Section 1: Background

The broad cross section of NYS lakes represented by the state Biological Survey (NYS BioSurvey, 1926-34), Adirondack Lake Survey Corporation study of Adirondack and downstate high elevation lakes (ALSC, 1984-1987), consultant and agency surveys using the Point Intercept Rake Toss Relative Abundance Method (PIRTRAM, mid 1990s-mid 2010s) and the Adirondack Watershed Institute survey of Adirondack lakes (AWI, 2012-2016) is summarized at length in White Paper1A. These plant surveys represent nearly 2000 lakes of all sizes and locations throughout the state, although each survey program focuses on lakes in specific geographic locations, specific lake types and survey objectives, or lakes in specific size ranges. However, these surveys can be evaluated against several measures of aquatic plant community conditions. This could include plant species frequency or abundance, measures of AIS frequency or abundance, floristic quality, and species richness (and how those change in response to management, water quality changes, etc). A discussion of species richness- the number of unique aquatic plant species in each lake- is provided in this White Paper.

Species richness is one component of floristic quality indices, or FQIs. Specifically, as discussed in White Paper 1C and White Paper 1G, FQI can be estimated by either Equation 1.1 or Equation 1.2:

Equation 1.1: $FQI = \bar{C} \times \sqrt{N}$, and $\bar{C} = \Sigma C / N$; where
N = number of unique plant species in a lake (=observed species richness, or oSR), and
C = coefficient of conservatism for each unique species

with non-native plants assigned a C value of 0, or

Equation 1.2: $FQI = 100 \times (\bar{C} \times \sqrt{N})/(10 \times \sqrt{(N+A)})$, where
N = number of native species,
A = number of non native species, and
$\bar{C}$ = mean coefficient of conservatism for all species

Species richness is typically calculated as the count of the number of unique plant species in a plant community, whether aquatic, terrestrial, or wetland. As discussed below, some surveys do not identify all plants to species level, confounding these calculations, but corrections can be made to compare species richness values from multiple programs.

Species richness represents one method for evaluating biodiversity, and is often considered a primary measure of plant community health (Engelhardt et al, 2002). The role of species richness in aquatic plant community health, including ecosystem function, nutrient and sediment uptake and retention, fish diversity and abundance, and prevention of AIS colonization, is assumed to be understood and is not discussed in this White Paper. It is presumed, for the purposes of this White Paper, that species richness is a positive attribute of a healthy ecosystem, and that optimizing species richness is a goal of all aquatic plant and watershed management programs.

Several factors may influence species richness. Some of these factors cannot be evaluated in these datasets due to the lack of supporting information collected by the associated survey programs, and many of these factors have been broadly discussed by other researchers. However, some factors can be evaluated in New York state lakes, and are discussed in this White Paper. This includes the number and density of survey sites, lake size (overall and littoral area), trophic state, latitude, public access, presence and dominance of AIS plants, and management actions. **However, it should be noted that surveys on nearly all of these lakes did not include enough survey sites to find the maximum number of plant species likely growing in the lake. This results in a calculation of observed Species Richness, or oSR, that falls short of the maximum species richness for a lake, although maximum species richness can be "projected" in some lakes. Since the lakes surveyed for aquatic plants in the four monitoring programs described above do not represent all types of NYS lakes, the evaluation below only provides very broad associations between the number of plant species and several lake factors. These data SHOULD NOT be used to predict species richness in unsampled (specific) lakes.**

However, when survey site-specific (granular survey) data are available, it is possible to use modified bootstrap analyses to project the species richness with varying densities of survey sites, as discussed in White Paper 1C, Section 5. The concept of a "Projected Species Richness", or pSR, is introduced in White Paper 1C and discussed further in Section 3 of this White Paper, and a detailed discussion of the methods used to convert oSR to pSR is provided in White Paper 1C. The calculated pSR can also be evaluated against some of the other factors cited above, and can include recommendations for adopting a process for calculating a pSR based on recommended survey site densities, based on achievable survey densities, historical NYSDEC guidance and site densities likely to balance the goals of maximizing species richness estimates and avoid overlap sampling using point-intercept grids and rake tosses. The factors that influence species richness are discussed in Section 5. The discussions of each factor may include evaluation of pSR (based on analyses of data available in some of the Study survey programs) or, if necessary, evaluations of oSR (based on existing sampling data).

Section 2: Observed Species Richness (oSR) in New York state lakes

Section 2.1- Summary of oSR values for each major monitoring program

Table 2.1- Range of Observed Species Richness (oSR) in Four Major NYS Monitoring Programs

Program	Years	N	10th % oSR	25th % oSR	Median oSR	75th % oSR	90th % oSR
NYS BioSurvey Adk	1920s-30s	114	1	4	16	29	36
NYS BioSurvey non Adk	1920s-30s	189	1	11	24	33	41
ALSC* Adk	1980s	1305	2	4	7	11	15
ALSC* Downstate	1980s	254	5	7	11	13	17
PIRTRAM	2000s-10s	49	4	6	11	18	26
AWI	2010s	90	7	11	14	18	22

*plants identified only to genera, so these are observed Genera Richness (oGR) values
N for each program represents one lake in each program and the associated average oSR
oSR data are unavailable for AWI lakes surveyed in 2015

As discussed above, the observed Species Richness (oSR) represents the maximum number of unique aquatic plants species- submergent, floating leaf, and those emergent plants consistently found in the lake margins- observed during an aquatic plant survey. White Papers 1A and 1B discuss at length the aquatic plant surveys cited in Section 1.1 above, and the implications for potentially suboptimal oSR calculations in the lakes surveyed in these programs. oSR values can be calculated for each lake in each monitoring program, with average oSR values calculated for each. Summary statistics for the oSR values for each program are presented in Table 2.1, displaying the 10^{th}, 25^{th}, 50^{th} (median), 75^{th} and 90^{th} percentile oSR values for the lakes surveyed in each program. The data for the NYS BioSurvey and ALSC programs were separated by geographic region- inside and outside the Adirondack Park. As seen below, this allows for a comparison between these programs and PIRTRAM lakes (which were almost exclusively limited to lakes outside the Adirondack Park) and AWI lakes (which were limited exclusively to lakes within the Adirondack Park). In addition. as discussed in White Paper 1A, plant identifications in the ALSC program were only reported to genus level, so the data summaries for that program are for observed Genera Richness, or oGR.

Data from the earliest and largest programs- the NYS BioSurvey from the 1920s-30s and the ALSC program- almost certainly include some lakes that were incompletely surveyed, resulting in a relatively large number of lakes with very few observed species. However, many of the NYS BioSurvey lakes had very high species richness, as seen in the higher median, 75^{th} and 90^{th} percentile oSR values for those lakes. These data further suggest that the lakes outside of the Adirondacks may have exhibited a higher observed species richness than lakes within the Park, although high oSR values were apparent in both subregions. Although the PIRTRAM program had a few more lakes with low observed species richness- associated with small AIS-dominated or eutrophic lakes- the distribution of oSR values was similar across the PIRTRAM and AWI programs. It is difficult to compare the ALSC oGR data in Table 2.1 to the oSR data from the other programs, since the former fails to account for many species within multiple genera.

Several factors may significantly influence changes in oSR values across the "species-ID" programs summarized in Table 2.1 (the NYS BioSurvey, PIRTRAM and AWI programs):.

1. *Intra-annual variability*. Species richness varies in all lakes, at least slightly, from year to year. Some of this variation is associated with incomplete surveys- the entire littoral zone cannot be surveyed in any year, and certainly not from year to year. oSR values presumable can also change in response to active management, as discussed in Section 4. However, some variation occurs naturally, since in any given year, some plants appear and disappear, although it is likely that reproductive materials (seeds, roots, propagules, etc.) are present in the sediment and germination can occur in future years under more favorable conditions. Section 2.2 evaluates interannual variability in species richness, specifically for those lakes with no active management, over a sufficiently small timeframe to allow for evaluation of interannual variability.
2. *Differences in surveyed lakes*. Each of these programs survey lakes that are mostly representative of the most actively used lakes in the regions they survey (NYS BioSurvey = statewide, AWI and ALSC Adk = Adirondacks, PIRTRAM and ALSC non Adk= outside the Adirondacks) and exhibit a fairly consistent lake size and geographic distribution between these programs. However, these programs include both some commonly sampled lakes and many lakes that were unique to each program. Some of the differences in oSR (or oGR) values in Table 2.1 may simply reflect different lakes. These potential discrepancies can be addressed by focusing evaluations on only those lakes commonly sampled in compared programs, recognizing that this can significantly reduce the number of evaluated lakes and therefore decrease the statistical rigor associated with these analyses. This is discussed further in Section 2.3.
3. *Differences in species-level identifications by plant type*. Although in theory each of these programs surveyed "equally" for submergent, floating leaf, and emergent plants, it appears that these plant habitats were not equally represented in these programs. For example, the NYS BioSurvey identified all species in all plant habitats, resulting in identifications of up to eleven different species of spikerush (*Eleocharis* sp), four different species of yellow water lily (*Nymphozantus* sp), and nine different species of muskgrass (*Chara* sp), to offer just one example each of emergent, floating leaf, and macroalga genera, respectively. This led to much higher oSR values as seen in Table 2.1. In contrast, the PIRTRAM and AWI programs generally lumped each of the species within these genera into a single assigned species or genera. In both programs, all spikerush were assigned the identification of either *Eleocharis acicularis* (likely the most common spikerush species in NYS lakes) or *Eleocharis* sp. Most submergent plant species- such as individual pondweeds (*Potamogeton sp*), naiads (*Najas* sp) and milfoils (*Myriophyllum* sp)- were identified and assigned species-level identifications, although a single genera name was assigned to a (very) few submergent plants (*Isoetes* sp, *Ranunculus* sp). These potential discrepancies can be addressed by "correcting" the NYS BioSurvey emergent, floating leaf and macroalga species identifications (and limited submergent species identifications) to the equivalent genera identification WHEN THE SAME GENERA IDENTIFICATIONS WERE THE DEFAULT ASSIGNMENTS IN THE PIRTRAM AND AWI PROGRAMS, at least when comparing results between

these programs. Note that this is not an issue for comparing results from the NYS BioSurvey and ALSC programs, since lakes in both programs were surveyed "equally" for submergent, floating leaf and emergent plants, although the NYS BioSurvey results would need to be "corrected" for comparison to ALSC lakes to include only plant genera.

4. *Changes over time*. It is likely that species richness has changed in many lakes over the last century, and perhaps even in 20 to 30 year intervals, due to many changes in lakes, including shoreline and watershed development, public access, water quality, AIS introduction, climate change and other factors. It is anticipated that these changes can be distinguished from differences in the program data in Table 2.1 due to differences in program lakes and survey details, as discussed above. The long-term changes in species richness, "corrected" for differences in survey lakes and survey methodologies, are discussed in Section 2.3.

Section 2.2- Annual variability in oSR values

Section 2.2.1- Variability in oSR frequently surveyed, unmanaged lakes

For many of the lakes evaluated in this White Paper, aquatic plant survey data was available from only a single year. It might be reasonable to assume that these data were representative of the surveyed lake, but absent multiyear data, this assumption cannot be checked. For example, the entire NYS BioSurvey and ALSC datasets include only single year sampling for more than 1400 lakes; while this represents a very rich dataset, interannual variability in species richness cannot be evaluated. In addition, as discussed below, active management can strongly influence species richness, so calculated species richness in lakes that are under active management can misrepresent "normal" species richness in these lakes.

Fortunately, the AWI dataset includes more than 25 lakes that were surveyed in two years, all within a four-year window. Although there may have been some small differences in sampling crews, methodologies, and other survey conditions, the differences in observed species richness in these two years can be evaluated (differences in projected species richness, described below, cannot be evaluated due to the lack of granular survey data in some of these lakes). In addition, the PIRTRAM dataset includes a long history of aquatic plant monitoring on select lakes, including multiple lakes with more than 10 years of data. Several of these lakes were sampled by the same survey teams in consecutive years, and some lakes were subject to aquatic plant management actions- some during all survey years, and some for which management occurred in some years but not others. Seven of these multi-year PIRTRAM survey lakes were not subject to management during any of the consecutive sampling years. Three other PIRTRAM lakes- Lake Waccabuc (9 years), Lake Ronkonkoma (4 years) and Java Lake (3 years) were surveyed for more than two years without any plant management actions, and without any new AIS introductions within these sampling windows. It should be noted that even more PIRTRAM lakes were surveyed over multiple years, but stark differences in the number of survey sites from year to year preclude a comparison of oSR values in these lakes).

Therefore, 32 lakes surveyed through AWI or PIRTRAM included multiple years of plant survey data in the absence of active plant management in any of the survey years, and all lakes were surveyed multiple times within a short window of time (minimizing any issues with natural long-term trends). A comparison of observed species richness in these lakes allows for an evaluation of the natural (or at least expected) variance in species richness as measurable in these programs. White Papers 1B and 1C identify the issues associated with the use of oSR in evaluating lake changes, and recommend the use of projected species richness (pSR) where possible. However, the 32 lakes evaluated in this section maintained a consistent number of survey sites in the two years of aquatic plant surveys, allowing for a comparison from year to year in oSR values. The variance in observed species richness in the 32 AWI or PIRTRAM lakes sampled in two consecutive years without management, and the three PIRTRAM lakes sampled for more than two years within a short window (without management) can also be evaluated.

Table 2.2.1- Summary Statistics for Unmanaged PIRTRAM or AWI Lakes Surveyed in Multiple Years

#Paired Survey Years	#Lakes w/Pairs	Mean oSR	StDev oSR	Mean Norm SD	Median Norm SD
2	32	14.9	4.9	31.4	29.7
3	1	5.7	0.6	10.2	
4	1	3.8	1.5	39.0	
9	1	18.2	1.6	8.6	

Table 2.2.1 provides the summary statistics- mean, median, standard deviation, and normalized standard deviation oSR- for the PIRTRAM or AWI lakes with two or more years of aquatic plant surveys and no aquatic plant management conducted at the lake (at least in those or recent previous years). The 32 lakes with two years of survey data had an average observed species richness of 14.9 ± 4.9 unique species (representing the mean of the two-year average species richness for each of the twice-surveyed lakes). The normalized standard deviation was (much) lower in two of the three lakes surveyed more than twice, as expected given the larger number of surveys included in the analysis (and influenced by the very low number of unique species in Lake Ronkonkoma, the only lake with four survey years).

Section 2.2.2- Discussion of results

These data suggest that oSR varied up to about 10-30% from year to year (= the normalized standard deviation) when lakes are sampled in two years, with a reduced variability in these data as more years of data are included in the summary statistics. This variance is similar whether the mean or median standard deviation was used. However, more data would be needed to accurately evaluate the relationship between annual variance in oSR and the number of survey years. Unfortunately, interannual changes in oGR cannot be evaluated with this dataset since only one year of genera richness data are available for each of the 1305 ALSC Adirondack and 254 ALSC Downstate lakes surveyed in that program. It is assumed that a similar interannual variability (of perhaps 10-30%) should be considered for evaluating genera richness data.

Therefore, any long-term change in oSR (or presumably oGR for the ALSC lakes) should exceed about 10-30% to reflect changes beyond the normal annual variability in these values.

Section 2.3- Long term changes in oSR (or oGR) across the four monitoring programs

Section 2.3.1- Background

It is presumed that most lakes exhibit long term changes in water quality, flora and fauna in response to many factors, including watershed land use changes (including shifts from forested land to residential, urban or agricultural lands, or forest restoration), increasing shoreline development and shifts from seasonal to permanent residences, cultural acidification, and climate change. It is unlikely that most of these changes could be detected within the short window of time in which most of the White Paper 1A monitoring programs were conducted, in part because the magnitude of these changes within this short timeframe were small relative to natural variability in these conditions (as discussed in Section 2.2), and in part because many of these changes occur over many generations, not just a few years.

However, some New York state lakes were surveyed (once) in the 1920s-1930s as part of the NYS BioSurvey, once in the 1980s as part of the ALSC, and/or once in the 2000s-2010s as part of the PIRTRAM or AWI programs. Although there were differences in the survey methodologies, and the ALSC dataset included only genera-level identification, long-term changes in 44 lakes surveyed in the 1920/30s and the 2000s-10s, 46 lakes surveyed in the 1920s/30s and the 1980s, and 45 lakes surveyed in the 1980s and the 2000s-10s can be evaluated.

Evaluation of differences in observed species richness in lakes surveyed in programs separated by decades can provide some insights about long-term changes in plant species diversity, particularly when coupled with data evaluating natural short-term variability. The four aquatic plant datasets summarized in White Paper 1A span nearly 100 years, and as noted above, there were about 45 lakes surveyed in each grouping of aquatic plant survey programs. The evaluation of these multi-program lakes is described below.

Long-term changes in oSR can be evaluated by looking at differences in these values in the associated monitoring programs (NYS BioSurvey, ALSC, PIRTRAM and AWI) as it relates to surveyed lakes and plant identifications. This can be achieved by focusing on lakes commonly surveyed across these programs and by limiting long-term evaluations to the plant species and genera documented (or subject to documentation) in these surveys. As noted above, the annual variability in observed species richness (oSR) in the PIRTRAM and AWI lakes ranged from 10% to 30%. Therefore, any long-term change in oSR (or oGR for the ALSC lakes) should exceed this 10% to 30% to reflect changes beyond the normal annual variability in these values.

Section 2.3.2- Changes in oGR from the 1920s to the 1980s

A comparison of the plant richness data collected in the 1920s-30s through the NYS BioSurveys and in the 1980s through the ALSC requires "converting" all plant identifications to genera, since the ALSC program only identified plants to genera level. However, since both the NYS BioSurvey and ALSC programs consistently accounted for all submergent, floating leaf and emergent plant genera, these data do not need to be further corrected by removing most emergent plants (as discussed above).

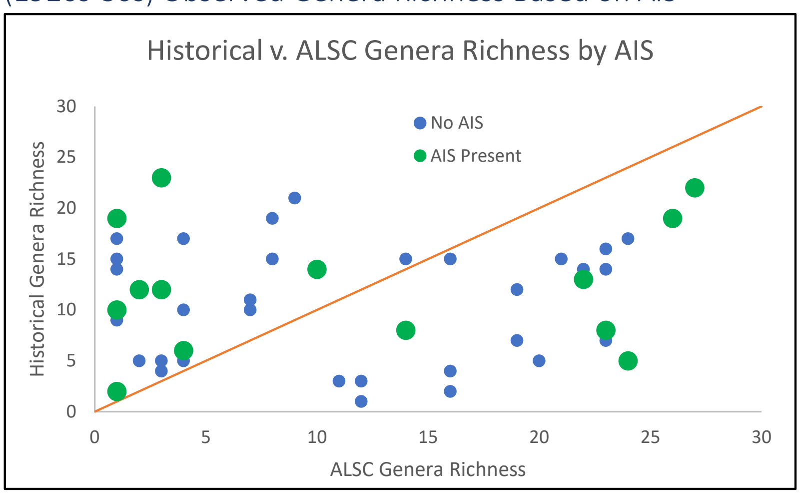
Table 2.3.2- Change in Range of Observed Genera Richness (oGR) in Commonly Surveyed Adirondack Lakes in the NYS BioSurvey and ALSC Program

Program	Years	N	10th % oGR	25th % oGR	Median oGR	75th % oGR	90th % oGR
NYS BioSurvey Adk	1920s-30s	24	6.3	8.3	13.0	21.3	23.0
ALSC Adirondack	1980s	24	4.0	5.0	11.5	15.0	15.7
% Change 1920s to 1980s			-37%	-40%	-12%	-30%	-32%

N = lakes completely surveyed in both the NYS BioSurvey and the ALSC Adirondack programs

Table 2.3.2 shows the distribution of the observed genera richness (oGR) data in the subset of lakes sampled in both the NYS BioSurvey and the ALSC program. Some of these lakes were clearly not completely surveyed, based on a very small number (<5) of genera observed in one survey and a very large number of genera observed in the other survey. When the lakes with very few observed genera in the NYS BioSurvey or ALSC were removed from the database (retaining those lakes with few observed genera in both surveys and more than 5 plants in both surveys), 24 lakes could be evaluated for changes in genera richness, as seen in Table 2.3.2. These data suggest that observed genera richness (oGR) decreased from the 1920s to the 1980s. **However, the decrease in oGR from the 1920s-30s to the 1980s appears to be about 30-35%, which may be only slightly larger than one standard deviation (= 10-30%) of the interannual variability in observed species richness (oGR), as summarized above. This suggests that much of the decrease in genera richness may be consistent with normal variability from year to year.** There was a significant difference in oGR between the NYS BioSurvey and the downstate ALSC lakes (average oGR = 23 from the 1920s-30s and oGR = 14 from the 1980s, or about 10-30% beyond normal variability in oGR from year to year), suggesting a long-term impact from changes in lake use and eutrophication. However, this represents only 5 lakes with complete aquatic plant surveys, so more data would be needed to verify these oGR changes.

Figure 2.3.2.1- Comparison of ALSC (1980s) and Historical (1920s-30s) Observed Genera Richness Based on AIS



This lack of significant change in genera richness is further apparent when reviewing the oGR relationship between the Adirondack region 1920s-30s and the 1980s lakes when accounting for AIS introduction and water quality changes. Figure 2.3.2.1 also shows the relationship between historical and more recent genera richness values in the same 25 lakes shown in Table 2.3.2 and an additional 19 lakes with incomplete plant surveys, but separates those for which AIS have been documented. For all of these lakes, it is assumed that all AIS introductions occurred since the 1920s-30s surveys, based on historical documentation of AIS introductions in New York state. Therefore, lakes with AIS present in the 1980s did not, in nearly all cases, have AIS at the time of the NYS BioSurveys. **This figure suggests that the presence of AIS, and in most cases a long history of AIS resulting in sufficient time to establish dominance by these invasive plants, does NOT appear to strongly influence genera richness.** It appears that as many lakes with AIS exhibited either an increase or decrease in genera richness since the 1920s-30s as had lakes without AIS present. These data may be influenced by the lack of information about actual dominance by AIS, changes with genera (such as the loss of most, but not ALL, species within a genera), or other differences between these two groups of lakes (AIS-present or AIS-absent) may mask the influence of AIS introduction on genera richness. This issue will be explored further in the evaluation of individual plants on aquatic plant communities in White Paper 1E and the evaluation of floristic quality indices in White Paper 1G.

The other historically significant factor cited above that might alter the relationship between historical changes in genera richness is cultural acidification. It has been well established that many hundreds of Adirondack lakes became culturally acidified sometime between the NYS BioSurveys of the 1920s-30s and the ALSC study of the 1980s. The ALSC study was designed to evaluate the impact of cultural acidification on water chemistry and lake ecology; the latter was focused primarily on fisheries, but the study also included macrophyte, zooplankton and phytoplankton collections. Some macrophyte species are adversely affected by lake acidity, and by sediment characteristics often associated with acidic lakes and their surrounding watersheds. Other water chemistry characteristics may also contribute to poor habitat for macrophyte growth, including dystrophic conditions and low ionic strength water. It has been well established that some plants, such as fanwort (*Cabomba caroliniana*), tend to favor slightly acidic water, and several aquatic plant taxa, including watershield (*Brasenia schreberi*), quillwort (*Isoetes* sp), pipewort (*Eriocaulon septangulaire*), some native milfoils, and water lobelia (*Lobelia dortmanna*), tend to be associated with water quality conditions found in the Adirondacks, whether due to water chemistry, sediment characteristics, or other related factors.

Figure 2.3.2.2 Comparison of ALSC (1980s) and Historical (1920s-30s) Observed Genera Richness Based on pH/Color

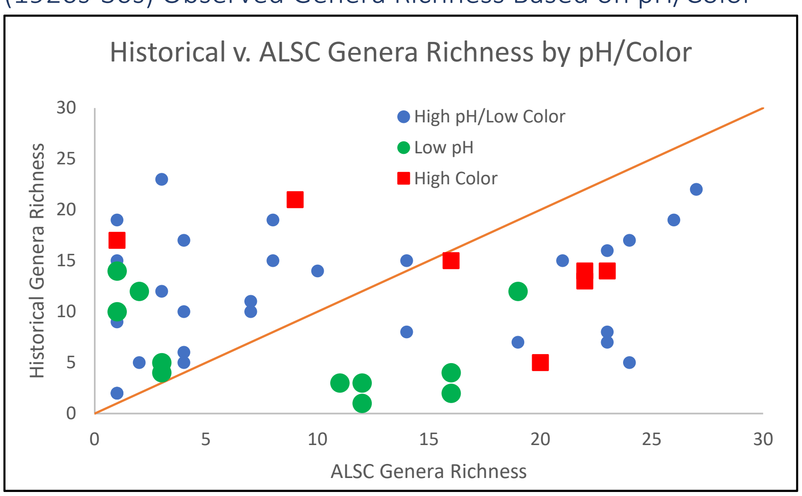


Figure 2.3.2.2 displays the genera richness for the same 46 lakes surveyed in the 1920s-30s NYS BioSurvey and the 1980s ALSC, but divided into three groups:

1. lakes with low pH. Although low pH can be defined in many ways, "low pH" is defined for this evaluation as less than 6.5, consistent with the New York state water quality standards (6 NYCRR Part 703).
2. lakes with high DOC or color, as a measure of dystrophy. Dissolved organic carbon imparts a brownish color to the water, reducing the ability of sunlight to reach the bottom and stimulate aquatic plant growth. The effective littoral area in these lakes tend to be smaller than in other lakes with similar bathymetry. Based on the ALSC literature and experience in other New York state lakes, DOC > 7 mg/l is presumed to significantly affect water clarity and is assumed to represent "high DOC" for this evaluation.
3. Lakes with high pH and low color.

These data show that lakes with depressed pH appear to have slightly lower genera richness than either highly colored or more alkaline, clearer lakes, but that neither pH nor color appeared to be a strong indicator of whether long-term changes in genera richness are occurring in the Adirondack lakes. As will be discussed below, long-term changes in SPECIES richness appear to be more common in lakes outside the Adirondacks than lakes within the Park, and Table 2.3.2 also appears to suggest that long-term changes in genera richness have not been apparent in the Adirondack lakes, after accounting for long-term changes in acidification, introduction of invasive species, and normal variability in species richness from year to year.

As noted above, long-term changes within genera may have occurred in these lakes, or difference in sampling methodologies may preclude a comprehensive evaluation in long-term changes in genera richness in New York state lakes from the 1920s-30s to the present day. Specifically, these analyses provide only limited information in changes in species richness relative to genera richness. The impact of large-scale changes in the **abundance** of invasive species will be evaluated in White Papers 1E through 1G, particularly as they relate to other measures of plant community health, including relative abundance of favorable or unfavorable plants, and floristic quality indices. However, as will be seen in an evaluation of species richness in Section 2.3.2 below, these data suggest that long-term changes in genera richness were more likely to be found in lakes outside the Adirondack Park than in lakes within the Park.

These preliminary findings indicating little change in oGR over a period of about 60 years in the Adirondacks but potentially some decrease in oGR beyond normal variability outside the Adirondacks bear further evaluation with additional study lakes.

Section 2.3.3- Changes in oSR from the 1920s to the 2000s Outside the Adirondacks

As discussed above and as seen in Table 2.1, the NYS BioSurvey had much higher oSR than did lakes in ALSC, PIRTRAM or AWI, even when including those NYS BioSurvey lakes that were incompletely surveyed (had fewer than 5 unique plant species). Some of this might be due to different lakes surveyed in these four programs. Some of this might be due to far more individual emergent and floating leaf species (and macroalga species) identified in NYS BioSurvey than in more recent programs. And some of this might reflect long-term changes in species richness due to other factors, including changes in lake and shoreline uses, introduction of invasive species, water quality changes, and climate change.

To correct for the differences in these programs, and to better evaluate long-term changes in species richness, Table 2.3.3 provides summary statistics for the observed species richness (oSR values for 16 lakes sampled in both the NYS BioSurvey from the 1920s-30s (outside of the Adirondack Park) and in the PIRTRAM surveys in the 2000s-10s. The oSR calculations in the NYS BioSurvey data presented in this Table include species level identifications for nearly all submergent plants, and genus level identifications for nearly all emergent and floating leaf

Table 2.3.3- Change in Range of Submerged/Floating Observed Species Richness (oSR) in Commonly Surveyed non-Adirondack Lakes in NYS BioSurvey and PIRTRAM

Program	Years	N	10th % oSR	25th % oSR	Median oSR	75th % oSR	90th % oSR
NYS BioSurvey non Adk	1920s-30s	16	14.6	21.0	22.0	25.3	32.4
PIRTRAM	2000s-10s	16	5.5	7.0	15.5	21.1	26.4
% Change 1920s to 1980s			-62%	-67%	-30%	-17%	-19%

N for each program represents average oSR for each lake in each program

plants, and for macroalga, consistent with the plant identification methodologies used in the PIRTRAM (and AWI) surveys. These results show a small (within to just above normal variability) to significant (more than 2-4x the normal variability) decrease in oSR from the 1920s-30s to the 2000s-10s, depending on which measure is used. It is not known if a similar change would be apparent with a larger dataset, since this evaluation is limited to only a few (16) lakes surveyed in both the NYS BioSurvey and the PIRTRAM programs, but as discussed further in Section 2.4. However, the range of change in oSR over this period (17-67%) may be consistent with the change in oGR seen in the (few) downstate ALSC lakes also surveyed in the NYS BioSurvey. **These data do suggest that at least some statistically significant change in species richness has occurred over this period.**

Section 2.3.4- Changes in oSR from the 1920s to the 2010s Within the Adirondacks

The data in Table 2.3.3 represent data from outside the Adirondack Park, in part because the PIRTRAM surveys were also entirely limited to lakes outside of the Park. However, there were also 29 lakes that appeared to be completely surveyed in both the 1920s-30s NYS BioSurvey and the 2020s AWI surveys. As noted above, the AWI surveys (like the PIRTRAM surveys) did not appear to completely survey emergent plants, and some floating and submergent plants were

Table 2.3.4- Change in Range of Submerged/Floating Observed Species Richness (oSR) in Commonly Surveyed Adirondack Lakes in NYS BioSurvey and AWI

Program	Years	N	10th % oSR	25th % oSR	Median oSR	75th % oSR	90th % oSR
NYS BioSurvey Adk	1920s-30s	29	8.9	13.3	19.0	22.3	26.0
AWI	2010s	29	9.8	13.0	16.0	19.0	24.2
% Change 1920s to 2010s			+10%	-2%	-16%	-15%	-7%

N for each program represents average oSR for lakes completely surveyed in both programs

only identified to genera level (although they were reported to species level), even if multiple species were present. Table 2.3.3 shows the change in observed submergent and floating leaf species richness in the NYS BioSurvey and AWI, with the NYS BioSurvey lakes "corrected" to the plant identification protocols used in the AWI (and PIRTRAM).

These data suggest that there was little if any change in oSR in the Adirondack lakes from the 1920s-30s- any change was likely within the normal annual variability in oSR. This is consistent with the lack of significant change in oGR in Adirondack lakes from the 1920s-30s to the 1980s cited in Table 2.3.2. The change in oGR in those lakes was larger than the change in oSR in the lakes reviewed in Table 2.3.4, although neither change appears to be statistically significant.

Section 2.4- Changes in Species Richness in Response to Active Management

As noted above, species richness can change significantly in response to active management, particularly herbicides, grass carp, drawdown and other major plant management actions that could substantially reduce targeted (or non target) plants for multiple years throughout most to all of the managed lake. Section 2.2 outlines the change in observed species richness from year to year in more than 25 lakes that were not actively managed for aquatic plants (or this management occurred many years before or after the surveys, but not at the time of the surveys). For other lakes, changes in species richness may exceed the normal annual variability in species richness calculated in Section 2.2.

The impact of active plant management on species richness is discussed in Section 4.11 below.

Section 2.5- Discussion of Changes in Species Richness from the 1920s to the Present

An evaluation of long-term changes in species richness from the 1920s-30s to the 2010s is affected by several inconsistencies between the monitoring programs conducted over this period. These inconsistencies include the lack of species-level identification of all plants in some programs, the lack of unique species-level identifications of all emergent and floating leaf plants and some submergent plant genera in some programs, and different lakes included in each of the programs. These inconsistencies can be addressed by limiting long-term evaluations to lakes common to multiple programs, "correcting" species richness calculations to assure consistencies across programs, and accounting for interannual variability in observed species richness (oSR) and observed genera richness (oGR) calculations.

The data presented in Tables 2.3.1 through 2.3.3 suggest that oSR values decreased from the 1920s-30s NYS BioSurvey to the present day outside of the Adirondacks. This may be due to an increase in lake and shoreline usage, eutrophication, introduction of AIS, climate change and other factors. This was also consistent with a decrease in genera richness in a few lakes outside of the Adirondacks sampled in both the 1920s-30s and the 1980s downstate ALSC, but the sample size was too small to verify that these changes were significant.

Although genera and species richness also decreased from the 1920s-30s to the present day within the Adirondacks, this decrease may have been within normal range of variability

found in these lakes- that is, this change may not have been beyond the expected 10-30% variability in species richness from one year to the next. Genera richness was lower in acidic lakes, but neither the acidic nor dystrophic (highly colored) lakes appeared to exhibit a long-term change in genera or species richness. The Adirondack region lakes that were not acidic- as documented in the AWI surveys- did not appear to exhibit a significant long-term change (from the 1920s-30s to the present day) in either species or genera richness. This may reflect fewer changes in shoreline or lake use, a lower rate of eutrophication, and fewer introductions of invasive species. None of these differences has been well documented, but the long-term changes in the Adirondack lakes were antidotally less significant than in lakes outside the Park under a longer-term threat from lake development, eutrophication and AIS introduction. It is likely, however, that these Adirondack lakes will be under increasing development and AIS introductions as these lakes are increasingly accessed by boaters, lakefront property owners, and other lake users.

Section 3- Comparison of Observed Species Richness (oSR) and Projected Species Richness (pSR)

Section 3.1- Background

Section 4 of White Paper 1C provides a summary of the problems in using observed species richness (oSR) for comparing lakes, whether these lakes were sampled in the same program, across multiple programs, or over a long period of time. While some of these surveys may have included the same number (and spatial distribution) of survey sites, most surveyed lakes possess a unique number of survey sites, due to survey goals, available resources, and other factors. As seen in White Paper 1C, using Cazenovia Lake in 2019 as an example, the observed species richness for any surveyed lake can vary significantly with variations in the number of surveyed sites.

In all surveyed lakes, observed species richness increases as the number of survey sites increases, although it is likely that each lake exhibits a “carrying capacity” of a maximum number of unique species. This asymptotic value- a practical maximum number of unique species- most likely is limited by space, depth, sediment characteristics, water quality, competition among plants and species, and other factors. Since an observed species richness represents a single point along this asymptotic regression, comparison of species richness values is strongly influenced by the number of survey sites.

As discussed at length in Section 2.1, the number of sampling sites surveyed at lakes sampled through each of the four monitoring programs cited in White Paper 1A varies from lake to lake, While the site densities in the PIRTRAM and AWI programs (the only programs with at least partial granular survey data) were generally similar, as seen in Table 2.2.1 in White Paper 1C, differences in survey site densities between these programs, between lakes within these programs, and even within lakes from year to year, may significantly impact observed species richness (oSR). For the NYS BioSurvey and ALSC lakes, the number of surveyed sites, and therefore the lake or littoral distribution of these sites, is not reported. It is also very clear that oSR increases as survey sites increase- while there is likely an upper end to the additional number of survey sites that will yield additional plant species, the variation in the number and distribution of survey sites, and other survey logistics can strongly impact oSR calculations and a comparison of oSR values between programs in the range of survey site densities found in these programs. In short, none of these programs (and likely no routine aquatic plant monitoring programs) achieve an optimal or standardized survey site density to accurately identify the actual species richness in a lake.

An example of this is provided in Figure 3.1 (reproduced from White Paper 1C) showing a regression of the “projected” species richness in Cazenovia Lake in 2019. The regression lines show the expected species richness at varying survey site ranges in the lake, based on a subsampling and bootstrap analysis of the actual granular survey site data from the lake. As seen in Figure 3.1, this regression is most accurate when split between the regressions of the (expected species richness for the) first 20 sites, and the regressions of the (expected species richness for) sites 20 through 300 (the lake was surveyed in 304 sites in 2019). This regression

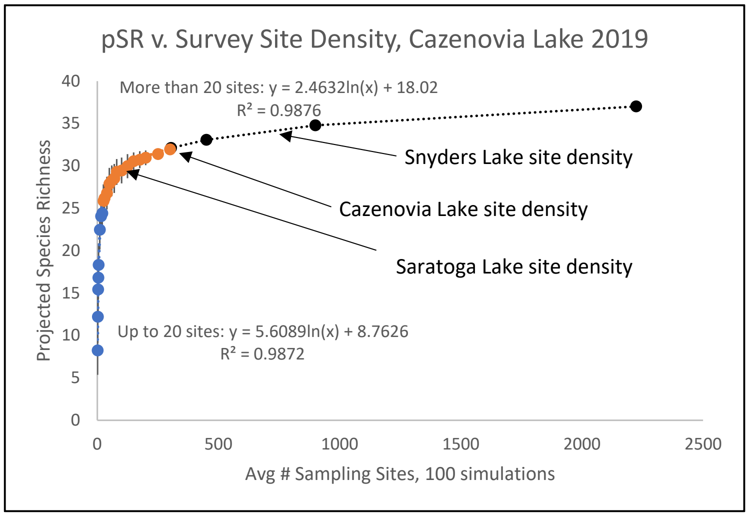


Figure 3.1- Comparison of oSR and pSR Values for Cazenovia Lake and various site densities

shows an observed species richness of 32 for Cazenovia Lake in 2019 at 304 sites, or a survey site density of 1.4 sites per littoral hectare. However, if the lake instead had been surveyed at the survey site densities used at other PIRTRAM lakes, the observed species richness would have been significantly different, ranging from 27 unique species (using the Kinderhook Lake survey site density of 0.2 sites per littoral hectare) to 36 unique species (using the Collins Lake survey site density of 7.6 sites per littoral hectare). This indicates, as discussed at length in Section 4.2 of White Paper 1C, and illustrated in Table 4.2 from White Paper 1C, that a standardized survey site density is needed to credibly compare lakes across multiple programs, multiple survey teams, and over time, mostly due to inconsistencies in survey site densities across these programs, survey teams, and time.

