Herbicide Treatment of *Potamogeton crispus* Analysis

Bone Lake, Polk County WI
2014

Prepared by Ecological Integrity Service, LLC
Amery, Wisconsin

Abstract

On May 28 and 29, 2014 eight beds of *Potamogeton cripus* (curly leaf pondweed-CLP) totaling 30.43 acres were treated with endothall at a target concentration of 2 ppm. The treatment was found to be effective at reducing the CLP growth that was quantified before treatment, based upon frequency. The frequency from before treatment to after treatment declined 63.6%. Compared to the 2013 post treatment frequency, the 2014 increased slightly from 9.3% in 2013 to 11.3% in 2014. The pretreatment frequency from 2013 decreased in 2014, from 87% in 2013 to 74.6% in 2014, demonstrating a potential long-term CLP reduction. The native species analysis showed a reduction in the frequency of one species (*Potamogeton robbinsii*) that was significant. There was an increase in frequency in 9 native species. This supports no adverse effect of the herbicide on native species. A turion density analysis showed a reduction in the mean turion density in all beds from 2013 to 2014. Beds 2-5 showed a reduction in mean turion density for the fourth straight year. The update in non-treated CLP bed maps was not possible as the CLP never grew close to the surface to allow viewing from the surface.

Introduction

On May 28 and 29, 2014 *Potamogeton crispus*-curly-leaf pondweed (CLP) was treated with the herbicide endothall (Aquatholl K). This was the 7th year of treatment on 3 of the 4 beds (Plots 2,3,4) and the 6th year in Plot 5. Beds 6-8 were treated in 2013 for the first time (so this is the second year of treatment). Figure 1 is a map showing the location of each bed treated and the acreage. Beds 6 and 7 were separated into parts to better determine mean depths for the applicator concentration calculation.

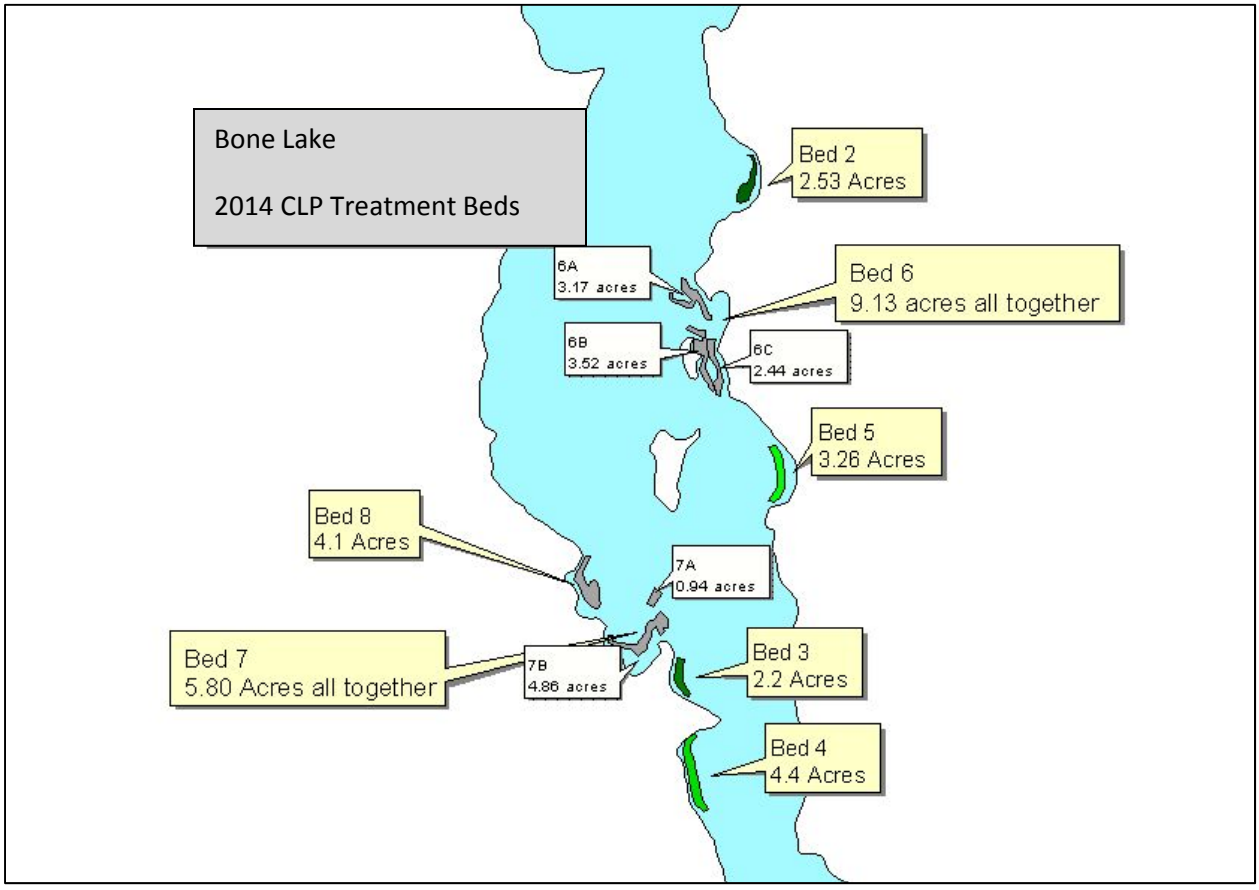


Figure 1: Map of CLP treatment beds for 2014.

The target concentration for each treatment bed was 2 parts per million (ppm). This was determined by using the acre feet of water within each bed. The treatment file prepared by the applicator stated that the 2 ppm target was fulfilled. Table 1 outlines the treatment bed specifications.

Bed	Area (acres)	Mean Depth (ft)	Acre feet	Treatment Date	Target concentration	Wind conditions @ treatment
2	2.53	9.1	23.02	5/28/2014	2 ppm	1-3 mph
3	2.2	7.4	16.28	5/28/2014	2 ppm	1-3 mph
4	4.4	8.5	37.40	5/28/2014	2 ppm	1-3 mph
5	3.26	8.2	26.73	5/29/2014	2 ppm	1-5 mph
6	9.13	7.3	66.65	5/29/2014	2 ppm	1-5 mph
7	5.8	9.1	52.78	5/28/2014	2 ppm	1-3 mph
8	4.1	8.2	33.62	5/28/2014	2 ppm	1-3 mph
Total	**30.46**		**375.11**			

Table 1: Summary of treatment bed characteristics.

Bed	Description
2	Bed 2 lies to the north on the east shore. It is the second smallest bed. This bed has been treated for 6 years prior to 2014. The depth drops off quickly on the lake side and gets quite shallow near shore. The CLP has been most dense in the southern portion of the bed and quite sporadic in coverage on the north. The effectiveness of treatment has been most consistent in this bed, but only very effective the last three years.
3	Bed 3 lies on the western shore just north of Bed 4. This bed is the smallest but has a history of being very dense, especially in the northern half of the bed. Treatment results have been inconsistent, but effective the last three years.
4	Until 2013, Bed 4 was the largest bed, but is now third largest. This bed borders deep water and has been very inconsistent in response to treatment. It has been speculated that wind may be a factor in the results so treatment has been limited to winds below 10 mph. The middle portion of the bed has been the most dense, with the north and south end being more sporadic. There are a large number of piers bordering this bed on shore.
5	This bed has been treated one less year than beds 2,3 and 4. It lies on the east shore, south of bed 2. Bed 5 has been very dense in the southern half of the bed. The treatment has been very inconsistent in terms of effectiveness including 2012, in which it responded the least of all beds to the herbicide. The 2013 treatment was more effective. It also borders deep water.
6	Bed 6 is made up of three separate areas. This is one of the densest areas of CLP on Bone Lake. Historically navigation channels have been established within the area of this bed. Also, the bed borders a sensitive habitat area established many years ago by the Wisconsin DNR. To reduce adverse effects on this area, the bay to the north of the bed has been avoided. This bed lies adjacent (east) of eagle island. Much of the bed reaches the surface each year.
7	Bed 7 is divided into two parts. One is a small portion to the north of the main part of the bed. The bed lies on the west shore north of bed 3. The bed is most dense in the middle portion with the west arm being very narrow in coverage and reduced in density as moving west. The small north portion that stands alone is dense, but in deep water (8-10 feet). Bed 7 historically has been very dense with CLP reaching the surface every year.
8	Bed 8 is just north of bed 7 on the west shore. It is relatively shallow and flat, but borders deep water on the lake side. This bed has been extremely dense in past years with CLP reaching the surface in most of the bed. Beds 6, 7 and 8 were treated first in 2013.

Table 2: Description of each treatment bed.

Methods

To conduct and analyze the treatment, two surveys are conducted following the protocol outlined in 2009 by the Wisconsin DNR. The first survey is referred to as a pretreatment survey. This involves going to predetermined GPS coordinates within the proposed treatment area. A high definition underwater camera as well as a rake is used to determine the presence of CLP at each sample point. Density is not measured as the plants are typically very small and density is very subjective and variable. The presence of CLP is simply determined. There are also points checked outside of the bed delineation to assure the boundary is correct (not recorded unless CLP was present).

The second survey is referred to as the post treatment survey. This survey involves going to the same GPS coordinates as the pre-treatment survey and doing a rake sample at the point. If any CLP is on the rake, the density of the CLP is recorded (see Figure 2 for reference). All other species are also recorded from the rake sample in order to verify no damage to the native plants.

Figure 2: Density rating system and example CLP rake sample.

When the surveys are complete, the frequency of occurrence is determined as well as the mean density for each bed and all beds combined. The frequency of occurrence for each native plant species sampled is also calculated. A chi-square analysis is then used to determine if the change in frequency is statistically significant ($p<0.05$). With a successful treatment, the chi-square analysis shows that the frequency of CLP is significantly reduced and the native plants are not significantly reduced.

The comparison for reduction is evaluated three ways. First, the result from the previous year's post treatment survey is compared to the present year post treatment survey. This reflects a long-term effectiveness. As more treatments are done in annual succession, these frequency values can become very similar since the CLP growth is reduced so much. This can make it appear the treatment is not progressing successfully since the frequency appears to not be reduced. Each year, turions which germinate in the fall/winter create new growth. The result may be a low

frequency in the post treatment survey, but with turion germination, high frequency CLP growth can result the following spring.

Second, in order to reflect the effect the treatment has on new spring growth, a second comparison is done. This compares the frequency of CLP in the spring, pre-treatment survey to the post treatment results in that same year. This shows what the CLP growth really was just before treating and the result after treatment.

The third evaluation is comparing the pretreatment survey of the previous year(s). Since the spring growth will reflect CLP growth after turion germination, a reduction in the pretreatment frequency can show an overall reduction in CLP due to reduced turion germination, thus reflecting an overall reduction in CLP and its turions.

In the end, we want to see a statistically significant reduction when comparing the pre-treatment frequency to the post treatment frequency. We would also like to see a consistent frequency reduction from year to year, depending on how low it is in both the pre and post treatment surveys of successive years. If the frequency in any post treatment survey is very low (less than 10% as an example), then lowering it even more may not be realistic. Turions can remain viable for several years, which can affect reduction amounts achieved.

In order to further reflect potential future growth and the cumulative success of treatments, a turion analysis is conducted in the fall following treatment. This analysis involves going to sample points near the middle of the CLP bed (assuming this will reflect the highest density). At each sample point a sediment sampler is lowered to the lake sediment and a sediment sample is obtained. Two samples are obtained from each side of the boat at each location. The samples are then sifted with a screened bucket to isolate the turions. The turions are then counted and the density of turions is calculated in turions/square meter. Consistently successful treatments should show a trend of reduced turion density each year. This way we know the treatments are killing plants prior to turion production, resulting in overall reduction in CLP in those beds.

a

b

c.

Figure 3: Pictures showing turion density methods. A shows sediment sample; b shows separation; c Shows separated turions.

Results

The pretreatment survey showed a return of CLP growth from turion germination in all beds. The post treatment survey in 2013 showed very little CLP growth in beds 2-8. In the spring, pretreatment survey in 2014, the frequency of CLP was extensive in beds 3, 6-8. In beds 2,4,5, the CLP was not as widespread with the frequency ranging from 44 to 52%, which is lower than in past years.

The post treatment survey in June 2014 resulted in very little CLP in all beds except for beds 7 and 8. This shows that the treatment was effective in all beds, except 7 and 8. Table 3 shows the frequency data. All beds resulted in a significant reduction when comparing the pretreatment frequency to the post treatment frequency. The post treatment frequency increased from 2013 to 2014 in beds 5,7 and 8. Overall, all beds had a significant reduction from before treatment to after treatment 2014. However, from post 2013 to post 2014, there was not a reduction, but a slight increase overall, largely due to beds 7 and 8. It was observed that the CLP sampled in the treatment beds after treatment was in water deeper than 10 feet.

Bed	2014 pretreat frequency	2014 posttreat frequency	2013 pretreat frequency	2013 post treat freq.	2014 pre to 2014 post freq. reduction/ significance	2013 post to 2014 post freq./reduction /significance	2013 pre to 2014 pre freq./reduction /significance
2	52.0%	8.0%	77.7%	22.0%	-44.0%	-14.0%	-25.7%
3	77.3%	4.5%	82.4%	11.8%	-72.8%	-7.3%	-5.1%
4	44.4%	2.2%	61.8%	**2.9%**	-42.2%	-0.7%	-17.4%
5	47.0%	8.8%	70.0%	0.0%	-38.2%	+8.8%	-23.0%
6	93.6%	4.8%	93.5%	7.8%	-88.8%	-3.0%	+0.1%
7	95.3%	23.3%	97.9%	8.5%	-72.0%	+14.8%	-2.6%
8	96.9%	31.2%	100.00%	18.2%	-65.7%	+13.0%	-3.1%
All beds	**74.6%**	**11.3%**	**87.0%**	**9.3%**	**-63.6%***	**+2.0%**	**-12.4%***
	***=statistically significant**				$P=5.1X10^{-56}$	No reduction Increase not significant p=0.39	P=0.0005

Table 3: Summary of treatment results and statistics.

