AQUATIC ECOSYSTEM RESEARCH
A Freshwater Conservation Company

Ball Pond

2022 Quantitative Aquatic Plant Survey

Prepared for the
Ball Pond Advisory Commission
New Fairfield, CT
December 20, 2022

EXECUTIVE SUMMARY

Aquatic Ecosystem Research was engaged by Ball Pond Advisory Commission to undertake a quantitative plant community study to serve as baseline data for use in future plant community management decision making processes. Below is a summary of the important findings from the survey:

- Study Design:
    - A geogrid was established in GIS that contained 393 sample points that were visited during the plant survey that took place on August 14th, 2022.
    - Each point was visited; and, the plant community was assessed visually and by sampling with a grapple.
- Basic Plant Community Statistics:
    - A total of 14 plant species were detected.
        - 11 rooted macrophytes
        - 2 lily species
        - 1 macroalgae
    - The top 4 most abundant aquatic plant species were:
        - *Eleocharis acicularis* (Dwarf Hair Grass)
        - *Najas minor* (Brittle Waternymph)
        - *Nuphar variegata* (Yellow Pondlily)
        - *Pontederia cordata* (Pickerelweed)
    - Fifty-two of the 393 points contained plant species (13%).
        - No plants were found at depths greater than 3m.
        - No rare or endangered species were detected.
        - One non-native species was detected:
            - *Najas minor*
    - The average rank abundance, corrected abundance, richness, and diversity at points with plants (i.e., 52 points) were 3.48, 0.46, 1.69, and 0.97, respectively.
        - These data suggest that Ball Pond's plant community was of low macrophyte productivity.
        - AER's opinion of the plant community in Ball Pond is that its productivity is very low and that any future management activities should focus on plant community expansion.
            - We hope to see a moderate increase in community productivity year over year because plant communities have significant impacts on water quality.

            - Further grass carp stockings should be carefully considered.
- Risk of Non-native Species Invasion:
    - The historical conductivity, pH, and alkalinity ranges suggest that Ball Pond is at risk for the MNP-group of the most common non-native species in New England.
        - MS = *Myriophyllum spicatum* (Eurasian Milfoil)
        - NM = *Najas minor* (Brittle Naiad)
        - PC = *Potamogeton crispus* (Curly-leaf Pondweed)
    - *Najas minor* is already present in the lake but not a nuisance levels.
- Aquatic Plant Community Management
    - AER's opinion of the plant community is that it needs to be allowed to expand before any further management is considered.
        - Much of the littoral zone is devoid of macrophytes.
        - This is likely impacting water quality in notable ways.
    - The plant community should be inspected yearly to assess the state of plant community.
    - Quantitative plant studies should be undertaken at 3 to 5-year intervals to develop an understanding of the plant community's trajectory.

INTRODUCTION

Purpose:

Aquatic Ecosystem Research was engaged by the Ball Pond Advisory Commission to conduct a quantitative survey of the plant community. That initiative was undertaken to examine the structure of the plant community, evaluate the impact of plant management initiatives, and create a baseline dataset for use in future plant management initiatives.

Lake Characteristics:

Ball Pond is a 85-acre lake located in New Fairfield, Connecticut (41° 27' 47.26"N, 73° 31' 26.58"W). The lake has a maximum depth of 15.4m (51ft), a mean depth of 7.3m (24ft), and it contains 6.65×10^8 gallons of water. The lake, which is ground water fed and in the Housatonic River drainage basin, is situated at an elevation of 784ft above sea level. Furthermore, the lake is oriented north to south, and its watershed is 246 acres. Ball Pond drains to Candlewood Lake via Ball Pond Brook.

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/buffering capacity, and specific assemblages of algae/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/buffering capacity, and algae/plant assemblages that are metabolically efficient when bicarbonate is the major form of carbon available for photosynthesis.

The bedrock present in the bedrock below the Ball Pond watershed is rusty schist and gneiss comprised of the minerals plagioclase, quartz, and muscovite. These minerals weather slowly and do not contribute significant ions loads to the local waters but does weather to a red to brown color.

METHODOLOGY

Experimental Design (Plant Survey):

Due to the fact that Ball Pond 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 Ball Pond, we established a 30mx30m grid that resulted in a total of 393 unique sampling (Fig. 1).

Plant Sampling and Data Collection (Plant Survey):

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 -10C and retained at AER's office. Finally, species that required confirmation were sent to Phytoid at the University of Wisconsin, Whitewater for genetic analysis.

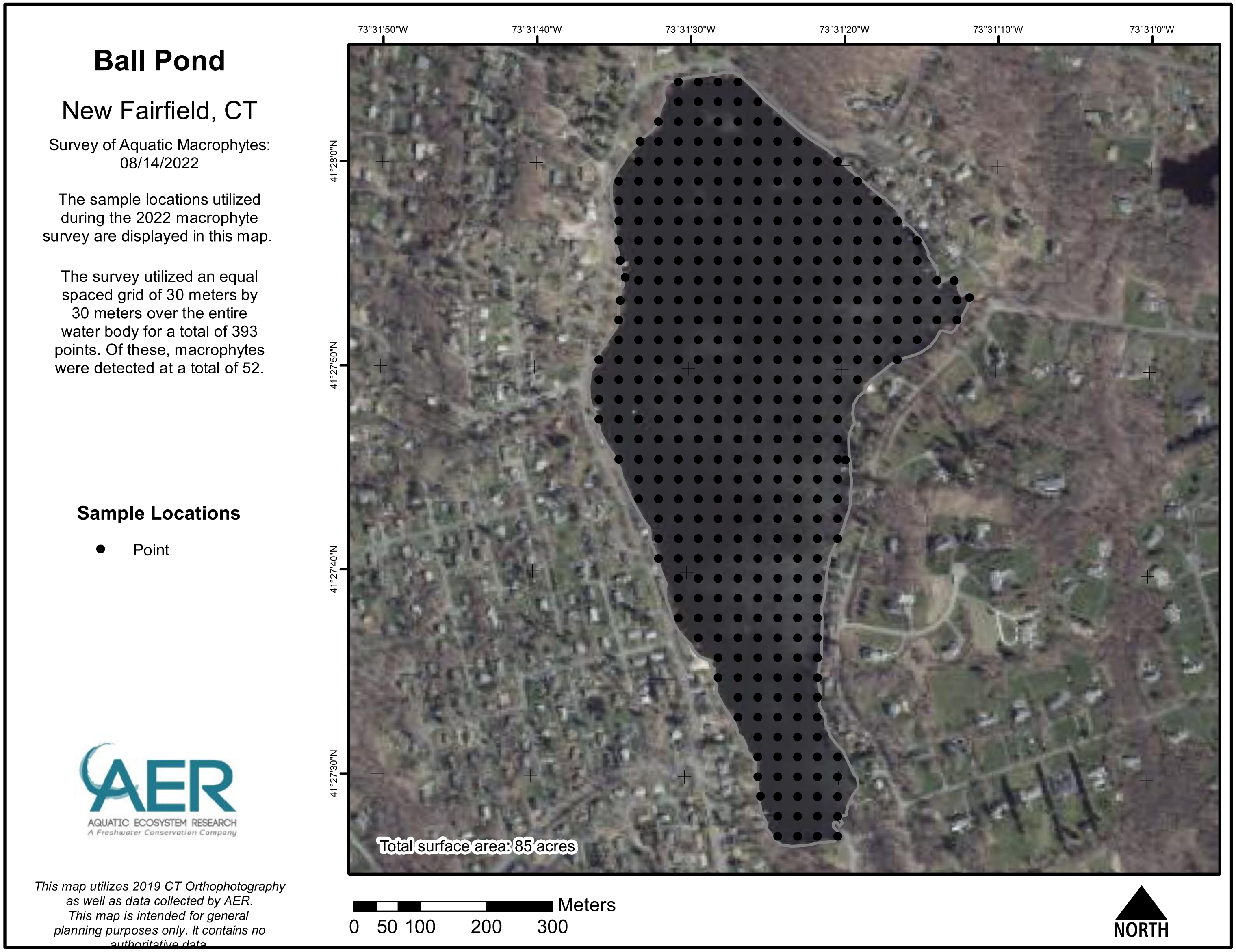
Data for species encountered at each point were logged in field notebooks by rank abundance where 1 was rare, 2 for present but not abundant, 3 for abundant but not dominant, 4 for dominant, or 5 for dense monoculture. Data were always logged with an identifier that coincided with the grid sample point.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

Data Processing and Analytical Techniques:

Field data, as they relate 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), 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 are 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 types 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).



Ball Pond

New Fairfield, CT

Survey of Aquatic Macrophytes:
08/14/2022

The sample locations utilized during the 2022 macrophyte survey are displayed in this map.

The survey utilized an equal spaced grid of 30 meters by 30 meters over the entire water body for a total of 393 points. Of these, macrophytes were detected at a total of 52.

Sample Locations

● Point

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This map utilizes 2019 CT Orthophotography as well as data collected by AER. This map is intended for general planning purposes only. It contains no authoritative data.

Figure 1. Ball Pond Sampling Grid

Table 1. Plant Community Statistics Overview

Ball Pond Species Inventory						
Species Name	**Common Name**	**Point Encounters**	**Percent of Points with Plants**	**Total Rank Abundance**	**Average Lake Rank Abundance**	**Average Abundance Where Present**
Ceratophyllum demersum	Coon Tail	1	1.92	2	0.01	2.00
Chara spp.	Musk Grass	6	11.54	9	0.02	1.50
Eleocharis acicularis	Dwarf Hair Grass	32	61.54	80	0.20	2.50
Elodea nuttallii	Western Waterweed	2	3.85	4	0.01	2.00
Elatine minima	Small Waterwort	1	1.92	2	0.01	2.00
Lemna minor	Common Duckweed	1	1.92	2	0.01	2.00
Najas guadalupensis	Southern Waternymph	6	11.54	12	0.03	2.00
Najas minor	Brittle Waternymph	16	30.77	24	0.06	1.50
Nuphar variegata	Yellow Pondlily	8	15.38	20	0.05	2.50
Nymphaea odorata	White Waterlily	1	1.92	2	0.01	2.00
Pontederia cordata	Pickerelweed	7	13.46	14	0.04	2.00
Potomogeton epihydrus	Ribbonleaf Pondweed	3	5.77	3	0.01	1.00
Potamogeton foliosus	Leafy Pondweed	1	1.92	2	0.01	2.00
Potamogeton natans	Broadleafed Pondweed	3	5.77	5	0.01	1.67

RESULTS

Genetic Plant Identification of Species in Question:
There were no species encountered that required confirmatory genetic identification.

