INTRODUCTION

Crooked Lake, Oconto County, is an approximate 143-acre drainage lake with a reported maximum depth of 37 feet. Gilkey and Bass Lakes, 20 and 12 acres, respectively, are smaller seepage lakes directly connected and flowing into to Crooked Lake. Gilkey Lake has a reported maximum depth of six feet and flows into Crooked Lake's northeast side, while Bass Lake has a reported maximum depth of 11 feet and is connected to Crooked Lake via a small channel on the lake's southeast side (Figure 1). Eurasian water milfoil (*Myriophyllum spicatum;* EWM) was first documented from Crooked, Gilkey, and Bass Lakes in 2002. Since 2008, the Crooked Lake Protection & Rehabilitation District (CLPRD) has been actively managing the EWM population through strategically targeted herbicide applications and volunteer or professional based hand harvesting removal efforts. Curly-leaf pondweed (*Potamogeton crispus*), another non-native exotic plant species commonly found in Wisconsin, was discovered within Crooked Lake in 2014. Limited hand-harvesting efforts were directed at the known CLP occurrences in 2014 and 2015 in an effort to maintain the low-density population in the lake.

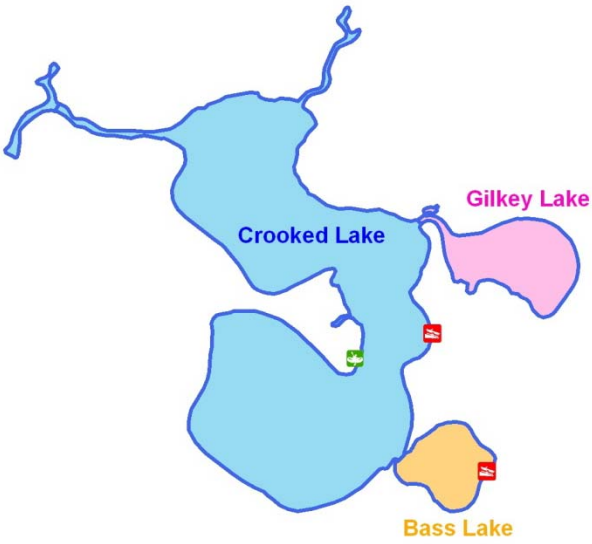


Figure 1. Crooked, Gilkey & Bass Lakes, Oconto County.

Surveys conducted in 2015 found the EWM and CLP populations in Crooked Lake to be relatively low and no herbicide control methods were recommended for 2016. A continued professional and volunteer based hand-harvesting strategy was determined to be the most appropriate action for AIS control in 2016. This report discusses the aquatic invasive species (AIS) monitoring and control activities conducted in 2016.

WDNR LONG-TERM EWM TRENDS MONITORING RESEARCH PROJECT

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. Because the state of Wisconsin's waters are managed for multiple uses (Statue 281.11), the WDNR wanted to understand if EWM populations would increase and cause either 1) ecological impacts to the lake and/or 2) reductions in ecosystem services (i.e. navigation, recreation, aesthetics, etc.) to lake users. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes is not that simplistic.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are most clear for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 2). Some lakes, such as Hancock Lake, maintained low EWM populations over the study averaging 2.3% between 2008 and 2015. At these low levels, there are likely no observable ecological impacts to the lake and are no

reductions in ecosystem services to lake users. The EWM population of Hancock Lake has increased in recent years to 5.2% in 2015 and over 10% in 2016 (preliminary data not shown in Figure 2).

Eurasian water milfoil populations in other lakes, such as Bear Paw Lake and Little Bearskin Lake trended to almost 25% only to decline to approximately 5% by the end of the study period. There are many factors that could contribute to the decline in the EWM population of these lakes, including climactic conditions and water quality parameters. Little Bearskin is known to contain a robust population of milfoil weevils, and this native insect may be having an impact on the EWM population within the lake. Boot Lake is a eutrophic system with low water clarity (approx. 3-ft Secchi depth) due to naturally high phosphorus concentrations. It is hypothesized that water clarity conditions in some years may favor EWM growth whereas in other years it may keep the population suppressed. Extreme changes in EWM populations like those observed on Weber Lake have also been documented. The EWM population in 2010-2011 was approximately 20% before spiking above 50% in 2012. Then the population declined back to approximately 15% in 2014 and 2015.

