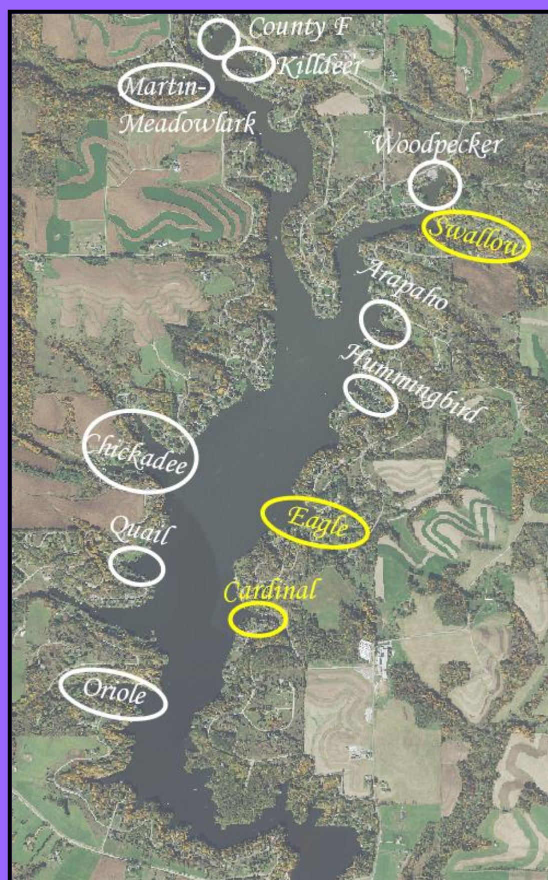
2019 Aquatic Plant Survey Report
Lake Redstone Bays

Sauk County, Wisconsin

Arapaho, Cardinal, Chickadee, County F, Eagle, Hummingbird, Killdeer, Martin-Meadowlark, Oriole, Quail, Swallow, & Woodpecker



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ABSTRACT

Aquatic plant surveys of twelve bays in Lake Redstone, Sauk County WI, were completed in 2019 as an ongoing effort to gauge effectiveness of Eurasian watermilfoil (*Myriophyllum spicatum,* EWM) control activities. Cardinal, Chickadee, Eagle, and Oriole Bays were surveyed July 17th, 2019. Although consistent timing of plant surveys in mid-to-late August is recommended, the July surveys were necessary to visit these bays before dredging began. Arapaho, County F, Hummingbird, Killdeer, Martin-Meadowlark, Quail, Swallow, and Woodpecker Bays were surveyed August 3-4th, 2019. Each bay has its own management history with varying stages of pre-and post-treatment monitoring for EWM. Although some bays had been treated with herbicide in past years in an effort to control EWM, no bays were treated with herbicide in spring 2019 because dredging was scheduled to remove sediment beginning in July 2019, which is also expected to reduce EWM occurrence even though it was not an objective of the dredging. The surveys employed methods from Hauxwell (2010), but with a higher resolution survey grid than would be used on a whole-lake scale. Surveys of Swallow, Eagle, and Cardinal Bays were executed to gauge the continued effectiveness of herbicide treatment in 2018 and provide information on pre-dredging conditions. The remaining nine bays were surveyed to provide information on the aquatic plant community before dredging occurred. EWM was found in 10 out of 12 bays in 2019 and was the most or second-most common plant in 6 of the bays. Chi-squared tests revealed no statistically significant (SS) increase in EWM in any of the bays when compared to 2018 data nor when compared to the first year of surveying in the bays. Littoral frequency for all plant species, native and non-native, was lowest in 2019 compared to all previous years for 9 out of 11 bays (2019 was the first survey year for County F Bay so no previous data exists for comparison). In other words, the vegetation was scarcer in 2019 compared to previous years. EWM occurrence was the lowest on record for all bays with the exception of Eagle Bay, for which the lowest year was 2018. When comparing ***native*** plant occurrence from the most recent previous survey to data collected in 2019, there was a SS decline in 9 species but no SS increase in any species.

Management Recommendations are as follows; 1) Protect native aquatic plants. 2) Control nuisance native vegetation with hand-pulling or raking, where permitted. 3) Continue water quality monitoring. 4) Conduct aquatic plant surveys of bays in 2020 and plan for a whole-lake aquatic plant survey of Lake Redstone in 2020 or 2021.

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INTRODUCTION

The Lake Redstone Protection District (LRPD) partnered with Aquatic Plant and Habitat Services to complete aquatic plant surveys of twelve bays in 2019 as a continued effort in gauging EWM control activities and to measure conditions before dredging commenced in 2019. Dredging occurred in Lake Redstone from July through December of 2019 to remove sediment from 27 locations, protect lake property values, meet obligations to maintain and improve the lake, and aim to improve water quality[1]. Cardinal, Eagle, and Swallow Bays were surveyed to gauge efficacy of herbicide treatment in 2018 and provide pre-dredging conditions of the aquatic plant communities in those bays. Arapaho, Chickadee, County F, Hummingbird, Killdeer, Martin-Meadowlark, Oriole, Quail, and Woodpecker Bays were surveyed to capture aquatic plant community conditions before dredging occurred.

Study Site

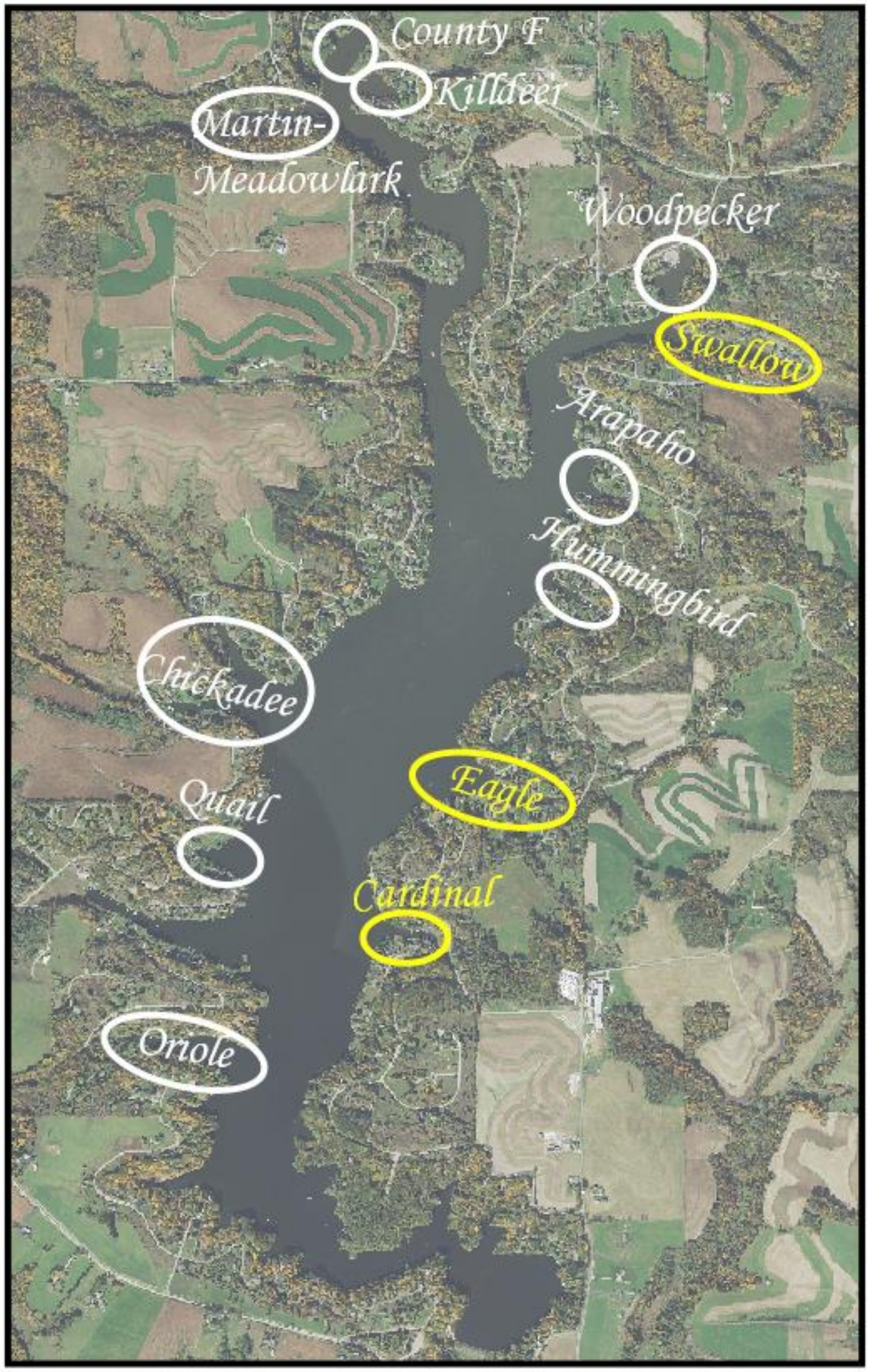
Lake Redstone is a drainage lake in Sauk County, Wisconsin with a surface area of 605 acres (245 hectares). The lake is an impoundment of Big Creek, which is a tributary of the Baraboo River, in Sauk County. The lake was created in 1965 with the construction of the dam on Big Creek initiated by a real estate developer with the intention of establishing 1,600 residential lots (Leverance & Panuska, 1997). The lake was dredged at 10 locations in the 1980's. Recent concerns about sedimentation prompted studies, one of which estimated annual sediment loading at 3,000 cubic yards per year[2]. Flooding in 2018 resulted in an additional 67,340 cubic yards of sediment loading in the bays[2]. The Lake District pursued dredging of 27 locations in 2019. The lake is considered an Area of Special Natural Resource Interest due to the presence of certain plant or animal species or unique ecological communities identified in the WDNR Natural Heritage Inventory. The twelve bays surveyed in 2019 are illustrated in Figure 1.

Water Chemistry & Clarity

Lake Redstone is one of 65 Long Term Trend Lakes in Wisconsin. Such lakes are monitored by volunteers and professionals from May through September annually to provide reference conditions for regional trophic classification and to track changes within and among lakes in Wisconsin. The lake has a flushing rate of about 1.8 times during the growing season (May-September), meaning an entire lake volume worth of water flows through the system nearly twice during that five-month monitoring period (Leverance & Panuska, 1997). Lake Redstone is classified as a eutrophic system based on data collected since 1979. Volunteers collect water samples for chlorophyll and phosphorus analysis while water clarity is measured in the field using a Secchi disk. Based on chlorophyll data, the trophic state index is 65, which is considered poor for reservoirs (WDNR, 2018).

[1] https://www.lakeredstonepd.org/dredging-meeting-minutes. June 2018 Dredging Informational Meeting PowerPoint Presentation.
[2] https://www.lakeredstonepd.org/dredging-meeting-minutes. A Proposal for Dredging on Lake Redstone. Lake Redstone Protection District. May 18, 2019

Figure 1 – Lake Redstone Map of Bays Surveyed in 2019



Bays labeled & circled in yellow were treated with herbicide in May 2018

GOALS AND OBJECTIVES

GOAL: The main goal was to survey aquatic plants in select bays at a higher resolution (compared to whole-lake survey) for making management decisions, specifically related to EWM management, and to gauge pre-dredging conditions of the aquatic plant communities.

OBJECTIVES:

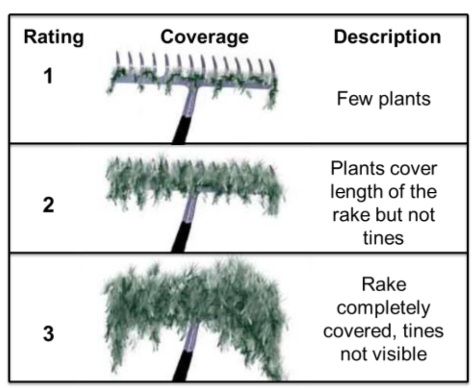
1. Complete a survey of all aquatic plants in twelve bays at pre-determined survey points.
2. Analyze data and create maps of plant distribution, sediment type, and depth.
3. Provide a final report.
4. Compare results of the previous surveys using Chi-squared tests to identify statistically significant changes in native and invasive plant species since 2014.

METHODS

Field Methods

Field methods followed the standardized protocol developed by the Wisconsin Department of Natural Resources (WDNR) in Hauxwell et. al (2010) and the surveys were completed on July 17th and August 3-4th, 2019. Previous plant survey dates are in List 1. Point-intercept maps were generated for Arapaho (55 pts), Cardinal (71 pts), both arms of Chickadee (121 pts), County F (73 pts), (Eagle (115 pts), Hummingbird (65 pts), Killdeer (62 pts), Martin-Meadowlark (56 pts), Oriole (104 pts), Quail (77 pts), Swallow (72 pts), and Woodpecker (86 pts) resulting in 957 sample points. The sample points were uploaded to handheld Garmin GPS that was used to navigate to each point in the bays. Points that were deeper than 12 feet were not surveyed based on previous findings that the maximum rooting depth in Lake Redstone was 12 feet in 2005 and 10 feet in 2012 (Berg, 2012). Furthermore, maximum rooting depth of any bay-wide survey since 2014 was 11 feet (Table 3). A double-sided rake head on a telescopic pole was used to sample each point for aquatic plants, depth, and dominant sediment type (muck, rock, or sand). The rake fullness rating for total coverage of plants on the rake and a separate rake fullness rating for each species present were recorded (Figure 2). Any survey points that were inaccessible were recorded as such and no sample was taken. Aquatic plants found within 6 feet of the sample point but not found on the rake were counted as visual observations. Plant identification was verified using Skawinski (2014).

Figure 2 – Rake Fullness Illustration



List 1 – Aquatic Plant Survey Dates

- August 11, 2014
- July 17-18, 2015
- August 17-18, 2016
- September 8-9, 2017
- August 24-25, 2018
- July 17, 2019 (Cardinal, Swallow, Eagle, and Oriole Bays before dredging).
- August 3-4, 2019 (Arapaho, Chickadee, Cty F, Hummingbird, Killdeer, Martin-Meadowlark, Quail, & Woodpecker before dredging).

Data Analysis Methods

Survey data were used to calculate statistics including Simpson Diversity Index, species richness, Nichols (1999) Floristic Quality Index, frequencies, rake fullness and number of visual sightings among other summary statistics. Following guidelines in Hauxwell (2010), species that were recorded as visuals (i.e., within 6 feet of a survey point but not sampled with the rake) were not included in Simpson Diversity Index and FQI calculations. Also, filamentous algae occurrence was not used in some statistical calculations but data was collected to gauge its frequency throughout the 12 bays.

Summary Statistics

Summary statistics provide a general overview of the plant community in each bay and can be used to make comparisons among the bays and within the same bay over time. However, ***these statistics should not be used to compare to other lakes where a whole-lake survey has been done***. Explanations of summary statistics are in Table 2. Floristic Quality Index (FQI, Nichols 1999) is listed in Table 1 but is worth providing more explanation. The FQI incorporates aquatic plant species associated with lake communities and native to Wisconsin by using the Coefficient of Conservatism (C) ranging from 0 to 10. The C value estimates the likelihood of a plant species occurring in an environment that is relatively unaltered from pre-settlement conditions. As human disturbance increases, species with a lower C value occur more frequently while more sensitive species with a higher C value occur less frequently. To calculate floristic quality, the mean C value of all species found in the lake is multiplied by the square root of the total number of plant species in the lake. Only plants found on the rake are included in the calculations. In other words, the FQI metric helps us understand how close the aquatic plant community is to one of undisturbed conditions. A higher FQI value assumes a healthier aquatic plant community. Floristic quality values can be compared on a statewide value, but Nichols (1999) recommends comparing values within one of the four ecoregional-lake types. Lake Redstone falls within the "Driftless" ecoregional-lake type. However, the ***FQI values for each bay or even mean values of all bays cannot be compared to other lakes in the driftless region because the bays are not representative of a whole-lake survey***.

Individual Species Statistics

Individual species statistics assess the plant species composition in the 12 bays and allow for comparisons of the plant community within the bays (Table 1).

Chi-squared tests

A chi-squared test of plant occurrence was done for all bays. The statistical test helps determine whether there is a significant difference between two data sets by comparing the number of sites a particular plant species was found in two different years. The alpha, or Type I error rate was set at 0.05, meaning there is a 5% chance of claiming there is a significant change when no real change has occurred. Chi-squared tests compared differences in plant occurrence from 2018 to 2019. The tests also compared differences from the first year of the bay being surveyed to 2019.

Table 2 – Summary Statistics Explanations

	Statistic	Explanation
1	Total number of sites visited	The total number of sites sampled, which is not necessarily equal to the number of survey points because some sites may not be accessible.
2	Total number of sites with vegetation	Number of sites where at least one plant was found on the rake (does not include moss, sponges, filamentous algae, or liverworts).
3	Maximum depth of plants	Depth of deepest site where at least one plant was found on the rake (does not include moss, sponges, filamentous algae, or liverworts).
4	Total number of sites shallower than maximum depth of plants	Number of sites where depth was less than or equal to the maximum depth where at least one plant was found on the rake.
5	Frequency of occurrence at sites shallower than maximum depth of plants	Total number of sites with vegetation (2) / Total number of sites shallower than maximum depth of plants (4).
6	Average number of species per site (split into four subcategories)	a) Shallower than maximum depth – the average number of species found per site at sites less than or equal to the maximum depth where at least one plant was found on the rake (4).
		b) Vegetated sites only – the average number of species found per site at sites where at least one plant was found on the rake (2).
		c) Native species shallower than maximum depth – Same explanation as 6(a), non-native species excluded from average.
		d) Native species at vegetated sites only – Same explanation as 6(b), non-native species excluded from average.
7	Species Richness (split into two subcategories)	a) Total number of species found on the rake at all sites (does not include moss, sponges, filamentous algae, or liverworts
		b) Including visuals – Same explanation as 7(a) and including visual observations within 6 feet of the sample sight
8	Simpson Diversity Index	Estimates the heterogeneity of a community by calculating the probability that two individuals randomly selected from the data set will be different species. The index ranges from 0-1, and the closer the value is to one, the more diverse the community. Visual observations (within 6 feet of sample point) are not included in calculation of index.
9	Coefficient of Conservatism (C)	This is not a statistical calculation, but rather a value assigned to each plant species based on how sensitive that species is to disturbance. C values range from 1 to 10 with higher values assigned to species that are more sensitive to disturbance (Nichols, 1999).
10	Floristic Quality Index	How similar the aquatic plant community is to one that is undisturbed (Nichols, 1999). This index only factors species raked at survey points and does not include non-native species. The FQI is calculated using coefficient of conservatism values (9).

Table 1 – Individual Species Statistics Explanations

Individual Statistic	Explanation
Average Rake Fullness	Mean rake fullness rating ranging from 1 to 3. See Rake Fullness Illustration.
Number of sites where a species was found	The total number of survey points where a particular species was found on the rake.
Number of visual sightings	The total number of times a particular species was visually observed within 6 feet of a sampling point, but not collected on the rake.
Frequency of Occurrence FOO (split into two subcategories)	a) Among vegetated sites only – The number of sites at which a particular species is found on the rake divided by the total number of vegetated sites (Table 2, #2).
	b) Among sites shallower than the maximum depth of plants – The number of sites at which a particular species is found on the rake divided by the total number of sites less than or equal to the maximum depth of plants (Table 2, #4). Also known as **littoral frequency.**
Relative frequency (%)	This value represents the degree to which a particular species contributes to the total of all observations. The sum of all relative frequencies is 100%.

RESULTS

The results for all 12 bays are summarized in Tables 3, 4, 5, and 6. Table 3 includes the summary statistics for 2019 as well as previous years. Table 4 covers floristic quality results for 2019 and previous years. Tables 5 and 6 list individual species found in each bay in 2019 and corresponding statistics for each species. Results are further described later in this section.

Table 3 – Summary Plant Statistics for All Bays 2014-2019

Bay & Year		1	2	3	4	5	6 Average # of species per site				7 Species Richness		8	
		Total # sites visited	Total # sites w/ vegetation	Max. depth of plants	Total # sites shallower than max. depth of plants	Littoral frequency**	a) Shallower than max. depth	b) Vegetated sites only	c) Native shallower than max. depth	d) Native at veg. sites only	a) Total # species on rake at all sites	b) Including visuals	Simpson's Diversity Index	Littoral frequency of EWM
Martin-Meadowlark	2014	52	45	4	52	86.5	2.25	2.6	1.81	2.41	7	9	0.8	42
	2015	54	30	3	50	60.0	1.12	1.87	1.12	1.87	7	8	0.75	0
	2016	54	50	4	54	92.6	2.63	2.84	2.41	2.83	8	9	0.83	22
	2017	55	37	3	48	77.1	1.54	2.00	1.31	1.80	6	6	0.79	23
	2018	56	35	3	53	66.0	1.11	1.69	1.04	1.72	7	7	0.72	6
	2019	51	10	3	49	20.4	0.27	1.30	0.22	1.22	3	4	0.62	0
Swallow	2014	70	43	4	64	67.2	1.36	2.02	0.83	1.56	7	7	0.69	52
	2015	71	37	5	71	52.1	0.72	1.38	0.69	1.32	8	10	0.66	1
	2016	72	44	4	65	67.7	1.23	1.82	1.09	1.65	7	7	0.70	9
	2017	72	40	4	66	60.6	1.30	2.15	0.98	1.76	8	8	0.78	29
	2018	72	29	4	58	50.0	0.71	1.41	0.71	1.41	5	7	0.56	0
	2019	71	23	4	62	37.1	0.37	1.00	0.37	1.00	1	3	0	0
Cardinal	2015	67	33	7	46	71.7	1.15	1.61	0.85	1.39	7	8	0.74	30
	2016	65	39	6	45	86.7	1.73	2.00	1.42	1.83	9	11	0.83	31
	2017	66	35	7	46	76.1	1.61	2.11	1.11	1.65	8	9	0.76	50
	2018	61	39	11	60	65.0	1.10	1.69	0.90	1.54	10	11	0.75	20
	2019	59	29	9	53	54.72	0.70	1.28	0.55	1.16	5	7	0.71	15
Chickadee (Both Arms)	2015	119	14	4.5	32	43.8	0.78	1.79	0.44	1.56	6	7	0.69	34
	2019	120	13	5	50	26.0	0.32	1.23	0.12	1.00	4	6	0.61	18
Oriole	2015	68	26	9	48	54.17	0.90	1.65	0.63	1.36	5	5	0.70	27
	2016	62	28	7	44	63.6	0.91	1.43	0.77	1.26	6	6	0.69	14
	2017	56	22	9.5	46	47.8	0.76	1.59	0.52	1.09	5	6	0.57	24
	2018	56	13	6	32	40.6	0.56	1.38	0.50	1.23	5	6	0.62	6
	2019	60	8	5	27	29.6	0.37	1.25	0.33	1.13	4	5	0.48	4
Eagle	2014	105	16	6.5	55	29.1	0.56	1.94	0.38	1.40	7	7	0.76	15
	2017	100	14	5	40	35.0	0.58	1.64	0.28	1.10	4	7	0.57	30
	2018	98	15	5	42	35.7	0.50	1.40	0.45	1.46	6	8	0.79	5
	2019	94	12	5	36	33.3	0.39	1.17	0.25	1.13	5	7	0.76	14
Hummingbird	2016	59	34	6	59	57.6	0.93	1.62	0.58	1.21	7	9	0.66	36
	2017	63	32	6	63	50.8	0.81	1.59	0.52	1.27	7	8	0.65	29
	2018	60	31	5.5	56	55.4	1.00	1.81	0.75	1.56	8	9	0.78	25
	2019	55	19	5	51	37.3	0.47	1.26	0.24	1.00	4	5	0.60	24
Woodpecker	2016	83	22	4.5	77	28.6	0.77	2.68	0.68	2.36	7	8	0.82	9
	2017	85	15	4	70	21.4	0.39	1.80	0.29	1.43	4	4	0.68	10
	2018	84	14	3.5	45	31.1	0.62	2.00	0.58	1.86	5	7	0.71	4
	2019	86	10	4	79	12.7	0.14	1.10	0.13	1.11	3	6	0.31	1
Arapaho*	2015	55	17	4	21	81.0	0.95	1.18	0.57	1.20	6	6	0.73	33
	2019	54	13	8	45	28.9	0.49	1.69	0.22	1.43	6	6	0.68	24
Killdeer	2017	62	5	3	10	50.0	1.00	2.00	0.60	2.00	4	4	0.72	40
	2019	61	4	4.5	32	12.5	0.16	1.25	0.16	1.25	2	2	0.48	0
Quail	2017	75	23	8.5	67	34.3	0.64	1.87	0.42	1.27	5	6	0.67	22
	2019	73	13	5	33	39.4	0.67	1.69	0.42	1.17	6	7	0.74	21
County F	2019	69	4	3.5	12	33.3	0.50	1.50	0.42	1.25	4	5	0.67	0

** Arapaho Bay was also surveyed in 2015, but was labeled "Tanager Bay"*

Table 4 – Floristic Quality Results for All Bays 2014-2019

Bay & Year		Coontail, *Ceratophyllum demersum*	Slender waterweed, *Elodea nuttallii*	Water stargrass, *Heteranthera dubia*	Small duckweed, *Lemna minor*	Slender naiad, *Najas flexilis*	White water lily, *Nymphaea odorata*	Long-leaf pondweed, *Potamogeton nodosus*	Small pondweed, *Potamogeton pusillus*	Large duckweed, *Spirodela polyrhiza*	Sago pondweed, *Stuckenia pectinata*	Wild celery, *Vallisneria americana*	N (native species only)	Mean C	FQI
Martin-Meadowlark	2014	X	X	-	X	-	X	-	-	X	-	-	5	5.0	11.5
	2015	X	X	-	X	-	X	X	-	X	X	-	7	5.0	13.2
	2016	X	X	-	X	-	X	X	X	X	-	-	7	5.6	14.7
	2017	X	X	-	X	-	X	-	X	-	-	-	5	5.4	12.1
	2018	X	X	-	X	-	X	-	-	X	-	-	5	5	11.2
	2019	-	-	-	X	-	X	-	-	-	-	-	2	5	7.1
Swallow	2014	X	-	-	X	-	X	-	-	X	X	-	5	4.2	9.4
	2015	X	X	-	X	-	X	-	X	X	-	-	6	5.3	13.1
	2016	X	X	-	X	-	X	-	-	X	-	-	5	5.0	11.2
	2017	X	X	-	X	-	X	-	X	X	-	-	6	5.3	13.1
	2018	X	X	-	X	-	X	-	-	X	-	-	5	5	11.2
	2019	-	-	-	-	-	X	-	-	-	-	-	1	6	6
Cardinal	2015	X	X	-	X	-	-	-	X	-	X	X	6	5.0	12.2
	2016	X	X	X	X	-	-	-	X	X	X	X	8	5.1	14.5
	2017	X	X	X	-	X	X	-	X	-	-	X	7	5.4	14.4
	2018	X	X	X	X	X	-	-	X	X	X	X	9	5.2	15.7
	2019	X	-	-	-	-	-	-	X	-	X	X	4	4.8	9.5
Chickadee (Both Arms)	2015	X	X	-	-	-	X	-	X	-	X	-	5	5.2	11.6
	2019	X	-	-	-	-	X	-	-	-	-	-	2	4.5	6.4
Oriole	2015	X	X	-	-	-	-	-	X	-	X	-	4	5.0	10.0
	2016	X	X	-	-	-	X	-	X	-	X	-	5	5.2	11.6
	2017	X	X	-	-	-	X	-	X	-	-	-	4	5.8	11.5
	2018	X	X	-	-	-	-	-	X	-	X	-	4	5.0	10.1
	2019	X	-	-	-	-	X	-	-	-	X	-	3	4	6.9
Eagle	2014	X	X	-	-	-	X	-	X	-	X	-	5	5.2	11.6
	2017	X	-	-	X	-	-	-	X	-	-	-	3	4.7	8.1
	2018	X	X	-	-	-	X	-	X	-	X	-	5	5.2	11.6
	2019	X	-	-	-	-	X	-	X	-	-	X	4	5.5	11
Hummingbird	2016	X	X	-	-	-	X	-	X	-	X	X	6	5.3	13.1
	2017	X	X	-	-	-	X	-	X	-	X	X	6	5.3	13.1
	2018	X	X	-	-	-	X	X	X	-	X	X	7	5.6	14.7
	2019	X	-	-	-	-	X	-	-	-	-	X	3	5	8.7
Woodpecker	2016	X	X	-	X	-	X	X	-	X	-	-	6	5.3	13.1
	2017	X	-	-	X	-	X	-	-	-	-	-	3	4.3	7.5
	2018	X	X	-	X	-	X	-	-	-	-	-	4	5	10
	2019	-	-	-	X	-	X	-	-	-	-	-	2	5	7.1
Arapaho*	2015	X	-	-	-	-	X	-	X	-	X	-	4	4.8	9.5
	2019	X	-	-	-	-	X	-	X	-	X	-	4	4.8	9.5
Killdeer	2017	X	-	-	X	-	X	-	-	-	-	-	3	4.3	7.5
	2019	-	-	-	X	-	X	-	-	-	-	-	2	5	7.1
Quail	2017	X	-	-	-	-	-	-	X	-	X	X	4	4.8	9.5
	2019	X	-	-	-	-	X	-	X	-	X	-	4	4.8	9.5
County F	2019	-	-	-	X	-	X	-	-	-	X	-	3	4.3	7.5

*This table includes only those species that were found on the rake at survey points and those that are listed in Nichols (1999). X=present. Herbicide treatment occurred during years listed in red text. * Arapaho Bay was also surveyed in 2015, but was labeled "Tanager Bay"*

Table 5 – Plant Species Results for Arapaho, Cardinal, Chickadee, County F, Eagle, & Hummingbird Bays, 2019

