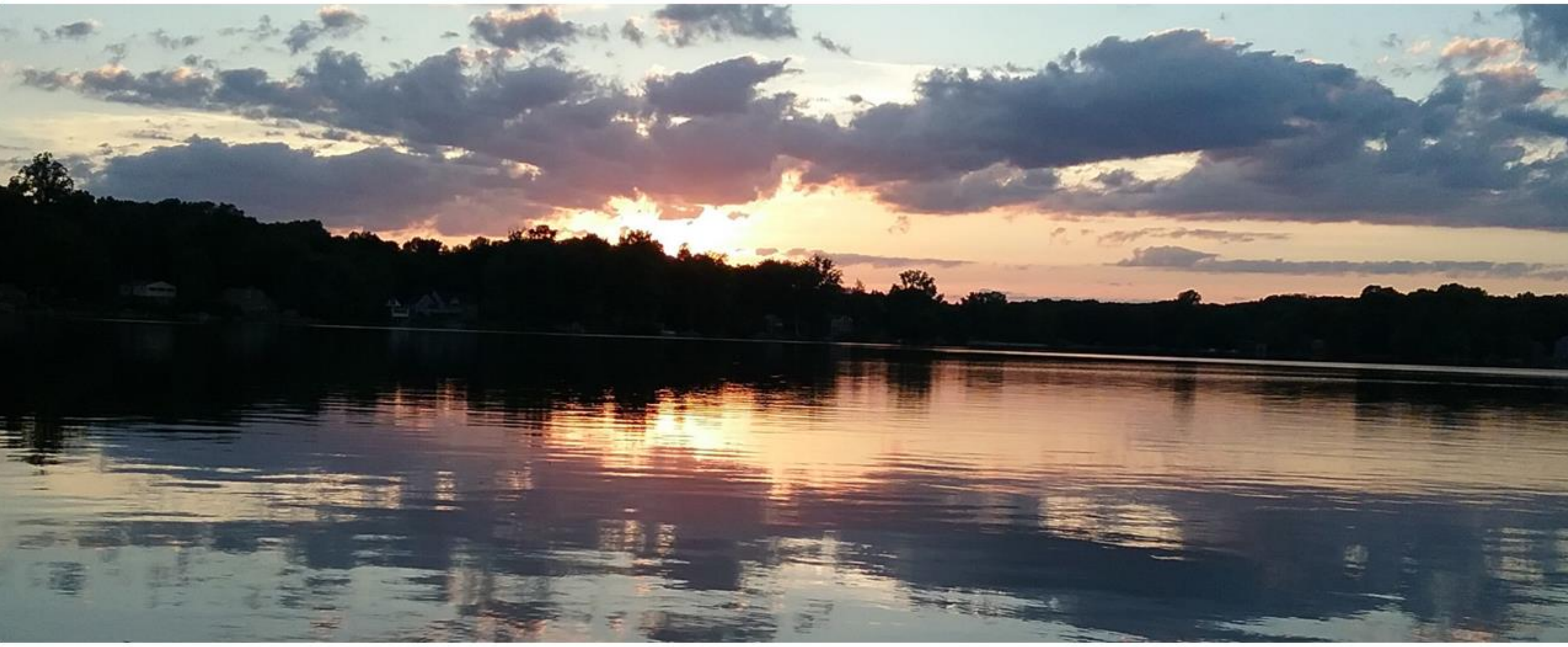
AQUATIC ECOSYSTEM RESEARCH
A Freshwater Conservation Company



Amston Lake

Aquatic Plant Community Assessment

Prepared for the
Amston Lake Tax District
Hebron, Lebanon and Colchester, CT

December 7, 2020

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EXECUTIVE SUMMARY

Aquatic Ecosystem Research was engaged by Amston Lake Tax District to undertake a quantitative plant community study. Below is a summary of the important findings from the survey:

- Study Design:
    - A geogrid was established in GIS that contained 314 sample points that were visited during the plant survey that took place on July 18th, 2020.
    - Each point was visited; and, the plant community was assessed visually and by sampling with a grapple.
- Basic Plant Community Statistics:
    - A total of 31 plant species were detected.
        - 25 rooted macrophytes
        - 3 lily-species
        - 2 unrooted, floating
        - 1 macroalgae
    - The top 4 most abundant aquatic plant species were:
        - *Potamogeton robbinsii* (Robbins Pondweed)
        - *Vallisneria americana* (Tape Grass)
        - *Potamogeton amplifolius* (Largeleaf Pondweed)
        - *Najas flexilis* (Nodding Waternymph)
    - Two-hundred and seventy-six of the 314 points contained plant species (88%).
        - No plants were found at depths greater than 6.25m.
        - No rare or endangered species were detected.
        - No non-native species were detected.
    - The average rank abundance, corrected abundance, richness, and diversity at points with plants (i.e., 276 points) were 5.53, 0.09, 2.6, and 1.27, respectively.
        - These data suggest that Amston Lake's plant community was productive, rich, and of moderate diversity.
        - AER's opinion of the plant community is that it is healthy and not in need of any major management activity.
            - Residential access to the lake was not limited by the plant community.
- Risk of Non-native Species Invasion:
    - The historical conductivity, pH, and alkalinity ranges suggest that Amston Lake is at risk for the Mixed-group of the most common non-native species in New England.
        - CC = *Cabomba caroliniana* (Fanwort)
        - MH = *Myriophyllum heterophyllum* (Variable-leaf Milfoil)
        - MS = *Myriophyllum spicatum* (Eurasian Milfoil)
        - NM = *Najas minor* (Brittle Naiad)
        - PC = *Potamogeton crispus* (Curly-leaf Pondweed)
- Aquatic Plant Community Management

- AER's opinion of the plant community is that there is no need for large-scale management.
- In situations where the District is experiencing conditions that are not preferential, the least intrusive methods would be benthic barriers or Diver Assisted Suction Harvesting (DASH) methods as administrated per regulations defined by the Amston Lake Ordinances
- The plant community should be inspected yearly to determine the presence or absence of non-native species
    - Early detection of non-native species is the most important part of their management.
- Quantitative plant studies should be undertaken at 5-year intervals to develop an understanding of the plant community's trajectory.

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INTRODUCTION

Purpose

Aquatic Ecosystem Research was engaged by the Amston Lake Tax District to evaluate summer water quality and to conduct a quantitative survey of the plant community. Those initiatives were undertaken to understand water quality trends, evaluate the structure of the pelagic algae community, to examine the structure of the plant community, to detect any non-native plant species, and to determine the future lake management needs. Prior to AER's data collection initiative, there were no major concerns about water quality; but, portions of the lake were experiencing localized plant community density conditions that the District feared could affect future recreational access. AER's report on water quality will be available later this year. The primary goal of this study is to evaluate the plant community to help steer future lake management initiatives.

Lake Characteristics and Residential Community

Amston Lake is a 193acre lake located on the border of Hebron and Lebanon, CT (41°37'29.65"N, 72°19'33.29"). The lake has a maximum depth of 7.9m (25.8ft), a mean depth of 2.8m (9.1ft), and it contains 5.69×10^8 gallons of water. The lake, which is on the border of the Connecticut and Thames River Basins, is situated at an elevation of 506ft above sea level with a watershed that is 680ac. Furthermore, it is part of the Salmon River Regional Basin, the shoreline is an estimated 3.5mi in length, and the lake is fully refreshed about every 1.13yrs. Finally, the lake has clear waters that are likely associated with the igneous/metamorphic bedrock geology of the local watershed and has limited public access.

Underlying Geological Conditions

Local geological conditions are an important set of components that result in the baseline water quality conditions of all lakes. For example, lakes located in areas with slow weathering igneous bedrock tend to be lower in total dissolved salts, have lower pH and buffering capacity, and specific assemblages of algae and plants that are metabolically efficient when carbon dioxide is the major form of carbon available for photosynthesis. Conversely, hard-water systems are normally found in areas with quick-weathering bedrock types that are sedimentary in nature; these lakes tend to have higher levels of total dissolved salts, higher pH and buffering capacity, and algae/plant assemblages that are metabolically efficient when bicarbonate is the major form of carbon available for photosynthesis.

Underlying the watershed of Amston Lake is one major geological formation; Hebron Gneiss, which was created during the Silurian or Ordovician period. The minerals in this formation, which are mostly schists and calc-silicates, which weather slowly and do not contribute ions to the local waters at a high rate. This feature of the local geology is likely the driving factor contributing to the relatively low concentrations of phosphorus and nitrogen; however, these rocks can contribute ions such sodium, calcium, and silicate, which can result in relatively high specific conductivities of local surficial waters where calc-silicates dominate. Regarding Amston Lake, the metamorphic schists appear to dominate the local area based on water chemistry.

Specific Goals of 2020 Amston Lake Initiative

The main goals of obtaining data associated with the water quality and plant community of Amston Lake were:

- Inventory all species of the plant community.
- Determine the presence of non-native aquatic macrophytes.
- Determine the presence of rare or endangered macrophyte species.
- Evaluate the impact of all macrophyte species on recreational access.
- Statistically model the likelihood of encountering any macrophyte species as depth increases.
- Examine the relationships among macrophyte richness, macrophyte diversity, depth, and other macrophyte species.
- Identify species that dominate the community or negatively impact recreational access.
- Create spatial distribution graphics associated with dominant species and/or problematic species.
- Identify data gaps and provide guidance on ecosystem monitoring.

METHODOLOGY

Experimental Design

Due to the fact that Amston Lake is a moderately large body of water, it was necessary to develop a comprehensive and feasible approach to surveying the aquatic plant community. Aquatic Ecosystem Research approached the issue of sampling effort and fiscal responsibility by developing a grid system for the lake.

Using Geographic Information Systems (GIS) AER's geospatial analyst established a geogrid for the lake where the corners of each grid block would act as a sample point. For Amston Lake, we established a 50mx50m grid that resulted in a total of 314 unique sampling points (Fig. 1).

