Rice Lake National Wildlife Refuge

Historic Wild Rice Mapping (1983 – 2004)[1]

by

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At Rice Lake, Mary Stefanski, refuge manager, and Michelle McDowell, refuge biologist, were kind hosts who provided invaluable insights into the history and management of the refuge.

Introduction

The Rice Lake National Wildlife Refuge in Aitkin County, Minnesota, is comprised of several units in adjacent Minnesota counties (Figure 1). The main unit of the refuge, established in 1935 to protect waterfowl habitat, is 18,000 acres and each year attracts hundreds of thousands of migratory birds that pass through the area. The centerpiece of the refuge is 3600-acre Rice Lake that produces a yearly crop of wild rice (*Zizania palustris* L.) (Rice Lake NWR, 2005). Archeological surveys have located burial mounds in the refuge, an indication of the long history of the wild rice crop and its importance to the local residents who still harvest it. Rice River, a tributary of the Mississippi River, drains Rice Lake. The terrain surrounding the lake is comprised of wooded terminal moraine with interspersed low-lying areas dominated by fens and black spruce bog.

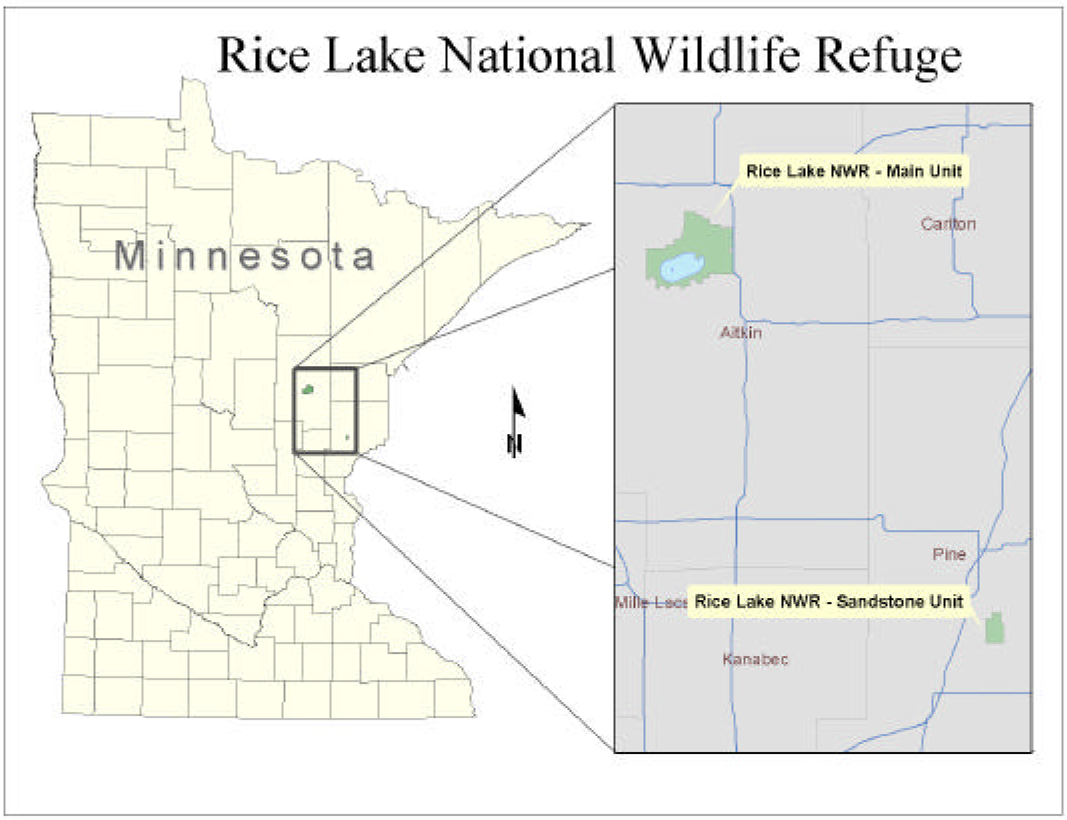

Figure 1. Geographic location of the project.

Wild rice is a cross-pollinating annual grass. It is probably the best known of the aquatic plants that grow on the edges and sheltered bays of central and northern Minnesota lakes and streams (Tester, 1995). Rice stands usually develop on muddy lake bottoms where moving water from inlets or from strong wave action is present (Tester, 1995). Seeds germinate early in June producing leaves that float on the surface. Fruiting stalks emerge from the water in mid-summer. By September, when the grain ripens, the stalks are 1 to 3 meters tall (Borman, Korth, & Temte, 1995). The density of the stands can vary from sparse individual stalks in open water to dense, almost impenetrable stands with more than 60 stems per square meter.

Several perennials comprise the other emergent vegetation on Rice Lake: pickerelweed (*Pontederia cordata*), lily pads (*Nuphar variegata, Nymphaea odorata*), water shield (*Brasenia schreberi*), river-bulrush (*Schoenoplectus fluviatilis*) and softstem-bulrush (*Schoenoplectus tabernaemontani*). Pickerelweed has glossy, ovate leaves with blue flower spikes and often forms spreading colonies in protected areas (Borman et al., 1995). The rhizomes overwinter with new leaves emerging in early spring. Waterfowl and muskrats eat the seeds. Pickerelweed rarely gets much higher than 0.5 meters. Lily pads and water shield are floating emergents producing new leaves each growing season from overwintering rhizomes. Softstem-bulrush grows in water less than 2 meters deep resprouting each spring from rhizomes. Large colonies of softstem-bulrush may develop though the emergent stems appear leafless (Borman et al., 1995).

