White Paper 1F-
Evaluation of Coefficients of Conservatism in NYS Lakes

Section 1: Background

White Paper 1D- Species Richness- summarizes how the lakes in the aquatic plant survey programs cited in White Paper 1A can be used to evaluate species richness. These analyses can be used to evaluate floristic quality indices (FQI) or assessments (FQA), which are used to assess an area's ecological integrity based on its plant species composition (Wilhelm and Masters, 1995), based on the relative frequency of plants typical of undisturbed (pristine) environments. FQI is discussed at length in White Paper 1G.

The two components of an FQI are a count of the number of unique species (i.e. species richness, or quantity) and the ecological integrity (quality) of the individual species that comprise the aquatic plant community. Specifically, as discussed in White Paper 1C, White Paper 1D, and White Paper 1G, FQI can be estimated by either Equation 1.1 or Equation 1.2:

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

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

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

Species richness (observed and projected) is discussed at length in White Paper 1D. The second part of Equation 1.1 is the coefficient of conservatism (or C value) assigned to each unique species. To best characterize the "quality" of the aquatic plants in a survey, the C value ranges from the highest values associated with the "best" plants, and the lowest values (or a 0 value) associated with the "worst" plants.

The most common definitions for these C values are as follows (McAvoy, 2020):

C = 8, 9, or 10. Plants with a narrow range of ecological tolerance, typical of a stable or advanced successional phase of a plant community, exhibiting a relatively high degree of reliability to a specific habitat type or native plant community, and with little tolerance to disturbance. Note that in some states, rare, threatened or endangered species are conferred this rank.

C = 4, 5, 6 or 7. Plants with an intermediate range of ecological tolerances, usually typical of one or more specific native plant communities, and can tolerate moderate disturbance.

C = 1, 2 or 3. Plants with a wide range of ecological tolerance found in a variety of plant communities, often early colonizers of disturbed sites, and opportunistic invaders of natural areas.

C = 0. All non-native plants

FQI calculations use simple equations to generate an aquatic plant community value that can serve several purposes. These equations, however, can be modified to address some of the shortcomings associated with the assigned C values, particularly related to weighting of individual species and challenges in assigning the proper value to plants identified in these surveys. These modifications will be discussed at length in the rest of this White Paper.

Section 2- Traditional C values in New York state lakes

Section 2.1- Background-

As noted above, the two major components of an FQI value involves the quantity (species richness) and quality (ecological value of each species) of the aquatic plant community. Species richness is evaluated at length in White Paper 1D. This evaluation suggests that the most accurate measure of species richness is *projected* species richness, calculated from the maximum number of aquatic plant species in a lake, based on the distributions of aquatic plants in each surveyed site, projected to a standardized value expected at a survey site density of 1 sites per littoral hectare.

The quality of the aquatic plants in a lake are defined by the C value. These C values are unique to each state, based on the ecological characteristics associated with plant species within the environment of the state. For many years, the development of FQIs for New York state lakes was limited by the lack of C values assigned to plants within New York state, even though botanists in many other similar (New England and midwestern) states had assigned C values for taxa in those states. A cursory look at the range of C values found little compatibility between states. For example, coontail (*Ceratophyllum demersum*), a common native aquatic plant, is assigned C values ranging from 2 (Ohio) to 6 (West Virginia). Similarly, horned pondweed (*Zanichellia palustris*) ranges from 4 to 10, and some plants like variable watermilfoil (*Myriophyllum heterophyllum*) are identified as non-native in some states (New York) but highly prized (C value of 9 or 10) in several other states.

Fortunately, New York state developed C values for more than 2000 plant species- aquatic and terrestrial- in 2012, using values assigned by two botanists commissioned by the New York Natural Heritage Program (Bried et al, 2012). Appendix 2.1 provides C values for the most common aquatic and semi-aquatic plants found in New York state lakes (referred to here as C_{ny} values); the listed values represent the average of the two botanists "scores" for each plant. These values can be combined with the number of unique aquatic plant species found in a survey to generate an FQI, using the formulae outlined in White Paper 1C and in Section 1 (but repeated again here)

Equation 2.1: $FQI = \bar{C} \times \sqrt{N}$, *and* $\bar{C} = \Sigma C / N$; where

N = number of unique plant species in a lake (=observed species richness, or oSR), and
C = coefficient of conservatism for each unique species

The development of aquatic plant community metrics as a means for evaluating aquatic life support is discussed at length in Section 10 of this White Paper.

Section 2.2- Monitoring Programs Used to Evaluate Traditional C_{ny} Values

Traditional FQI, calculated using equation 2.1 above, requires a count of species richness and sufficiently detailed identification of aquatic plants in a lake to assign C values for each identified plant (species or genus). This equation requires the computation of mean C values representing the arithmetic average of all C values for all aquatic plant species found in the aquatic plant survey.

Of the four major monitoring programs discussed in White Paper 1A, the NYS BioSurvey of more than 300 lakes in the 1920s-30s, the PIRTRAM surveys of about 50 lakes in the 1990s-2010s, and the AWI surveys of about 85 lakes in the 2010s identified plants to species level, allowing for a computation of traditional C_{ny} values. As noted in White Paper 1D, the NYS BioSurvey appeared to focus equally on emergent, floating leaf, and submergent plant species, allowing for a direct computation of all C_{ny} values (and by extension FQI) for the entire lake and shoreline aquatic plant community. The PIRTRAM and AWI surveys focused primarily on species level identification of submergent macrophytes (with some submergent plants identified only to genera), and genus level identification for most floating leaf plants, emergent plants, and submergent macroalga. These genus-level (only) identification of some aquatic plant taxa represents a challenge for mean C and FQI calculations, since each unique species within most genera are assigned unique C_{ny} values, requiring a single C_{ny} value to be assigned to these genera "labels" that could differ significantly from the actual plant species residing in the lake.

These discrepancies from program to program (and over time) limits cross-program and timeline comparison of lakes unless the NYS BioSurvey plant identifications are "corrected" for the species identification filters described above for the PIRTRAM and AWI lakes. In addition, a modified C value system can correct for some of these issues, as discussed below. These corrections and modifications can increase the opportunities for comparisons over time and between programs, although intra-program evaluations remain the focus for these evaluations.

The ALSC data only identified plants to genera level, precluding the use of floristic quality indices to evaluate aquatic plant communities. While it is possible to develop C values at genera level for many of these plants, the wide range and species-specific differences in C values within many plant genera using the New York C_{ny} value system (Appendix 2.1) greatly limits the use of genera-specific C values (although as discussed in Sections 4 and 5, genera-specific C values may be more applicable in a modified C value system). Therefore, these analyses do not include the large (1550+ lake) ALSC dataset.

Section 2.3- Traditional C (C_{ny}) values in NYS lakes

Section 2.3.1- Summary of NYS BioSurvey, PIRTRAM and AWI Lakes data

Table 2.3.1.1 shows the statistical spread of traditional coefficient of conservatism (C_{ny}) values for the NYS BioSurvey lakes, PIRTRAM and AWI lakes using the New York C value system and Appendix 2.1. These statistics include only those lakes for which at least 5 plants were identified in each lake, indicating a higher likelihood of a complete survey.

Table 2.3.1.1- C Values for the NYS BioSurvey, PIRTRAM and AWI Program Lakes

C value measure	10th%	25th%	Median	75th%	90th%
NYSBioSur_Cny_all	4.3	4.7	5.0	5.5	6.0
NYSBioSur_Cny_sfe	4.4	4.7	4.9	5.4	6.0
PIRTRAM_Cny	2.2	3.3	3.8	4.4	4.9
AWI_Cny	4.7	5.0	5.2	5.5	5.8

Legend-
NYSBioSur_all = NYS BioSurvey Lakes with all identified species in all habitats (limited to lakes with oSR > 5; N = 237)
NYSBioSur_Sfe = NYS BioSurvey lakes with submergent plants to species, floating and emergent plants to genera (identifications for all plants consistent w/PIRTRAM and AWI survey methodology)

PIRTRAM = PIRTRAM surveyed lakes (N = 48 lakes using average C value per lake)
AWI = AWI surveyed lakes (N = 85 lakes using average C value per lake)

Cny = C values using NY-derived Coefficients of Conservatism (Appendix 2.1)

As discussed at length in White Papers 1A through 1E, aquatic plants surveyed through the NYS BioSurvey lakes in all habitats- submergent, floating leaf and emergent areas- were identified to species level, while for the PIRTRAM and AWI programs, only submergent macrophytes were generally identified to species level (floating leaf and emergent plants were generally identified to genera, even if these plants were "assigned" a species identification). Table 2.3.1.1 also includes average C values for the 237 NYS BioSurvey lakes with at least five plants for which, in general, submergent macrophytes were identified to species level (with some exceptions), and other plants were identified to genera. This allows for a direct comparison to the more recent PIRTRAM and AWI lakes, which followed the plant identification patterns described above. In this table and in all subsequent tables, these are referred to as the *Adjusted C_{ny} values* (C_{nysfe} and C_{msfe}).

Table 2.3.1.2- FQI and C Values in Non Adirondack NYS BioSurvey and PiRTRAM Lakes, Using the NY C Value System

FQI Measure	10th%	25th%	Median	75th%	90th%
NYSBioSur_Cny_sfe_ Non Adks	4.3	4.6	4.7	4.9	5.1
PIRTRAM_Cny	2.2	3.3	3.8	4.4	4.9

Legend-
NYSBioSur_all = NYS BioSurvey Lakes with all identified species in all habitats w/ oSR >5; N = 154)
NYSBioSur_Sfe = NYS BioSurvey lakes with submergent plants to species, floating and emergent plants to genera (identifications for all plants consistent w/PIRTRAM and AWI survey methodology)

PIRTRAM = PIRTRAM surveyed lakes (N = 48 lakes using average C value per lake)
Cny = C values using NY-derived Coefficients of Conservatism (Appendix 2.1)

These data show that the traditional (New York C value-based) mean C values for the lakes surveyed in the 1920s-30s NYS Biological Survey were consistently higher than the lakes surveyed in the 1990s-2010s PIRTRAM surveys, but were comparable to those in the 2010s AWI surveys. However, this difference in C values between the NYS BioSurvey and either PIRTRAM or AWI lakes was relatively small; as will be seen in White Paper 1G, much of the difference in the FQI values between the older and newer datasets reflects much higher oSR values in the NYS BioSurvey lakes. This was discussed at length in the White Paper 1D summary of species richness..