Section 4.4 of White Paper 1C identifies several survey site densities for consideration as a standardized aquatic plant survey site density. A "maximum" survey site density of 4 sites per littoral acre, corresponding to the largest survey site density possible without running the risk of rake toss area "grid" overlaps, was considered in these discussions. However, it is likely that this very high survey site density is not achievable in most surveys, requires extremely high numbers of survey sites in very large lakes and a greater likelihood of estimated species richness that exceeds the 'carrying capacity' for many small lakes, and calculates a projected species richness that most likely falls outside the limits of extrapolating existing survey results. In short, this maximum survey site density is likely too large, even for projecting species richness values from existing survey site data. A survey site density of 1 site per littoral hectare, however, is far more likely to fall within the practical range of existing surveys (as seen in Tables 4.1 and 4.2 in White Paper 1C) and therefore within the extrapolation range for regressions of existing survey data, is large enough to generate relatively stable species richness values for most lakes, and could be achieved in future surveys, allowing for the use of calculated rather than projected species richness values. For these reasons, **a standardized survey site density of 1 site per littoral hectare is recommended for future surveys, and as a basis for calculating projected species richness in lakes with survey site densities that are either (slightly) higher or lower than this recommended standardized site density.**

Section 5 of White Paper 1C outlines a process by which existing granular survey site data, available in most PIRTRAM lakes, can be used to convert observed species richness (oSR) values into projected species richness (pSR) values at any survey site density, including the aforementioned recommended standardized survey site density of 1 site per littoral hectare. In short, subsampling methods can be used to estimate the expected species richness at any survey site density interval, and to project the estimated species richness at a survey site density above the actual survey site density. These species richness estimates or projections can be used to calculate a projected species richness for any lake (with granular survey site data) at the 1 site per littoral hectare standardized site density, allowing for a comparison of species richness values between lakes, between programs, over time, and in any surveyed lake from year to year.

Section 3.2- Monitoring Programs Used to Project Survey Sites (and Species Richness)

As discussed above, the process for projecting species richness requires granular site survey data (indicating the frequency and/or abundance of all plants at each surveyed site). These data are available for some of the PIRTRAM lakes, as seen in Appendix 3.2.1. Note that for some PIRTRAM lakes, only summary data are available, showing the total number of surveyed sites and the number of survey sites associated with each of the relative abundance categories (number of sites with dense quantities of Plant X, number of sites with moderate quantities of Plant X, etc.). In the absence of the granular data indicating presence or relative abundance at each site, pSR values cannot be accurately estimated. Although the species distribution of all aquatic plants at each of the AWI rake toss sites and the weed bed sites could be equilibrated to allow for a single “rake toss equivalent” distribution for each plant, this would require some assumptions about the distribution of the plants within the beds that could compromise the ability to project species richness. For the NYS BioSurvey lakes and ALSC lakes, granular survey data are not available, so projected species richness values cannot be calculated.

Therefore, projected species richness as a function of the (projected) number of survey sites can be evaluated for some of the PIRTRAM lakes, but not for the NYS BioSurvey lakes, the ALSC lakes, or the AWI lakes.

Section 3.3- Estimating Projected Species Richness (pSR)

Section 3.3.1- Background

As discussed above, species richness can be estimated from granular survey site data using resampling methods. Specifically, these methods allow for estimates of cumulative species richness at varying survey site intervals, as seen in Figure 3.1 for Cazenovia Lake. These estimated cumulative species richness values can be projected to any survey site density that exceeds the actual survey site density, including the recommended survey site density of 1 site per littoral hectare.

While observed species richness (oSR) can be calculated for all of the lakes included in the NYS BioSurvey, the AWI, and the PIRTRAM programs, projected species richness (pSR) can be estimated only for the PIRTRAM lakes with granular survey site data.

Table 3.3- oSR and pSR in PIRTRAM Lakes with granular survey data

Lake Name	Year	Littoral Area (ha)	#Survey Sites	oSR	pSR
Ballston Lake	2006	48	34	8	9.3
Big Fresh Pond	2006	13	19	9	8.5
Blydenburgh Lake	2012	40	27	4	4.3
Blydenburgh Lake	2014	40	27	4	3.3
Cazenovia Lake	2010	225	304	32	30.9
Cazenovia Lake	2011	225	304	32	30.8
Cazenovia Lake	2012	225	304	32	29.5
Cazenovia Lake	2013	225	304	34	35.4
Cazenovia Lake	2014	225	304	36	31.0
Cazenovia Lake	2015	225	304	32	35.4
Cazenovia Lake	2016	225	304	30	33.4
Cazenovia Lake	2017	225	304	31	31.2
Cazenovia Lake	2018	225	304	32	31.9
Cazenovia Lake	2019	225	304	31	31.4
Collins Lake	2007	5	38	17	8.3
Creamery Pond	2008	4	18	7	3.3
Creamery Pond	2009	4	18	6	4.7
Creamery Pond	2010	4	21	6	6.9
Creamery Pond	2011	4	21	7	5.5
Creamery Pond	2012	4	21	5	5.3
Creamery Pond	2013	4	21	4	4.8
Hards Pond	2010	12	18	12	10.5
Hards Pond	2011	12	18	8	7.1
Java Lake	2008	21	16	5	6.1
Java Lake	2009	21	16	6	6.8
Java Lake	2010	21	16	6	5.2
Kinderhook Lake	2006	109	20	7	9.2
Kinderhook Lake	2007	109	20	7	8.5
Lake Luzerne	2010	24	168	34	21.6
Lake Ronkonkoma	2009	21	22	4	4.1
Lake Ronkonkoma	2010	21	22	4	3.8
Lake Ronkonkoma	2011	21	22	2	1.8
Lake Ronkonkoma	2012	21	22	6	5.5
Lake Ronkonkoma	2014	21	22	3	3.0
Lamoka Lake	2006	166	180	26	28.0
Lamoka Lake	2008	166	180	29	31.9
Lamoka Lake	2009	166	180	25	26.6
Morehouse Lake	2010	35	30	14	15.5
Quaker Lake	2010	64	30	7	8.3
Saratoga Lake	2010	657	241	22	24.4
Saratoga Lake	2011	657	304	23	24.3
Saratoga Lake	2012	657	304	24	25.9
Snyders Lake	2002	15	40	6	5.8
Snyders Lake	2003	15	48	7	6.1
Snyders Lake	2004	15	57	5	4.4
Snyders Lake	2005	15	32	7	7.0
Snyders Lake	2006	15	40	9	7.5
Snyders Lake	2007	15	57	12	8.8
Snyders Lake	2008	15	57	12	8.9
Snyders Lake	2009	15	55	16	11.9
Snyders Lake	2010	15	44	16	12.5
Snyders Lake	2011	15	51	12	9.2
Waneta Lake	2006	170	146	15	15.0
Waneta Lake	2008	170	146	19	19.6
Waneta Lake	2009	170	146	19	18.9

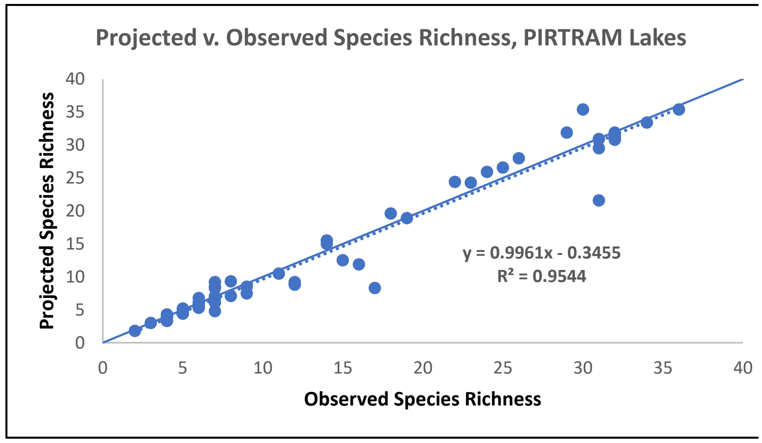
Section 3.3.2- Comparison of oSR and pSR data

Table 3.3 summarizes the observed species richness (oSR) and projected species richness (pSR) for the PIRTRAM lakes based on the projected standardized survey site density (= 1 site per hectacre of littoral area). These pSR estimates are generated using the granular survey data lakes (lake years) for 56 PIRTRAM lake-years. As noted above, this analysis was limited to those lakes for which granular plant species distribution data are available for each surveyed site, allowing for the application of the modified bootstrap method and variance analyses described in Section 5 in White Paper 1C. This Table also includes the size of the littoral area and the number of sites in the actual surveys. The difference between oSR and pSR is influenced by available survey resources (particularly the number, density and distribution of surveyed sites), and ultimately the goal of the monitoring programs.

As discussed in White Paper 1C, the pSR is derived from the logarithmic or power relationship(s) between the number of survey sites and the estimated species richness at defined intervals of survey sites. Unfortunately, the actual maximum (projected) species richness cannot be known for any lake, so a standardized survey site density is used to project a standardized species richness (pSR) for lakes. Fortunately, the logarithmic (or power) relationship between the number of survey sites and species richness in each of the lakes is very strong (with regression coefficients- R^2 - generally between 0.95 and 1.0) and suggestive of a continuation of these trends. The specific regressions and associated correlations for each of the lakes summarized in Table 3.3 can be found in Appendix 3.2.1.

Although not explicitly shown in Table 3.3, the projected number of plant survey sites, calculated as a standardized way to compare lakes and based on a high density of plant survey sites achieved in several PIRTRAM surveys, is equivalent to 4x the littoral area of the lake (in acres). So, for example, the pSR for Ballston Lake in Table 3.3 represents the projected number of unique aquatic plant taxa in 48 (=48 ha littoral area x 1 sites per littoral ha) plant survey sites. This number was calculated from the logarithmic relationship between the cumulative number of plant taxa and increments of increasing number of survey sites, using the modified bootstrap methods outlined in Section 5 in White Paper 1C. This pSR value of 9.3 is only slightly larger than the observed species richness (oSR) of 8, even though the actual survey site density (in this in Ballston Lake was 0.7 sites per littoral hectare. This suggests that a relatively close relationship between oSR and pSR, unless there is an extremely large difference between the actual survey site density and the standardized survey site density (= 1 site per littoral hectare).

Figure 3.3.1- Comparison of oSR and pSR for PIRTRAM Lakes

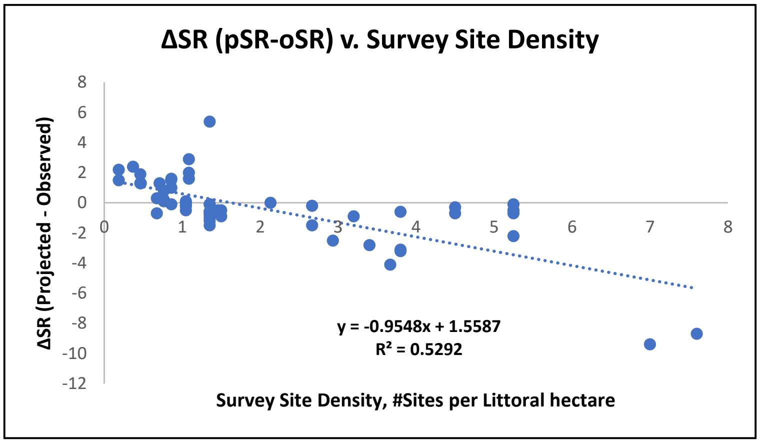


This relationship is further summarized in Figure 3.3.1, which shows a very strong regression ($R_2 > 0.95$) between oSR and oSR for the PIRTRAM lakes. As noted above, this figure includes lakes with survey site densities ranging from fewer than 0.1 sites per littoral hectare to greater than 6 sites per littoral hectare, yet still indicates a very strong regression.

Figure 3.3.1 shows that the regression line exhibits a slope that is nearly identical to the slope of the 1:1 line (corresponding to oSR = pSR), with some lakes above and some lakes below this line. This could allow for a rough approximation of projected species richness values in lakes that only have oSR, such as those in the NYS BioSurvey. This may only be considered for lakes without granular site data, since it ignores site-specific information (and lake-specific relationships between actual surveyed number of sites and a standardized 1 site per littoral hectare site density), but as noted throughout this White Paper, granular survey site data should be the basis for pSR calculations. This is discussed in more detail below in Section 4. However, Section 4 also outlines an alternative process using fewer survey sites for “converting” oSR values to pSR values for lakes with granular survey site data. This very close relationship between oSR and pSR suggests that oSR data can be used to evaluate differences between lakes, over time, and between programs, as done in Sections 2 and 5 of this White Paper, IF pSR data are not available.

Figure 3.3.2 shows the relationship between the difference in species richness (pSR -oSR) as it relates to survey site density. Those lakes with positive ΔSR values (those with higher projected species richness than observed species richness) generally have lower survey site densities, while

Figure 3.3.2- Difference in Species Richness (pSR-oSR) v. Survey Site Density



those with negative ΔSR values have higher survey site densities. This data- indicating whether survey site densities influence projected species richness- explains more than half ($R^2 = 0.53$) of the variation between pSR and oSR, suggesting that that survey site densities influence the relationship between oSR and pSR in Figure 3.3.1. This provides further justification for the use of a standardized survey site density when estimating (projected) species richness.

The data presented in Appendix 3.2.1 summarize these logarithmic regressions and tables showing the expected number of cumulative unique taxa at survey sizes ranging from 4 littoral hectares per site to 4 sites per littoral acre (as well as the number of sites- "existing"- in the actual plant survey at that lake). Appendix 3.2.1 also shows the number of survey sites calculated to identify increasing percentages of the total maximum projected number of taxa (=pSR) in the lake, based on a survey site density of 4 sites per littoral acre (in the case of Ballston Lake, = 474 sites). As noted above, although the larger PIRTRAM survey dataset included more lakes than shown in this Appendix, these analyses were limited to those lakes for which granular data (the presence and/or abundance of all plant taxa at every surveyed site). This information- showing the number of survey sites required to estimate various percentages of the pSR- is discussed at length below.

The pSR estimates are dependent in part on the number of "runs" used to estimate species richness at any given number of survey sites. The accuracy of these estimates depends on the variance associated with the number of runs. The species richness estimates stabilize as the number of runs increase, so determining the approximate number of runs required to stabilize these estimates optimizes the process for estimating projected species richness.

This variance was evaluated using the methods described in Section 5.4 of White Paper 1C. The optimal number of survey sites, and the number of runs required to achieve stability in cumulative mean and standard deviation values, are summarized for each lake-year in the PIRTRAM dataset in Table 5.4.1.2 in White Paper C. This analysis determined that approximately 100 computational runs stabilized the estimate of cumulative mean and standard deviations of species richness for each lake year. Therefore 100 computational runs were used in calculating pSR values at discrete numbers of sampling sites, as summarized in Table 3.2.1. **Note that this does not correspond to the amount of sampling required to find the pSR- this is discussed at length in Section 4.**

Section 3.4- Discussion

Species richness can be calculated for each of the lakes surveyed in the 1920s-30s NYS BioSurvey, through the aggregate of PIRTRAM surveys conducted by NYS lake researchers and managers in the 1990s to 2010s, and in the AWI program from 2012 to 2016, and genera richness can be calculated in the ALSC lakes surveyed in the 1980s. These four programs represent nearly 2000 lakes throughout New York state, and comprise as a group the largest aquatic plant surveys ever conducted in New York state.

However, observed species richness (oSR) and observed genera richness (oGR) calculations can be challenging to compare across programs, and in some cases between lakes surveyed in the same program. This is perhaps not surprising; the concept of species richness, an attempt to quantify the diversity of species in an ecological community, was not explicitly developed for evaluating aquatic plants.

oSR calculations have some advantages. For example, oSR calculations benefit greatly from the ability of analysts to simply count the unique number of plant species or genera in a lake (or marginal areas). This allows for generating oSR values without “granular” information about individual surveyed sites, and therefore allows for calculating oSR for the 300+ NYS BioSurvey lakes and (oGR) for the 1550+ ALSC lakes, two enormous datasets. For this reason, oSR data are used in many of the analyses in this White Paper, and where appropriate in White Papers 1E and 1F.

However, oSR in lakes is limited, at times significantly, by the inability to observe or otherwise survey an entire lake, and even in those littoral areas where aquatic plants are likely to grow. Most surveys use some retrieval device, such as a two-sided rake deployed in PIRTRAM and AWI lakes, to collect unobserved plants, but these devices collect plants incompletely and cannot traverse the entire lake bottom. In short, no aquatic plant survey can completely survey an entire littoral zone, much of which is located in deep and murky water, so the identity of every plant taxa in lake can't be known.

Despite the wide variation in survey site densities in the lakes summarized in Figure 3.3.1, the strong correlation between oSR and pSR in the PIRTRAM lakes almost certainly indicates that even the lower survey site densities in some of the PIRTRAM lakes are sufficient to find the majority of plants in these lakes. This might reflect relative consistency in survey methodologies in PIRTRAM lakes, despite having multiple surveying organizations involved in surveying the lakes included in the PIRTRAM summaries. This is further illustrated in Figure 3.1.2, which shows that the regressions describing the projected species richness for Cazenovia Lake for nearly the entire range of survey site densities reported in PIRTRAM lakes show a decreasing efficiency in finding “more” unique plants. In other words, even the lakes with the lowest survey site densities- 0.2 sites per littoral hectare in Kinderhook Lake- still have sufficiently dense enough survey site distribution to find the majority of the (projected) number of plants in the lake (corresponding to the flattening of the logarithmic curve in Figure 3.2.1). This indicates that as long as larger surveyed lakes exhibit a survey site density much greater than 0.1-0.2 sites per littoral hectare, projected species richness could be estimated from observed species richness, as discussed in more detail below. For smaller lakes, it is likely that a survey site density approaching 1 site per littoral hectare would be needed to assure a reasonable estimate of pSR from oSR data. While the pSR does not provide the identify of all aquatic plants likely to be found in the lake, at least beyond those documented in the oSR calculations, it is likely that those "missing" plants are a very minor part of the aquatic plant community, since they were not found in the existing plant survey matrix. Therefore it is reasonable to assume that no invasive aquatic plants were missed in these surveys. This is discussed further in Section 4 below.

Although pSR is likely more accurate and definitely more comparable across programs, insufficient granular aquatic plant survey data are available to generate pSR estimates for most lakes. For example, pSR cannot be directly estimated in the NYS BioSurvey and ALSC lakes, since granular survey site data (which plants are found at each survey site, and at what abundance) is not available. In some cases, oSR can be used to estimate pSR since Figure 3.3.1 shows a very strong regression between oSR and pSR; and in these cases, pSR estimates can take advantages of these much larger (NYS BioSurvey and ALSC) datasets. As seen in Section 5 of this White Paper, some of the factors influencing species richness can be evaluated using oSR data, and some can be evaluated using only pSR data.

However, to improve the accuracy of these projected Species Richness values, granular survey site data (and littoral area info) should be obtained if they had been collected, and site specific pSR values should be calculated. For future surveys, there is no doubt a practical upper limit to the achievable survey site density for future monitoring programs, based on available time and resources. However, a sufficient number of sites within each lake should be surveyed (and documented with granular information about individual plant frequency and abundance at each site) to generate high quality pSR values. This is discussed at length in Section 4.

Section 4- Sampling Effort Required to Estimate Species Richness

Section 4.1- Background

As noted above in Section 3, projected species richness (pSR) is more useful and reproduceable than observed species richness (oSR), and the former is most accurate when calculated from "granular" survey site data (documenting the frequency and abundance of each plant species at each site) rather than applying a statewide regression to individual lakes (Figure 3.3). Section 3 and White Paper 1C recommend that pSR values be generated from oSR data extrapolated to a standardized site density of 1 sites per littoral hectare. This survey site density is based on the range of "achievable" survey site densities found in the PIRTRAM lakes, as seen in Tables 4.1 and 4.2 in White Paper 1C, which showed that most PIRTRAM lakes exceeded this survey site density.

As discussed above, pSR values can be estimated from defining the relationship between the actual aquatic plant surveys sites and the cumulative number of unique taxa in intervals of sites, the latter of which can be estimated using modified bootstrap methods outlined in Section 5 of White Paper 1C. So, for example, the logarithmic regression describing the relationship between the number of survey sites and the cumulative unique number of taxa in up to 304 sites in Cazenovia Lake can be used to estimate the species richness in about 225 littoral sites (1 site per littoral hectare) in the lake. However, many lake communities do not have the resources or volunteer availability or interest to achieve even the survey site densities recommended for use in the PIRTRAM surveys cited above.

A continuing evaluation of the PIRTRAM survey dataset may successfully identify even smaller site densities and survey sizes to develop a reasonably accurate pSR estimate for these lakes, as discussed in other White Papers. These same data can be used to estimate pSR based on smaller increments of plant surveys. One method for estimating the maximum number of unique plant taxa in a lake (the pSR) is to extrapolate the logarithmic regression of the cumulative number of unique taxa in smaller discrete numbers of plant survey sites to the number of survey sites associated with a 1 site per hectare grid. So, for example, a regression of the expected number of unique taxa in 1, 2 and 3 sites in Ballston Lake (or any other combination of survey sites) can be extrapolated to estimate the number of plant taxa in 48 plant survey sites (= 1 site per hectare of littoral area in Ballston Lake) and compared to the calculated estimate of plant taxa using the regression of the entire range of plant survey sites (as shown in Appendix 3.2.1). This allows for an estimate of the amount of sampling effort required to estimate overall species richness. While the estimates of species richness with these small numbers of survey sites are presumably not as accurate as the estimates from, in the case of Ballston Lake, 30 survey sites, this analysis can provide information about the error in this truncated estimate relative to the much larger sampling effort required to gain a more accurate estimate of overall species richness. The same process can then be conducted stepwise in increasing numbers of survey sites until the error (associated with the estimated mean number of unique plant taxa and variance) is sufficiently small.

The process used for evaluating projected species richness through analysis of cumulative species richness in discrete sample site intervals is discussed at length in Section 5 of White Paper 1C.

Section 4.2- Monitoring Programs Used to Evaluate Species Richness by Reduced Sampling Effort

As discussed above, the aquatic plant survey data from only those lakes with available granular survey data can be used to estimate pSR based on a defined representative number of plant survey site density. The 56 lake-years of granular aquatic plant survey data for the PIRTRAM lakes summarized in Table 3.3 can be used for the analysis.

The AWI data from 2012 to 2013 COULD be used if the use of "equivalent" point-intercept sites (estimated from visual plant bed data) combined with actual rake toss data can be assumed to be equivalent to point-intercept data equally distributed throughout the littoral zone. Alternatively, the point-intercept data could be 'converted' to weed bed area equivalents, with each "bed" representing a single point. However, either method would involve significant assumptions about the distribution of plants or rake toss sites within each bed, so the AWI data should not be used for these analyses. Neither the NYS BioSurvey data nor the ALSC data can be used for this analysis, for reasons identified earlier in this White Paper (regarding the lack of granular survey site data). Should granular survey site data become available for either of those programs, or any NYS lakes sampled in the future, pSR and the effort required to estimate this value could be calculated.

Section 4.3- Most Efficient Sampling Effort for Projected Species Richness

As discussed at length in Section 5 in White Paper 1C, an ANOVA analysis of the cumulative mean and standard deviation of species richness in the PIRTRAM lakes summarized in Table 3.3 show a very high variability in the number of survey sites needed to "optimize" sampling, defined here as the point (number of sites) at which additional survey sites generate only a marginal increase in species richness. However, this analysis did not evaluate the amount of sampling required to accurately estimate projected species richness (pSR), defined as the minimal amount of sampling required to estimate pSR within an acceptable error range, although the same methods can be used. Determining the minimal amount of sampling required to accurately estimate pSR provides important information to surveyors, lake managers, government officials, and lake associations seeking to estimate pSR and floristic quality indices (FQIs), as discussed in White Paper 1G. However, the processes for estimating the optimal amount of sampling or the projected species richness may not be adequate for identifying the amount of sampling required to meet other survey objectives, including finding any and all locations of specific invasive species (such as pioneering individual hydrilla plants), finding all projected species, or evaluating conditions in a specific location representing areas smaller than one hectare.

Section 4.4- pSR Estimates Based on Truncated Plant Survey Data

Table 4.4 shows the mean, standard deviation, and median % of the pSR (at a survey site density of 1 site per littoral hectare) found in logarithmic regressions using numbers of sites in three consecutive groups of sites in the PIRTRAM plant surveys with granular site data (Table 3.3). The values in the Sites 1-3 column represent the estimated mean, standard deviation, and median % of the standardized pSR estimated from a regression of the mean number of cumulative unique plant taxa associated with 1 site, 2 sites, and 3 sites for all 56 PIRTRAM lake-years,

Table 4.4.1- Estimated % of Projected Species Richness (pSR) Based on Regressions of PIRTRAM Survey Site Data (Comparing Truncated Regressions to Regressions from the Entire Plant Survey Dataset

	Estimated % of pSR at 1 site/ha via Logarithmic Regression of Cumulative #Taxa in the following plant survey sites									
	Sites 1-3	Sites 2-4	Sites 3-5	Sites 4-10	Sites 5-15	Sites 10-20	Sites 15-25	Sites 20-30	Sites 25-40	Sites 30-50
Mean	103%	105%	103%	105%	105%	102%	102%	102%	102%	103%
StDev	21%	19%	15%	11%	9%	12%	7%	6%	6%	6%
Median	102%	103%	102%	102%	103%	102%	100%	100%	101%	102%

comparing these estimates to the projected standardized species richness using the regressions of the entire plant survey dataset.

As seen in Table 4.4.1, Sites 4-10 represent the percentage of the projected species richness from a regression of the estimated species richness in 4 sites, 5 sites, and 10 sites, relative to projected species richness from the entire plant survey dataset (in Cazenovia Lake, for example, 304 sites). Sites 15-25 represent the values in 15 sites, 20 sites, and 25 sites, and so on (as per the calculation of cumulative mean number of taxa in 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 40, and 50 sites described above). Note that the regressions used above correspond to three points associated with the number of survey sites. Regressions were also conducted on four or more points, but these data were similar to those from the three-point regressions and therefore are not included here. It should also be noted that the percentages of projected plant taxa associated with different combinations of survey sites varies from lake to lake. Appendix 4.2.1 summarizes the expected total number of plant taxa in each lake (lake-year) based on logarithmic regressions of various combination of plant survey sites. The color coding of some cells in the table correspond to the first instance (fewest number of plant survey sites required) of the (regression-) estimated total species richness being within about 10% of the calculated species richness (yellow cells), and the first instance of regression-estimated total species richness within about 5% of the calculated value (red cells).

The data in Appendix 4.2.1 represents the raw data used to generate Table 4.3. Note that this analysis did not include all potential permutations of survey sites- for example the estimated pSR using the regressed average number of unique taxa with most combinations of sites- say 1, 6 and

11 survey sites, or even 9, 10 and 11 survey sites. Table 4.3 presumes that any small discrepancies associated with adding a single survey site beyond 5 sites would be minimized by focusing primarily on increments of 5-10 sites, without missing the majority of the regression surveys shown in Appendix 4.2.1. The assumptions used to generate Table 4.3 are also needed to prevent evaluating a nearly infinite number of survey site combinations.

These data show that the projected species richness (at a standardized survey site density of 1 site per littoral hectare) calculated from the regression of pSR values at 15, 20, and 25 sites is within 2% of the projected species richness at the standardized survey site density (= 1 site per littoral hectare), with a standard deviation less than 10%- this is the first site permutation regression that has an accuracy of more than 95% with a standard deviation less than 10%. Figure 4.4 also shows that the pSR (at the standardized survey site density) calculated from the permutations for all "higher" site densities (20, 25, and 30 sites, etc.) are also equally accurate, indicating that a minimum of 25 survey sites should be sufficient to estimate pSR calculated from the entire dataset.

To distinguish the difference between large and small lakes, Table 4.4.2 separates the data from Table 4.4.1 into large lakes (littoral area > 100 hectares) and small lakes (littoral area < 100 hectares). These data show that while a minimum of 25 sites are needed to estimate pSR in large lakes, 10-15 sites may be sufficient to evaluate pSR in small lakes.

Table 4.4.2- Estimated % of Projected Species Richness (pSR) Based on Regressions of PIRTRAM Survey Site Data (Comparing Truncated Regressions to Regressions from the Entire Plant Survey Dataset

		Estimated % of pSR at 1 site/ha via Logarithmic Regression of Cumulative #Taxa in the following plant survey sites									
		Sites 1-3	Sites 2-4	Sites 3-5	Sites 4-10	Sites 5-15	Sites 10-20	Sites 15-25	Sites 20-30	Sites 25-40	Sites 30-50
if LA > 100	Mean	111%	115%	112%	112%	111%	106%	104%	103%	103%	104%
	SD	22%	23%	18%	14%	11%	11%	7%	7%	7%	6%
if LA < 100	Mean	102%	103%	102%	103%	103%	102%	101%	102%	103%	103%
	SD	19%	13%	10%	5%	5%	12%	5%	4%	2%	2%

Section 4.5- Discussion

The analysis summarized in Section 3 indicates that projected species richness (pSR) is a more accurate and reproduceable measure of species richness than is observed species richness (oSR), primarily due to inconsistencies in the number and density of survey sites in the littoral zone of surveyed lakes. Actual species richness may not be measurable due to the inability of surveyors to sample the entirety of the littoral zone, particularly submerged areas requiring sample collection rather than observation, although the data presented in Figure 3.1 suggests that nearly all aquatic plants are found as survey site densities increase. Nonetheless, species richness evaluations improve when standardized survey site densities are used, even if this requires projecting species richness values to that site density.

As discussed in White Paper 1C and in Section 3 of this White Paper, a survey site density of 1 site per littoral hectare is recommended to define a standardized pSR. In the absence of a precise number and identity of all aquatic plant species in a lake, White Paper 1C outlines a process for generating pSR values (at a density of 1 site/littoral hectare) from the distribution (frequency and abundance) of aquatic plant species in each of the surveyed sites. This value can be estimated in all of the PIRTRAM lakes, and presumably in any lake with "granular" survey site data- that is, a documentation of the frequency and abundance of each plant species at each surveyed site.

Although most of the PIRTRAM aquatic plant surveys summarized in these White Papers were conducing using sufficient resources to survey 1 site per littoral hectare, it is also possible that future aquatic plant surveys may also be unable to generate even the 0.2 to 7 sites per littoral hectare density reported in each of the PIRTRAM lakes in this study. Fortunately, the analysis summarized in Section 4.1 to 4.4 above outlines a process by which fewer survey sites (a lower density of survey sites) may be sufficient to generate accurate pSR estimates, recognizing that the other goals of surveys with higher site densities, such as finding all AIS or RTE species, evaluating plant communities in very small subject plots, etc., might not be met with truncated surveys, as discussed in White Papers 1E through 1G.

Table 4.5: Expected % of Observed (oSR) and Projected (pSR) Species Richness Obtained from 15 (small lake) and 25 (large lake) survey sites

Littoral area	15 Survey sites		25 Survey sites	
	% oSR	% pSR	% oSR	% pSR
<100 ha (small lakes)	93	102		
>100 ha (large lakes)			81	79

Section 4.4 above, specifically Tables 4.4.1 and 4.4.2, indicates that survey sizes of 15 to 25 sites should be sufficient to estimate projected species richness (pSR) to within 10% of the actual value computed at the standardized survey site density (= 1 site per littoral hectare), with a low standard deviation, using the methods outlined in Section 5 of White Paper 1C. Therefore, these smaller survey sizes appear to be sufficient to generate an accurate approximation of the pSR using only a fraction of the sites required to actually observe all of the species comprising this pSR.

In addition, Table 4.5 shows the percentage of unique plants expected given only 15 sites surveyed in small lakes (defined here as < 100 hectares of littoral area) and given only 25 sites in larger lakes. With few exceptions, these truncated surveys appear to be sufficient to find between 80-95% of all actually observed taxa, and 80-100% of all projected taxa (note that pSR is lower than oSR in some very small lakes with very high survey site densities, leading to %pSR values above 100 in Table 4.5). It is not known if a 25 site survey in "larger" lakes would be sufficient to find such a high number of plants for very large lakes- the PIRTRAM dataset suggest that these estimates may be accurate for large lakes with up to 700 hectares (1750 acres) of littoral area, which is larger than all but a few lakes surveyed in the NYS BioSurvey, ALSC, PIRTRAM or AWI studies.

It should also be noted that Tables 4.4.1, 4.4.2 and 4.5 only evaluate regressions using small "consecutive" intervals of plant survey sites, such as regressions from 1, 2 and 3 sites, 5, 10 and

15 sites, and so on. The accuracy of the pSR calculations could be even higher if different permutations of sites- say 5 sites, 15 sites and 25 sites- are used. An evaluation of a near infinite number of permutations to discover the greatest accuracy in projecting species richness values is beyond the scope of this White Paper, but could be considered by future analysts with greater computation abilities.

Truncated surveys can find a high percentage of the plants that would be found using the standardized survey site density of 1 site per littoral hectare. Appendix 3.1 shows that, for small lakes with a littoral area less than 40 hectares, a 15 site survey would find at least 85% of all plants likely to be observed using a standardized survey density of 1 site per hectare (and more than 95% in most of these lakes). For large lakes, a 40 site survey would find at least 70-75% of plants normally found in these standardized surveys, and more than 90% of the plants in many lakes.

Additional survey sites may provide less variance (and therefore greater confidence) in the data, but the differences in the estimated species richness and confidence in the data are small relative to the significant increase in sampling effort required to add additional survey sites. While adding additional survey sites may also find additional species, including potentially some unusual exotic plants or protected plant species not found in this 15-25 site survey, this additional sampling effort is not likely to significantly improve the estimates of the overall species richness or find a significantly greater number of unique plant species not seen in the smaller survey. These larger surveys would also be unlikely to find otherwise undiscovered AIS, since those plants tend to be common or abundant enough to be found in most smaller surveys, as discussed in White Paper 1E. **It should be noted that these smaller surveys may not be sufficient to meet other plant survey objectives, including finding ALL (or a specific) AIS or RTE species, including very new arrivals of single plants. Methods for addressing these other objectives are discussed in White Paper 1E through 1G, respectively.**

The findings in Section 4 suggest the following:

1. For existing surveys:
   a. all individual survey site data (indicating presence and relative abundance at each site for each plant on the overall lake plant species list, referred to as "granular survey site data") should be sought and documented. If not previously known, the size of the littoral area should also be determined. Projected species richness (pSR) should be calculated from littoral area data and the granular survey site data, using the modified bootstrap method described in this White Paper
   b. for lakes without granular survey site data, pSR should be estimated from the oSR – pSR regressions provided in Figure 3.3.1, but these pSR values should be clearly identified as estimates given the lack of granular survey site data.
   c. Figure 3.3.1 should be updated to account for oSR and pSR values from additional existing lakes with granular survey site data, to improve the regressions and future estimates of pSR from lakes with (only) oSR data

2. For new surveys:

a. Plant surveys should be conducted using a survey site density of 1 site per littoral hectare to generate actual species richness (expected to be = pSR) values equivalent to those calculated from the PIRTRAM lakes data in this White Paper.

b. Surveys with only limited resources should include at least 15 sites for small (< 100 ha littoral area) and at least 25 sites for larger lakes, distributed throughout the littoral zone, to generate a reasonable estimate for pSR. Note that large sample sizes (survey site densities exceeding 1 site per littoral hectare) may be needed to address other aquatic plant survey outputs discussed in White Papers 1E and 1F.

Section 5: Factors influencing species richness

Section 5.1- Background

Species richness appears to be strongly influenced by several factors. Some of these are static- do not change from year to year or represent an inherent baseline condition of the lake- while others are more dynamic, varying from year to year based on changes in conditions or in the surveys used to evaluate species richness. And other factors fall between static and dynamic- they could theoretically change from year to year, but in reality are fairly stable and changed little over the multi-year period in which a lake may have been surveyed in the programs outlined in White Paper 1A. These factors are summarized below.

1. Site frequency/Number of survey sites. The number of sites surveyed for aquatic plants in each of the Study programs is a dynamic factor that represents a balance between available time and resources, NYSDEC or other permitting requirements, size of the lake, and other factors. The relationship between the number of survey sites and the observed species richness (oSR) associated with those sites, and the projected number of survey sites and projected Species Richness (pSR), was discussed earlier in this White Paper. The optimal number of survey sites for finding AIS, finding protected species, optimizing sampling effort (based on several survey objectives), and for estimating floristic quality can also be estimated. These discussions are referenced in Section 4.1 of this White Paper,but are largely deferred to White Paper 1E- Plant Lists and Evaluation of AIS and Individual Species, White Paper 1F- Coefficients of Conservatism, and White Paper 1G- Floristic quality. However, the relationship between survey site density and species richness is discussed in Section 5.2. It should be noted that the number of survey sites is not known for the NYS BioSurvey lakes, ALSC lakes, and most-to-all of the AWI lakes, but the number of survey sites are defined for the PIRTRAM lakes.
2. Lake size. It is highly likely that species richness is connected to lake size (a static factor)- the larger lakes tend to have more plant species, given more available habitat (larger littoral area) and, at least in some larger lakes, more deep water to expand the littoral zone and support colonization and establishment of any plants that may be depth dependent. However, while lake size data are available for the vast majority of the Study Lakes, it is expected that littoral area (corresponding to the portions of the lake where plants can grow, as discussed below) is a much stronger influence. Nevertheless, the impact of lake size on species richness is evaluated in Section 5.3. Lake size is known for all of the lakes summarized in White Paper 1A.
3. Littoral area. As noted above, littoral area represents the portion of the lake in which sufficient light transmission exists to support colonization by aquatic plants. The definition of littoral area varies significantly within water quality studies, but for this study *a priori* is represented by the lake area within the first 15 feet of the lake, regardless of whether slope, flow, sediment type, or other factors will actually allow for plants to grow at a particular depth. Unfortunately, littoral area is not known for many of the NYS BioSurvey and ALSC lakes. The relationship between littoral area (as defined here) and species richness is also discussed in Section 5.3, along with the impact of lake area on

species richness. Littoral area is generally a static factor- although the actual littoral area in a lake could change slightly from year to year due to water quality conditions (related to light transmission), water level variations, and other factors, for the purposes of these evaluations, it is considered to be static.