Disturbance is potentially a factor in the natural cycle of wild rice. Variations in water depth tend to give annual species, like wild rice, a competitive advantage over perennials (Carson, 2002). In the case of wild rice, stable water levels are critical during the 'floating leaf' stage, where a sudden change in water level has the potential to rip the plant from the substrate (Oelke et al., 1997). The effects of flood events on wild rice distribution were studied in the shallow backwater areas of the northern Mississippi River over a twenty-year period. Results from this study suggest that floods can act as "reset" mechanisms – removing some species and reestablishing some others – while recharging the sediments with nutrients after flushing away accumulated organic matter (Tyser, Rogers, Owens, & Robinson, 2001).

On Rice Lake, control structures and dikes have been erected to control flooding. In 1939, the Civilian Conservation Corp established a large camp at the refuge and replaced the rail line that bisected the refuge from east to west with a roadbed. At about that time, dikes were constructed on the east side of the lake and a water control structure was established on the Rice River. These structures have stabilized water levels on the lake and Rice River by controlling spring flooding and late summer drawdown. The long-term effects of water control on the lake are unknown though anecdotal evidence and vegetation surveys done by refuge staff suggest an increase in pickerelweed in recent years (Carson, 2002).

In an effort to get a better understanding of long-term trends on the lake, the University of Minnesota, in cooperation with Region 3 of the U.S. Fish and Wildlife Service has created a series of digitized spatial databases to document the distribution of wild rice on Rice Lake from 1983 through 2004. Aerial photos from seven individual years in that time period – 1983, 1993, 1995, 1996, 1998, 2001 and 2004 – were digitized, orthorectified and used as a thematic reference to create a three-class representation (wild rice, other vegetation, and open water) of lake vegetation in a geographic information system (GIS) for each of the years analyzed. To create a spatial analysis of the wild rice and 'other vegetation' distribution over the entire time period, data from all the years were combined to produce a composite map.

Products

The products created for this project were:

- A 3-class GIS of lake vegetation in ESRI ArcView shapefile and geodatabase formats for the years: 1983, 1993, 1995, 1996, 1998, 2001 and 2004.
- Lake vegetation cover maps in 96 dpi TIF format for each year;
- Area summaries of the three mapped classes
- A combined analysis of wild rice distribution on the lake for the twenty-one year period

- A combined analysis of other vegetation distribution on the lake for the twenty-one year period.
- Metadata for each digital product;
- A CD-ROM of all digital products.

Project Milestones

This historic rice mapping project was started in June 2004. Site visits to Rice Lake NWR occurred at the height of the growing season during late July 2004 and just after rice harvest in October 2004. Image processing was begun in November 2004 and completed in April 2005 at the University of Minnesota.

Spatial data product development occurred during April and May 2005. Data analysis was complete in May 2005 with the final report completed in July 2005.

Methods

Spatial Reference

The *spatial* reference used for the Rice Lake main unit was the 2003 FSA orthophoto for Aitkin County, Minnesota (Source: U.S. Department of Agriculture, Farm Services Agency (FSA), Aerial Photography Field Office). All aerial photos in the project were orthorectified or georeferenced using the 2003 FSA orthophoto as the ground reference. The 2003 FSA orthophoto for Aitkin County, Minnesota tested 2.7 meters horizontal accuracy at a 95% confidence level (Federal Geographic Data Committee, 1997).

Thematic Reference

The *classification* reference for the project was a set of aerial photos taken during the period of maximum growth of emergent vegetation on the lake for each of the years analyzed.

Rice Lake Photo Set Summary

Year	Flight Date	Photo Type	Photo Scale	Scan ppi	Pixel (m)	Total Images
1983	August 2, 1983	Ektachrome Slide	1:40000	800	1.25	3
1993	August 13, 1993	Natural Color Print	1:8000	400	0.5	20
1995	August 31, 1995	Color Infrared Print	1:8000	400	0.5	20
1996	August 26, 1996	Color Infrared Print	1:8000	400	0.5	19
1998	August 21, 1998	Color Infrared Print	1:8000	400	0.5	18
2001	September 4, 2001	Color Infrared Print	1:8000	400	0.5	18
2004	August 20, 2004	Color Infrared Scan	1:8000	800	0.25	18

The three 1:40000 natural color transparencies for 1983 were scanned at 800 pixels per inch (ppi) by a commercial contractor, HAS Images, Inc. of Dayton, OH to a digital TIFF format. The resulting pixel size was ~1.25 meters. The three images that covered the lake area were georeferenced in ESRI's ArcMap (ArcView 8.3) using the 2003 FSA orthophoto of Aitkin County, MN as a spatial reference. A histogram stretch was used to enhance textural features of the images and to reduce the specular reflection of sunlight reflecting off areas of open water.

The 20 natural color 1:8000 prints for 1993 were scanned to a digital format at 400 ppi using a flatbed scanner for a resulting pixel size of 0.5 meters. The photos were orthorectified using ERDAS Imagine 8.3 using the 2003 FSA orthophotos as a horizontal spatial reference and a 30-meter resolution Digital Elevation Model (DEM) as the vertical reference.

All remaining years – 1995, 1996, 1998, 2001, and 2004 – were captured as color-infrared aerial photographs.

The years 1995, 1996, 1998 and 2001 were color infrared prints that were scanned to a digital format at 400 ppi using a flatbed scanner at the University of Minnesota. The 2004 images were taken directly from film negative to a digital format by HAS Images at 800 ppi. Each year's images were orthorectified using the same process as 1993's images.

Thematic Classification

A classification scheme was created to represent the emergent vegetation present on Rice Lake:

- **Mostly wild rice**
  This classification identifies areas where more than 50% of the dominant emergent vegetation is wild rice (*Zizania palustris*). This would be considered a dense wild rice stand.