Long term reduction can be demonstrated by comparing the pretreatment surveys of previous years. Since the turions will germinate in spring, this frequency reflects the CLP bed growth best. The pretreatment survey frequency decreased from 2013 to 2014 (from 87% to 74.6%). This is good and shows that the CLP is being reduced overall. This reduction is statistically significant (p=0.0005).

Beds 2-5, which have been treated for several years are showing significant reduction.

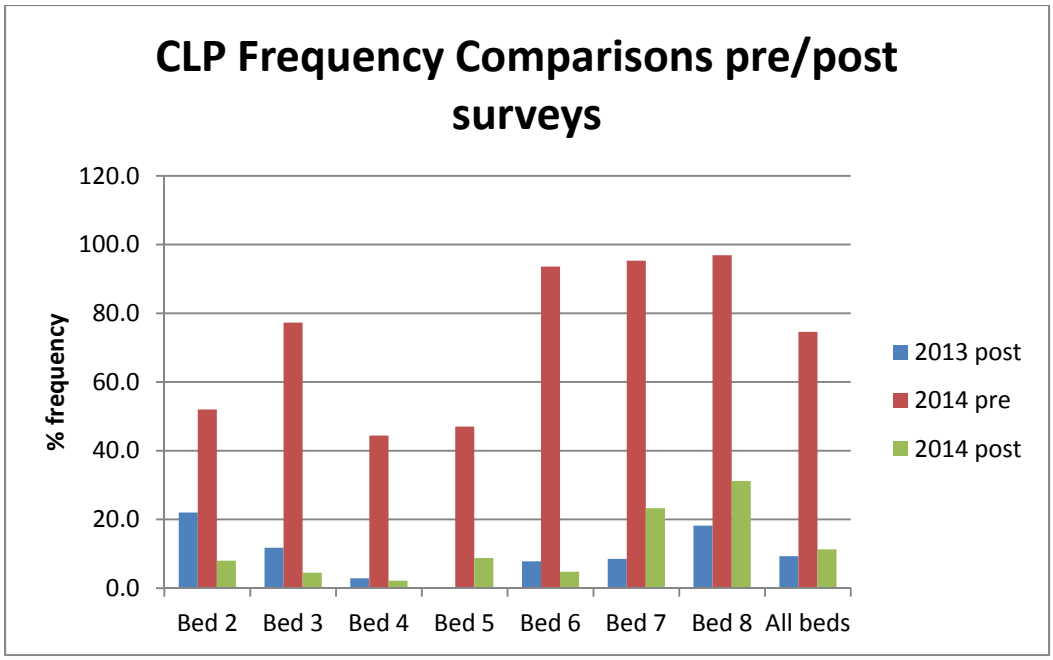


Figure 4: Graph showing comparison of the frequency of occurrences from surveys.

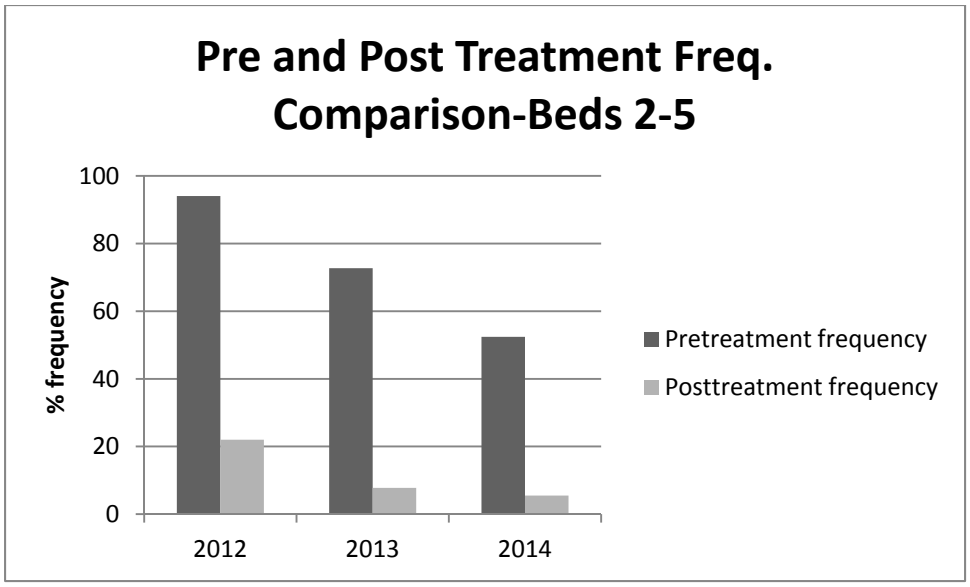


Figure 5: Graph showing frequency changes over last three years in beds 2-5 (treated more years).

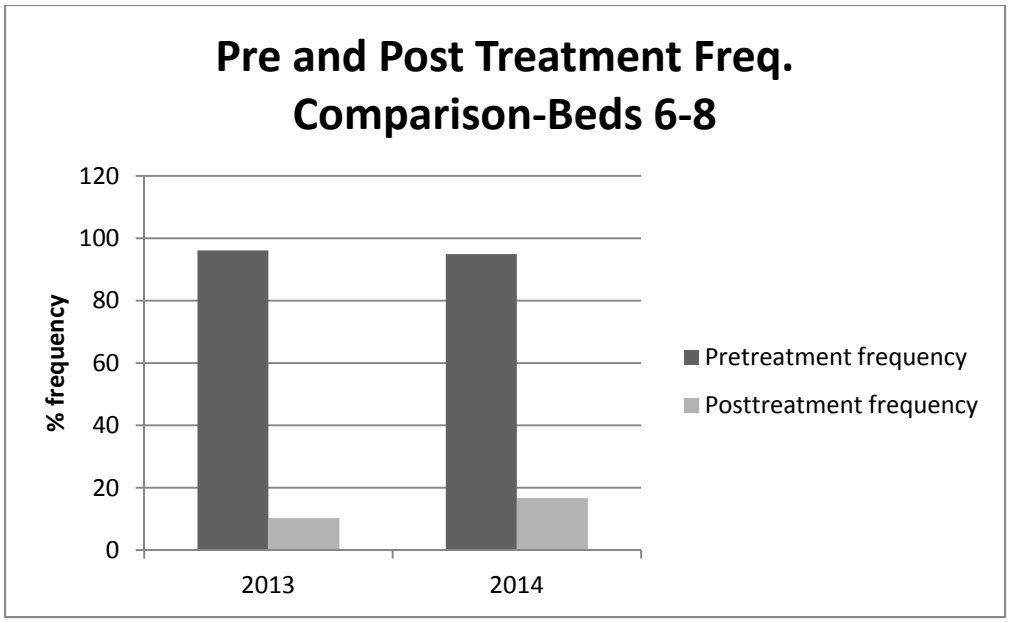


Figure 6: Graph showing frequency changes over last two years for beds 6-8 (treated only 2013 and 2014).

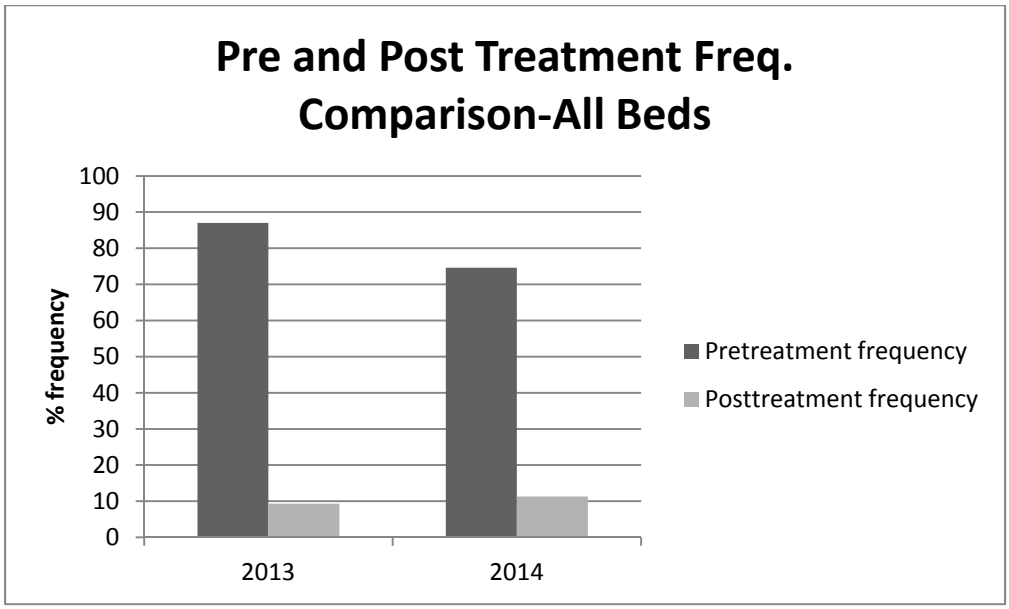


Figure 7: Graph showing frequency changes over last two years for all beds.

In addition to a reduction in frequency, a reduction in density was also achieved in most beds, except 7 and 8. Table 4 summarizes the density changes from the post treatment surveys on 2013 and 2014. An overall density change (post treatment survey) was from a mean of 0.10 in 2013 to a mean of 0.14 in 2014. This is a slight increase and is due to the higher density in beds 7 and 8. Figure 8 is a graph showing the number of sample points with the density ratings from post treatment surveys. See figures 9-15 showing CLP maps from pretreatment surveys and post treatment surveys.

Mean density Comparison	2012	2013	2014
Posttreatment mean density all beds	n/a	0.1	0.14
Posttreatment mean density beds 2-5	0.28	0.08	0.06

Table 4: Mean density all beds after treatment 2012-2014.

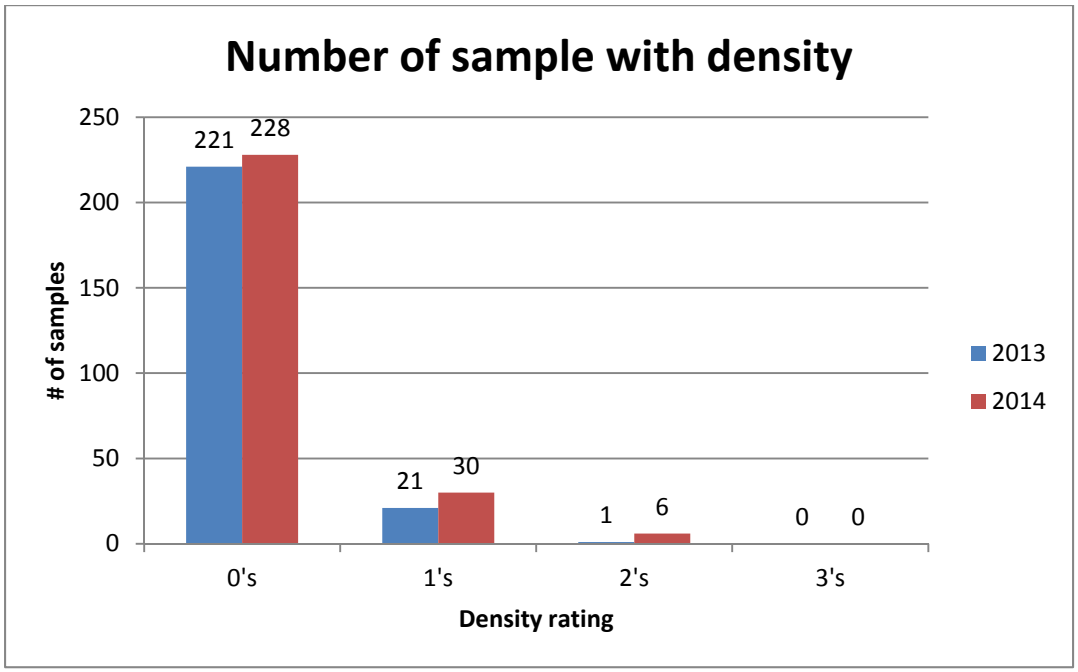


Figure 8: Number of sample point with density ratings 0-3, post treatment surveys 2013-2014.

