PROJECT UPDATE - 2014

Using cloud based software and GIS automation to quantify and evaluate changes in aquatic vegetation and substrate composition following the infestation of zebra mussels in the Iowa Great Lakes

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Abstract - In 2012, four live juvenile zebra mussel *Dreissena polymorha* were discovered in the Iowa Great Lakes. By 2013, both juvenile and adult zebra mussels were found in several of the interconnected lakes, confirming the presence of a reproducing population. Zebra mussels are known as ecosystem engineers because their intense filtering behavior can modify the physical environment by increasing light penetration, thus likely influencing the distribution and diversity of submersed macrophytes. Effects of aquatic invasive species can be documented by monitoring macrophytes as they are a well-suited indicator of ecological health due to their immobility and ease of sampling and identification. Limited detailed aquatic macrophyte vegetation mapping data for this diverse chain of lakes exists. Recent advances in GPS and sonar technology coupled with cloud-based software have substantially expanded the ability for fisheries managers to conduct lake-based bathymetric and habitat evaluations with limited time and investment. In 2014, we mapped each lake with a Lowrance HDS sonar unit and uploaded files to a web-based server so that data could be post-processed and viewed. In addition, physical estimates of aquatic macrophyte density and diversity were collected using the point intercept sampling method in each lake. Average aquatic plant biovolume (percent of water column taken up by vegetation) ranged from 3.8% in Lower Gar to 19.2% in East Okoboji Lake. Distinct vegetation beds in shallow bays and deeper weed lines were well represented using 35m-100m transect spacing. In the entire chain of lakes we sampled 2,060 vegetation points and identified 18 species ranging in abundance from <1% of the rake coverage to well over 100% (i.e., mats of vegetation). We plan to repeat this study in 2015 and periodically after that so macrophyte-based IBI's (i.e., maximum depth of plant growth, 95% occurrence, percentage of littoral zone vegetated, number of species with frequency over 10%, relative frequency of submersed species, relative frequency of sensitive species, relative frequency of tolerant species, and number of native taxa) can be calculated and tracked over time to document changes in the ecological health of the Iowa Great Lakes.

Introduction – The Iowa Great Lakes is an interconnected chain of diverse and complex lakes that encompasses approximately 11,500 acres in Northwest Iowa. In September 2012, a single live juvenile zebra mussel *Dreissena polymorha* was discovered on a settlement plate sampler in Upper Gar Lake. Inspections of boat hoist and docks that fall by Iowa Department of Natural Resources (DNR) officials revealed three additional juvenile zebra mussels. Although no zebra mussels were detected on plate samplers in 2013, boat hoist and dock inspections that fall documented both juvenile and adult specimens in several of the interconnected lakes (Figure 1), confirming the presence of a reproducing population. All indicators suggest that we are at the forefront of a substantial zebra mussel infestation.

Figure 1. Juvenile and adult zebra mussels found on East Okoboji Lake boat hoist, 2013.

Zebra mussels are known as ecosystem engineers because their intense filtering behavior can modify physical environments by increasing light penetration, and in turn changing the distribution and diversity of submersed macrophytes. In Oneida Lake, New York, submersed aquatic macrophyte response was substantial following infestation of zebra mussels (Zhu et al. 2006). In that case history, average depth of light penetration increased 16%, maximum depth of macrophyte colonization increased 59%, species richness and frequency of occurrence increased, and the macrophyte community changed from low-light-tolerant species to those that tolerate a wide range of light conditions (Zhu et al. 2006). Unfortunately, information regarding aquatic macrophyte and substrate composition in the Iowa Great Lakes is limited, therefore impacting the ability to document potential changes in macrophyte distribution and abundance following a zebra mussel infestation. Pammel (Iowa State Highway Commission 1917) developed a list of macrophyte species present and relative abundance for many lakes within the Iowa Great Lakes chain in 1915. Much later, Phillips (1998) compared percent change in species composition among Pammel's (1917) study and found that species composition decreased substantially. Others have also either documented species lists or completed localized macrophyte coverage maps (Crum and Bachman 1973, Shimek 1897, 1915, 1917; Sigler 1948; Phillips 2008; IA DNR AIS team), but none have quantified biovolume (i.e., percentage of the water column taken up by vegetation) of aquatic macrophytes or calculated macrophyte-based IBI's in the Iowa Great Lakes. Macrophytes are a well-suited indicator of ecological health due to their immobility and ease of sampling and identification. Therefore it is important that macrophyte surveys are conducted pre-infestation to monitor potential effects of zebra mussels. In addition, it is unknown how specific lakes within the diverse chain of lakes will react to a zebra mussel infestation, thus documentation of pre-infestation macrophyte conditions is necessary so that long-term impacts can be followed. Therefore, the objective of this study is to quantify and evaluate changes in aquatic vegetation and substrate composition in the Iowa Great Lakes following the infestation of zebra mussels.

Methods – Recent advances in GPS and sonar technology coupled with cloud-based software have substantially expanded the ability for fisheries managers to conduct lake-based bathymetric and habitat (i.e., macrophyte density and distribution, substrate composition) evaluations with limited time-investment. ciBiobase by Contour Innovations (recently purchased by Navico) is a web-based company that provides simple and affordable lake mapping GIS automation software to analyze and compare critical lake metrics over time. Unlike many mapping companies, the equipment requirements to obtain these important geo-referenced data are relatively inexpensive. Mapping was conducted with either a Lowrance Elite 7 HDI or a Lowrance HDS 7 Gen2 unit ($500-$1,500) and uploaded to the ciBiobase website for data checking and interpolation. In 2014, these units coupled with web-based GIS automation were used to collect bathymetric, macrophyte biovolume, and substrate composition data for West Okoboji, East Okoboji, Minnewashta, Upper and Lower Gar, and Spirit Lake. Roving transects (40-100 m spacing near littoral area, 100 m spacing in basins; Table 1) were conducted by Iowa DNR and Iowa Lakeside Laboratory staff in July and August 2014 throughout each lake basin to ensure complete coverage of each lake when aquatic macrophytes were fully developed (Figure 2). Data files were uploaded daily for data checking and interpolation and smooth raster surfaces were created via a kriging process (i.e., web-based GIS automation software) to create bottom depth contour, macrophyte coverage, and bottom hardness files. These raw grid shapefiles were downloaded from the web server and AcrMap 10.1 was used to recreate raster grid files and lake bathymetric maps.