- **Mostly other vegetation**
  This classification identifies areas where the dominant emergent vegetation isn't wild rice. Plants in this classification include: pickerelweed (*Pontederia cordata*), lily pads (*Nuphar variegata, Nymphaea odorata*), water shield (*Brasenia schreberi*), river bulrush (*Schoenoplectus fluviatilis*) and soft-stem bulrush (*Schoenoplectus tabernaemontani*).

- **Mostly open water**
  This classification identifies areas of predominantly open water, defined as having less than 50% coverage by emergent vegetation. It should be noted that sparse to moderate distributions of wild rice tended to fall into this classification as would moderate stands of soft-stem bulrush.

Spatial Data Development

The spatial database created for this project was projected in Universal Transverse Mercator (UTM), Zone 15, North American Datum of 1983 (NAD83). All units are in meters. Mapping was done at a scale of 1:5000.

For each year analyzed, a geodatabase feature class was developed using ESRI ArcMap (ArcView 8.3). Polygons were drawn on-screen to represent areas for each class as determined through visual interpretation of the aerial photographs. One vegetation class was assigned to each polygon by giving the attribute field, CLASS_ID, a value:

- 0 (no class assigned)
- 1 (mostly wild rice)
- 2 (mostly open water)
- 3 (mostly other vegetation)

Topological checks were performed to ensure that the polygons did not overlap and completely accounted for the entire extent. The standard minimum mapping unit (MMU) of 1 hectare or roughly two and a half acres was applied to all thematic classes. Any polygon smaller than the MMU was merged into the nearest neighboring polygon having the most similar class by removing the boundary between them.

No accuracy assessment of the data was performed. For the older photography, no reliable ground data were available. For the 2004 photography, a more detailed classification and accuracy assessment were conducted as part of a separate project.

Results

Emergent vegetation on lakes and wetland areas forms a continuum of various species. Rice Lake is no exception. In establishing the classes that represent areas of vegetation on the lake, the term ‘mostly’ is literally taken to mean ‘more than 50% coverage’. Figures 2 through 8 show the digitized 3-class maps created for years 1983, 1993, 1995, 1996, 1998, 2001 and 2004 respectively. Areas designated as open water on the maps may have as much as 49% coverage of emergent vegetation. In most cases, this vegetation would be sparse to moderate wild rice or sparse soft-stem bulrush.

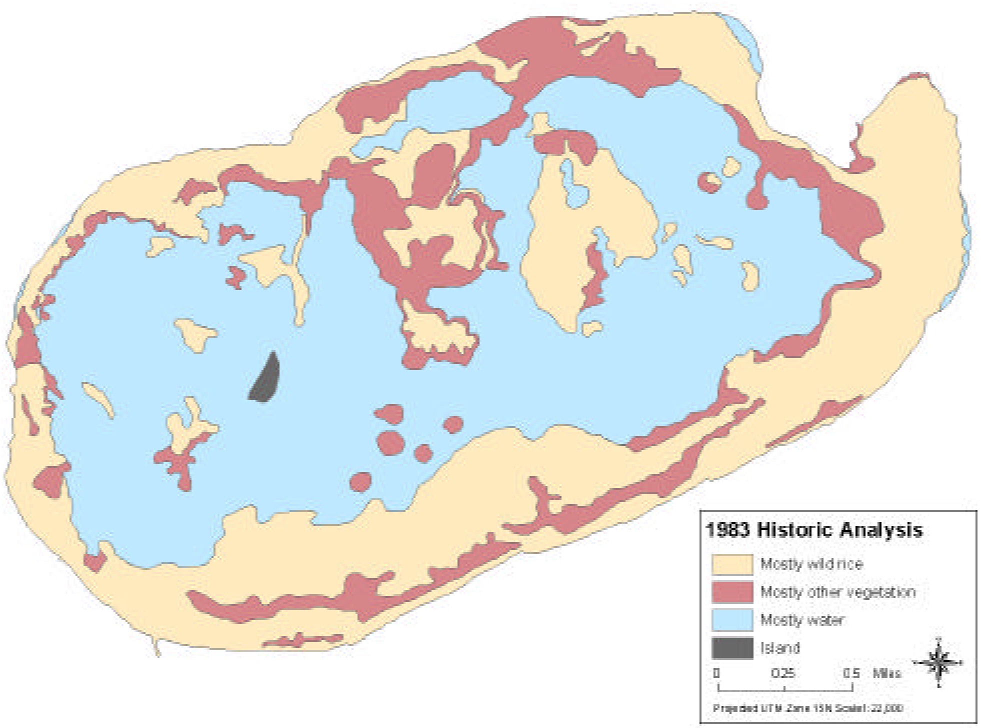

Figure 2. Map showing classes of emergent vegetation on Rice Lake in 1983.

Color-infrared photography provided the best differentiation of the wild rice from ‘other vegetation’ due to each unique photo signature. Pickerelweed, a primary component of the ‘other vegetation’ classification, has a distinct red color signature as well as a texture comprised of distinct circular dots. Floating emergents, like lily pads, appeared bright white in large broadly circular areas. The signature for wild rice was a consistent light-pinkish color that dissipated quickly as the density thinned.