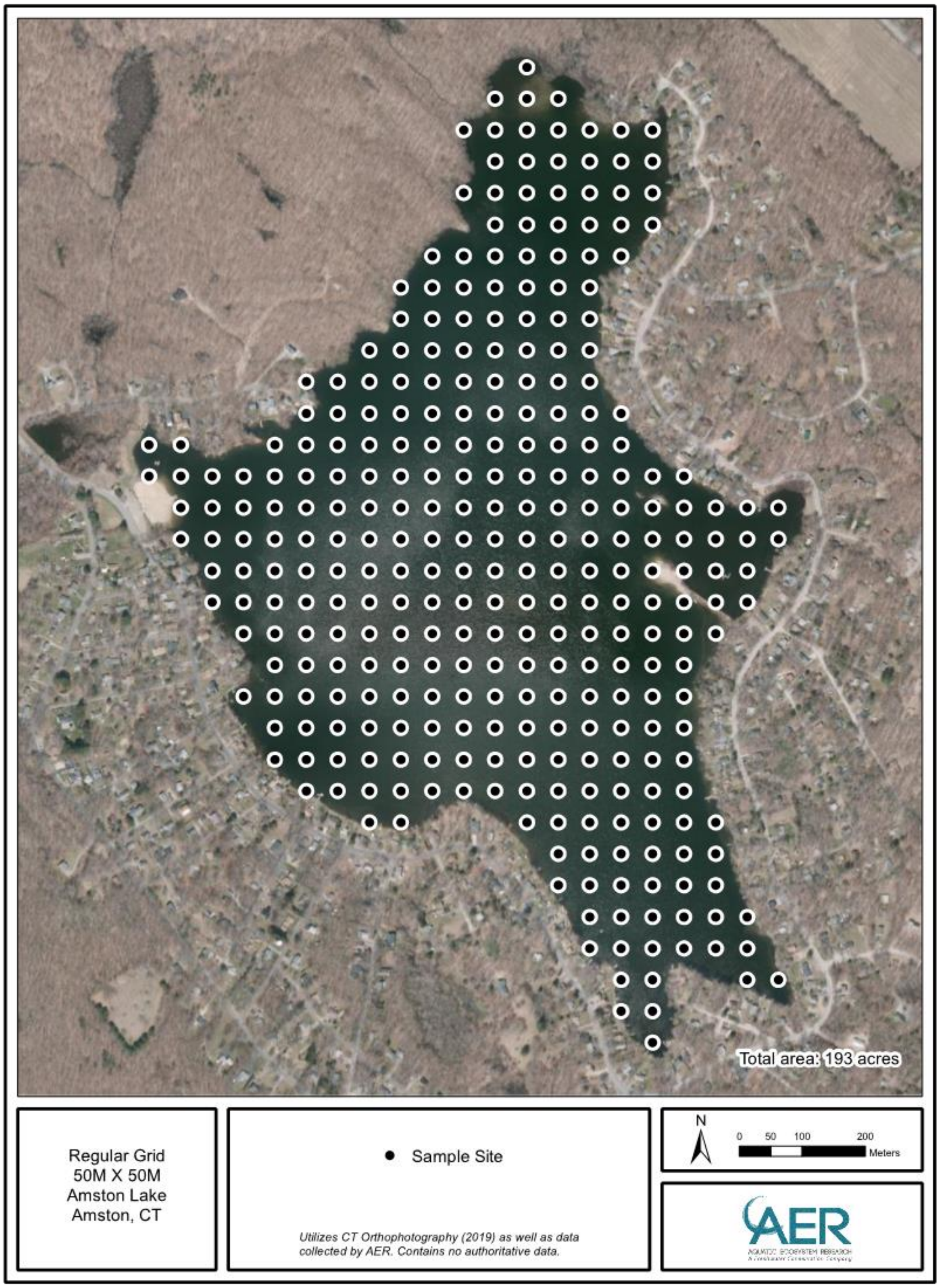


Figure 1. Amston Lake Sampling Grid.

Plant Sampling and Data Collection

Each grid point was located using a Garmin GPS unit with <3m accuracy. At each point the plant community was assessed visually and sampled using a grapple. The sample technique was composed of two individual grapple tosses – one to each side of the boat. Plants were identified visually using Crow and Hellquist (2000) and a *Potamogeton spp.* supplemental key, which was provided by C. Barre Hellquist. This supplement was used because there have been some significant changes to the taxonomic characteristics utilized in the identification of *Potamogeton* species. A representative sample of each species was retained and photographed using a high-resolution (i.e., 20Mpixel) digital camera. Those photos were stored in AER's digital herbarium. If rare species were found, a representative sample was frozen at -10°C and retained at AER's office.

Data were logged in field notebooks by rank abundance where 1 was rare, 2 for present but not abundant, 3 for abundant but not dominant, 4 for dominant, or 5 for dense monoculture. Data were always logged with an identifier that coincided with the grid sample point. Those data were transferred to lake-specific Excel spreadsheets for further processing.

Data Processing and Analytical Techniques

Field data, as they related to individual sample points, were logged as an attribute table in the survey grids. Each sample point coincided with a series of variables, which included latitude, longitude, depth, and all of the species detected during the survey. The species data were logged in that attribute table with the rank order abundance and used in probability-of-occurrence calculations. If the species was absent, the species variable was given a value of 0. Species data were then used to calculate richness (i.e., total number of species at the point), diversity (the number of species corrected for the rank abundance of each), total abundance (sum of all rank abundances for all species), and corrected abundance (average of all rank abundances corrected for local richness and lake richness).

The data matrix was loaded into Geographic Information System (GIS) software to undertake a variety of analytical protocols. Firstly, we used the richness and diversity variables to develop spatial assessments of those plant community characteristics. Those data, which had the potential to range from zero to infinity, were interpolated to determine how richness and diversity were distributed throughout the lake and to identify areas of high species richness/diversity. Secondly, the individual species variables were used to develop a spatial assessment of all dominant species distributions. Those data were interpolated to determine the estimated coverage of each dominant species at any point throughout the lake. Coverage maps were created by assigning rank abundance vales to each point and interpolating data from adjacent points in an iterative fashion throughout the sample grid.

After conducting the spatial analyses, those matrices were used to calculate some basic statistics (i.e., number of detections and percent of community). Finally, AER's statistician regressed depth vs. richness, diversity, and individual species abundances to examine those relationships. We also evaluated the relationships among the abundant species and the richness/diversity variables. During the development, we evaluated three different type of explanatory models: 1) linear, 2) polynomial, and 3) logistic. The final model was chosen based on fit; the characteristic used in model selection was the coefficient of determination (r^2).

RESULTS

Basic Plant Community Findings

Aquatic macrophytes were found at 276 of the 314 grid points, which suggests that 88% of the waterbody houses one or more plant species. In total, twenty-five submerged/rooted aquatic macrophytes, 3 lily-pad species, 2 unrooted floating species, and 1 macroalgae were encountered among the 314 points visited in Amston Lake on July 18th, 2020. The most common species detected during this survey was *Potamogeton robbinsii* (Robbin's Pondweed) with a total rank abundance of 602. Furthermore, it was found at 240 points, which accounts for 86.9% of all points where plants were found (276 points). Its average rank abundance among all points was 1.92; and, its average rank abundance among points where it was found was 2.51.

The second most common species found was the rooted macrophyte *Vallisneria americana* (Tape Grass). It was found at 105 of the 314 points with a total rank abundance of 238. Thirty-eight percent of the points where plant species were found housed *Vallisneria americana.* The average lake-wide rank abundance was 0.76 and the average rank abundance among points where it was detected was 2.27.

The third most common species detected in Amston Lake was *Potamogeton amplifolius* (Large-leaf Pondweed); it was detected at 128 of the 314 lake-wide points (40.8%) and had a total rank abundance of 226. *Potamogeton amplifolius* exhibited an average lake-wide rank abundance of 0.72 and an average rank abundance among points where it was present of 1.77.

The fourth most common species was *Najas flexilis* (Nodding Waternymph). That species was detected at 49 of the 314 grid points (15.6%) and was found to have a total rank abundance of 97. Furthermore, its average abundance lake-wide was 0.31 and an average total rank abundance of 1.98 where it was present. For a complete list of species detections and associated statistics, see Table 1.

Table 1. Plant species inventory at Amston Lake on July 18, 2020 and associated statistics.

Species Name	Common Name	Point Encounters	Percent of Points with Plants	Total Rank Abundance	Average Lake Rank Abundance	Average Abundance Where Present
Brasenia schreberii	Watershield	20	7.25	55	0.18	2.75
Ceratophyllum demersum	Coontail	8	2.90	12	0.04	1.50
Chara spp.	Musk Grass	28	10.14	39	0.12	1.39
Eleocharis acicularis	Dwarf Hair Grass	7	2.54	13	0.04	1.86
Eriocaulon aquaticum	Common Pipewort	7	2.54	12	0.04	1.71
Elodea canadensis	American Waterweed	9	3.26	13	0.04	1.44
Elatine minima	Small Waterwort	4	1.45	5	0.02	1.25
Elodea nuttallii	Western Waterweed	18	6.52	29	0.09	1.61
Lemna minor	Common Duckweed	1	0.36	3	0.01	3.00
Myriophyllum humile	Low Watermilfoil	1	0.36	2	0.01	2.00
Myriophyllum tenellum	Slender Watermilfoil	9	3.26	21	0.07	2.33
Najas flexilis	Nodding Waternymph	49	17.75	97	0.31	1.98
Nuphar variegata	Yellow Pondlily	4	1.45	8	0.03	2.00
Nymphaea odorata	White Waterlily	20	7.25	48	0.15	2.40
Pontederia cordata	Pickerelweed	11	3.99	16	0.05	1.45
Potamogeton amplifolius	Large Leaf Pondweed	128	46.38	226	0.72	1.77
Potamogeton bicupulatus	Snailseed Pondweed	1	0.36	2	0.01	2.00
Potamogeton epihydrus	Ribbonleaf Pondweed	6	2.17	10	0.03	1.67
Potamogeton illinoiensis	Illinois Pondweed	2	0.72	2	0.01	1.00

Table 1. Continued.

Species Name	Common Name	Point Encounters	Percent of Points with Plants	Total Rank Abundance	Average Lake Rank Abundance	Average Abundance Where Present
Potamogeton natans	Floating Pondweed	12	4.35	25	0.08	2.08
Potamogeton pusillus	Small Pondweed	8	2.90	14	0.04	1.75
Potamogeton robbinsii	Robbins Pondweed	240	86.96	602	1.92	2.51
Potamogeton spirilus	Spiral Pondweed	1	0.36	1	0.00	1.00
Potamogeton zosteriformes	Flatstemmed Pondweed	1	0.36	1	0.00	1.00
Sagittaria graminea	Grassy Arrowhead	4	1.45	6	0.02	1.50
Typha lattifolia	Cattail	1	0.36	2	0.01	2.00
Utricularia macrorrhyza	Common Bladderwort	1	0.36	2	0.01	2.00
Utricularia gibba	Humped Bladderwort	3	1.09	4	0.01	1.33
Utricularia purpurea	Purple Bladderwort	5	1.81	11	0.04	2.20
Utricularia radiata	Floating Bladderwort	3	1.09	4	0.01	1.33
Vallisneria americana	Tape Grass	105	38.04	238	0.76	2.27
Wolffia sp.	Watermeal	1	0.36	3	0.01	3.00

Spatial Distributions of Plant Community Characteristics

Mapping of the corrected rank abundance variable (Fig. 2) suggests that the majority of the lake is suitable for a productive plant community; and that where plants are present, the community is on the middle to higher end of the rank abundance spectrum (i.e., average abundance per point = 5.5). The corrected abundance variable accounts for the average of all species abundances, the number of species at any given point, and the total number of species within the lake. For Amston Lake, this variable ranges from 0 to 0.17; the lowest values were found to be isolated to the deepest areas of the lake and are represented by a dark brown color in the Figure 2. The dark purple-colored areas are those with the greatest abundance of plant material; the highest values for corrected abundance exist in the southern cove and in large patches throughout the western shoreline; there are also patches of high corrected plant abundance randomly distributed throughout the rest of the lake. The majority of the lake houses corrected plant abundances between 0.07 and 0.10, which are represented by colors ranging from light brown to grey (Fig. 2). Overall, the plant community exhibited an average value of 0.09 for the variable of corrected abundance among points where plants were detected.

Richness, which is the total number of species detected at any given point, was mapped using GIS and spatial statistics. The richness variable – when overlaid with the geogrid – ranged from 0 to 13; and, the average number of species per point where plants were found was 2.6 (Fig. 3). Effectively, that means that there is an average of 3 unique plant species at any given point; however, any given point's number of species was distinctly related to location. There were no species found in the deep portions of the lake where the depth of water was greatest or where human disturbances limited plant establishment (i.e. darkest green color, Fig. 3). The average of 2.6 species per point is in the moderate range for recreational lakes, which is a positive ecological feature when one considers that the lake is also free of non-native species. The richest areas that were found during this survey were in the northern cove where between 10 and 13 species were detected. The majority of the lake houses between 1 and 2 species; but, the near-shoreline areas generally house more species than deeper waters, which is a common feature of aquatic macrophyte communities.

Diversity, which describes the evenness of the plant community, was projected across the sampling grid. That endeavor resulted in a map that shows a distinct transition from the low diversity central area to more diverse near shore area (Fig. 4). Where plants were present, the average diversity was 1.27 (0.7 lakewide), which suggests that the majority of the lake is dominated by a few species; but that is not a fair description of the lake's diversity characteristics because a large area of the basin has a depth where the majority macrophyte species become limited by light.