The difference in mean C values between these datasets suggests a decrease in floristic quality over time, since mean C values are an important component of the FQI equations (as seen in equation 1.1). However, this may also reflect a few other factors:

1. Differences in plant identification among the programs. As discussed above in White Papers 1A and 1D, the NYS BioSurvey included species level identifications for all plant habitats- submergent, floating leaf, and emergent plants- while the PIRTRAM and AWI surveys generally conducted genus level identifications for all but submergent macrophytes. This led to the development of *Adjusted C Values* for the NYS BioSurvey lakes to facilitate comparisons across programs- these are found in Tables 2.3.1.1 through 2.3.1.3 as *sfe* values). However, as seen in Table 2.3.1.1, even when using adjusted C values, the earlier surveys still had higher FQI values.

2. Geographic differences. The NYS BioSurvey lakes were distributed throughout the state, while the AWI and PIRTRAM lakes were mostly confined to the Adirondack and non-Adirondack regions, respectively. These geographic differences are apparent when the NYS BioSurvey data are divided into geographic regions (and *adjusted* C values are used to account for surveying differences), as seen in Table 2.3.1.3.

Table 2.3.1.3- C Values in Adirondack NYS BioSurvey and AWI Lakes, Using the NY C Value System

FQI Measure	10th%	25th%	Median	75th%	90th%
NYSBioSur_Cny_sfe_Adks	4.8	5.0	5.3	5.6	5.7
AWI_Cny	4.7	5.0	5.2	5.5	5.8

Legend-
NYSBioSur = NYS BioSurvey Lakes w/oSR >5 inside the Adirondacks (N=83 lakes)
Sfe = submergent plants to species, floating and emergent plants to genera (consistent w/PIRTRAM and AWI survey methodology)
AWI = AWI surveyed lakes (N = 85 lakes using average C value per lake)
Cny = C values using NY-derived Coefficients of Conservatism (Appendix 2.1)

3. Invasive species. The vast majority of the NYS BioSurvey lakes do not possess any invasive species, and the AWI lakes generally have fewer invasive plant species than other lakes in the state- both of these findings are discussed at length in White Paper 1E. However, many of the PIRTRAM lakes possess invasive species- and in fact, the frequency and abundance of these invasive species may be a major reason for conducting the plant surveys on these lakes. This seems to be apparent from Tables 2.3.1.1 to 2.3.1.3, which shows much lower average C values in the PIRTRAM lakes than in the AWI lakes, which show (only) slightly lower C values than the NYS BioSurvey lakes. These

differences may reflect the different lakes comprising each dataset- but the impact of invasive species on mean C_{ny} values is discussed at length in Section 2.4, Section 4 and other parts of this White Paper.

4. Different lakes. Although the NYS BioSurvey was well distributed throughout New York state, and the AWI and PIRTRAM surveys included a representative geographic and size cross section of actively used lakes through the Adirondack and non-Adirondack regions, respectively, these three distinct programs involved different lakes. A comparison of floristic quality over time benefits greatly from focusing these comparisons on lakes commonly surveyed in each of these programs, recognizing that this decreases the datasets used for the evaluation (and therefore the potential statistical power of these analyses).

An evaluation of changes in traditional mean C_{ny} values from the 1920s-30s (NYS BioSurvey) to the present (PIRTRAM and AWI) is conducted in Section 2.3.3 below.

Section 2.3.2- Impact of Lake or Littoral Size on Traditional C_{ny} values FQI Values

Section 2.3.2.1- Evaluation of Lake or Littoral Size on Floristic Quality

As discussed in White Paper 1D, species richness is strongly influenced by the size of the lake, or more specifically, the size of the littoral zone. Since species richness is a significant component of the floristic quality calculation, it is expected that the FQI will also be strongly influenced by lake or littoral zone size. However, species richness is a *"counting" statistic*- observed species richness (oSR) values generally increase as the number of survey sites, lake size and littoral area increase- with oSR values reaching some asymptotic peak after surveying many sites.

In contrast, coefficients of conservatism is a *"rate" statistic*, with mean C values varying in response to several factors. For example, a lake with many occurrences of plants with very high C values (highly sensitive plants) and few occurrences of poor quality plants will see a decrease in mean C values as the number of survey sites increase, since adding more sites increases the likelihood of finding some low quality plants. Likewise, lakes with many occurrences of highly insensitive (low C value) plants but few occurrences of high quality plants will see an increase in mean C values as the number of survey sites increase. While in both cases mean C values will reach some asymptotic value at a high survey site density, due to a very limited number of "new" plants found after adding additional sampling sites, these asymptotes are reached differently in these two lake examples.

The work summarized in White Paper 1D indicates that plant community metrics (species richness) should be more closely tied to littoral area than to lake area, since the former more strongly connects to "opportunities" for plant community establishment. This relationship can also be evaluated for coefficients of conservatism. Unfortunately, littoral area is not known for many of the NYS BioSurvey lakes. This is due primarily to the lack of bathymetric data for these lakes (without even considering any changes in bathymetry that have occurred in the nearly 100 years since these surveys were conducted). Littoral area can be estimated for most of the

PIRTRAM and AWI lakes. Therefore this section evaluates the relationship between lake area and mean C values in the NYS BioSurvey lakes, and the relationship between littoral area and coefficients of conservatism in the PIRTRAM and AWI lakes.

Table 2.3.2.1 shows that mean C values, adjusted for plant identification "inconsistencies" with the PIRTRAM and AWI programs (as discussed above) increase only slightly as lake area increases in the NYS BioSurvey lakes, and it is likely that the typical C values in these lakes, using the C_{ny} value scale, do not exhibit any statistical difference as lake area changes. These "findings" are consistent with the relationship between littoral area and mean C values seen in the PIRTRAM (Table 2.3.2.2) and AWI (Table 2.3.2.3) lakes dataset. These PIRTRAM and AWI data also indicate relative stability in C values across the range of littoral areas (mean C values are slightly higher in the largest PIRTRAM and smallest AWI lakes, but no clear relationship exists between mean C values and littoral area). This suggest that any changes in FQI (White Paper 1G) related to lake and littoral area are due to changes in species richness (oSR or pSR) rather than an "increase" in more ecologically favorable plants as lake or littoral areas increase.

Table 2.3.2.1- Adjusted C Values in NYS BioSurvey Lakes by Lake Size

Lake Area	#Lakes	Cny_sfe
0-10ac	39	4.9
10-25ac	32	5.0
25-50ac	28	4.8
50-100ac	29	4.7
100-200ac	44	4.9
200-400ac	45	5.0
400-600ac	33	5.0
600-2000ac	30	5.0
>2000ac	23	5.1

Legend
Cny_sfe - corrected C values using NY-derived Coefficients of Conservatism (Appendix 2.1)
Sfe = submergent plants to species, floating and emergent plants to genera (consistent w/PIRTRAM and AWI survey methodology)

Table 2.3.2.2- C Values in PIRTRAM Lakes by Littoral Area

Littoral Area	#Lakes	Cny
0-50ac	18	3.7
50-100ac	12	3.9
100-200ac	9	3.4
200-500ac	5	3.5
>500ac	4	5.3

Legend
Cny - Mean NY-derived C values (Appendix 2.1)

Section 2.3.2.2- Discussion of Results

The data summarized in Tables 2.3.2.1 through 2.3.2.3 demonstrate that although the PIRTRAM lakes exhibit lower mean C values than the NYS BioSurvey and AWI lakes (for reasons cited in Section 2.2), with few exceptions, there is no clear relationship between littoral or lake area (and presumably survey site densities) and coefficients of conservatism (as defined by mean C_{ny} values) in lakes in any of these programs. It is possible that these findings mask an actual spatial influence on mean C_{ny} values, for example, a higher likelihood of low quality plants (with lower C_{ny} values) in larger lakes masking what would otherwise be an overall increase in mean C values. However, this is not apparent from the data used to generate Tables 2.3.2.1 through 2.3.2.3, although it *could* be more apparent if C values were computed using a system that

Table 2.3.2.3- C Values in AWI Lakes by Littoral Area

Littoral Area	#Lakes	Cny
0-50ac	13	5.7
50-100ac	6	5.4
100-150ac	16	5.1
150-200ac	9	5.2
200-300ac	8	5.4
300-500ac	5	5.2
>500ac	12	5.2

Legend
Cny - Mean NY-derived C values (Appendix 2.1)

assigns a greater penalty for invasive species. For example, for a lake with 25 plant species and an average C value of 5, adding an invasive plant would only decrease the average C value to 4.8, too small to show up as significantly different in the Tables above. However, for a lake with 9 plant species with an average C value of 5, the penalty would be slightly greater (reducing the C value to 4.5, although this difference still may not show up in these tables. As discussed further in Section 3 below, the C value (and therefore mean C value) penalty for invasive species using a different C value scale may be more significant and should be considered, since it is presumed by most aquatic ecologists that invasive species represent a *significant* ecological problem for aquatic plant communities.

These data suggest that the quality of the individual plants is not strongly influenced by the size of the lake or the littoral area, but that overall floristic quality indices increase in response to increases in species richness in these larger lakes. The latter is discussed at length in White Paper 1D and especially in White Paper 1G.

Section 2.3.3- Changes in Traditional C_{ny} Values over Time

As with evaluations of observed (oSR) and projected (pSR) species richness, the summary of C values in the three programs evaluated in Table 2.3.1 may be influenced by differences in the lakes surveyed, even though the 237 NYS BioSurvey lakes (with at least 5 plants) were distributed throughout the state and the AWI and PIRTRAM lakes were generally comprised of Adirondack and non-Adirondack lakes, respectively, that were typical of other lakes in these areas. Fortunately, focusing an evaluation of floristic quality on these lakes allows for a comparison of floristic quality over time, since these surveys span nearly a 100 year period in which overall lake changes (related to shoreline development and cultural acidification) and AIS introduction were prominent.

Table 2.3.3.1- C Values in Commonly Surveyed Non Adirondack NYS BioSurvey and PIRTRAM Lakes, Using the NY C Value System

C Value Measure	10th%	25th%	Median	75th%	90th%
NYSBioSur_Cny_sfe_ Non Adks	4.5	4.7	4.8	4.9	5.1
PIRTRAM_Cny	2.2	3.3	3.6	4.3	4.7

Legend-
NYSBioSur = NYS BioSurvey Lakes w/oSR >5 inside the Adirondacks (N=14 lakes)
Sfe = submergent plants to species, floating and emergent plants to genera (consistent w/PIRTRAM and AWI survey methodology)
PIRTRAM = PIRTRAM surveyed lakes (N = 14 lakes using average C value per lake)
Cny = C values using NY-derived Coefficients of Conservatism (Appendix 2.1)

Table 2.3.3.1 shows the range of C_{ny} values in the 14 lakes surveyed in both the NYS BioSurvey in the 1920s-30s, and in the 1990s-2010s PIRTRAM survey. It should be noted that the NYS BioSurvey lakes were only surveyed once, while some of the PIRTRAM lakes were surveyed multiple times (and the data in Table 2.3.3.1 represent the average of the C_{ny} values for each of these lakes). It should also be noted that, as with the data in Tables presented in this Section, adjusted C_{ny} values (correcting the NYS BioSurvey plant lists for consistency with the PIRTRAM and AWI plant identification methodologies) are used to facilitate comparisons across programs.

