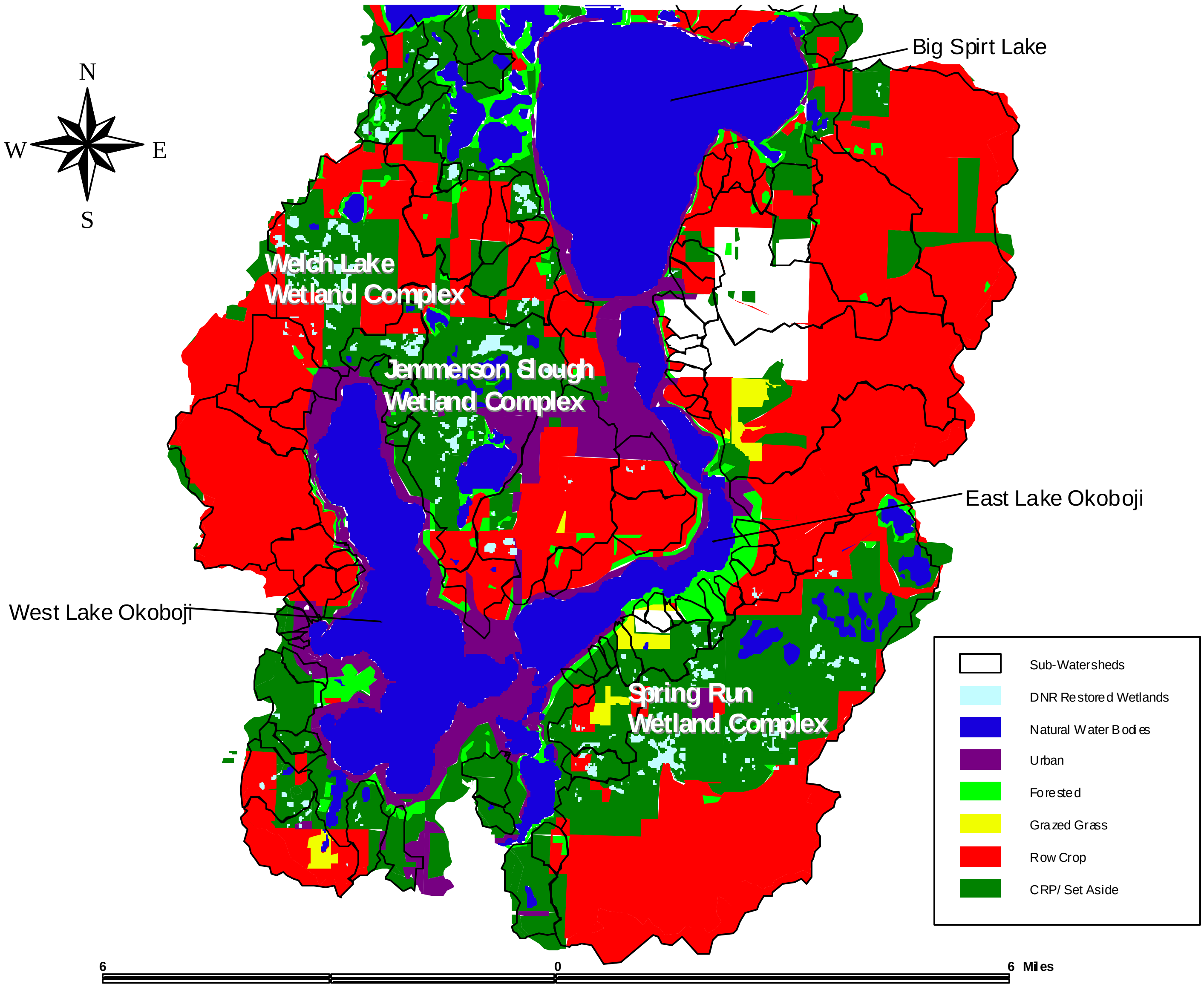
(1) To determine the number, location, and size of the restored wetlands in the Iowa Great lakes watershed.
(2) To determine the composition, abundance, and distribution of the vegetation and biomass of living and dead vegetation in selected restored wetlands.
(3) To estimate nutrient removal capacity of selected restored wetlands by measuring nutrient input and output concentrations.
(4) To measure the nutrient losses from subwatersheds primarily in row crops with and without restored wetlands.

