The Three Lakes Council

2018 Aquatic Macrophyte Surveys at Three Lakes

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2018 Aquatic Macrophyte Surveys at Three Lakes: Lake Waccabuc

The Three Lakes Council

Lewisboro, New York

Introduction

In 2018, the Three Lakes Council contracted SŌLitude Lake Management (SŌLitude) to map the aquatic plant growth and communities throughout each system of Three Lakes, specifically to document and manage any presence of Brazilian waterweed (*Egeria densa*). As a part of this three-lake system, located in Lewisboro, NY, Lake Waccabuc was infested with the invasive Brazilian elodea discovered in 2008. In response to this initial discovery, an intensive Diver-Assisted Suction Harvesting (DASH) program was implemented. **Regrowth of Brazilian elodea has not been documented since 2010.** With concern for the potential infestation from the two other waterbodies in the system (Lakes Oscaleta and Rippowam), as well as additional threats of other non-native aquatic growth, aquatic macrophyte surveys were performed at each lake in 2018 (See other report). Aquatic macrophyte surveys have been performed at Lake Waccabuc every year since 2008 (excluding 2009). This report includes the following: aquatic macrophyte abundance, distribution and discussion, as well as an evaluation of the Floristic Quality Index results and discussion. Maps from the aquatic macrophyte survey and aquatic macrophyte library are included in the appendix of this report.

Methodology

Point Intercept Submersed Aquatic Plant Mapping

The Point Intercept Method (PIM) of sampling macrophytes is designed to determine the extent of submersed aquatic plant growth within an area of concern. The total number of sample locations is typically based on the total acreage of a waterbody, where one sample location per acre is surveyed at a given site. However, the littoral zone is restricted to the shoreline and various coves of Lake Waccabuc. The point-intercept locations within the lake were determined by a 40-m grid data layer placed over an orthophoto bathymetric map of the lake and logged during the 2010 survey using a GPS unit with sub-foot accuracy. The logged points from 2010 have been revisited annually.

A total of 120 sites were sampled in Lake Waccabuc on July 20 and 31, 2018. During every survey, each predetermined georeferenced point was accessed by boat or canoe in a feasible order. At each point, the real-time GPS coordinates of the sample location were recorded using a Trimble Geo 7X, a handheld GNSS system.

The Point Intercept Methodology (PIM), developed by the US Army Corps of Engineers and modified by Cornell University was used for this survey (Lord and Johnson 2006). However, the referred methodology only requires one rake toss. At Lake Waccabuc **three rake tosses** were executed at each site, as with the previous surveys, for enhanced detection of target species and other species occurring infrequently. The tosses were conducted from opposite sides of the boat and were labeled and recorded A, B, and C respectively (Table 1). The following data was collected for each rake toss: overall abundance of floating and submersed macrophyte growth, relative abundance of each species, and any other pertinent field notes regarding the sample location. The abundance scale defined by this methodology was used to categorize the observed macrophyte growth for each rake toss:

Table 1: PIM Descriptions	
Abundance	**Description**
Z: Zero	no plants on rake
T: Trace	Fingerful on rake
S: Sparse	Handful on rake
M: Medium	Rakeful of plants
D: Dense	Difficult to bring into boat

The overall and relative abundance values from the three rake tosses were translated into a numeric value before further data analysis: 0 for no plants, 1 for trace, 2 for sparse, 3 for medium, and 4 for dense plants. For example, if toss A was Dense (4), toss B was Sparse (2), and toss C was Medium (3) for the same macrophyte, the mean abundance would be Medium (4+2+3=9/3=3). Raw abundance data with mean calculations can be found in Appendix A.

Any macrophyte specimen requiring further identification was collected and placed in a Ziploc-type bag with a reference to the sampled location. Regionally appropriate taxonomic keys were used for identification.

Lake Waccabuc

Macrophyte Abundance and Distribution

Table 2 provides the presence of all species from each survey year and the percent change from 2017 to 2018 per species. Graphs displaying the abundance and distribution from year to year for each macrophyte are located in Appendix.

Two invasive macrophytes were present during the 2018 survey: brittle naiad and Eurasian watermilfoil. Ranging from one to four invasive macrophytes found throughout the ten-year data set, Brazilian elodea has not been documented since 2008 and 2010 (2009 control management), and water chestnut was only documented in 2014. Since then no water chesnut has been found.

Comparing from 2017 to 2018, one non-native species in Lake Waccabuc had a positive percent change of 66.6%. The percent change for water chestnut and Brazilian elodea can be disregarded based on consistency of absence occurring from the surveyed locations (0.0%). Leaf pondweed had the highest positive percent change at 320.0%. Other aquatic macrophytes with substantial percent changes were floating bur-reed, small duckweed and arrowhead rosettes. Aquatic macrophytes that displayed negative percent changes were: common waterweed, creeping bladderwort, curly-leaf pondweed, Eurasian water milfoil, floating filamentous algae, quillwort, Robbin's pondweed, slender naiad, spatterdock, pondweed species and watershield.

Located in Table 2, the Type column is a quick classification of the macrophyte. Abbreviations are as follows: **A-Algae, E-Emergent, S-Submersed, F-Floating leaf or Free Floating.** The results of each species are discussed below. Red entries indicate invasive species and Green entries indicate algae species.

Table 2. 2008 – 2018: Aquatic Macrophytes

Common Name	Scientific Name	2008	2010	2011	2012	2013	2014	2015	2016	2017	2018	% Change
Arrowhead (rosette)	*Sagittaria graminea**	X	X	X	X	X	X	X	X	X	X	+71.4%
Bassweed	*Potamogeton amplifolius*	X	X	X	X	X	X	X	X	X	X	+11.4%
Benthic Filamentous Algae	-	X	X	X	X	X	X	X	X	X	X	+7.0%
Brazilian Elodea	*Egeria densa*	X	X									0.0%
Brittle Naiad	*Najas minor*		X	X		X	X	X	X	X	X	+66.6%
Common Waterweed	*Elodea canadensis*	X	X	X	X	X	X	X	X	X	X	-63.6%
Coontail	*Ceratophyllum demersum*	X	X	X	X	X	X	X	X	X	X	+23.3%
Creeping Bladderwort	*Utricularia gibba*	X	X	X	X	X	X	X	X	X	X	-42.9%
Curly-leaf Pondweed	*Potamogeton crispus*	X		X		X	X	X	X	X		-100.0%
Dwarf Watermilfoil	*Myriophyllum tenellum*	X	X	X	X	X	X	X	X	X	X	+100.0%
Eurasian Watermilfoil	*Myriophyllum spicatum*	X	X	X	X	X	X	X	X	X	X	-25.0%
Flat-stem Pondweed	*Potamogeton zosteriformis*	X										0.0%
Floating Bur-reed	*Sparganium fluctuans**							X		X	X	+100.0%

Floating Filamentous Algae	-	X	X	X	X	X	X	X	X	X	X	-64.3%
Great Duckweed	*Spirodela polyrhiza*				X	X	X	X	X		X	+
Leafy Pondweed	*Potamogeton foliosus*	X	X	X	X	X	X	X	X	X	X	+320.0%
Quillwort	*Isoetes sp.*									X		-100.0%
Ribbon-leaf Pondweed	*Potamogeton epihydrus*		X	X	X	X	X	X	X	X	X	+100.0%
Robbin's Pondweed	*Potamogeton robbinsii*	X	X	X	X	X	X	X	X	X		-100.0%
Slender Naiad	*Najas flexilis*			X						X		-100.0%
Small Duckweed	*Lemna minor*		X		X	X	X	X	X	X	X	+266.7%
Spatterdock	*Nuphar variegata*	X	X	X	X	X	X	X	X	X	X	-4.5%
Spiral-fruited Pondweed	*Potamogeton spirillus*	X	X	X	X	X						0.0%
Pondweed Species	*Potamogeton sp.**						X	X	X	X	X	-72.7%
Water Chestnut	*Trapa natans*						X					0.0%
Watermeal	*Wolffia columbiana*				X			X	X		X	+
Water Stargrass	*Zosterella dubia*		X	X	X	X	X	X	X	X	X	0.0%
Watermoss	*Fontinalis sp.**				X	X						0.0%
Watershield	*Brasenia schreberi*	X	X	X	X	X	X	X	X	X	X	-2.7%
White Water Lily	*Nymphaea odorata*	X	X	X	X	X	X	X	X	X	X	+6.1%

Table 1. Summary of the species collected/observed during each survey since 2008.

At Lake Waccabuc, 120 sites were assessed to determine the abundance and distribution of submersed and floating vegetation. Submersed vegetation was collected at 95 sites or at 79% abundance in the basin. Overall, 21 different aquatic plants (including benthic and filamentous algae) were observed. Two invasive aquatic plant species was found in Lake Waccabuc. Dense abundance of submersed macrophytes were supported at seven (or 7%) of the sites surveyed. Medium abundances were observed at ten sites (or 11%), while sparse amounts were present at 23 sites (or 24%). Trace abundances of submersed macrophytes was accounted for 55 sites (or 58%).

Eight floating macrophyte species were observed at Lake Waccabuc. A total of 64 sites (53%) supported floating macrophyte growth. Nuisance level abundances of floating macrophytes were present at 16 (or 25%) sites. Medium abundances were observed at 14 sites (or 22%) and sparse abundances were observed at 21 sites (or 33%). Trace amounts were accounted for at 13 (or 20%)

of the sites that contained floating macrophytes. The appendix contains additional information on each individual plant species.

The dominate submersed aquatic macrophyte was, Eurasian watermilfoil, a highly invasive submersed macrophyte, present at most sites (75 sites or 63%) throughout the survey. Trace abundances were present at 74 sites (or 99%) of the sites surveyed. Meanwhile, one site (1%) was observed at sparse levels, located around the island. The distribution of the Eurasian watermilfoil was scattered throughout the main shorelines.

Coontail, which was the second most common submersed macrophyte, was observed at 53 sites (or 44%) of the sites surveyed. Dense amounts of coontail was observed at two sites (4%), while one site was recorded at medium abundance (2%). Sparse abundances were observed at nine sites (or 17%) and trace abundances were observed at 41 sites (77%). The majority of the coontail occurrences were concentrated at the mouth of the canal and in the canal itself. Other areas were scattered with trace and sparse amounts throughout the shorelines.

A total of 46 sites (or 38%) of benthic filamentous algae was observed. Dense amounts were observed at two sites (4%) and medium abundances accounted for six (13%) of the sites surveyed. Sparse abundances of benthic filamentous algae were present at 11 sites (or 24%). Trace amounts were also observed at 27 sites (59%). Higher concentrations of benthic filamentous algae were observed at the northern cove and at the mouth of the canal.

Bassweed was observed throughout Lake Waccabuc at 39 sites (33%), but at fairly low abundances. Most of the sites made up of trace abundances (30 sites, or 77%). Sparse amounts were accounted for at five sites (13%). One site (3%) was observed at medium abundance, while three sites (8%) at dense abundances of bassweed were also recorded. Bassweed was scattered throughout the shorelines, decreasing in density towards the western end of the lake. Various abundances were distributed throughout the northern cove, southern shoreline, and mouth of the canal area.

Water stargrass, a desirable native species, was present at 30 sites (or 25%) at low abundances. Trace amounts were observed at 27 sites (or 90%) and three sites (10%) were observed at sparse levels. Most of the water stargrass was located towards the western end of the lake at low abundances, and higher abundances were located along the southern and southeastern areas of the lakes.

Leafy pondweed was observed at 21 (or 18%) of the sites surveyed. All sites were observed at trace abundances scattered along the northern and southern shorelines. Low abundances were present around the island and in the canal.

Arrowhead rosettes were observed along the shorelines at 12 sites (or 10%). At low abundances, the majority of the sites (11 or 92%), were considered to be trace. One site (8%) was observed at sparse abundance located along the northern shoreline. Low abundances were observed scattered throughout the shorelines.

Ribbon-leaf pondweed, a native species, was observed at eight sites at Lake Waccabuc. Trace amounts were observed at four sites (50%). One site (13%) was observed at sparse abundance and three sites (or 38%) were found at medium abundances. Robust communities of ribbon-leaf pondweed were observed in the canal. Ribbon-leaf pondweed were also observed at the eastern and western end of the lake.

A presence of a thin-leaf pondweed species was observed at six sites (5%) at trace abundances. Biologists suspect that this species is spiral-fruited pondweed, however, due to a lack of defining characteristics, such as seeds, they were unable to identify this pondweed down to species. This pondweed species was present in the northern cove, along the northwestern shoreline, scattered along the southern main shoreline, as well as at the mouth of the canal.

Brittle naiad, a low growing invasive species, was observed at five sites (4%) at trace abundances. This species was located scattered along the southern shoreline and one location along the northern shoreline.

Common waterweed was observed at four sites (3%) at trace abundances. This native species was present in the northern cove and along the northern shoreline towards the mouth the canal.

Creeping bladderwort, a free-floating species often found at the surface, was observed at four sites (3%). Three sites were identified at trace abundances, while the remaining site was considered sparse. Concentrations of this population was observed in the canal, with abundances increasing outside of the canal along the eastern shoreline.

Dwarf water milfoil was accounted for at two sites (2%) at trace abundances. Dwarf milfoil continues to occur at the northwestern end of the lake where it has historically occurred, in addition to the other site located along the northeastern cove towards the canal.

White water lilies were observed at 52 sites (or 43%) of the sites surveyed. A number of sites were considered to have nuisance level abundance. Dense abundances were observed at seven sites (13%) and medium abundances were present at six sites (12%). Sparse abundances were recorded at 13 sites (25%) and trace abundances were observed at 26 sites (50%). Scattered throughout the basin, the majority of the white-water lilies were concentrated in the area outside of the canal. Heavier densities were scattered throughout towards the western and northern areas of the lake.

Watershield, often mixed in with other lily species, was observed at 36 sites (30%) at various abundances. Dense abundances were observed at three sites (8%) and medium abundances were found at nine sites (25%) of the sites surveyed. Sparse and trace amounts were evenly distributed through 12 sites (33%) each. Heavier populations occurred at the eastern end of the lake and lighter abundances were present at the opposite end of the lake.

Spatterdock, also known as yellow lily, was observed at 21 sites (or 18%). Nuisance levels were observed at dense abundances (three or 12%) and medium abundances at one (or 5%) sites. Sparse amounts were recorded at seven (33%) sites and trace abundances occurred at ten (or 48%) sites. Spatterdock was present throughout the eastern end of the lake mixed in with other lily species. Densities decreased along the shorelines approaching towards the western end of the lake.

Common watermeal was observed at 11 sites (9%) at low abundances. Trace amounts were observed nine (82%) sites and sparse abundances were observed at two sites (18%). Watermeal was present in the canal leading out into the open water just outside of the canal area. An abundance of watermeal was located in the northern cove at two sites.

Small duckweed, often mixed in with common watermeal, was observed at 11 sites (9%) at Lake Waccabuc. The majority of these sites were found at non-nuisance levels. Trace abundances were documented at ten sites (91%) and sparse abundances were observed at one site (9%). Small duckweed was observed in the canal and scattered throughout the opening to the canal. Two locations were also recorded in the northern cove.

A total of ten sites (or 8%) of floating filamentous algae were observed. One dense site (10%) was accounted for and one sparse site (10%) was recorded. Trace amounts of filamentous algae supported eight sites (80%). Filamentous algae were observed along the northeastern shorelines and southeastern shorelines. Heavier populations were observed in the north cove.

Great duckweed was observed at six (5%) of the sites surveyed. Trace abundances were observed at four sites (67%), while two other sites were observed at sparse abundance. Great duckweed was observed in the canal and just outside of the canal area. Sparse amounts were recorded in the north cove.

Floating-leaf bur-reed was observed at two sites (2%) at low abundances. One site recorded at trace abundance (50%) and the other site (50%) supported sparse abundances. Bur-reed was located in the canal at Lake Waccabuc.

Floristic Quality Index Results (FQI):

In order to determine the 'naturalness' of the sites examined and to evaluate the structures of plant communities, a methodology called the Floristic Quality Index (FQI) can be used to quantify this. A panel of botanists go through wetland, terrestrial and aquatic macrophytes to assign a Coefficient of Conservatism (CC) numerical value. Botanists in the Northeast recently re-evaluated and organized these values into regional scales, verses using individual state developed lists. These scales are based on the plants' ecological tolerance within their vegetative communities, which is further explained in Table 2 below. All CC values for this project were derived from FQI

database, based on the location of the site (Freyman, 2016). These CC lists are generally re-evaluated and updated every 5 to 7 years. Due to the intended use of this methodology, mostly for wetland and terrestrial systems, some aquatic macrophytes are not present in the lists they developed. Therefore, numbers were assigned to them in order to complete the formulas, by making an educated guess.

Table 3: Definitions of Co-efficient of Conservatism (CC)

Co-efficient of Conservatism	Definitions
0	Invasive species; low tolerance
1 – 3	Native bordering invasive level or widespread native, not a typical part of plant community
4 – 6	Native with an intermediate or narrow range of tolerances; May persist under some anthropogenic disturbances.
7 - 10	Native community with a very narrow range of tolerances, sensitive to anthropogenic disturbances

Source: (New England Water Interstate Water Pollution Control Commission, 2013)

For organizational purposes, the calculated average percent value of the CC was defined into three sections (shown in Table 3) to report the results, as well as following along with the definitions in Table 3. Total richness, being the aquatic macrophyte diversity, was accounted for per year. The number of native species, invasive species, as well as the percentages were calculated.

The following formulas listed below in Table 4 include examining more in-depth about the calculations of native and invasive species. The FQI formula calculates the native species only. The total mean C, is also known as the average for both native and invasive species. Total N represents the entire number of species in the equation. Native mean C is representative of the average coefficient value of the native species within that year. Native N is the number of native species present within that system. The total number of species was counted, along with breaking down the number (and percentage) of native species and non-native species.

Table 4: FQI Metrics Definitions:		
Metric	**Description**	**Definition**
Total Mean C	$I = \overline{C}\sqrt{n}$	Mean C value for both native and non-native species
Native Mean C	Average (C_{Native})	Mean coefficient value of native species
Total FQI	Average (C_{Native} and $C_{Non\text{-}Native}$)	Only native species
Total N	Number of Native species + Number of Non-native specie	Total number of species

Source: (Mid-Atlantic Wetland Working Group, 2019)

Below is a list of all the aquatic macrophytes present over the years with the assigned Co-efficient of Conservatism (CC) values. Those with asterisks in Table 5 indicate a Solitude Lake Management Biologist assigned a number as it was not available on the list botanists developed. Algae or macroalgae species were not included in these formulas, due to these species not being "true aquatic macrophytes", according to the FQI index. Each year based on the presence of the aquatic macrophyte CC the following values were calculated to determine the results utilizing the formulas above.

Table 5: Aquatic Macrophyte Co-efficient Conservatism Values			
Aquatic Macrophyte	**Scientific Name**	**Coefficient Conservatism (CC)**	**Type**
Arrowhead (rosette)	*Sagittaria graminea**	7	S
Bassweed	*Potamogeton amplifolius*	7	S
Benthic Filamentous Algae	-	-	A
Brazilian Elodea	*Egeria densa*	0	S
Brittle Naiad	*Najas minor*	0	S
Common Waterweed	*Elodea canadensis*	4	S
Coontail	*Ceratophyllum demersum*	4	S
Creeping Bladderwort	*Utricularia gibba*	7	S
Curly-leaf Pondweed	*Potamogeton crispus*	0	S
Dwarf Water Milfoil	*Myriophyllum tenellum*	8	S
Eurasian Water Milfoil	*Myriophyllum spicatum*	0	S
Flat-stem Pondweed	*Potamogeton zosteriformis*	6	S
Floating Filamentous Algae	-	-	A
Floating Bur-reed	*Sparganium fluctuans**	8	S
Great Duckweed	*Spirodela polyrhiza*	3	F
Leafy Pondweed	*Potamogeton foliosus*	5	S
Quillwort	*Isoetes lacustris **	9	S
Robbin's Pondweed	*Potamogeton robbinsii*	5	S
Ribbon-leaf Pondweed	*Potamogeton epihydrus*	5	S
Slender Naiad	*Najas flexilis*	4	S
Small Duckweed	*Lemna minor*	2	F
Spatterdock	*Nuphar variegata*	4*	F
Spiral fruited Pondweed	*Potamogeton spirillus*	6	S

Pondweed Species	*Potamogeton sp.*	5*	S
Waterchesnut	*Trapa natans*	0	F
Watermoss	*Fontinalis sp.*	5*	S
Watermeal	*Wolffia columbiana*	3	F
Water Stargrass	*Zosterella dubia*	6	S
Watershield	*Brasenia schreberi*	6	F
White Water Lily	*Nymphaea odorata*	5	F

-Red indicates an invasive species and green indicates an algae species.

Table 6: 2008 – 2018 Lake Waccabuc FQI Results

FQI Results	2008	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total Avg C:	4.6	4.3	4.6	4.8	4.5	4.2	4.5	4.3	4.8	4.8
Native Avg C:	5.7	5.4	5.5	5.1	5.2	5.2	5.2	5.1	5.6	5.4
Total FQI:	18.4	18.7	19.5	20.9	20.1	18.8	20.6	19.2	22.0	20.9
Native FQI:	20.6	20.9	21.3	21.6	21.4	20.8	22.1	21.0	23.8	22.3
% C value 0:	18.8	21.1	16.7	5.3	15.0	20.0	14.3	15.0	14.3	10.5
% C value 1-3:	0.0	5.3	0.0	15.8	10.0	10.0	14.3	15.0	4.8	15.8
% C value 4-6:	56.3	52.6	61.1	57.9	55.0	50.0	47.6	50.0	52.4	47.4
% C value 7-10:	25.0	21.1	22.2	21.1	20.0	20.0	23.8	20.0	28.6	26.3

Table 7: 2008 – 2018 Lake Waccabuc Richness Results

Richness	2008	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total Richness:	16	19	18	19	20	20	21	20	21	19
Native Species:	13 (81.3%)	15 (78.9%)	15 (83.3%)	18 (94.7%)	17 (85%)	16 (80%)	18 (85.7%)	17 (85%)	18 (85.7%)	17 (89.5%)
Invasive Species:	3 (18.8%)	4 (21.1%)	3 (16.7%)	1 (5.3%)	3 (15%)	4 (20%)	3 (14.3%)	3 (15%)	3 (14.3%)	2 (10.5%)

FQI Results Discussion:

The species richness per year was fairly similar from 2010 through 2018, with an outlier of 16 species recorded in 2008 (Table 7). Species richness over the ten years of data averages out to n=19.3. High percentages of native species year per year remained greater than 78.9% with an average of n=16.4 species in the past ten years. Years with the highest number of invasive species were recorded in 2010 and 2014. An average number of invasive macrophytes (n=2.9) was derived from the data set. In 2012, there was only one invasive species observed and this also was the year with the highest native species percentage at 94.7%. It's possible that such a robust native community could have been outcompeting the invasive species during that time. In comparison to 2014, there were four invasive species, being the highest number of invasive macrophytes observed at Lake Waccabuc in the last ten years. However, curly-leaf pondweed could have impacted the FQI results, as this is a typical seasonally influenced invasive species that occurs.

The overall richness, number of native species and invasive species in the yearly plant assemblages are very consistent. A slight increase was observed in 2017 with a record of 21 aquatic macrophytes observed out of the data set. The year with the least amount of diversity was observed in 2008 and the year with the most was recorded during the 2017 survey. In 2012, 2015 and 2017 were the years with the highest native species observed.

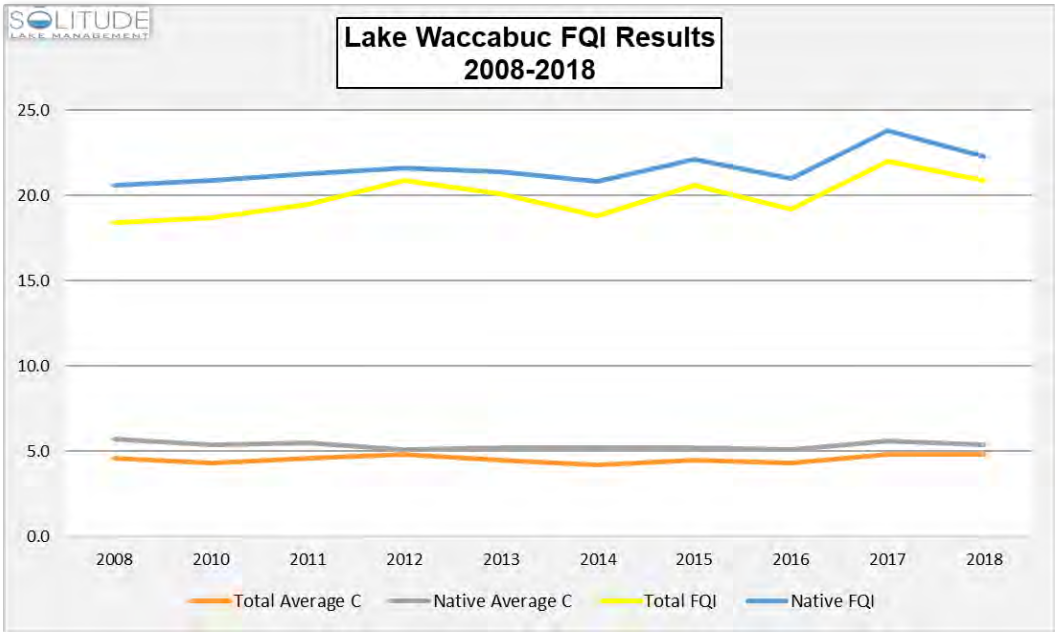

Figure 1. FQI Results Lake Waccabuc 2008 – 2018

The total average FQI remained steady throughout the ten-year data set. As displayed on Figure 1 there was little variation between the results, as one would expect these results to be slightly higher as they are solely viewing natives in this formula, which averaged out at n=5.3 over the entire data set. Both native FQI and total FQI results were nearly identical, with the total FQI being slightly lower. Therefore, this formula provides another avenue in viewing this data. As displayed, it continues to show minimal variation.

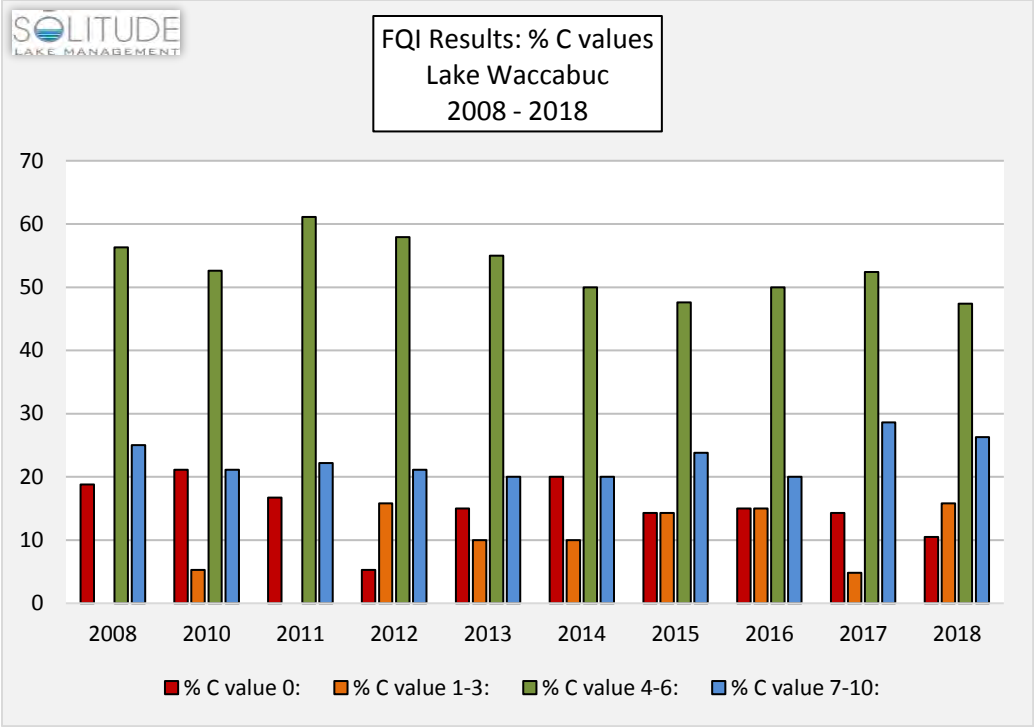

Figure 2. FQI Results: % C Values – Lake Waccabuc – 2008 – 2018

Based on the dataset, the percent average value for zero generated at <21.1% for invasive species. The average percent values of 1 - 3 calculated out at <15.8% and was present for every year, except for 2008 and 2011. Its possible conditions were not suitable those years for that valued set of macrophytes. While the average percent values of 4 – 6 was <61.1%, this being consistently the highest percentages out of the rest of the average percent values. In other words, most of the aquatic macrophytes in the assemblages per year was comprised of CC values ranging from 4 – 6. The average percent values of 7 – 10 was <28.6%, as shown on Figure 2, these valued species have been fairly consistent throughout the last ten years. Based on these results it seems that natural variation is apparent throughout the data, with slight fluctuations from year to year. Water temperatures and other suitable conditions are more than likely influencing the seasonal variations of growth within these plant communities. Overall, the aquatic macrophyte community at Lake Waccabuc is stable.