Bay Name	Common Name	Scientific Name	Frequency of Occurrence at Vegetated Sites	Littoral Frequency	Relative Frequency	# Sites	Average Rake Fullness	# Visual
Arapaho*	Eurasian water milfoil	*Myriophyllum spicatum*	84.62	24.44	50.00	11	1.09	6
	Coontail	*Ceratophyllum demersum*	38.46	11.11	22.73	5	1.00	1
	White water lily	*Nymphaea odorata*	15.38	4.44	9.09	2	1.00	5
	Small pondweed	*Potamogeton pusillus*	15.38	4.44	9.09	2	1.00	2
	Curly-leaf pondweed	*Potamogeton crispus*	7.69	2.22	4.55	1	1.00	0
	Sago pondweed	*Stuckenia pectinata*	7.69	2.22	4.55	1	2.00	0
Cardinal	Coontail	*Ceratophyllum demersum*	58.62	32.08	45.95	17	1.12	1
	Eurasian water milfoil	*Myriophyllum spicatum*	27.59	15.09	21.62	8	1.13	24
	Filamentous algae		20.69	11.32	-	6	1.00	0
	Small pondweed	*Potamogeton pusillus*	17.24	9.43	13.51	5	1.00	1
	Wild celery	*Vallisneria americana*	13.79	7.55	10.81	4	1.00	4
	Sago pondweed	*Stuckenia pectinata*	10.34	5.66	8.11	3	1.00	0
	Slender waterweed	*Elodea nuttallii*	0.00	0.00	0.00	0	0.00	1
	White water lily	*Nymphaea odorata*	0.00	0.00	0.00	0	0.00	2
Chickadee	Eurasian water milfoil	*Myriophyllum spicatum*	69.23	18.00	56.25	9	1.33	6
	Coontail	*Ceratophyllum demersum*	23.08	6.00	18.75	3	1.00	0
	White water lily	*Nymphaea odorata*	23.08	6.00	18.75	3	2.00	2
	Curly-leaf pondweed	*Potamogeton crispus*	7.69	2.00	6.25	1	2.00	0
	Small pondweed	*Potamogeton pusillus*	0.00	0.00	0.00	0	0.00	1
	Wild celery	*Vallisneria americana*	0.00	0.00	0.00	0	0.00	1
County F	White water lily	*Nymphaea odorata*	75.00	25.00	50.00	3	1.33	3
	Curly-leaf pondweed	*Potamogeton crispus*	25.00	8.33	16.67	1	1.00	0
	Small duckweed	*Lemna minor*	25.00	8.33	16.67	1	1.00	2
	Sago pondweed	*Stuckenia pectinata*	25.00	8.33	16.67	1	1.00	0
	Filamentous algae		25.00	8.33		1	1.00	4
	Arrowhead	*Sagittaria sp.*	0.00	0.00	0.00	0	0.00	1
Eagle	Eurasian water milfoil	*Myriophyllum spicatum*	41.67	13.89	35.71	5	1.00	7
	White water lily	*Nymphaea odorata*	25.00	8.33	21.43	3	1.33	5
	Wild celery	*Vallisneria americana*	25.00	8.33	21.43	3	1.33	0
	Small pondweed	*Potamogeton pusillus*	16.67	5.56	14.29	2	1.00	3
	Coontail	*Ceratophyllum demersum*	8.33	2.78	7.14	1	1.00	0
	Curly-leaf pondweed	*Potamogeton crispus*	0.00	0.00	0.00	0	0.00	2
	Sago pondweed	*Stuckenia pectinata*	0.00	0.00	0.00	0	0.00	1
Hummingbird	Eurasian water milfoil	*Myriophyllum spicatum*	63.16	23.53	50.00	12	1.08	15
	Coontail	*Ceratophyllum demersum*	47.37	17.65	37.50	9	1.33	0
	Wild celery	*Vallisneria americana*	10.53	3.92	8.33	2	1.00	1
	White water lily	*Nymphaea odorata*	5.26	1.96	4.17	1	1.00	7
	Filamentous algae		5.26	1.96	-	1	1.00	1
	Small pondweed	*Potamogeton pusillus*	0.00	0.00	0.00	0	0.00	4

** Arapaho Bay was also surveyed in 2015, but was labeled “Tanager Bay”*

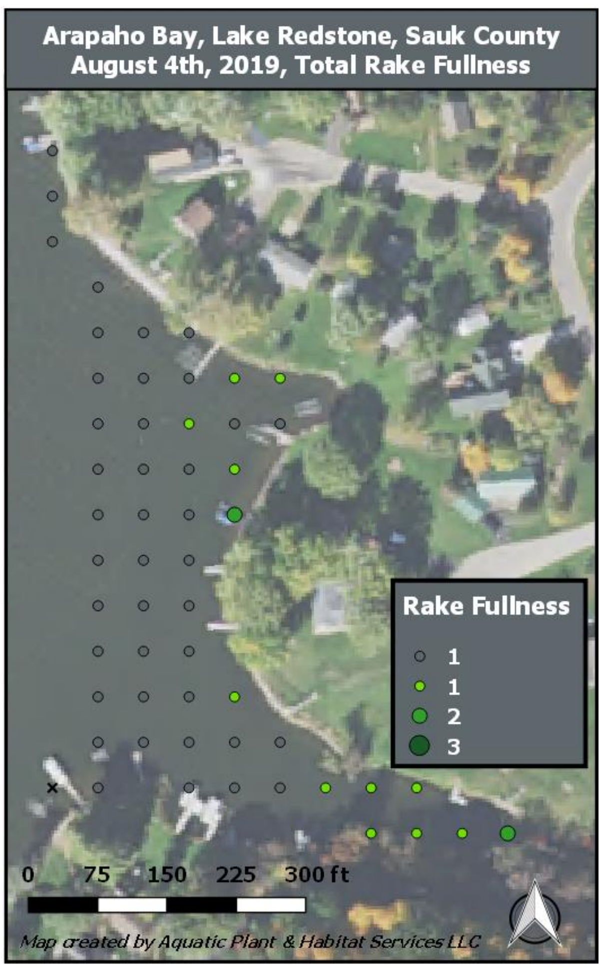
Table 6 – Plant Species Results for Killdeer, Martin-Meadowlark, Oriole, Quail, Swallow, & Woodpecker Bays, 2019

Bay Name	Common Name	Scientific Name	Frequency of Occurrence at Vegetated Sites	Littoral Frequency	Relative Frequency	# Sites	Average Rake Fullness	# Visual
Kill deer	White water lily	*Nymphaea odorata*	75.00	9.38	60.00	3	1.00	8
	Small duckweed	*Lemna minor*	50.00	6.25	40.00	2	1.00	7
Martin Meadow	White water lily	*Nymphaea odorata*	60.00	12.24	46.15	6	1.17	10
	Small duckweed	*Lemna minor*	50.00	10.20	38.46	5	1.00	9
	Filamentous algae		30.00	6.12	-	3	1.00	6
	Curly-leaf pondweed	*Potamogeton crispus*	20.00	4.08	15.38	2	1.00	1
	Eurasian water milfoil	*Myriophyllum spicatum*	0.00	0.00	0.00	0	0.00	3
Oriole	Coontail	*Ceratophyllum demersum*	87.50	25.93	70.00	7	1.29	2
	Filamentous algae		37.50	11.11	-	3	1.00	0
	Eurasian water milfoil	*Myriophyllum spicatum*	12.50	3.70	10.00	1	1.00	6
	White water lily	*Nymphaea odorata*	12.50	3.70	10.00	1	3.00	0
	Sago pondweed	*Stuckenia pectinata*	12.50	3.70	10.00	1	1.00	0
	Curly-leaf pondweed	*Potamogeton crispus*	0.00	0.00	0.00	0	0.00	2
Quail	Coontail	*Ceratophyllum demersum*	61.54	24.24	36.36	8	1.00	0
	Eurasian water milfoil	*Myriophyllum spicatum*	53.85	21.21	31.82	7	1.29	11
	Sago pondweed	*Stuckenia pectinata*	23.08	9.09	13.64	3	1.00	1
	Small pondweed	*Potamogeton pusillus*	15.38	6.06	9.09	2	1.00	0
	Curly-leaf pondweed	*Potamogeton crispus*	7.69	3.03	4.55	1	1.00	2
	White water lily	*Nymphaea odorata*	7.69	3.03	4.55	1	1.00	4
	Wild celery	*Vallisneria americana*	0.00	0.00	0.00	0	0.00	3
Swallow	White water lily	*Nymphaea odorata*	100.00	37.10	100.00	23	1.65	21
	Filamentous algae		13.04	4.84	-	3	1.00	3
	Eurasian water milfoil	*Myriophyllum spicatum*	0.00	0.00	0.00	0	0.00	2
	Curly-leaf pondweed	*Potamogeton crispus*	0.00	0.00	0.00	0	0.00	2
Woodpecker	White water lily	*Nymphaea odorata*	90.00	11.39	81.82	9	1.78	14
	Filamentous algae		20.00	2.53	-	2	1.00	1
	Eurasian water milfoil	*Myriophyllum spicatum*	10.00	1.27	9.09	1	2.00	5
	Small duckweed	*Lemna minor*	10.00	1.27	9.09	1	1.00	6
	Curly-leaf pondweed	*Potamogeton crispus*	0.00	0.00	0.00	0	0.00	2
	Arrowhead	*Sagittaria sp.*	0.00	0.00	0.00	0	0.00	2
	Sago pondweed	*Stuckenia pectinata*	0.00	0.00	0.00	0	0.00	1

Arapaho Bay

This was the second survey of Arapaho Bay, the first taking place in 2015 using the name "Tanager Bay." A total of 54 points were sampled and the maximum rooting depth was 8 feet at only one sample point, at which EWM was the only species found. The next-deepest maximum rooting depth in the bay was 5 feet. Forty-five sample points were ≤8 feet deep and only 13 of those sites had vegetation. A total of 6 species were found including EWM (maps in Appendix A). Same as the last plant survey in 2015, Eurasian watermilfoil and coontail were the most common species found at 24% and 11% of littoral survey points respectively (both species found at 33% in 2015). Together they accounted for 73% of the total relative frequency, indicating the plant community is homogeneous as was the case in 2015 when those species accounted for 70% of the total relative frequency (Table 5). The Simpson Diversity Index was 0.68 on a scale from 0 to 1. The FQI only factors species raked at survey points and does not include invasive species. Therefore, 4 species were counted yielding a floristic quality of 9.5 and an average C value of 4.8 (Table 4). Chi-squared tests revealed no statistically significant (SS) changes in the aquatic plant community when comparing 2015 to 2019.

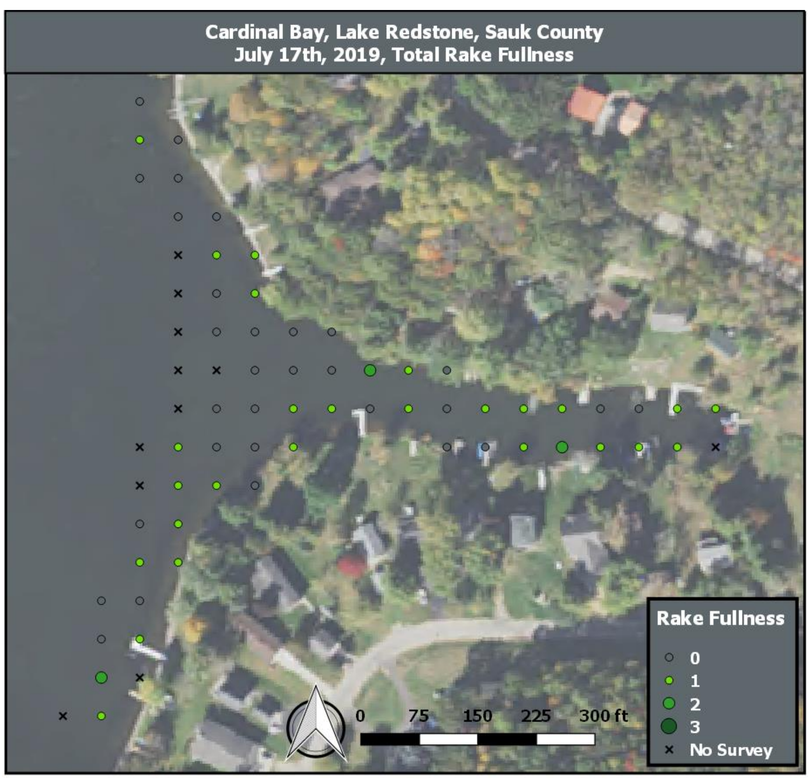
Figure 3 – Arapaho Bay Total Rake Fullness Map



Cardinal Bay

This was the fifth consecutive aquatic plant survey of Cardinal Bay (2015-2019). A total of 71 survey waypoints were attempted in Cardinal Bay, 59 of which were surveyed because 8 points were too deep (>12 feet) and 4 were obstructed by docks. The maximum rooting depth was 9 feet at one sample point. The next-deepest maximum rooting depth in the bay was 6 feet. Fifty-three survey points were ≤9 feet and 29 of those sites had vegetation (Table 3). A total of 7 species were found including EWM and two species were “visual only” (maps in Appendix B). Filamentous algae is not counted as one of the 7 species. Same as 2017 and 2018, coontail and Eurasian watermilfoil were the most common species found at 32% and 15% of littoral survey points respectively (48% and 20% in 2018). Together they accounted for 68% of the total relative frequency, indicating the plant community remains homogeneous with similar total relative frequency values in 2017 and 2018 (Table 5). The Simpson Diversity Index for Cardinal Bay was 0.69 on a scale from 0 to 1. The FQI only factors species raked at survey points and does not include invasive species. Therefore, 4 species were counted producing a much lower floristic quality of 9.5 when compared to 15.7 in 2018. Chi-squared tests revealed a statistically significant (SS) decrease in slender naiad and coontail when comparing 2018 to 2019, and SS decrease in filamentous algae and slender waterweed when comparing 2015 to 2019 (Appendix M).

Figure 4 – Cardinal Bay Total Rake Fullness Map



Chickadee Bay

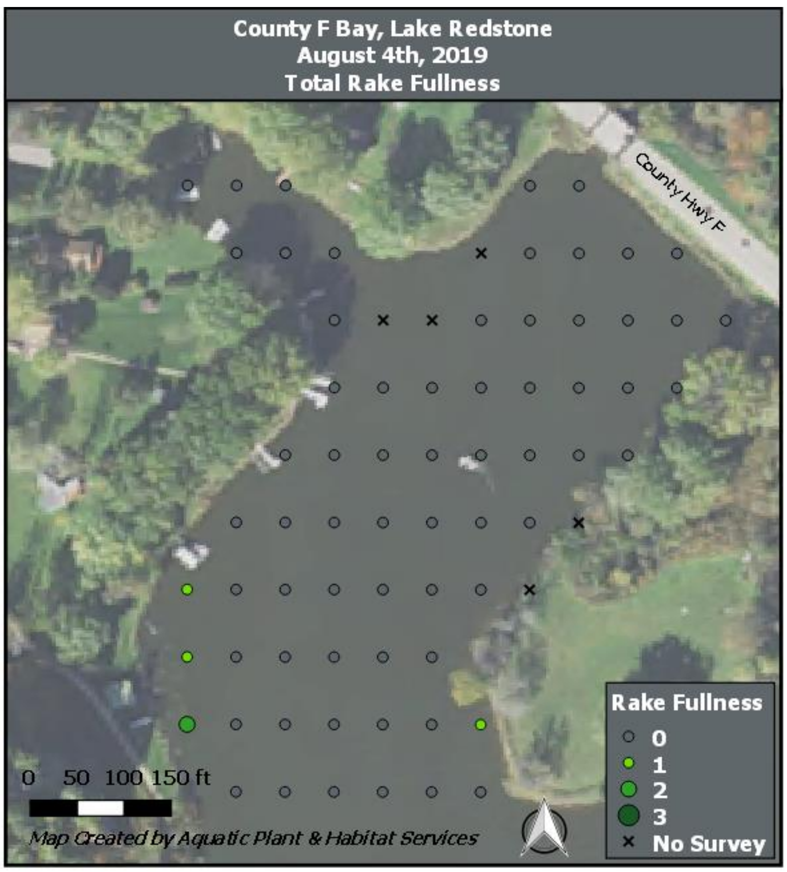
This was the second survey of Chickadee, the first of which occurred in 2015. The south arm of Chickadee Bay was also surveyed 2016 through 2018. Only results from the 2015 and 2019 surveys are listed here. There were 120 points surveyed in Chickadee Bay 50 of which were the same depth or shallower than the maximum rooting depth of 5 feet. Only 13 sites had vegetation present (Table 3). A total of 6 species were found, two of which were "visual only" (maps in Appendix C). EWM and coontail were the most common species found at only 18% and 6% of littoral survey points respectively. Together they accounted for 75% of the total relative frequency, indicating a homogeneous, albeit sparse, plant community in the bay (Table 5). Chi-squared tests of all plant species revealed there were no SS changes between the 2015 and 2019 surveys of the bay. The Simpson Diversity Index for South Chickadee Bay was low at 0.61 on a scale of 0 to 1. The FQI only factors species raked at survey points and does not include visuals or aquatic invasive species. Therefore, only 2 species were included in the calculation, resulting in a floristic quality of 6.4 and average C value of 4.5 (Table 4).

Figure 5 – Chickadee Bay Total Rake Fullness Map

County F

This was the first survey of the bay near County Highway F. There were 73 sample points attempted, 69 of which were actually surveyed because 2 sites were terrestrial and 2 sites were not accessible due to anchored boats and swimmers. The maximum rooting depth was 3.5 feet and only 12 sample points were 3.5 feet deep or shallower. Only 4 sites had vegetation present (Table 3). A total of 5 species were found, including curly-leaf pondweed and one of which was visual only (maps in Appendix D). White water lily was the most common species found at 25% of littoral survey points and accounted for 50% of the total relative frequency, indicating a homogeneous plant community in the bay (Table 5). The Simpson Diversity Index was 0.67 on a scale of 0 to 1. The FQI only factors species raked at survey points and does not include visuals or aquatic invasive species. Therefore, 3 species were included in the calculation, resulting in a floristic quality of 7.5 and average C value of 4.3 (Table 4).

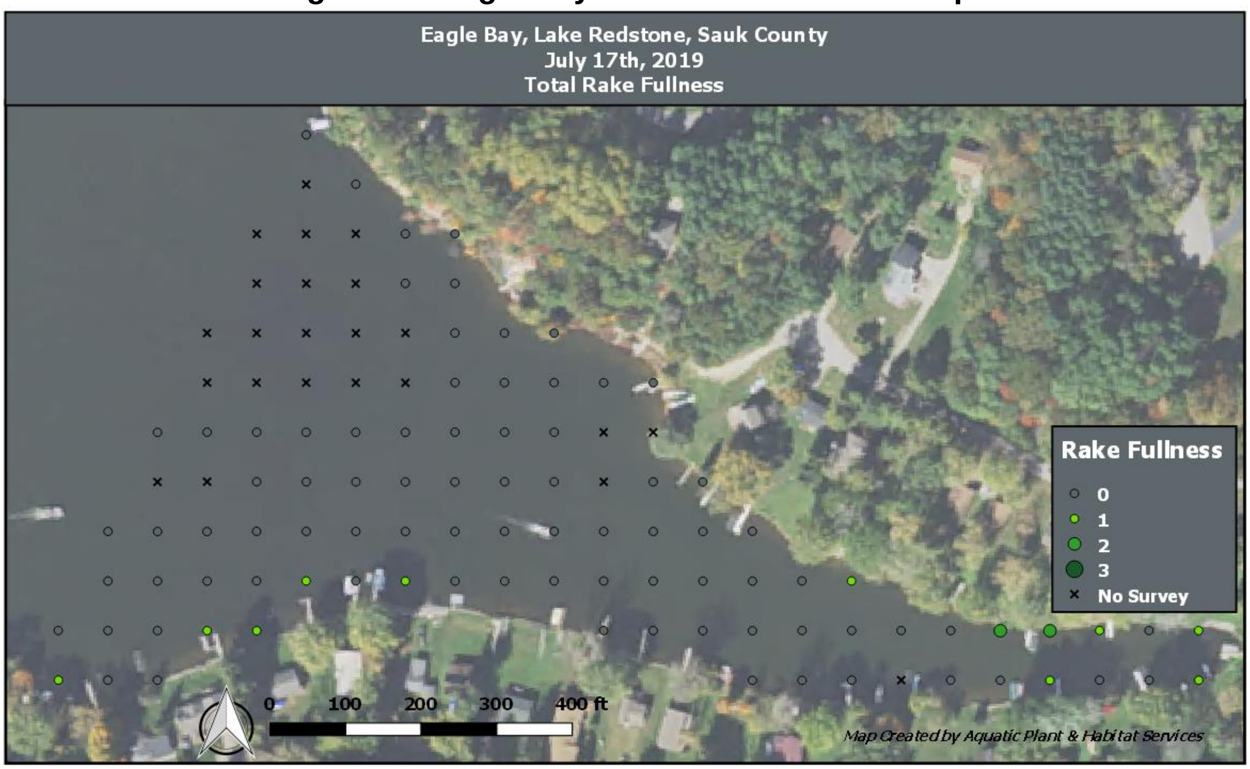
Figure 6 – County F Bay Total Rake Fullness Map



Eagle Bay

This was the fourth survey of Eagle Bay (2014 & 2017-2019). In Eagle Bay, 94 points were surveyed and 36 points were the same depth or shallower than the maximum rooting depth of 5 feet. Twelve of those sites had vegetation (Table 3). A total of 7 species of aquatic plants were found, two of which were "visual only" (maps in Appendix E). Eurasian watermilfoil and white water lily were the most common species found at low littoral frequency of 14% and 8%, respectively. Together they accounted for 57% of the total relative frequency, suggesting the plant community is homogeneous (Table 5). The Simpson Diversity Index was 0.76 on a scale from 0 to 1. The FQI only factors species raked at survey points and does not include visuals or aquatic invasive species. Therefore, 4 species were included in the calculation, yielding a floristic quality of 11 with an average C value of 5.5 (Table 4). Chi-squared tests revealed a statistically significant decrease in coontail when comparing 2014 data to 2019 and when comparing 2018 to 2019 (Appendix M).

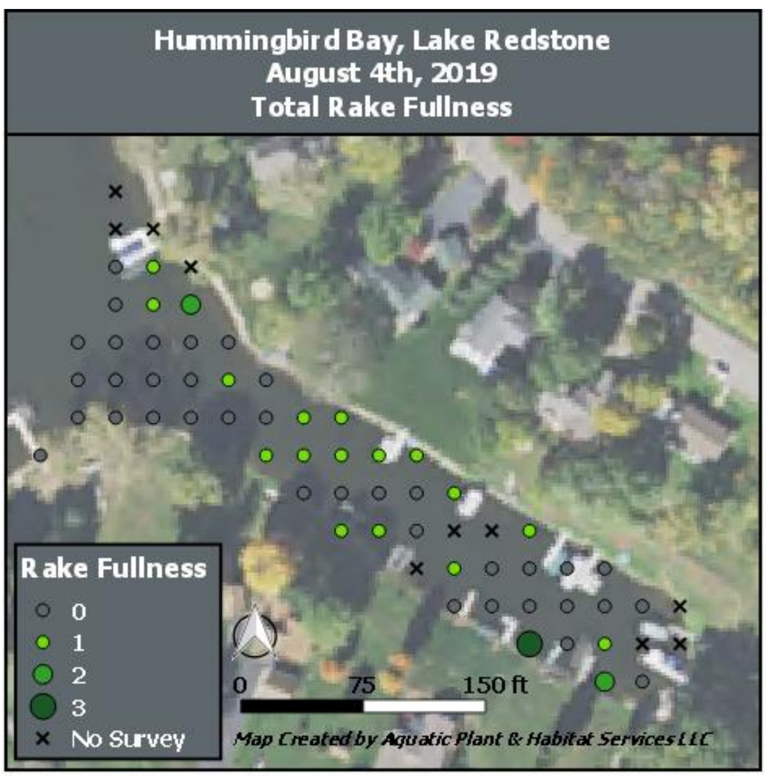
Figure 7 – Eagle Bay Total Rake Fullness Map



Hummingbird Bay

This was the fourth consecutive survey of Hummingbird Bay (2016-2019). Fifty-five points were surveyed out of a possible 65 because 6 points were obstructed by piers, one point was terrestrial, and 3 points were not accessible due to swimmers. There were 51 points the same depth or shallower than the maximum rooting depth of 5 feet and 19 of those sites surveyed had vegetation (Table 3). A total of 5 species of aquatic plants were found, one of which was "visual only" (maps in Appendix F). Filamentous algae is not counted as one of the 5 species. Eurasian watermilfoil and coontail were the most common species found at 24% and 18% of littoral survey points respectively (25% and 34% in 2018). Together they accounted for 88% of the total relative frequency (59% in 2018), indicating a much more homogeneous plant community in 2019 (Table 5). The Simpson Diversity Index was 0.60 (0.78 in 2018) on a scale from 0 to 1. The FQI only factors species raked at survey points and does not include visuals or aquatic invasive species. Therefore, 3 species were included in the calculation, yielding a floristic quality of 8.7 with an average C value of 5 (Table 4). Chi-squared tests revealed a statistically significant decrease in small pondweed, slender waterweed, and sago pondweed in 2019 when compared to data from 2018. There was also a statistically significant decrease in coontail when comparing data from 2016 and 2019 (Appendix M).

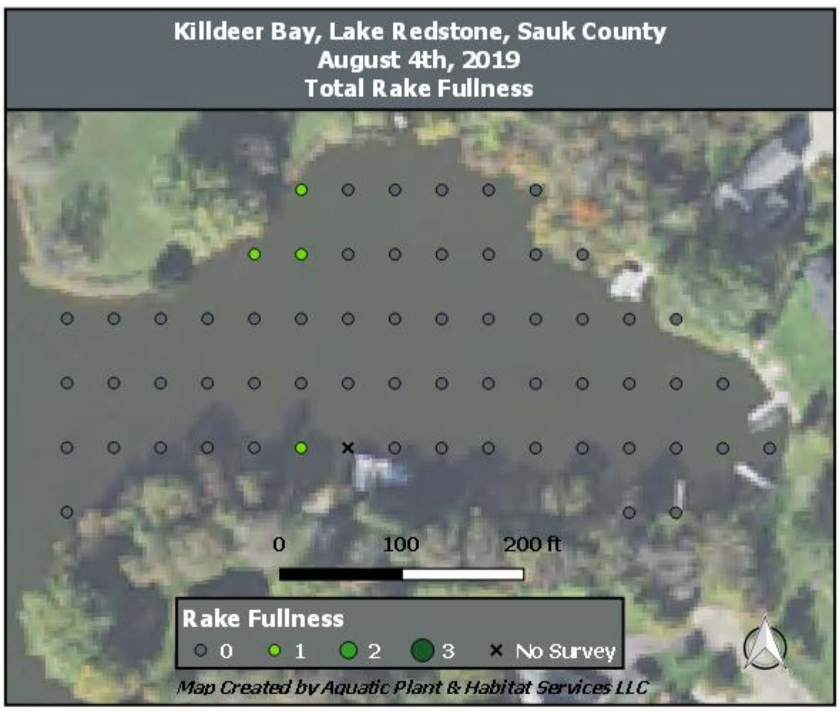
Figure 8 – Hummingbird Bay Total Rake Fullness Map



Killdeer Bay

This was the second survey of Killdeer Bay (2017 & 2019). Sixty-one points were surveyed out of a possible 62 because 1 point was obstructed by piers. There were 32 points the same depth or shallower than the maximum rooting depth of 4.5 feet and only 4 of those sites surveyed had vegetation (Table 3). A total of 2 species of aquatic plants were found, including white water lily and small duckweed (maps in Appendix G). The Simpson Diversity Index was 0.48 on a scale from 0 to 1. The floristic quality value was of 7.1 with an average C value of 5 (Table 4). Chi-squared tests revealed a statistically significant decrease in EWM in 2019 when compared to data from 2017 (Appendix M).

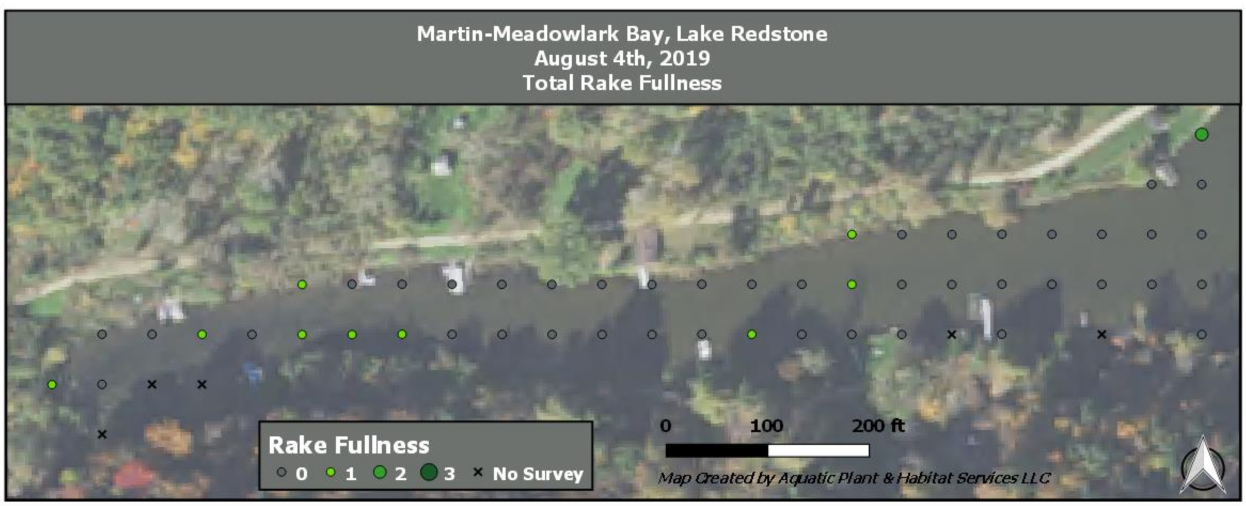
Figure 9 –Killdeer Bay Total Rake Fullness Map



Martin-Meadowlark Bay

This was the sixth consecutive survey of Martin-Meadowlark Bay (2014-2019). Fifty-one points were surveyed and 49 were the same depth or shallower than the maximum rooting depth of 3 feet. Ten of those sites surveyed had vegetation (Table 3). A total of 4 species of aquatic plants were found, one of which was visual only and not counting filamentous algae (Maps in Appendix H). White water lily and small duckweed were the most common species found at 12% and 10% of littoral survey points respectively (42% and 36% in 2017). Together they accounted for 85% of the total relative frequency, indicating a highly homogeneous plant community (Table 6). Chi-squared tests of all plant species revealed a statistically significant (SS) decrease in the occurrence of small duckweed, white water lily, and coontail when comparing 2014 and 2019 data AND when comparing 2018 and 2019 data. There was also a SS decrease in EWM, filamentous algae, and large duckweed in 2019 data when compared to 2014. The Simpson Diversity Index for Martin-Meadowlark Bay was 0.62 on a scale from 0 to 1. The FQI only factors species raked at survey points and does not include visuals or aquatic invasive species. Therefore, only 2 species were included in the calculation, yielding a floristic quality of 7.1 with an average C value of 5 (Table 4).