Results

(1) Restored Wetland Inventory. All available data on restored wetlands in the Iowa Great Lakes watershed were obtained from the Dickinson County offices of the Iowa Department of Natural Resources and the Natural Resources and Conservation Service of the USDA. Information available about these restored wetlands was highly variable and often very limited. Digitized land-use and topographic maps of the watershed were used to collect data on the location, area, and catchment size of each restored wetland (Figure 1).

By the end of the summer of 2002, there were 278 restored wetlands in the Iowa Great lakes watershed. For the most part, these restored wetlands were found in clusters or complexes on large tracts of land managed by the Iowa Department of Natural Resources. In these areas, the uplands have mostly been taken out of row crops and converted to some type of perennial grassland. The total area of these 278 restored wetlands is only 360 ha (888 acres) or 1.2% of the upland area of the Iowa Great Lakes watershed. The total area of the potential catchments of these restored wetlands is about 6,429 ha (15,873 acres) or 21.5% of the upland area of the Iowa Great Lakes watershed. This represents the maximum area of the potential catchments of these 278 wetlands and was derived from an analysis of terrain models. The actual catchments undoubtedly have a smaller area. In short, most of the restored wetlands in the watershed are small (ca. 1.3 ha or 3.19 acres) and they are located primarily in a small number of publicly owned areas that are no longer in row crops. Consequently, most of these wetlands do not intercept significant amounts of agricultural runoff.

Figure 1. Map of the Iowa Great Lakes Region with land use practices, delineated subwatersheds, and restored wetlands shown.



(2) Vegetation of Restored Wetlands. To investigate whether the state of development of restored wetlands affects their capacity as nutrient sinks, five restored wetlands were selected for monitoring and detailed sampling of their vegetation. Finding suitable wetlands whose nutrient inputs and outputs could be monitored proved difficult. An analysis of available records for restored wetlands eliminated the majority of them from consideration. Most of the wetlands received little or no agricultural runoff and lacked well-defined inputs and outputs that could be sampled. Of the 278 sites examined only about 30 were identified in preliminary screening as potential study sites. Of these 30 wetlands, the five that could be most reliably sampled were selected based on site evaluations. The selected wetlands ranged in size from 0.313 ha (0.773 acres) to 3.59 ha (8.865 acres), and their catchments ranged from 14.6 ha (36 acres) to 114.5 ha (283 acres).

In the summer of 2001, sampling of the vegetation and standing crop of the five selected restored wetlands was initiated. Each wetland was divided into a series of parallel zones and each zone was sampled using a randomly located transect in the zone. Samples were collected in quadrats placed at random intervals along these transects. The cover of each species in each 1m x 1 m quadrat was recorded and then all aboveground vegetation clipped and bagged. All standing crop samples were oven dried and weighed. Tables 1 and 2 summarize the vegetation data for each of these five wetlands. In general, their vegetation was similar and dominated by a small number of common wetland species. The vegetation of four of the five wetlands was dominated by *Phalaris arundicnacea* (reed canary grass) and *Typha glauca* (cattail). The vegetation of the fifth wetland (wetland 8), which was a dammed up stream and deeper than the others, was dominated by submerged aquatics, *Potamogeton* spp. (pondweeds). Other common species were *Scirpus fluviatilis* (great river bulrush) and *Scirpus validus* (soft-stem bulrush). Although there were submerged aquatic and emergent zones in these wetlands, they were not as dense or species rich as those found around comparable extant prairie potholes in NW Iowa.

The mean standing crop or biomass in restored wetlands ranged from 40 to 735 g/m^2 and averaged 430 g/m^2 (Table 1). This is considerably lower than standing crops found in natural wetlands in northern Iowa, ca. 600 to 1,000 g/m^2. The standing dead component of the vegetation was again dominated by *Phalaris*, *Typha* , and *Scirpus* species. The standing dead or necromass ranged from 23 to 393 g/m^2 and averaged 260 g/m^2 (Table 2).

(3) Restored Wetland Nutrient Inputs and Outputs. In the five wetlands whose vegetation was sampled, nutrient concentrations of inputs and outputs were estimated weekly using grab samples in 2001 and 2002. All of the water samples collected were analyzed for total nitrogen (TN) and total phosphorous (TN) using standard methods.