4. Trophic state. As discussed in White Paper1A, water quality data are not available for nearly all Study lakes surveyed through the NYS BioSurvey, PIRTRAM program, and AWI program, and very little temporal water quality data are available for the ALSC study lakes. However, water quality data were collected in parallel water quality monitoring programs for many of these lakes, so species richness can be evaluated against trophic state (as a surrogate for multiple water quality indicators) for several lakes. This is evaluated in Section 5.4. As with littoral area, it is presumed that trophic state is a mostly static factor in most of these lakes, since most lakes do not exhibit a strong change in trophic state from one year to the next, at least for lakes surveyed within a few years.
5. Latitude (location). Although all of New York state can be characterized as temperate, the growing seasons differ from the extreme southern areas near the Atlantic coast, with moderating temperatures and winds, and the extreme northern areas near the Canadian border. Long Island, New York city, and the far southern Hudson Valley are considered “humid subtropical” on the Koppen climate type scale, while most of the rest of the state is described as either “warm-summer” or “hot-summer” humid continental. This results in different growing seasons, as summarized through the USDA growing zones (New York state is comprised of hardiness growing zones 4 through 7). Longer growing seasons associated with warmer weather clearly influence differences in native and invasive plant growth from the northern to southern US. The impact of latitude on species richness in New York state is evaluated in Section 5.5. Latitude should be considered a static factor.
6. Public access. It is presumed in most AIS literature that lakes with public access, particularly boat ramps, are more susceptible to AIS introduction (and perhaps colonization). Differences between species richness in lakes with public (state, county, or town) boat launches and in private lakes are explored in Section 5.6. Public access should be considered a static variable in these evaluations, since the ability of the public to access a waterbody (and by extension the ability to transport invasive or other plant species to a lake) does not change from year to year.
7. Presence of AIS, rare, threatened or endangered species (RTE) or other specific plants, particularly those associated with specific trophic states or background water chemistry (including pH), may influence species richness. This is evaluated briefly in Section 5.7, but the impact of AIS on aquatic plant community structure is discussed in much more detail in White Papers 1E through 1G. This is probably a static factor- it is presumed for these analyses that survey lakes should be assigned a binary “yes” or “no” re: the presence of AIS or threatened plants- any small variation in the presence of either AIS or RTE plants in these lakes from year to year is presumed to be an artifact of survey efficacy, not actual changes in the presence or absence of these plants.

8. Aquatic plant management. Aquatic plant management activities are driven by the perceived or actual imbalance of problematic plants relative to benign or beneficial plants- usually excessive levels of invasive or nuisance native plants. The species richness in these lakes may change in response to management, whether by effectively restoring native plant communities or decreasing both invasive and native plants through the application of a management technique (herbicides and other chemical controls, grass carp and other biological controls, and drawdown and other physical controls). It should be noted that these changes in species richness might not signal an improvement or degradation in floristic quality- these changes are better addressed through other measures outlined in White Paper 1G. The impact of aquatic plant management on species richness is discussed in Section 5.8. Aquatic plant management is definitely a dynamic variable- some lakes are managed only in some years, for reasons outlined in more detail in Section 5.8.
9. Floristic quality. Since the number of unique plant species (species richness) is embedded in formulae used to calculate floristic quality, the relationship between species richness and floristic quality is well established. However, within narrow ranges of species richness, floristic quality can differ significantly. The relationship between floristic quality and species richness is discussed at length in White Paper1G- Floristic Quality, which is dedicated exclusively to Floristic Quality. Floristic quality indices (FQI) should be considered dynamic factors that vary from year to year.

As discussed at length in Sections 3 and 4, p**rojected species richness (pSR) is the preferred method** for evaluating the (estimated) number of plant species in a lake as a result of assigning a specific and standardized survey site density and projecting the "standardized" species richness based on the distribution of plant species found in actual survey sites (the latter resulting in observed species richness, or oSR). However, converting oSR to pSR requires granular survey site data (the frequency and abundance of individual plant species at each survey site), which is not available for most surveyed lakes, including those surveyed in the NYS BioSurvey and ALSC program, and is available in only a modified form in the AWI surveys. So while pSR data are preferred to oSR data, in reality only oSR data are available for some lakes. **Fortunately, as seen in Figure 3.3.1, there is a strong relationship between oSR and pSR** in most PIRTRAM lakes, at least given the definitions of pSR used here (= projected species richness at 1 site per littoral hectare), so **many of the factors influencing species richness can be evaluated using oSR** as needed (and as discussed below). That said, the limitations of the oSR (or pSR) data in evaluating these factors are outlined in the discussion.

Section 5.2- Survey Site Density and Species Richness

Section 5.2.1- Background

It is expected that observed species richness (oSR) in surveyed lakes depends on the number of sites surveyed and evaluated for the presence of aquatic plants. Higher survey site densities lead to more sites surveyed within a defined littoral zone, likely resulting in more observed plants. In each of the aquatic plant survey programs cited in White Paper 1A, as the number of survey sites increase, species richness (a "counting" statistic, as opposed to a "rate" statistic) will also increase, or at least the cumulative species richness will stabilize using more sites than were surveyed in most monitoring programs. This observation is the foundation for the recommendation (outlined in White Paper 1C, and Section 3 of this White Paper) to adopt pSR as a measure to evaluate aquatic plant communities, since the latter standardizes the density of survey sites (and therefore the number of survey sites) within a defined littoral area for each lake. As discussed at length, a standardized density of aquatic plant survey sites within a littoral zone defined as 1 site per littoral hectare corresponds to a balance between the need to survey as much of the littoral zone as feasible, finding most aquatic plants in the lake, and avoiding overlapping survey errors.

Any change in oSR as a result of the density of survey sites needs to be separated from the absolute number of survey sites within a surveyed area (the littoral zone). As discussed in more detail in Section 5.3, oSR is expected to increase as the littoral area of a lake increases, for the same reasons as discussed with the relationship between oSR and survey site density- a larger littoral area provides more opportunities for plants to be observed and documented in the oSR value.

Section 5.2.2- Monitoring Programs Used to Evaluate Species Richness Based on the Density of Survey Sites

Species richness can be evaluated for lakes in several of the aquatic plant monitoring programs cited in White Paper 1A. Specifically, plant taxa were identified to species level in the Biological Survey (appx. 300 lakes), the PIRTRAM program (appx. 50 lakes) and the AWI plant survey program (appx. 150 lakes). For lakes sampled in the ALSC (upstate or downstate), with plants only identified to genera, species richness cannot be calculated using traditional means.

However, only the PIRTRAM dataset outlines the number of survey sites for each of the surveyed lakes, with granular data available summarizing the frequency and abundance of each plant at each surveyed site. As discussed at length above, species level identifications are required to calculate species richness. Species-level identifications are also available for both the NYS BioSurvey lakes and the AWI lakes. However, the number of sites surveyed in the NYS BioSurvey is not known, and the AWI data includes a mixture of rake toss granular data and plant bed data that does not include granular frequency and abundance data throughout the plant beds. Therefore, neither the NYS BioSurvey nor the AWI data can be used for these analyses.

Section 5.2.3- oSR and Survey Site Density

Table 5.2.3.1- Relationship between oSR and Survey Site Density in PIRTRAM Lakes

#Sites/Littoral hectare	# Lakes	oSR
0-0.8	9	10.2
0.8-1.2	11	14.5
1.2-2.4	9	13.4
2.4-4.0	10	12.5
> 4.0	9	13.8

Table 5.2.3.1 shows that oSR in the PIRTRAM lakes does not change significantly as survey site densities increase in these lakes. While oSR appears to be higher when the survey site density exceeds 0.8 sites per littoral hectare, these oSR values appear to stabilize from a site density of 0.8 to more than 4 per littoral hectare. Although not shown in Table 5.2.3.1, the standard deviation in these oSR values exceeds the difference between each of the survey site density categories. This suggests that the survey site density

does not influence species richness, despite the "intuitive" expectation that species richness will increase as the opportunities for finding plants increases.

However, as noted in Section 5.2.1, survey site densities need to be evaluated separately from the size of the littoral area, since it is also expected that the latter will also strongly influence species richness (for the same reasons as cited above). One way to evaluate these factors separately is to look at oSR changes based on changes in survey site densities within narrow defined littoral areas.

Table 5.2.3.2 summarizes the relationship between oSR and survey site densities within these narrow ranges of littoral area. **These data show that observed species richness (oSR) appears to increase with increasing survey site densities** in most lakes, ranging from less than 25 hectares to about 200 hectares of littoral area. However, this cannot be evaluated in the largest lakes (those with more than 200 hectares of littoral area) due to the limited number of large lakes available for evaluation.

Table 5.2.3.2- Relationship between oSR and Survey Site Density in PIRTRAM Lakes at Various Littoral Areas

Site Density	Littoral Area	N	oSR
0-1 sites/ha	<25 ha	4	5.3
1-3 sites/ha	<25 ha	7	6.8
>3 Sites/ha	<25 ha	12	12.0
0-1 sites/ha	25-50ha	4	10.0
1-3 sites/ha	25-50ha	5	10.7
>3 Sites/ha	25-50ha	4	15.5
0-1 sites/ha	50-200ha	4	13.6
1-3 sites/ha	50-200ha	4	21.8
>3 Sites/ha	50-200ha	0	
0-1 sites/ha	>200ha	2	21.7
1-3 sites/ha	>200ha	1	32.0
>3 Sites/ha	>200ha	1	24.8

Section 5.2.4- Discussion

These data confirm the expectation that species richness increases with the density of survey sites within the littoral area, due to a higher number of opportunities (survey sites) for finding additional plant species. Tables 5.2.3.1 and 5.2.3.2 summarizes an attempt to separate the influences of survey site density with the influence of the size of the littoral area, the latter of which also increases the opportunities for surveyors to find additional plants. The influence of the size of the littoral area on species richness is discussed in more detail in Section 5.3.

The influence of survey site density can confound an evaluation of the impact of other factors on species richness, including littoral area. More importantly, differing survey site densities can significantly impact evaluation of species richness of groups of lakes surveyed in different programs (which presumably exhibit different survey site densities), or even the same lake surveyed using different survey site densities. For these reasons, and consistent with the findings cited earlier in this White Paper, it is recommended that pSR be calculated at a standardized survey site density of 1 site per littoral hectare from observed species richness values and granular survey site data "set", using the methods outlined in Section 5 in White Paper 1C.

Section 5.3- Lake and Littoral Area and Species Richness

Section 5.3.1- Background

It is expected that species richness is strongly dependent on both lake and littoral area, since, as with survey site density discussed in Section 5.2, larger lake and littoral areas exhibit more opportunities (space) to find additional species, thereby increasing species richness. However, these factors significantly overlap in many lakes- the lakes with the largest surface area often have the largest littoral area- and may overlap with the number of survey sites (and survey site density). Therefore the effects of these factors need to be evaluated independently, at least as much as possible.

Although lake size may influence species richness, it is more likely that the size of the littoral zone more strongly influences species richness, since macrophytes will only grow within littoral zones. Lake size is a static factor that, within the confines of small variations in water level due to flooding, drought, withdrawal, evapotranspiration and other factors, and therefore lake size can be explicitly defined for each lake. Littoral area, however, is somewhat more dynamic than lake area; not only can the lake area change slightly, but the depth to which sufficient light reaches the lake bottom to support plant growth can change far more significantly in many lakes. Other factors, such as slope, sediment characteristics, water clarity, color and other water quality factors, water pressure, and the type of plants in the lake vary from lake to lake, over time, and over space. The actual littoral zone cannot be consistently and accurately measured for most lakes at all times, but for the purposes of these White Papers, the littoral zone is defined as the area of the lake less than 15 feet deep at the time bathymetry was collected (and is also therefore a static factor). This definition appears to be consistent with the deepest range of aquatic plant growth in most PIRTRAM lakes, although the ALSC historically used a depth of 10 feet to define the littoral zone in both clear- and colored- Adirondack lakes (and some clearwater lakes show evidence of submergent plants growing in water deeper than 15 feet).

Littoral area estimates generally require detailed bathymetric maps. For the majority of the NYS BioSurvey lakes, bathymetry, or at least bathymetry at the scale required to estimate the portion of the lake shallower than 15 feet, is not available. While the ALSC lakes include bathymetry for most of the surveyed lakes, the littoral area of these lakes (<15 feet deep) has not been defined, although the area of the lake less than 10 feet deep has been calculated for these lakes. Continuing work on the concepts outlined in these White Papers could calculate the (<15 feet) littoral area for the 1300+ ALSC lakes surveyed for aquatic plants, but as noted previously in this White Paper, the ALSC surveys included “only” aquatic plant ID to genera level, precluding the use of these data in determining (at least traditional) species richness. This work- estimating littoral area < 15 feet deep based on bathymetry available at the time of the ALSC surveys, could be undertaken by other researchers interested in evaluating genera richness.

For the majority of the PIRTRAM and AWI lakes, the littoral area is calculated from existing bathymetry, including bottom contour maps posted on the NYSDEC website (https://www.dec.ny.gov/outdoor/9920.html), the ALSC website (http://www.adirondacklakessurvey.org/historic.php), and other sources. The lakeshore and various contour lines on these maps can be outlined using manual planimetry (for example, sketching areas using Adobe sketching tools) and compared to lake areas defined in the NYS Fisheries Index Number (FIN) system. If 15 foot contour lines are not available for a lake, the areas for the 10 foot and 20 foot contours are linearly extrapolated to estimate the littoral area associated with a projected 15 foot contour line. For the small number of lakes with metric contour lines, the 15 foot contour was estimated from the displayed 5 meter contour line.

Section 5.3.2- Monitoring Programs Used to Evaluate Species Richness Based on Lake and Littoral Area

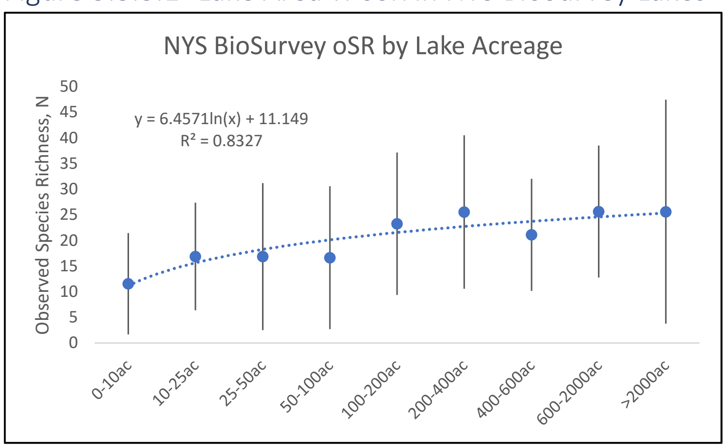
Three of the major NYS aquatic plant monitoring programs- the NYS BioSurvey, the PIRTRAM "program" and the AWI program- provide information to evaluate observed species richness (oSR). For these programs, the surface area of the surveyed lakes can be compared to oSR values. This allows for the use of large datasets- about 50 PIRTRAM lakes, more than 100 AWI lakes, and more than 300 NYS BioSurvey lakes- in evaluating the influence of lake area on species richness. However, as discussed at length in Section 4, projected species richness (pSR) is likely a far more accurate measure of species richness than is oSR, due to wide variations in survey site densities within and across these programs. In addition, it is expected that littoral area is a more accurate measure of "opportunities" for plant growth since most rooted aquatic plants are incapable of colonizing lake areas deeper than the littoral zone. As discussed above, granular survey site data and littoral areas are needed to estimate pSR.

There is no granular survey site data for the NYS BioSurvey- individual survey site granular (frequency and abundance estimates for each plant at each site) data were either not collected or have been lost over the last 100 years. For the AWI survey, rake toss granular data are combined with single estimates of aquatic plant frequency and abundance for entire weed beds; this prevents a clean conversion of these data into granular survey site data akin to that collected in the PIRTRAM study lakes. Therefore, only the PIRTRAM lakes can be used to evaluate the impact of littoral area on projected species richness (pSR).

Section 5.3.3- Influence of Lake and Littoral Area on oSR and pSR

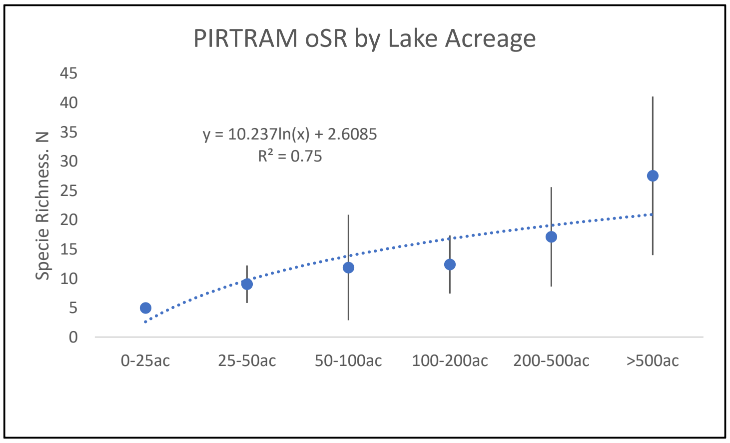
Figures 5.3.3.1 to 5.3.3.3 show the relationship between lake area and observed species richness (oSR) for the NYS BioSurvey (Figure 5.3.3.1), PIRTRAM (Figure 5.3.3.2) and AWI (Figure 5.3.3.3) lakes. The oSR data from the lakes in each of these programs shows a general increase in observed species richness (oSR) as the size of the lake (surface area) increases, although for each of these programs, this oSR increase is not consistent in each increment of increasing area. In addition, the error bars around each average value suggests a variance that

Figure 5.3.3.1- Lake Area v. oSR in NYS BioSurvey Lakes



might be higher than the change in observed species richness associated with increasing lake areas. Perhaps most importantly, the apparent (if statistically insignificant) increase in oSR associated with lake acreage may in fact mask the more important change associated with littoral area, since there is a general increase in littoral area with increases in lake areas.

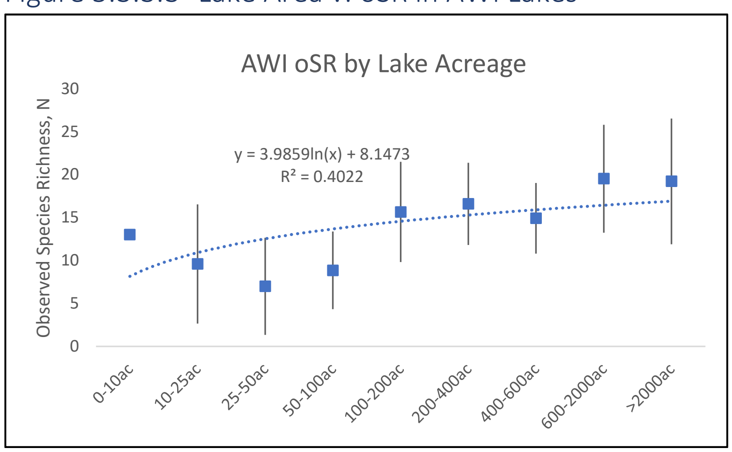
Figure 5.3.3.2- Lake Area v. oSR in PIRTRAM Lakes



To address these apparent conflicts, Table 5.3.3.1 shows the change in projected species richness (pSR) in PIRTRAM lakes based on increments of littoral areas- as discussed above, pSR is calculated as the estimated projected species richness at a standardized survey site density of 1 site per littoral hectare. Note that the number of lakes was much smaller than the 50 or so PIRTRAM lakes summarized in Figure 5.3.3.2, since the documentation of some of the lakes in this figure did not include the granular survey site data needed to convert oSR data to pSR. These data show a general increase in pSR values as the size of the littoral area increases, recognizing that each littoral area range includes only a few lakes (and therefore suffers from a lack of statistical rigor found in larger datasets).

This general increase in pSR with littoral area is not apparent in the pSR values falling between a littoral area of 30 and 200 acres. As discussed throughout Section 5, several factors appear to influence species richness and may be masking the apparent influence of littoral area on pSR in this range of littoral areas. One such influencing factor is trophic state, at discussed at length in Section 5.4. Evaluating only those lakes with a littoral area between 30 and 200 acres, Table 5.3.3.2 shows that within this relatively narrow range of littoral areas, trophic state strongly influences projected species richness.

Figure 5.3.3.3- Lake Area v. oSR in AWI Lakes



As discussed above, it may be important to separate the apparent influence of littoral area on species richness from the statistical correlation between lake area and species richness. Table 5.3.3.3. shows pSR values in several PIRTRAM lakes with nearly identical littoral areas but significantly different lake areas.

Each of the lakes in this table has similar trophic state (i.e. all of these lakes are mesoeutrophic to eutrophic) to avoid the influence of trophic state on species richness. **These data show that, for the lakes with similar littoral areas that exceed 10ha, pSR values do not appear to change with large changes in lake surface areas, although this is not apparent with the smallest lakes.**

Section 5.3.4- Discussion

The data presented in Section 5.3.3 demonstrate an increase in species richness (observed or projected) as either lake area or littoral area increases. As discussed above, this is expected given that increases in lake or littoral area increase the opportunities for additional plants to colonize and be surveyed, thereby increasing species richness. Other factors may be influencing these relationships, as seen in each of the Figures and Tables in Section 5.3- these factors include lake area (most lakes with large surface areas also exhibit large littoral areas) and trophic state (the oSR and pSR values in these Figures include a mix of trophic states that complicate comparison between groups of lakes). There are only a few lakes evaluated for projected species richness (pSR) as it relates to littoral area and trophic state (Tables 5.3.3.1 and 5.3.3.2) and differences in lake area relative to littoral area (Table 5.3.3.3), and it is possible that these apparent trends will not be sustained in larger datasets. However, these data do suggest that at least some relationships are apparent, and that **when trophic state and lake area are removed from the evaluation of Table 5.3.1, it appears that projected species richness increases as littoral areas increase.**

Table 5.3.3.1- Impact of Littoral Area on pSR in PIRTRAM Lakes

Littoral Area	#Lakes	pSR
0-30ac	3	7.4
30-55ac	4	6.6
55-100ac	3	13.6
100-200ac	2	8.8
200-500ac	3	18.5
>500ac	2	28.5

Table 5.3.3.2- Impact of Trophic State on pSR in PIRTRAM Lakes with Littoral Area between 30 and 200 acres

Trophic state	#Lakes	pSR
Oligotrophic	2	18.6
Mesotrophic	3	8.3
Eutrophic	4	5.7

This finding has important implications for evaluating pSR values in any specific lake. As discussed in Section 6, the development and application of any aquatic plant metrics using species richness should account for littoral area, a static factor that strongly influences the projected species richness in each lake. However, when evaluating long-term

Table 5.3.3.3- pSR Values in PIRTRAM Lakes with Similar Littoral Area and Trophic State but Different Surface Area

Lake	Littoral Area (ha)	Surface Area (ha)	pSR
Creamery Pond	4	4	5.1
Collins Lake	5	23	8.3
Hards Pond	12	12	8.8
Big Fresh Pond	13	34	8.5
Snyders Lake	15	45	8.2
Java Lake	21	21	6.0
Lake Ronkonkoma	21	92	3.6

changes in a lake or comparing lakes with similar littoral areas, the relationship between pSR and littoral area is less relevant.

Section 5.4- Trophic State and Species Richness

Section 5.4.1- Background

Species richness in any lake may be a function of lake productivity, perhaps akin to the expected relationship between lake productivity and the amount and type of phytoplankton growth. However, the relationship between phytoplankton and trophic state involves some redundancy, since phytoplankton growth (measured as chlorophyll *a*) is in itself a measure of lake productivity, and both phytoplankton growth and trophic state are a function of phosphorus levels. On the other hand, it is likely that macrophyte growth is often limited by nitrogen, which is not a direct measure of trophic state (at least in NYS), and trophic state is generally derived from open water chemistry conditions, while macrophytes tend to grow in the littoral zone. Nonetheless, it is expected that the higher water clarity and therefore depth of the photic zone, greater expected diversity in lake substrates, and reduced competition for nutrients by phytoplankton associated with lower lake productivity, would result in a greater diversity of aquatic plants in mesotrophic and oligotrophic lakes, even though sediment nutrition may be higher in more productive lakes.

It is expected that mesotrophic to slightly oligotrophic lakes also exhibit a wider annual and seasonal variation in water quality conditions than do eutrophic lakes, perhaps selecting for a wide variety of aquatic plants that can thrive across the range of productivity levels found in these lakes (recognizing that highly acidic lakes, which tend to be hyperoligotrophic, and highly colored dystrophic lakes, which may defy traditional trophic state characterization, tend to have reduced aquatic plant growth and low species richness). Finally, lower water clarity has been demonstrated to more strongly select for invasive plants, since these plants are often capable of growing in low light conditions. As discussed throughout this White Paper, lower species richness is often associated with dominance (in frequency of sites and abundance within these sites) of invasive species.

Therefore, it is anticipated that species richness will increase with lower lake productivity.

Section 5.4.2- Monitoring Programs Used to Evaluate Trophic Status and Species Richness

As noted above and in White Paper 1A, water quality data are generally not available for the NYS BioSurvey lakes, so the trophic status of these lakes cannot be accurately determined (and any existing water quality data, such as water clarity, may be up to 100 years old and were collected during only single sampling sessions). The ALSC plants were only identified to genera, so species richness can't be evaluated despite at least some trophic data collected in the ALSC program. While some of the AWI lakes were also analyzed through other water quality monitoring programs (including the Adirondack Lake Assessment Program, or ALAP), it is likely that most of these lakes would be characterized as oligotrophic or mesotrophic (and projected species richness (pSR) estimates cannot be obtained without converting either plant bed data or rake toss data to equivalent grid-based point intercept rake toss data distributed homogeneously throughout the littoral zone).

Therefore, evaluations of the impact of trophic state on projected species richness is limited to the PIRTRAM lakes with granular survey data, although as will be seen in Section 5.4.3, species richness will need to be evaluated as observed species richness (oSR) in the slightly larger PIRTRAM dataset due to only a limited number of lakes in each trophic state and in each (littoral area) size range for which projected species richness (pSR) values are available.

Section 5.4.3- Influence of Trophic State on Species Richness

The relationship between trophic state and species richness was introduced briefly in Table 5.3.3.2, which looked at pSR in nine PIRTRAM lakes with a littoral area between 30 and 200 acres, to minimize the influence of littoral area (Section 5.3) and species richness. These lakes ranged from oligotrophic to eutrophic. The data in Table 5.3.3.2 suggests that pSR was significantly higher in the lakes with lower lake productivity, and lower in the lakes with higher lake productivity, as expected. Unfortunately, there were not enough PIRTRAM lakes with granular survey site data in each trophic state and littoral area category to extend these findings across the range of lakes (in regards to water quality conditions and littoral area sizes) surveyed in New York state.

Table 5.4- Impact of Trophic State on oSR in PIRTRAM Lakes with Range of Littoral Areas

Trophic State	Littoral Area	#Lakes	Avg oSR
Meso/oligotrophic	<25 ha	6	13.2
Eutrophic	<25 ha	17	7.8
Meso/oligotrophic	25-50ha	8	14.3
Eutrophic	25-50ha	5	8.2
Meso/oligotrophic	50-200ha	4	18.8
Eutrophic	50-200ha	4	16.6
Meso/oligotrophic	>200ha	3	38.6
Eutrophic	>200ha	2	21.7

To address these data limitations, Table 5.4 compares observed species richness (oSR) in lakes with lower algal productivity (oligotrophic and mesotrophic lakes) to oSR values in more productive (eutrophic) lakes within several ranges of littoral area. As seen in this Table, oSR values increase as the size of the littoral area increases, as expected given the findings in Section 5.3 of this White Paper (via Table 5.3.3.2), and consistent with expectations that species richness increases with more space for plants to grow. However, this table also shows that oSR values were slightly to significantly larger in lakes with lower productivity than in lakes with higher productivity across the entire range of littoral values.

Section 5.4.4- Discussion of Results

Tables 5.3.3.2 suggest that pSR was highest in lakes with the lowest lake productivity in lakes with a littoral area between 30 (small) and 200 acres (large), and Table 5.4 suggest that oSR was also highest in low productivity lakes across the entire range of littoral area sizes surveyed in the PIRTRAM study lakes. Both tables reflect an apparent pattern based on relatively small numbers of lakes, and other factors- such as the presence of invasive species or public access, and challenges in using observed species richness values- may have masked any contradictory findings. **However, these data are consistent with the expectation that species richness is**

highest in lakes with high water clarity and reduced competition for growth nutrients from phytoplankton. As noted above, the lakes with low water clarity and high nutrient levels tend to select for invasive species, since these generalist plants can thrive in low light conditions and despite increased competition from phytoplankton. AIS are also more likely to take up growing habitats (space) that could otherwise be occupied by native plants. The relationship between species richness and the presence (and relative abundance) of invasive species is discussed more in Section 5.7 of this White Paper.

However, these findings also suggest that a more detailed study should be conducted evaluating the influence of trophic state on species richness. Such a study would involve more lakes across the trophic spectrum and would include lakes with small and large littoral areas. It is anticipated that future researchers will be able to explore these relationships as more lakes (with trophic status data) are surveyed for aquatic plants, preferably using PIRTRAM-like methods.

Section 5.5- Latitude and Species Richness

Section 5.5.1- Background

Another factor that might influence species richness is latitude, since lower latitudes (in the northern hemisphere) experience longer growing seasons and warmer weather, both of which may allow for more and different types of plants to grow. Within New York, the variation in growing season is not as significant as the variation between any part of New York and southern states supporting different aquatic plants, but at least antidotally, the growing season in Long Island and New York City is longer than in the northern Adirondacks. While a universal distinction between "north" and "south" has not been developed, the PIRTRAM lakes appear to be fairly evenly distributed above and below the 42 degree North latitude line, roughly corresponding to the northern Pennsylvania border. This also roughly corresponds to the difference between USDA plant hardiness growing zones 3 through 5 ("north") and 6 through 7 ("south") (https://www.gardeningknowhow.com/wp-content/uploads/2004/10/new_york_map_lg.gif).

As noted above, multiple factors may be influencing species richness, including number of survey sites, lake area, and trophic state, as well as long-term changes in lake conditions. The analyses summarized in Section 5.5 attempt to limit the evaluation of latitude on species richness to specific categories associated with littoral area and trophic condition, to limit the variations in species richness associated with these other factors. In addition, and as noted above, although projected species richness (pSR) appears to be a much stronger indicator of lake species richness than in observed species richness (oSR), the former requires granular survey site data that are not available for some PIRTRAM lakes, and for all AWI lakes (without significant "site" manipulation), all ALSC lakes, and all NYS BioSurvey lakes. Therefore, the influence of latitude on species richness in this section focuses on oSR values, due to an insufficiently large database of pSR values.

Section 5.5.2- Monitoring Programs Used to Evaluate Latitude and Species Richness

As discussed at length above, only the PIRTRAM and AWI lakes can be used to evaluate the effect of latitude on species richness, since this impact is evaluated using oSR calculated on lakes surveyed within a short window of time. Although the use of projected species richness would be preferred, confining these analyses to pSR would limit the ability to evaluate latitude on species richness within narrow ranges of littoral areas and trophic status, since both of the latter can strongly influence species richness, as seen in Sections 5.3 (littoral area) and 5.4 (trophic status). It should be noted that the 42 degree latitude demarcation of "north" includes all lakes above the 42 degree latitude line and therefore combines Adirondack and non-Adirondack lakes. As discussed elsewhere in this White Paper, it is reasonable to assume that lakes within and outside the Adirondack Park may be significantly different (from each other) even if they share similar latitudes, due to ecological conditions unique to the Adirondack Park. For that reason, the oSR evaluations for the AWI lakes, limited entirely to the Adirondacks, supplement the oSR evaluations for the "north" PIRTRAM (which primarily fall outside of the Adirondacks) in comparison to "south" lakes, allowing the reader to distinguish those lakes within the Park from those outside the Park. This is further discussed below in Section 5.5.3.

Section 5.5.3- Influence of Latitude on Species Richness

Table 5.5.3 shows the observed species richness (oSR) for the "North" (latitude above 42 degrees) and "South" (latitude below 42 degrees) PIRTRAM lakes and the AWI lakes in varying intervals of littoral areas. This table also shows the percentage of eutrophic lakes in each lake category and size range, since (as seen in Section 5.4) there may be a strong relationship between species richness and trophic state. Trophic data are not available for many of the AWI lakes, since the AWI plant surveying program is distinct from the AWI water quality monitoring programs (White Paper 1A). However, it should be assumed that the vast majority of AWI lakes surveyed for aquatic plants were either mesotrophic or oligotrophic.

Table 5.5.3: oSR v. Littoral Area by Latitude for PIRTRAM and AWI Lakes

Littoral Area Range	Latitude	# Lakes	oSR	%Eutrophic
0-50ac	South	14	8.2	79%
	North	3	12.8	67%
	AWI	18	9.2	NA
50-100ac	South	6	7.0	67%
	North	6	16.1	17%
	AWI	7	15.1	NA
100-200ac	South	3	13.5	33%
	North	7	13.2	43%
	AWI	31	16.5	NA
200-500ac	South	4	14.1	50%
	North	11	14.6	55%
	AWI	17	15.2	NA
>500ac	South	0		
	North	5	31.8	40%
	AWI	21	20.5	NA

This table shows that for lakes with a littoral area greater than 100 acres, the oSR values for the North and South PIRTRAM lakes are similar (recognizing that there were no "South" PIRTRAM lakes with a littoral area greater than 500 acres). Perhaps not coincidentally, the percentage of eutrophic North and South lakes in this size range was similar. Among these larger lakes, the oSR values in the AWI lakes were slightly higher; this reflects at least in part the relative lack of eutrophic lakes (presumably with lower oSR values) in the Adirondacks.

In the smaller size range (<100 acre littoral area), the North PIRTRAM lakes possessed higher oSR values than did the South PIRTRAM lakes in the same size range, with the oSR values in the AWI lakes falling between these two extremes. However, it is likely that much of this difference reflects the higher percentage of eutrophic lakes in the PIRTRAM program below the 42 degree latitude line, and could reflect the differences in survey design in the PIRTRAM and AWI programs.

Section 5.5.4- Discussion of Results

Table 5.5.3 indicates that, for most lakes with littoral areas greater than 100 acres, there is not a significant difference in observed species richness (oSR) at lakes north or south of the 42 degree latitude line, whether considering lakes inside or outside the Adirondacks. This relative consistency in oSR values across the PIRTRAM and AWI programs occurs despite differences in the survey designs in these two programs. These data suggest that, at least for larger lakes, the differences from southern New York to northern New York in temperatures, length of the growing season and perhaps intensity of the solar radiation may be small enough to exert only a limited impact on species richness in lakes. These relative consistencies also occur despite what are no doubt significant differences in the watershed and characteristics of the lakes comprising these datasets in regards to elevation, sediment characteristics, water quality (even within trophic categories), and other factors.

For smaller lakes- those with littoral areas less than 100 acres- the northern lakes (including those within the Adirondack Park) had much higher oSR values than did the southern lakes. As noted above, some of this could be explained by the higher percentages of eutrophic lakes south of the 42 degree latitude line, bringing down the average oSR for the southern lakes. The wide gap in percentages of eutrophic lakes between the northern/AWI and southern lakes in the 50-100 acre littoral area range may in fact be sufficient to explain the differences in oSR values between these two lake groups. Table 5.4 shows that, in the 50-100 acre (or 20-40 hectare) littoral area range, meso-oligotrophic lakes have oSR values about 75% higher than eutrophic lakes. When these values are applied to the 50-100 acre littoral area oSR values for the northern and southern lakes, corrected for the percentage of eutrophic lakes in each category, the differences in oSR values between the northern and southern lakes essentially disappear.

In the smallest size range (littoral area < 50 acres), the northern lakes have oSR values about 60% higher than in southern lakes, although the AWI (Adirondack) lakes have oSR values closer to the southern lakes oSR values (despite few if any eutrophic lakes). The absolute differences between these average oSR values are relatively small, and might be strongly influenced by other factors, such as the presence or dominance of invasive species. These data might also be influenced by the small sample size- only a few northern PIRTRAM lakes fall within this littoral size range. **Although these analyses would benefit from significantly larger datasets, the data in Table 5.5.3 suggest that latitude, at least within New York state, does not appear to strongly influence species richness.**

Section 5.6- Public Access and Species Richness

Section 5.6.1- Background

It has been long established that public access- specifically, public use of lakes by outside trailed power boats- contribute to the spread of invasive species. Hitchhiking plants, including roots, seeds, fragments, and other reproductive structures, can attach to trailers, propellers, and other parts of a boat in contact with plants. While the transport of invasive plants is often facilitated by the uprooting of canopy-forming or near-launch beds of invasive plants, the same mechanism might also support transit of other native plants, even if those plants comprise a lesser component of the aquatic plant community. Moreover, some of these boats were previously recreating on other lakes, including some lakes found a great distance away, that may harbor plants not otherwise found in the next visited lake. Therefore, the presence of any (native or invasive) plant in a lake may be enhanced by the availability of public access, and therefore species richness could be higher in lakes with public access.

Lake access can be characterized for this White Paper in one of three categories:

a. hard boat ramps supporting trailers and therefore powered boats (although this may also include marinas and dirt launches with sufficient depth to support trailed boats);
b. hand carry boat launches supporting non-trailed boats (canoes, kayaks, and some smaller motored boats), including public beaches, adjacent public parkland, fishing piers, wildlife management areas and other public egress points; and
c. private access limited to lakefront residents and invited guests, including non-transitory power boats (and, at least in theory, lakes with no access)

For the purposes of this evaluation, category (a) is separated from the other two categories, since it is presumed that the vast majority of aquatic plant transport is associated with larger powered motorboats and their trailers. A more refined future analysis could conduct a similar analysis using each of the three lake access categories listed above.

Section 5.6.2- Monitoring Programs Used to Evaluate Public Access and Species Richness

Information about public access is available for some of the lakes surveyed in the programs in White Paper 1A. As discussed above, species richness cannot be calculated from the ALSC dataset due to the lack of species-level plant identifications, and it is not known if the present lake access information for the NYS BioSurvey lakes was applicable at the time of the surveys (from 1926-1934). In addition, public access status is not available, even in the present, in many of the NYS BioSurvey lakes.

As with the evaluation of the influence of latitude on species richness, an evaluation of public access may best be conducted when other factors are held steady. This includes trophic state (limiting the evaluation to eutrophic lakes, given the higher percentage of eutrophic lakes in the study candidate pool) and lake or littoral size (limiting the evaluation to smaller lakes). As with the assessments of other factors influencing species richness, projected species richness (pSR) appears to be a superior assessment tool relative to observed species richness (oSR). However, if public access needs to be assessed in a subset of PIRTRAM lakes within a narrow size (littoral area) and (eu) trophic range to minimize influences of other factors on species richness, oSR needs to be used to avoid drawing conclusions from extremely small datasets (although as will be seen in Table 5.6.3.1, even the oSR dataset is quite limited). Fortunately, as seen in Figure 3.3.1, there is a strong relationship between oSR and pSR in most PIRTRAM lakes.

A separate evaluation of AWI lakes is also conducted, reviewing the relationship between oSR and public access only in those Adirondack lakes surveyed by AWI, based on the assumption that oSR may be comparable across lakes in the same monitoring program. Unfortunately, since most of the AWI lakes are NOT eutrophic, they cannot be evaluated in the same analysis as the PIRTRAM lakes, given the strong relationship between trophic state and species richness.

Section 5.6.3- Evaluation of Public Access and Species Richness

Table 5.6.3.1 shows the relationship between oSR and littoral area for eutrophic PIRTRAM lakes with and without public powerboat access (boat ramps), across various littoral area ranges. Both the size range and trophic filters were applied to avoid interference with either of those factors on species richness. These data suggest that oSR values did not appear to be consistently dependent on the availability of boat access, although it is clear that the very limited number of lakes in each category precludes a comprehensive evaluation of public access on species richness. There were more than 2 lakes in each littoral size category in only the “No Ramp” option in the 0-25 and 25-100 acre size ranges, and the other size categories do not include enough lakes to evaluate the influence of public access on PIRTRAM lakes. In short, there are insufficient numbers of lakes in each littoral area range and access category (“ramp” or “no ramp”) to evaluate the impact of public access on oSR.