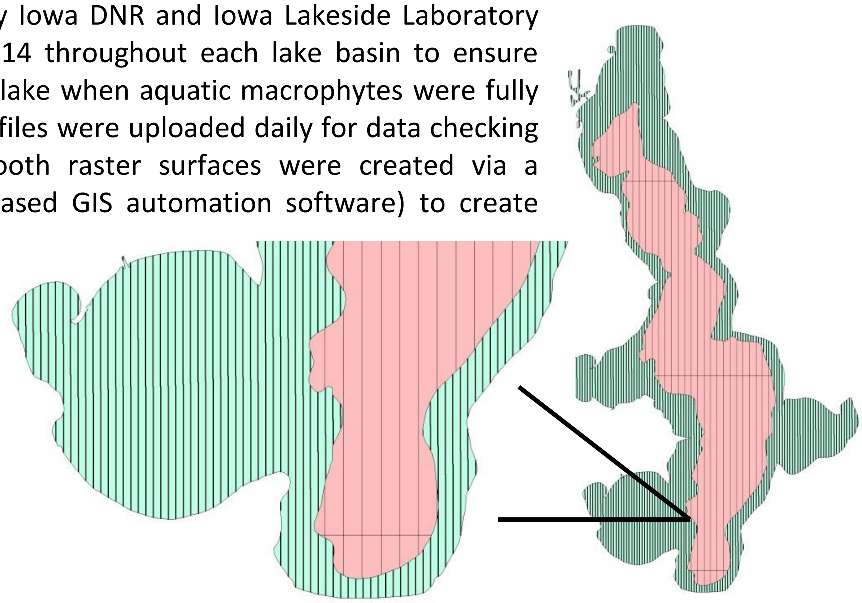

Figure 2. Transect spacing to map the littoral area (40 m spacing in <10.7 m deep) and basin (100 m spacing) of West Okoboji, 2014. Emerson and Browns bay are maximized to show detail.

Using maximum depth of aquatic macrophyte colonization data obtained from the sonar mapping project, a point intercept vegetation survey was conducted following the procedures outlined in the Iowa DNR (2013). Specifically, submersed aquatic plants were sampled at predetermined points that were selected using ArcMap 10.1 software by overlaying a grid within the selected portion of the lake identified as maximum plant growth. Vegetation was also sampled at points that extended beyond the area of the maximum plant growth to document absence of aquatic plants in areas where plants could grow given substantial increases in water clarity. The number of points sampled and spacing between points for each lake varied slightly (Table 1). These procedures were used for each lake and survey crews navigated to each uploaded point using a handheld GPS or the boat GPS unit and points were sampled using either a double sided rake or a weighted rake (depending on water depth) and rake density was visually estimated (Figure 3). Species were then separated and percent composition was estimated and recorded for each sampling point (Iowa DNR 2013). The point intercept method, although more time consuming than transect methods, provides quantitative and spatially explicit data and are better suited for assessing changes in macrophyte communities and IBI indices (Beck et al. 2010; Vondracek et al. 2014), thus works well for GIS interpolated data. In addition, using procedures described by Beck et al. (2010), macrophyte-based IBI's were calculated using metrics obtained from this survey (e.g., maximum depth of plant growth, 95% occurrence, percentage of littoral zone vegetated, number of species with frequency over 10%, relative frequency of submersed species, relative frequency of sensitive species, relative frequency of tolerant species, and number of native taxa). These metrics will be tracked over time to compare the ecological health of the Iowa Great Lakes.

Figure 3. Point vegetation sampling via a double sided rake (top right) and via a weighted rake (bottom right). Rake density was visually estimated by comparing each sampled points density to the chart on the left (IA DNR 2013). The sample was then separated out by species percent composition was estimated (bottom right; wild celery, flatstem pondweed, northern milfoil, and coontail represented in photo).

2014 Results – Sonar mapping began 3 July 2014 with mapping the basin of Spirit Lake. Spirit Lake basin was completed on 7 July 2014 and crews began mapping the littoral area between 9 July and 1 August 2014. In all, 25 mapping files were created for Spirit Lake and all files were uploaded and post-processed within 48-h of mapping. All mapping for East Okoboji, Upper and Lower Gar, and Minnewashta lakes was completed between 9 July 2014 and 8 August 2014 (N = 27 files). The littoral area of West Okoboji was mapped between 16 July 2014 and 25 August 2014; whereas the basin of West Okoboji was mapped on 30 October, 6 November, and 14 November 2014. In all, 73 files were created, uploaded and post-processed for West Okoboji. Combined, it took approximately 163 h, or 70 acres mapped/h, to map the entire chain of lakes.

Table 1. Sonar transect (littoral and basin) and point intercept aquatic vegetation spacing used for each lake within the Iowa Great Lakes, 2014. The number of vegetation points sampled for each lake is also provided.