The decrease in C values from the 1920s-30s surveys to the 1990s-2010s surveys varied from about 10% to 50%, with an average of about 25%. As noted in White Paper 1D (and discussed further in White Paper 1G), observed species richness (oSR) values also decreased from the 1920s-30s NYS BioSurvey results to the more contemporary PIRTRAM results. This indicates that the decrease in floristic quality between the NYS BioSurvey and PIRTRAM lakes, from the 1920s-30s to the 1990s-2010s, appears to reflect **both a decrease in the number of plant species (the species richness) AND a decrease in the quality of plants**. As discussed below, the primary "culprit" for at least the decrease in quality of plants is likely the introduction of invasive plants. This is also consistent with the larger NYS BioSurvey and PIRTRAM datasets, suggesting that these findings appear to apply to many lakes outside the Adirondacks (not just those surveyed in these two programs).

Table 2.3.3.2- C Values in Commonly Surveyed Adirondack NYS BioSurvey and AWI Lakes, Using the NY C Value System

FQI Measure	10th%	25th%	Median	75th%	90th%
NYSBioSur_Cny_sfe_ _Adks	4.8	4.9	5.3	5.6	5.7
AWI_Cny	4.7	5.0	5.2	5.5	5.8

Legend-
NYSBioSur = NYS BioSurvey Lakes w/oSR >5 inside the Adirondacks (N=23 lakes)
Sfe = submergent plants to species, floating and emergent plants to genera (consistent w/PIRTRAM and AWI survey methodology)
AWI = AWI surveyed lakes (N = 14 lakes using average C value per lake)
Cny = C values using NY-derived Coefficients of Conservatism (Appendix 2.1)

The findings are slightly different when looking at the 23 Adirondack lakes surveyed in the NYS BioSurvey and AWI programs (with at least five plants found in each survey, to avoid including lakes with incomplete surveys), as presented in Table 2.3.3.2. These data show that the C values in these lakes, the quality of the individual plants, did not change significantly from the 1920s-30s to the present day, even though a relatively small percentage of these lakes were invaded by exotic plants (albeit those that generally did not (yet) become dominant plants in these lakes).

Section 2.4- Discussion of Traditional C_{ny} Value Findings

Section 2 of this White Paper provides a summary of the New York coefficients of conservatism (C values), for three major monitoring programs. This Section also looks at the impact of lake and littoral area on C values used to generate FQI (the relationship between lake and littoral area and species richness was discussed at length in White Paper 1E), and long-term changes in FQI over a nearly 100 year period of time.

These findings indicate that C_{ny} values were highest in the more than 250 NYS BioSurvey lakes sampled for aquatic plants in the 1920s to 1930s, even when C_{ny} values were *adjusted* for plant identification methods used in more recent surveys. These C_{ny} values were higher relative to lakes sampled more recently in PIRTRAM outside of the Adirondacks, whether considering all PIRTRAM lakes or just the smaller subset of PIRTRAM lakes also sampled in the NYS BioSurvey. This points to several factors, discussed in more detail in the species richness discussion in White Paper 1D, that influenced aquatic plant communities in the last century, including increasing shoreline development, water quality changes (including lake acidification and eutrophication across the state), increasing lake usage, and the introduction of invasive species.

C_{ny} decreased much less over this period in Adirondack lakes, whether considering all lakes within the Adirondacks surveyed in either the NYS BioSurvey and AWI programs, or just the 23 lakes surveyed in both programs. In fact, the difference in C_{ny} values over time in the Adirondacks may be negligible relative to the normal variability in C_{ny} values from lake to lake. This suggests a much smaller influence of the factors cited above in regard to PIRTRAM lakes outside of the Adirondacks- these AWI Adirondack lakes generally have lower shoreline development, less lake use (especially year round use), lower lake productivity, and lower frequency and abundance of invasive species, both on an absolute scale and relative to the 1920s-30s.

It is not known how much of this influence is dependent on the methods used here to evaluate the value of aquatic plant species (C values). Specifically, the impact of New York C value designations and the lack of corrections for plant frequency and abundance may be driving some of these findings. The use of alternative C values systems and weighted coefficients of conservatism is explored later in this White Paper.

However, these data suggest that these Adirondack lakes become more susceptible to a decrease in floristic quality, as measured by changes in the quality of the individual plants (as defined by C values) as well as the number of the quantity of these plant species (as defined by species richness). This susceptibility increases as these lakes become more heavily developed and used by lake residents and visitors, and as these lakes become more productive and as more invasive species migrate to the Adirondacks. In other words, as Adirondack lakes become more developed, more heavily used, more productive, and more accessible to invasive species colonization, they may exhibit a loss in the quality and quantity of the plant species similar to the long-term changes seen in lakes outside the Adirondacks. These threats should drive the need for continuing protection of Adirondack lakes from increased lake use, eutrophication, and invasive species introductions.

Section 3- Simplified C Value Scale

Section 3.1- Background

The strengths and limitations of FQIs are discussed in greater detail elsewhere, for example Spyreas (2019), and a detailed discussion of FQI is beyond the scope of this New York state summary. However, there appears to be some significant limitations to the use of equations 1.1 and 1.2 in generating FQIs in New York state lakes, including the following, and these will be discussed as part of this report. **Most of these relate to issues associated with C values.**

- results can be strongly affected by sampler experience and expertise (affecting number and types of plants identified, particularly for difficult-to-identify plants). For example, many aquatic plant botanists cannot identify all or even most of the nearly 1200 aquatic plant taxa potentially found in New York state lakes (and therefore cannot accurately assign a C value to plants that were identified). As an example, there are at least a dozen narrow or thin leafed pondweeds, nearly all of which cannot be accurately identified to species level in the absence of seeds (which are often not produced, retrievable, or easily distinguished at the time or given the circumstances of the survey). These pondweeds have C_{ny} values that range from 4 (*Potamogeton foliosus* and several others) to 9 (*Potamogeton strictifolius* and several others). Many monitoring programs, given insufficient distinguishing characteristics, by default assign these plants the label *Potamogeton* sp. The same issue occurs with native water starworts (*Callitriche* sp., C values ranging from 3 to 7), quillworts (*Isoetes* sp), water lilies, and several other genera.

- time of year and sampling intensity (density of survey sites) influences species richness (and to a lesser extent mean C values). This factor was discussed at length in White Paper 1D;
- plants collected in some historical datasets are not identified to species level, or present programs identify plants in some habitats (submergent macrophytes) to species level, and other habitats (floating and emergent macrophytes, and submergent macroalga) to genera, limiting the use of C values (this issue is an extension of the identification challenges for some genera discussed above)
- invasive species are assigned a 0 value, recognizing their limited ecological value but ignoring their presence in the plant community (and in some iterations, equation 2.1.1 may not be included in either part of the FQI calculation). In addition, all "exotic" plants are assigned a C value of 0, regardless of their relative invasiveness, even though not all exotic plants are equally "bad";
- the C value and FQI scale may be difficult to interpret, particularly since invasive species may not be included and since FQIs have not been calculated for many lakes for which botanists may have an intuitive sense of "value";
- most importantly, plant frequency and abundance are not included in calculations

Some of these limitations, such as sampler experience and expertise, affect all surveys, while others, such as survey timing or intensity, may be dictated by other factors unrelated to FQI calculations. Some of these limitations can presumably be tested by deeper evaluation of survey results. However, many of the other, and most important, limitations can be addressed by evaluating modifications to the assigned C values used in the FQI formulae. Some of these modifications are described below.

Specifically, many of these issues can be addressed by creating an alternative C value system that addresses plant collection and identification issues (by reducing the number of plant species or genera requiring a very high that a plant is NOT one of a few plants rather than a plant is a specific plant), issues relating to differing habitats subject to species- (versus genera-) level identifications (by assigning nearly all native benign species and genera to a single C value), issues related to relative invasiveness (by assigning different C values based on invasiveness) and challenges in interpreting data (by assigning clear and distinct delineations, rather than gradations, between good and bad plants)

Section 3.2- Introducing the concept of modified C values

The conventional C value scale runs from 1 to 10 (with invasive plants assigned a score of 0), a wide spread that allows clear distinctions between good and “bad” plants. However, it is not clear from the resulting FQI values if a plant community dominated by many poor quality plants (those with low C values but large N values) is better than a plant community with fewer (low N) but higher quality (high C value) plants. This is particularly complicated by invasive plants, which are not assigned a C value, but still usually figure into the N calculation in equation 1.1 (and thus presumably could result in a higher FQI than if that invasive plant were not present). In addition, the quality of an aquatic plant species in some lakes differs from the quality of the same species in another lake, due to interactions with nearby plants, substrate, morphometry, water quality, and other factors, including frequency and abundance. For most lakes, these differences are small, but should (or at least could) result in small changes in C values from lake to lake. It is likely that some species represent poor quality in nearly all lakes, some represent high quality in nearly all lakes, and most others represent “normal” quality in other lakes, despite some differences in C values.

The use of the New York C value system also impacts the use of the resulting FQI values in regional evaluations, since these C values differ from one state to another. For example, as discussed in Section 2.1, variable watermilfoil is considered invasive (C value = 0) in New York state but highly prized (C value = 10) in other states.

The C value system was developed by botanists to evaluate the ecological value of individual plants, but these values may not necessarily be related to factors that influence the human use and perception of the plant communities housing these plants, including relative invasiveness, surface coverage, threat to spread, and management challenges. In addition, the concept for coefficients of conservatism was largely developed to evaluate terrestrial, not aquatic, ecosystems.