Table 5.6.3.1- oSR v. Littoral Area based on Public Access in Eutrophic PIRTRAM Lakes

Littoral Area	Access	# Lakes	oSR
0-25 ac	Ramp	2	4.4
0-25 ac	No Ramp	15	8.3
25-100 ac	Ramp	0	
25-100 ac	No Ramp	5	8.2
100-200 ac	Ramp	2	21.7
100-200 ac	No Ramp	2	11.5
>200 ac	Ramp	2	26.5
>200 ac	No Ramp	0	

This analysis was expanded, given the small number of lakes in each category in Table 5.6.3.1, to include the larger AWI dataset, as summarized in Table 5.6.3.2. An evaluation of the data in this table appears to confirm the data-sparse results from Table 5.6.3.1, showing little difference in oSR values for lakes with boat ramp access compared to those lakes without boat ramps, across the entirety of the littoral size ranges. Although variance was not analyzed in any of these size ranges, it is reasonable to assume that the differences in each littoral area range between lakes with access and lakes without access were not statistically significant.

Table 5.6.3.2- oSR v. Littoral Area based on Public Access in All AWI Lakes

Littoral Area	Access	# Lakes	oSR
0-25 ac	Ramp	0	
0-25 ac	No Ramp	13	9.4
25-100 ac	Ramp	5	12.8
25-100 ac	No Ramp	7	12.3
100-200 ac	Ramp	11	17.0
100-200 ac	No Ramp	20	16.3
200-500 ac	Ramp	6	14.7
200-500 ac	No Ramp	11	15.5
>500 ac	Ramp	13	21.3
>500 ac	No Ramp	8	19.3

Section 5.6.4- Discussion of Results

These results do not show a significant difference in species richness in lakes with public access compared to lakes without public access. This appears to be in conflict with expectations, since it is well documented that at least invasive species are commonly transported into lakes through public access points. There may be several reasons why this is not apparent from the data presented in Tables 5.6.3.1 and 5.6.3.2:

- Problems with conducting this analysis using oSR rather than pSR. As discussed at length in Section 4, pSR is a preferred metric to oSR, given differences in survey site densities in some surveyed lakes. Unfortunately, there are not enough lakes with pSR values in each category to use that metric. It is not known if a similar lack of evidence that public access influences species richness would be apparent if there were enough lakes with pSR data to refine these tables, thereby standardizing the species richness measurements across each analyzed size category.
- Differences between AIS and other plants. Most of the narrative around plant introductions from public boat launches revolves around invasive species. Since AIS often dominate aquatic plant communities in lakes, particularly near public launches (where they may have been initially deposited), it is often assumed that AIS are more likely than native plants to be transported through public access points. Even though boat steward inspection programs encourage the removal of any (all) plants from boat props and trailers, AIS introductions may be more strongly connected to public access points. And since AIS usually represent only a small percentage of all species comprising the oSR or pSR in a lake, any changes in species richness associated solely with AIS may not be apparent when counting all plant species. AIS colonization is addressed further in Section 5.7 below and in White Paper 1E.
- The number of species (i.e. species richness) may not change, but those (likely AIS) plants that are transported into lakes via boat launches may be appearing at much higher frequency or abundance. This may be due to continuous introductions through these launches, or (more likely) explosive growth and expansion once individual invasive plants are introduced and become established. As noted above, AIS as an increasing percentage of an aquatic plant community- in both frequency of sites within lakes and abundance within these sites- is discussed in more detail in Section 5.7 below and in White Paper 1E.

For these reasons, although the data presented in Table 5.6.3.1 and 5.6.3.2 do NOT indicate that species richness changes in lakes with public access points, the effects of public access may be more apparent in evaluating other metrics, such as invasive species introduction, dominance (frequency and/or abundance) of these invasive species, or changes in floristic quality indices (FQI) in response to these introductions, as discussed in White Papers 1E through 1G. A much larger dataset would be needed to verify that species richness is not significantly affected by public access.

Section 5.7- AIS Dominated Lakes and Species Richness

Section 5.7.1- Introduction

The need for invasive species prevention and management derives in part from the expectation, borne out by multiple studies, that invasive species can significantly impact plant diversity, the latter of which can be measured by species richness. Invasive species have been demonstrated to occupy space, selectively consume available nutrients, shade and reduce available sunlight for low lying plants, and otherwise out-compete native plants. However, one of the primary mechanisms by which invasive species enter a lake- transport by boats- can also introduce native plants that ultimately contribute to species richness calculations, as discussed in Section 5.6 of this White Paper. The role in invasive species in suppressing native plant densities is further evaluated in White Papers 1E through 1G, but this White Paper evaluates the impact of invasive species on species richness.

A distinction likely needs to be established between the *presence* of an invasive species and the *dominance* of these invaders. Some invasive species have, at least temporarily, little effect on species richness prior to their establishment and explosive growth. These plants, although already highly invasive in many lakes and eventually invasive in most lakes, may not yet have crowded out the habitat for other plants. In fact, since these pre-invasive plants are new to a lake, they may actually increase species richness, at least initially. Later, plants that are among the most common in a lake, in frequency or abundance, have the potential for overtaking an aquatic plant community. These distinctions- *present* versus *dominant*- may manifest themselves in different impacts to species richness.

Section 5.7.2- Monitoring Programs Used to Evaluate Invasive Plants and Species Richness

Neither the NYS BioSurvey program nor the ALSC program can be used to evaluate the impact of invasive species on species richness, since the vast majority of AIS were not present in the state prior to the end of the BioSurvey program in the 1930s, and the ALSC program does not include species-level identification of plants needed to determine species richness.

The New York version of the iMapInvasives program (https://www.nyimapinvasives.org/) documents the presence, and in some cases the extent, of AIS (those exotic and invasive plants defined in NYCRR Part 575) in lakes throughout the state. While this is an incomplete dataset, since most of the nearly 16,000 lakes, ponds and reservoirs with greater than 0.1 acres of surface area have never been surveyed for aquatic plants, it is presumed that the completeness of the PIRTRAM and AWI surveys would likely find any AIS present on the surveyed lakes. However, it should also be noted that the PIRTRAM and AWI surveys found nearly all of the AIS species, and certainly all of the dominant AIS species, that were reported in the iMapInvasives database for lakes surveyed in these programs. As discussed above, observed species richness (oSR) was calculated for all of the PIRTRAM and AWI lakes, and projected species richness (pSR) was calculated for some PIRTRAM lakes.

Section 5.7.3- Evaluation of Invasive Plants and Species Richness

Nearly all of the lakes in Appendix 1.1 and 1.2 in White Paper 1A have at least one invasive plant. This is not surprising, since more than 700 New York state lakes have been documented with AIS since the mid-1990s (Kishbaugh, 2018; iMapInvasives database), a timeframe after which the PIRTRAM and AWI programs became established. Most of these lakes are heavily used by the public, either through public boat launch sites or lake resident access, the same cross-section of lakes most likely to be surveyed by agencies or lake consultants. Therefore, the "mere" presence of an AIS cannot be used in evaluating the impact of AIS on species richness in the PIRTRAM program or in most lakes outside the Adirondack Park. In many of these lakes, AIS have been present for many years, and are often well established in these lakes. The likely impact of AIS is associated with "dominance" of AIS, defined here as being among the two or three most frequent and/or abundant plants in the lake.

However, many Adirondack lakes have only recently been invaded by some of these AIS, due to the distance from these lakes to long infected lakes, the extensive use of boat stewards on those Adirondack lakes with public boat ramps, and perhaps due to water quality and sediment characteristics in these lakes. For these lakes, surveyed through the AWI program, lakes with AIS dominance and AIS presence are differentiated from those without any evidence of AIS- this may help to identify lakes vulnerable to ecological change as AIS species increase in frequency and abundance in these lakes.

Table 5.7.3.1 – oSR in PIRTRAM Lakes by AIS Dominance and Littoral Area

Littoral Area	AIS Category	# Lakes	oSR	% Eutrophic
0-25 ac	AIS Dominated	15	7.8	87%
	Not AIS Dominated	7	12.5	57%
25-100 ac	AIS Dominated	13	11.9	38%
	Not AIS Dominated	4	16.5	0%
100-200 ac	AIS Dominated	5	16.9	80%
	Not AIS Dominated	0		
>200 ac	AIS Dominated	3	34.7	33%
	Not AIS Dominated	2	27.5	50%

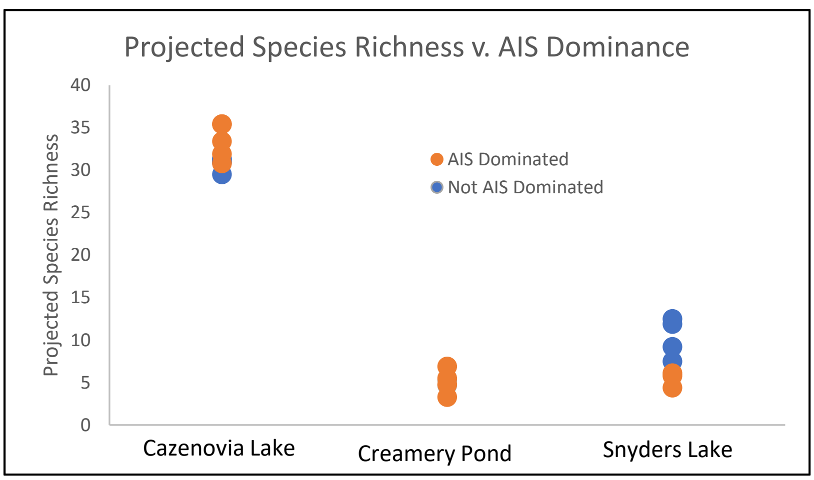


Figure 5.7.3- pSR v. AIS Dominance in Select PIRTRAM Lakes

Table 5.7.3.1 shows the oSR in PIRTRAM lakes across various (littoral area) size ranges, based on whether AIS are among the two most frequency reported or abundant plants (i.e. dominant) in these lakes. This table also shows the percentage of eutrophic lakes in each grouping, since (as per Section 5.5 of the White Paper) trophic state can strongly influence species richness. The data in Table 5.7.3.1 show that species richness is higher in lakes without dominance by AIS, at least in lakes with littoral areas less than 100 acres, but there are too few lakes with higher littoral areas in the PIRTRAM dataset to evaluate the impact of AIS dominance on oSR. In addition, most of the smaller AIS dominant lakes are eutrophic, but it is not known how much of the suppression of species richness in these lakes is due to reduced light transmission associated with higher trophic state (see Section 5.5) and how much is due to AIS dominance.

The latter point- the impact of AIS dominance of species richness independent of trophic state- is evaluated in Figure 5.7.3. This figure looks at three lakes with relatively stable trophic state that were surveyed over multiple years- Cazenovia Lake (>200ac littoral, mesotrophic), Creamery Pond (<25ac littoral, eutrophic) and Snyders Lake (<25ac littoral, mesoeutrophic). The orange dots in Figure 5.7.3 show the projected species richness (pSR) in the years when AIS (Eurasian watermilfoil in Cazenovia Lake and Snyders Lake, hydrilla in Creamery Pond) were the among the most frequent or abundant plants in the lake. The blue dots correspond to years when these AIS were not among the most frequent or dominant. Again, as noted earlier, pSR is defined here as the projected species richness at a standardized survey site density of 1 site per littoral hectare.

These data suggest that AIS dominance did not strongly influence pSR in Cazenovia Lake or Creamery Pond, but may have suppressed pSR in Snyders Lake. However, as discussed at length in Section 5.8, each of these lakes were at least periodically managed for invasive plants during the years covered in Figure 5.7.3. In addition, this management was sporadic- herbicides in some years in all three lakes, grass carp stocking in the middle of this period in Creamery Pond- and this management rather than a high frequency or abundance of AIS may have strongly influenced species richness. Unfortunately, the PIRTRAM dataset does not include enough lakes surveyed for a long enough period of time to include many years of both AIS dominance and native plant dominance to evaluate this factor.

However, the AWI dataset generally involves lakes that have not been actively managed, or at least have been managed using species-specific and localized management actions (such as hand harvesting. Table 5.7.3.2 indicates that the AWI lakes, like the PIRTRAM lakes evaluated in Table 5.7.3.1, “suffer” from a very limited number of lakes with small littoral areas across the range of AIS abundance. The oSR in lakes with less than 100 littoral acres in Table 5.7.3.2 is highly variable, so the impact of AIS presence or dominance on species richness cannot be evaluated (note that pSR values could not be calculated due to the lack of granular survey site data in these lakes). The larger lakes show higher oSR values in lakes with AIS (whether

Table 5.7.3.2 – oSR in AWI Lakes by AIS Dominance and Littoral Area

Littoral Area	AIS Category	# Lakes	oSR
0-25 ac	AIS Dominated	0	
	AIS Present	1	25.0
	Not AIS Dominated	12	8.1
25-100 ac	AIS Dominated	2	28.5
	AIS Present	1	9.0
	Not AIS Dominated	9	9.3
100-200 ac	AIS Dominated	2	17.5
	AIS Present	6	18.3
	Not AIS Dominated	23	16.0
>200 ac	AIS Dominated	7	18.1
	AIS Present	12	23.4
	Not AIS Dominated	18	14.6

dominant or not) than in lakes without AIS, although the differences in the average oSR values in these lakes may reflect the influences of other factors discussed elsewhere in this White Paper. At the least, these data do suggest that the presence or dominance of AIS species does not appear to strongly influence species richness.

Section 5.7.4- Discussion of Results

The results from Figure 5.7.3 and Tables 5.7.3.1 and 5.7.3.2 do not show a strong influence on species richness by the presence or dominance of invasive species. This appears to be contradictory to expectations and the long-standing narrative that invasive species introductions and colonization (dominance) negatively impact the aquatic plant communities in lakes. However, this "finding" does appear to be consistent with the lack of a strong connection between public boat access (Section 5.6) and species richness, since the former is also expected to be the portal for the introduction (and eventual colonization) of invasive species in lakes. Many of the explanatory reasons cited in Section 5.6 for the lack of connection between public access and species richness may apply here.

To reiterate the factors that might explain these apparently contradictory findings:

a. The datasets used in the analyses in Section 5.7 are small and may not represent findings in other parts of the state, or in other Adirondack lakes. This small dataset includes a blending of potential impacts from other factors cited above, including trophic state, littoral area (even within confined small ranges of littoral area cited in these figures and tables) and normal variability in species richness from year to year.
b. As noted above, the presence or dominance of AIS may reflect habitat supporting any plant growth, and thus might also support a larger number of native plants. This may be of particular concern in the Adirondacks, where reduced species richness may reflect other factors, including lake acidity, poor sediment nutrition, dystrophy, high elevation, and reduced transit of plant materials due to "natural" plant migration. Therefore, although AIS introduction and increasing abundance (whether transmitted through boat launches) may ultimately impact species richness and other aquatic plant community metrics, they may be associated with lakes that are capable of supporting many plant species, including AIS.
c. It is presumed that one of the primary concerns about AIS introduction and dominance is the alteration of the balance of otherwise healthy and diverse aquatic plant communities. Most, if not all, of the lakes characterized in Section 5.7 represent "mature" AIS invasions, in which any ecological or floral habitat changes resulting from AIS introduction and establishment had occurred long before the first of these surveys (and therefore sometime between the NYS BioSurveys of the 1920s and 1930s and the PIRTRAM/AWI surveys of the 2000s and 2010s). Some of this is addressed in Section 2 of this White Paper, showing the long-term changes in plant communities in response to AIS introduction (and other factors). The use of "Genera Richness" calculations involving lakes sampled during the 1980s ALSC surveys and the later PIRTRAM/AWI surveys may be instructive in evaluating changes in these lakes as AIS dominance

became established, but the more contemporary data may not be useful in establishing a relationship between AIS dominance and projected species richness.

d. Perhaps most importantly, species richness may not be the best metric for evaluating impacts on aquatic plant communities from AIS introductions and establishment (dominance) in lakes. These might be better addressed through shifts in frequency of occurrence (number of sites within a lake) or abundance (quantities within these sites) from native plants to invasive plants, as discussed at length in White Paper 1E, or in changes in floristic quality indices, as discussed at length in White Papers 1F (re: coefficients of conservatism) or 1G (floristic quality). These White Papers should be consulted in considering the breadth of impacts from introduction of invasive species.

The analyses outlined in Section 5.7 of this White Paper should continue to be conducted as the number of aquatic plant survey datasets increase. These additional analyses may be more successful in evaluating the relationship between introduction and abundance of invasive species and species richness.

Section 5.8- Plant management and species richness

Section 5.8.1- Background

Although species richness is not expected to change significantly over a short timeframe, since all aquatic plants in lakes are either perennials or annuals with recurring “new” reproduction, the observed and projected species richness (oSR and pSR, respectively) can vary at least slightly from year to year, and could change significantly over time. This White Paper evaluated the impact of several mostly static factors on species richness, including lake and littoral area (section 5.3), geographic setting, as defined by latitude (section 5.5), and public access (section 5.6), as well as dynamic or semi-dynamic factors such as trophic state (section 5.4), and the presence and relative abundance of invasive species (section 5.7). The interannual variability in species richness was also explored- these data suggest that species richness “normally” changes by as much as 10-30% each year. Annual variability involves several other factors, including “natural” annual variability in species richness (most likely reflecting variance from incomplete surveying and the imperfections associated with PIRTRAM and other sampling methods) and long-term changes in species richness, both of which were discussed at length in Section 2.2.

Within the context of these factors, species richness can change in any given lake from year to year due to aquatic plant management, resulting in changes in species richness in surveys after early season lake management, or in surveys conducted in the subsequent years after the residual effects of these long-term management actions, particularly grass carp and some systemic herbicide applications. The evaluation of these impacts is described below.

Section 5.8.2- Monitoring Programs Used to Evaluate Invasive Plants and Species Richness

The PIRTRAM program represents the only aquatic plant monitoring program among those described in White Paper 1A with both multiple years of aquatic plant surveys and active management of aquatic plants during at least some of those years. The PIRTRAM program included surveys of about 50 lakes, some of which were sampled annually for more than a decade. This program affords an opportunity to evaluate annual changes in species richness, whether measured as oSR or pSR.

This dataset includes some lakes that have not been managed for aquatic macrophytes and those that have been managed (through either localized management actions such as hand harvesting or small-scale herbicides, or large-scale operations such as drawdown, grass carp, or lake-wide herbicide treatments). But lakes in both categories have multiple years of plant surveys that allow for assessing both interannual variance (as summarized in Section 2 above) and the impact of management on species richness. These categories of lake 'types' can be broken out as follows, with lakes reviewed individually and summarized collectively**.** For the purposes of this exercise, it is assumed that algaecide-only treatments have limited impacts of macrophyte species richness, so this analysis is limited to those lakes with partial- or whole-lake herbicide treatments.

The "managed" PIRTRAM lake group- those with multiple years of lake surveys and at least one year of management- include Adirondack Lake, Cazenovia Lake, Chautauqua Lake, Cranberry Lake, Creamery Pond, Donahue Pond, Glen Lake, Katonah Lake, Lake Luzerne, Lamoka Lake, Monroe Mills Pond, Robinson Pond, Saratoga Lake, Snyders Lake, and Waneta Lake. The unmanaged lakes group is comprised of Cayuga Lake, Blydenburgh Lake, Hards Pond, Java Lake, Kinderhook Lake, Lake George, Lake Oscaleta, Lake Rippowam, Lake Ronkonkoma, Lake Waccabuc, and Tuxedo Lake- it is presumed for the purposes of this evaluation that neither the hydrilla herbicide treatments in the inlet(s) to Cayuga Lake, nor the highly selective hand harvesting of Brazilian elodea in Lake Waccabuc and Eurasian watermilfoil in Lake George, significantly impacted species richness in the lake surveys.

As discussed at length previously in this White Paper, species richness appears to be strongly influenced by several static and dynamic factors, including the size of the littoral area and trophic status. Evaluation of species richness as it relates to active aquatic plant management should account for these factors. Unfortunately, there is not a sufficiently large dataset of lakes in each littoral size category and trophic state to evaluate aquatic plant management across all of these categories. Therefore, although all of the PIRTRAM lakes listed above could in theory be included in the analyses discussed below, these analyses will be limited to those smaller eutrophic lakes, as seen in Table 5.8.3.1. However, long-term changes in species richness can also be evaluated in a (different) subset of lakes drawn from the PIRTRAM lakes cited above.

Section 5.8.3- Evaluation of plant management on species richness

As discussed above, the relationship between aquatic plant management and species richness was evaluated using the PIRTRAM dataset in three ways:

a. comparing species richness in managed and unmanaged lakes filtered for trophic state and littoral area;
b. evaluating species richness in managed lakes immediately before and after management, removing data from lakes when pre-management conditions also correspond to post-management conditions (example- removing year 2 from consideration when a lake was managed in year 1 and year 3); and

c. evaluating species richness in the long-term dataset for lakes that were actively managed only periodically

Table 5.8.3.1: oSR and pSR by Management, Filtered by Trophic State and Size of Littoral Area

Category	Trophic	Littoral	#Lakes	oSR	pSR
Managed	Eutrophic	<100	2	11.4	6.7
Not managed	Eutrophic	<100	5	6.4	6.7
Category	Trophic	Littoral	#Lakes	oSR	pSR
Managed	Mesotrophic	<100	1	10.2	8.2
Not managed	Mesotrophic	<100	2	8.0	8.4

Table 5.8.3.1 summarizes the oSR and pSR in small to slightly larger eutrophic PIRTRAM lakes, and in small mesotrophic PIRTRAM lakes that were managed, and those lakes that were not managed for aquatic plants. It should be noted that this table includes only those PIRTRAM lakes with granular survey stie data and therefore both oSR and pSR calculations- oSR-only comparisons could also include other PIRTRAM lakes without available pSR data. These data show a higher oSR in managed lakes than in unmanaged lakes in both groups of PIRTRAM lakes, but pSR values in both groups were comparable. The datasets in all groups were very small and the differences between oSR in unmanaged and managed lakes is well within the 10-30% annual variability found from year to year in species richness in lakes surveyed over multiple years, as discussed previously in this White Paper (these data also support the rationale for using projected rather than observed species richness values were possible). These data suggest that (projected) species richness was similar in managed and unmanaged lakes, although these findings are strongly impacted by the size of the datasets.

The relationship between plant management and species richness is also evaluated in Table 5.8.3.2, which shows evaluated the changes in oSR and pSR in small eutrophic lakes that were managed, looking at the difference in species richness in the year immediately before management and in the year after management (giving the active management "agent"- an herbicide or grass carp stocking- a year to take hold).

Table 5.8.3.2: oSR and pSR Pre-and Post-Treatment in Small Eutrophic PIRTRAM Lakes

Lake Group	*Trophic State*	*Littoral Area (ha)*	*#Lakes*	*oSR*	*pSR*
Pre-Treatment	Eutrophic	<25	2	6.5	5.1
Post Treatment Yr 1	Eutrophic	<25	3	9.3	6.1

As with Table 5.8.3.1, there are only a few lakes represented in Table 5.8.3.2, but this very limited dataset suggests that oSR and pSR values increased after management, even after correcting for lake years representing both pre- and post-management conditions. However, as with the differences between managed and unmanaged lakes summarized in Table 5.8.3.1, the interannual variability in species richness (about 10-30% from year to year, as discussed earlier in this White Paper) is close to the increase in species richness seen in pre- and post-treatment conditions. This suggests that while species richness may increase in response to treatment, it may not be statistically larger than the normal change in specie richness from year to year.

As noted above, another way to evaluate the influence of plant management on species richness is to review the long-term changes in several lakes. Fortunately, several PIRTRAM lakes have been sampled for several years and have been managed for aquatic plants during at least part of this span. These include the lakes with long-term species richness summarized below. Note that when granular survey data are available, both oSR and pSR values are evaluated. If granular data are not available, only oSR data are presented. It should also be noted that these individual lakes were chosen for this evaluation due to a blend of treatment and no treatment years; several PIRTRAM lakes were managed every (surveyed) year and therefore are not strong candidates for evaluating the impact of plant management on species richness.

a. *Adirondack Lake*- this lake was first surveyed by Cornell Cooperative Extension in the mid-1990s, with sampling (at the same sites) assumed by the NYSDEC and Hamilton County SWCD from 2001 to 2017. Figure 5.8.3.1 shows the long term oSR change over the period associated with NYSDEC sampling, with red arrows corresponding to years in which triploid grass carp (*Ctenopharyngodon idella*) were stocked (note that pSR cannot be calculated due to the heterogenous spacing of survey sites). oSR generally increased after stocking, but the lag between lake response and stocking varied over this period. In addition, the 2008 and 2012 (over-) stockings led to a decrease in oSR that continued for at least five years after stocking. As will be discussed in other White Papers, the impact of the grass carp stocking on other plant metrics- plant frequency and abundance and floristic quality- was at times significant, resulting in a substantial loss of overall aquatic plant coverage. It should be noted that these grass carp stockings were in response to nuisance growth of native plants (particularly *Potamogeton amplifolius* and *Potamogeton natans*) rather than in response to invasive plant growth.

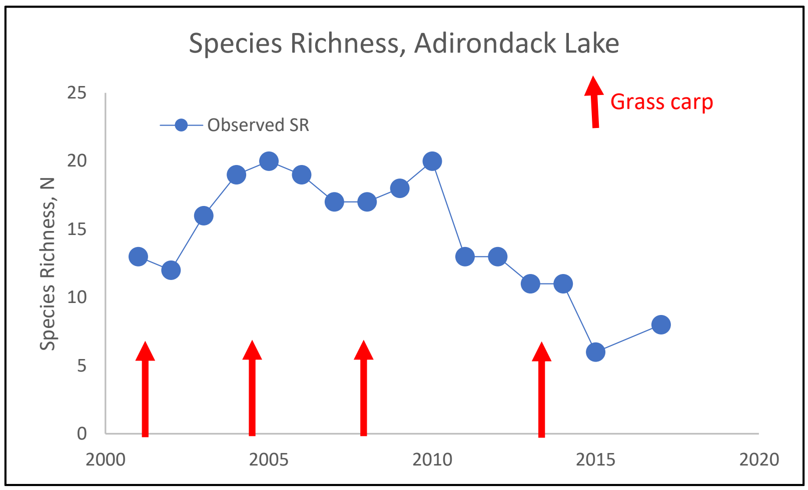


Figure 5.8.3.1: oSR in Adirondack Lake 2001-2017

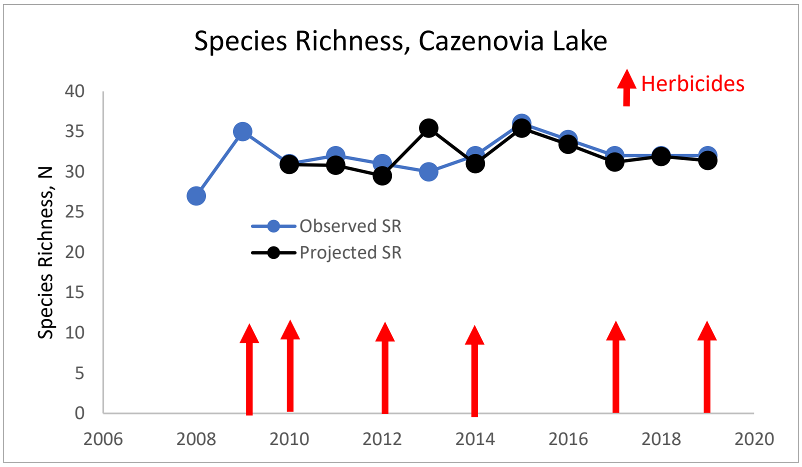


Figure 5.8.3.2: oSR and pSR in Cazenovia Lake 2008-2019

b. *Cazenovia Lake* has been treated periodically with aquatic herbicides since the late 2000s, and has been surveyed nearly annually by Racine-Johnson Aquatic Ecologists (and Allied Biological, Inc). Some treatments occurred over large portions of the lake, while in other years only a portion of the lake was treated. Figure 5.8.3.2 shows the change in oSR and pSR in Cazenovia Lake from 2008-2019, and the years in which aquatic herbicide treatments have occurred. Figure 5.8.3.2 suggests that the herbicide applications had only a small (and seemingly inconsistent) effect on oSR in Cazenovia Lake (although impacts on plant frequency, abundance, and floristic quality indices will be discussed in other White Papers). However, pSR did appear to increase slightly after several of the treatments, and did appear to decrease in the time period leading up to most of these herbicide treatments). These herbicide treatments were in response to perceived excessive growth of *Myriophyllum spicatum*.

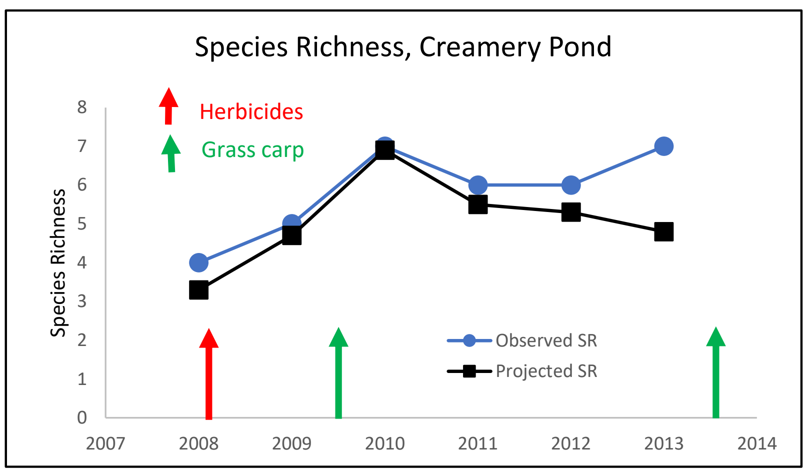


Figure 5.8.3.3: oSR and pSR in Creamery Pond, 2008-2013

c. *Creamery Pond* was the first New York state lake with documented populations of *Hydrilla verticillata* in 2008; prior to that time, aquatic plant communities in the lake had not been documented by the NYSDEC. The lake was aggressively managed and surveyed through the mid-2010s; more recent surveys indicated a significant decrease in *Hydrilla verticillata* in response to a second grass carp stocking after the last documented survey. Figure 5.8.3.3 shows changes in oSR and pSR in Creamery Pond in response to the herbicide treatments shortly after the hydrilla discovery, and the subsequent grass carp stockings. These data show a general increase in oSR over time, although the number of unique aquatic species were low in every year, most likely due to the small lake size (overall and littoral area) and the relatively poor water quality. pSR levels dropped after the first few years of the grass carp stocking, suggesitng that a second stocking may have been warranted. As discussed later in White Paper 1F, overall native plant frequency and abundance was very low, particularly after grass carp had consumed significant quantities of *Ceratophyllum demersum* and *Wolffia sp.* levels decreased, perhaps in response to the stocking (after an expected lag between fish stocking and measurable plant consumption). A major "blow out" of the outlet in 2011 due to Hurricanes Irene and Lee may also have contributed to a decrease in the pSR values of the lake.

d. *Snyders Lake* was one of the first fluridone treated lakes in New York state, at a time when the lake was dominated by a monoculture of *Myriophyllum spicatum*. The lake was later spot treated with endothall to address locally dense populations of *Najas minor*; this plant was the pioneering colonizer of the lake after the significant macrophyte eradication associated with the fluridone shows the changes in oSR and pSR in Snyders Lake from the late 1990s to the early 2010s. The lake was slow to respond to both the 1997 and 2003 treatments in regards to returning species richness, perhaps due to near monocultures of target plants and higher than expected herbicide concentrations, but the overall number of plant species generally increased after the herbicide treatments. Both oSR and pSR increased significantly from 2004 (one year post-treatment) to the early 2010s.

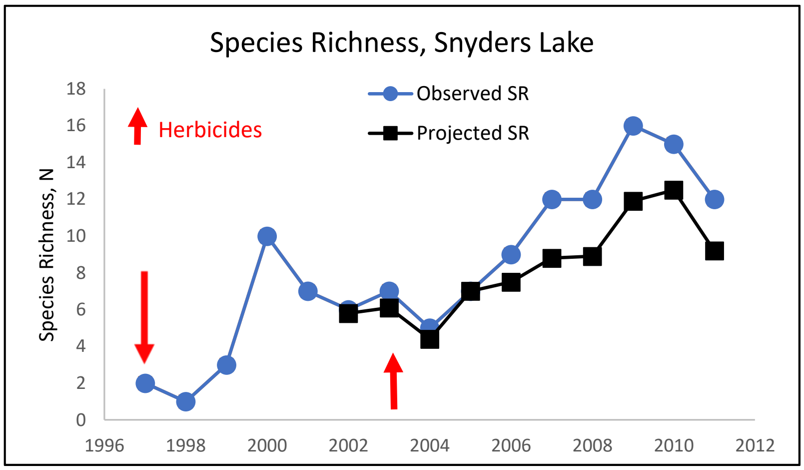


Figure 5.8.3.4: oSR and pSR in Snyders Lake, 1997-2011

Section 5.8.4- Discussion of Results

The impact of aquatic plant management on species richness was evaluated in this White Paper in three ways. The analyses shown in Table 5.8.3.1, comparing oSR between managed and unmanaged PIRTRAM lakes with similar littoral areas and water quality conditions (as determined by trophic state), showed slightly higher oSR levels in managed lakes than in unmanaged lakes, when considering both moderately and highly productive lakes. However, there were not very many lakes in any of the lake size and trophic state groupings cited in Table 5.8.3.1, and pSR levels were similar in managed and unmanaged lakes. More data are needed to more effectively evaluate these relationships.

These isssues- slightly higher than expected oSR in managed lakes in very limited datasets- are addressed in Table 5.8.3.2 evaluating species richness changes in lakes pre- and post-management, and in Figures 5.8.3.1 through 5.8.3.4 looking at a timeline of changes in species richness in four specific lakes that have a long history of management.

In general, these analyses suggest that species richness may increase slightly in response to lake management actions, but the lake response may be lagged for a few years. Table 5.8.3.2 suggests that in the first year after treatment, both oSR and pSR was higher than in the year before treatment, at least for small eutrophic lakes (there were an insufficient number of mesotrophic or oligotrophic lakes in any size range, and too few larger eutrophic lakes in this dataset to evaluate the impact of pre- and post- treatment changes in species richness). The increase in pSR post treatment may have been larger than the normal range of variability in species richness from year to year, although even more lakes' data would likely be needed to identify this increase as statistically significant. Likewise, for two of the PIRTRAM lakes evaluated over the long-term in Figures 5.8.3.1 through 5.8.3.4- Creamery Pond and Snyders Lake- there was a long-term increase in both oSR and pSR, while pSR generally changed only slightly in the long-term in frequently-treated Cazenovia Lake. Observed species richness decreased significantly in frequently-stocked Adirondack Lake.

The analysis of normal (sampling, environmental,…) variance previously in this White Paper suggests that observed species richness varies about 30% from year to year when the number of survey sites remains constant. The long-term data from two of the lakes evaluated in Section 11.4- Snyders Lake and Creamery Pond- suggest that species richness increased beyond that expected given normal variance. This may reflect both successful management in controlling highly invasive plants IN LAKES WITH SIGNIFICANT SUPPRESSION OF NATIVE PLANT SPECIES BY THESE INVADING PLANTS. oSR and pSR appeared to increase over the period of observation in Cazenovia Lake, but at a rate that was probably lower than the normal variability from year to year in species richness, and species richness (oSR) actually decreased in Adirondack Lake. Both lakes were treated (herbicides in Cazenovia Lake, grass carp in Adirondack Lake) several times within a 10-15 year window, and both did not appear to have suppressed native plant populations prior to treatment or extremely high levels of invasive plants (in fact, no invasive plants had been detected in Adirondack Lake). **Although it would be inappropriate to draw conclusions based on long-term evaluation of so few lakes, these data suggest that species richness is more likely to be positively influenced by plant management actions in lakes with very high AIS populations and/or significant depression of native plant communities. While there may be a slight increase in species richness immediately after aquatic plant management methods are used (relative to pre-management conditions), it is not clear if this increase is larger than the normal variability in species richness (i.e. the small increases in species richness may not be statistically significant).** These tentative findings bear further evaluation with additional study lakes.

It is reasonable to assume that aquatic plant management is more likely to influence other measures of aquatic plant community health, including the frequency and abundance of species plants (particularly those aquatic plants explicitly targeted by or impacted by the management action) and floristic quality. These other metrics are evaluated at length in other White Papers.

Section 6: Projected species richness and number of survey sites

Section 6.1- Background

Section 5.3 discusses at length the relationship between projected species richness and littoral area. As expected, species richness increases with littoral area, since larger lakes provide more opportunities (space) for aquatic plants to grow. As the number of survey sites in a lake increases, species richness increases, and the larger number of survey sites in larger lakes tend to yield higher species richness values. This is apparent whether evaluating individual lakes- see for example the relationship between projected species richness values and survey sites in Cazenovia Lake in 2019 (Figure 3.1) and in NYS BioSurvey lakes (Figure 5.3.3.1), PIRTRAM lakes (Figure 5.3.3.2) and AWI lakes (Figure 5.3.3.3)- even if some small lakes have high species richness values and some large lakes have lower values (due to water quality, access, AIS, or other factors discussed at length in Section 5).

However, it is not clear from these analyses if the relationship between species richness and littoral area cited above is primarily a function of more growing space (found in increasing quantities as littoral area increases), or if there is a fundamental difference in smaller versus larger lakes. Fortunately, the process by which species richness is projected at various numbers of survey sites (or survey site densities) can be used to evaluate whether larger lakes are inherently different (in regards to species richness) than smaller lakes. Specifically, the projected species richness at a discrete number of survey sites, independent of littoral area sizes, can be compared across a wide range of lake (littoral area) sizes to evaluate this impact. As discussed at length in Section 6, this can have significant implications for defining species richness metrics for lakes.

Section 6.2- Monitoring Programs Used to Species Richness Based on Number of Survey Sites

The ALSC program cannot be used to evaluate species richness (observed or projected) due to the lack of species-level identifications of surveyed plants. Three of the major NYS aquatic plant monitoring programs discussed in these White Papers- the NYS BioSurvey, the PIRTRAM "program" and the AWI program- provide information to evaluate observed species richness, but as discussed above, only the PIRTRAM lakes have the granular survey site data needed to project species richness values across a range of survey site numbers or densities for each lake. Since the evaluation of species richness at specific numbers of survey sites requires projected species richness data, only the PIRTRAM program can be used in this Section.

