Section 1- Plant Lists and Individual Species in New York State Biological Surveys

Section 1.1- NYS BioSurvey aquatic plant survey methodology and surveyed lakes

White Paper 1A provides details about the New York State Biological Surveys (henceforth referred to as the NYS BioSurveys) from the mid-1920s to the late 1930s. The NYS BioSurveys and the aquatic plant surveys conducted within that program can be summarized as follows:

- The NYS BioSurveys included 304 lakes for which aquatic plant surveys were conducted from the mid-1920s to the late 1930s, most likely in mid- to late-summer. All lakes were surveyed one time.
- Surveyed lakes were slightly larger than the typical NYS lake, but typical of other lakes included in most later monitoring programs, including the PIRTRAM and AWI programs discussed in Sections 3 and 4 of this White Paper
- Surveyed lakes were a representative geographic cross-section of all lakes in the state
- Aquatic plant surveys identified plants to species level, and defined a relative abundance value (abundant, common, present, occasional, and rare) for each observed plant in each lake, but not for individual survey sites within each lake (the latter is referred to as granular survey site data)
- The number and distribution of survey sites, lakewide or within the littoral zone, were not reported for any surveyed lake.
- Relative abundance of individual plant species can be evaluated across but not within lakes, and plant frequency cannot be evaluated within surveyed lakes.
- Although species-level identification was provided for all plants, survey results for these lakes were for some analyses "converted" to genera-level identification for comparison to and consistency with future monitoring programs (PIRTRAM and AWI), particularly for emergent or floating leaf plants and for macroalgae

Section 1.2- NYS BioSurvey aquatic plant survey results

Table 1.2.1 shows the most common aquatic plant species found during the New York State Biological Surveys (hereafter referred to as the NYS BioSurveys) from the early 1920s to the late 1930s, based on the percentage of lakes in which each plant species was found in this period. Table 1.2.1 indicates a balance of submergent, floating and emergent plants among the most common plants in more than 300 lakes distributed throughout the state, although the majority of the most common taxa are emergent or floating leaf plants. It should be noted that most of the genera cited in Table 1.2.1 are represented by multiple individual species not generally identified (to species level) in subsequent (PIRTRAM and AWI) surveys- for example, most recent surveys did not identify individual species in the yellow water lily (*Nuphar* sp), Bur reed (*Sparganium* sp), Bul rush (*Scirpus* sp), Spike rush (*Eleocharis* sp), white water lily (*Nymphaea* sp) and arrowhead (*Sagittaria* sp) genera, even though multiple species may have been present in these later surveys. For these genera and a few others, the NYS BioSurvey results were summarized by genera for comparison to these more contemporary surveys discussed below.

Table 1.2.1- Most common aquatic plants species in 1920s-30s NYS BioSurvey (N = 303)

Species Scientific Name	Species Common Name	%Lakes	Rank
Nuphar sp	Yellow water lily	62.7%	1
Sparganium sp	Bur reed	61.7%	2
Scirpus sp	Bul rush	61.1%	3
Eleocharis sp	Spike rush	59.7%	4
Nymphaea sp	White water lily	57.1%	5
Sagittaria sp	Arrowhead	57.1%	5
Najas flexilis	Slender naiad	55.7%	7
Utricularia vulgaris	Common bladderwort	50.9%	8
Ceratophyllum demersum	Coontail	46.2%	9
Elodea canadensis	Common waterweed	43.7%	10
Pontederia cordata	Pickerelweed	43.7%	10
Potamogeton pusillus	Small pondweed	43.7%	10
Potamogeton epihydrus	Ribbonleaf pondweed	41.8%	13
Vallisneria americana	Eelgrass, tapegrass	39.0%	14
Potamogeton natans	Floating leaf pondweed	38.7%	15
Typha sp	Cattail	37.3%	16
Zosterella dubia	Water stargrass	34.0%	17

These results include aquatic plant species associated with a wide range of water quality conditions, bottom sediment characteristics, water depths and other factors. These findings suggest that many of the factors that might have affected aquatic plant community dynamics in the last century, including lake shoreline development (and its associated impact on bottom sediment characteristics), water quality, acidification, and increasing lake usage, had not significantly affected aquatic plant communities at that time. However, changes in the aquatic plant communities in lakes throughout the state and in particular regions or individual waterbodies since the mid-1920s are discussed at length later in this White Paper.

Table 1.2.2- Most common aquatic plants species in 1920s-30s NYS BioSurvey outside the Adirondacks (N = 189)

Species Scientific Name	Species Common Name	%Lakes	Rank
Najas flexilis	Slender naiad	69.8%	1
Ceratophyllum demersum	Coontail	68.3%	2
Scirpus sp	Bulrush	67.2%	3
Sagittaria sp	Arrowhead	66.7%	4
Eleocharis sp	Spikerush	63.5%	5
Nuphar sp	Yellow water lily	63.0%	6
Sparganium sp	Bur reed	63.0%	6
Nymphaea sp	White waterlily	61.4%	8
Utricularia vulgaris	Common bladderwort	58.2%	9
Elodea canadensis	Common waterweed	56.1%	10
Zosterella dubia	Water stargrass	52.4%	11
Typha sp	Cattail	52.4%	11
Pontederia cordata	Pickerelweed	51.3%	13
Lemna minor	Lesser duckweed	48.1%	14
Vallisneria americana	Eelgrass, tapegrass	48.1%	14
Potamogeton pusillus	Small pondweed	47.6%	16

As expected, aquatic plant communities are different in the Adirondacks (comprised of many small, high elevation, nutrient poor, less-intensively-used or accessed lakes) compared to other regions of the state. Table 1.2.2 shows the most common (frequently reported) NYS BioSurvey aquatic plants outside of the Adirondacks, and Table 1.2.3 shows the most

Table 1.2.3- Most common aquatic plants species in 1920s-30s NYS BioSurvey inside the Adirondacks (N = 114)

Species Scientific Name	Species Common Name	%Lakes	Rank
Nuphar sp	Yellow water lily	62.3%	1
Sparganium sp	Bur reed	59.6%	2
Eleocharis sp	Spikerush	53.5%	3
Potamogeton epihydrus	Ribbonleaf pondweed	53.5%	3
Scirpus sp	Bul rush	50.9%	5
Nymphaea sp	White water lily	50.0%	6
Potamogeton natans	Floating leaf pondweed	45.6%	7
Utricularia vulgaris	Common bladderwort	45.6%	7
Potamogeton pusillus	Small pondweed	43.0%	9
Lobelia dortmanna	Water lobelia	42.1%	10
Eriocaulon sp	Pipewort	41.2%	11
Isoetes sp	Quillwort	41.2%	11
Sagittaria sp	Arrowhead	41.2%	11
Brasenia schreberi	Watershield	39.5%	14
Dulichium arundinaceum	Three-way sedge	39.5%	14
Najas flexilis	Slender naiad	39.5%	14
Myriophyllum tenellum	Slender watermilfoil	37.7%	17
Potamogeton spirillus	Spiral pondweed	37.7%	17

frequently observed plants found in lakes within the Adirondacks. Note that these represent subsets- 189 lakes outside of the Adirondack Park, and 114 lakes within the Adirondack Park- of the 303 NYS BioSurvey lakes included in Table 1.2.1. For example, while slender naiad (*Najas flexilis*) and coontail (*Ceratophyllum demersum*) are the most frequently observed plants in the NYS BioSurvey lakes outside of the Adirondack Park (Table 1.2.2), they were only the 14th and 29th most common plants, respectively, in the Adirondack region lakes surveyed at that time. Likewise, the two most common plants in the Adirondack lakes sampled in the NYS BioSurvey in the 1920s and 1930s- yellow water lily (*Nuphar sp*) and bur reed (*Sparganium sp*)- were (tied for) the 6th most common plants outside of the Adirondacks. Coontail is often, although not universally, associated with higher trophic states, as is duckweed (*Lemna minor*), and neither of these plants were commonly reported in the Adirondacks during the NYS BioSurvey of the 1920s and 1930s. Likewise, quillwort (*Isoetes sp*), pipewort (*Eriocaulon sp)*, water lobelia (*Lobelia dortmanna*) and slender watermilfoil (*Myriophyllum tenellum*) are often associated with lower trophic states (more favorable water quality), and were commonly found in the Adirondacks but not outside the Park. While this may reflect water quality differences between these regions, even a century ago, this may also reflect what are well-defined differences in habitat, particularly sediment types, across these regions.

In general, emergent or floating leaf plants- yellow water lily (*Nuphar sp*), bur reed (*Sparganium* sp), bul rush (*Scirpus sp*), and spike rush (*Eleocharis* sp), and white water lily (*Nymphaea sp)*, comprised most of the ten most common aquatic plants commonly found both within the Adirondacks and outside the Adirondacks. However, it should be noted that several of the species within these genera were more common in one region or the other. Among submergent species, only slender naiad (*Najas flexilis*), common bladderwort (*Utricularia vulgaris*), and small pondweed (*Potamogeton pusillus*) were among the 16 most common species both within and outside the Adirondacks.

Table 1.2.4- Most abundant aquatic plants species in 1920s-30s NYS BioSurvey (N = 303)

Species Scientific Name	Species Common Name	Abund	Rank
Scirpus sp	Bul rush	6824	1
Eleocharis sp	Spikerush	5970	2
Najas flexilis	Slender naiad	5669	3
Elodea sp	Common waterweed	5492	4
Ceratophyllum demersum	Coontail	5184	5
Nymphaea sp	White water lily	4290	6
Nuphar sp	Yellow water lily	3998	7
Vallisneria americana	Eelgrass	3753	8
Zosterella dubia	Water stargrass	3544	9
Potamogeton amplifolius	Largeleaf pondweed	3497	10
Sparganium sp	Bur reed	3418	11
Potamogeton natans	Floating leaf pondweed	3125	12
Sagittaria sp	Arrowhead	3078	13
Myriophyllum sibericum	Northern watermilfoil	2954	14
Chara sp	Musk grass	2859	15
Brasenia schreberi	Watershield	2826	16
Potamogeton robbinsii	Robbins pondweed	2710	17
Typha sp	Cattail	2596	18
Potamogeton epihydrus	Ribbonleaf pondweed	2489	19

Based on weighted abundance on $\log_5$ scale

Tables 1.2.1 through 1.2.3 identify the plants, whether submergent, floating, or emergent, reported to be most often observed in the NYS BioSurvey lakes, both inside or outside the Adirondack Park. However, these plant lists do not provide any information about the relative abundance in these plants- some of these plants may have only been found in a single location in some of these lakes, while others may have grown in high densities throughout the lake. Fortunately, the NYS BioSurveys collected relative abundance data from nearly all of the survey lakes, as discussed at length in White Paper 1A. A single abundance "assignment" for each plant in each lake- for example "Occasional" coontail present in Long Lake- does not provide much granular data about the absolute distribution of this plant through the lake. However, these data can provide an approximation of relative abundance of each plant in these lakes. Furthermore, since a single evaluation for each plant for each lake does not account for the absolute amount of the plant in large lakes or small lakes, these results can be compared across all NYS BioSurvey lakes to estimate relative abundance. Table 1.2.4 shows the most abundant plants in the 303 NYS BioSurvey lakes sampled from the mid-1920s to the late 1930s, using a $\log_5$ scale assigning a 125/25/15/5/1 score to each of the abundant / common / present / occasional / rare designations reported for each plant in each NYS BioSurvey lake (as discussed in White Papers 1 and 2), comparing all lake results. Tables 1.2.5 and 1.2.6 divided the 303 NYS BioSurvey lake dataset into the 189 non-Adirondack lakes (Table 1.2.5) and 114 Adirondack lakes (Table 1.2.6). These data summarize the most abundant aquatic plants in the surveyed New York state lakes at that time, as opposed to the most common aquatic plants in these lakes summarized in Tables 1.2.1 through 1.2.3.

Table 1.2.4 indicates that the most common plants in the NYS BioSurvey were not necessarily the most abundant plants, although there was significant overlap among the list of most common (Tables 1.2.1 through 1.2.3) and most abundant (Tables 1.2.4 through 1.2.6) plants. For example,

Table 1.2.5- Most abundant aquatic plants species in 1920s-30s NYS BioSurvey Lakes outside the Adirondacks (N = 189)

Species Scientific Name	Species Common Name	Abund	Rank
Ceratophyllum demersum	Coontail	4762	1
Elodea sp	Common waterweed	4431	2
Najas flexilis	Slender naiad	4337	3
Scirpus sp	Bul rush	3826	4
Eleocharis sp	Spikerush	3343	5
Zosterella dubia	Water stargrass	3103	6
Nymphaea sp	White water lily	2955	7
Vallisneria americana	Eelgrass	2704	8
Potamogeton amplifolius	Water stargrass	2537	9
Myriophyllum sibericum	Northern watermilfoil	2352	10
Spirodela polyrhiza	Greater duckweed	2185	11
Potamogeton robbinsii	Robbins pondweed	1747	12
Sparganium sp	Bur reed	1722	13
Potamogeton zosteriformis	Flatstemmed pondweed	1628	14
Potamogeton praelongus	Whitestem pondweed	1578	15

Based on weighted abundance on $\log_5$ scale

the two most common plants found in the statewide NYS BioSurvey- yellow water lily (*Nuphar* sp) and bur reed (*Sparganium* sp) were only the 7th and 11th most abundant plants. Likewise, the two most abundant plants statewide, bul rush (*Scirpus* sp) and spikerush (*Eleocharis* sp), were "only" the 3rd and 4th most common plants. This distinction was much less pronounced outside of the Adirondacks, where the vast majority of the most frequent plants (Table 1.2.2) were also among the most abundant plants (Table 1.2.5). This suggests a strong balance in aquatic plant communities overall- most plants were either common and abundant, or uncommon and less likely to grow densely. Within the Adirondacks, however, more plants were either frequent or abundant but not both. For example, only one of the four most common plants- spikerush

Table 1.2.6- Most abundant aquatic plants species in 1920s-30s NYS BioSurvey Lakes within the Adirondacks (N = 114)

Species Scientific Name	Species Common Name	Abund	Rank
Scirpus sp	Bul rush	2998	1
Eleocharis sp	Spikerush	2627	2
Potamogeton natans	Floating leaf pondweed	2026	3
Brasenia schreberi	Watershield	1907	4
Nuphar sp	Yellow water lily	1897	5
Sparganium sp	Bur reed	1696	6
Potamogeton epihydrus	Ribbonleaf pondweed	1629	7
Eriocaulon sp	Pipewort	1490	8
Chara sp	Muskgrass	1410	9
Utricularia purpurea	Purple bladderwort	1357	10
Nymphaea sp	White water lily	1335	11
Najas flexilis	Slender naiad	1332	12
Sagittaria sp	Arrowhead	1286	13
Carex sp	Water sedge	1280	14
Myriophyllum tenellum	Slender watermilfoil	1062	15
Elodea sp	Common waterweed	1061	16
Vallisneria americana	Eelgrass, tapegrass	1049	17
Potamogeton richardsonii	Richardsons pondweed	963	18

Based on weighted abundance on $\log_5$ scale

(*Eleocharis* sp)- was also among the four most abundant plants (Tables 1.2.3 and 1.2.6), although yellow water lily (*Nuphar* sp), bur reed (*Sparganium* sp) and ribbonleaf pondweed (*Potamogeton epihydrus*) were among the seven most abundant plants. Likewise, watershield (*Brasenia schreberi*) and muskgrass (*Chara* sp) were among the most abundant but not most common plants.

A broader discussion of the plants exhibiting the most significant differences between presence and abundance is provided below. The former- those common plants that generally are found at lower densities than expected given their persistence throughout the state- may be indicative of plants that do not gain competitive advantages, but can thrive in a wide variety of conditions. The latter- those plants found at a much lower frequency but more likely to grow densely- may represent more recent introductions to some of these lakes, or plants that may crowd out large swaths of the lake bottom after initial colonization.