Finally, accurate assignment of C values is contingent upon accurate identification of aquatic plant species. For some easy identifications such as water chestnut, this is not an issue for C value assignment and FQI calculations. For many other aquatic plants found in New York state, accurate identification is very difficult even if fully mature plants with flowering structures (seeds, turions, flowers), intact surface and subsurface leaves, root systems, and other distinct characteristics are present, collectable, and distinguishable. This uncertainty is exacerbated by high levels of “plasticity” (phenological variance) within many aquatic plant species. Since plants “ideal” for identification are often not present or observed, accurate species identification is highly dependent on the skill and experience of the surveyor or analyst and the tools used to retrieve these plants for inspection. Among the many examples of inconsistently identified plants as discussed above include the narrow-leafed pondweeds, many of which require fully mature plants with flowering structures, seeds, and intact root systems, the naiads, waterweeds (*Elodea canadensis* and *Elodea nuttallii* are indistinguishable in many lakes), native milfoils, and watermeal. As a result, many of these challenging plants, including macroalga, many floating leaf plants, and most emergent plants, are only identified to genera in some plant surveys. Unfortunately, the New York C value (C_{ny}) system does not assign C values to plant genera.

White Paper 1F-
Evaluation of Coefficients of Conservatism in NYS Lakes

One way to reduce the uncertainty and problems associated with the existing C value system is to develop a simplified scale. A simplified scale should cover the same wide range as the existing New York (0-10) C_{ny} value scale, but should include negative values representing exotic plants. This could result in clean boundaries between plant communities dominated by invasive plants (resulting in negative mean C values and FQIs) and those dominated by native plants (resulting in positive mean C values and FQIs). This simplified scale should also distinguish between invasive (ecologically and economically problematic plants) and more benign exotic (not ecologically or problematic plants, at least in most waterbodies), and between beneficial ("good") and nuisance ("bad") native plants. In addition, in the absence of clear information about any negative value, or poor quality, of some of these plants, the default designation for most plants should be "beneficial", or at least "benign", for native plants, since most of these plants should be identified as beneficial to the overall aquatic plant community. This would also reduce the consequences of the uncertainty of accurate species-level identifications, since the vast majority of the similar plants would fall within the "benign" category and would be assigned the same C value even if the identification is not accurate. *This is of particular concern in aquatic ecosystems, where many surveyed plants cannot be observed directly, but instead need to be collected using coarse devices that might miss many of the plant structures necessary for accurate identifications*. There are also fewer aquatic plant identification experts than those with expertise with wetland and terrestrial plants, for many of the reasons cited above- as will be seen below, a modified C value system would reduce (by more than 90%) the number of unique aquatic plant species identifications required to develop FQIs. Finally, a simplified system should still account for plants that warrant special protection due to their rarity, vulnerability or unusual value for the aquatic ecosystem.

The proposed simplified (heretofore called "modified" C or C_m) C value scale would range from -5 to 5 (akin to the 0/1 to 10 scale for the existing C_{ny} value scale), with all plants assigned into one of six categories (Kishbaugh, 2020):

- -5 = very highly invasive (non-native) plants
- -3 = moderate to highly invasive (non-native) plants, including regionally invasive plants
- -1 = non-native plants with low invasiveness
- +1 = nuisance native plants
- +3 = benign (beneficial) native plants
- +5 = protected (rare, threatened, or endangered) native plants

The modified C_m value scale exploits two regulatory lists adopted in New York State. The Protected Plant List (rare, threatened, endangered, and exploitably vulnerable species), reported in 6 NYCRR 193.3 (https://www.dec.ny.gov/docs/wildlife_pdf/2019rareplantlists.pdf) identifies those high value aquatic plants that warrant protection. As per the modified C value scale summarized above, these plants would be assigned a modified C_m value of +5. These plants are among the most valued in an aquatic ecosystem, and would presumably result in a higher mean C and FQI value. There are more than 60 native protected aquatic plants in New York state.

White Paper 1F-
Evaluation of Coefficients of Conservatism in NYS Lakes

The Regulatory System for Non-Native Species (http://www.dec.ny.gov/animals/63402.html) characterizes the invasiveness of all non-native plants in New York state for the purpose of establishing restrictions on the sale, transport, and possession of these plants. The NYS non-native regulatory system relied on evaluations of invasiveness by regional and state experts through the state Partnerships for Regional Invasive Species Management, including NYSDEC, Natural Heritage Program, the Nature Conservancy and various botanical garden staff. “Very highly” invasive plants would be assigned a C_m value of -5, while “moderately” to “highly” invasive plants (on a statewide or regional basis, due to the periodic or seasonal lack of very highly invasive growth) would be assigned a C_m value of -3, while all other non-native plants would be assigned a C_m value of -1. Assigning negative values to all exotic plants allowed for the likelihood that lakes dominated by invasive species (and therefore ‘larger’ negative C_m values) would be characterized by negative mean C values and FQIs, indicating a negative floristic quality. This seems intuitively reasonable. There are about 30 non-native aquatic plants in New York state.

The other proposed C_m values would be +3 and +1. Some native aquatic plants grow to nuisance levels in many New York state lakes, and have been the subject of active management by lakefront property owners or lake associations. These include submergent plants such as large leafed or leafy pondweed, coontail, and purple or large bladderwort, floating leaf plants such as watermeal and some water lilies, and emergent plants such as cattails. It is recognized that many of these plants do NOT grow to nuisance levels in all lakes, but these aquatic plant species are often cited as impacting recreational uses, aesthetics or lake access. These plants would be assigned a C_m value of +1. All other native plants not identified as commonly growing at nuisance levels (C_m value = +1) or as protected plants (C_m value = +5) would be assigned a C_m value of +3. As noted above, the vast majority of New York state aquatic plants by default fall into this category. While corralling all other plants into a C_m = +3 category blunts the botanically-significant ecological value of these plants, this default designation reduces many of the issues associated with imperfect collections and identifications, while retaining the distinctions between invasive plants, exotic plants, nuisance plants, protected plants, and “all others”. There are only a few native plants that grow abundantly enough- to nuisance levels- in enough lakes to warrant a +1 ranking on the modified C_m scale. The vast majority (>75%) of aquatic plants found in New York state would be identified as +3 or “benignly beneficial”, consistent with the view from botanists that native plants are an important component of aquatic ecosystems. That said, some additional work may be appropriate to make sure the delineations cited here between C_m = +1 and C_m = +3 are accurate for each (native, non-RTE) aquatic plant in New York state lakes. This work could be conducted by the Northeast Aquatic Plant Management Society, aquatic plant managers (from agencies or management firms) in several states, and other experts. However, this “default” assignment of a C_m of +3 would allow plant surveyors to focus energies on determining if multiple species within a challenging genera are present rather than frustrations that insufficient clues exist to take these identifications down to species level (assuming, of course, sufficient attention is taken to assure that these plants are not protected species).

Following the same example provided above, if multiple narrow-leafed pondweeds appear to be present, based on the existing characteristics set assigned to each specimen, and if there is reasonable certainty that none of these specimen represent protected plants, each specimen can be assigned a default label of *Potamogeton* sp 1, *Potamogeton* sp 2, etc, and ALL PLANTS WOULD BE ASSIGNED A C_m VALUE OF +3. This would also direct further effort to seeking expert assistance, from the NYS Natural Heritage Program and others, to accurately identify protected plants (using, for example, existing distribution maps to determine if RTEs have previously been reported in a surveyed waterbody and to develop simplified RTE-specific plant identification dichotomous keys to take in the field to collect and archive suspected plants), a laudable effort to improve the NYS RTE distribution maps (and thus achieve another goal associated with conducting plant surveys).

Table 3.2 identifies the assigned modified C values (= C_m) for exotic and native plants, depending on the extent of invasiveness defined by the proposed regulatory system, and for native plants, depending on their protected status or whether they are frequently associated with nuisance conditions. Should a simplified C_m value system be considered by more state managers and botanists, further discussions may be warranted about whether specific individual native plants should be considered highly beneficial (C_m value = +5), beneficial (C_m value = +3) or nuisance (C_m value = +1), and whether the state invasiveness rankings are appropriate (and therefore whether a specific non-native plant should be assigned a ranking of -1, -3, or -5).

Table 3.2: Modified C Values (C_m) for Aquatic Plants in New York State

Category	***Modified C_m Value***	***Representative Plants***
Protected Plants	+5	Water marigold, Farwellii's milfoil, Fineleaf pondweed, Lesser bladderwort
Beneficial Native Plants	+3	Slender naiad, Bur reed, Stonewort, most pondweeds, Common waterweed, Duckweed, Watershield
Nuisance Native Plants	+1	Purple bladderwort, Coontail, Largeleaf pondweed, Watermeal, Water lilies, Leafy pondweed
Exotic Plants with "Low" Invasiveness	-1	Water shamrock, Pond water starwort, Brittle naiad, Twoleaf waterweed
Exotic Plants with "High" Invasiveness	-3	Brazilian elodea, Fanwort, Curlyleaf pondweed, Yellow floating heart, Parrotfeather
Exotic Plants with "Very High" Invasiveness	-5	Eurasian watermilfoil, Water chestnut, European frogbit, Hydrilla, Starry stonewort

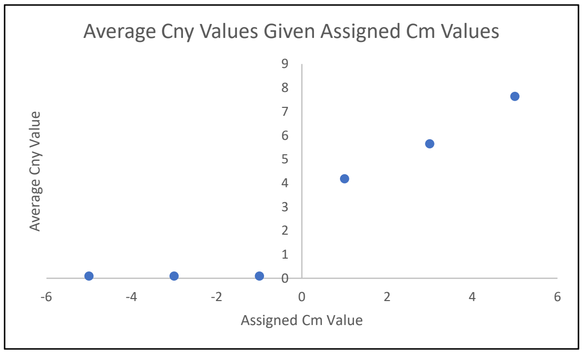
Note- starry stonewort, charaphytes, and aquatic mosses have been assigned C_m values even though C_{ny} values were not assigned to these non vascular aquatic plants. However, filamentous algae was not assigned either a C_{ny} value or a C_m value. Reference: Kishbaugh, 2020.

The proposed modified C_m values for each of the aquatic and semi-aquatic plants commonly found in New York state, and reported in the aquatic plant surveys for the lakes summarized in White Paper 1A are provided in Appendix 2.1.