Table 3 summarizes the annual input and output concentrations of TN and TP. The overall mean input concentration of TN for all five wetlands over both years was 19.0 mg/l while the mean annual output concentration was 2.93 mg/l. This is a mean reduction in TN concentrations of about 85%. However, wetland catchments were too small and flows were too low and variable to estimate mass loading to the wetlands or mass reductions by the wetlands during the study period. Only 2 of the 5 wetlands received flow for more than a few weeks after sampling was initiated in 2001, and there was little flow entering any of the wetlands during 2002 due to drought conditions. Two of the wetlands had no outflow at all during 2002. Although it is clear that all five wetlands reduced TN significantly over both years, it is not clear whether they significantly affected TP. The overall mean total phosphorus concentration in the inputs of these five restored wetlands was 0.189 mg/l and the overall mean concentration in the outputs was 0.108 mg/l. However, inflow and outflow TP concentrations were too variable to draw any conclusions regarding reductions.

There is no correlation between nutrient reduction and either living or dead biomass. For example, wetland 8, whose total biomass was only 40 g/m^2, and wetland 16, whose biomass was 735 g/m^2, in 2001 had TN reduction of 83% and 87%, respectively. Nothing in our data suggests that the nutrient removal capacity of restored wetlands is limited because they do not yet have comparable vegetation or biomass to that of the extant wetlands in the region.

Table 1. Percent frequency of the most common species found in restored wetlands and their mean total biomass.

Species	Wetland 1	7	8	12	16
			Submerged Species		
Ceratophyllum demsersum	53%	30%	0%	7%	8%
Lemna minor	7%	11%	0%	33%	56%
Lemna trisulca	13%	21%	0%	21%	0%
Myriophylum spicatum	40%	14%	0%	42%	2%
Potamogeton spp.	33%	49%	83%	18%	25%
			Emergent Species		
Alisma plantago-aquatica	0%	4%	0%	4%	0%
Eleocharis palustris	0%	8%	0%	2%	0%
Leersia orryzoides	13%	1%	3%	2%	0%
Phalaris arundinacea	60%	6%	20%	40%	81%
Sagittaria latifolia	0%	4%	3%	1%	0%
Scirpus fluviatilis	33%	14%	0%	7%	2%
Scirpus validus	40%	30%	3%	1%	19%
Sparganium eurycarpum	7%	0%	15%	1%	2%
Typha glauca	20%	93%	0%	33%	65%
			Other Species		
Asclepias incarnata	7%	1%	0%	0%	4%
Carex spp.	7%	0%	3%	0%	2%
Cirsium arvense	7%	25%	8%	0%	2%
Mentha arvensis	13%	3%	0%	0%	0%
Polygonum spp.	0%	34%	0%	1%	2%
Minor species	0%	0%	0%	2%	0%
Number of Quadrats	15	71	40	84	48
Mean biomass (g/m^2)	452	412	272	40	735
Basin Area (acres)	0.77	4.70	1.87	8.33	3.66

Table 2. Percent frequency of standing dead species and their mean total necromass.