The majority of the plants in the first category- more common than abundant- include species that are very uncommon, but were usually found individually or in very small quantities. On both a statewide basis and outside the Adirondack Park, this includes vernal water starwort (*Callitriche palustris*), shiny pondweed (*Potamogeton lucens*, now likely considered one of several different hybridized species), hidden-fruit bladderwort (*Utricularia geminiscapa*), and horsetail (*Equisetum limnosa*). Within the Adirondacks, lesser duckweed (*Lemna minor*), green arrow arum (*Peltandra virginica*), spiral pondweed (*Potamogeton spirillus*) and horsetail were among the more common than abundant plants, but none of these plants were particularly common in NYS BioSurvey lakes. **Among the 20 most common plants, only pickerelweed (*Pontederia cordata*) and small pondweed (*Potamogeton pusillus*) were much more common than abundant on a statewide basis and outside the Adirondacks, and small pondweed, spiral pondweed (*Potamogeton dimorpus,* now *Potamogeton spirillus*) and common bladderwort (*Utricularia vulgaris*) were very common plants within the Adirondacks that were much more common than abundant**. The "more common than abundant" category also includes brittle naiad (*Najas minor*), an exotic plant that was nonetheless not particularly common in the 1920s and 1930s surveys.

The latter category- more abundant than common- also includes many plants that were not particularly abundant, but were observed growing more densely in only a few locations. And as with the previous category of plants, several plants could be characterized as more abundant than common on both a statewide basis and outside the Adirondacks. This list includes water chestnut, as discussed below. Other plants more abundant than common both statewide and outside the Adirondacks include an aquatic moss (*Drepanocladus aduncus*), water arum (*Calla palustris*), and waterthread pondweed (*Potamogeton capillaceus*, now *Potamogeton bicupulatus*), **while only star duckweed (*Lemna trisulca*) was both more abundant than common AND among the most 20 abundant plants outside of the Adirondacks**. Within the Adirondacks, American shoreweed (*Littorella americana*), water parsnip (*Sium suave*) and curly-leafed pondweed (*Potamogeton crispus*) were much more abundant that common, but even *P.crispus* was still found at relatively low densities within the Park (despite the fact that this invasive plant had been observed in New York state for about 50 years). **Northern watermilfoil**

(*Myriophyllum exalbescens,* now *Myriophyllum sibericum*), muskgrass (*Chara* sp) and large leaf pondweed (*Potamogeton amplifolius*) were both more abundant than common AND among the 20 most abundant plants in the region.

Section 1.3- Discussion of results

The following is an attempt to summary the very long recitation of plant distributions in NYS BioSurvey lakes discussed in Section 1.2.

The NYS BioSurveys from the 1920s and 1930s indicate a wide variety of aquatic plants- submergent, floating leaf and emergent- present in lakes throughout the state. Tables 1.2.2 and 1.2.3 show some significant differences between lakes within the Adirondack Park and those falling outside the Park. This might reflect comparable differences in water quality, lakeshore development, elevation, access, lake use, and other related factors. For example, among the most common plants within the Adirondacks includes quillwort, pipewort, water lobelia and slender watermilfoil, which are most associated with lower trophic state (i.e. less algal productivity) and perhaps lower conductivity. In contrast, plants often associated with higher trophic state, including coontail and lesser duckweed, are more common outside of the Park. The plants most common throughout the state are primarily emergent or floating leaf plants, including both yellow and white water lilies, bur reed, bul rush and spike rush, and only slender naiad, common bladderwort and small pondweed can be characterized as submergent plants among the 20 most common plants in both the Adirondacks and outside the Adirondacks.

The list of the most abundant plants differs somewhat from the list of most common plants, although both lists include some overlap between the Adirondacks and lakes outside the Adirondack Park. Outside of the Park, the most common plants- coontail, slender naiad, bulrush and spikerush- were also among the most abundant plants during these 1920s-1930s surveys. The overlap was not quite as significant within the Park, although most of the seven most common plants were also among the seven most abundant plants- spikerush, yellow water lily, bur reed, and ribbonleaf pondweed. In general, the most abundant plants outside of the Adirondacks tended to be submergent plants, while the most abundance plants within the Park were emergent or floating leaf plants. Without a detailed evaluation of the shoreline and water quality characteristics of these lakes, the reasons for these differences cannot be closely analyzed. However, it is possible that reduced shoreline and nearshore uses associated with the less developed Adirondack lakes may lead to a relatively higher density of emergent and floating leaf plants. Likewise, more shoreline development in lakes outside of the Pak may result in a relatively higher density of submergent plants. Unfortunately, neither shoreline density and disturbance information nor extensive water quality data for the lakes surveyed in the 1920s-1930s NYS BioSurvey are available to evaluate these factors.

Significant differences in abundance versus frequency can also be evaluated. This can be done by identifying those plants that are more common than abundant relative to those plants that are more abundant than common (as determined by analyzing relative frequency rankings compared to relative abundance rankings). The absolute differences in these rankings are dominated by plants that are neither very common nor very abundant but exhibit “intermediate” rankings for one category (for example, ranked 50th most common but 100th most abundant).

The "more common than abundant" plants that are (also) relatively common include pickerelweed and small pondweed outside the Adirondacks, and small pondweed, spiral pondweed and common bladderwort inside the Adirondacks. This indicates that these plants were found in many lakes, but generally did not grow in high quantities in most of these lakes. At least at that time, these plants did not appear to be bed-forming, but instead were more likely to be growing as isolated individual plants or in small quantities. Both pickerelweed and common bladderwort are often associated with dense beds in more contemporary settings- this may reflect a change in habitat (shoreline development, bottom characteristics, and/or water quality) over time that has been exploited by these plants in recent years.

The "more abundant than common" plants include star duckweed outside of the Adirondacks, and northern watermilfoil, muskgrass and large leaf pondweed within the Adirondacks, suggesting that these plants were not found in large number of lakes, but grew relatively densely where found. Each of these plants are often associated with dense weed growth and have been subject to aquatic plant management in some lakes, although northern watermilfoil and star duckweed appear to have been crowded out by exotic (Eurasian watermilfoil) or nuisance (lesser duckweed) plant species that have increased in frequency and abundance over the last century.

Several exotic plants were similarly "unbalanced"- either much more common than abundant, or more abundant than common- but were still neither very common nor very abundant at the time of these NYS BioSurveys. For example, brittle naiad, an invasive exotic plant species first observed in the Hudson River in the 1930s, was likely just recently colonized in the state at the time of the NYS BioSurveys, and thus had not yet established dense beds in many locations. In other words, it was indicative of an exotic plant not yet exhibiting invasive characteristics at that time (early in its infestation cycle). Likewise, water chestnut, a highly invasive exotic plant first observed in New York state in the early 1880s in Collins Lake in the Capital District, likely became well established in a few nearby lakes- but not the Adirondack Park- in the intervening half century. This plant exhibited both exotic and invasive characteristics, although it was still relatively uncommon outside of the Mohawk River and surrounding smaller ponded waters. As noted above, curly-leafed pondweed was more abundant than common, but this might reflect the timing of the NYS BioSurveys (mid-to-late summer) and the growth cycle of this exotic plant, which tends to grow early and therefore only lakes with dense growth were captured in the surveys occurring later in the summer.

These results also suggest that these two broad geographic regions in New York state- the Adirondacks and the non-Adirondack "region"- should be evaluated separately. Fortunately, as discussed below, the other major NYS aquatic plant monitoring programs discussed in White Paper 1A- the ALSC, the PIRTRAM program, and the AWI program- can be neatly divided into Adirondack and non-Adirondack survey lakes.

It should also be noted that invasive species, or at least submergent invasive species, were not common in the NYS BioSurvey lakes. Curly leafed pondweed (*Potamogeton crispus*) was the most common invasive plant, found in just under 13% of the surveyed lakes, making it only the 51st most common plant in these lakes. It also ranked only 53rd in abundance. Except for variable watermilfoil (*Myriophyllum heterophyllum*), no other invasive species were found in more than 3

(out of 303) lakes in the NYS BioSurvey. Other now-common invasive plants were either not yet reported (Eurasian watermilfoil, hydrilla) or had only started to spread through the state (brittle naiad, fanwort…).

On the other hand, water marigold (*Megalodonta beckii*), a protected plant, was found in more than 20% of the lakes and ranks as the 35th most common plant in these surveys. Other protected or vulnerable plants were present at higher percentages than many of the exotic plants more commonly found in NYS lakes in recent years. This includes water lobelia (*Lobelia dortmanna*), cited as an "exploitably vulnerable native plant", was also found in a high percentage (>17%) of NYS BioSurvey lakes, and more than 40% of the surveyed lakes within the Adirondack Park (but < 5% outside the Adirondacks).

Long-term changes in both invasive and protected species are discussed in more detail in Section 5.

Section 2- Plant Lists and Individual Genera in the Adirondack Lake Survey Corporation (ALSC) surveys

Section 2.1- ALSC aquatic plant survey methodology and surveyed lakes

White Paper 1A provides details about the Adirondack Lake Survey Corporation (henceforth referred to as the ALSC) study of more than 1500 lakes within the Adirondack Park and more than 250 downstate high elevation lakes from the mid- to late-1980s. The ALSC and the aquatic plant surveys conducted in that program can be summarized as follows:

- The ALSC included 1305 lakes within the Adirondack Park and 254 lakes in the downstate region for which aquatic plant surveys were conducted, in mid- to late-summer, as part of larger water quality and biological evaluations. All lakes were surveyed one time.
- As with the NYS BioSurvey, the ALSC lakes were generally smaller (<500 acres in surface area) than the typical NYS lake, and also smaller than lakes sampled in the NYS BioSurvey, PIRTRAM or AWI program.
- ALSC lakes represented a variety of water quality conditions, but included a preponderance of smaller, high elevation, acidic (both culturally and naturally) lakes, and slightly over-represented some regions (the Lake Champlain basin) and underrepresented other regions (the Mohawk River basin). However, the ALSC lakes included many lakes from throughout the Adirondack Park and in the high elevation downstate region (within the Lower Hudson River basin).
- Aquatic plant surveys identified plants only to genera level, and did not assign relative abundance values for any lakes.
- The number and distribution of survey sites, lakewide or within the littoral zone, were not reported for each surveyed lake.
- Plant (genera) frequency only can be evaluated across all ALSC lakes, not within lakes.
- Aquatic plant species-level identifications in other (NYS BioSurvey, PIRTRAM, and AWI) programs needed to be converted to genera level for comparison with ALSC data.
- 44 lakes were surveyed in the ALSC and NYS BioSurvey within the Adirondack Park

Section 2.2- ALSC aquatic plant survey results

Although the ALSC aquatic plant surveys only identified plants to genus level, the very large number of surveyed lakes (1305 within the Adirondack Park and 254 downstate lakes) provides an opportunity to evaluate aquatic plant communities in a large geographic region, and provides a basis for comparison to lakes surveyed about 60 years earlier. Table 2.2.1 shows the most common genera found in the 1305 ALSC Adirondack lakes, and Table 2.2.2 shows the most common genera found in the 254 downstate lakes surveyed in the ALSC. The majority of the 15 most common genera in ALSC Adirondack and downstate lakes were found in emergent or floating leaf habitats. Pondweeds (*Potamogeton sp*) were among the three most common genera in both the Adirondacks and downstate lakes, but no other submergent genera were common in both the upstate (Adirondack) and downstate regions.

Table 2.2.1- Most common aquatic plant genera in ALSC Adirondack Lakes (N=1305)

Genera Scientific Name	Genera Common Name	%Lakes	Rank
Nuphar sp	Yellow water lily	76.2%	1
Utricularia sp	Bladderwort	60.8%	2
Potamogeton sp	Pondweed	53.1%	3
Sparganium sp	Bur reed	52.6%	4
Carex sp	Water sedge	52.2%	5
Sphagnum sp	Sphagnum	51.2%	6
Dulichium sp	Three-way sedge	40.9%	7
Nymphaea sp	White water lily	36.2%	8
Eriocaulon sp	Pipewort	35.7%	9
Brasenia sp	Watershield	33.0%	10
Iris sp	Iris/flag	29.9%	11
Juncus sp	Common rush	27.0%	12
Pontederia sp	Pickerelweed	22.5%	13
Hypericum sp	St. Johns wort	18.9%	14
Typha sp	Cattail	18.6%	15

In contrast, several floating (yellow water lily- *Nuphar* sp, white water lily- *Nymphaea sp*) and emergent (bur reed- *Sparganium* sp, water sedge- *Carex* sp, iris/flag- *Iris* sp, sphagnum- *Sphagnum* sp, common rush- *Juncus* sp, St. Johns wort- *Hypericum* sp, and cattails- *Typha* sp) were commonly found in all regions of the state. Although several of these genera may include exotics species- curly-leafed pondweed (*Potamogeton crispus*) among the *Potamogetons*, for example- it is likely that the majority of the ALSC lakes had no invasive species in the mid-1980s. This is seen with the lack of any fanwort (*Cabomba* sp) or water chestnut (*Trapa* sp) species found in the ALSC upstate surveys, and no fanwort found in the ALSC downstate lakes, although these plants have since intruded into these regions.

Table 2.2.2- Most common aquatic plant genera in ALSC Downstate Lakes (N=254)

Genera Scientific Name	Genera Common Name	%Lakes	Rank
Potamogeton sp	Pondweed	52.8%	1
Carex spp	Water sedge	46.1%	2
Iris sp	Flag	45.3%	3
Nuphar sp	Yellow water lily	44.5%	4
Lythrum sp	Loosestrife	41.3%	5
Myriophyllum sp	Milfoil	40.9%	6
Sparganium sp	Bur reed	38.6%	7
Typha sp	Cattail	37.0%	8
Nymphaea sp	White water lily	35.0%	9
Sagittaria sp	Arrowhead	33.1%	10
Ceratophyllum sp	Coontail	32.7%	11
Hypericum sp	St. Johns wort	30.7%	12
Juncus sp	Common rush	29.9%	13
Elodea sp	Waterweed	29.1%	14
Sphagnum sp	Sphagnum	29.1%	14

Since these broad genera include a mix of invasive, nuisance, benign, favorable, and protected plants, the ALSC data presented in Tables 2.2.1 and 2.2.2 provide few insights about the relative favorability of the aquatic plant communities in the Adirondack region or equivalent downstate region, at least when evaluated in a vacuum.