Summary of Findings

- Eurasian watermilfoil growth and continues to be the most dominant macrophyte within Lake Waccabuc.
- **No Brazilian elodea and water chestnut were found.** For the eighth consecutive year, no Brazilian elodea was collected or observed and for the fourth year no water chestnut was collected or observed.
- Two non-native macrophytes were documented during the 2018 survey: Eurasian watermilfoil and brittle naiad.

- Consistent with the last few survey years, white waterlily continues to be the dominant floating-leaf macrophyte within Lake Waccabuc.
- Macrophyte diversity increased after 2008, and has remained relatively consistent since.
- Lake Waccabuc has maintained overall high species diversity and supported a suitable water clarity of 1.55 meters on the sampling date.
- Overall, FQI values are considered to be favorable and have displayed only natural variation as we would expect occurring among the ten-year data set.
- The year with the least amount of diversity was 2008 and the year with the most was recorded during the 2017 survey.
- 2012, 2015 and 2017 were the years with the highest native species observed.
- The survey performed in 2012 was the year only one invasive species was recorded and in 2014 there were four invasive species, the highest number of invasive macrophytes observed at Lake Waccabuc in the last ten years.

Recommendations

In 2019, we highly recommend a repetition of the SAV mapping within Lake Waccabuc. Monitoring is also important for examining and understanding the abundance and distribution of non-native and native macrophytes throughout the aquatic systems. As shown in the FQI results, we can interpret this growing data set through other potential avenues of analysis.

The point-intercept methodology continues to work well in monitoring and quantifying the growth of aquatic macrophytes in Lake Waccabuc. If Brazilian elodea or water chestnut should re-infest Lake Waccabuc, the point-intercept survey is ideal to direct short- or long-term management efforts in a cost-effective manner. Based off of 2018 SAV mapping, 2 to 3 days of vegetation monitoring is recommended at Lake Waccabuc in 2019.

However, it's possible that other infestations could appear or may not be within the boundaries of the survey and non-native growth can be overlooked, especially when an infestation is small or intermittent. The Three Lakes Council should consider the implementation of an additional diver survey in the North Cove specifically for Brazilian elodea. The Eurasian water milfoil population of Lake Waccabuc appears to be stable and local management via hand-pulling is likely enough to reduce impacts to recreational activity. There are other notably invasive macrophyte infestations nearby, such as water chestnut and hydrilla. Since early detection and rapid response (similar to the Brazilian elodea discovery) is the most cost effective and suitable method to control these macrophytes, detection is essential.

As always, Solitude Lake Management would like to take this opportunity to thank you for allowing us to be of service to the Three Lakes Council. We look forward to working with you in the 2019 season.

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Appendix

Aquatic macrophyte Library (includes all macrophyte species from each lake)

2008 – 2018 Percent Abundance Graphs

2018 Survey Maps

FQI Figures

THE THREE LAKES COUNCIL:
AQUATIC MACROPHYTE PICTURE LIBRARY

Table of Contents

Arrowhead – submersed rosette (*Sagittaria* sp.)

Arrowhead Native (Submersed Rosette): This is the submersed rosette of a species of arrowhead. The submersed rosette lacks both flowers and seeds, so further identification is not possible. Arrowhead has emergent leaves, and usually inhabits shallow waters at pond or lake edges, or along sluggish streams. It can tolerate a wide variety of sediment types and pH ranges. Arrowhead is very suitable for constructed wetland development due to its tolerance of habitats, and ability to act as a nutrient sink for phosphorous. Typical arrowhead reproduction is via rhizomes and tubers although seed production is possible if conditions are ideal. Arrowhead has high wildlife value, providing high-energy food sources for waterfowl, muskrats and beavers. Arrowhead beds provide suitable shelter and forage opportunities for juvenile fish as well.

Bassweed (*Potamogeton amplifolius*)

Large-leaf pondweed, Musky weed

Bass Weed Native: Bass weed has robust stems that originate from black-scaled rhizomes. The submersed leaves of bass weed are among the broadest in the region. The submersed leaves are arched and slightly folded, attached to stems via stalks, and possess many (25-37 veins). Floating leaves are produced on long stalks (8-30 cm). Stipules are large, free and taper to a sharp point. Flowers, and later in the season fruit are densely packed onto a spike. Bass weed prefers soft sediments in water one to 4 meters deep. This plant is sensitive to increased turbidity and also has difficulty recovering from top-cutting, from such devices as boat propellers and aquatic plant harvesters. As its name implies the broad leaves of this submersed plant provides abundant shade, shelter and foraging opportunities for fish. The high number of nutlets produced per plant make it an excellent waterfowl food source.

Brazilian Elodea (*Egeria densa*)

Egeria, Anacharis, Brazilian waterweed

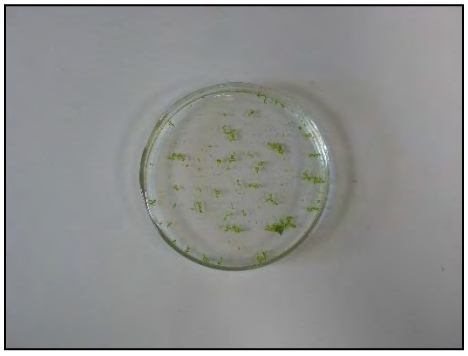
Brazilian Elodea Invasive: Brazilian elodea is an aggressive exotic invasive submersed plant that originated from South America. It was introduced via the aquarium hobby trade, and is a top selling plant used as an oxygenator. The stems can be several meters long, and the strap-like leaves are situated in whorls of three to six, but usually four. The leaves are finely serrated, and are tightly packed together near the end of the stem. Brazilian elodea can be rooted or free floating, and due to its highly branching nature, can quickly reach nuisance densities and crowd out or block light penetration for desirable native submersed plants. Although it can be confused with *Hydrilla*, another invasive submersed plant, its lack of tuber production and leaf structure differentiates it. Although it can produce white flowers, it reproduces vegetatively in the United States. Waterfowl consume Brazilian elodea, and fish and invertebrates use the stems for refuge and habitat.

Brittle Naiad (*Najas minor*)

Brittle water nymph, European naiad

Brittle Naiad Invasive: Brittle naiad is a submersed annual that flowers in August to October. It resembles other naiads, except its leaves are highly toothed with 6-15 spinules on each side of the leaf, visible without the aid of magnification. The leaves are opposite, simple, thread-like, and usually lime-green in color, often with a "brittle" feel to them. Brittle naiad fruit are narrow, slightly curved, and marked with 10-18 longitudinal ribs, resembling a ladder. Brittle Naiad has been introduced from Europe in the early 1900's, and can be found in most of the northeastern states. Brittle naiad prefers sandy and gravel substrates, but can tolerate a wide range of bottom types. It's tolerant of turbid and eutrophic conditions. Waterfowl graze on the fruit.

Common Watermeal (*Wolffia columbiana*)



Common Watermeal Native: Common watermeal appears as pale green globes of vegetative matter without roots, stems or true leaves. Its one of the world's smallest flowering plants, but flowers are rarely found and require magnification to see. Watermeal usually reproduces by budding. Watermeal is typically found on the surface, intermingled with duckweeds. Its drifts with the water's current or wind, and therefore it grows independent of water depth, clarity or sediment type. In the fall it produces winter buds that sink to the bottom. In the spring, the buds become buoyant and float to the surface. Waterfowl, fish, and muskrats all include watermeal in their diets.

Common Waterweed (*Elodea canadensis*)

Elodea

Common Waterweed Native: Common waterweed has slender stems that can reach a meter in length, and a shallow root system. The stem is adorned with lance-like leaves that are attached directly to the stalk that tend to congregate near the stem tip. The leaves are populated by a variety of aquatic invertebrates. Male and female flowers occur on separate plants, but it can also reproduce via stem fragmentation. Since common waterweed is disease resistant, and tolerant to low-light conditions, it can reach nuisance levels, creating dense mats that can obstruct fish movement, and the operation of boat motors.

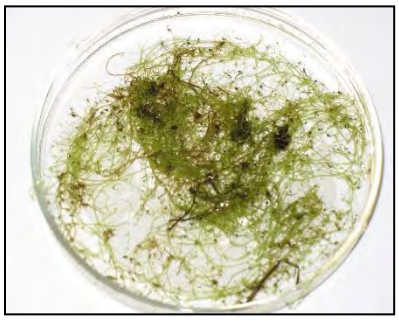
Coontail (*Ceratophyllum demersum*)

Hornwort

Coontail Native: Coontail has long trailing stems that lack true roots, although it can become loosely anchored to sediment by modified leaves. The leaves are stiff, and arranged in whorls of 5-12 at each node. Each leaf is forked once or twice, and has teeth along the margins. The whorls of leaves are spaced closer at the end of the stem, creating a raccoon tail appearance. Coontail is tolerant of low light conditions, and since it is not rooted, it can drift into different depth zones. Coontail can also tolerate cool water and can over winter as a green plant under the ice. Typically, it reproduces via fragmentation. Bushy stems of coontail provide valuable habitat for invertebrates and fish (especially during winter), and the leaves are grazed on by waterfowl.

Creeping Bladderwort (*Utricularia gibba*)

Humped bladderwort, cone-spur bladderwort



Creeping Bladderwort Native**:** Creeping bladderwort is a small (usually less than 10 cm long), delicate, free-floating stem. It often forms tangled mats in quiet shallow waters, often associated with bogs, or stranded on soil. It is sometimes mistaken for algae. It has short side braches that fork once or twice, a defining characteristic. Small bladders, used to capture live prey, are situated on these side branches. Small yellow snap-dragon-like flowers are produce on a short stalk. Mats of creeping bladderwort offer limited cover and foraging opportunities for fish.

Curly-leaf Pondweed (*Potamogeton crispus*)

Curly-leaf Pondweed Invasive: Curly-leaf pondweed has spaghetti-like stems that often reach the surface by mid-June. Its submersed leaves are oblong, and attached directly to the stem in an alternate pattern. The margins of the leaves are wavy and finely serrated, hence its name. No floating leaves are produced. Curly-leaf pondweed can tolerate turbid water conditions better than most other macrophytes. In late summer, Curly-leaf pondweed enters its summer dormancy stage. It naturally dies off (often creating a sudden loss of habitat and releasing nutrients into the water to fuel algae growth) and produces vegetative buds called turions. These turions germinate when the water gets cooler in the autumn and give way to a winter growth form that allows it to thrive under ice and snow cover, providing habitat for fish and invertebrates.

Dwarf Water Milfoil (*Myriophyllum tenellum*)

Dwarf Water Milfoil Native: Dwarf milfoil, which does not look anything like other milfoil species, has slender unbranched stems ranging from 2 cm to 15 cm in height. The leaves are reduced to scales or “bumps”. If the tips rise out of the water, they are capable of producing pale flowers and nut-like fruits. The toothpick-like stems arise from rhizomes in a chain. Dwarf milfoil is often small and overlooked, preferring sandy bottoms in waters up to four meters deep. Dwarf water milfoil provides suitable spawning habitat for panfish and adequate shelter for small invertebrates. The rhizome networks also help stabilize bottom sediments.

Eurasian Watermilfoil (*Myriophyllum spicatum*)

Asian Water Milfoil

Eurasian Watermilfoil Invasive: Eurasian water milfoil has long (2 meters or more) spaghetti-like stems that grow from submerged rhizomes. The stems often branch repeatedly at the water's surface creating a canopy that can crowd out other vegetation, and obstruct recreation and navigation. The leaves are arranged in whorls of 4 to 5, and spread out along the stem. The leaves are divided like a feather, resembling the bones on a fish spine. Eurasian watermilfoil is an exotic originating in Europe and Asia, but its range now includes most of the United States. It's ability to grow in cool water and at low light conditions gives it an early season advantage over other native submersed plants. In addition to reproducing via fruit production, it can also reproduce via fragmentation. Waterfowl graze on Eurasian watermilfoil, and its vegetation provides habitat for invertebrates. However, studies have determined mixed beds of pondweeds and wild celery can support more diverse invertebrate populations.

Filamentous Algae

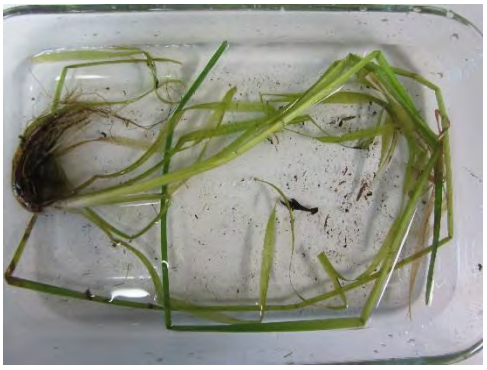
Floating Filamentous Algae, Benthic Filamentous Algae

Filamentous Algae: Filamentous algae is a chain or series of similar algae cells arranged in an end to end manner. Benthic filamentous algae is attached to a hard substrate, such as logs, rocks, a lake bottom, or even other aquatic plants. When growing in heavy densities, benthic filamentous algae can appear as brown or green mats of vegetation that can reach the surface. When large pieces break off the bottom substrate they become floating filamentous algae patches. Benthic filamentous algae can comprise an entire range of morphologies, but flagellated taxa are far less common.

Flat-stem Pondweed (*Potamogeton zosteriformis*)

Flat-stem Pondweed Native: Flat-stem pondweed is freely branched, emerging from a delicate rhizome system. The stems are strongly flattened with an angled appearance. The long leaves are stiff and linear with a prominent midvein, and numerous fine parallel veins. This prominent midvein distinguishes this pondweed from water stargrass. The stipules are firm and free situated in the leaf axils. Flat-stem pondweed lacks floating leaves. Flat-stem pondweed inhabits a variety of water depths from shallow water to water several meters deep. It prefers soft sediment types. Although it produces nut-like fruits, it over winters primarily by rhizomes and winter buds. It can be a locally important food source to fauna, such as waterfowl, muskrat, deer, beaver, and moose. It also provides suitable habitat and food for fish and aquatic invertebrates.

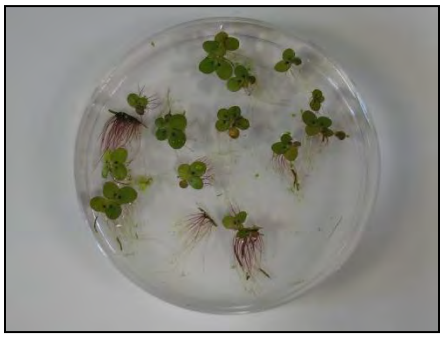
Floating Bur-reed (*Sparganium fluctuans*)



Floating Bur-reed Native: Floating bur-reed is an aquatic perennial that grows along rhizomes in static or slow-moving water. The leaves are limp, strap-shaped, float on the water's surface, often growing in the direction of any flow. At maturity (July-September), the floating bur-reed produce an emergent flowering spike that supports few white flowers with an appearance of small, fluffy cotton balls. From the flowers, floating bur-reed produces spiky fruits (seed heads) that are primarily dispersed by water. The fruits are water-repellent and can remain floating for several months. Various species of bur-reed display the floating leaves.

Great Duckweed (*Spirodela polyrhiza)*

Large Duckweed



Great Duckweed Native: Great duckweed is the largest of the duckweeds, but it is still very small compared to other aquatic macrophytes. It has simple flattened fronds with irregular oval shapes, often up to 1 cm in length and 2.5 to 8.0 mm long. The frond surface is usually green with a conspicuous purple dot. The underside of the frond is magenta with a cluster of 5-12 roots that dangle into the water. Indeed, peering at great duckweed from under the water grants it the appearance a tiny jellyfish. Although great duckweed produces flowers, it usually reproduces via budding, and like other duckweeds, it is capable of rapid growth. It often occurs with other duckweeds, and since it is free floating, it can be moved via the wind or water currents. It derives its nutrients from the water column and often occurs in eutrophic systems. It's an excellent food source for waterfowl, and is also used by muskrat and fish. The dense mats offer shade and cover for fish.

Leafy Pondweed (*Potamogeton foliosus*)

Leafy Pondweed Native: Leafy pondweed has freely branched stems that hold slender submersed leaves that become slightly narrower as they approach the stem. The leaf contains 3-5 veins and often tapers to a point. No floating leaves are produced. It produces early season fruits in tight clusters on short stalks in the leaf axils. These early season fruits are often the first grazed upon by waterfowl during the season. Muskrat, beaver, deer and even moose also graze on the fruit. It inhabits a wide range of habitats, but usually prefers shallow water. It has a high tolerance for eutrophic conditions, allowing it to even colonize secondary water treatment ponds.

Quillwort (*Isoetes sp.*)

Quillwort Native: Quillwort is a low-growing, submersed aquatic plant with many leaves forming from a basal structure called a corm. The size of the hollow leaves is dependent on the species. Quillwort is actually a lycopod, and does not have 'true' rhizomes or seeds. Instead, quillwort has pseudo-rhizomes and megaspores. The megaspores act like seeds, and are found in the expanded bases of each leaf; the megaspores are the primary method for species identification of quillwort genus.

Ribbon-leaf Pondweed (*Potamogeton epihydrus*)

Ribbon-leaf Pondweed Native: Ribbon-leaf pondweed has flattened stems and two types of leaves. The submersed leaves are alternate on the stem, lack a leaf stalk, and are long tape-like in shape. Each leaf, which can reach lengths up to 2 meters long, has a prominent stripe of pale green hollow cells flanking the midvein, and 5 to 13 other veins. Stipules are not fused to the leaf. Floating leaves are egg or ellipse-shaped, and supported by a leaf stalk about as long as the leaf itself. Fruiting stalks are located at the top of the stem and packed with flattened disk-shaped fruits. It is typically found growing in low alkalinity environments, and in a variety of substrates. Seeds are highly sought after by all manner of waterfowl.

Robbins Pondweed (*Potamogeton robbinsii*)

Fern Pondweed

Robbins Pondweed Native: Robbins pondweed has robust stems that emerge from spreading rhizomes. The leaves are strongly ranked creating a fern-like appearance most clearly seen while still submerged. Its distinct closely-spaced fern-like leaves give it a unique appearance among the pondweeds of our region. Each leaf is firm and linear, with a base that wraps around the stem. At the stem it has ear-like lobes fused with a fibrous stipule. No floating leaves are produced. Robbins pondweed thrives in deeper water, and under some circumstances, it can over winter green. Robbins pondweed creates suitable invertebrate habitat, and cover for lie-in-wait predaceous fish, such as pickerel and pike.

Slender Naiad (*Najas flexilis*)

Bushy Pondweed

Slender Naiad Native: Slender naiad has fine-branched stems that can taper to lengths of one meter, originating from delicate rootstalks. Plant shape varies; sometimes compact and bushy, other times long and slender, depending on growing conditions. The leaves are short (1-4 cm long) and finely serrated, tapering to a point. It is found in a variety of habitats, and can colonize sandy or gravelly substrates. If conditions are ideal, it can reach nuisance densities. It is a true annual, and dies off in the fall, relying on seed dispersal to return the next year. It is an important food source for waterfowl.

Small Duckweed (*Lemna minor*)

Water Lentil, Lesser Duckweed

Small Duckweed Native: Small duckweed is a free floating plant, with round to oval-shaped leaf bodies typically referred to as fronds. The fronds are small (typically less than 0.5 cm in diameter), and it can occur in large densities that can create a dense mat on the water's surface. Each frond contains three faint nerves, a single root (a characteristic used to distinguish it from other duckweeds), and no stem. Although it can produce flowers, it usually reproduces via budding at a tremendous rate. Its population can double in three to five days. Since it is free floating, it drifts with the wind or water current, and is often found intermixed with other duckweeds. Since it's not attached to the sediment, it derives nutrients directly from the water, and is often associated with eutrophic conditions. It over winters by producing turions late in the season. Small duckweed is extremely nutritious and can provide up to 90% of the dietary needs for waterfowl. It's also consumed by muskrat, beaver and fish, and dense mats of duckweed can actually inhibit mosquito breeding.

Southern Naiad (*Najas guadalupensis*)

Southern Water Nymph, Bushy Pondweed

Southern Naiad Native (*Najas guadalupensis*. Common Names: Southern water nymph, bushy pondweed.): Southern naiad is an annual aquatic plant that can form dense stands of rooted vegetation. Its ribbon-like leaves are dark-green to greenish-purple, and are wider and less pointed than slender naiad. Flowers occur at the base of the leaves, but are so small, they usually require magnification to detect. Southern naiad is widely distributed, but is less common than slender naiad in northern zones. Southern naiad reproduces by seeds and fragmentation.

Spatterdock (*Nuphar variegata*)

Yellow Pond Lily, Bullhead Pond Lily

Spatterdock Native: Spatterdock leaf stalks emerge directly from a submerged fleshy rhizome. Spatterdock has heart-shaped leaves with a prominent notch. Depending on the habitat, these leaves can be held aloft via erect stems. A distinguishing characteristic of spatterdock is the leaf stalk, which bears a winged margin. Flowering occurs in the summer and, the flowers open during the day and close at night. Spatterdock typically inhabits quiet water less than two meters deep with a soft substrate, such as ponds, shallow lakes and slow-moving streams. The leaves offer shade and protection for fish, and the leaves, stems, and flowers are grazed upon by muskrats, beaver, and sometimes, even deer.

Spiral-fruited Pondweed (*Potamogeton spirillus*)

Spiral-fruited Pondweed Native: Spiral-fruited pondweed has slender stems that originate from a delicate, spreading rhizome. The stems tend to be compact and have numerous branches. Submersed leaves are linear with a curved appearance. Floating leaves are delicate, ellipse-shaped and range from 7 to 35 mm long and two to 13 mm wide. Stipules are fused to the leaf blade for more than half of their length. Nut-like fruits are produced on stalks of varies lengths. Shorter stalks tend to be on lower axils with fruit arranged in a compact head, while longer stalks tend to appear on upper axils, with fruit arranged in a cylindrical head. The fruit itself is a flatten disc with a sharply-toothed margin. Its smooth sides appear like a tightly coiled embryo, a distinguishing characteristic. Spiral-fruited pondweed prefers shallow water with sandy substrate, but can inhabit a wide range of bottom substrates. It serves as an important stabilizer and cover for fish fry and invertebrates.

Water Bulrush (*Scirpus subterminalis, Schoenoplectus subterminalis)*

Bulrush

Water bulrush **Native** (*Scirpus subterminalis*; = *Schoenoplectus subterminalis*). Common names: water bulrush, bulrush. Water bulrush is a truly aquatic bulrush, with only the tips of fertile stems poking above the water's surface, if any. The slender, limp stems originate from a delicate rhizome, typically less than 2.0 mm diameter. The hair-like stems can reach lengths up to 1.0 meter, and occur in flowing or still-water environments. The leaves are sheathed at the base, and become crescent-shaped above the sheath. This basal sheathing is a distinct characteristic that sets water bulrush apart from spikerush species. The leaves have one to five length-wise veins and scattered cross-veins. The leaves are often covered with a fine coating of algae in nutrient-poor environments. Researchers believe the bulrush plants are a phosphorus source for the algae. When nutlets are produced, they are three-angled with a slender beak. Water bulrush prefers shallow water, but can become established in depths exceeding 1.0 meter. Water bulrush stands produce grass-like meadows which provide suitable habitat for invertebrates and juvenile fish.

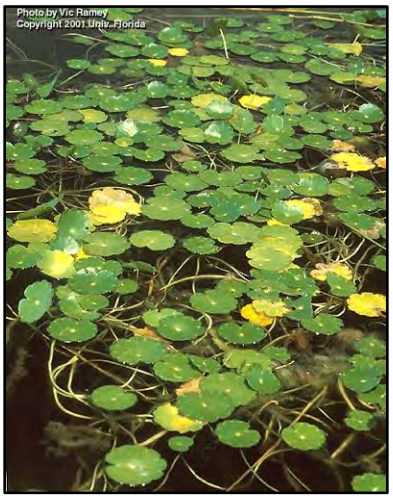
Water Chestnut (*Trapa natans*)

Water nut

Water Chestnut Invasive: Water chestnut is native to Europe and Asia, and was first observed in the United States in the late 1800's in Massachusetts. Water chestnut has two types of leaves, submerged and floating rosettes. The submersed leaves are delicate, opposite and contain numerous adventitious roots. Floating leaves are strongly toothed triangular leaves displayed in a rosette fashion, supported by long petioles with spongy inflated bladders for buoyancy. These petioles can reach lengths of up to 16 feet. Water chestnut prefers to inhabit nutrient-rich slow moving waters in lakes, ponds or streams. Although water chestnut can reproduce via fragmented rosettes, the plant produces numerous single-seeded horned nuts armed with sharp ½" barbs. After maturation, these nuts fall off the plant and over winter, producing 10-15 new rosettes the

following season. These nuts can inflict painful wounds to swimmers if stepped on. Studies have shown a water chestnut can lie dormant on a lake bottom for up to 12 years, and still germinate. Water chestnut is a poor source of food for waterfowl. High densities of water chestnut can inhibit boating and fishing.

Water Pennywort (*Hydrocotyle sp.*)



Water Pennywort: Water pennywort varies in appearance depending on the species, but most possess the same general characteristics. The leaves are circular, umbrella-shaped, and about the size of a half-dollar coin. The leaves are shiny green and leathery in texture with long leaf stalks attached to the center. The color of pennywort flowers can be white, green, or yellow. Fruit are typically egg-shaped with a flattened appearance. Pennywort can become a nuisance as they can form dense mats in lakes, pond, rivers, or marshes. The seeds of pennywort provide food for some waterfowl and the plants themselves provide habitat for aquatic biota. Several species of water pennywort, including native and invasive, are common throughout the United States, especially in Florida.

Water Stargrass (*Zosterella dubia*)

Water Stargrass Native: Water stargrass has slender free-branched stems that originate from rhizomes. The leaves are narrow and alternate, attaching directly to the stem. Leaves can be up to 15 cm long, and lack a prominent midvein, a distinguishing characteristic. Water stargrass can inhabit a wide range of water depths and sediment types, and can tolerate reduced clarity environments. Yellow star-shaped flowers are produced by midsummer, but reproduction is usually via over wintering rhizomes. Water stargrass is a locally important waterfowl food source, and provides suitable cover and foraging for fish.

Water-thread Pondweed (*Potamogeton diversifolius*)

Variable-leaf Pondweed, Snailseed Pondweed

Water-thread Pondweed Native (*Potamogeton diversifolius*. Common Names: Water-thread pondweed, variable-leaf pondweed, snailseed pondweed.): Variable-leaf pondweed have freely-branched stems emerging from slender rhizomes. The submersed leaves are narrow and linear with one obvious midvein bordered by a row of hollow cells. The floating leaves are shaped like an ellipse, but are usually less than 4 cm long, Variable-leaf pondweed fruit spikes are produced in two distinct forms. It occurs in lakes, ponds, rivers and streams and prefers soft sediment and water less than 2 meters deep. Waterfowl graze on the fruit, and local fauna often graze on the stems and leaves.

Water Moss (*Fontinalis* sp.)

Water Moss Native: Water mosses are submerged mosses that are attached to rocks, trees, logs, and other hard substrates by false rootlets located at the base of their stems. The stems are dark-green to brown, and about one foot long. The leaves share a similar color as the stems, and are usually ovate with fine-toothed margins. Water moss is utilized by aquatic invertebrates, and as a breeding site for small fish. Water moss rarely reaches nuisance levels.

Watershield (*Brasenia schreberi*)

Watershield Native: Watershield is a floating-leaf aquatic plant similar to water lilies. Its stem and leaves are elastic, and are attached to a rooted rhizome that acts as an anchor and source of stored nutrients. The leaf stalks are attached to the middle of the leaf, creating a bull's eye effect, hence its name water target. The leaves are green on the upper surface, and purple underneath. Maroon to purple flowers peak above the water's surface on short, stout stalks. Watershield is usually coated with a clear gelatinous slime on the stem and underside of the leaves. Watershield prefers soft-water lakes and ponds in

sediments containing decomposing organic matter. The whole plant is consumed by waterfowl, and the floating leaves provide shade and cover for fish.

White Water Lily (*Nymphaea* odorata)

Fragrant Water Lily

White Water Lily Native: White water lily leaf stalks emerge directly from a submerged fleshy rhizome. White water lilies have round floating leaves. Flowering occurs during the summer, and the flowers open during the day, and close during the night. Water lilies typically inhabit quiet water less than two meters deep, such as ponds, shallow lakes and slow-moving streams. The leaves offer shade and protection for fish, and the leaves, stems, and flowers are grazed upon by muskrats, beaver, and sometimes even deer.

