All Habitat SERVICES, LLC.

Rogers Lake Quantitative Plant Study.

Prepared for The Towns of Lyme and Old Lyme, Connecticut

Prepared by All Habitat Services LLC.
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October 16th, 2014

Ralph Eno
First Selectman
480 Hamburg Rd.
Lyme, CT 06371

Bonnie Reemsnyder
First Selectman
52 Lyme St.
Old Lyme, CT 06371

Dear Bonnie and Ralph,

Thank you for the opportunity to provide you with this comprehensive report, which covers the community structure and distribution of species in Rogers Lake. Our findings indicate that there is 31 acres of non-native plant species invasion and that those species intermingle with the majority of native species.

In this report we conclude that the majority of plant community diversity and abundance exists in the 1-2m zone of the lake. Additionally, that same zone houses significant populations of the species *Cabomba caroliniana* and *Myriophyllum heterophyllum*. This poses a serious challenge to the future plant management initiatives because it is important to maintain the areas of aquatic plant diversity. However, that complexity will be addressed in the plant management report; the approach presented there will retain that important feature of the plant community while enhancing the recreational and ecological values of Rogers Lake.

Again, we thank you for the opportunity to serve your environmental assessment needs and look forward to helping you manage your beautiful resources in the future.

Sincerely,
ALL HABITAT SERVICES, LLC

Mark June-Wells, Ph.D.
Director of Water Resource Services
NALMS Certified Lake Manager
ESA Certified Ecologist

EXECUTIVE SUMMARY:

Twenty-seven species of aquatic plants were found in Rogers Lake, which ranks it among the highest in Connecticut for plant species diversity. *Najas guadalupensis* was found to be the most dominant species and two non-native species were detected. The two non-native species were *Myriophyllum heterophyllum* (Variable-leaf Milfoil) and *Cabomba caroliniana* (Fanwort). They were also significant contributors to the total biomass of the plant community and were present in high density throughout 32% of the littoral zone (~31 acres). Three species of lilies were found in shallow waters, which were having a significant negative impact on residents' access to the lake.

Aquatic plant species diversity and richness were found to be greatest in the first 1.5m of water. In that region of the littoral zone, the majority of species are present and the total plant biomass is essentially evenly distributed among species. This property of the Rogers Lake plant community is, therefore, essential to the health of the system. The greatest amount of plant biomass (total abundance) was found to exist in the 1-2m depth range in Rogers Lake. This finding coincides with the result obtained concerning the diversity and richness measures. Consequently, these areas are both the most diverse and densely populated. The most productive, diverse part of the Rogers Lake plant community is in waters between one and two meters deep. Though management is required to create suitable recreational conditions for humans, the biggest challenge facing the future management of the plant community is the retention of the diversity currently residing in the 1-2m zone.

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INTRODUCTION

The plant community of Rogers Lake (Lyme/Old Lyme, CT) was surveyed during the week of August 17th. The purposes for this survey were to inventory all plant species, map the general locations of aquatic macrophyte species, statistically model the plant community, determine the extent of non-native plant invasions, evaluate the impacts of aquatic plant species densities on the recreational value of the lake, and to develop an aquatic plant management plan specifically for Rogers Lake.

Physical Features of Rogers Lake:

Rogers Lake (41°21'30.20N, 72°17'52.74W) is a 260 acre water body with maximum and mean depths of 19.2m (63ft) and 5.8m (19ft), respectively (Jacobs and O'Donnell, 2002). The lake extends 1.92km on the north/south axis and is comprised of two distinct basins. The northern basin is the deepest, with a maximum depth of 19.2m; it extends 0.70km north/south and 1.4km east/west. The southern basin has a maximum depth of 9.8m (32ft); it extends 0.6km north/south and 0.6km east west. A shallow area separates these two basins; in that area the max depth is 1.8m (6ft). Overall, the lake contains a total of 4,940 acre-feet or 1,609,704,000 gallons of water and is sustained by at least 6 streams from the 4,819-acre watershed (Frink and Norvell 1984, ACT & NEAR 2003). The watershed to lake area ratio is 18.53. Finally, the littoral zone of the lake (i.e. the depth range where plants can grow – 0.1 to 5m) is about 94.1acres or 36.15% of the water body.

STUDY METHODOLOGY

Rogers Lake was visited 6 times during the week of August 17th. The scope of this study included the evaluation of the following qualitative plant community characteristics: 1) Plant species inventory and 2) General locations of all plant species. Furthermore, the scope included the examination of the following quantitative plant community features: 1) The mathematical contribution of each species to the total community biomass, 2) A statistical model of plant community characteristics as they relate to abiotic factors, and 3) A total assessment of non-native plant invasion (i.e. acreage). Ultimately, the aforementioned measures would be used to develop a comprehensive aquatic plant management plan specifically for Rogers Lake. To obtain the goals outlined above, the following protocols were used.

Plant Inventory and Qualitative Plant Species Mapping:

On the day of August 17th and 18th, the species inventory and qualitative plant species mapping were conducted. The littoral zone (0.1-5m) was surveyed by slowly motoring throughout its entirety and identifying aquatic macrophyte species following the taxonomy of Crow and Hellquist 2000. Individual species were identified visually by Mark June-Wells, Ph.D. after obtaining a sample with a grapple or long handled rake. Each species was logged on a data sheet, which was later converted to an inventory list. Furthermore, the distribution of each littoral zone species was physically overlaid on a blank map. That map was then converted to a digital form using ARC GIS ®.

Quantitative Plant Surveying:

To evaluate the mathematical properties of the plant community and develop statistical models, a data gathering initiative was conducted from August 19th to August 21st. In Rogers Lake, 25 geo-referenced points were established at depths ranging from 0.1-5.0m. These points were organized by depth; five depth classes were denoted (0-1, 1-2, 2-3, 3-4, and 4-5m) and each class contained 5 points. At each point the boat was anchored, oriented perpendicular to the nearest shoreline, and the depth was measured off the front of the boat using a weighted drop line. The plant community was sampled using a grapple tied to a 20m line. At each point, four grapple tosses (two to each side of the boat) were conducted by throwing the grapple parallel to the nearest shore out to the full length of the line. Plant species were identified on site and their abundance was evaluated using a rank abundance technique. The abundance of each species was evaluated by two independent observers and was given a rating of 1 - rare, 2 – present but not abundant, 3 – abundant but not dominant, 4 - dominant, or 5 – dense monoculture.

Those data were compiled in an Excel Spreadsheet ® and various abiotic/plant community parameters were calculated. Light reaching the bottom at each point was calculated using the following formula: $\mathbf{I_z = e^{(-kz)} * I_o}$ where I_z = intensity at depth (z), e is Euler's number, k is the attenuation coefficient of light in water (1.7) multiplied by the Secchi depth for the lake, z is the depth, and I_o is the solar constant (340w/m^2). Point diversity was calculated using Shannon's Diversity Index $\mathbf{[-\Sigma(p_i * \ln(p_i)) - (S\text{-}1/2N)]}$ where p_i is the fraction of the community each species is representative of, S is the total lake richness, and N is the total abundance at each point. Point richness was calculated by counting the number of species encountered at each point. Total point abundance was calculated by taking the sum of all species' rank abundance values at each individual point. Finally, the relative contribution of each species to the community was calculated by taking the sum of each individual species' rank abundance values across all points, dividing it by the total rank abundance of all species in the lake, and multiplying the quotient by 100.

Those statistics were then used to develop the plant community models. General Linear Models (GLM) were employed to determine which mathematical models best fit those data. Models were assessed using Akaike Information Criteria (AIC); in each case the model with the lowest AIC was chosen (i.e. best fit). Those analyses were conducted in R for the following variables as they relate to light and depth: 1) Total Point Abundance, 2) Diversity, and 3) Richness.