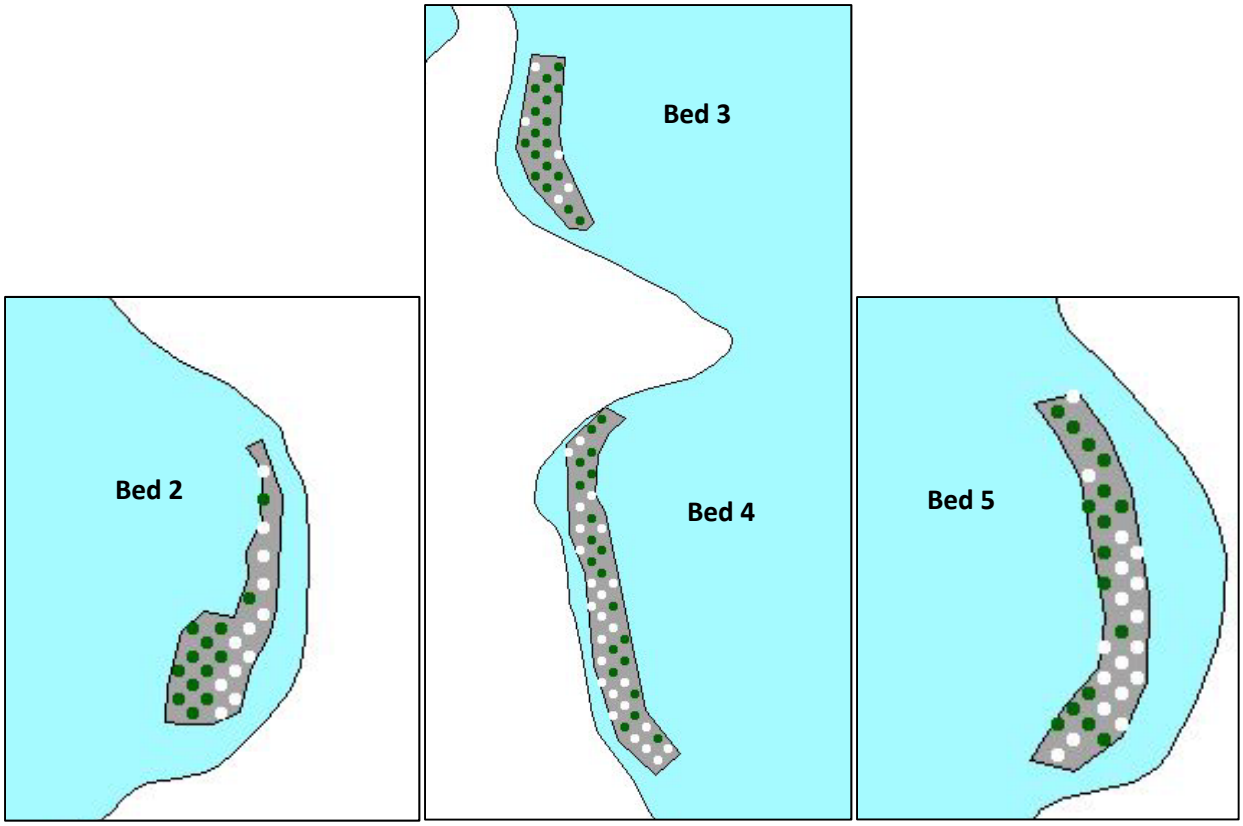


Figure 9: Map of beds 2-4 pretreatment presence of CLP prior to treatment 2014.

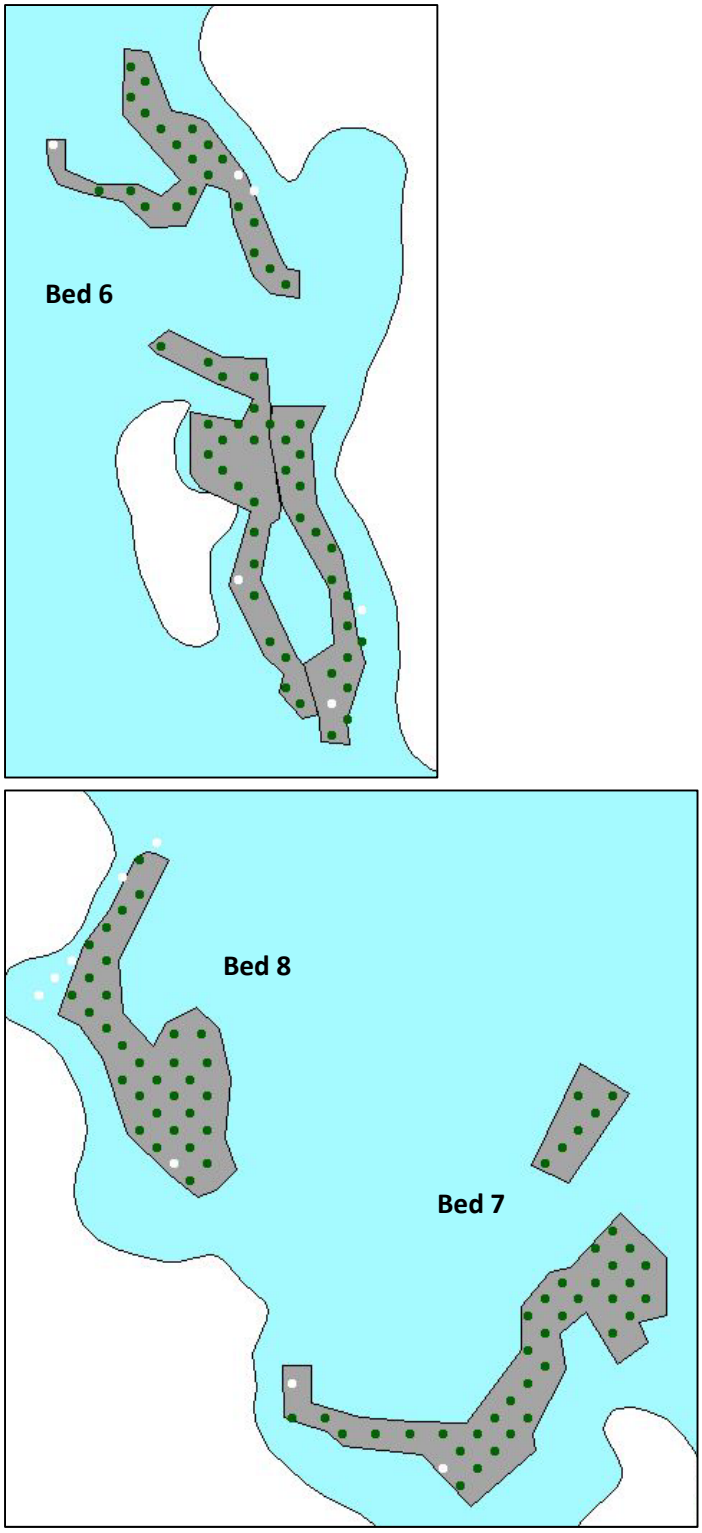


Figure 10: Map of beds 5-8 presence of CLP, prior to treatment 2014.

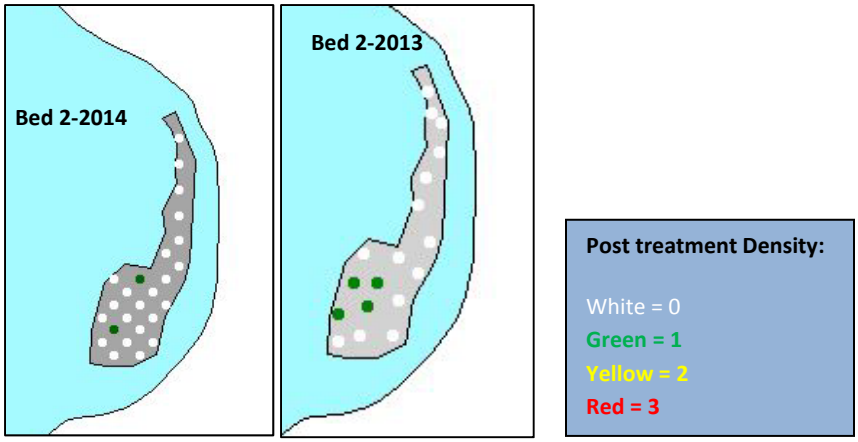


Figure 11: Density map of CLP in bed 2, post treatment 2013 and 2014.

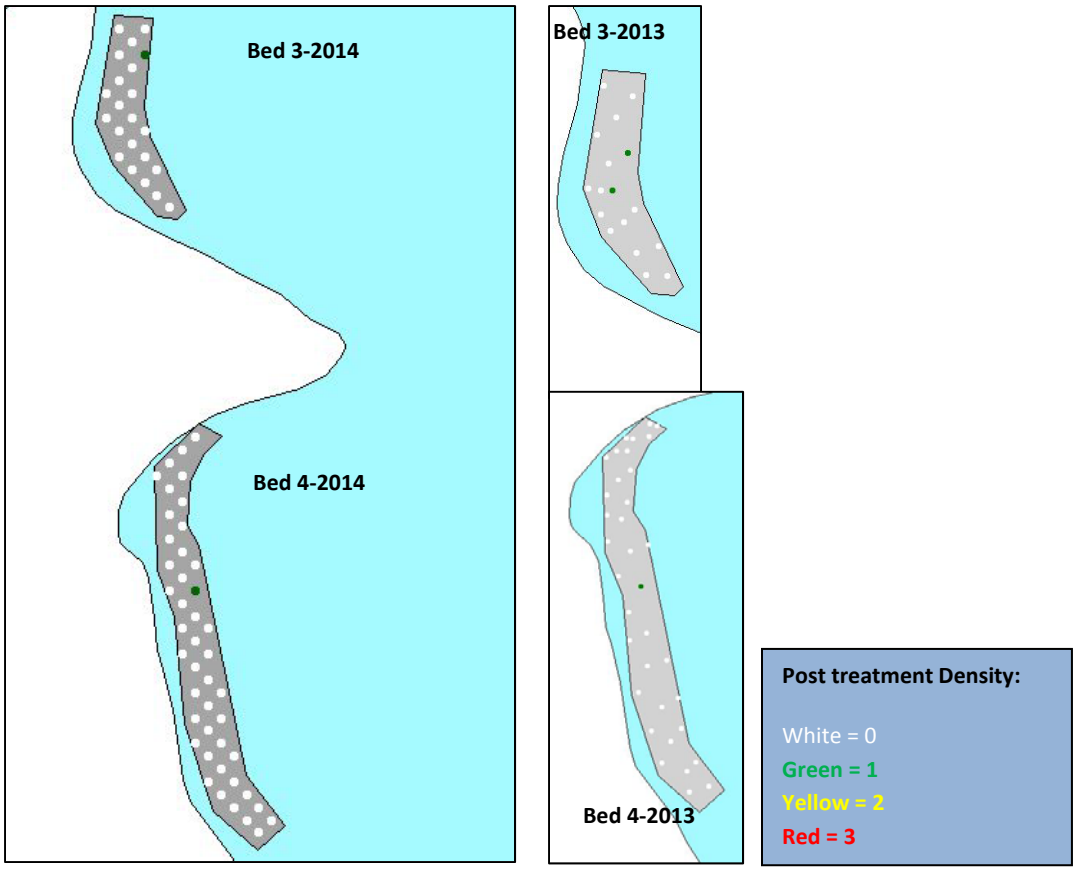


Figure 12: Map of CLP distribution and density beds 3 and 4, 2013 and 2014.

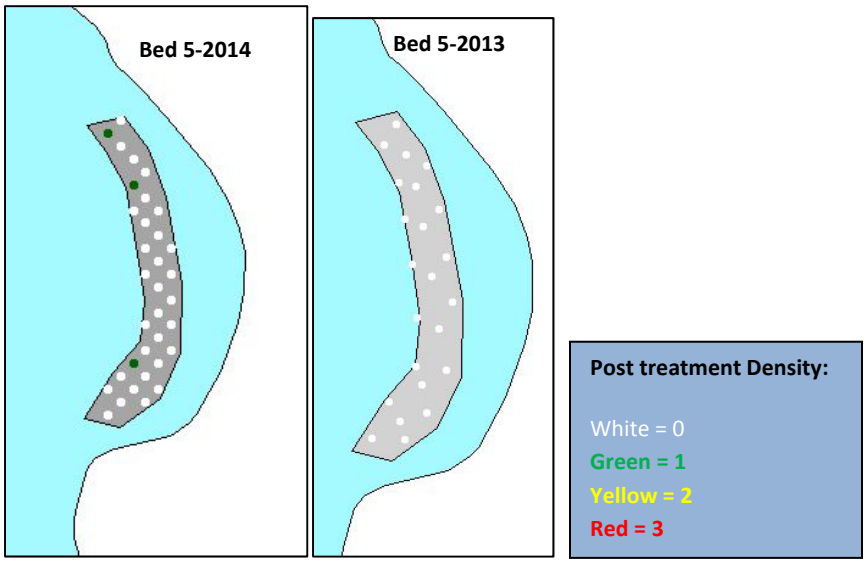


Figure 13: Density map of CLP in bed 5, post treatment 2013 and 2014.