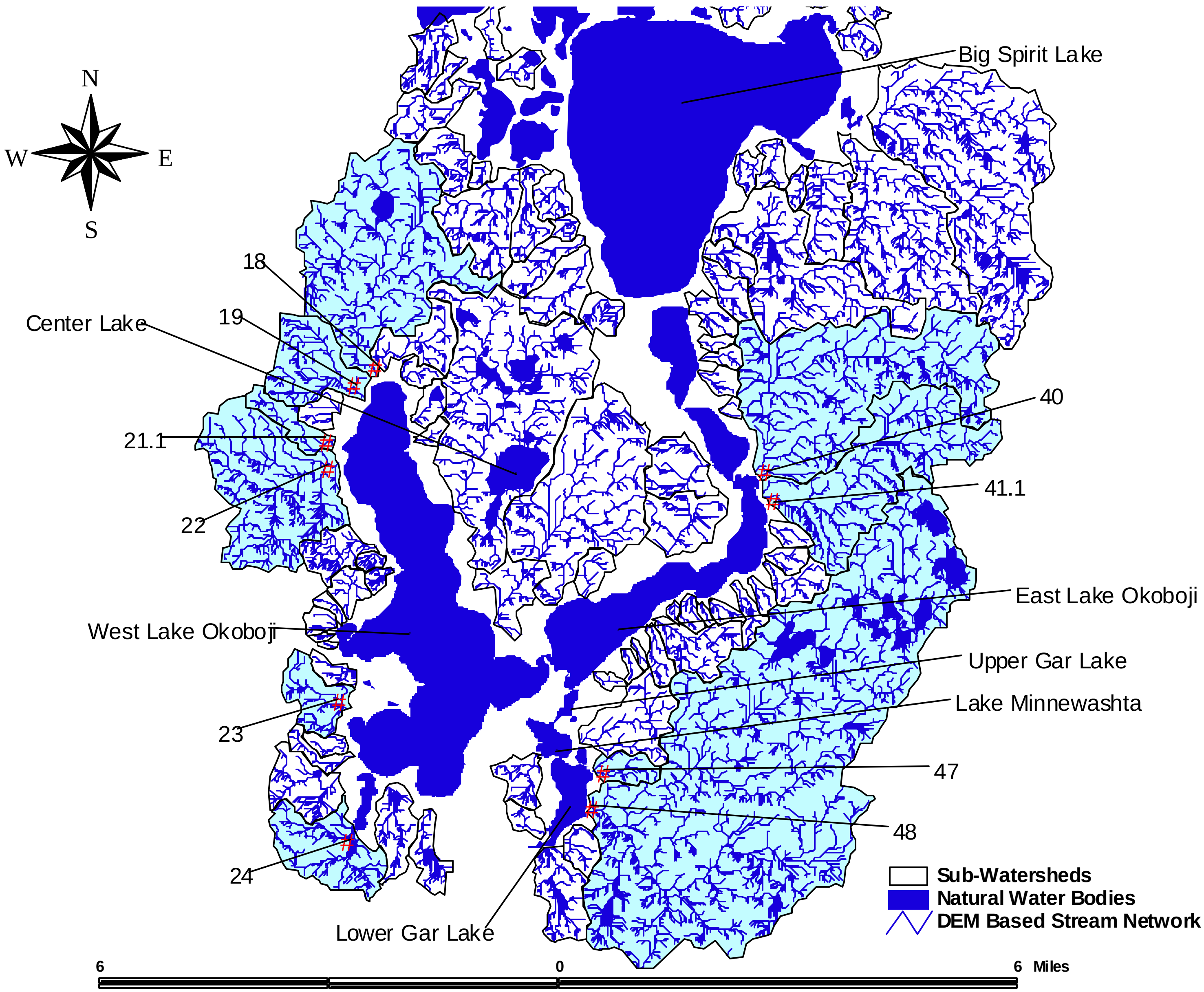
Species	Wetland 1	7	8	12	16
			Submerged Species		
Ceratophyllum demsersum	0%	1%	0%	0%	0%
Lemna minor	0%	0%	0%	0%	2%
Myriophylum spicatum	0%	0%	0%	1%	0%
Potamogeton spp.	0%	0%	0%	1%	0%
			Emergent Species		
Alisma plantago-aquatica	0%	0%	0%	1%	0%
Eleocharis palustris	0%	3%	0%	0%	0%
Leersia orryzoides	7%	0%	0%	1%	0%
Phalaris arundinacea	13%	0%	5%	32%	75%
Scirpus fluviatilis	13%	7%	0%	1%	2%
Scirpus validus	13%	8%	0%	0%	0%
Sparganium eurycarpum	7%	0%	0%	2%	2%
Typha glauca	20%	66%	0%	21%	44%
			Other Species		
Asclepias incarnata	0%	1%	0%	0%	2%
Carex spp.	7%	0%	0%	0%	0%
Cirsium arvense	0%	11%	0%	0%	0%
Mentha arvensis	0%	1%	0%	0%	0%
Polygonum spp.	0%	3%	0%	0%	0%
Minor species	0%	1%	0%	0%	0%
Number of Quadrats	15	71	40	84	48
Mean necromass (g/m^2)	114	511	23	168	393

Table 3. Annual mean concentrations (mg/l) of total nitrogen (TN) and total phosphorus (TP) in the inflows and outflows from five restored wetlands in Dickinson County, Iowa.