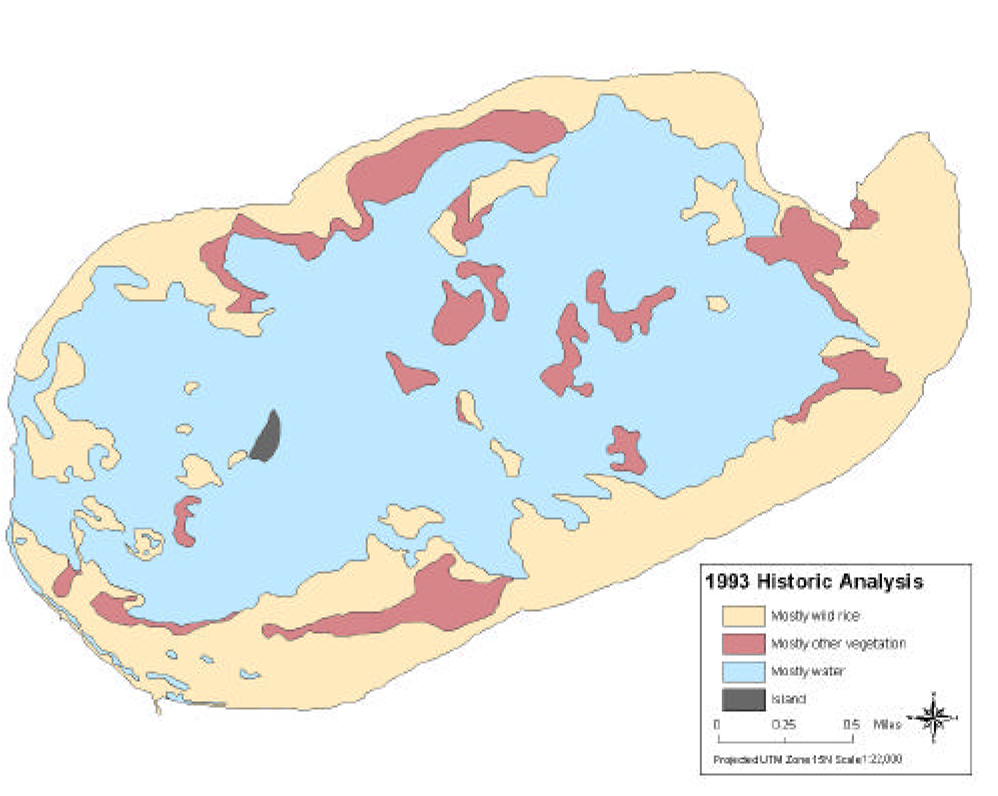

Figure 3. Map showing classes of emergent vegetation on Rice Lake in 1993.

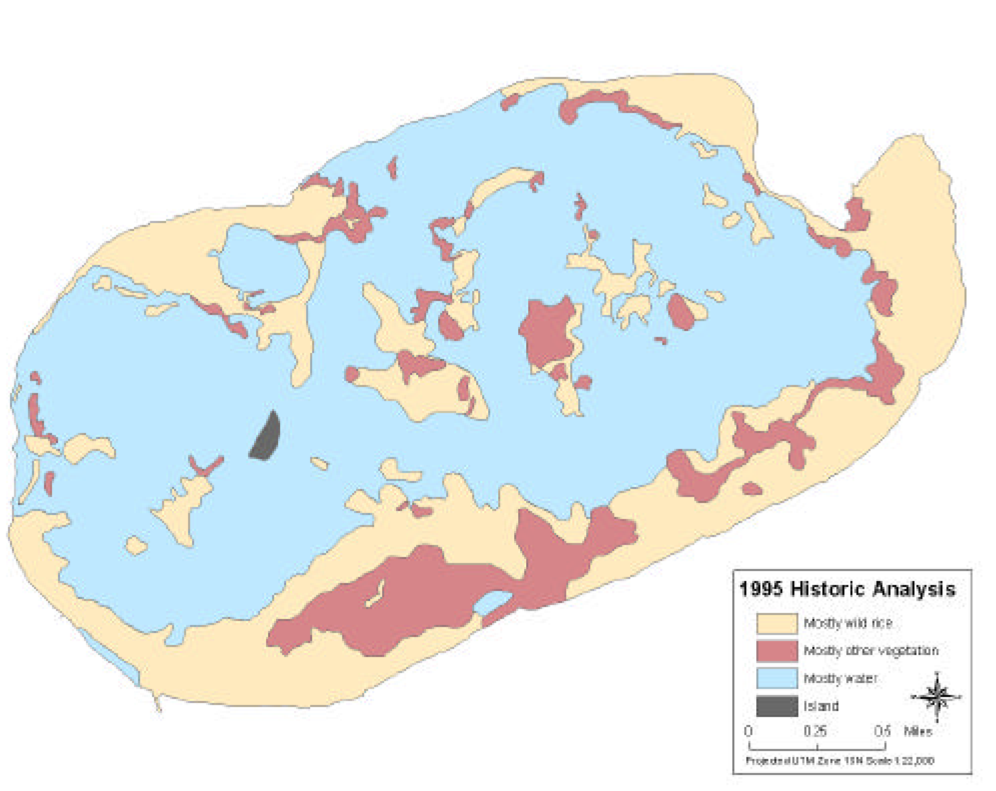

Figure 4. Map showing classes of emergent vegetation on Rice Lake in 1995.