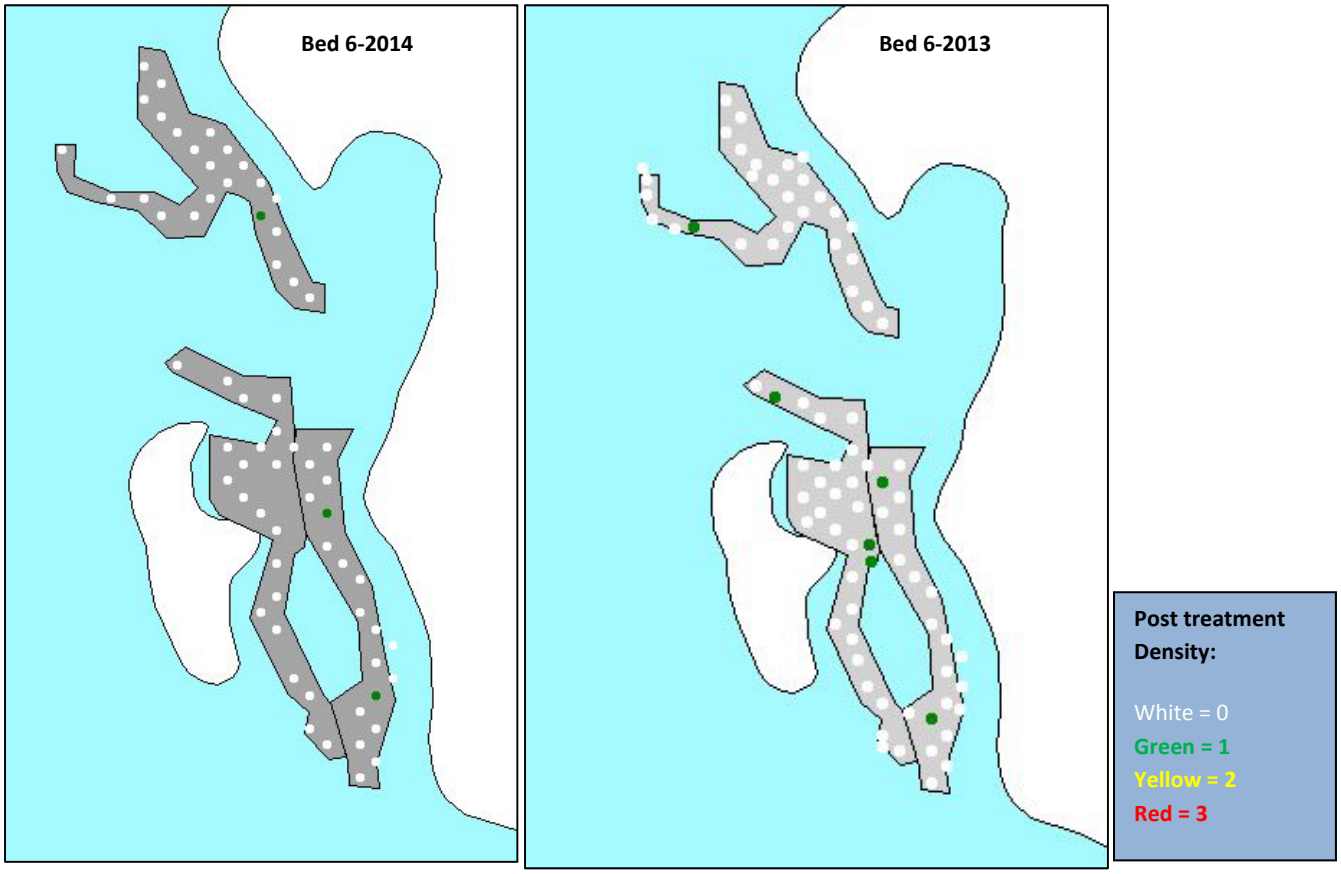


Figure 14: Density map of CLP in bed 6, post treatment 2013 and 2014.

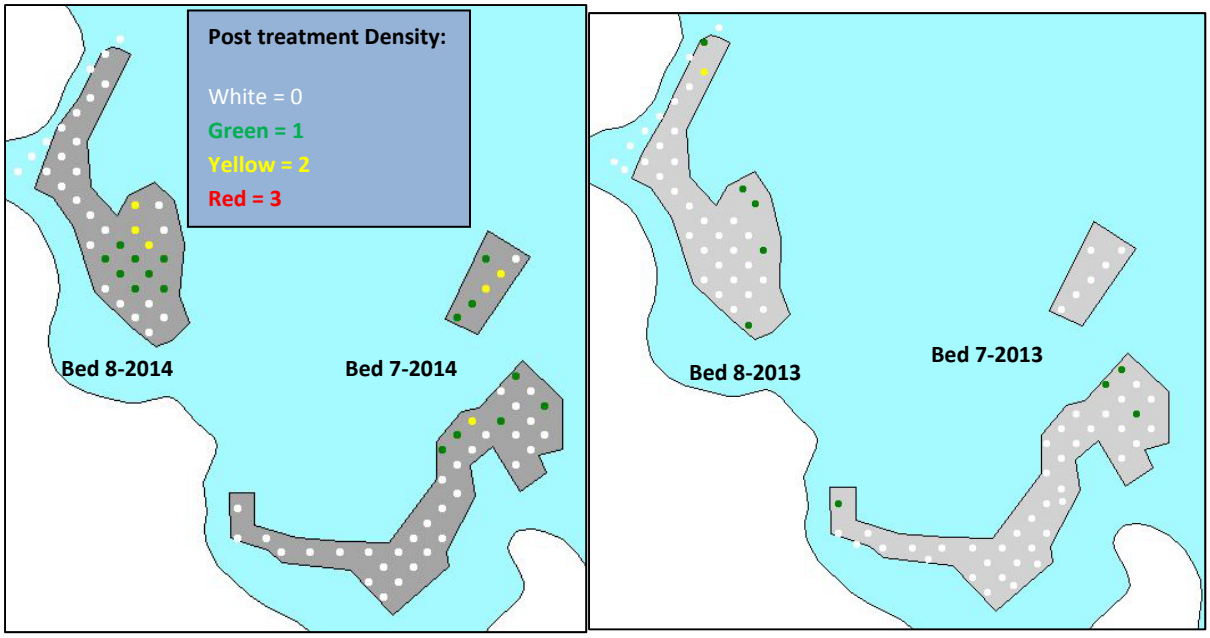


Figure 15: Density map of CLP in beds 7 and 8, post treatment 2013 and 2014.

Native plant species analysis

The frequency of native plants is also compared between the 2013 post treatment results to the previous year's (2014) post treatment results. This is to verify that the CLP was targeted with little or no adverse effects on the native plant community. Table 5 shows that there was a significant reduction ($p < 0.02$) in one native plant, fern pondweed (*Potamogeton robbinsii*). Fern pondweed has a low frequency in 2013 and no frequency in 2014. The cause for reduction is unknown, but such a small frequency in 2013 didn't allow for much reduction in 2014 thus a small change appears more significant. The frequency of 9 other native species increased. If the herbicide had affected native plants, one would expect other native species to decrease, which did not happen. It appears the CLP was targeted with little to no effect on the native plants.

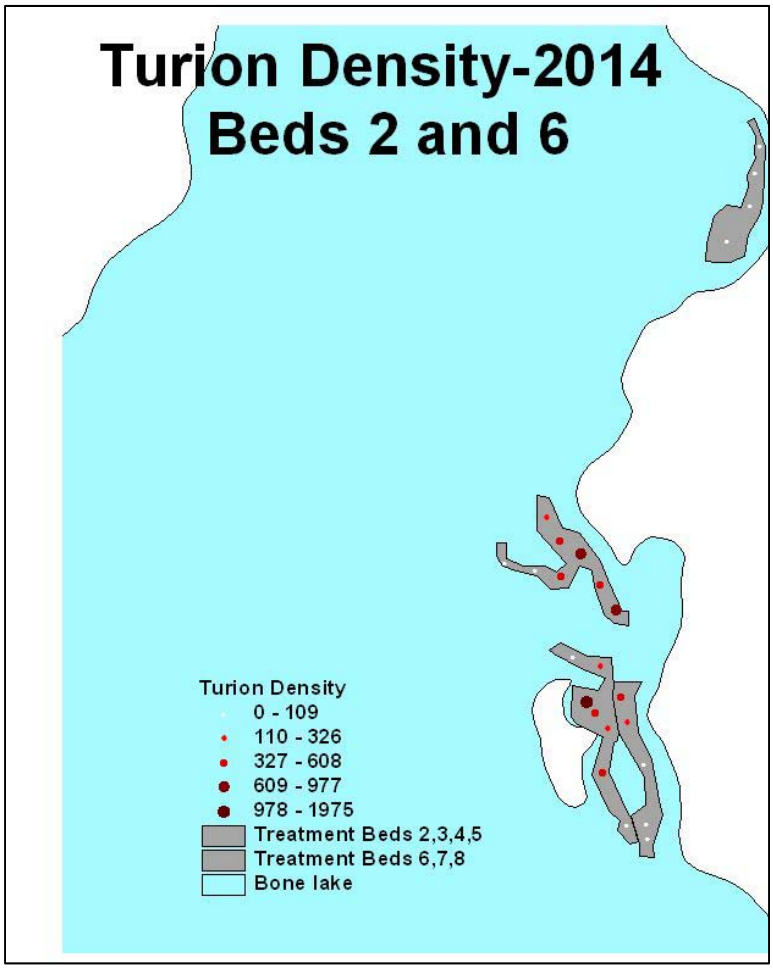
YEAR	*Potamogeton zosteriformis*	*Potamogeton richardsonii*	*Nitella sp.*	*Lemna triscula*	*Heterantehra dbuia*	*Ceratophyllum demersum*	*Bidens beckii*	*Potamogeton praelongis*	*Najas flexilis*	*Vallisneria americana*	*Myriophyllum sibiricum*	*Stuckenia pectinatus*	*Potamogeton robbinsii*	*Ranunculus aquatilis*	*Saggittaria sp.*
2013	0.01	0.00	0.01	0.06	0.01	0.33	0.004	0.02	0.004	0.00	0.03	0.00	0.02	0.004	0.004
2014	0.00	0.01	0.01	0.16	0.02	0.39	0.01	0.02	0.01	0.06	0.08	0.01	0.00	0.00	0.00
Change	**-**	**+**	**n/c**	**+**	**+**	**+**	**+**	**n/c**	**+**	**+**	**+**	**+**	**-**	**-**	**-**
Reduction Significant	no												Yes P= 0.01	no	no

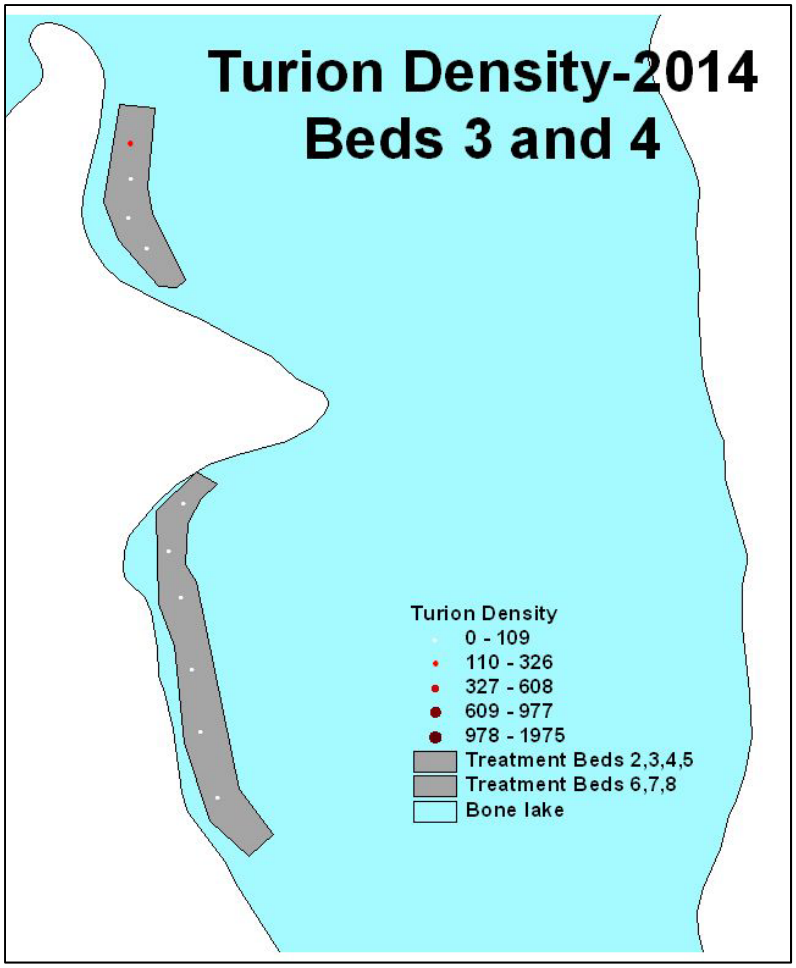
Table 5: Summary of native species frequency changes from 2013 to 2014 (from post treatment surveys).

Turion analysis

An annual measurement of turion density within each treatment bed may be a good indicator of longterm CLP reduction. As effective treatments occur in succession, the CLP is unable to replace the turions that germinated the previous year. As more turions germinate into new plants, followed by those plants getting killed before turion analysis, a lower turion density should result. This also allows management decisions to be made based upon potential new growth the following spring.

