Tracking Change in Land Cover Within Lake Onalaska, Navigation Pool No. 7, Upper Mississippi River Between 1975 and 1994

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Abstract

Percent land cover as well as land cover type were compared using automated coverages of Lake Onalaska for the years 1975, 1989, and 1994. Lake Onalaska is a shallow (mean depth = 1.3m), 2,800 ha impounded lake, which is a vital part of Navigation Pool 7 of the Upper Mississippi River. Changes were observed using the modified thirteen-class land cover/land use coverages by performing statistical summaries and overlay analyses.

Overall, between 1975 and 1994 within Lake Onalaska, there were declines of 481 hectares (11.5%) of submergent and rooted floating leaf vegetation types. Open water habitat increased by 397.8 hectares (9.5%). Emergent vegetation increased 30.6 hectares (6.2%) from 1975-1989 and decreased 13.4 hectares (2.6%) between 1989 and 1994 for a total gain of 17.2 hectares (3.5%). Areas of *Sagittaria* (arrowhead) declined by 14.0 hectares (4.1%) in the period between 1975 and 1989. There was an increase of *Sagittaria* between 1989 and 1994 of 62.4 hectares (18.9%) with a net overall increase of 48.4 hectares (14.1%).

Introduction

Distribution and abundance of vegetation within the Upper Mississippi River System (UMRS) has changed dramatically since the inundation of the river in the 1930s. These changes, because of the construction of Locks and Dams, have been depicted as elevated river stages (Grubaugh and Anderson, 1988), increased surface area (Chen and Simons, 1986), and higher sedimentation rates behind dams (Bhowmik and Adams, 1986). Because of the rivers importance as an economic and recreational resource it is important to have a better understanding of how these changes have affected its landscape and surrounding floodplain. Understanding these changes can better inform river managers so they can make better decisions in the future.

In past years, Lake Onalaska, in Pool 7 of the UMRS, was known as a heavily vegetated and nutrient rich impounded lake (Green, 1960). It was an area known for its fish and wildlife populations. It is believed that this area has become less productive and the amount of submersed and emergent vegetation has been diminishing. There are many possible assumptions that can be made to explain such change in vegetation within the landscape, such as successional changes, increased sedimentation rates, change in

hydrograph, the influence of pesticides and herbicides from agricultural runoff, and/or the lack of useable nutrients within the system.

In an effort to characterize the magnitude of such change in Lake Onalaska, this project was developed to analyze digital land cover/land use coverages of the area over a period of time using a geographic information system (GIS). In this way trends can be explored and theories can be generated to help explain changes that have occurred.

The objectives of this study were to:

- characterize the change in the amount and type of land cover within the area of Lake Onalaska between 1975 and 1994
- understand the past trends to assist managers in the future
- explore trends and generate theories

In recent years, there have been many monitoring efforts as well as a number of research projects that have focused on the Lake Onalaska area. These efforts have attempted to document some of the trends that have taken place and explain the driving forces behind such changes.

Methods

The Mississippi River, in its entirety, is comprised of 2,320 miles of waterway that extends from Lake Itasca, Minnesota to the Gulf of Mexico. It is a great system that is home to more than 154 species of freshwater fish and over 50 freshwater mussels. The river also acts as a migration corridor for thousands of bird species. The UMRS refers to the upper 1,300 miles of waterway that forms the borders of five states (Minnesota, Wisconsin, Iowa, Illinois, Missouri).

As part of the UMRS, Pool 7 is approximately 11.8 river miles long. It extends from Lock and Dam 6, at Trempealeau, Wisconsin to Lock and Dam 7, at Dresbach, Minnesota. Lake Onalaska, a vital part of Pool 7, lies between the Black River Delta and the spillway of Lock and Dam 7. The lake is shallow (mean depth = 1.3 m) and encompasses 2,800 hectares of open water, islands, and channel ways (Figure 1).

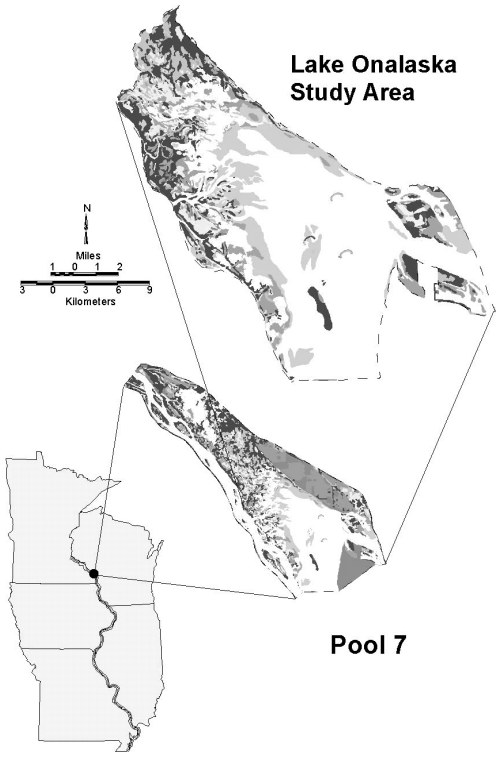

Figure 1. Location of Pool 7 and the Study Area

Lake Onalaska was known for its aquatic vegetation since it was formed by impoundment in 1937 (Green, 1960). The study area that was chosen for this analysis consisted of all of Lake Onalaska and areas just up river. The west study area boundary follows the main channel from lock and dam 7 to river mile 709.0. The upper study area

boundary follows the Black River System from the main channel back to where it enters the Mississippi River floodplain. The east boundary is the shoreline that borders the city of Onalaska, Wisconsin and the lower boundary is the spillway and shoreline around the LaCrosse Airport.