Section 2.3- Long Term Changes Between 1920s/30s NYS BioSurvey and 1980s ALSC

However, at both a regional perspective and with specific waterbodies sampled in both the NYS BioSurvey and the ALSC, the effects of 50+ years of lake and watershed changes on aquatic plant communities can be evaluated by comparing the NYS BioSurvey and ALSC plant survey results. These survey results can be compared from two perspectives:

Table 2.3.1- Largest change in frequency between NYS BioSurvey Adirondack lakes (N=114) and ALSC Adirondack lakes (N=1305)

Genera Scientific Name	Genera Common Name	Δ%Lakes	Rank
Sphagnum sp	Sphagnum	49%	1
Iris sp	Iris/flag	30%	2
Carex sp	Water sedge	23%	3
Hypericum sp	St. John's wort	19%	4
Nymphozantus sp	Yellow water lily	14%	5
Calla sp	Water arum	10%	6
Myrica sp	Bayberry	9%	7
Juncus sp	Rush	9%	8
Typha sp	Cattail	6%	9
Lysimachia sp	Loosestrife	2%	10
Dulichium sp	Three way sedge	1%	11
Phragmites sp	Phragmites	1%	12
Myriophyllum sp	Watermilfoil	-45%	1
Najas sp	Naiad	-37%	2
Lobelia sp	Water lobelia	-37%	2
Eleocharis sp	Spikerush	-37%	2
Isoetes sp	Quillwort	-36%	5
Scirpus sp	Bul rush	-32%	6
Sagittaria sp	Arrowhead	-24%	7
Vallisneria sp	Eelgrass, tapegrass	-23%	8
Elodea sp	Waterweed	-23%	8
Glyceria sp	Mannagrass	-22%	10
Nymphoides sp	Floating heart	-20%	11
Potamogeton sp	Pondweed	-19%	12
Ranunculus sp	Water crowfoot	-18%	13
Mariscus sp	Saw sedge	-18%	13
Bidens sp	Water marigold	-16%	15
Chara sp	Muskgrass	-16%	15
Pontederia sp	Pickerelweed	-14%	17
Nymphaea sp	White water lily	-14%	17
Ceratophyllum sp	Coontail	-12%	19

a. *A regional comparison*, looking at the 1920s-30s NYS BioSurvey lakes from the Adirondacks (N = 114) and the 1980s ALSC Adirondack lakes (N= 1305). If each of these lake datasets are assumed to be representative of the (aquatic plant communities in the) lakes within the Adirondack Park, regional changes in aquatic plant communities from the 1920s/30s to the mid-1980s can be evaluated. The discussions in Section 2.2 both use these assumptions and presume that these assumptions are not accurate, as noted below. Although the geographic boundary of the ALSC Adirondack lakes (= the Adirondack blue line) was well defined in the ALSC and by extension the NYS BioSurvey, a similarly well-defined boundary for the downstate region is not available. This method- comparing lakes within a region over time- was also adopted in evaluating long-term

changes between the 1920s/30s NYS BioSurvey and both the AWI and PIRTRAM lakes, as discussed in Sections 3 and 4 below.

b. *A common-lakes comparison*, looking at the 44 lakes surveyed in both the NYS BioSurvey and the ALSC Adirondack aquatic plant surveys. Although this dataset is smaller than the dataset used for the regional comparison described above, it does provide an opportunity to directly compare the same lakes over a long timeframe. As noted above, a similarly strong overlap between the NYS BioSurvey and the ALSC Downstate lakes does not exist- fewer than 10 lakes were commonly surveyed in both the NYS BioSurvey and ALSC Downstate programs. Therefore, this common-lakes comparison was limited to the Adirondack region. As with the regional comparison discussed above, this common-lakes comparison approach was used in evaluating long-term changes between the 1920s/30s NYS BioSurvey and the more contemporary AWI and PIRTRAM surveys.

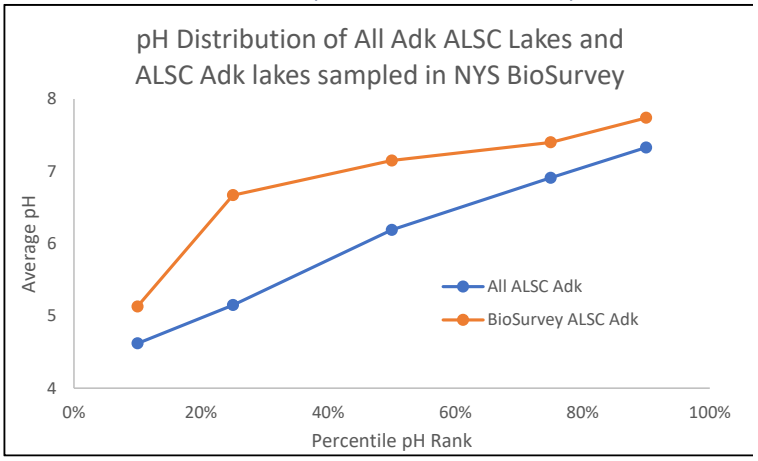
Table 2.3.1 shows the aquatic plant genera that changed the most from the 1920s-30s NYS BioSurvey to the 1980s ALSC. This table includes a summary of changes in plant genera from all of the 114 lakes within the Adirondacks surveyed in the NYS BioSurvey lakes, and all of the 1305 lakes surveyed in the ALSC within the Adirondack Park. Most of these lakes were not surveyed in both programs. The NYS BioSurvey represents a broad range of lake types (large and small, heavily and gently used, high and poor water quality, etc.), while the Adirondack ALSC lakes are primarily small, perched at high elevation, and are more likely to be acidic than some of the other lakes within the Adirondack Park.

Table 2.3.2- # Genera with Frequency Changing from NYS BioSurvey to ALSC Adirondack programs, All lakes in both surveys

Status	# Genera
# Genera Increasing	16
# Genera Decreasing	54

Some of the differences in genera between the NYS BioSurvey and the ALSC may reflect differences in monitoring design, although both surveys appear to be equally likely to observe (and record) emergent or submergent plants. This table shows that far more genera were likely to decrease in frequency (percentage of lakes counting this genera) from the 19203/30s to the 1980s. This is also apparent in Table 2.3.2, which shows that the number of genera decreasing over this period was more than 3x greater than the number of genera increasing over the 50-60 years between these surveys. Table 2.3.1 indicates that nearly all of the genera increasing over the 50-60 years were emergent plants-particularly iris/flag (*Iris* sp), water sedge (*Carex* sp), St. John's wort (*Hypericum* sp), yellow water lily (*Nymphozantus* sp, now *Nuphar* sp), and perhaps sphagnum moss (it is not known if the *Sphagnum* sp found in either survey were near-shore terrestrial or aquatic). However, the genera decreasing from the 1920s/30s to the 1980s included several submergent plants, including milfoils (*Myriophyllum* sp), naiads (*Najas* sp), water lobelia (*Lobelia* sp), quillwort (*Isoetes* sp), eelgrass (*Vallisneria* sp) and waterweed (*Elodea* sp). Both *Lobelia* sp. and *Myriophyllum* sp. include species that are protected or vulnerable, further emphasizing the risk of invasive species taking over a lake.

Figure 2.3.1- pH Distribution in all 1305 ALSC Adirondack lakes and 44 lakes surveyed in NYS BioSurvey and ALSC



As noted above, the NYS BioSurveys and the ALSC program may be comprised of different lakes. The former, even within the Adirondacks, included a wide range of lake types, while the ALSC program included more small, high elevation, acidic lakes (recognizing that the ALSC program included other lakes for comparison to lakes presumed to be affected by cultural acidification). Figure 2.3.1 shows the pH distribution of all 1305 ALSC Adirondack lakes and the 44 lakes surveyed in both the NYS BioSurvey and the ALSC (Adirondack) programs. While these 44 lakes may not be completely representative of all of the NYS BioSurvey lakes, since the ALSC program was limited to lakes smaller than about 500 hectares, these data do show that these 44 lakes were much more alkaline than the typical ALSC lake. This suggests that a long-term evaluation of changes in plant genera from the 1920s-30s to the 1980s should include an evaluation of lakes surveyed in both programs, even though the results from this much smaller dataset (N=44 vs. N=303 to 1305) may not be as statistically robust.

Table 2.3.3 summarizes the aquatic plant genera that changed the most from the 1920s-30s NYS BioSurvey to the 1980s ALSC, similar to Table 2.3.1, but limited only to the 44 lakes surveyed in both programs. This smaller dataset showed a similar but weaker pattern than was seen with the larger dataset comprising Table 2.3.1- over the 50-60 years between the 1920s/30s NYS BioSurvey and the 1980s ALSC- the frequency of emergent and floating leaf genera was more likely to increase, while the frequency of submergent genera was more likely to decrease. Although there were some differences in the specific genera increasing (and decreasing) in the entirety of the NYS BioSurvey and ALSC dataset versus the smaller list of lakes common to both monitoring programs, Table 2.3.4 shows that the number of genera decreasing over this period was only about 50% higher in the 44 commonly sampled lakes (compared to about 340% over the entire lake datasets) than the number of genera decreasing over this period.

Section 2.4- Discussion of Results

An evaluation of the ALSC lake aquatic plant communities benefits greatly from the very large dataset (N = 1305 lakes within the Adirondacks and N = 254 downstate lakes), but this evaluation is significantly compromised by the lack of species level identification, individual survey site data (within each surveyed lake) and the lack of abundance data.

Table 2.3.3- Largest change in frequency between lakes surveyed in both the NYS BioSurvey and ALSC Adirondack program (N=44)

Genera Scientific Name	Genera Common Name	Δ%Lakes	Rank
Iris sp	Iris/flag	36%	1
Sphagnum sp	Sphagnum moss	30%	2
Brasenia sp	Watershield	25%	3
Carex sp	Water sedge	23%	4
Typha sp	Cattail	23%	4
Juncus sp	Rush	20%	6
Nymphaea sp	White water lily	18%	7
Pontederia sp	Pickerelweed	16%	8
Elodea sp	Waterweed	16%	8
Eriocaulon sp	Pipewort	16%	8
Hypericum sp	St. Johns wort	14%	11
Nitella sp	Stonewort	14%	11
Sparganium sp	Bur reed	14%	11
Myrica sp	Bayberry	11%	14
Fontinalis sp	Aquatic moss (generalized)	11%	14
Lobelia sp	Water lobelia	-30%	1
Najas sp	Naiad	-25%	2
Scirpus sp	Bul rush	-25%	2
Myriophyllum sp	Watermilfoil	-23%	4
Glyceria sp	Mannagrass	-20%	5
Chara sp	Muskgrass	-18%	6
Vallisneria sp	Eelgrass	-16%	7
Mariscus sp	Saw sedge	-16%	7
Ranunculus sp	Water crowfoot	-16%	7
Eleocharis sp	Pipewort	-14%	10
Isoetes sp	Quillwort	-11%	11
Polygonum sp	Smartweed	-11%	11
Nymphoides sp	Floating heart	-11%	11

The data in Tables 2.2.1 and 2.2.2 suggest a mix of submergent, floating leaf, and emergent plants, but the large number of individual species within several of these genera preclude a detailed evaluation of specific plant taxa. These data do suggest differences between the Adirondack and downstate lakes- for example, bladderwort (*Utricularia* sp) are the second most common genera in the ALSC Adirondack lakes but not among the 15 most common genera within the downstate ALSC lakes. Likewise, both cattails (*Typha* sp) and milfoils (*Myriophyllum* sp) appear to be far more common downstate than within the Adirondacks. For most plants, the differences between the relative (ranking) and absolute (% counts) frequency of specific plant taxa in the Adirondacks and downstate lakes are probably either not significant or reflect incomplete or inconsistent surveys between lakes.

Table 2.3.4- # Genera with Frequency Changing from NYS BioSurvey to ALSC Adirondack programs (N = 44); only lakes sampled in both surveys

Status	# Genera
Increasing Frequency	19
Decreasing Frequency	28

The results from Table 2.3.1 and 2.3.3 suggest a significant shift in aquatic plant communities in the Adirondacks from a mix of emergent, floating leaf, and submergent plants in the 1920s-30s to dominance primarily by emergent plants in the 1980s.

As noted above, the larger ALSC Adirondack dataset includes lakes that became acidified as well as those for which other factors changed, while Figure 2.3.1 shows that the acidity status of the 44 lakes sampled in both the NYS BioSurvey and the ALSC did not change.

The much larger number of decreasing genera from the 1920s-30s to 1980s in the larger ALSC dataset suggests that much of the decrease in frequency of particularly submergent genera reflects the impact of cultural acidification. The smaller change in non-acidic lakes seen in Tables 2.3.3 and 2.3.4, however, suggests that other factors- increasing lake and shoreline use, slow cultural eutrophication, early introduction of invasive species, etc- may have also contributed to a decrease in the frequency of submergent genera.

The data presented in Table 2.3.3 also suggest that particular submergent genera- water lobelia (*Lobelia* sp), naiads (*Najas* sp), and watermilfoil (*Myriophyllum* sp)- seem to be vulnerable to lake changes, whether acidification, lake use, shoreline or land use, or other factors that influence plant community dynamics. Two of these genera- naiads and watermilfoils- include at least one invasive species that may be crowding out native species within these genera. It should be noted that while Eurasian watermilfoil (*Myriophyllum spicatum*) and brittle naiad (*Najas minor*), two highly invasive plants in these genera, are presently widespread in New York, these plants have not yet significantly impacted large portions of the Adirondacks. However, as these plants become more widespread, at least in the areas that have sufficient habitat to support these plants, some of the submergent genera listed in Table 2.3.3 may become even more vulnerable to replacement by these exotic plants. This will be further discussed below.

The lack of abundance data in the ALSC surveys precludes a similar evaluation of the “more common than abundant” and “more abundant than common” plants as evaluated in the 1920s-30s NYS BioSurveys (Section 1.3). In addition, the lack of species level identifications precludes an evaluation of whether invasive submergent plants, introduced to New York state lakes from the late 1880s to the early 2000s, were found at higher levels in the ALSC lakes (relative to the NYS BioSurvey). This lack of species-level identification also precludes an evaluation of changes in protected and vulnerable species over this period.

Section 3- Plant Lists and Individual Species in PIRTRAM surveys

Section 3.1- PIRTRAM aquatic plant survey methodology and surveyed lakes

White Paper 1A provides details about the Point-Intersect Rake Toss Relative Abundance Methodology (PIRTRAM) surveys conducted since the mid-1990s by the Racine-Johnson Aquatic Ecologists, Darrin Freshwater Institute, Allied Biological, and the NYSDEC Division of Water and partners (including lake associations) using common sampling methodologies. The PIRTRAM surveys, as outlined in White Paper 1A, can be summarized as follows:

- The PIRTRAM subset of lakes included more than 200 aquatic plant surveys conducted on more than 50 lakes throughout the state from the mid-2000s to the late 2010s. Nearly all of these lakes are located outside of the Adirondack Park
- These lakes were slightly larger than the typical NYS lake, but were comparable in size and geographic distribution to lakes surveyed for water quality by the NYSDEC through the NY Citizens Statewide Lake Assessment Program (CSLAP) and the Lake Classification and Inventory (LCI) survey. CSLAP and the LCI are fairly representative of lakes in NYS that are used by lake residents and visitors for multiple purposes, and are representative of those lakes that are managed by lake residents and local government to support multiple uses.
- Nearly all surveys used point-intercept grids equally distributed throughout the littoral zone using an overlay system, although not all grids (and corresponding survey points within the littoral zone) were surveyed in many PIRTRAM lakes
- Most emergent and floating leaf plants, and all macroalga, were identified only to genera, so direct comparison to the NYS BioSurvey may be limited in some cases. Many emergent plants were NOT included in these surveys; this habitat was almost certainly under-represented in these surveys. Comparisons to the NYS BioSurvey lakes, including evaluation of long-term changes, required "converting" some of the identifications of the NYS BioSurvey lakes to match the plant and habitat types identified only to genus in PIRTRAM lakes
- Some lakes were surveyed in multiple years- in some cases many consecutive years- while other lakes were surveyed during only a single year
- Relative abundance measurements were collected at each site in nearly all lakes; it is presumed that these measurements were comparable to the relative abundance measures in the NYS BioSurvey lakes discussed in Section 2 (and the AWI lakes discussed in Section 4). The "granular survey site" data in the PIRTRAM surveys allowed for evaluations of plant frequency and plant abundance between PIRTRAM lakes and to summary data for other programs.
- 14 PIRTRAM lakes were also surveyed as part of the NYS BioSurvey

Section 3.2- PIRTRAM aquatic plant survey results

The PIRTRAM aquatic plant surveys included fewer lakes than the NYS BioSurvey (N= 303), ALSC (N=1305 in the Adirondacks, N = 254 in the downstate region) and the AWI (N = 114 for all years, N = 90 excluding incomplete 2015) surveys. However, the PIRTRAM surveys appear to be the only ones with the consistent use of point-intercept and rake-toss methodologies and

granular and abundance survey site data for lakes throughout the state. In addition, unlike the other surveys, the PIRTRAM surveys included multiple lakes with multiple years of survey data, allowing for an evaluation of variance and long-term response to management actions.