Lake	Acres Mapped	Littoral Transect	Basin Transect	Point Intercept	N Point Sampled
Spirit Lake	5,352	60 m (<6 m)	100 m (>6 m)	100 m	571
East Okoboji	1,846				
Above Hwy 9		100 m	100 m	150 m	60
Below Hwy 9		100 m	100 m	80 m	531
West Okoboji	3,889	40 m (<10.7 m)	100 m (>10.7 m)	100 m	731
Upper Gar	38	100 m	100 m	80 m	22
Minnewashta	123	100 m	100 m	80 m	44
Lower Gar	252	100 m	100 m	150 m	32

The percent of lake surface area that had aquatic vegetation was highest in West Okoboji (59.5%) and lowest in Lower Gar and Spirit Lake (25.7%; Table 2). Average aquatic plant biovolume (percent of water column taken up by vegetation) ranged from 3.8% in the Lower Gar to 19.2% in East Okoboji Lake (Table 2); likewise, these two lakes had the highest and lowest aquatic plant biovolume in areas where vegetation was present (links to individual vegetation analysis reports are provided in Appendix 2). Lake depth, bottom hardness, and biovolume imagery for each lake are provided in Figures 4-7. Distinct vegetation beds in shallow bays and deeper weed lines were well represented using 35m-60m transect spacing and the 100 m transect spacing in East Okoboji and the Lower Chain. Bottom mapping was also conducted during the point intercept vegetation survey and these data improved mapping precision in the littoral areas of each lake. The upper end of East Okoboji was mapped during two separate days and captured a time period as vegetation (primarily flatstem pondweed) began to undergo senescence (Figure 5). Curlyleaf Pondweed beds were the only other areas where substantial senescence was documented; however, these vegetation beds were nearly absent by the time the mapping project began. Substrate hardness was also well represented as known rock points and piles were captured from the sonar mapping (Figures 4-7). Water depth imagery collected via sonar overlaid with a 1977 depth contour file nearly mimicked prior work (Figure 8).

A point intercept aquatic vegetation survey was conducted between 29 July 2014 and 1 August 2014 in Spirit Lake, 4 August 2014 and 8 August 2014 in East Okoboji, 18 August 2014 and 23 September 2014 in West Okoboji and on 7 August 2014 in the Lower Chain. In the entire chain of lakes, we sampled 2,060 vegetation points and identified 18 species ranging in abundance from <1% of the rake coverage to well over 100% (i.e., mats of vegetation; Table 1 and Figure 9). Aquatic plant maximum depth, relative frequency, species diversity, and percentage of littoral area coverage was highest in West Okoboji Lake and lowest in the Lower Chain lakes (Table 3). Likewise, the relative frequency of aquatic vegetation in point surveys varied substantially by lake (Figure 10). Wild celery was the only submersed aquatic plant that occurred in all lakes at a relative frequency > 0.10 (Table 4). Other species were found in lakes at relative frequencies of ≥ 0.10 were coontail, chara spp., northern milfoil, claspingleaf pondweed, and flatstem pondweed. Seven submersed aquatic species were found in all lakes (Table 4). Emergent or floating leaf species were only found in Spirit Lake and were generally confined to Anglers Bay and the Grade (north end).

Table 2. Percent area covered (PAC), average aquatic plant biovolume (BVp; BVw), depth range mapped, average depth, number of points taken, and average water temperature (˚F) from sonar mapping in the Iowa Great Lakes, summer 2014.

	Spirit Lake	East Okoboji	West Okoboji	Upper Gar/Minnewashta	Lower Gar
PAC	25.7%	30.7%	59.5%	40.1%	24.0%
Avg BVp	33.1%	62.7%	29.6%	47.3%	15.9%
Avg BVw	8.5%	19.2%	17.6%	19.0%	3.8%
Depth Range (m)	0.18-6.85	0.19-6.41	0.25-42.34	0.23-4.62	0.22-3.01
Avg Depth (m)	3.67	2.32	5.24	1.93	1.00
No. Points	88,561	60,380	139,387	8,752	2,659
Avg Water Temp (˚F)	74.2	76.5	72.9	76.2	76.6

PAC = Percent Area Covered - refers to the overall surface area that has vegetation growing
Avg BVp = Biovolume (plant) - refers to the percentage of the water column taken up by vegetation when vegetation exists
Avg BVw = Biovolume (water) - refers to the average percentage of the water column taken up by vegetation regardless of whether or not vegetation exists

Table 3. Aquatic vegetation metrics collected via a point intercept vegetation survey in the Iowa Great Lakes, 2014.

	Lake			
Metric	Spirit Lake	East Okoboji	West Okoboji	Lower Chain
Maximum depth of plant growth (m)	4.3	3.4	10.9	2.4
Maximum depth of plant growth, 95% occurrence (m)*	3.7	2.9	6.9	2.1
Percentage of littoral vegetated	0.87	0.47	0.89	0.36
Number of species with relative frequency over 10%	3	2	5	1
Relative frequency of submersed species	0.70	0.34	0.74	0.27
Relative frequency of sensitive species	0	0	0	0
Relative frequency of tolerant species	0.10	0.06	0.57	0.07
Number of native taxa (including Chara)	13	12	13	9

*depth where 95% of the plant growth occurred within the basin

Table 4. Relative frequency of individual species in three lakes and the Lower Chain of the Iowa Great Lakes collected via a point intercept vegetation survey, 2014.

	Spirit Lake	East Okoboji	West Okoboji	Lower Chain
Algae	0.0582	0.0155	0.0236	0.0098
Coontail	0.0743	0.0224	0.4256	0.0686
Chara spp.	0.5663	0.0344	0.4089	
Canada Waterweed		0.0034	0.0014	
Star Duckweed		0.0017	0.0459	
Northern Milfoil	0.0422	0.0017	0.2114	0.0196
Bushy Pondweed	0.0582	0.0878	0.0362	0.0686
Curlyleaf Pondweed	0.0261	0.0344	0.0014	
Leafy Pondweed		0.0275	0.0028	0.0294
Illinois Pondweed	0.0040		0.0111	
Longleaf Pondweed	0.0020			
Sago Pondweed	0.0321	0.0189	0.0668	0.0392
Claspingleaf Pondweed	0.1185	0.0482	0.0848	
Flatstem Pondweed	0.0482	0.2978	0.1057	0.0294
Unidentified Pondweed	0.0020	0.0017		0.0588
Wild Celery	0.3092	0.1411	0.2309	0.1078
Water Stargrass	0.0080	0.0103	0.0292	0.0294
Softstem Bullrush	0.0060			
Narrowleaf Cattail	0.0020			
Water Lotus	0.0060			