Basic Plant Community Findings:
Aquatic macrophytes were found at 52 of the 393 grid points, which suggests that 13% of the waterbody houses one or more plant species. In total, thirteen submerged/rooted aquatic macrophytes and 1 macroalgae were encountered among the 393 points visited in Ball Pond on August 14th, 2022. The most common species detected during this survey was *Eleocharis acicularis* (Dwarf Hair Grass) with a total rank abundance of 80. Furthermore, it was found at 32 points, which accounts for 61.5% of all points where plants were found (52 points). Its average rank abundance among all points was 0.20; and, its average rank abundance among points where it was found was 1.54.

The second most common species found was the rooted macrophyte *Najas minor* (Brittle Waternymph). It was found at 16 of the 393 points with a total rank abundance of 24. Thirty-one percent of the points where plant species were found also housed *Najas minor*. The average lake-wide rank abundance was 0.06 and the average rank abundance among points where it was detected was 1.50.

The third most common species detected in Ball Pond was *Nuphar variegata* (Yellow Pondlily); it was detected at 8 of the 393 lake-wide points and had a total rank abundance of 20. *Nuphar variegata* exhibited an average lake-wide rank abundance of 0.05 and an average rank abundance among points where it was present of 2.00.

The fourth most common species was *Pontederia cordata* (Pickerelweed). That species was detected at 7 of the 393 grid points and was found to have a total rank abundance of 14. Furthermore, its average abundance lake-wide was 0.04 and an average total rank abundance of 2.00 where it was present. For a complete list of species detections and associated statistics, see Table 1.

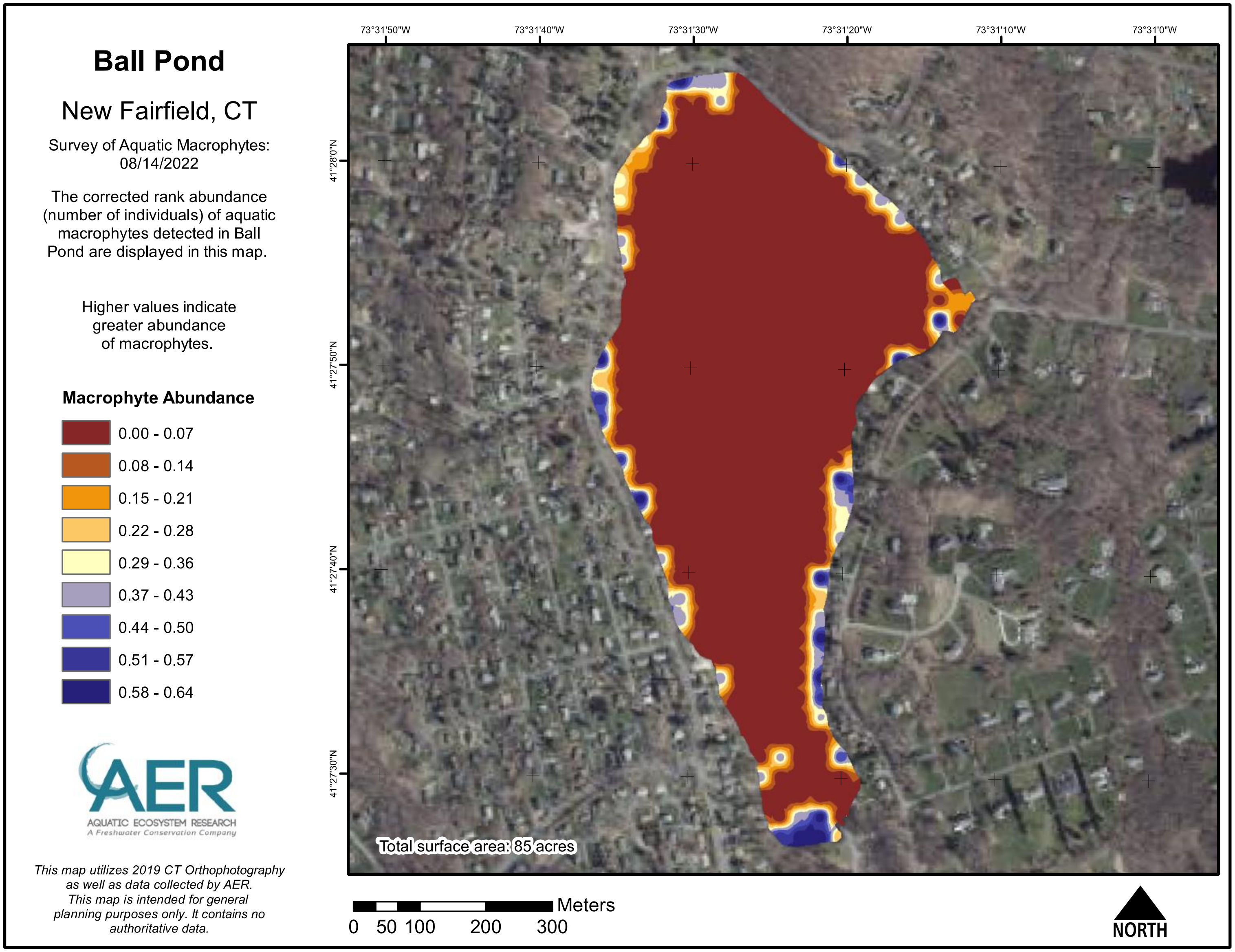
Spatial Distributions of Plant Community Characteristics:
Mapping of the corrected rank abundance variable (Fig. 2) suggests that the majority of the plant community density is present in distinct patches in shallow water near shore; and that where plants are present, the community is on the lower to middle of the rank abundance spectrum (i.e., average

abundance per point = 3.8). The corrected abundance variable accounts for average of all species abundances, the number of species at any given point, and the total number of species within the lake. For Ball Pond, this variable ranges from 0 to 0.64; the lowest values were found throughout most of the littoral zone (e.g., brownish red). The dark purple-colored areas are those with the greatest abundance of plant material; the highest values for corrected abundance exist in small patches around the shoreline. The majority of the lake houses corrected plant abundances between 0.00 and 0.14, which are represented by colors ranging light brown to reddish-brown (Fig. 2). Overall, the plant community exhibited an average value of 0.06 for the corrected abundance variable among all points.

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 5; and, the average number of species per point where plants were found was 1.7 (Fig. 3). Effectively, that means that there is an average of 2 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 in areas where human disturbances limited plant establishment (i.e., darkest green color, Fig. 3).

The average of 1.7 species per point is in the low range for recreational lakes. The richest areas that were found during this survey were along the north-western shoreline where between 4 to 5 species were detected and in patches along the southeastern shoreline where between 3 to 4 species were detected. On average, 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. However, we would expect more plant community productivity and richness in a lake like Ball Pond.

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 low diversity areas, which were represented throughout most of the lake, to more small/isolated diverse patches (Fig. 4). Where plants were present, the average diversity was 0.97 (0.06 lake-wide), 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.



Ball Pond

New Fairfield, CT

Survey of Aquatic Macrophytes:
08/14/2022

The corrected rank abundance (number of individuals) of aquatic macrophytes detected in Ball Pond are displayed in this map.

Higher values indicate greater abundance of macrophytes.

Macrophyte Abundance

- 🟥 0.00 - 0.07
- 🟫 0.08 - 0.14
- 🟧 0.15 - 0.21
- 🟨 0.22 - 0.28
- ⬜ 0.29 - 0.36
- 🟪 0.37 - 0.43
- 🟦 0.44 - 0.50
- 🟦 0.51 - 0.57
- 🟦 0.58 - 0.64

This map utilizes 2019 CT Orthophotography as well as data collected by AER. This map is intended for general planning purposes only. It contains no authoritative data.

Figure 2. Spatial Distribution Map of Corrected Plant Community Abundance

Ball Pond

New Fairfield, CT

Survey of Aquatic Macrophytes:
08/14/2022

The richness (number of unique species) of aquatic macrophytes detected in Ball Pond are displayed in this map.

Higher values indicate areas with a greater number of macrophyte species.

Macrophyte Richness

🟩 0.0 - 1.0
🟨 1.1 - 2.0
🟧 2.1 - 3.0
🟫 3.1 - 4.0
⬜ 4.1 - 5.0

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Figure 3. Spatial Distribution Map of Plant Species Richness.

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 Ball Pond, Shannon's H' is within the low range of values in near shore areas; that suggests that the plant community as a whole is dominated by a few species. Furthermore, the low overall productivity and limited richness characteristics of the Ball Pond plant community suggest that there has been a major disturbance that limited its distribution, productivity, richness, and diversity characteristics.

Eleocharis acicularis was found to be distributed in shallow waters in patches along the shoreline (Fig. 5). In areas where depth was greater than 1.5m (5ft) *E. acicularis* was rare; but, in areas that were shallower it was often one of the dominant species. Overall, *E. acicularis* was found to be the most common plant spatially. Upon the application of spatial statistics to those point data that were collected on August 14th, 2022, it becomes clear that the probability of encountering *E. acicularis* at any given point that is shallower than 1.5m (5ft) is moderate (Fig. 5).

Najas minor (Brittle Waternymph) was found to be distributed in small patches throughout shoreline of Ball Pond (Fig. 6). It was also found in areas of higher diversity and richness. *Najas minor* was rare in waters deeper than 2.5m (8ft). Finally, it was the second most widely distributed species in Ball Pond.

Nuphar variegata (Yellow Waterlily) was distributed in one large patch near the boat launch and in small patches along the eastern shoreline (Fig.7); it was not found in areas deeper than 1.5m (5ft). Its presence coincided with some areas of high diversity and richness (Fig. 7). It was the third most abundant and widely distributed aquatic macrophyte encountered in Ball Pond during the August 14th, 2022, survey.

Pontederia cordata (Pickerelweed) was the fourth most abundant and spatially distributed aquatic macrophyte species encountered during the August 14th survey. Its spatial distribution does coincide with the spatial distributions of diversity or richness. *Pontederia cordata* was found to be distributed in random patches along the shoreline and was largely absent in deep water areas (i.e., >1.5m, Fig. 8).

Ball Pond

New Fairfield, CT

Survey of Aquatic Macrophytes:
08/14/2022

The diversity (using Shannon's diversity index) of aquatic macrophytes detected in Ball Pond are displayed in this map.

Higher values indicate areas with greater macrophyte diversity.