The following analyses were completed using a Geographic Information System (GIS) and Environmental Systems Research Institute's (ESRI), Arc/Info software. The data that were utilized for this project consisted of Arc/Info land cover/land use coverages of pool 7 for the years 1975, 1989, and 1994. These coverages were transferred from the data library of the U. S. Geological, Upper Midwest Environmental Sciences (UMESC) in Onalaska WI.

The Great River Environmental Action Team I (GREAT I) automated the 1975 coverage from 1:9,600-scale color infrared photography. The interpreted data were transferred to 1:24,000-scale United States Geological Survey (USGS) quadrangle maps and manually digitized. The coverage was then converted to an Arc/Info coverage by the EMTC.

The 1989 and 1994 coverages were automated by the EMTC under the Long Term Resource Monitoring Program (LTRMP) from 1:15,000-scale color infrared photography. Photo interpretation was performed with a stereoscope. The interpreted data were transferred to mylar overlays, registered to a USGS 7.5' quadrangle map, and manually digitized into a GIS as Arc/Info coverages.

Summary statistics, such as total hectares of land cover and percent land cover were compared using polygon coverages. Further analyses were rendered utilizing rasterized coverages of the study area that were created in the Grid module of Arc/Info. Employing the rasterized coverages, overlay analyses were completed to reveal what changes occurred over the nineteen-year period. The operation looked at the type of land cover that existed for one year and compared it to that present in a later year. This was done by looking at the same exact cells (cell size of five meters) within the two coverages to see if they were classified as the same land cover class. If the two cells being compared differed in classification, then the change was noted. This comparison of cells was done for the entire coverage and for the periods 1975 to 1989, 1989 to 1994, and the entire period 1975 to 1994.

There were two steps that had to be taken to perform this analysis. First, the coverages were converted into rasterized format, and secondly a condition statement was used focusing on one land cover class to make the comparison between the coverages. For instance, when open water was analyzed, the condition statement looked at areas of open water in 1975 and identified how those areas existed in 1989. An area report that was generated showed the amount of area that remained unchanged over time. It also showed the amount of area and the vegetation type that the area changed into, if indeed a change did occur.

This analysis showed how much of the area remained unchanged and how much of the area changed into a different land cover class. This gives a better spatial representation of the change that has taken place within the landscape. From this, theories were developed to try to pin point the driving mechanisms causing the change in plant presence within Lake Onalaska.

Results

General Trends among Classes

Land cover analysis for the three years 1975, 1989, and 1994 were done to help understand how the Lake Onalaska area has changed. An eleven-class vegetation classification was used to classify land cover/land use types. It utilized the existing original thirteen-class classification, but modified it by combining three classes that were comprised of submergent-rooted floating-emergent, rooted floating-emergent, and emergent vegetation. These were grouped into a class of rooted floating/emergent vegetation. This modification was done to help alleviate discrepancies that occurred because of a difference in interpretation as the coverages were created by different organizations with different interpreters.

An example of the type of change is shown graphically in figure 2. Some of the changes that took place (Table 1 and Figure 3) included an increase in open water and areas of grasses/forbs, with a considerable reduction in submergent vegetation, submergent rooted floating vegetation, and rooted floating vegetation.

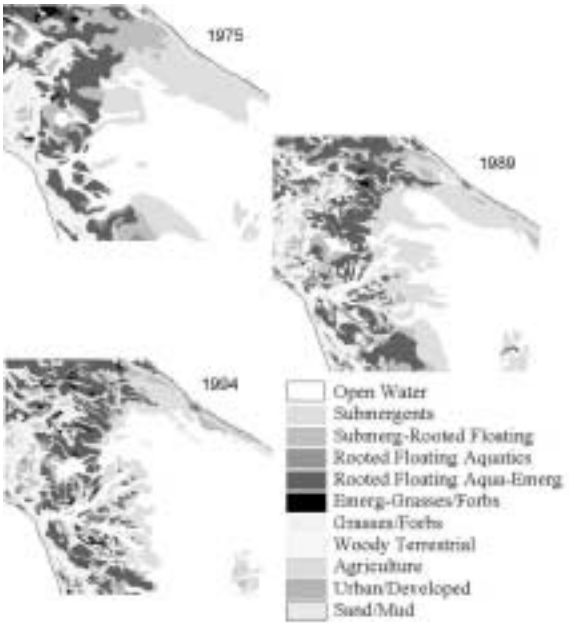

Figure 2. Area of Change 1975, 1989, 1994

To help understand the changes in the areas of vegetation over the nineteen-year period, the changes are divided into three periods, the first from 1975 to 1989, the second from 1989 to 1994, and the third from 1975 to 1994.