Mean Turion Density	(T's/sq meter)			
Bed	**2011**	**2012**	**2013**	**2014**
2	75	27	34.7	10.9
3	269	65	79.4	48.8
4	512	47	29.8	36.2
5	274	161	64.5	76
All (2-5)	296	75	49.6	43.0
6			421.6	384.1
7			165.3	178.4
8			489.4	271.3
All(6-8)			358.8	277.9


Turion Density-2014
Beds 2 and 6
Turion Density
0 - 109
110 - 326
327 - 608
609 - 977
978 - 1975
Treatment Beds 2,3,4,5
Treatment Beds 6,7,8
Bone lake


Turion Density-2014
Beds 3 and 4
Turion Density
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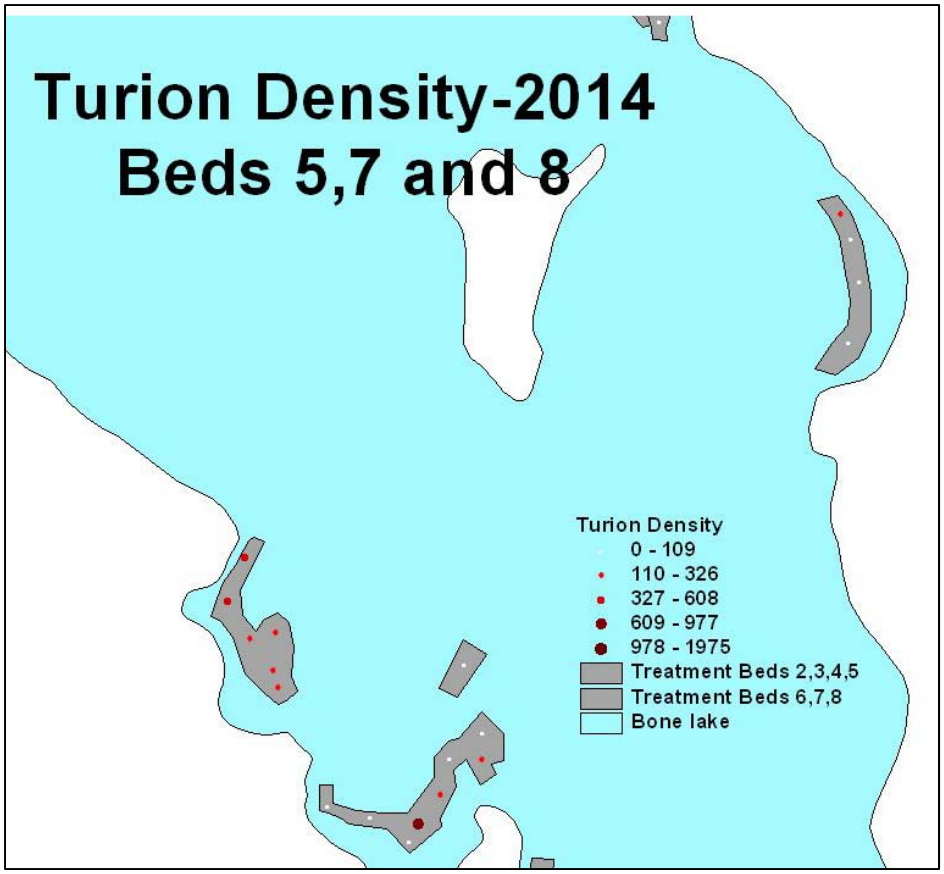
978 - 1975
Treatment Beds 2,3,4,5
Treatment Beds 6,7,8
Bone lake


Turion Density-2014
Beds 5,7 and 8
Turion Density
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110 - 326
327 - 608
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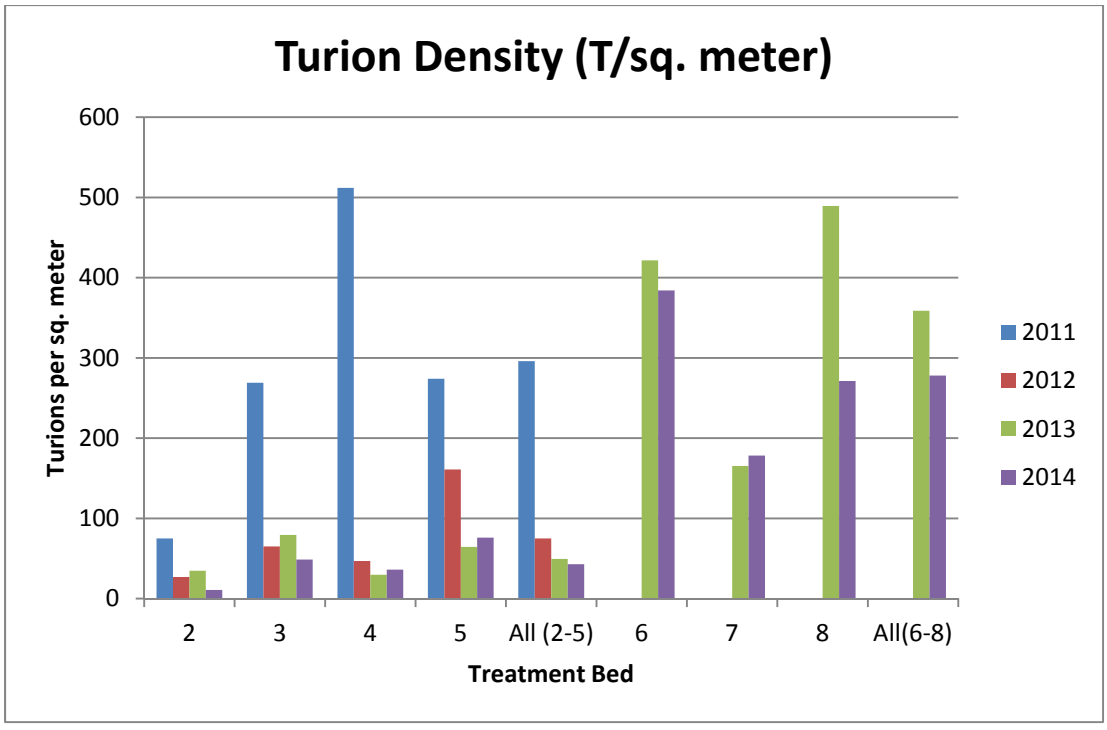
978 - 1975
Treatment Beds 2,3,4,5
Treatment Beds 6,7,8
Bone lake

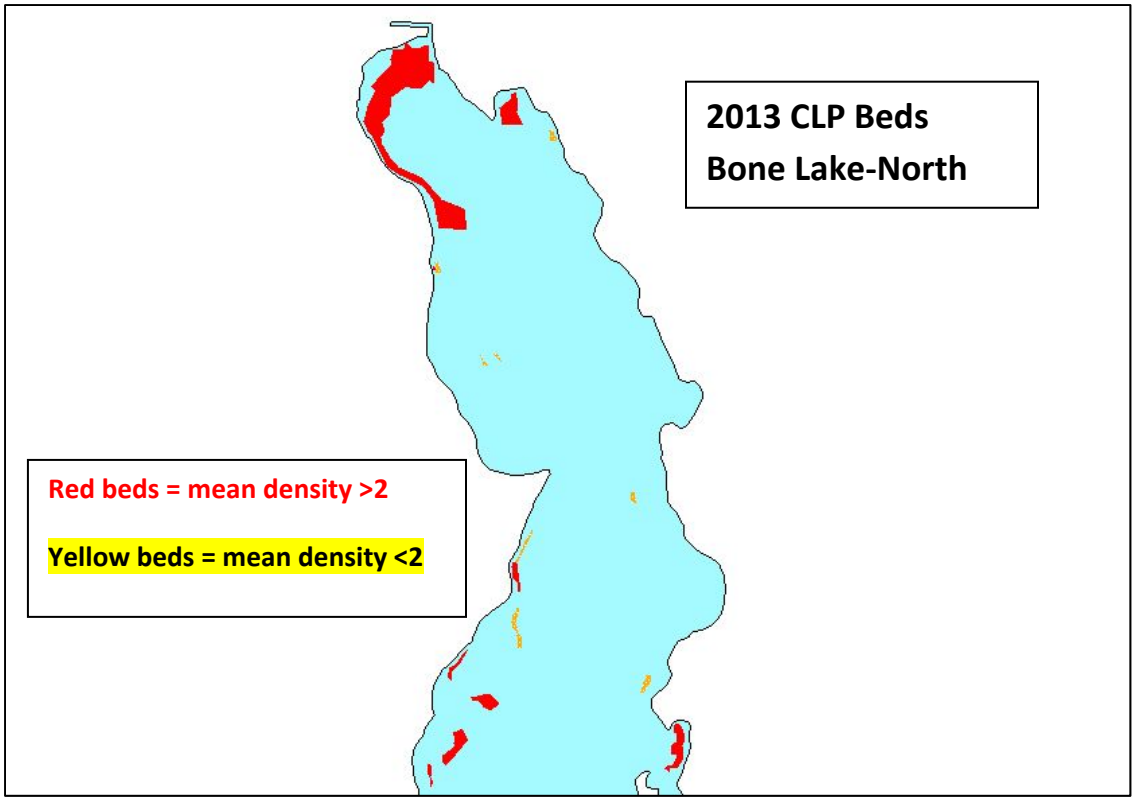

Turion Density (T/sq. meter)
Turions per sq. meter
600
500
400
300
200
100
0
2
3
4
5
All (2-5)
6
7
8
All(6-8)
Treatment Bed
2011
2012
2013
2014

The turion density data analysis shows that in beds 2-5 (turions sampled since 2011), turions are continuing to decline. The reduction is slowing, but this is to be expected since successful treatments are reducing fewer plants, thus less change in turion production. In beds 6-8 (treated and turions analyzed on last two seasons) are also showing turion density reduction. Bed 7 increased slightly, but that is likely due to sampling variability, but there was still no overall reduction in 2014. The average for all beds 6,7 and 8 show a reduction from 358.8 in 2013, to 277.9 in 2014.

CLP bed mapping

Each year after the post treatment survey is conducted the CLP on Bone Lake is mapped. The beds that have estimated mean CLP density of 2+ and growth of CLP at or near the surface (allowing the CLP to be viewed from the surface) are delineated and mapped in GIS as "dense" beds. Those beds that have CLP at or near the surface, but the coverage is more sporadic and the mean density is estimated to be less than 2 are mapped as "less dense" beds. All of the CLP in the lake is not mapped, only the beds that are dense and clearly near the surface. If these areas should occur in a treatment bed, the delineated area is included in the map. Figure 18 shows the resulting map from 2013. The red areas are dense beds (density >2) and the yellow areas are less dense beds (density <2).

In 2014, the untreated beds were checked during the post treatment survey on June 12, 2014. At this time the CLP was not anywhere near the surface, with robust CLP sampled on the rake, but none visible from the surface. The beds were checked on subsequent days in June (June 19, and June 24). On June 24, the CLP was starting to die. This indicates that the peak growth was not likely missed and the CLP never got close to the surface. As a result, the beds could not be checked and re-delineated in 2014. An update will be conducted in 2015.



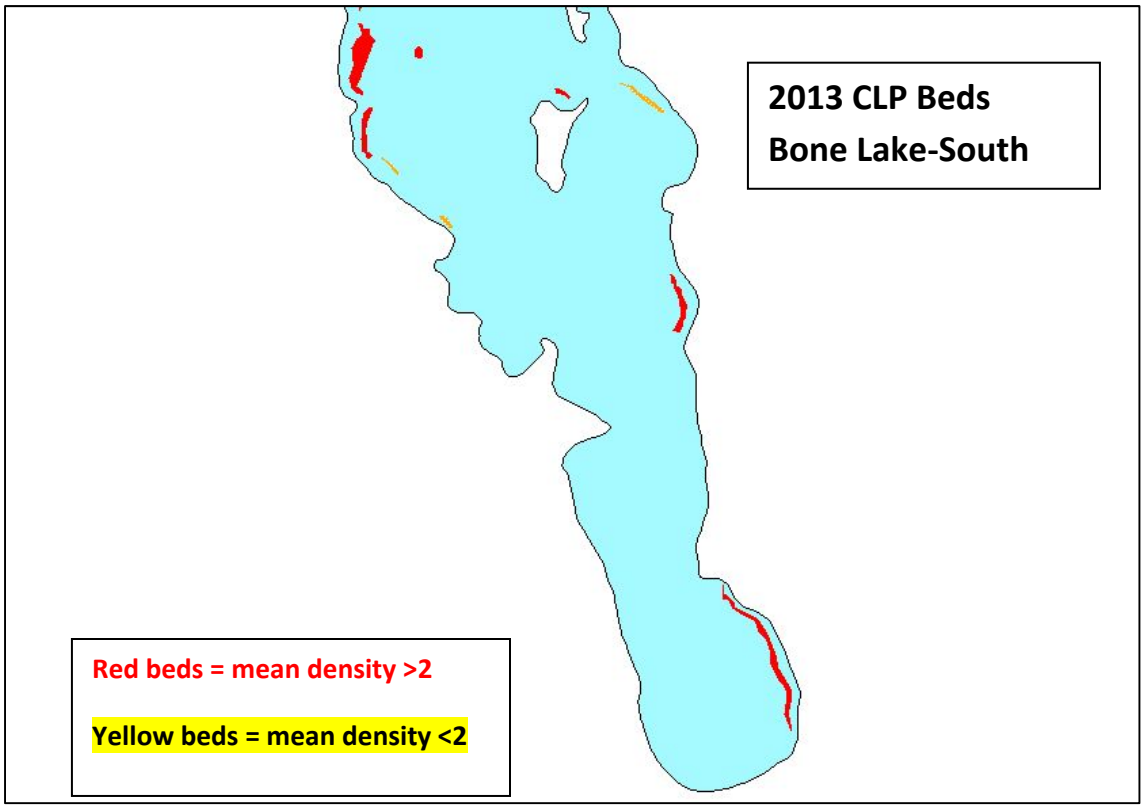


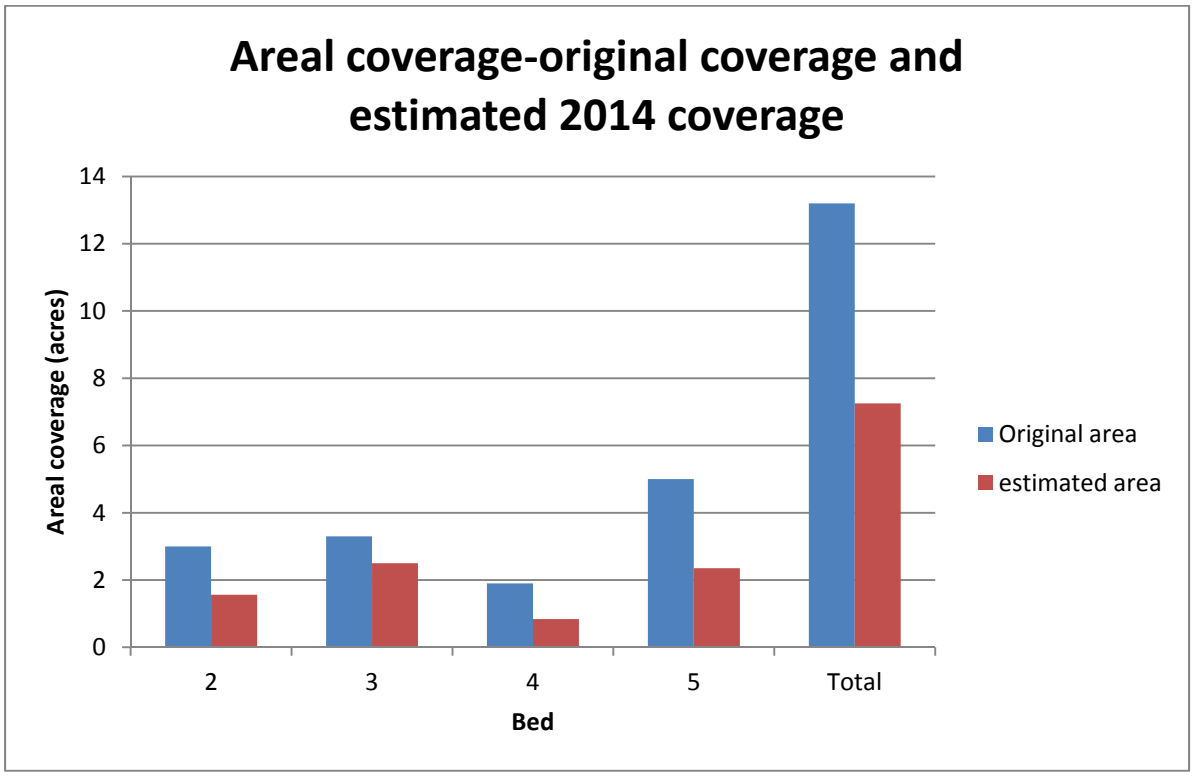
Figure 16: Map of CLP beds delineated in June 2013 during estimated peak growth.