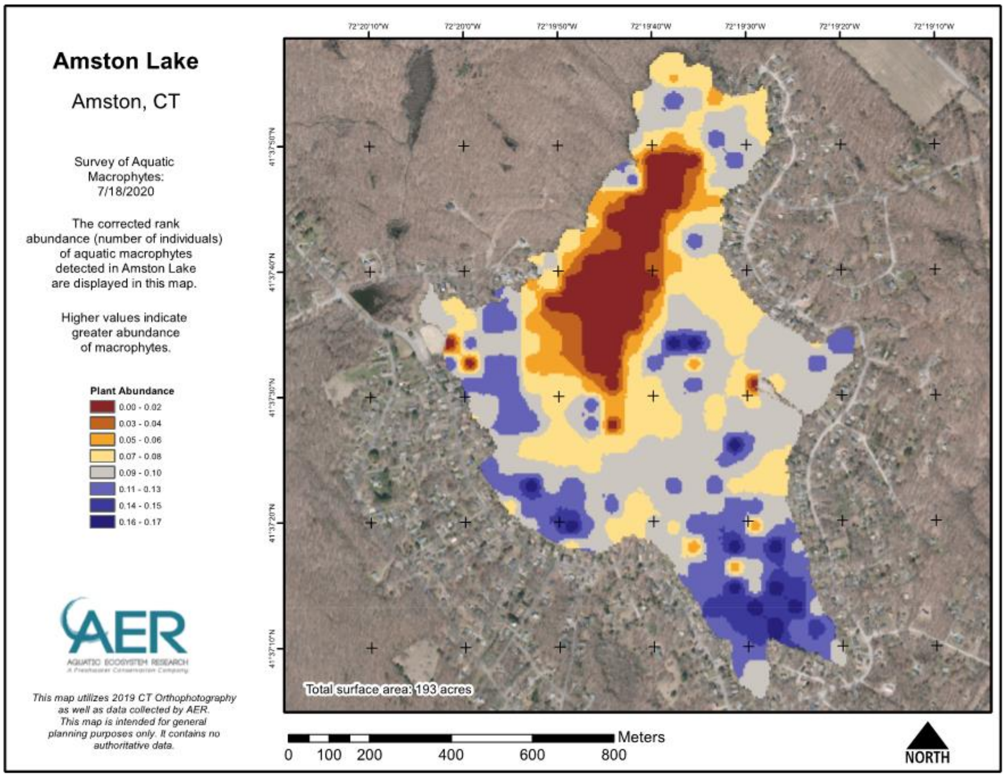


Figure 2. Spatial Distribution Map of Corrected Plant Community Abundance

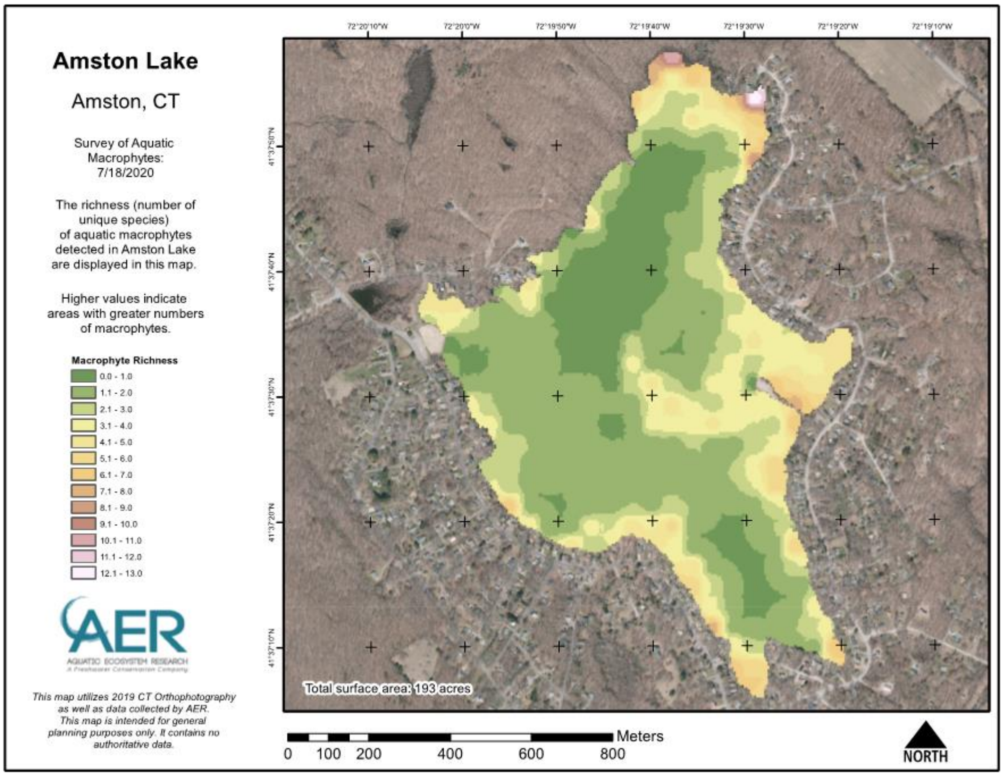


Figure 3. Spatial Distribution Map of Plant Species Richness.

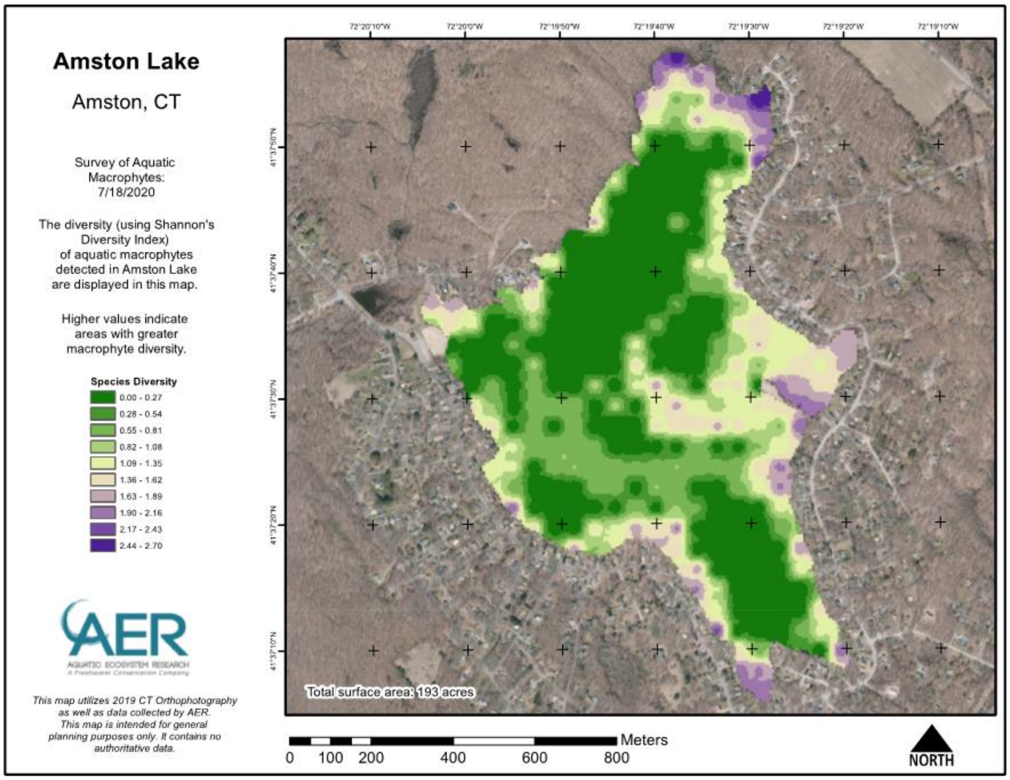


Figure 4. Spatial Distribution Map of Plant Community Diversity.

Shannon's Diversity Index (H'), which is the most commonly used diversity index, has a range of 0 to 5, and typically is found to have values between 1.5 and 3.5; however, that range of values is generally calculated in areas where light conditions are consistent. That is not the case with lakes because water depth and clarity are variable in their effects on light availability. In Amston Lake, Shannon's H' is within that common range of values in isolated near shore areas; that suggests that the plant community as a whole is dominated by a few species. However, there are numerous diversity hotspots distributed throughout the lake (Fig. 4). The most notable diversity hotspot in the lake is the northern cove, where the highest diversity values were calculated. Furthermore, the shoreline north of the peninsula and the south western cove also exhibit higher diversity than the majority of the lake.

Potamogeton robbinsii (Robbin's Pondweed) was found to be ubiquitously distributed throughout the littoral zone of the lake (Fig. 5). In areas where depth was greater than 5.0m (16ft) *P. robbinsii* was rare; but, in areas that were shallower it was often the dominant species. Overall, *P. robbinsii* was found to be the most common plant both numerically and spatially. Upon the application of spatial statistics to those point data that were collected on July 18th, 2020, it becomes clear that the probability of encountering *P. robbinsii* at any given point that is shallower than 5.0m (16ft) is high (Fig. 5).

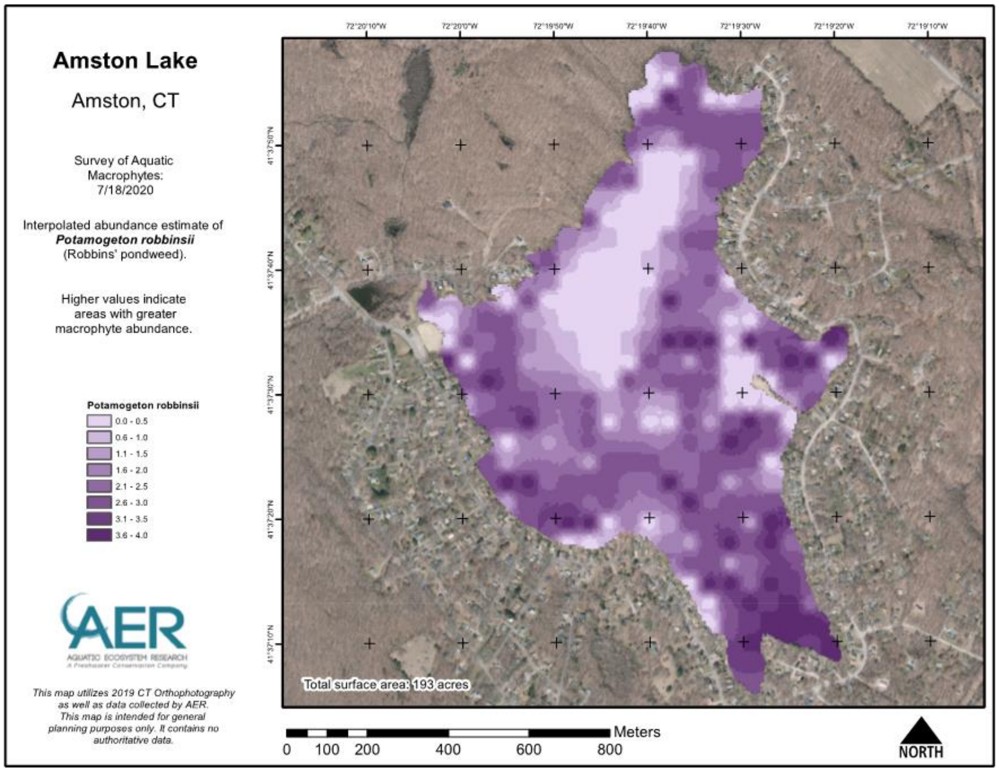


Figure 5. Spatial Distribution Map of *Potamogeton robbinsii* (Robbins Pondweed).