Table 1. Total hectares, total hectare change, and percent change of land cover in Lake Onalaska, 1975, 1989, and 1994

		Total Hectares			Total Hectare Change			Percent Change		
		1975	1989	1994	75-89	89-94	75-94	75-89	89-94	75-94
Open Water	(OPEN)	2069.4	2247.9	2467.2	178.5	219.3	397.8	8.6	9.8	19.2
Submergents	(SUB)	721.8	494.1	393.7	-227.7	-100.4	-328.1	-31.5	-20.3	-45.5
Sub-Rooted Floating	(SRF)	343.3	306.6	218.4	-36.7	-88.2	-124.9	-10.7	-28.8	-36.4
Rooted Floating Aquatics	(RFA)	32.6	18.7	4.6	-13.9	-14.1	-28.0	-42.6	-75.4	-85.9
Rooted Floating/Emergent	(RFE)	422.8	465.9	440.7	43.1	-25.2	17.9	10.2	-5.4	4.2
Emergent-Grasses/Forbs	(EGF)	67.1	54.7	66.5	-12.4	11.8	-0.6	-18.5	21.6	-0.9
Grasses/Forbs	(GF)	32.3	100.8	95.6	68.5	-5.2	63.3	212.1	-5.2	196.0
Woody Terrestrial	(WT)	499.7	490.5	502.6	-9.2	12.1	2.9	-1.8	2.5	0.6
Agriculture	(AGR)	1.1	0.5	0.1	-0.6	-0.4	-1.0	-54.5	-80.0	-90.9
Urban/Developed	(UD)	1.4	2.2	2.5	0.8	0.3	1.1	57.1	13.6	78.6
Sand/Mud	(SM)	0.7	10.3	0.3	9.6	-10.0	-0.4	1371.4	-97.1	-57.1

* Negative values reflect a decrease

Over the nineteen-year period between 1975 and 1994 there was a total increase of 398 hectares of open water in the Lake Onalaska study area. In the first period, there was an increase of 178.4 hectares, and in the second period there was an increase of 219.3 hectares.

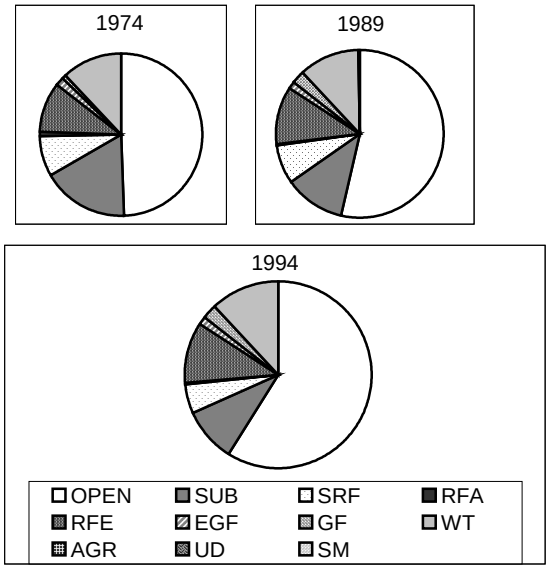

Figure 3. Land cover for 1975, 1989, 1994

Submergent vegetation exhibited a declining trend over the same nineteen-year period. Between the period of 1975 to 1994, there was a decrease in area of submergent vegetation of 328.1 hectares. Most of the decrease took place during the first period, between 1975 and 1989 when a 227.7 hectares decrease was noted. A decrease of 100.4 hectares occurred during the second period, between 1989 and 1994.

A similar pattern of decrease was observed for the submergent-rooted floating class. From 1975 to 1994 a total of 124.9 hectares of submergent-rooted floating vegetation changed. Between 1975 and 1989 there was a decrease of 36.7 hectares and of 88.3 hectares between 1989 and 1994.

In the class containing rooted floating aquatics a trend of decrease was evident. For the total period the decrease was 28.0 hectares. A decrease of 13.9 hectares occurred in the first period and a decrease of another14.1 in the second.

For the class of rooted floating/emergent vegetation there was an increase of 17.9 hectares from 1975 to 1994. Of this, an increase of 43.1 hectares was noted during the first period. This was accompanied by a slight decrease during the second period, between 1989 and 1994 (25.2 hectares).

The class comprised of emergent-grasses/forbs displayed a small decrease in area from 1975 to 1994 (0.6 hectares). A decrease of 12.4 hectares was noted during the first period and an increase of 11.8 hectares during the second.

The class that consisted of grasses/forbs, during the entire period, exhibited an increase in area of approximately 63.3 hectares, from 32.3 hectares to 95.6 hectares. Between 1975 and 1989 there was a gain of 68.5 hectares while a decrease of 5.2 hectares occurred between 1989 and 1994.

Woody terrestrial vegetation exhibited a slight increase in area over the total period. There was a total gain of 2.8 hectares of woody terrestrial vegetation. A decrease of woody terrestrial vegetation occurred during the first period when 9.2 hectares disappeared. Then during the second period the woody terrestrial vegetation increased 12.1 hectares.