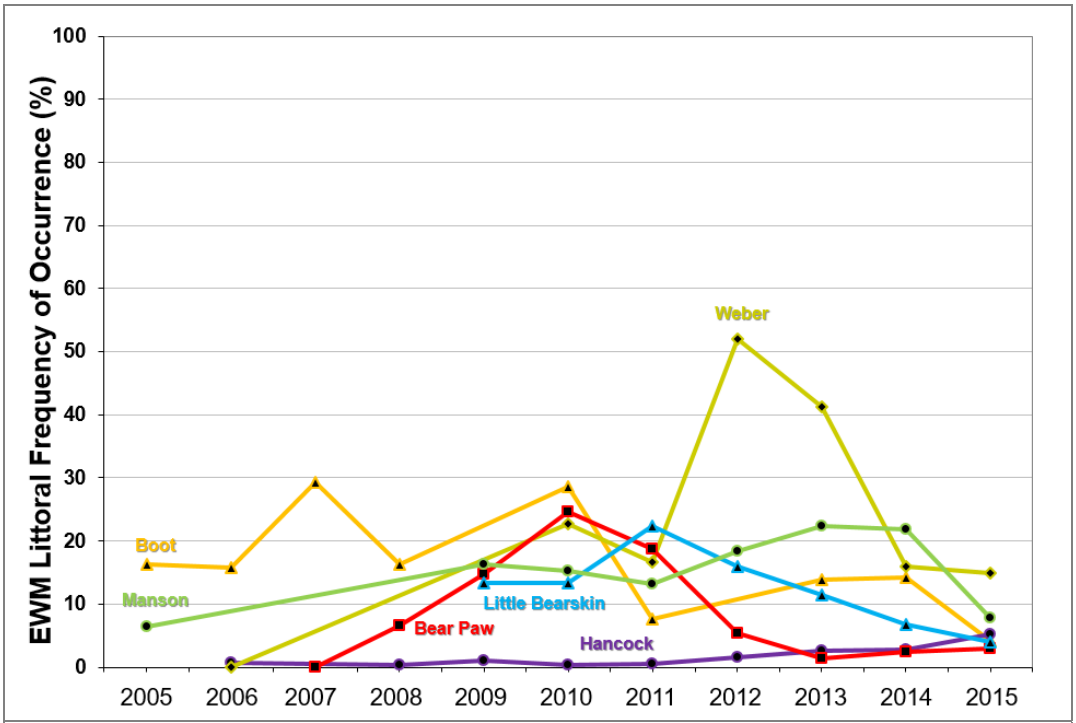


Figure 2. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from the WDNR Bureau of Science Services.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Some lake managers interpret these data to suggest that in some circumstances, it is not appropriate to manage the EWM population as in some years the population may become less. However, even a lowered EWM population of approximately 10% exceeds the comfort level of many riparians because it is potentially approaching a level than may be impactful to the function of the lake as well as not allowing the lake

to be enjoyed by riparians as it had been historically. Some lake groups, like the CLPRD, choose to manage the EWM population to keep it at a lowered level.

MONITORING METHODOLOGIES

A set of mapping surveys were used within this project to coordinate and qualitatively monitor the hand-harvesting efforts (Figure 3). The first monitoring event on Crooked Lake in 2016 was the Early Season Aquatic Invasive Species Survey (ESAIS). This late-spring/early-summer survey provides an early look at the lake to help guide the hand-harvesting management to occur on the system. Following the hand-harvesting, Onterra ecologists completed the Late-Summer EWM Peak-Biomass Survey, the results of which serve as a post-treatment assessment of the hand-harvesting. The hand-removal program would be considered successful if the density of EWM within the hand-removal areas was found to have either remained approximately the same or decreased from the ESAIS Survey to the Late-Summer Peak-Biomass Survey.

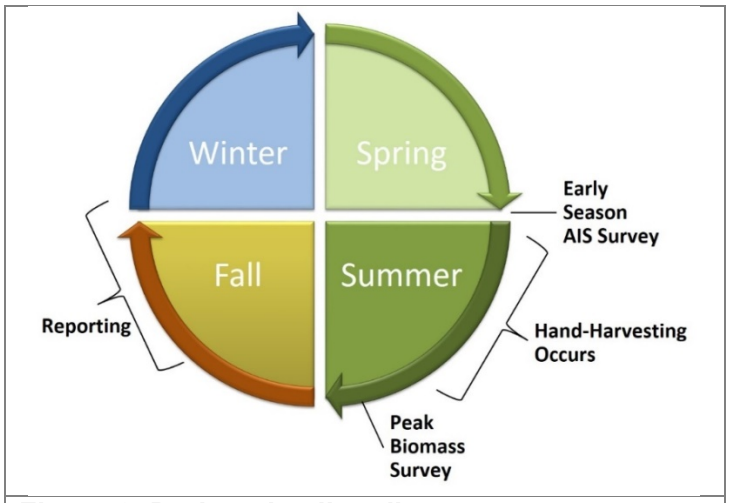


Figure 3. Project timeline diagram.