	Total Nitrogen (TN)		Total Phosphorus (TP)	
Sample Location	2001	2002	2001	2002
Wetland 1				
1_IN_E	20.88	19.45	0.091	0.06
1_IN_S	20.4	No Flow	0.118	No Flow
1_OUT	6.53	7.65	0.063	0.052
Wetland 7				
7_IN	22.66	No Flow	0.089	No Flow
7_OUT	2.08	No Flow	0.054	No Flow
Wetland 8				
8_IN	17.5	26.2	0.506	0.165
8-OUT	2.94	5.24	0.145	0.178
Wetland 12				
12_IN	7.49	8.15	0.236	0.303
12_OUT	0.65	0.83	0.211	0.083
Wetland 16				
16_IN	14.96	13.197	0.236	0.086
16_OUT	2.02	1.4	0.117	0.07

(4) Subwatershed Nutrient Outputs. In 2000, 2001, and 2002, grab samples were collected at the outflows from 10 selected subwatersheds (Figure 2) differing in predominant land use and in extent of restored wetlands (Table 4). All of the water samples were analyzed for total nitrogen and total phosphorous. There were five subwatersheds that were mostly cropland (19, 21.1, 22, 40, and 41), 2 intermediate subwatersheds with extensive wetland restoration and with less than 50% cropland (18, 48), and two subwatersheds (23, 47) nearly entirely in restored wetlands and set-aside programs. The remaining subwatershed was 69% cropland transitioning to pasture with a pastured wetland (24).

Figure 2. Map of Iowa Great Lakes region with 10 selected subwatersheds and sampling locations shown.



Nitrate concentrations were closely related to subwatershed land use, being highest in subwatersheds with predominantly cropland and falling to near detection limits in subwatersheds with extensive wetland restoration and set-aside. Nitrate comprised the major fraction of TN in subwatersheds with much cropland and the pattern of TN concentrations was similar to that of nitrate. As in the case of nitrate, TN concentrations were closely related to subwatershed land use, with highest concentrations in subwatersheds dominated by cropland and lowest concentrations in subwatersheds with little or no cropland. The mean annual concentration of TN in outflows from the five subwatersheds mostly in row crops ranged from 5.26 to 19.0 mg/l (Table 4). For the 2 subwatersheds with greatest extent of restored wetlands and the least amount of land in cultivation, mean annual TN concentrations in outflows ranged were 1.0 and 1.6 mg/L. The two intermediate subwatersheds had mean annual TN concentrations of 4.34 and 6.31 mg/L. A comparison of long-term patterns in TN concentrations (Figure 3) illustrates the separation in TN concentrations among subwatersheds with extensive cropland (40), versus intermediate amounts of cropland (48), versus no significant cropland (47). In general, concentrations of TN were lower in outflows from subwatersheds with extensive wetland restoration and conversion of cropland to set-aside. However, the relative contribution of wetland restoration and set-aside programs is obscured by the correlation of these land use changes. Subwatersheds with extensive wetland restoration tended to have extensive cropland conversion.

TP concentrations displayed more short-term variability than TN concentrations and were less clearly related to subwatershed land use. A comparison of long-term patterns in TP concentrations (Figure 4) illustrates considerable overlap in TP concentrations across subwatersheds with land use ranging from extensive cropland (40), through intermediate amounts of cropland (48), to no significant cropland (47). Mean annual TP concentrations (Table 4) in the subwatersheds predominantly in cropland ranged from 0.069 to 0.168 mg/L, while in subwatersheds with the least cropland and the greatest extent of wetland restoration and set-aside mean annual TP concentrations were 0.086 and 0.106 mg/L. The two intermediate subwatersheds had mean annual TP concentrations of 0.109 and 0.180 mg/L. Subwatersheds with extensive set-aside and restored wetlands do not consistently have lower TP concentrations in their outflows than those predominantly in row crops and without restored wetlands.

Nutrient concentrations in weekly grab samples may not reflect the true, flow-weighted average concentrations in subwatershed outflows, and this is especially likely in the case of TP. Weekly grab samples fail to capture major flow events, during which much of the TP load to the lakes is probably transported, and patterns in TP concentrations cannot be assumed to reflect patterns in P mass export from subwatersheds or P mass loading to the lakes. The pattern of flow events is likely to be a primary determinant of nutrient loading to the lakes. This can be illustrated by comparing the long-term patterns in nutrient loading crudely estimated from TN and TP concentrations and relative water yield for the region based on stream flow measurements (Figure 5 and 6). Patterns in TN and TP concentrations (Figures 3 and 4) do not reflect patterns in TN and TP mass transport (Figures 5 and 6). Better estimates of nutrient loading require continuous flow measurements and automated sampling of subwatershed outflows to estimated flow-weighted concentrations and mass transport. These data are needed in order to calibrate watershed scale models of nutrient loading and develop a targeted approach to wetland siting for nutrient reduction in the IGL watershed. In the summer of 2003, selected IGL subwatersheds were instrumented with automated samplers with continuous flow monitoring to address this need.