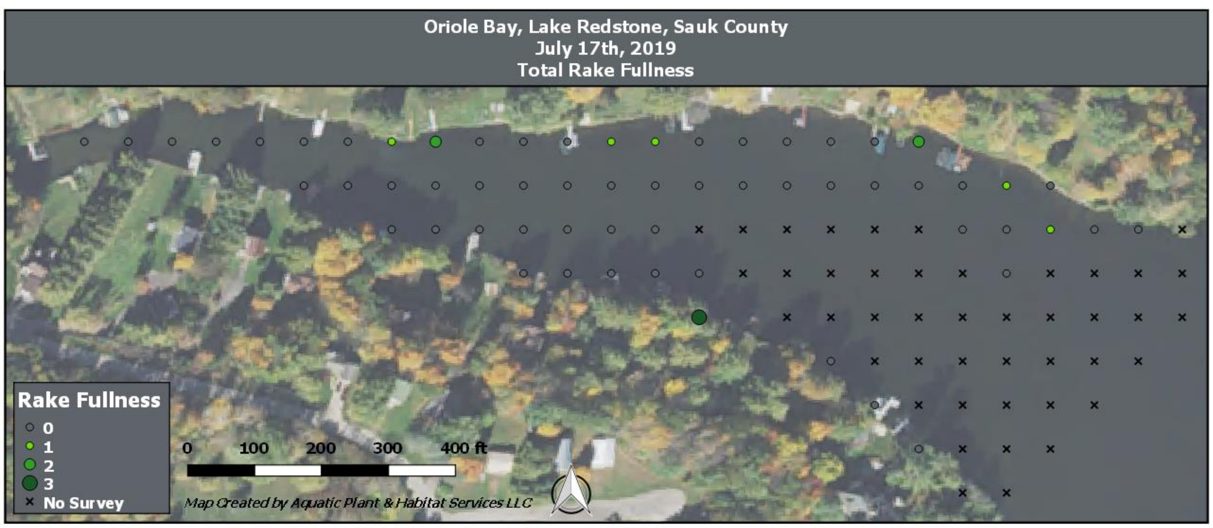
Figure 10 – Martin-Meadowlark Bay Total Rake Fullness Map



Oriole Bay

This was the fifth consecutive survey of Oriole Bay (2015-2019). A total of 104 predetermined survey waypoints exist in Oriole Bay but about half are consistently deeper than 12 feet. This year there were 60 points actually surveyed with a maximum rooting depth of 5 feet. There were 27 survey points ≤5 feet deep and 8 sites had vegetation. A total of 5 species of aquatic plants were found, one of which was "visual only" and not including filamentous algae. Maps of plant species can be found in Appendix I. Coontail was the most common species found at 26% of littoral survey points and accounted for 70% of the total relative frequency, indicating the plant community in Oriole Bay is highly homogeneous (Table 6). Chi-squared tests of all plant species revealed a statistically significant (SS) decrease in coontail, EWM, and slender waterweed when compared to 2015 data. There was also a SS decrease in small pondweed between the 2018 and 0219 data sets (Appendix M). The Simpson Diversity Index for Oriole Bay was 0.48 on a scale from 0 to 1. The FQI does not include aquatic invasive species. Therefore, 3 species were included in the calculation, yielding a floristic quality of 6.9 with an average C value of 4 (Table 4).

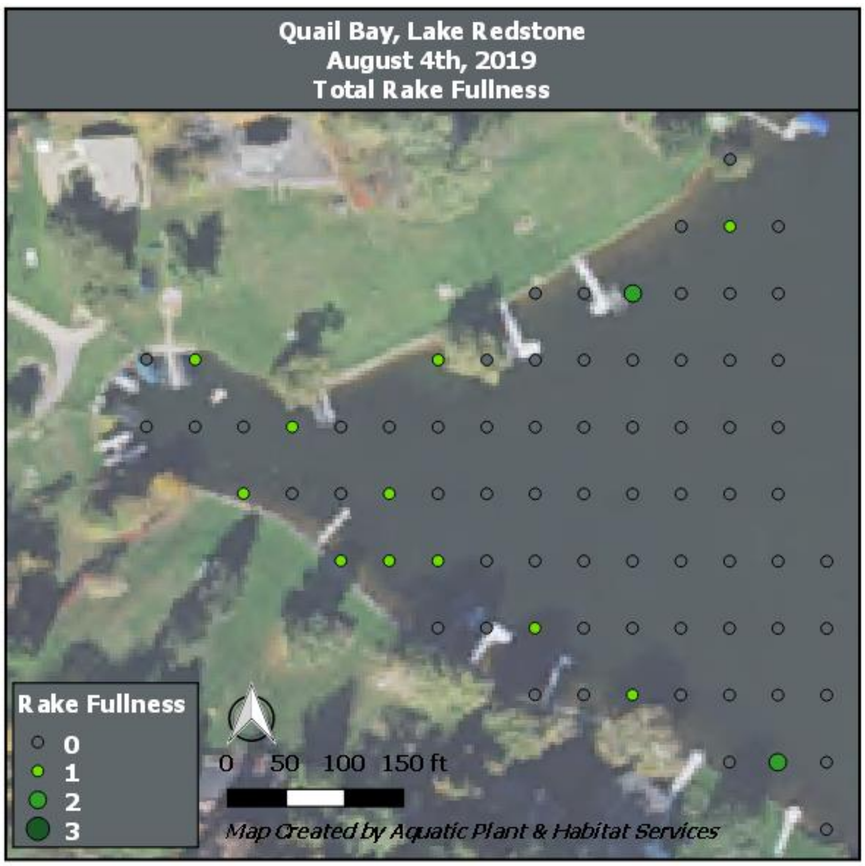
Figure 11 – Oriole Bay Total Rake Fullness Map



Quail Bay

This was the second plant survey of Quail Bay (2017 & 2019). There were 73 points surveyed, 33 of which were shallower than the maximum rooting depth of 5 feet and 13 sites had vegetation (Table 3). A total of 7 species of aquatic plants were found in Quail Bay, one of which was "visual only". Maps of plant species can be found in Appendix J. Coontail and EWM were the most common species found at 24% and 21% of littoral survey points respectively. Together they accounted for 68% of the total relative frequency indicating the plant community of Quail Bay is homogeneous (Table 6). Chi-squared tests of all plant species revealed a statistically significant (SS) decrease in coontail and wild celery when compared to 2017 (Appendix M). The Simpson Diversity Index was 0.74 on a scale from 0 to 1. The FQI only factors species raked at survey points and does not include aquatic invasive species. Therefore, 4 species were included in the calculation, yielding a floristic quality of 9.5 with an average C value of 4.8 (Table 4).

Figure 12 – Quail Bay Total Rake Fullness Map



Swallow Bay

In Swallow Bay all 71 points were surveyed, 62 were shallower than the maximum rooting depth of 4 feet. There were 23 sites with vegetation present, all of which were white water lily making Swallow Bay the most homogeneous bay surveyed in 2019 (Table 3). Two other plant species were documented as “visual” observations but not found on the sample rake. Maps of plant species can be found in Appendix K. Chi-squared tests of all plant species revealed a statistically significant (SS) decrease in small duckweed, coontail, and large duckweed when compared to 2018 data. Chi-squared test of the 2014 data compared to 2019 revealed a SS increase in white water lily and decrease in filamentous algae, coontail, EWM, and large duckweed (Appendix M). Since only one species was found on the rake, the Simpson Diversity Index for Swallow Bay was actually zero on a scale from 0 to 1. The FQI only factors species raked at survey points and does not include aquatic invasive species. Therefore, only 1 species (white water lily) was included in the calculation, yielding a floristic quality of 6 with an average C value of 6 (Table 4).

Figure 13 – Swallow Bay Total Rake Fullness Map

Woodpecker Bay

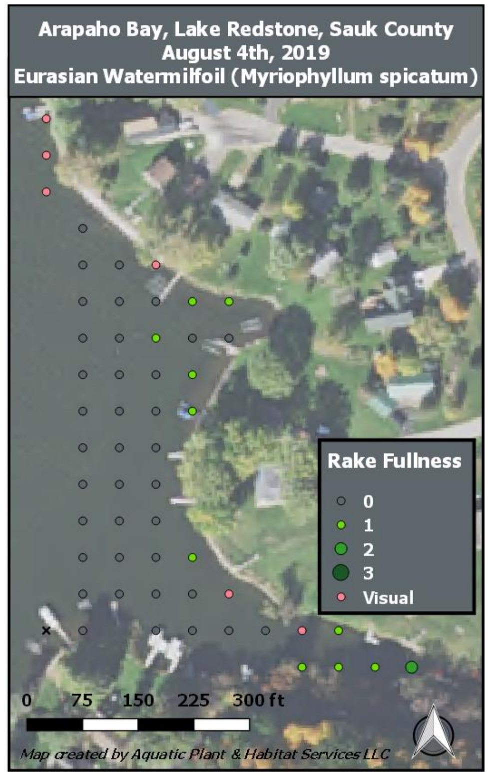
This was the fourth consecutive aquatic plant survey of Woodpecker Bay (2016-2019). A total of 86 survey waypoints were surveyed, 79 of which were shallower than the maximum rooting depth of 4 feet. Vegetation was present at 10 survey points (Table 3). A total of 6 species of aquatic plants were found, three of which were "visual only". Maps of plant species can be found in Appendix L. White water lily was the most common species found at 11% of littoral survey points and with a relative frequency of 82% indicates the plant community is highly homogeneous (Table 6). A chi-squared test comparing data from 2016 and 2019 revealed a statistically significant decrease in large duckweed, small duckweed, EWM, filamentous algae, and coontail (Appendix M). There was also a SS decrease in coontail and small duckweed between 2018 and 2019. The Simpson Diversity Index was very low at 0.31 on a scale from 0 to 1. The FQI does not include aquatic invasive species or visual observations. Therefore, 2 species were included in the calculation, yielding a floristic quality of 7.1 with an average C value of 5 (Table 4).

Figure 14 – Woodpecker Bay Total Rake Fullness Map

Eurasian Watermilfoil & Management History

Eurasian watermilfoil (EWM) was found in all bays except County F and Killdeer. It was the most common plant in four bays and second-most common plant in another four bays. Littoral frequency of EWM was lower in all bays except Eagle Bay when compared to 2018, although some of the decreases were not statistically significant. There was no herbicide treatment of any bays in spring 2019 because dredging was scheduled to commence in July. Each bay has its own management history and an assessment of EWM in each bay is included in this section. The timing of annual surveys should be taken into consideration when interpreting these results because they occurred in July, August, and September (see List 1).

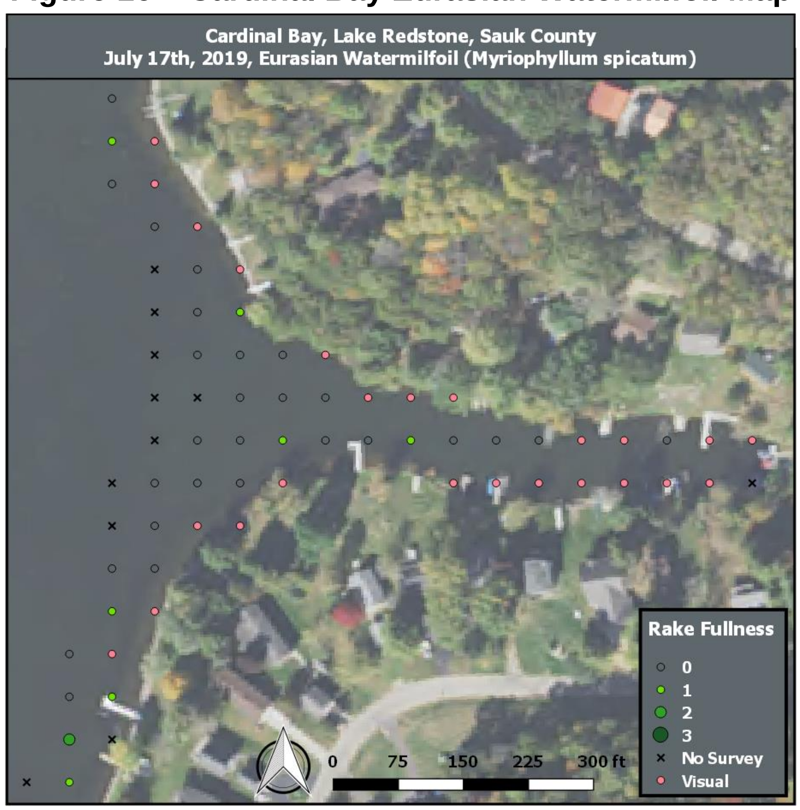
Figure 15 – Arapaho Bay Eurasian Watermilfoil Map



Arapaho Bay EWM

EWM was the most common plant with scattered distribution at 11 sample points and visual observation at another 6 points. EWM littoral frequency was 24% in 2019 and 33% in 2015. No herbicide treatment has occurred in Arapaho Bay. A chi-squared test of EWM revealed no significant change in EWM between 2015 and 2019.

Figure 16 – Cardinal Bay Eurasian Watermilfoil Map



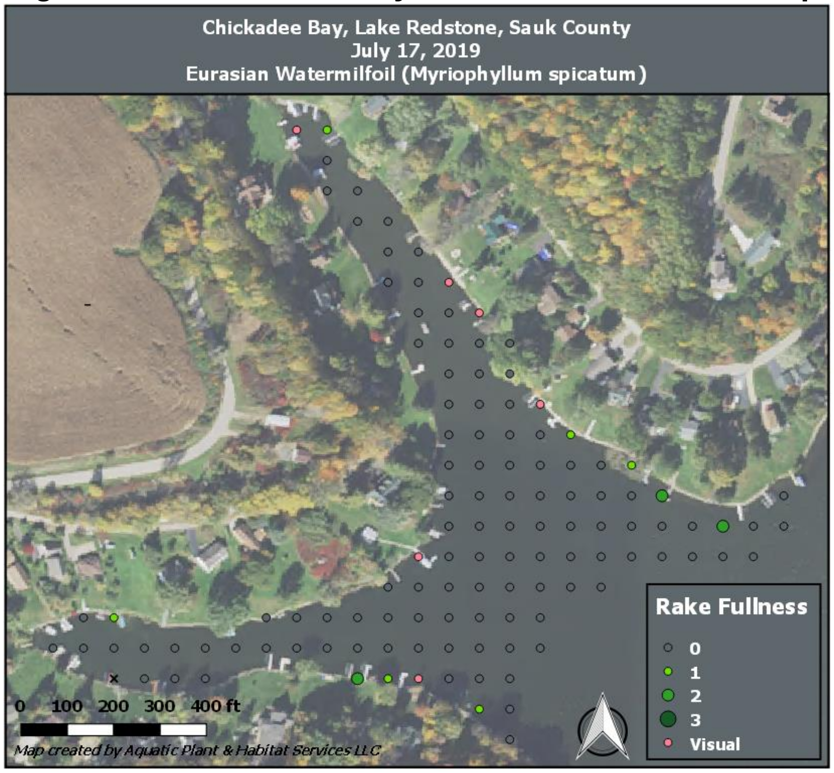
Cardinal Bay EWM

EWM was the second-most common plant with occurrence at 8 points and visual observation at another 24 points. EWM littoral frequency was 15% in 2019, 20% in 2018, 50% in 2017, 31% in 2016, and 30% in 2015. Herbicide was applied in Cardinal Bay in spring of 2016 and 2018. A chi-squared test of EWM revealed no significant change in EWM between 2015 and 2019 nor between 2018 and 2019.

Chickadee Bay EWM

EWM was the most common aquatic plant in 2019 and was found at 9 sites and 6 visual observations. EWM littoral frequency was 18% in 2019, 22% in 2018, 28% in 2017, 11% in 2016 and 55% in 2015. Herbicides were applied to the southern arm of Chickadee Bay in spring of 2016 to combat EWM. A chi-squared test of EWM revealed no significant change between the whole-bay survey in 2015 and 2019.

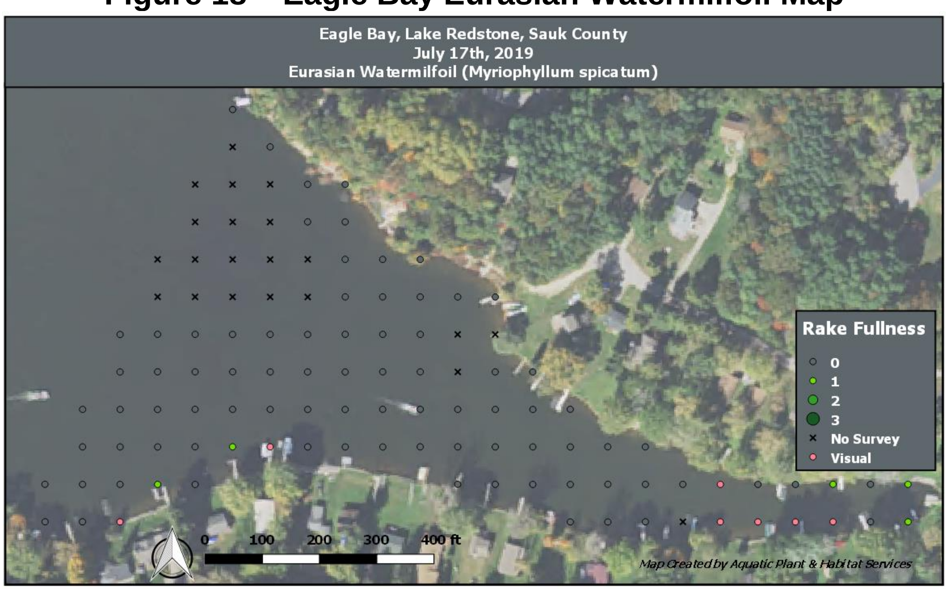
Figure 17 – Chickadee Bay Eurasian Watermilfoil Map



Eagle Bay EWM

EWM was the most common plant species found at 5 survey points and another 7 visual observations. Littoral frequency of EWM was 14% in 2019, 5% in 2018, 30% in 2017, and 15% in 2014. Herbicide treatment was done in spring 2018 to control EWM. Comparisons between 2018 and 2019 using chi-squared tests reveal no statistically significant different in EWM occurrence. The same is true when comparing 2014 data to 2019.

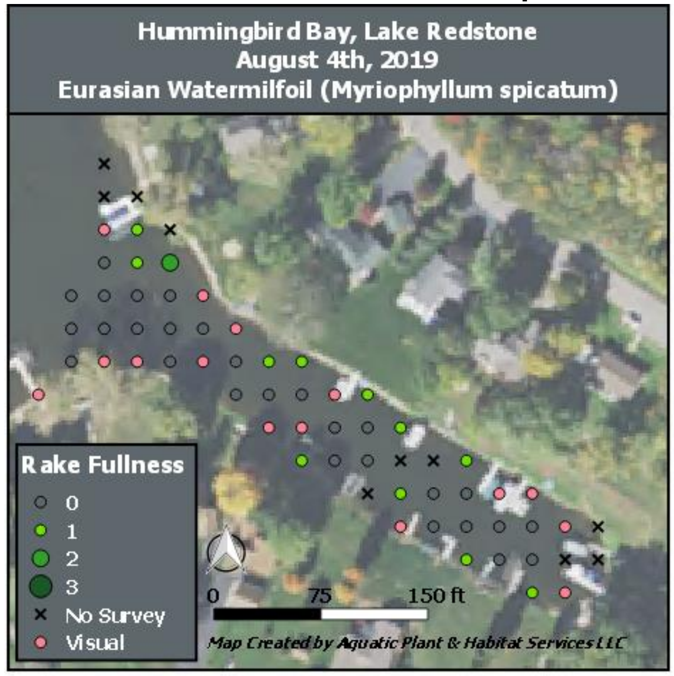
Figure 18 – Eagle Bay Eurasian Watermilfoil Map



Hummingbird Bay EWM

EWM was found at 12 survey points and another 15 visual observations, making it the most common plant species distributed throughout Hummingbird Bay. EWM littoral frequency was 24% in 2019, 25% in 2018, 29% in 2017 and 36% in 2016. Herbicide treatment was conducted in Hummingbird Bay in spring 2017. There was no statistically significant difference in EWM between 2018 and 2019 nor between data from 2016 compared to 2019.

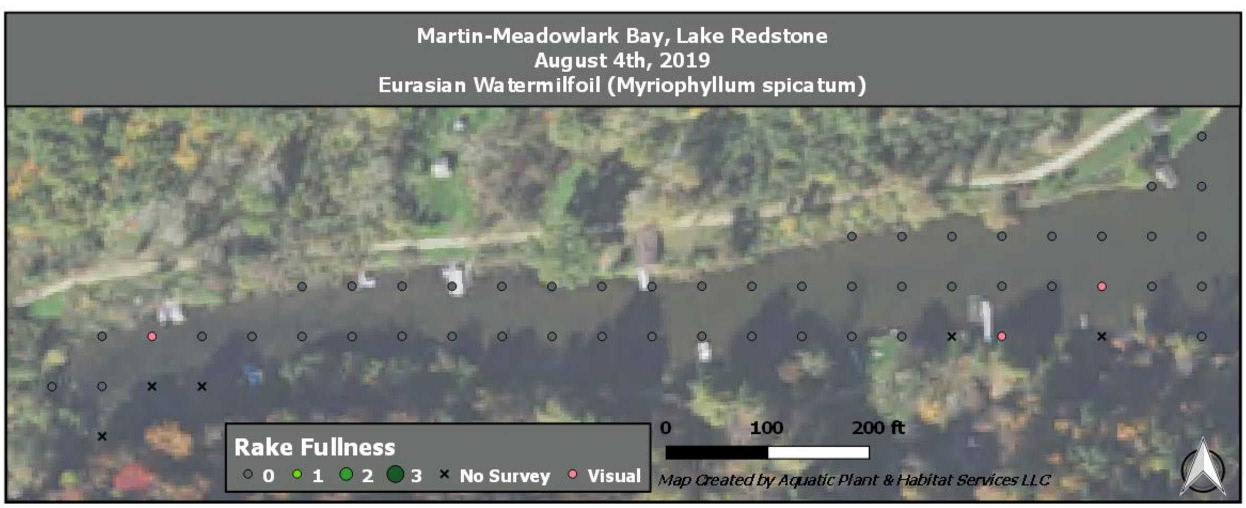
Figure 19 – Hummingbird Bay Eurasian Watermilfoil Map



Martin-Meadowlark Bay EWM

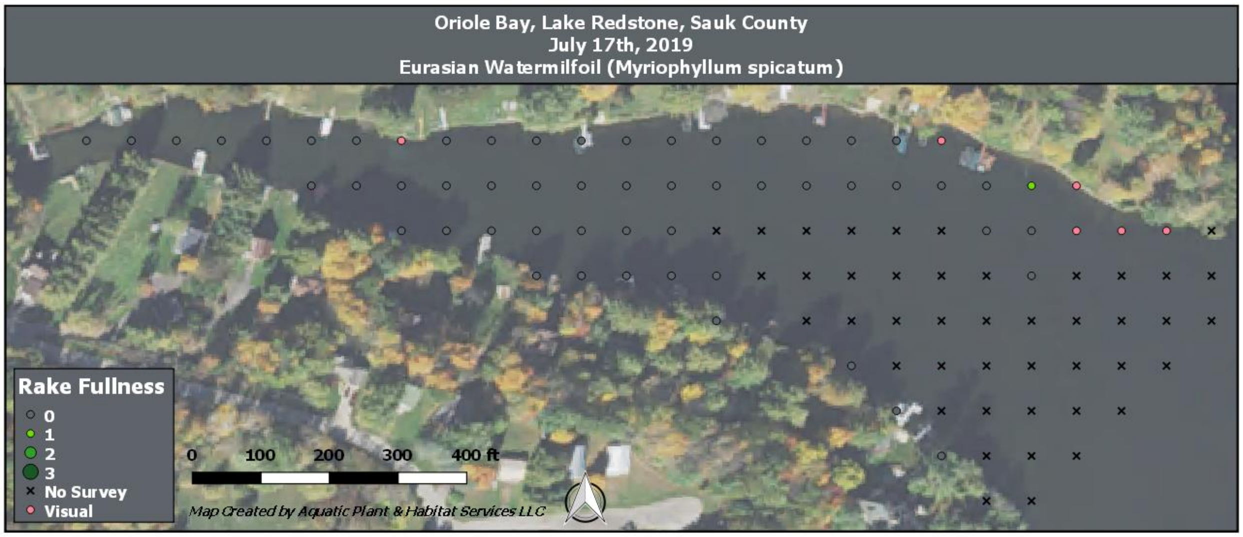
EWM was uncommon in the bay with only 3 visual observations. EWM littoral frequency was 0% in 2019, 6% in 2018, 23% in 2017, 22% in 2016, 0% in 2015, and 42% in 2014. Herbicide treatment was done in 2015 to control EWM. There was a significant decrease in EWM in 2019 when compared to 2014.

Figure 20 – Martin-Meadowlark Bay Eurasian Watermilfoil Map



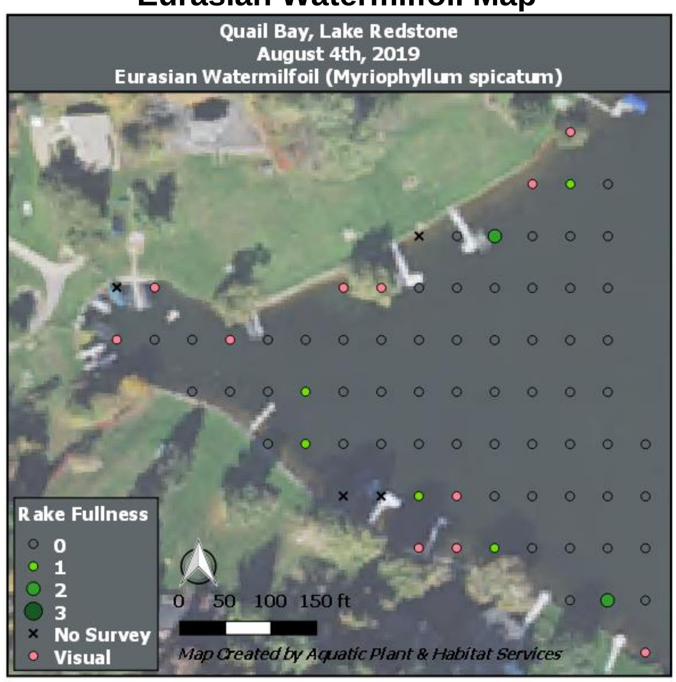
Oriole Bay EWM
EWM was found at only 1 site and visual observation at another 6 points making it a species of low occurrence in 2019, but still the second-most common species because aquatic plant occurrence was low overall. Littoral frequency was 4% in 2019, 6% in 2018, 24% in 2017, 14% in 2016, and 27% in 2015. Herbicide treatment was done in 2016 to control EWM. A chi-squared test of EWM 2019 compared to 2015 revealed a significant decrease in occurrence. There was no significant change in EWM from 2018 to 2019.

Figure 21 – Oriole Bay Eurasian Watermilfoil Map



Quail Bay EWM
EWM was found at 7 survey points and another 11 visual observations, making it the second-most common plant species distributed throughout Quail Bay. EWM littoral frequency was 21% in 2019 and 22% in 2017. Herbicide treatment has not been conducted in Quail Bay. There was no statistically significant difference in EWM between 2017 and 2019.

Figure 22 – Quail Bay Eurasian Watermilfoil Map



Swallow Bay EWM

EWM was only observed visually at two sites in 2019 and only one site in 2018, and therefore the littoral frequency was 0% both years. By contrast, littoral frequency of EWM was 29% in 2017, 9% in 2016, 1% in 2015, and 52% in 2014. Herbicide treatment was done in spring 2015 and 2018 to control EWM. A chi-squared test of the 2014 EWM data compared to 2019 reveals a significant decrease in EWM. There was no significant change in EWM between 2018 and 2019.

Figure 23 – Swallow Bay Eurasian Watermilfoil Map

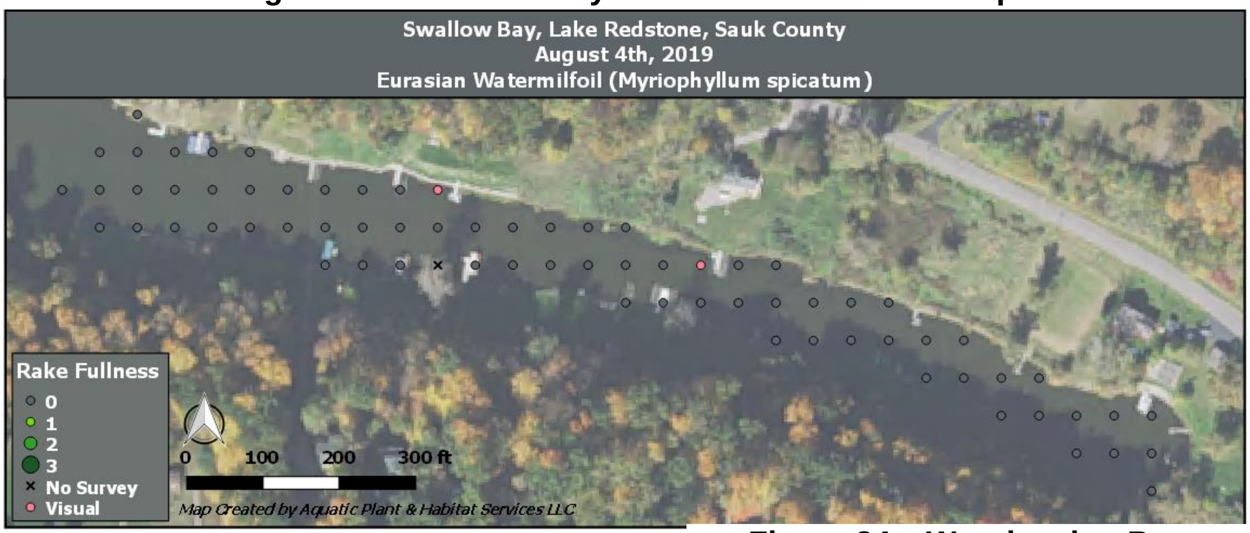
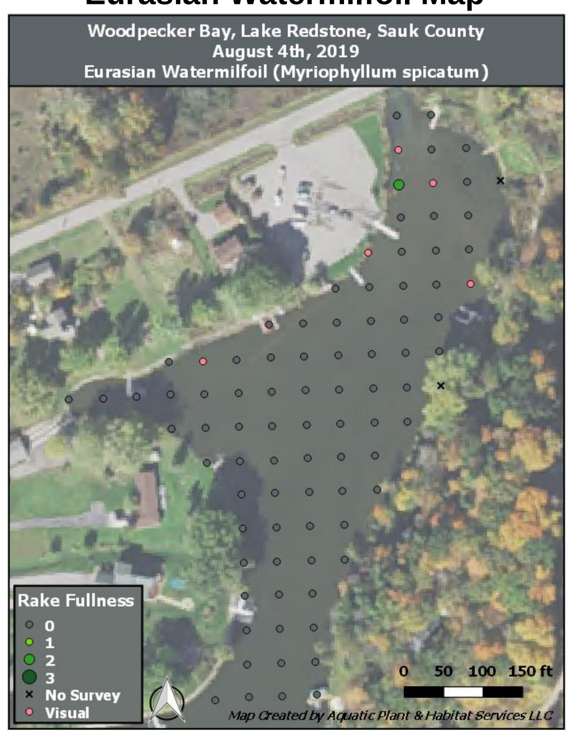


Figure 24 – Woodpecker Bay Eurasian Watermilfoil Map



Woodpecker Bay EWM

EWM was found at 1 survey point and 5 visual observations. The littoral frequency was 1% in 2019, 4% in 2018, 10% in 2017, and 9% in 2016. Herbicide treatment was conducted in the northern section of the bay in spring of 2017. There was a statistically significant decrease in EWM when compared to 2016. There was no significant difference in EWM between 2018 and 2019.