Invasive Plant Mapping:

Following the aforementioned examinations, which elucidated the locations of non-native plant species, the distribution of non-native plant species was mapped. This initiative occurred on the 22nd of August and was conducted with the use of a boat and a Garmin ® ETREX 200 GPS system (2.5m accuracy). The patches of invasive species that were identified during the littoral zone survey were revisited and were mapped by slowly motoring around the outer limits of each patch. Where patches extended to shore, the shoreline was used as the outer limit of those patches. Where single individuals were present or very small patches existed, a point was logged in the GPS system. Those data that were collected during this initiative were compiled in ARC MAP ® and the acreage of each significant patch was calculated.

RESULTS:

Twenty-seven species were encountered during the Rogers Lake survey initiatives (Table 1). No rare or state listed species were found but two non-native species were encountered; namely, *Cabomba caroliniana* and *Myriophyllum heterophyllum*. The common names of those species are Fanwort and Variable-Leaf Milfoil, respectively (figs. 1, 2). *Cabomba caroliniana* and *M. heterophyllum* accounted for 4.14 and 8.29% of the total plant community but their breadth of invasion was wide (Table 2, figs. 3, 4). Furthermore, they were often found interspersed with lily species, which compounds their negative impacts on recreational activities. Their density coupled with the density of the lily species has a significant impact on lake access. Three "lily-pad" species were found; they were *Brasenia schreberi, Nuphar variegata,* and *Nymphaea odorata*. These species generally comingled with each other and the aforementioned non-native species; they were distributed throughout Rogers Lake in water depths of 0.5 to 2m. These species tended to be most dominant in areas where recreation activities are important; and, in some cases are inhibiting residents' recreational access. *Brasenia schreberi, N. variegata,* and *N. odorata* accounted for 6.22, 1.55, and 4.66% of total community abundance; however, where these species were present, they were present in high density and intermingled with dense patches of the non-native species (Table 2, figs. 3, 4).

The most dominant member of the plant community was *Najas guadalupensis* (Common Water Nymph). It accounted for 22.79% of the total community abundance (Table 2, fig. 3) and could be found in water depths ranging from 1 to 5m. It intermingled with all species and was dominant in the 3-5m zone where it only occasionally was found to be competing with *Potamogeton robbinsii.* The second most abundant species found during these surveys was *Utricularia gibba*. It accounted for 10.36% of the total species abundance and could be found throughout the littoral zone. Furthermore, there were often numerous *Utricularia* species, commonly known as Bladderwort species, present together. The other species of this genus that were found, in order of community dominance, were *U. radiata, U. macrorhiza, U. purpurea,* and *U. geminiscapa* (Table 2, figs. 3, 4). The most widely distributed of the *Utricularia* species were *U. gibba* and *U. radiata*; they could be found throughout majority of the littoral zone (fig. 4).

Overall the plant community of Rogers Lake is very rich. There were a total of 27 species detected during the week of August 17th. That number of species is double the average number of species detected in Connecticut lakes between 2004 and 2014 (CAES IAPP Database 2014). The plant community diversity on a point-by-point basis suggests that this lake may rank in the upper 10% when diversity is compared across Connecticut Lakes (June-Wells et al in press). This means that any given point in the plant community will contain more species that are more evenly contributing to the total abundance compared to other similar points in other lakes. However, we must acknowledge that there are significant populations of *C. caroliniana* and *M. heterophyllum*, which may compromise the aforementioned plant community statistics. Furthermore, those species are currently inhibiting access and recreational activities for some residents; thus, management of the non-native species is required. That necessity will be covered further in future reports. See tables 1/2 and figures 3/4 for the complete community inventory and species abundances.

Statistical Models – Community Structure:

The majority of the structure-metrics characterizing the aquatic plant community of Rogers Lake were best-explained using 2nd or 3rd order polynomial models. However, a linear model best explained the relationship between community diversity and depth (fig. 5). That model (y= -0.2533x + 1.771) shows a linear decrease in community diversity with depth (r^2=0.32), meaning that the more shallow regions of the lake contain more species, each of which is contributing to the total abundance in relatively equal portions. When community diversity was regressed against light (a surrogate for depth), a polynomial model best explained those data. That model ($y = 5E^{-5}x^2 + 0.0173x + 0.286$) shows that the majority of the diversity is located where light levels are between 150 and 200w/m^2 (r^2=0.35). Overall, this means that there is an optimum depth/light-level that supports the greatest amount of community diversity (fig. 6). The polynomial light/diversity curve is more precise than the linear depth/diversity curve because it accounts for the absolute limits of aquatic macrophyte growth (i.e. shore and the end of the littoral zone). Using that curve to pinpoint the optimum light level and comparing that value to the logarithmic relationship between light and depth (fig. 7) we find that community diversity is greatest within 1.0-1.5 meter depth-range.

Total abundance was regressed against light and depth; a third order polynomial model of depth vs. total abundance ($y = 0.2604x^3 - 2.9426x^2 + 7.1429x + 6.1181$) exhibited the greatest explanatory value (r^2= 0.45) compared to the second order polynomial relationship between light and total abundance (figs. 8, 9). These results suggest that the abundance of plant biomass is greatest in the areas where depth is between 1 and 2m (fig. 8). The relationship between light and total abundance (fig. 9) suggests that more plant biomass exists in the 1.0-1.5 meter depth range; however, the relative explanatory power of that model is marginally less than the aforementioned depth/total abundance model. These results support the idea that the majority of the plant biomass occurs in the first 2m of water volume.

Species richness was regressed against light and depth; a second order polynomial model of light vs. species richness ($y = -0.0002x^2 + 0.0745x - 0.0372$) explained the pattern of those collected data. That model exhibited greater explanatory power compared to the depth vs. species richness model (r^2=0.39 vs. 0.37). At this point it is necessary to recall the relationship between light and depth (fig. 7) and relate that result to the relationship of light vs. species richness (fig. 10).

Species richness is greatest in areas where light is ~175w/m^2, which occurs at ~1.0 meters of depth. The model constructed for depth vs. richness suggests that species richness is greatest in the 1.0-1.5m range, which is nominally different from the aforementioned result (fig. 11). Overall, these results suggest that the richness of the plant community is greatest in areas where light is high (i.e. ~1.0m to ~1.5m) but disturbances from waves and ice are not a significant detriment to the plant community (i.e. 0.1 – 0.5m).

Acreage of Non-native Species:

The area of Rogers Lake that can support plant life is about 94.1 acres or 36.15% of the total water body. The total acreage of non-native species that exists in patches greater than 0.1acres was found to be 30.5 acres. Therefore, 32% of the littoral zone is currently inhabited by the non-native species *C. caroliniana* and *M. heterophyllum*. The most significant patches of these species are located at the southern tip of the lake - near the town beach and in the central portion of the lake near the boat launch as well as the areas circa the islands (figs. 12-15). At the southern end of Rogers Lake there are two large patches of non-native species; the total acreage of those patches is 7.99 acres. In the central portion of the lake there are three notable patches that total 19 acres of dense non-native species growth. Aside from the aforementioned patches in the southern portion of the lake, it is essentially free of non-native species except for a single small patch (denoted by a star on the map, fig. 13). The northern portion however, contains numerous small patches and small new infestations (denoted as stars on map, figs. 14, 15).

DISCUSSION:

Overall, the Rogers Lake plant community was found to be very rich; it contains 27 species, which is double the average number of species in Connecticut lakes (CAES IAPP 2014). Two non-native species were found during this survey; they were *Cabomba caroliniana* and *Myriophyllum heterophyllum*, which are known by the common names of Fanwort and Variable-leaf Milfoil, respectively. These species tend to inhabit lakes containing waters with specific conductance and alkalinity values between 39-107µs/cm and 0.1-28.5mg/L $CaCO_3$, respectively (June-Wells et al. 2013). The aforementioned ranges for those specific water chemistry parameters match the historical and current water chemistry of Rogers Lake; and, those species currently inhabit 30.5 acres of the littoral zone (32%). Assessing the water chemistry preferences of other non-native aquatic macrophytes in the region (i.e. Eurasian Milfoil and Curly Leaf Pondweed) suggests that the risk of invasion by those species is low (~10-20% risk, see June-Wells et al. 2013).