Section 3.3- Evaluation of Simplified (Modified, C_m) and C_{ny} Values

Section 3.3.1- Comparison of Modified C_m and NYS C_{ny} Values

Figure 3.3.1.1- Comparison of Individual C Values Using C_{ny} and C_m Systems



Legend- C_{ny} = C values using NY C Values
C_m = C values using modified C Values

As discussed above, the New York C_{ny} values are derived from expert (external) estimates for the ecological value of more than 2000 aquatic, semi-aquatic, and terrestrial plant species found in New York state. These values differ from the expert estimates in other states, owing to regional differences in habitat, ecological conditions, synergistic interactions between taxa, and presumably some variance in professional opinions. However, as noted above, appropriate assignment of C values is dependent upon accurate identification of these plant species, despite known plasticity between and within New York ecological regions, challenges in accurate identifications in various stages of plant growth during survey seasons, incomplete collection and preservation of distinguishing physiological features unique to each plant, and various levels of expertise among surveyors. These and other factors may result in inaccurate plant identifications and subsequent inaccurate assignment of C_{ny} values using the New York scales. The proposed modified C_m value scale summarized above addresses many of these issues, but requires reasonable correlation with the New York C value scale for the use of a modified C value scale to be considered.

The relationship between the New York C values (C_{ny}) and the proposed modified C value (C_m) system is explored briefly in Figure 3.3.1.1, showing the typical C_{ny} value corresponding to each C_m assigned value. As expected, each of the negative C_m value (corresponding to exotic plants) are defined as = 0 in the C_{ny} system. The balance of the C_m values exhibit a strong linear relationship with the typical C_{ny} values in Figure 3.3.1.1, indicating a strong relationship between C_{ny} and C_{m}. As noted above, the C_{ny} and C_m values for each of the aquatic plants potentially found in any of the lake surveys highlighted in White Paper 1A can be found in Appendix 2.1 Figure 3.3.1.1 is reproduced and discussed further in White Paper 1G as related to interpretation of FQI calculations derived using C_{ny} and C_m values.

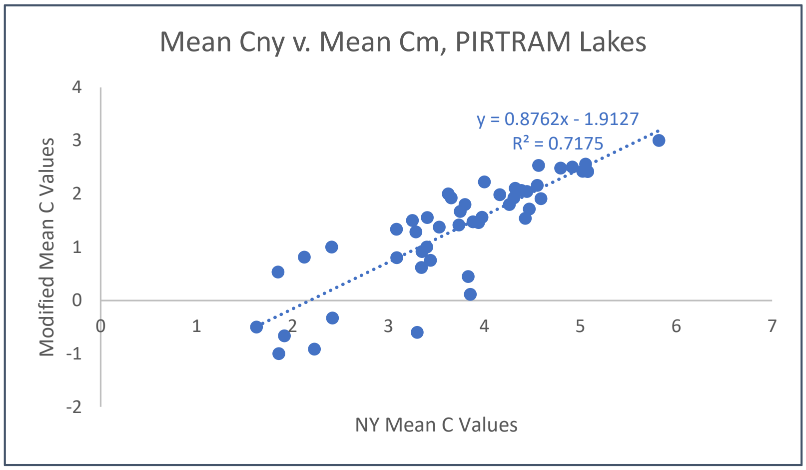


Figure 3.3.1.2: Comparison between NY (Cny) and Modified (Cm) C Values (in PIRTRAM lakes)

Figure 3.3.1.1 shows the relationship between the mean New York C_{ny} value and proposed modified C_m value scale ("systems") for plants collected in the PIRTRAM lakes. Note that these mean values are NOT corrected for plant frequency or abundance, using the same mean C value formula shown in Equation 1.2 and used in most FQI calculations. As discussed above, the New York (and other states') C_{ny} value scale ranges from 0 (invasive plants) to 10 (highly sensitive plants), while the modified C_m value scale ranges from -5 (highly invasive plants) to +5 (protected plants). The regression line in Figure 3.3.1.2 shows a strong correlation between the New York (C_{ny}) and modified C (C_m) values, with the greatest scatter occurring when both New York and modified C values are lowest- in lakes with a relatively large number of invasive plants. Although the scale range in the two "systems" are essentially identical- both have a 10 point spread- the slope of the best fit line is 0.87 (less than 1). This may be due to the larger range of C value assignments for exotic plants in the modified C_m value system (from -5 to -1) than in the NY C_{ny} value systems (in all of these systems, all exotic plants are assumed to be invasive and assigned a value of 0). This may account for the larger data spread when mean C values are low, due to the presence of exotic/invasive plants.

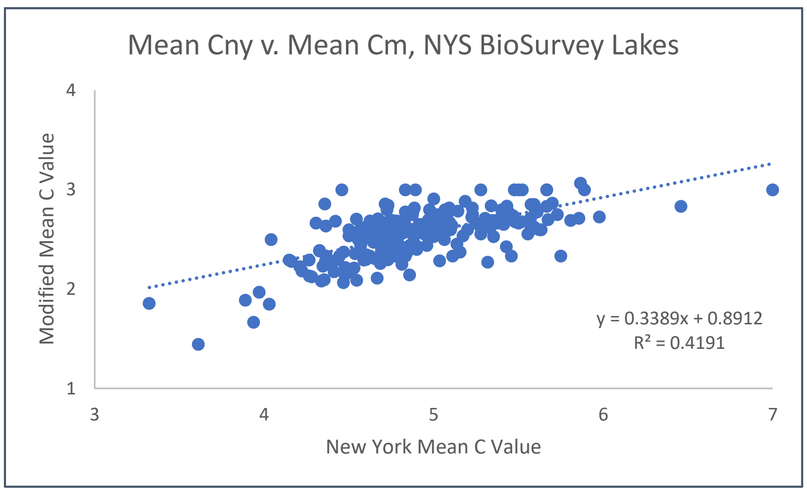


Figure 3.3.1.3: Comparison between NY (Cny) and Modified C (Cm) Values (in 257 NYS BioSurvey lakes)

The same relationship can be explored with the NYS BioSurvey and AWI datasets, as seen in Figures 3.3.1.2 and 3.3.1.3. These data show a much weaker relationship between the NY and modified C values for the NYS BioSurvey and AWI lakes. There may be several reasons for these discrepancies:

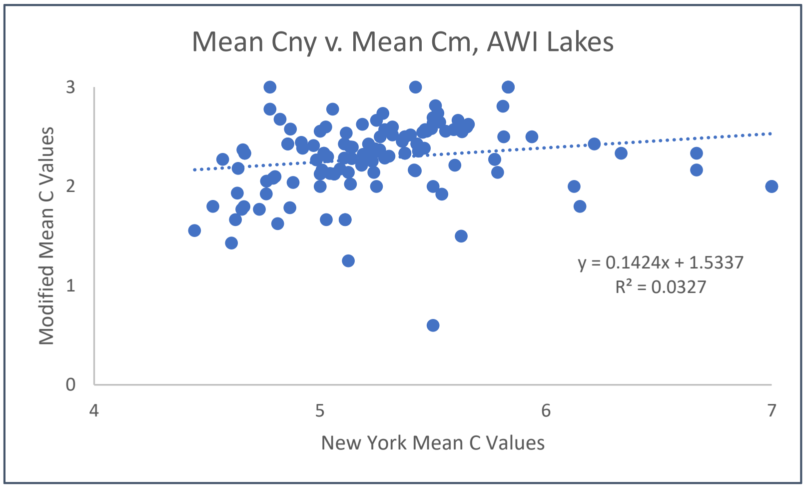


Figure 3.3.1.4: Comparison between NY and Modified C Values (in AWI lakes)

1. Few if any AIS are found in the majority of the NYS BioSurvey and AWI lakes. The modified C_m system is enhanced by a large difference in the C values for exotic and invasive plants (all with negative C values) and for native plants. Figure 3.3.1.1 shows that several PIRTRAM lakes have mean C_m below 0, indicating high levels of AIS, while no AWI or NYS BioSurvey lakes have mean C_m below 1. This phenomenon is discussed further in White Paper 1E.
2. There are relatively few nuisance native species in the Adirondack lakes (as evaluated through AWI) and the NYS BioSurvey dataset (collected when few plants were found at nuisance levels) compared to PIRTRAM. The modified C_m system includes some separation of nuisance native plants ($C_m = 1$) from benign native plants ($C_m = 3$ or 5). As seen in Figure 3.3.1.1, most PIRTRAM lakes have mean C_m below 2 (indicating high levels of nuisance or AIS), while few NYS BioSurvey or AWI lakes have mean C_m below 2 (Figures 3.3.1.2 and 3.3.1.3).
3. The Adirondacks (AWI lakes) may include more highly beneficial plants, based on high C_{ny}), but unless these were protected plants, they would be lumped with the $C_m = 3$ (benign) category. This may indicate a potential flaw with the C_m delineations and may suggest a need for more plants to be characterized as $C_m = 5$.

These data suggest that as AIS continue to spread throughout the state, the C_m system may be an increasingly valuable alternative to the C_{ny} system, given the wide separation between highly invasive and benign native plants, and the assignment of negative C_m values to invasive species.

Section 3.3.2- Evaluation of Modified C Values and Littoral Area

The relationship between the New York and modified C value systems is further evaluated against other factors that appear to influence species richness, since mean C values in both systems are computed for all plant species in these lakes. Tables 2.3.2.1 through 2.3.2.3 indicate that the NY C values do not appear to change with littoral area. Table 3.3.2 shows only a slight increase in modified C (C_m) values as littoral (or lake) areas increase, notwithstanding an apparent outlier in the PIRTRAM dataset for lakes with littoral areas between 50 and 100 acres.

This slight increase in C_m as littoral or lake area increases in these lakes may be due to decreasing influence of AIS (i.e. few to no additional AIS species added to the plant list) as littoral area increases and species richness increases. However, it is just as likely that the small differences in mean C values as littoral area increases in Table 3.3.2 are not statistically significant.