EARLY SEASON AIS SURVEY (ESAIS)

On June 3, 2016, Onterra ecologists completed the Early-Season AIS Survey on the Crooked Lake system. During this meander-based survey, the entire littoral areas of the lakes were surveyed for exotic plants. The EWM/CLP population located during the survey was mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *Highly Scattered* to *Surface Matting*. Point-based techniques were applied to AIS locations that were considered as *Small Plant Colonies* (<40 feet in diameter), *Clumps of Plants*, or *Single or Few Plants*.

While EWM is usually not at its peak growth at this time of year, the water is typically clearer during the early summer allowing for more effective viewing of submersed plants, and EWM is often growing higher in the water column than many of the native aquatic plants at that time of year. The EWM mapped during the Early-Season AIS Survey is refined during the Late-Summer Peak-Biomass survey. Curly-leaf pondweed (*Potamogeton crispus*; CLP) is at or near its peak growth in early summer before naturally senescing (dying back) in mid-summer, making early summer the most probable time to locate this species. Onterra ecologists located several CLP occurrences in the approximate area in which it was documented in 2014-2015 in the eastern portion of Crooked Lake during the June 2016 survey as well as a newly discovered concentration of plants further north in Crooked Lake (Map 1). Two *single or few* CLP plant occurrences were also located in Bass Lake near the border with Crooked Lake during the June survey (Map 1). The locations of EWM and CLP occurrences located during early summer were used to finalize the hand-harvesting control strategy and were provided to the professional hand-harvesting firm to aid in their hand-removal efforts (Map 1). The largest known

concentrations of AIS were given first priority for control by professional hand-harvesting with other known AIS populations to be targeted if sufficient time allowed. Site E-16 was given first priority for CLP control activities and Site C-16 was given first priority for EWM control efforts (Map 1).

HAND HARVESTING CONTROL ACTIVITIES

The CLPRD hired Lake and Pond Solutions Co. to professionally hand-harvest EWM/CLP in 2016. Lake and Pond Solutions utilizes Diver Assisted Suction Harvest (DASH) allowing for EWM to be suctioned out of the lake creating minimal fragmentation and spread of the plant. The DASH system is considered a form of mechanical harvesting and thus requires a WDNR permit prior to being implemented. Lake and Pond Solutions was contracted for one day of work in 2016 on Crooked Lake and scheduled a visit for mid-July. Since CLP had likely formed turions and begun to die back by mid-July, the hand-harvesting efforts were focused on the EWM populations identified during the June survey. On July 15, 2016, Lake and Pond Solutions harvested a total of 46 pounds of EWM from two sites in Crooked and Bass Lakes over the course of 13.5 combined diver hours. Details of the hand-harvesting efforts as reported by Lake and Pond Solutions are included as appendix to this report (Appendix A).

2016 EWM PEAK BIO-MASS SURVEY RESULTS

On September 16 & 28, 2016, Onterra ecologists visited Crooked Lake to complete the EWM Peak Biomass survey. This meander-based survey, which mimics the methodology used in the ESAIS survey, is completed late in the growing season (August/September) when EWM has reached its peak growth stage. Because EWM should be at or near its maximum density, the results of this survey provide an understanding of where EWM is in the lake and what its full impact on the ecology of the lake may be. As a result, these data are useful in determining the efficacy of control actions used during the summer months as well assisting in the next year's control planning.

During the survey, the EWM population was found to be relatively low with all occurrences of EWM mapped with point-based methodologies consisting of either *clumps of plants* or *single or few plants*. No colonized areas of EWM requiring polygon or area-based mapping were located anywhere in the lake (Map 2).

A total of 46 pounds of EWM was removed during Lake and Pond Solutions visit to Crooked Lake. During the June 2016 ESAIS survey, a *clump of plants* and a *single or few plants* EWM occurrence was located in Site G-16 (Figure 4). Professional divers removed a total of 24 pounds of EWM over 7.5 diver hours from Site G-16. The post hand-harvesting survey found a *clump of plants* remained in the site approximately 15 feet away from where a clump had been previously marked (Figure 4). A few additional *single or few* EWM plants were located just outside of Site G-16 during the September survey. Professional divers removed an additional 22 pounds of EWM from Site C-16 over six diver hours. The pre-hand-harvesting survey showed a *highly scattered* colony as well as a few *single or few* EWM plants present in Site C-16 (Figure 4). Following the removal efforts, no colonized EWM remained in Site C-16 and just one *clump of plants* as well as several *single or few plants* were located (Figure 4). Site G-16 and C-16 each saw successful EWM control in 2016 following the hand-harvesting actions.