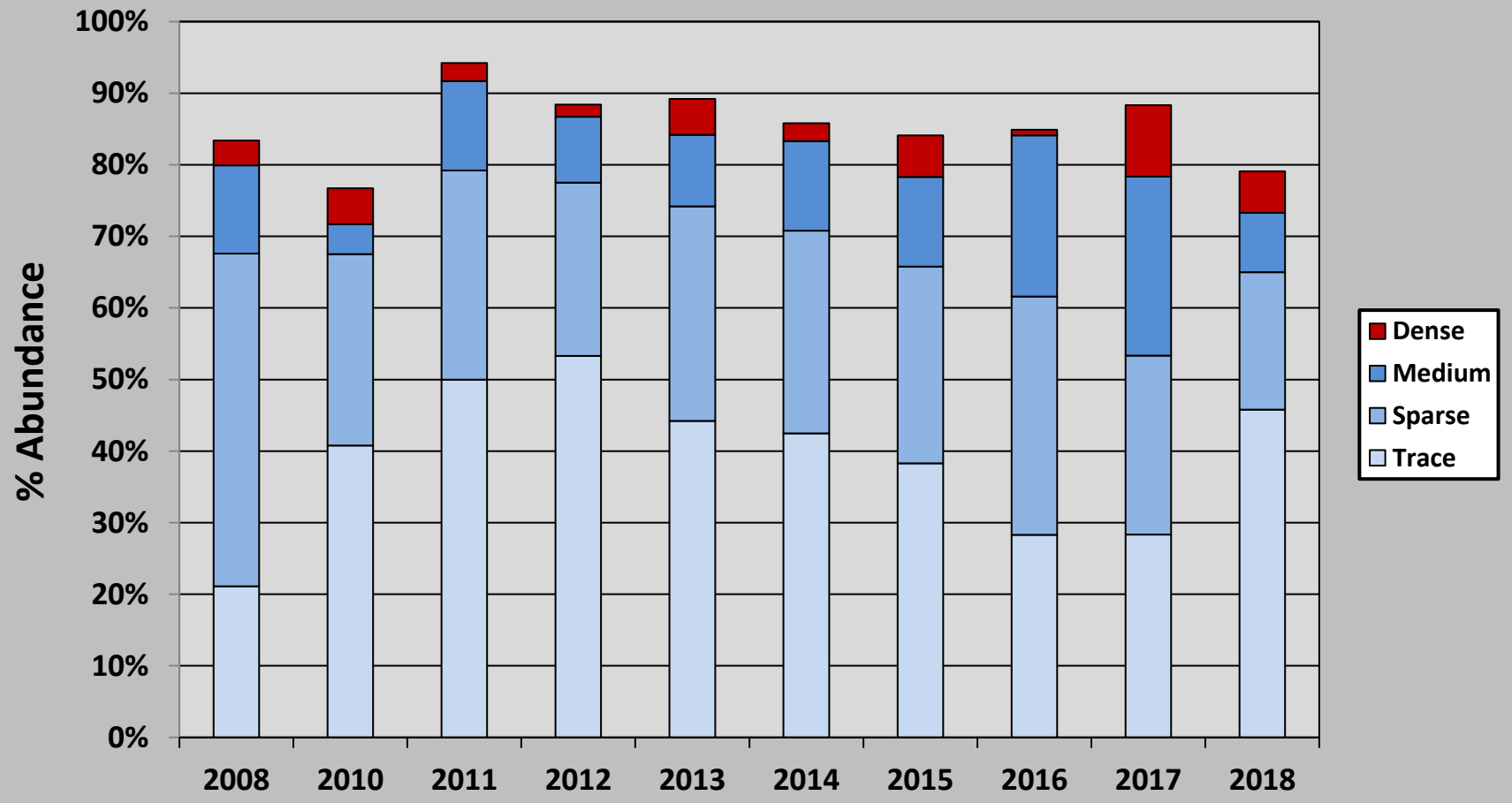
Wild celery (*Vallisneria Americana*)

Eel-grass, Tape-grass

Tape-grass (*Vallisneria americana*. Common Names: Wild celery, eel-grass, tape-grass. **Native**.): Tape-grass has long flowing ribbon-like leaves that have a basal arrangement from a creeping rhizome. The leaves can be up to two meters long, have a cellophane-like texture, with a prominent center stripe and finely serrated edges. The leaves are mostly submersed, although they can reach the surface allowing the tips to trail. Male and female flowers are produced on separate plants, but reproduction is usually via over wintering rhizomes and tubers. Tape-grass usually inhabits hard substrate bottoms in shallow to deep water. It can tolerate a wide variety of water chemistries. Tape-grass is the premiere food source for waterfowl, which greedily consume all parts of the plant. Canvasback ducks (*Aythya valisneria*) enjoy a strong relationship with tape-grass, going so far to alter their migration routes based on tape-grass abundance. Extensive beds of tape-grass are considered good shade, habitat and feeding opportunities for fish.

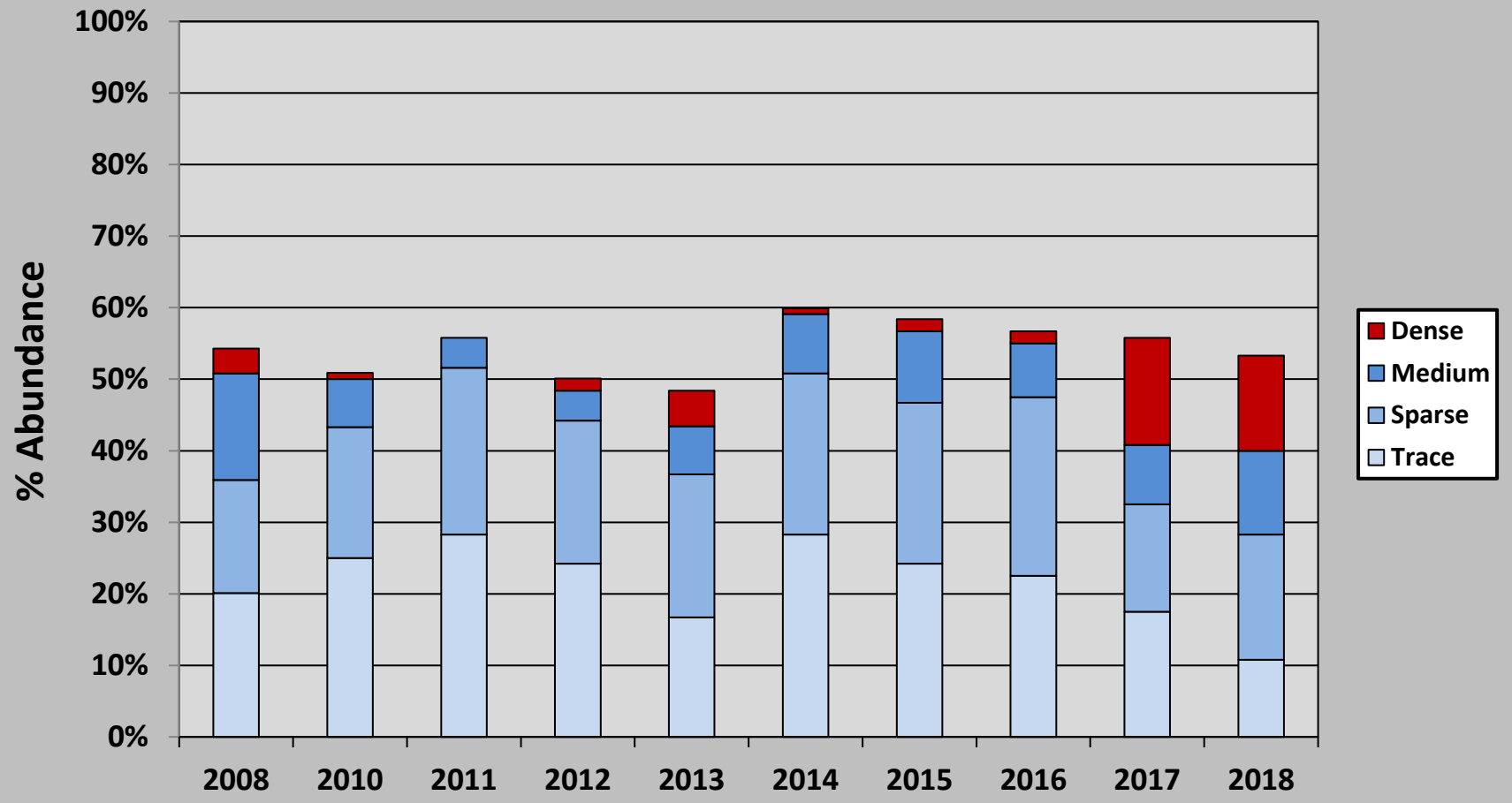
SOLITUDE LAKE MANAGEMENT

Total Submersed Vegetation
2008 to 2018 Percent Abundance
Lake Waccabuc



SOLITUDE LAKE MANAGEMENT

Total Floating Vegetation
2008 to 2018 Percent Abundance
Lake Waccabuc

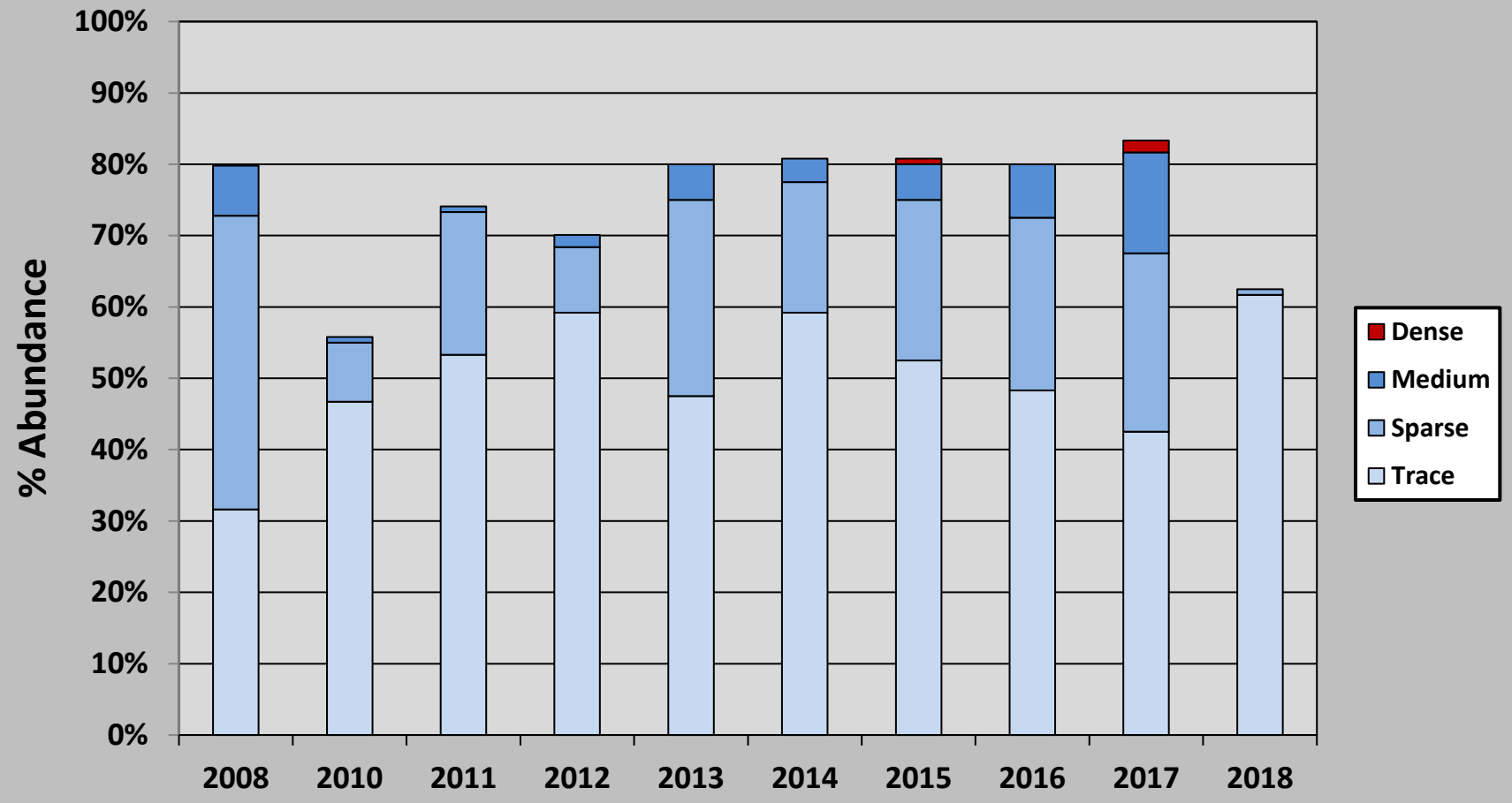


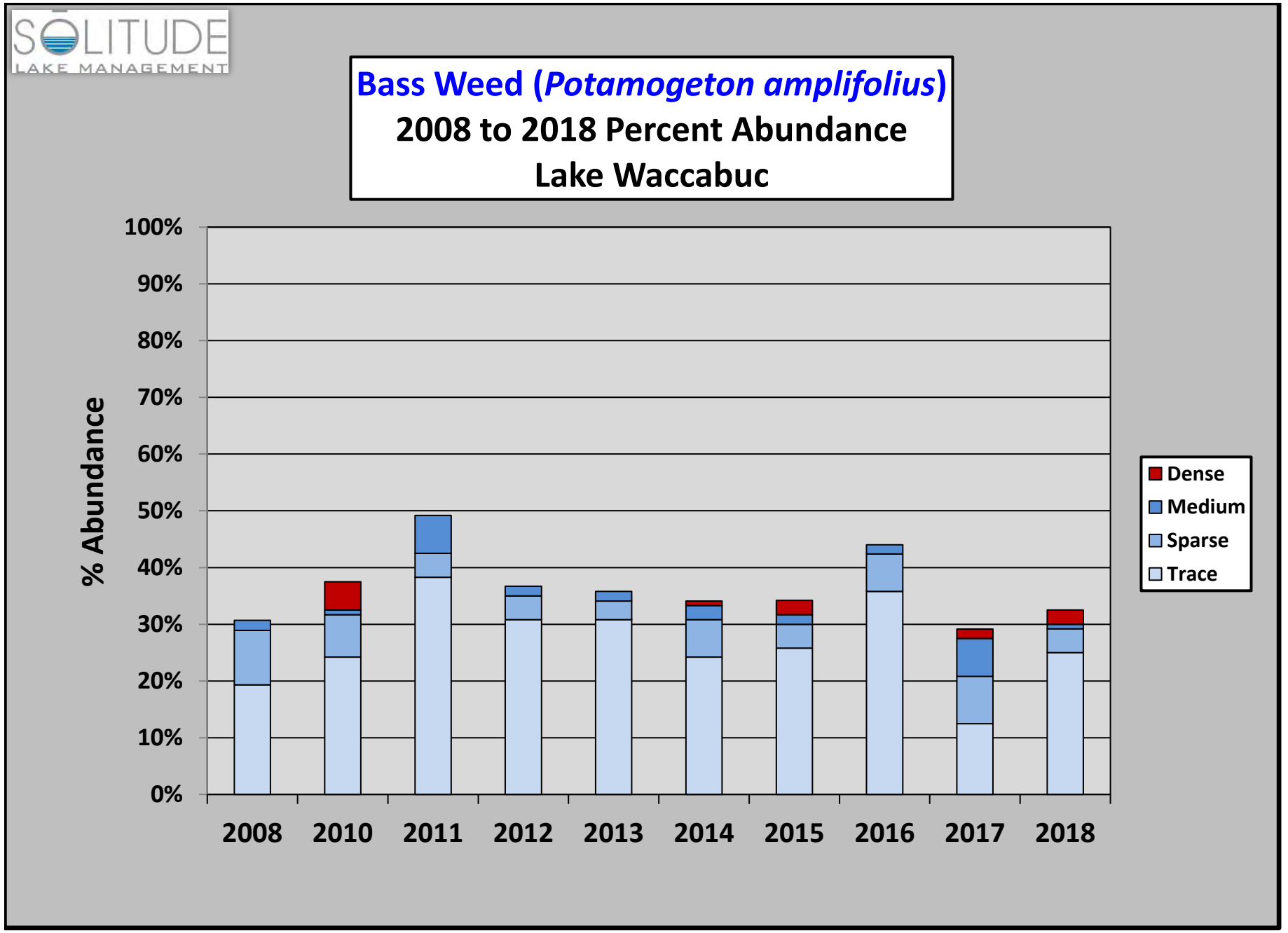
SOLITUDE LAKE MANAGEMENT

Eurasian Water Milfoil (*Myriophyllum spicatum*)

2008 to 2018 Percent Abundance

Lake Waccabuc




SOLITUDE
LAKE MANAGEMENT
Bass Weed (Potamogeton amplifolius)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2008
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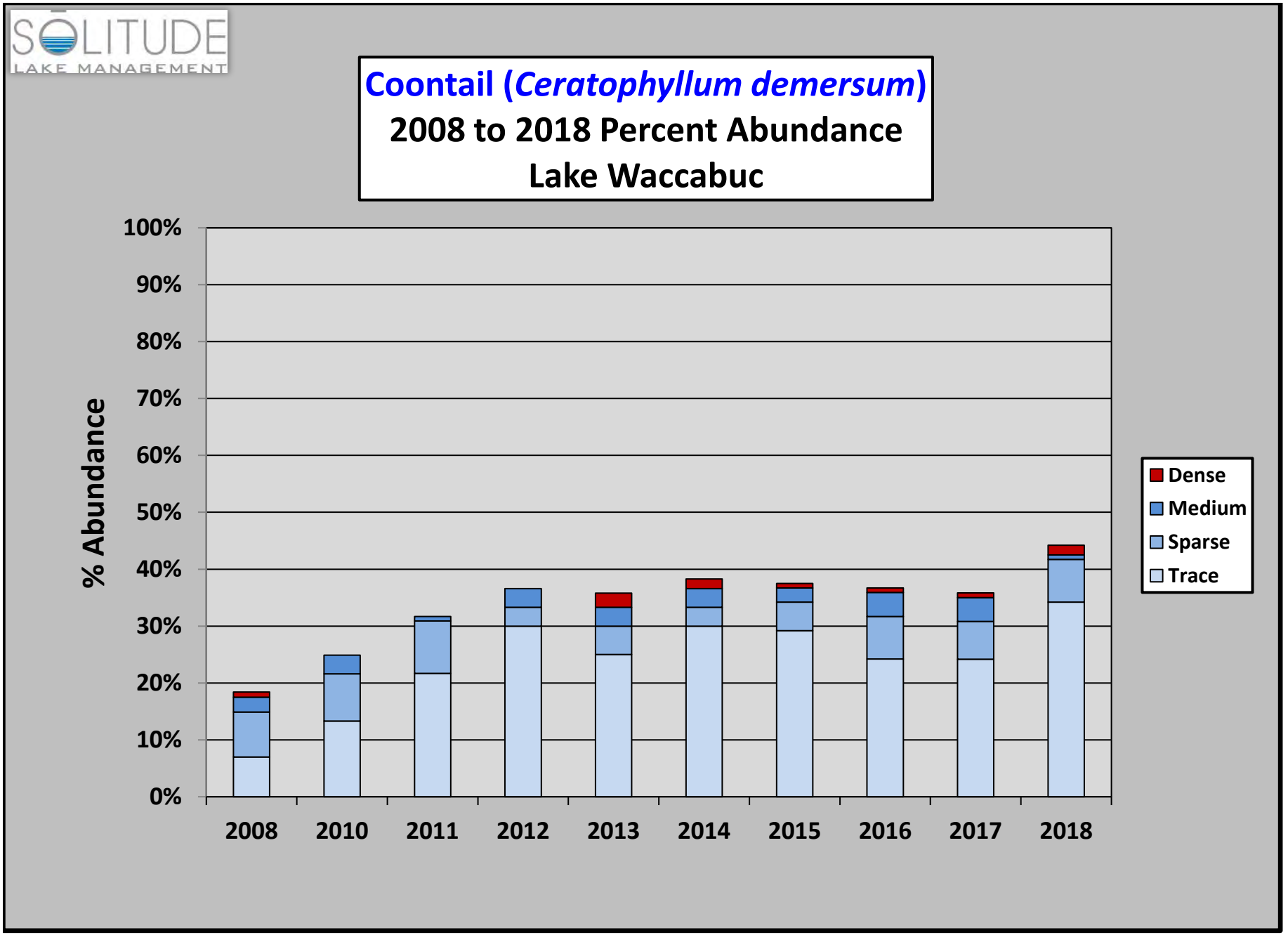
Dense
Medium
Sparse
Trace


SOLITUDE
LAKE MANAGEMENT
Coontail (Ceratophyllum demersum)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
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20%
10%
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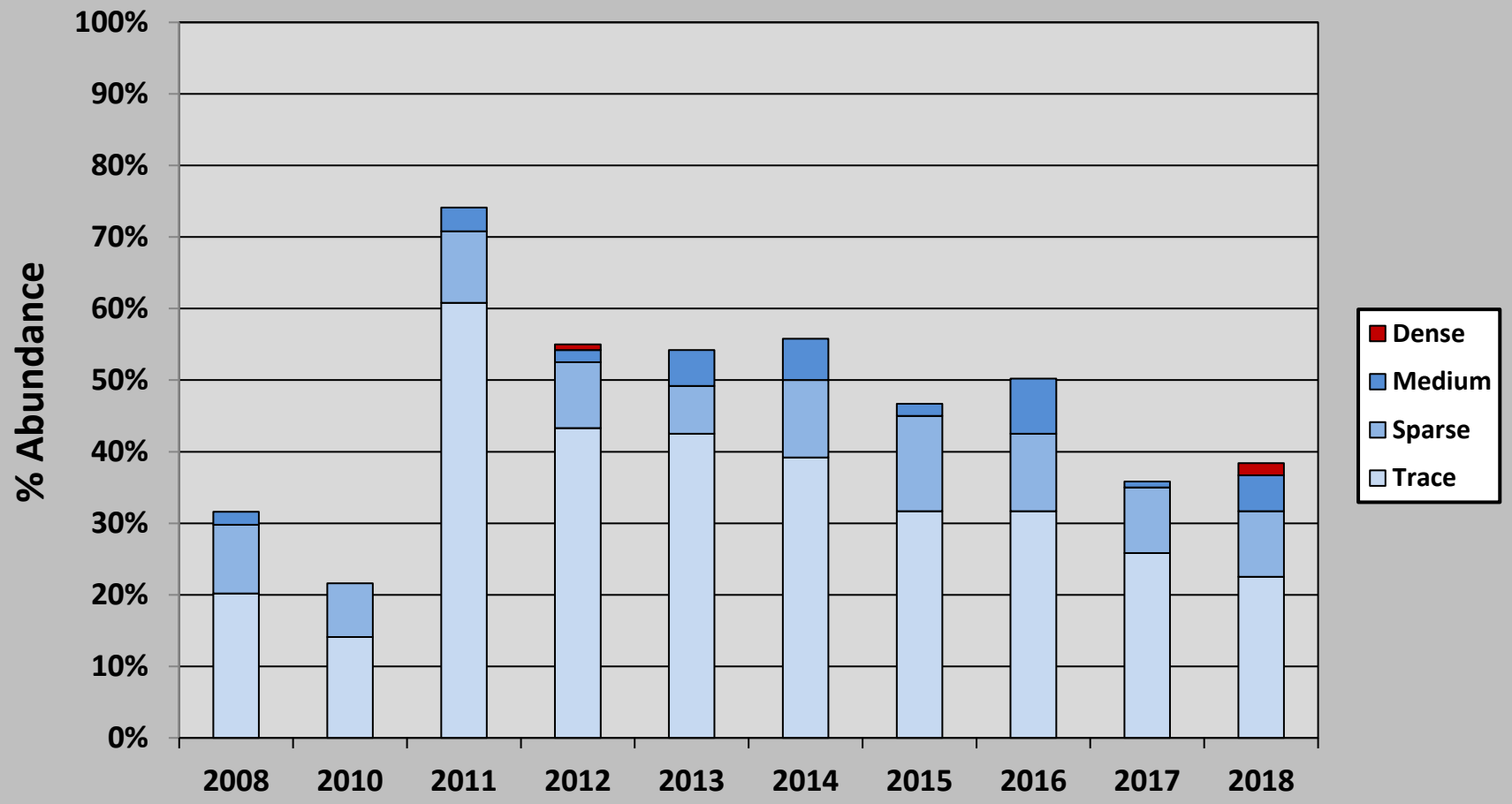
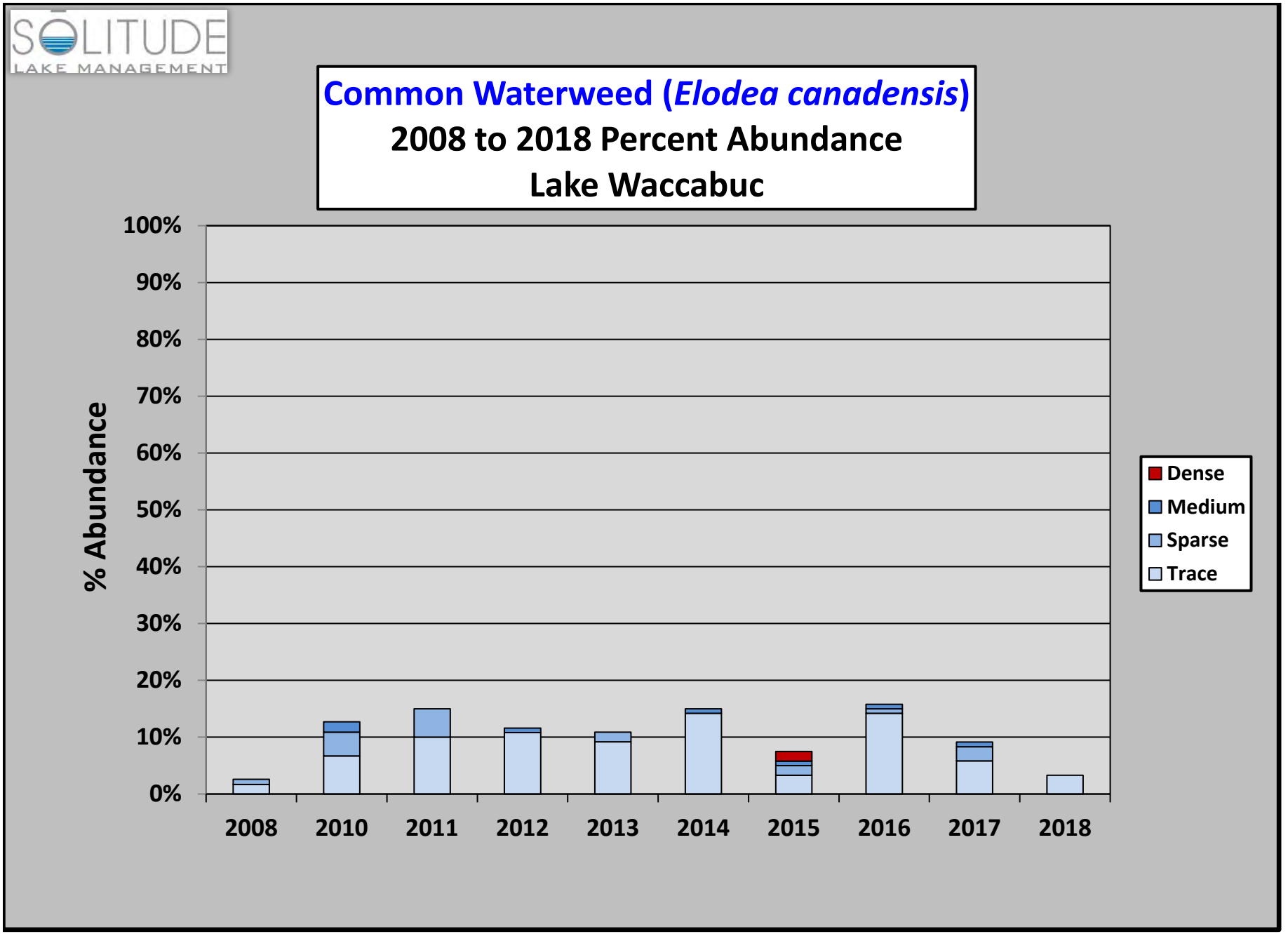
SOLITUDE LAKE MANAGEMENT