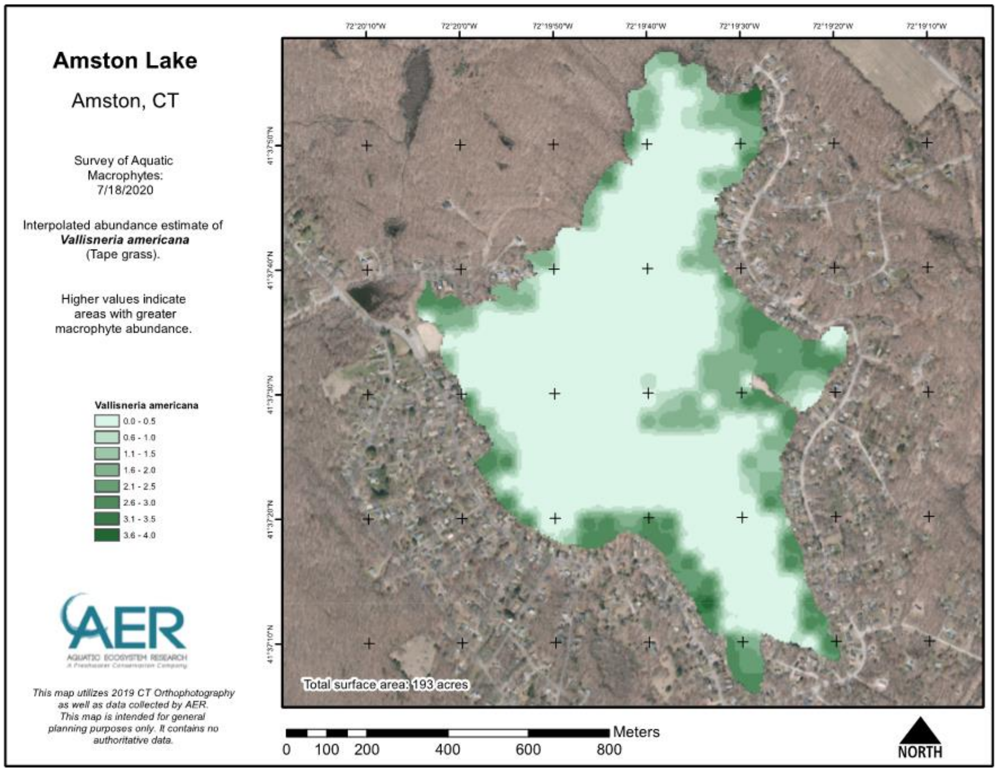


Figure 6. Spatial Distribution Map of *Vallisneria americana* (Tape Grass).

Vallisneria americana (Tape Grass) exhibited a spatial distribution that encompassed the entirety of the near shore areas (Fig. 6); it was not found in areas deeper than 3.0m (10ft). Its abundance coincided with areas of high diversity and richness (Fig. 6). It was the second most abundant aquatic macrophyte encountered in Amston Lake during the July 18th, 2020 survey; *V. americana* also rank second in terms of total abundance and third most common spatially. It was found to be distributed in the majority of near-shore areas and those areas surrounding the shallow central portion of the lake.

Potamogeton amplifolius (Large-leaf Pondweed) was found to be distributed throughout Amston Lake in large patches throughout most of the littoral zone (Fig. 7). It was also found in areas of high diversity and richness. Furthermore, *P. amplifolius* was rare in waters deeper than 3.0m (10ft). Finally, it was the third most abundant species in Amston Lake numerically but was the second most common species spatially.

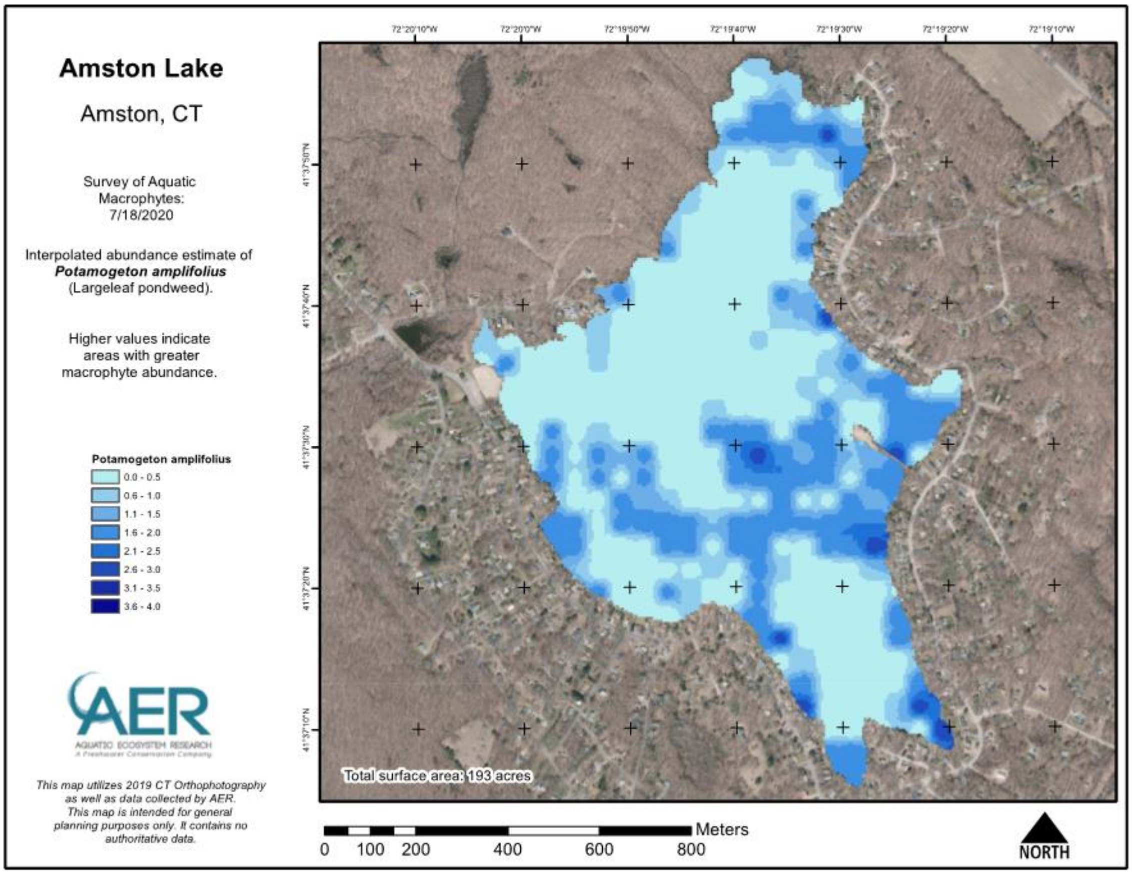


Figure 7. Spatial Distribution Map of *Potamogeton amplifolius* (Largeleaf Pondweed).

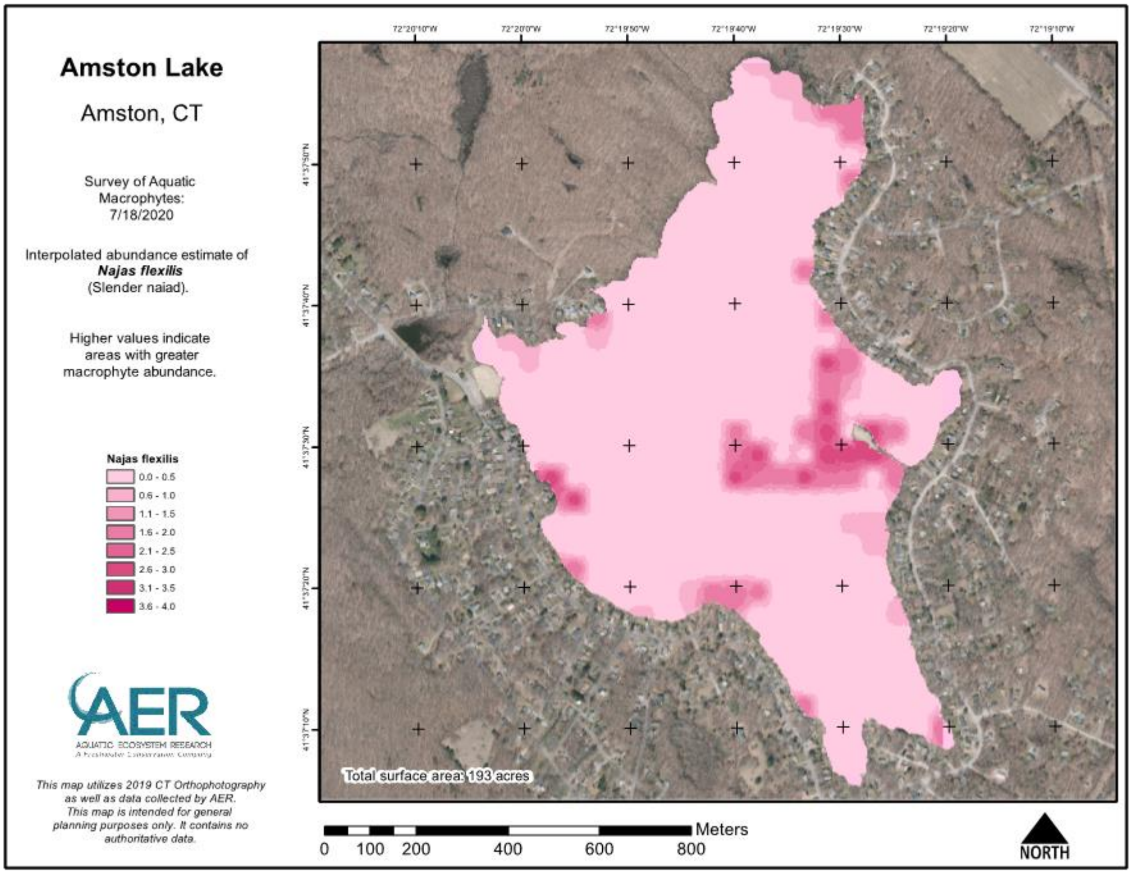


Figure 8. Spatial Distribution Map of *Najas flexilis* (Nodding Waternymph).

Najas flexilis (Nodding Waternymph) was the fourth most abundant aquatic macrophyte species encountered during the July 18th survey. Its spatial distribution does coincide with the spatial distributions of diversity or richness. *Najas flexilis* was found to be distributed in a patchy manner throughout the body of the lake. It favored near shore areas and was largely absent in deep water areas (i.e., >3.0m, Fig. 8).

Statistical Features of the Plant Community

Aquatic Ecosystem Research deployed GLM (General Linear Models) to explore how a variety of abiotic and biotic variables are related. Firstly, total rank abundance was regressed against depth and we found that a 2nd order polynomial model best explained those data interactions (r^2=0.49, Fig. 9). Additionally, when we regressed corrected abundance vs. depth, we found that a 2nd order polynomial model also best explained the distribution of plant abundance (r^2=0.46, Fig. 10). Both models of abundance vs. depth suggest that the majority of plant abundance is present in the shallowest reaches of the lake; the area between 0.50m and 3.0m house the majority of the plant community biomass.