DISCUSSION

Aquatic Plants are Necessary for Healthy Lakes

Aquatic plants serve important functions in lake systems. They provide structural habitat for small invertebrates that are an important food source for juvenile game fish and adult panfish. Plants also provide structural habitat for juvenile and small fish to hide from predators and vice versa as larger predators may lurk in the shadows of plants in wait of forage. Aquatic plants also provide foraging and/or hiding structure for reptiles, amphibians, and waterfowl. The shorelines of lakes are buffered from wave action when aquatic plants absorb some of the wave energy. Aquatic plants are important consumers of nutrients that would otherwise be available for nuisance algal growth. For these reasons, native aquatic plants should be protected in lakes and a healthy aquatic plant community should be promoted.

There are times when native aquatic plants grow to nuisance levels that hinder the aforementioned functions and also negatively impact recreation. An overabundance of vegetation can cause oxygen depletion in the water as plants decompose, thereby reducing the oxygen available to fish and other aquatic organisms.

Chi Square Results

With the August 2019 survey results, there was a statistically significant decline in 9 native[3] plant species when compared to the most recent previous results. There were no SS increases in any native species when comparing 2019 to the most recent previous surveys.

If we compare the August 2019 to the first year surveyed for each of the bays that have been surveyed for three years or more there is a statistically significant decrease in five native plant species and filamentous algae and increase in one native plant species.[4] Although EWM occurrence was the lowest recorded for all bays except Eagle Bay, none of the declines were SS when compared to 2018 data (the topic of decreased EWM occurrence is discussed later in the Discussion). Based on these results, it seems as though there is an overall decline in native plant occurrence in the bays that are being studied. There is also an overall decline in EWM and filamentous algae occurrence.

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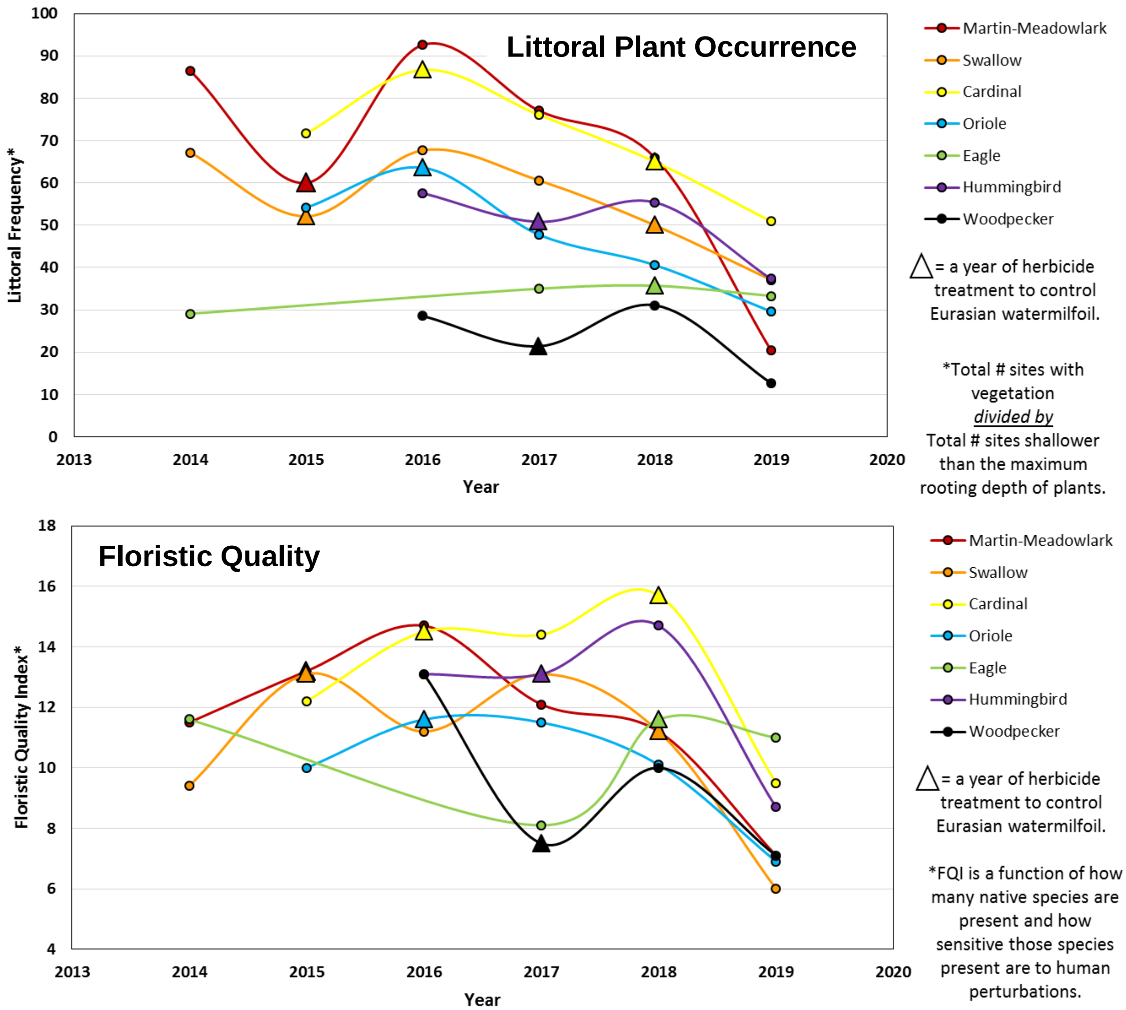
[3] Coontail SS decrease in 6 bays, small duckweed SS decrease in 3 bays, white water lily SS decrease in one bay, large duckweed SS decrease in one bay, slender naiad SS decrease in one bay, wild celery SS decrease in one bay, small pondweed SS decrease in 2 bays, sago pondweed SS decrease in one bay, and slender waterweed SS decrease in one bay.

[4] Coontail SS decrease in 6 bays, small duckweed SS decrease in 2 bays, white water lily SS decrease in one bay, large duckweed SS decrease in three bays, and slender waterweed SS decrease in two bays. White water lily SS increase in 1 bay.

Reduced Plant Occurrence & Floristic Quality

Graphs in Figure 25 illustrate data already listed in Table 3 & Table 4 for bays surveyed for >3 years. One graph charts a function of the total number of sites where plants *do* occur vs. the total number of sites where plants *could* occur, AKA littoral frequency. This function factors in water clarity because it only includes points that are equal to or shallower than the maximum depth of aquatic plants. In theory, if water clarity declines so do the number of points shallower than the maximum depth of plants. This graph shows that littoral frequency was lowest in 2019 compared to all previous years for 6 out of 7 bays[5]. The graph also illustrates a general decline in plant occurrence for 4 bays since 2016. The floristic quality graph charts a function of the number of native species present and how sensitive those species are to human perturbations. This year (2019) marked the lowest floristic quality value for 6 out of 7 bays charted. These trends could be due to environmental factors such as the historic flooding in the area that also likely impacted aquatic plant growth the following year in (2019).

Figure 25 – Littoral Plant Occurrence & Floristic Quality Graphs

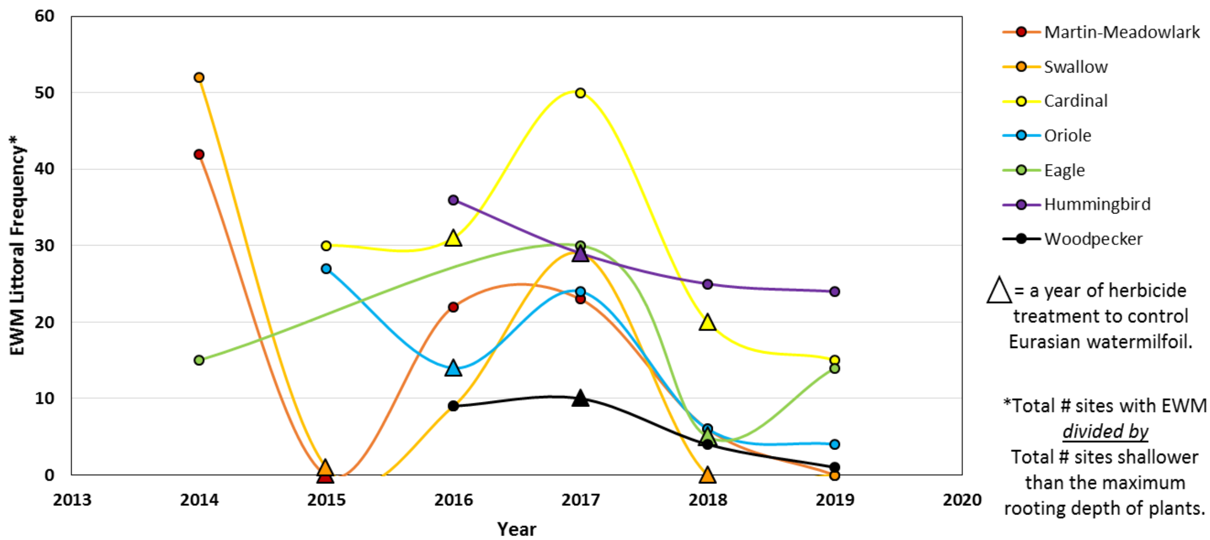


[5] Littoral frequency was also lowest in 2019 for Arapaho, Chickadee, and Killdeer.

EWM Control Activities – Are They Working?

One way to measure the success of herbicide use is to assess littoral frequency of EWM before and after treatment. Figure 26 illustrates EWM littoral frequency in all bays that were treated with herbicide. Each bay is further discussed below. ***In summary, most herbicide treatments were successful in statistically significant reductions of EWM littoral frequency the summer immediately following spring treatment.*** This is also known as the first season following herbicide treatment, hence could also be summarized by saying that herbicide treatments were successful in SS reductions of EWM for at least one season after herbicide treatment. An entire calendar year following herbicide treatment would be 2 seasons after treatment.

Figure 26 – EWM Littoral Frequency Graph



Cardinal Bay

Herbicide treatment in spring of 2016 resulted in NO statistically significant (SS) reduction of EWM when compared to survey results of 2015 and in fact the EWM littoral frequency was highest one year following herbicide treatment in 2017. These findings suggest the herbicide treatment in 2016 was not successful. Herbicide treatment in spring of 2018 resulted in a SS reduction of EWM when compared to survey results of 2017 and littoral frequency continued to decline in 2019. These findings suggest the herbicide treatment in 2018 was successful. However, plant occurrence in most bays in 2018 and 2019 has been lower than previous years. ***In summary, the first herbicide treatments in Cardinal Bay was unsuccessful in reducing littoral frequency of EWM while the second treatment was successful in reducing EWM for 2 seasons (one of which was statistically significant). EWM occurrence has not returned to pre-treatment levels of 2015 & 2017.***

Eagle Bay

Herbicide treatment in spring of 2018 resulted in a SS reduction of EWM when compared to survey results of 2017. These findings suggest the herbicide treatment in 2018 was successful. However, EWM increased in 2019, but that increase was not SS. ***In summary, herbicide treatment in Eagle Bay was successful in significantly reducing littoral frequency of EWM for one season.***

Hummingbird Bay

Herbicide treatment in spring of 2017 resulted in a slight reduction of EWM when compared to survey results of 2016, but the reduction was not SS. Littoral frequency continued to decline in in 2018 and 2019, but these decreases were not SS. These findings suggest the herbicide treatment in 2017 was successful. However, plant occurrence in most bays in 2018 and 2019 has been lower than previous years. ***In summary, the one herbicide treatment of EWM in Hummingbird Bay in 2017 was successful in reducing littoral frequency for three seasons, but none of the reductions were statistically significant.***

Martin-Meadowlark Bay

Herbicide treatment in spring of 2015 resulted in a statistically significant (SS) reduction of EWM when compared to survey results of 2014. EWM was higher again in 2016 (SS increase) and 2017. No other herbicide treatment occurred, but EWM decline in 2018 was SS followed by further decline (not SS) in 2019. Plant occurrence in most bays in 2018 and 2019 has been lower than previous years. ***In summary, the herbicide treatment of EWM in Martin-Meadowlark Bay was successful in reducing littoral frequency for 1 season. EWM occurrence has not returned to high pre-treatment levels of 2014.***

Oriole Bay

Herbicide treatment in spring of 2016 resulted in a reduction of EWM when compared to survey results of 2015, but the reduction was not SS. Unfortunately, EWM rebounded to pre-treatment levels in 2017. No other herbicide treatment occurred, but EWM decline in 2018 was SS followed by further decline (not SS) in 2019. This trend coincides with reduced plant occurrence in most bays in 2018 and 2019. ***In summary, Herbicide treatment in Oriole Bay was successful in reducing EWM for one season.***

Swallow Bay

Herbicide treatment in spring of 2015 resulted in a statistically significant (SS) reduction of EWM when compared to survey results of 2014. EWM was higher again in 2016 and significantly higher in 2017. Herbicide treatment in spring of 2018 resulted in a SS reduction of EWM when compared to survey results of 2017 and littoral frequency continued at zero 2019. These findings suggest the herbicide treatment in 2015 was successful for one season and the treatment in 2018 was successful for two seasons. However, plant occurrence in most bays in 2018 and 2019 has been lower than previous years. ***In summary, the first herbicide treatments was successful in SS EWM reduction for 1 season while the second treatment was successful in SS EWM reduction for 2 seasons, the first of which was SS. EWM has not returned to high pre-treatment levels of 2014.***

Woodpecker Bay

Herbicide treatment in the northernmost area of the bay in spring of 2017 resulted in a slight reduction of EWM on a bay-wide scale when compared to survey results of 2016, but the reduction was not SS. Littoral frequency continued to decline in in 2018 and 2019, but these decreases were not SS. These findings suggest the herbicide treatment in 2017 was successful. However, plant occurrence in most bays in 2018 and 2019 has been lower than previous years. ***In summer, herbicide treatment of EWM in Woodpecker Bay in 2017 was successful in reducing littoral frequency for three seasons, but none of the reductions were SS.***

General Management Recommendations

Similar to previous years' recommendations, aquatic plants with low frequency of occurrence and/or higher conservatism value should be protected. These species include sago pondweed, small pondweed, slender waterweed, slender naiad, white water lily in some bays, long-leaf pondweed, water stargrass, and wild celery. Coontail was the most or second-most commonly occurring plant in 6 bays and may pose hindrance to navigation in some of the bays. Hand removal of nuisance aquatic plants, such as coontail in some instances, is permitted by Chapter NR 109 but the removal cannot occur in a designated sensitive area (identified in Sefton & Graham 2009) without a permit, is limited to a single area no more than 30 feet wide measured along shore, and must not harm the overall aquatic plant community.

Volunteer water monitoring and early detection of aquatic invasive species is an important component of lake management. Continued water monitoring and AIS surveying is recommended, although no active control of CLP is also reasonable due to its low occurrence.

Eurasian watermilfoil (EWM) was found in ten out of twelve bays[6]. EWM occurrence was lowest on record for 11 bays, with the only exception being Eagle Bay. Curly-leaf pondweed (CLP) was found in nine bays and always at low frequency. The Lake Redstone Protection District has done commendably in funding pre-post plant surveys, yielding valuable data since 2014. Due to the dredging operations in 2019, one would expect continued low occurrence of EWM in 2020

[6] EWM was not documented in Killdeer Bay nor in County F Bay in 2019.

due to sediment and EWM root removal. EWM may continue to cause nuisance conditions at near-shore areas and around docks. These issues can be addressed with hand-pulling of EWM, especially where workers can wade and reach the EWM without snorkel or SCUBA gear due to low water clarity and limited visibility.

Table 7 - Management Recommendations Summary

1. Protect native aquatic plants as they provide important structural habitat and contribute to a healthy lake system.
2. If necessary, shore land owners can hand pull or rake nuisance vegetation in a <30-foot-wide area that is contiguous and parallel to shore. Designated sensitive areas require a permit.
3. Continue volunteer water quality monitoring.
4. Conduct aquatic plant surveys of bays in 2020 and plant for a whole-lake aquatic plant survey of Lake Redstone in 2020 or 2021.

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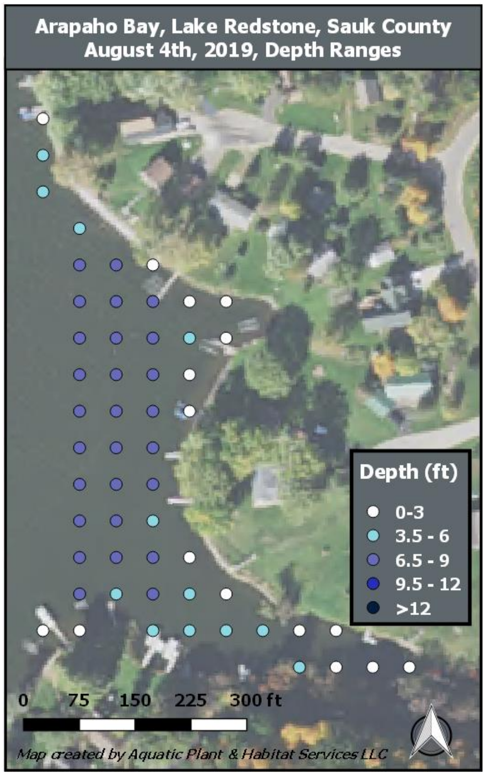
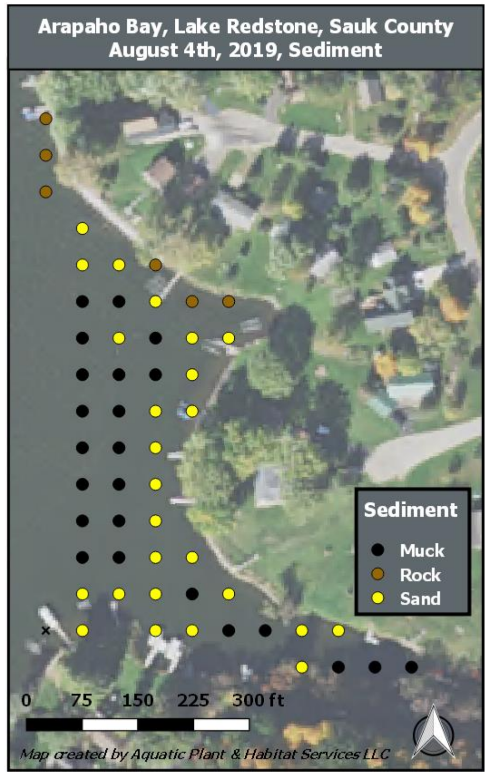
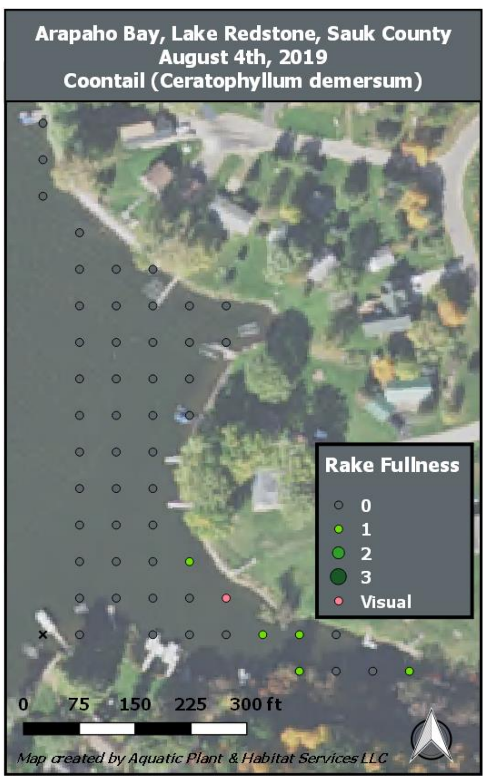
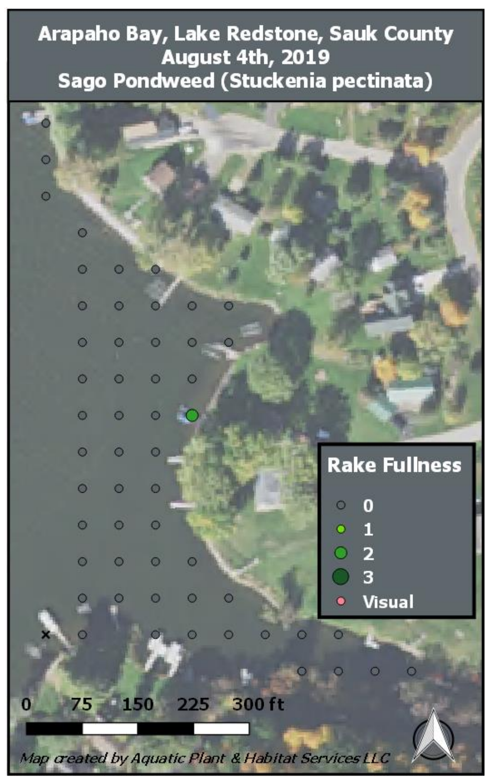
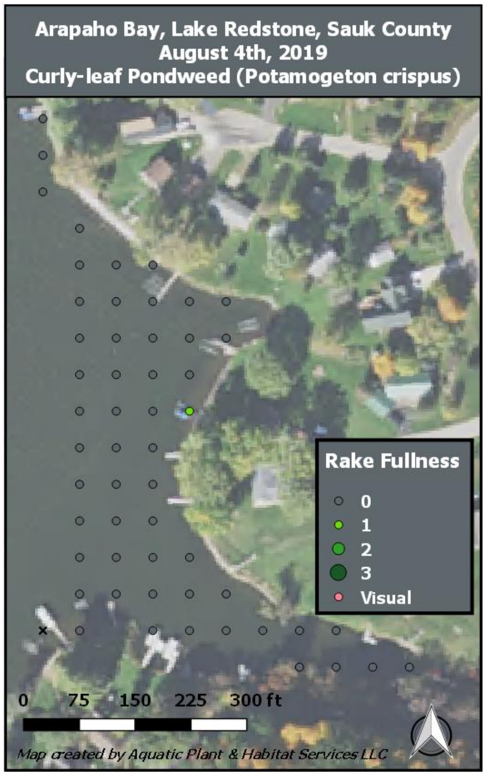
APPENDIX A – ARAPAHO BAY MAPS

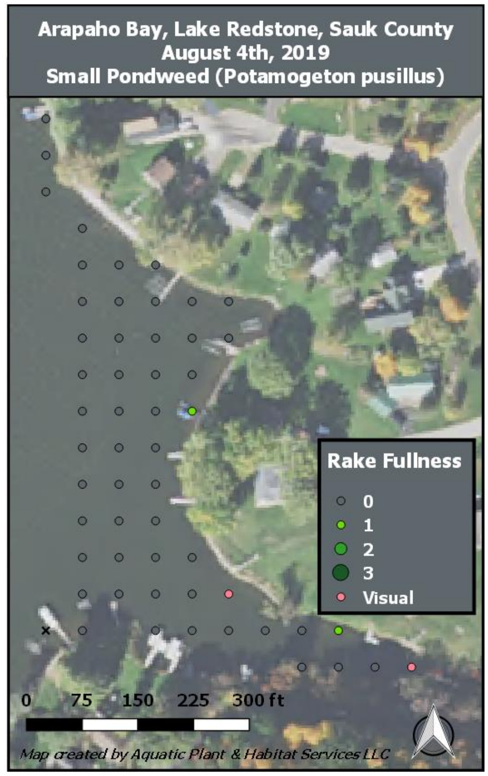


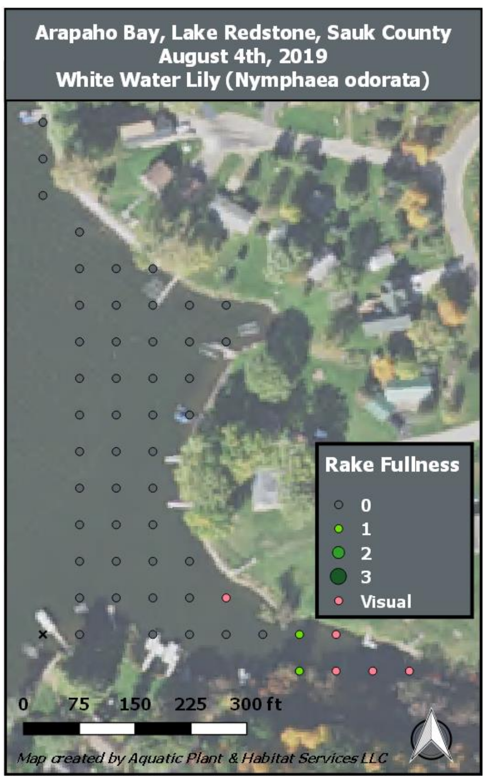




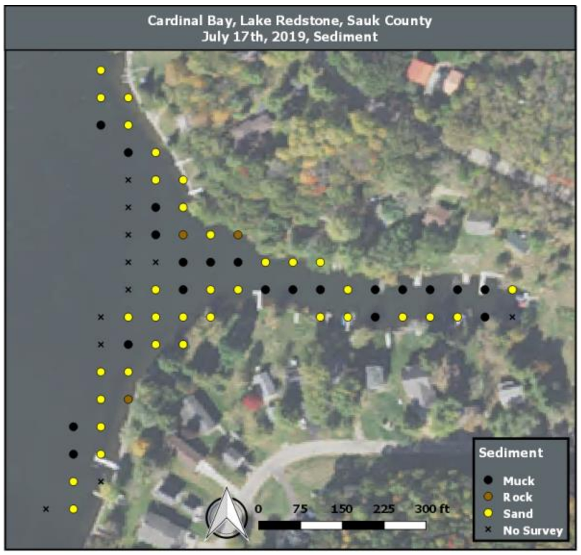


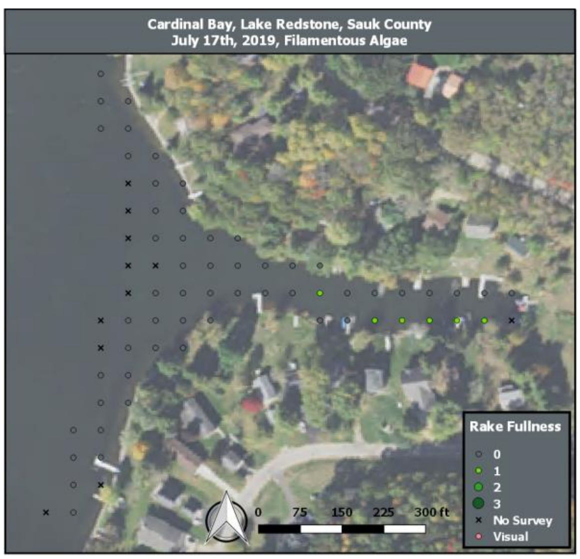

Arapaho Bay, Lake Redstone, Sauk County
August 4th, 2019
Curly-leaf Pondweed (Potamogeton crispus)
Rake Fullness
0
1
2
3
Visual
0 75 150 225 300 ft
Map created by Aquatic Plant & Habitat Services LLC

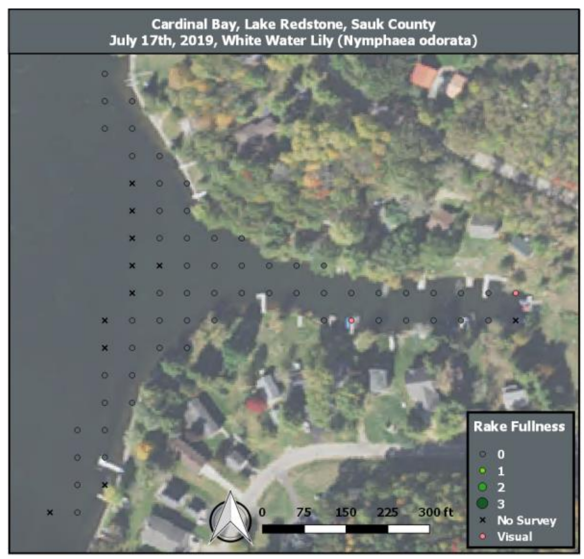

Arapaho Bay, Lake Redstone, Sauk County
August 4th, 2019
Small Pondweed (Potamogeton pusillus)
Rake Fullness
0
1
2
3
Visual
0 75 150 225 300 ft
Map created by Aquatic Plant & Habitat Services LLC


Arapaho Bay, Lake Redstone, Sauk County
August 4th, 2019
White Water Lily (Nymphaea odorata)
Rake Fullness
0
1
2
3
Visual
0 75 150 225 300 ft
Map created by Aquatic Plant & Habitat Services LLC