However, since these White Papers were developed, aquatic plant survey data collected by the Lower Hudson Partnership for Regional Invasive Species Management (PRISM) were provided to the author. As discussed at length in White Paper 2, these survey data, collected through 116 surveys on 71 lakes from 2020-2022, used the same collection and identification methodology described for the PIRTRAM lakes (White Paper 1A), providing additional information about the relationship between the number of survey sites and projected species richness. Therefore, these data can also be used for these analyses.

Section 6.3- Influence of Number of Survey Sites on Species Richness

Evaluating the influence of the number of survey sites on species richness across a range of littoral areas requires separating the influence of the number of survey sites from the influence of littoral area. The latter has been demonstrated in Section 5.3 of this White Paper in each of the aquatic plant survey programs cited in White Paper 1A. As expected, species richness increases as littoral areas increase, since the latter involves more potential sites for establishment of these plants. However, while Cazenovia Lake (with 225 hectares of littoral area) has a higher species richness than Creamery Pond (with 4 hectares of littoral area), it is not clear if this greater species richness would also be apparent if evaluated at the same number of survey sites in both lakes.

The subsampling methods discussed earlier in this White Paper can generate logarithmic regressions describing the estimated change in projected species richness values at any number of survey sites or survey site density. The number of sites evaluated should be large enough to offset the discontinuity seen with projected species richness in fewer than 5 evaluated sites, but be small enough to include most small lakes without an overextension of the projection regressions. Therefore, 5 site, 15 site, and 30 site regressions were evaluated for this study.

Figure 6.3.1- 5 Site Projected SR v. Littoral Area

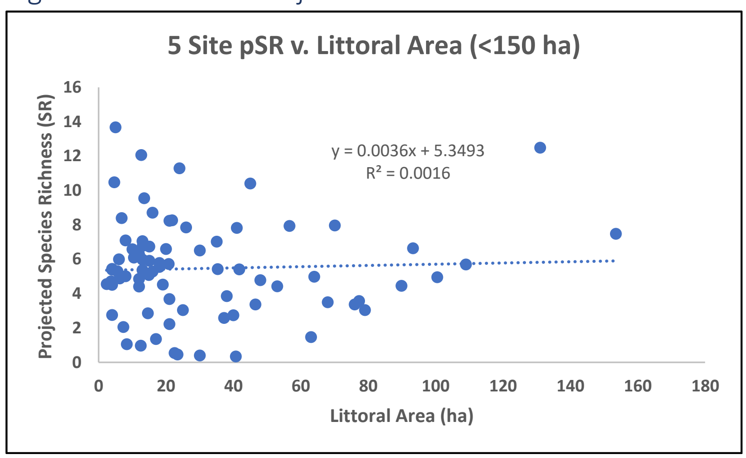
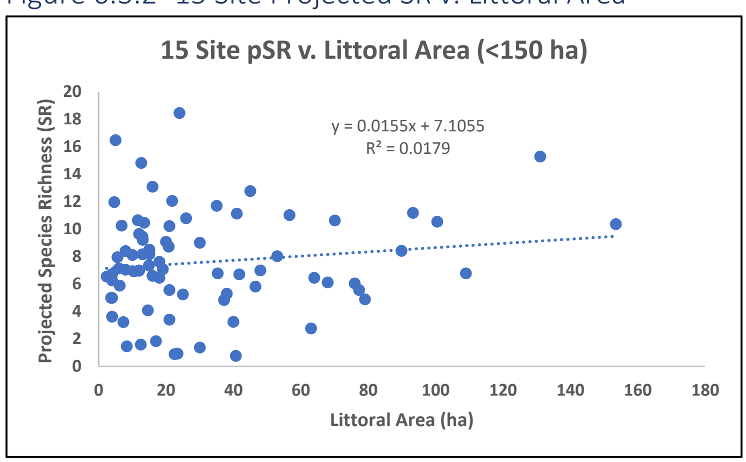


Figure 6.3.2- 15 Site Projected SR v. Littoral Area



Figures 6.3.1 and 6.3.2 show that, at least for littoral areas up to 150 hectares (or more than 99% of all NYS lakes), the relationship between projected species richness at 5 and 15 sites and littoral areas is both flat (very low slope) and weak (very poor correlation). Although not shown here, a similar relationship was also apparent when evaluating 30 site SR values. These figures do not include three very large

PIRTRAM lakes- Chautauqua Lake (littoral area = 2060ha), Saratoga Lake (littoral area = 660ha) and Cazenovia Lake (littoral area = 225 ha) that may drive these relationships and may not be representative of other similarly-sized lakes. For the balance of the lakes included in Figures 6.3.1 and 6.3.2, however, these data suggest that species richness at a specific number of sites will be highly variable across the range of littoral area sizes, without any clear pattern related to littoral area size. This suggests that deviation from the normal range of SR values at 5 sites and 15 sites (as well as 30 sites) can be used to evaluate how projected species richness compares to ***expected*** species richness in any lake.

Table 6.3 shows the projected species richness (pSR) at a standardized survey site density of 1 site per littoral hectare and the pSR at both 5 sites and 15 sites for each of the PIRTRAM lakes (the data from the LH PRISM lakes are presented in White Paper 2). The summary in Table 6.3 also includes the projected species richness values for each lake at 10 sites, yielding results as expected given those at 5 and 15 sites, and further

Table 6.3- Various Species Richness Values at PIRTRAM Lakes

LakeName	Year	Littoral Area	pSR	SR5	SR10	SR15
Ballston Lake	2006	48	9.3	4.8	6.3	7.0
Big Fresh Pond	2006	13	8.5	6.0	7.9	9.3
Blydenburgh Lake	2012	40	4.3	2.7	3.2	3.5
Blydenburgh Lake	2014	40	3.3	2.8	3.0	3.0
Cazenovia Lake	2010	225	30.9	15.6	20.5	23.0
Cazenovia Lake	2011	225	30.8	13.0	17.6	20.0
Cazenovia Lake	2012	225	29.5	14.6	18.3	20.5
Cazenovia Lake	2013	225	35.4	19.2	23.7	25.1
Cazenovia Lake	2014	225	31.0	14.5	18.3	20.3
Cazenovia Lake	2015	225	35.4	18.9	23.4	25.5
Cazenovia Lake	2016	225	33.4	17.8	21.8	23.9
Cazenovia Lake	2017	225	31.2	19.0	22.7	24.0
Cazenovia Lake	2018	225	31.9	18.6	21.9	24.1
Cazenovia Lake	2019	225	31.4	18.3	22.5	24.1
Cazenovia Lake	2020	225	32.2	17.7	22.0	23.0
Cazenovia Lake	2021	225	30.4	16.6	20.4	22.3
Chautauqua Lake	2015	2060	31.6	8.9	10.3	11.7
Chautauqua Lake	2017	2060	28.4	8.2	9.2	10.3
Chautauqua Lake	2019	2060	30.9	9.4	11.1	12.3
Chautauqua Lake	2021	2060	37.8	10.2	13.1	14.5
Collins Lake	2007	5	8.3	13.7	15.4	16.5
Creamery Pond	2008	4	3.3	3.4	3.8	4.0
Creamery Pond	2009	4	4.7	4.9	5.5	5.9
Creamery Pond	2010	4	6.9	7.3	8.6	8.9
Creamery Pond	2011	4	5.5	6.2	6.8	7.0
Creamery Pond	2012	4	5.3	5.6	6.7	7.0
Creamery Pond	2013	4	4.8	4.9	6.3	7.7
Hards Pond	2010	12	10.5	7.5	9.8	11.6
Hards Pond	2011	12	7.1	5.1	6.8	7.7
Java Lake	2008	21	6.1	3.6	4.9	5.8
Java Lake	2009	21	6.8	4.5	5.8	6.0
Java Lake	2010	21	5.2	2.9	4.2	4.9
Kinderhook Lake	2006	109	9.2	5.5	6.5	6.7
Kinderhook Lake	2007	109	8.5	5.9	6.7	6.9
Lake Luzerne	2010	24	21.6	11.3	16.0	18.5
Lake Oscaleta	2008	8	7.8	7.0	7.9	8.1
Lake Oscaleta	2016	8	8.3	7.6	8.4	8.8
Lake Oscaleta	2018	8	8.1	7.0	8.3	8.7
Lake Oscaleta	2020	8	7.3	6.8	7.7	8.0
Lake Rippowam	2008	4	2.4	2.5	2.8	2.9
Lake Rippowam	2016	4	2.7	3.0	3.6	4.2
Lake Rippowam	2018	4	2.2	2.8	3.5	4.1
Lake Rippowam	2020	4	2.4	2.7	3.0	3.3
Lake Ronkonkoma	2009	21	4.1	3.0	3.5	3.7
Lake Ronkonkoma	2010	21	3.8	2.2	3.1	3.6
Lake Ronkonkoma	2011	21	1.8	1.2	1.5	1.7
Lake Ronkonkoma	2012	21	5.5	2.9	4.3	5.2
Lake Ronkonkoma	2014	21	3.0	1.8	2.4	2.9
Lake Waccabuc	2008	20	8.4	5.3	7.0	7.7
Lake Waccabuc	2010	20	10.2	6.4	8.2	9.1
Lake Waccabuc	2013	20	10.0	6.6	8.0	9.1
Lake Waccabuc	2014	20	10.2	7.0	8.3	9.1
Lake Waccabuc	2015	20	10.7	7.2	8.8	9.7
Lake Waccabuc	2016	20	10.6	7.1	8.6	9.5
Lake Waccabuc	2017	20	9.1	6.7	8.2	9.3
Lake Waccabuc	2019	20	9.7	6.5	8.2	9.0

suggesting that any of these pSR values could be credibly considered for evaluating lakes, since these (5 site, 10 site, 15 site) pSR calculations are not strongly influenced by littoral areas (also shown in Table 6.3).

Section 6.4- Discussion of Results

The data presented in Section 6.3 show that projected species richness (pSR) does not appear to be influenced by littoral area when the same number of survey sites (presumably distributed throughout the lake) are compared in each surveyed lake. This finding was apparent in both the PIRTRAM and the Lower Hudson PRISM lakes. Although there is a wide variation in projected species richness within each of the 5 site and 15 site levels, this variation appears to be more attributable to other factors (water quality, presence of AIS, other factors discussed in Section 5 of this White Paper) than to the size of the littoral area. This finding can be used to evaluate those lakes with higher- or lower-than-expected species richness relative to the expected projected species richness in the PIRTRAM lakes presented in Table 6.3 and the LH PRISM lakes included in Figures 6.3.1 and 6.3.2 and discussed further in White Paper 2.

Table 6.3- Species Richness Values at PIRTRAM Lakes (cont)

LakeName	Year	Littoral Area	pSR	SR5	SR10	SR15
Lamoka Lake	2006	160	28.0	15.0	18.5	20.5
Lamoka Lake	2008	160	31.9	14.5	18.3	20.6
Lamoka Lake	2009	160	26.6	14.5	17.3	18.6
Morehouse Lake	2010	35	15.5	7.0	9.5	11.7
Quaker Lake	2010	64	8.3	5.0	5.9	6.5
Saratoga Lake	2010	657	24.4	9.0	12.1	13.5
Saratoga Lake	2011	657	24.3	7.1	9.6	10.6
Saratoga Lake	2012	657	25.9	7.5	9.8	11.3
Snyders Lake	2002	15	5.8	4.4	5.2	5.7
Snyders Lake	2003	15	6.1	4.5	5.2	5.7
Snyders Lake	2004	15	4.4	3.4	4.1	4.4
Snyders Lake	2005	15	7.0	6.1	6.7	7.0
Snyders Lake	2006	15	7.5	6.2	7.2	7.7
Snyders Lake	2007	15	8.8	6.3	7.6	8.8
Snyders Lake	2008	15	8.9	6.4	8.2	8.9
Snyders Lake	2009	15	11.9	8.2	10.8	12.2
Snyders Lake	2010	15	12.5	8.6	11.2	12.6
Snyders Lake	2011	15	9.2	5.0	7.0	8.8
Waneta Lake	2006	170	15.0	4.6	6.3	8.1
Waneta Lake	2008	170	19.6	9.0	11.1	12.5
Waneta Lake	2009	170	18.9	7.1	9.2	10.7

Legend:
Littoral area measured in hectares
SR5, SR15, SR30 = projected species richness at 5, 10 and 15 sites

Figure 6.4 shows the mean and 75th percentile values for species richness at the PIRTRAM and LH PRISM lakes at 5 sites (blue) and 15 sites (orange); while the 30 site data were not shown, they showed a similar spread and a poor relationship with littoral area. Figure 6.4 also shows the (high) outlier lakes- those with very high projected species richness even at 5 and 15 site "collections". As expected, projected species richness was higher at 15 sites than at 5 sites, since the former represents a larger area evaluated. But as seen in Figures 6.3.1 and 6.3.2, the range from the high to low values in each dataset represent variability to factors other than littoral area size, such as water quality, presence of AIS, and other factors cited in Section 5. The range of projected species richness values shown in Figure 6.4 can be used to identify those lakes that fall outside the expected range of projected species richness values using a survey of 5 sites and a survey of 15 sites.

Figure 6.4- Variability in pSR at 5 and 15 Sites

This process involves looking at the first standard deviation in projected species richness above and below these mean values for 5 site and 15 site surveys, as seen in Table 6.4. The data for all lakes with < 150 hectares littoral area (Tables 6.3.1 and 6.3.2) can be compared to the slightly smaller dataset for lakes with < 100 hectares littoral area, to see if the three lakes with 100-150 hectares of littoral area are controlling the regressions (as did the very large PIRTRAM lakes, as discussed above). Table 6.4 shows very similar means and standard deviations using the entire (78 lake) <150ha dataset or the slightly smaller (75 lake) <100ha dataset. The implications for these findings are discussed in Section 7. Table 6.4 can be further refined by including a future dataset of larger (>150ha littoral area) lakes for which ranges of projected species richness can be calculated; at present, a robust large lake dataset does not exist.

Section 7: Potential species richness metrics

Section 7.1- Background

The information provided in Sections 1 through 6 in this White Paper summarizes the development and use of species richness calculations in New York state lakes, particularly those using the PIRTRAM aquatic plant sampling methodology. These analyses recommend the use of projected species richness (pSR) given the limitations of observed species richness (oSR) values due to incomplete surveys, varying survey site densities, and other factors. However, while these data indicate that pSR values are most likely to accurately represent species richness in lakes, there is no universally accepted species richness scoring system that can be used to evaluate the condition of the aquatic plant community. Such a scoring system would likely require comparing species richness values in individual lakes to the species richness values in unimpacted or minimally impacted lakes- the latter are usually termed *reference* lakes. Reference conditions- the concept of which is discussed further in White Paper 1G- would be associated with no to very minimal shoreline development or disturbance (which the 2007 National Lake Assessment showed to exhibit a significant impact on shoreline flora and fauna), favorable water quality and sediment characteristics, and native aquatic plant communities.

Table 6.4- Summary Statistics for Projected Species Richness for Lakes With < 150ha and < 100ha at 5 Sites and 15 Sites

Littoral Area	SR5	-1SD SR5	+1SD SR5		SR15	-1SD SR15	+1SD SSR15	N
<150 ha	5.5	2.6	8.3		7.6	4.0	11.2	78
<100 ha	5.3	2.6	8.1		7.5	3.9	11.0	75

There are also no associated aquatic life evaluations, using pSR (or oSR) data, available for these lakes, as manifested in aquatic life “scores” associated with species richness. Such a scoring system would no doubt recognize that higher pSR values likely represent a more valuable aquatic plant community than would lower pSR values. The data in Sections 1 through 6 indicate that species richness is highly dependent on several factors, including the size of the littoral area and trophic state, but that larger lakes (i.e. those with larger littoral areas) do not necessarily exhibit higher species richness than smaller lakes. The latter finding suggests that deviations from ***expected*** projected species richness (pSR) might represent a means for generating species richness metrics.

It should be noted that the existing PIRTRAM or Lower Hudson PRISM data are most likely not representative of reference (un- or minimally impacted) conditions. This would suggest that a single pSR or oSR value, even when framed as a relative deviation from expected pSR values, cannot be used to define “good”, “fair”, or “poor” species richness. However, in the absence of reference conditions, existing non-reference data can provide an initial species richness scoare that could be further refined with the addition of reference data. This would recognize that species richness is an important component of floristic quality indices (FQIs) that, as seen in White Paper 1G, can generate metrics consistent with other measures of the quality of the aquatic plant community.

However, Section 6 indicates that there is no clear relationship between the size of the littoral area (at least up to 150 ha littoral area) and projected species richness values at specific numbers of survey sites, despite a strong increase in species richness as overall littoral area increases. As noted in Section 6, this suggests that the relationship between species richness and littoral area is primarily a function of an increasing number of survey sites, not a fundamental difference in species richness between smaller and larger lakes (recognizing that projected species richness data are not available for many lakes with littoral areas > 150 hectares, although further recognizing that < 1% of all NYS lakes have littoral areas > 150 hectares). Some of the other factors that influence species richness noted earlier in this White Paper, including trophic state, access, and presence of invasive species, likely apply across all sizes of lakes and should be considering factors in assessing floristic quality. Therefore, a species richness metric could be developed evaluating the actual projected species richness at specific numbers of survey sites compared to the expected projected species richness. This is discussed further in Section 7.2.

Other potential species richness metrics related to (future) assignment of reference waterbodies and the resulting generation of species richness values associated with reference conditions are also discussed in Sections 7.3 through 7.5.

Section 7.2- Projected species richness v. expected species richness using existing (non-reference) waterbodies

As discussed earlier, reference conditions are most likely not found in PIRTRAM or Lower Hudson PRISM lakes. Most of the PIRTRAM lakes were surveyed due to concerns about aquatic plant communities (due to excessive or increasing shoreline or lake use, habitat loss, recreational or aesthetic problems, or the presence of AIS), factors not typically associated with reference conditions. The Lower Hudson PRISM lakes reside in a region of the state with extensive lakefront usage, colonization by AIS, and degraded water quality. In addition, many of the lakes from Harriman State Park have public access and are proximate to other lakes with significant AIS populations (however these lakes were initially colonized), so even those with limited recreational or residential use may still be at least somewhat compromised. Therefore, these data are unlikely to represent reference conditions. The reference condition concept is discussed further in Section 7.3 below.

Table 7.2.1- Projected Species Richness Scores At 5 Site and 15 Site pSR Evaluations

Score	5 Site Projected SR	15 Site Projected SR
Poor	<2.6	<4.0
Fair	2.6-8.3	4.0-11.2
Good	>8.3	>11.2

However, the relatively large number of surveyed lakes, wide range in water quality, habitats, size of littoral zones, and (at least some) variation in relative AIS presence render these lakes representative of "typical" New York state lakes (as discussed at length in White Paper 1A and White Paper 2). Therefore, comparing the projected species richness of individual lakes to the ***expected*** species richness in the collective surveyed lakes allows for at least an initial assessment of species richness. Table 6.3 shows the comparison of projected species richness (pSR) at a standardized survey site density (= 1 site per littoral hectare) to the pSR at 5 and 15 (homogeneously distributed) survey sites in each of the PIRTRAM lakes; comparable data are presented for the Lower Hudson PRISM lakes in White Paper 2. As discussed above, the distribution of species richness values at 5 sites and 15 sites across the range of littoral sizes (at least up to 150 hectares) appears to be random, and Figures 6.3.1 and 6.3.2 suggest that the statistical spread of these data can be used to identify those lakes for which the projected species richness (at 5 and 15 sites) can be evaluated against expected species richness at least within this (littoral) size range. Table 7.2.1 offers projected species richness scores of “poor” for those lakes which projected species richness, at 5 sites and 15 sites, fall below 1 standard deviation from the mean (expected) projected species richness, scores of “good” for those lakes with pSR greater than 1 standard deviation above the expected pSR, and assigns a score of “fair” to all lakes for which pSR falls within one standard deviation of the expected pSR at 5 and 15 sites.

Table 7.2.2- Species Richness Scores at PIRTRAM Lakes

Lake Name	Year	pSR5Sites	pSR15 Sites	pSR5 Score	pSR15 Score
Ballston Lake	2006	4.8	7.0	Fair	Fair
Big Fresh Pond	2006	6.0	9.3	Fair	Fair
Blydenburgh Lake	2012	2.7	3.5	Fair	Poor
Blydenburgh Lake	2014	2.8	3.0	Fair	Poor
Cazenovia Lake	2010	15.6	23.0	Good	Good
Cazenovia Lake	2011	13.0	20.0	Good	Good
Cazenovia Lake	2012	14.6	20.5	Good	Good
Cazenovia Lake	2013	19.2	25.1	Good	Good
Cazenovia Lake	2014	14.5	20.3	Good	Good
Cazenovia Lake	2015	18.9	25.5	Good	Good
Cazenovia Lake	2016	17.8	23.9	Good	Good
Cazenovia Lake	2017	19.0	24.0	Good	Good
Cazenovia Lake	2018	18.6	24.1	Good	Good
Cazenovia Lake	2019	18.3	24.1	Good	Good
Cazenovia Lake	2020	17.7	23.0	Good	Good
Cazenovia Lake	2021	16.6	22.3	Good	Good
Chautauqua Lake	2015	8.9	11.7	Good	Good
Chautauqua Lake	2017	8.2	10.3	Fair	Fair
Chautauqua Lake	2019	9.4	12.3	Good	Good
Chautauqua Lake	2021	10.2	14.5	Good	Good
Collins Lake	2007	13.7	16.5	Good	Good
Creamery Pond	2008	3.4	4.0	Fair	Poor
Creamery Pond	2009	4.9	5.9	Fair	Fair
Creamery Pond	2010	7.3	8.9	Fair	Fair
Creamery Pond	2011	6.2	7.0	Fair	Fair
Creamery Pond	2012	5.6	7.0	Fair	Fair
Creamery Pond	2013	4.9	7.7	Fair	Fair
Hards Pond	2010	7.5	11.6	Fair	Good
Hards Pond	2011	5.1	7.7	Fair	Fair
Java Lake	2008	3.6	5.8	Fair	Fair
Java Lake	2009	4.5	6.0	Fair	Fair
Java Lake	2010	2.9	4.9	Fair	Fair
Kinderhook Lake	2006	5.5	6.7	Fair	Fair
Kinderhook Lake	2007	5.9	6.9	Fair	Fair
Lake Luzerne	2010	11.3	18.5	Good	Good
Lake Oscaleta	2008	7.0	8.1	Fair	Fair
Lake Oscaleta	2016	7.6	8.8	Fair	Fair
Lake Oscaleta	2018	7.0	8.7	Fair	Fair
Lake Oscaleta	2020	6.8	8.0	Fair	Fair
Lake Rippowam	2008	2.5	2.9	Poor	Poor
Lake Rippowam	2016	3.0	4.2	Fair	Fair
Lake Rippowam	2018	2.8	4.1	Fair	Fair
Lake Rippowam	2020	2.7	3.3	Fair	Poor
Lake Ronkonkoma	2009	3.0	3.7	Fair	Poor
Lake Ronkonkoma	2010	2.2	3.6	Poor	Poor
Lake Ronkonkoma	2011	1.2	1.7	Poor	Poor
Lake Ronkonkoma	2012	2.9	5.2	Fair	Fair
Lake Ronkonkoma	2014	1.8	2.9	Poor	Poor
Lake Waccabuc	2008	5.3	7.7	Fair	Fair
Lake Waccabuc	2010	6.4	9.1	Fair	Fair
Lake Waccabuc	2013	6.6	9.1	Fair	Fair
Lake Waccabuc	2014	7.0	9.1	Fair	Fair
Lake Waccabuc	2015	7.2	9.7	Fair	Fair
Lake Waccabuc	2016	7.1	9.5	Fair	Fair
Lake Waccabuc	2017	6.7	9.3	Fair	Fair

The individual lake (lake-year) pSR scores for all of the PIRTRAM lakes are provided in Table 7.2.2, while those for the Lower Hudson PRISM lakes are provided in White Paper 2. It should be noted that these scores are not weighted for plant frequency or abundance, consistent with the use of species richness values in the floristic quality equations (Equation 1.1). As discussed at length in White Paper 1F, these frequency- and abundance-based weighting factors are applied to the coefficients of conservatism (C values).

These pSR-based scores show “fair” to “good” assessments related to species richness in most PIRTRAM lakes, with “poor” species richness scores invasive species (such as Blydenburgh Lake, where hydrilla represents more than 95% of the aquatic plant community), when AIS were first introduced (Lake Ronkonkoma, also dominated by hydrilla) and or those AIS-dominated lakes prior to active plant management (Creamery Pond in 2008). Each of the lakes with poor pSR scores were dominated by hydrilla, but additional data would be needed to determine if this highly invasive AIS species is more likely than other species, including Eurasian watermilfoil, to dominate an aquatic plant community. The vast majority of the other lakes exhibited either "fair" or "good" conditions, as seen in Table 7.2.3.typically associated with lakes completely dominated by

Table 7.2.2 also shows similar pSR-based scores whether species richness data are projected at 5 sites or 15 sites- the data from 30 sites (not presented here) are similar to those from 5 and 15 sites. In fact, more than 90% of all lakes exhibited similar pSR scores whether 5 sites, 15 sites, or 30 sites were used to evaluate species richness.

In the absence of reference data for developing species richness-based metrics, the criteria summarized in Table 7.2.1 should be used for lakes with granular survey site data (to allow for generating pSR regressions required to project species richness at any number of survey sites) to create pSR-based scores at 5 and 15 sites. **It is recommended that the Table 7.2.1 criteria be used for BOTH 5 site and 15 site pSR estimates to generate a composite pSR score for each surveyed lake.**

Table 7.2.2- Species Richness Scores at PIRTRAM Lakes (cont)

Lake Name	Year	pSR5Sites	pSR15 Sites	pSR5 Score	pSR15 Score
Lake Waccabuc	2019	6.5	9.0	Fair	Fair
Lake Waccabuc	2021	6.7	9.3	Fair	Fair
Lamoka Lake	2006	15.0	20.5	Good	Good
Lamoka Lake	2008	14.5	20.6	Good	Good
Lamoka Lake	2009	14.5	18.6	Good	Good
Morehouse Lake	2010	7.0	11.7	Fair	Good
Quaker Lake	2010	5.0	6.5	Fair	Fair
Saratoga Lake	2010	9.0	13.5	Good	Good
Saratoga Lake	2011	7.1	10.6	Fair	Fair
Saratoga Lake	2012	7.5	11.3	Fair	Good
Snyders Lake	2002	4.4	5.7	Fair	Fair
Snyders Lake	2003	4.5	5.7	Fair	Fair
Snyders Lake	2004	3.4	4.4	Fair	Fair
Snyders Lake	2005	6.1	7.0	Fair	Fair
Snyders Lake	2006	6.2	7.7	Fair	Fair
Snyders Lake	2007	6.3	8.8	Fair	Fair
Snyders Lake	2008	6.4	8.9	Fair	Fair
Snyders Lake	2009	8.2	12.2	Fair	Good
Snyders Lake	2010	8.6	12.6	Good	Good
Snyders Lake	2011	5.0	8.8	Fair	Fair
Waneta Lake	2006	4.6	8.1	Fair	Fair
Waneta Lake	2008	9.0	12.5	Good	Good
Waneta Lake	2009	7.1	10.7	Fair	Fair

Legend:
SR5, SR15- projected species richness at 5 and 15 sites
Score = SR-based assessment using Table 7.2.1

Table 7.2.3- Summary of pSR Scores at PIRTRAM Lakes

Category	SR 5 % Lake Years	SR 15 % Lake Years
Poor	5%	12%
Fair	68%	56%
Good	29%	35%

Legend:
SR5, SR15- pSR at 5 and 15 sites

Section 7.3- Limits on defining reference species richness values

Another method for evaluating species richness values would involve identifying a reference waterbody dataset, using a process similar to that used by the US Environmental Protection Agency in the numeric nutrient criteria development process (https://www.sciencedirect.com/science/article/abs/pii/S1001074217308215). This methodology defines reference waterbodies as minimally impacted for attainment of designated uses, recognizing that there are presently few waterbodies for which no impacts exist. There is no comprehensive measure of whether all uses, particularly those related to aquatic life, are attained in a candidate reference waterbody. However, "minimally" impacted conditions can be interpreted as existing in those lakes for which those factors that most influence aquatic plant communities- shoreline development, presence of AIS, manipulation through drawdown, largescale herbicide use, and water quality degradation- are minimized. The process of defining reference lakes requires balancing the desire to find truly impaired lakes with a recognition that in some regions (highly urbanized or historically agricultural areas, for example), even minimally impacted lakes are still influenced by some stressors that preclude the presence of "pristine" conditions.

The four monitoring programs cited in White Paper 1A (and the Lower Hudson PRISM data discussed in White Paper 2) cannot contribute many lakes to a New York aquatic plant reference waterbody dataset. The extent of shoreline development, manipulation, and water quality degradation in most of NYS BioSurvey lakes is not known, littoral area is not known, and pSR values cannot be computed for these lakes without granular survey site data. However, as seen below, this dataset may be indicative of "representative" (rather than reference) lake conditions across the state, and therefore could be used to define and develop species richness scores.

The size and acidity status of most ALSC lakes does not support assigning reference status to these lakes, although reference conditions could (and should) be defined for at least some lakes that are naturally acidic (and small). In addition, only genera richness, not species richness, can be computed for the ALSC lakes. The AWI lakes might represent a reasonable cross section of mid-sized AWI lakes with public (or private) access, but Figure 5.3.3.3 indicates only a moderate relationship between lake or littoral area and oSR. In addition, these lakes are limited to the Adirondacks, and pSR cannot be calculated in many of these lakes due to lack of granular survey site data. Finally, the PIRTRAM dataset likely does not include any "minimally impacted" lakes since most of these lakes were surveyed in response to or in anticipation of plant management actions, suggesting at least some recreational impact, even when evaluated within the context of historically impacted conditions in any of these lakes.

Until waterbodies that would otherwise be considered minimally impacted (through independent measures) are surveyed for aquatic plants, several options remain for either defining reference conditions or using these plant survey data to define species richness scores based on a comparison to a representative statewide relationship between species richness and lake or littoral area. These are discussed below.

Section 7.4- Assigning species richness scores based on representative historical statewide data

As noted above, none of the monitoring programs cited in White Paper 1A provide an explicit list of reference waterbodies, but the NYS BioSurvey does include lakes surveyed throughout the state (with a reasonable cross section of lake sizes and geographic setting to characterize the "typical" NYS lake) and may represent a broad swath of impacted and minimally impacted lakes at least compared to more contemporary lakes that are more likely to have experienced shoreline developmental and lake usage pressure, and other factors that are most likely to result in aquatic plant "impacts" (i.e. NOT "minimally impacted" conditions).

Figure 7.4- NYS BioSurvey Modified Species Richness v. Lake Area

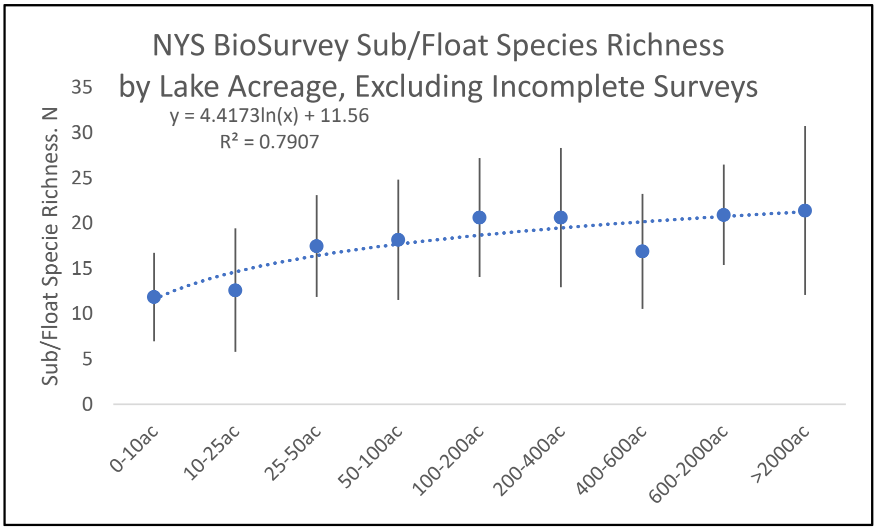


Figure 5.3.3.1 shows only a moderate relationship between lake size and species richness- note that bathymetric data are available on too few NYS BioSurvey lakes to estimate littoral area in these lakes. This figure is adversely affected by some lakes that were incompletely surveyed (based on a very small number of unique plants found in the lake) and included species-level identifications in all habitats (submergent, floating leaf and emergent plants), even though emergent plant species (as opposed to genera) were generally not included in the PIRTRAM or AWI survey results.

Table 7.4- Observed Species Richness (oSR) Scores Based on Figure 7.4

Lake Area	Expected oSR	Poor oSR	Fair oSR	Good oSR
0-10 ac	11.6	< 4.9	4.9 - 18.2	> 18.2
10-25 ac	14.6	< 6.8	6.8 - 22.4	> 22.4
25-50 ac	16.4	< 5.6	5.6 - 27.2	> 27.2
50-100 ac	17.7	< 6.7	6.7 - 28.7	> 28.7
100-200 ac	18.7	< 6.6	6.6 - 30.8	> 30.8
200-400 ac	19.5	< 7.7	7.7 - 31.2	> 31.2
400-600 ac	20.2	< 6.4	6.4 – 34.0	> 34.0
600-2000 ac	20.7	< 5.6	5.6 - 35.9	> 35.9
>2000 ac	21.3	< 9.3	9.3 - 33.2	> 33.2

To account for the habitat identification differences among the White Paper 1A monitoring programs and incomplete surveys in some NYS BioSurvey lakes, Figure 7.4 summarizes the relationship between lake area and species richness for the NYS BioSurvey, with data modified for (considering) only submergent and floating leaf plants identified to the same level (species-level for most submergent species, with genera-level identifications for some submergent plants (including macroalgae) and all floating leaf plants) as in the PIRTRAM and AWI (and likely future PIRTRAM-driven) surveys. These data indicate an increase in species richness as lake area (and presumably littoral area) increases, with normalized standard deviations ranging from 27% to 54%. If it is assumed that the NYS BioSurvey lakes, corrected for habitat-focused identifications (limiting data to submergent and floating leaf plants) and presumed complete plant surveys, are a representative cross section of historical lake observed species richness (oSR) in New York state, then these data could be used to define oSR scores ranging from “good” to “poor”. Specifically, these data could be translated to the following oSR scores, with specific ranges for each score and lake area interval outlined in

Table 7.4. The scores outlined in Table 7.4 assume that “poor” species richness can be assigned to those values that are more than 1 standard deviation below the Figure 7.4 regression line for each lake area range, and “good” species richness is assigned to those values more than 1 standard deviation above the regression, with “fair” species richness associated with values that fall within 1 standard deviation of this regression.

For example, a lake with a surface area of 75 acres and a species richness of 20 would fall within the “fair” assessment, based on an observed species richness for that lake size that falls within -1SD to +1SD, or normal variability, for the typical NYS BioSurvey lake. The discontinuity in these data, as seen in a decrease in some FQI scores as lake area intervals increase in Table 7.4, can be minimized or even eliminated by generating regressions for each FQI score across the range of lake areas (smoothing the data rather than using discrete values).

This method for assigning species richness scores provides a basis for evaluating species richness and assigning scores compared to historical NYS plant data. These data indicate a fairly steady increase in expected and scored species richness as lake area increases, consistent with other findings in White Paper 1D. The use of this method also allows species richness scores to be combined with other plant community metrics (summarized in White Papers 1E, 1F, and 1G) to develop aquatic life or aquatic plant assessments.

However, this method suffers from some problems. The assumption that historical NYS BioSurvey is a representative cross-section of NYS lakes in the present may be specious, given the lack of information about water quality, shoreline development, and lake use of more than 300 lakes surveyed close to 100 years ago. As seen in Figure 6.3 and Table 6.3, this method uses lake area, not littoral area (due to the lack of bathymetry for most of these lakes), even though littoral area is likely more closely aligned to species richness than is lake area (as discussed throughout White Paper 1D). Observed rather than projected species richness is used, owing to the lack of granular survey site data, subjecting these measures to potential problems with survey site densities and other factors cited above. These data also show a wide range of “fair” species richness scores, consistent with the high variability in oSR values in each lake area interval, which may not accurately represent the most appropriate oSR scores for these lakes, although this method may correctly identify (some) high and low quality lakes. However, until other species richness scoring methods can be developed, this method provides a starting point for evaluating lake species richness values.

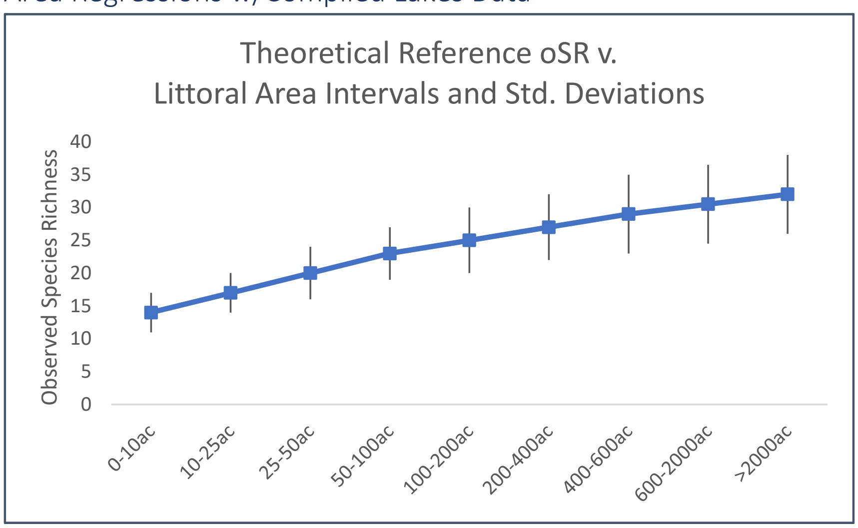
Section 7.5- Assigning species richness scores based on existing or future “reference” plant survey data

Section 7.4 outlines a process by which species richness scores are generated from regressions and associated variance of species richness against lake area for the approximately 300 NYS BioSurvey lakes. These scores assume that the NYS BioSurvey lakes are a representative cross section of all reference lakes, an assumption that cannot be easily evaluated given the lack of information about lake water quality, shoreline and watershed uses, and lake uses that are nearly 100 years old. As noted in Section 6.3, this approach has benefits and drawbacks, although in the absence of data to generate other approaches, this approach can be used to generate at least preliminary species richness scores.