Macrophyte Diversity

- 🟩 0.00 - 0.20
- 🟩 0.21 - 0.40
- 🟩 0.41 - 0.60
- 🟩 0.61 - 0.80
- 🟨 0.81 - 1.00
- ▨ 1.01 - 1.20
- 🟪 1.21 - 1.41
- 🟪 1.42 - 1.61
- 🟪 1.62 - 1.81

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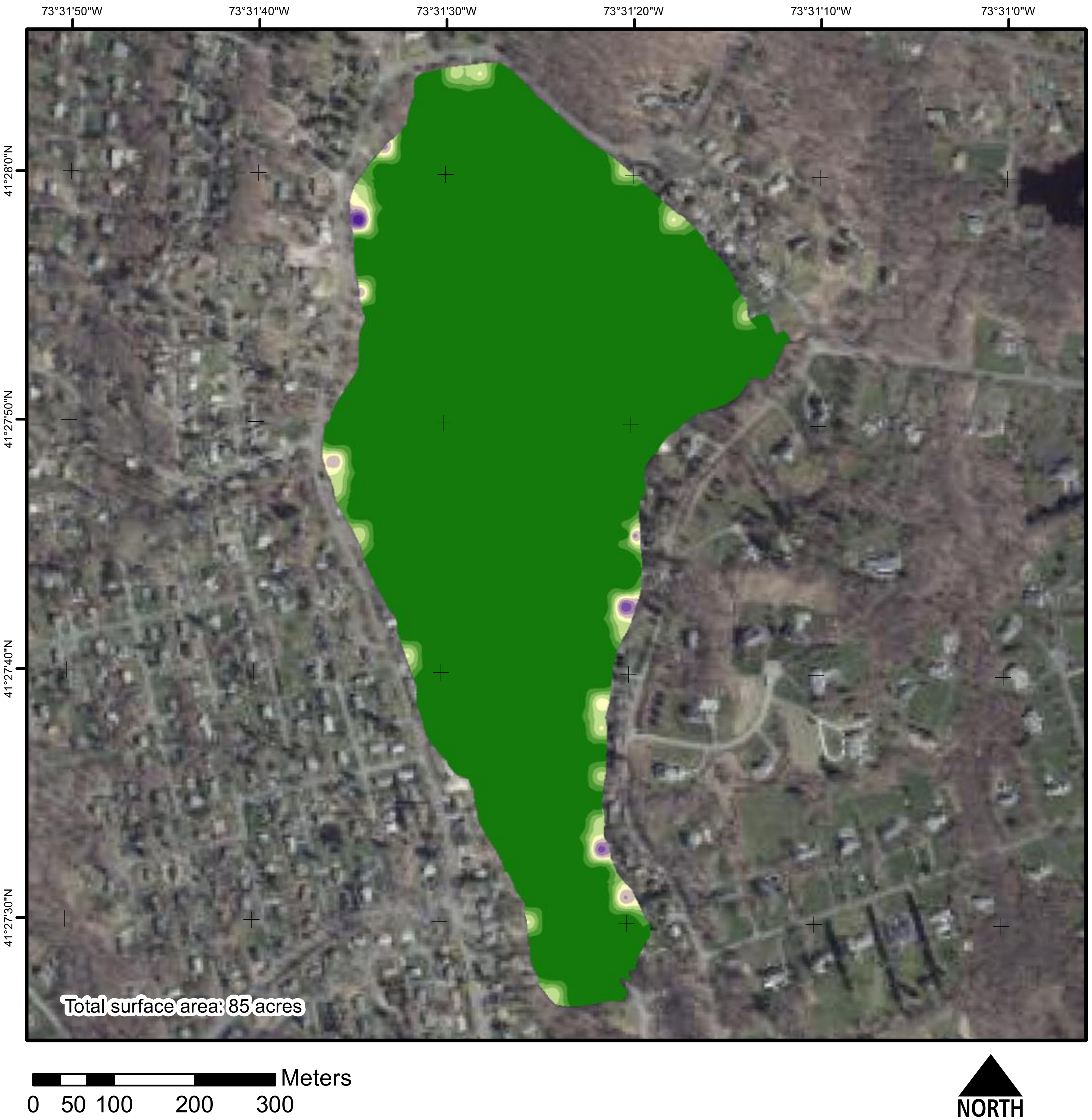

Figure 4. Spatial Distribution Map of Plant Community Diversity

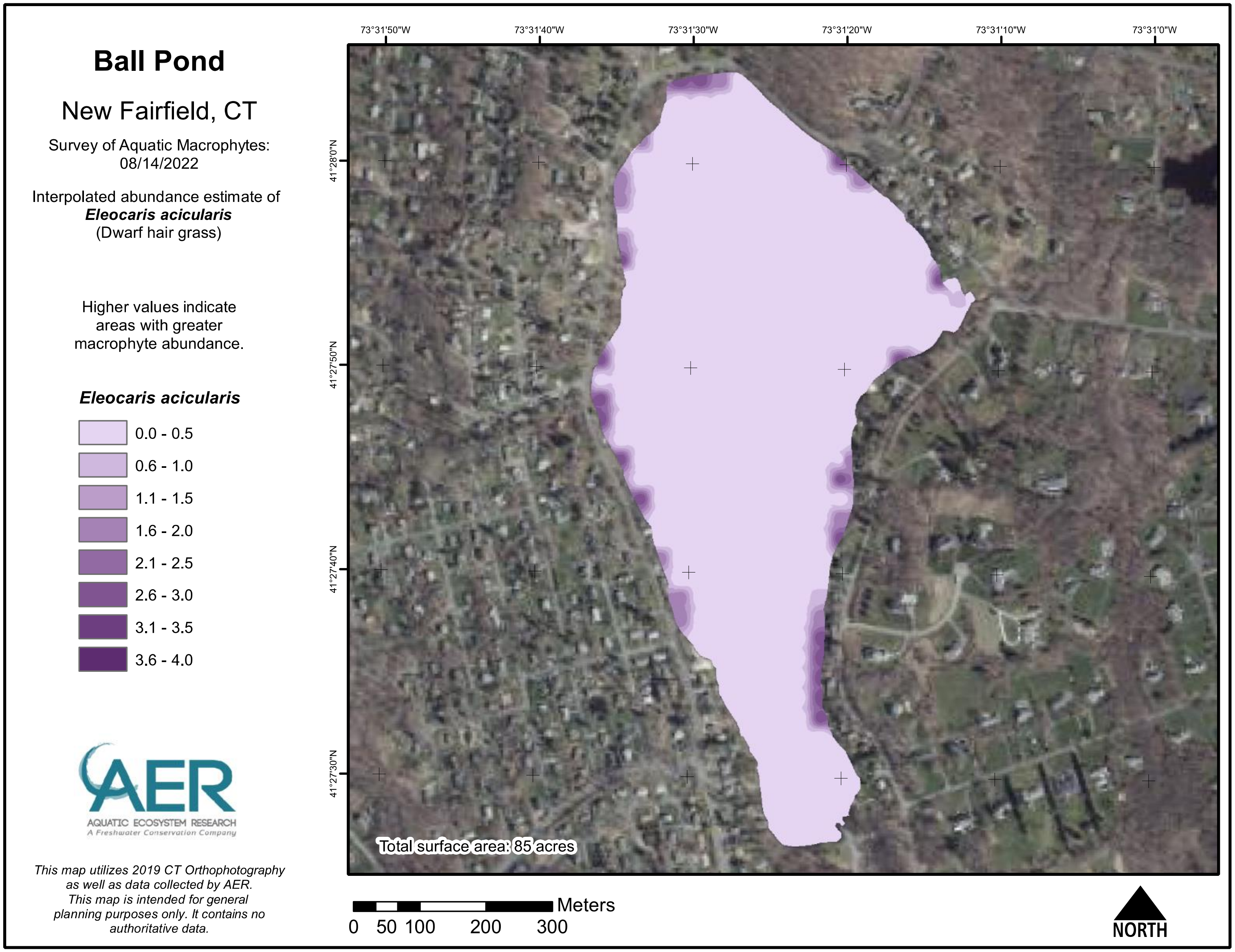

Figure 5. Spatial Distribution Map of *Eleocharis acicularis* (Dwarf Hair Grass)

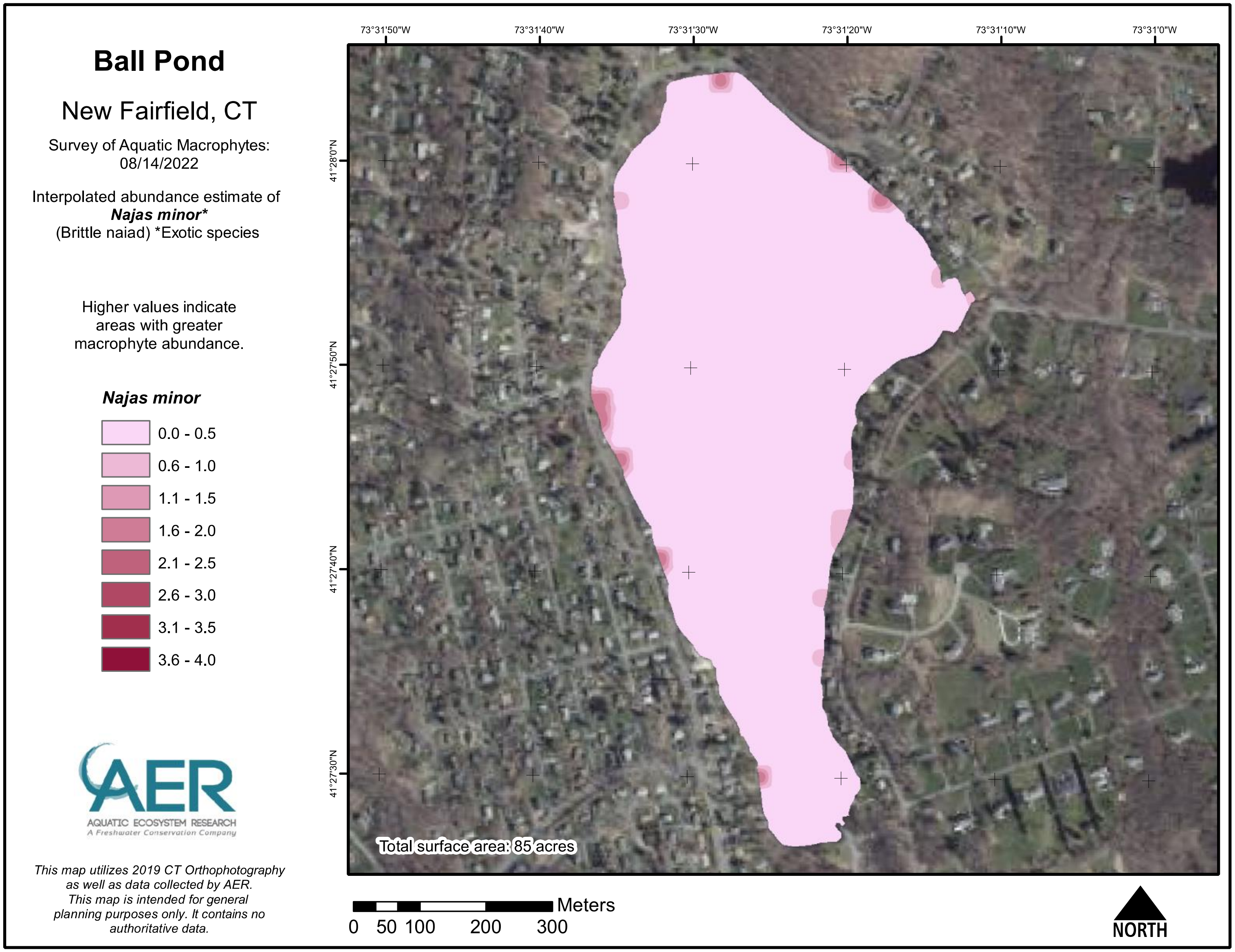

Figure 6. Spatial Distribution Map of *Najas minor* (Brittle Waternymph)