Table 3.2.1- Most common aquatic plant species in PIRTRAM Lakes (N=164)

Species Scientific Name	Species Common Name	%Lakes	Rank
Ceratophyllum demersum	Coontail	65.9%	1
Myriophyllum spicatum	Eurasian watermilfoil	64.0%	2
Elodea sp	Common waterweed	51.8%	3
Potamogeton crispus	Curly-leafed pondweed	50.0%	4
Najas flexilis	Slender naiad	48.2%	5
Nymphaea odorata	Fragrant white water lily	48.2%	5
Potamogeton foliosus	Leafy pondweed	41.5%	7
Chara sp	Muskgrass	41.5%	7
Potamogeton pusillus	Small pondweed	39.0%	9
Vallisneria americana	Eelgrass, tapegrass	39.0%	9
Zosterella dubia	Water stargrass	39.0%	9
Lemna minor	Lesser duckweed	37.0%	12
Nitella sp	Stonewort	34.1%	13
Potamogeton zosteriformis	Flatstemmed pondweed	33.5%	14
Potamogeton amplifolius	Large leaf pondweed	32.3%	15
Najas minor	Brittle naiad	31.1%	16
Najas quadalupensis	Southern naiad	31.1%	16
Nuphar sp	Yellow water lily, spadderdock	29.9%	18
Fontinalis sp	Aquatic moss (generalized)	29.3%	19

Table 3.2.1 shows the most common aquatic plant species in the PIRTRAM lakes, based on the number of survey lakes in which each aquatic plant was identified. Note that this table includes duplicate years for some lakes (with each survey year representing a unique datapoint, even if the lake had been previously surveyed). This was necessary to avoid having to determine if a plant found in a single year but not other surveyed years (for a single lake) should be counted as an observed plant. The data presented in Table 3.2.1 shows that for the PIRTRAM lakes, invasive plants (Eurasian watermilfoil, curly leafed pondweed, and brittle naiad) or submergent plants commonly found at nuisance levels in more productive lakes (coontail, muskgrass, common waterweed, and southern naiad) were most frequently reported. As noted above, it is likely that common emergent plants, including bur reed, bul rush, and arrowhead, were not reported by PIRTRAM surveyors but may have been present at the lake. Many of the plants reported in Table 3.2.1 are also bed-forming plants capable of highly abundant plant growth in these lakes.

This was further evaluated in Table 3.2.2, which looked at the frequency with which each aquatic plant was among the most frequently observed plant in the lake (as opposed to the most lakes in which a plant was observed in Table 3.2.1). Table 3.2.2 eliminates the duplicate surveys for each lake, instead identifying only the five most frequently observed plants when considering all years in which a lake was surveyed. Although this method, as summarized in Table 3.2.2, tends to select for the most frequently observed plants rather than any plant that was observed in a survey, there is a strong overlap in the results between the methods used in Table 3.2.1 and Table 3.2.2. For example, coontail (*Ceratophyllum demersum*), Eurasian watermilfoil (*Myriophyllum*

spicatum) and common waterweed (*Elodea* sp) were the most frequently reported plants using both methods. However, leafy pondweed (*Potamogeton foliosus*), muskgrass (*Chara* sp), small pondweed (*Potamogeton pusillus*) and water stargrass (*Zosterella dubia*) were found in many lakes, but much less often were among the most frequently observed plants in the PIRTRAM lakes. Likewise, fanwort (*Cabomba caroliniana*), Robbins pondweed (*Potamogeton robbinsii*) and watermeal (*Wolffia* sp) were often among the most frequently reported plants in some lakes, but were less often among those found within many lakes. The latter are more likely characteristic of either invasive (in the case of fanwort) or nuisance (in the case of Robbins pondweed and watermeal) growth.

Table 3.2.2- Most frequently among most frequent aquatic plant species in PIRTRAM Lakes (N = 47)

Species Scientific Name	Species Common Name	%Lakes	Rank
Ceratophyllum demersum	Coontail	38.3%	1
Myriophyllum spicatum	Eurasian watermilfoil	38.3%	1
Elodea sp	Common waterweed	29.8%	3
Nymphaea odorata	Fragrant white water lily	17.0%	4
Cabomba caroliniana	(Carolina) fanwort	10.6%	5
Najas flexilis	Slender naiad	8.5%	6
Potamogeton crispus	Curly-leafed pondweed	8.5%	6
Potamogeton robbinsii	Robbins pondweed	8.5%	6
Wolffia sp	Watermeal	8.5%	6
Fontinalis sp	Aquatic moss (generalized)	6.4%	10
Hydrilla verticillata	Hydrilla / water thyme	6.4%	10
Lemna minor	Lesser duckweed	6.4%	10
Nitella sp	Stonewort	6.4%	10
Vallisneria americana	Eelgrass / tapegrass	6.4%	10
Brasenia schreberi	Watershield	4.3%	15
Chara sp	Musk grass	4.3%	15
Egeria densa	Brazilian elodea	4.3%	15
Najas minor	Britle naiad	4.3%	15
Potamogeton amplifolius	Large leaf pondweed	4.3%	15
Potamogeton pusillus	Small pondweed	4.3%	15

However, invasive or nuisance plant growth is more likely associated with a high abundance of plants within a lake, rather than plants more often among the most common plants in some lakes. The method used for evaluating aquatic plant abundance in the NYS BioSurvey lakes- assigning a $\log_5$ abundance value for each plant in each lake (as seen in Tables 1.2.4 through 1.2.6) requires a single value for each plant for each lake to compare abundance across lakes. This method cannot be used for the PIRTRAM lakes, since single values for each plant were defined FOR EACH SITE for each lake, thereby giving greater weight to the larger lakes with more survey sites. Fortunately, as noted above, relative abundance was evaluated at each surveyed site at nearly all PIRTRAM lakes, and these data can be evaluated to determine which plants are more often growing extensively in these PIRTRAM lakes. A different method was used to evaluate relative abundance, as described below.

Table 3.2.3 identifies the aquatic plants most frequently determined to be among the most abundant plants in each lake, based on defining plant abundance using a $\log_5$ scale for converting PIRTRAM relative abundance scales (abundant = 5, common = 4,….) to a weighted relative

abundance $\log_5$ scale (abundant = 125, common = 25, ….) as described in White Paper 1C. For example, in Table 3.2.3, the 48.9% value for Eurasian watermilfoil indicates that this plant was among the (five) most abundant plants in 48.9% of all the PIRTRAM lakes. This provides relative abundance data for each lake (based on a ranking of most abundant plants in each lake), allowing for a comparison across lakes.

These data indicate that many of the most abundant plants (Table 3.2.3) were also among the most frequently observed plants (Table 3.2.1)- that is, they were found both at many lakes and in many sites within these lakes. The only plants that were among the 10 most frequent plants (most lakes) not among the 10 most abundant plants (most sites within lakes) include curly leafed pondweed (*Potamogeton cripsus*), Robbins pondweed (*Potamogeton robbinsii*) and watermeal (*Wolffia* sp). The only plants among the most abundant but not most frequent were water chestnut (*Trapa natans)* and muskgrass (*Chara* sp.).

Table 3.2.3- Most frequently among most abundant aquatic plant species in PIRTRAM Lakes (N =164)

Species Scientific Name	Species Common Name	%Lakes	Rank
Myriophyllum spicatum	Eurasian watermilfoil	48.9%	1
Ceratophyllum demersum	Coontail	42.6%	2
Elodea canadensis	Common waterweed	38.3%	3
Najas flexilis	Slender naiad	21.3%	4
Nymphaea odorata	Fragrant white water lily	21.3%	4
Chara sp	Musk grass	17.0%	6
Nitella sp	Stonewort	17.0%	6
Cabomba caroliniana	(Carolina) fanwort	12.8%	8
Trapa natans	Water chestnut	12.8%	8
Brasenia schreberi	Watershield	10.6%	10
Fontinalis sp	Aquatic moss (generalized)	10.6%	10
Myriophyllum heterophyllum	Variable watermilfoil	10.6%	10
Najas minor	Brittle naiad	10.6%	10
Potamogeton amplifolius	Large leaf pondweed	10.6%	10
Potamogeton crispus	Curly-leafed pondweed	10.6%	10
Potamogeton pusillus	Small pondweed	10.6%	10

Section 3.3- Long Term Changes Between 1920s/30s NYS BioSurvey and 2000s-2010s PIRTRAM

As with the NYS BioSurvey and the ALSC, the effects of 50+ years of lake and watershed changes on aquatic plant communities can be evaluated by comparing the NYS BioSurvey from the 1920s-30s and the 2000s-2010s PIRTRAM plant survey results. And as with the NYS BioSurvey and ALSC evaluation, these survey results can be compared from two perspectives- a *regional comparison* and a *common lakes comparison*. The former includes all of the NYS BioSurvey lakes from outside the Adirondacks (N=189 lakes, each surveyed once) and the PIRTRAM lakes absent those from within the Adirondacks (N=146 surveys and 47 lakes). Unfortunately, only 14 lakes (with 28 PIRTRAM surveys) outside of the Adirondacks were surveyed in both the NYS BioSurvey and PIRTRAM programs.

Table 3.3.1- Biggest change in plant frequency, BioSurvey to PIRTRAM for lakes outside the Adirondack Park (N = 189 NYS BioSurvey lakes and N = 146 PIRTRAM surveys on 47 lakes)

Species Scientific Name	Species Common Name	%BioSurvey Lakes	%PIRTRAM Lakes	%Change
Myriophyllum spicatum	Eurasian watermilfoil	0%	64%	+64%
Potamogeton crispus	Curly-leafed pondweed	20%	50%	+30%
Najas minor	Brittle naiad	2%	31%	+30%
Sphagnum sp	Sphagnum moss	0%	25%	+25%
Najas guadalupensis	Southern naiad	7%	31%	+24%
Ranunculus longirostris	White water buttercup	3%	21%	+18%
Potamogeton foliosus	Leafy pondweed	25%	41%	+17%
Nitellopsis obtusa	Starry stonewort	0%	16%	+16%
Chara sp	Muskgrass	28%	41%	+14%
Nitella sp.	Stonewort	22%	34%	+12%
Hydrilla verticillatum	Hydrilla, water thyme	0%	11%	+11%
Scirpus sp	Bul rush	67%	0%	-67%
Sparganium sp	Bur reed	63%	5%	-57%
Eleocharis sp	Spikerush	63%	7%	-56%
Sagittaria sp	Arrowhead	67%	15%	-52%
Pontederia cordata	Pickerelweed	51%	0%	-51%
Typha sp	Cattail	52%	9%	-43%
Spirodela polyrhiza	Greater duckweed	38%	0%	-38%
Utricularia vulgaris	Common bladderwort	58%	26%	-32%
Polygonum sp	Smartweed	39%	7%	-32%
Dulichium arundinaceum	Three-way sedge	31%	0%	-31%
Myriophyllum exalbescens	Northern watermilfoil	32%	2%	-30%
Potamogeton natans	Floating leaf pondweed	38%	10%	-27%
Ludwigia palustris	Marsh seedbox	28%	1%	-27%
Eriocaulon sp	Pipewort	29%	2%	-26%
Peltandra virginica	Green arrow arum	25%	0%	-25%
Potamogeton gramineus	Variable leaf pondweed	39%	13%	-25%

Table 3.3.1 shows the plant species exhibiting the most significant increase or decrease in frequency between the 1920s-30s NYS BioSurvey and the contemporary PIRTRAM surveys, using the entire NYS BioSurvey dataset (N = 189 lakes) and the entire PIRTRAM dataset (N = 146 surveys in 47 lakes) outside of the Adirondacks. As seen in Table 3.3.2, nearly 4x as many species decreased than increased from the NYS BioSurveys of the 1920s-30s to the PIRTRAM surveys conducted about 80 years later. Some of these plant species or genera- particularly emergent plants such as bul rush, bur reed, spikerush, arrowhead, and cattails- were clearly under-reported in the PIRTRAM surveys,

Table 3.3.2- # Species with Frequency Changing from NYS BioSurvey to PIRTRAM (N = 189 to N = 146); all lakes sampled in both surveys

Status	# Species
Increasing Frequency	36
Decreasing Frequency	121

Table 3.3.3- Biggest change in plant frequency, BioSurvey to PIRTRAM (includes only lakes in both surveys) in lakes outside the Adirondack Park (N = 28 surveys on 14 lakes)

Species Scientific Name	Species Common Name	%BioSurvey Lakes	%PIRTRAM Lakes	%Change
Myriophyllum spicatum	Eurasian watermilfoil	0%	92%	+92%
Najas guadalupensis	Southern naiad	19%	69%	+50%
Chara sp	Muskgrass	38%	77%	+39%
Nitella sp.	Stonewort	19%	54%	+35%
Najas minor	Brittle naiad	0%	35%	+35%
Potamogeton crispus	Curly-leafed pondweed	50%	81%	+31%
Ranunculus longirostris	White water buttercup	0%	31%	+31%
Nitellopsis obtusa	Starry stonewort	0%	23%	+23%
Lemna trisulca	Star duckweed	38%	58%	+20%
Scirpus sp	Bul rush	100%	0%	-100%
Sagittaria sp	Arrowhead	100%	4%	-96%
Eleocharis sp	Spikerush	94%	8%	-86%
Pontederia cordata	Pickerelweed	81%	0%	-81%
Potamogeton epihydrus	Ribbonleaf pondweed	81%	0%	-81%
Sparganium sp	Bur reed	88%	8%	-80%
Utricularia vulgaris	Common bladderwort	81%	12%	-70%
Dulichium arundinaceum	Three-way sedge	69%	0%	-69%
Potamogeton compressus	Flat-stemmed pondweed	56%	0%	-56%
Potamogeton dimorphus	Spiral pondweed	56%	0%	-56%
Brasenia schreberi	Watershield	63%	8%	-55%
Isoetes sp	Quillwort	56%	3%	-53%
Potamogeton gramineus	Variable leaf pondweed	69%	19%	-50%
Nymphaea sp	White water lily	94%	50%	-44%
Spirodela polyrhiza	Greater duckweed	44%	0%	-44%
Nymphozantus sp.	Yellow water lily	88%	47%	-41%
Eriocaulon septangulare	Pipewort	44%	4%	-40%

which tended to focus on submergent and floating leaf plants. As discussed at length in White Paper 1A, pickerelweed was well reported in some PIRTRAM surveys but not in others, so this plant was explicitly removed from the database to avoid questions about its representativeness in some lakes. However, there were a few submergent or floating plant species in Table 3.3.1 which appeared to have decreased over the last 80 years- these plants were clearly "subject" to observation in both sets of surveys, but appear to have reduced significantly outside of the Adirondacks. This includes floating leaf and variable leaf pondweeds (*Potamogeton natans* and *Potamogeton gramineus*), common bladderwort (*Utricularia vulgaris*), and Northern watermilfoil (*Myriophyllum exalbescens*, now known as *Myriophyllum sibericum).*

Table 3.3.4- # Species with Frequency Changing from NYS BioSurvey to PIRTRAM (N = 28 surveys on 14 lakes); all lakes sampled in both surveys

Status	# Species
Increasing Frequency	28
Decreasing Frequency	73

Table 3.3.5- Biggest change in plant abundance, BioSurvey to PIRTRAM (includes all lakes in both surveys) in lakes outside the Adirondack Park (N = 189 BioSurvey; N =146 PIRTRAM surveys in 47 lakes)

Species Scientific Name	Species Common Name	Rel. Change Rank
Myriophyllum spicatum	Eurasian watermilfoil	+47.0
Najas minor	Brittle naiad	+29.6
Cabomba caroliniana	(Carolina) fanwort	+27.2
Hydrilla verticillatum	Hydrilla, water thyme	+27.0
Egeria densa	Brazilian elodea	+22.0
Myriophyllum heterophyllum	Variable watermilfoil	+13.2
Eriocaulon sp	Pipewort	+13.0
Nitellopsis obtusa	Starry stonewort	+12.0
Potamogeton hillii	Hill's pondweed	+12.0
Scirpus sp	Bul rush	-47.7
Myriophyllum exalbescens	Northern watermilfoil	-43.0
Spirodela polyrhiza	Greater duckweed	-42.6
Lemna trisulca	Star duckweed	-40.6
Carex sp	Water sedge	-40.3
Potamogeton richardsonii	Richardson's pondweed	-39.6
Polygonum sp	Smartweed	-38.9
Juncus sp	Rush	-38.3
Potamogeton gramineus	Variable leaf pondweed	-37.9
Glyceria sp	Mannagrass	-36.3
Decodon verticillatus	Three-way sedge	-35.9
Pontederia cordata	Pickerelweed	-34.9
Wolffia punctata	Watermeal	-34.6
Elatine minima	Small waterwort	-33.6
Sparganium sp	Bur reed	-33.3

Table 3.3.1 also clearly shows that invasive exotic plants, cited in bold font, increased in frequency over this period, with Eurasian watermilfoil (*Myriophyllum spicatum*), curly-leafed pondweed (*Potamogeton crispus*), brittle naiad (*Najas minor*), starry stonewort (*Nitellopsis obtusa*), and hydrilla (*Hydrilla verticillata*) all among the plant species increasing in frequency by more than 10%. The remaining plant species increasing in frequency in Table 3.3.1 include several native plants that often grow to nuisance levels (southern naiad and leafy pondweed) and macroalga (muskgrass and stonewort), although it should be noted that this table lists plant species increasing in frequency, not (necessarily) abundance.