An alternative approach, summarized in Sections 7.5 and 7.6, is to identify reference lakes for which aquatic plant communities are associated with minimally impacted conditions, presumably related to those lake uses most strongly tied to aquatic plants (aquatic life, fishing, and perhaps recreation). One option is to identify previously sampled lakes as reference lakes based on criteria established by the state or federal government. For example, the NYSDEC generally confers reference condition to those streams with total natural cover (forest, wetland, open water etc…) > 75% and impervious surface cover < 2% (https://www.epa.gov/wqc/bioassessment-and-biocriteria-program-status-new-york-streams-and-wadeable-rivers). US EPA and its consultants have also outlined a process for assigning reference conditions based on water chemistry, land use cover, and distance from roads to the lake shoreline (Herbity et al, 2013), although it should be noted that some of the issues outlined in Section 7.4 in regards to missing bathymetry and water quality data for lakes surveyed in one of the White Paper 1A programs might still apply to these lakes.

An example of this approach is shown in Figure 7.5.1, showing a *theoretical* relationship between observed species richness and littoral area for reference lakes, using the definitions adopted by northeastern lakes (using methods outlined by USEPA or by Herbity et al, 2013, among other options), or adopted by the NYSDEC. It should be noted that reference waterbodies have not been defined for New York state lakes. Figure 7.4.1 shows the "expected" species richness (= regression line) for various ranges of littoral area, with the typical variance represented by error bars generated by standard deviation. Using this example, the following species richness scores can be defined, assuming that reference conditions by definition indicate "good" values:

Figure 7.5.1- Example of Reference Waterbody oSR v. Littoral Area Regressions w/Compiled Lakes Data



- "Very good" species richness > 1SD above the regression line
- "Good" species richness for values between -1SD and +1SD, or the range of standard deviations shown in Figure 7.5.1
- "Fair" species richness for values between -1SD and -2SD below the regression line

- “Poor” species richness for values < -2SD below the regression line. Alternatively, “poor” could be defined as lakes exhibiting at least 25% invasives (and therefore 25% of the species richness value, consistent with the Florida plant community designations outlined in White Paper 1F).

Figure 7.5.2- Example of Reference Waterbody oSR v. Littoral Area Regressions w/Individual Lakes Data and Prediction Intervals

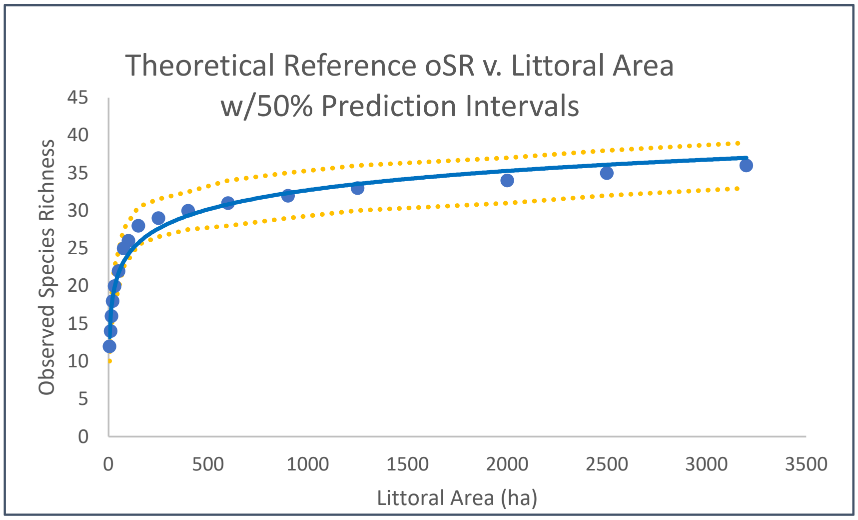


Figure 7.5.1 shows the mean and standard deviations for all lakes that fall within the littoral area intervals provided on the X axis. This approach, used in Section 6.3 with the NYS BioSurvey dataset for a representative cross-section of lakes, includes sufficient numbers of lakes in each littoral area (or lake area) range to evaluate typical values and variance. However, another approach, most likely involving smaller datasets, builds these regressions and 50% prediction intervals from individual points, not all points that fall within a littoral area interval.

An example of this is in Figure 7.5.2, which shows a regression based on discrete lake values (rather than cumulative data from lakes within a range), and the 50% prediction intervals drawn from those discrete points. This approach might be more appropriate for a much smaller dataset, but these prediction intervals may be very wide if the regression equation indicates a poor correlation between oSR and littoral area. Note that the differences in small changes of oSR or littoral area may not be apparent with (littoral area) data that are not log transformed- a similar plot can be developed for log transformed data- but actual datapoints associated with the regressions and prediction intervals can be used to estimate values on each plot.

Using this approach, the following species richness scores can be assigned:

- Very good” species richness > first 50% prediction interval
- “Good” species richness for values between the lower and upper prediction intervals
- “Fair” species richness for values between the first and (not shown in Figure 6.4.2) second lower prediction interval
- “Poor” species richness for values below the second lower prediction interval (or, as suggested above, lakes with >25% invasives).

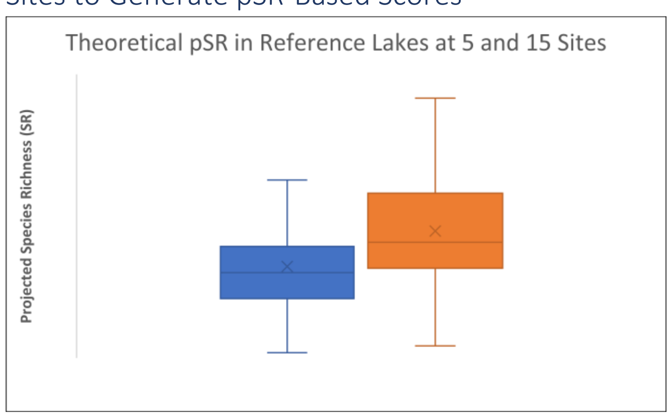
It should be noted that the approaches outlined in Figures 7.5.1 and 7.5.2 employ “asymmetric” definitions of species richness scores- “very good” lakes are defined as those with species richness “only” one standard deviation above (Figure 7.5.1) or the first 50% prediction interval above (Figure 7.5.2) the regression line, while “poor” lakes fall two standard deviations or the second prediction interval below the regression. This apparent dichotomy occurs because the reference dataset used in these figures is more likely to represent higher quality lakes, requiring a larger deviation from normal (the regression line) to represent poor conditions. It should also be noted that these approaches compare observed species richness (oSR) values since granular survey site data are not available on many lakes to compute projected species richness (pSR). However, the theoretical approach applies to both oSR and pSR, and the latter is preferred if available for ALL lakes used in generating the regressions and if available for any lakes compared to these regressions.

These approaches involve the following processes:

a. defining reference waterbodies, using methodologies developed for the region by USEPA or for the state by the NYSDEC:
b. calculating species richness (preferably pSR from granular survey site data) and littoral areas for each waterbody, by either
    i. plotting either mean and standard deviation error bars for species richness for all lakes within defined littoral or lake area intervals (Figure 6.4.1) or
    ii. plotting individual points (Figure 7.5.2); species richness v. littoral or lake area;
c. calculating regressions (Figure 7.5.1) or both regressions and 50% prediction intervals (Figure 7.5.2).
d. comparing non-reference lakes to these regressions and associated measures of variance to determine the most appropriate species richness score for these lakes (and counting the number of AIS relative to all plants, as suggested above).

In addition, the same general approach can be used by limiting the analysis summarized in Section 6 if the assumptions that projected species richness does not change significantly with littoral area at defined (5 site and 15 site) survey sizes for reference lakes. Since it is not known if the lack of a strong relationship between pSR and littoral area at these defined survey sites is an artefact of the PIRTRAM and Lower Hudson PRISM program lakes, it is not yet known if this approach, rather than the approaches shown in Figures 7.5.1 or 7.5.2, can be used to generate species richness scores. However, if it can be shown that reference lakes follow the same general (lack of high correlation) pattern seen in Figures 6.3.1 and 6.3.2, then the general pattern shown in Figure 7.5.3 can apply as follows, recognizing that the majority (likely at least 75%) of reference waterbodies would exhibit favorable species

Figure 7.5.3- Reference pSR Values at Defined # Sites to Generate pSR-Based Scores



richness values (given minimally impacted conditions associated with reference waterbodies):

"Poor" = < 5th percentile value associated with reference pSR values at 5 sites and 15 sites. Note that the 5th percentile is chosen since individual pSR values in some reference waterbodies may be unexpectedly low due to factors unrelated to reference definitions.

"Good" = >25th percentile of the reference pSR values at 5 sites and 15 sites;

"Fair" = within the 5th to 25th percentile of the reference pSR values at 5 and 15 sites

The 25th percentile designation is consistent with the USEPA threshold used to identify those reference waterbodies that exhibit water quality characteristics consistent with at least slightly impacted conditions, to account for outliers in the reference waterbody dataset. It is assumed here that more stringent criteria could be applied to an aquatic plant community reference dataset, thereby allowing for a less conservative outlier threshold (5th percentile), while still recognizing that slightly suboptimal conditions may still exist in some (up to 25$^{\%}$ of) reference waterbodies, particularly those considered to be "minimally impacted" rather than "unimpacted" by aquatic plants..

It is not known if the resulting pSR score for surveyed lakes (relative to reference lakes) would be slightly lower than the scores generated in Table 7.2.1, since reference lakes would likely exhibit higher pSR values than the typical NYS lake summarized in Table 7.2.1. However, the process summarized above regarding the interpretation of the theoretical Figure 7.5.3 pSR ranges assumes that reference waterbodies exhibit high species richness values, and that most NYS lakes would fall below the range of pSR values shown in Figure 7.5.3.

Section 7.6- Defining reference conditions or reference waterbodies

Section 7.5 outlines a process by which reference waterbodies can be used to develop pSR scores at defined numbers of survey sites, assuming that there is no clear relationship between pSR and littoral area at these defined (numbers of) survey sites. This can be done with either existing data or conducting new surveys on future lakes. For the former, some combination of shoreline development, watershed land uses, and road networks can be identified, using historical land use data. However, attempting to define historical plant surveyed lakes as reference lakes must recognize that for at least the NYS BioSurvey lakes, this information may not be available. Littoral areas also cannot be defined for many of these lakes, since bathymetry from that time was either not available or cannot be resurrected. However, using historical plant survey data minimizes the amount of new sampling that needs to be conducted, and conceivably could be done with existing datasets. As noted above, the NYS BioSurvey and AWI surveys are most likely to include some reference lakes, given the higher potential for minimally developed shorelines, watershed land uses more likely to be associated with "original" conditions, the lack of AIS in most lakes, and extensive plant surveys conducted on many of these lakes. ALSC data cannot be used given the lack of species-level identifications in these lakes, and the PIRTRAM lakes are generally not candidates for reference lakes due to the strong overlap with management actions on these lakes. If historical data were used, it is likely that lake area would need to be converted to littoral area for conformance with the more accurate area measurements used in the PIRTRAM program and most future surveyed lakes.

For new surveys, shoreline development, watershed areas (associated with specific land uses) and distribution of roads can be defined for lakes over a broad range of littoral areas (with lake bathymetry conducted on lakes as needed to identify the extent of the littoral zone). Once candidate reference lakes were defined, using the regional or state landscape-level criteria summarized in Section 7.3 above, detailed aquatic plant surveys could be conducted on a subset of these lakes representing the range of littoral area. It should be noted that trophic state should not be explicitly used as a filter for defining reference lakes. While the data presented in this White Paper indicate that trophic state can strongly influence species richness, this "dynamic" factor (versus the "static" factor of littoral area) should not be evaluated independently- suppression of species richness in response to trophic state should not be a reason for artificially assigning a more favorable score to the species richness values for a lake.

Any new plant surveys conducted to build littoral area-based species richness regressions for candidate reference lakes should include the following attributes:

1. collection of bathymetry data to calculate littoral area
2. collection of plant presence and relative abundance at each site to identify the most frequently occurring and most abundant plants, and to correct floristic quality estimates by weighing values for relative frequency or abundance (see White Papers 1F and 1G)
3. sufficient survey site density to accurately calculate projected species richness (pSR). As noted above, this would ideally mean surveying at a survey site density of 1 site per littoral hectare, but should include at least 15 sites on small lakes and 25-40 sites on large lakes to estimate pSR (and meet other survey objectives)
4. species level identifications of all submergent macrophytes, including all exotic plants, nuisance native plants, and protected plants (see White Paper 1E), and at least genera level identification of all submergent macroalgae, and all floating leaf plants.

Section 8- Recommendations to Improve Species Richness Evaluations

This White Paper summarizes observed and projected species richness in large groups of New York state lakes, and provides several recommendations to improve the calculation and use of these measures in evaluating floristic quality. These include the following, discussed at length in Sections 1 through 7:

1. There are some inconsistencies across multiple programs in determining the scope of species richness calculations. For example, some programs equally identify submergent, floating leaf, and emergency plants to species level, while others focus on species-level identification for submergent plants, species- or genera-level identification for floating leaf plants, and only marginal recording of emergent plants. Analysts should seek consistency when evaluating data, and should standardize the data across habitats (for example, calling all yellow water lilies *Nuphar* sp if most programs appear to default to genera-identification).

2. Given the recommended use of point-intercept rake toss data to evaluate several aquatic plant community measures (species richness, coefficients of conservatism (C values), floristic quality indices (FQI),…) in these White Papers, evaluations by default should be limited to submergent and floating leaf plants.
3. Species richness calculations suffer from inconsistencies in the number of survey sites since species richness (and in many cases modified FQI, or mFQI, as discussed in White Paper 1G) increases as survey sites increase. Species richness, and by extension C values and mFQI, should be evaluated at a standardized survey site density of 1 site per littoral hectare, to compare lakes across programs or individual lakes over time. This will result in the use of projected rather than observed species richness, which will improve consistency in comparing lakes even in recognition that a projected species richness value will often be lower than an observed species richness. However, standardized values require granular survey site data to generate regressions showing changes in cumulative species richness values at any survey site density. This is achieved by using subsampling methods outlined in White Paper 1C. As discussed below, the projected species richness at 5 and 15 sites can be used to generate pSR scores for each lake, based on the assumption (valid in at least PIRTRAM and LH PRISM lakes) that pSR values are not strongly influenced by littoral area at a consistent (defined) number of survey sites.
4. Truncated surveys- using fewer survey sites to estimate projected (standardized) species richness- can achieve a high degree of accuracy while reducing the use of surveying resources. Truncated surveys can also be used to find many (but not all) of the plants growing in the lake, likely including most of the invasive species.

In addition to these general recommendations, several other actions can be taken to improve the use of species richness:

1. A single value for "optimal" species richness cannot be determined, even when calculated using a standardized survey site density, since species richness will generally be greater in large lakes than in small lakes. Such a single value designation would afford a more favorable assessment in large lakes than in small lakes, even if other measures indicate poor floristic quality in the former and high floristic quality in the latter. The best way to identify a littoral area gradient in optimal species richness is to identify and survey reference waterbodies with minimal floristic impacts (however defined) across a wide range of littoral areas. Such a reference dataset does not presently exist in New York state, but could be built through a process by which these waterbodies are identified and surveyed. However, while species richness is generally higher in larger lakes, projected species richness (pSR) values at specific numbers of survey sites do not change significantly with increases in the size of littoral areas. This information can be used to compare pSR values for any lake at 5 sites and 15 sites to the expected pSR values in PIRTRAM and LH PRISM lakes at the same number of sites to identify those lakes with "good" and "poor" pSR values. This can serve as an interim scoring system for evaluating species richness until a sufficient number of reference waterbodies can be defined and surveyed to develop an improved pSR scoring system.

2. Even with the adoption of a C_m system that reduces the need to accurately identify all plants, including those assigned the $C_m = 3$ value, there remains a need to enhance aquatic plant identification skills to improve use of species richness valus and mFQIs. This would inspire a higher confidence in C values, an accurate species richness count, and improved associated FQI values and scores. This could be done with enhanced ID workshops focusing on RTEs, exotics, and the few regional nuisance native plant species (collectively representing less than 10% of all aquatic plants), but could also be done by supporting collaborations between plant ID experts and plant survey teams.

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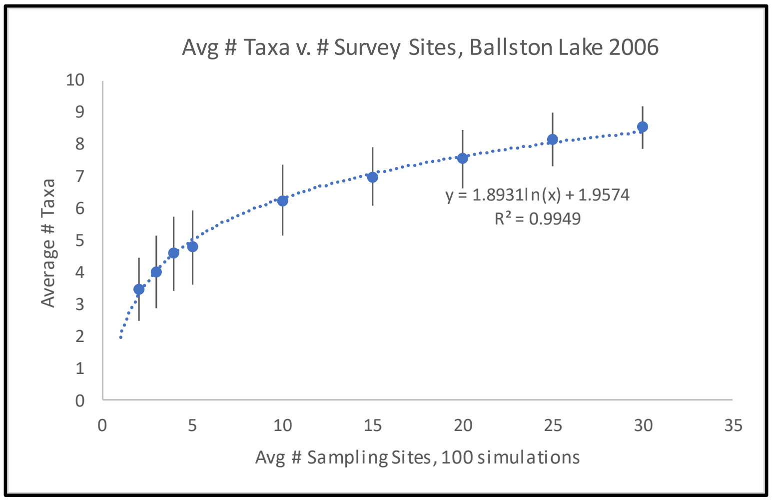
Appendix 3.2.1- Taxa Distribution by Survey Sites for PIRTRAM Lakes

Ballston Lake 2006 Plant Survey conducted by Lake Association

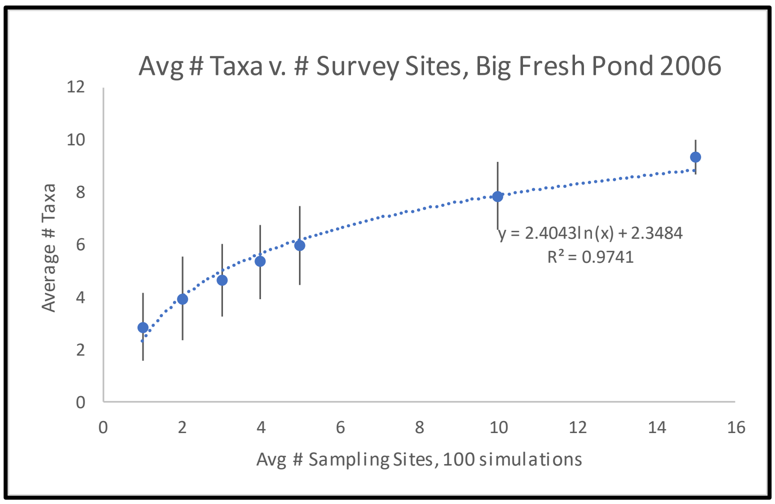


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	4
60	7
70	11
80	18
90	30

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	474	192	96	48	24	12	34	34
Taxa in X sites	13.6	11.9	10.6	9.3	8.0	6.7	9.0	8.6
% STD	147%	128%	114%	100%	86%	72%	97%	93%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Big Fresh Pond 2006 Plant Survey conducted by DEC DOW Albany

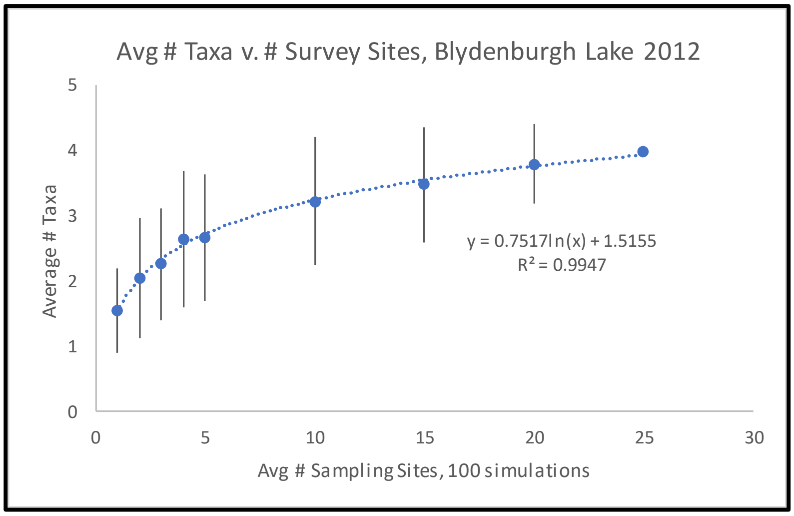


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	2
60	3
70	4
80	6
90	9

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	128	52	26	13	6.5	3.25	19	19
Taxa in X sites	14.0	11.8	10.2	8.5	6.8	5.2	10	9.4
% STD	165%	139%	120%	100%	80%	61%	117%	111%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Blydenburgh Lake 2012 Plant Survey conducted by DEC R1 DFW

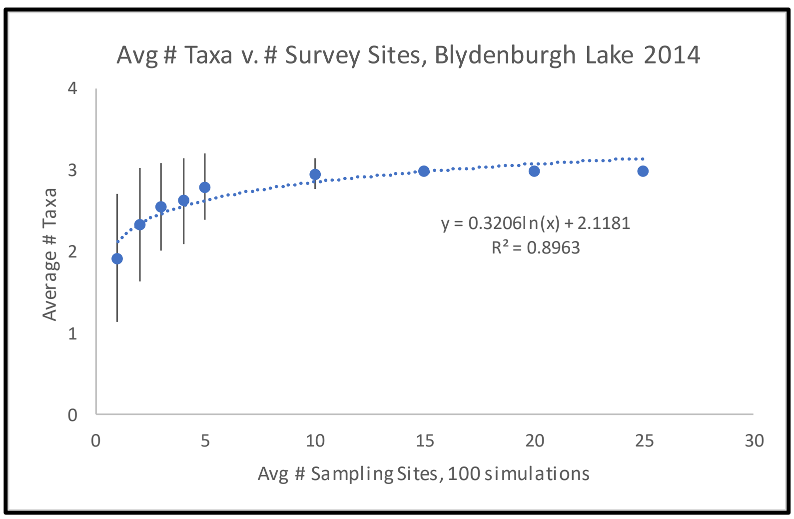


%STD Taxa	#Sites
10	0
20	0
30	1
40	1
50	2
60	4
70	7
80	13
90	23

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	395	160	80	40	20	10	27	27
Taxa in X sites	6.0	5.3	4.8	4.3	3.8	3.2	4	4.0
% STD	140%	124%	112%	100%	88%	76%	93%	93%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Blydenburgh Lake 2014 Plant Survey conducted by DEC R1 DFW

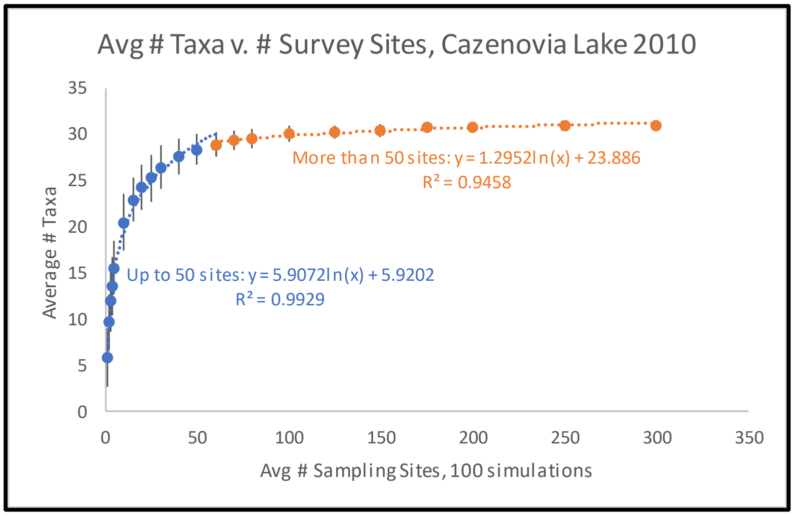


%STD Taxa	#Sites
10	0
20	0
30	0
40	0
50	0
60	1
70	2
80	5
90	14

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	395	160	80	40	20	10	27	27
Taxa in X sites	4.0	3.7	3.5	3.3	3.1	2.9	3	3.2
% STD	122%	113%	94%	88%	82%	76%	80%	85%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2010 Plant Survey conducted by Racine Johnson AE

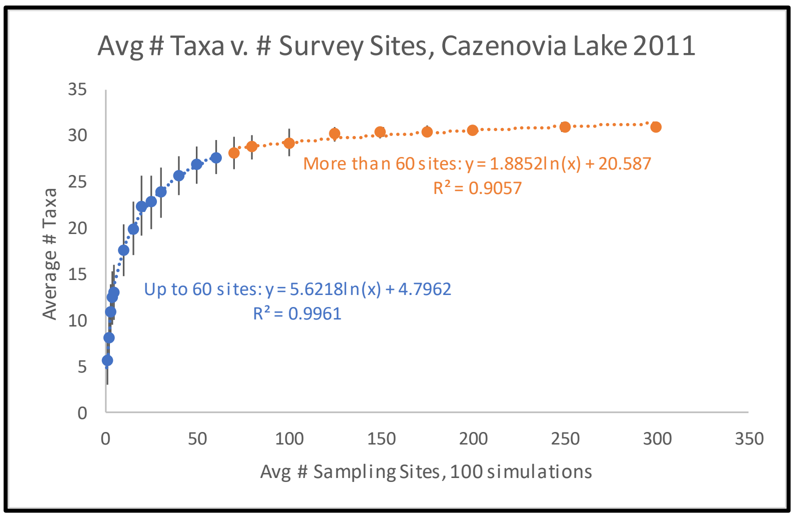


%STD Taxa	#Sites
10	0
20	1
30	1
40	3
50	6
60	12
70	25
80	53
90	109

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	33.9	32.7	31.8	30.9	30.0	29.1	31	31.3
% STD	132%	119%	110%	100%	90%	81%	93%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2011 Plant Survey conducted by Racine Johnson AE

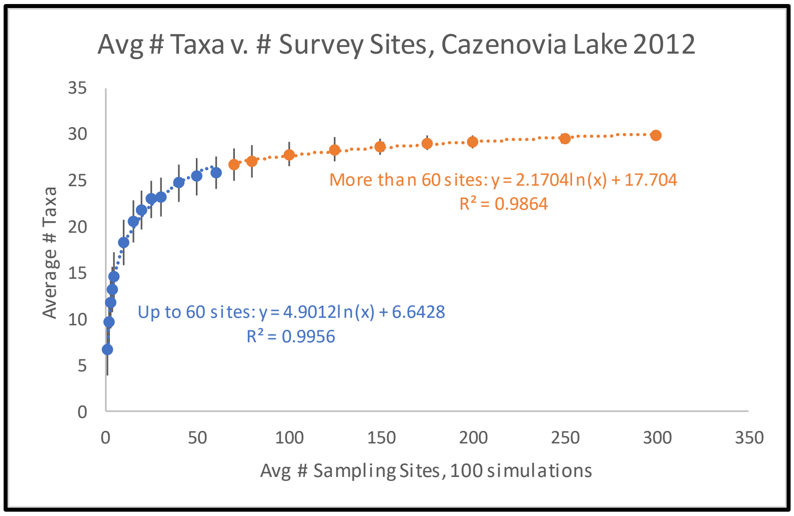


%STD Taxa	#Sites
10	1
20	1
30	2
40	4
50	8
60	15
70	30
80	59
90	115

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	35.1	33.4	32.1	30.8	29.5	28.2	31	31.4
% STD	134%	121%	110%	100%	90%	79%	95%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2012 Plant Survey conducted by Racine Johnson AE

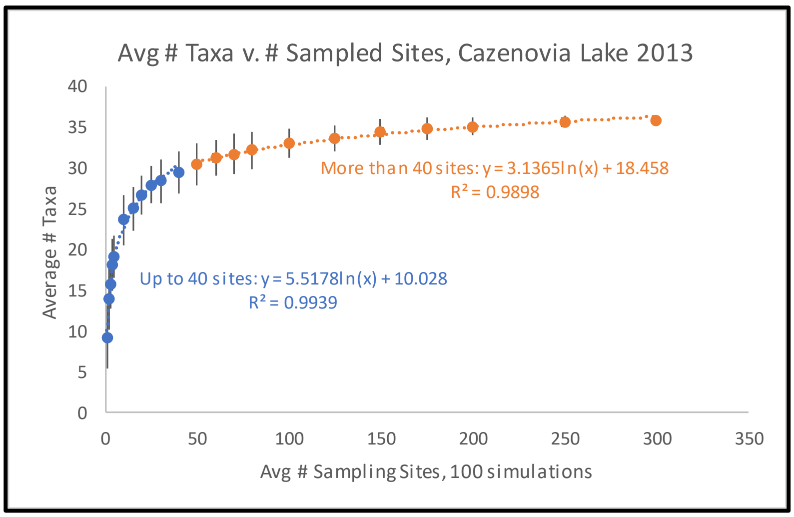


%STD Taxa	#Sites
10	0
20	1
30	1
40	3
50	6
60	12
70	25
80	52
90	108

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	34.4	32.5	31.0	29.5	28.0	26.5	30	30.1
% STD	134%	121%	110%	100%	90%	79%	95%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2013 Plant Survey conducted by Racine Johnson AE

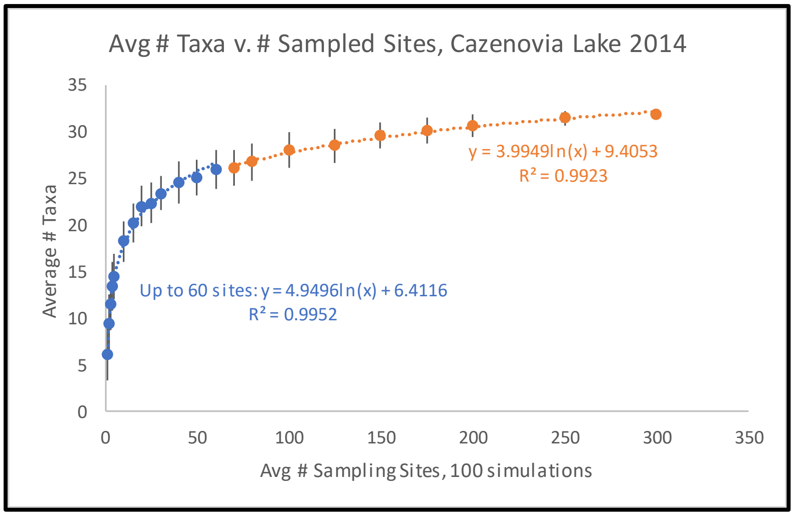


%STD Taxa	#Sites
10	0
20	0
30	1
40	2
50	4
60	9
70	21
80	46
90	102

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	42.6	39.8	37.6	35.4	33.3	31.1	36	36.4
% STD	134%	121%	110%	100%	90%	79%	95%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2014 Plant Survey conducted by Racine Johnson AE

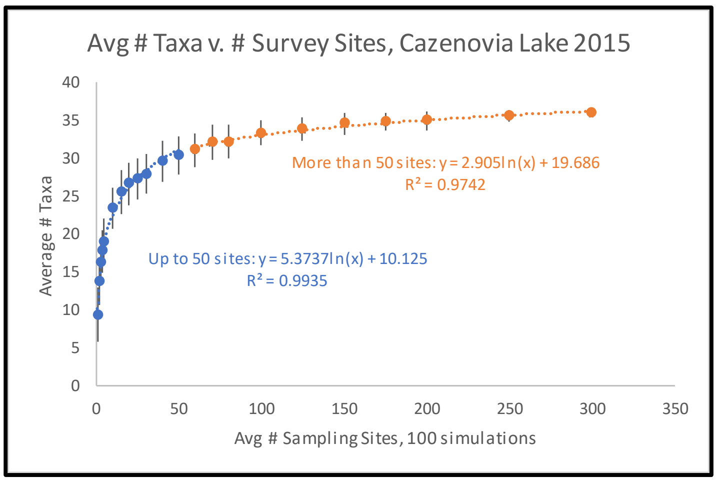


%STD Taxa	#Sites
10	0
20	1
30	2
40	3
50	7
60	14
70	27
80	55
90	111

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	40.2	36.6	33.8	31.0	28.3	25.5	32	32.2
% STD	134%	121%	110%	100%	90%	79%	95%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2015 Plant Survey conducted by Racine Johnson AE

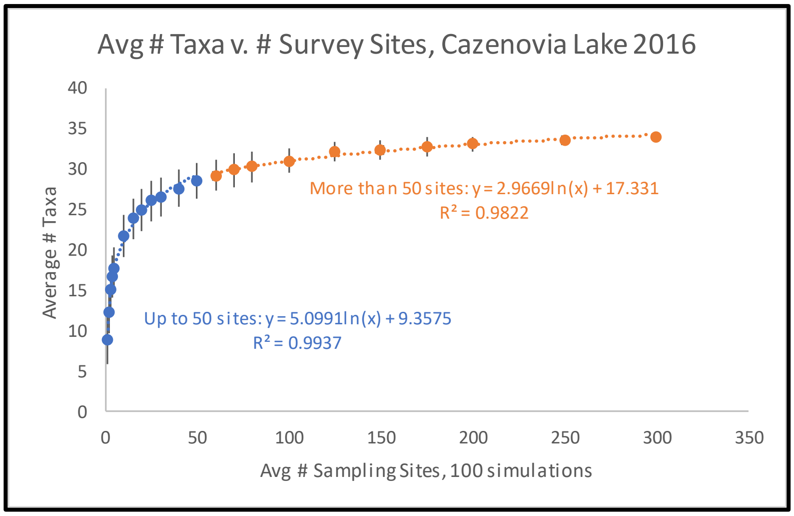


%STD Taxa	#Sites
10	0
20	0
30	1
40	2
50	4
60	10
70	21
80	46
90	102

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	42.1	39.4	37.4	35.4	33.4	31.4	36	36.3
% STD	134%	121%	110%	100%	90%	79%	95%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2016 Plant Survey conducted by Racine Johnson AE

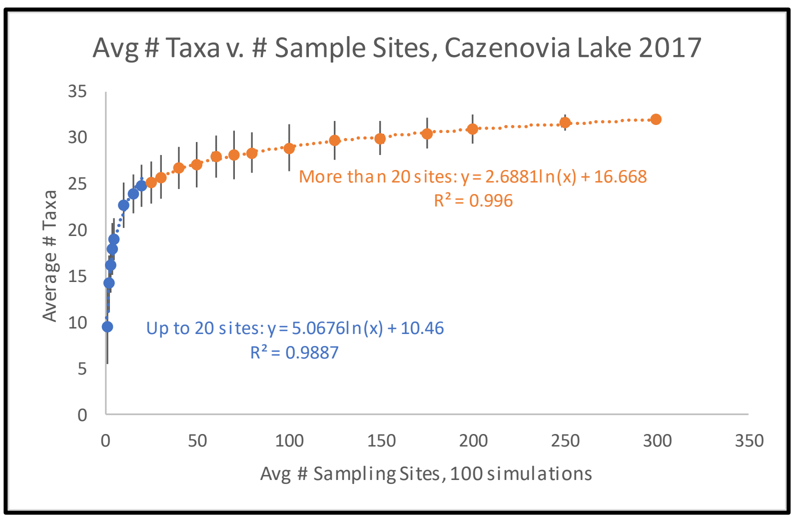


%STD Taxa	#Sites
10	0
20	0
30	1
40	2
50	4
60	10
70	21
80	47
90	103

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	40.2	37.5	35.5	33.4	31.3	29.3	34	34.3
% STD	134%	121%	110%	100%	90%	79%	95%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2017 Plant Survey conducted by Racine Johnson AE

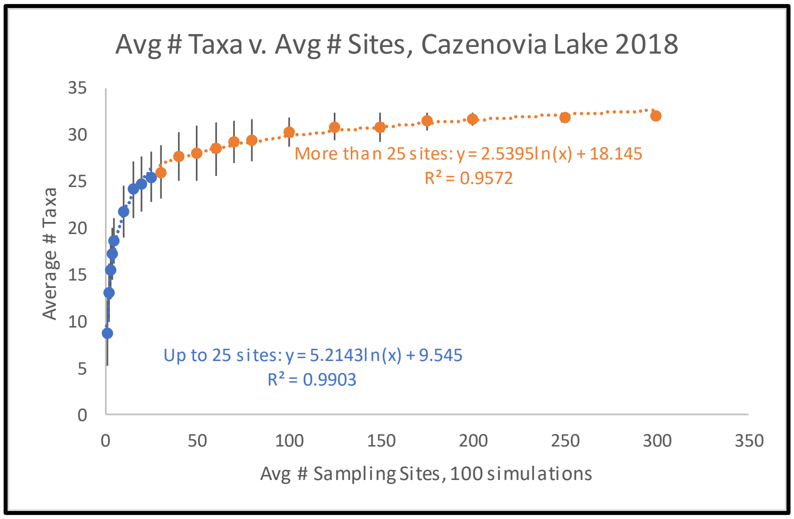


%STD Taxa	#Sites
10	0
20	0
30	0
40	1
50	3
60	6
70	15
80	38
90	92

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	37.4	35.0	33.1	31.2	29.4	27.5	32	32.0
% STD	126%	116%	108%	100%	92%	84%	100%	103%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2018 Plant Survey conducted by Racine Johnson AE

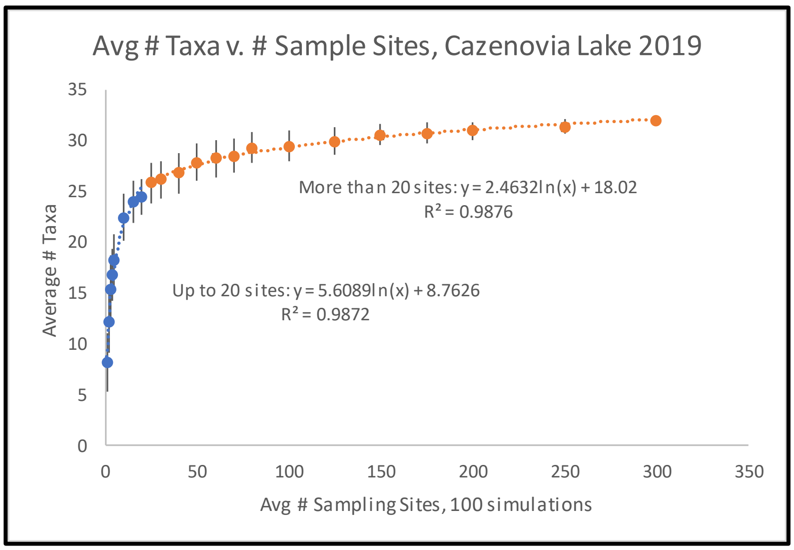


%STD Taxa	#Sites
10	0
20	0
30	1
40	2
50	3
60	8
70	18
80	42
90	98

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	37.7	35.4	33.7	31.9	30.1	28.4	32	32.7
% STD	127%	117%	108%	100%	92%	83%	97%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Cazenovia Lake 2019 Plant Survey conducted by Racine Johnson AE