2015 and Beyond - The Lowrance sonar units coupled with an intense point intercept aquatic vegetation survey proved to be a very successful technique to obtain a detailed snapshot of aquatic vegetation distribution, abundance, and diversity within the Iowa Great Lakes during the 2014 growing season. Although zebra mussels have already been detected in East Okoboji, West Okoboji and the Lower Chain lakes, their populations have not exceeded the level thought to influence aquatic vegetation diversity or density and these data should be adequate to describe aquatic vegetation metrics pre zebra mussel's expansion. In addition, zebra mussels have yet to be discovered in Spirit Lake; hence the aquatic macrophytes metrics found in this study will serve as a good indicator to pre-zebra mussel establishment. Since there can be substantial annual variation in aquatic plant communities, these methods need to be repeated in 2015 so that managers can capture this potential variation and account for it in future analysis. However, these data do not come without a price tag and substantial time commitment. For example, in 2014, over 531 h were accumulated by Fisheries staff to prepare, conduct, enter data, and review data files for this project. In 2015 and beyond surveys, mapping of the lake basins will not be required and would cut approximately 25% of the time to map and review data files. Therefore, two individuals dedicated solely to mapping and conducting vegetation surveys during July and the first half of August would be sufficient for continue monitoring. In addition, an annual license fee of approximately $2,000 will be required from ciBiobase to use the cloud-based GIS automation. Financial support and/or seasonal staffing will be required to complete a similar survey in 2015.

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Sorting through mats of aquatic vegetation on West Okoboji, 2014.

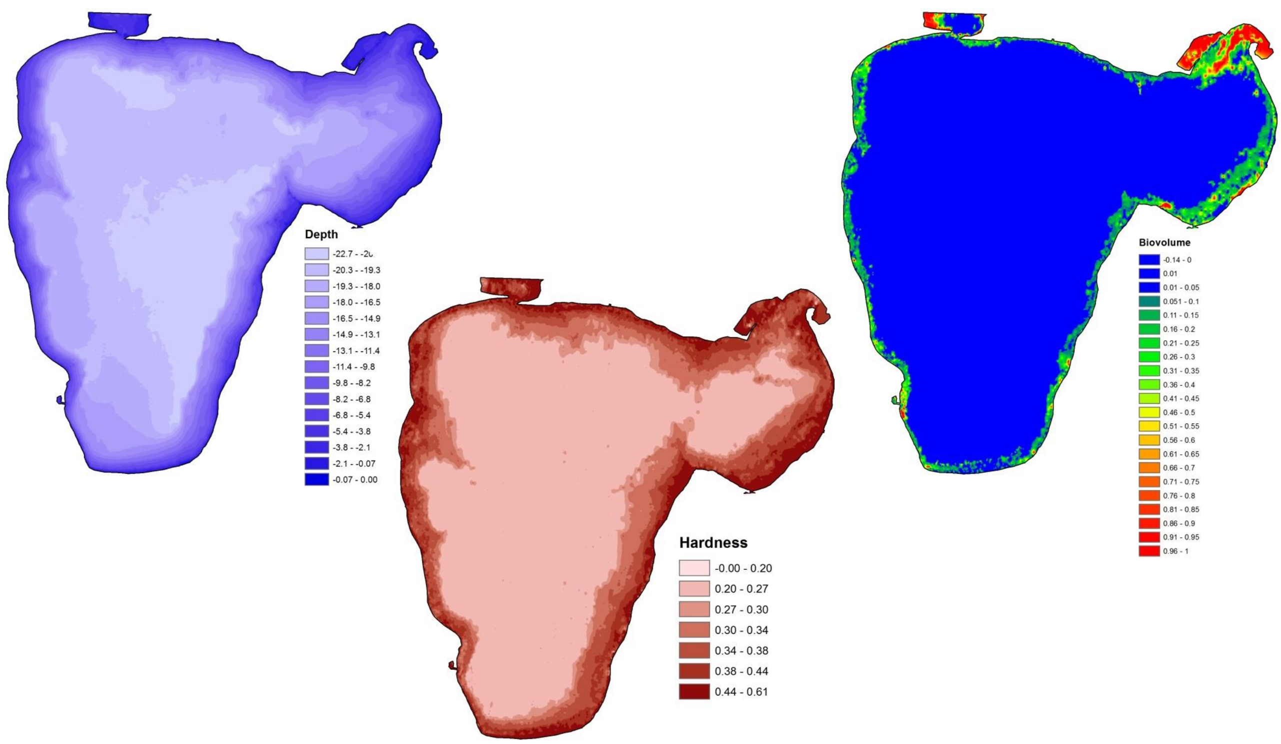

Figure 4. Spirit Lake depth, bottom hardness, and aquatic plant biovolume estimated via sonar mapping, summer 2014.