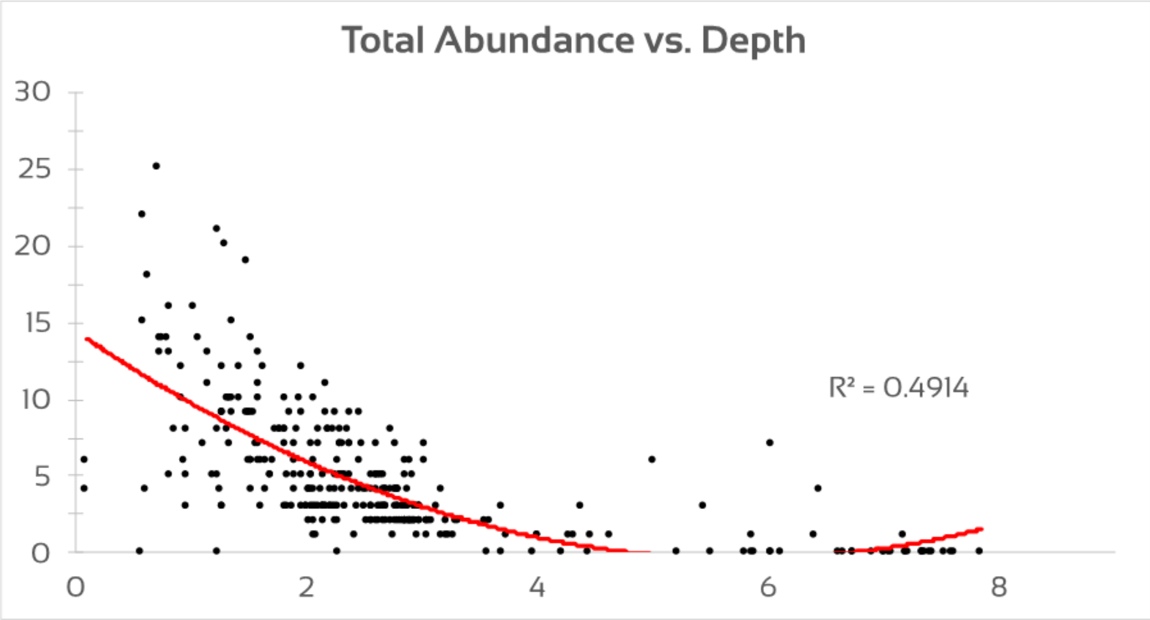


Figure 9. Polynomial Regression Model of Total Abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

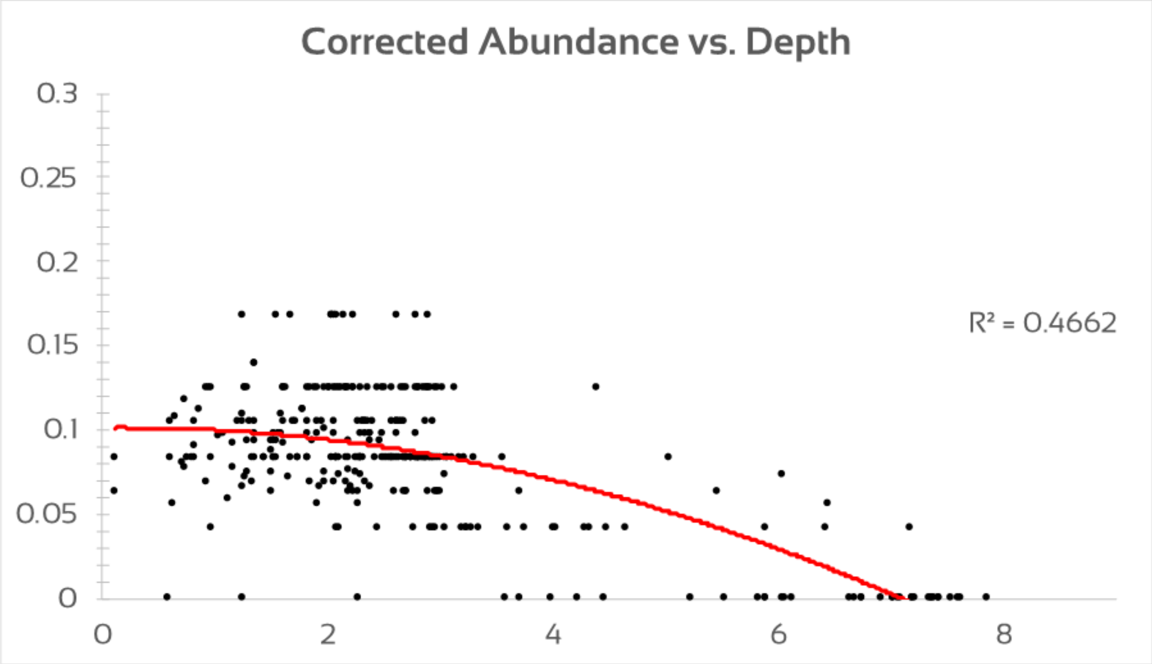


Figure 10. Polynomial Regression Model of Corrected Abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

The examination of diversity vs depth suggested that the distribution or community evenness (diversity) followed a linear model (r^2=0.25, Fig. 11). Diversity was found to decrease with depth and the most diverse areas were between 0.10 (0.33ft) and 2.5m (8.0ft). That finding was further supported by the results of AER's regression of richness vs. depth. When those two variables were examined together, a polynomial model was found to best explain that relationship (r^2=0.43, Fig. 12). Richness was greatest in shallow waters and decreased in a linear fashion as depth increased. The 0.10 to 2.5m range was found to house the greatest number of individual plant species.

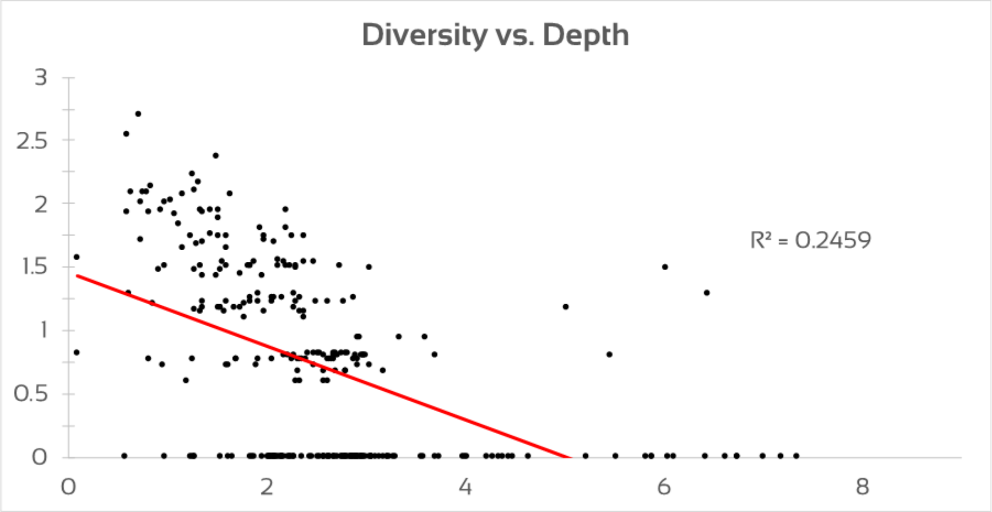


Figure 11. Linear Regression Model of Community Diversity (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

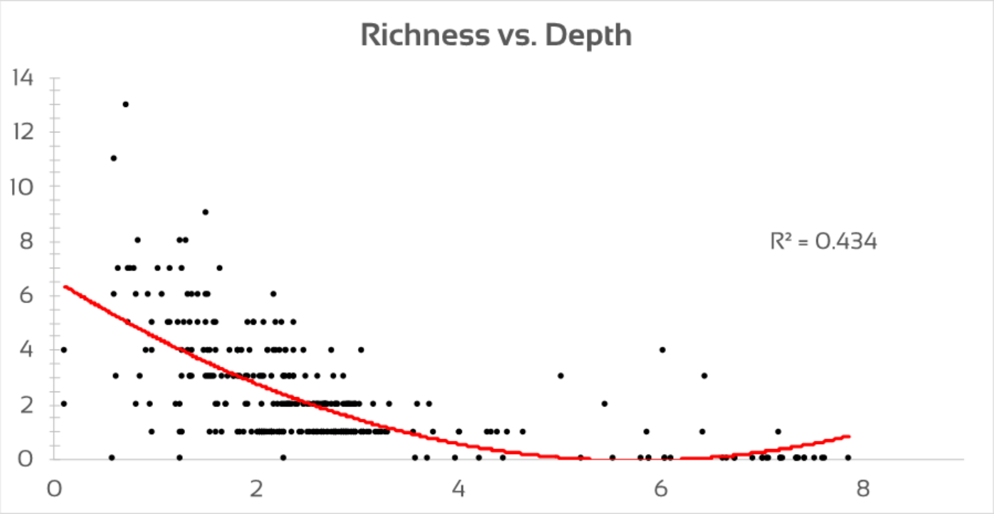


Figure 12. Polynomial Regression Model of Community Richness (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

To understand individual species relationships with abiotic and biotic factors, the four most abundant species were regressed against depth, richness, and diversity variables. *Potamogeton robbinsii* was found to be the most abundant species in Amston Lake; when its abundance was regressed against depth, it was found to follow a 2nd order polynomial model (r^2=0.25, Appendix 1). The amount of variance explained in that species' data was moderate (i.e., 25%), which suggests that more than depth is dictating the abundance distribution of *P. robbinsii.* However, the model suggests that *P. robbinsii* has an average abundance of 2.25 in areas that are shallower than 3m deep.

When *Vallisneria americana* (Tape Grass) was regressed against depth it was found that a weak to moderate linear relationship existed (r^2=0.20, Appendix 1). That suggests that the abundance of *V. americana* was not strongly tied to the availability of light and that other factors are contributing to the distribution of that species' abundance. *Vallisneria americana* is often found in the shallow and middle depth strata in lakes; therefore, we assert that community competition phenomena are probably more important in determining the distribution of *V. americana* in Amston Lake.

When *Potamogeton amplifolius* (Large-leaf Pondweed) was regressed against depth, a weak polynomial relationship was found to best described its abundance distribution within the lake's depth profile (r^2=0.12, Appendix 1). That model suggests that *P. amplifolius* requires light but that light availability is not the primary driving factor determining its distribution; instead, its distribution is more likely a result of interspecies relationships and the availability of open area within the littoral zone of Amston Lake. *Najas flexilis* (Nodding Waternymph) was found to exhibit a very weak linear relationship with depth (r^2=0.05, Appendix 1). However, those data suggest that *N. flexilis* is most common in the 0.5 to 2m range.

To further understand relationships among the most abundant aquatic macrophyte species in Amston Lake, the total abundance variable of each species was regressed against both diversity and richness. When richness was regressed against *Potamogeton robbinsii* total abundance, the analysis suggested that a linear relationship was the best explanatory model (r^2=0.00, Appendix 1). However, the relationship between the two variables was very weak and positive in nature, which suggests that the abundance of this species does not affect the richness of the local community (Appendix 1).

When that species was used in the regression of diversity vs. its abundance, an equally weak linear model was developed (r^2=0.01, Appendix 1). That model suggested that the abundance of *P. robbinsii* explained 1.00% of the variance in diversity data; and that as its abundance increased, diversity decreased marginally, which suggests that the abundance of *P. robbinsii* is not impacting local diversity.

When diversity and richness were regressed against the abundance of *Vallisneria americana* two polynomial relationships were resolved with variance accountings of 62.47 and 54.49%, respectively. The relationship between diversity and *V. americana* abundance was strong in nature (r^2=0.62, Appendix 1) and suggests that when *V. americana* abundance is between 2.0 and 2.75 that plant community diversity is at its greatest. When richness was regressed against the abundance of *V. americana* it was found that there was a strong relationship between the two variables (r^2=0.54). That model suggests that where *V. americana* exhibits an abundance between 2.5 and 3.0 that there are more unique species present (Appendix 1).

Diversity and richness were also regressed against the abundance of *Potamogeton amplifolius* (Large-leaf Pondweed); the resulting models were both linear in nature and they explained 39.67 and 28.21% of the variance in those datasets. The diversity model was strong in its explanatory value and suggested that as the abundance of *P. amplifolius* increased so did the diversity of the local area; however, *P. amplifolius* was never found to exceed and abundance of 3, which could limit the model's explanatory value and mask its impact on the structure of Amston Lake's plant community (Appendix 1). That pattern was also found when richness was regressed against its abundance, but the relationship was weaker (r^2=0.28, Appendix 1).