Benthic Filamentous Algae
2008 to 2018 Percent Abundance
Lake Waccabuc




SOLITUDE
LAKE MANAGEMENT
Common Waterweed (Elodea canadensis)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
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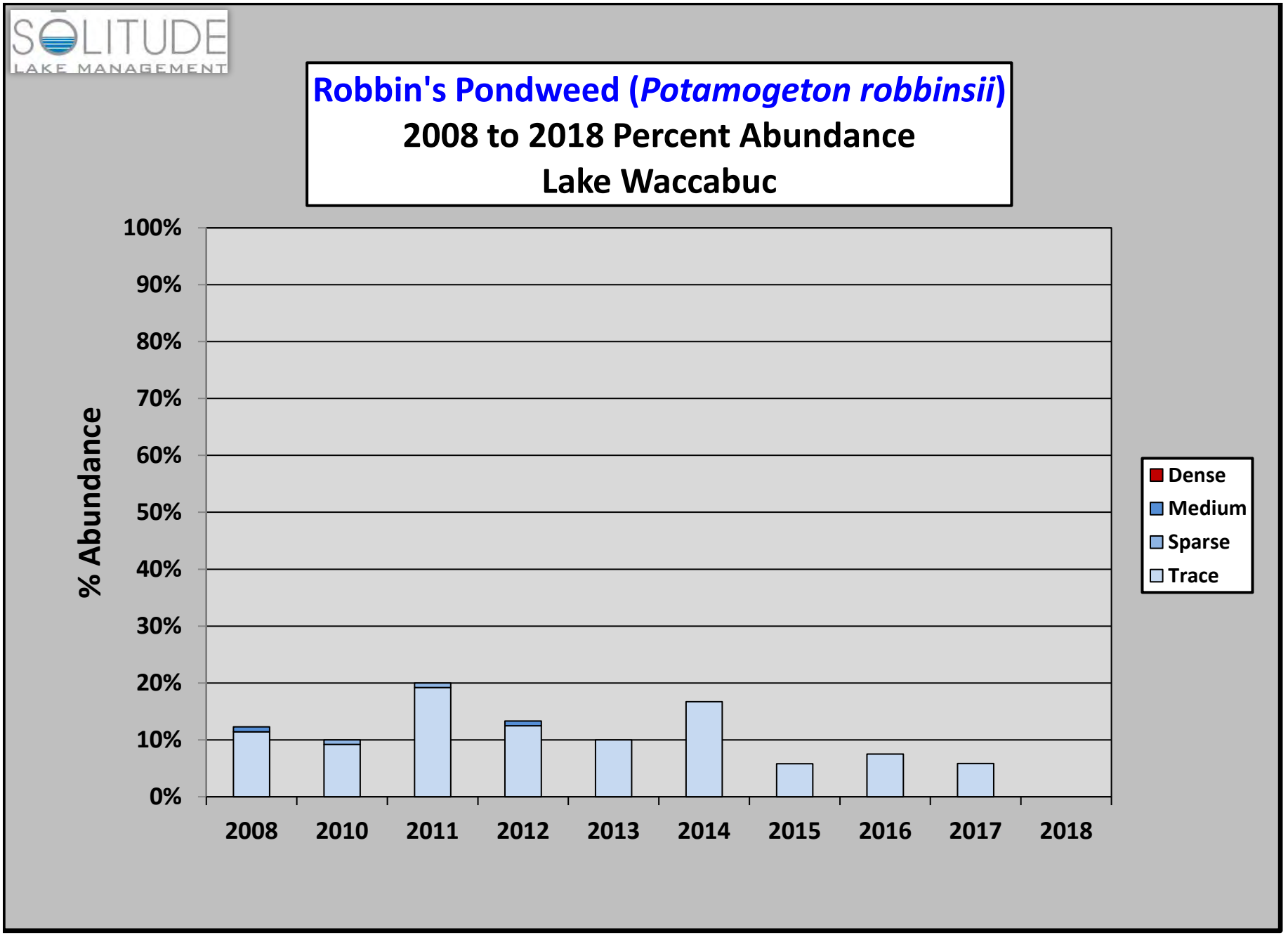
SOLITUDE
LAKE MANAGEMENT
Robbin's Pondweed (Potamogeton robbinsii)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
50%
40%
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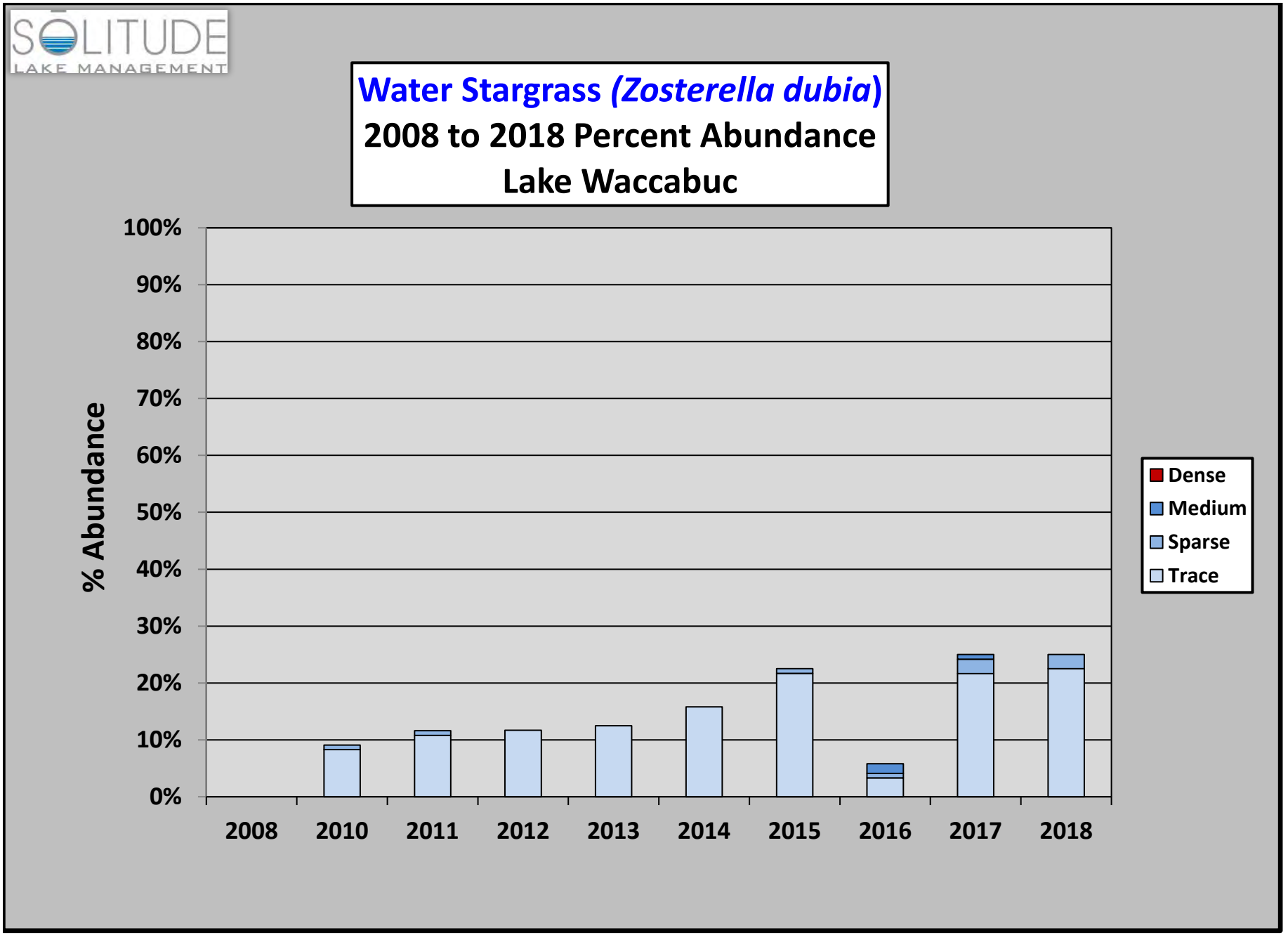
SOLITUDE
LAKE MANAGEMENT
Water Stargrass (Zosterella dubia)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
50%
40%
30%
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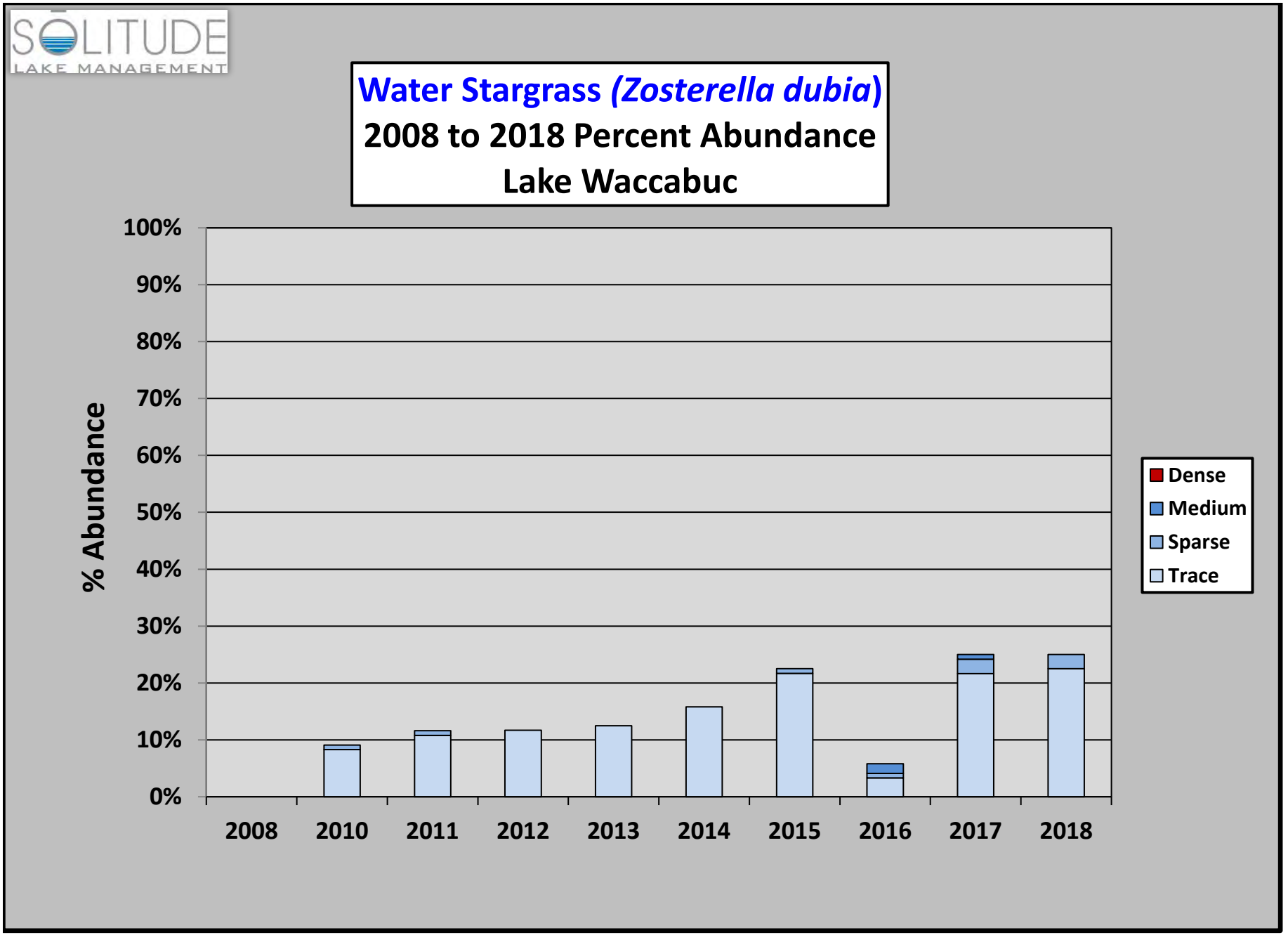
Trace


SOLITUDE
LAKE MANAGEMENT
Water Stargrass (Zosterella dubia)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
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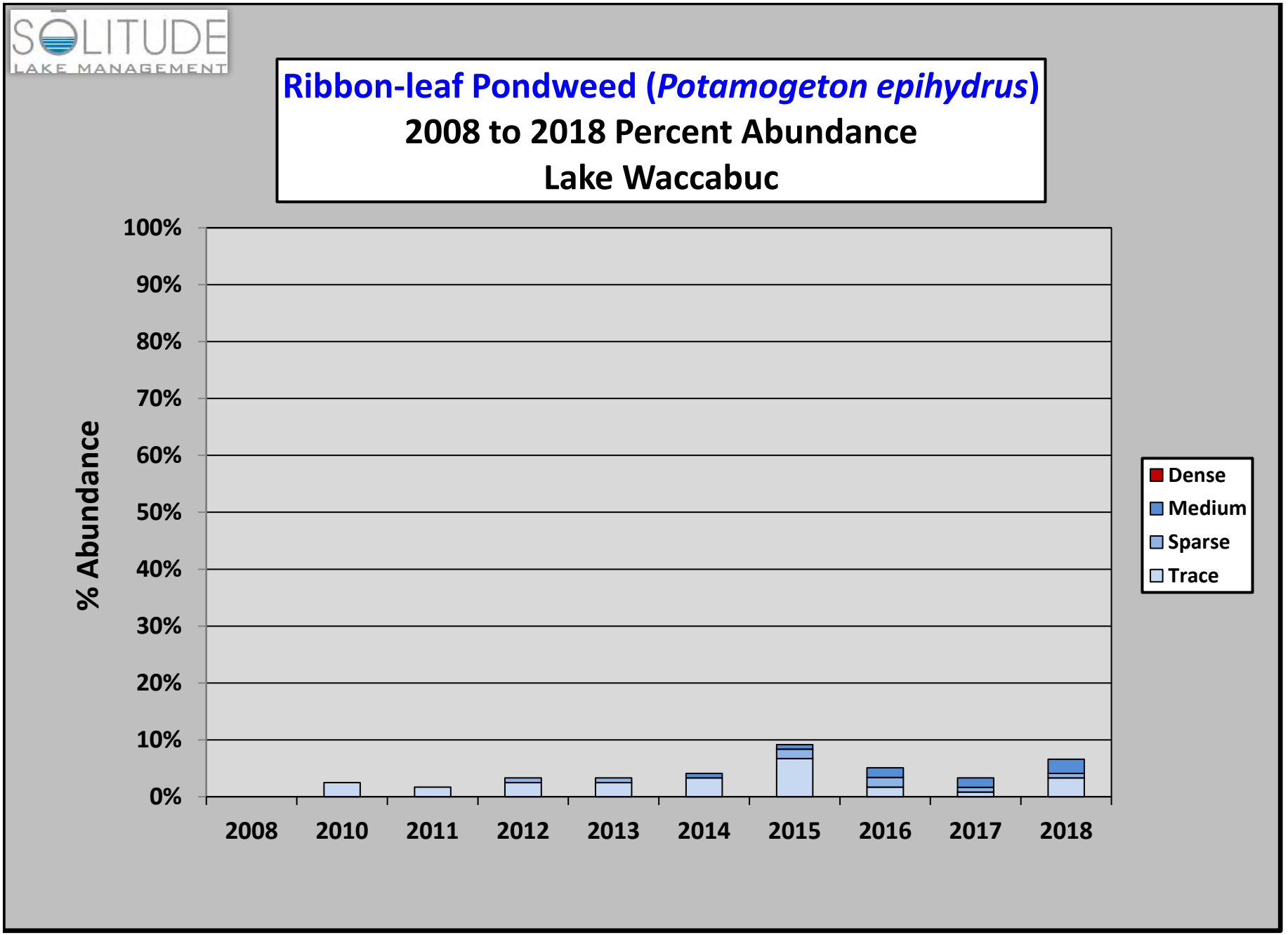
SOLITUDE
LAKE MANAGEMENT
Ribbon-leaf Pondweed (Potamogeton epihydrus)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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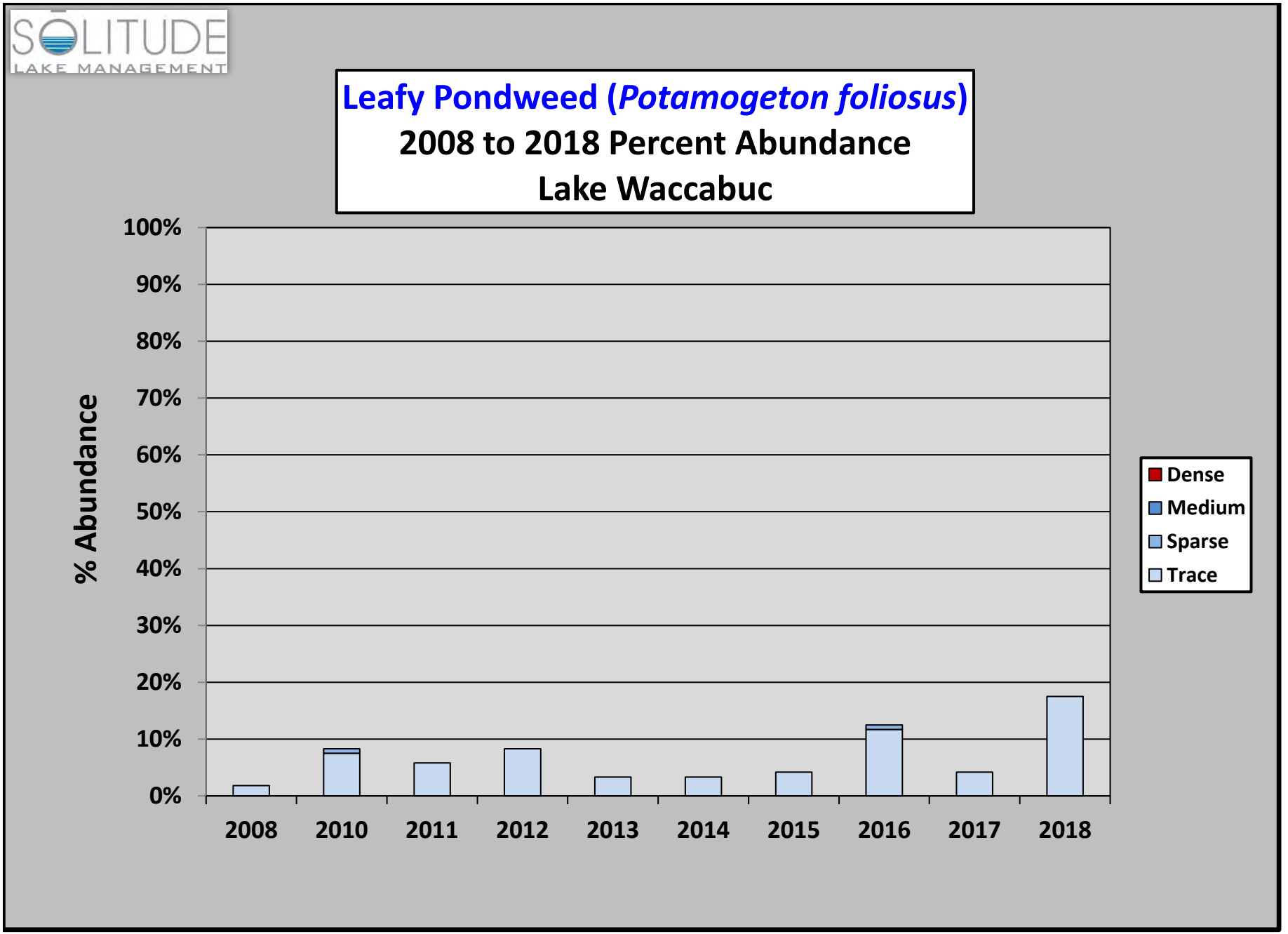
Sparse
Trace


SOLITUDE
LAKE MANAGEMENT
Leafy Pondweed (Potamogeton foliosus)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
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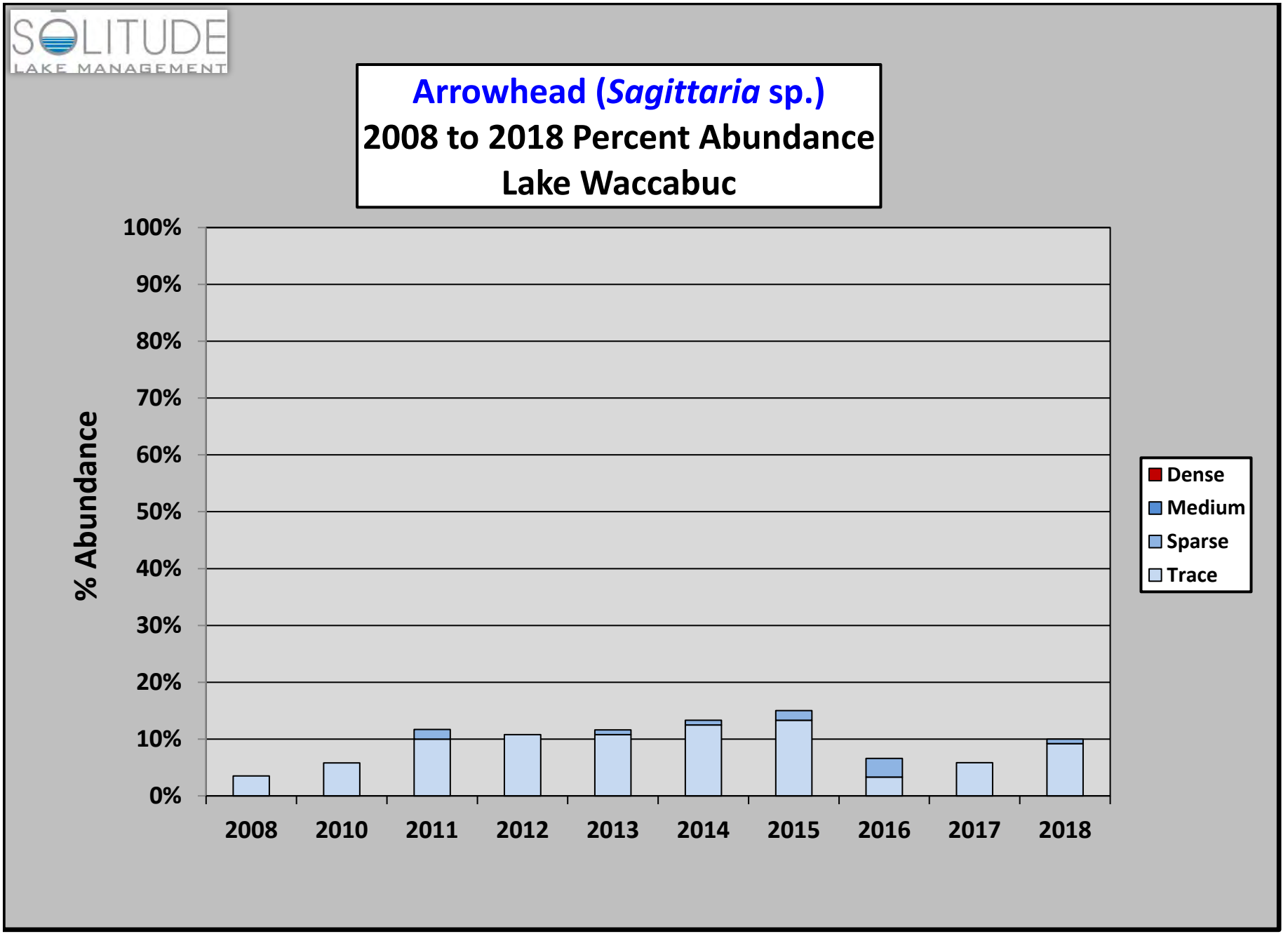
Trace