Although there is significant variation in the concentration of TN in outflows from subwatershed to subwatershed, as expected, restored wetlands and land set-aside programs are effective in reducing nitrate losses from subwatersheds. For total phosphorus, thought to be the major nutrient responsible for algal blooms in most lakes, the outcome is less clear. The results from the subwatershed studies parallel those from the restored wetland studies. In both cases, TN concentrations are reduced consistently, but TP varies much more, both spatially and temporally.

Table 4. Mean annual concentration (mg/l) of total nitrogen (TN) and total phosphorus (TP) from selected subwatersheds of the Iowa Great Lakes. Subwatersheds arranged by land use.

Watershed			Total Nitrogen (TN)				Total Phosphorus (TP)			
	Acres	% Row Crop	2000	2001	2002	Mean	2000	2001	2002	Mean
Predominately Row Crop										
E3(40)	2980	85	5.92	7.54	8.86	7.44	0.11	0.166	0.095	0.124
E4(41)	1946	95	9.16	10.72	14	11.29	0.101	0.189	0.089	0.126
W14(19)	660	88	3.25	5.51	7.01	5.26	0.092	0.137	0.088	0.106
W13(22)	1760	93	5.16	10.91	12.53	9.53	0.14	0.275	0.089	0.168
W14(21.1)	236	100	17.34	19.15	20.52	19	0.076	0.063	0.068	0.069
Mixed Row Crop and Grassland										
G3(48)	9359	38	4.69	3.45	4.87	4.34	0.09	0.146	0.091	0.109
W2(18)	2702	45	5.78	7.08	6.08	6.31	0.169	0.212	0.16	0.18
Predominately ungrazed grassland										
G6(47)	185	0	1.28	1.02	0.69	1	0.099	0.125	0.095	0.106
W10(23)	371	0	No flow	2.88	1.76	1.56	No flow	0.165	0.094	0.086
Other										
W9(24)	743	69	No flow	1.54	3.38	1.64	No flow	0.286	0.439	0.242

Figure 3. Comparison of measured concentrations of Total N for 2000 to 2002 in streams draining selected watersheds in the Iowa Great Lakes Region with different land use.

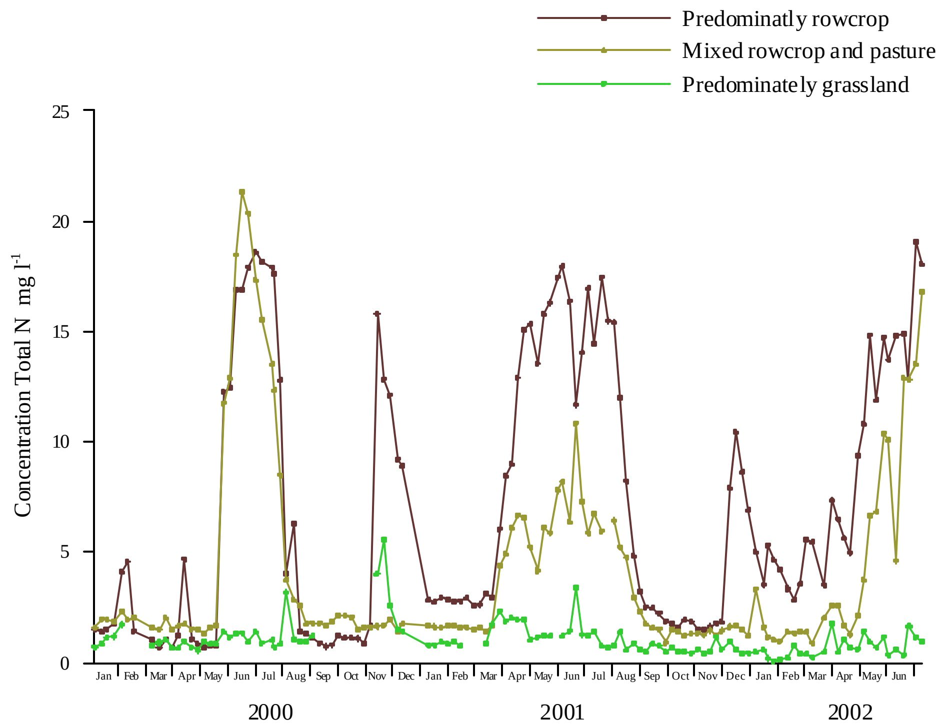


Figure 4. Comparison of measured concentrations of Total P for 2000 to 2002 in streams draining selected watersheds in the Iowa Great Lakes Region with different land use.