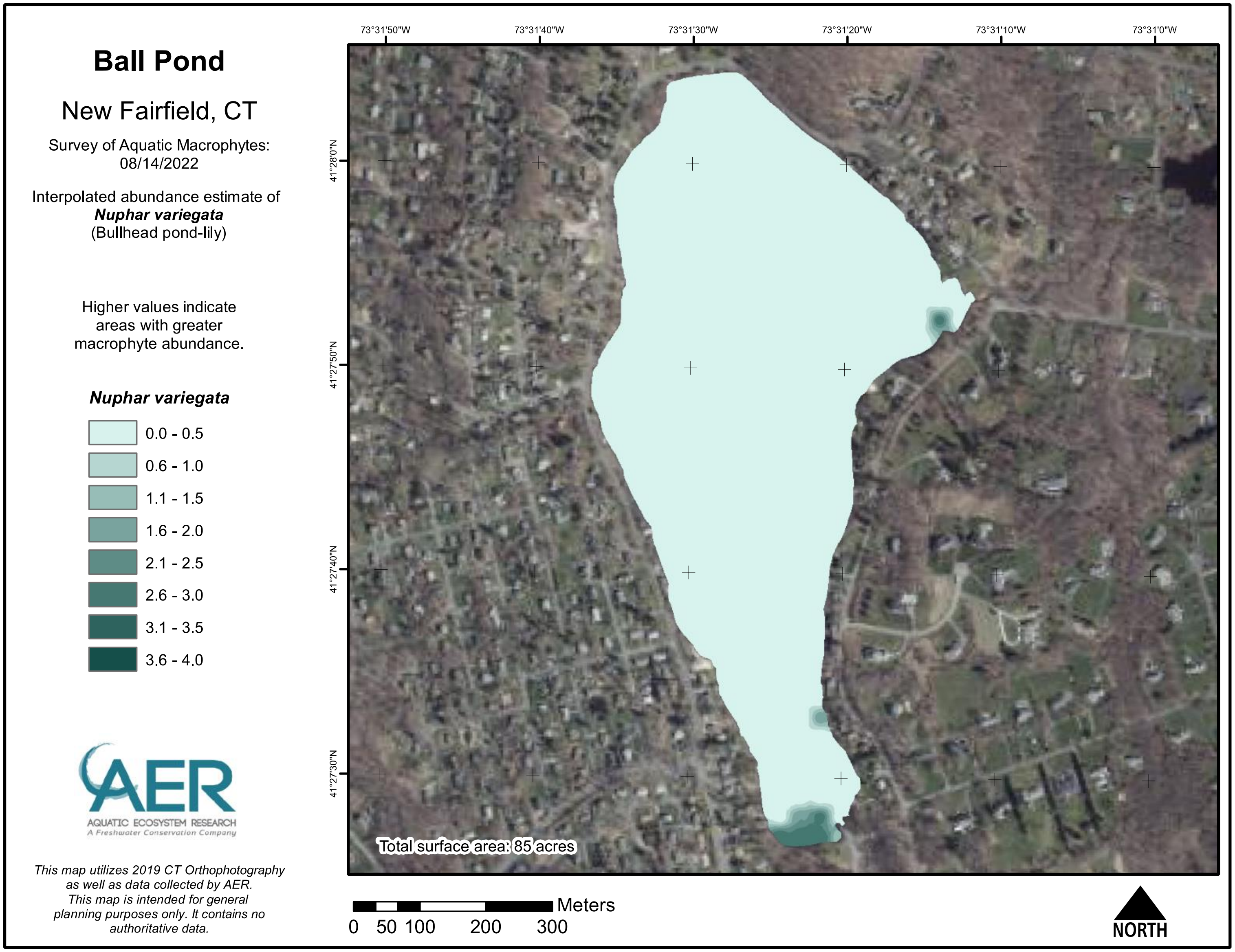

Figure 7. Spatial Distribution Map of *Nuphar variegata* (Yellow Waterlily)

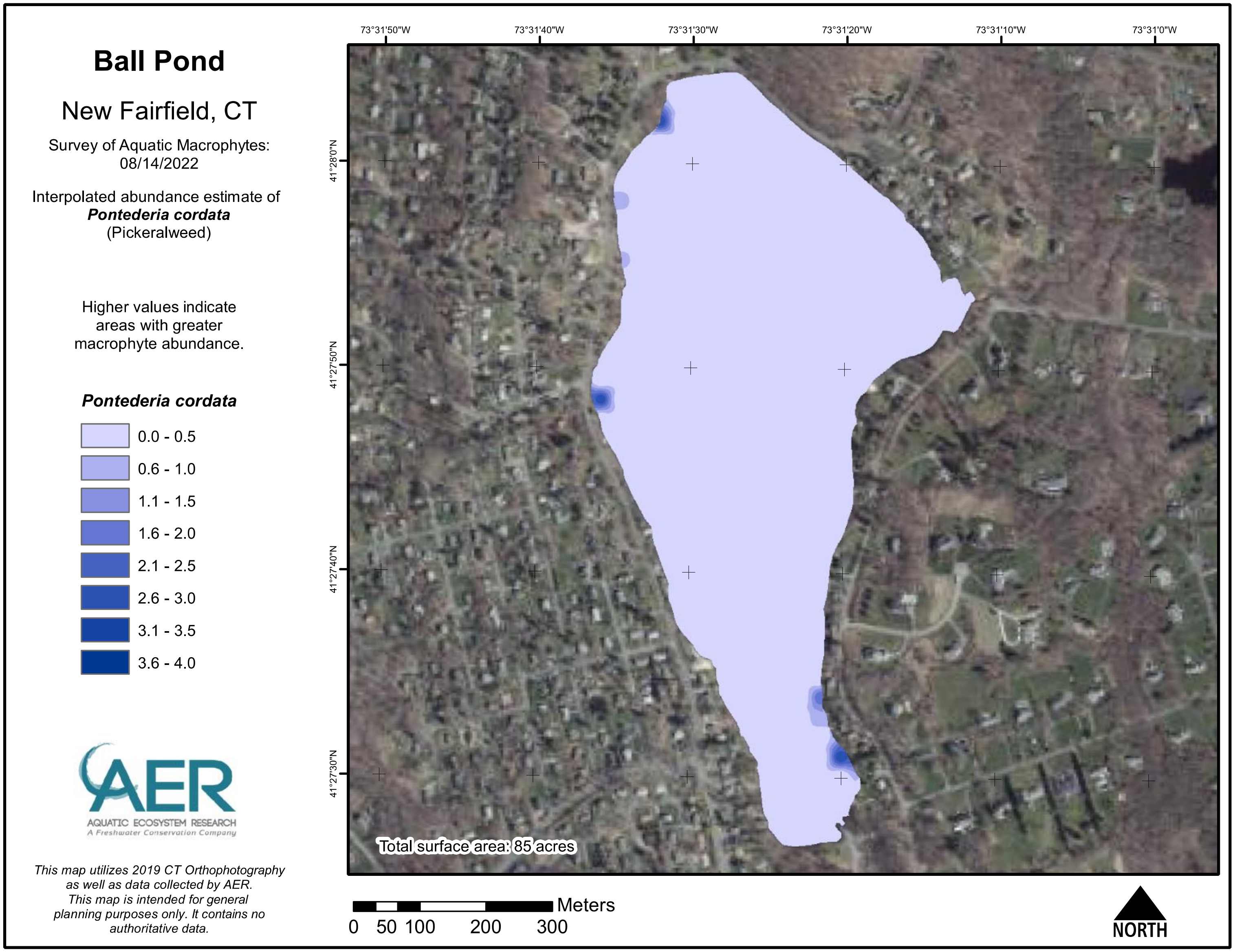

Figure 8. Spatial Distribution Map of *Pontederia cordata* (Pickerelweed)

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 linear model best explained those data interactions (r^2=0.17, Fig. 9). Additionally, when we regressed corrected abundance vs. depth, we found that a linear model best explained the distribution of plant abundance (r^2=0.20, Fig. 10). Both models of abundance vs. depth suggest that most of the plant abundance is present in the shallowest reaches of the lake and that factors other than depth are affecting the overall structure of the plant community (i.e., low r^2-values).

The examination of diversity vs depth suggested that the distribution of community evenness (diversity) followed a linear model (r^2=0.06, Fig.11). Diversity was found to decrease with depth and the most diverse areas were between 0.10m (0.33ft) and 1.0m (3.3ft). However, the r^2-value suggests that depth was not the major influencing factor effecting diversity. That finding was further supported by the results of AER's regression of richness vs. depth. When those two variables were examined together, a linear model was found to best explain that relationship (r^2=0.15, Fig. 12). Richness was greatest in shallow waters and decreased as depth increased. The 0.10 to 1.0m range was found to house the greatest number of individual plant species.

To understand individual species relationships with abiotic and biotic factors, the four most abundant species were regressed against depth, richness, and diversity variables. *Eleocharis acicularis* was found to be the most abundant species in Ball Pond; when its abundance was regressed against depth, it was found to follow a linear model (r^2=0.13, Fig.13). The amount of variance explained in that species' data was low (i.e., 12.6%), which suggests that something other than depth is impacting the abundance of *E. acicularis.*

When *Najas minor* was regressed against depth it was found that a weak linear relationship existed (r^2=0.04, Fig.14). That suggests that the abundance of *N. minor* was impacted more strongly by factors other than depth. When *Nuphar variegata* was regressed against depth, a weak linear relationship was found to best described its abundance distribution within the lake's depth profile (r^2=0.04, Fig.15). That model suggests that light availability is not the primary driving factor determining the distribution of *N. variegata*.