SOLITUDE
LAKE MANAGEMENT
Arrowhead (Sagittaria sp.)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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80%
70%
60%
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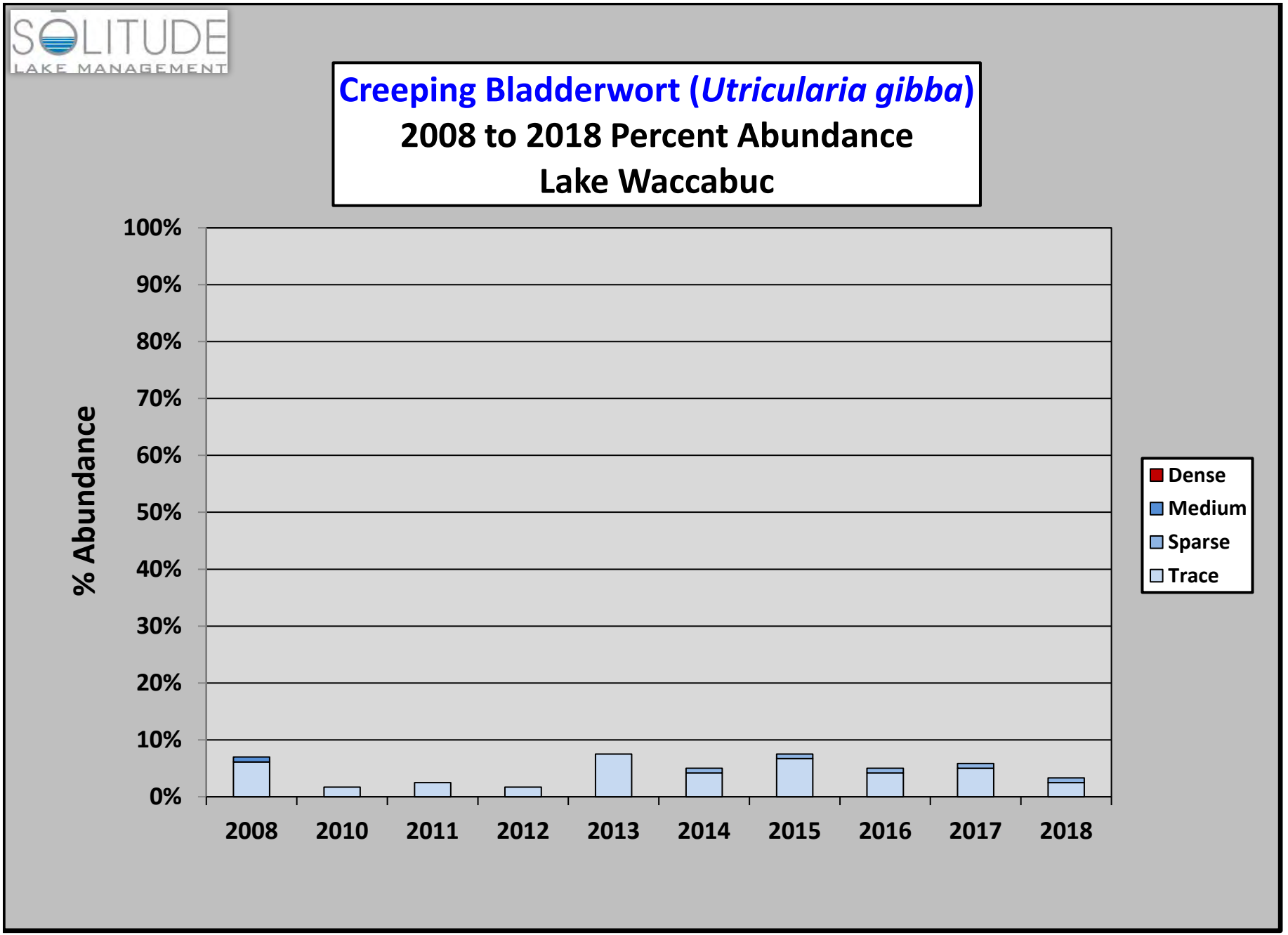
Creeping Bladderwort (Utricularia gibba)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
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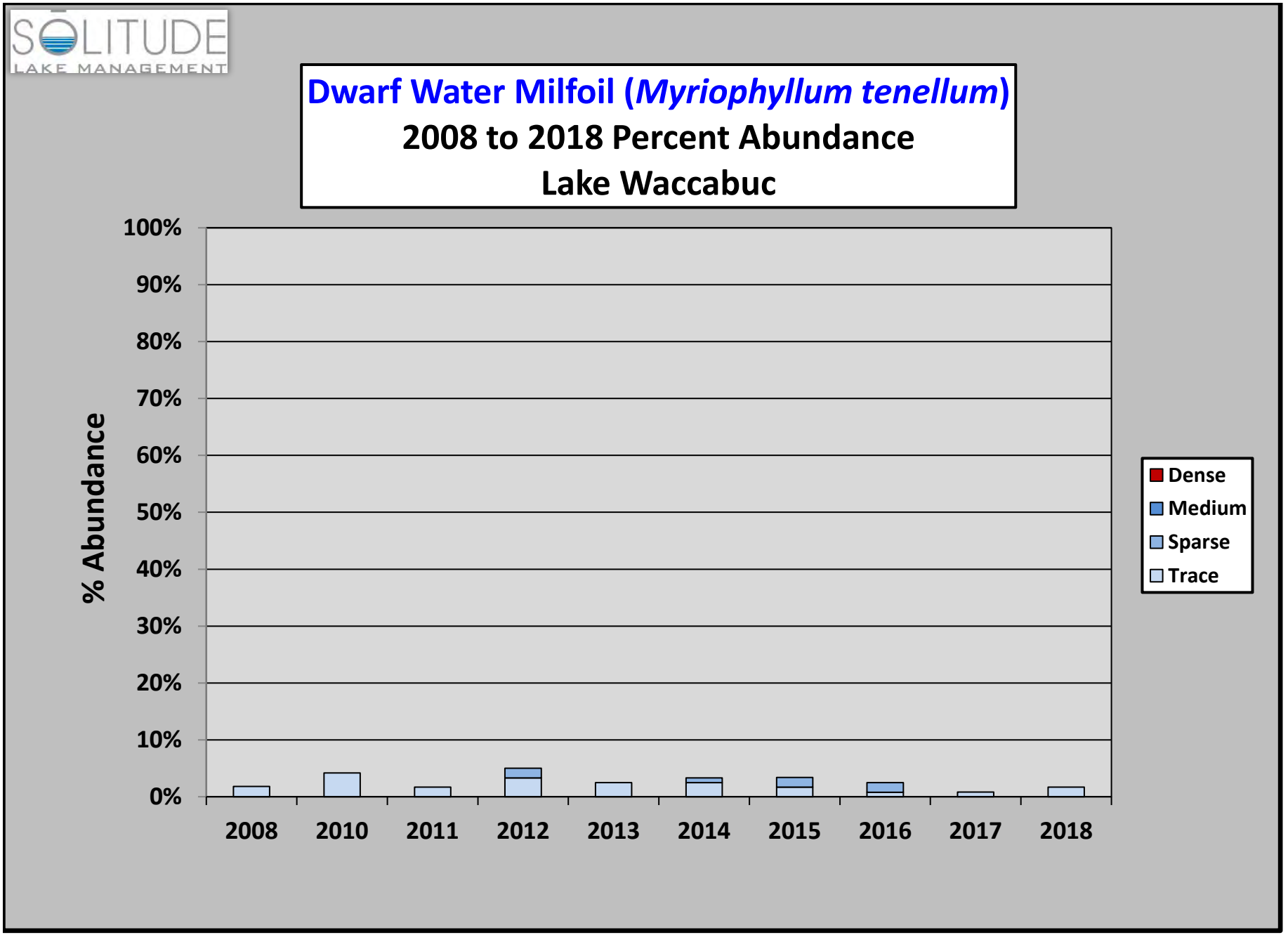
SOLITUDE
LAKE MANAGEMENT
Dwarf Water Milfoil (*Myriophyllum tenellum*)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
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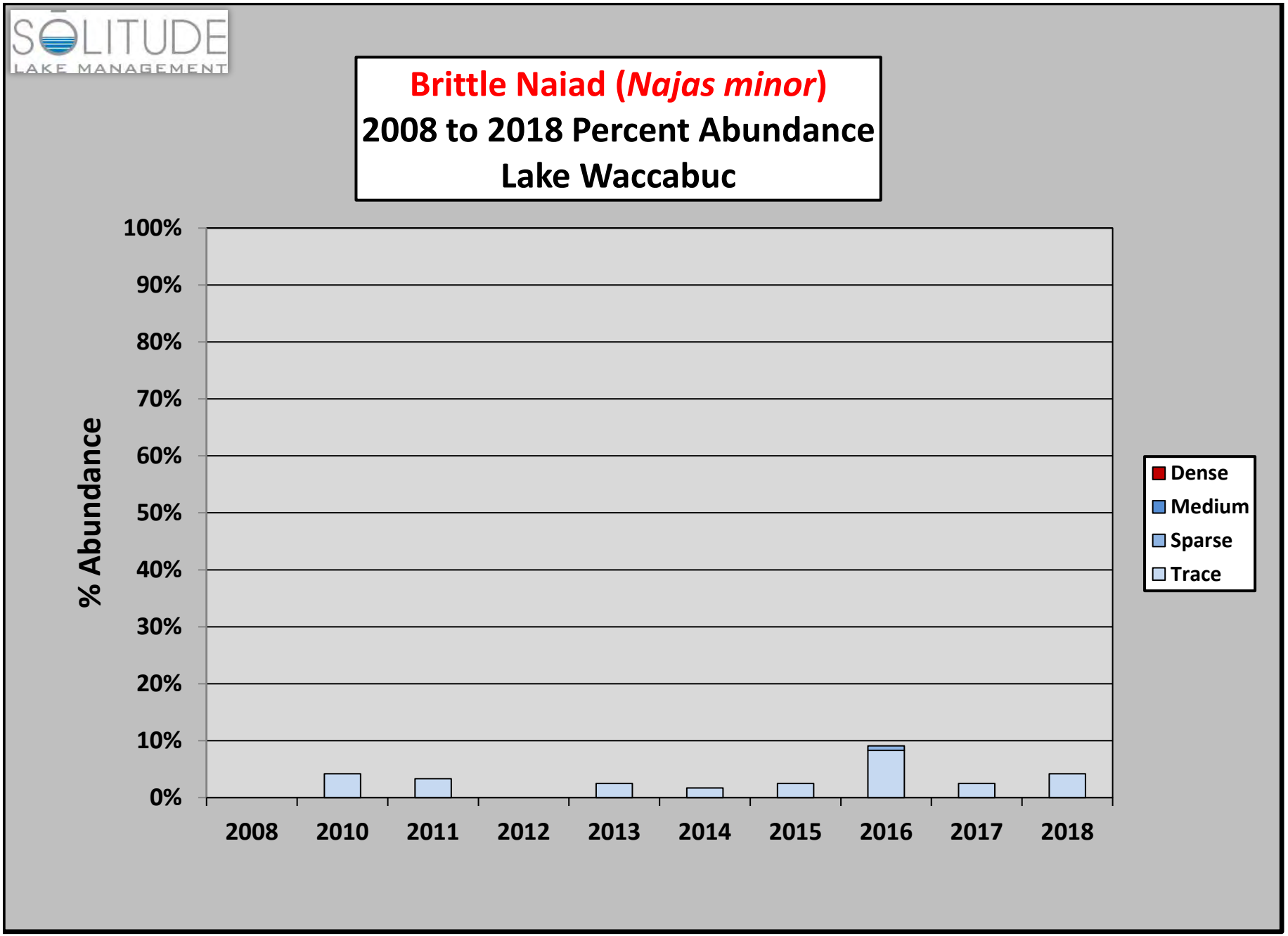
SOLITUDE
LAKE MANAGEMENT
Brittle Naiad (*Najas minor*)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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80%
70%
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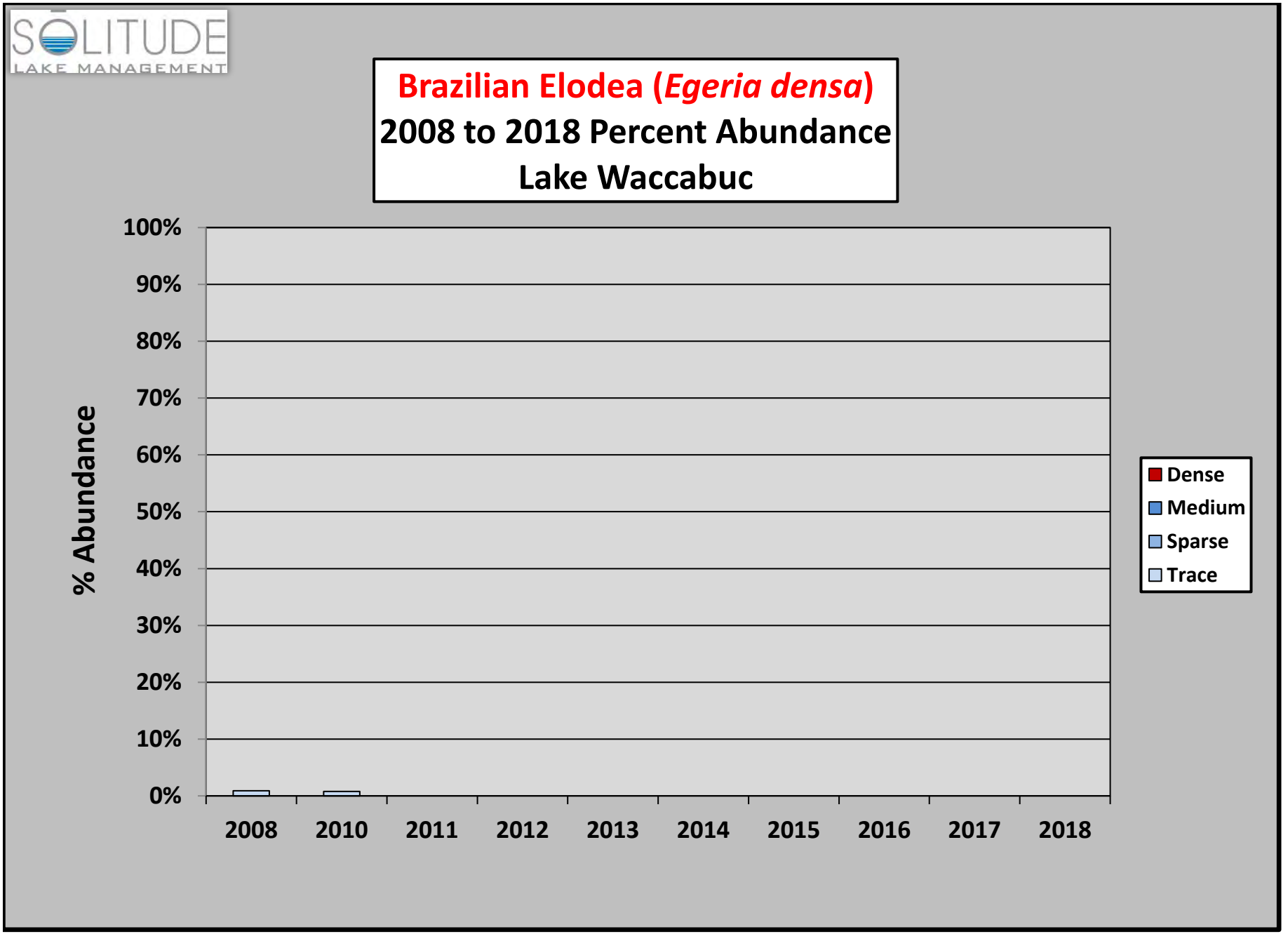
SOLITUDE
LAKE MANAGEMENT
Brazilian Elodea (*Egeria densa*)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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80%
70%
60%
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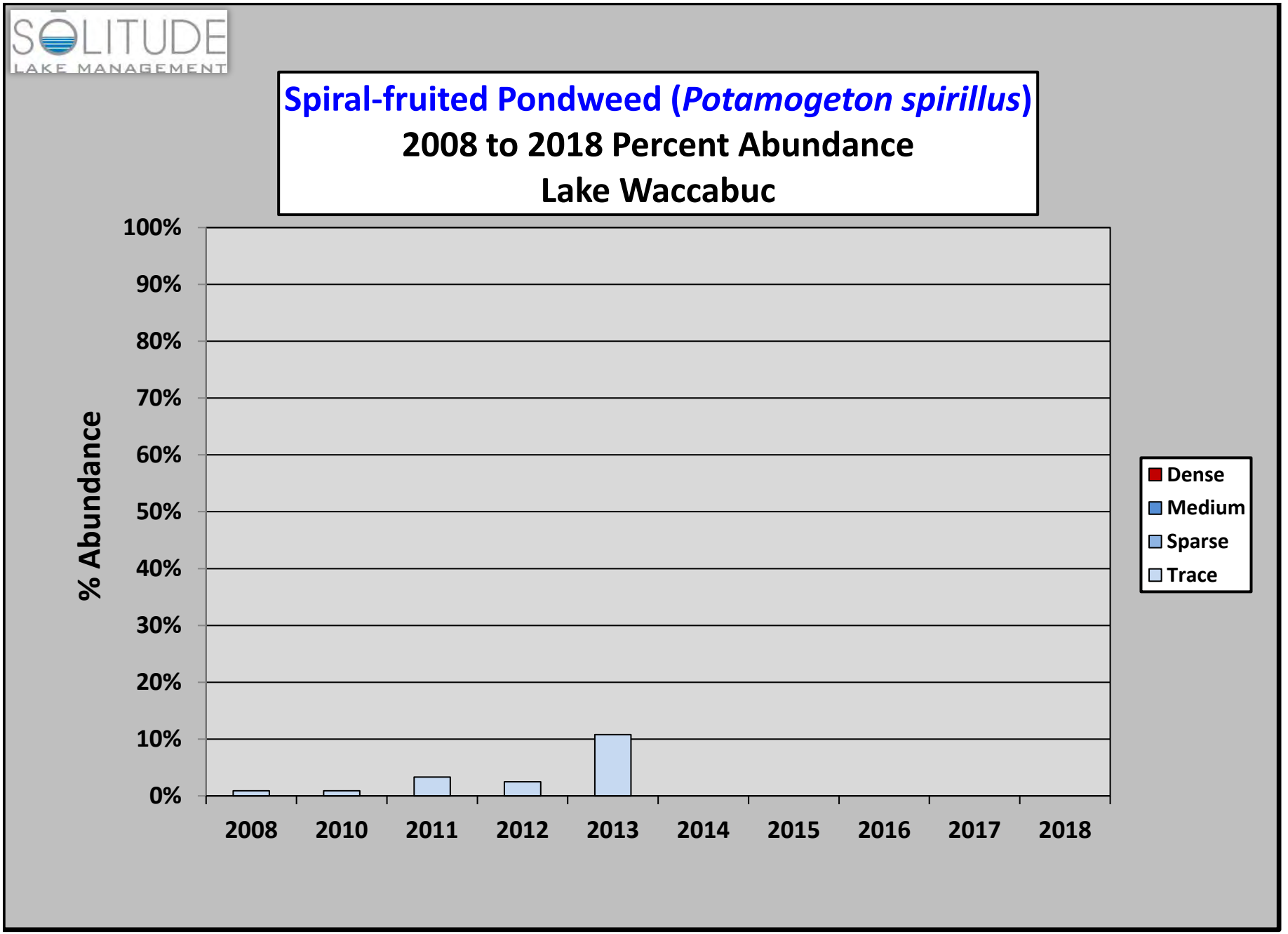
Trace


SOLITUDE
LAKE MANAGEMENT
Spiral-fruited Pondweed (Potamogeton spirillus)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
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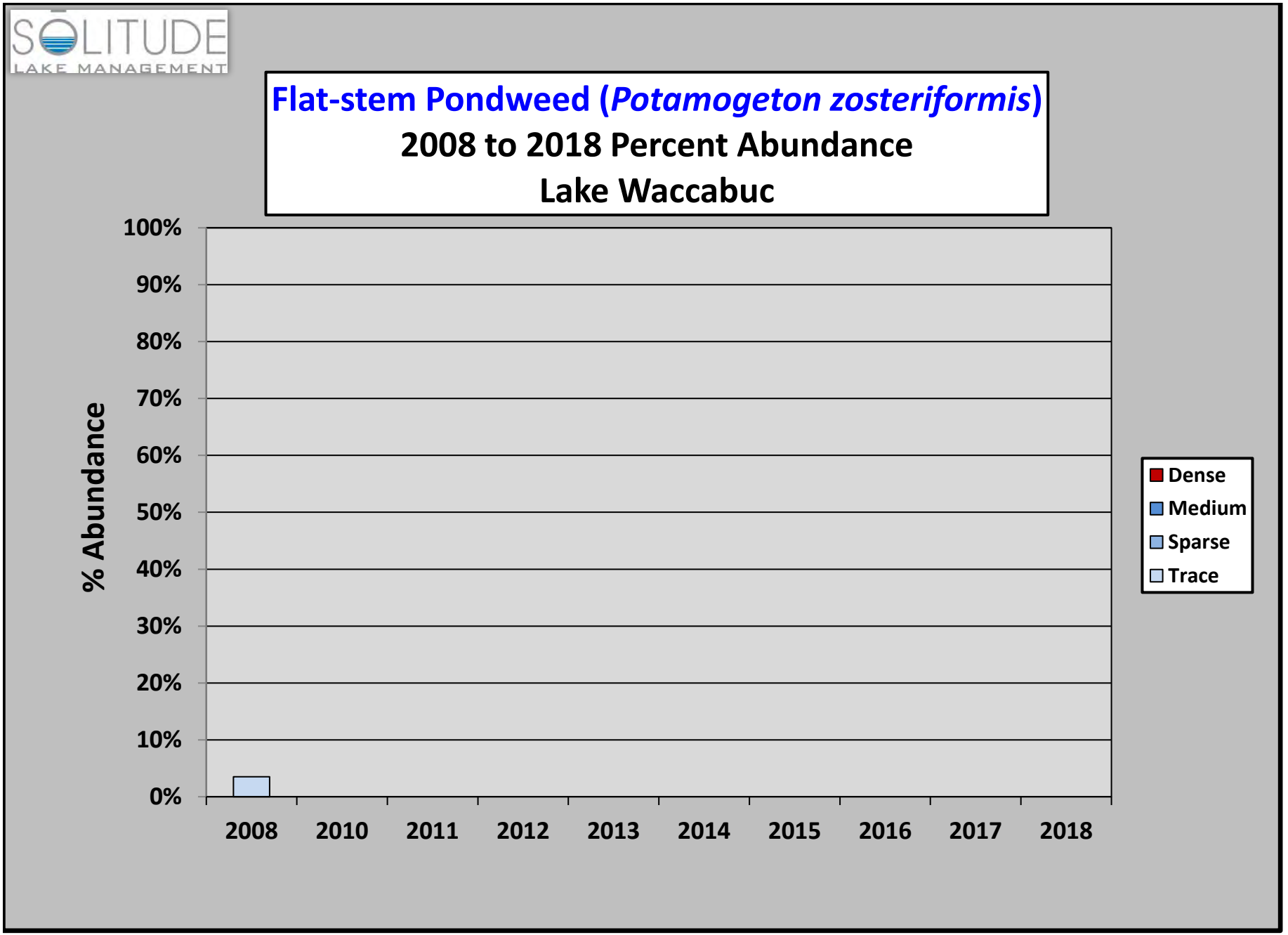
SOLITUDE
LAKE MANAGEMENT
Flat-stem Pondweed (Potamogeton zosteriformis)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
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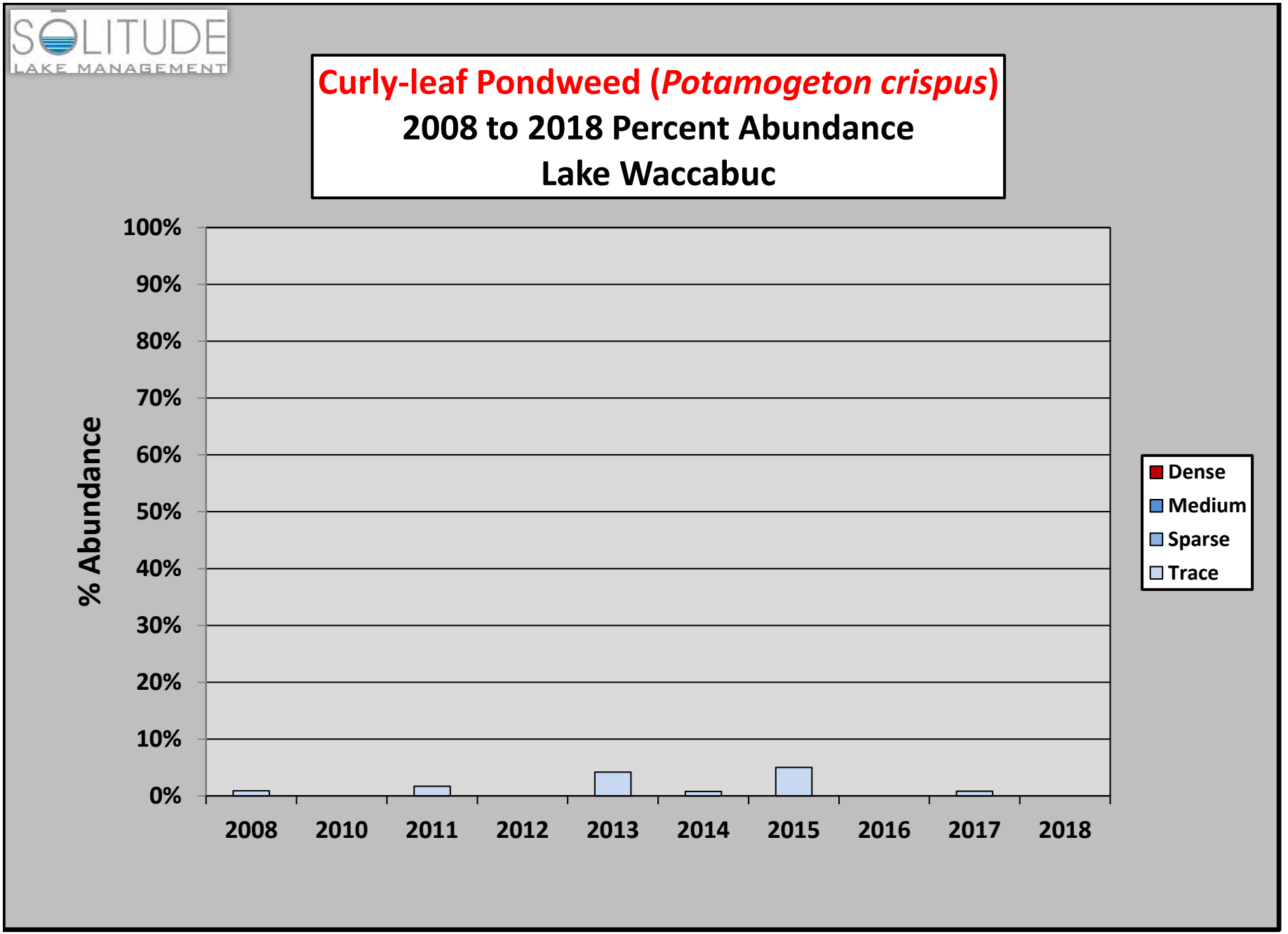
SOLITUDE
LAKE MANAGEMENT
Curly-leaf Pondweed (Potamogeton crispus)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
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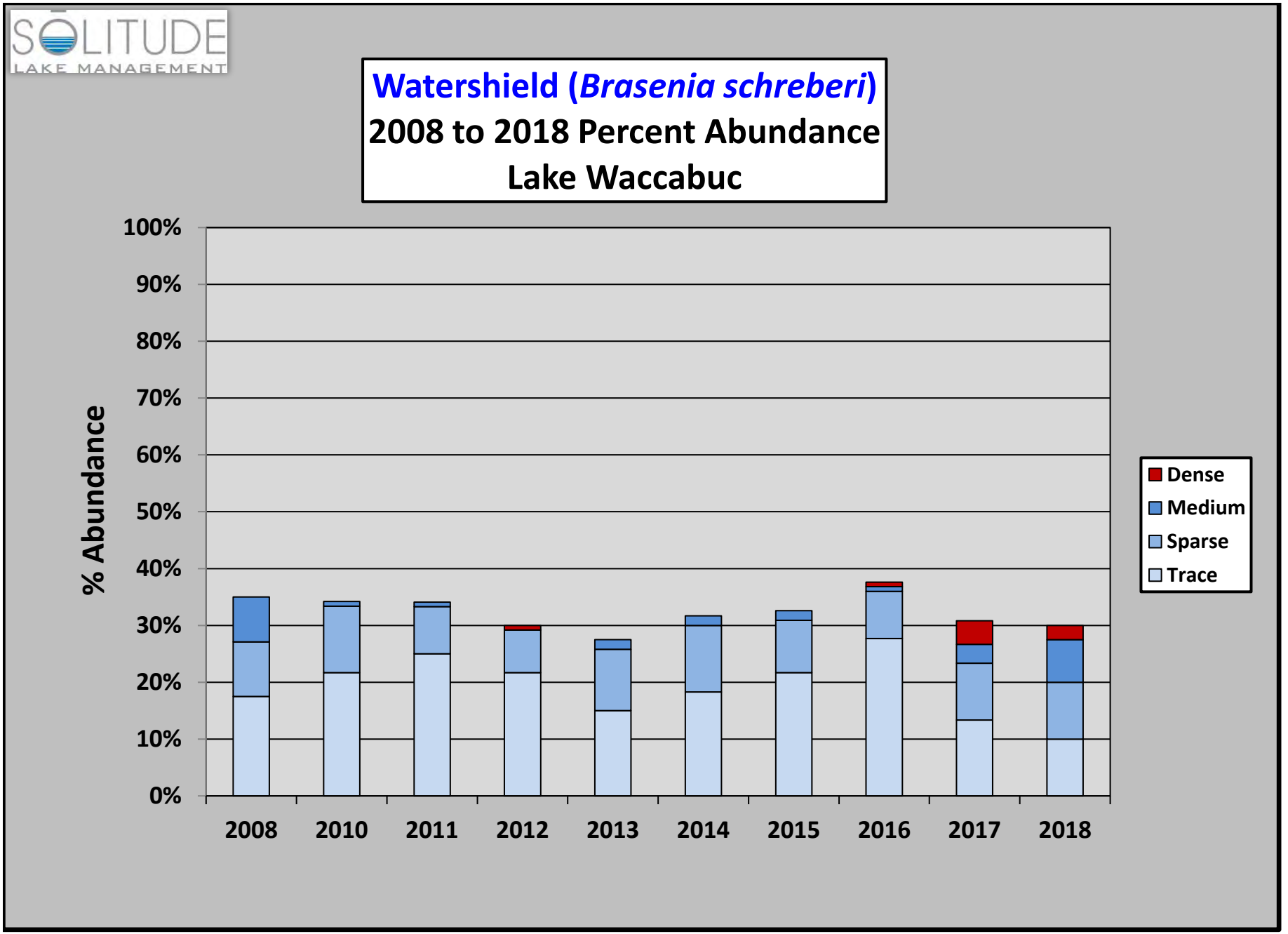
SOLITUDE
LAKE MANAGEMENT
Watershield (Brasenia schreberi)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
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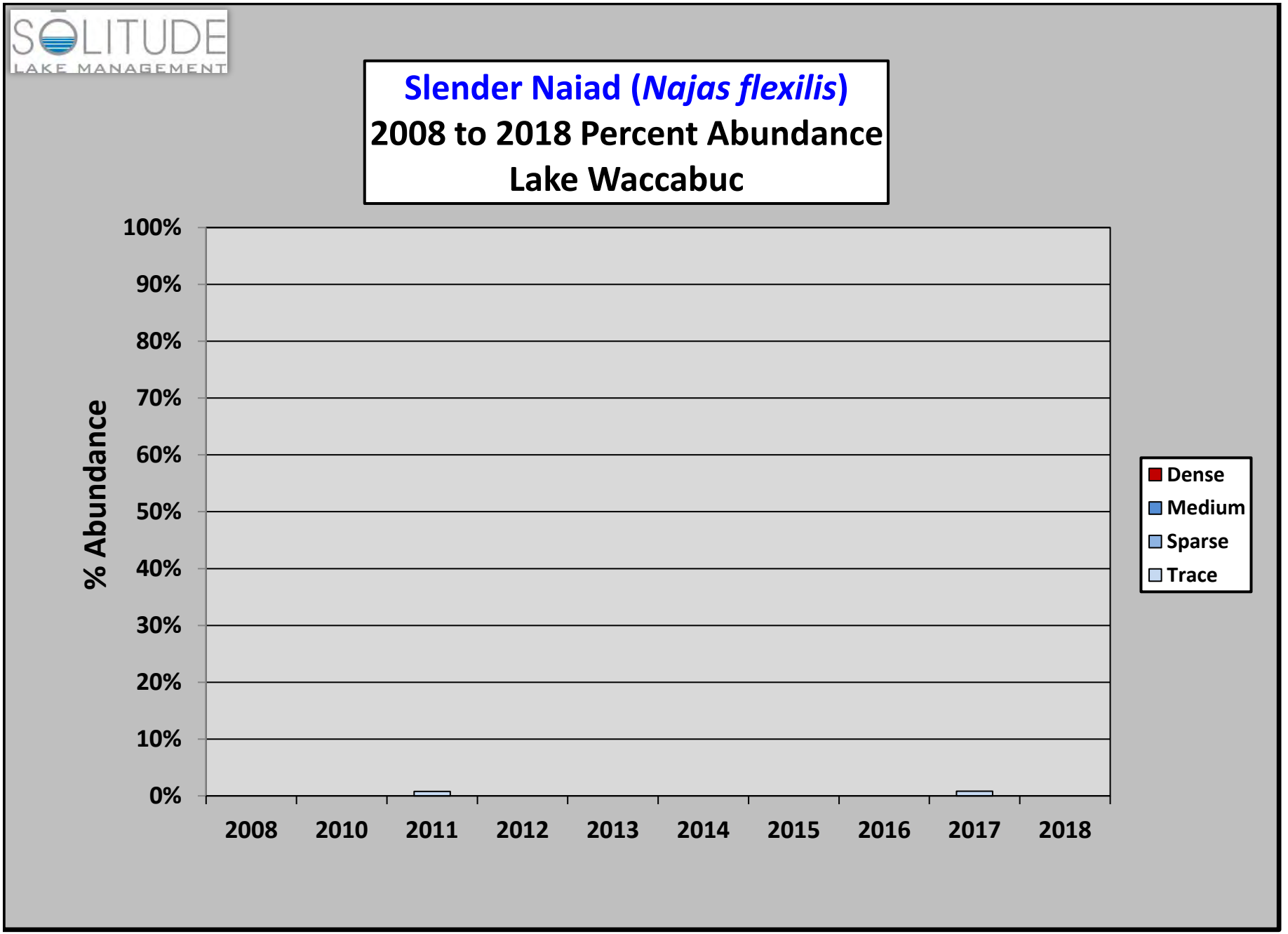
SOLITUDE
LAKE MANAGEMENT
Slender Naiad (*Najas flexilis*)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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80%
70%
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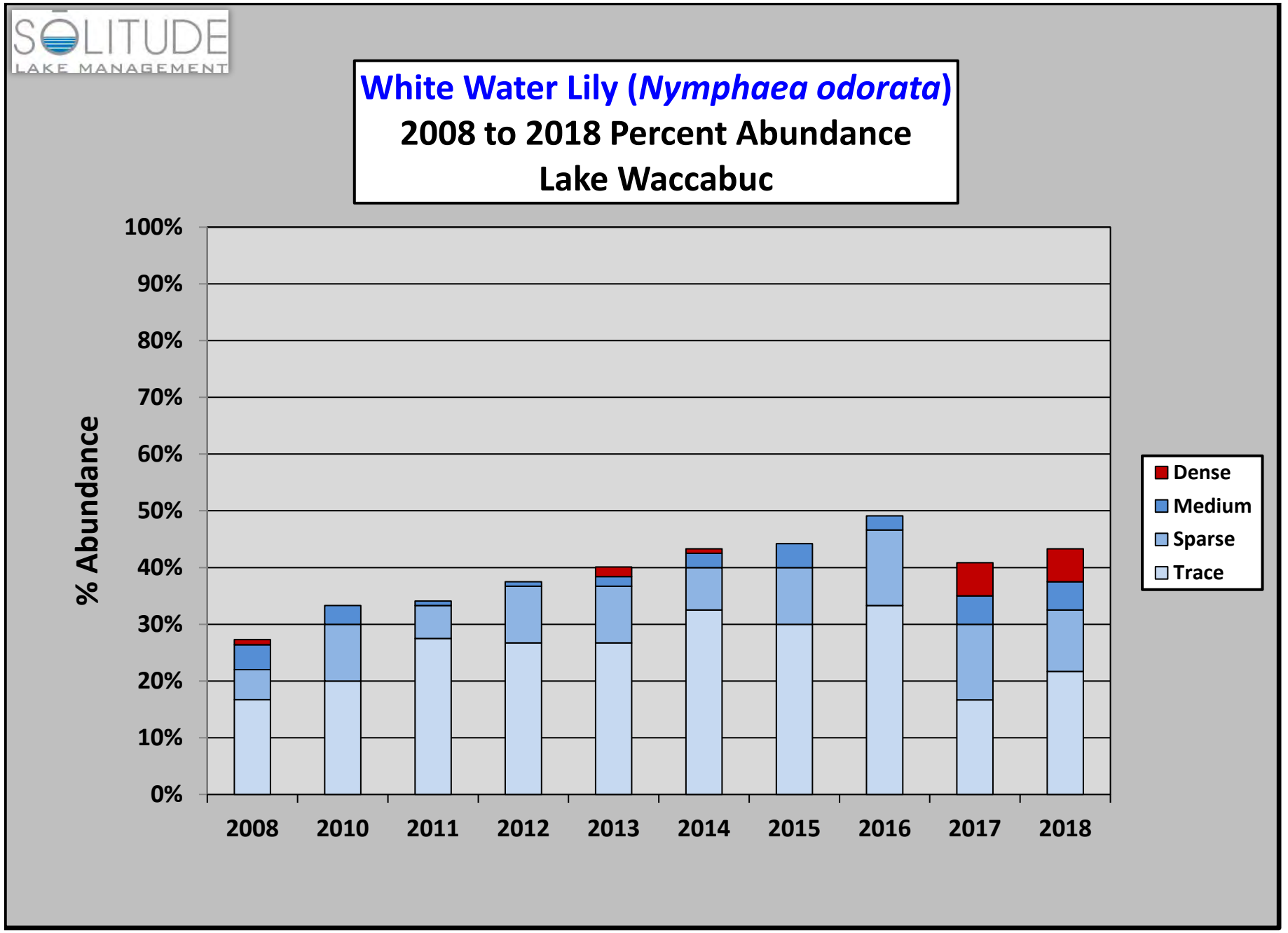
White Water Lily (Nymphaea odorata)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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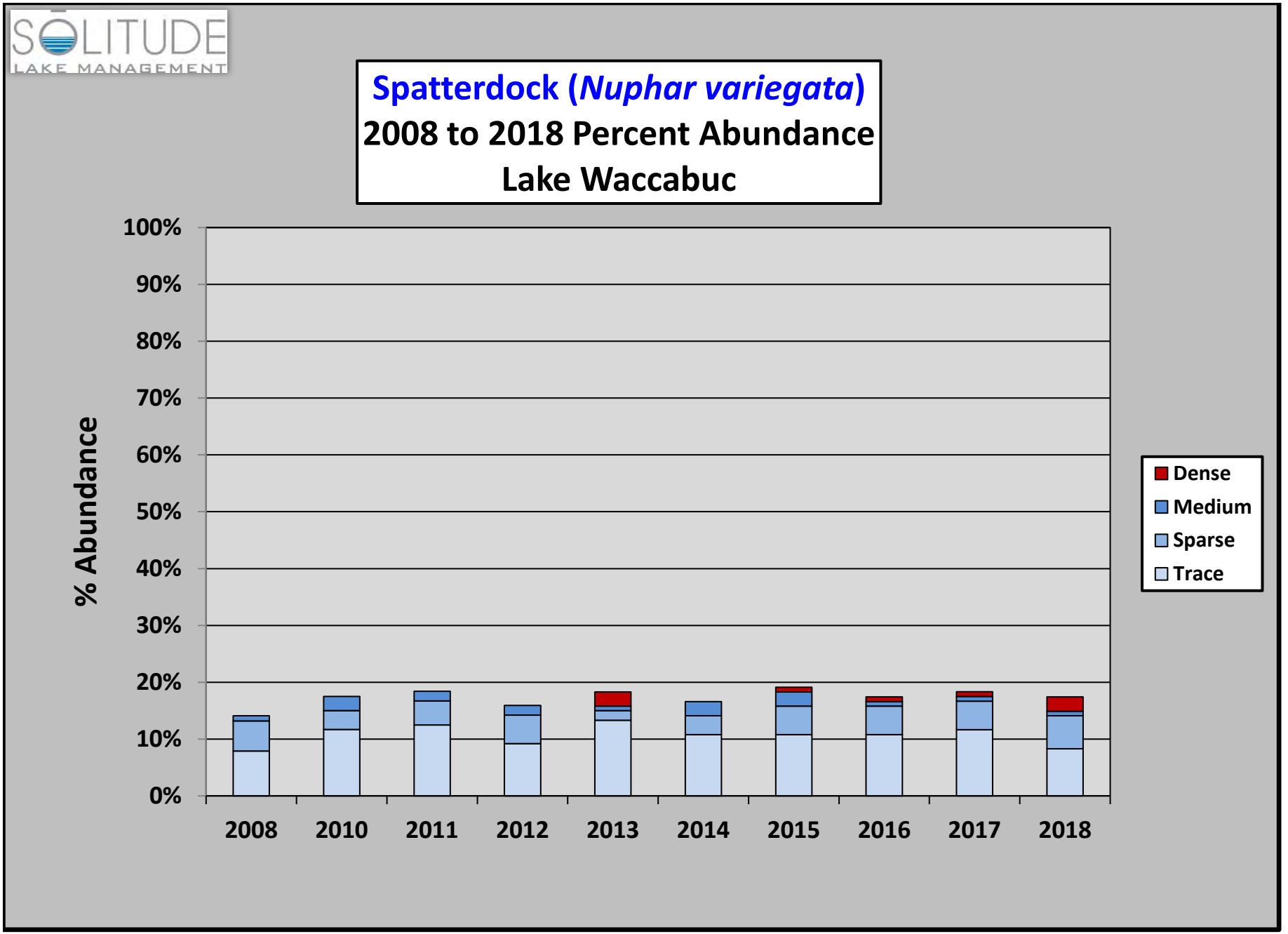
SOLITUDE
LAKE MANAGEMENT
Spatterdock (Nuphar variegata)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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80%
70%
60%
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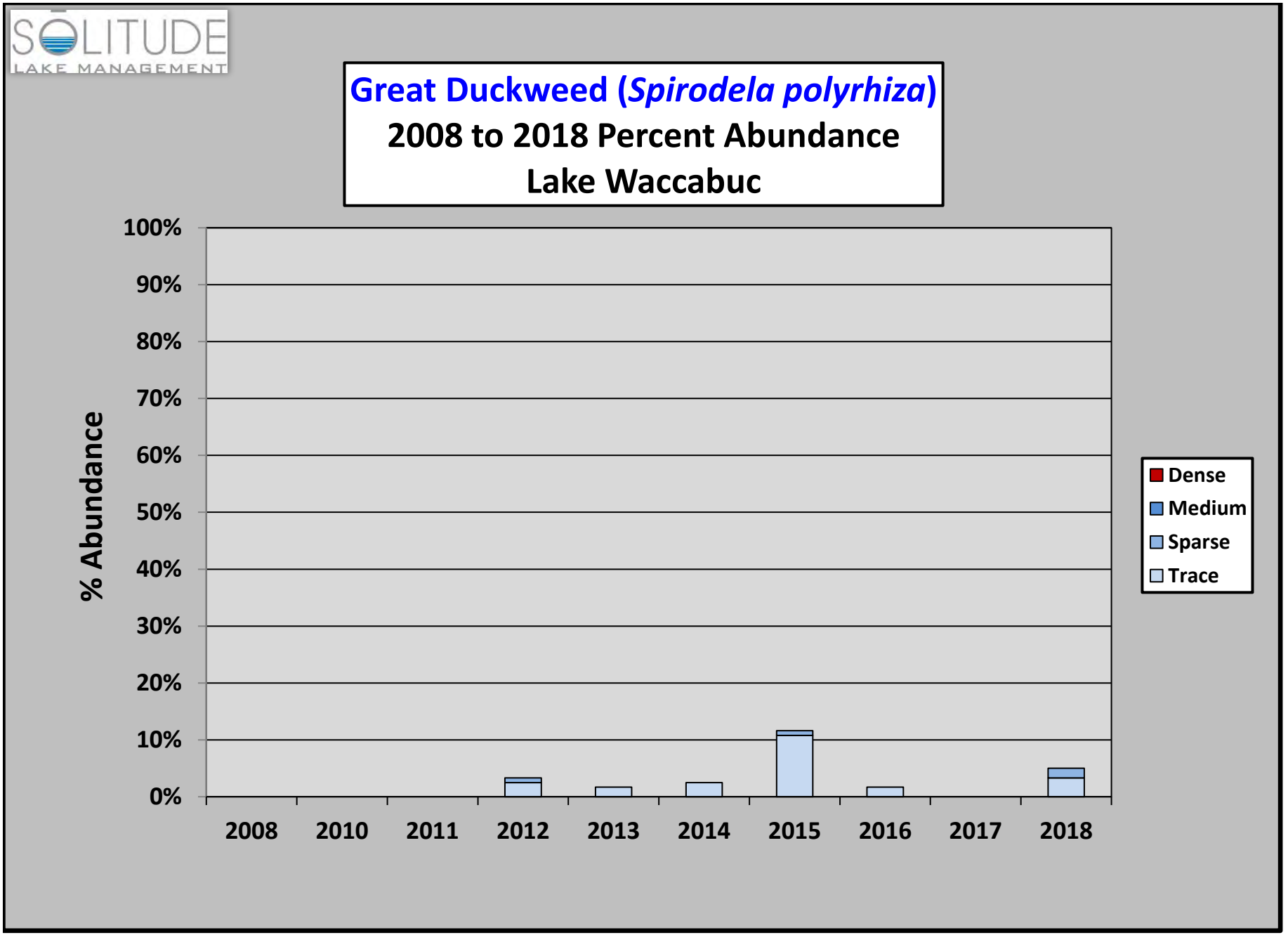
Trace