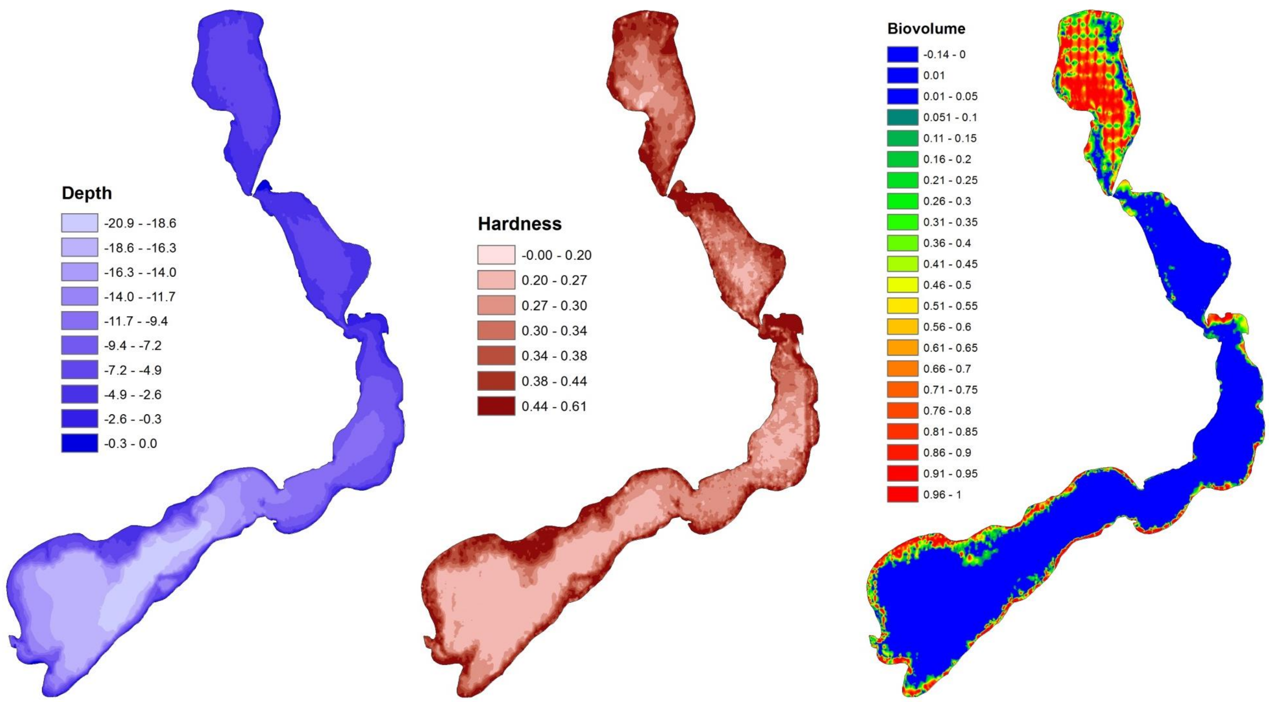

Figure 5. East Okoboji depth, bottom hardness, and aquatic plant biovolume estimated via sonar mapping, summer 2014.

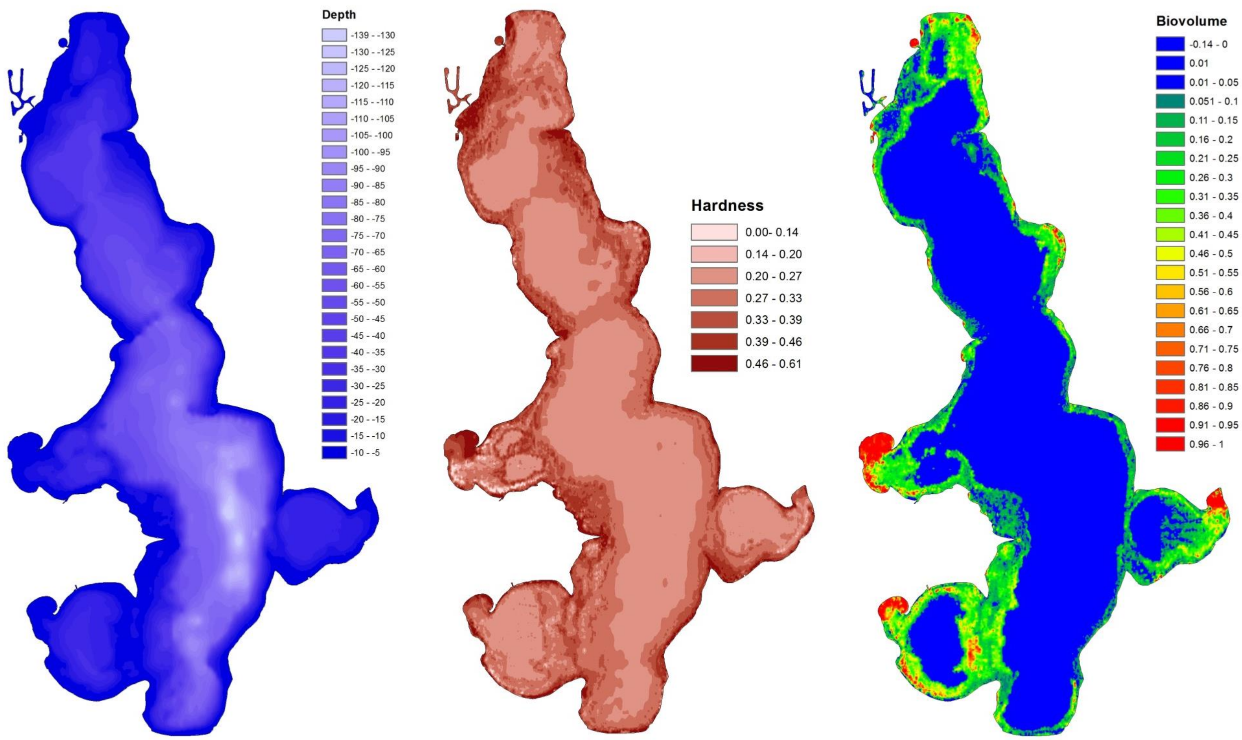

Figure 6. West Okoboji depth, bottom hardness, and aquatic plant biovolume estimated via sonar mapping, summer 2014.