As discussed in White Paper 1E, AIS and nuisance native plants, those with the lowest C_m values, are often among the most frequently counted and most abundant plants in these lakes, across the range of all littoral areas, and higher littoral areas (and therefore more survey sites) are less likely to result in more AIS found than more native plants found. The slightly larger increase in C_m with littoral area in AWI lakes than in NYS BioSurvey lakes in Table 3.3.2 may be due to relatively more AIS in AWI lakes than in lakes surveyed in the 1920s and 1930s, although neither dataset includes large numbers of invasive species. The discontinuity between C_m and littoral area increases in PITRAM lakes may be due to the relatively small number of lakes in each littoral area range in Table 3.3.2- while the NYS BioSurvey and AWI datasets include more than 100 lakes each, fewer than 50 lakes were surveyed through PIRTRAM. The same discontinuity occurred with the C_{ny} system- the highest C_{ny} values occurred in the lakes with the smallest and largest littoral areas (Table 2.3.2.2), and slightly higher C_{ny} values in the larger NYS BioSurvey lakes. This also suggests that the C_m system would be an acceptable alternative to the C_{ny} system, with all of the benefits in using a modified C value system (as discussed in Section 3.3.4 below). **It is anticipated that C_m would increase very slightly with littoral area as more surveyed lakes were added to the PIRTRAM dataset, particularly in those regions of the state (outside the Adirondacks) where invasive species are more widespread. However, as noted above, since C_m is a "rate" statistic, any relationship between littoral area and mean C_m values is by necessity very weak, as discussed further below in Section 4.**

Table 3.3.2- C_m Values in NYS BioSurvey, PIRTRAM and AWI Lakes by Littoral Area (Lake Area for NYS BioSurvey Lakes)

Littoral Area	Cm NYSBioSur	Cm PIRTRAM	Cm AWI
0-50ac	2.5	1.2	2.2
50-100ac	2.5	1.6	2.2
100-200ac	2.6	1.2	2.3
200-500ac	2.6	1.2	2.4
>500ac	2.6	1.7	2.4

Legend: Cm = modified C value
NYS BioSurvey results for lake, not littoral, area

Section 3.3.3- Evaluation of Modified and New York C Values and Trophic State

As discussed in White Paper 1D, there is a moderately strong relationship between species richness and trophic state- species richness is highest in less productive lakes, most likely due to the inability of invasive and nuisance species to either colonize and grow abundantly in low productivity water or sediments, or the limits to competitive advantages conferred to these plants due to high light transmission in lakes. This relationship held across the entire range of littoral areas found in New York state (and PIRTRAM) lakes, and would indicate that FQI values are higher in lakes with lower productivity than in lakes with higher productivity.

Figure 3.3.3 shows the relationship between the modified C values (C_m) and New York C values (C_{ny}), replicating Figure 3.3.1.1 exploring the influence of AIS on this relationship. However, in Figure 3.3.3, meso-oligotrophic (mesotrophic or oligotrophic) lakes were separated from eutrophic lakes. This relationship is explored to evaluate the potential connection between eutrophication (and a presumed proclivity for AIS dominance) and any differences between the New York C and modified C_m value systems. Figure 3.3.3 shows that both the regression lines summarizing the best fit of the data, and the regression coefficient describing the extent of the correlation, are very similar whether looking at eutrophic lakes or those lakes with lower productivity (mesotrophic or oligotrophic lakes).These data shows that, in general, both C_m and C_{ny} values were much lower in eutrophic lakes than in meso-oligotrophic lakes, consistent with the expectation that AIS and nuisance native plants (assigned lower C_m and C_{ny} values) comprise a much higher relative component of the aquatic plant community (as will be seen in Section 4 below, this is even more pronounced when considering frequency and abundance within lakes). The data in this Figure also suggests that the relationship between C_m and C_{ny} is nearly identical across the trophic spectrum, although the deviation from the best-fit line is strongest for eutrophic lakes (again, as noted above, reflecting the assignment of multiple negative values based on invasiveness in the C_m system relative to a single C = 0 assignment for the C_{ny} system.

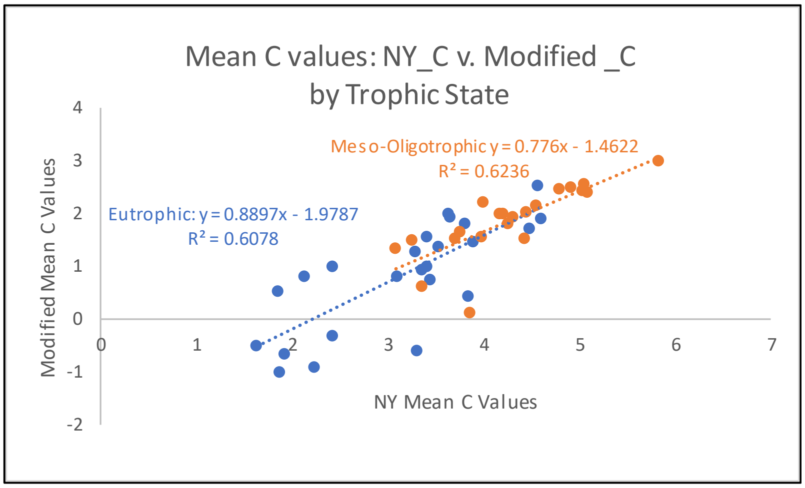


Figure 3.3.3: Comparison between NY and Modified C Values based on trophic state in PIRTRAM Lakes

In short, **these data suggest that the modified C_m value system will yield similar results (in regard to mean C values as used in FQI and other calculations) to those generated using the C_{ny} value system.** As discussed earlier, the modified C_m value system exhibits several advantages over the C value system used in New York and other states, **at least in regard to evaluating aquatic ecosystems. An evaluation of the underlying data presented in Section 3 of this White Paper indicate there might be significant value in adopting a modified C_m value system for evaluating aquatic ecosystems**, although additional effort should be dedicated to properly assigning the most appropriate C_m value for all of the New York aquatic macrophytes, charaphytes, aquatic mosses, and other significant components of the rooted aquatic environment. Except where noted, the modified C_m value system will be used in this report to evaluate floristic quality and other potential applications of these aquatic plant surveys.

Section 4- Projected Modified Coefficients of Conservatism (C_m) Mean Values

Section 4.1- Background

Section 4 of White Paper 1C provides a summary of the problems in using observed species richness (oSR) for comparing lakes, whether these lakes were sampled in the same program, across multiple programs, or over a long period of time. These problems include inconsistencies in survey site densities and the number of survey sites (given a general increase in oSR as survey sites increase) and a need for an optimal number of survey sites that balances the need to cover sufficient littoral areas to include all growing habitats and depths while avoiding so many survey sites that an asymptotic limit to the number of unique plant species is approached, as well as procuring an achievable number of sites. These findings lead to a recommendation for the use of a standardized survey site density of 1 site per littoral hectare, as discussed at length in White Paper 1D. For most lakes- those with both fewer and more survey sites than prescribed by this standardized survey site density- species richness values need to be "projected" using subsampling tools outlined in White Paper 1C. These projected species richness (pSR) values can be used to compare lakes over time and across programs, although as discussed at length in White Papers 1C and 1D, this requires "granular" survey site data (presence or relative abundance data for each plant at each surveyed site). The same approach is appropriate for evaluating coefficients of conservatism (C values), whether mean C values (as used in FQI equations 1.1 and 1.2) modified using a simplified scale (as discussed in Section 3 above), or if corrected for frequency or relative abundance, as discussed below.

In all surveyed lakes, observed species richness increases as the number of survey sites increases, although it is likely that each lake exhibits a "carrying capacity" or asymptotic value of a maximum number of unique species. Thus observed species richness represents a single point along this asymptotic regression. However, the relationship between coefficients of conservatism (as mean C values) and the number of survey sites is more complicated. This is discussed at length in White Paper 1C, which outlines a justification for the use of standardized survey site densities. Specifically, Figures 4.3.1.1 through Figure 4.3.1.3 in White Paper 1C shows the three most common relationships between mean C values and survey sites- steady increase in mean C transitioning into a slight tailing off of mean C values as survey sites increase (Cazenovia Lake, Figure 4.3.1.1), a steady increase with no tailing off of mean C values (Lake Luzerne, Figure 4.3.1.2), and wide variations in mean C values leading to a steady asymptotic increase (or decrease) in mean C values (Blydenburgh Lake, Figure 4.3.1.3). Given the variable relationship between mean C values and the number of survey sites in all three categories of lakes, a standardized survey site density should be used to define mean C values for comparison between lakes, over time, and for use in floristic quality indices calculations (White Paper 1G).

Section 3 of this White Paper advances the argument that a modified C value system (C_m) exhibits distinct advantages over the traditional New York C value system (C_{ny}); unless otherwise noted, the modified C_m system is used for evaluating mean C values projected to a standardized survey site density, corrections to mean C_m values based on plant frequency or relative abundance, and for floristic quality indices (FQI) calculations.

Section 4.2- Monitoring Programs Used to Project Survey Sites (and mean C_m values)

As discussed above, the process for projecting modified coefficient of conservatism (pC_m) requires granular site survey data (indicating the frequency and/or abundance of all plants at each surveyed site). These data are available for some of the PIRTRAM lakes, as seen in Table 4.3 below. Note that for some PIRTRAM lakes, only summary data are available, showing the total number of surveyed sites and the number of survey sites associated with each of the relative abundance categories (number of sites with dense quantities of Plant X, number of sites with moderate quantities of Plant X, etc.). In the absence of the granular data indicating presence or relative abundance at each site, pC_m cannot be accurately estimated. Although the species distribution of all aquatic plants at each of the AWI rake toss sites and the weed bed sites could be equilibrated to allow for a single “rake toss equivalent” distribution for each plant, this would require some assumptions about the distribution of the plants within the beds that could compromise the ability to project mean coefficients of conservatism. For the NYS BioSurvey lakes and ALSC lakes, granular survey data are not available, so pC_m values cannot be calculated.

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

Section 4.3- Estimating Projected Mean C_m Values in PIRTRAM Lakes

Section 4.3.1- Comparison of Mean Projected and Observed C_m Values

Table 4.3 compares various measures of mean coefficients of conservatism (C_m) for a subset of the PIRTRAM lakes. This table includes the “observed” mean C_m value using all of the survey sites for each lake (referred to here as oCm_ all) and the “projected” C_m value at the standardized survey site density (= 1 site per littoral hectare) calculated from the granular survey site data using the methods outlined in White Paper 1C. So, for example, Table 4.3 shows that the observed mean C_m value for Ballston Lake in 2006 was 1.0 using all 34 survey sites, but would be projected to be 1.2 at a standardized survey site density of 48 sites.

Note that Table 4.3 includes all of the lakes with granular survey site data that were surveyed for one year, and a subset of the lakes with granular survey site data that were surveyed in multiple years. However, to show the variation across all surveyed years, data from all surveyed years were analyzed for one large lake (Cazenovia Lake) and for one small lake (Lake Waccabuc) in Table 4.3. In addition, there were a few lakes included in Table 4.3- Chautauqua Lake, Oscaleta Lake, Rippowam Lake- for which granular survey site data were not available at the time of the species richness analyses summarized in White Paper 1D.