The 2013 CLP mapping resulted in an area of 48.4 acres of dense beds and 4.7 acres of less dense beds. Historically the CLP coverage has varied immensely from year to year. In past years more than 80 acres were mapped, while other years had around 50 acres mapped. 2013 had a total of 53.1 acres mapped. The reduction in the treatment beds (through an effective 2013 treatment) resulted in much less coverage since the treatment areas totaled about 30.5 acres.

Discussion

The CLP herbicide treatment for 2014 was effective in beds 2-6, and limited in beds 7 and 8. The 30.45 acres of CLP treated went from high frequency, extensive coverage to only a small number of locations that CLP was sampled after treatment in beds 2-6. In beds 7 and 8, the CLP was reduced from before treatment, but the deeper water areas had quite a large amount of CLP after treatment. The reduction in frequency of occurrence was found to be statistically significant through a chi-square analysis from the pre-treatment to the post treatment. There was also a significant reduction from the pretreatment 2013 to the pretreatment 2014. Due to beds 7 and 8, there was not a significant reduction in the post treatment surveys from 2013 to 2014. This could mean more turion production in beds 7 and 8, thus limiting reduction in these beds.

The areal coverage appears to be declining in beds 2-5. If the areal coverage is estimated based upon the 2014 pretreatment survey, and compared to the original areal coverage (recorded from 2011 statistics) of these beds, a reduction of 45% has occurred in these beds. Figure 17 is a graph showing these comparisons and indicates a reduction in areal coverage from the CLP treatments.



The density was also reduced immensely in beds 2-6, but not in beds 7 and 8. The survey also showed a significant reduction in one native species, but it is speculated that this is not due to herbicide as the frequency of this species was low in 2013 and there was an increase in 8 other native species frequency.

There have been three successive years of effective CLP treatment in beds 2-5. With continued effective treatments in the future, the CLP can be further reduced in coverage and turion production, hopefully leading to little CLP left in these beds. In beds 6-8 treatment has only been for two years and will need to continue for a minimum of 3 more years. Bed 6 has had two successful treatments. Beds 7 and 8 had successful treatment in 2013, but not in 2014. The cause(s) for the reduced effectiveness in the deeper areas of these beds need to be evaluated prior to the 2015 treatment.

The turion analysis conducted in fall, 2014 showed continued turion density reduction. The mean turion density in beds 2-5 decreased for the fourth straight year. In beds 6-8 (only treated for two seasons), there was also a reduction in the mean turion density. This data supports continued successful treatments and the long-term reduction goal in the CLP.

References

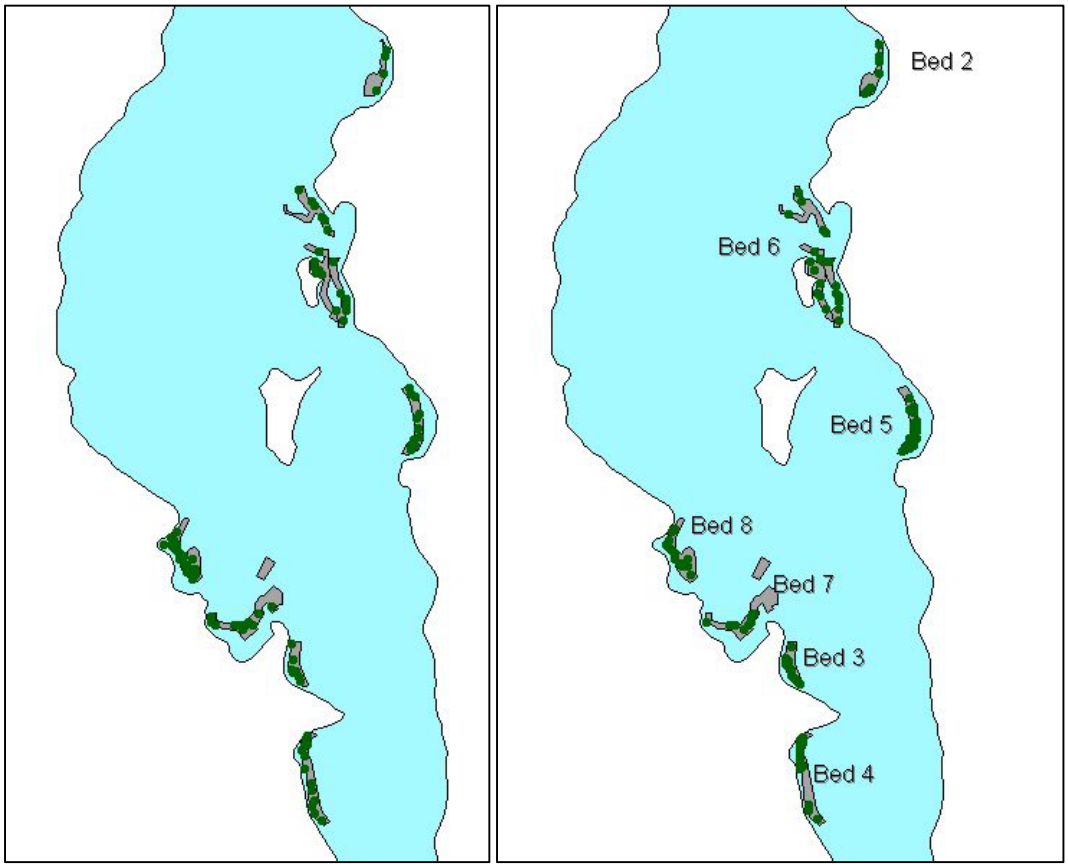
Borman, Susan, Robert Korth and Jo Tempte. *Through the Looking Glass.* University of Wisconsin-Extension. Stevens Point, Wisconsin. 1997. 248 p.

Crow, Garrett E. and C. Barre Hellquist. *Aquatic and Wetland Plants of Northeastern North America*. The University of Wisconsin Press. Madison, Wisconsin. Volumes 1 and 2. 2000. 880p.

University of Wisconsin-Extension. *Aquatic Plant Management in Wisconsin*. April 2006 Draft. 46 p.

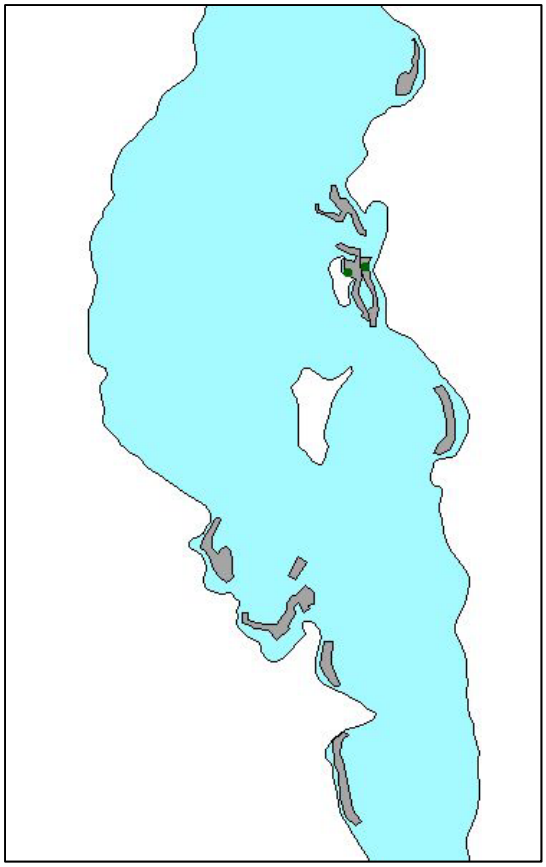
UW-Extension. Aquatic Plant Management website. http://www4.uwsp.edu/cnr/uwexlakes/ecology/apmguide.asp appendix d.

Appendix-Maps of native species, 2013 and 2014 post treatment surveys.



2013 **2014**

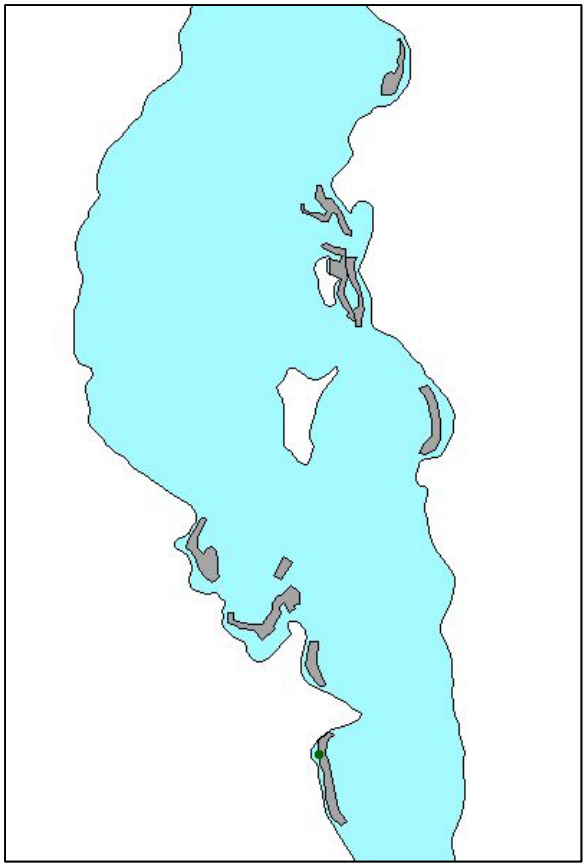
Coontail-*Ceratophyllum demersum*



Not present in 2014

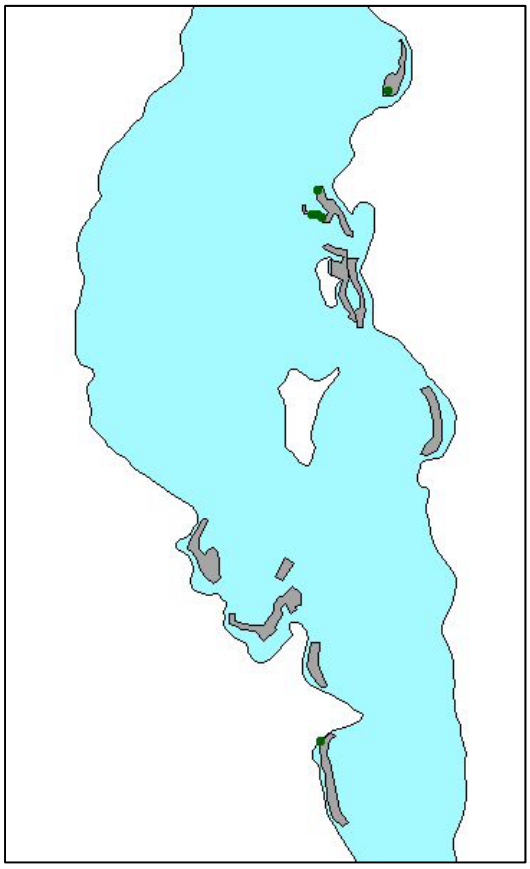
2013

Arrowhead rosette-*Sagittaria sp.*



2013 ***Not present in 2014.***

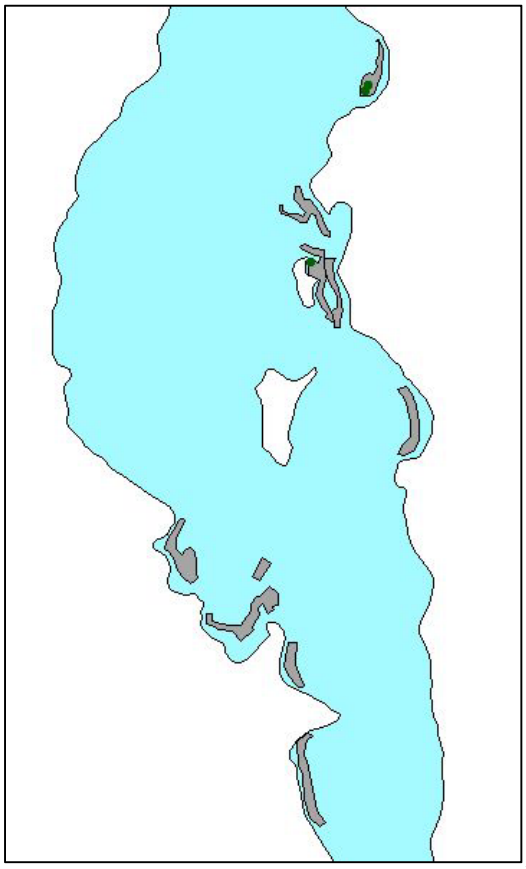
Stiff water crowfoot-*Rununculus aquatilis*