SOLITUDE
LAKE MANAGEMENT
Great Duckweed (Spirodela polyrhiza)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
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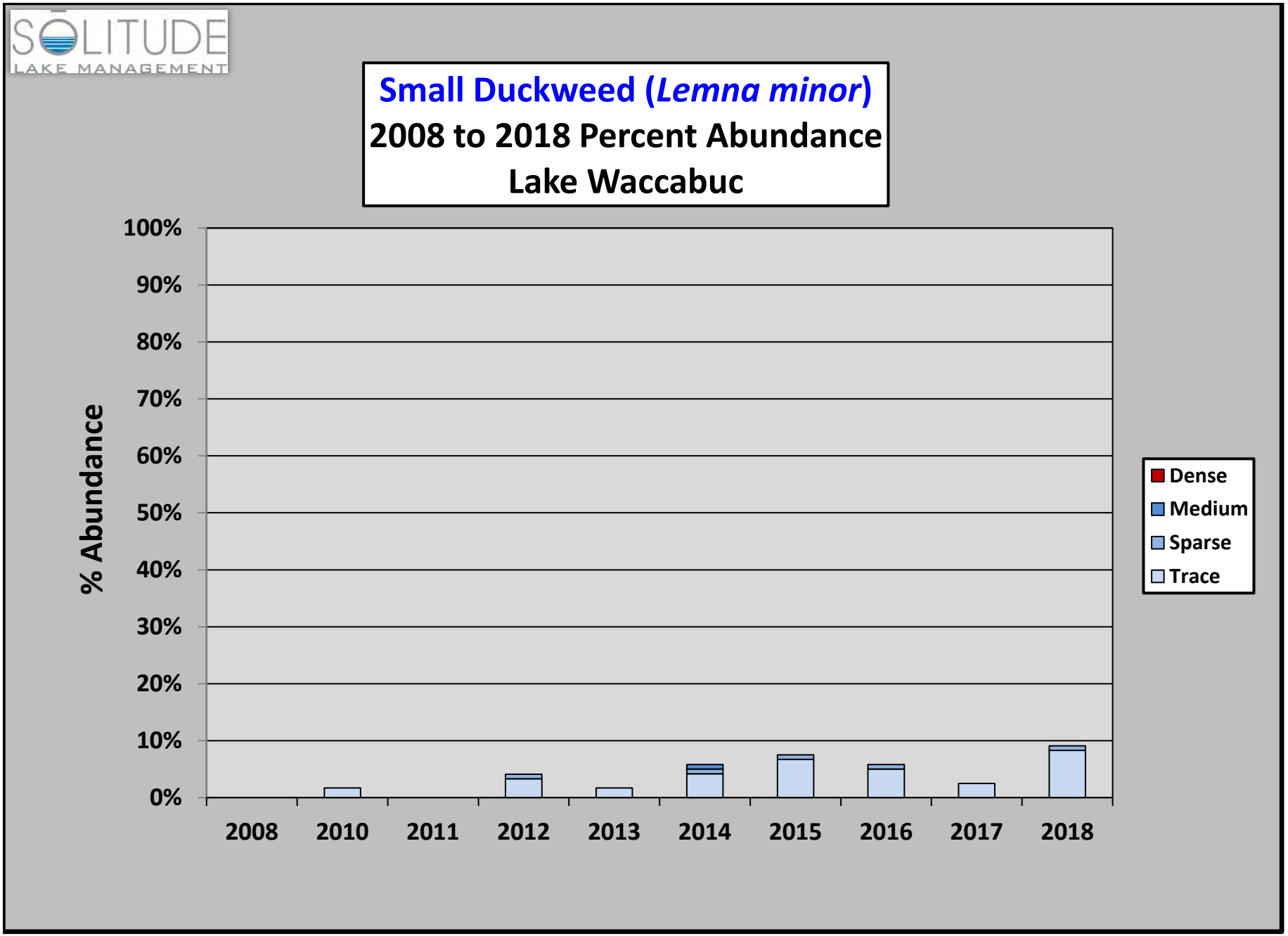
SOLITUDE
LAKE MANAGEMENT
Small Duckweed (Lemna minor)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
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70%
60%
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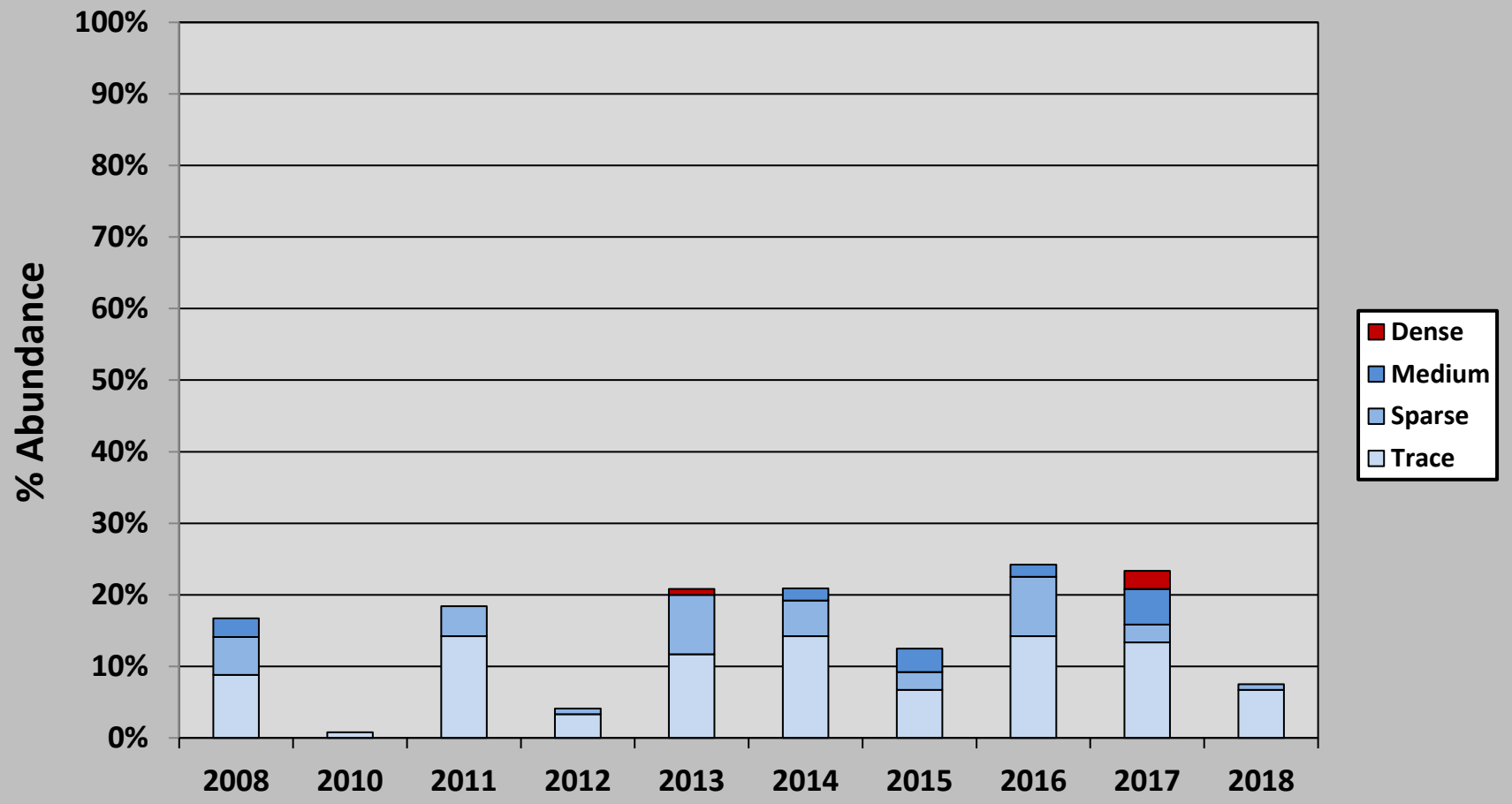
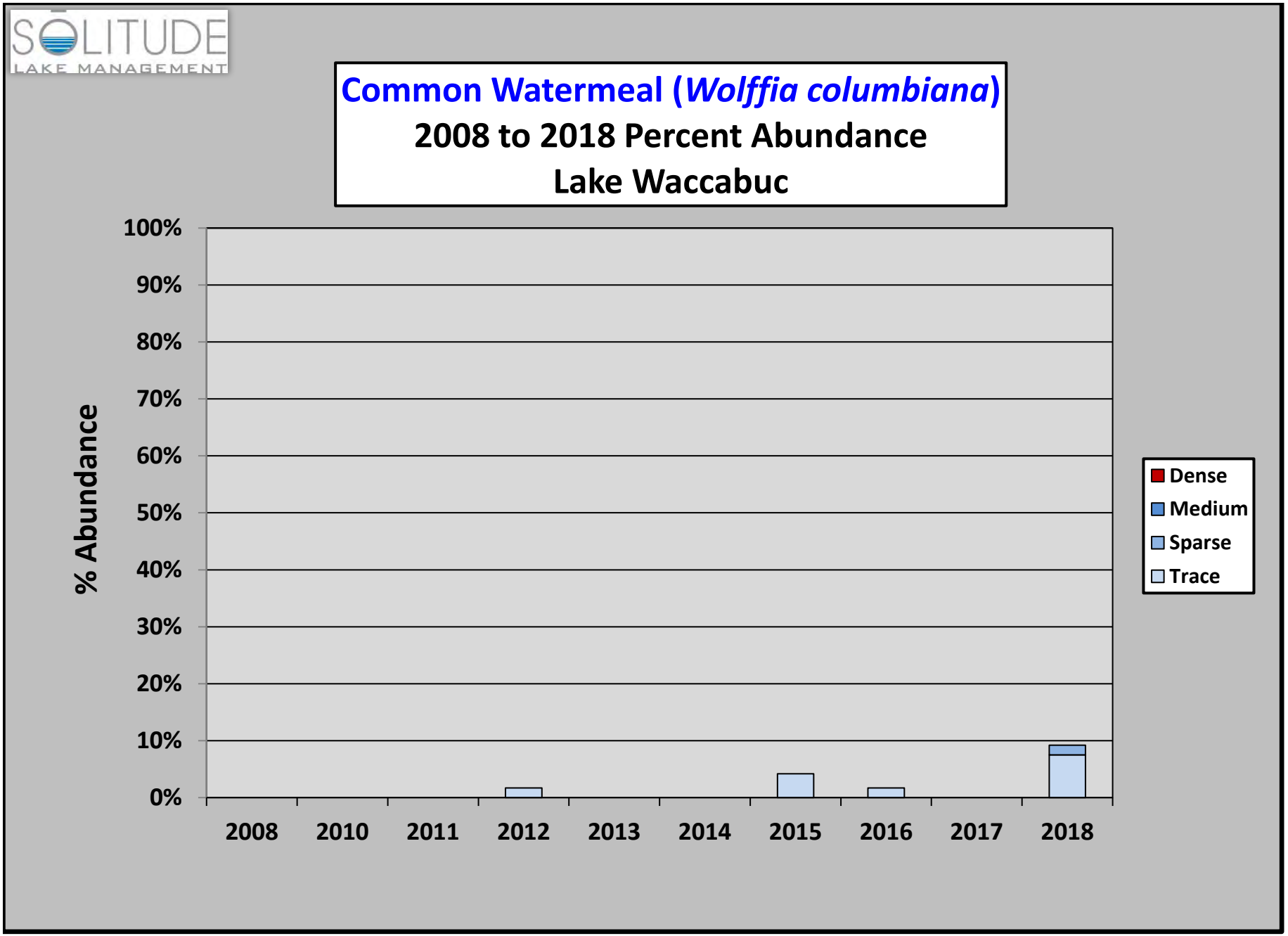
SOLITUDE LAKE MANAGEMENT