Aquatic plant species diversity and richness were found to be greatest in the first 1.5m of water. In that region of the littoral zone, the majority of species are present and the total plant biomass is essentially evenly distributed among species. In an ecological sense, these areas are of significant importance because ecologists believe that diverse areas house a wider variety of interactions, which constitute ecosystem function (Ogden et al. 2013). This property of the Rogers Lake plant community is, therefore, essential to the health of the system. Furthermore, it proposes a significant management challenge. These areas house the greatest amount of non-native species and native species that will need management if we intend to enhance the recreational value of the lake to its residents. This topic will be covered in depth in future reports.

The greatest amount of plant biomass (total abundance) was found to exist in the 1-2m depth range in Rogers Lake. This finding coincides with the result obtained concerning the diversity and richness measures. Consequently, these areas are both the most diverse and densely populated. The most productive, diverse part of the Rogers Lake plant community is in waters between one and two meters deep. The reason for this is likely that this water depth provides a variety of suitable conditions for plants, which includes protection from wave/ice disturbance, protection from water level fluctuations, light conditions suitable for many species to grow and thrive, and soil conditions that are enriched due to accumulated organic matter/nutrients. Though management is required to create suitable recreational conditions for humans, the biggest challenge facing the future management of the plant community is the retention of the diversity currently residing in the 1-2m zone.

CITATIONS:

Aquatic Control Technologies and Northeast Aquatic Research LLC, **2003**. *Diagnostic Feasibility Study of Rogers Lake – Lyme/Old Lyme, Connecticut.*

Crow, G.E. & Hellquist, C.B. **2000**. *Aquatic and Wetland Plants of Northeastern North America.* The University of Wisconsin Press

Frink, C.R. & Norvell, W.A., **1984**. *Chemical and Physical Properties of Connecticut Lakes*. The Connecticut Agricultural Experiment Station Bulletin 817

Jacobs, R.P. & O'Donnell, E.B. **2002**. *A Fisheries Guide to Lakes and Ponds of Connecticut.* Connecticut Department of Environmental Protection Bulletin 35

June-Wells, M.R., Gallagher, F.J., Gibbons, J., & Bugbee, G.J. **2013**. *Water Chemistry Preferences of Five Nonnative Aquatic Macrophyte Species in Connecticut: A Preliminary Risk Assessment Tool.* The Journal of Lake and Reservoir Management 29:303-316

June-Wells, M.R., Gallagher, F.J., Gibbons J., & Bugbee G.J. **In press***.* *The Influences of Water and Hydro-soil Chemistries on the Structure of Lentic Plant Assemblages.*

Ogden, L., Heynen, N., Oslender, U., West, P., Kassam, K.A., & Robbins, P. **2013** *Global assemblages, resilience, and earth stewardship in the anthropocene.* Fronteirs in Ecology and the Environment, 7, 341-348

TABLES:

Table 1:

Rogers Lake Aquatic Plant Species Inventory
Brasenia schreberi
Cabomba caroliniana
Ceratophyllum demersum
Elatine minima
Eleocharis acicularis
Elodea nuttallii
Gratiolia aurea
Lobelia dortmana
Ludwigia lacustris
Myriophyllum heterophyllum
Najas flexilis
Najas guadalupensis
Nuphar variegata
Nymphaea odorata
Pontederia cordata
Potamogeton amplifolius
Potamogeton epihydrus
Potamogeton natans
Potamogeton robbinsii
Sagittaria graminea
Sparganium spp.
Utricularia geminiscapa
Utricularia gibba
Utricularia macrorhiza
Utricularia purpurea
Utricularia radiata
Vallisneria americana

Table 2:

Rogers Lake Aquatic Plant Community Composition

Species	Percent of Community
Brasenia schreberi	6.22
Cabomba caroliniana	4.15
Eleocharis acicularis	1.55
Elatine minima	1.55
Elodea nuttallii	3.63
Gratiola aurea	1.04
Myriophyllum heterophyllum	8.29
Najas guadalupensis	22.80
Nuphar variegata	1.55
Nymphaea odorata	4.66
Pontederia cordata	0.52
Potamogeton amplifolius	4.15
Potamogeton robbinsii	8.29
Sagittaria graminea	4.66
Sparganium spp.	1.55
Utricularia geminiscapa	0.52
Utricularia gibba	10.36
Utricularia macrorhiza	2.07
Utricularia purpurea	0.52
Utricularia radiata	5.70
Vallisneria americana	6.22

FIGURES:

Figure 1: *Cabomba caroliniana*

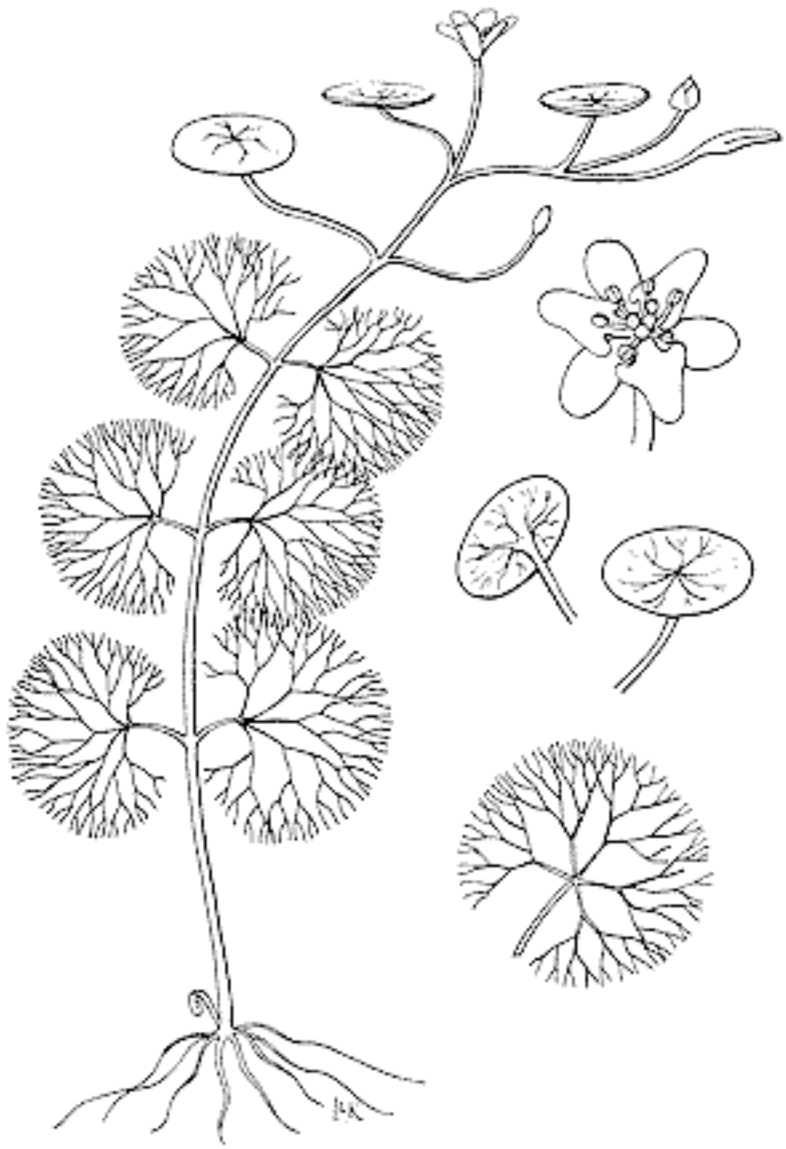

Figure 2: *Myriophyllum heterophyllum*

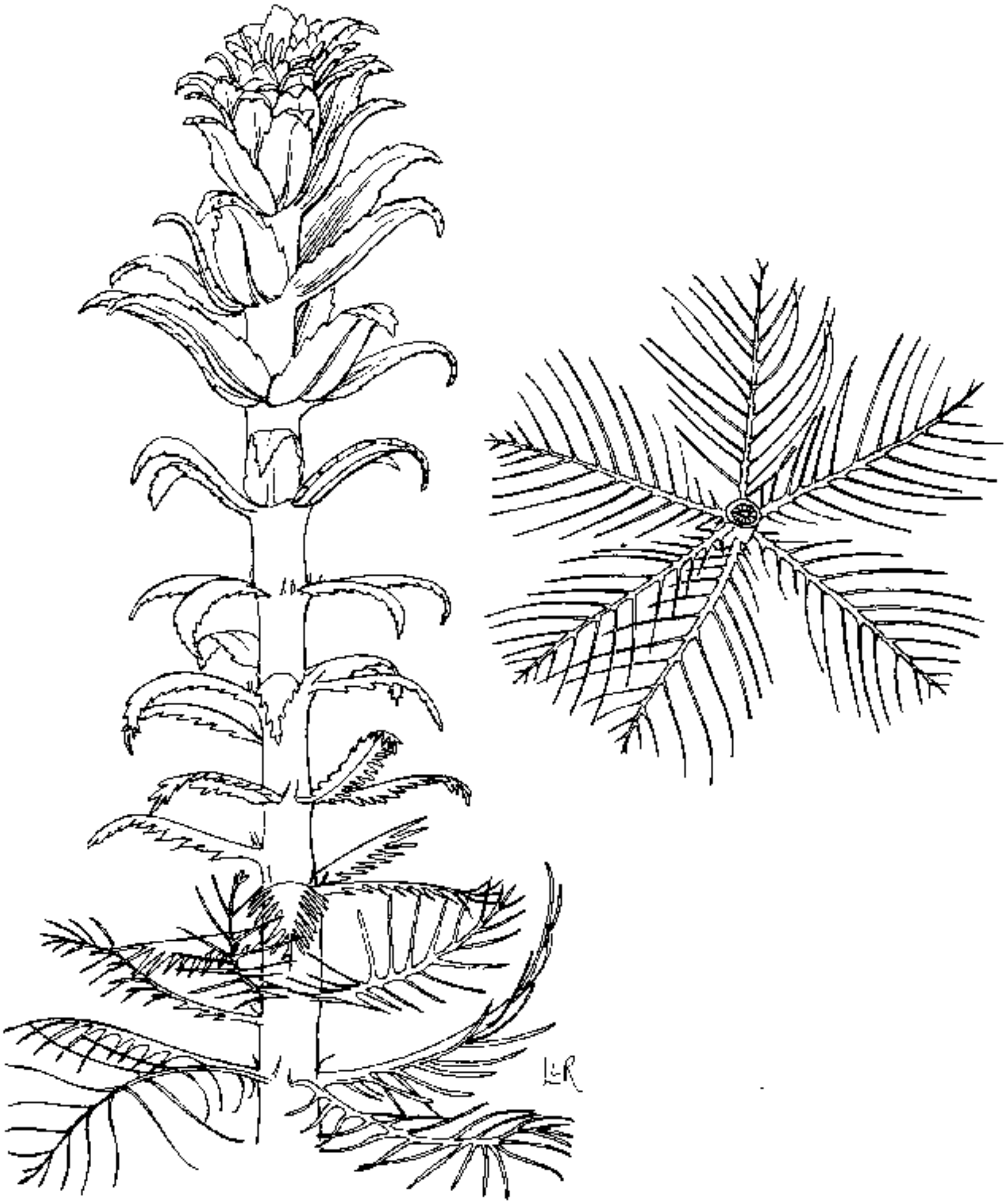

Figure 3: Pie Chart of the Rogers Lake Plant Community.

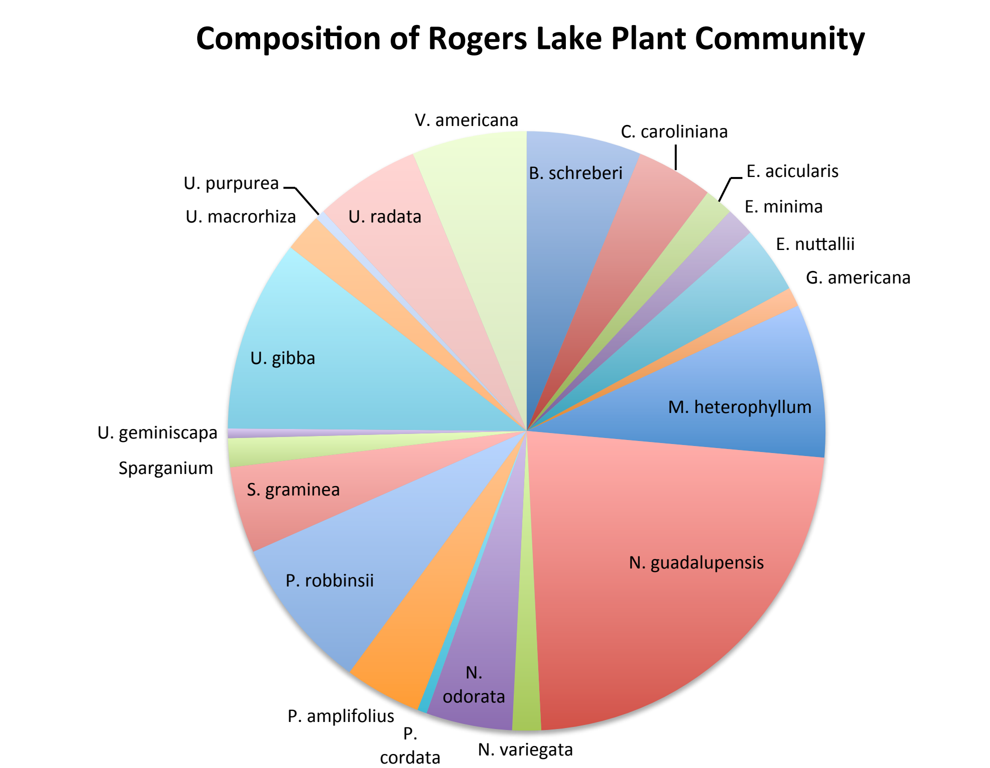

Figure 4: Rogers Lake Vegetation Map.