The relationship between *Najas flexilis'* abundance and community diversity was found to be best explained by a polynomial model (r^2=0.35, Appendix 1). That relationship was strong in nature and suggest that as its abundance increases to a value of 2.0 that diversity increases also; but diversity then decreases as *N. flexilis* abundance increases to 3.0. When richness was regressed against the abundance of that species, a polynomial relationship was resolved (r^2=0.38, Appendix 1). The relationship was relatively strong and suggested that when *N. flexilis* increases in abundance to a value of 2 that richness reaches its peak; but as its abundance further increases, community richness decreases. However, *N. flexilis* was never found to exceed and abundance of 3, which could limit the model's explanatory value and mask its impact on the structure of Amston Lake's plant community.

DISCUSSION

Overall, the Amston Lake's plant community exhibits moderate productivity and is moderately diverse; the plant community was also not found to house any non-native or rare/endangered species. The residents have noted that some species of aquatic macrophytes are becoming more abundant; however, there were no signs that aquatic macrophytes were impinging upon recreational access in most sections of the lake. This section will briefly discuss the ecological benefits of aspects of the current plant community and provide information about localized management strategies that may be deployed to manage areas of high plant abundance.

The analysis of the plant community suggests that the most productive areas of the plant community exist between 0.10 and 2.0m of depth. Additionally, the depth ranges between 0.5 to 2.0m house the greatest species richness and community diversity. We also found that the dominant species of the community are most productive in that same depth range. Our findings also suggest that there are strong relationships among the richness and diversity variables and three of the most abundant species (i.e., *Vallisneria americana, Potamogeton amplifolius,* and *Najas flexilis*).

Ultimately, these findings create a situation where balancing any need for management and ecosystem conservation is of the utmost importance. In short, Amston Lake contains a total richness that is greater than the regional average of 13spp, is a community that has resisted invasion from non-native species, and has high average diversity. All of the aforementioned characteristics suggest that the plant community is healthy and ecologically functional. Therefore, it is important to ask the following questions as they apply to management: 1) What do we – as residents – expect out of our lake? and 2) What does our lake expect out of us?

Management Approach

Amston Lake houses a diverse and rich plant community that has resisted invasion by non-native species. Therefore, it is our opinion that any major disturbance to that community could have adverse impacts over the long term.

So, what do we expect out of our lake? Most people living the "lake-life" expect to have access to their water body to swim or boat, enjoyment of the scenery during the spring/summer/fall, and to experience increasing property values over time. To meet those expectations, it is sometimes necessary to take some management action.

But, what does the lake expect out of its residents? This esoteric question is difficult to answer because the natural world does not speak to us directly; instead, we as managers need to anticipate the outcomes of our actions and how those actions might impact the recreational asset. Therefore, lakes expect us to be good stewards and to keep them in good health where natural diversity is maintained, and the plant community is managed with a tempered hand.

For those reasons – including the current healthy state of Amston Lake – we would only recommend localized, subtle mechanical management. We believe that the status of the lake is "healthy" due to the water quality conditions and the native diversity of the plant community; additionally, we believe that any heavy-handed approach to managing the plant community will result in short-term benefits (i.e., limited plant community) but long-term negative impacts (i.e., diminished water quality/non-native plant invasion).

Overall, we do not see a need for large scale management of Amston Lake's aquatic macrophyte community; however, some steps can be taken to manage local boating/swimming areas and areas of high plant community productivity.

- General Plant Management
  - For Property Adjacent Swim Areas, Docking Areas, and Resident Beaches
    - We prescribe methods considered less obtrusive and consistent with the regulations of the Amston Lake Ordinances. These include:
    - Benthic Barriers:
      - Aquatic Ecosystem Research recommends that the District deploy benthic barriers within their swim and docking areas to manage plants that are compromising their access.
      - Timing:
        - Benthic barriers can be installed at the end of May. They can then be removed during at the beginning of July.
          - The approach is still under review, but the preliminary results suggest that full control can be achieved with just four weeks of barrier deployment.
          - This will have to be done yearly to maintain results.
          - Over time, this process will result in a less productive local plant community due to the exhaustion of rhizome material and removal of roots.
    - Diver Assisted Suction Harvesting (DASH)
      - AER also recommends DASH as an alternative option to benthic barriers to manage small portions of the plant community that compromise recreational access or for areas where benthic barriers are likely to be disturbed (i.e., public swim areas).
      - Timing:
        - DASH can be deployed during the middle to late part of June to remove the plant community from recreationally important areas.
      - Cooperation:
        - Diver Assisted Suction Harvesting is expensive on a per unit basis but some

of those costs can be mitigated by community cooperation and planning to obtain bulk pricing from a competent vendor.

- Surveys
    - The plant community should be inspected yearly to detect non-native species invasions early – should they be introduced.
        - Estimated Cost: $1,500.00
    - A quantitative plant survey should be undertaken at 3 to 5-year intervals.
        - Estimated Cost: $6,000.00

DESCRIPTION OF RECOMMENDED MANAGEMENT OPTIONS

Diver Assisted Suction Harvesting

Diver Assisted Suction Harvesting (DASH) is a mechanical harvesting technique that involves the use of a barge supported pump and a diver on the lake bottom who hand picks plant stems and feeds them into the inlet hose of the pump system. The harvested material is sucked from the lake bottom, up to the barge where it is collected and bagged and later disposed of.

On a per acre basis, this method is slow and expensive. It is generally not a practical approach to manage large-scale infestations of aquatic plants. However, it is well suited for managing residential swim areas and public beach access.

Benthic Barriers

Benthic barriers are portable panels of porous synthetic fabric. These panels can be placed on the bottom of ponds and lakes to control aquatic plant growth. Benthic barriers are usually used to control small infestations. The panels remain out of sight throughout the control period. They are useful in water too deep for harvesting or where chemical application is not acceptable. Once benthic barriers are installed, an immediate open area of water is created. This could be desirable for areas around boat docks, swimming areas, and public beaches. Benthic barriers also create a maintenance issue because they often require re-positioning, additional weight placement, and can sometimes trap air bubbles underneath them, which allows sunlight to reach the plants and subsequently allows growth to continue. This approach is not commonly used to control large infestations. Finally, this technique would be applicable to the management of *V. americana*.

CONCLUSIONS

Overall, the plant community of Amston Lake is healthy and rich; it does not contain any rare/endangered or non-native species. The lake's water chemistry suggests that it is at risk for all of the common non-native species (*Cabomba caroliniana, Myriophyllum heterophyllum, Myriophyllum spicatum, Najas minor, & Potamogeton crispus;* June-Wells, et. al 2013). We recommend physical approaches to managing the plant community where necessary. Finally, we recommend to the Board of Directors that areas of the lake that are experiencing nuisance plant populations in swim/docking areas investigate the use of benthic barriers or hiring of a company to execute DASH within those swim/docking areas. These recommendations need to be in accordance with all Amston Lake ordinances and bylaws established by the District, and are not meant to supersede any existing requirements or procedures.

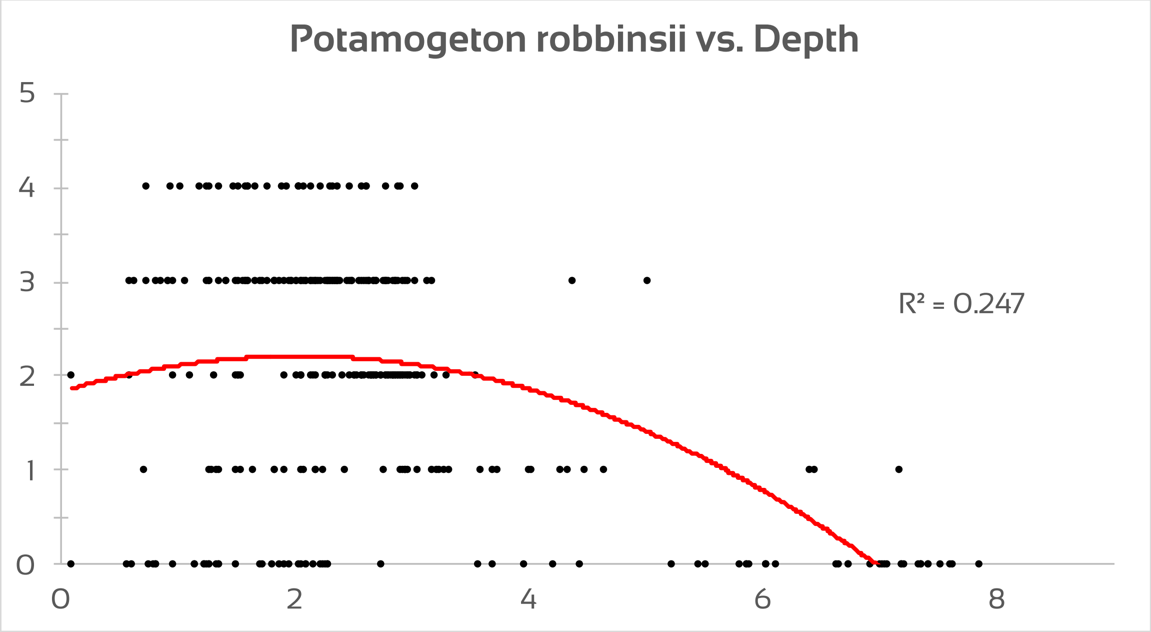
REFERENCES

Crow G and Hellquist CB. 2000. Aquatic and Wetland Plants of Northeastern North America, Volume II: A Revised and Enlarged Edition of Norman C. Fassett's A Manual of Aquatic Plants, Volume II: Angiosperms: Monocotyledons Repository, the University of Chicago Press

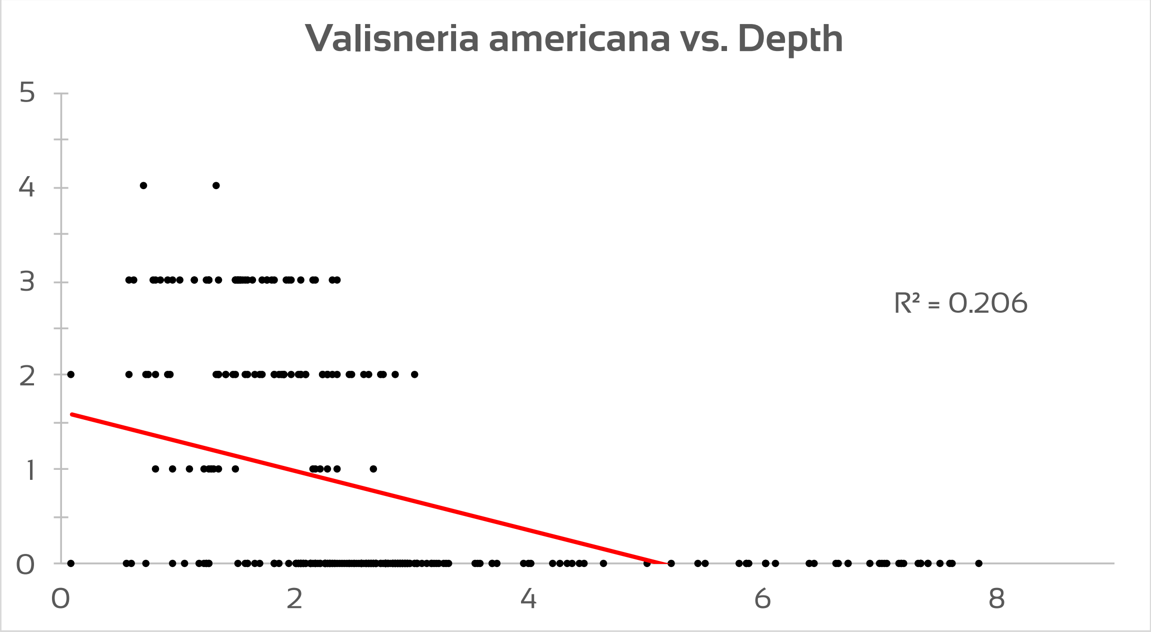
Mark June-Wells, Frank Gallagher, Jordan Gibbons & Gregory Bugbee (2013) Water chemistry preferences of five nonnative aquatic macrophyte species in Connecticut: a preliminary risk assessment tool, Lake and Reservoir Management, 29:4, 303-316