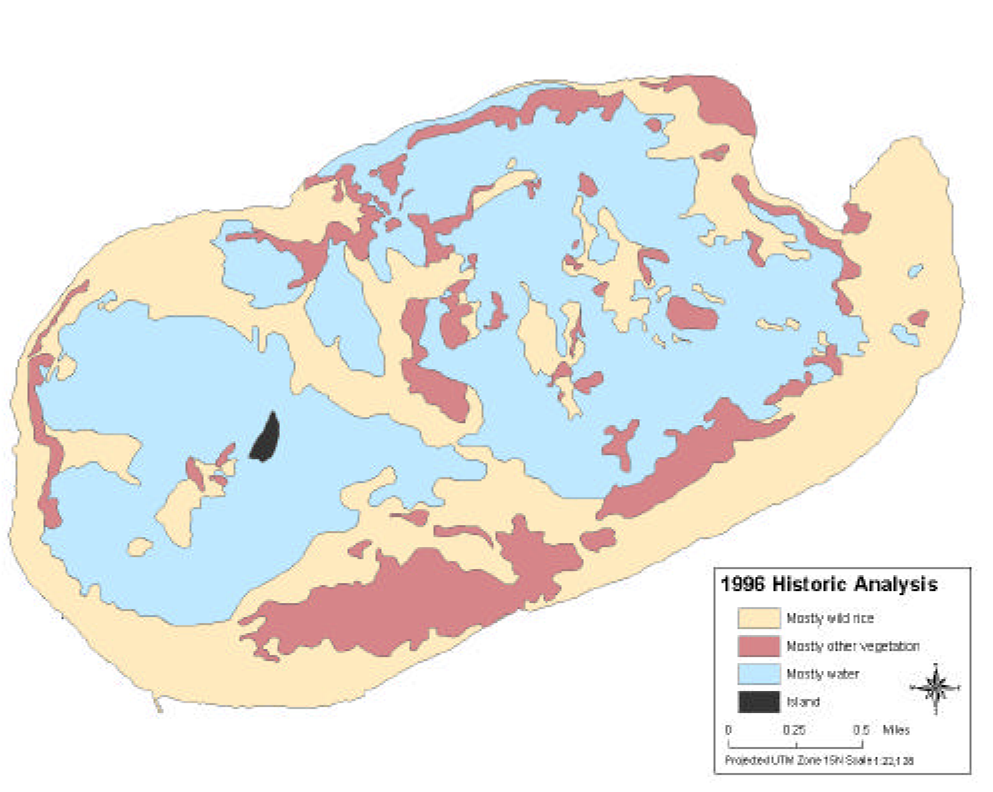

Figure 5. Map showing classes of emergent vegetation on Rice Lake in 1996.

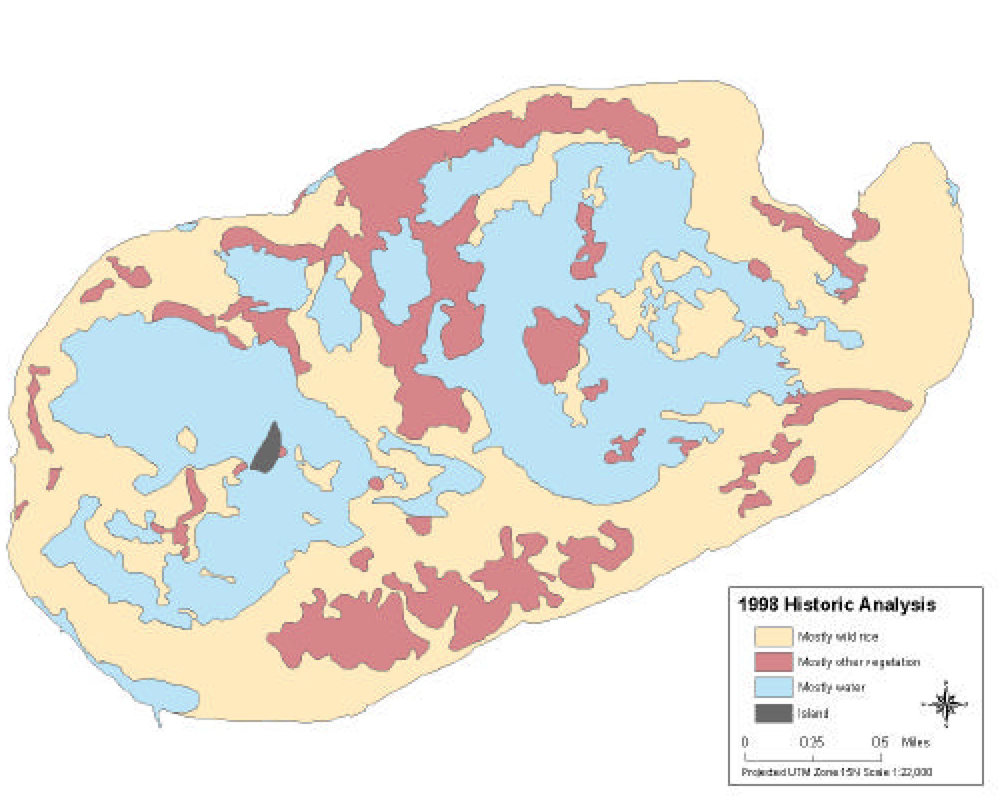

Figure 6. Map showing classes of emergent vegetation on Rice Lake in 1998.