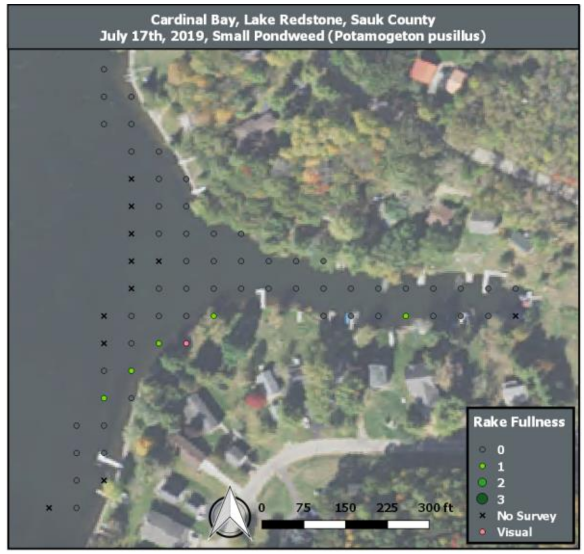
APPENDIX B – CARDINAL BAY MAPS

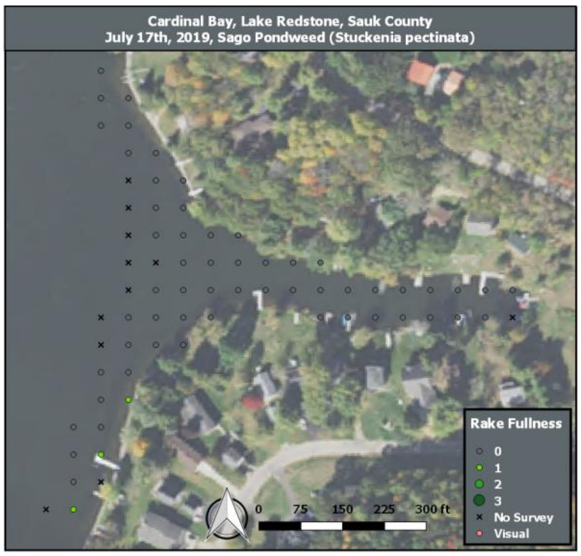


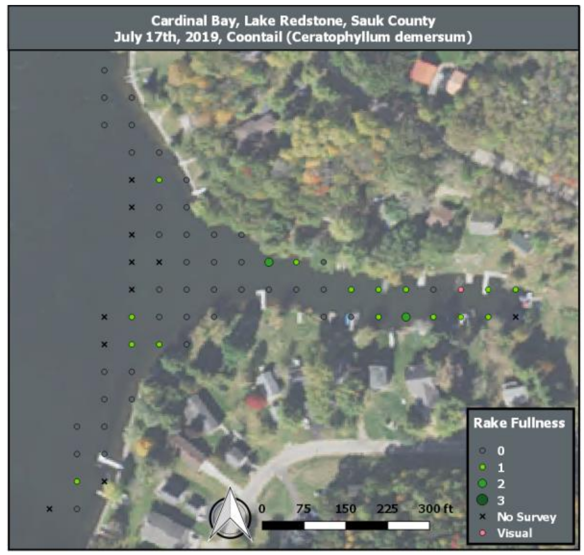


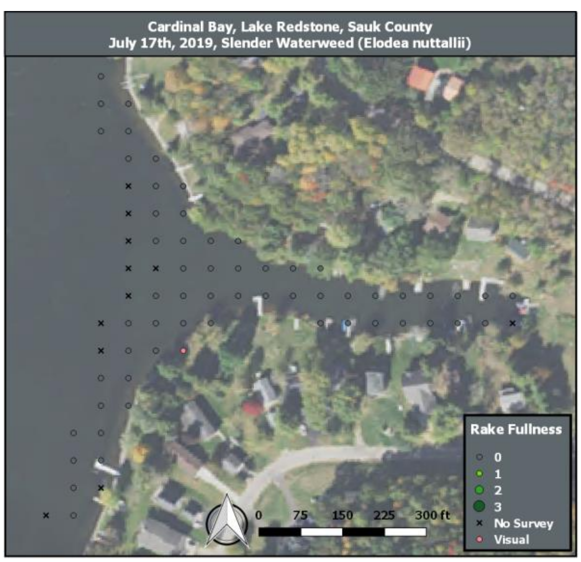



Cardinal Bay, Lake Redstone, Sauk County
July 17th, 2019, Wild Celery (Vallisneria americana)
Rake Fullness
0
1
2
3
No Survey
Visual
0 75 150 225 300 ft

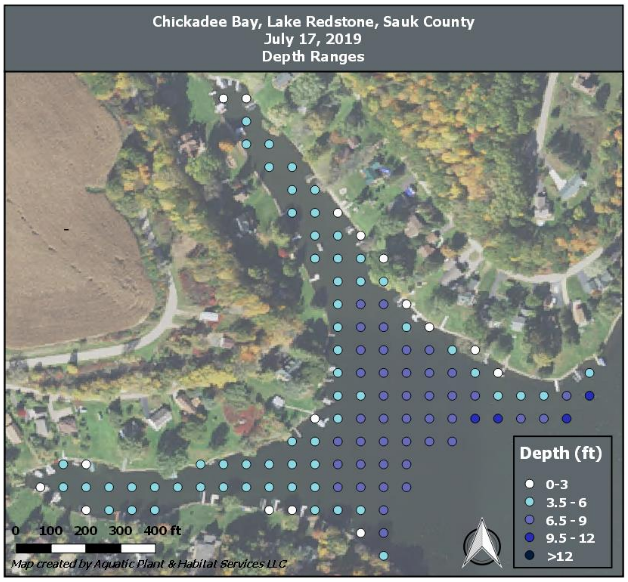

Cardinal Bay, Lake Redstone, Sauk County
July 17th, 2019, Small Pondweed (Potamogeton pusillus)
Rake Fullness
0
1
2
3
No Survey
Visual
0 75 150 225 300 ft

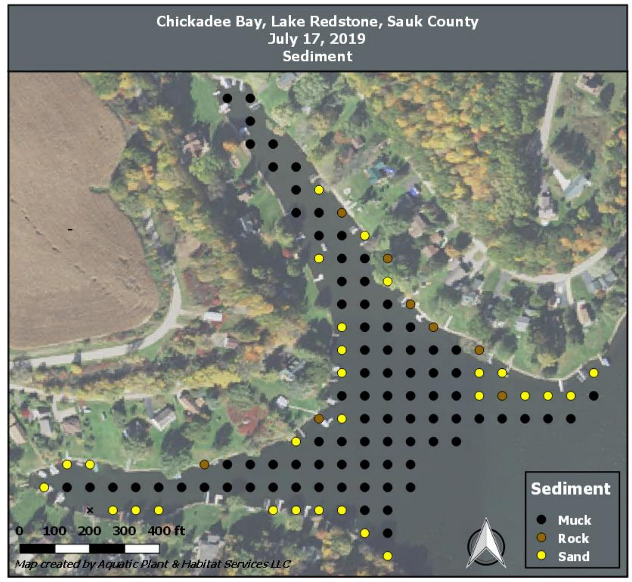

Cardinal Bay, Lake Redstone, Sauk County
July 17th, 2019, Sago Pondweed (Stuckenia pectinata)
Rake Fullness
0
1
2
3
No Survey
Visual
0 75 150 225 300 ft


Cardinal Bay, Lake Redstone, Sauk County
July 17th, 2019, Coontail (Ceratophyllum demersum)
Rake Fullness
0
1
2
3
No Survey
Visual
0 75 150 225 300 ft


Cardinal Bay, Lake Redstone, Sauk County
July 17th, 2019, Slender Waterweed (Elodea nuttallii)
Rake Fullness
0
1
2
3
No Survey
Visual
0 75 150 225 300 ft

APPENDIX C - CHICKADEE BAY MAPS



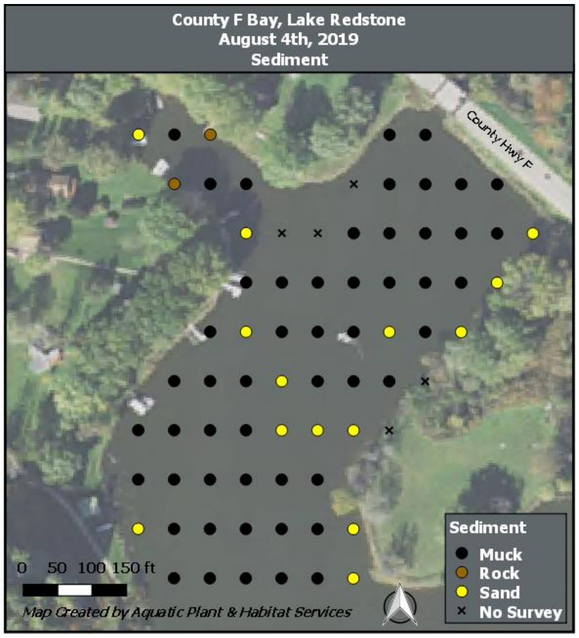


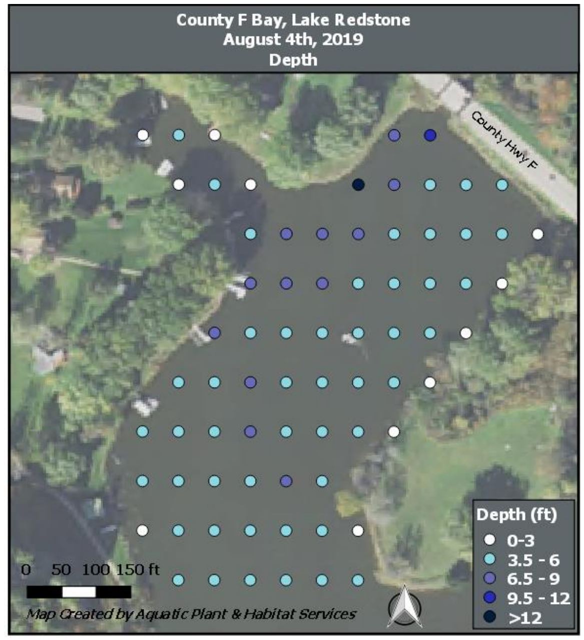

Chickadee Bay, Lake Redstone, Sauk County
July 17, 2019
Wild Celery (Vallisneria americana)
Rake Fullness
0
1
2
3
Visual
0 100 200 300 400 ft
Map created by Aquatic Plant & Habitat Services LLC

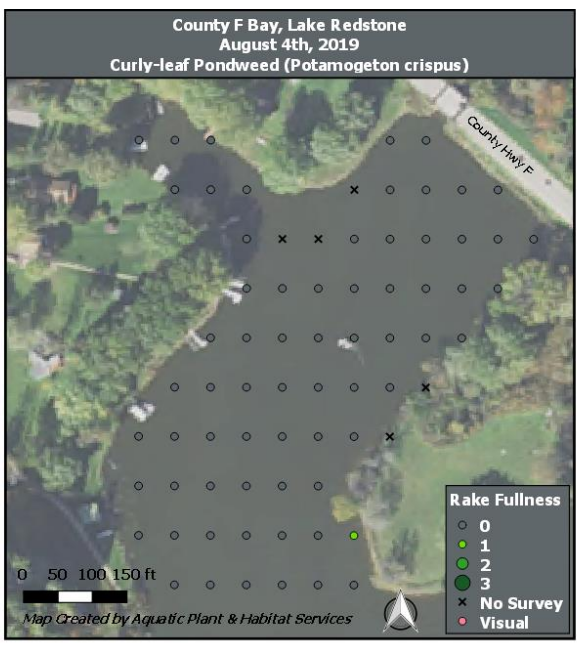

Chickadee Bay, Lake Redstone, Sauk County
July 17, 2019
White Water Lily (Nymphaea odorata)
Rake Fullness
0
1
2
3
Visual
0 100 200 300 400 ft
Map created by Aquatic Plant & Habitat Services LLC

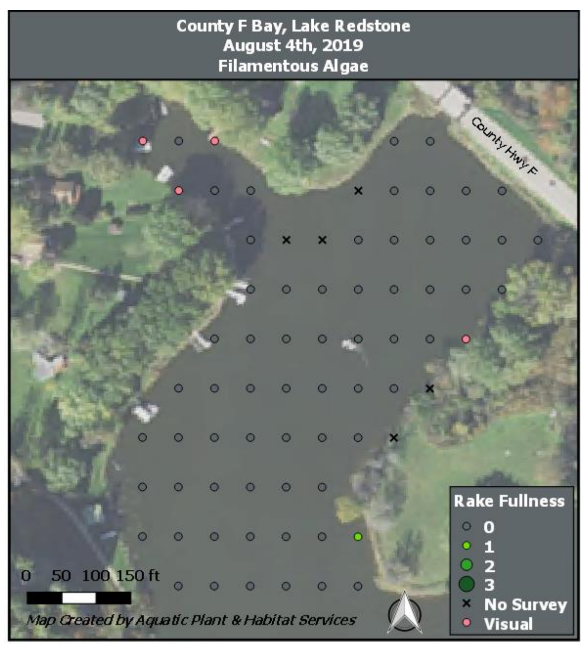

Chickadee Bay, Lake Redstone, Sauk County
July 17, 2019
Small Pondweed (Potamogeton pusillus)
Rake Fullness
0
1
2
3
Visual
0 100 200 300 400 ft
Map created by Aquatic Plant & Habitat Services LLC

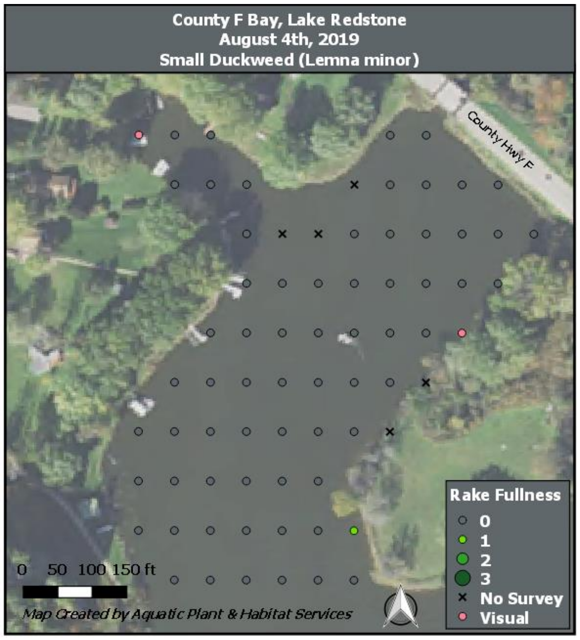
APPENDIX D – COUNTY F BAY MAPS










County F Bay, Lake Redstone
August 4th, 2019
Small Duckweed (Lemna minor)
County Hwy F
Rake Fullness
0
1
2
3
No Survey
Visual
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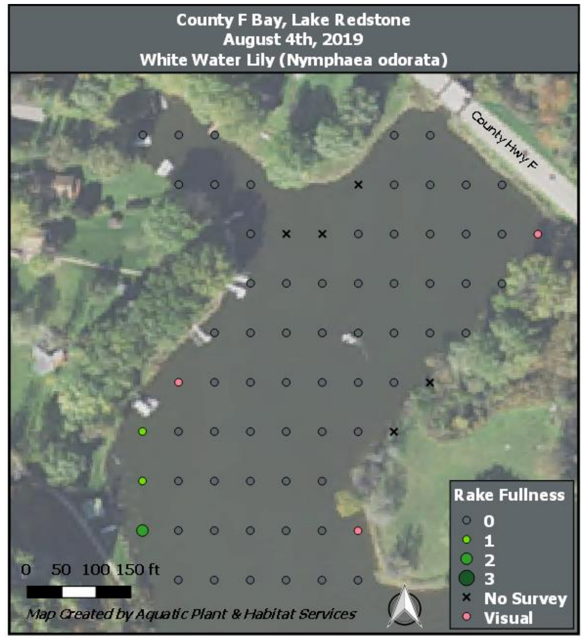
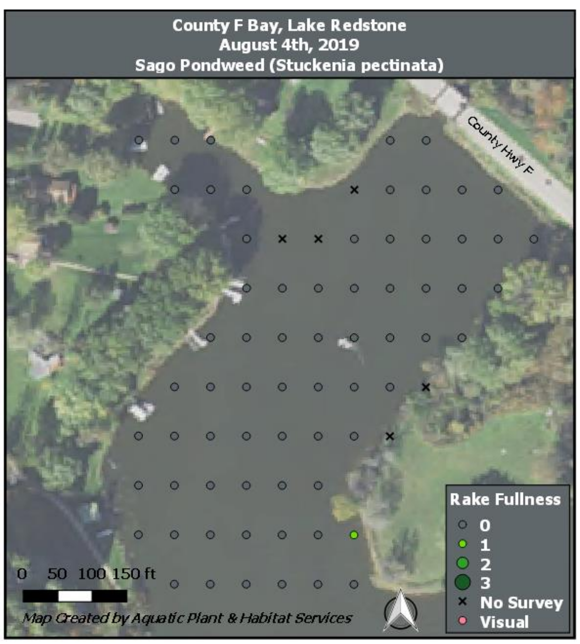
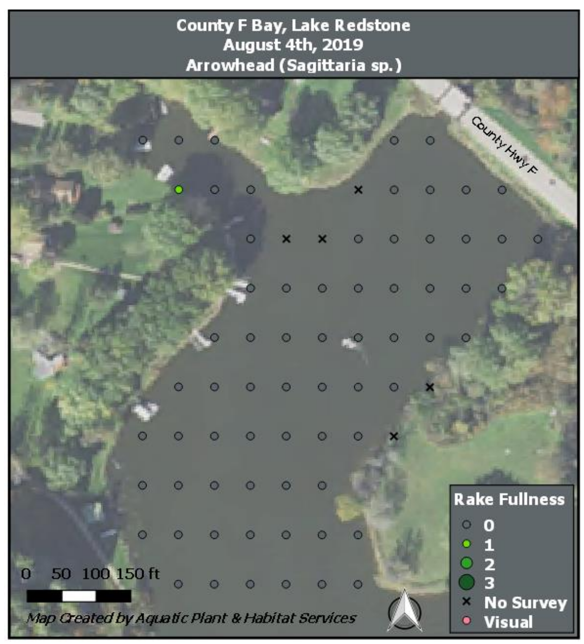
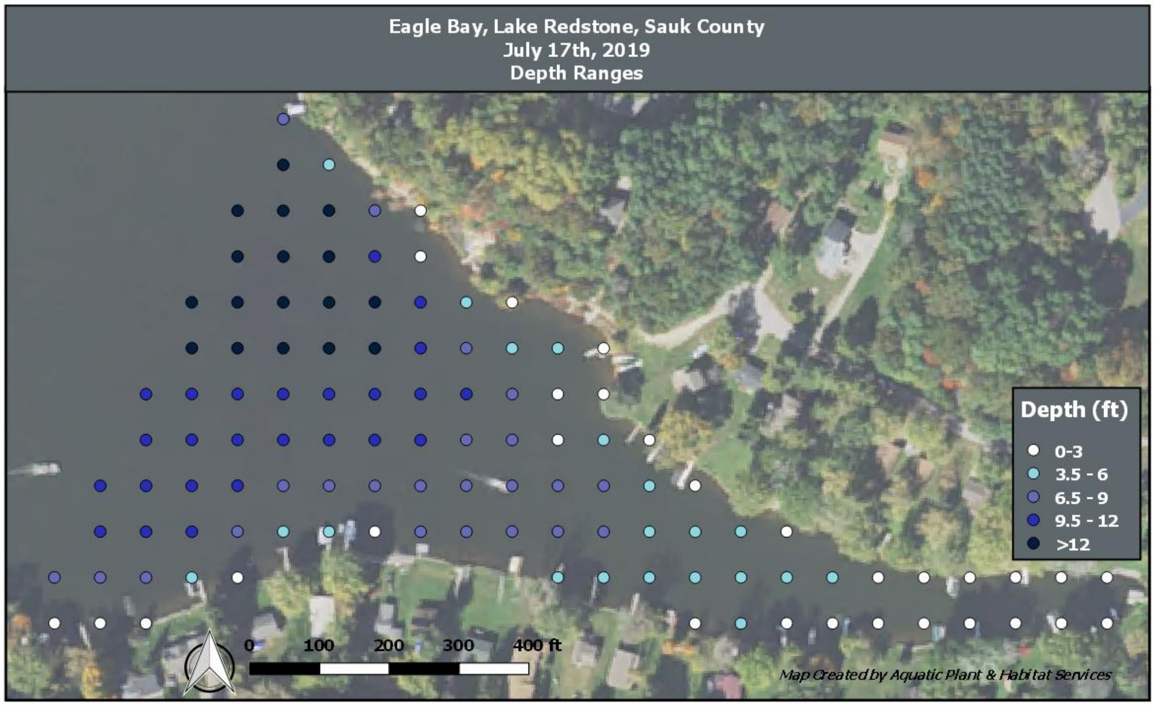
Map Created by Aquatic Plant & Habitat Services

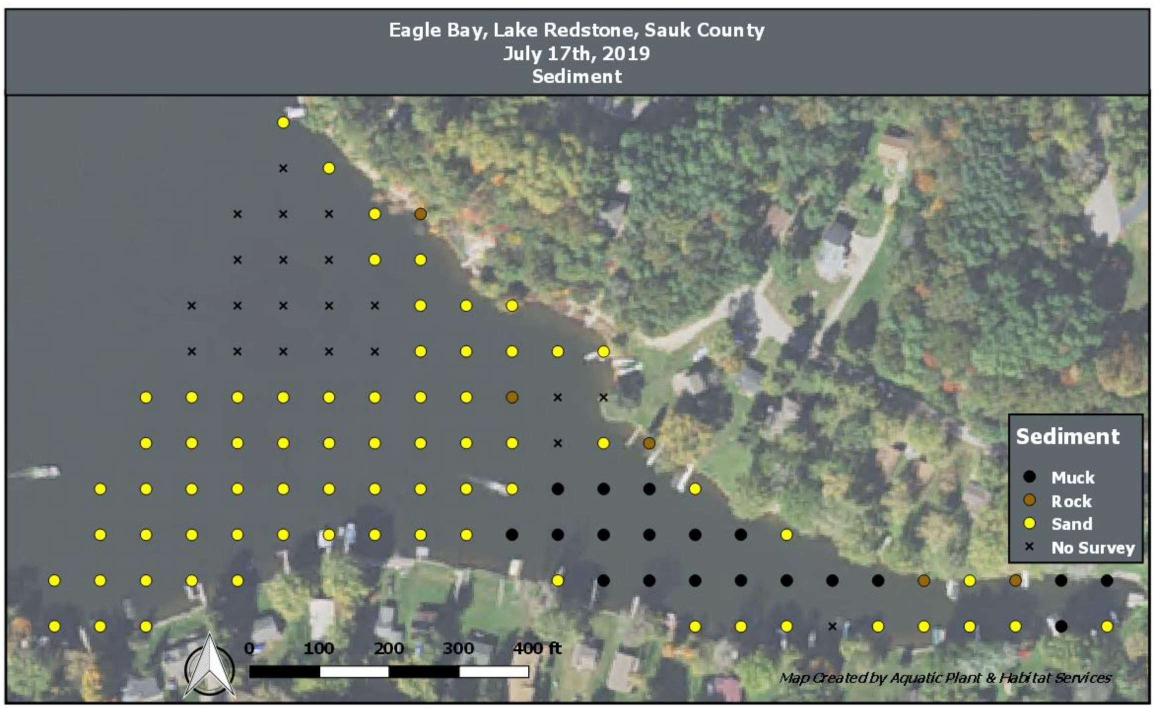

County F Bay, Lake Redstone
August 4th, 2019
White Water Lily (Nymphaea odorata)
County Hwy F
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services

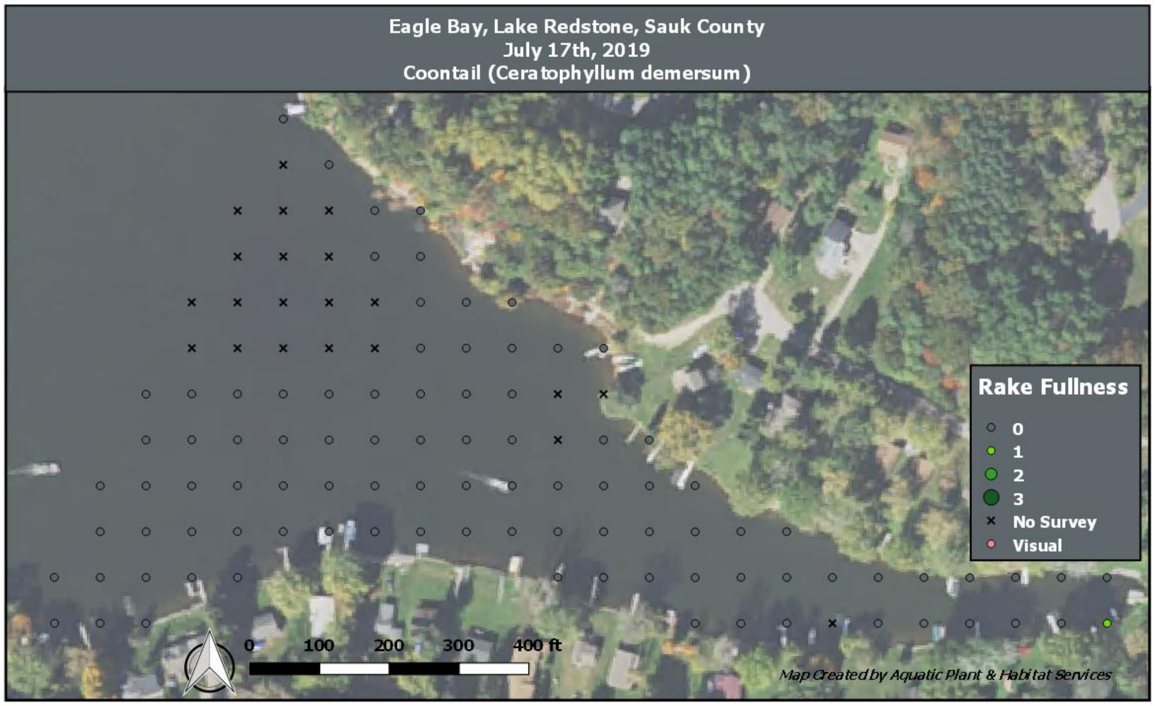

County F Bay, Lake Redstone
August 4th, 2019
Sago Pondweed (Stuckenia pectinata)
County Hwy F
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services

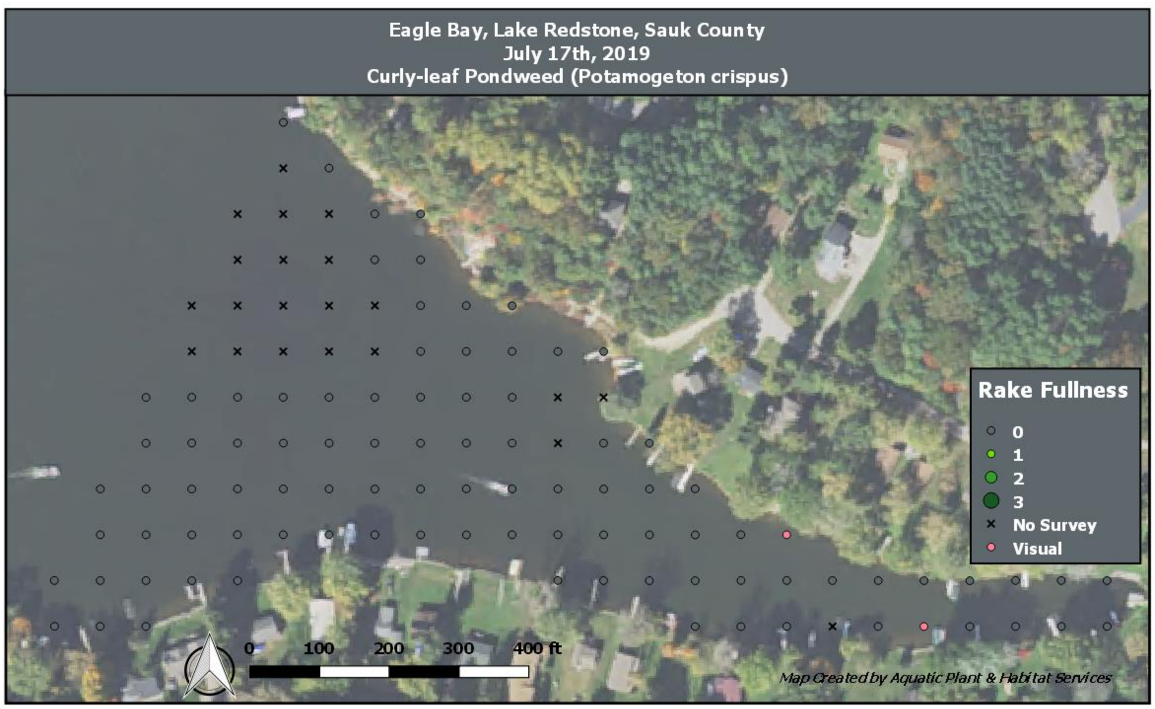

County F Bay, Lake Redstone
August 4th, 2019
Arrowhead (Sagittaria sp.)
County Hwy F
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services