A more defined evaluation of long-term change focuses on those plant species that increased in lakes common to both the NYS BioSurveys and the PIRTRAM surveys. Unfortunately, only 28 surveys were conducted on 14 lakes included in both surveys, so the sample size for this evaluation is very limited. Table 3.3.3 shows a very significant overlap with Table 3.3.1, indicating similar results that whether long-term changes are evaluated on the entire large dataset (N = 189 lakes in the NYS BioSurvey and N = 146 surveys on 47 PIRTRAM) lakes or the smaller "common lakes" dataset (N = 28 surveys on 14 lakes). A few additional submergent pondweeds- ribbonleaf pondweed (*Potamogeton epihydrus*), flat-stemmed pondweed (*Potamogeton compressus*, now *Potamogeton zosteriformis*), spiral pondweed (*Potamogeton*

dimorphus, now *Potamogeton spirillus*)- and quillwort (*Isoetes* sp) decreased in frequency in the commonly sampled lakes. Table 3.3.4 shows that even in this smaller dataset, the number of plant species decreasing from the 1920s-30s surveys to the 2000s-10s surveys was substantially higher than the number of plants species increasing over this period.

As noted above, Tables 3.3.1 through 3.3.4 identify the plant species that exhibited the most significant change in frequency between the 1920s-30s NYS BioSurvey and the 2000s-10s PIRTRAM surveys (and the number of plant species increasing or decreasing over this period). These same data can also be evaluated for changes in abundance, using the entire NYS BioSurvey and PIRTRAM surveys datasets outside the Adirondacks, and the smaller subset of lakes surveyed in both programs. This can provide an additional evaluation of change over time. Tables 3.3.5 and 3.3.6 evaluate the plant species that exhibited the most significant change in abundance over this period, based on changes in plant species abundance in all non-Adirondack lakes included in both surveys (Table 3.3.5), and only those non-Adirondack lakes included in both surveys (Table 3.3.6).

Table 3.3.6- Biggest change in plant abundance, BioSurvey to PIRTRAM (includes only lakes sampled in both surveys) in lakes outside the Adirondack Park (N = 28 surveys in 14 lakes)

Species Scientific Name	Species Common Name	Rel. Change Rank
Myriophyllum spicatum	Eurasian watermilfoil	28.0
Najas minor	Brittle naiad	25.0
Cabomba caroliniana	(Carolina) fanwort	22.0
Myriophyllum heterophyllum	Variable watermilfoil	19.0
Egeria densa	Brazilian elodea	14.0
Hydrilla verticillatum	Hydrilla, water thyme	14.0
Potamogeton hillii	Hills pondweed	14.0
Utricularia minor	Lesser bladderwort	14.0
Sagittaria sp	Arrowhead	-28.7
Scirpus sp	Bul rush	-28.7
Sparganium sp	Bur reed	-26.7
Pontederia cordata	Pickerelweed	-25.7
Potamogeton epihydrus	Ribbonleaf pondweed	-25.7
Dulichium arundinaceum	Three-way sedge	-24.4
Potamogeton gramineus	Variable leaf pondweed	-24.4
Brasenia schreberi	Watershield	-23.7
Lemna minor	Lesser duckweed	-23.7
Isoetes sp	Quillwort	-22.7
Potamogeton amplifolius	Large leaf pondweed	-22.7
Potamogeton spirillus	Spiral pondweed	-22.7
Potamogeton praelongus	White stem pondweed	-20.8
Spirodela polyrhiza	Greater duckweed	-19.8
Lemna trisulca	Star duckweed	-19.1
Ludwigia palustris	Marsh seedbox	-19.1
Peltantra virginica	Green arow arum	-19.1
Polygonum sp	Smartweed	-19.1
Potamogeton natans	Floating leaf pondweed	-19.1
Potamogeton richardsonii	Richardson's pondweed	-19.1
Stuckenia pectinatus	Sago pondweed	-19.1

As discussed above, two slightly different measures were used to evaluate species abundance in the NYS BioSurvey and PIRTRAM lakes. For the NYS BioSurvey lakes, when a single relative abundance measure (abundant, common, present, occasional, or rare) was used to describe the amount of each plant in each lake, small and large lakes can be readily compared, since all lakes were evaluated on the same scale. For these lakes, weighted abundance values- created by converting the relative abundance measures to weighted relative abundance using a $\log_5$ scale (abundant = 125, common = 25, present = 15, occasional = 5, rare = 1)- can be generated and the "most abundant" plants can be identified among all of the plants found in these surveys. However, for the PIRTRAM surveys, relative abundance values were generated for each plant for each lake AT EACH SITE, so the weighted relative abundance score for larger lakes with more survey sites would be much larger than the score in smaller lakes with fewer lakes.

Therefore, for the PIRTRAM surveys, abundance is evaluated by determining the (usually five) most abundant plants in each lake, and determining the frequency by which each plant was among the most abundant plants in all lakes. The relative abundance score using both measures- weighted abundance values for NYS BioSurvey lakes, and frequency among the (five) most abundant plants for PIRTRAM lakes- were ranked and compared.

Table 3.3.5 identifies the plant species that changed the most in abundance from the 1920s-30s (non-Adirondack) NYS BioSurvey (N = 189 lakes) to the 2000s-10s (non-Adirondack) PIRTRAM study (47 lakes in 146 surveys). Table 3.3.6 provides the same measure for just the 14 lakes (in 28 surveys) evaluated in both the NYS BioSurvey and PIRTRAM programs. **Table 3.3.5 shows that nearly all of the plants for which plant abundance increased over this period were invasive plants- Eurasian watermilfoil, brittle naiad, fanwort, hydrilla, Brazilian elodea, variable watermilfoil, and starry stonewort. It should be noted that this is a defining characteristic of invasive plants-the ability to spread rapidly and become common in invaded lakes**. Although the smaller subset of commonly-sampled lakes affords lower statistical significance than the larger datasets, Table 3.3.6 shows that the same invasive plants also increased in abundance more than all other plants from the 1920s-30s to the 2000s-10s.

These tables showed that many plant species or genera decreased significantly from the 1920s-30s NYS BioSurvey to the PIRTRAM surveys. As discussed above regarding evaluation of plant frequency, many of these plants are emergent plant species- bul rush, bur reed, arrowhead, water sedge, pickerelweed, three-way sedge- not routinely included in the species count for many PIRTRAM lakes. The latter surveys focused primarily on submergent and floating leaf plants. Among the submergent and floating leaf plants, northern watermilfoil, greater and lesser duckweed, Richardson's pondweed, variable leaf pondweed and small waterwort were among the plants decreasing in abundance in all lakes, while among the commonly sampled lakes (Table 3.3.6), several other pondweeds- ribbonleaf pondweed, large leaf pondweed, spiral pondweed, and several other submergent or floating leaf plants appeared to decrease in abundance. Combining these tables, these data suggest that Richardson's pondweed (*Potamogeton robbinsii*), variable leaf pondweed (*Potamogeton gramineus*), greater (*Spirodela polyrhiza*) and star duckweed (*Lemna trisulca*), and northern watermilfoil (*Myriophyllum sibericum*) appeared

to decrease in the most in abundance over the 80 years between the NYS BioSurveys and the PIRTRAM surveys.

Section 3.4- Discussion of Results

Tables 3.2.1 and 3.2.2 indicate that primarily submergent and floating leaf plants were the most frequent and abundant plants in the PIRTRAM lakes. This may be indicative of the PIRTRAM sampling methodology, which generates survey grids that often underrepresent the marginal area of lakes where emergent and floating leaf plants tend to grow, and in some cases explicitly exclude these plants to focus on those (submergent) plants likely subject to large scale evaluation and management. The most frequent and common plants are highly represented by invasive species- particularly Eurasian watermilfoil (*Myriophyllum spicatum*), fanwort (*Cabomba caroliniana*), curly leafed pondweed (*Potamogeton crispus*)- and native plants that frequently grow to nuisance levels- coontail (*Ceratophyllum demersum*), common waterweed (*Elodea* sp), water lilies (*Nymphaea* sp and *Nuphar* sp), and leafy pondweed (*Potamogeton foliosus*).

The plants listed in Table 3.2.3 represent the most abundant plants in the PIRTRAM lakes, while the plants listed in Table 3.2.1 represent the most common plants in the PIRTRAM lakes. The data in these two tables indicate a significant overlap in the most common and most abundant plants, with coontail (*Ceratophyllum demersum*), Eurasian watermilfoil (*Myriophyllum spicatum*), common waterweed (*Elodea sp*), slender naiad (*Najas flexilis*), muskgrass (*Chara* sp), and fragrant white water lily (*Nymphaea* sp) all among the nine most common and abundant plants in the PIRTRAM lakes. Several plants- leafy pondweed (*Potamogeton foliosus*), eelgrass (*Vallisneria americana*), and water stargrass (*Zosterella dubia*)- were among the plants that were (much) more common than abundant, while fanwort (*Cabomba caroliniana*), water chestnut (*Trapa natans*), aquatic moss (*Fontinalis* sp), variable watermilfoil (*Myriophyllum heterophyllum*) and brittle naiad (*Najas minor*) were more abundant than common. With the exception of water moss, all of the "more abundant than common" plants are exotic plants, with most introduced into New York state within the last century. These plants may hold interim spots on the "more abundant than common" list as (or at least if) they become more widespread in the state, should habitats, boat launch transit, and other factors allow them to thrive in new settings.

These lists of "more common than abundant" and "more abundant than common" in PIRTRAM can be contrasted with similar lists generated in the NYS BioSurvey from the 1920s-30s. Several emergent plants cited as either "more common than abundant" (green arrow arum, pickerelweed) or "more abundant than common" (water arum, water parsnip, American shoreweed) in the NYS BioSurvey were likely under-counted or not reported in the PIRTRAM surveys and thus cannot be evaluated for consistency across programs. In addition, several submergent or floating leaf plants that were unbalanced (more common than abundant or more abundant than common) in the NYS BioSurvey Adirondack lakes cannot be evaluated through PIRTRAM due to the lack of survey lakes within the Adirondack Park. Focusing on submergent or floating leaf plants outside the Adirondack Park, NO plants were more common than abundant in both the 1920s-30s NYS BioSurvey and the 2000s-10s PIRTRAM surveys, and NO plants were more abundant than common in both surveys. **However, the PIRTRAM surveys indicate that the latter list- those plants more abundant than common- were dominated by "regional" exotic plants, while**

the list of plants that were BOTH common and abundant include both highly invasive and highly nuisance plants. Specifically, the plants that were more abundant than common include invasive plants like fanwort (*Cabomba caroliniana*), water chestnut (*Trapa natans*), brittle naiad (*Najas minor*) and variable watermilfoil (*Myriophyllum heterophyllum*) that are generally limited to specific geographic regions, and have not yet invaded many parts of the state. It is likely that hydrilla (*Hydrilla verticillata)* and starry stonewort (*Nitellopsis obtusa*) will soon be added to this list. The plants that were both common and abundant include statewide invasive (Eurasian watermilfoil- *Myriophyllum spicatum*) plants, and nuisance native plants- coontail (*Ceratophyllum demersum*), slender naiad (*Najas flexilis*), white water lily (*Nymphaea sp*) and common waterweed (*Elodea sp*) that expanded significantly within waterbodies after initial colonization- in some cases, behaving like exotic plants. If these surveys were expanded into early summer, it is likely that curly-leafed pondweed (*Potamogeton crispus*) would be added to this list.

Tables 3.3.1 through 3.3.6 identify the plants that increased and decreased the most from the 1920s-30s surveys to the 2000s-10s surveys for plant frequency (Table 3.3.1/3) and abundance (Tables 3.3.5/6). Curly leafed pondweed and several native plants increased in frequency in many lakes, but were not among the plants that increased in abundance. As noted earlier, curly leafed pondweed is an early season plant for which abundance measures in late summer surveys are not representative of spring-to-early-summer abundance levels. In other words, differences in the frequency vs. the abundance of this plant may have been influenced by the survey methodology. The discrepancy in the change in frequency vs. abundance for several native plants- southern naiad, leafy pondweed, and both macroalga (muskgrass and stonewort)- appears to indicate the lack of nuisance-level plant growth in these plants, even though many of them are commonly associated with nuisance conditions.

Otherwise the plants that increased the most significantly from the 1920s-30s to the 2000s-10s, whether evaluated by a change in plant frequency or plant abundance, are those plants considered exotic and invasive to New York state. It is likely that the decrease in abundance for many of the plants listed in Tables 3.3.5 and 3.3.6 are associated with survey differences between the NYS BioSurvey and PIRTRAM, particularly related to emergent plants and identification of some species within common genera. However, as discussed below, these findings- particularly the loss of some species within genera containing highly invasive plants (northern vs. Eurasian watermilfoil) and the loss of some water quality sensitive plants (several pondweeds) appears to be consistent with narratives related to the impacts of invasive species introductions and water quality changes in aquatic plant community integrity. Potential changes in some of these vulnerable native plants, particularly pondweeds, duckweeds, and northern watermilfoil, should continue to be evaluated.

Finally, as discussed above, submergent invasive species increased in frequency and abundance in New York state lakes since the NYS BioSurveys. Section 1.3 shows that curly-leafed pondweed and variable watermilfoil were the only plants found in more than a few NYS BioSurvey lakes, and the lack of species-level identifications in the 1980s ALSC prevents an evaluation of changes in invasive species spread since the 1920s-30s. By the time of the

PIRTRAM surveys, mostly occurring outside of the Adirondacks, many of the invasive species more commonly occurring in NYS lakes by 2020, particularly Eurasian watermilfoil, curly-leafed pondweed, and water chestnut, had become established in these lakes. Eurasian watermilfoil, water chestnut, and brittle naiad increased significantly over this period in the (non-Adirondack) PIRTRAM lakes, while curly-leafed pondweed increased at a slightly lower rate. This might reflect the explosive increase in Eurasian watermilfoil and brittle naiad since their introduction to many regions of the state since the NYS BioSurvey, and the longer lag (and therefore slower increase) in curly-leafed pondweed since its introduction in the 1880s (although water chestnut was also introduced at that time).

Meanwhile, among the protected plants, the frequency and abundance of water marigold had decreased somewhat since the 1920s-30s, although it was still among the 30 most frequently reported plants in these lakes. Water lobelia was not seen in any PIRTRAM lakes, although as noted in Section 1.3, this plant was not common outside of the Adirondacks. Few of the other protected or vulnerable plants report in the NYS BioSurvey were seen in the PIRTRAM lakes.