APPENDIX 1. STATISTICAL MODELING OF THE FOUR MOST IMPORTANT AQUATIC PLANT SPECIES AT AMSTON LAKE

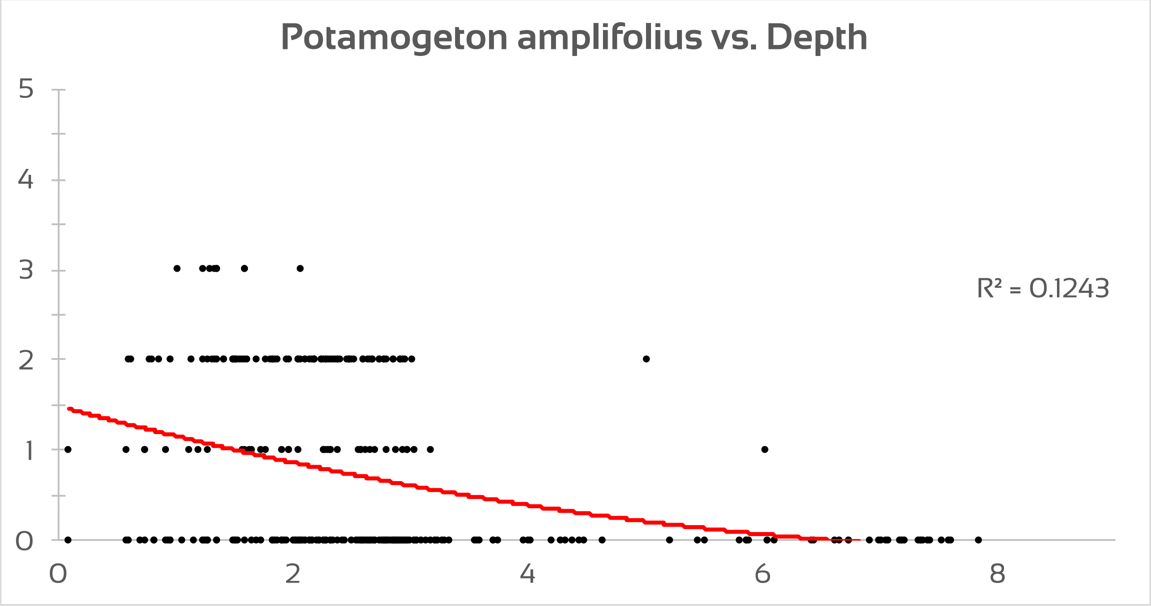
Polynomial Regression Model of Potamogeton robbinsii (Robbins Pondweed) abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.



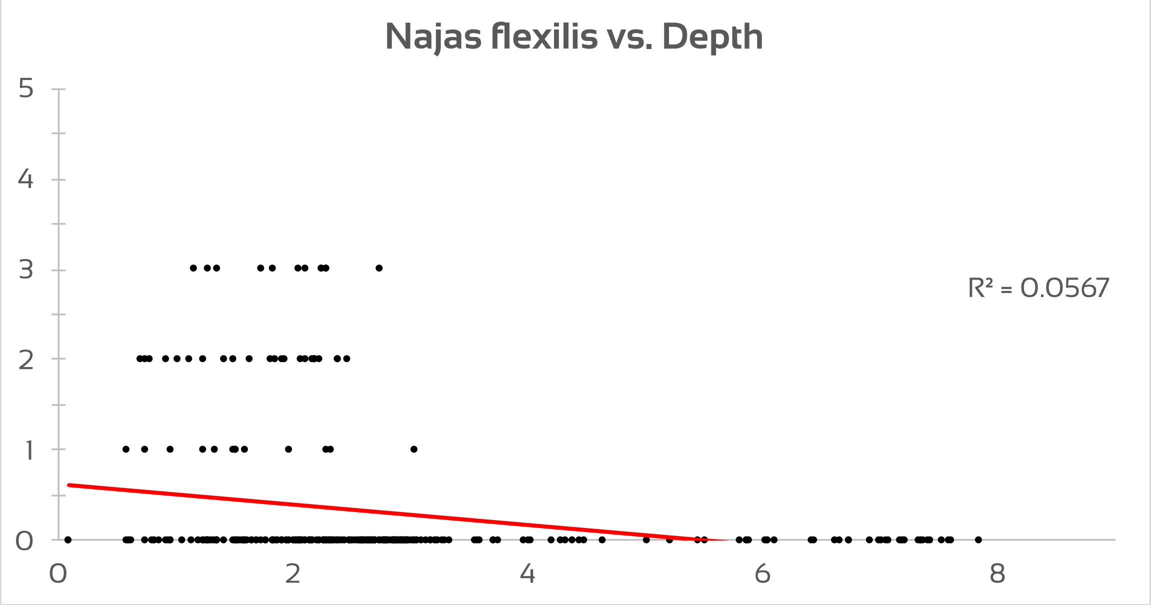
Linear Regression Model of Vallisneria americana (Tape Grass) abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.



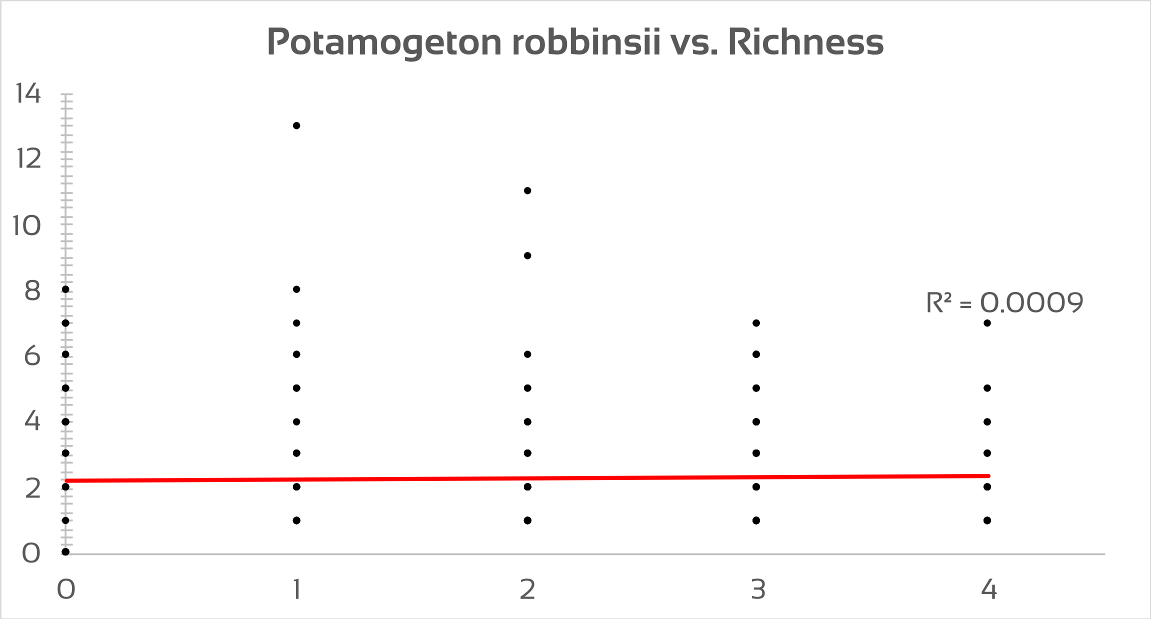
Polynomial Regression Model of Potamogeton amplifolius (Largeleaf Pondweed) abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.



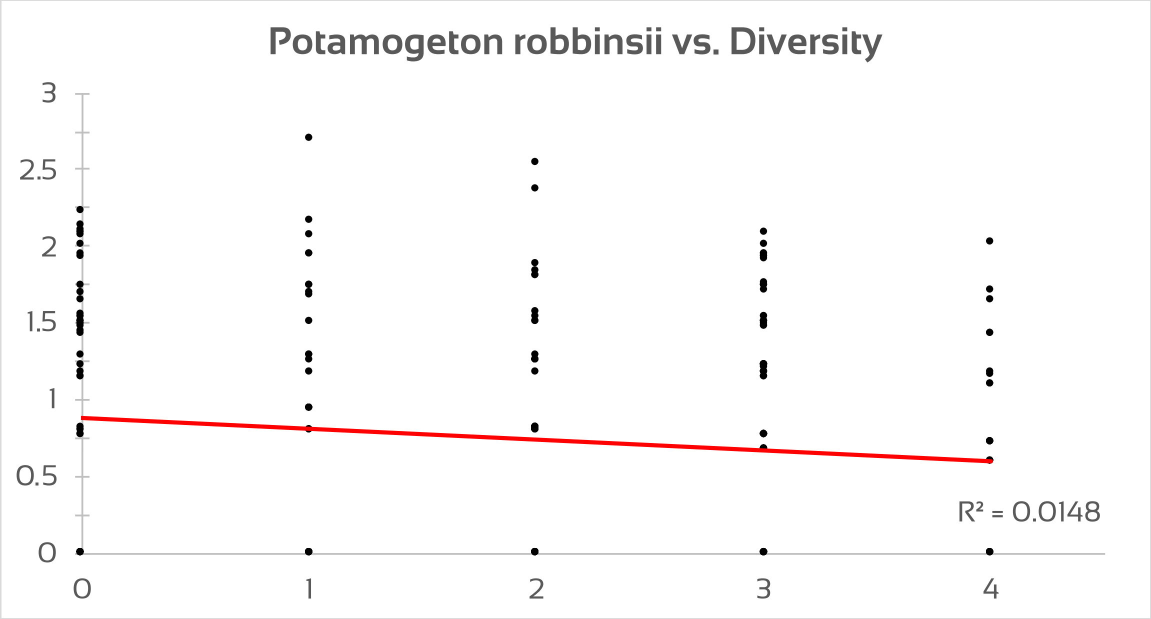
Linear Regression Model of Najas flexilis (Nodding Waternymph) abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.