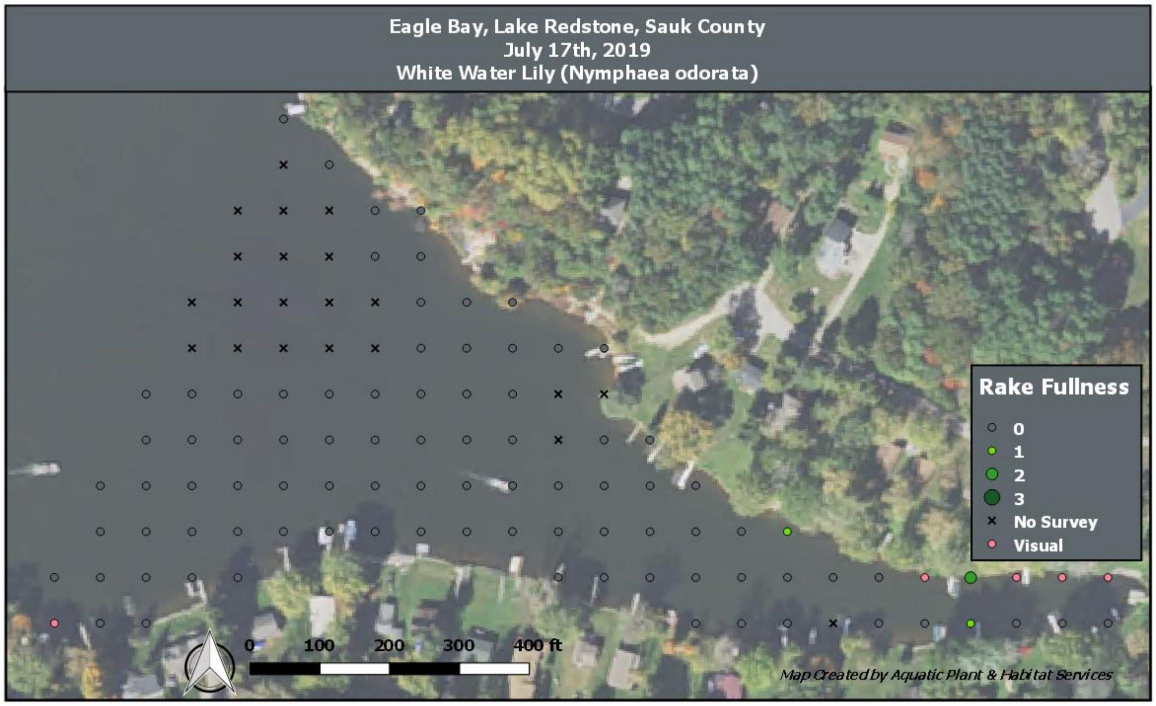
APPENDIX E – EAGLE BAY MAPS



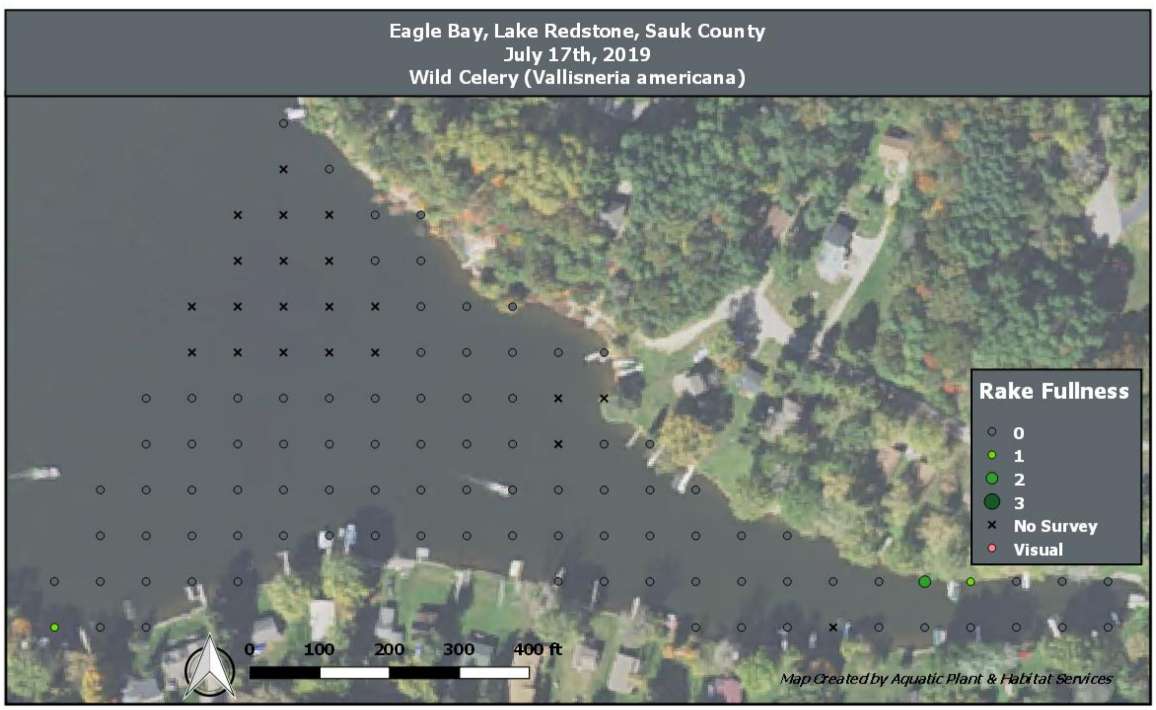



Eagle Bay, Lake Redstone, Sauk County
July 17th, 2019
Coontail (Ceratophyllum demersum)
Rake Fullness
0
1
2
3
No Survey
Visual
0
100
200
300
400 ft
Map Created by Aquatic Plant & Habitat Services

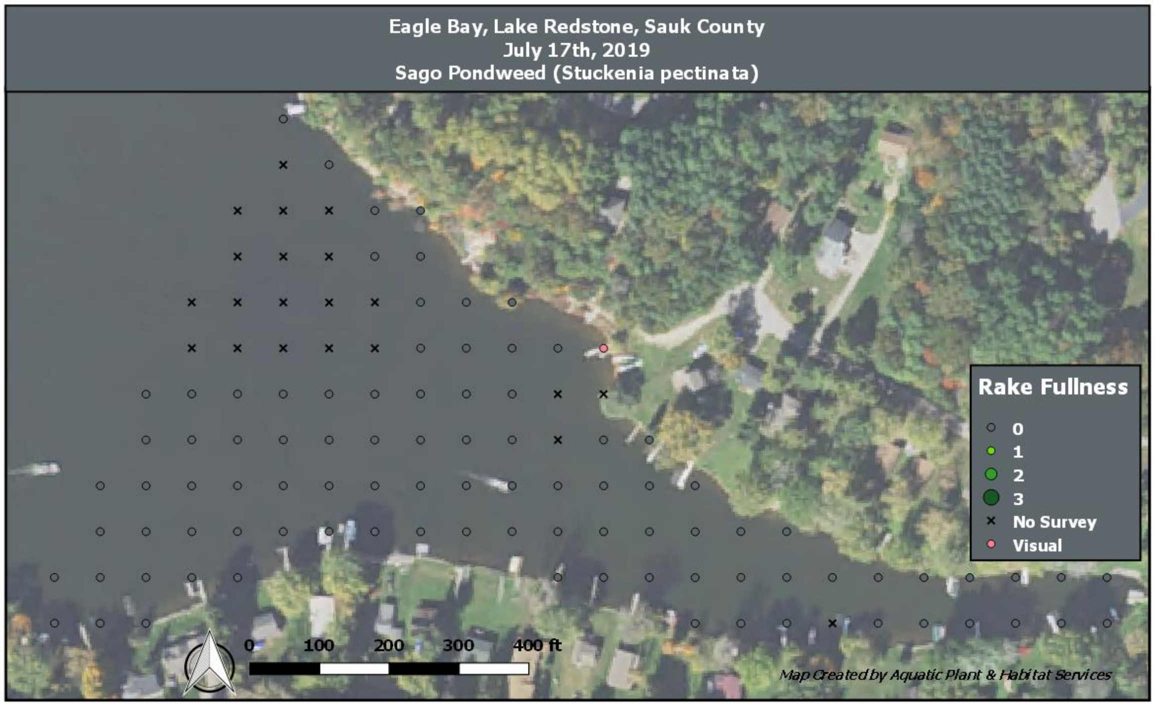

Eagle Bay, Lake Redstone, Sauk County
July 17th, 2019
Curly-leaf Pondweed (Potamogeton crispus)
Rake Fullness
0
1
2
3
No Survey
Visual
0
100
200
300
400 ft
Map Created by Aquatic Plant & Habitat Services

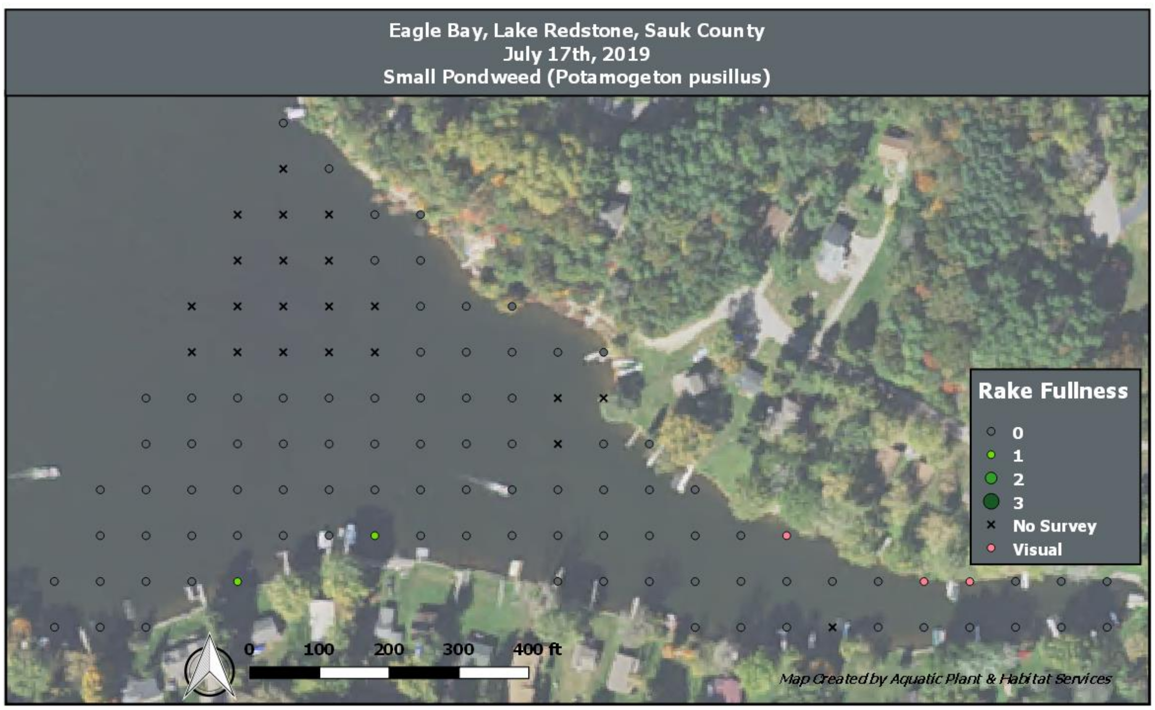


Eagle Bay, Lake Redstone, Sauk County
July 17th, 2019
White Water Lily (Nymphaea odorata)
Rake Fullness
0
1
2
3
No Survey
Visual
0
100
200
300
400 ft
Map Created by Aquatic Plant & Habitat Services

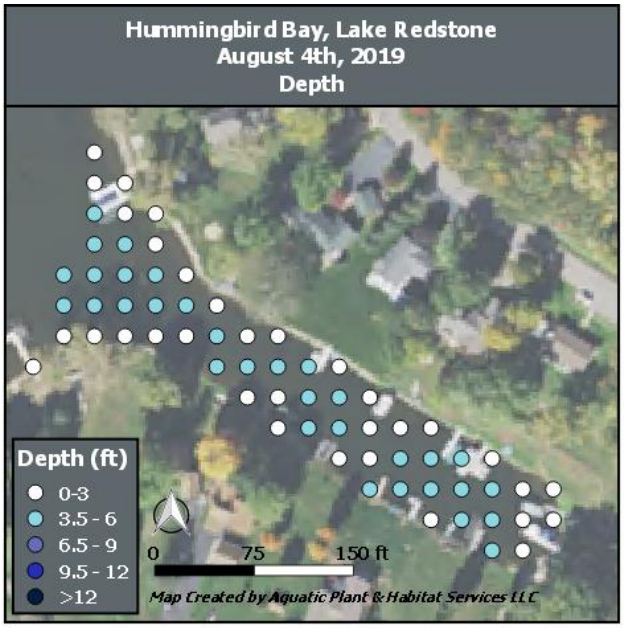


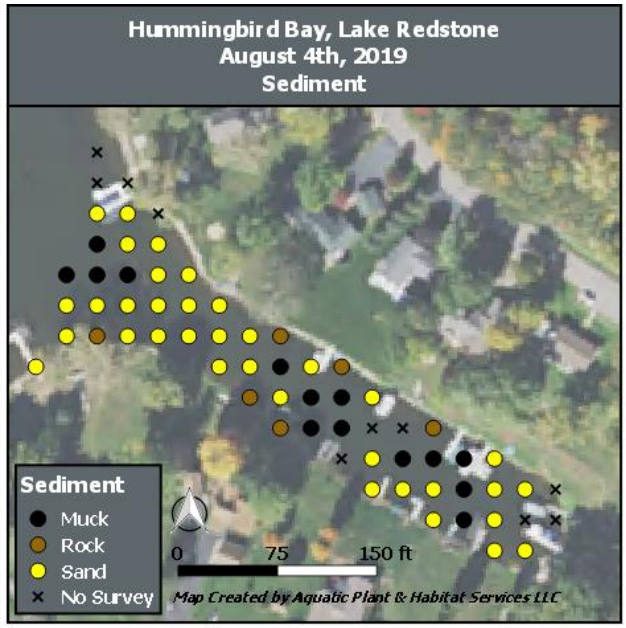
Eagle Bay, Lake Redstone, Sauk County
July 17th, 2019
Wild Celery (Vallisneria americana)
Rake Fullness
0
1
2
3
No Survey
Visual
0
100
200
300
400 ft
Map Created by Aquatic Plant & Habitat Services

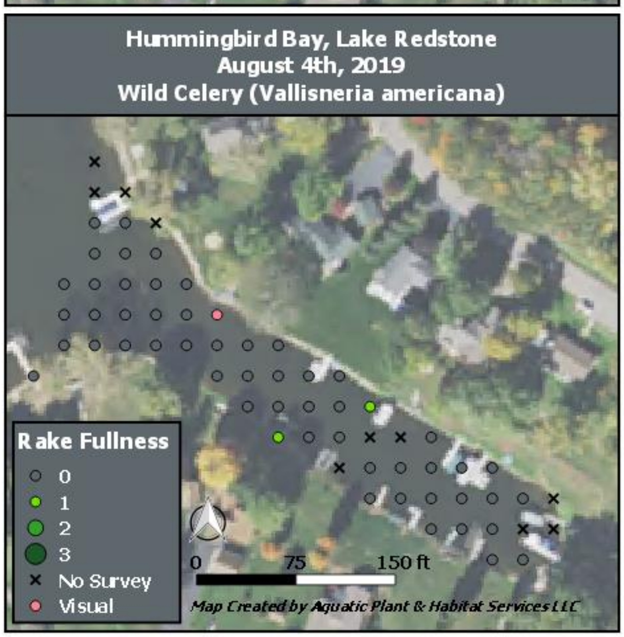

Eagle Bay, Lake Redstone, Sauk County
July 17th, 2019
Sago Pondweed (Stuckenia pectinata)
Rake Fullness
0
1
2
3
No Survey
Visual
0
100
200
300
400 ft
Map Created by Aquatic Plant & Habitat Services

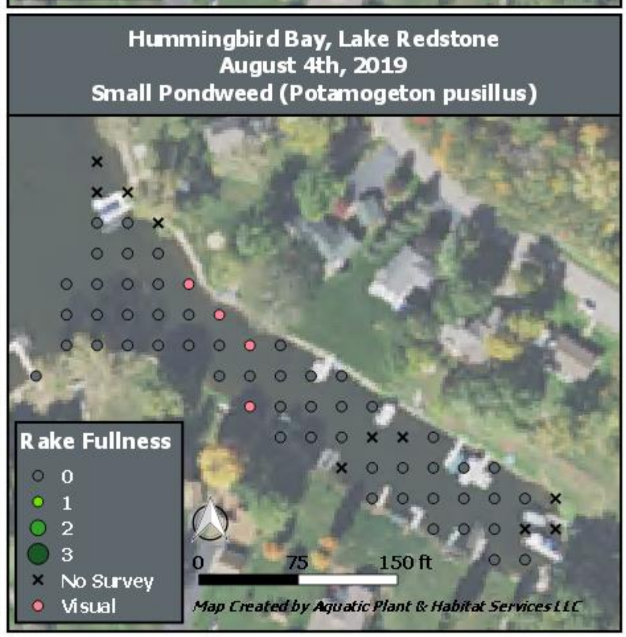

Eagle Bay, Lake Redstone, Sauk County
July 17th, 2019
Small Pondweed (Potamogeton pusillus)
Rake Fullness
0
1
2
3
No Survey
Visual
0
100
200
300
400 ft
Map Created by Aquatic Plant & Habitat Services

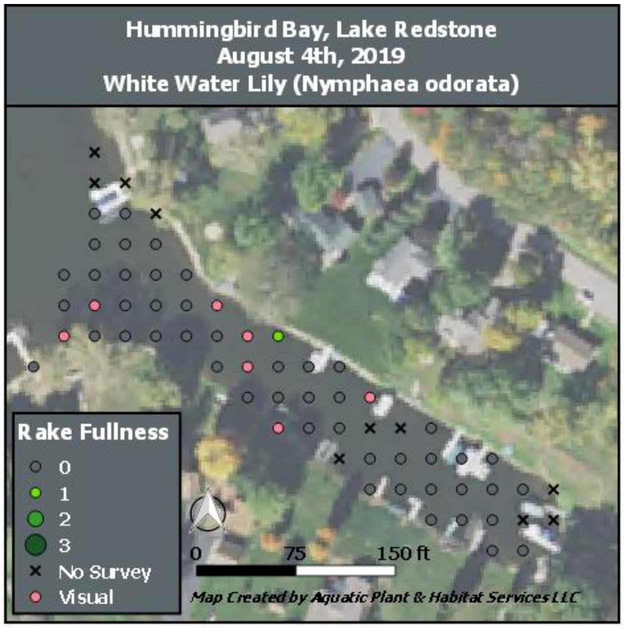
APPENDIX F – HUMMINGBIRD BAY MAPS

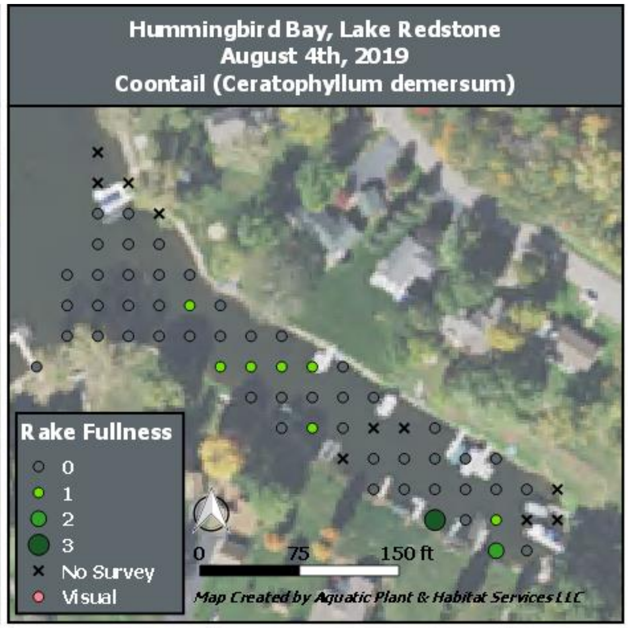


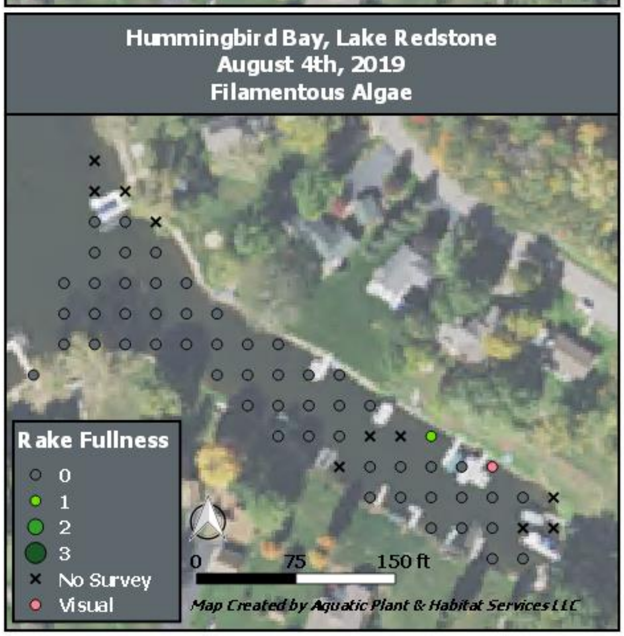




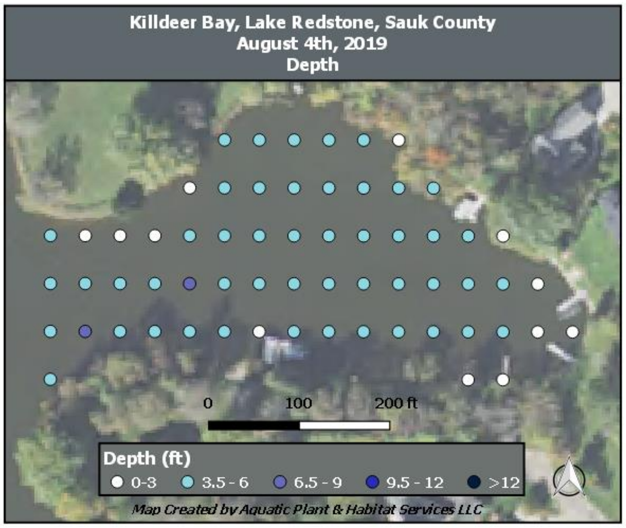


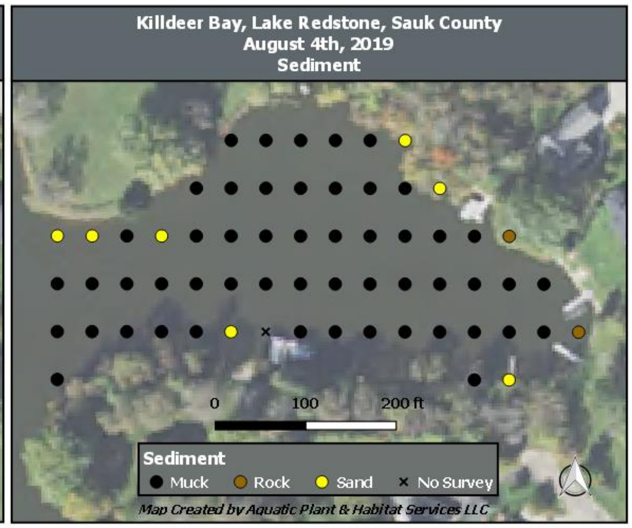

Hummingbird Bay, Lake Redstone
August 4th, 2019
White Water Lily (Nymphaea odorata)
Rake Fullness
0
1
2
3
No Survey
Visual
0
75
150 ft
Map Created by Aquatic Plant & Habitat Services LLC

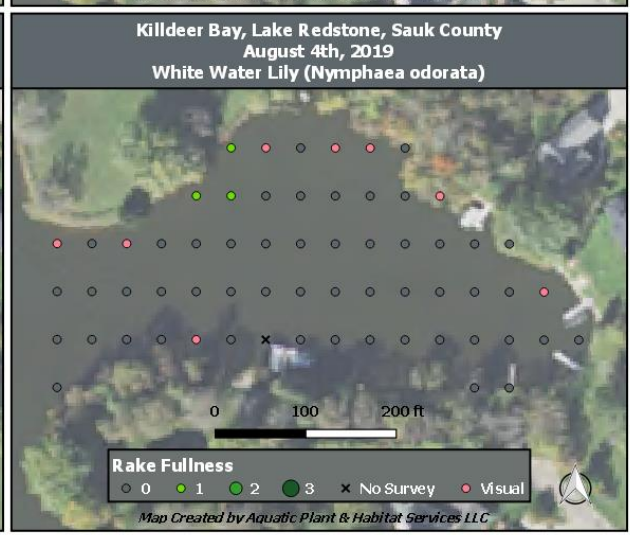

Hummingbird Bay, Lake Redstone
August 4th, 2019
Coontail (Ceratophyllum demersum)
Rake Fullness
0
1
2
3
No Survey
Visual
0
75
150 ft
Map Created by Aquatic Plant & Habitat Services LLC


Hummingbird Bay, Lake Redstone
August 4th, 2019
Filamentous Algae
Rake Fullness
0
1
2
3
No Survey
Visual
0
75
150 ft
Map Created by Aquatic Plant & Habitat Services LLC