Table 4.3 shows that mean C_m values in the PIRTRAM lakes range from -3.7 (Lake Ronkonkoma) to 3.2 (Morehouse Lake), indicating a range of lakes dominated by invasives to lakes dominated by benign or even protected plants. There does not appear to be a clear relationship between the size of the lake (littoral area) and the mean C_m values, consistent with the findings in Section 3 above. The data from Cazenovia Lake and Lake Waccabuc suggest that

Table 4.3- Comparison of Various Mean Cm Values

Year Lake	Year	Sites	Std. Density	pCm_ 1/ha	oCm_ all
Ballston Lake	2006	34	48	1.2	1.0
Big Fresh Pond	2006	19	13	2.6	2.6
Blydenburgh Lake	2012	27	40	-1.4	-1.5
Blydenburgh Lake	2014	27	40	-0.3	-0.3
Cazenovia Lake	2010	304	225	1.7	1.8
Cazenovia Lake	2011	304	225	1.9	1.9
Cazenovia Lake	2012	304	225	1.8	1.8
Cazenovia Lake	2013	304	225	1.8	1.8
Cazenovia Lake	2014	304	225	1.7	1.6
Cazenovia Lake	2015	304	225	1.8	1.8
Cazenovia Lake	2016	304	225	1.7	1.7
Cazenovia Lake	2017	304	225	1.7	1.6
Cazenovia Lake	2018	304	225	1.6	1.6
Cazenovia Lake	2019	304	225	1.7	1.6
Cazenovia Lake	2020	304	225	1.7	1.7
Cazenovia Lake	2021	304	225	1.9	1.9
Chautauqua Lake	2015	332	2060	2.1	2.0
Chautauqua Lake	2017	354	2060	2.3	1.8
Chautauqua Lake	2019	366	2060	2.0	2.1
Chautauqua Lake	2021	366	2060	1.9	1.8
Collins Lake	2007	38	5	0.5	1.2
Creamery Pond	2008	19	4	0.0	0.5
Creamery Pond	2010	21	4	0.3	-0.1
Creamery Pond	2012	21	4	0.6	1.0
Hards Pond	2011	19	12	2.3	2.3
Java Lake	2008	16	21	1.7	1.7
Java Lake	2009	16	21	2.0	2.0
Java Lake	2010	16	21	1.1	1.0
Kinderhook Lake	2006	20	109	-0.6	-1.0
Kinderhook Lake	2007	20	109	-0.5	-1.0
Lake Luzerne	2009	58	24	2.3	2.4
Lake Luzerne	2010	152	24	2.3	2.5
Lake Rippowam	2008	45	4	-1.4	-1.0
Lake Rippowam	2016	60	4	-1.2	1.0
Lake Rippowam	2018	60	4	-1.3	0.3
Lake Rippowam	2020	60	4	-1.4	-0.5
Lake Ronkonkoma	2010	22	21	1.5	1.5
Lake Ronkonkoma	2014	22	21	-3.7	-3.7

a wide variation in mean C_m values over time is not apparent, although some variation was apparent in other heavily managed lakes, such as Snyders Lake and Creamery Pond, and in other unmanaged lakes, such as Blydenburgh Lake and Java Lake. However, the data presented in Table 4.3 suggest that the modified C_m system is sufficient to detect significant differences in surveyed waterbodies, such as those dominated by invasive plant species relative to those dominated by native plant species.

Table 4.3 also shows the relationship between the observed (or more accurately, in some cases calculated) mean C_m values at the actual number of survey sites and the projected mean C_m values at the standardized survey site density of 1 site per littoral hectare. Figure 4.3 indicates a strong relationship between the observed and projected mean C_m values outlined in Table 4.3. Some of this overlap is to be expected, particularly for lakes for which the number of survey sites is similar to the standardized survey site density for that lake (in other words, for lakes with survey site densities approaching the standardized 1 site per littoral hectare value). Most of the divergence between observed and projected mean C_m values in Table 4.3 (the difference between columns 5 and 6) correspond to lakes with a wide divergence between the actual and standardized survey site densities for those lakes. For example, in Figure 4.3.1, the data points highest above the regression line (around pCm = -1) correspond to Lake Rippowan, which has a very high number of survey sites (= 60) relative to the standardized survey site density (= 4 sites in 4 hectares of littoral area). Likewise, the data points in Figure 4.3 that are furthest below the regression line correspond to an oCm of approximately 2 or a pCm of approximately -1, correspond to Quaker Lake and Kinderhook Lake, respectively. These lakes have a very high standardized survey site density (= 64 sites and 109 sites, respectively) relative to the number of actual survey sites (30 and 20, respectively).

Table 4.3 (cont)- Comparison of Various Mean Cm Values

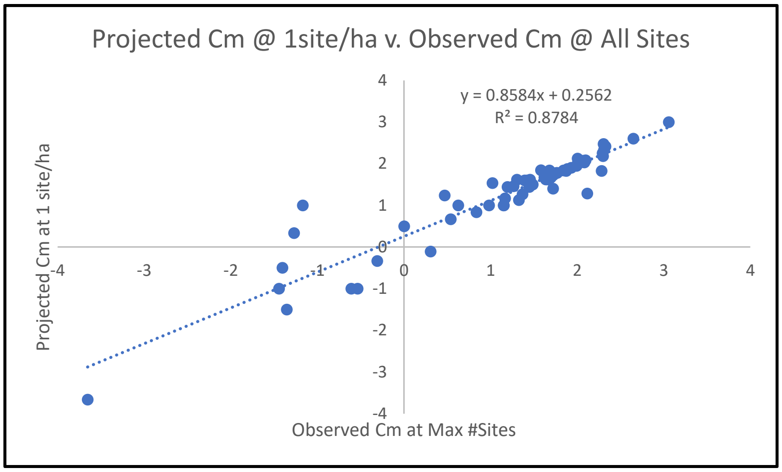
Year Lake	Year	Sites	Std. Density	pCm_ 1/ha	oCm_ all
Lake Waccabuc	2008	114	20	1.3	1.1
Lake Waccabuc	2010	120	20	1.4	1.4
Lake Waccabuc	2013	120	20	1.4	1.6
Lake Waccabuc	2014	120	20	1.7	1.4
Lake Waccabuc	2015	120	20	1.6	1.7
Lake Waccabuc	2016	120	20	1.6	1.8
Lake Waccabuc	2017	120	20	1.7	1.8
Lake Waccabuc	2019	120	20	1.4	1.6
Lake Waccabuc	2021	120	20	1.3	1.5
Lamoka Lake	2006	169	160	2.1	2.1
Lamoka Lake	2009	180	160	2.3	2.3
Morehouse Lake	2010	30	35	3.1	3.0
Oscaleta Lake	2008	60	8	1.3	1.6
Oscaleta Lake	2016	87	8	1.5	1.6
Oscaleta Lake	2018	88	8	1.2	1.4
Oscaleta Lake	2020	89	8	1.0	1.5
Quaker Lake	2010	30	64	2.1	1.3
Saratoga Lake	2010	241	657	2.3	2.2
Saratoga Lake	2011	320	657	2.1	2.0
Saratoga Lake	2012	304	657	2.1	2.1
Snyders Lake	2002	40	15	0.5	0.7
Snyders Lake	2005	32	15	1.0	1.0
Snyders Lake	2008	57	15	0.8	0.8
Snyders Lake	2011	51	15	1.2	1.2
Waneta Lake	2006	146	170	1.4	1.3
Waneta Lake	2009	146	170	2.0	1.9

Std. Density = # survey sites @ standardized density of 1 site/ha
pCm_ 1/ha = projected mean Cm at standardized 1 site/ha
oCm_ all = observed mean Cm using all survey sites (column 3)

For most other lakes, the observed mean C_m values are similar to the projected mean C_m values at a survey site density of 1 site per littoral hectare. This is due to relative stability in mean C_m values once a certain number of sites are surveyed, as seen in Figures 4.3.1.1 through 4.3.1.3 in White Paper 1C. This is apparent in a further inspection of Figure 4.3.1, which shows a high correlation between projected and observed mean C_m values (R^2 = 0.85), a slope that is close to 1 (= 0.86) and a small intercept (= 0.26).

However, the differences in these values may be large enough to warrant the use of projected rather than observed mean C_m values, particularly since this allows for continuity with the need for using projections (to a standardized survey site density) to estimate species richness (White Paper 1D). Therefore, the use of projections (to a standardized survey site density of 1 site per littoral hectare) seems to be warranted for both calculations of species richness and for calculations of mean C_m values.

Figure 4.3.1- Comparison of Projected and Observed Cm



These findings presume that the process for projecting mean C_m values will closely replicate actual (observed) measurements. Figure 4.3.1 summarizes the close relationship between observed mean C_m values at all (actual) survey sites and a projected mean C_m at the standardized survey site density of 1 site per little hectare. As discussed above, this Figure reflects a high level of stability in mean C_m values once a certain survey site density is achieved, as seen in Section 4.3 in White Paper 1C. However, this does not evaluate the relationship between observed (or calculated) mean C_m and the projected mean C_m at the standardized survey site density.

Figure 4.3.2- Comparison of Projected and Observed Cm at the Standardized Survey Site Density of 1 site per littoral ha

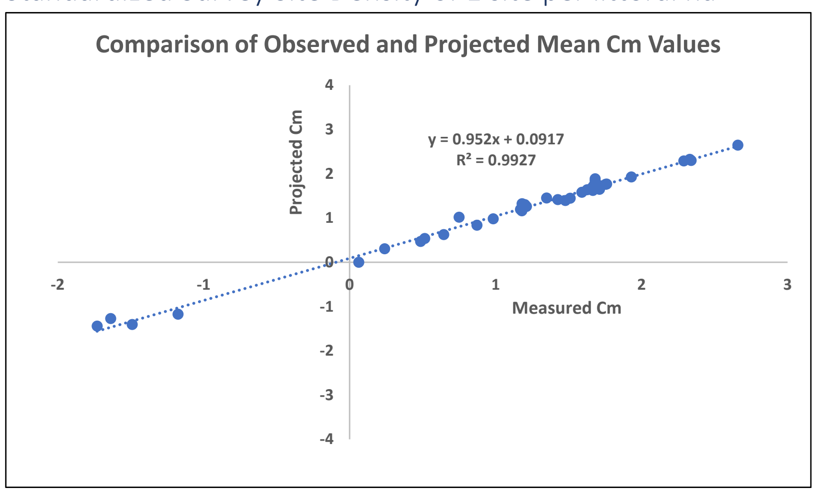


Figure 4.3.2 shows a very strong relationship (R^2 = 0.99, slope = 0.95, intercept = 0.1) between projected and observed mean C_m values in the PIRTRAM lakes. This is to be expected, since the projected values include the datapoints associated with the observed values, but it also suggests that these regression equations (and the subsampling methods used to project mean C_m values at any survey site density) can accurately characterize the relationship between mean C_m values and the range of survey site densities. This further suggests that this process can be used to estimate mean C_m values for surveyed lakes.