The final three classes (agriculture, urban/developed, and sand/mud) encompassed such a small amount of area that the data may seem deceiving. Agriculture decreased in coverage from 1.1 hectare in 1975 to 0.1

hectare in 1994. There was a 0.6 hectares decrease during the first period and a 0.4 hectares decrease during the second period. The urban/developed cover type displayed the opposite trend. There was an increase of 1.1 hectares overall, with a 0.8 hectares increase between 1975 to 1989, and a 0.3-hectare between 1989 and 1994.

The sand and mud class showed some change. There was a total decrease of 0.4 hectares over the two periods. During the first period there was an increase of 9.6 hectare of sand and mud, which was due to disturbance during the excavation of materials (materials were removed to build a highway nearby and vegetation was disturbed in the process) from an area within the study area. The disturbed area was within Rose Bud Island. During the period between 1989 and 1994 there was a decrease of 10.0 hectares in the amount of sand and mud. The major change that took place happened on Rose Bud Island within the excavation area where sand and mud changed grasses and forbs. It was in this area that vegetation was able to reestablish itself. Another change that took place as the result of another construction project that should be noted was the addition of three islands within Lake Onalaska. They were constructed in 1989 as part of a habitat rehabilitation and enhancement project (HREP) with funds from the Army Corp of Engineers to improve wildlife habitat and reduce wind fetch.

Lastly, this analysis showed a 30.6-hectare increase of emergent vegetation during the first period and a 13.4-hectare decrease during the second period. Between 1975 and 1994 the increase was 17.2 hectares (Figure 4 and Table 3).

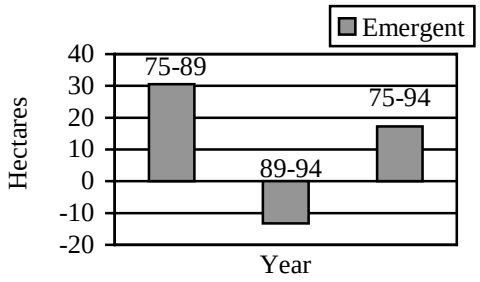

Figure 4. Change in area of emergent vegetation 1975-1994.

Table 3. Comparison of Emergent Vegetation and Sagittaria

		Total Hectares	% of Total Land Cover		Total Change (ha)	%Change
	75	489.9	11.7	**75-89**	30.6	6.23
EMERGENTS	**89**	520.4	12.4	**89-94**	-13.4	-2.56
	94	507.1	12.1	**75-94**	17.2	3.51
	75	343.6	8.2	**75-89**	-14.0	-4.07
SAGITTARIA	**89**	329.6	7.9	**89-94**	62.4	18.90
	94	391.9	9.3	**75-94**	48.4	14.06

Selecting and focusing on a particular species of emergent vegetation was undertaken next. The species chosen was *Sagittaria* (duck potato), an emergent species that has been an important aspect of Lake Onalaska's success. It was selected because of its abundance in the lake and its importance

as a food source for migrating waterfowl (Korschgen, et al. 1988). All polygons that had Sagittaria present in them were selected from the main coverages, regardless of how the polygons were classified in the 11-class classification. A statistical analysis was then run on the newly selected data set.

Analysis showed there to be a decrease of 14.0 hectares of *Sagittaria* during the first period from 1975 to 1989 (Figure 5). The analysis also showed that there was an increase in *Sagittaria* between 1989 and 1994 of 62.3 hectares, with a total increase in area during the combined two periods of 48.3 hectares.

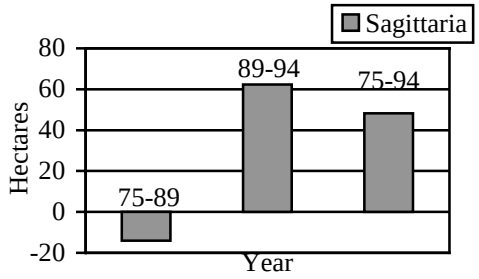

Figure 5. Change in area of the emergent vegetation *Sagittaria* 1975-1994

Overlay analysis for 1975 and 1989

Additional analyses were completed to help understand how changes in land cover occurred by identifying the areas of change and tracking into which land cover type those areas transformed. Overlay analyses were performed on the coverages by overlaying the 1975 coverage with the 1989, the 1989 coverage with the 1994 coverage, and the 1975 coverage with 1994 coverage.

There were 2069.4 hectares of open water in 1975 and 2247.8 hectares in 1989. Changes are summarized in Tables 4 and 5. Of the total area of open water in 1975, 1715.5 hectares still existed in 1989, while 224.3 hectares of the total area in 1975 changed to submergent vegetation in 1989. Some areas that were classified as open water in 1975 also changed to other classes in 1989. The loss of open water to submergent vegetation was offset by the 400.7 hectares loss of submergent vegetation to open water in 1989. There were 721.8 hectares of submergent vegetation in 1975 compared to 494.2 hectares in 1989.