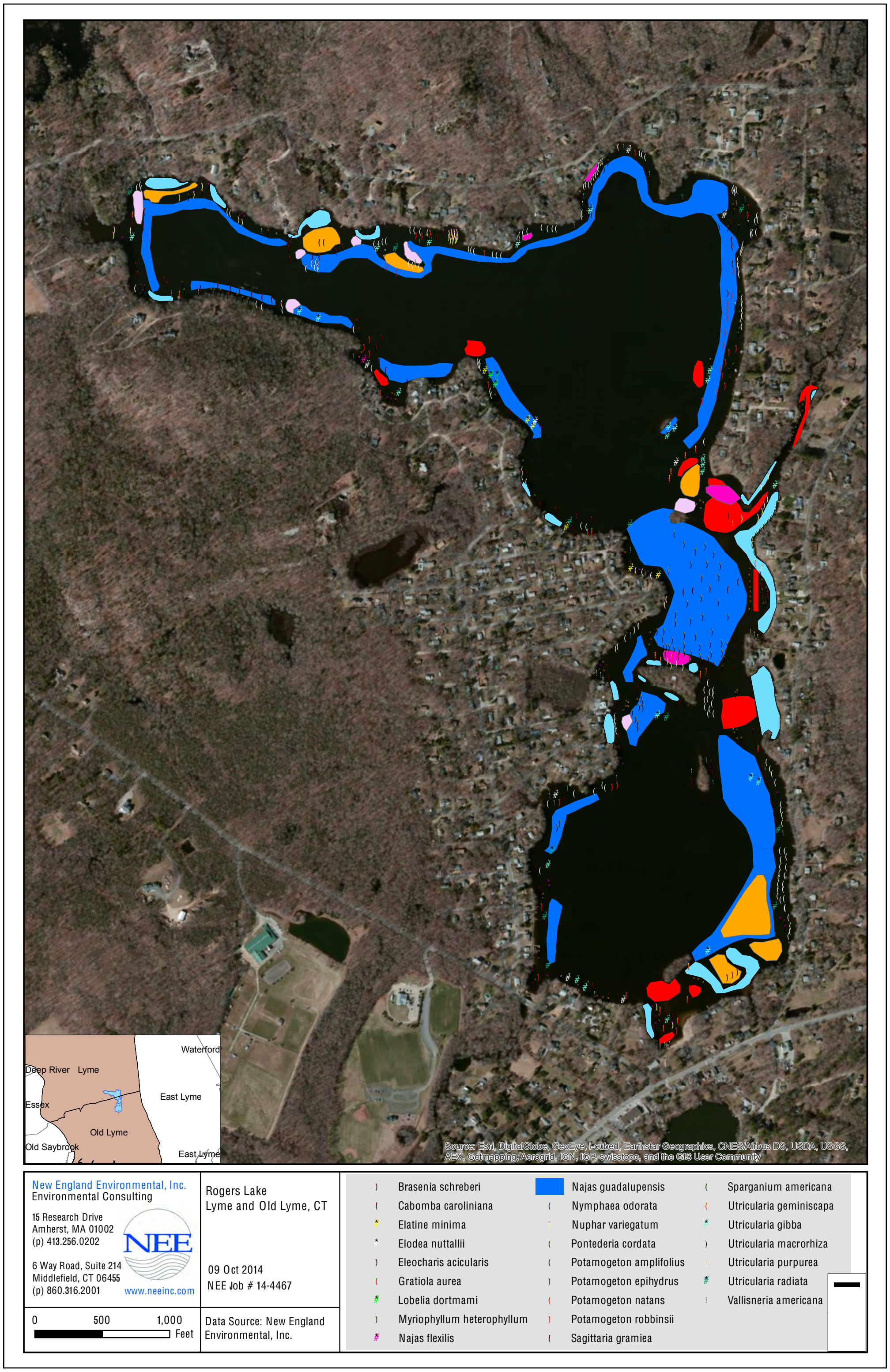

Figure 5: The Relationship Between Depth (in meters) and Diversity in Rogers Lake.

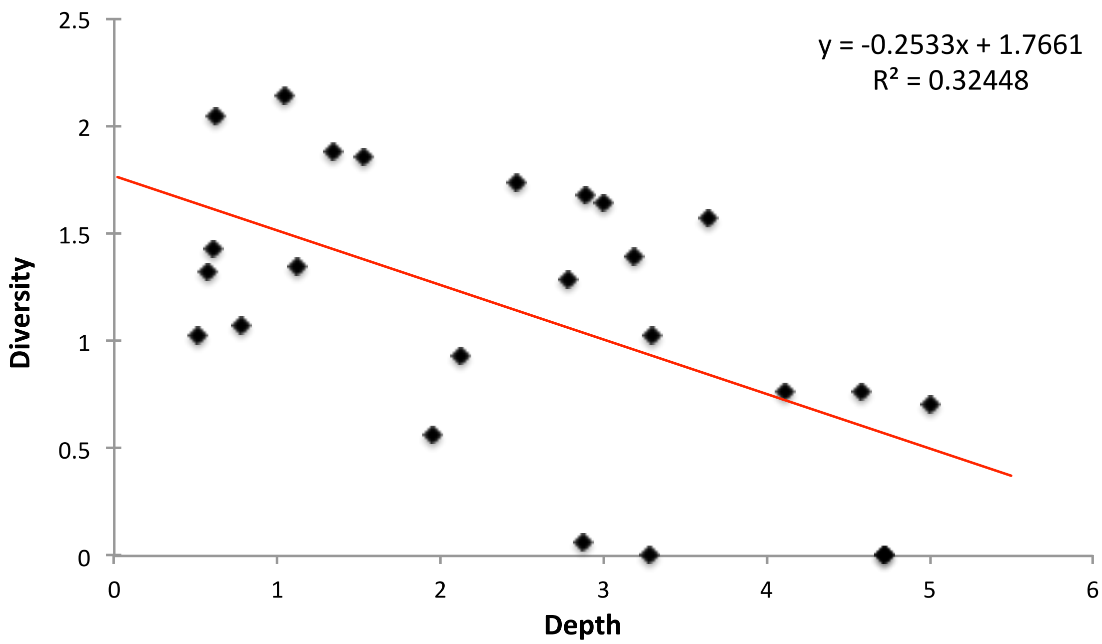

Figure 6: The Relationship Between Light (W/m2) and Diversity in Rogers Lake.

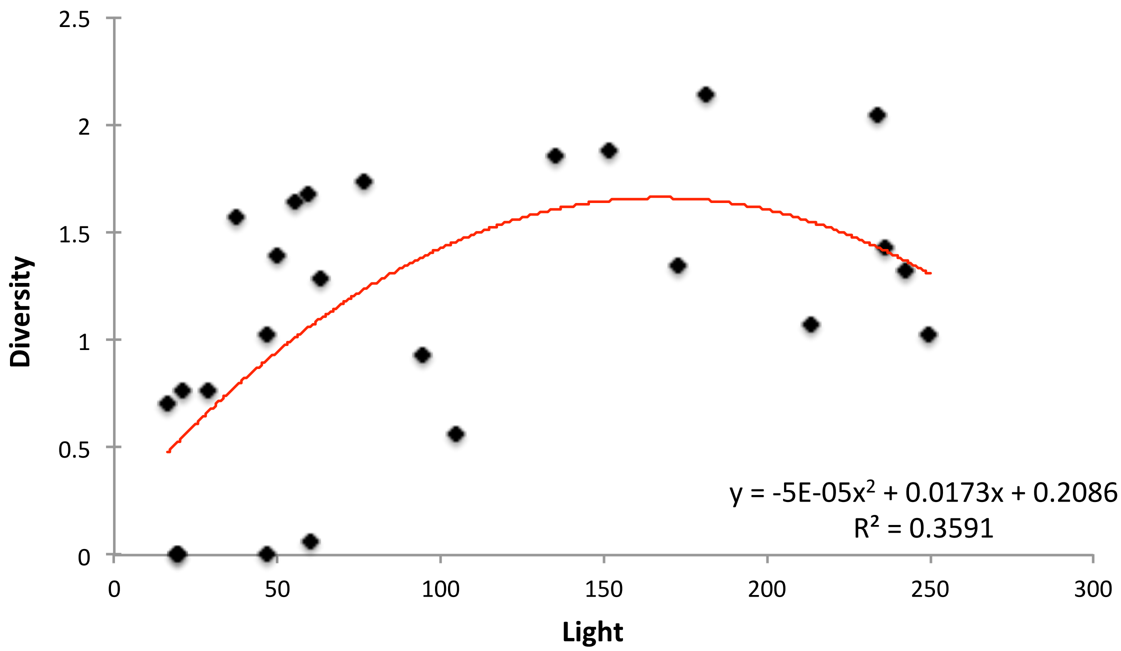

Figure 7: The Relationship Between Light (W/m^2) and Depth (in meters) in Rogers Lake.