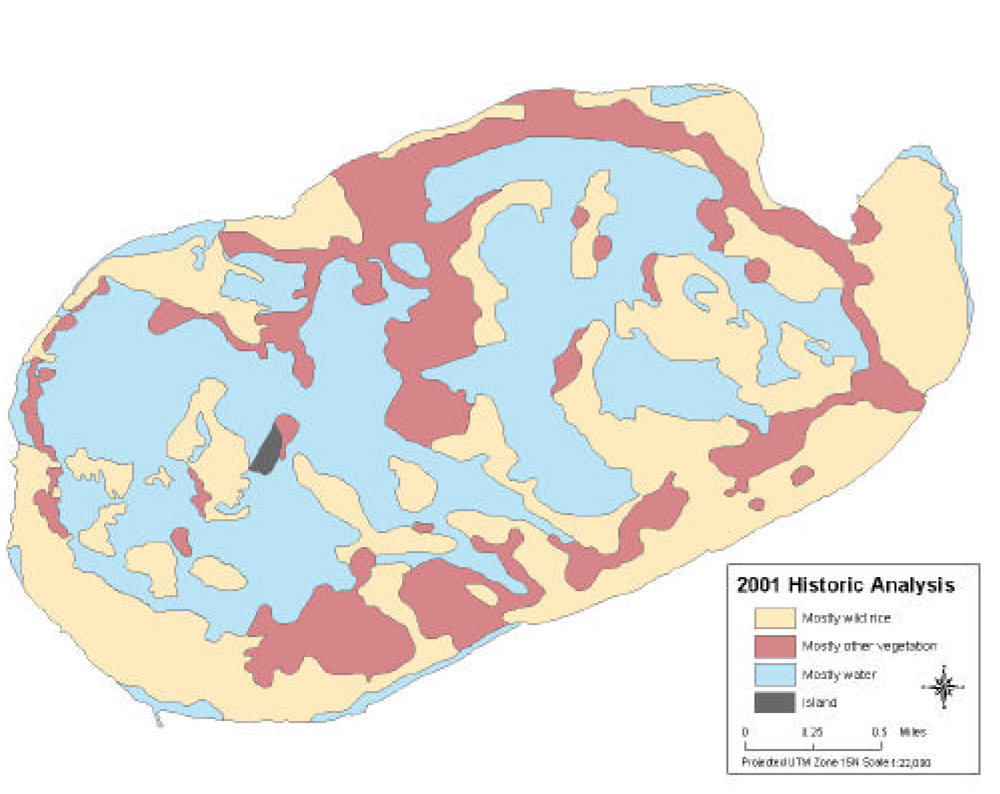

Figure 7. Map showing classes of emergent vegetation on Rice Lake in 2001.

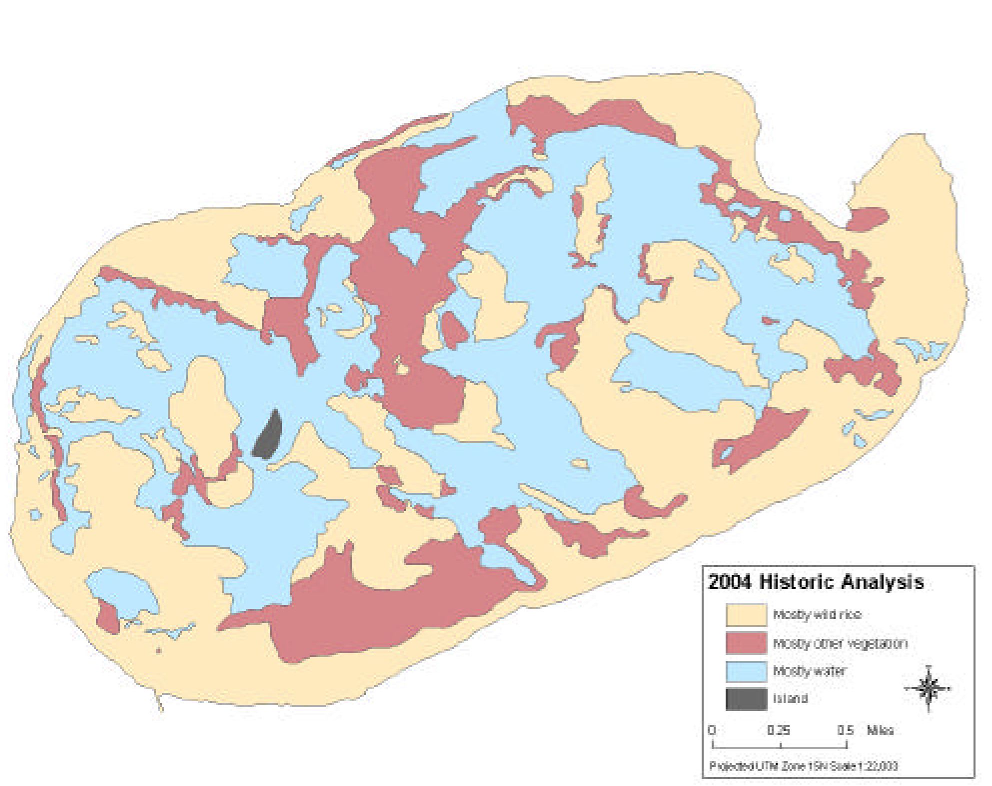

Figure 8. Map showing classes of emergent vegetation on Rice Lake in 2004.

In the natural color photos from 1983 and 1993, however, these color signatures were less obvious. Everything that wasn't predominantly open water was colored either white or varying shades of gray. Texture differences appearing as tonal changes in gray color between the different plant species became more important than color in the natural photos. But these texture differences were very subtle. Pickerelweed, for example, was generally obscured with its small circular patches often extremely difficult to separate from surrounding rice and floating vegetation. The texture of wild rice in these photos was more easily detectable as was that of floating vegetation. Because of the difficulty in separating the pickerelweed from other vegetation, it is likely that more thematic errors occurred in the interpretation of the natural color photos. Since no accuracy assessment was performed on the classification using these older photographs, it is impossible to determine this with any certainty.

There were problems in the interpretation of the color-infrared photos as well due to the physiognomy of the vegetation. The wild rice, being an annual grass, often attains a mature height of several meters and produces a spreading seed stalk. These physical characteristics can obscure the vegetation below the rice completely. The pickerelweed, usually half a meter tall, was particularly hard to detect when in dense beds of rice. Since the pickerelweed spreads both vegetatively and by seed it would be expected to slowly expand into additional areas over time. Though the growth form of pickerelweed may create competition with the wild rice in the early stages of growth each year, it is more likely that the pickerelweed removes nutrients that the wild rice would otherwise be available (Carson, 2002). In contrast, most years it is the wild rice that acts to shelter the pickerelweed from the wind. As can be seen in figures 2 - 8, the densest areas of 'other vegetation' are often on the edge of the wild rice beds or embedded in them.

In years where the rice was less dominant on the lake (e.g. 1995), 'other vegetation' was easier to discern. Since visual coverage of the rice was the critical factor for determining dominance, this should be considered when evaluating the results. Even if the other vegetation on the lake remained stable from year to year, the rice can obscure it from the photos during a good rice growing year.

Table 1 details the area by class for each of the years in the study.

Table 1. Acreage Totals for each mapped class on Rice Lake by year.