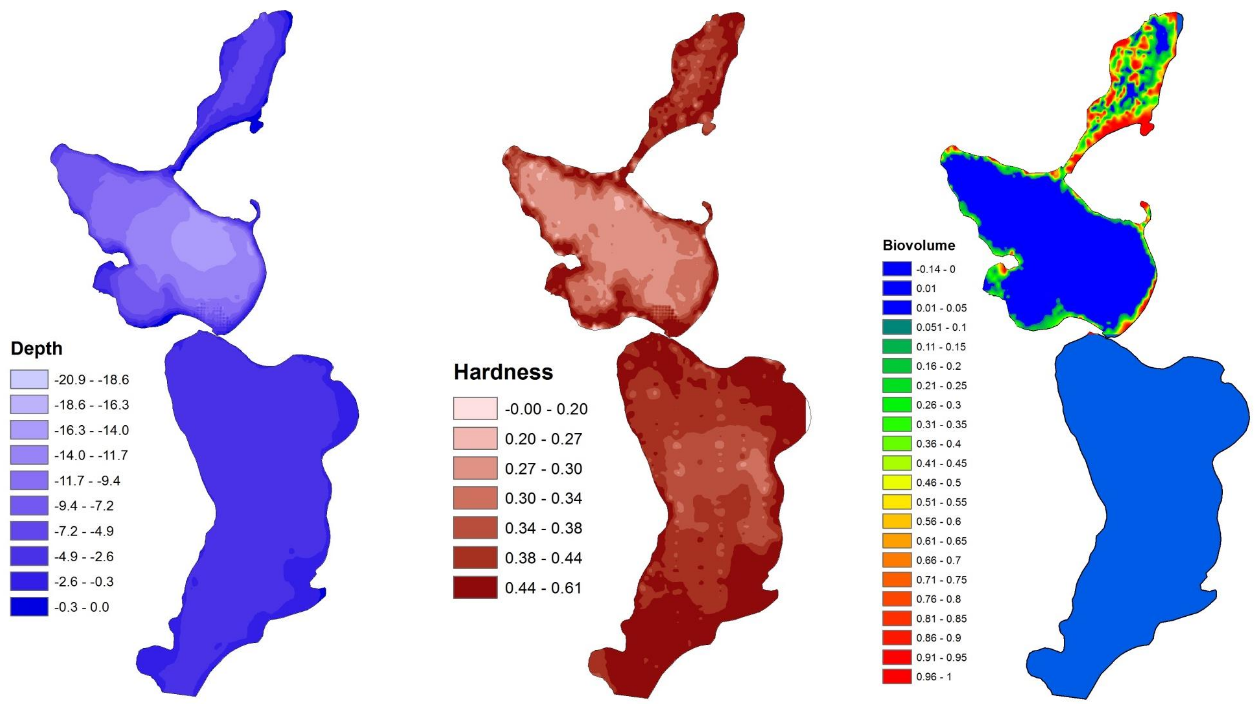

Figure 7. Lower chain depth, bottom hardness, and aquatic plant biovolume estimated via sonar mapping, summer 2014.

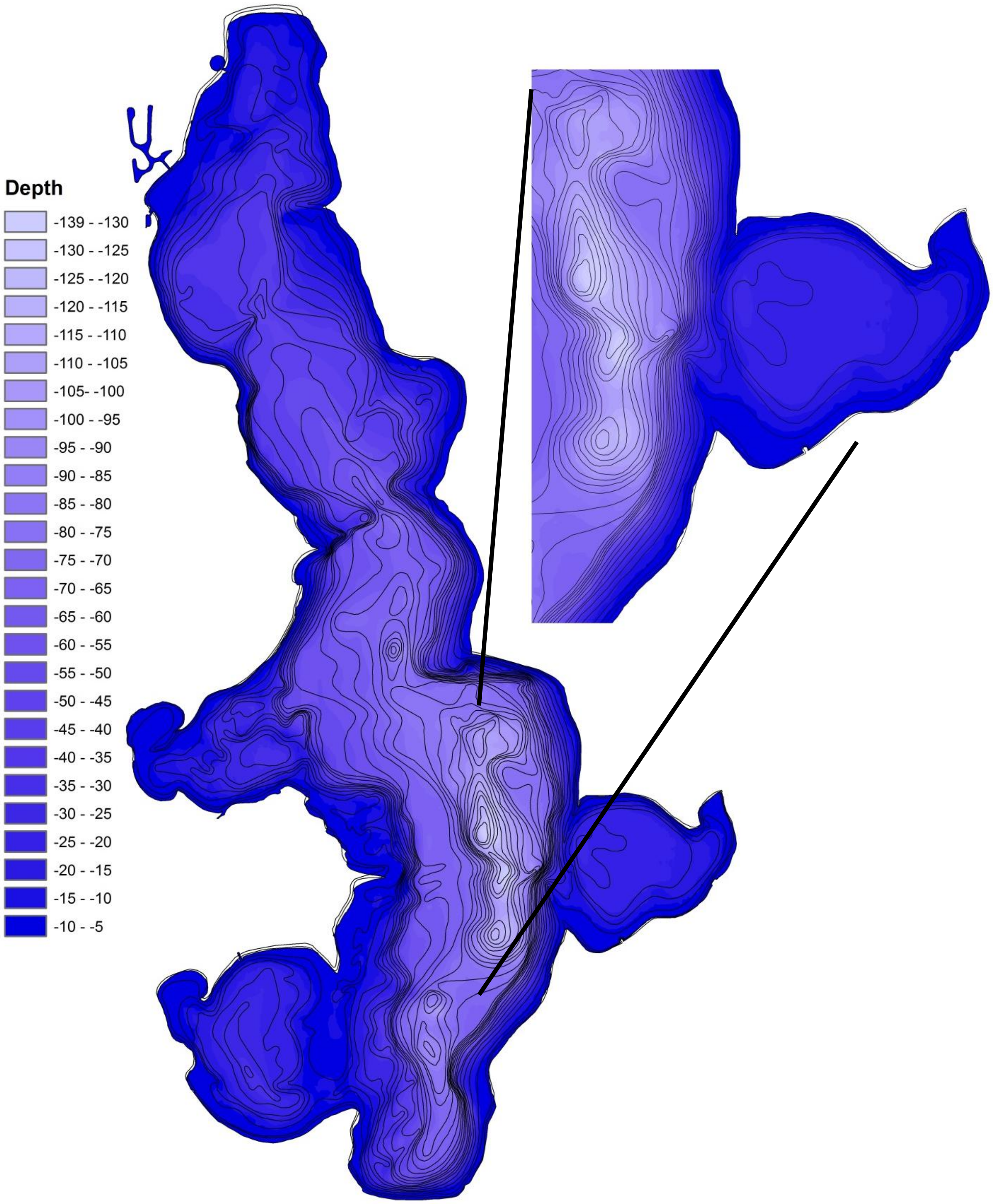

Figure 8. West Okoboji depth (ft) grid imagery from sonar mapping overlaid with existing 1977 contour file.