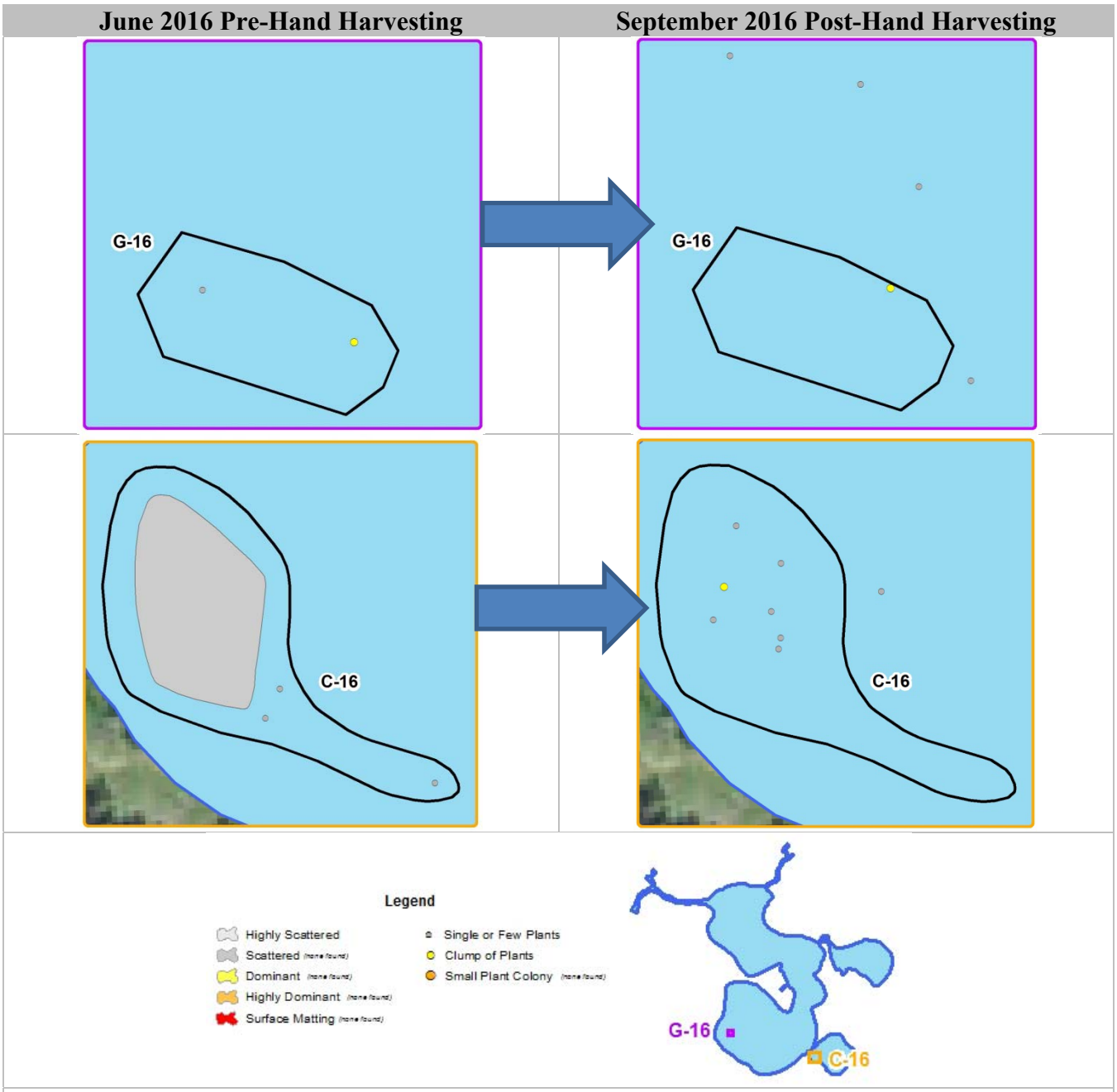


Figure 4. June 2016 pre- and September 2016 Post- Professional Hand-Harvesting EWM Survey Results-Sites G-16 & C-16.