A more detailed long-term evaluation of invasive and protected plants is provided in Section 5.

Section 4- Plant Lists and Individual Species in AWI surveys

Section 4.1- AWI aquatic plant survey methodology and surveyed lakes

White Paper 1A provides details about the aquatic plant surveys conducted by the Adirondack Watershed Institute (AWI surveys) from 2012 through 2016. The individual lake survey reports from 2012 and 2013, and the program reports (including a synopsis of individual surveys) are available from 2014 through 2016, all from the AWI website (https://www.adkwatershed.org/all-publications). These plant surveys are distinct from AWI water quality monitoring reports available for many of the same lakes. The AWI surveys, as outlined in White Paper 1A, can be summarized as follows:

- The AWI surveys included 114 lakes in the four years (all but 2015 in the period from 2012 to 2016) with detailed survey data, with most lakes sampled in only a single year. 35 lakes were surveyed in 2015, with some overlap from previous or subsequent years.
- These surveys used both systematic (point-intercept) rake toss surveys and surface evaluations of weed beds in 2012 and 2013, and surface evaluation of weed beds only in 2014 and 2016 (it is likely that the 2015 surveys also used surface evaluation of weed beds, but details were not provided in that report)
- Detailed frequency and relative abundance data were provided for all rake toss and weed bed sites for 60 lakes in 2012 and 2013, and for weed beds in 2014 and 2016. It is presumed that the relative abundance assignments were scalable to those provided in the NYS BioSurvey- each on a five point scale- with details provided in White Papers 1A and 1C.
- Single abundance values were reported for each plant for each weed bed, regardless of bed size (although weed bed sizes were provided). For 2015, plant frequency distribution was provided for the collective of all surveyed lakes, but only the three most and least abundant species were reported for each lake (as well as individual plant species found in rake tosses, but not weed beds). Individual survey site data and individual lake abundance or frequency lists were not provided.
- Surveys included submergent, floating leaf, and emergent plants. It is likely that some plants, particularly emergent and floating leaf plants and macroalga, were only identified to genera level, and some of these were assigned to the name of the most common species within that genera.
- The lack of granular survey site data for all sites (including plant beds) influences an evaluation of frequency or abundance between lakes, but allows for evaluations between programs and over time. However, plant bed data can be converted into equivalent rake toss data to provide an estimate of relative plant abundance in these lakes. As with PIRTRAM, comparisons to the NYS BioSurvey lakes, including evaluation of long-term changes, also required “converting” some of the identifications of the NYS BioSurvey lakes to match the plant and habitat types identified only to genus in AWI lakes
- 44 lakes surveyed in the 1920s-30s NYS BioSurvey were also included in the 2010s AWI surveys.

Section 4.2- AWI aquatic plant survey results

The AWI aquatic plant surveys included 114 lakes with detailed survey data, and another 30 lakes with program summary data. This represents fewer lakes than the NYS BioSurvey (N= 303 lakes) and ALSC (N=1305 lakes in the Adirondacks, N = 254 lakes in the downstate region) programs, but more than in the PIRTRAM surveys (N = 47 lakes). However, the AWI surveys have an advantage over the larger NYS BioSurvey and ALSC study due to survey site data available for some of these lakes, and species level identifications and relative abundance data available for all lakes, although few lakes were surveyed over a long period of time. This allows for an evaluation of this dataset as a representation of the Adirondacks (or a least a subset of the most used and managed lakes within the Adirondack Park), and for an evaluation of long-term changes in individual plant species.

Table 4.2.1- Most common aquatic plant species in AWI Lakes (N = 144)

Species Scientific Name	Species Common Name	%Lakes	Rank
Nuphar sp	Yellow water lily, spadderdock	85.1%	1
Sparganium sp	Bur reed	83.1%	2
Nymphaea sp	Fragrant white water lily	78.6%	3
Potamogeton epihydrus	Ribbonleaf pondweed	78.6%	3
Brasenia schreberi	Watershield	75.3%	5
Eriocaulon sp	Pipewort	72.7%	6
Utricularia purpurea	Purple bladderwort	69.5%	7
Utricularia vulgaris	Common bladderwort	64.9%	8
Nitella sp	Stonewort	62.3%	9
Eleocharis sp	Spikerush	61.0%	10
Potamogeton natans	Floating leaf pondweed	57.8%	11
Potamogeton amplifolius	Large leaf pondweed	55.8%	12
Sagittaria graminea	Arrowhead	55.2%	13
Vallisneria americana	Eelgrass, tapegrass	51.9%	14
Potamogeton robbinsii	Robbins pondweed	49.4%	15
Lobellia dortmanna	Water lobelia	38.3%	16
Potamogeton perfoliatus	Clasping leaf pondweed	37.7%	17
Potamogeton gramineus	Variable pondweed	37.0%	18
Isoetes sp	Quillwort	35.7%	19
Najas sp	Naiad	34.4%	20

Table 4.2.1 shows the most common aquatic plant species in the AWI lakes, based on the number of survey lakes in which each aquatic plant was identified. This table includes the 2015 data (which summarizes frequency data on the entire lakes dataset but not on individual lakes) and duplicate surveys on a few lakes, for reasons described earlier. As discussed above, Table 4.2.1 includes a mix of plant species and plant genera, with the latter most often associated with emergent or floating leaf plants or macroalga. It is not known if multiple species were observed in these genera (during the surveys), but these were reported only to genera level since the associated plant species are rarely invasive and can be extremely challenging to identify in a large-scale program (note that the recent PIRTRAM surveys also frequently identify emergent or floating leaf plants only to genera). It should also be noted that *Najas* sp is probably *Najas flexilis* in most lakes, but absent seeds these plants can be difficult to identify to species level.

This table shows that emergent and floating leaf plants, particularly yellow water lily (*Nuphar* sp), bur reed (*Sparganium* sp), white water lily (*Nymphaea* sp), watershield (*Brasenia schreberi*), and pipewort (*Eriocaulon* sp), were the most frequently observed plants in the AWI Adirondack lakes. Each of these plants were found in more than 70% of the surveyed lakes. The most common submergent plants were several species of pondweeds and bladderwort; both genera include species that are often found in lakes with softwater and low nutrients.

Table 4.2.2- Most frequently among most common aquatic plant species in AWI Lakes (N = 89), weighted by area of plant beds

Species Scientific Name	Species Common Name	%Lakes	Rank
Sparganium sp	Bur reed	65.2%	1
Nuphar sp	Yellow water lily	62.9%	2
Nymphaea sp	Fragrant white water lily	52.8%	3
Brasenia schreberi	Watershield	47.2%	4
Potamogeton epihydrus	Ribbonleaf pondweed	44.9%	5
Sagittaria graminea	Arrowhead	32.6%	6
Eriocaulon sp	Pipewort	31.5%	7
Eleocharis sp	Spikerush	28.1%	8
Potamogeton amplifolius	Large leaf pondweed	22.5%	9
Myriophyllum heterophyllum	Variable watermilfoil	14.6%	10
Potamogeton perfoliatus	Clasping leaf pondweed	13.5%	11
Utricularia purpurea	Purple bladderwort	12.4%	12
Najas sp	(Slender) naiad	10.1%	13
Utricularia vulgaris	Common bladderwort	10.1%	13
Lobellia dortmanna	Water lobelia	9.0%	15
Potamogeton robbinsii	Robbins pondweed	7.9%	16
Vallisneria americana	Eelgrass, tapegrass	7.9%	16
Potamogeton natans	Floating leaf pondweed	6.7%	18
Myriophyllum spicatum	Eurasian watermilfoil	6.7%	18

As discussed in Section 3 in regard to the PIRTRAM surveys, the availability of "granular" survey site data- assigned relative abundance and frequency to each survey site in each lake- allows for a second evaluation of plant frequency- the frequency with which each plant is among the most frequently observed plants in a lake. This method likely works against plants found at few sites in many lakes, but is more likely to identify plants found in many sites in a smaller number of lakes (and of course those plants found in many sites in many lakes). However, unlike the PIRTRAM surveys, for which plant survey sites are point-intercept rake toss sites equally distributed across the littoral zone, the AWI surveys include a mix of rake toss and plant bed data. As noted above, the size of plant beds was reported, so the plant bed data can be weighted by plant bed acreage. This can be balanced against an estimated "size" of rake ross sites of 0.078 acres, corresponding to a 10m radius associated with the tethered rake toss "extent".

Table 4.2.2 identifies the aquatic plants that were most frequently among the most common plants in the AWI lakes, weighted by the size of the weed beds and an estimated areal extent represented by each rake toss. So, for example, plants reported in the largest weed beds were considered to occur more frequently than plants found only in smaller beds. This table does NOT include the 2015 AWI data, since the most frequently reported plants in individual lakes is not available. The data from Table 4.2.2 indicate a very strong overlap with Table 4.2.1, suggesting

that either method- identifying the plants found (in small or large quantities) in the most lakes (as summarized in Table 4.2.1) or the plants most likely among the most common plants in most lakes (more likely selecting for those plants found at the highest frequency WITHIN lakes).

As discussed in Section 3.2 (evaluation of PIRTRAM data), the differences between Tables 4.2.1 and 4.2.2 provide some insights about those plants found at higher or lower frequency in many AWI and Adirondack lakes (Table 4.2.1) relative to those plants found in higher frequency in slightly fewer lakes (Table 4.2.2). There was a very strong overlap between these tables, suggesting that most of the plants that were among the most frequently reported plants in most lakes (Table 4.2.2) were also reported in many lakes (Table 4.2.1), indicating that most of these plants were found in many sites in each reported lake. Two invasive milfoil species- variable watermilfoil (*Myriophyllum heterophyllum*) and Eurasian watermilfoil (*Myriophyllum spicatum*) were among the most frequently reported plants in many lakes without being among the plants found in the most lakes. In other words, these invasive plants were more likely to be found at a high frequency in fewer lakes. On the other end of the scale, variable leaf pondweed (*Potamogeton gramineus*) and quillwort (*Isoetes* sp) were found at lower frequency in many lakes but less frequently reported at higher frequencies within lakes.

Table 4.2.3- Most frequently among most abundant aquatic plant species in AWI Lakes (N = 119)

Species Scientific Name	Species Common Name	%Lakes	Rank
Nymphaea odorata	Fragrant white water lily	51.3%	1
Brasenia schreberi	Watershield	47.1%	2
Nuphar variegata	Yellow water lily	42.9%	3
Sparganium sp	Bur reed	37.8%	4
Eleocharis sp	Spikerush	36.1%	5
Eriocaulon sp	Pipewort	33.6%	6
Potamogeton amplifolius	Large leaf pondweed	25.2%	7
Potamogeton epihydrus	Ribbon leaf pondweed	16.8%	8
Myriophyllum heterophyllum	Variable water milfoil	16.0%	9
Sagittaria sp	Arrowhead	15.1%	10
Utricularia purpurea	Purple bladderwort	12.6%	11
Utricularia vulgaris	Common bladderwort	9.2%	12
Najas sp	(Slender) naiad	8.4%	13
Potamogeton robbinsii	Robbins pondweed	8.4%	13
Lobelia dortmanna	Water lobelia	6.7%	15
Myriophyllum spicatum	Eurasian watermilfoil	5.9%	16
Nitella sp	Stonewort	5.9%	16
Potamogeton natans	Floating leaf pondweed	5.9%	16
Potamogeton perfoliatus	Clasping leaf pondweed	5.9%	16

None of the evaluations above directly evaluate plant abundance. However, as with the NYS BioSurvey and PIRTRAM surveys, relative abundance of individual plants can be evaluated in the AWI dataset. As noted above, abundance data in a mixed rake toss/plant bed survey matrix can be weighted by the areal extent of relative abundance data in each survey site- this was done with the AWI dataset (as described above). Table 4.2.3 identifies the plant species (or genera) most frequently among the most abundant plant in each lake, weighted by areal coverage of the

Table 4.3.1- Biggest change in plant frequency, BioSurvey to AWI for lakes within the Adirondack Park (N = 114 NYS BioSurvey lakes and N = 146 AWI lakes)

Species Scientific Name	Species Common Name	%BioSurvey Lakes	%AWI Lakes	%Change
Utricularia purpurea	Purple bladderwort	28%	69%	+41%
Nitella sp.	Stonewort	25%	62%	+38%
Potamogeton amplifolius	Large leaf pondweed	19%	56%	+37%
Brasenia schreberi	Watershield	39%	75%	+36%
Eriocaulon sp	Pipewort	41%	73%	+31%
Potamogeton robbinsii	Robbins pondweed	20%	49%	+29%
Nymphaea sp	White water lily	50%	79%	+29%
Potamogeton epihydrus	Ribbonleaf pondweed	54%	79%	+25%
Myriophyllum heterophyllum	Variable watermilfoil	2%	26%	+24%
Sparganium sp	Bur reed	60%	83%	+23%
Vallisneria americana	Eelgrass, tapegrass	29%	52%	+23%
Nymphozantus sp.	Yellow water lily	62%	85%	+23%
Utricularia intermedia	Flat-leafed bladderwort	9%	29%	+20%
Potamogeton bupleuroides	Clasping leaf pondweed	18%	38%	+20%
Utricularia vulgaris	Common bladderwort	46%	65%	+19%
Myriophyllum spicatum	Eurasian watermilfoil	0%	17%	+17%
Scirpus sp	Bul rush	51%	0%	-51%
Dulichium arundinaceum	Three-way sedge	39%	0%	-39%
Potamogeton dimorphus	Spiral pondweed	38%	3%	-34%
Pontederia cordata	Pickerelweed	37%	6%	-31%
Carex sp	Water sedge	29%	0%	-29%
Potamogeton richardsonii	Richardson's pondweed	20%	1%	-20%
Juncus sp	Rush	18%	0%	-18%
Ranunculus sp	Water buttercup	18%	0%	-18%
Potamogeton pusillus	Small pondweed	43%	25%	-18%
Mariscus mariscoides	Sawgrass	18%	0%	-18%
Equisetum limosum	Horsetail	17%	1%	-16%
Myriophyllum tenellum	Slender watermilfoil	38%	22%	-16%

rake tosses and weed beds. The data in Table 4.2.3, roughly identifying the most abundant plants in the AWI survey lakes, can be contrasted with the most frequently reported plants in Table 4.2.1. The results from Table 4.2.1 and 4.2.3 show a very strong overlap between the most frequently reported plants (Table 4.2.1) and the most abundant plants (Table 4.2.3). The few plants that were identified as frequently occurring (Table 4.2.1) but not among the most abundant plants (Table 4.2.3) include eelgrass (*Vallisneria americana*), quillwort (*Isoetes* sp), and variable pondweed (*Potamogeton gramineus*). Two of these plants- quillwort and variable pondweed- were also among the plants cited above (via Table 4.2.2) were more common than abundant. Likewise, both evaluations indicate that variable watermilfoil (*Myriophyllum heterophyllum*) and Eurasian watermilfoil (*Myriophyllum spicatum*) are among the plants identified as more

abundant than frequently occurring. In other words, multiple methods outlined above indicate a small number of plants for which frequently and abundance are out of balance. This is discussed further in Section 4.4.