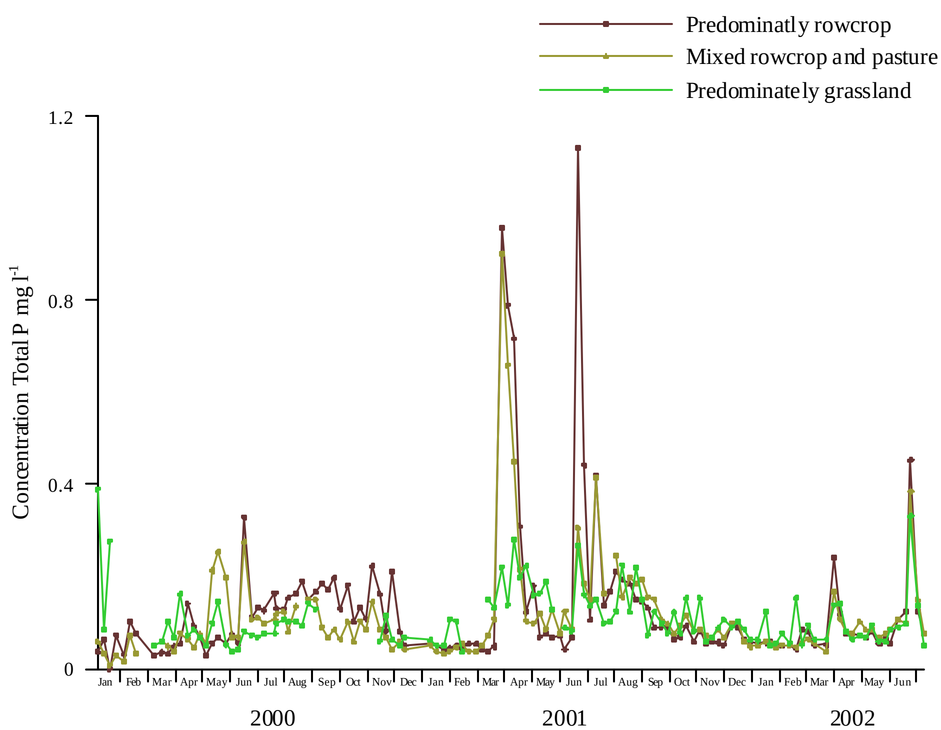


Figure 5. Estimated loading rates of Total N for 2000 to 2002 in streams draining selected watersheds in the Iowa Great Lakes Region with different land use.