Table 4. What 1975 Land cover Classes Became in 1989 (percent)

	OW	**SUB**	**SR**	**RF**	**RFE**	**EGF**	**GF**	**WT**	**AGR**	**UD**	**SM**
Open Water (OW)	82.9	10.8	1.8	0.5	1.3	0.3	0.5	1.6	0	0.1	0.1
Submergent (SUB)	55.5	31.6	8.0	0.1	2.9	0.1	0.1	1.5	0	0.1	0.1
Sub-Rooted Floating (SR)	18.0	9.1	38.0	0.6	30.9	1.3	0.3	1.8	0	0	0
Rooted Floating (RF)	9 6	3.9	29.0	4.5	44.3	5.0	1.9	1.8	0	0	0
Root F-Emergent (RFE)	10.2	1.4	12.2	0.8	56.1	5.0	5.9	7.7	0	0	0.9
Emer-Grass/Forb (EGF)	3.6	0	2.2	0	27.4	14.4	35.9	16.4	0	0	0
Grasses/Forbs (GF)	1.2	0.2	0.1	0	1.6	0	21.0	74.2	1.2	0	0.5
Woody Terrestrial (WT)	4.2	0.6	3.5	0.1	8.2	2.1	6.5	74.0	0	0	0.7
Agriculture (AGR)	0	0	0	2.8	0	1.9	0.9	94.3	0	0	0
Urban/Developed (UD)	17.5	16.8	0	13.1	0	0	51.1	0.7	0	0.7	0
Sand/Mud (SM)	0	0	31.8	0	0	0	0	40.9	0	0	27.3

* The underline marks the amount of area that remained unchanged

Table 5. What 1975 Land cover Classes Became in 1989 (hectares)

	OW	SUB	SR	RF	RFE	EGF	GF	WT	AGR	UD	SM	1975
Open Water (OW)	1715.5	224.3	38.1	10.4	27.0	6.6	9.4	34.0	0	1.6	2.4	2069.4
Submergent (SUB)	400.7	227.9	57.9	0.6	21.0	0.8	1.0	11.2	0	0.5	0.4	721.8
Sub-Rooted Floating (SR)	61.8	31.3	130.4	2.1	106.2	4.4	1.1	6.0	0	0	0	343.3
Rooted Floating (RF)	3.1	1.3	9.5	1.5	14.5	1.6	0.6	0.6	0	0	0	32.6
Root F-Emergent (RFE)	43.0	5.9	51.4	3.2	237.2	21.1	24.9	32.5	0	0	3.6	422.8
Emer-Grass/Forb (EGF)	2.4	0	1.5	0	18.4	9.7	24.1	11.0	0	0	0	67.1
Grasses/Forbs (GF)	0.4	0.1	0	0	0.5	0	6.8	23.9	0.4	0	0.2	32.3
Woody Terrestrial (WT)	20.8	3.2	17.6	0.7	41.2	10.5	32.3	370.0	0.1	0	3.4	499.7
Agriculture (AGR)	0	0	0	0	0	0	0	1.0	0	0	0	1.1
Urban/Developed (UD)	0.2	0.2	0	0.2	0	0	0.7	0	0	0	0	1.4
Sand/Mud (SM)	0	0	0.2	0	0	0	0	0.3	0	0	0.2	0.7
1989 Total	2247.8	494.2	306.6	18.7	465.9	54.7	100.8	490.5	0.5	2.2	10.3	

* The underline marks the amount of area that remained unchanged

Only 227.9 hectares of submergent vegetation occurred at a common location both years.

In the submergent-rooted floating land cover class, 130.4 hectares of the total area existed in the same location between the two periods, while 106.2 hectares existed as rooted floating-emergent vegetation. There was a decrease of 61.8 hectares of submergent-rooted floating leaf vegetation to open water and 31.3 hectares classified as submergent vegetation.

In the rooted floating leaf vegetation class there was a total of 32.6 hectares in 1975 and 18.7 hectares in 1989. There was only 1.5 hectares of the area that existed in the same location between the two coverages. The remainder was divided into areas such as 3.1 hectares of open water, 1.3 hectares of submergent vegetation, 9.5 hectares of submergent-rooted floating leaf vegetation, and 14.5 hectares of rooted floating-emergent vegetation.

For the class of rooted floating-emergent vegetation, 237.2 hectares of what was identified in 1975 remained in the same location in 1989. Other major areas that were identified as rooted floating-emergent vegetation in 1975 existed as open water (43.0 hectares), submersed-rooted floating vegetation (51.4 hectares), and woody terrestrial (32.5 hectares) in 1989. In the emergent-grass/forbs class less area shared a common classification between the two coverages. Only 9.7 hectares of the total in 1975 still existed unchanged in 1989. Most changed to grasses/forbs (24.1 hectares) while a good percentage existed as rooted floating-emergent vegetation (18.4 hectares), and woody terrestrial (11.0 hectares). For the grass/forbs class most of the area existed as woody terrestrial in 1989 (23.9 hectares) and only 16.3 hectares of the area shared the same classification between the two periods.

As for woody terrestrial vegetation, 370.0 hectares of the total area in 1975 remained in the same location, while the only major differences were that 41.2 hectares which existed as rooted floating-emergent vegetation, and 32.3 hectares existing as grass/forbs in 1989. Some small differences were also seen with the agriculture, urban developed, and sand/mud.