Table 4.3.2- # Species with Frequency Changing from NYS BioSurvey to AWI (N = 114 to N = 146); all lakes sampled in both surveys

Status	# Species
Increasing Frequency	46
Decreasing Frequency	74

Section 4.3- Long Term Changes Between 1920s/30s NYS BioSurvey and 2010s AWI

As with the NYS BioSurvey and the ALSC or PIRTRAM, the effects of 50+ years of lake and watershed changes on aquatic plant communities can be evaluated by comparing the NYS BioSurvey from the 1920s-30s and 2010s AWI plant survey results. And as with the NYS BioSurvey and ALSC/PIRTRAM evaluation, these survey results can be compared from two

Table 4.3.3- Biggest change in plant frequency, BioSurvey to AWI for lakes within the Adirondack Park surveyed in both programs (N = 44)

Species Scientific Name	Species Common Name	%BioSurvey Lakes	%AWI Lakes	%Change
Sparganium sp	Bur reed	68%	95%	+27%
Myriophyllum heterophyllum	Variable watermilfoil	0%	26%	+26%
Myriophyllum spicatum	Eurasian watermilfoil	0%	9%	+9%
Scirpus sp	Bul rush	61%	0%	-61%
Potamogeton natans	Floating leaf pondweed	57%	2%	-55%
Potamogeton pusillus	Small pondweed	52%	0%	-52%
Dulichium arundinaceum	Three-way sedge	52%	0%	-52%
Isoetes sp	Quillwort	52%	0%	-52%
Utricularia vulgaris	Common bladderwort	57%	5%	-52%
Pontederia cordata	Pickerelweed	50%	0%	-50%
Potamogeton dimorphus	Spiral pondweed	48%	0%	-48%
Najas flexilis	Slender naiad	52%	5%	-48%
Myriophyllum tenellum	Slender watermilfoil	43%	0%	-43%
Lobelia dortmanna	Water lobelia	52%	14%	-39%
Vallisneria americana	Eelgrass	39%	2%	-36%
Sagittaria sp	Arrowhead	52%	20%	-32%
Carex sp	Water sedge	32%	0%	-32%
Eleocharis sp	Spikerush	66%	34%	-32%
Mariscus mariscoides	Sawgrass	30%	0%	-30%
Nymphoides lacunosum	Little floating heart	32%	2%	-30%
Potamogeton gramineus	Variable leaf pondweed	30%	2%	-27%
Nitella sp.	Stonewort	30%	2%	-27%
Chara sp	Muskgrass	27%	0%	-27%
Glyceria sp	Mannagrass	27%	0%	-27%
Utricularia resupinata	Lavender bladderwort	27%	0%	-27%
Ranunculus sp	Water buttercup	25%	0%	-25%
Potamogeton robbinsii	Robbins pondweed	27%	2%	-25%

perspectives- a regional comparison and a common lakes comparison. The former includes all of the NYS BioSurvey lakes from within the Adirondacks (N=114 lakes, each surveyed once) and the AWI lakes- all within the Adirondacks (N=146 surveys, including some duplicate surveys). 44 lakes within the Adirondacks were surveyed in both the NYS BioSurvey and AWI programs.

Table 4.3.1 shows the plant species exhibiting the most significant increase or decrease in frequency between the 1920s-30s NYS BioSurvey and the 2010s AWI programs, using the entire NYS BioSurvey dataset (N = 114 lakes) and the entire AWI dataset (N = 146) within the Adirondacks. Table 4.3.3 shows the plant species changing the most in frequency among the 44 lakes included in both survey datasets. As seen in Table 4.3.2, many more plant species decreased than increased from the NYS BioSurveys of the 1920s-30s to the AWI surveys conducted about 80+ years later, and this difference was even more pronounced when considering just the lakes common to both surveys (Table 4.3.4).

Table 4.3.4- # Species with Frequency Changing from NYS BioSurvey to AWI (N = 44); only lakes sampled in both surveys

Status	# Species
Increasing Frequency	7
Decreasing Frequency	77

Some of these plant species or genera that decreased over this period- particularly emergent plants such as bul rush, three-way sedge, water sedge, rush and sawgrass- were clearly under-reported in the AWI surveys, although all plant types were subject to evaluation in the AWI surveys. Among both the larger dataset (Table 4.3.1) and the commonly surveyed lakes (Table 4.3.3), the submergent plants for which plant frequency decreased the most significantly from the 1920s-30s NYS BioSurvey and the 2010s AWI surveys include spiral pondweed (*Potamogeton dimorphus,* now *P. spirillus*) and water buttercup (*Ranunculus* sp). Additional evaluation may be needed to determine if the other submergent and floating leaf plants listed in Tables 4.3.1 and 4.4.3 are in fact decreasing in frequency or if changes reported in these tables are an artifact of the associated sampling programs.

Many submergent plants, including purple bladderwort (*Utricularia purpurea*), stonewort (*Nitella* sp), large leaf pondweed (*Potamogeton amplifolius*), Robbins pondweed (*Potamogeton robbinsii*) and ribbonleaf pondweed (*Potamogeton epihydrus*), were among the plant species increasing in frequency between the 1920s-30s NYS BioSurvey and the 2000s AWI survey when considering all lakes in both survey programs (Table 4.3.1). However, as seen in Table 4.3.3, very few plants increased in frequency when considering only those 44 lakes commonly surveyed in both the 1920s-30s NYS BioSurveys and the 2010s AWI surveys. The only plants that increased in commonly surveyed lakes include bur reed, variable watermilfoil and Eurasian watermilfoil; the latter two are invasive exotic plants. It is not known if the other plants that increased over this period in the larger dataset (all lakes) but not the commonly surveyed lakes indicate that the larger NYS BioSurvey and AWI surveys represent very different lakes or if these differences would be less prominent with larger datasets.

When evaluating changes in plant abundance, using the ranking methods described above, the differences between the larger NYS BioSurvey Adirondack (N= 114) and AWI datasets (N = 146) compared to the commonly sampled lakes in both surveys (N = 44) appear to be much

Table 4.3.5- Biggest change in plant abundance, BioSurvey to AWI for lakes within the Adirondack Park (N = 114 NYS BioSurvey lakes and N = 146 AWI lakes)

Species Scientific Name	Species Common Name	Rel Change Rank
Myriophyllum spicatum	Eurasian watermilfoil	+22.0
Myriophyllum heterophyllum	Variable watermilfoil	+15.6
Nymphoides peltata	Yellow floating heart	+11.0
Utricularia inflata	Swollen bladderwort	+7.0
Scirpus sp	Bul rush	-38.6
Carex sp	Water sedge	-33.9
Pontederia cordata	Pickerelweed	-31.1
Glyceria sp	Mannagrass	-30.0
Megalodonta beckii	Water marigold	-29.6
Potamogeton bicupulatus	Snail seed pondweed	-28.9
Chara sp	Muskgrass	-28.8
Dulichium arundinaceum	Three-way sedge	-27.8
Juncus sp	Rush	-27.4
Gratiola aurea	Golden hedgehyssop	-26.7
Myriophyllum tenellum	Slender watermilfoil	-26.6
Potamogeton confervoides	Algae-like pondweed	-26.0
Zosterella dubia	Water stargrass	-25.6
Ranunculus sp	Water buttercup	-24.9

smaller. Tables 4.3.5 and 4.3.6 show the plants with the most significant change in relative abundance between the 1920s-30s and the 2010s, using the entire NYS BioSurvey Adirondacks and AWI datasets (Table 4.3.5, N = 114 and 146, respectively) and only the lakes commonly sampled in both surveys (Table 4.3.6, N = 44). Whether considering all of the BioSurvey and AWI lakes, or just those included in both programs, the only plants that increased in abundance from the 1920s-30s to the 2010s were three invasive plants (Eurasian watermilfoil- *Myriophyllum spicatum*, variable watermilfoil- *Myriophyllum heterophyllum*, and yellow floating heart- *Nymphoides peltata*) and, to a lesser extent, a native plant that in some lakes grows extensively (swollen bladderwort- *Utricularia inflata*). This observation is consistent with the general narrative about the spread of invasive plants, as discussed further in Section 4.4.

Tables 4.3.5 and 4.3.6 show that emergent plants were most likely to decrease in abundance from the 1920s-30s surveys to the 2010s surveys, although as discussed above regarding plant frequency, this may be indicative of not including many emergent plants in these (more recent) surveys, given a focus on submergent invasive species in the AWI (and PIRTRAM) surveys. Among submergent plants, muskgrass (*Chara* sp), snailseed pondweed (*Potamogeton bicupulatus*), and water marigold (*Megalodonta beckii*) decreased in relative abundance from the 1920s-30s to the 2010s, regardless of whether the entire or common datasets were evaluated. Other plants cited as decreasing in abundance in Tables 4.3.5 and 4.3.6 may be specific to the lakes included in these surveys, although the decrease in abundance in slender watermilfoil (*Myriophyllum tenellum*), algae-like pondweed (*Potamogeton confervoides*), water stargrass (*Zosterella dubia*) and water buttercup (*Ranunculus* sp) in the larger dataset (Table 4.3.5) warrant further evaluation. Slender watermilfoil and water buttercup did also decrease in frequency from the 1930s-30s to the 2010s (Table 4.3.1), and algae-like pondweed and water marigold are on the state rare, threatened and endangered species list.

Section 4.4- Discussion of Results

As discussed above, there is a strong consistency between methods evaluating plant frequency with both the AWI and PIRTRAM datasets- based on a strong overlap between plants reported in Tables 3.2.1 and 4.2.1 (highest frequency of any occurrence of a plant) and Tables 3.2.2 and 4.2.2 (highest frequency of most frequently observed plants). This suggests that **either method can be used to evaluate plant frequency. Since the former method- a simple measure of the frequency of occurrence of each plant in surveyed lakes- can be evaluated in nearly all aquatic plant survey datasets, it is recommended that plant frequency be evaluated by a simple count of the number of lakes in which each plant taxa has been documented.**

Table 4.3.6- Biggest change in plant abundance, BioSurvey to AWI for lakes within the Adirondack Park (N = 44 lakes surveyed in both programs)

Species Scientific Name	Species Common Name	Rel Change Rank
Myriophyllum spicatum	Eurasian watermilfoil	+18.0
Myriophyllum heterophyllum	Variable watermilfoil	+17.0
Nymphoides peltata	Yellow floating heart	+17.0
Utricularia inflata	Swollen bladderwort	+8.0
Scirpus sp	Bul rush	-30.6
Chara sp	Muskgrass	-29.2
Carex sp	Water sedge	-26.9
Pontederia cordata	Pickerelweed	-24.0
Nitella sp.	Stonewort	-23.3
Isoetes sp	Quillwort	-22.9
Juncus sp	Rush	-21.4
Potamogeton bicupulatus	Snail seed pondweed	-21.0
Megalodonta beckii	Water marigold	-20.3
Mariscus mariscoides	Sawgrass	-19.9
Najas flexilis	Slender naiad	-19.3
Potamogeton pusillus	Small pondweed	-19.2
Drepanocladus fluitans	Aquatic moss	-18.8
Potamogeton robbinsii	Robbins pondweed	-18.6
Dulichium arundinaceum	Three-way sedge	-18.5
Glyceria sp	Mannagrass	-18.1

The differences between Table 4.2.1 and 4.2.2 represent those plants that may be found in many sites in some lakes (Table 4.2.2) relative to those plants found in potentially fewer sites in many lakes (Table 4.2.1). The former method accounts for all plants in all lakes, while the latter generally excludes those plants only found in few sites within lakes, even if they are found in many lakes. The very strong overlap between these tables indicate that most plants found in many lakes were also found at relatively high frequencies WITHIN lakes. **Those plants more likely to be found at "more" sites within lakes than in a similarly large number of lakes were two watermilfoil invasive species- Eurasian watermilfoil and variable leaf watermilfoil. This was also confirmed by looking at the differences between the most frequently reported plants (Table 4.2.1) and the most abundant plants (Table 4.2.3).** Those plants that were found at relatively lower frequency within AWI lakes, but at lower levels in many lakes, include plants (quillwort and variable leaf pondweed) that may be more water quality sensitive than other plants, but different plants (leafy pondweed, muskgrass, small

pondweed, and water stargrass) were included in the list of plants in PIRTRAM lakes found in many lakes but less often among the most frequently plants in these lakes. Given the lack of concurrence in the "many lakes but lower frequency within lakes" list of PIRTRAM and AWI lakes, the data associated with these plants warrants more detailed evaluation.

As noted above, invasive plants- Eurasian watermilfoil, variable watermilfoil, and yellow floating heart (Tables 4.3.5 and 4.3.6), and perhaps an oft-nuisance native plant- swollen bladderwort- are among the few plants that increased in relative abundance from the 1920s-30s to the 2010s, including in lakes surveyed specifically in both time periods. **This is consistent with the narrative that invasive or highly nuisance plants frequently take over plant communities. It should be noted that two of these plants- Eurasian watermilfoil and variable watermilfoil- are also among the plants that increased in frequency over this period in both the larger datasets and the lakes common to both surveys. This observation may have implications for the next exotic plants to come into the Adirondacks, reflecting a concern that new invaders can spread rapidly between and within lakes once crossing the threshold to previously uninhabited areas.**

Eurasian watermilfoil is a statewide invasive plant, while variable watermilfoil and yellow floating heart appear to be common regional invasive plants within the Adirondacks. It is likely that once other regional invasive plants such as fanwort, brittle naiad, and perhaps hydrilla become established within Adirondack lakes, they might also become "more abundant than common". Curly leafed pondweed is also likely to highly invasive in many Adirondack lakes, but this spring-blooming plant might be missed by many of these surveys.

Several protected or vulnerable plants found in many of the Adirondack lakes surveyed in both the NYS BioSurvey and AWI programs decreased significantly from the 1920s-30s to the 2010s, including water lobelia (from 52% of lakes in the NYS BioSurvey to 14% of AWI lakes) and water marigold (21% of NYS BioSurvey lakes to 0% of AWI lakes). Other protected or vulnerable species found at smaller quantities in the NYS BioSurvey lakes were not found in any of the AWI lakes. This indicates both a general change in the frequency of many plant species over this period and a specific vulnerability of specific protected plants.

Section 5- Overall Discussion and Summary of Results

This White Paper evaluates the frequency and abundance of each aquatic plant in four distinct and spatially separated major New York state aquatic plant surveys. These surveys share enough common lakes, common sampling and reporting methodologies, and are representative (enough) cross sections of New York state lakes to provide some insights about regional patterns and long-term changes in aquatic plant communities. These four major monitoring programs are described at length in White Paper 1A, and are summarized in Section 1 of this White Paper.

In general, plant communities in the lakes surveyed in the four programs described above were evaluated by frequency and abundance. Both measures were evaluated in multiple ways:

- Frequency was evaluated by a count of the number of lakes in which each plant was observed, and separately by a count of the number of lakes in which a plant is among five most frequently reported plants (based on the number of sites within the lake reporting each plant). The former represents the "traditional" count of plant frequency, and was used for lakes in the NYS BioSurvey, PIRTRAM, and AWI, while the latter is limited to those programs for which individual (granular survey) site data are available (PIRTRAM and some AWI lakes). Genera frequency was evaluated, using the first method cited above, in the ALSC lakes.
- Abundance was evaluated using a $\log_5$ relative abundance scale, as described in White Paper 1C, and limited to those lakes for which relative abundance measures are available for each lake. Relative abundance values for the NYS BioSurvey lakes were assigned to each plant in each lake, since all abundance data was compressed to a single value per plant per lake regardless of lake size. Values were assigned for each plant at each site at each lake for the PIRTRAM lakes, since granular site data were available, and values were weighted by the size of the weed beds and an areal estimate for each rake toss site in the AWI lakes. These abundance values were evaluated in two ways- a ranking of the most abundant species in all NYS BioSurvey lakes, and a ranking of the plants most frequently among the five most abundant species in each PIRTRAM and AWI lakes. These ranked lists were compared to standardize abundance method data across these three programs- NYS BioSurvey, PIRTRAM, and AWI. Since relative abundance was not reported for individual plants in the ALSC dataset, abundance could not be evaluated in these lakes.

There were significant challenges in evaluating results from these four programs, since the plant survey data were collected and/or reported in different ways in each program. These challenges included inconsistent plant identifications (species level for some plants in some programs, genera level for other plants), the lack of "granular" site data- presence and relative abundance evaluations for each plant at each site within each surveyed lake- in some programs, and the mix of plant bed and individual site data in other programs. However, given the strong geographic overlap within these programs, frequency and abundance data were evaluated in different ways to facilitate a comparison of results between lakes within each program, long-term changes in plant communities as characterized by these programs, and changes in both aquatic invasive species (AIS) and protected (rare, threatened or endangered) species.