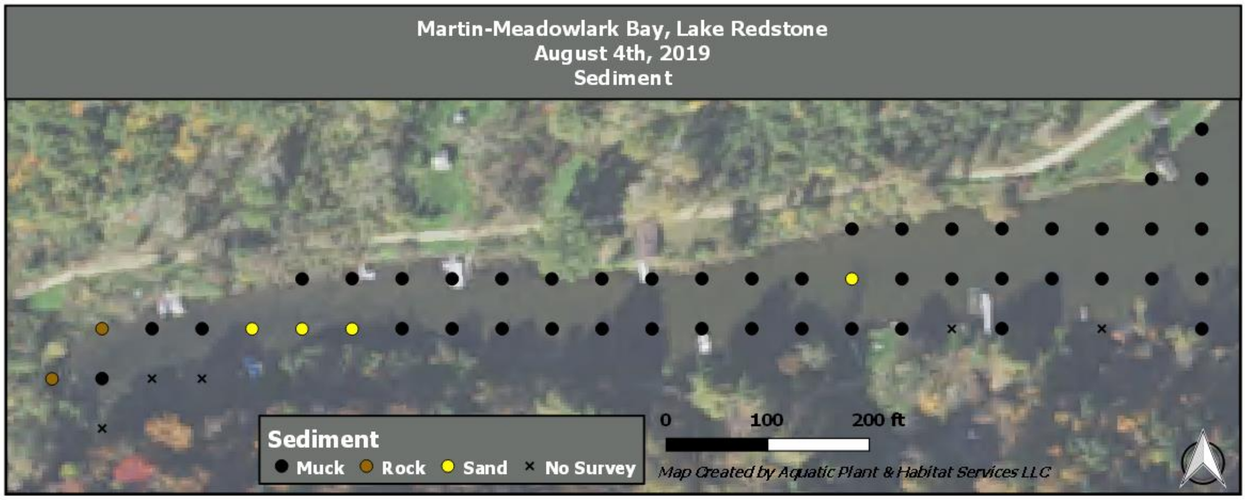
APPENDIX G – KILLDEER BAY MAPS

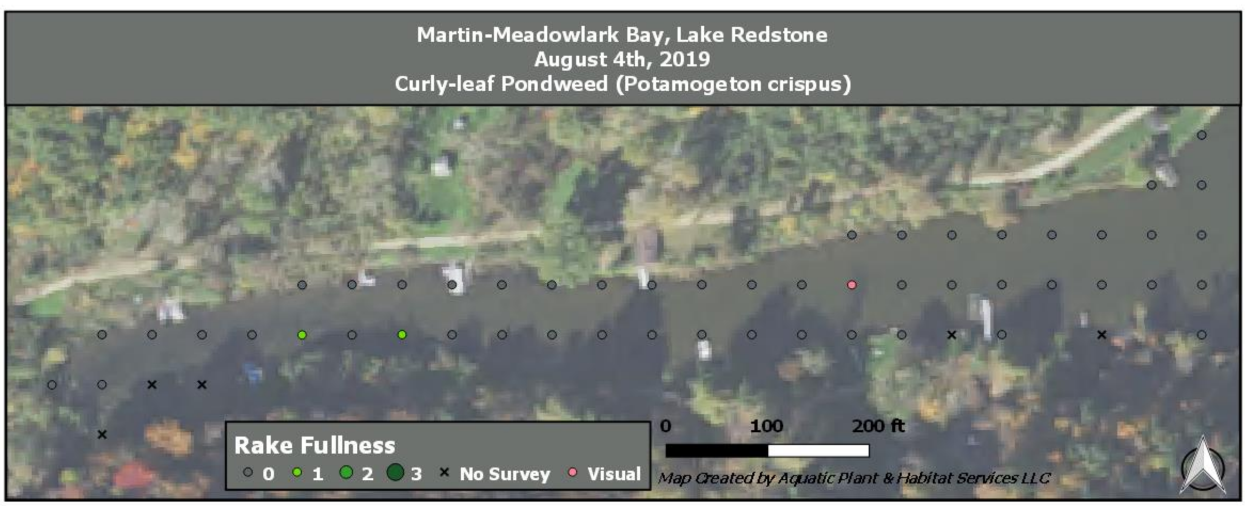


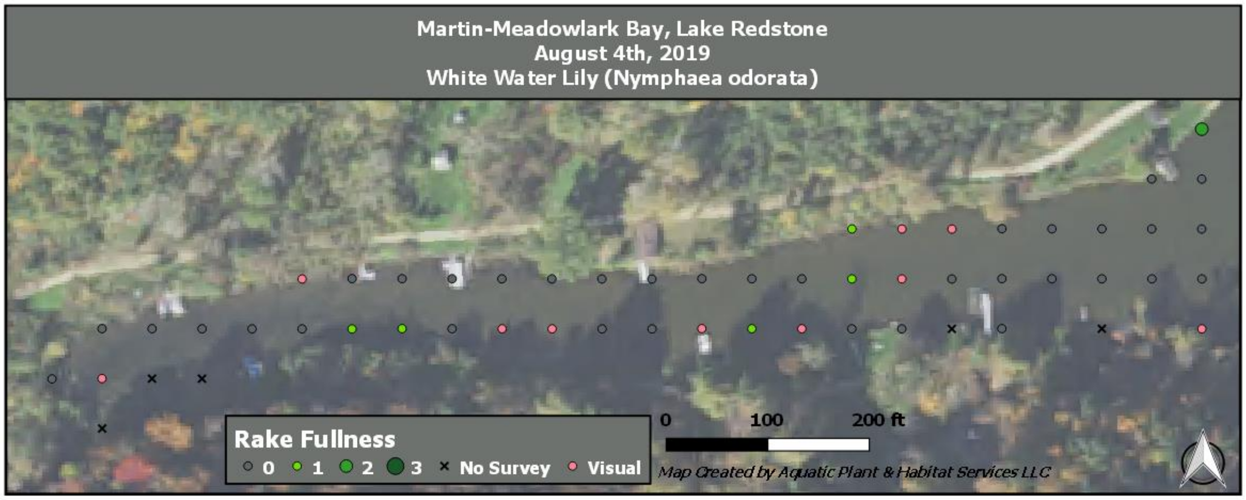


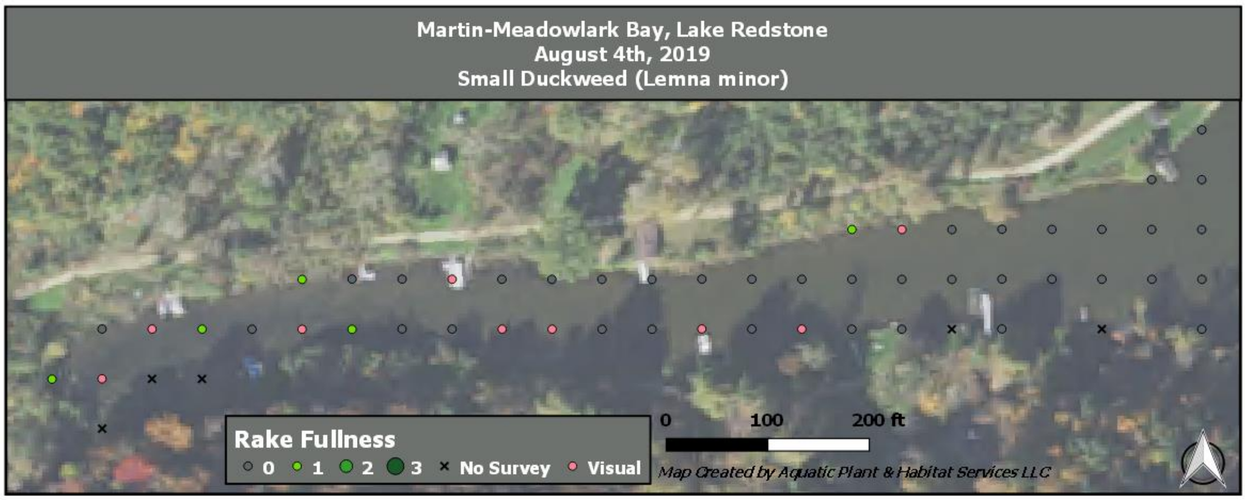


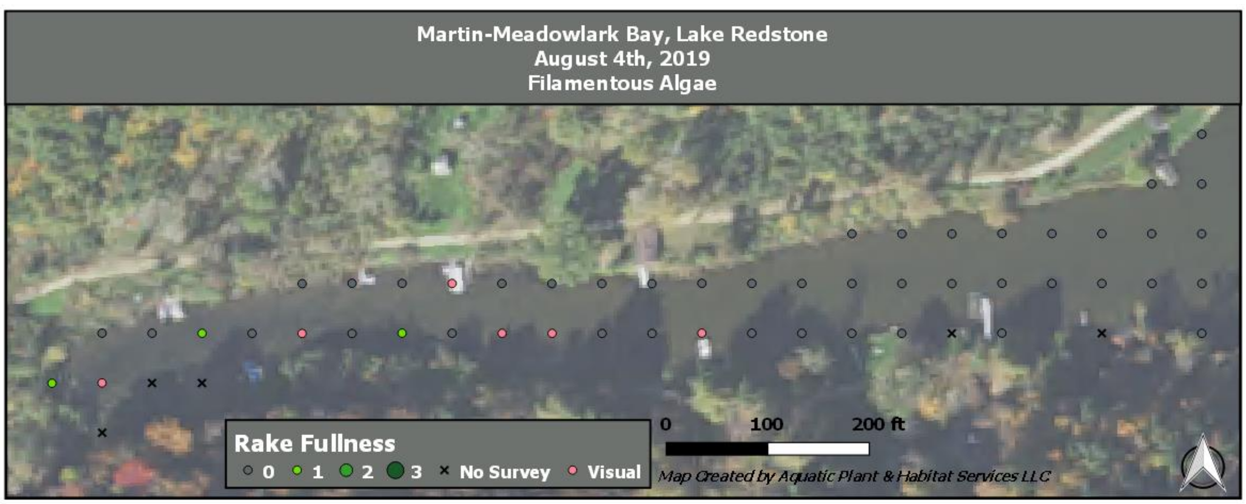
APPENDIX H – MARTIN-MEADOWLARK BAY MAPS



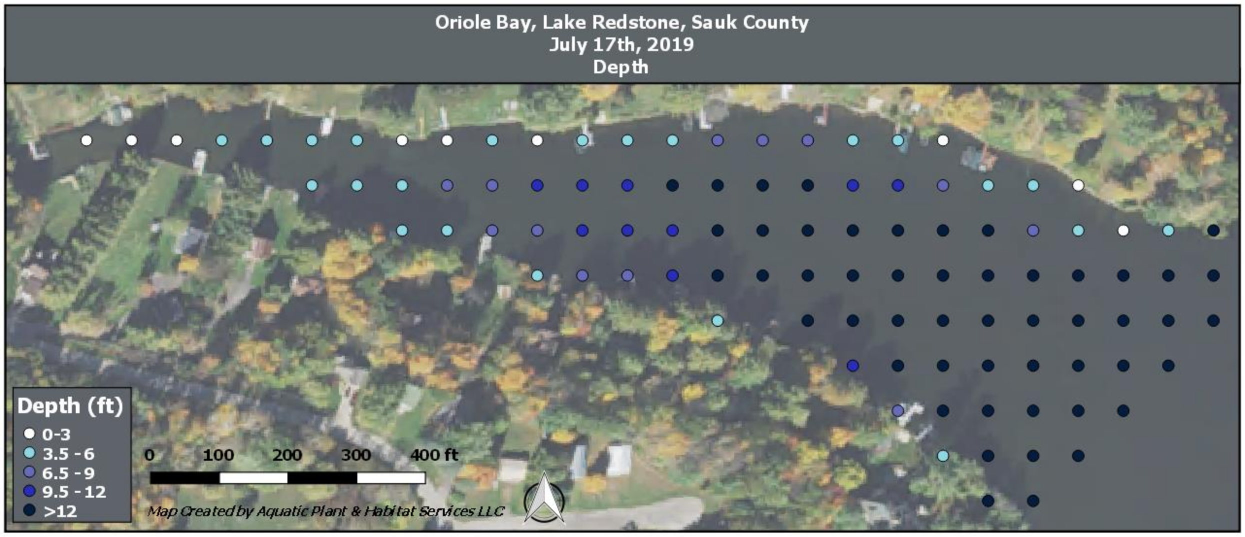


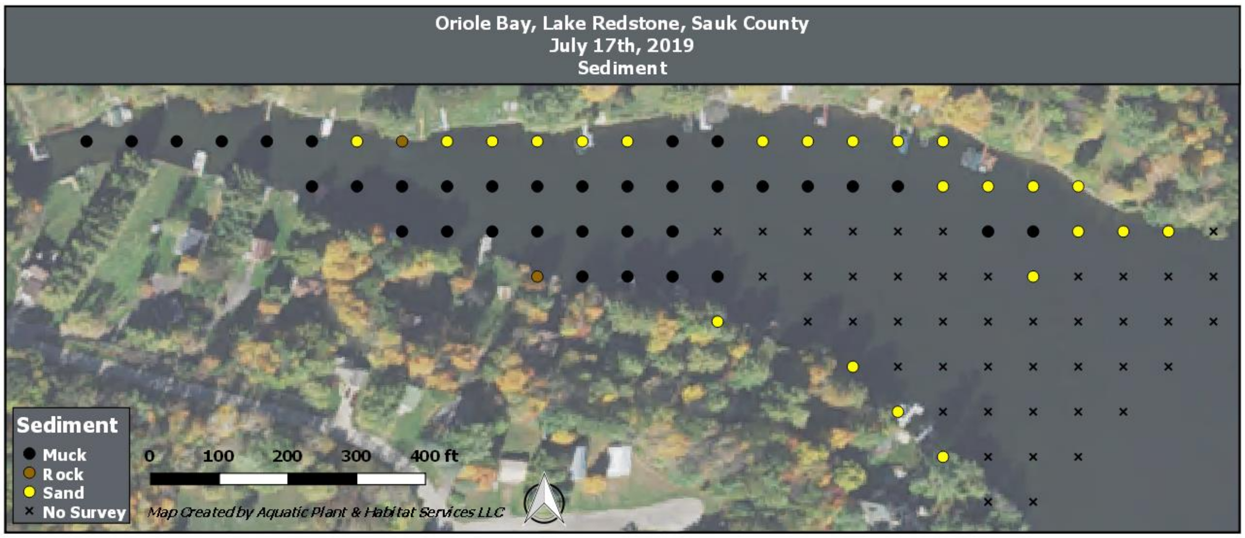

Martin-Meadowlark Bay, Lake Redstone
August 4th, 2019
White Water Lily (Nymphaea odorata)
Rake Fullness
0 1 2 3 No Survey Visual
0 100 200 ft
Map Created by Aquatic Plant & Habitat Services LLC

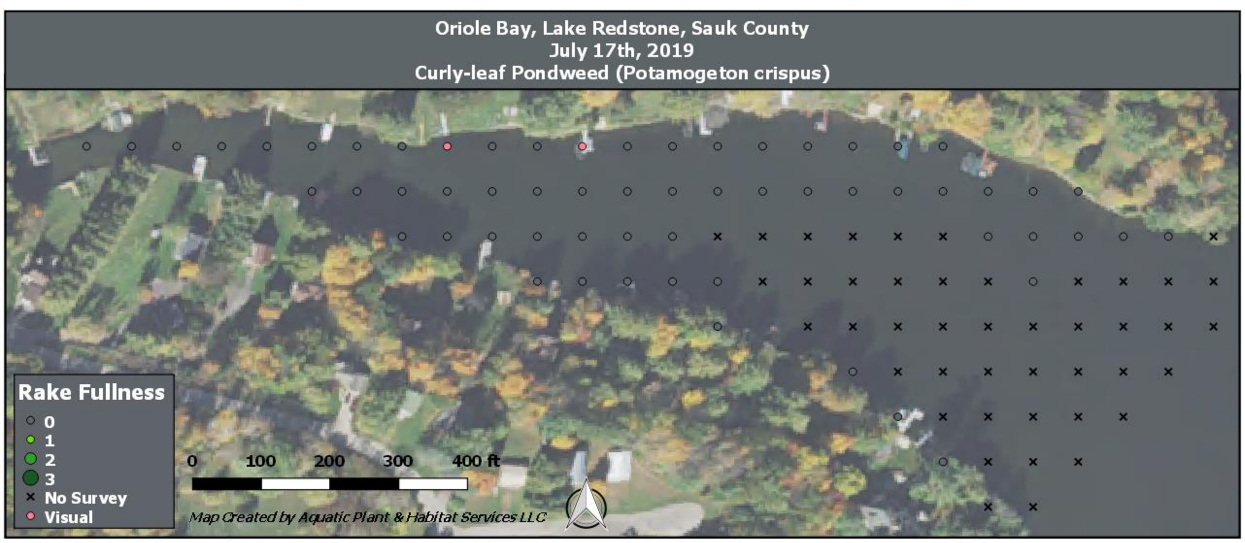

Martin-Meadowlark Bay, Lake Redstone
August 4th, 2019
Small Duckweed (Lemna minor)
Rake Fullness
0 1 2 3 No Survey Visual
0 100 200 ft
Map Created by Aquatic Plant & Habitat Services LLC

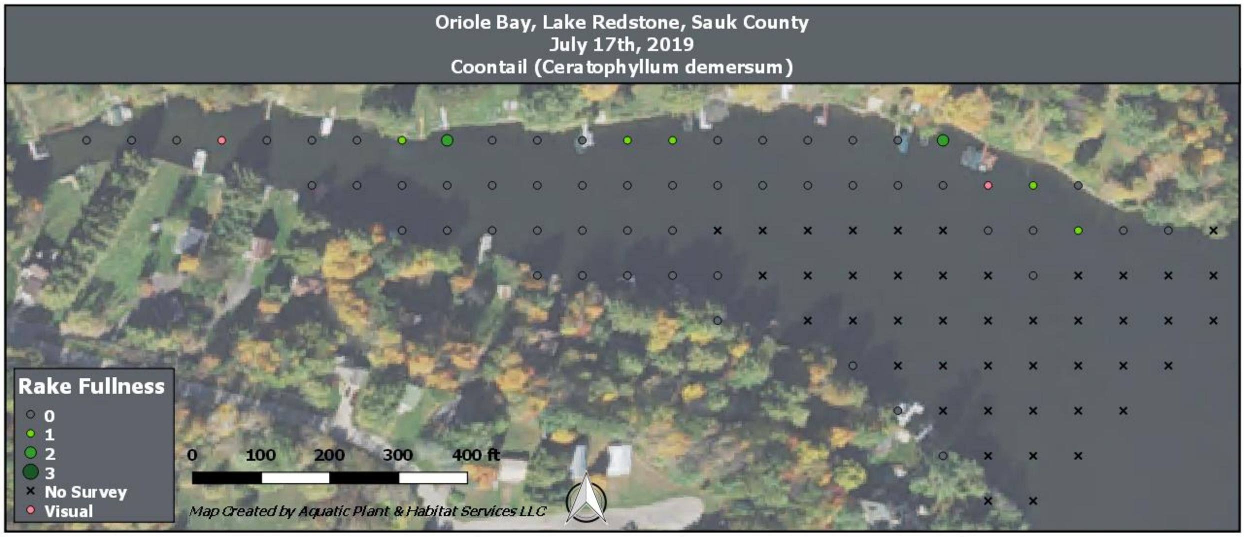

Martin-Meadowlark Bay, Lake Redstone
August 4th, 2019
Filamentous Algae
Rake Fullness
0 1 2 3 No Survey Visual
0 100 200 ft
Map Created by Aquatic Plant & Habitat Services LLC

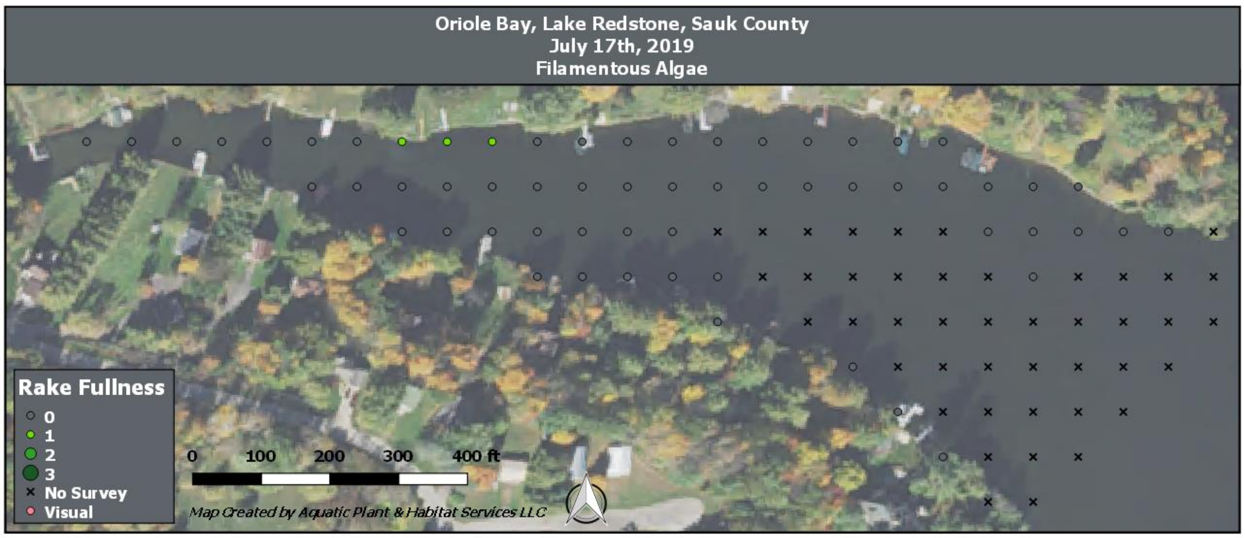
APPENDIX I – ORIOLE BAY MAPS

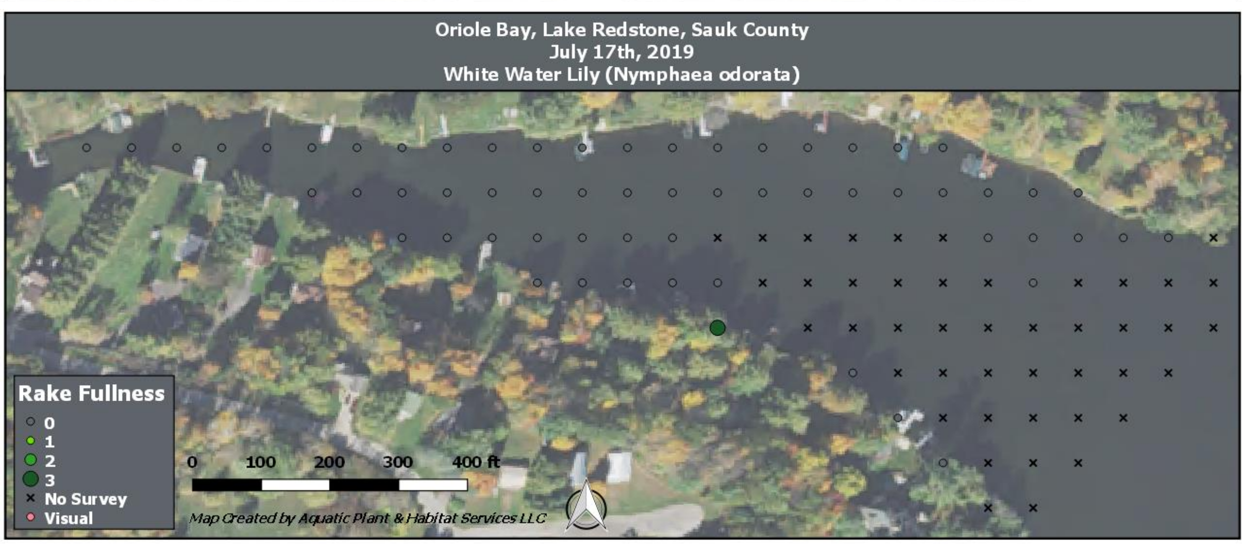


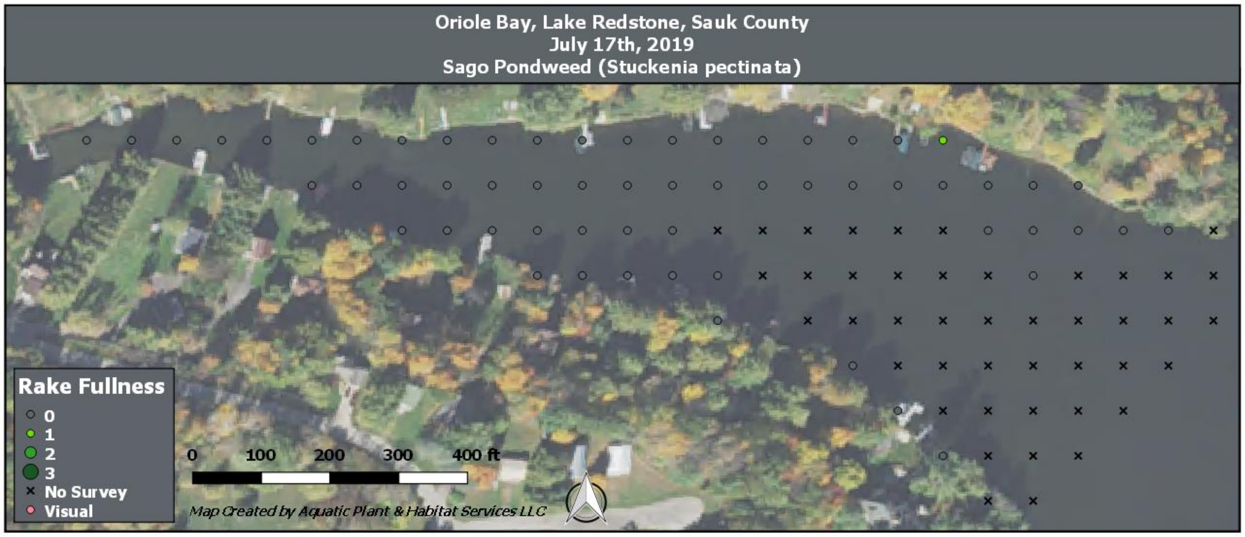




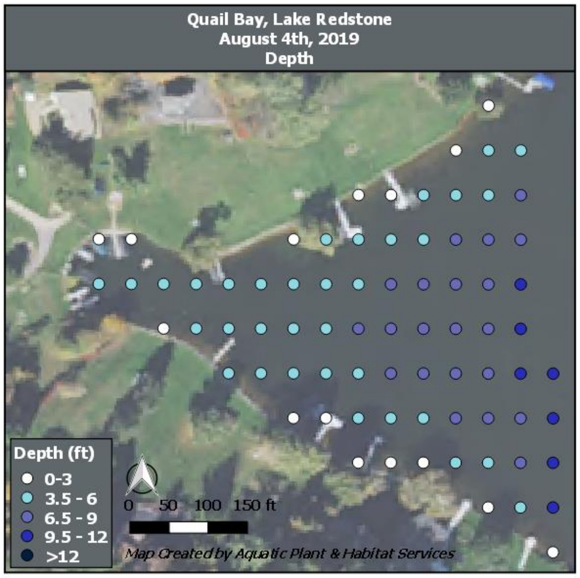

Oriole Bay, Lake Redstone, Sauk County
July 17th, 2019
Coontail (Ceratophyllum demersum)
Rake Fullness
0
1
2
3
No Survey
Visual
0 100 200 300 400 ft
Map Created by Aquatic Plant & Habitat Services LLC

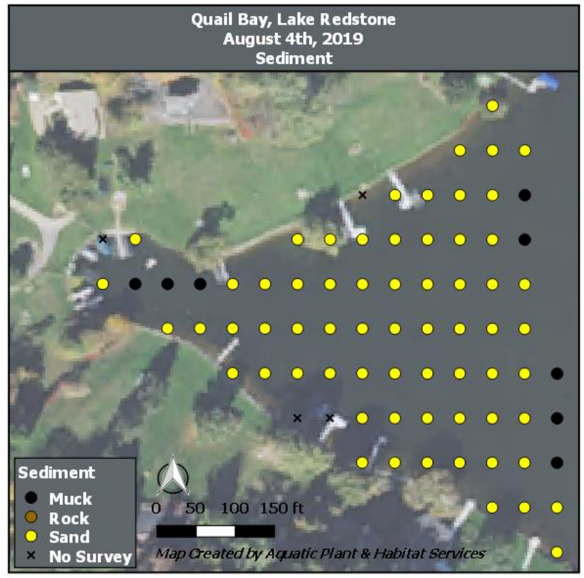

Oriole Bay, Lake Redstone, Sauk County
July 17th, 2019
Filamentous Algae
Rake Fullness
0
1
2
3
No Survey
Visual
0 100 200 300 400 ft
Map Created by Aquatic Plant & Habitat Services LLC

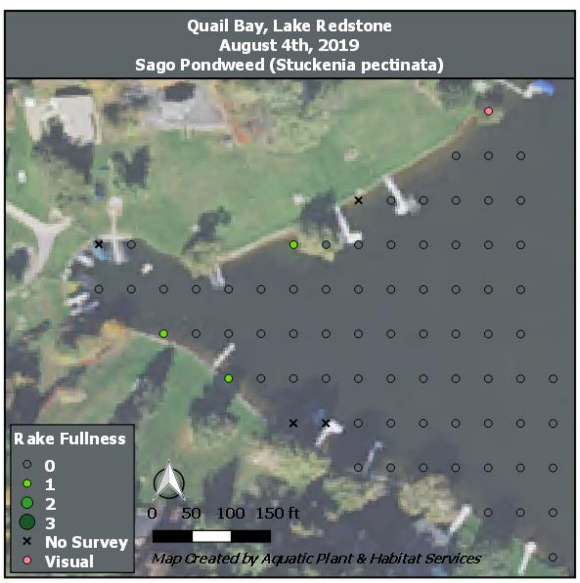

Oriole Bay, Lake Redstone, Sauk County
July 17th, 2019
White Water Lily (Nymphaea odorata)
Rake Fullness
0
1
2
3
No Survey
Visual
0 100 200 300 400 ft
Map Created by Aquatic Plant & Habitat Services LLC

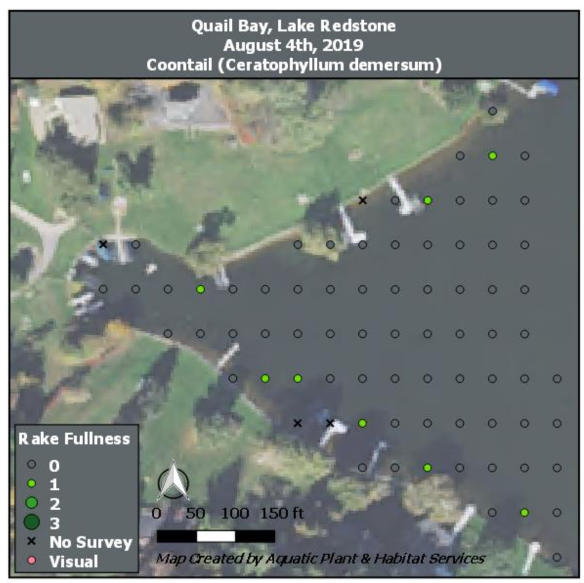

Oriole Bay, Lake Redstone, Sauk County
July 17th, 2019
Sago Pondweed (Stuckenia pectinata)
Rake Fullness
0
1
2
3
No Survey
Visual
0 100 200 300 400 ft
Map Created by Aquatic Plant & Habitat Services LLC

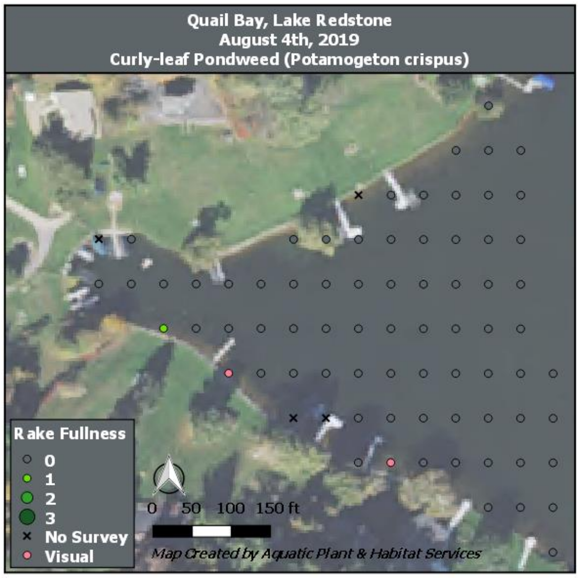
APPENDIX J – QUAIL BAY MAPS

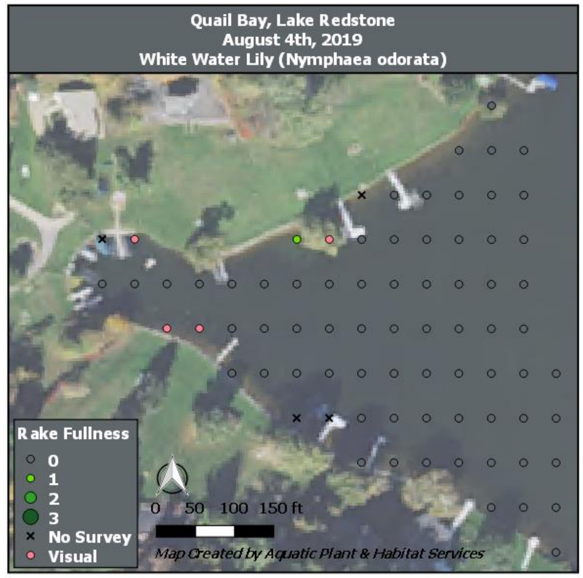


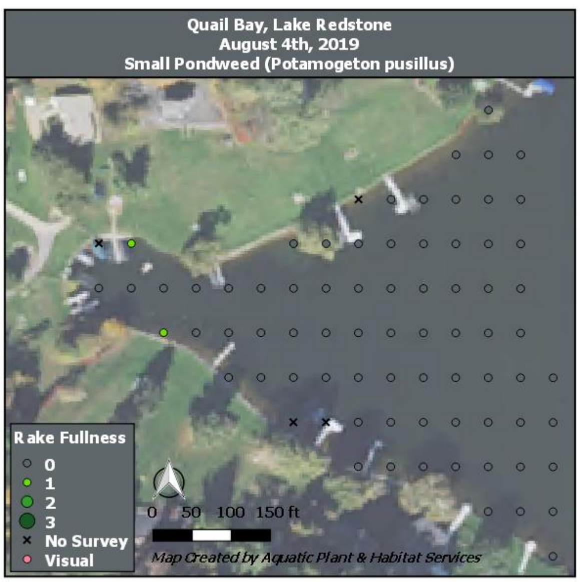


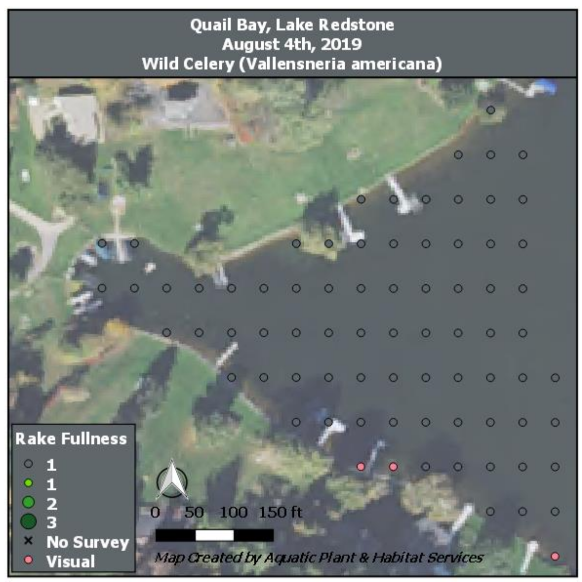




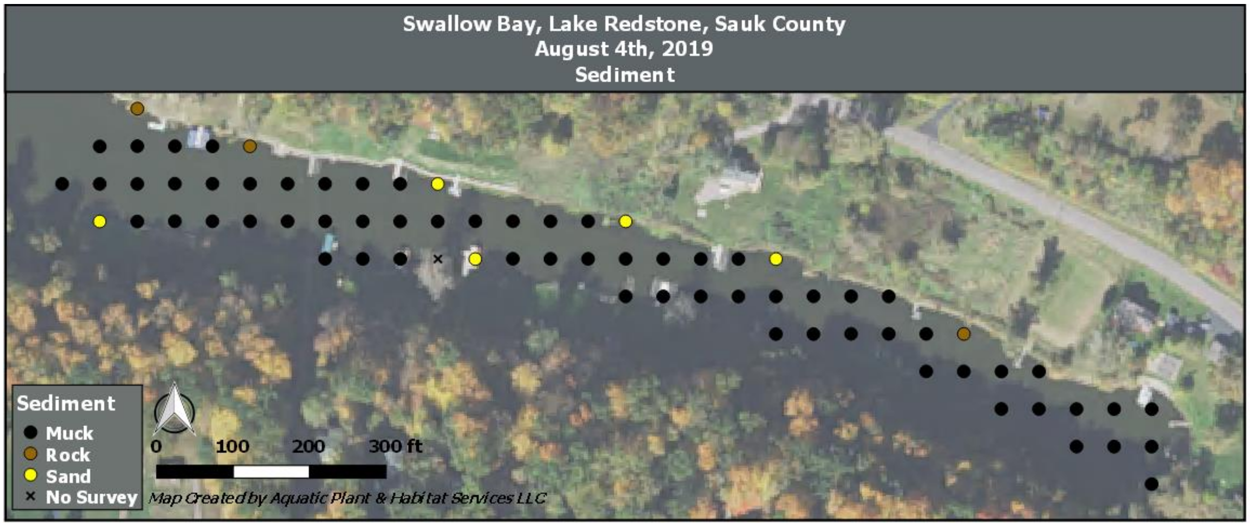

Quail Bay, Lake Redstone
August 4th, 2019
Curly-leaf Pondweed (Potamogeton crispus)
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services