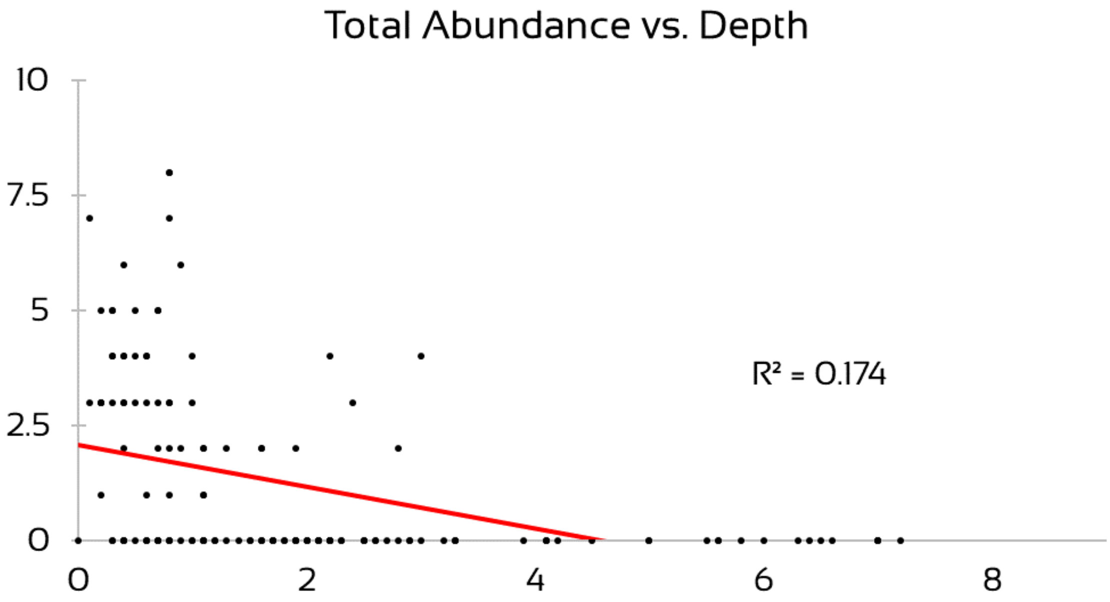

Figure 9. Linear Regression Model of Total Abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

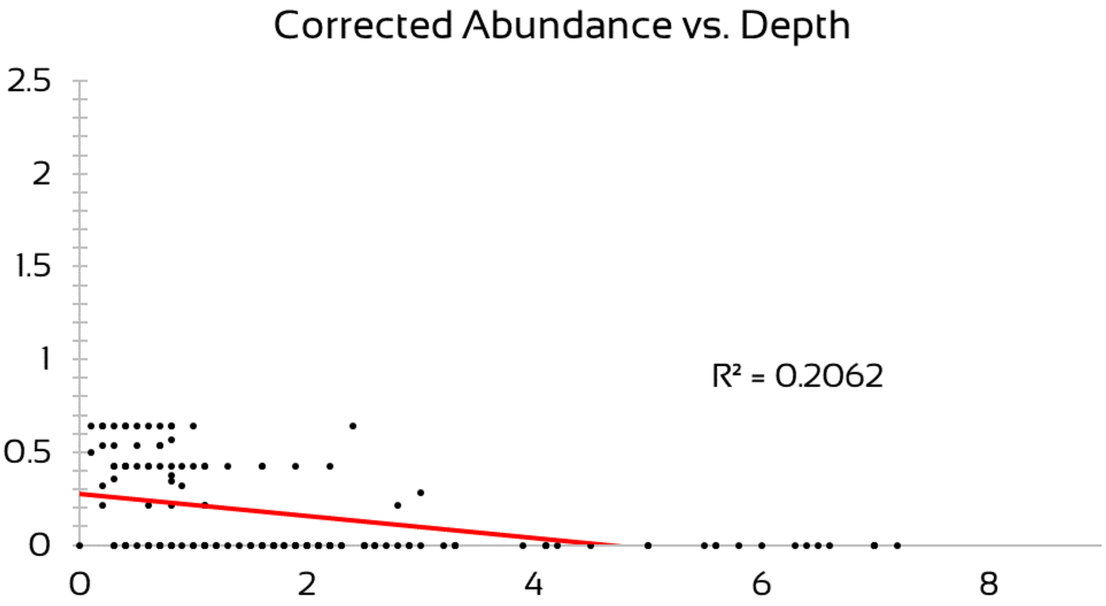

Figure 10. Linear Regression Model of Corrected Abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

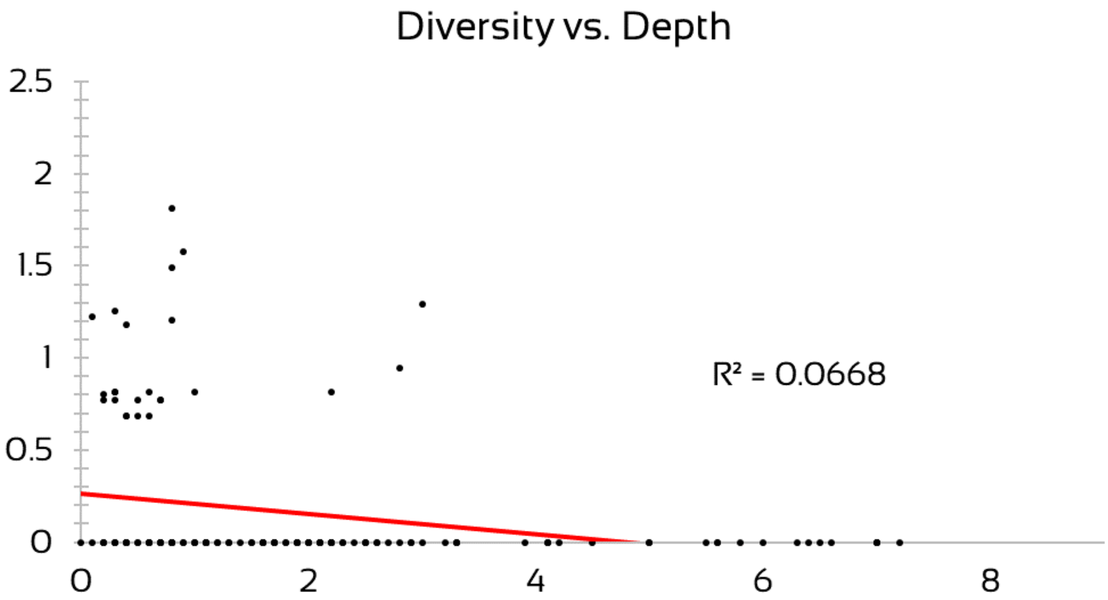

Figure 11. Linear Regression Model of Community Diversity (y-axis) vs. depth (x-axis). The red line indicates the model’s estimation.

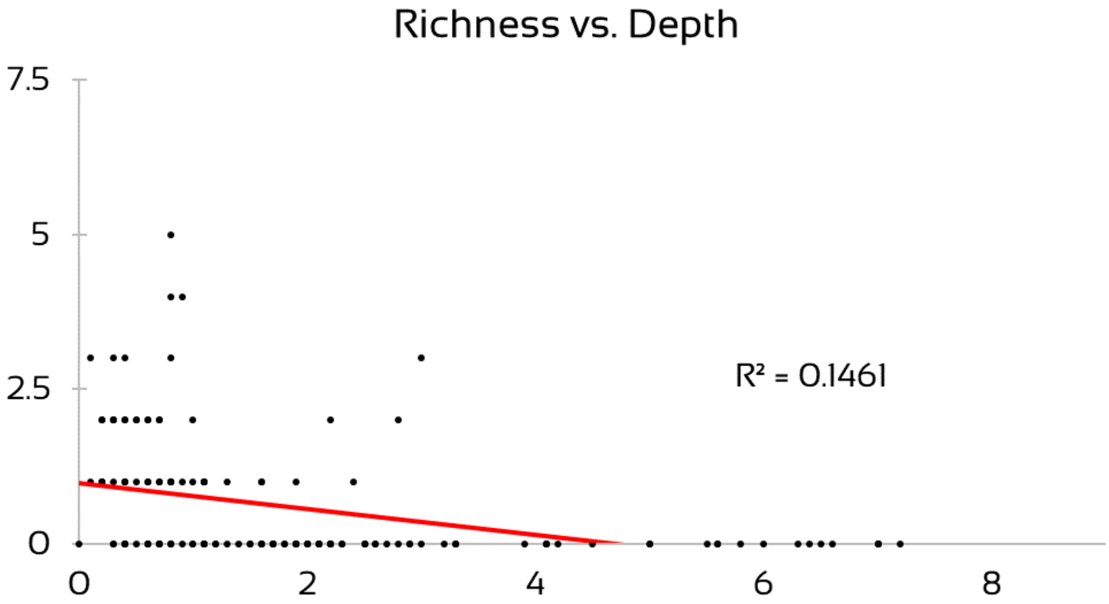

Figure 12. Linear Regression Model of Community Richness (y-axis) vs. depth (x-axis). The red line indicates the model’s estimation.

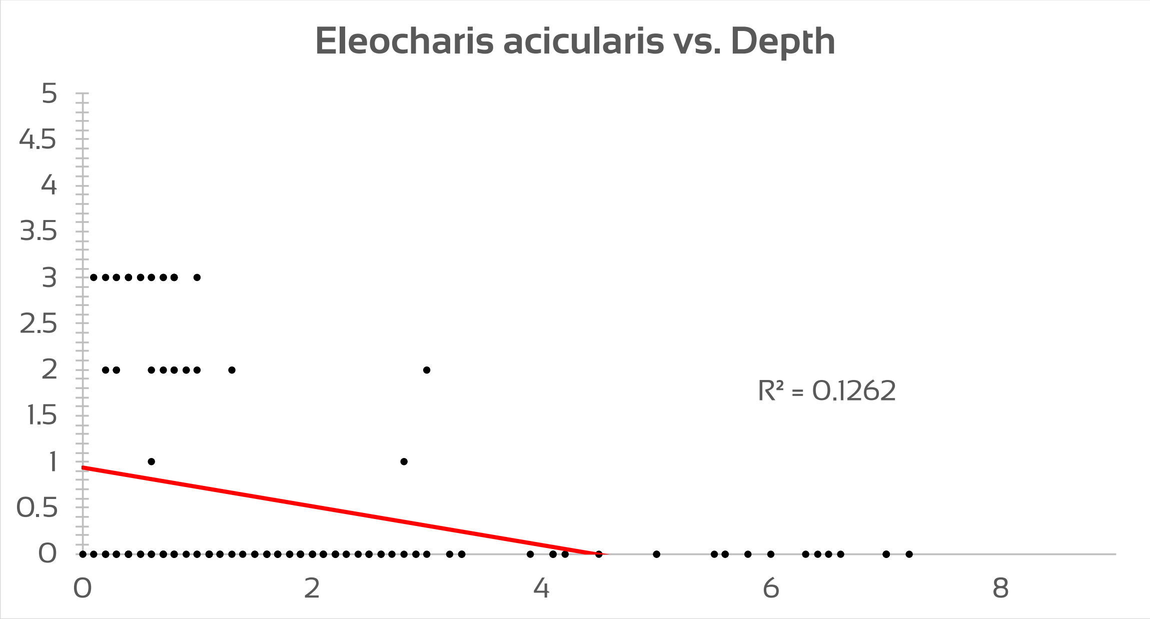

Figure 13. Linear Regression Model of *Eleocharis acicularis* abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