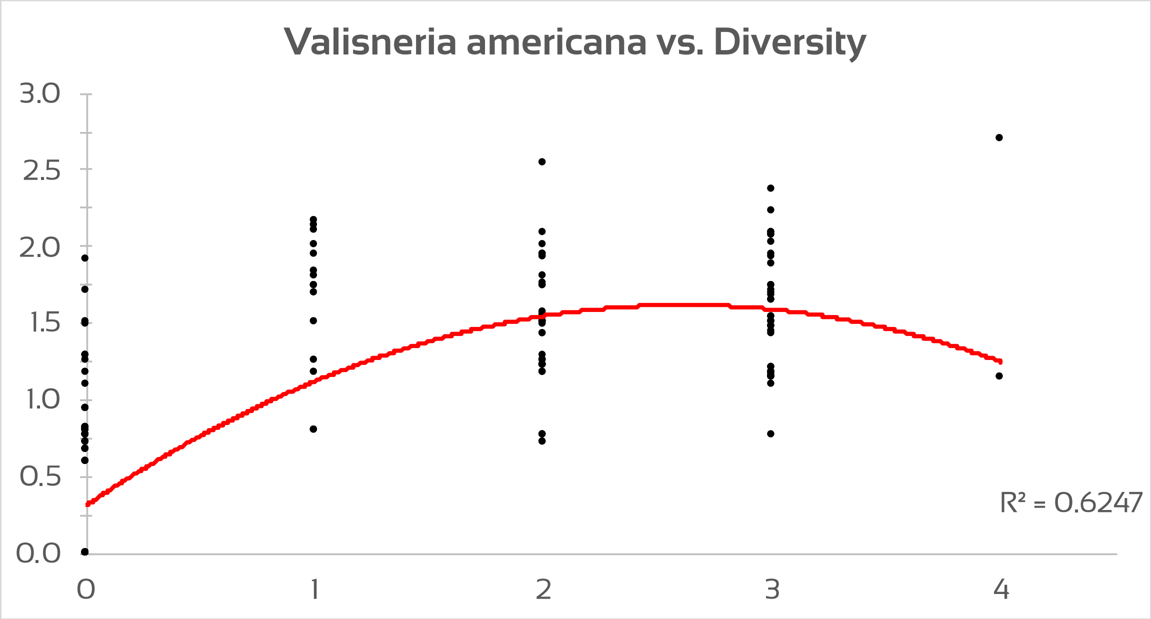
Linear Regression Model of Richness (y-axis) vs. Potamogeton robbinsii abundance (x-axis). The red line indicates the model's estimation.



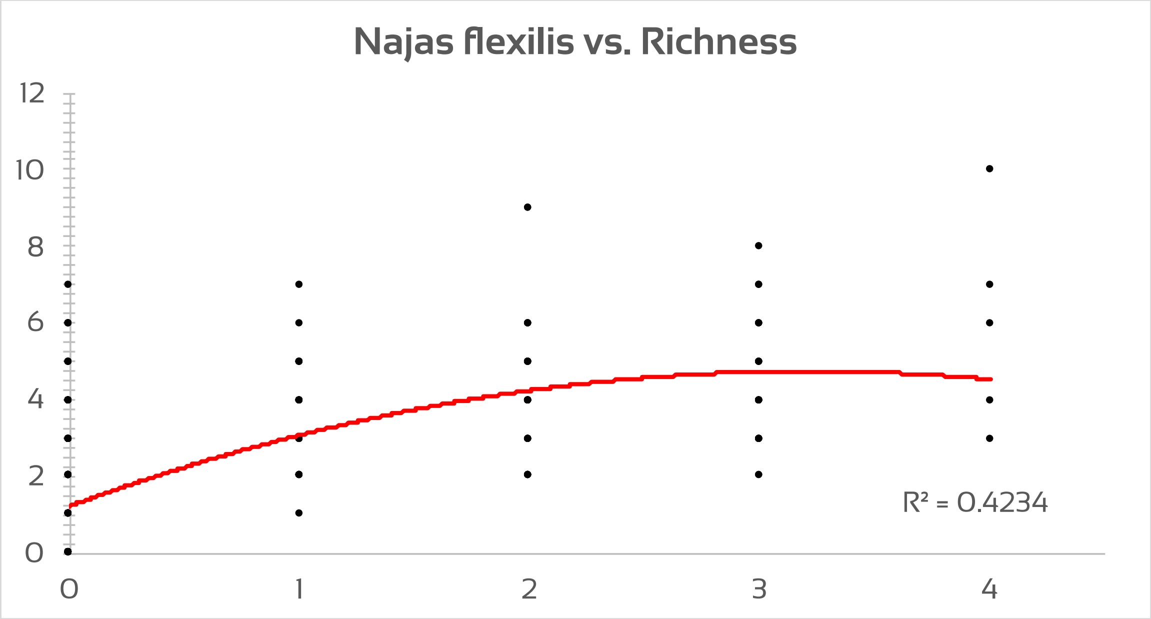
Linear Regression Model of Diversity (y-axis) vs. Potamogeton robbinsii abundance (x-axis). The red line indicates the model's estimation.



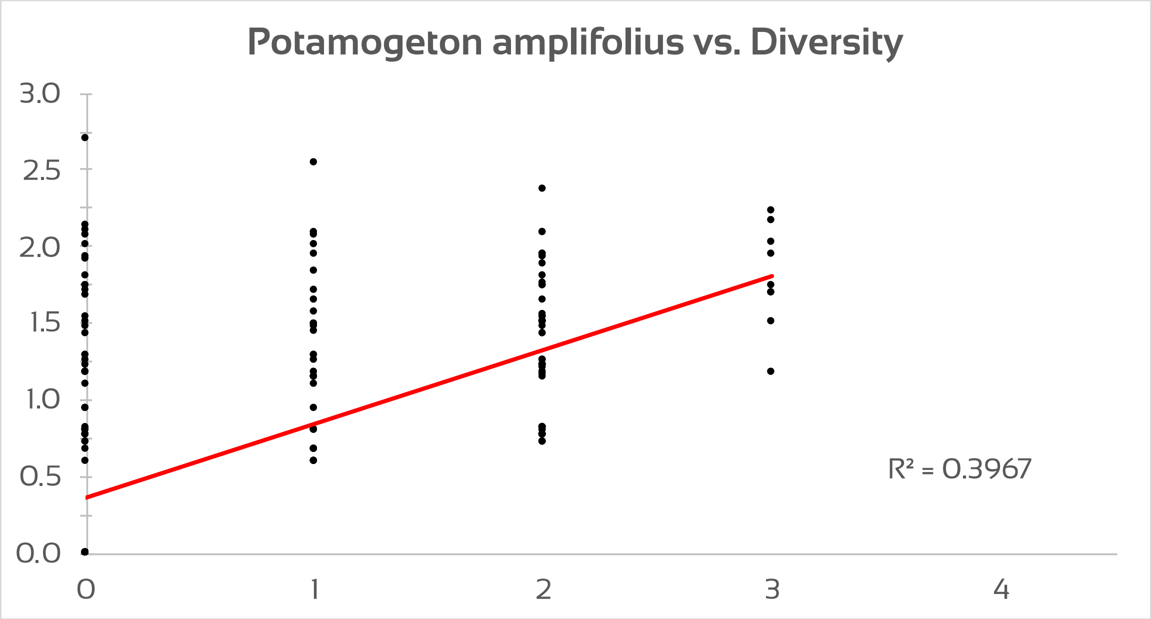
Polynomial Regression Model of Diversity (y-axis) vs. Vallisneria americana abundance (x-axis). The red line indicates the model's estimation.



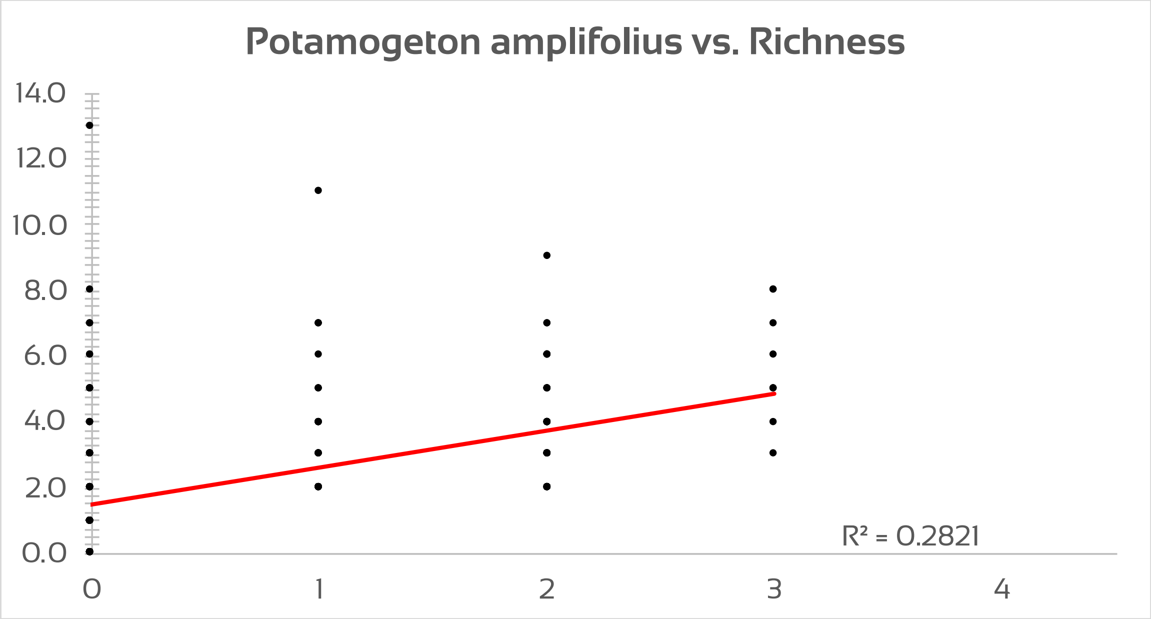
Polynomial Regression Model of Richness (y-axis) vs. Vallisneria americana abundance (x-axis). The red line indicates the model's estimation.



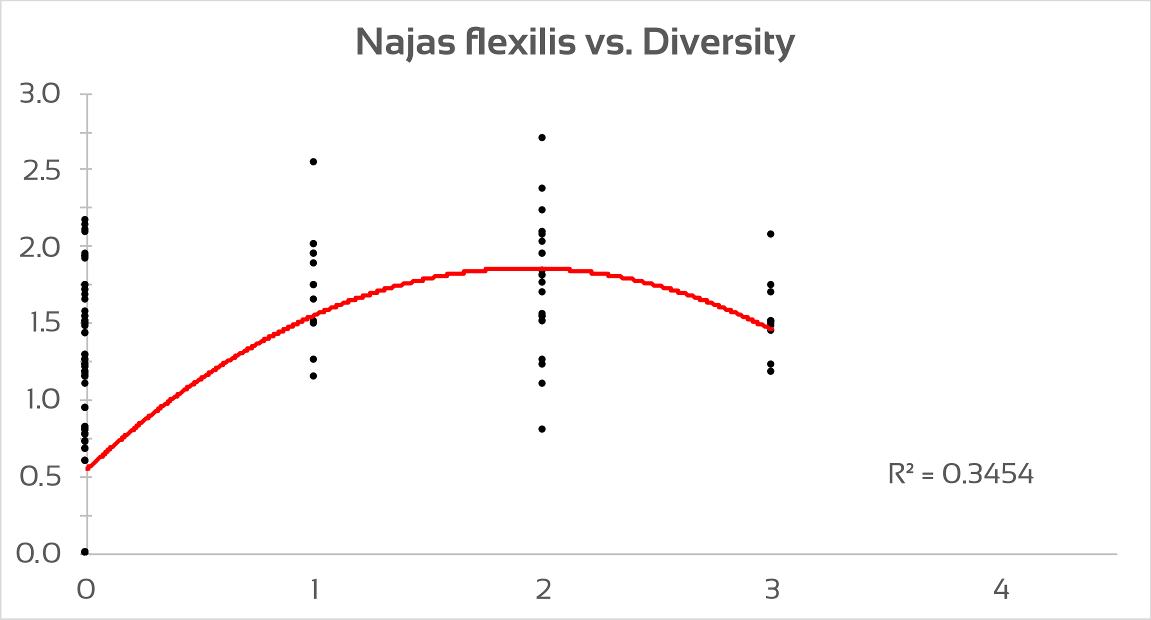
Linear Regression Model of Diversity (y-axis) vs. Potamogeton amplifolius abundance (x-axis). The red line indicates the model's estimation.



Linear Regression Model of Richness (y-axis) vs. Potamogeton amplifolius abundance (x-axis). The red line indicates the model's estimation.



Linear Regression Model of Diversity (y-axis) vs. Najas flexilis abundance (x-axis). The red line indicates the model's estimation.



Linear Regression Model of Richness (y-axis) vs. Najas flexilis abundance (x-axis). The red line indicates the model's estimation.