Not present 2014

2013

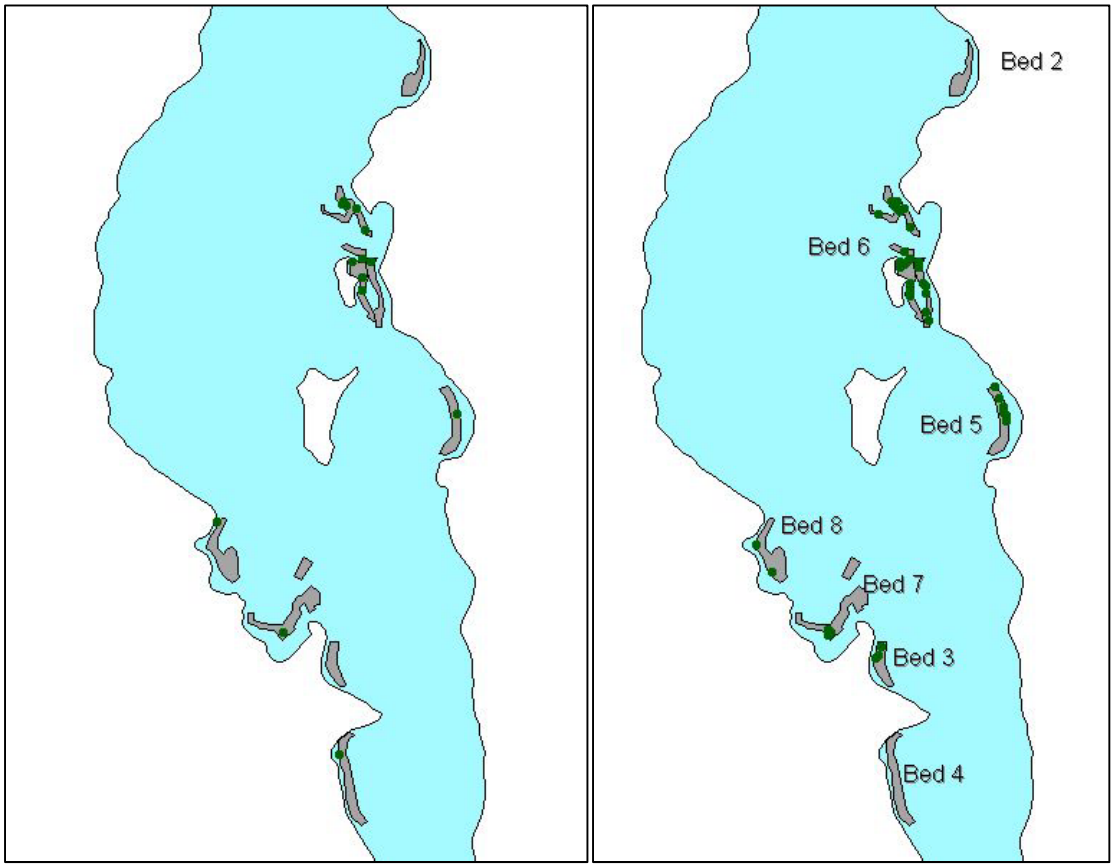
Fern pondweed-*Potamogeton robbinsii*



Not present 2014.