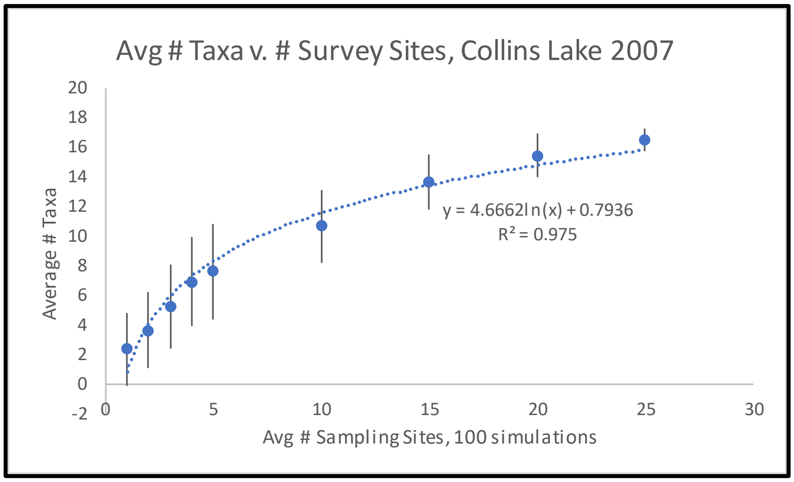


%STD Taxa	#Sites
10	0
20	0
30	1
40	2
50	4
60	8
70	19
80	43
90	98

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	2223	900	450	225	112.5	56.25	304	304
Taxa in X sites	37.0	34.8	33.1	31.4	29.7	27.9	32	32.1
% STD	128%	117%	108%	100%	92%	83%	98%	104%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Collins Lake 2007 Plant Survey conducted by DEC DOW Albany

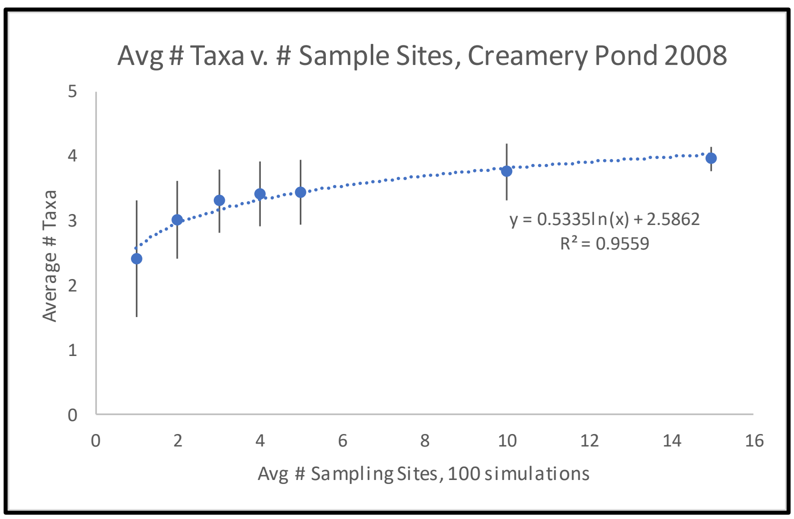


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	2
60	2
70	3
80	4
90	4

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	49	20	10	5	2.5	1.25	28	28
Taxa in X sites	19.0	14.8	11.5	8.3	5.1	1.8	17	16.3
% STD	229%	178%	139%	100%	61%	22%	205%	197%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Creamery Pond 2008 Plant Survey conducted by DEC DOW Albany

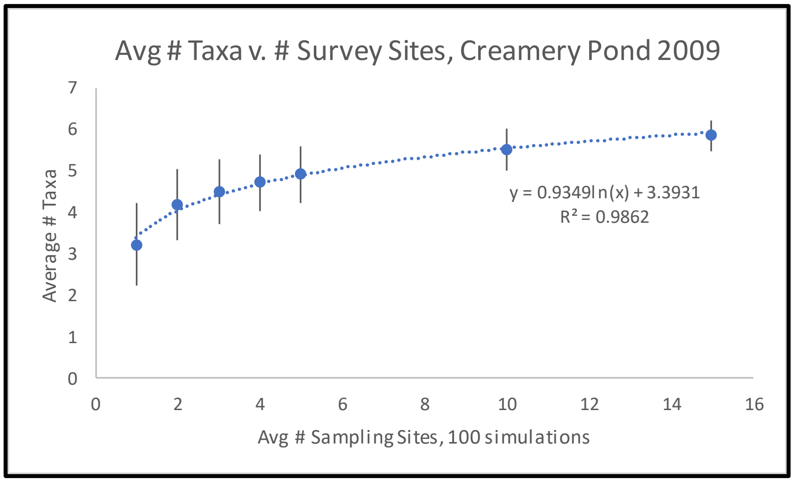


%STD Taxa	#Sites
10	0
20	0
30	0
40	0
50	0
60	0
70	1
80	1
90	2

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	40	16	8	4	2	1	18	18
Taxa in X sites	4.5	4.1	3.7	3.3	3.0	2.6	4	4.1
% Max	137%	122%	111%	100%	89%	78%	120%	124%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Creamery Pond 2009 Plant Survey conducted by DEC DOW Albany

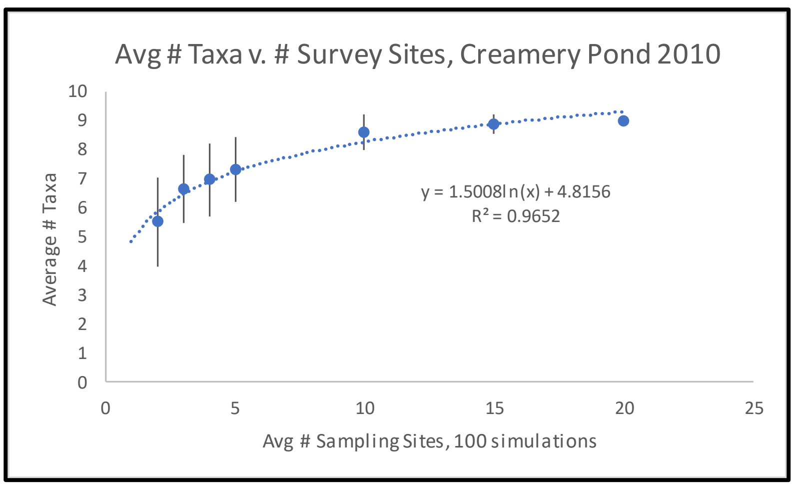


%STD Taxa	#Sites
10	0
20	0
30	0
40	0
50	0
60	1
70	1
80	1
90	2

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	40	16	8	4	2	1	18	18
Taxa in X sites	6.8	6.0	5.3	4.7	4.0	3.4	6	6.1
% STD	146%	128%	114%	100%	86%	72%	128%	130%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Creamery Pond 2010 Plant Survey conducted by DEC DOW Albany

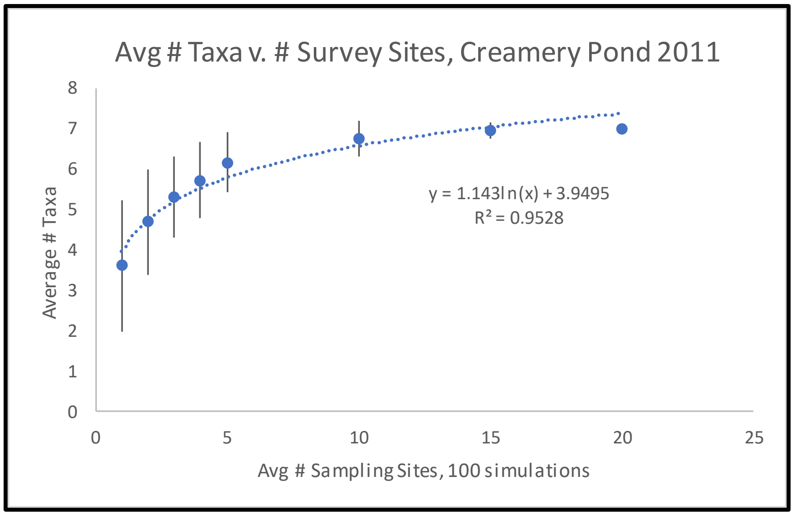


%STD Taxa	#Sites
10	0
20	0
30	0
40	0
50	0
60	1
70	1
80	2
90	3

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	40	16	8	4	2	1	21	21
Taxa in X sites	10.3	9.0	7.9	6.9	5.9	4.8	9	9.4
% STD	150%	130%	115%	100%	85%	70%	131%	136%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Creamery Pond 2011 Plant Survey conducted by DEC DOW Albany

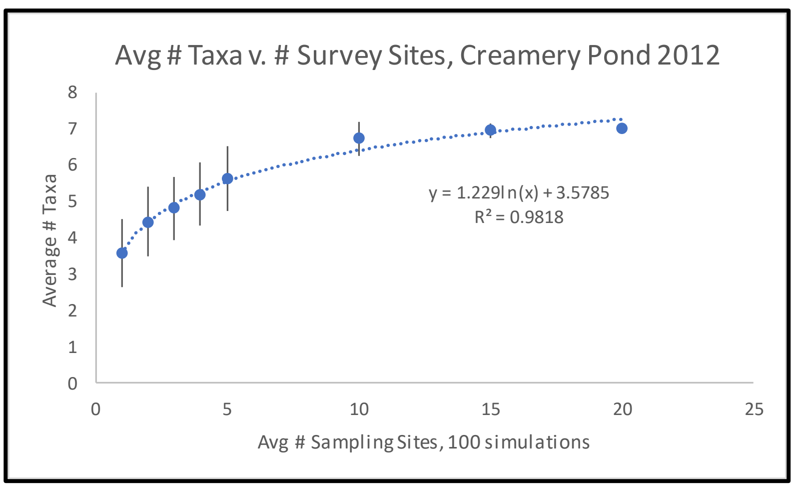


%STD Taxa	#Sites
10	0
20	0
30	0
40	0
50	0
60	1
70	1
80	2
90	2

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	40	16	8	4	2	1	21	21
Taxa in X sites	8.2	7.1	6.3	5.5	4.7	3.9	7	7.4
% STD	147%	129%	114%	100%	86%	71%	126%	134%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Creamery Pond 2012 Plant Survey conducted by DEC DOW Albany

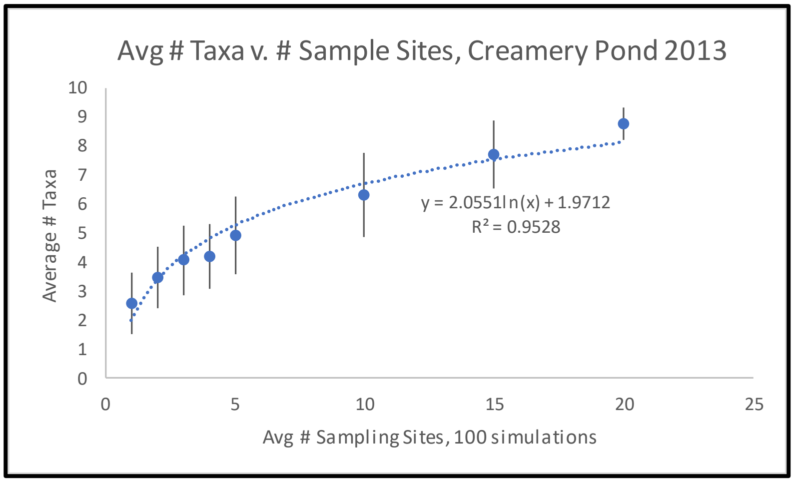


%STD Taxa	#Sites
10	0
20	0
30	0
40	0
50	0
60	1
70	1
80	2
90	3

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	40	16	8	4	2	1	21	21
Taxa in X sites	8.1	7.0	6.1	5.3	4.4	3.6	7	7.3
% STD	153%	132%	116%	100%	84%	68%	133%	139%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Creamery Pond 2013 Plant Survey conducted by DEC DOW Albany

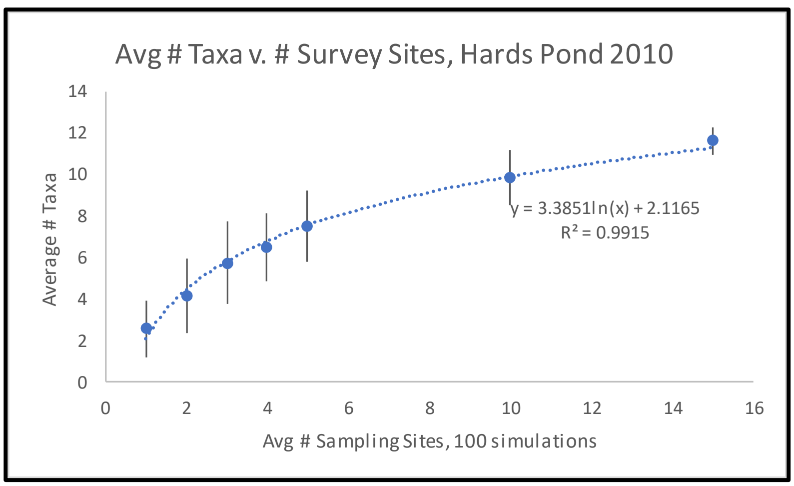


%STD Taxa	#Sites
10	0
20	1
30	1
40	1
50	1
60	2
70	2
80	3
90	3

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	40	16	8	4	2	1	21	21
Taxa in X sites	9.5	7.7	6.2	4.8	3.4	2.0	9	8.2
% STD	198%	159%	130%	100%	70%	41%	187%	171%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Hards Pond 2010 Plant Survey conducted by DEC R1 DFW

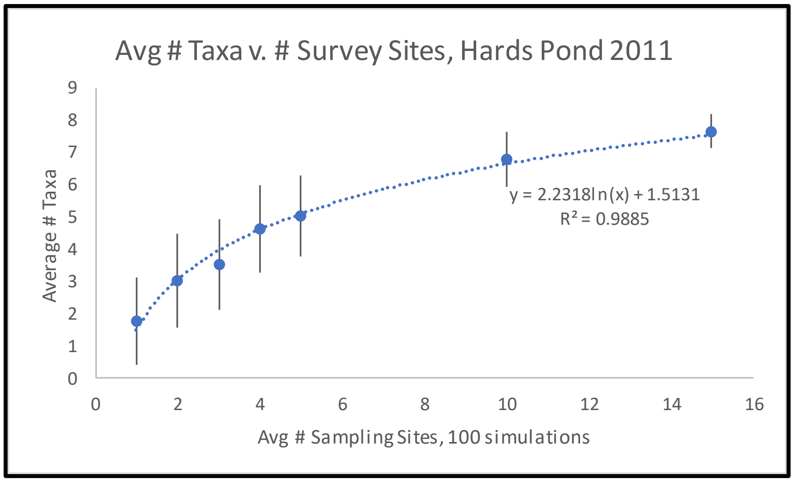


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	3
60	3
70	5
80	6
90	9

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	119	48	24	12	6	3	16	16
Taxa in X sites	18.3	15.2	12.9	10.5	8.2	5.8	12	11.5
% STD	174%	145%	122%	100%	78%	55%	114%	109%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Hards Pond 2011 Plant Survey conducted by DEC DOW Albany

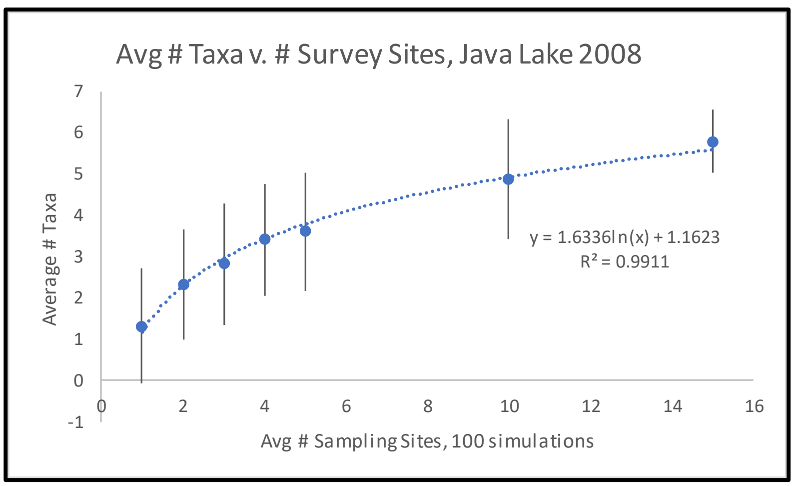


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	2
60	3
70	5
80	6
90	9

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	119	48	24	12	6	3	19	19
Taxa in X sites	12.2	10.2	8.6	7.1	5.5	4.0	8	8.1
% STD	172%	144%	122%	100%	78%	56%	113%	115%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Java Lake 2008 Plant Survey conducted by the Lake Association

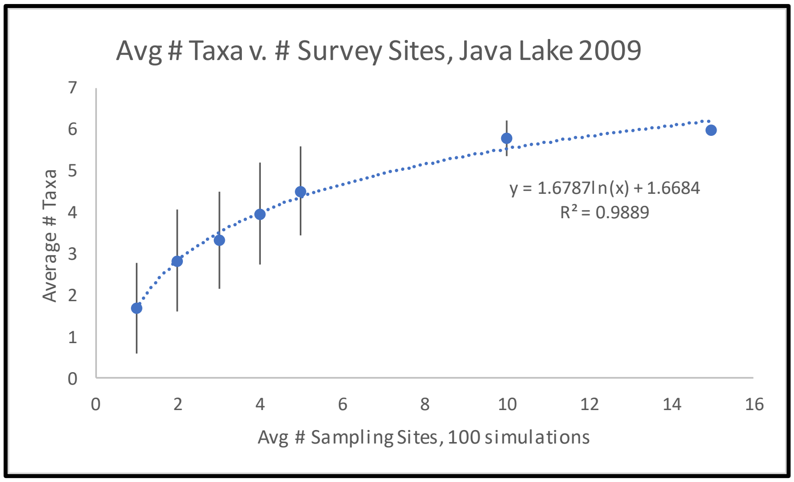


%STD Taxa	#Sites
10	1
20	1
30	2
40	2
50	3
60	5
70	7
80	10
90	14

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	207	84	42	21	10.5	5.25	16	16
Taxa in X sites	9.9	8.4	7.3	6.1	5.0	3.9	6	5.7
% STD	161%	137%	118%	100%	82%	63%	98%	93%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Java Lake 2009 Plant Survey conducted by DEC DOW Albany

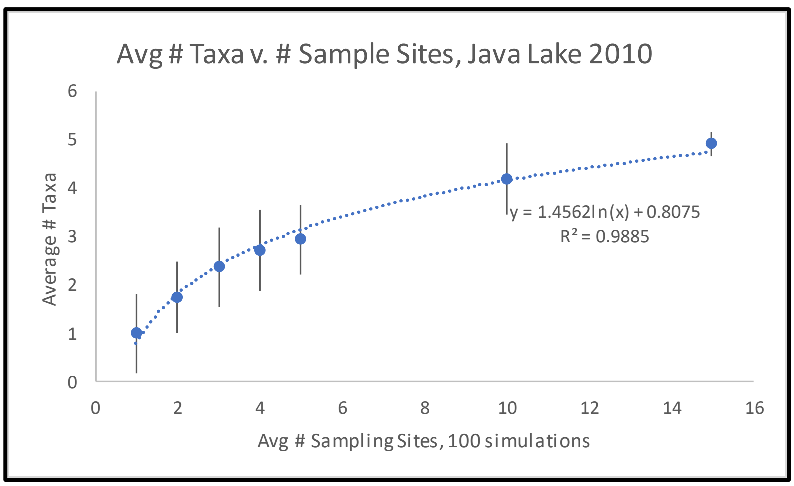


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	3
60	4
70	6
80	9
90	14

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	207	84	42	21	10.5	5.25	16	16
Taxa in X sites	10.6	9.1	7.9	6.8	5.6	4.5	6	6.3
% STD	157%	134%	117%	100%	83%	66%	89%	93%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Java Lake 2010 Plant Survey conducted by the Lake Association

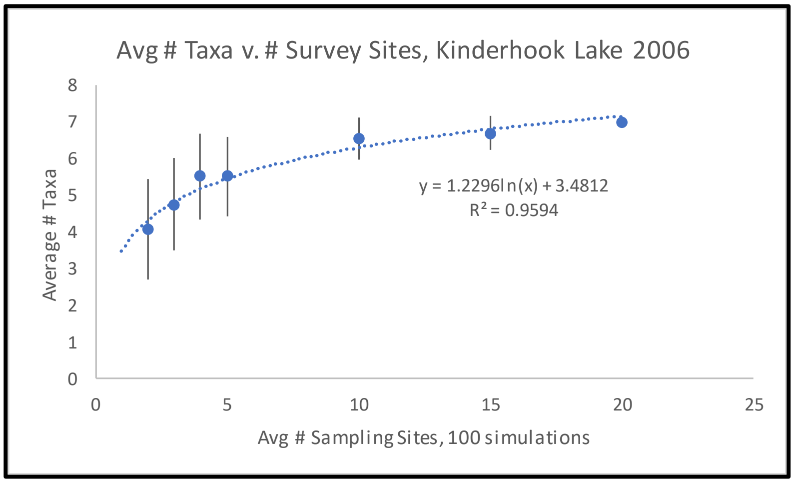


%STD Taxa	#Sites
10	1
20	1
30	2
40	2
50	3
60	5
70	7
80	10
90	15

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	207	84	42	21	10.5	5.25	16	16
Taxa in X sites	8.6	7.3	6.3	5.2	4.2	3.2	5	4.8
% STD	164%	139%	119%	100%	81%	61%	95%	92%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Kinderhook Lake 2006 Plant Survey conducted by the Lake Association

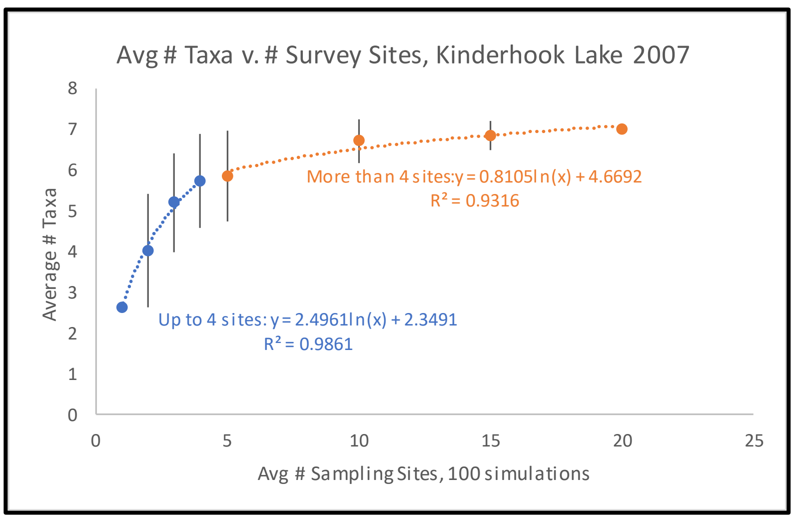


%STD Taxa	#Sites
10	0
20	0
30	1
40	1
50	3
60	5
70	11
80	24
90	51

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	1077	436	218	109	54.5	27.25	20	20
Taxa in X sites	12.1	11.0	10.1	9.2	8.4	7.5	7	7.2
% STD	130%	118%	109%	100%	91%	82%	76%	77%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Kinderhook Lake 2007 Plant Survey conducted by the Lake Association

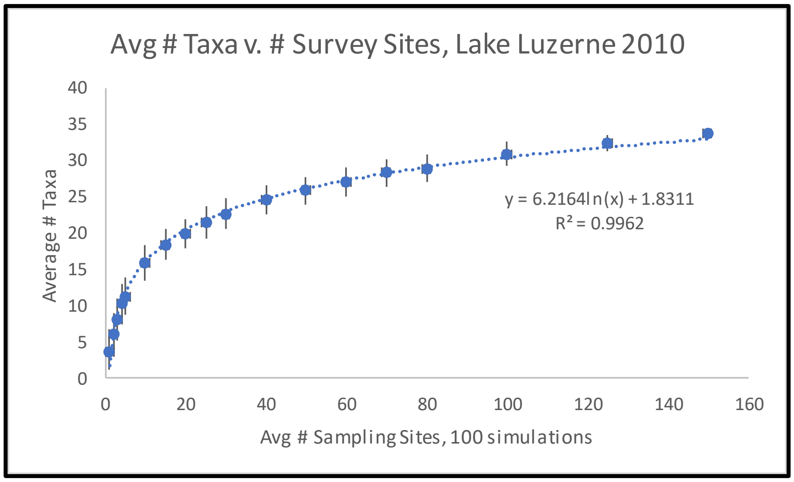


%STD Taxa	#Sites
10	0
20	0
30	0
40	1
50	2
60	5
70	10
80	23
90	50

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	1077	436	218	109	55	27	20	20
Taxa in X sites	10.3	9.6	9.0	8.5	7.9	7.3	7	7.1
% STD	129%	118%	109%	100%	91%	82%	75%	78%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lake Luzerne 2010 Plant Survey conducted by DFWI

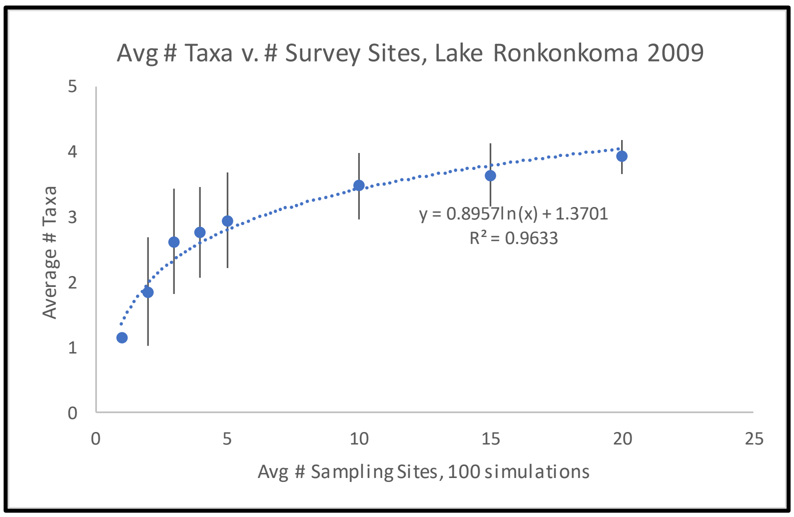


%STD Taxa	#Sites
10	1
20	1
30	2
40	3
50	4
60	6
70	8
80	12
90	17

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	237	96	48	24	12	6	152	152
Taxa in X sites	35.8	30.2	25.9	21.6	17.3	13.0	34	33.1
% STD	166%	140%	120%	100%	80%	60%	158%	153%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lake Ronkonkoma 2009 Plant Survey conducted by DEC R1 DFW

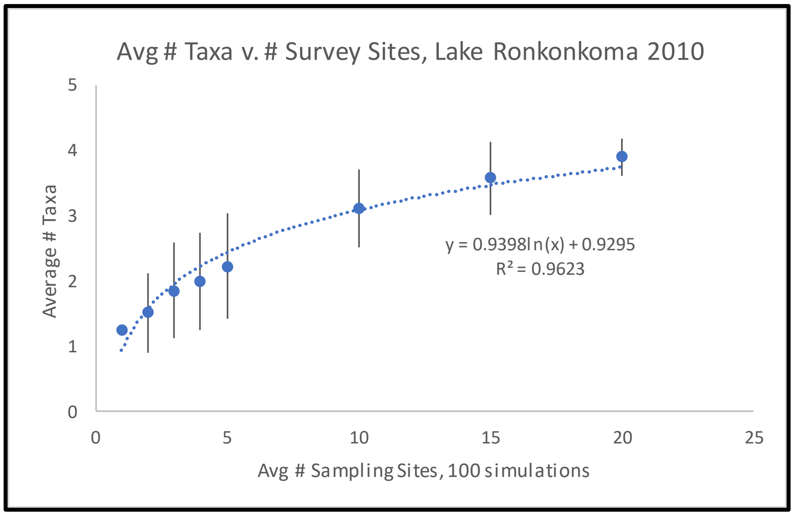


%STD Taxa	#Sites
10	0
20	1
30	1
40	1
50	2
60	3
70	5
80	8
90	13

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	207	84	42	21	10.5	5.25	22	22
Taxa in X sites	6.1	5.3	4.7	4.1	3.5	2.9	4	4.1
% STD	150%	130%	115%	100%	85%	70%	98%	101%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lake Ronkonkoma 2010 Plant Survey conducted by DEC R1 DFW

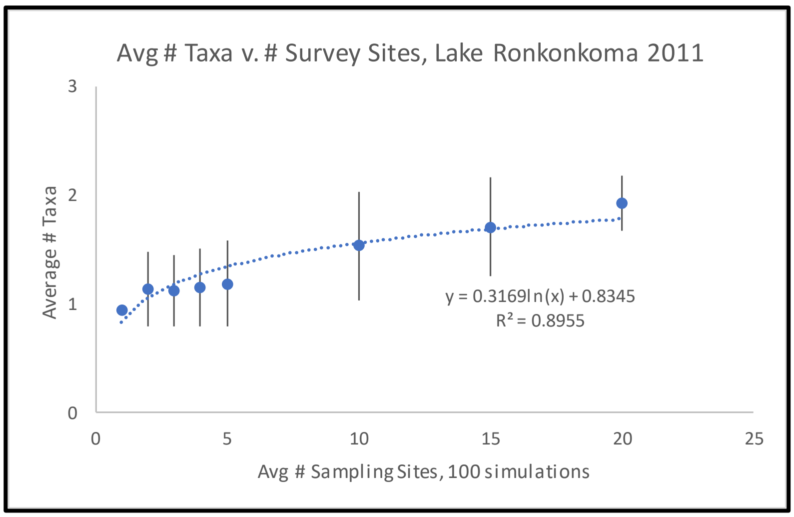


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	3
60	4
70	6
80	9
90	14

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	207	84	42	21	10.5	5.25	22	22
Taxa in X sites	5.9	5.1	4.4	3.8	3.1	2.5	4	3.8
% STD	157%	134%	117%	100%	83%	66%	106%	101%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lake Ronkonkoma 2011 Plant Survey conducted by DEC R1 DFW

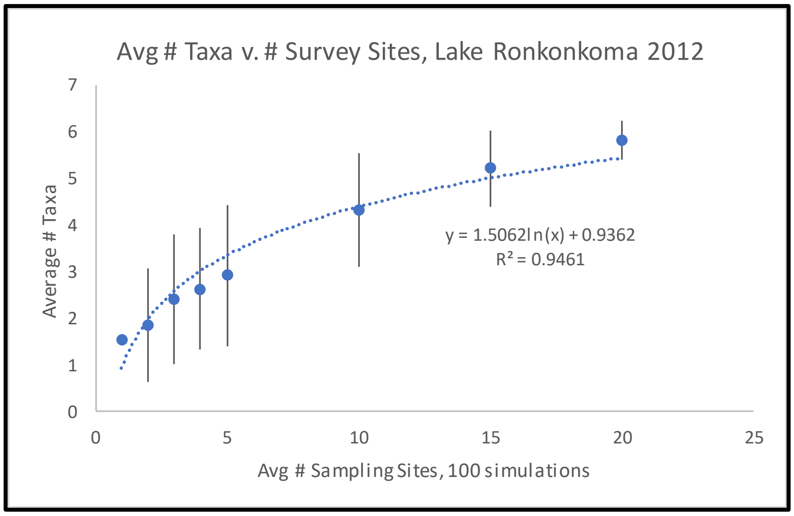


%STD Taxa	#Sites
10	0
20	0
30	0
40	1
50	1
60	2
70	4
80	7
90	12

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	207	84	42	21	10.5	5.25	22	22
Taxa in X sites	2.5	2.2	2.0	1.8	1.6	1.4	2	1.8
% STD	140%	124%	112%	100%	88%	76%	111%	101%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lake Ronkonkoma 2012 Plant Survey conducted by DEC R1 DFW

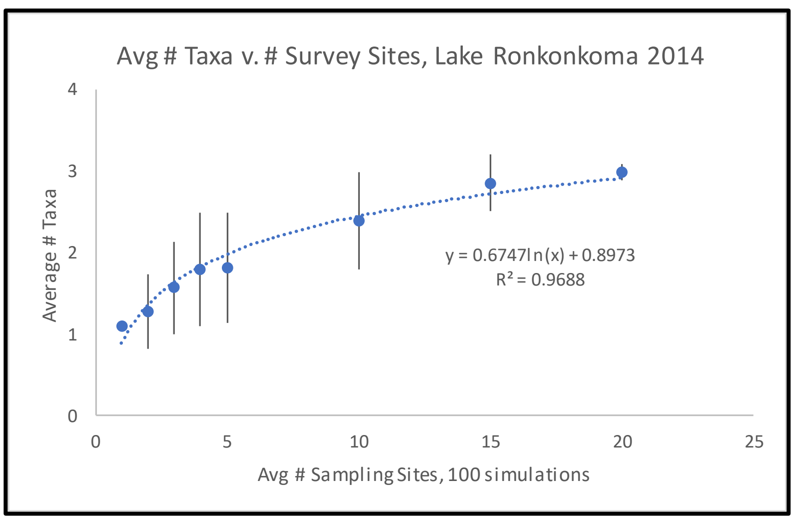


%STD Taxa	#Sites
10	1
20	1
30	2
40	2
50	3
60	5
70	7
80	10
90	15

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	207	84	42	21	10.5	5.25	22	22
Taxa in X sites	9.0	7.6	6.6	5.5	4.5	3.4	6	5.6
% STD	162%	138%	119%	100%	81%	62%	109%	101%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lake Ronkonkoma 2014 Plant Survey conducted by DEC R1 DFW

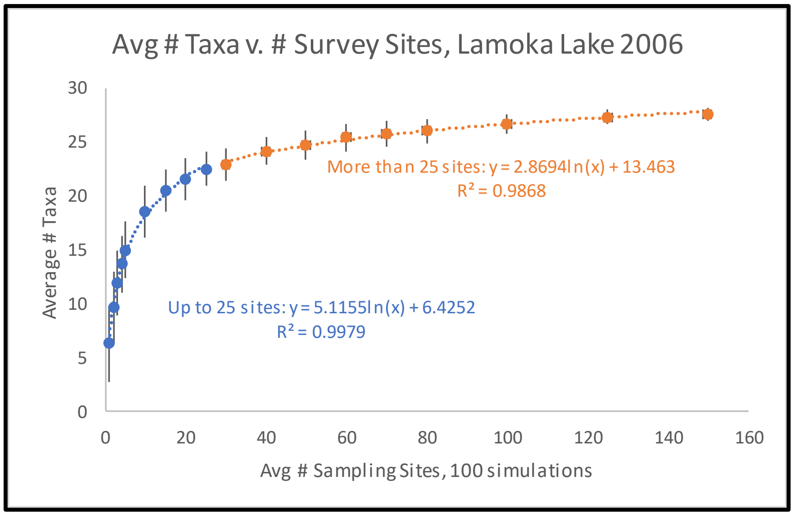


%STD Taxa	#Sites
10	0
20	1
30	1
40	2
50	2
60	4
70	6
80	9
90	14

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	207	84	42	21	10.5	5.25	22	22
Taxa in X sites	4.5	3.9	3.4	3.0	2.5	2.0	3	3.0
% STD	152%	132%	116%	100%	84%	68%	102%	101%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lamoka Lake 2006 Plant Survey conducted by Racine Johnson AE

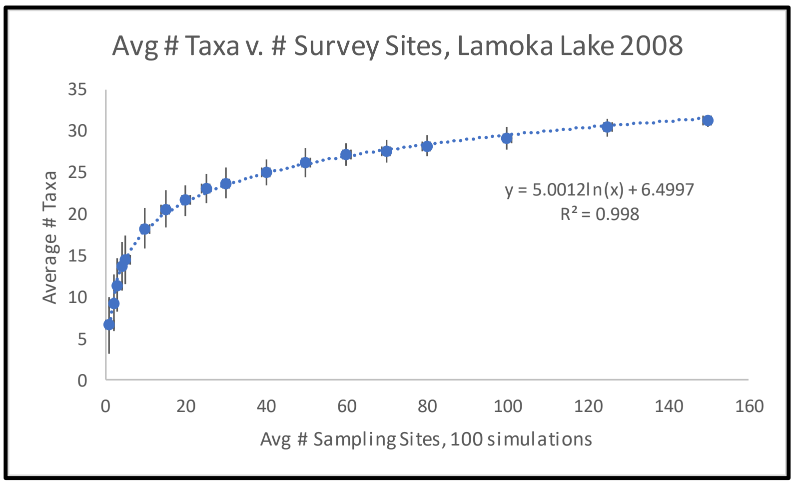


%STD Taxa	#Sites
10	0
20	1
30	1
40	3
50	5
60	10
70	20
80	41
90	81

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	1581	640	320	160	80	40	180	180
Taxa in X sites	34.6	32.0	30.0	28.0	26.0	24.0	28	28.4
% STD	133%	120%	110%	100%	90%	80%	95%	102%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lamoka Lake 2008 Plant Survey conducted by Racine Johnson AE

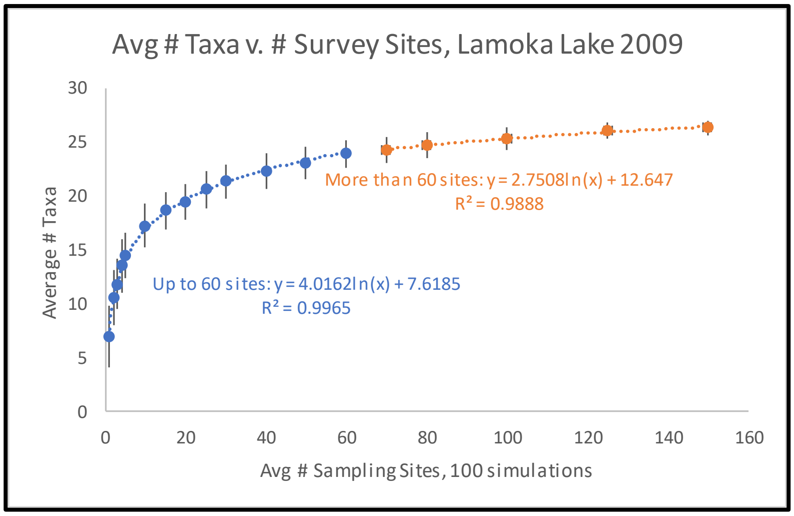


%STD Taxa	#Sites
10	1
20	1
30	2
40	3
50	7
60	12
70	24
80	45
90	85

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	1581	640	320	160	80	40	180	180
Taxa in X sites	43.3	38.8	35.3	31.9	28.4	24.9	32	32.5
% STD	136%	122%	111%	100%	89%	78%	100%	102%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Lamoka Lake 2009 Plant Survey conducted by Racine Johnson AE