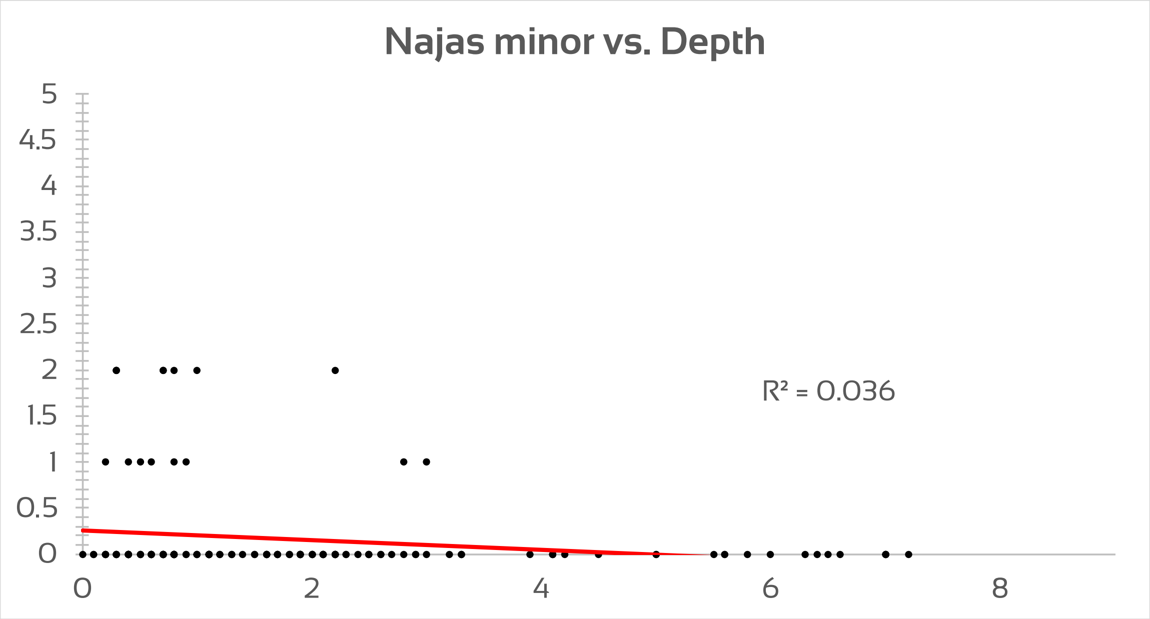

Figure 14 Linear Regression Model of *Najas minor* abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

Pontederia cordata was found to exhibit a very weak linear relationship with depth (r^2=0.02, Fig. 16). Those data suggest that *P. cordata is* most common in the 0.1 to 0.5m range.

To further understand relationships among the most abundant aquatic macrophyte species in Ball Pond, the total abundance variable of each species was regressed against both diversity and richness. When richness was regressed against *Eleocharis acicularis* total abundance, the analysis suggested that a polynomial relationship was the best explanatory model (r^2=0.56, Fig. 17). The relationship between the two variables was moderate to strong and positive in nature, which suggests that the abundance of this species coincides with richness of the local community (Fig. 17). When that species was used in the regression of local diversity vs. its abundance a moderate polynomial model was developed (r^2=0.42, Fig. 18). That model suggested that the abundance of *E. acicularis* explained 44.2% of the variance in diversity data; and that as its abundance increased, diversity increased, which suggests that the abundance of *E. acicularis* coincides local diversity.

When diversity and richness were regressed against the abundance of *Najas minor,* two polynomial relationships were resolved with variance accountings of 46.6 and 41.0%, respectively. The relationship between diversity and *N. minor* abundance was moderate in nature (r^2=0.47, Fig. 19) and suggests that when *N. minor* abundance is between 1.0 and 1.5, that plant community diversity is at its greatest. When richness was regressed against the abundance of *N. minor*, it was found that there was a moderate relationship between the two variables (r^2=0.41). That model suggests that where *N. minor* exhibits an abundance between 1.0 and 1.5, that there are more unique species present (Fig. 20).

Diversity and richness were also regressed against the abundance of *Nuphar variegate*; the resulting models were both linear in nature and they explained 0.4 and 4.1% of the variance in those datasets. The diversity model was weak in its explanatory value and suggested that the abundance of *N. variegata* did not relate to the diversity of the local area (Fig. 21). That pattern was also found when richness was regressed against its abundance, and that relationship was similarly low in its explanatory value (r^2<0.01, Fig. 22).

The relationship between *Pontederia cordata* abundance and community diversity was found to be best explained by a linear model (r^2=0.17, Fig. 23). That relationship was weak in nature but suggests that as its abundance increases, that diversity increases also. When richness was regressed against the abundance of that species, a linear relationship was resolved (r^2=0.18, Fig. 24). The relationship was weak but suggested that when *P. cordata* increases in abundance, so too does richness.

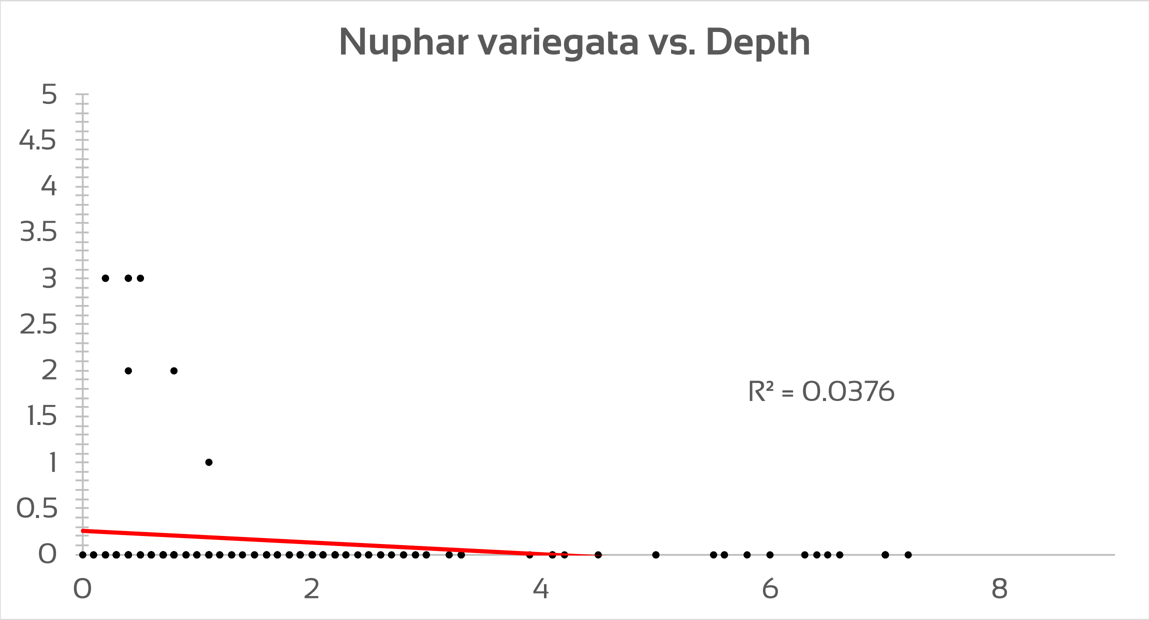

Figure 15. Linear Regression Model of *Nuphar variegata* abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation

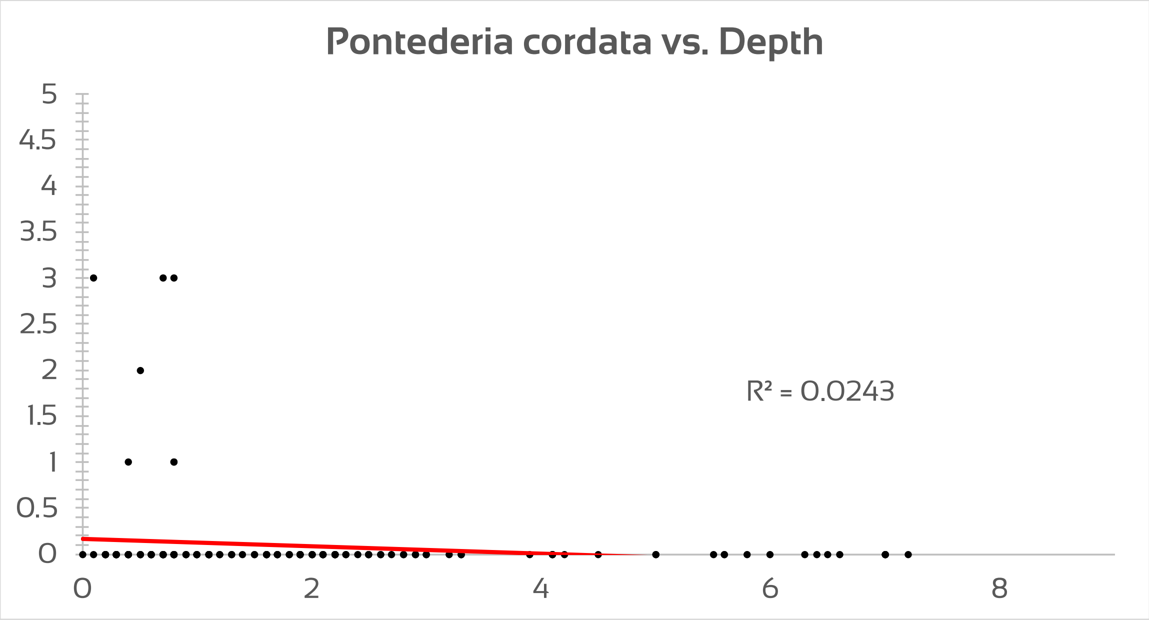

Figure 16. Linear Regression Model of Pontederia cordata abundance (y-axis) vs. depth (x-axis). The red line indicates the model's estimation.