1983	**Class**	**Area %**	**Polygons**	**Acres**	**Area (m^2)**
	Mostly rice	37.9%	21	1,378	5,577,974
	Mostly water	47.5%	7	1,726	6,984,674
	Mostly other	14.6%	28	531	2,149,606
	Total	**100.0%**	**56**	**3,635**	**14,712,254**
1993	**Class**	**Area %**	**Polygons**	**Acres**	**Area (m^2)**
	Mostly rice	34.4%	15	1,250	5,058,588
	Mostly water	56.2%	10	2,043	8,267,840
	Mostly other	9.4%	16	342	1,385,826
	Total	**100.0%**	**41**	**3,635**	**14,712,254**
1995	**Class**	**Area %**	**Polygons**	**Acres**	**Area (m^2)**
	Mostly rice	31.4%	31	1,142	4,621,718
	Mostly water	58.5%	4	2,126	8,603,727
	Mostly other	10.1%	37	367	1,486,808
	Total	**100.0%**	**72**	**3,635**	**14,712,254**

Year	Class	Area %	Polygons	Acres	Area (m^2)
1996	**Class**	**Area %**	**Polygons**	**Acres**	**Area (m^2)**
	Mostly rice	39.2%	19	1,424	5,763,614
	Mostly water	46.4%	6	1,688	6,832,730
	Mostly other	14.4%	43	523	2,115,910
	Total	**100.0%**	**68**	**3,635**	**14,712,254**
1998	**Class**	**Area %**	**Polygons**	**Acres**	**Area (m^2)**
	Mostly rice	47.6%	12	1,729	6,997,121
	Mostly water	35.5%	13	1,290	5,218,737
	Mostly other	17.0%	33	617	2,496,395
	Total	**100.0%**	**58**	**3,635**	**14,712,254**
2001	**Class**	**Area %**	**Polygons**	**Acres**	**Area (m^2)**
	Mostly rice	38.8%	23	1,411	5,710,891
	Mostly water	40.7%	13	1,479	5,985,270
	Mostly other	20.5%	20	745	3,016,092
`	**Total**	**100.0%**	**56**	**3,635**	**14,712,254**
2004	**Class**	**Area %**	**Polygons**	**Acres**	**Area (m^2)**
	Mostly rice	46.7%	30	1,698	6,872,603
	Mostly water	35.8%	24	1,301	5,263,318
	Mostly other	17.5%	32	637	2,576,334
	Total	**100.0%**	**86**	**3,635**	**14,712,254**

Figure 9 displays the data in Table 1 graphically. From these results it is difficult to tell if the ‘other vegetation’ class is having a negative effect on the total acreage of wild rice. All that can be said is that ***all*** emergent vegetation, including wild rice, has increasing coverage on the lake. But this may merely be a cyclical effect that can’t be observed in the twenty-year period studied. Whether the increased vegetation is due to other reasons, like stable water levels on the lake, changes in annual precipitation, or general climatic conditions, cannot be judged without collecting and analyzing additional data.

There is likely a synergistic effect between the rice, the pickerelweed and the floating emergents. Areas of sparse rice on the edges of dense rice beds act to stabilize the wave action of the water and allow the floating emergents a better foothold into new territory. On the other hand, dense rice can choke out areas of vegetation by the size of the plants and the sheer density of the canopy.

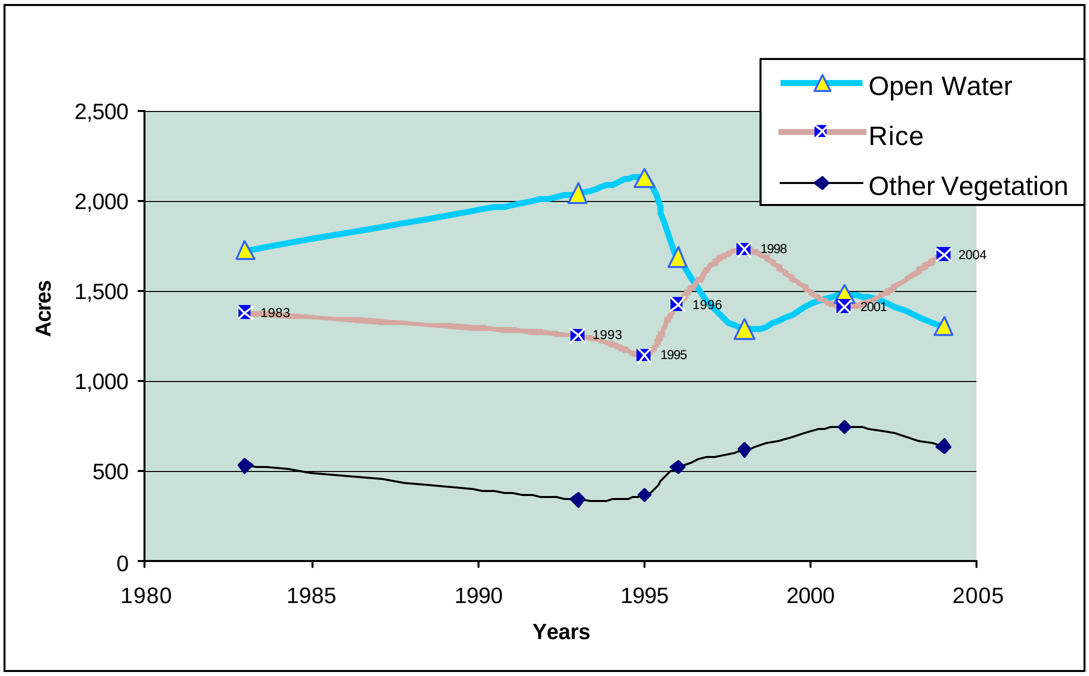

Figure 9. Graph of acreage per class by year.