The key findings from these four monitoring programs are summarized below, with results summarized by most common and most abundant plants in each program, plants for which frequency and abundance are out of balance, long-term changes in plants since the 1920s-30s plant surveys, with a particular focus on changes in invasive and protected species over this period.

- In the 1920s-30s NYS BioSurvey, emergent and floating leaf plants were more common and abundant than submergent plants both inside and outside the Adirondacks. The most common submergent plants in the Adirondacks appeared to include water quality sensitive plants, while the plants most commonly reported outside the Adirondacks include water quality insensitive plants- those native plants that grow to nuisance levels in some lakes. Outside the Adirondacks, most of the frequently occurring plants from the 1920s-30s were also among the most abundant plants, but inside the Adirondack Park, there was less of an overlap between these lists. The most abundant plants outside the Park were generally submergent plants, while the most abundant plants inside the Park were generally emergent. This might be due to more extensive shoreline development outside the Adirondack Park at that time (selecting for submergent plants).

  Small pondweed (*Potamogeton pusillus*) was only plant inside and outside the Adirondacks that was more frequent than abundant (found in smaller quantities in many lakes); this list includes some nuisance native plants that now are associated with nuisance growth in weed beds, indicating a more stable 1920s-30s environment that has since become exploited by these plants. Those plants that were more abundant than frequent (found in higher quantities in fewer lakes) include both nuisance and exotic plants, including water chestnut (*Trapa natans*), brittle naiad (*Najas minor*), and curly-leafed pondweed (*Potamogeton crispus*). It is likely that many of the latter invasive plants had not yet spread rapidly throughout the state; Eurasian watermilfoil (*Myriophyllum spicatum*), fanwort (*Cabomba caroliniana*) and hydrilla (*Hydrilla verticillate*) had not yet been found or reported in the state.

- The 1980s ALSC surveys found mostly emergent and floating leaf plants both inside the Adirondack Park and downstate, and some overlap in the plants between these regions. Among emergent and floating leaf plants, yellow water lily (*Nuphar* sp), water sedge (*Carex* sp), and bur reed (*Sparganium* sp) were the most common plants in both regions, while pondweeds (*Potamogeton* sp) and naiads (*Najas* sp) were common submergent plants in both the Adirondack and downstate ALSC lakes. Bladderwort (*Utricularia* sp) was far more common in the lakes within the Adirondack Park, while cattails (*Typha* sp) and milfoils (*Myriophyllum* sp) were far more common downstate. It is presumed that the latter included Eurasian watermilfoil (*Myriophyllum spicatum*), although this cannot be verified since the ALSC program only identified plants to genera level. In addition, the most abundant genera could not be identified, since the ALSC surveys did not report relative abundance in any of the surveyed lakes. This also precludes an evaluation of which plants were out of balance- far more common than abundant (found in many lakes

but few sites within these lakes) or far more abundant than common (found in fewer lakes but many sites within these lakes).

Far more genera decreased than increased from 1920s-30s, whether considering the more acidic lakes in the larger ALSC dataset or the smaller subset of (non-acidic) lakes common to both the NYS BioSurvey and ALSC. This may reflect both impacts of acidification and non-acidification factors relating to eutrophication, AIS introduction and increasing lake and shoreline use. Some genera, particularly submergent plants such as water lobelia (*Lobelia* sp), naiads (*Najas* sp), and milfoils (*Myriophyllum* sp), appeared to be particularly vulnerable to these changes. The most significant increases were in sphagnum moss (*Sphagnum* sp), iris flag (*Iris* sp), water shield (*Brasenia* sp) and water sedge (*Carex* sp), all emergent or floating leaf plants. Only one submergent plant- waterweed (*Elodea* sp)- was among the 10 plants that increased the most from the NYS BioSurvey to the ALSC. This suggests that lake acidification and increased lake and shoreline use (along with other changes in the intervening 50-60 years) exhibited a far greater effect on submergent plants than emergent plants.

- The most frequently reported and most abundant plants in the 2000s-2010s (with a few earlier years) PIRTRAM lakes were submergent and floating leaf plant species or genera, and specifically either invasive (Eurasian watermilfoil- *Myriophyllum spicatum*, and probably curly-leafed pondweed- *Potamogeton crispus*) or nuisance native plants (coontail- *Ceratophyllum demersum* and common waterweed- *Elodea canadensis*). This probably reflects the focus of the surveys- to evaluate active management or the need for management, which usually involves invasive species impacting lake uses (or in some case nuisance native plants). These findings also indicate that, by the time of the PIRTRAM surveys, several invasive species were widespread throughout New York state and had taken over plant communities in many lakes.

  In fact, with the exception of water moss (*Sphagnum* sp.), all of the plants that were more abundant than common in the PIRTRAM surveys were exotic invasive plants. Many of these were "regionally" exotic plants, including fanwort (*Cabomba caroliniana*), water chestnut (*Trapa natans*), brittle naiad (*Najas minor*), and variable watermilfoil (*Myriophyllum heterophyllum*). These plants grow invasively in only some parts of the state, most likely due to competitive advantages associated with these habitats. This also suggests that within these habitats, these plants have exhibited a "mature" or stable expansion. It is expected that new regional invaders might first be more common than abundant, but will eventually expand significantly within lakes; this includes hydrilla (*Hydrilla verticillata*) and starry stonewort (*Nitellopsis obtusa*). The only plants that were more common than abundant were leafy pondweed (*Potamogeton foliosus*), eelgrass (*Vallisneria americana*) and water stargrass (*Zosterella dubia*)- in general, these plants are not associated with nuisance weed growth, and these data do not indicate that any of these plants are particularly vulnerable to extirpation with long-term changes in these lakes.

Invasive and to a lesser extent (commonly understood to be) nuisance native plants increased in both frequency and abundance in PIRTRAM lakes more than did other native plants since the 1920s-30s surveys. This particularly includes Eurasian watermilfoil (*Myriophyllum spicatum*), brittle naiad (*Najas minor*), fanwort (*Cabomba caroliniana*), and variable watermilfoil (*Myriophyllum heterophyllum*). This list will no doubt expand to include hydrilla (*Hydrilla verticillata*), water chestnut (*Trapa natans*), and starry stonewort (*Nitellopsis obtusa*) as these plants continue to expand rapidly throughout the state. Outside the Adirondacks, there was a significant decrease in observed emergent plants, but this is most likely due to differences in sampling methodology between NYS BioSurvey and PIRTRAM (with the former including plants from all habitats, and the latter focusing primarily on submergent and floating-leaf plants). Some water quality-sensitive plants and native species within genera that included invasive species (such as native milfoils, naiads, and pondweeds) also appeared to decrease in frequency and abundance over this period. Some of these species may be particularly susceptible to long-term changes.

- The 2010s AWI plant survey lakes results showed that native floating leaf and emergent plants were the most common plants reported, with yellow water lily (*Nuphar* sp), bur reed (*Sparganium* sp), white water lily (*Nymphaea* sp), ribbonleaf pondweed (*Potamogeton epihydrus*) and watershield (*Brasenia schreberi*) found in more than 75% of all surveyed lakes, and the first three among the most frequently reported plants in more than half of the lakes when the results are weighted by the size of the weed beds in each lakes. There was a strong overlap between the most frequently reported plants and the most abundant plants. Among the plants for which frequency exceeded abundance (found in many lakes, but in fewer sites within these lakes) included quillwort (*Isoetes* sp) and variable pondweed (*Potamogeton gramineus*). Other water quality sensitive plants were also more frequent than abundant, indicating a vulnerability to continuing changes in lake habitat, as discussed below. Two invasive milfoils- Eurasian watermilfoil (*Myriophyllum spicatum*) and variable watermilfoil (*Myriophyllum heterophyllum*)- were more abundant than common, indicating a high density within lakes, including potentially large weed beds, but relatively fewer infested lakes. These plants are among the first submergent exotic plants to invade the Adirondacks beyond the perimetry, and it is expected that additional invaders reaching and colonizing the interior Adirondacks may also become more abundant than frequent in these lakes. However, it is also expected that these invasive milfoils will eventually increase in both frequency and abundance, similar to the longer-term change in several invasive plants outside of the Adirondacks, and despite significant efforts to keep these plants out of these vulnerable lakes.

  Most plants in the AWI lakes decreased in frequency and abundance from the 1920s-30s to the 2010s. This may be indicative of differing survey methodology, particularly for several emergent plant species likely undercounted in most recent (PIRTRAM and AWI) surveys. However, as noted with the ALSC dataset, this decrease in frequency and abundance of many aquatic plant genera from the 1920s-30s to 1980s (ALSC) and 2010s (AWI) also appears to be in response to changes in lake acidification and lake and

shoreline development and usage over this period (as well as the slow increase in AIS introductions in the Adirondack lakes over this period). There were also a few plants that increased in both frequency and abundance over this period; this small list includes both several invasive plants (Eurasian watermilfoil, variable water milfoil, and yellow floating heart (*Nymphoides peltata*)) and swollen bladderwort (*Utricularia inflata*), a native plant that often grow to nuisance levels. Bur reed (*Sparganium* sp*)* increased in frequency, but not abundance- it is not known if this is an artifact of the survey programs or if it represents a real change in lake habitats for this emergent plant.

As discussed at length above, aquatic invasive species represented an increasing part of the aquatic plant community between the 1920s-30s NYS BioSurveys and the more contemporary PIRTRAM and AIS surveys. It is not known if a formal cumulative summary of aquatic invasive species was tabulated prior to at least the late 20th century, but the number of infected waterbodies and the impact of these invasives on aquatic ecology and waterbody recreational uses have been well documented since then, culminating in a database maintained by the iMapInvasives program (https://www.nyimapinvasives.org/).

Only a few aquatic invasive species were identified in the 303 lakes surveyed in the NYS BioSurveys from the 1920s and 1930s, led by curly leafed pondweed (*Potamogeton crispus*). This plant, first identified in NYS in the 1880s, was found in 41 lakes, representing only 13% of the surveyed lakes, and ranking as only the 51st most frequently observed and 53rd most abundant plant. Although water chestnut (*Trapa natans*) was first documented in New York state in the early 1880s (in Collins Lake in the Capital District), it was reported in only two NYS BioSurvey lakes about 40-50 years later, despite a slow expansion through the Mohawk and Hudson River system over this period. Likewise, brittle naiad (*Najas minor*) and fanwort (*Cabomba caroliniana*) had been first documented around the time of the NYS BioSurveys in the Hudson River and Long Island, respectively, but had only been found in a few surveyed lakes. Variable watermilfoil (*Myriophyllum heterophyllum*) was perhaps the 2nd most common AIS at the time of the NYS BioSurveys, having been found in 13 lakes, but until recently, there remained some questions about whether this plant was in fact native to the state.

By the time of the PIRTRAM and AWI surveys in the last twenty years, invasive species spread, colonization, and establishment in lakes had exploded throughout the state. As seen in Table 5.1 and discussed at length in Sections 3 and 4 above, several aquatic invasive plants were among the most common and abundant plants in New York state. Eurasian watermilfoil (*Myriophyllum spicatum*), which had not been found in New York state at the time of the NYS BioSurveys, was reported in nearly 60 of the 200 or so PIRTRAM and AWI lakes, with most of these found outside of the Adirondack Park. In fact, Eurasian watermilfoil was among the most common and abundant plant in most of the lakes outside of the Adirondack Park by the 2000s-2010s, as seen in Table 3.2.1 and Table 3.2.3. Table 5.1 also shows that it is by far the most common AIS plant species in the state, having been documented in nearly 450 lakes, ponds and reservoirs by 2020. **It is likely that the introduction and spread of Eurasian watermilfoil played a significant role in the decrease in many submergent aquatic plant species from the 1920s-30s surveys**

to the present day, as discussed at length in Section 3 (and as discussed below regarding changes in protected plant species).

The most common AIS in the 1920s-30s, curly leafed pondweed, is now the 2nd most common AIS in New York state lakes. It was also very common in the PIRTRAM lakes, but less common in the AWI lakes. The apparent undercount of this plant in Table 5.1 (relative to a high frequency overall in the state) reflects the timing of the aquatic plant surveys in these studies (late summer) relative to peak growth of this submergent plant (late spring to early summer). It also indicates that most regions of the Adirondacks have thus far been spared this plant. Likewise, variable watermilfoil has probably been overcounted in the "PIRTRAM/AIS" surveys due to a high frequency and abundance of this plant in the Adirondacks (where it likely thrives in the relatively softwater and depressed pH levels in many of these lakes) relative to its much less frequent occurrence outside of the Adirondacks and high elevation downstate lakes. Water chestnut (and to a lesser extent European frogbit (*Hudrocharis morsus-ranae*)) are probably undercounted in the PIRTRAM and AWI lakes, since it is much more commonly found in small ponds and flowing waters outside of the Adirondacks, neither of which are well represented among the lakes surveyed in PIRTRAM or AWI. Most of the other plants in Table 5.1 are either found in far fewer waterbodies or are adequately represented in these surveyed lakes. Two possible exceptions are hydrilla (*Hydrilla verticillata*) and starry stonewort (*Nitellopsis obtusa*), two submergent invasive plants first documented in New York state waterways in the late 2000s and the late 1970s, respectively, but only recently starting to expand beyond a few locations. It is likely that these plants will be among the most abundant and then the most frequently reported plants in New York state lakes absent targeted interventions when the plants are first documented.

Table 5.1- # Aquatic Invasive Species in Monitoring Programs from 1920s to 2010s

Invasive plant	#BioSurvey lakes	#PIRTRAM / AWI lakes	#All NYS Lakes
	1920s-30s	2000s-10s	2020
Myriophyllum spicatum	0	57	445
Potamogeton cripsus	41	30	279
Trapa natans	2	10	202
Myriophyllum heterophyllum	13	45	89
Najas minor	3	15	81
Hydrocharis morsus-ranae	0	1	66
Cabomba caroliniana	2	6	54
Hydrilla verticillata	0	4	27
Nitellopsis obtusa	0	5	22
Egeria densa	0	2	21
Nympoides peltata	0	8	14
Ludwigia peploides	0	0	4
Pistia stratioles	0	1	3

On the other end of the same scale, protected plants by their nature are not common to New York state lakes. The two most common protected aquatic plants in the NYS BioSurvey were water marigold (*Megalodonta beckii*- considered on the Rare Plant Watch List in 2010, though not listed on the 2020 Rare Plant List) and water lobelia (*Lobelia dortmanna*), found in 22% and 42%, respectively, of the NYS BioSurvey lakes in the 1920s-30s that were also sampled through

the PIRTRAM or AWI programs. These plants were only found in 7% and 10%, respectively of the same lakes during the 2000s-20s PIRTRAM and AWI surveys. This significant loss in protected plants suggest that lake changes (acidification, increased lake use and shoreline development, eutrophication, climate change, etc.) and AIS introduction may have contributed to the loss of sensitive plants. This was also seen in the decrease in some of the milfoil, naiad, and pondweeds over the same period. There was also an apparent loss in some rarer plants that were not seen in any of the recent surveys. This might reflect an under-representation of specific uncommon plants in the lakes included in PIRTRAM and AWI, as well as an increased vulnerability of some plants to the long-term changes in lakes cited above. However, it should be noted that the apparent disappearances of some protected plants (*Ceratophyllum echinatum, Azola caroliniana, Callitriche hermaphroditica*) found in very few if any recently surveyed lakes may not be taken of evidence of a significant change, since these plants were found in very few if any NYS BioSurvey lakes. The likelihood of finding such rare plants in multiple surveys is very slight. More extensive surveys, particularly in lakes with historical records of these protected plants, may be needed to properly evaluate whether protected plants have become even more endangered.

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