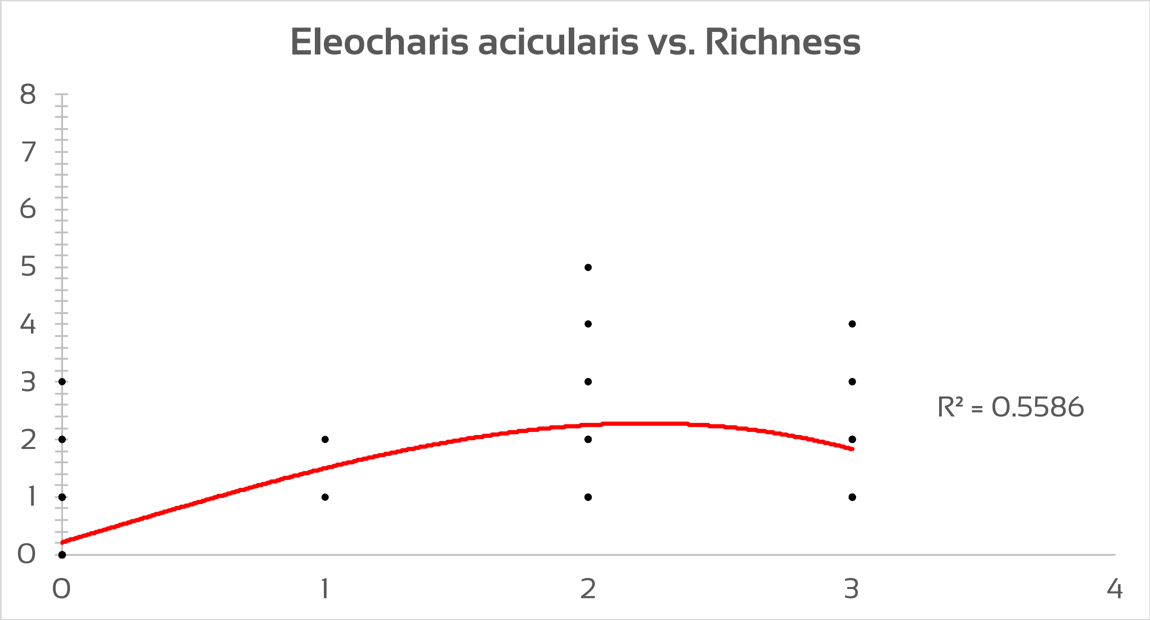

Figure 17. Polynomial Regression Model of Richness (y-axis) vs. *Eleocharis acicularis* abundance (x-axis). The red line indicates the model's estimation.

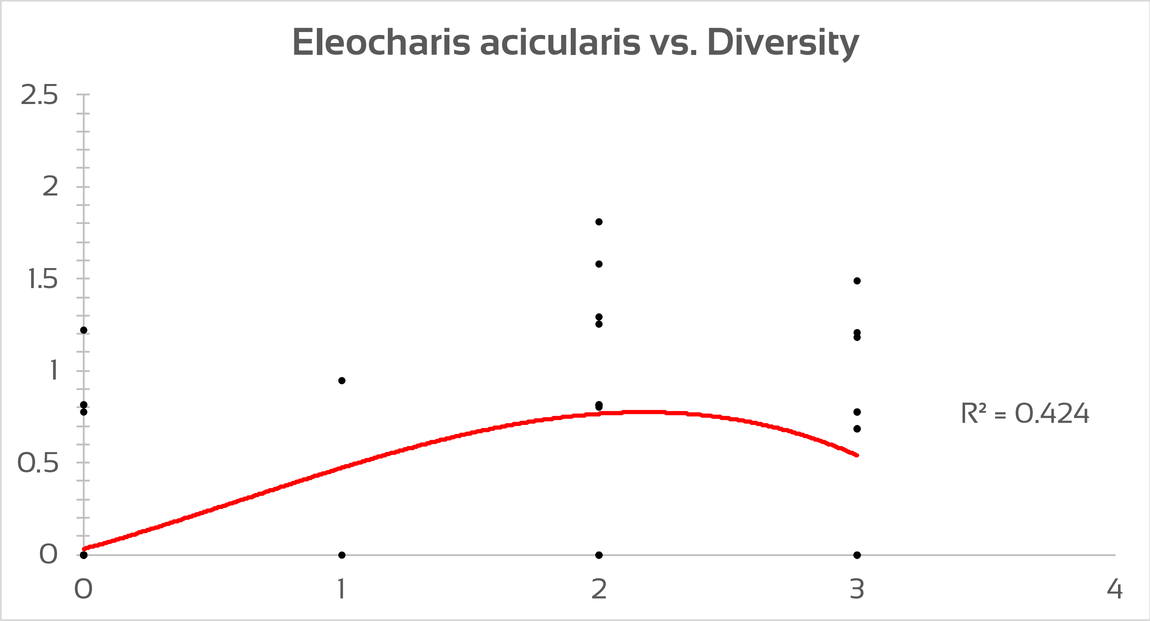

Figure 18. Polynomial Regression Model of Diversity (y-axis) vs. *Eleocharis acicularis* abundance (x-axis). The red line indicates the model's estimation.

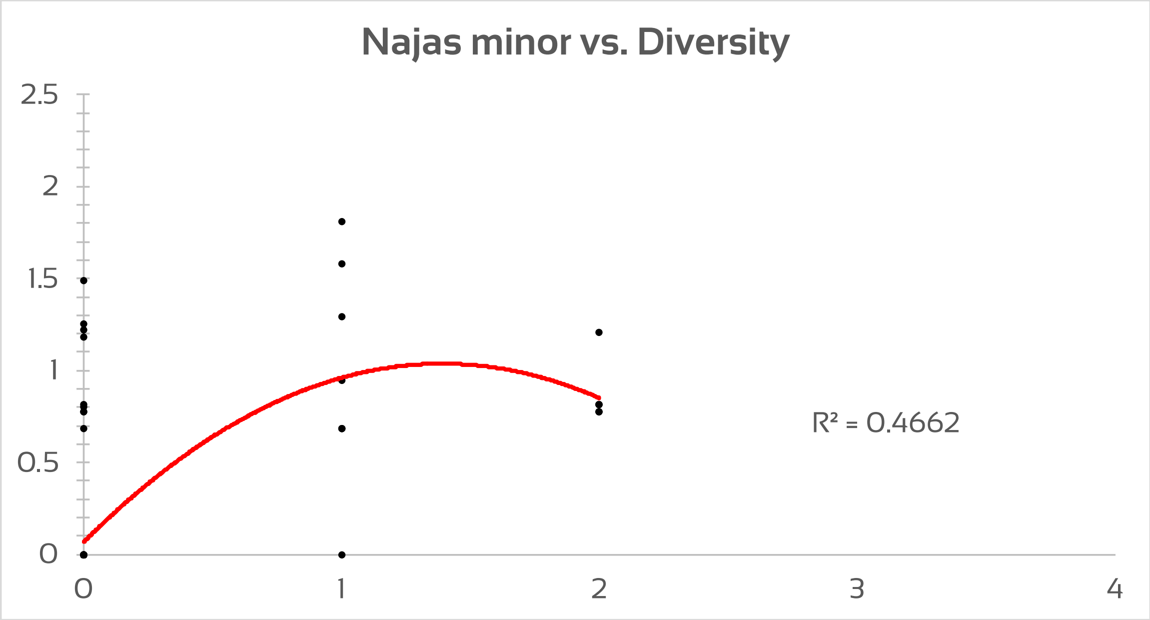

Figure 19. Polynomial Regression Model of Diversity (y-axis) vs. Najas minor abundance (x-axis). The red line indicates the model's estimation.

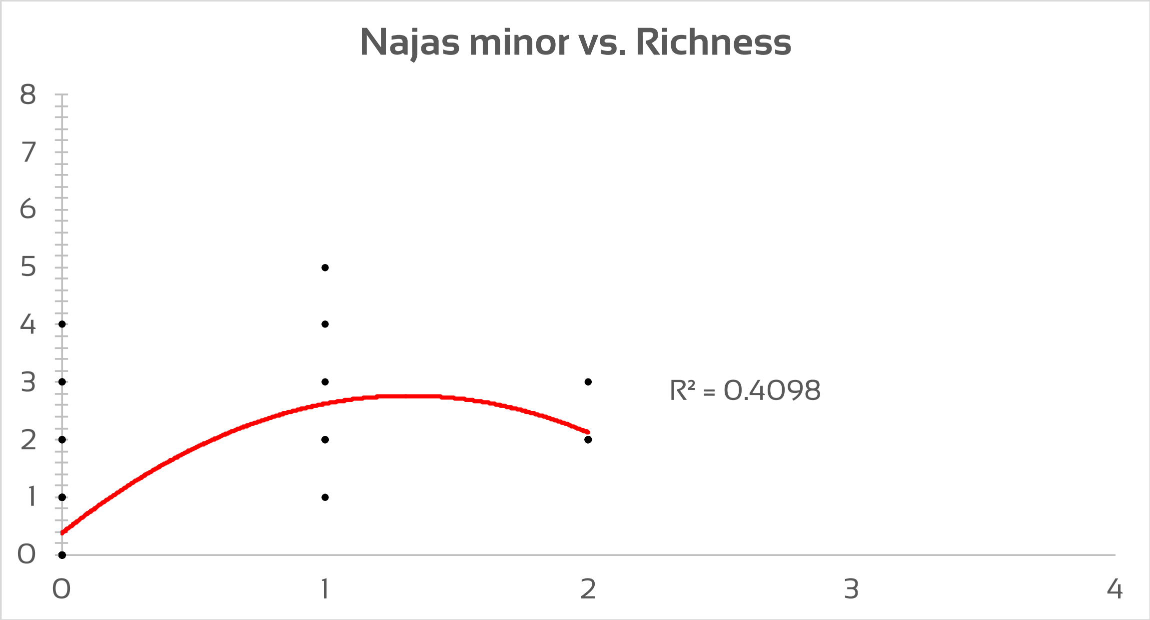

Figure 20. Polynomial Regression Model of Richness (y-axis) vs. Najas minor abundance (x-axis). The red line indicates the model's estimation.

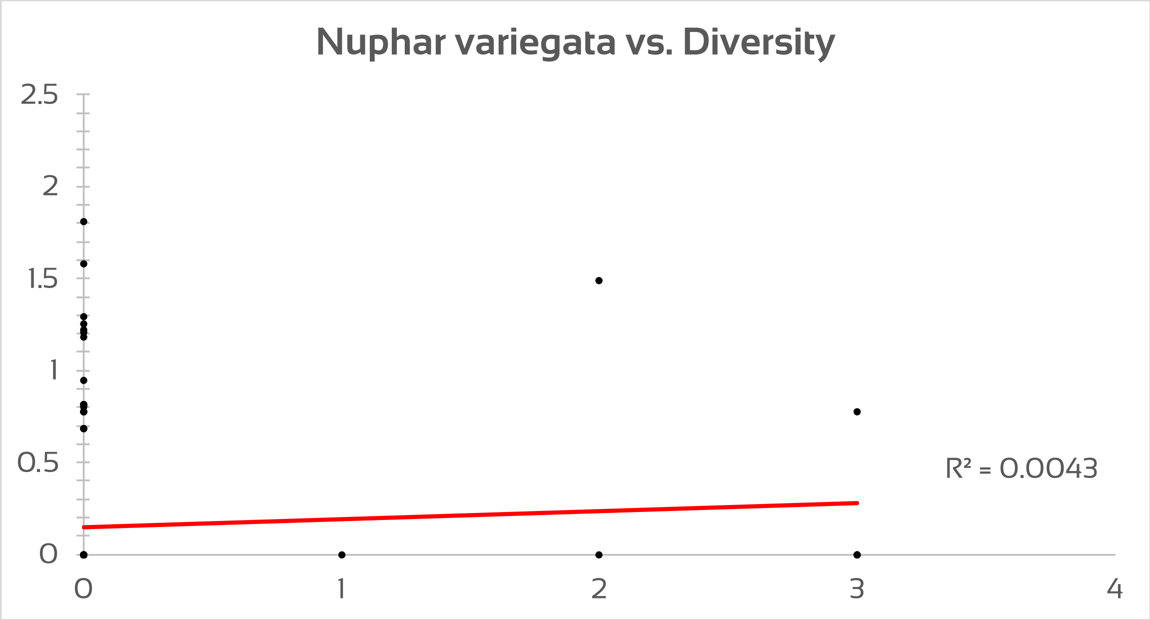

Figure 21. Linear Regression Model of Diversity (y-axis) vs. *Nuphar variegata* abundance (x-axis). The red line indicates the model's estimation.