CONCLUSIONS & DISCUSSION

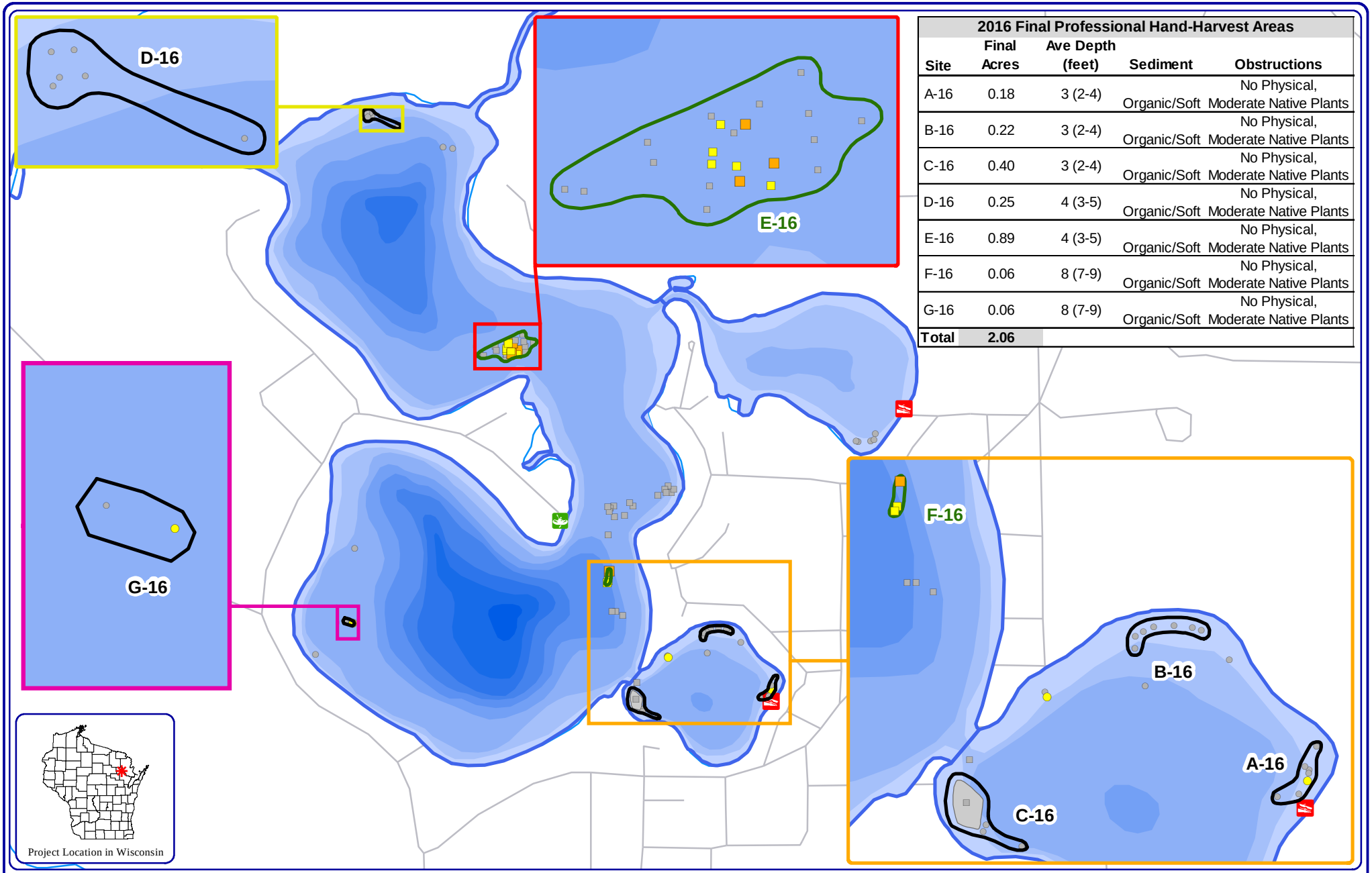
Overall, the EWM control efforts in Crooked Lake were successful with reductions of EWM being evident in both of the hand-harvesting control sites. The late summer 2016 survey indicated that EWM continues to exist at low levels in the Crooked Lake system. The CLP population in Crooked Lake was found to have expanded somewhat since previous surveys, although is still considered relatively modest (Map 3). In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition.

However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance. While it is not known how CLP will react in Crooked Lake, it is recommended that the known plant occurrences be monitored in 2017 and considered for hand-removal likely through a professional based effort. The hand-harvesting should occur as early as possible so that the plants can be removed before they are able to produce and deposit their reproductive structures (turions). Continued monitoring of these areas following hand-removal will be required to determine if these efforts were effective and if CLP has since spread to other areas of these lakes.

The CLP population has increased incrementally since first being detected during June 2014. The population level observed in 2016 is still considered to be relatively low and is likely not causing any significant negative impacts to the ecology of the lake. Traditionally, CLP control consists of numerous annual herbicide treatments conducted a few weeks following ice-off. The treatment will kill each year's plants before they are able to produce reproductive turions (asexual seed-like structures). After multiple years of treatment, the turion supply in the sediment becomes exhausted and the CLP population decreases significantly. Normally a control strategy such as this includes five or more years of repetitive treatments to the same areas. Research indicates that herbicide treatments targeting relatively small sites (5 acres or less) often do not reach the necessary concentration exposure times (CET's) necessary to achieve successful results. Based on the current CLP population in the lake, any potential herbicide treatment would be small in size and likely would not meet control expectations due to rapid dissipation of the herbicide out of the application area. If the CLP population continues to expand in Crooked Lake, further considerations for using herbicide control actions may be undertaken.