To create a representation of the distribution of wild rice on the lake over the entire study period a spatial analysis was performed that created a composite map (Figure 10). In this map, areas of darker color had wild rice more consistently than areas of lighter color. The wild rice tends to dominate in sheltered bays and shorelines.

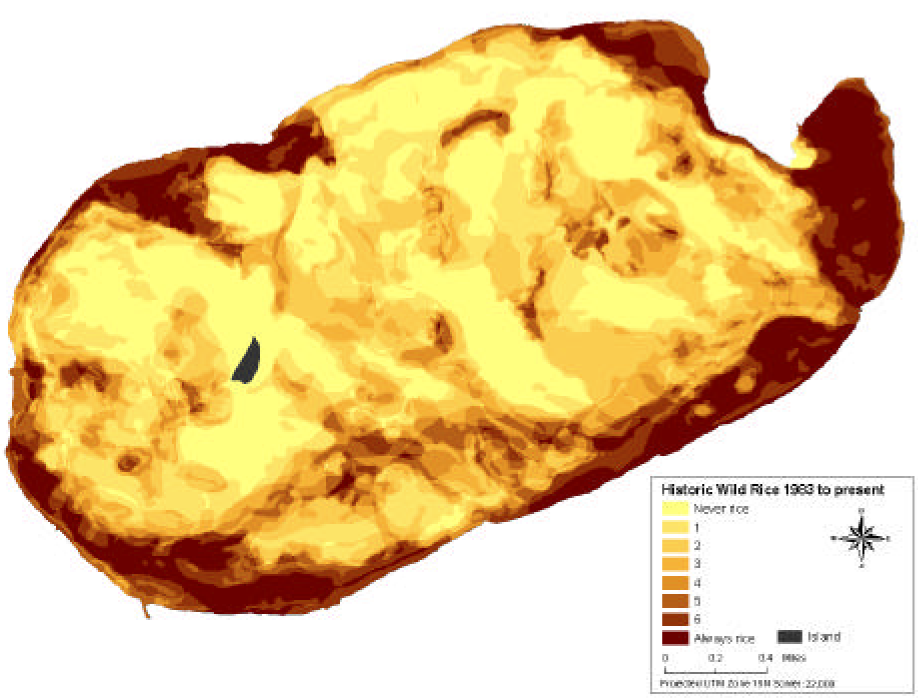

Figure 10. Composite map showing the distribution of wild rice on Rice Lake from 1983 to 2004.

Figure 11 shows ‘other vegetation’ presented in the same unioned format. Here darker areas tend to be dominated by ‘other vegetation’ most of the time.

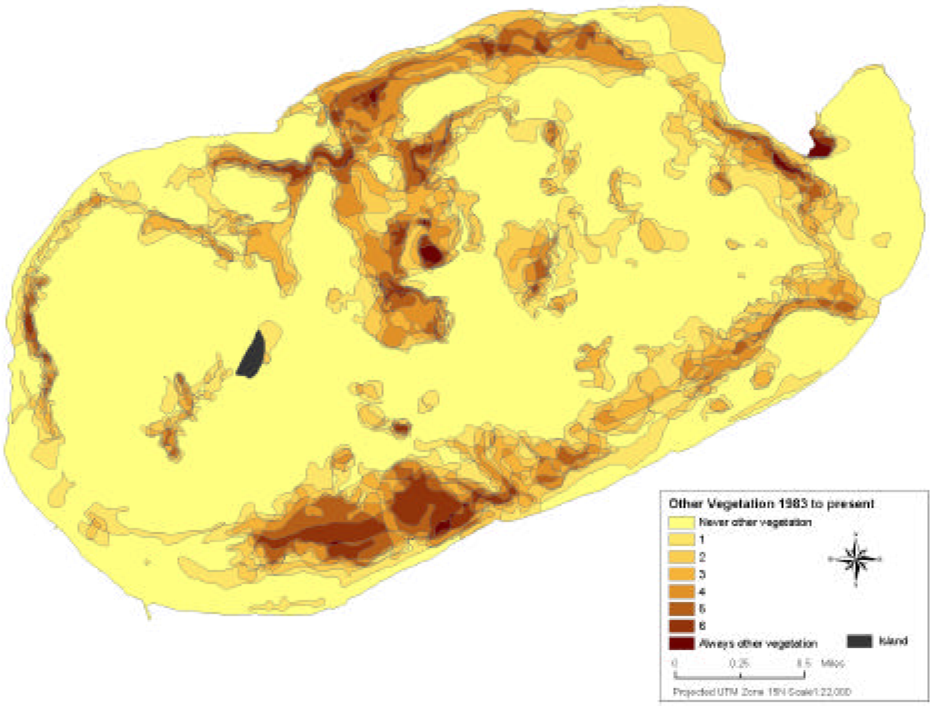

Figure 11. Composite map showing the distribution of 'other vegetation' on Rice Lake from 1983 to 2004.

Summary

In an effort to get a better understanding of long-term trends on the lake, the University of Minnesota in cooperation with Region 3 of the U.S. Fish and Wildlife Service has created a series of digitized spatial databases that document the distribution of wild rice on Rice Lake from 1983 through 2004. Aerial photos from seven years – 1983, 1993, 1995, 1996, 1998, 2001 and 2004 – were digitized, orthorectified and used as a thematic reference to create a three-class representation – wild rice, other vegetation, and open water – of lake vegetation in a geographic information system for each of the years analyzed. To conduct a spatial analysis of the wild rice and ‘other vegetation’ distribution over the entire time period, data from all the years were unioned to produce a composite map.

From these results, ***all*** emergent vegetation, including wild rice, has shown increased coverage on the lake for the twenty-year period studied. There is potentially a synergistic effect between the wild rice and the other emergents, but without further data it can’t be determined whether this effect is adversely impacting the wild rice.

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