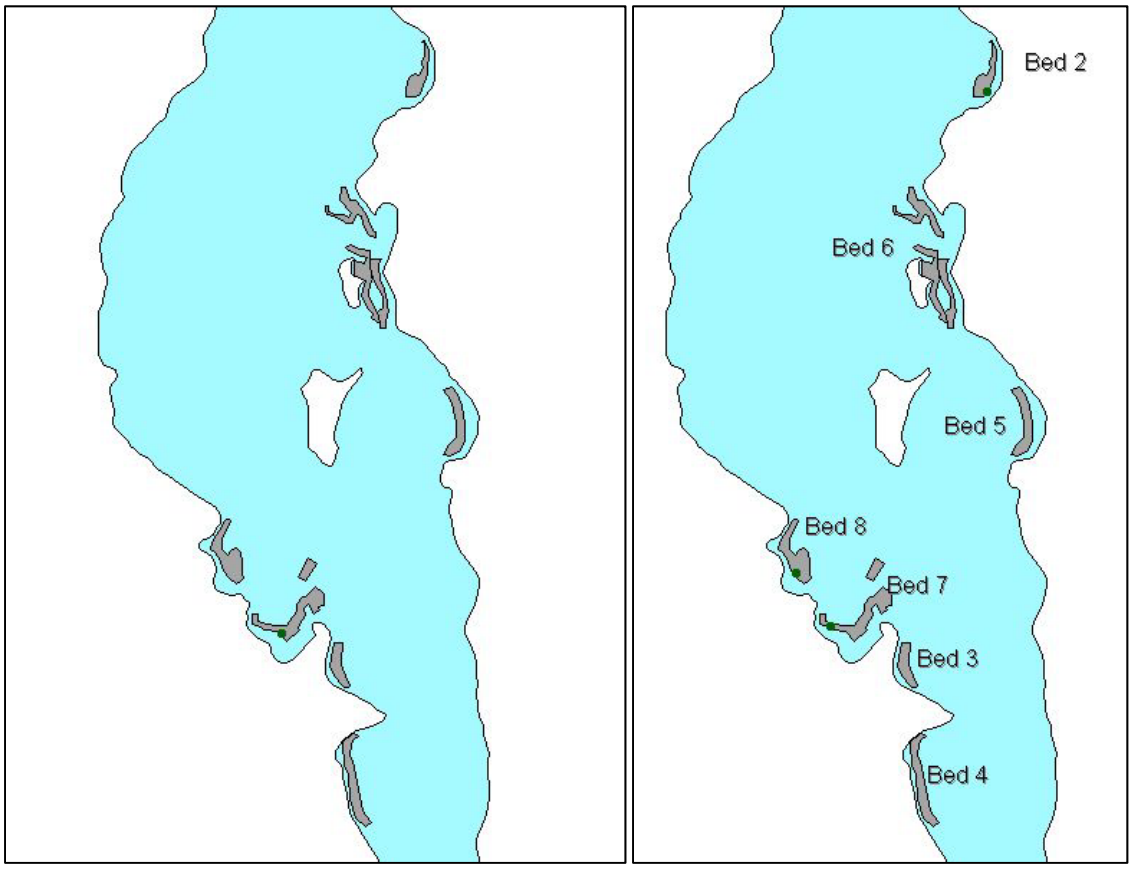
2013

Flatstem pondweed-*Potamogeton zosteriformis*



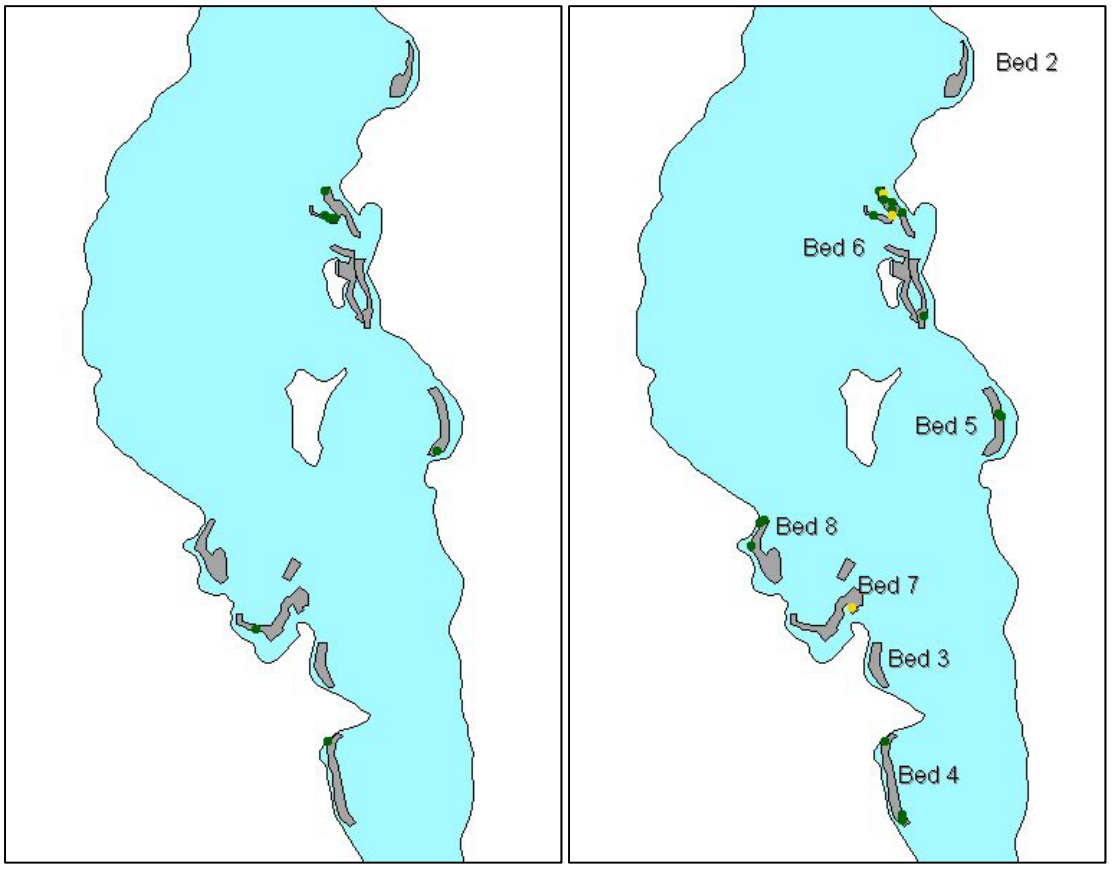
2013 ***2014***

Forked duckweed-*Lemna trisulca*



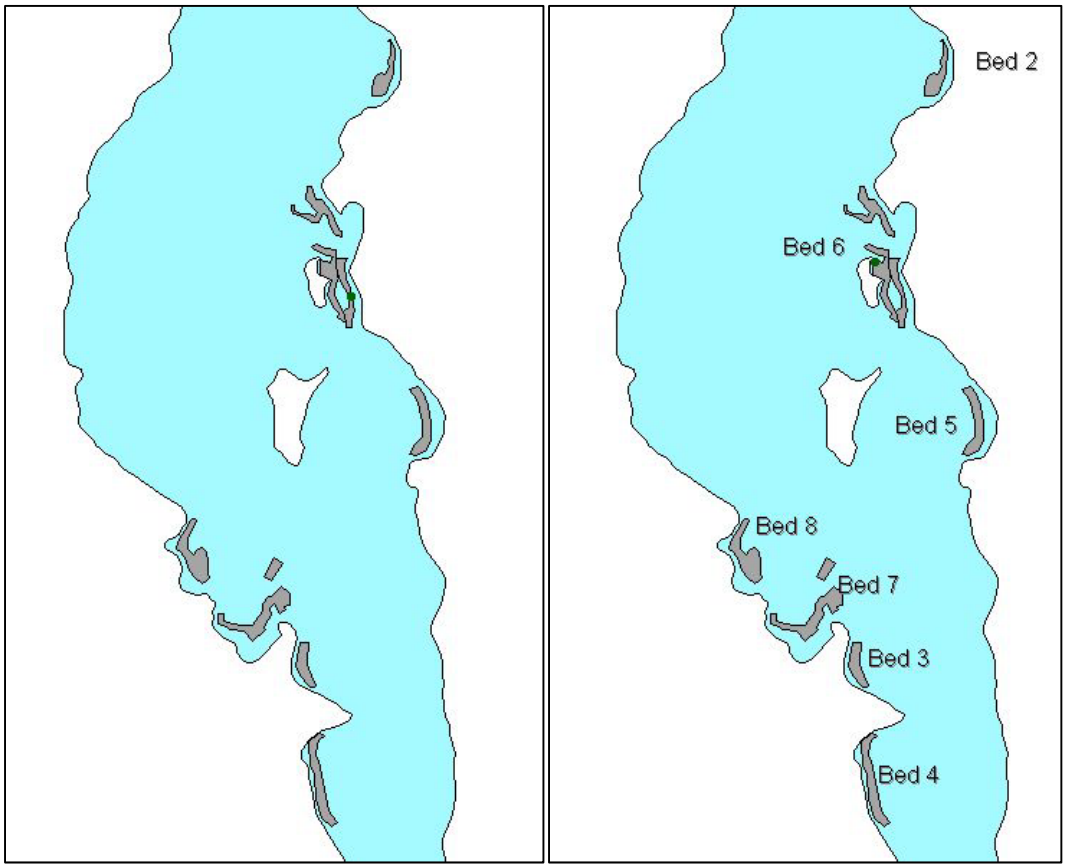
2013 **2014**

Water marigold-*Bidens beckii*



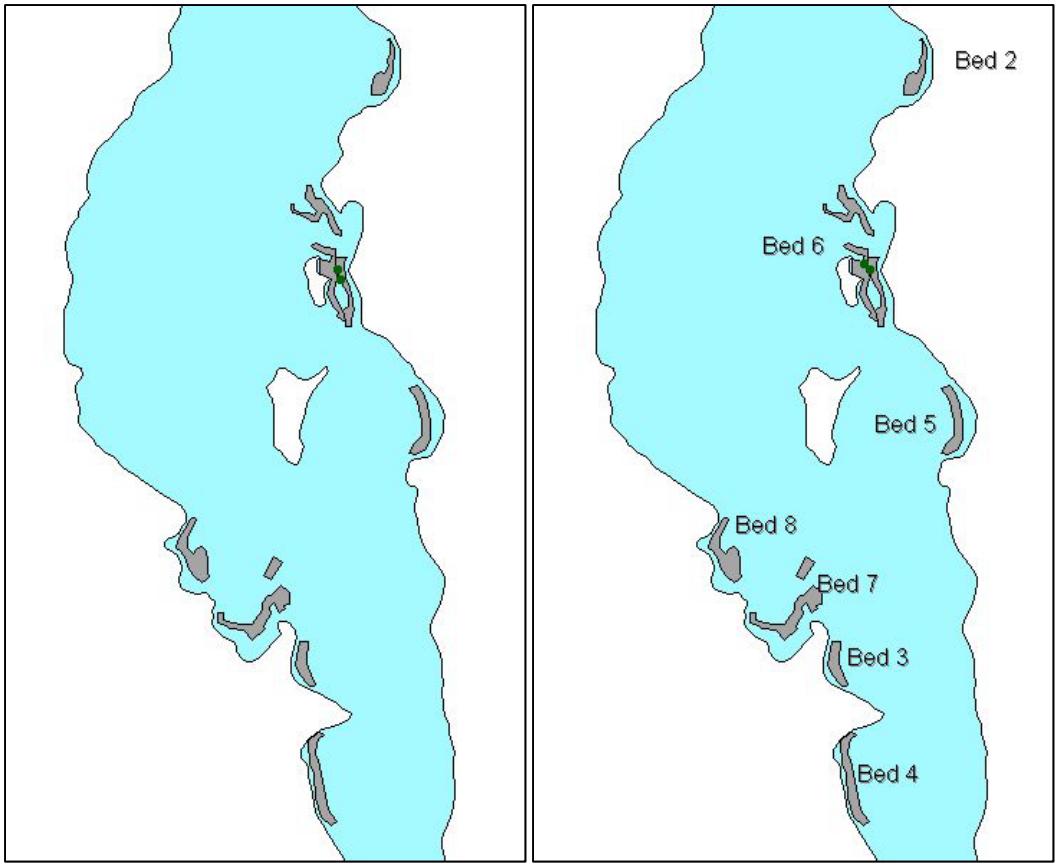
2013 **2014**

Northern water-milfoil-*Myriophyllum sibiricum*



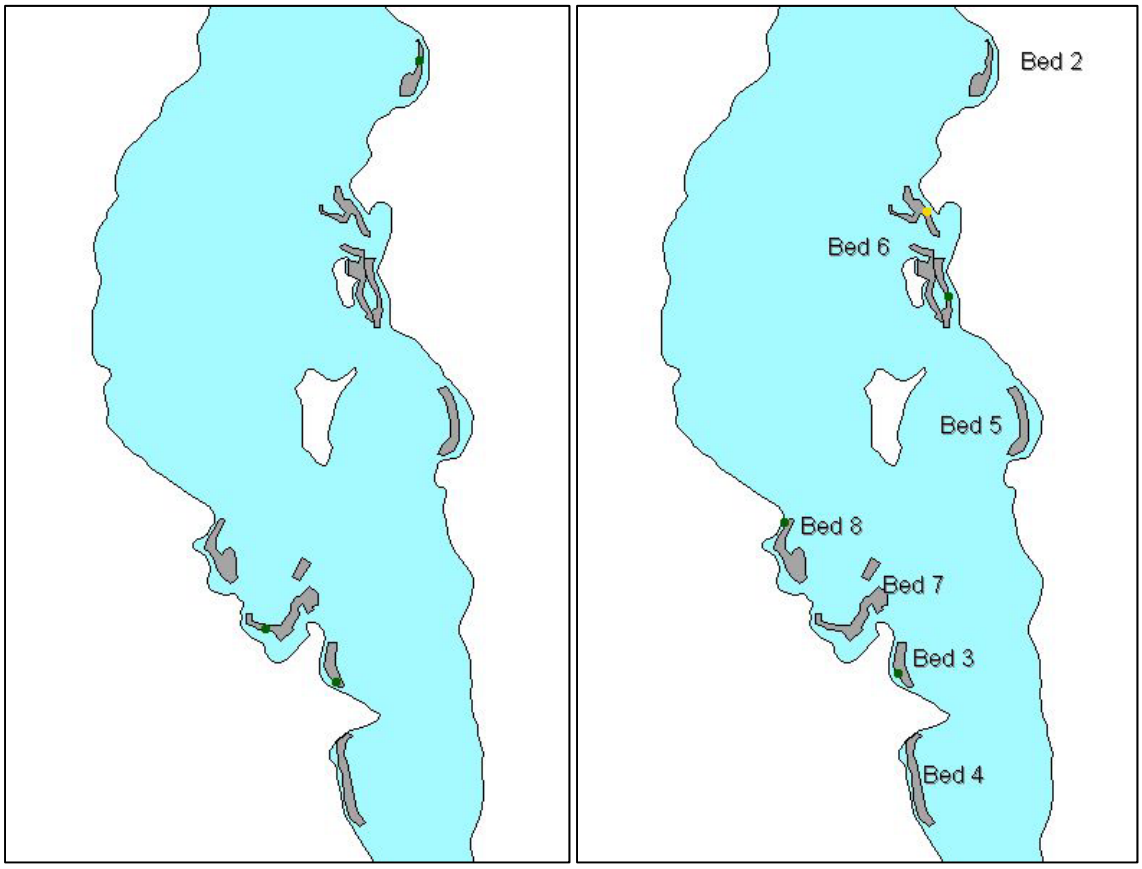
2013 ***2014***

Bushy pondweed-*Najas flexilis*



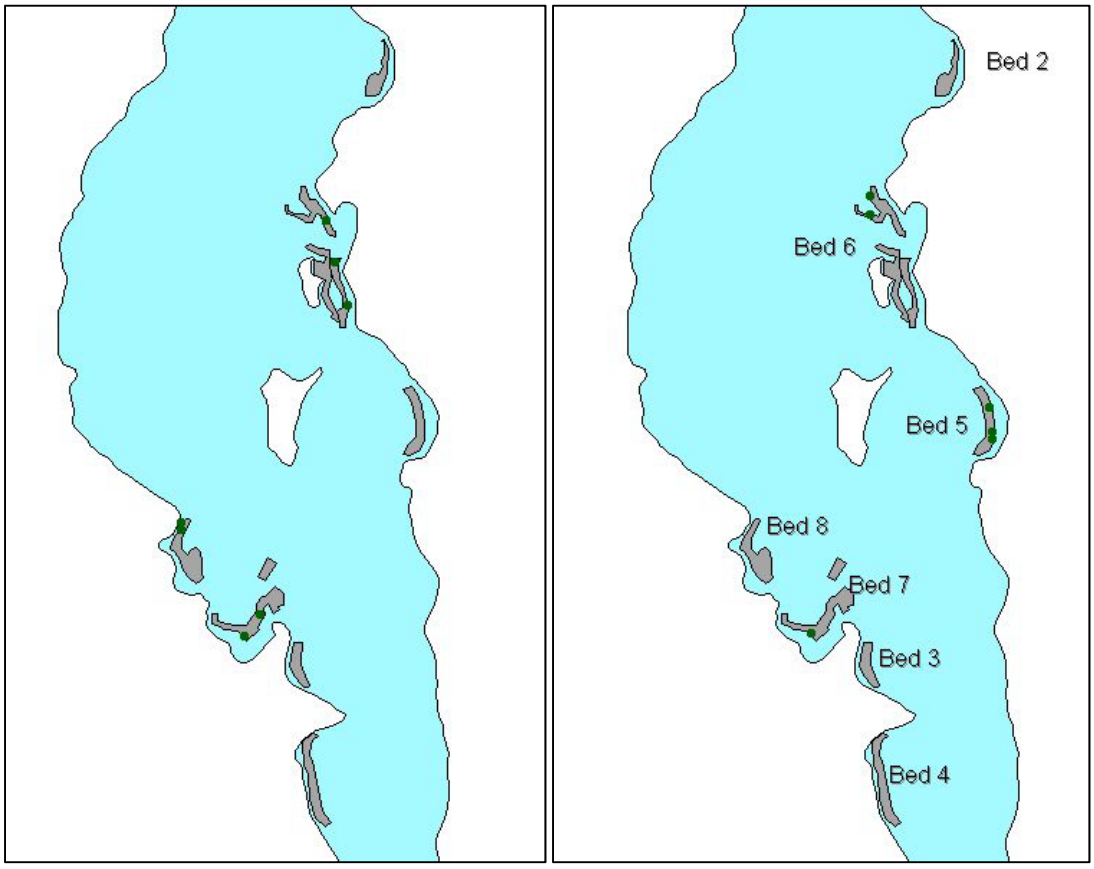
2013 **2014**

Stonewort-*Nitella sp.*



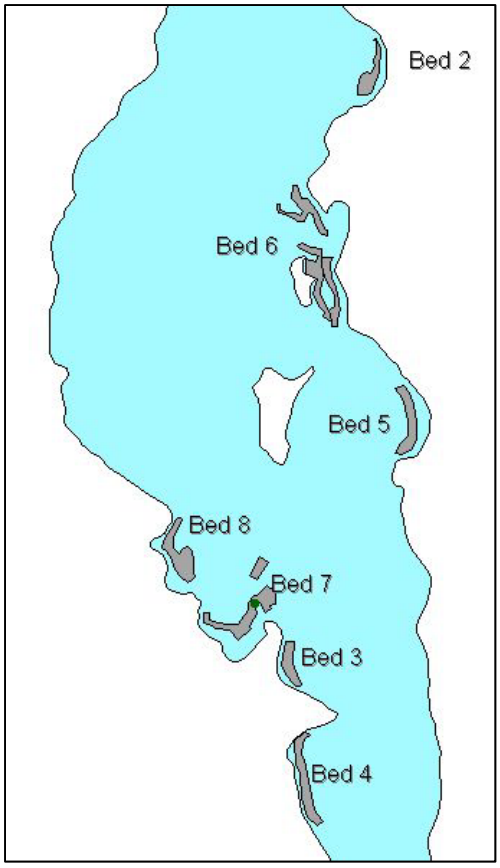
2013 **2014**

Water stargrass-*Heteranthera dubia*



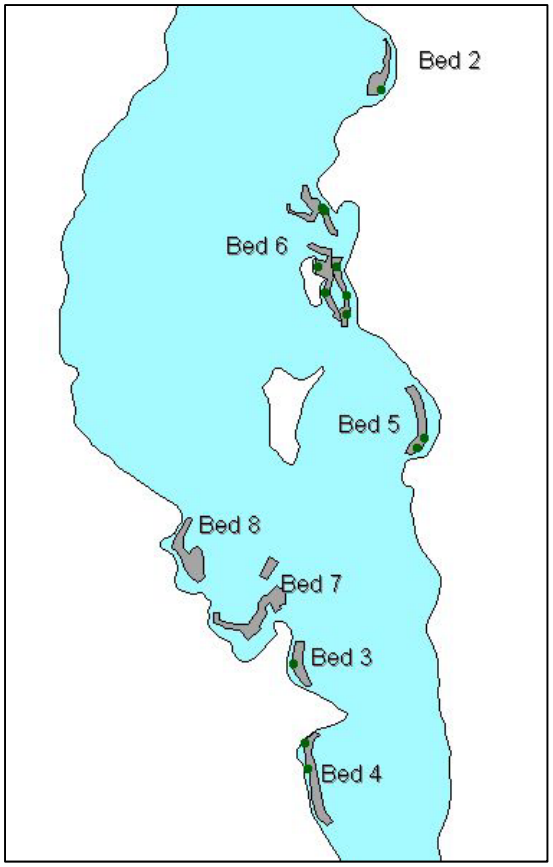
2013 **2014**

White-stem pondweed – *Potamogeton praelongus*



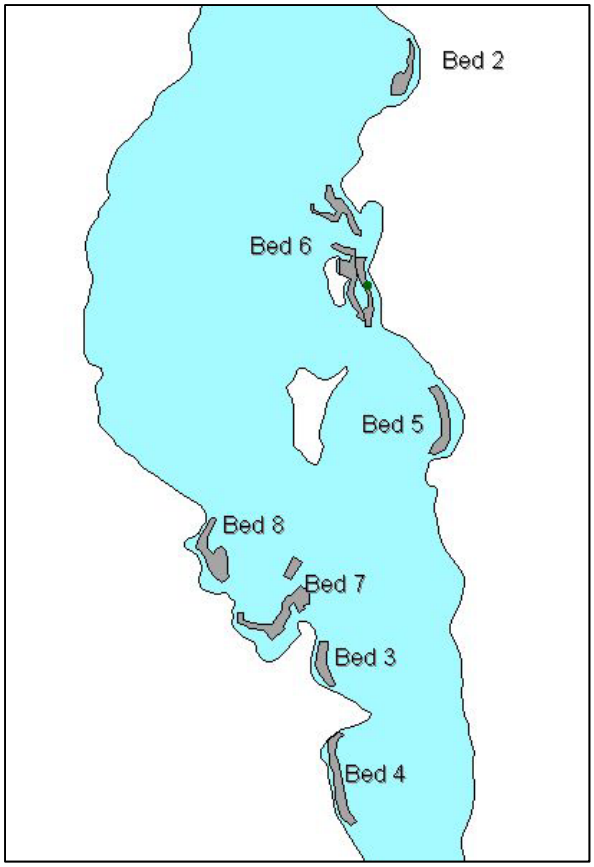
2014

Sago pondweed-*Stuckenia pectinata*



2014

Wild celery-*Vallisneria Americana*



2014

Clasping pondweed-*Potamogeton richardsonii*