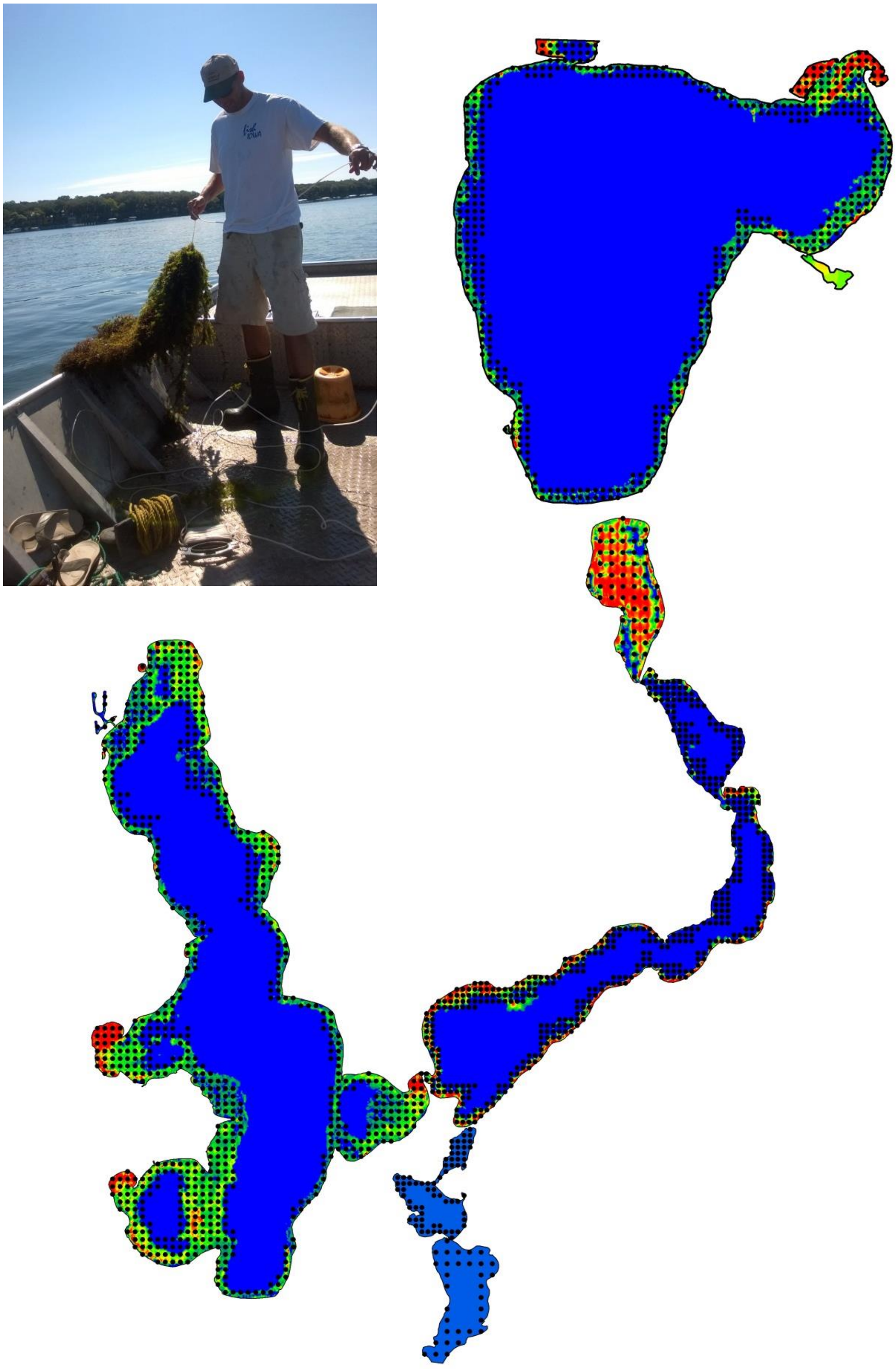

Figure 9. Point intercept sampling locations for the Iowa Great Lakes, summer 2014.