Overlay analysis for 1989 and 1994

In the analysis that was performed by overlaying the 1989 coverage and the 1994 coverage, 2,041.1 hectares of the area classified as open water remained the same, 127.5 hectares became submergent vegetation and 19.4 hectares became either submergent-rooted floating vegetation and rooted floating-emergent vegetation. The remainder of the area was allocated among the other seven classes. Submergent vegetation lost 300.2 hectares of its area to open water, 19.3 hectares to the submergent-rooted floating class, and 9.6 hectares to the rooted floating-emergent class, while only 159.2 hectares existed in the same location in 1994.

Submergent-rooted floating vegetation lost 58.0 hectares of its area to open water, 55.0 hectares to submergent vegetation, 58.0 hectares to rooted floating-emergent vegetation, and 11.7 hectares to woody terrestrial vegetation. Only 118.6 hectares existed in the same location in 1994 as it did in 1989. The rooted floating class demonstrated a complete change. There were no areas that were classified as rooted floating in 1989 that existed in 1994. The area changed to open water (3.9 hectares), submergent vegetation (3.1 hectares), submergent-rooted floating vegetation (6.8 hectares), rooted floating-emergent (3.4 hectares), and woody terrestrial (1.0 hectares).

For the rooted floating-emergent vegetation class, 292.5 hectares of the 440.7 hectares that existed in 1994 remained unchanged from 1989. There was a loss of 42.0 hectares of its area to open water as well as a 36.6 hectare changed to submergent vegetation and 39.7 hectares of the area to submergent-rooted floating vegetation. There were also changes with a 25.6-hectare changed to emergent-grass/forbs land cover and a 22.5-hectare conversion of area to woody terrestrial vegetation.

The class of emergent-grass/forbs was dispersed among the other land cover coverages from 1989 to 1994 with only 211.9 hectares of the area existing unchanged. Most of the change took place because 49.7 hectares of the area classified as emergent-grass/forbs in 1989 was classified as rooted floating-emergent vegetation in 1994. Other changes were found where 10.4 hectares and 6.3 hectares of the areas were classified as grass/forbs and woody terrestrial. As for the grass/forbs class, 45.1 hectares of the area remained unchanged in its classification, while 22.1 hectares of the area existed as woody terrestrial, 13.8 hectares of the area existed as rooted floating-emergent vegetation, and 11.9 hectares of the area existed as emergent-grass/forbs in 1994. The class of woody terrestrial saw little change with 407.0 hectares of its area classified the same between the two periods.

As for the land cover class of agriculture, urban/developed, and sand/mud, 0.2 hectares of the area classified as agriculture existed as grass/forbs and most (1.0 hectare) of the area of the land cover type, urban/developed was reclassified as open water. The sand/mud class was reclassified as grass/forbs (5.6 hectares) and woody terrestrial (3.2 hectares). These data for changes between 1989-94 are summarized in tables 6 and 7.

Table 6. What 1989 Land cover Classes Became in 1994 (percent)

	OW	SUB	SR	RF	RFE	EGF	GF	WT	AGR	UD	SM
Open Water (OW)	90.8	5.7	0.9	0.1	0.9	0.1	0.4	1.1	0	0.1	0
Submergent (SUB)	60.7	32.2	3.9	0	1.9	0.2	0	0.9	0	0	0
Sub-Rooted Floating (SR)	18.9	17.9	38.7	0.4	18.9	1.0	0.3	3.8	0	0	0
Rooted Floating (RF)	21.0	16.3	36.3	0	18.3	2.4	0.6	5.1	0	0	0
Root F-Emergent (RFE)	9.0	7.9	8.5	0.3	62.8	5.5	1.2	4.8	0	0	0
Emer-Grass/Forb (EGF)	5.8	1.1	4.8	0	36.0	21.8	19.0	11.5	0	0	0
Grasses/Forbs (GF)	4.7	1.8	0.8	0	13.7	11.8	44.7	22.0	0	0.6	0
Woody Terrestrial (WT)	2.6	1.9	2.2	0.1	4.8	1.9	3.5	83.0	0	0	0
Agriculture (AGR)	0	0	15.2	0	0	0	43.5	19.6	21.7	0	0
Urban/Developed (UD)	48.1	22.2	0	0	0	0	13.4	7.4	0	8.8	0
Sand/Mud (SM)	2.6	2.4	0.2	0	3.1	0	54.2	31.2	0	3.2	2.9

* The underline marks the amount of area that remained unchanged

Table 7. What 1989 Land cover Classes Became in 1994 (hectares)

	OW	SUB	SR	RF	RFE	EGF	GF	WT	AGR	UD	SM	1989
Open Water (OW)	2041.1	127.5	19.4	1.7	19.9	3.0	10.1	24.0	0	1.2	0	2247.8
Submergent (SUB)	300.2	159.2	19.3	0	9.6	1.0	0.1	4.6	0	0.2	0	494.1
Sub-Rooted Floating (SR)	58.0	55.0	118.6	1.3	58.0	3.1	1.0	11.7	0	0	0	306.6
Rooted Floating (RF)	3.9	3.1	6.8	0	3.4	0.5	0.1	1.0	0	0	0	18.7
Root F-Emergent (RFE)	42.0	36.6	39.7	1.3	292.5	25.6	5.5	22.5	0	0	0	465.8
Emer-Grass/Forb (EGF)	3.2	0.6	2.7	0	19.7	11.9	10.4	6.3	0	0	0	54.7
Grasses/Forbs (GF)	4.7	1.8	0.8	0	13.8	11.9	45.1	22.1	0	0.6	0	100.8
Woody Terrestrial (WT)	12.7	9.2	11.0	0.3	23.5	9.5	17.2	407.0	0	0	0	490.5
Agriculture (AGR)	0	0.0	0.1	0	0	0	0.2	0.1	0.1	0	0	0.5
Urban/Developed (UD)	1.0	0.5	0	0	0	0	0.3	0.2	0	0.2	0	2.2
Sand/Mud (SM)	0.3	0.3	0	0	0.3	0	5.6	3.2	0	0.3	0.3	10.3
1994 Total	2467.1	393.7	218.4	4.6	440.7	66.5	95.5	502.6	0.1	2.5	0.3	