Floating Filamentous Algae
2008 to 2018 Percent Abundance
Lake Waccabuc




SOLITUDE
LAKE MANAGEMENT
Common Watermeal (*Wolffia columbiana*)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
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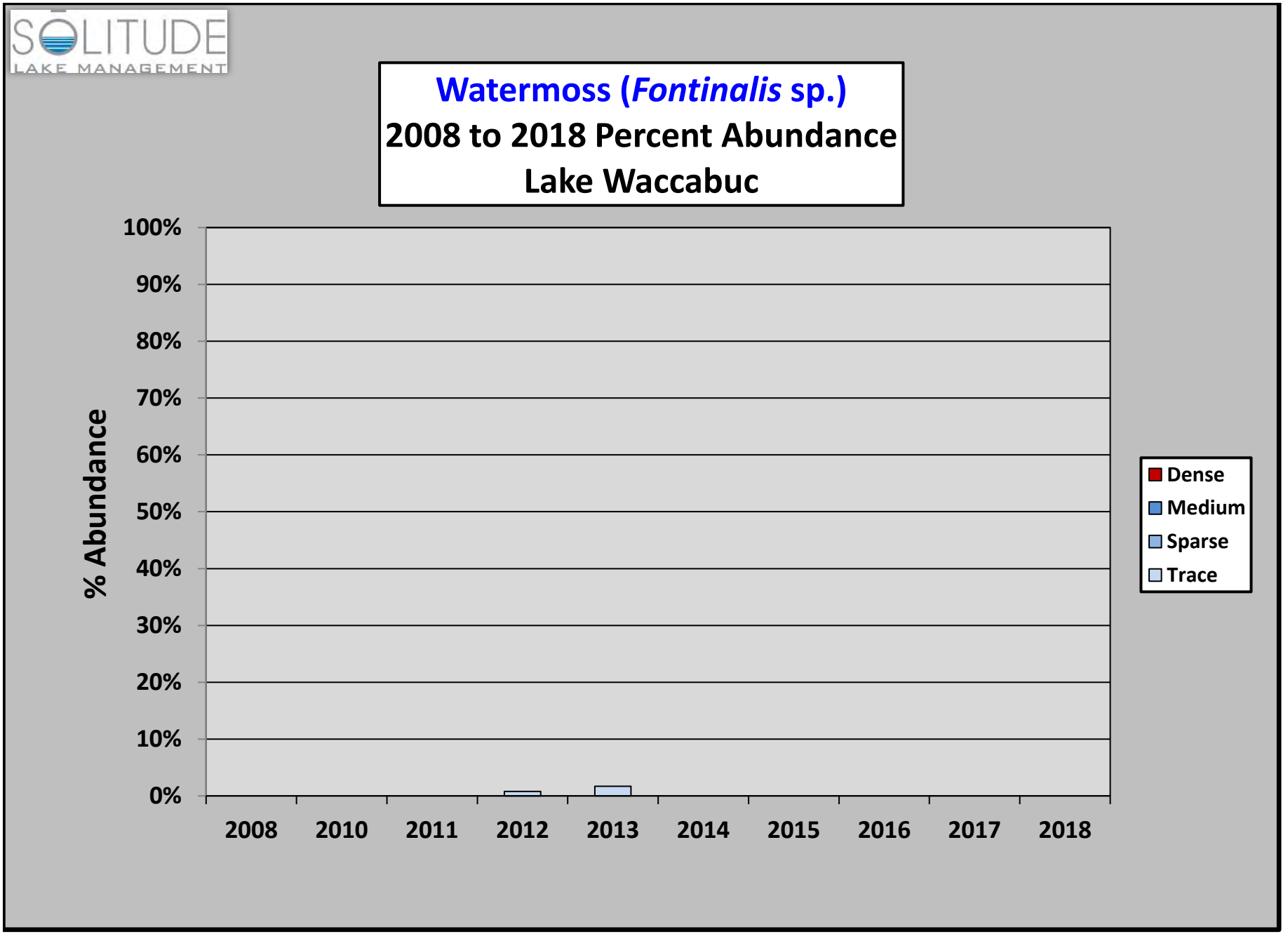
Watermoss (*Fontinalis* sp.)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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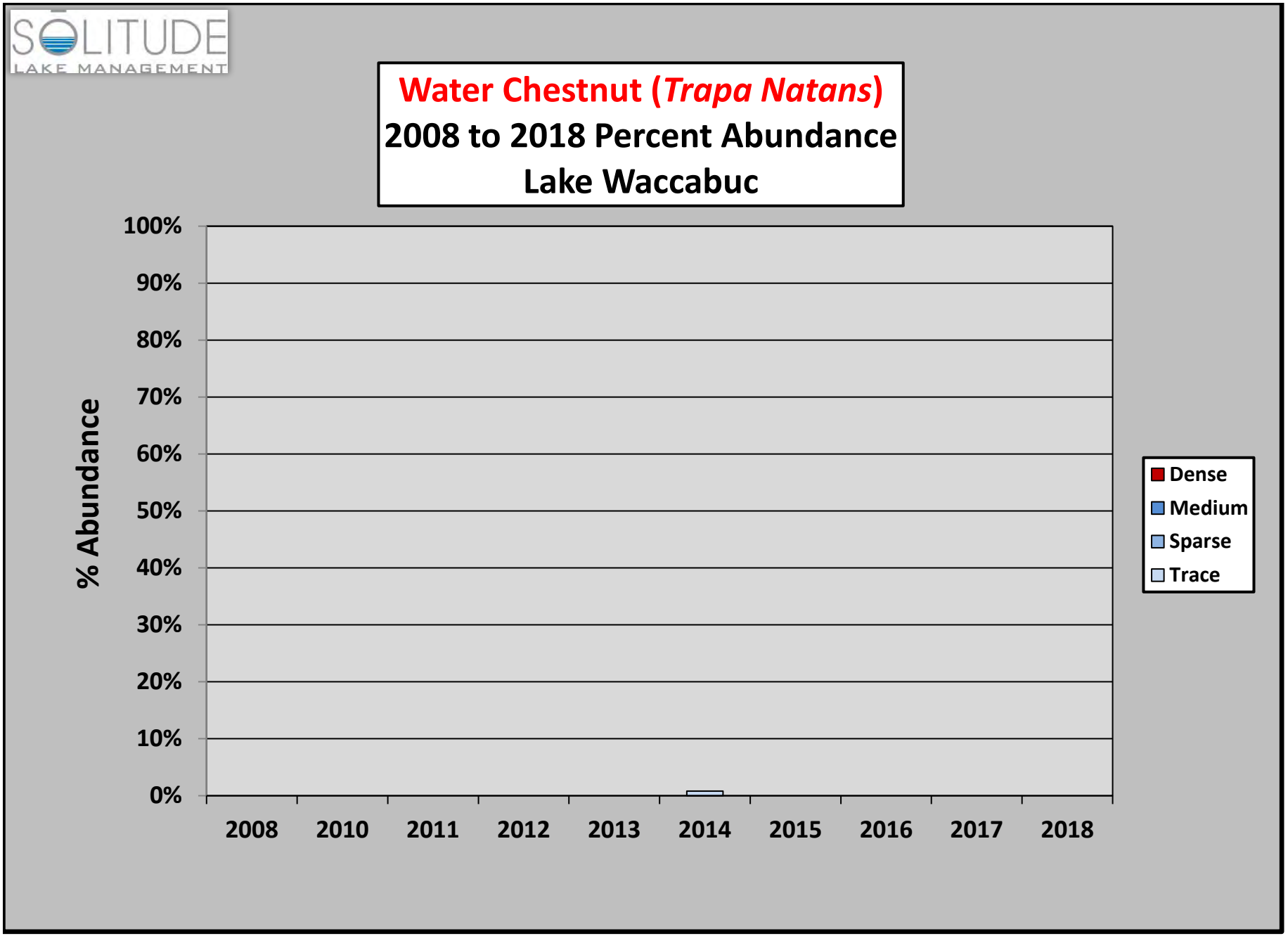
SOLITUDE
LAKE MANAGEMENT
Water Chestnut (*Trapa Natans*)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
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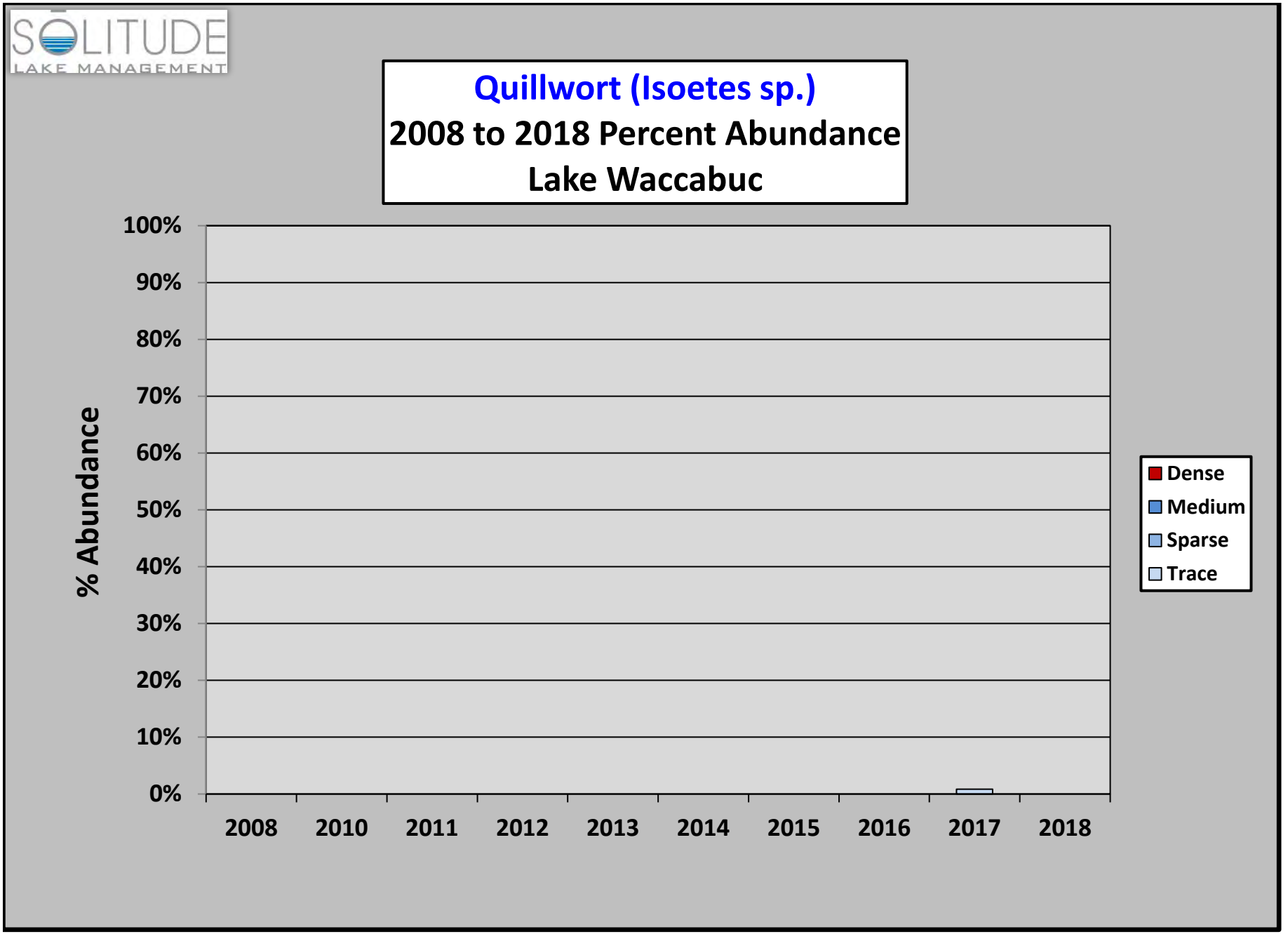
Quillwort (Isoetes sp.)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
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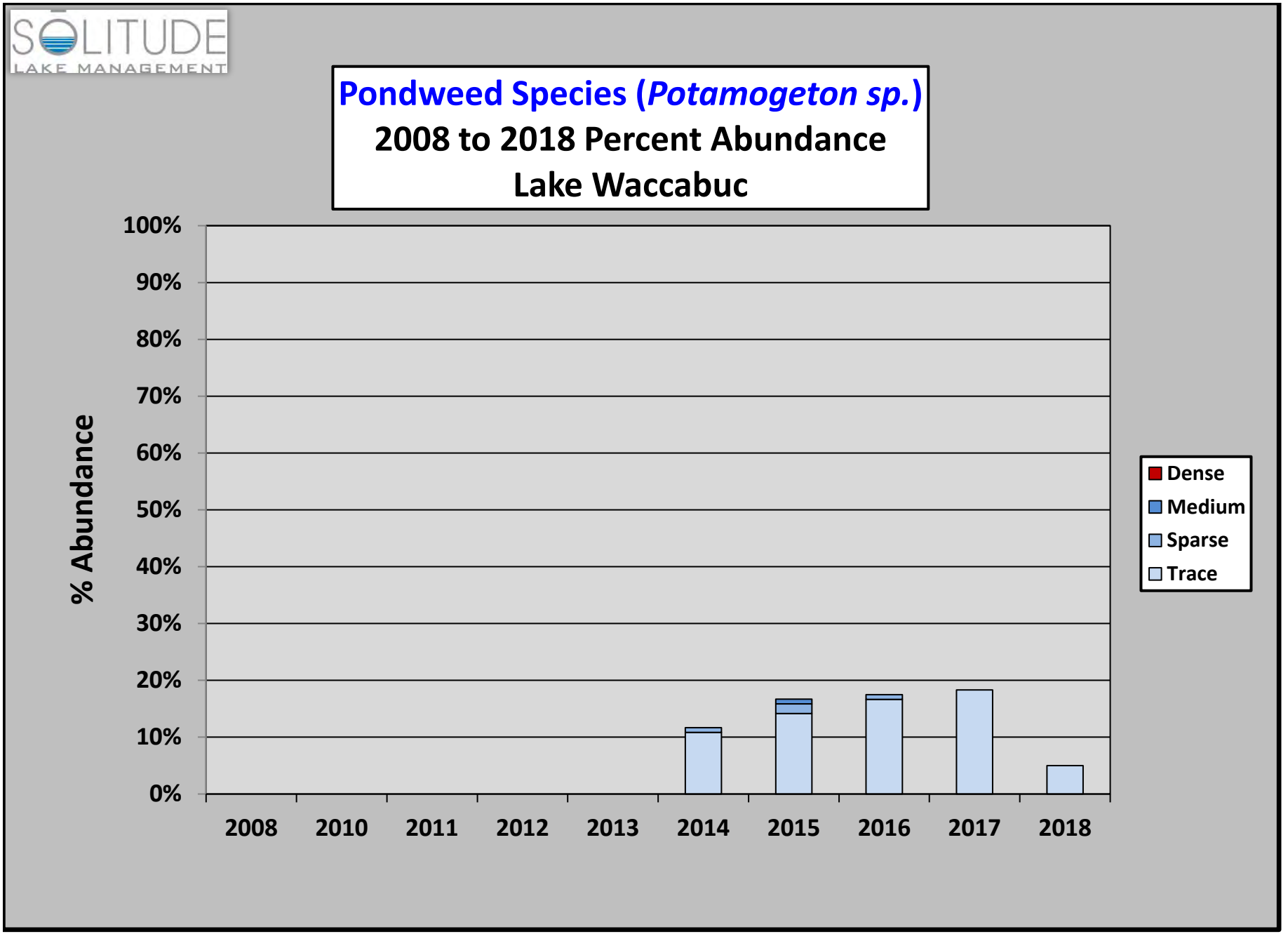
SOLITUDE
LAKE MANAGEMENT
Pondweed Species (Potamogeton sp.)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
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80%
70%
60%
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Sparse
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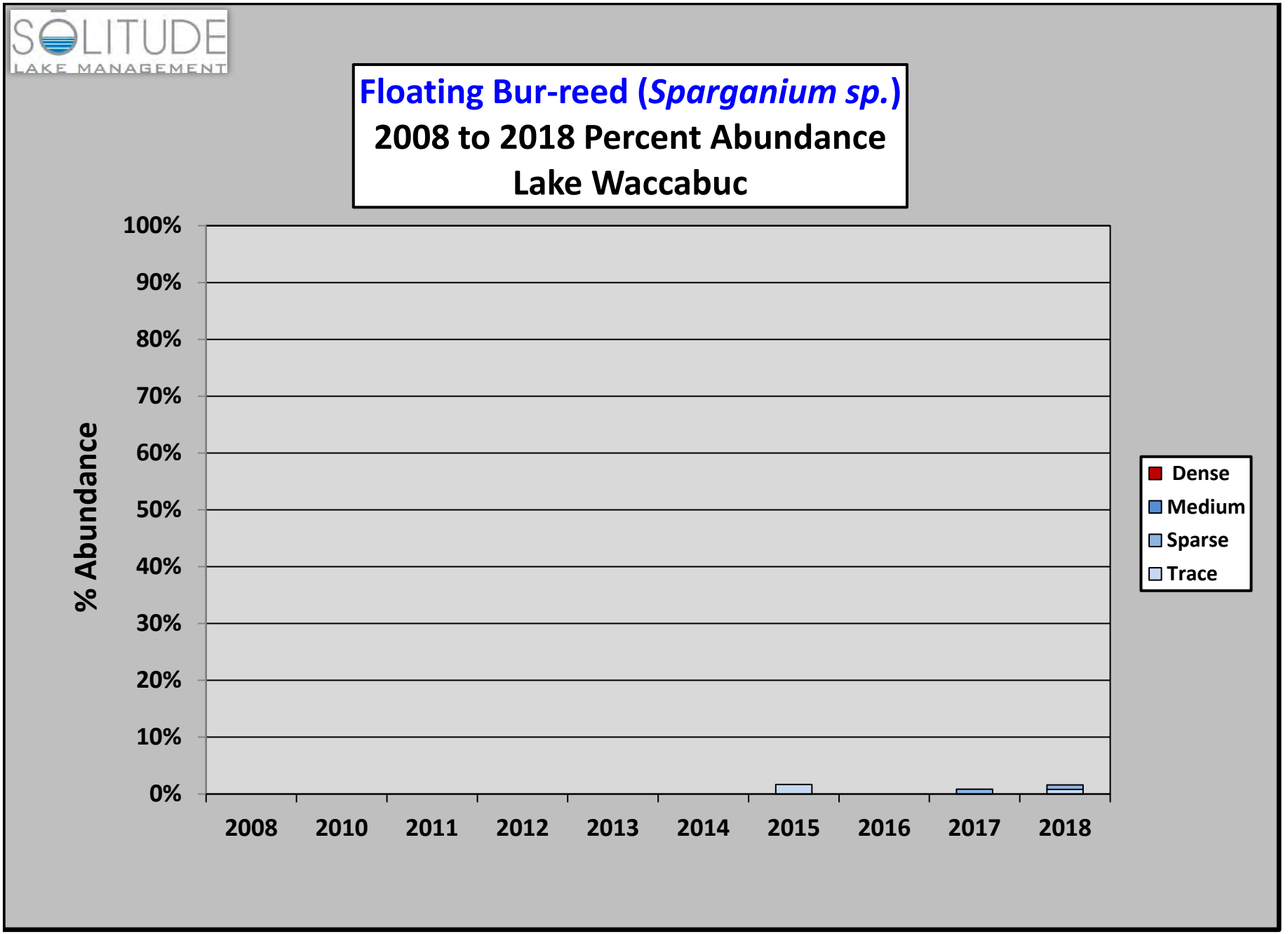
Floating Bur-reed (Sparganium sp.)
2008 to 2018 Percent Abundance
Lake Waccabuc
% Abundance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2008
2010
2011
2012
2013
2014
2015
2016
2017
2018
Dense
Medium
Sparse
Trace

Floating Aquatic Plant Density

Trace

Medium

Sparse

Dense

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Submersed Aquatic Plant Density

Trace

Medium

Sparse

Dense

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Lake Waccabuc
Aquatic Macrophyte Abundance Distribution
July 20 & 31, 2018

	Total		Trace		Sparse		Medium		Dense	
	Sites	%	Sites	%	Sites	%	Sites	%	Sites	%
TOTAL SITES	120									
TOTAL SUBMERSED VEGETATION	95	79%	55	58%	23	24%	10	11%	7	7%
EURASIAN WATER MILFOIL	75	63%	74	99%	1	1%	0	0%	0	0%
COONTAIL	53	44%	41	77%	9	17%	1	2%	2	4%
BENTHIC FILAMENTOUS ALGAE	46	38%	27	59%	11	24%	6	13%	2	4%
BASSWEED	39	33%	30	77%	5	13%	1	3%	3	8%
WATER STARGRASS	30	25%	27	90%	3	10%	0	0%	0	0%
LEAFY PONDWEED	21	18%	21	100%	0	0%	0	0%	0	0%
ARROWHEAD (ROSETTE)	12	10%	11	92%	1	8%	0	0%	0	0%
RIBBON-LEAF PONDWEED	8	7%	4	50%	1	13%	3	38%	0	0%
PONDWEED SPECIES	6	5%	6	100%	0	0%	0	0%	0	0%
BRITTLE NAIAD	5	4%	5	100%	0	0%	0	0%	0	0%
COMMON WATERWEED	4	3%	4	100%	0	0%	0	0%	0	0%
CREEPING BLADDERWORT	4	3%	3	75%	1	25%	0	0%	0	0%
DWARF WATER MILFOIL	2	2%	2	100%	0	0%	0	0%	0	0%
TOTAL FLOATING VEGETATION	64	53%	13	20%	21	33%	14	22%	16	25%
WHITE WATER LILY	52	43%	26	50%	13	25%	6	12%	7	13%
WATERSHIELD	36	30%	12	33%	12	33%	9	25%	3	8%
SPATTERDOCK	21	18%	10	48%	7	33%	1	5%	3	14%
COMMON WATERMEAL	11	9%	9	82%	2	18%	0	0%	0	0%
SMALL DUCKWEED	11	9%	10	91%	1	9%	0	0%	0	0%
FLOATING FILAMENTOUS ALGAE	10	8%	8	80%	1	10%	0	0%	1	10%
GREAT DUCKWEED	6	5%	4	67%	2	33%	0	0%	0	0%
BUR-REED	2	2%	1	50%	1	50%	0	0%	0	0%

Sample Point Location

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Sample Point

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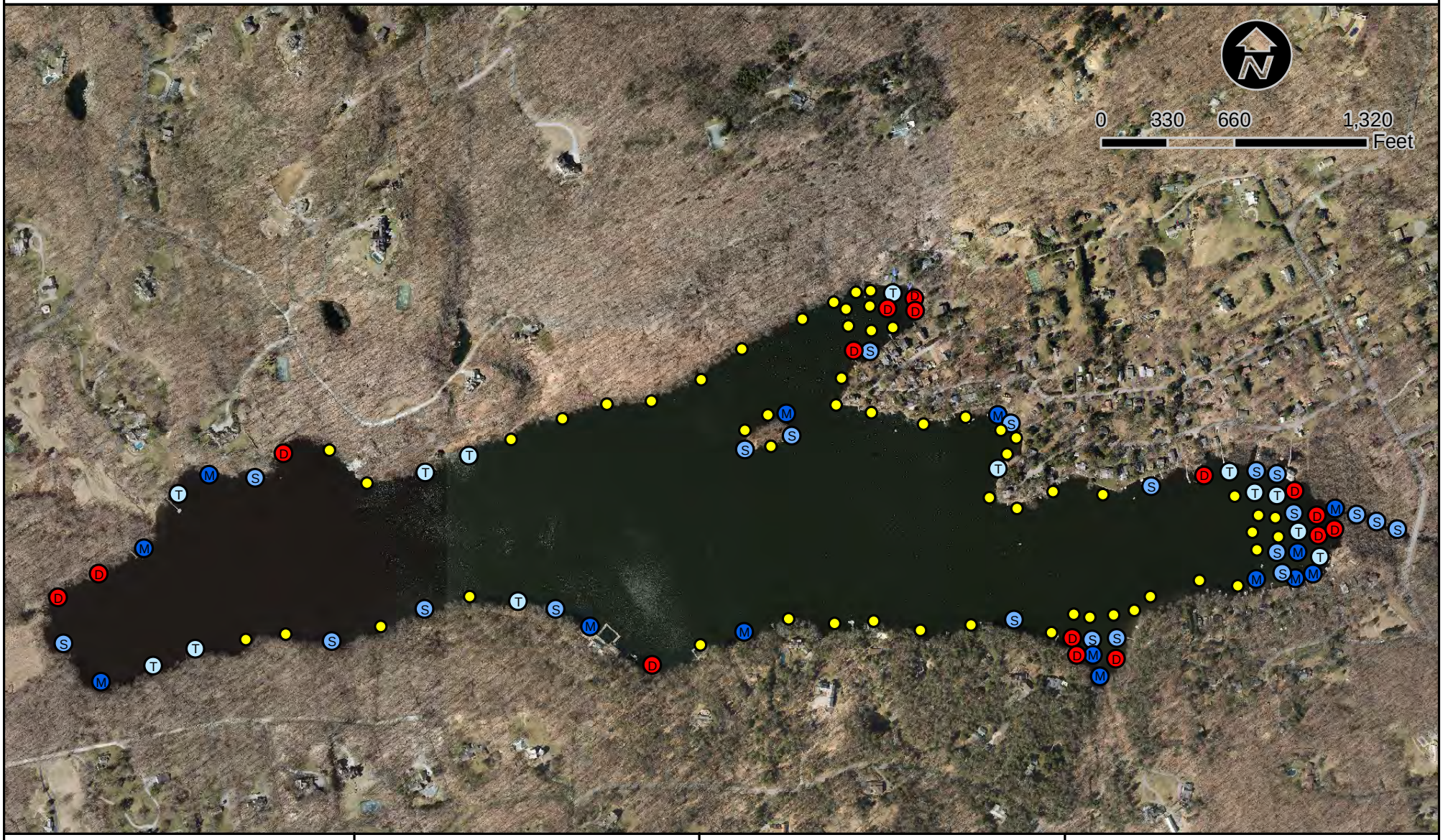
Total Floating Vegetation Distribution



Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	64	53%
Trace	13	20%
Sparse	21	33%
Medium	14	22%
Dense	16	25%

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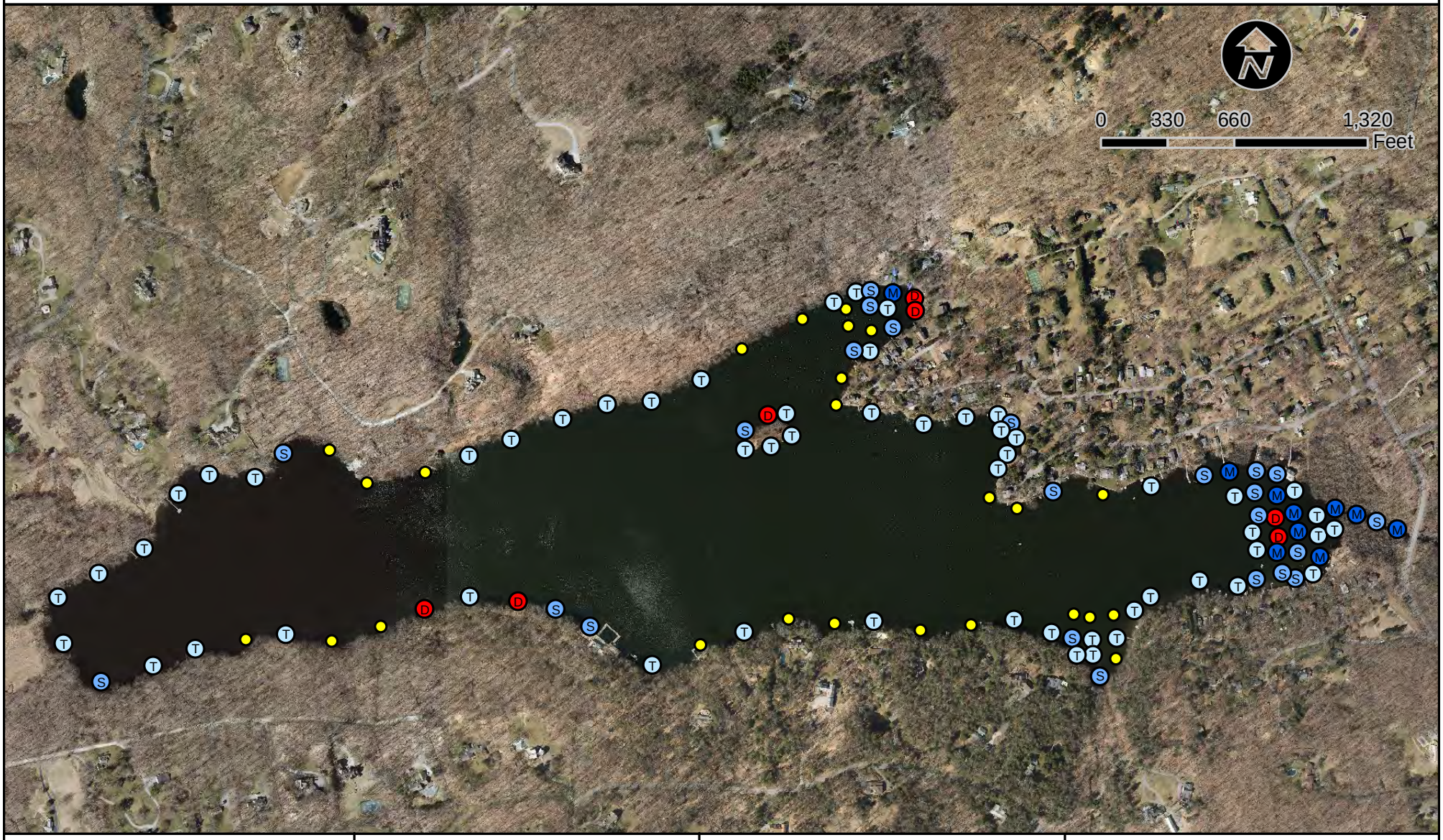
Total Submersed Vegetation Distribution



Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	95	79%
Trace	55	58%
Sparse	23	24%
Medium	10	11%
Dense	7	7%

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Arrowhead Rosette (*Sagittaria sp.*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	12	10%
Trace	11	92%
Sparse	1	8%
Medium	0	0%
Dense	0	0%

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Bassweed (*Potamogeton amplifolius*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	39	33%
Trace	30	77%
Sparse	5	13%
Medium	1	3%
Dense	3	8%

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Benthic Filamentous Algae Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	46	38%
Trace	27	59%
Sparse	11	24%
Medium	6	13%
Dense	2	4%

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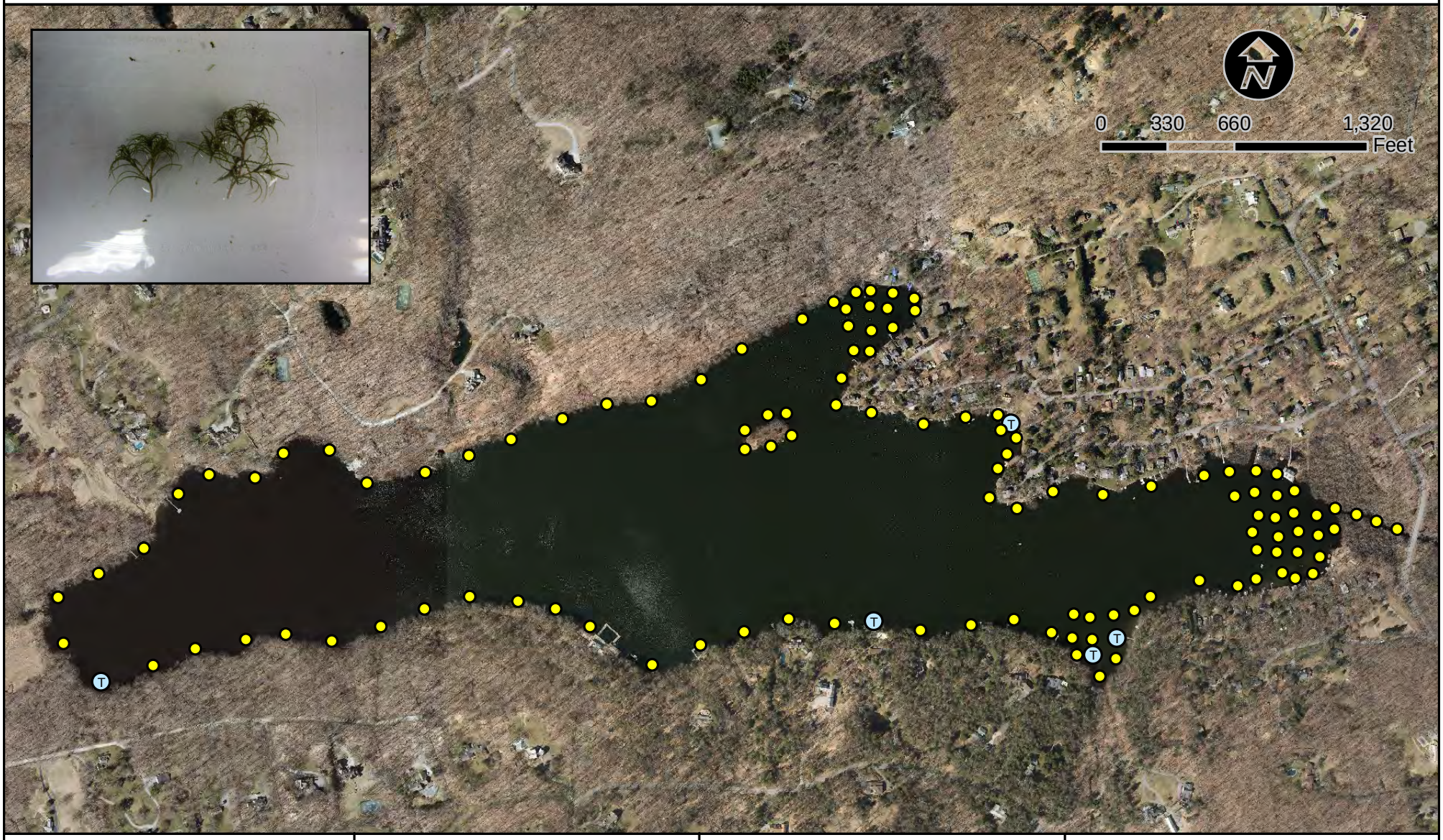
Brittle Naiad (*Najas minor*) Distribution



Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	5	4%
Trace	5	100%
Sparse	0	0%
Medium	0	0%
Dense	0	0%

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Floating Bur-reed (*Sparganium fluctuans*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	2	2%
Trace	1	50%
Sparse	1	50%
Medium	0	0%
Dense	0	0%