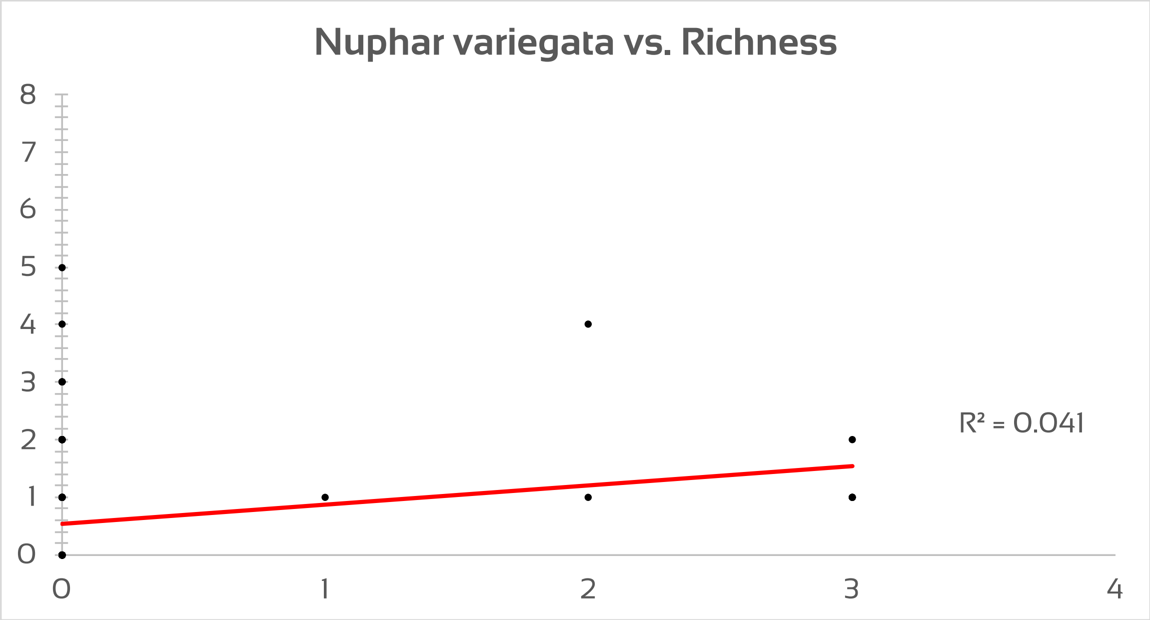

Figure 22. Linear Regression Model of Richness (y-axis) vs. *Nuphar variegata* abundance (x-axis). The red line indicates the model's estimation.

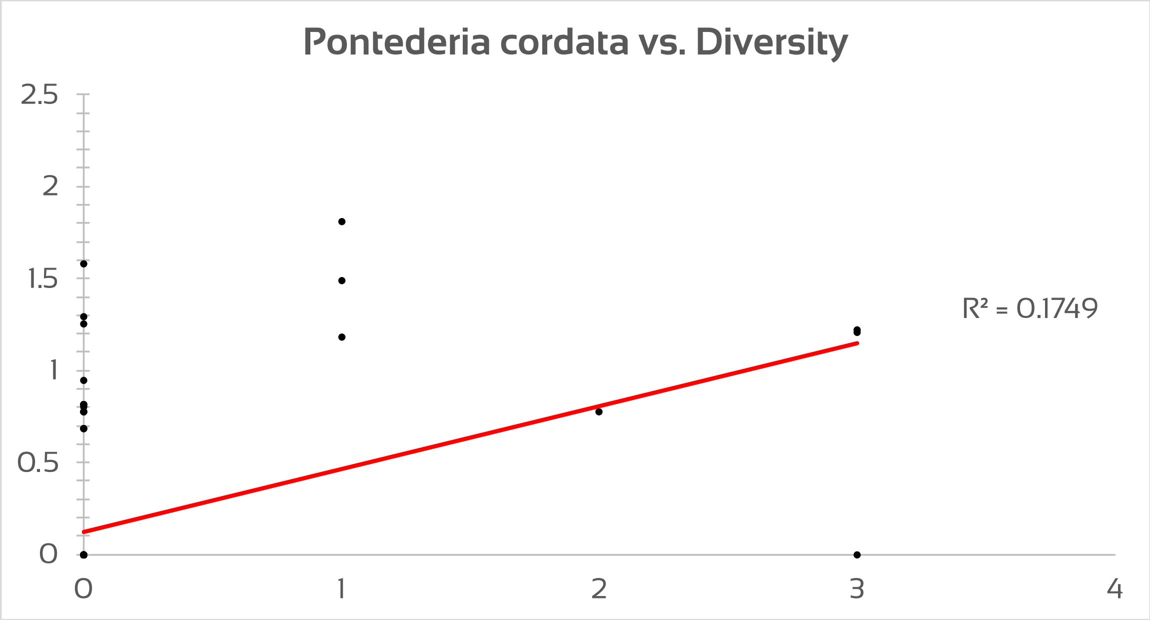

Figure 23. Linear Regression Model of Diversity (y-axis) vs. *Pontedaria cordata* abundance (x-axis). The red line indicates the model's estimation.

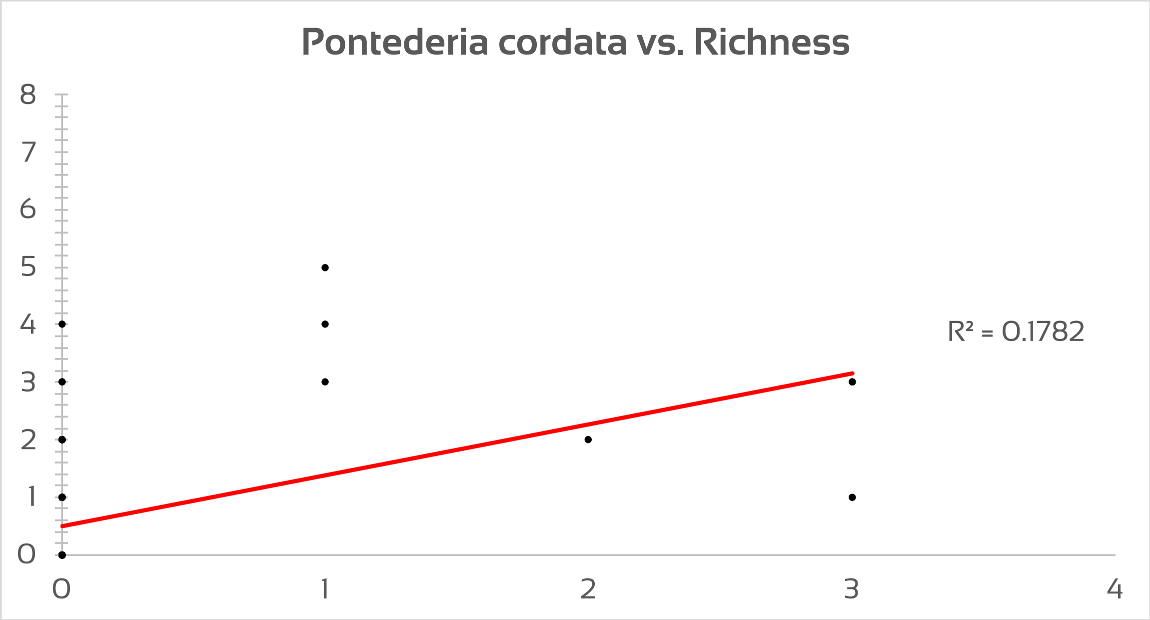

Figure 24. Linear Regression Model of Richness (y-axis) vs. Pontederia cordata abundance (x-axis). The red line indicates the model's estimation.

DISCUSSION

Overall, the Ball Pond's plant community exhibits low to moderate productivity and is moderately diverse; the plant community was also not found to house any rare or endangered species. 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. 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 weak to moderate relationships among the richness and diversity variable and all of the most abundant species.

Ultimately, these findings create a situation where balancing any need for management and ecosystem conservation is of the utmost importance. In short, Ball Pond contains a total richness that is lower than the regional average of 13 species and a community with low diversity. All of the aforementioned characteristics suggest that the plant management has been effective in reducing total plant productivity but at the expense maintaining richness/diversity. 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:
Ball Pond houses a low productivity plant community with limited diversity. Therefore, it is our opinion that any further major disturbances 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 waterbody 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 state of Ball Pond – we would recommend that no further plant management is undertaken including further stocking of Grass Carp.

Overall, we do not see a need for any additional large-scale management of Ball Pond's aquatic macrophyte community; in fact, we believe it is necessary to allow the plant community to rebound to a condition where more of the littoral zone is inhabited by plants. Therefore, we recommend the following:

- On-going Plant Management
    - Surveys
        - The plant community should be inspected yearly to qualitatively evaluate the state of the plant community.
            - These types of surveys are important to determine the state of the plant community and localized management needs.
            - Estimated Cost: $1,500.00
        - A quantitative plant survey should be undertaken at 3 to 5-year intervals.
            - These types of surveys are important to understand the trajectory of the plant community and to reassess the features of the overall management plan.
            - Estimated Cost: $7,500.00
    - Restocking of Grass Carp
        - The current population of Grass Carp appears to be providing significant pressure on the plant community.
        - The population should be supplemented when plant surveys suggest that the plant community has expanded.
    - Property Adjacent Swim Areas, Docking Areas, and Resident Beaches
        - Benthic Barriers:
            - ***Aquatic Ecosystem Research recommends that homeowners deploy benthic barriers – if***

    necessary – 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.

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* but not *B. schreberii*.

CONCLUSIONS:

Overall, the plant community of Ball Pond exhibits low productivity; it does not contain any rare/endangered species. The lake's water chemistry suggests that it is at risk for *Myriophyllum spicatum, Najas minor, & Potamogeton crispus*, one of which is present in Ball Pond (June-Wells, et. al 2013). We recommend that no action is taken to manage the plant community and that future management needs be dictated by plant survey data. Finally, we recommend that individual residences experiencing nuisance plant populations in their swim/docking area deploy benthic barriers or hire a company to execute DASH within those small areas.