* The underline marks the amount of area that remained unchanged

Overlay analysis for 1975 and 1994

An overlay analysis was also done to identify changes over the total periods, comparing 1975 and 1994. Between these two coverages, 1839.0 hectares of the area classified as open water in 1975 existed as open water in 1994 (Table 8). Only 169.4 hectares of the area classified as submergent vegetation remained in 1994 with 483.4 of the area converted to open water. For submergent-rooted floating vegetation, only 92.7 hectares of its area existed unchanged over the nineteen-year period. According to the data, 83.0 hectares of the submergent-rooted floating vegetation area existed as open water, 70.1 hectares existed as submergent vegetation, and 84.5 hectares existed as rooted floating-emergent vegetation.

In the class of rooted floating leaf vegetation there were no areas in 1975 that existed in the same location in 1994. The areas were converted to open water (9.5 hectares), submergent-rooted floating vegetation (8.7 hectares), and rooted floating-emergent vegetation (9.9 hectares). The class of rooted floating-emergent vegetation remained unchanged for 232.2 hectares of the area between 1975 and 1994.

Table 8. What 1975 Land cover Classes Became in 1994 (percent)

	OW	SUB	SR	RF	RFE	EGF	GF	WT	AGR	UD	SM
Open Water (OW)	88.9	5.4	1.7	0	1.3	0.4	0.4	1.8	0	0.1	0
Submergent (SUB)	67.0	23.5	5.3	0	2.2	0.3	0.1	1.5	0	0.1	0
Sub-Rooted Floating (SR)	24.2	20.4	27.0	0.6	24.6	1.6	0	1.5	0	0	0
Rooted Floating (RF)	29.2	4.9	26.8	0.0	30.2	1.4	2.2	5.4	0	0	0
Root F-Emergent (RFE)	8.1	7.5	7.1	0.2	54.9	7.2	5.7	9.2	0	0	0
Emer-Grass/Forb (EGF)	3.8	1.9	3.3	0.2	30.9	5.4	37.5	17.1	0	0	0
Grasses/Forbs (GF)	1.4	0	1.1	0.1	1.2	0.2	18.3	77.4	0.3	0	0
Woody Terrestrial (WT)	2.9	1.6	2.2	0.1	10.0	3.1	6.0	74.1	0	0	0.1
Agriculture (AGR)	0	0	0.9	0	0	0	0	99.1	0	0	0
Urban/Developed (UD)	27.2	10.3	20.6	0	0	0	0	8.8	0	33.1	0
Sand/Mud (SM)	0	25.4	0	0	0	0	22.4	52.2	0	0	0

* The underline marks the amount of area that remained unchanged

Table 9. What 1975 Land cover Classes Became in 1994 (hectares)

	OW	SUB	SR	RF	RFE	EGF	GF	WT	AGR	UD	SM	1975
Open Water (OW)	1839.0	111.6	34.6	0.8	27.3	8.8	8.4	37.2	0	1.6	0	2069.4
Submergent (SUB)	483.4	169.4	38.4	0	15.7	2.5	1.0	11.0	0	0.4	0	721.8
Sub-Rooted Floating (SR)	83.0	70.1	92.7	2.2	84.5	5.4	0.2	5.3	0	0	0	343.3
Rooted Floating (RF)	9.5	1.6	8.7	0.0	9.9	0.5	0.7	1.8	0	0	0	32.7
Root F-Emergent (RFE)	34.4	31.6	30.2	0.8	232.2	30.3	24.3	39.1	0	0	0	422.8
Emer-Grass/Forb (EGF)	2.5	1.3	2.2	0.1	20.7	3.6	25.2	11.5	0	0	0	67.1
Grasses/Forbs (GF)	0.5	0	0.4	0	0.4	0.1	5.9	25.0	0.1	0	0	32.3
Woody Terrestrial (WT)	14.5	7.8	10.9	0.6	49.9	15.4	29.9	370.3	0	0	0.3	499.7
Agriculture (AGR)	0	0	0	0	0	0	0	1.1	0	0	0	1.1
Urban/Developed (UD)	0.4	0.1	0.3	0	0	0	0	0.1	0	0.5	0	1.4
Sand/Mud (SM)	0	0.2	0	0	0	0	0.2	0.4	0	0	0	0.7
1994 Total	2467.2	393.7	218.4	4.6	440.7	66.5	95.6	502.6	0.1	2.5	0.3	

* The underline marks the amount of area that remained unchanged

The emergent-grass/forbs land cover class changed in its composition over the two periods. Only 3.6 hectares remained unchanged while 11.5 hectares occurred as woody terrestrial and 20.7 hectares of the total were classified as rooted floating-emergent vegetation. Meanwhile, 25.2 hectares were classified as grass/forbs.