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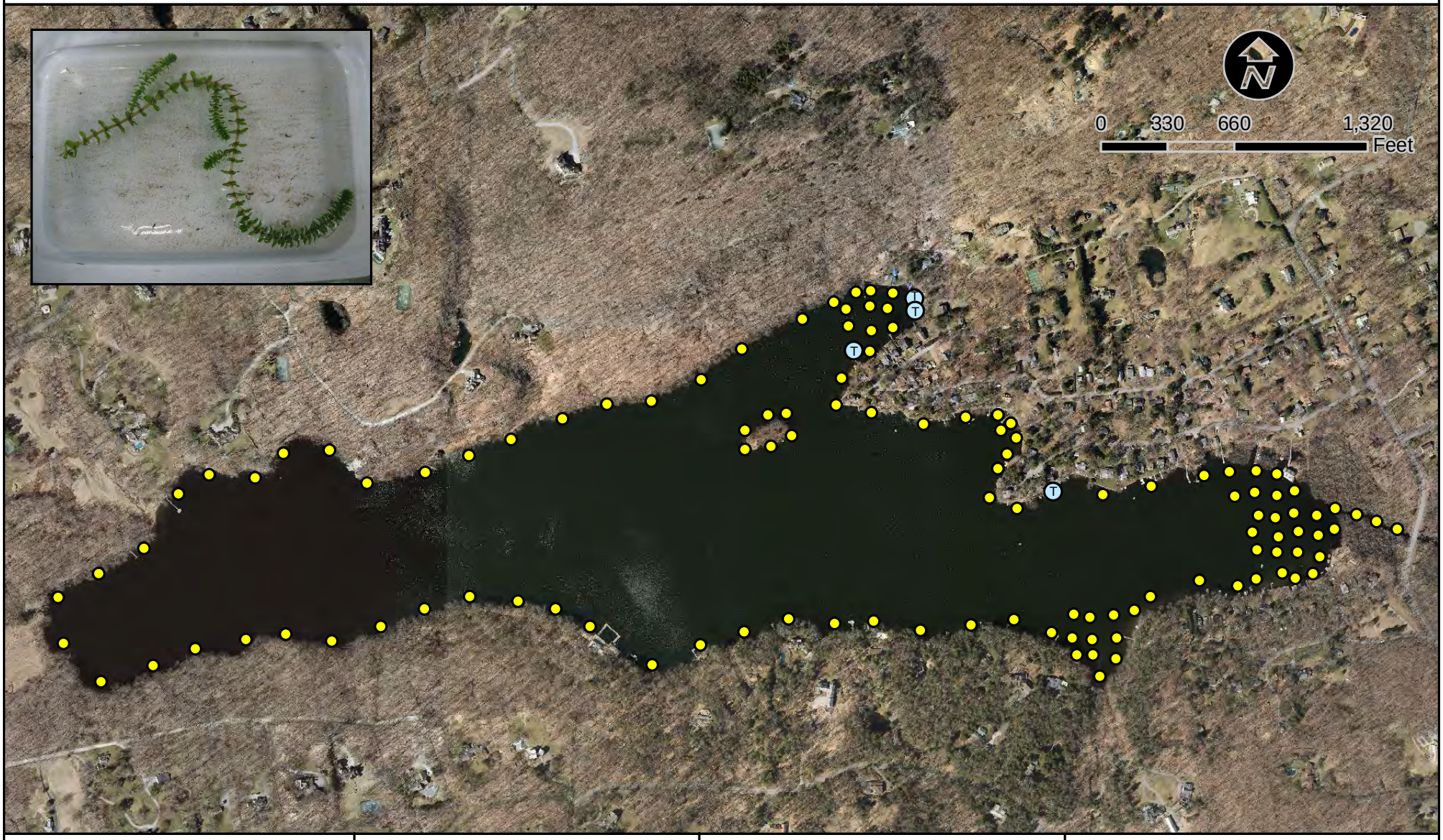
Common Waterweed (*Elodea canadensis*) Distribution



Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	4	3%
Trace	4	100%
Sparse	0	0%
Medium	0	0%
Dense	0	0%

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Coontail (*Ceratophyllum demersum*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	53	44%
Trace	41	77%
Sparse	9	17%
Medium	1	2%
Dense	2	4%

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Creeping Bladderwort (*Utricularia gibba*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	4	3%
Trace	3	75%
Sparse	1	25%
Medium	0	0%
Dense	0	0%

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Dwarf Water Milfoil (*Myriophyllum tenellum*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	2	2%
Trace	2	100%
Sparse	0	0%
Medium	0	0%
Dense	0	0%

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Eurasian Water Milfoil (*Myriophyllum spicatum*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	75	63%
Trace	74	99%
Sparse	1	1%
Medium	0	0%
Dense	0	0%

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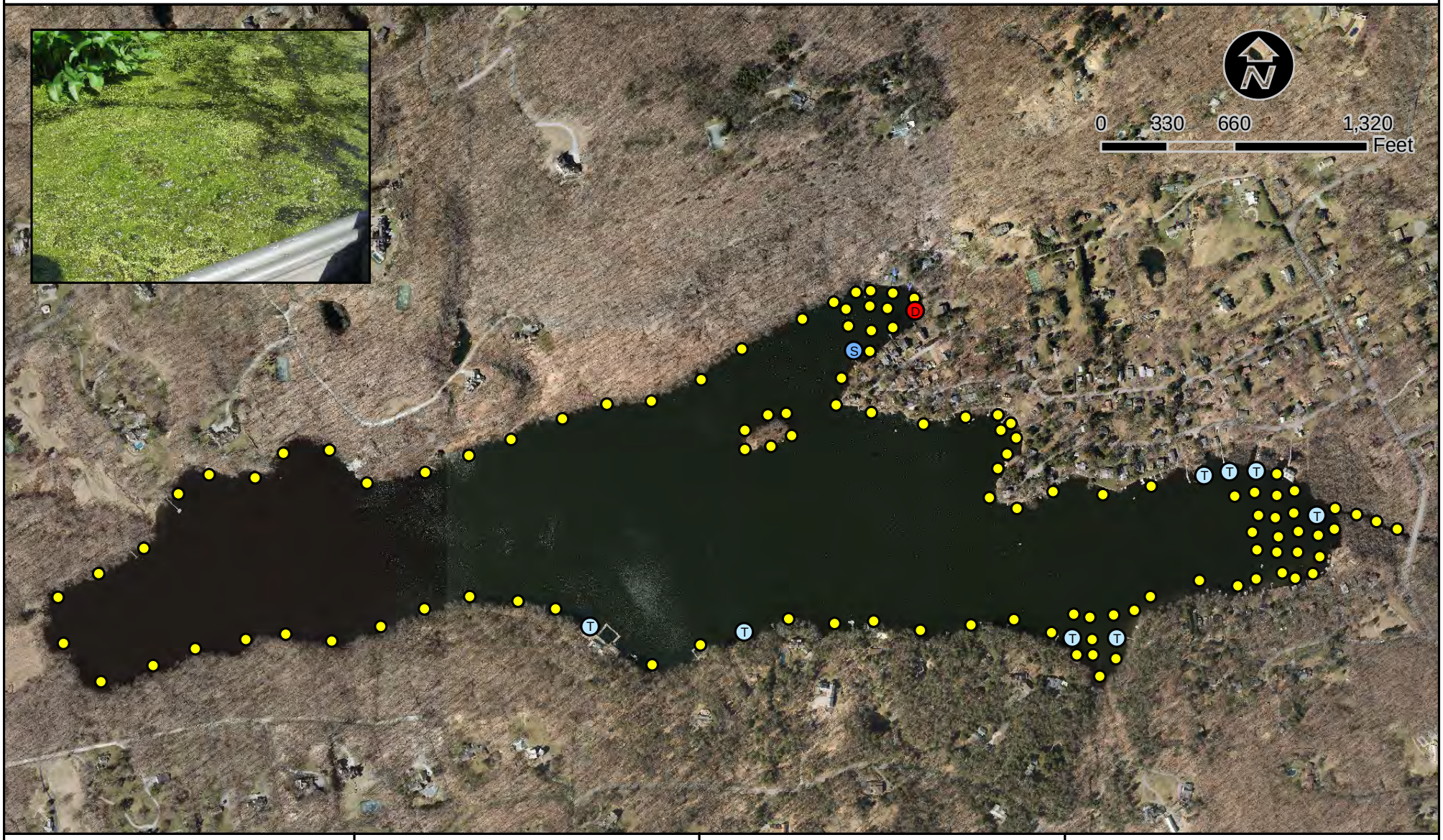
Floating Filamentous Algae Distribution



Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	10	8%
Trace	8	80%
Sparse	1	10%
Medium	0	0%
Dense	1	10%

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Great Duckweed (*Spirodela polyrhiza*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	6	5%
Trace	4	67%
Sparse	2	33%
Medium	0	0%
Dense	0	0%

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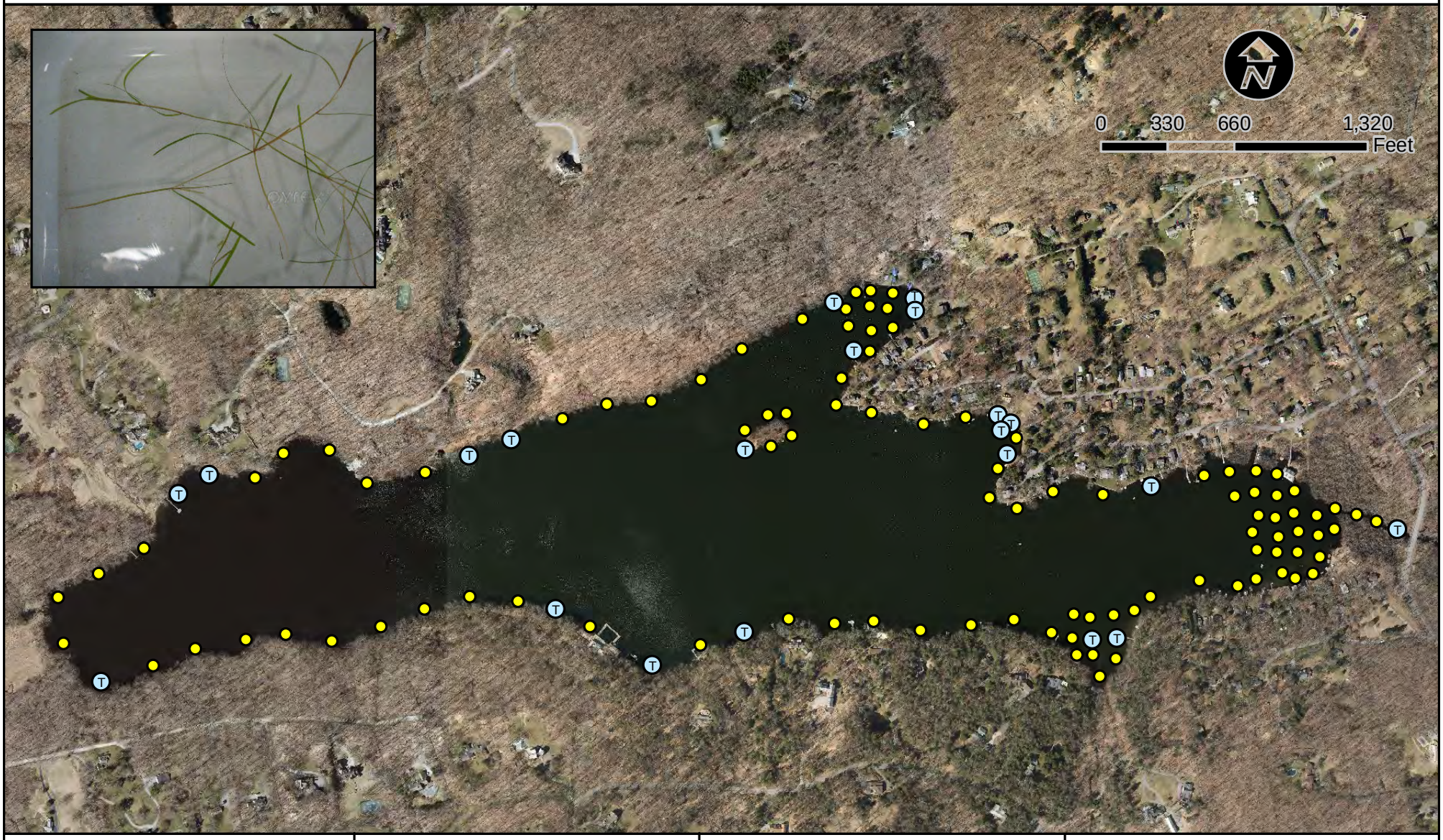
Leafy Pondweed (*Potamogeton foliosus*) Distribution



Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	21	18%
Trace	21	100%
Sparse	0	0%
Medium	0	0%
Dense	0	0%

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Pondweed Species (*Potamogeton sp.*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	6	5%
Trace	6	100%
Sparse	0	0%
Medium	0	0%
Dense	0	0%

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Ribbon-leaf Pondweed (*Potamogeton epihydrus*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	8	7%
Trace	4	50%
Sparse	1	13%
Medium	3	38%
Dense	0	0%

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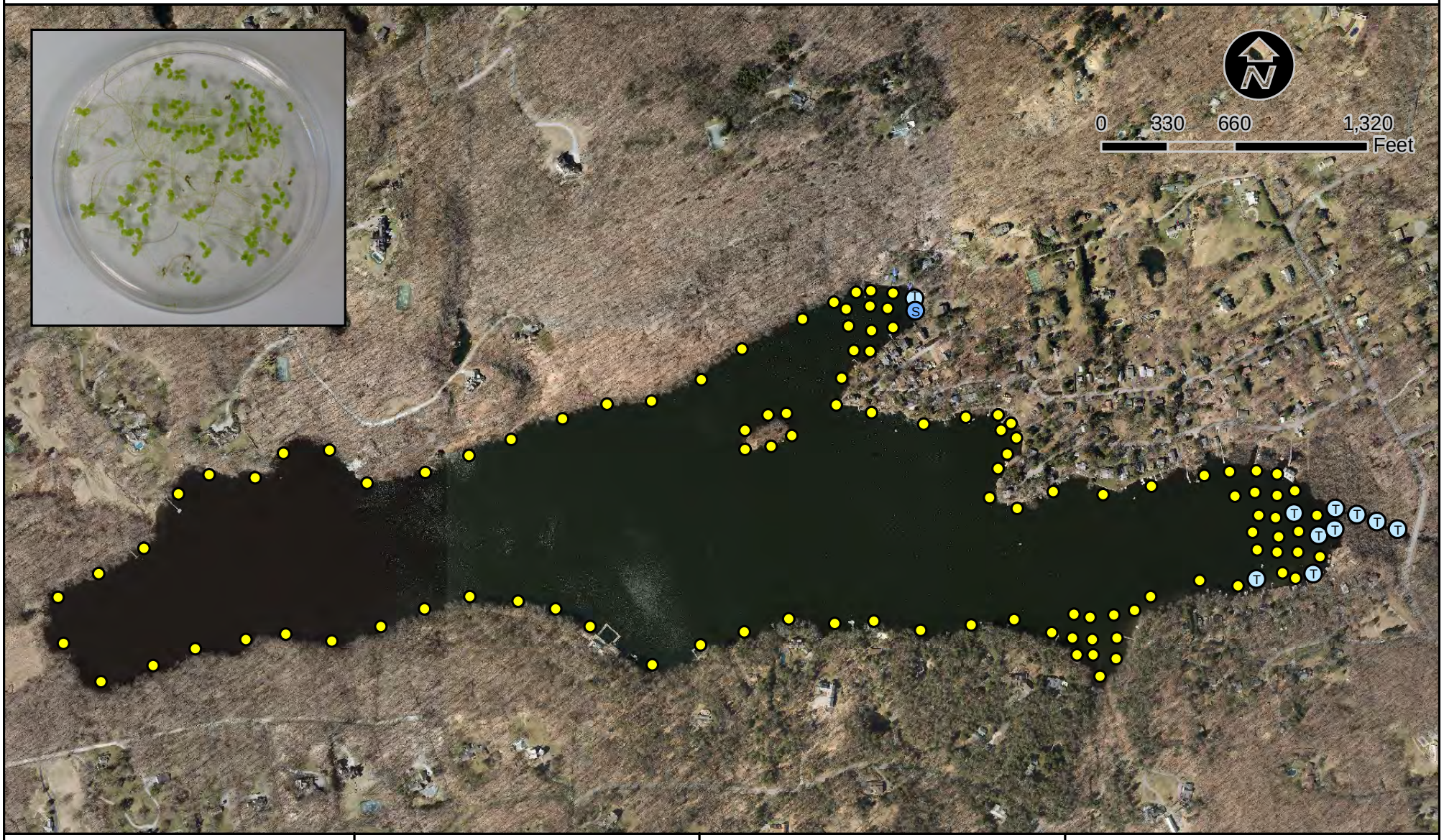
Small Duckweed (*Lemna minor*) Distribution



Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	11	9%
Trace	10	91%
Sparse	1	9%
Medium	0	0%
Dense	0	0%

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Common Watermeal (*Wolfia columbiana*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	11	9%
Trace	9	82%
Sparse	2	18%
Medium	0	0%
Dense	0	0%

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Spatterdock (*Nuphar variegata*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	21	18%
Trace	10	48%
Sparse	7	33%
Medium	1	5%
Dense	3	14%

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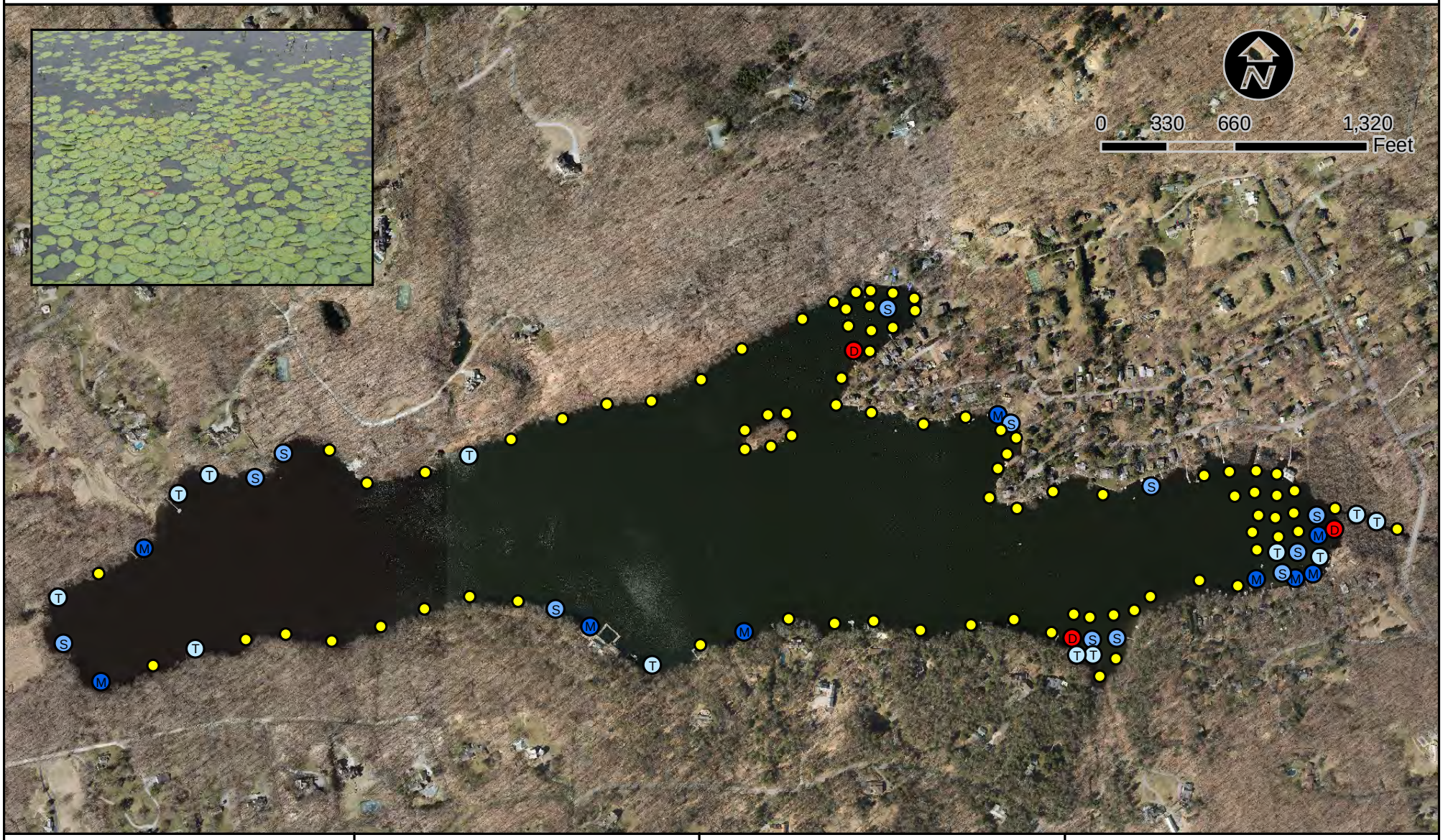
Watershield (*Brasenia schreberi*) Distribution



Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	36	30%
Trace	12	33%
Sparse	12	33%
Medium	9	25%
Dense	3	8%

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White Water Lily (*Nymphaea odorata*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- T = Trace Plants
- S = Sparse Plants
- M = Medium Plants
- D = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	52	43%
Trace	26	50%
Sparse	13	25%
Medium	6	12%
Dense	7	13%

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Water Stargrass (*Zosterella dubia*) Distribution

Lake Waccabuc
Aquatic Vegetation Survey
July 20 & 31, 2018

Total Sample Sites: 120

Plant Density Legend

- = No Plants
- = Trace Plants
- = Sparse Plants
- = Medium Plants
- = Dense Plants

Percent Distribution

Abundance	Sites	Percent
Total	30	25%
Trace	27	90%
Sparse	3	10%
Medium	0	0%
Dense	0	0%

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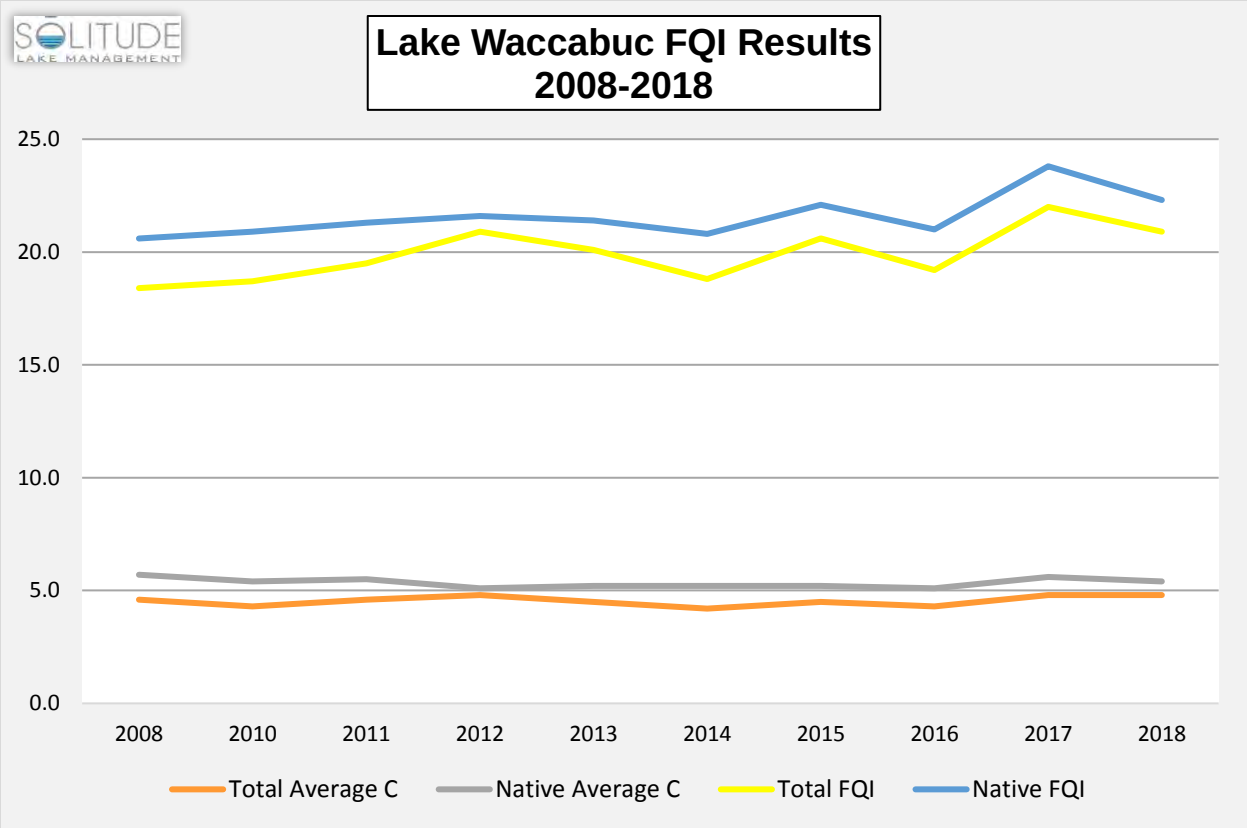
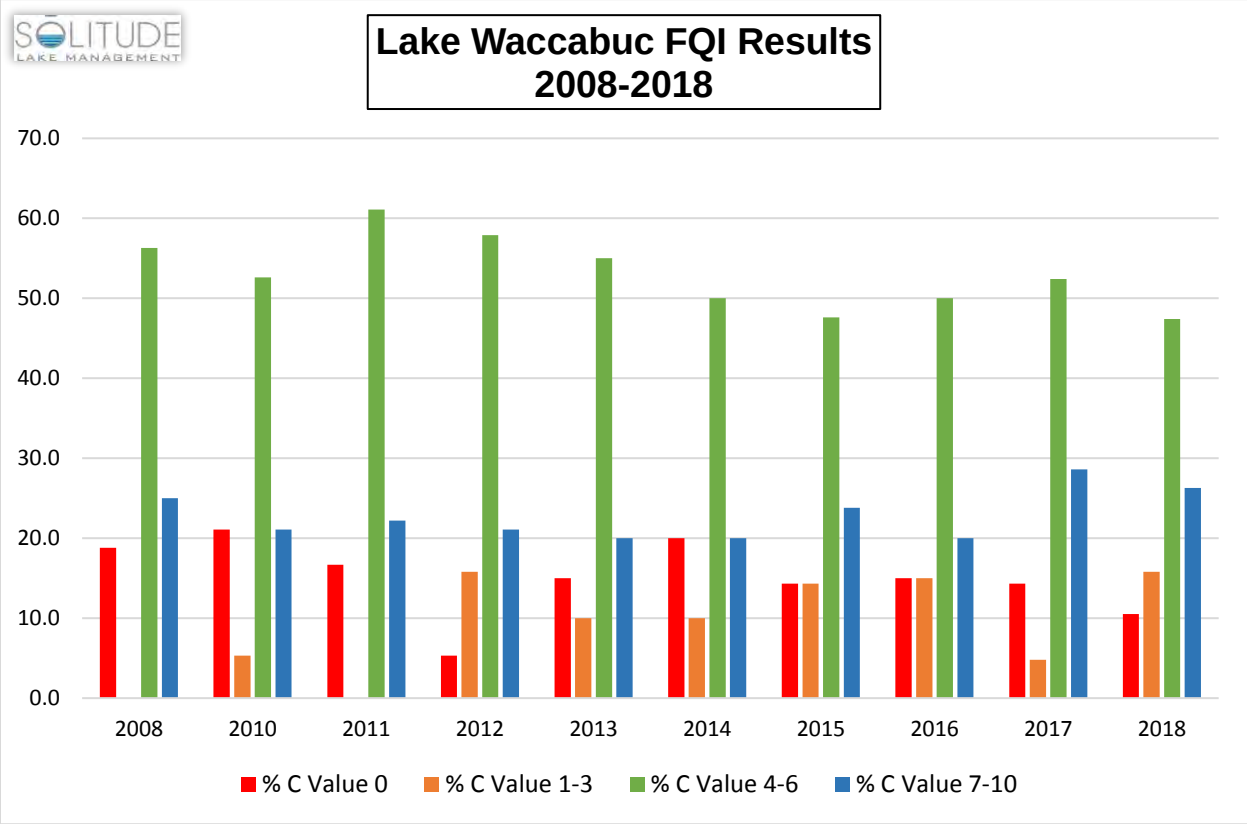

Lake Waccabuc FQI Results
2008-2018
25.0
20.0
15.0
10.0
5.0
0.0
2008
2010
2011
2012
2013
2014
2015
2016
2017
2018
Total Average C
Native Average C
Total FQI
Native FQI


Lake Waccabuc FQI Results
2008-2018
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2008
2010
2011
2012
2013
2014
2015
2016
2017
2018
% C Value 0
% C Value 1-3
% C Value 4-6
% C Value 7-10