With the current low EWM and CLP populations in Crooked Lake, no herbicide control methods are warranted at this time. It is recommended that both the CLP and EWM populations be monitored in 2017 through a June ESAIS survey and a late summer EWM Peak-Biomass Survey. It is proposed that Onterra conduct the 2017 ESAIS Survey as early in the seasonal spectrum as possible (i.e. late-May or early-June), to maintain ample opportunity within the summer growing season to conduct the hand-harvesting activities if warranted.

The CLPRD has been awarded an, AIS-Education, Prevention, & Planning Grant from the WDNR that will result in an updated Comprehensive Lake Management Plan for the system. The management planning process will result in the creation of a long-term strategy to address all matters of concern, not just the presence of EWM and CLP. It would include assessments of the water quality, watershed, shoreline condition, fisheries, native aquatic plant communities, and stakeholder perceptions on the lake. An important component of this process will allow the CLPRD to objectively review their ongoing AIS management activities, outline appropriate thresholds of when specific control strategies warrant implementation, and establish measureable success criteria standards to monitor future control strategies. Continued discussion with the CLPRD, particularly as the development of a Comprehensive Lake Management Plan gets underway; regarding the 2017 control strategy may result in an evolved strategy being formulated.



2016 Final Professional Hand-Harvest Areas				
Site	Final Acres	Ave Depth (feet)	Sediment	Obstructions
A-16	0.18	3 (2-4)	Organic/Soft	No Physical, Moderate Native Plants
B-16	0.22	3 (2-4)	Organic/Soft	No Physical, Moderate Native Plants
C-16	0.40	3 (2-4)	Organic/Soft	No Physical, Moderate Native Plants
D-16	0.25	4 (3-5)	Organic/Soft	No Physical, Moderate Native Plants
E-16	0.89	4 (3-5)	Organic/Soft	No Physical, Moderate Native Plants
F-16	0.06	8 (7-9)	Organic/Soft	No Physical, Moderate Native Plants
G-16	0.06	8 (7-9)	Organic/Soft	No Physical, Moderate Native Plants
Total	**2.06**			

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Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016