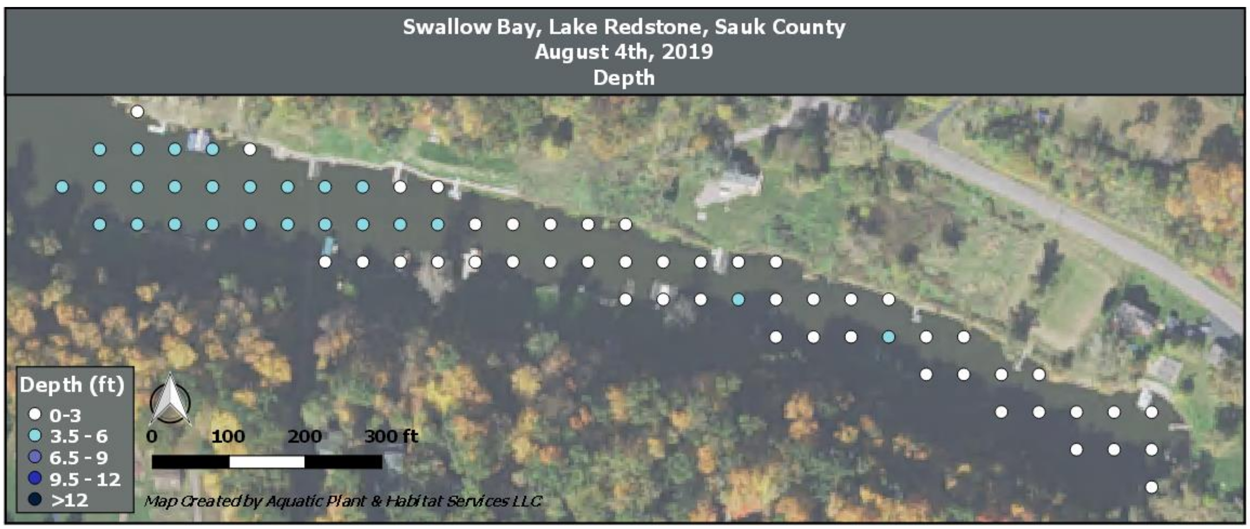

Quail Bay, Lake Redstone
August 4th, 2019
White Water Lily (Nymphaea odorata)
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services

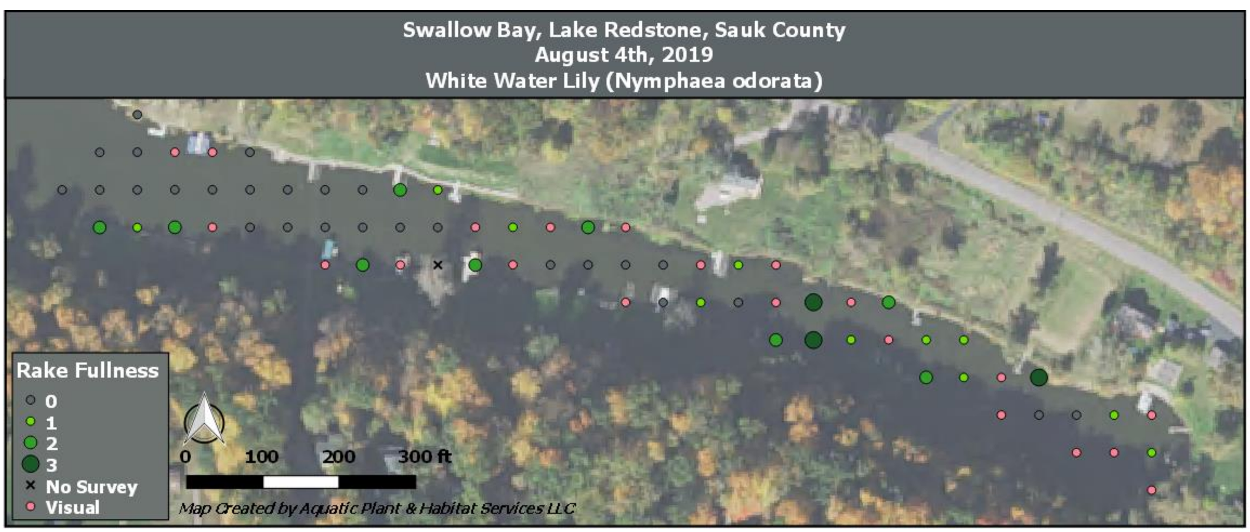

Quail Bay, Lake Redstone
August 4th, 2019
Small Pondweed (Potamogeton pusillus)
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services

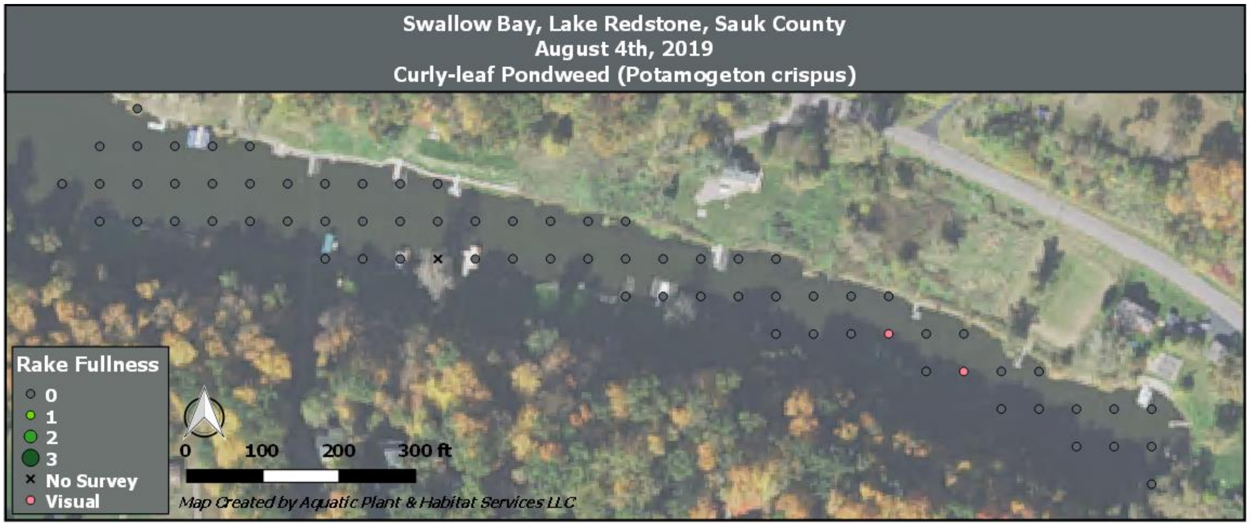

Quail Bay, Lake Redstone
August 4th, 2019
Wild Celery (Vallensneria americana)
Rake Fullness
1
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services

APPENDIX K – SWALLOW BAY MAPS



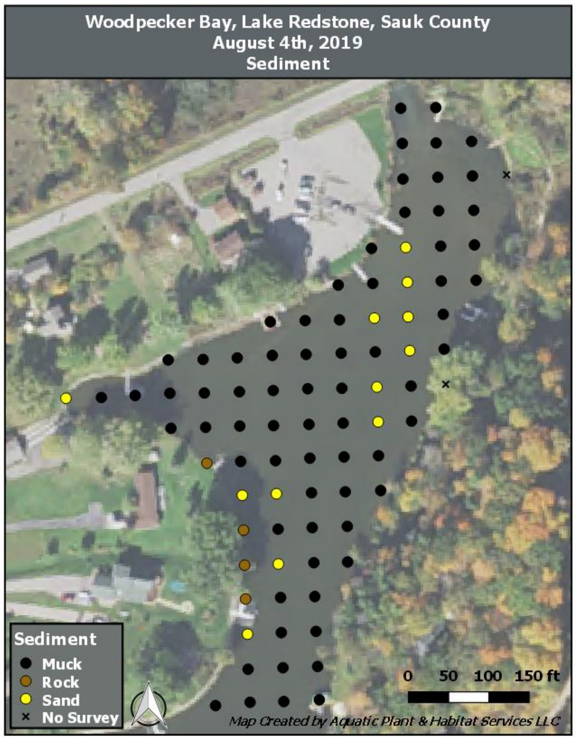


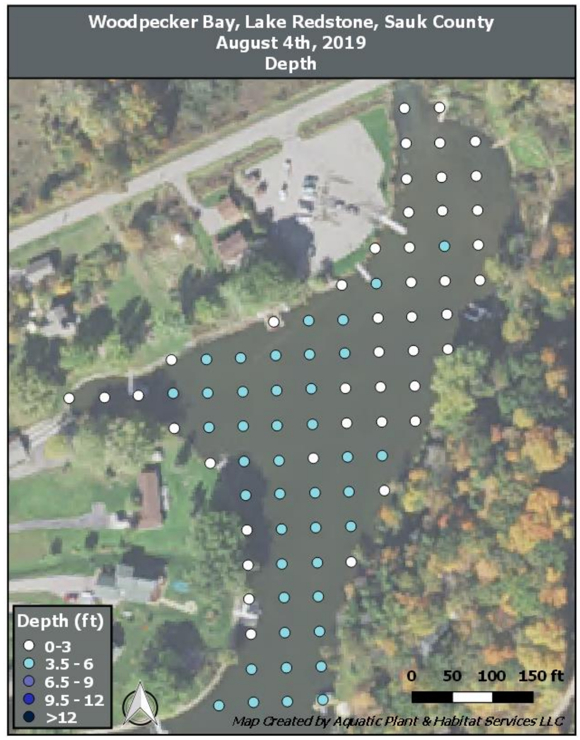


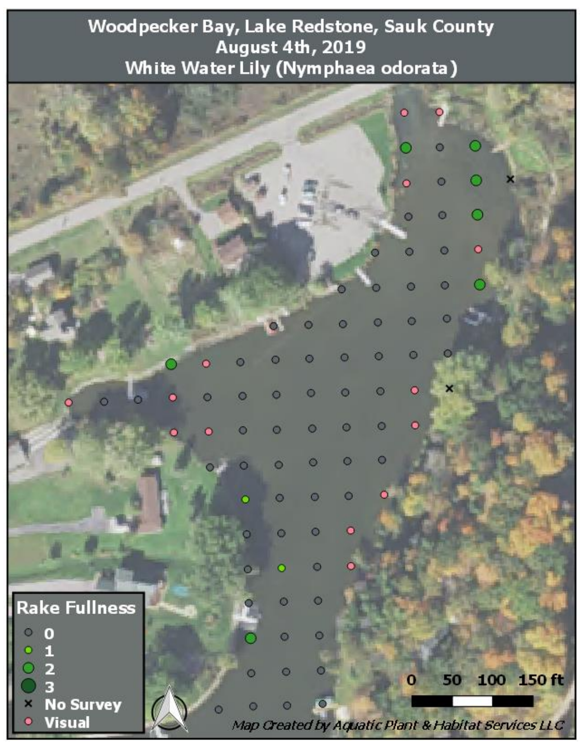

Swallow Bay, Lake Redstone, Sauk County
August 4th, 2019
Curly-leaf Pondweed (Potamogeton crispus)
Rake Fullness
0
1
2
3
No Survey
Visual
0 100 200 300 ft
Map Created by Aquatic Plant & Habitat Services LLC


Swallow Bay, Lake Redstone, Sauk County
August 4th, 2019
Filamentous Algae
Rake Fullness
0
1
2
3
No Survey
Visual
0 100 200 300 ft
Map Created by Aquatic Plant & Habitat Services LLC

APPENDIX L – WOODPECKER BAY MAPS








Woodpecker Bay, Lake Redstone, Sauk County
August 4th, 2019
Curly-leaf Pondweed (Potamogeton crispus)
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services LLC

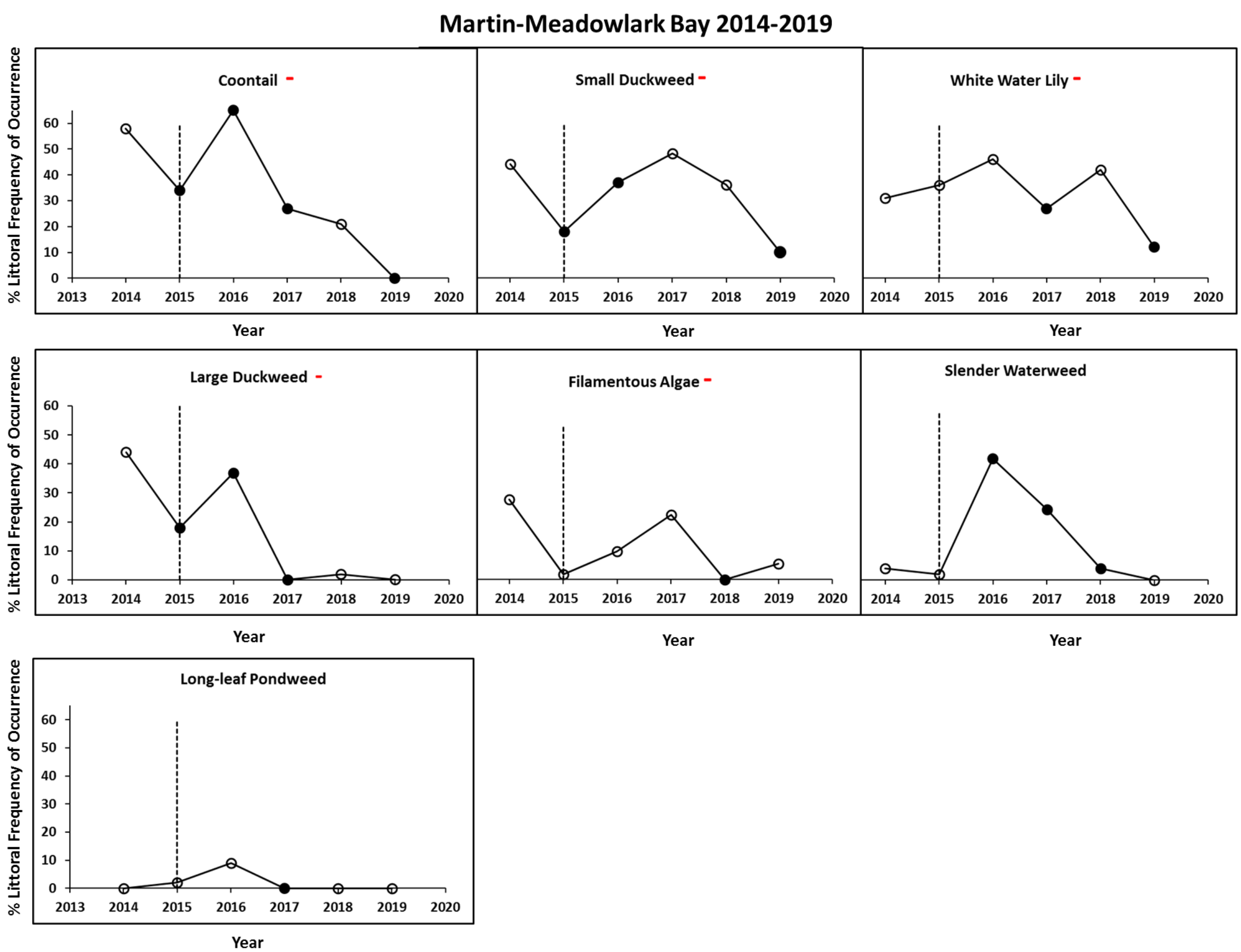

Woodpecker Bay, Lake Redstone, Sauk County
August 4th, 2019
Arrowhead (Sagittaria sp.)
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services LLC


Woodpecker Bay, Lake Redstone, Sauk County
August 4th, 2019
Filamentous Algae
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services LLC

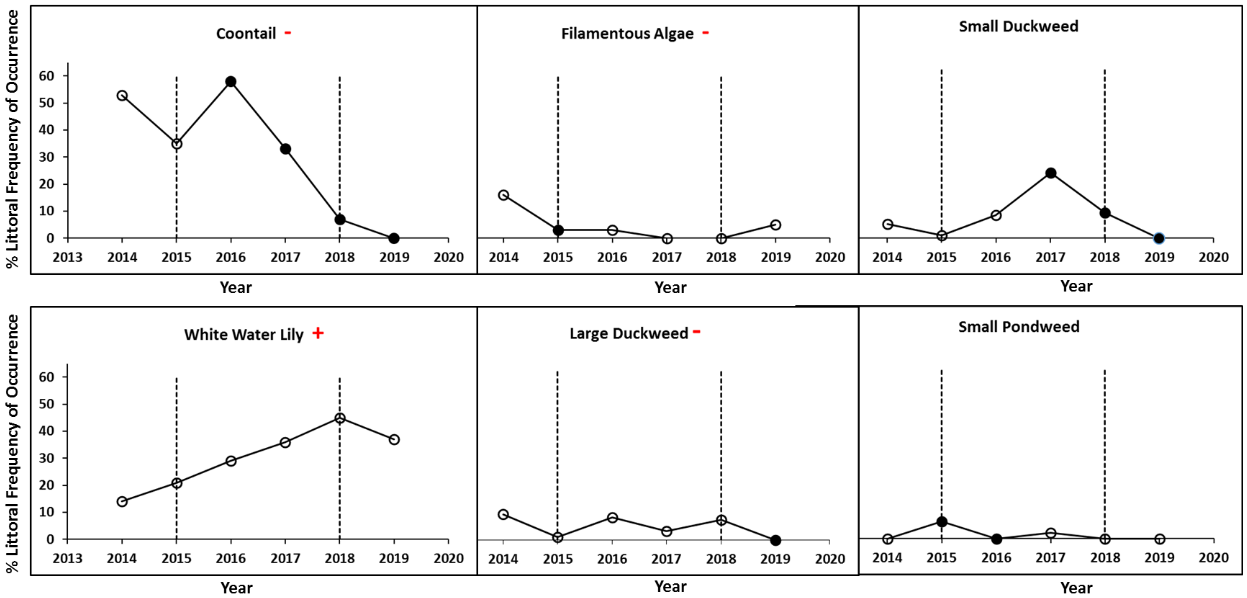

Woodpecker Bay, Lake Redstone, Sauk County
August 4th, 2019
Small Duckweed (Lemna minor)
Rake Fullness
0
1
2
3
No Survey
Visual
0 50 100 150 ft
Map Created by Aquatic Plant & Habitat Services LLC

APPENDIX M – CHI-SQUARED TEST GRAPHS

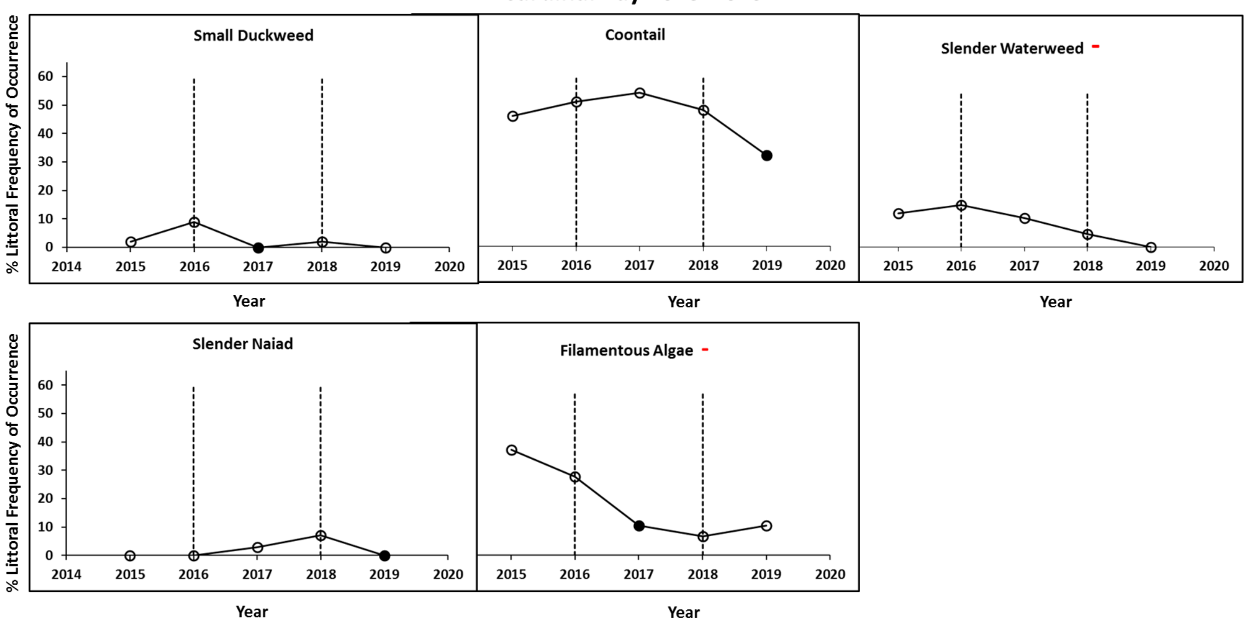
Percent littoral frequency (# sites plants found at points shallower than maximum rooting depth) is on the y-axis and each year a plant survey was completed is on the x-axis. Only species with a statically significant change (using Chi-squared tests) for at least one of the years are displayed. The dashed vertical lines represent years when herbicide treatments were done. Open circles represent ***no*** statistically significant change, solid circles represent a statistically significant change. Statistically significant changes between the first year of surveying and 2019 data are represented by **+** or **–** adjacent to plant names.



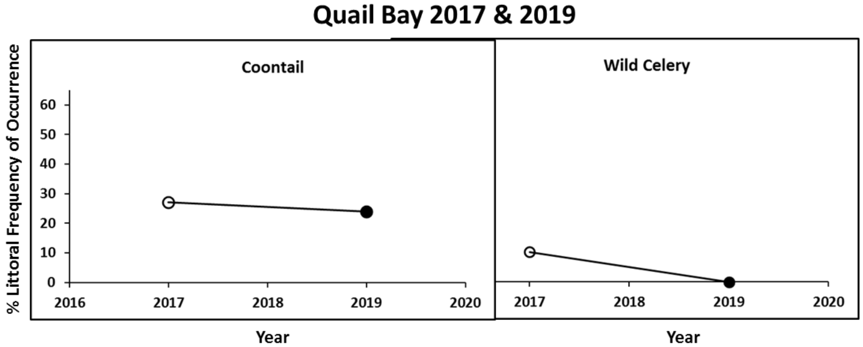
Swallow Bay 2014-2019



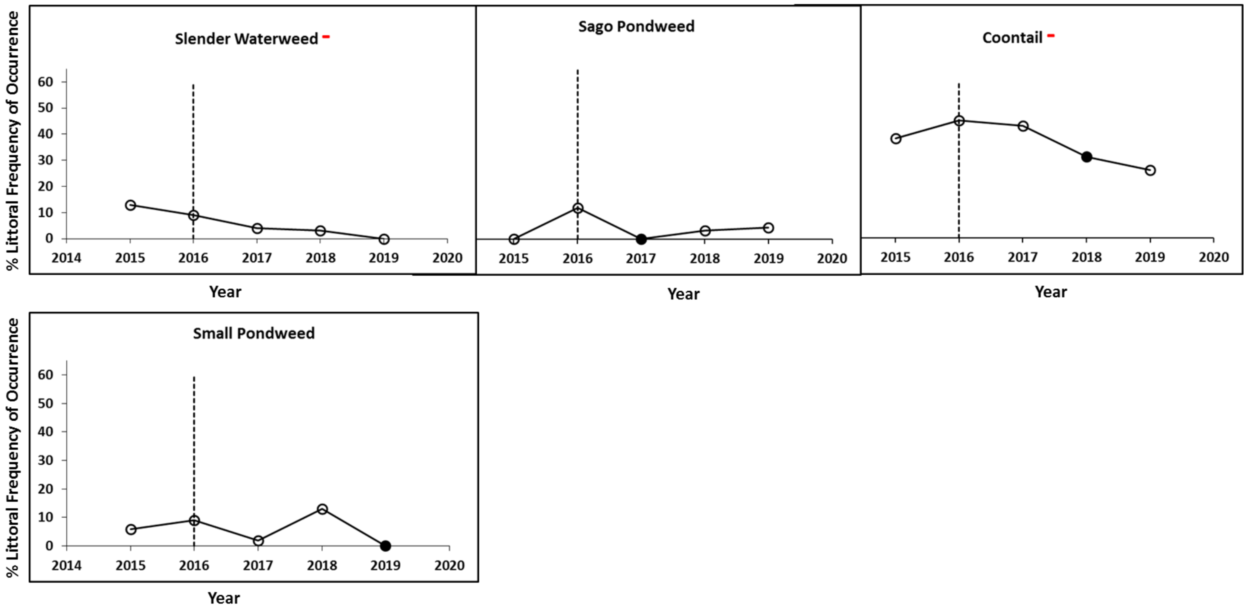
Cardinal Bay 2015-2019



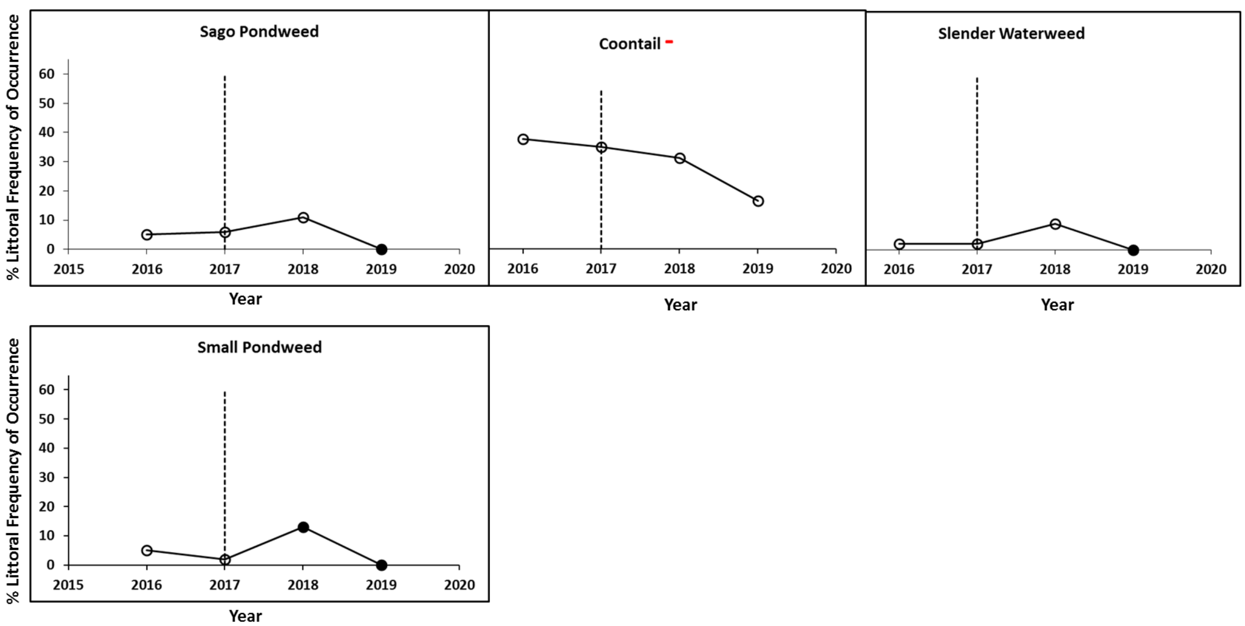
Quail Bay 2017 & 2019



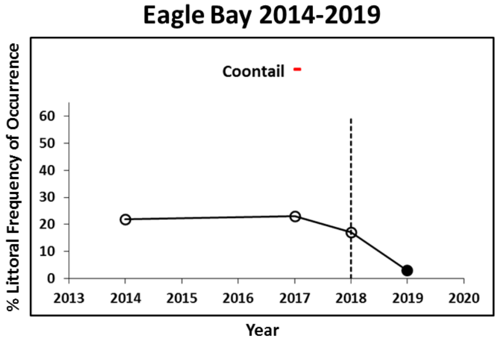
Oriole Bay 2015-2019



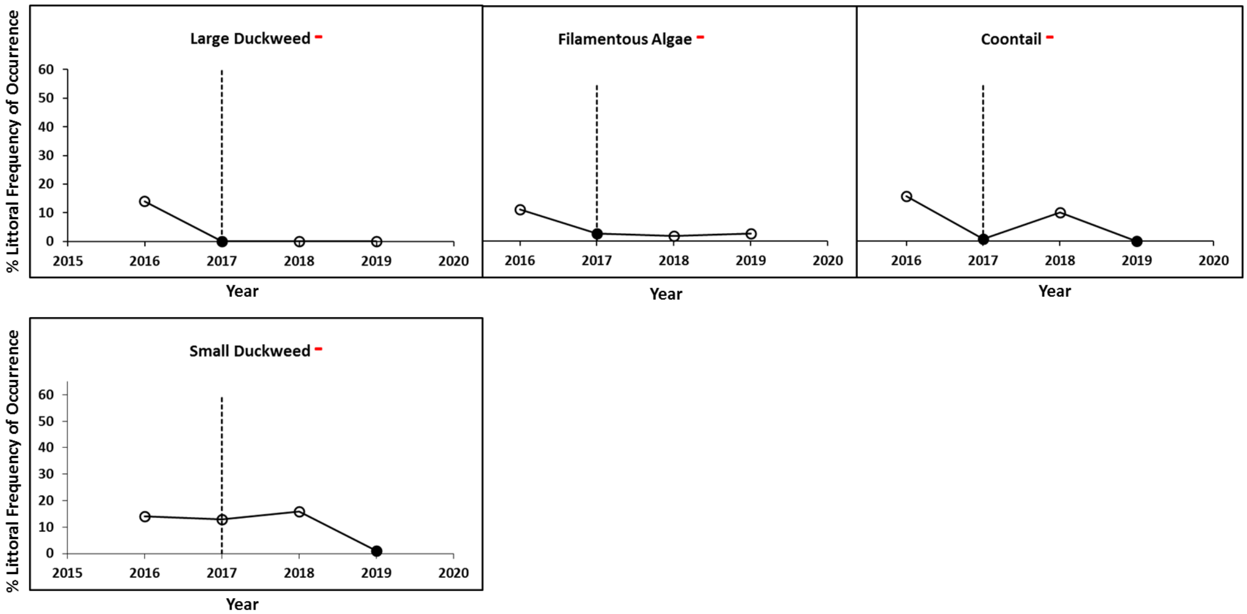
Hummingbird Bay 2016-2019



Eagle Bay 2014-2019



Woodpecker Bay 2016-2019



Chi-squared Test Results for Eurasian Watermilfoil