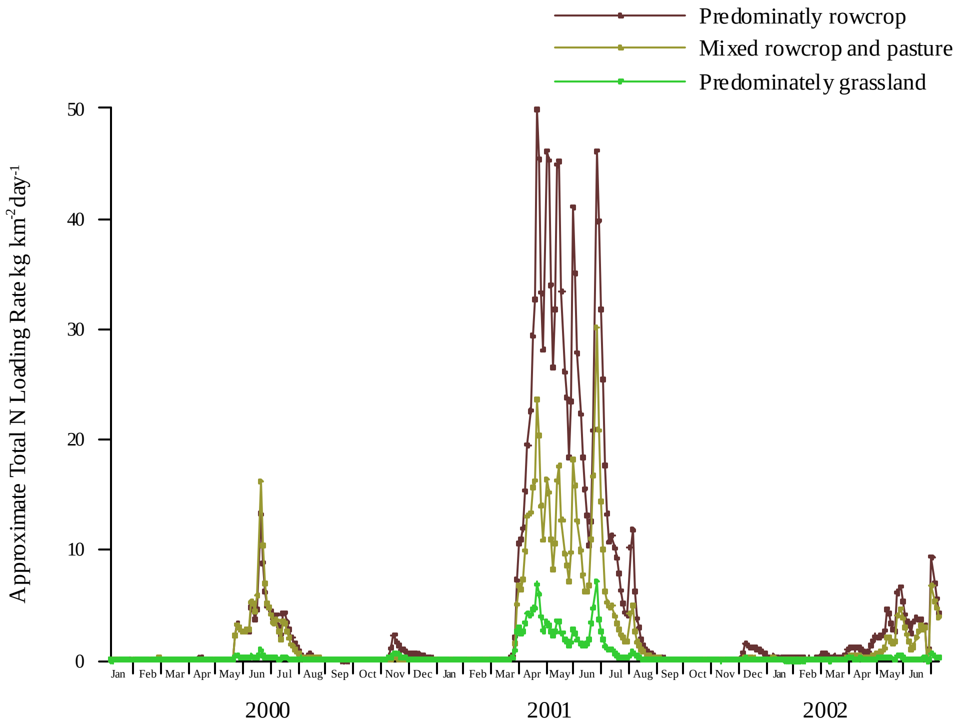
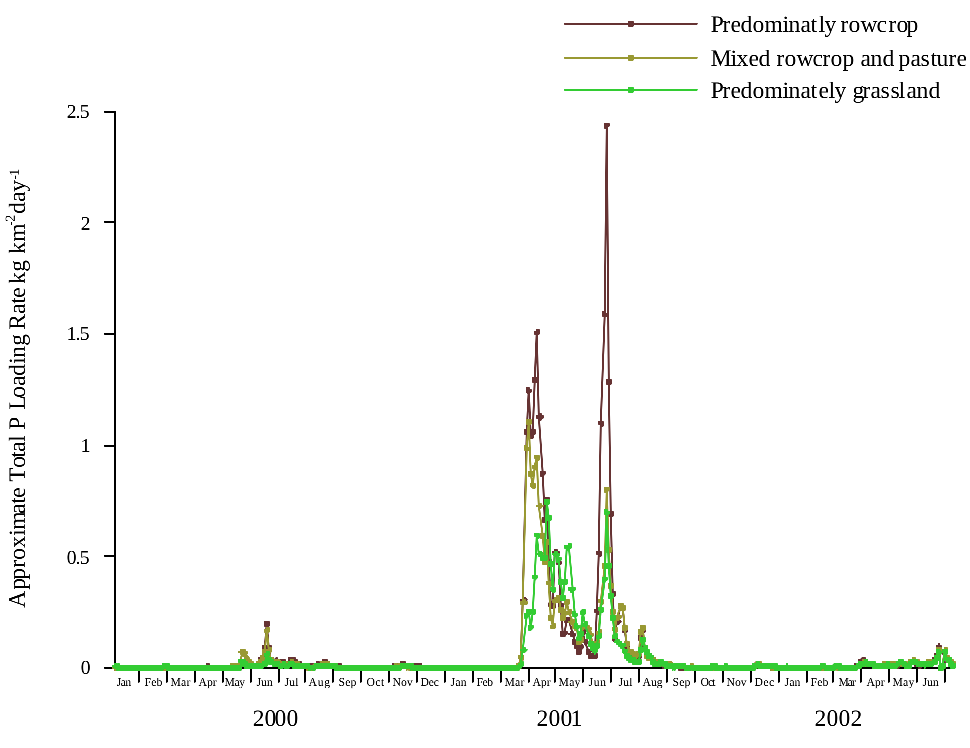


Figure 6. Estimated loading rates of Total P for 2000 to 2002 in streams draining selected watersheds in the Iowa Great Lakes Region with different land use.



Conclusions

Although nearly 280 wetlands have been restored in the Iowa Great Lakes watershed, at best, these wetlands intercept runoff from about 20% of the uplands in the watershed. For TN, this suggests that nitrogen inputs may have been reduced by about 15%. For TP, they would be reduced less than 10%. Consequently, it is not surprising that nutrient concentration in the Iowa Great Lakes has not begun to decline. When all sources of nutrients into these lakes are considered (dry fallout, wet fallout, internal loadings, urban runoff, etc.), the effects of wetland and upland restorations on nutrient levels in the lakes are still too small to be detectable.

Publications and Presentations

All of the research is ongoing and no publications have resulted yet. One thesis should be completed in the next year. A presentation on some of the preliminary results was made at the annual Midwest Limnology Conference. This study was featured in the Leopold Letters newsletter (Vol. 13, No.4, Winter 2001). It was also discussed in an interview on WOI Radio's noontime show. Currently, a graduate student, Brandon Dittman, is using data collected on the characteristics of restored wetlands for a creative component as part of his MS degree in Water Resources.