For the class of grasses/forbs, 725.0 hectares of the total was classified in 1994 as woody terrestrial vegetation and only 5.9 hectares of the total remained unchanged. Meanwhile, in the land cover class of woody terrestrial, only 49.9 hectares of the total was classified as rooted floating-emergent, for which 370.3 hectares of the total remained unchanged throughout the nineteen-year period.

Discussion

There are definite changes that occurred during the nineteen-year period. In most cases, the data shows either a steady increase or decrease in land cover while there were other classes of land cover that showed a more variable pattern during the two periods. The greatest change that was observed between 1975 and 1994 was the increase in open water, and emergent and grasses/forbs vegetation, along with the significant

decreases in submergent and rooted floating vegetation.

Many assumptions can be made to explain the reasons for the large shift in land cover for the classes of open water and submergent vegetation. The decrease in submergent vegetation may be attributed to many different factors. The first one could be because of drought, which would affect the water level within the pool. A low water period caused by drought was seen in 1987-1989. An extended period such as this could have lead to a lack of sediment nutrients, high algal and epiphytic densities affecting water clarity (Rogers 1994), or high concentrations of herbicides.

A second influence may have been from high water (flood of 1993). Flooding can affect submersed vegetation in a number of ways depending on the timing, duration, and magnitude of the event. The negative consequences of a flood event are burial of beds by sediments, reduced light penetration (increase suspended solids and higher water level), and uprooting due to high current velocities (Rogers 1994). These factors may have had some affect on the decrease of submergent and rooted floating leaf vegetation. High water could also be a factor in that during periods of higher water levels, the submersed vegetation is further underwater and less visible. If at during the time that the aerial photographs were taken, the river was experiencing high water elevations, the submersed vegetation beds may have been under estimated. On the other hand, if the river was experiencing normal water levels, the submersed vegetation would be better measured.

The increase in emergent and grasses/forbs vegetation may be attributed to other natural events. Many scientists have documented sedimentation within Lake Onalaska. McHenry and Ritchie (1978) gave estimates of 2.1 cm per year between 1954 and 1964 and a lower rate of 1.66 cm per year between 1964 and 1977. Korschgen, *et al*. (1987) showed that within Lake Onalaska since impoundment (1937) to 1983, the mean water depth changed from 1.52 meters to 1.43 meters. This was a decrease in mean water depth of 9 cm with an overall sedimentation rate of 0.2 cm per year.

There is also a progression of sediments in the delta area where water enters the lake from the main channel of the river at Sommers chute (Boma, UMESC, pers, comm.). Some of these factors may be the driving force behind a successional change from open water to submerged macrophyte beds, to emergent macrophyte beds, and finally developing into grassy and wooded terrestrial areas (Bhowmik and Adams, 1989).

It may also be a fact that the lake has reach equilibrium and there is only accumulation of sediments occurring in certain areas, (Gaugush, UMESC, pers. comm.). For example, around the man-made islands (HREP islands) that were build in 1989, where sediments are being scoured in high water velocity areas and sediments are being deposited in low water velocity areas.

Data Limitations

Throughout the project there were a few discrepancies that may have been due to the accuracy of the coverages and their limitations. For instance, the 1975 coverage was created by the GREAT I, and not by the EMTC who created the

1989 and 1994 coverages. Therefore, it is possible that delineations between vegetation types and how the land cover was classified may be different. The 1975 coverage was originally classified using a fifty-eight-class classification system. It was not until recently that the 1975 coverage was reclassified by the EMTC to fit a thirteen-class classification system. During the reclassification process the class of rooted floating-emergent vegetation was not used due to the fact that the data were classified into other classes. Because of this, the classes had to be even more generalized by combining the classes of submergent-rooted floating-emergent, rooted floating-emergent, and emergent into one class, creating an eleven-class classification system. As the data become more generalized, the less opportunity one has to define any trends that may be occurring.

Some of the error may occur during the photo interpretation phase of the process where variation in interpreter, the interpreter's discretion, and the pen size used to make the land cover delineations may create discrepancies. Another source of error may be while transferring the data to a base map. Error can be introduced due to any inaccuracies of the base map and since the scale of the base map (1:24,000) may be at a smaller scale then the infrared photographs (1:15,000), data may be lost or less accurate.

During the automation phase, when the information is digitized into the computer, there is also opportunity for error to occur, human error as well as computer-generated error (root mean square).

To directly overlay the coverages for such an analysis assumes that the coverages are highly accurate. Even the slightest inaccuracy may have skewed the results. So it is important to keep in mind the limitations of the data.

The complete answers to these questions cannot come from this analysis. The analysis showed that changes have occurred in the nineteen-year period. However there may be many possible explanations. Further analysis is needed to bring a better understanding and to help explain the causes of these changes within Lake Onalaska. A better understanding will help managers make the right decision for healthier resource management.

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