Map Date: June 7, 2016
File Name: Crooked_EWM_June16.mxd

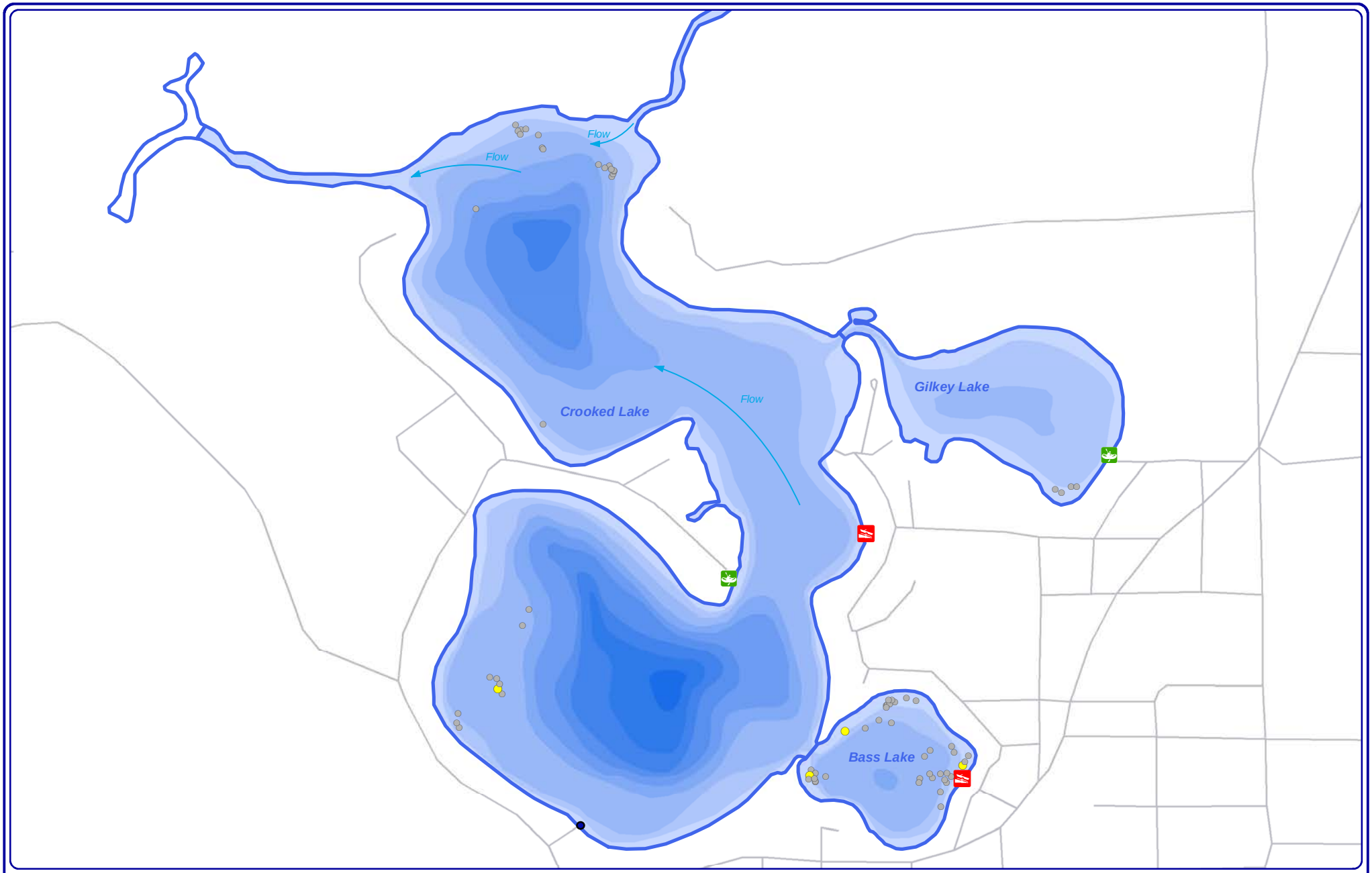
EWM Survey Results
Onterra, June 2016

- Highly Scattered
- Scattered *(none found)*
- Dominant *(none found)*
- Highly Dominant *(none found)*
- Surface Matting *(none found)*
- Single or Few Plants
- Clump of Plants
- Small Plant Colony
- 2016 Finall EWM Hand Harvesting Site

CLP Survey Results
Onterra, June 2016

- Single or Few Plants
- Clump of Plants
- Small Plant Colony
- 2016 Final CLP Hand Harvesting Site

Map 1
Crooked Lake
Oconto County, Wisconsin
June 2016 ESAIS Survey Results & Hand Harvesting Strategy



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Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2016

Map Date: October 31, 2016
File Name: Crooked_EWM_PB_Sept16.mxd

Project Location in Wisconsin

Legend

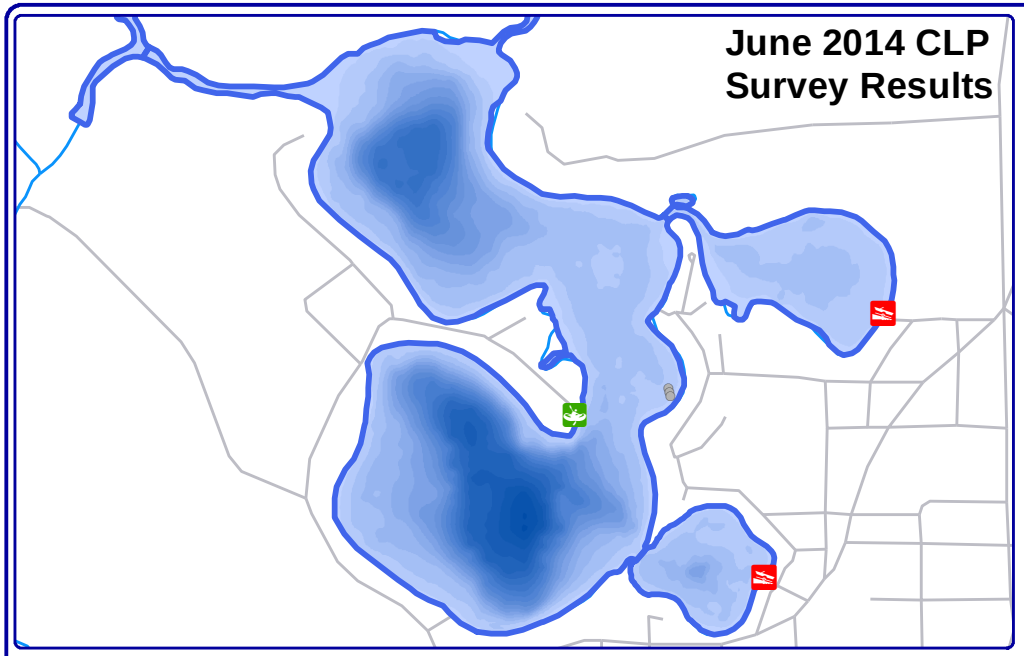
- Highly Scattered *(none found)*
- Scattered *(none found)*
- Dominant *(none found)*
- Highly Dominant *(none found)*
- Surface Matting *(none found)*
- Single or Few Plants
- Clump of Plants
- Small Plant Colony *(none found)*