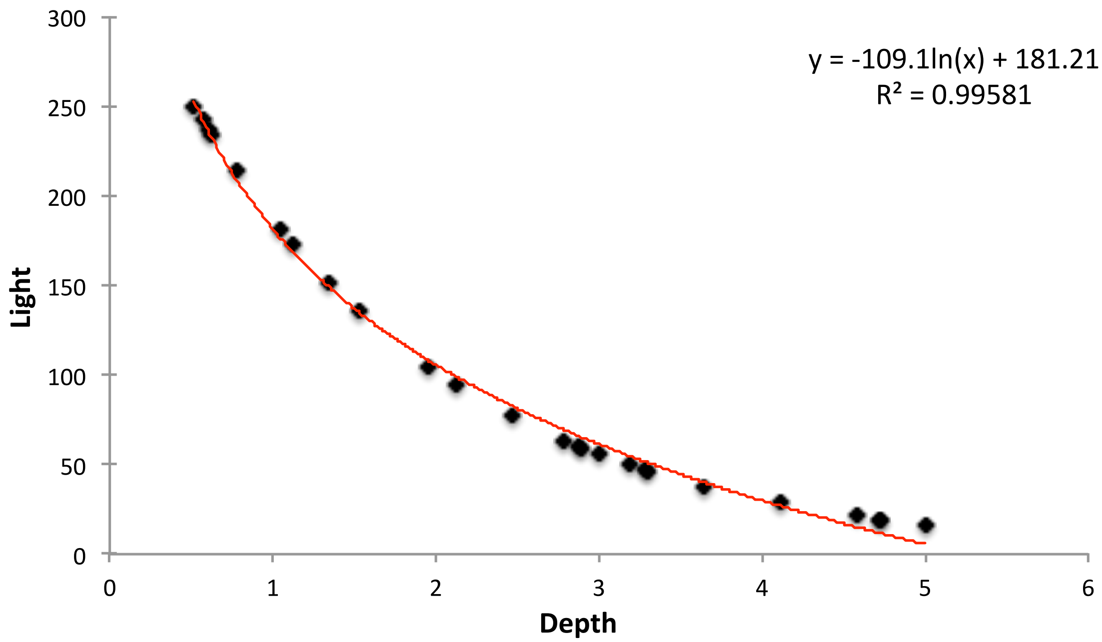

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Figure 8: The Relationship Between Depth (in meters) and Total Plant Abundance in Rogers Lake.

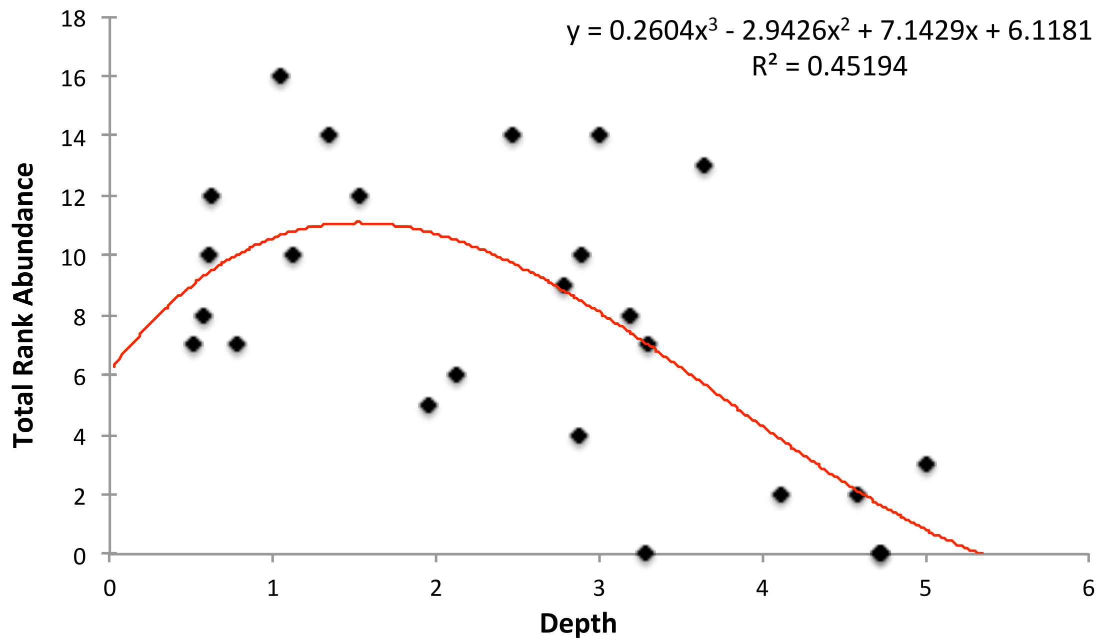

Figure 9: The Relationship Between Light (W/m^2) and Total Plant Abundance in Rogers Lake.

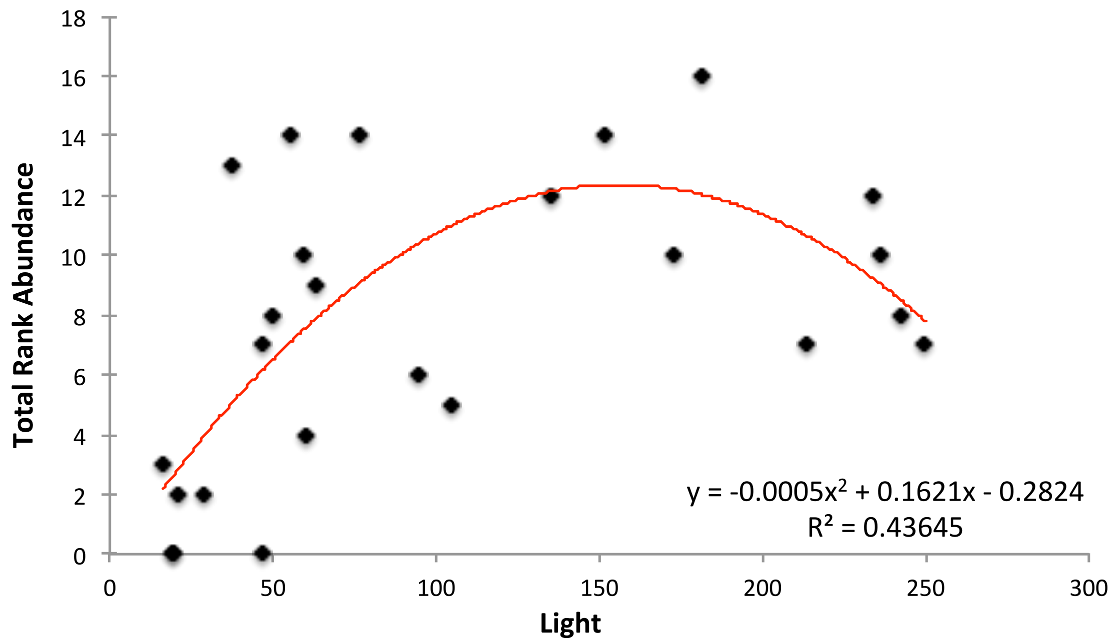

Figure 10: The Relationship Between Light (W/m^2) and Total Species Richness in Rogers Lake.

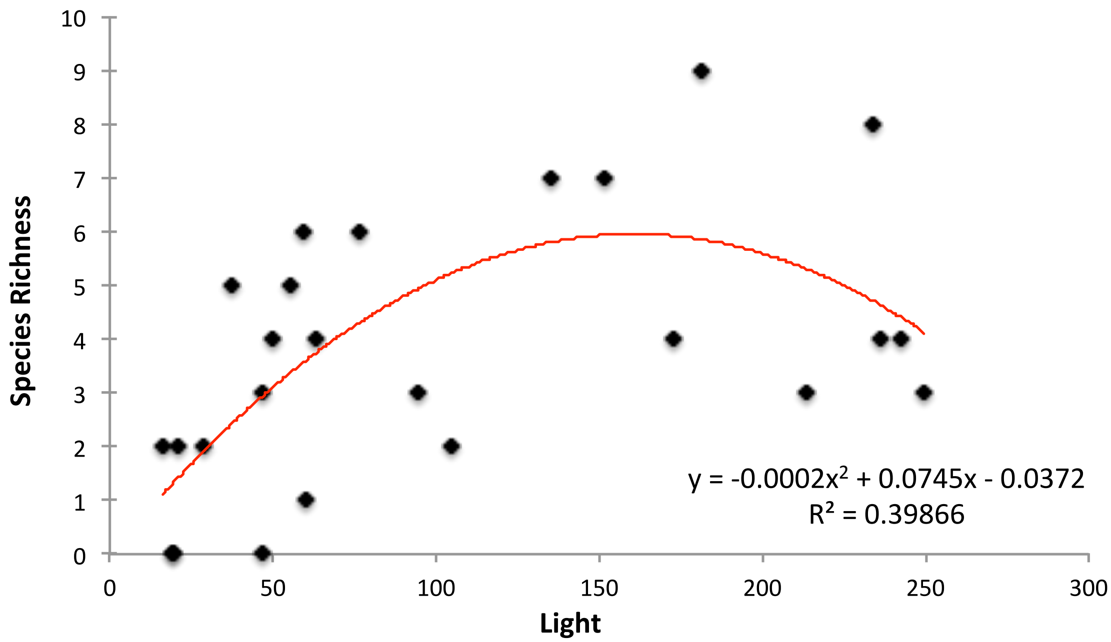

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Figure 11: The Relationship Between Depth (in meters) and Total Species Richness in Rogers Lake.