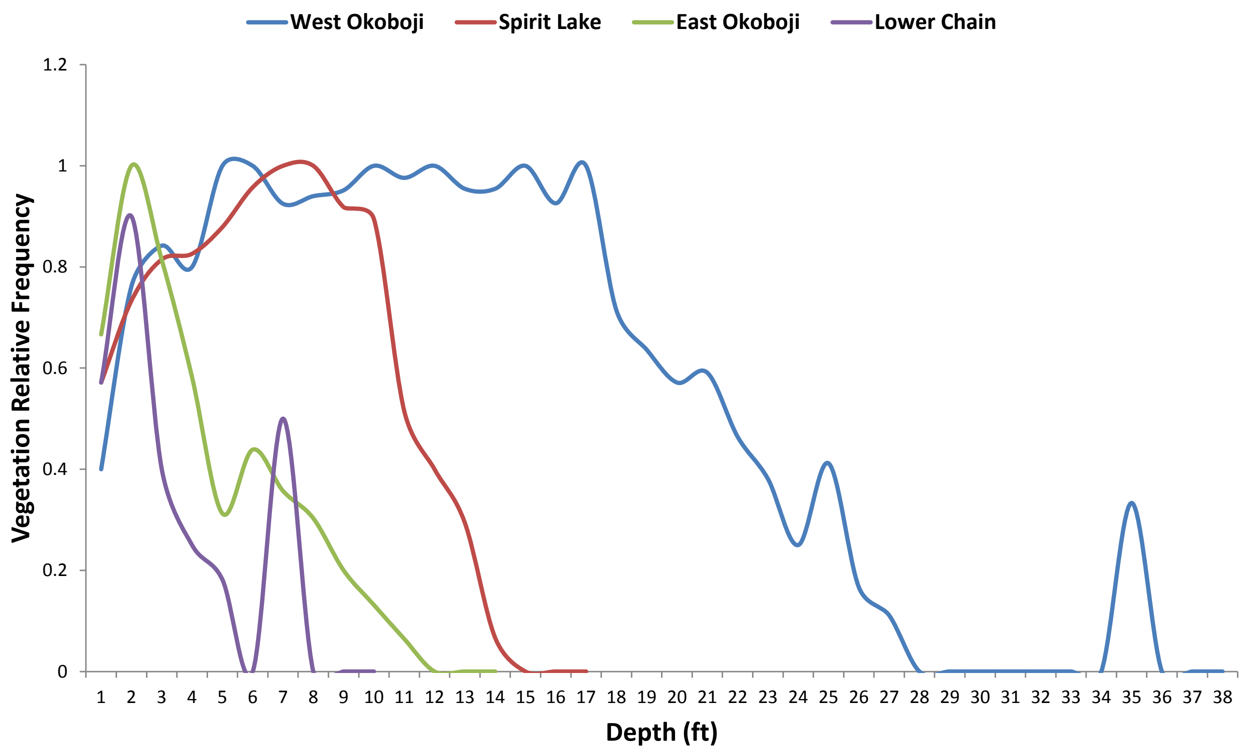

Figure 10. Relative frequency of aquatic plants by depth range (pooled by 1 ft intervals) found in point transect vegetation survey in West Okoboji, Spirit, East Okoboji, and the Lower Chain lakes, 2014.

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Appendix

Appendix 1. Emergent, floating leaf, and submergent aquatic vegetation found in the Iowa Great Lakes chain via transect surveys conducted from 1996-2004 (provided by IA DNR AIS team). Relative abundance (infrequent; common, frequent) for each species was categorized for each lake.

Species Common Name	**Code**	Type	East Okoboji	Lower Gar	Minne-washta	Spirit Lake	Upper Gar	West Okoboji
American Water Lotus	**NLU**	Emergent				R		
Arrowhead	**SAS**	Emergent	R				I	R
Blue Flag Iris	**IVE**	Emergent						R
Broadleaf Arrowhead	**SAL**	Emergent	R			R	I	R
Bulrush	**SCS**	Emergent		R		I	R	
Cattail	**TSP**	Emergent	I	I	I	I	I	I
Giant Burreed	**SEU**	Emergent					R	
Hardstem Bulrush	**SCA**	Emergent	R			I		
Prairie Cordgrass	**SPE**	Emergent						R
Purple Loosestrife	**LSA**	Emergent			R			R
Reed Canarygrass	**PAR**	Emergent	F	F	I	R	I	R
River Bulrush	**SCF**	Emergent	R	R		R		
sedge	**CSP**	Emergent		R		R	R	R
small's spikerush	**ESM**	Emergent		R			R	
smartweed	**PYS**	Emergent	I	R	R	R		
Softstem Bulrush	**SCV**	Emergent		R		I	R	
swamp milkweed	**AIN**	Emergent						R
water smartweed	**PYA**	Emergent				R		
Big Duckweed	**SPO**	Floating leaf	R	R	R	R	R	R
Little Duckweed	**LMI**	Floating leaf	I	R		I	I	R
Star Duckweed	**LTR**	Floating leaf						R
Watermeal	**WCO**	Floating leaf	R	I	I	R	I	R
Bushy Pondweed	**NFL**	Submergent-PW	F	F	I	F	I	I
claspingleaf pondweed	**PRI**	Submergent-PW	F	I	F	F	I	F
Curlyleaf Pondweed	**PCR**	Submergent-PW	F	I	F	F	F	R
flatstem pondweed	**PZO**	Submergent-PW	F	F	F	F	F	F
floatingleaf pondweed	**PNA**	Submergent-PW				R		R
Fries Pondweed	**PFR**	Submergent-PW	I		I	R	R	R
Horned Pondweed	**ZPA**	Submergent-PW	I	I		R	I	
Illinois Pondweed	**PIL**	Submergent-PW	F	R		F	R	F
Largeleaf Pondweed	**PAM**	Submergent-PW	I		R	I		I
Leafy Pondweed	**PFO**	Submergent-PW	I	R	I	I	I	I
longleaf pondweed	**PNO**	Submergent-PW	R		R	R		R
pondweed	**PSP**	Submergent-PW	I				R	
Slender Pondweed		Submergent-PW				I		
small pondweed	**PPU**	Submergent-PW	I	R	R	I	I	R
whitestem pondweed	**PPR**	Submergent-PW	R			I		R
Bladderwort	**UVU**	Submergent						R
Bushy Naiad		Submergent				F		
Canadian waterweed	**ECA**	Submergent	I	F	F	I	F	I
coontail	**CDE**	Submergent	F	F	F	F	F	F
muskgrass	**CVU**	Submergent	I		R	F	I	F
Northern Watermilfoil	**MSI**	Submergent	I	I	R	F	F	F
sago pondweed	**PPE**	Submergent	F	F	F	F	F	F
Water Stargrass	**ZDU**	Submergent	F	F	F	F	I	I
whitewater crowfoot	**RLO**	Submergent		R				I
Widgeon Grass	**RMA**	Submergent				R		R
Wild Celery	**VAM**	Submergent	F	F	F	F	F	F

Appendix 2. Links to individual lake vegetation analysis reports (ciBiobase.com).

East Okoboji Vegetation Analysis Report Link
http://files12.contourinnovations.com/ReportOutput/f9dec6f0-a146-4e49-87aa-65e5f46a77aa/report.htm

West Okoboji Vegetation Analysis Report Link
http://files12.contourinnovations.com/ReportOutput/ad6fa7f1-c3d8-440c-bed0-332a036042b2/report.htm

Spirit Lake Vegetation Analysis Report Link
http://files12.contourinnovations.com/ReportOutput/9101dd45-9c05-4e7e-b78c-33cdf2db70e8/report.htm

Upper Gar and Minnewashta Lake Vegetation Analysis Report Link
http://files12.contourinnovations.com/ReportOutput/d5afa0f8-6ef3-4fa7-98c7-e9d43d96f96d/report.htm

Lower Gar Lake Vegetation Analysis Report Link
http://files12.contourinnovations.com/ReportOutput/642e61d9-f42c-42d7-90fd-fbe4ce07d88f/report.htm

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