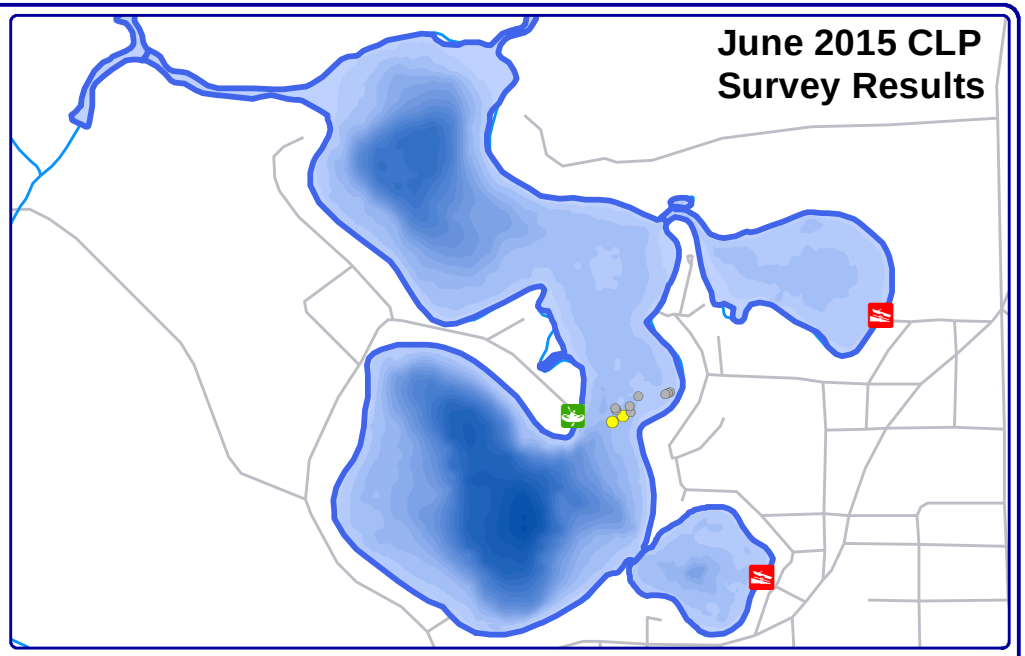
Map 2

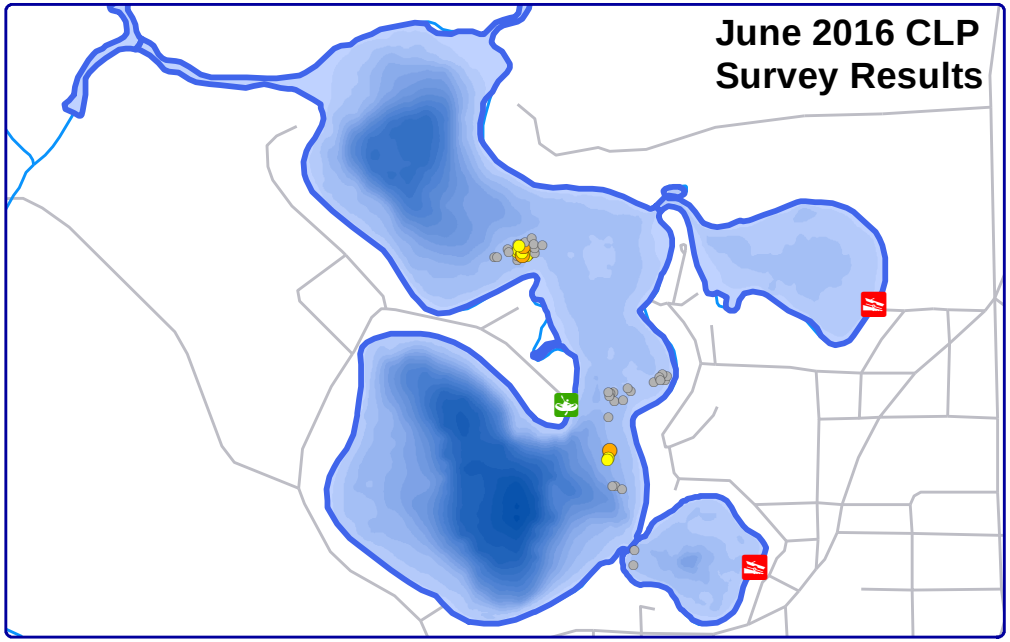
Crooked Lake

Oconto County, Wisconsin

September 2016 EWM Survey Results







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Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2014-2016
Map Date: January 3, 2017
File Name: Map3_Crooked_CLP_Progression_2014-2016.mxd

Project Location in Wisconsin

Legend

- Highly Scattered *(none found)*
- Scattered *(none found)*
- Dominant *(none found)*
- Highly Dominant *(none found)*
- Surface Matting *(none found)*
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 3

Crooked Lake

Oconto County, Wisconsin

CLP Progression 2014 - 2016