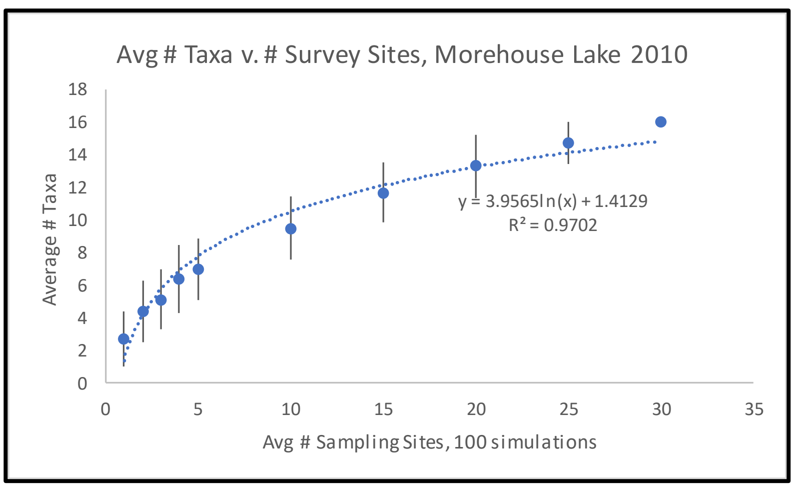


%STD Taxa	#Sites
10	0
20	1
30	1
40	2
50	5
60	9
70	19
80	38
90	78

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	1581	640	320	160	80	40	180	180
Taxa in X sites	32.9	30.4	28.5	26.6	24.7	22.8	27	26.9
% STD	132%	119%	110%	100%	90%	81%	99%	102%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Morehouse Lake 2010 Plant Survey conducted by DEC DOW Albany

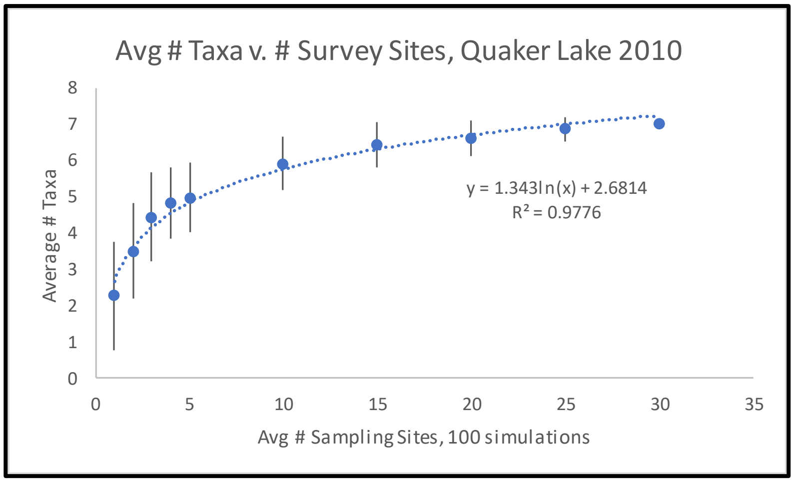


%STD Taxa	#Sites
10	1
20	2
30	2
40	3
50	5
60	7
70	11
80	16
90	24

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	346	140	70	35	17.5	8.75	30	30
Taxa in X sites	24.5	21.0	18.2	15.5	12.7	10.0	16	14.9
% STD	159%	135%	118%	100%	82%	65%	103%	96%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Quaker Lake 2010 Plant Survey conducted by DEC DOW Albany

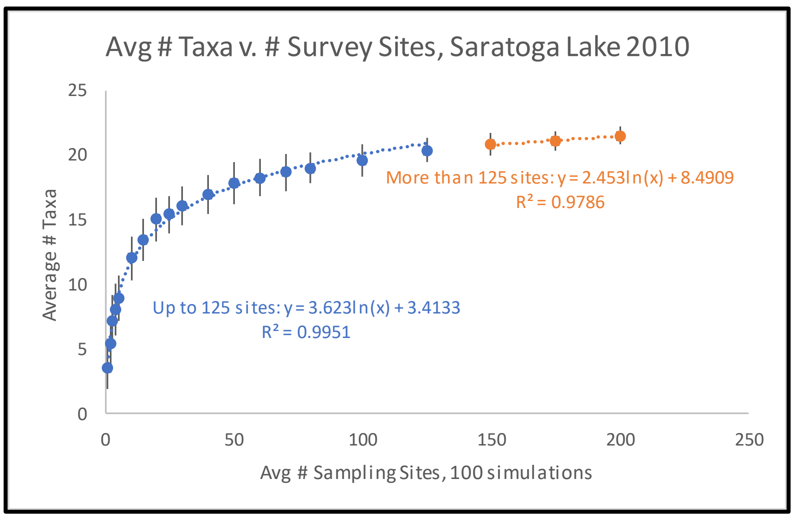


%STD Taxa	#Sites
10	0
20	0
30	1
40	2
50	3
60	5
70	10
80	19
90	35

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	632	256	128	64	32	16	30	30
Taxa in X sites	11.3	10.1	9.2	8.3	7.3	6.4	7	7.2
% STD	137%	123%	111%	100%	89%	77%	85%	88%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Saratoga Lake 2010 Plant Survey conducted by DFWI

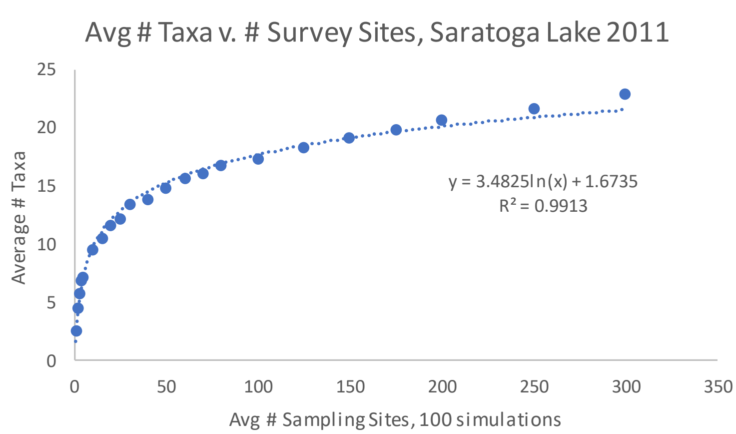


%STD Taxa	#Sites
10	1
20	2
30	3
40	7
50	15
60	32
70	69
80	146
90	310

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	6491	2628	1314	657	329	164	241	241
Taxa in X sites	30.0	27.8	26.1	24.4	22.7	21.0	22	21.9
% STD	130%	118%	109%	100%	91%	82%	83%	87%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Saratoga Lake 2011 Plant Survey conducted by DFWI

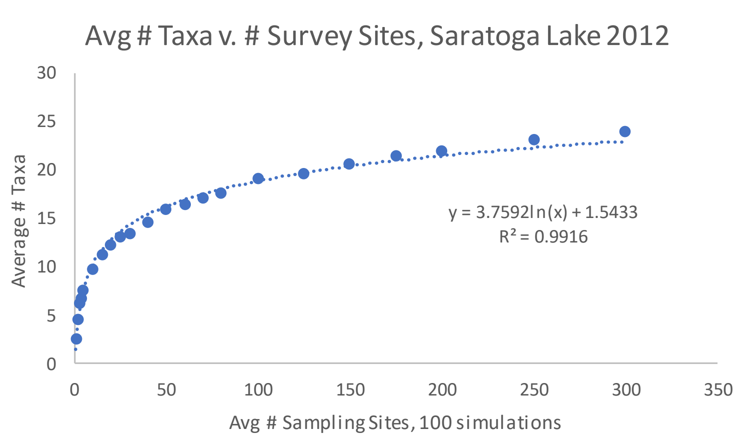


%STD Taxa	#Sites
10	1
20	2
30	5
40	10
50	20
60	40
70	81
80	163
90	327

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	6491	2628	1314	657	328.5	164.25	304	304
Taxa in X sites	32.2	29.1	26.7	24.3	21.9	19.4	23	21.6
% STD	133%	120%	110%	100%	90%	80%	95%	89%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Saratoga Lake 2012 Plant Survey conducted by DFWI

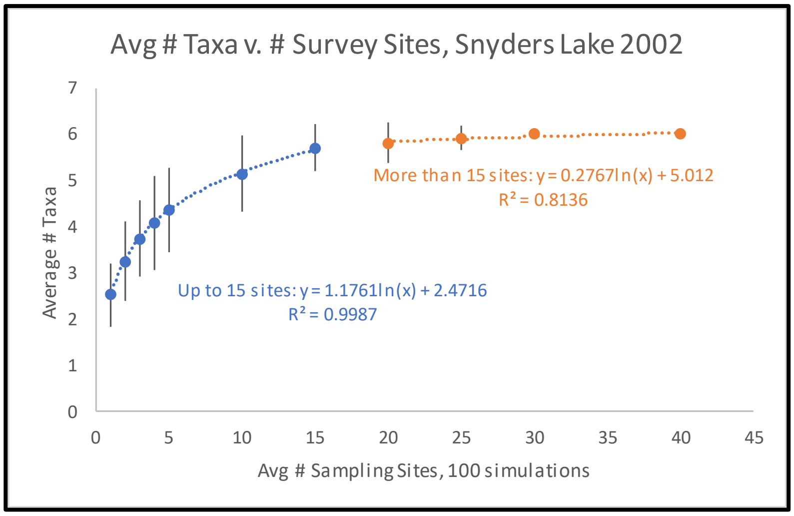


%Max Taxa	#Sites
10	1
20	3
30	5
40	10
50	21
60	42
70	83
80	165
90	330

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	6491	2628	1314	657	328.5	164.25	304	304
Taxa in X sites	34.5	31.1	28.5	25.9	23.3	20.7	24	23.0
% STD	133%	120%	110%	100%	90%	80%	93%	89%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2002 Plant Survey conducted by DEC DOW Albany

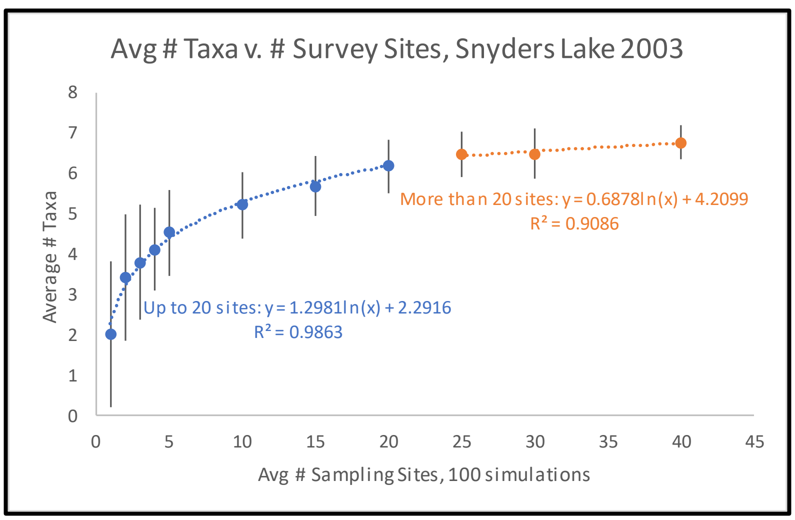


%STD Taxa	#Sites
10	0
20	0
30	0
40	1
50	1
60	2
70	3
80	5
90	9

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	40	40
Taxa in X sites	6.4	6.1	6.0	5.8	5.6	5.4	6	6.0
% STD	143%	126%	113%	100%	87%	74%	111%	118%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2003 Plant Survey conducted by DEC DOW Albany

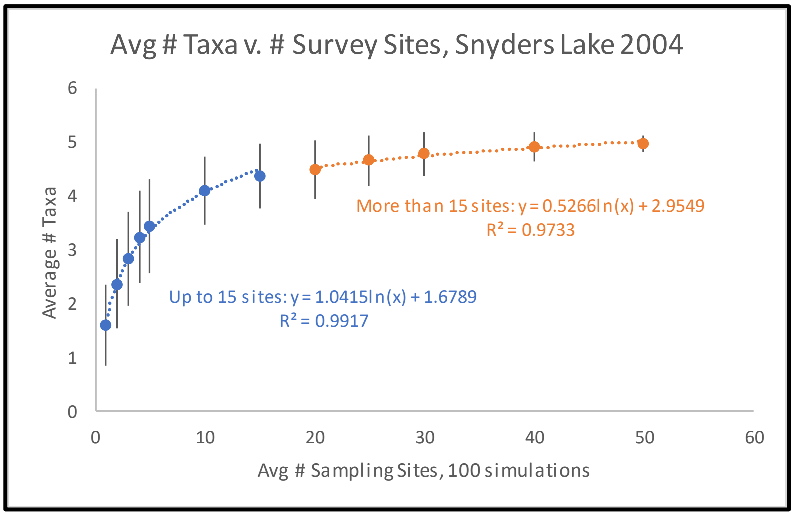


%STD Taxa	#Sites
10	0
20	0
30	1
40	1
50	2
60	2
70	4
80	6
90	9

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	48	48
Taxa in X sites	7.6	7.0	6.5	6.1	5.6	5.1	7	6.9
% STD	150%	130%	115%	100%	85%	70%	122%	125%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2004 Plant Survey conducted by DEC DOW Albany

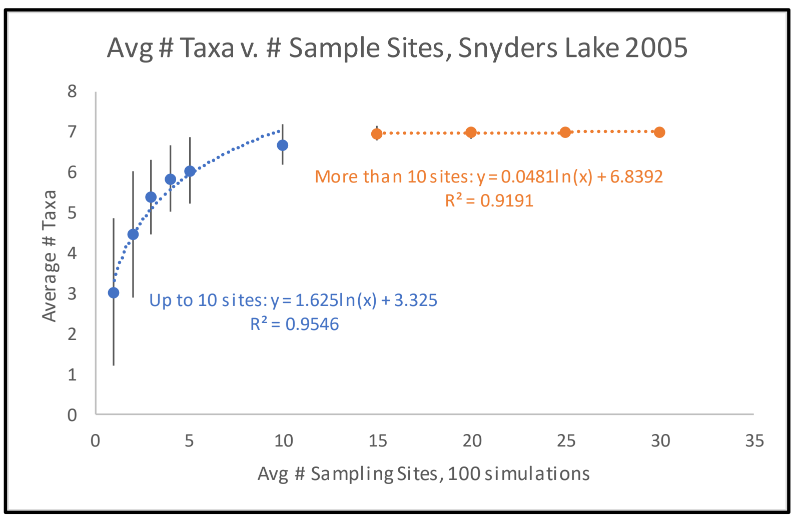


%STD Taxa	#Sites
10	0
20	0
30	0
40	1
50	1
60	2
70	3
80	6
90	9

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	57	57
Taxa in X sites	5.6	5.1	4.7	4.4	4.0	3.7	5	5.1
% STD	147%	128%	114%	100%	86%	72%	119%	127%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2005 Plant Survey conducted by DEC DOW Albany

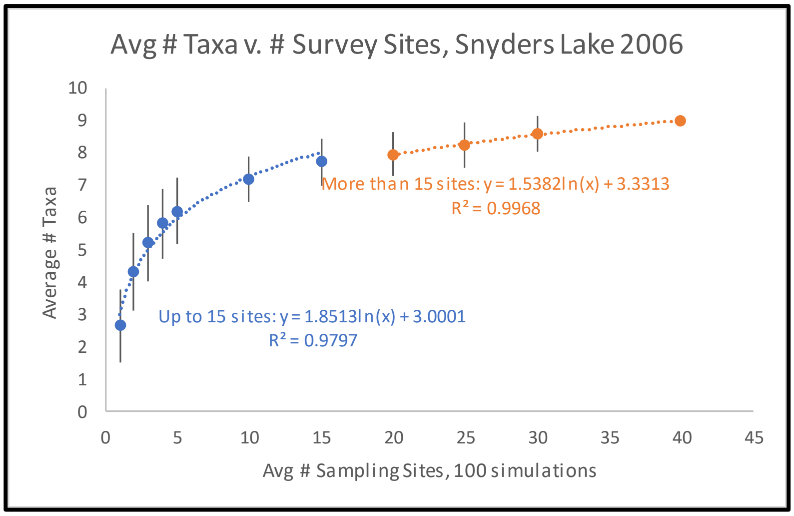


%STD Taxa	#Sites
10	0
20	0
30	0
40	0
50	1
60	1
70	2
80	4
90	8

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	32	32
Taxa in X sites	7.1	7.0	7.0	7.0	6.9	6.9	7	7.0
% STD	137%	122%	111%	100%	89%	78%	103%	112%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2006 Plant Survey conducted by DEC DOW Albany

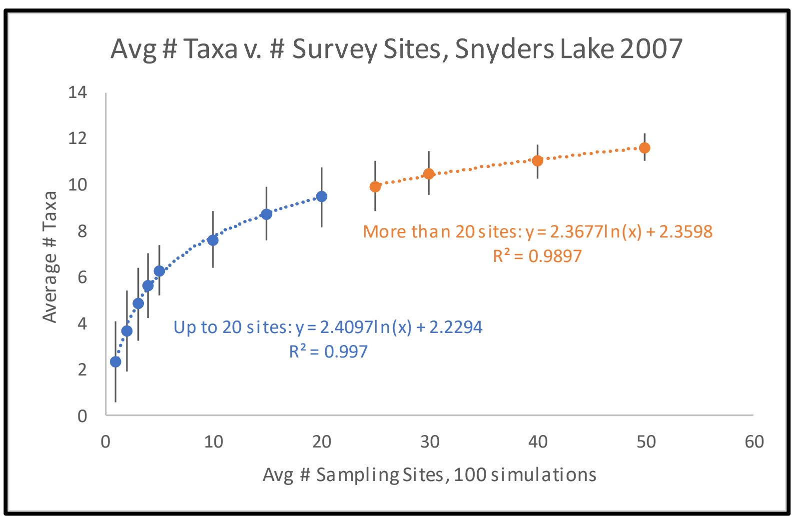


%STD Taxa	#Sites
10	0
20	0
30	1
40	1
50	1
60	2
70	4
80	6
90	9

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	40	40
Taxa in X sites	11.0	9.6	8.6	7.5	6.4	5.4	9	9.0
% STD	148%	129%	115%	100%	85%	71%	118%	121%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2007 Plant Survey conducted by DEC DOW Albany

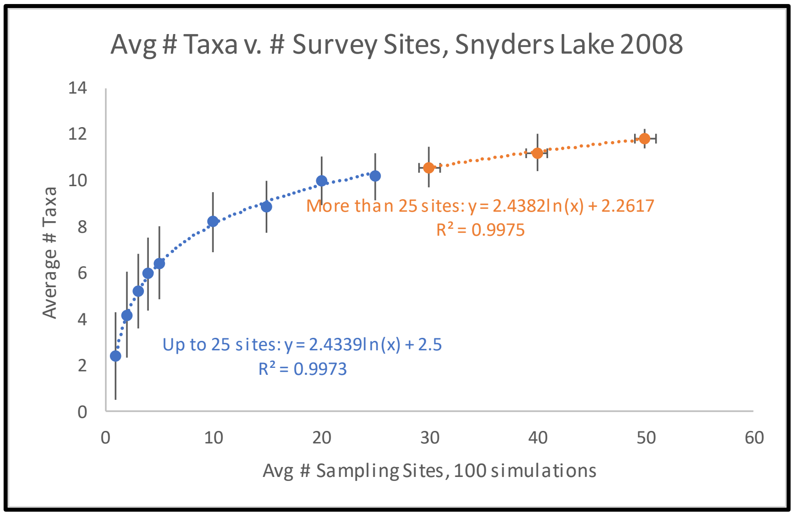


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	2
60	3
70	5
80	7
90	10

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	57	57
Taxa in X sites	14.2	12.1	10.4	8.8	7.1	5.5	12	11.9
% STD	163%	138%	119%	100%	81%	62%	137%	137%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2008 Plant Survey conducted by DEC DOW Albany

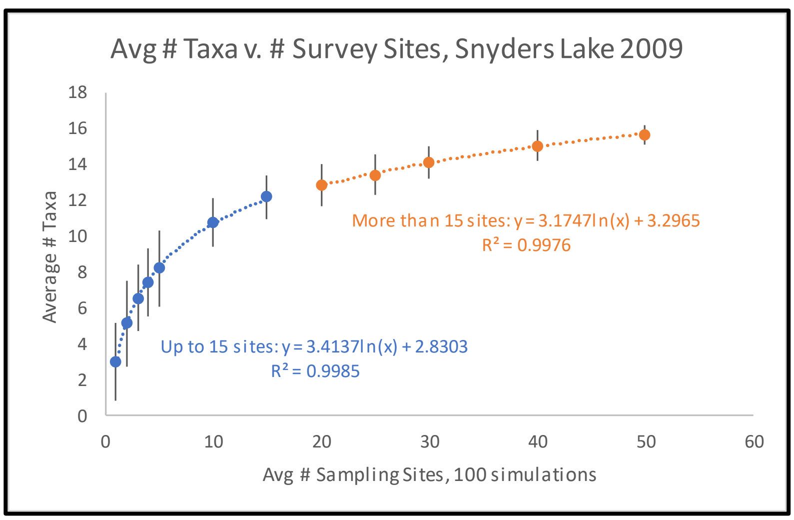


%STD Taxa	#Sites
10	0
20	1
30	1
40	2
50	2
60	3
70	5
80	7
90	10

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	57	57
Taxa in X sites	14.4	12.2	10.6	8.9	7.2	5.5	12	12.1
% STD	161%	137%	118%	100%	82%	63%	133%	135%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2009 Plant Survey conducted by DEC DOW Albany

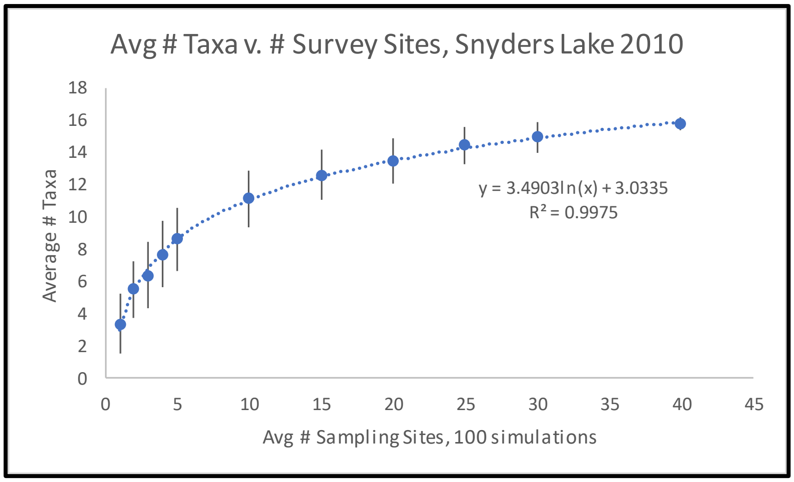


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	2
60	4
70	5
80	7
90	10

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	55	55
Taxa in X sites	19.2	16.3	14.1	11.9	9.7	7.5	16	16.0
% STD	163%	138%	119%	100%	81%	62%	135%	136%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2010 Plant Survey conducted by DEC DOW Albany

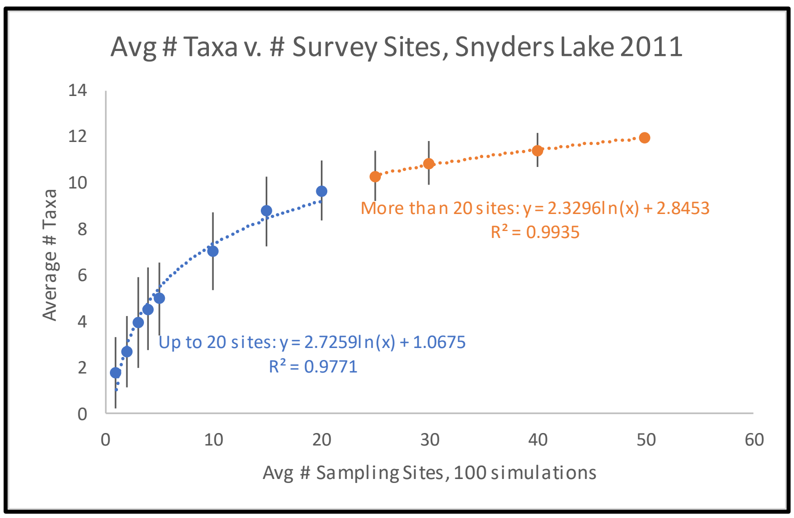


%STD Taxa	#Sites
10	1
20	1
30	1
40	2
50	2
60	3
70	5
80	7
90	10

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	7.5	3.75	44	44
Taxa in X sites	20.5	17.3	14.9	12.5	10.1	7.6	16	16.2
% STD	164%	139%	119%	100%	81%	61%	128%	130%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Snyders Lake 2011 Plant Survey conducted by DEC DOW Albany

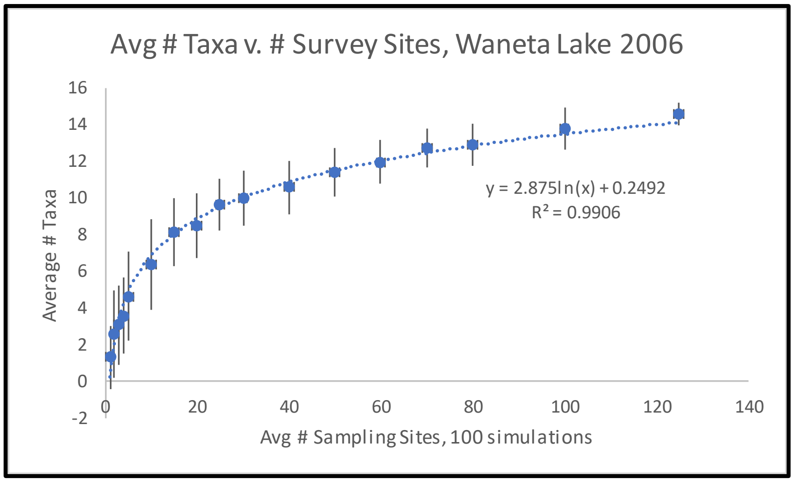


%STD Taxa	#Sites
10	1
20	1
30	2
40	2
50	3
60	4
70	6
80	8
90	11

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	148	60	30	15	8	4	51	51
Taxa in X sites	14.5	12.4	10.8	9.2	7.5	5.9	12	12.0
% STD	175%	145%	123%	100%	77%	55%	139%	140%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Waneta Lake 2006 Plant Survey conducted by Racine Johnson AE

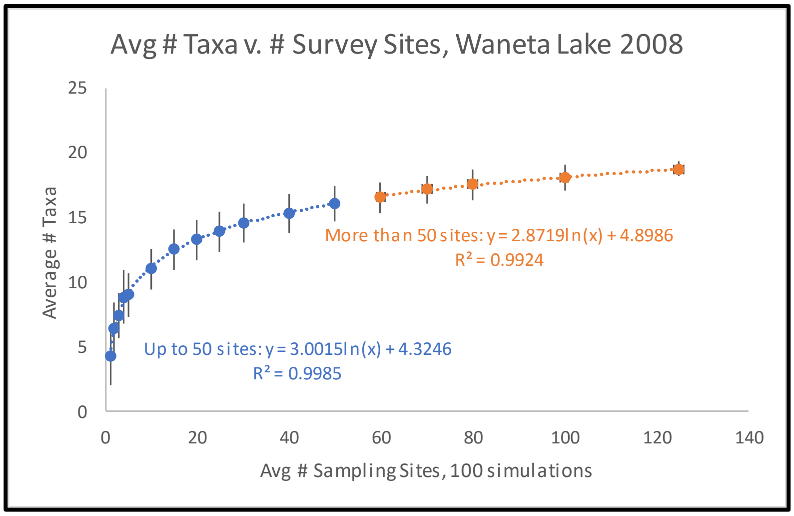


%STD Taxa	#Sites
10	2
20	3
30	4
40	7
50	12
60	21
70	35
80	60
90	101

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	1680	680	340	170	85	42.5	146	146
Taxa in X sites	21.6	19.0	17.0	15.0	13.0	11.0	15	14.6
% STD	144%	127%	113%	100%	87%	73%	100%	97%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Waneta Lake 2008 Plant Survey conducted by Racine Johnson AE

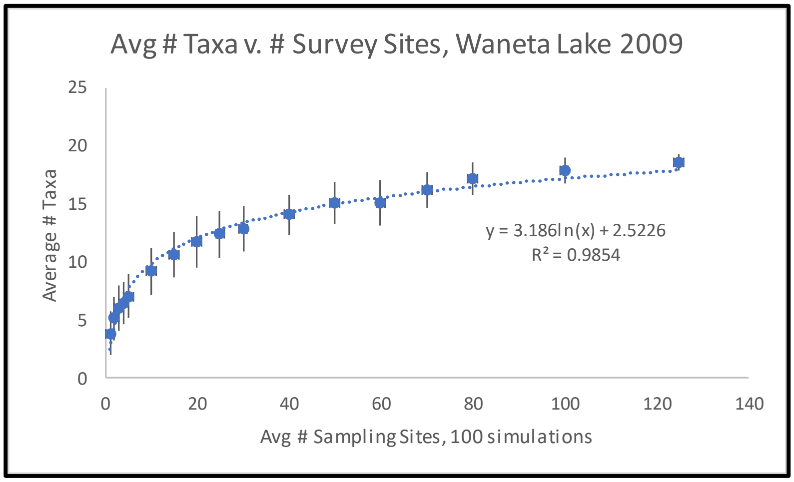


%STD Taxa	#Sites
10	0
20	1
30	2
40	3
50	6
60	12
70	24
80	46
90	88

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	1680	680	340	170	85	43	146	146
Taxa in X sites	26.2	23.6	21.6	19.6	17.7	15.7	19	19.2
% STD	135%	121%	111%	100%	89%	79%	96%	98%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Waneta Lake 2009 Plant Survey conducted by Racine Johnson AE



%STD Taxa	#Sites
10	1
20	1
30	3
40	5
50	9
60	16
70	29
80	52
90	94

	0.25 ac per site	0.25 ha per site	0.5 ha per site	1 ha per site	2 ha per site	4 ha per site	Existing Survey	Modeled Existing
# Sites (X)	1680	680	340	170	85	42.5	146	146
Taxa in X sites	26.2	23.3	21.1	18.9	16.7	14.5	19	18.4
% STD	139%	123%	112%	100%	88%	77%	101%	97%

(STD number of sites and taxa correspond to standardized site frequency of 1 site per hectare)

Appendix 4.2.1- Estimated % of Projected Species Richness via Logarithmic Regression of PIRTRAM Cumulative #Taxa by Lake Year

Lake Name	Year	Sites 1-3	Sites 2-4	Sites 3-5	Sites 4-10	Sites 5-15	Sites 10-20	Sites 15-25	Sites 20-30	Sites 25-40	Sites 30-50	Sites 40-60	Sites 50-70	Sites 60-80	Sites 70-100
Ballston Lake	2006	89%	91%	89%	99%	101%	99%	104%	104%						
Big Fresh Pond	2006	82%	90%	99%	101%	103%									
Blydenburgh Lake	2012	92%	105%	104%	96%	99%	101%	105%							
Blydenburgh Lake	2014	122%	111%	114%	104%	97%	92%	91%							
Cazenovia Lake	2010	116%	115%	137%	141%	134%	122%	114%	120%	117%	110%	108%	107%	103%	102%
Cazenovia Lake	2011	134%	122%	91%	116%	121%	126%	116%	101%	118%	116%	111%	106%	106%	103%
Cazenovia Lake	2012	107%	115%	121%	120%	119%	117%	114%	104%	107%	109%	99%	106%	108%	103%
Cazenovia Lake	2013	119%	118%	126%	121%	114%	104%	115%	107%	99%	102%	104%	103%	101%	101%
Cazenovia Lake	2014	105%	116%	121%	113%	111%	113%	104%	97%	105%	97%	98%	97%	96%	104%
Cazenovia Lake	2015	123%	117%	110%	121%	119%	108%	99%	97%	107%	107%	103%	107%	102%	102%
Cazenovia Lake	2016	117%	127%	115%	117%	117%	109%	106%	102%	100%	103%	102%	104%	103%	101%
Cazenovia Lake	2017	136%	126%	130%	124%	117%	104%	98%	96%	104%	100%	102%	103%	95%	98%
Cazenovia Lake	2018	132%	130%	131%	117%	118%	111%	98%	100%	113%	108%	97%	104%	104%	103%
Cazenovia Lake	2019	137%	141%	126%	132%	123%	101%	105%	112%	96%	104%	106%	98%	105%	100%
Collins Lake	2007	76%	94%	93%	93%	89%	71%	92%							
Creamery Pond	2008	107%	103%	102%	102%	100%									
Creamery Pond	2009	105%	101%	101%	101%	101%									
Creamery Pond	2010	108%	102%	101%	101%	102%	100%								
Creamery Pond	2011	104%	104%	104%	105%	109%	117%								
Creamery Pond	2012	98%	98%	99%	99%	102%	121%								
Creamery Pond	2013	93%	88%	92%	89%	89%	63%								
Hards Pond	2010	90%	98%	99%	100%	102%									
Hards Pond	2011	82%	98%	110%	102%	101%									
Java Lake	2008	90%	97%	96%	99%	105%									
Java Lake	2009	94%	96%	115%	107%	98%									
Java Lake	2010	90%	98%	87%	103%	106%									
Kinderhook Lake	2006	118%	133%	112%	101%	97%	87%								
Kinderhook Lake	2007	158%	166%	119%	110%	104%	91%								
Lake Luzerne	2010	75%	96%	101%	99%	100%	97%	98%	98%	98%	99%	100%	95%	98%	93%
Lake Ronkonkoma	2009	124%	125%	93%	99%	95%	96%								
Lake Ronkonkoma	2010	75%	84%	85%	106%	106%	105%								
Lake Ronkonkoma	2011	82%	64%	77%	103%	104%	108%								
Lake Ronkonkoma	2012	69%	83%	78%	103%	107%	108%								
Lake Ronkonkoma	2014	79%	103%	87%	98%	106%	104%								
Lamoka Lake	2006	115%	125%	125%	118%	116%	110%	107%	101%	104%	104%	101%	101%	98%	100%
Lamoka Lake	2008	90%	116%	111%	101%	106%	100%	99%	102%	98%	100%	102%	98%	96%	98%
Lamoka Lake	2009	113%	108%	123%	107%	104%	97%	103%	111%	103%	101%	104%	103%	100%	100%
Morehouse Lake	2010	69%	80%	93%	89%	97%	106%	108%	110%						
Quaker Lake	2010	134%	132%	99%	106%	108%	101%	98%	100%						
Snyders Lake	2002	96%	98%	99%	98%	99%	97%	99%	99%						
Snyders Lake	2003	108%	90%	100%	94%	93%	95%	94%	99%	100%					
Snyders Lake	2004	106%	111%	109%	102%	100%	99%	100%	98%	100%	103%				
Snyders Lake	2006	120%	116%	112%	104%	103%	102%	103%	100%						
Snyders Lake	2007	153%	107%	107%	97%	99%	100%	100%	100%						
Snyders Lake	2008	105%	106%	103%	104%	101%	103%	101%	108%	102%	100%				
Snyders Lake	2009	99%	99%	98%	103%	103%	101%	102%	100%	98%	101%				
Snyders Lake	2010	88%	93%	107%	102%	101%	100%	101%	100%	104%					
Snyders Lake	2011	124%	90%	78%	89%	94%	94%	96%	96%	100%	102%				
Waneta Lake	2006	65%	60%	100%	97%	103%	103%	100%	109%	90%	98%	103%	108%	104%	102%
Waneta Lake	2008	98%	109%	104%	93%	102%	103%	98%	104%	101%	99%	100%	102%	103%	99%
Waneta Lake	2009	75%	71%	74%	94%	98%	104%	100%	94%	102%	108%	96%	98%	119%	108%
Saratoga Lake	2010	100%	116%	105%	124%	120%	121%	116%	98%	107%	109%	107%	99%	101%	101%
Saratoga Lake	2011	90%	97%	84%	93%	93%	90%	93%	108%	97%	89%	108%	101%	100%	101%
Saratoga Lake	2012	90%	88%	79%	90%	92%	95%	95%	89%	94%	110%	105%	95%	103%	114%

White Paper1D- Evaluation of Species Richness in NYS Lakes

Lake Name	Year	Sites 80-125	Sites 100-150	Sites 125-175	Sites 150-200	Sites 175-250	Sites 200-300
Ballston Lake	2006						
Big Fresh Pond	2006						
Blydenburgh Lake	2012						
Blydenburgh Lake	2014						
Cazenovia Lake	2010	101%	100%	101%	100%		
Cazenovia Lake	2011	104%	103%	100%	99%		
Cazenovia Lake	2012	102%	100%	100%	100%		
Cazenovia Lake	2013	101%	101%	101%	100%		
Cazenovia Lake	2014	100%	100%	101%	100%		
Cazenovia Lake	2015	102%	101%	101%	99%		
Cazenovia Lake	2016	103%	101%	99%	100%		
Cazenovia Lake	2017	101%	100%	99%	100%		
Cazenovia Lake	2018	103%	98%	100%	101%		
Cazenovia Lake	2019	98%	101%	100%	99%		
Collins Lake	2007						
Creamery Pond	2008						
Creamery Pond	2009						
Creamery Pond	2010						
Creamery Pond	2011						
Creamery Pond	2012						
Creamery Pond	2013						
Hards Pond	2010						
Hards Pond	2011						
Java Lake	2008						
Java Lake	2009						
Java Lake	2010						
Kinderhook Lake	2006						
Kinderhook Lake	2007						
Lake Luzerne	2010	90%	95%				
Lake Ronkonkoma	2009						
Lake Ronkonkoma	2010						
Lake Ronkonkoma	2011						
Lake Ronkonkoma	2012						
Lake Ronkonkoma	2014						
Lamoka Lake	2006	100%	99%				
Lamoka Lake	2008	99%	99%				
Lamoka Lake	2009	101%	100%				
Morehouse Lake	2010						
Quaker Lake	2010						
Snyders Lake	2002						
Snyders Lake	2003						
Snyders Lake	2004						
Snyders Lake	2006						
Snyders Lake	2007						
Snyders Lake	2008						
Snyders Lake	2009						
Snyders Lake	2010						
Snyders Lake	2011						
Waneta Lake	2006	105%					
Waneta Lake	2008	100%					
Waneta Lake	2009	104%					
Saratoga Lake	2010	104%	103%				
Saratoga Lake	2011	99%	105%	107%	111%	110%	112%
Saratoga Lake	2012	104%	99%	111%	107%	107%	108%

Legend- yellow and red coding = first stable instance of estimated % max total taxa within 10% and 5% of actual standardized pSR taxa respectively; maroon coding = estimated % max taxa within 10% AND 5% using same survey combos.