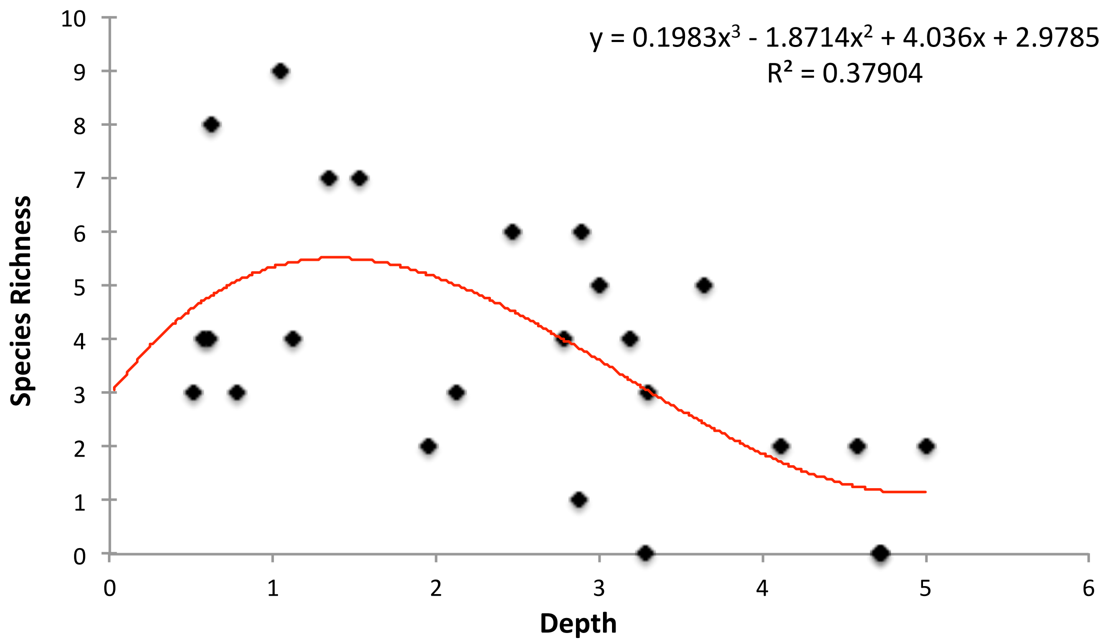

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Figure 12: Non-native Species' Patches (acres) in the Central Portion of Rogers Lake. Stars Denote Isolated Non-native Species Stems.

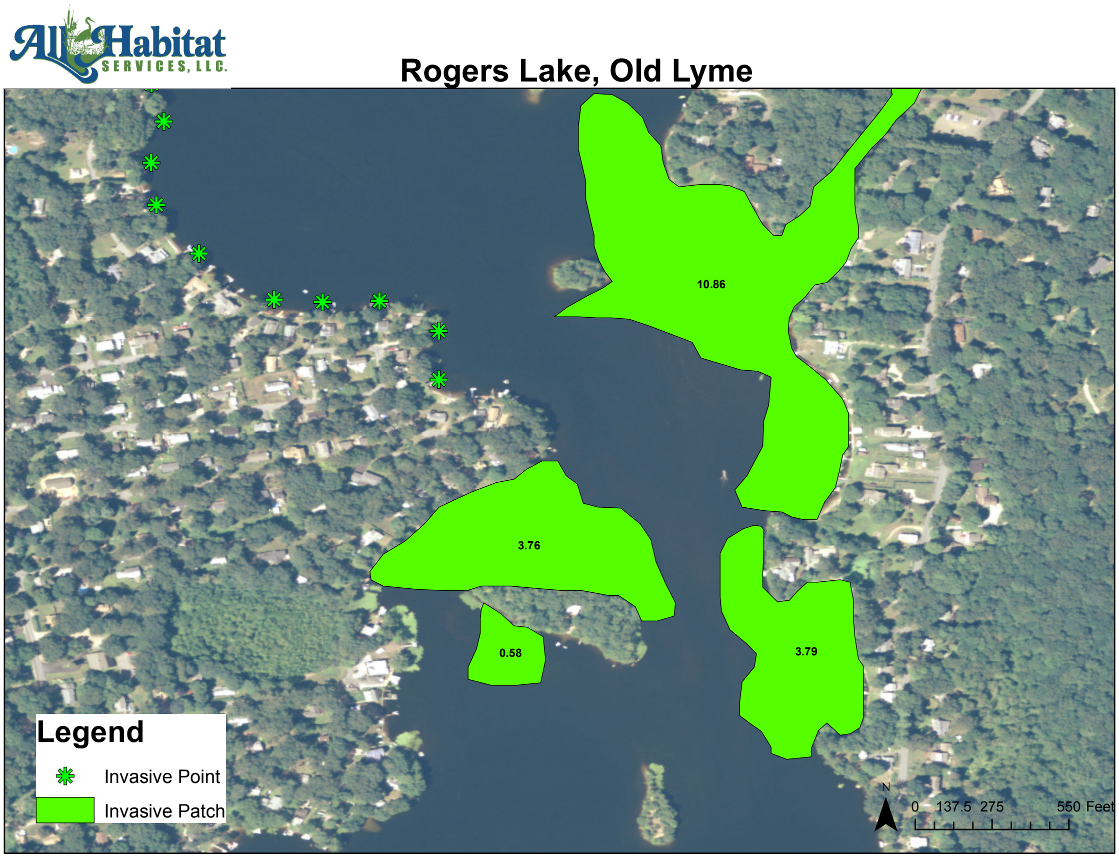

Figure 13: Non-native Species' Patches (acres) in the Southern Portion of Rogers Lake. Stars Denote Isolated Non-native Species Stems.

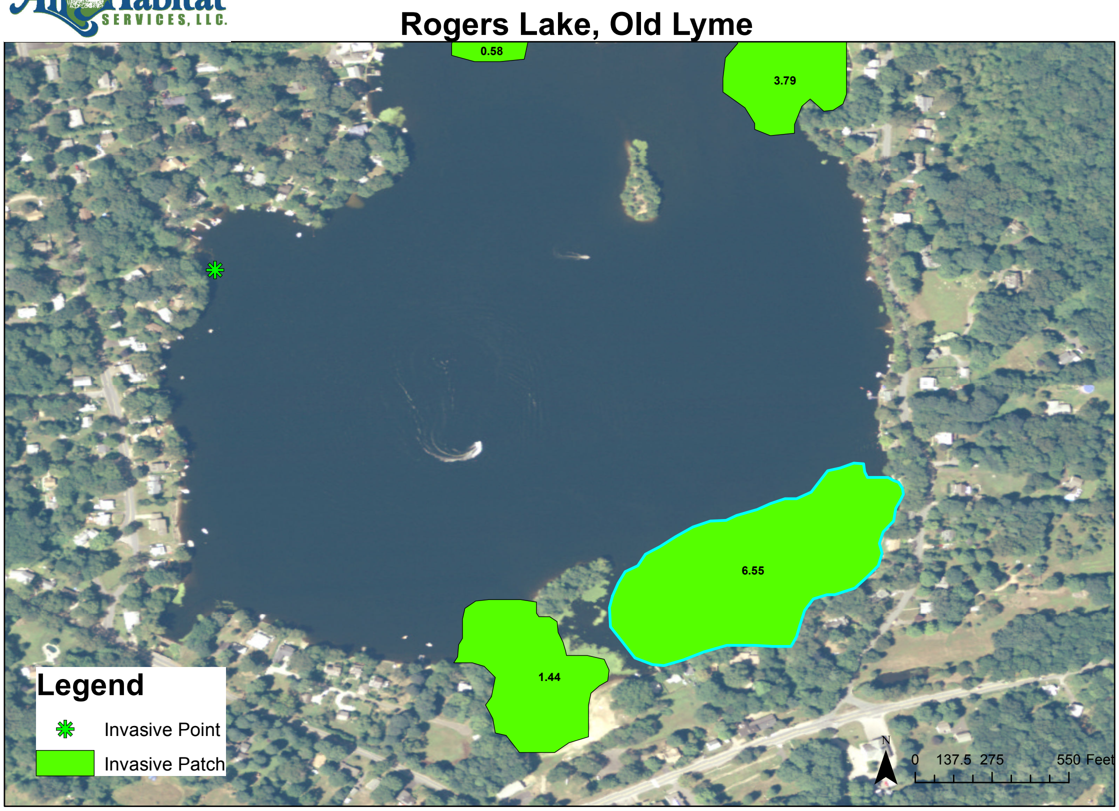

Figure 14: Non-native Species' Patches (acres) in the Northern - Central Portion of Rogers Lake. Stars Denote Isolated Non-native Species Stems.

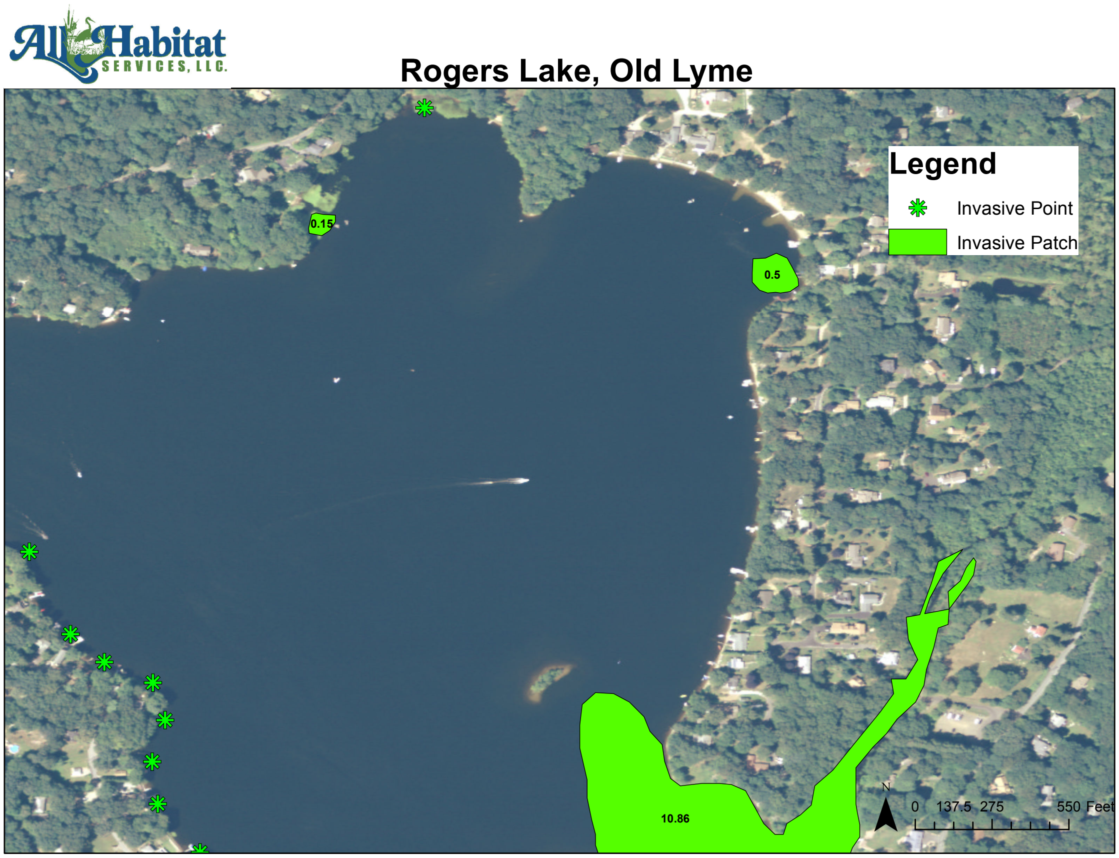

Figure 15: Non-native Species' Patches (acres) in the Northern Portion of Rogers Lake. Stars Denote Isolated Non-native Species Stems.

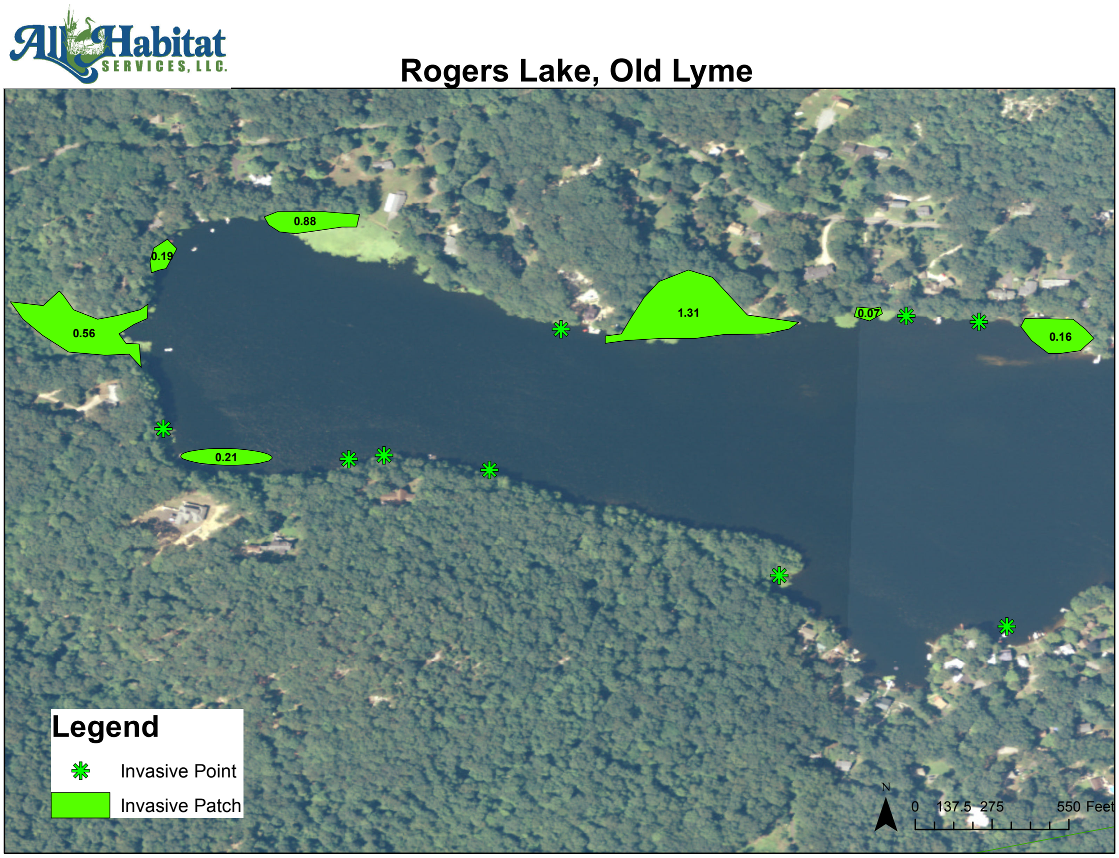

Figure 16: Lily Species Patches (acres) that are Compromising Recreational Access in the Central Portion of Rogers Lake.