Section 4.4- Estimating Mean C_m From Truncated Surveys

Section 4 of White Paper 1D summarizes a process by which projected species richness (pSR) can be estimated from truncated aquatic plant surveys. This process uses regression (and other) analyses to project the species richness at any survey site density (including the recommended standardized survey site density of 1 site per littoral hectare) using a much smaller number of survey sites. Table 4.4.2 in White Paper 1D indicates that 10-15 sites are sufficient to estimated the pSR at 1 site per littoral hectare at an accuracy of more than 95% for small lakes- those with less than 100 hectares of littoral area, although for lakes smaller than 10-15 hectares of littoral area, observed species richness (oSR) values can be computed or measured at the 1 site per littoral hectare survey site density. For larger lakes, Table 4.4.2 in White Paper 1D indicates that a similarly high accuracy of estimating pSR can be achieved with a truncated survey of 25 sites. A similar approach can be used to estimate mean C_m at the same survey site density of 1 site per littoral hectare.

Table 4.4.1- First Regression Achieving Various % of pC_m in All PIRTRAM Lakes

	First >50%	First >75%	First >90%
%±30%	1-15	5-15	5-25
%±20%	5-15	5-15	10-25
%±10%	5-15	none	none
%±5%	15-25	none	none

Table 4.4.1 summarizes the relationship between the number (and regression) of survey sites required for at least 50% (or 75% or 90%) of lakes to estimate a projected mean C_m value that falls within 30% (or 20%, or 10%, or 5%) of the mean C_m value at a standardized survey site density of 1 site per littoral hectare. The raw data for these analyses is provided in Appendix 4.4, with summary data for all lakes, for small and large lakes, and for those lakes with the number of survey sites greater than (or less than) the standardized survey site density of 1 site per littoral hectare.

These data indicate, for example, that the projected mean C_m value can be estimated within 30% of the “actual” value in more than 50% of the PIRTRAM lakes using only 15 survey sites (from a regression of the estimated C_m values in 1-15 sites). The data presented in Table 4.4.1 indicate that 15 to 25 sites are sufficient to estimate mean C_m values at an accuracy of 95% in more than half of the surveyed lakes, although “improving” this estimate to include at least 75% or 90% of the lakes will decrease the accuracy to closer to 70-80%.

As discussed at length in White Paper 1D, while the same range (15-25 survey sites) are required to estimated species richness projected (pSR) at a survey site density of 1 site per littoral hectare, these data found that the higher end of survey sites were required for larger lakes. As seen in Tables 4.4.2 and 4.4.3, the same recommendations apply to using truncated surveys to estimate pC_m in both small and large lakes. Table 4.4.2 shows 15 sites (at various regressions) are sufficient to estimate pC_m in more than 75% of small lakes (< 40 hectare littoral area) to an accuracy of at least 90%, and in more than 50% of lakes to an accuracy of more than 95%. Likewise, in larger lakes (littoral area > 40 hectares), 25 sites are needed to estimate pC_m in half of the

Table 4.4.2- First Regression Achieving Various % of pC_m in All Small PIRTRAM Lakes

	First >50%	First >75%	First >90%
%±30%	1-15	5-15	5-15
%±20%	5-15	5-15	5-25
%±10%	5-15	5-15	none
%±5%	5-15	none	none

Table 4.4.3- First Regression Achieving Various % of pC_m in All Large PIRTRAM Lakes

	First >50%	First >75%	First >90%
%±30%	1-15	5-15	15-40
%±20%	5-15	5-25	none
%±10%	10-25	none	none
%±5%	none	none	none

surveyed lakes at an accuracy of 90%, but this accuracy is reduced to about 80% to accurately assess more than 75% of surveyed lakes. Note that even at 25 surveyed sites, 95% accuracy cannot be achieved using truncated surveys.

These data confirm the findings in White Paper 1D regarding species richness, indicating that regressions of **15 survey sites may be sufficient to accurately (with 90-95% accuracy) the estimated mean C_m in small lakes at a standardized survey site density of 1 site per littoral hectare, and 25 sites may be sufficient to estimate, within 80-90% accuracy, these mean C_m values in large lakes**. However, at discussed below, these mean C_m values should be corrected for relative frequency and abundance to more accurately characterize aquatic plant communities. This will also impact the recommended number of truncated aquatic plant survey sites to accurately characterized mean C_m values.

Section 5- Weighted C_m and evaluation of plant frequency

Section 5.1- Background Information

As introduced in White Paper 1C Section 3, traditional measures of floristic quality- specifically, the coefficients of conservatism- do not account for plant frequency or abundance. This leads to FQI calculations that are blind to the number and relative abundance of plants (as opposed to the number of plant species), likely resulting in differences in actual floristic quality- ecosystem function, sediment retention, fish habitat, recreational impediments, etc- despite similarities in calculated floristic quality. The balance of this Section explores incorporating plant frequency into assessments of coefficients of conservatism.

Section 5.2- Monitoring Programs Used to Evaluate FQI and Plant Frequency

As with evaluation of species richness (White Paper 1D) and plant lists and individual (particularly AIS) species (White Paper 1E), the evaluation of coefficients of conservatism (C values) potentially involves the four datasets summarized in White Paper 1A- the 1920s-30s NYS BioSurvey, the 1980s ALSC, the 1990s-2010s PIRTRAM surveys, and the 2010s AWI surveys. The ALSC aquatic plant surveys did not identify plants to species levels, precluding the use of C values and floristic quality indices (FQIs) in evaluating aquatic plant communities. While unweighted FQI values can be calculated for the NYS BioSurvey and AWI survey lakes, both programs have significant limitations for applying a (frequency- or abundance-driven) weighting factor to these data.

While the NYS BioSurvey surveys assigned a single relative abundance value for each plant in each lake, no individual site data ("granular site data") are provided for any of the lakes. These data are not sufficiently refined to assign a plant frequency-weighting factor to these plant survey results, and any abundance-weighting factors cannot be compared to those generated for lakes with granular (individual site specific) abundance data. For example, *Najas flexilis* was assigned a relative abundance of "common" in the NYS BioSurvey in White Lake in Sullivan County in 1935, but the PIRTRAM surveys in the same lake in 2009 found, in 219 surveyed sites, 6 occurrences of "moderate" growth, 41 occurrences of "sparse" growth, and 70 occurrences of "trace" growth. These two surveys, and the abundance-weighted FQI values, cannot be easily compared, even if one assumes that "common" is equivalent to "moderate". In addition, relative abundance was not measured in some NYS BioSurvey lakes- plants were only cited as "present" or (by default) "absent".

Likewise, the AWI surveys include a mix of rake toss sites (for which relative abundance designations were assigned for each plant) and plant bed sites (for which the same designations were assigned, but as with the NYS BioSurvey, only a single designation was assigned for each plant for the entire bed). Although frequency- or abundance-weighed FQI values could be assigned to the AWI and NYS BioSurvey lakes, these would not be comparable between programs and could not be used as a basis for generating a plant community-based aquatic plant metric.

Therefore, only the PIRTRAM dataset, with granular plant survey data including species frequency for each site for each lake, can be used to generate and evaluate weighted C values. However, since many other aquatic plant surveys (not evaluated here) offer both granular survey (relative) abundance data and frequency data, interpretation of the results from these surveys may be enhanced by applying the plant frequency weighting methods described below. As discussed briefly above and in detail in White Paper 1A, about 50 lakes were surveyed using the PIRTRAM methodology, some of which were sampled for multiple years. The PIRTRAM dataset is the basis for these evaluations in the balance of Section 4.

Section 5.3- C Values Corrected for Plant Frequency

Corrections to the mean C values in surveyed lakes for plant frequency are discussed at length in White Paper 1C. The weighting factors associated with plant frequency (and abundance, summarized below) can be assigned to the C_m values in the FQI equations provided in Equation 1.1 and 1.2, since the weighting would influence the quality of the plant community rather than the number of plant species. These weighting factors can be used to evaluate mean C_m values corrected for relative or absolute frequency (note that this section is reproduced from the information presented in White Paper 1C, Section 8):

a. *Relative or normalized frequency* refers to a means for evaluating those plants that occur at a higher frequency than other plants, regardless of the absolute frequency. The formula used to calculate normalized weighted frequency mean C_m values is as follows:

Equation 5.3.1: $C_{(m)}$_nf = *sum of (all sites counts x C_m value for species) / sum of all sites taxa counts*

where "m" refers to modified, "n" refers to normalized and "f" refers to frequency

b. *Absolute or unbounded frequency* refers to the means for evaluating those plants that are more frequently found than other plants, regardless of the relative frequency. These corrections can be calculated by taking the sum of all species counts x the C_m value for each species (the numerator in Equation 5.3.1), and divide this by the "opportunities" for plant frequency, resulting in Equation 5.3.2:

Equation 5.3.2: $C_{m\_uf\_}$ *= sum of (all sites counts x* C_m *value for species) / (number of plant species x number of survey sites*).

where "u" refers to unbounded frequency

The C_{m_nf} values generally fall within the same range (scales) as both the traditional C_{ny} and modified C_m values, and therefore the modified FQI values using the modified C_m values corrected for normalized frequency can be evaluated using criteria established for uncorrected C values (as discussed in White Paper 1G). Other criteria are needed to evaluate modified C_m values corrected for unbounded or absolute frequency (C_{m_uf}), since these C values reside on a different scale than can accurately be characterized using uncorrected FQI criteria. These are summarized in Section 5. **However, absolute or unbounded frequency corrections are much more easily applied to projected individual (component) and mean (community) C_m values, as discussed in White Paper 1C, so modified C values corrected for unbounded frequency (C_{m_uf}) are calculated for the PIRTRAM dataset and discussed below.**

Section 5.4- Estimating Projected Mean C_m Values Corrected for Absolute (Unbounded) Frequency in PIRTRAM Lakes

Section 5.4.1- Background

As previously discussed, the standard FQI formula does not account for the frequency or abundance of plants found during a plant survey. One of the consequences of using a simple formula with only species richness (usually oSR) and typical coefficients of conservatism (mean C_{ny} value) is the inability of the FQI calculation to recognize significant changes in plant community dynamics- frequency and abundance of plants- in response to lake management actions. In fact, the FQI in many lakes, particularly large moderately-to-unproductive lakes, does not change significantly in response to large scale management actions. While it is possible that floristic quality does not change significantly after extensive modification due to whole lake herbicide treatments, grass carp stocking, or other large scale management actions (consistent with literature suggesting FQI does not change with frequency or abundance corrections), the lack of change in many New York lakes after management is difficult to reconcile with at least local response to these management actions.

As discussed in Section 3, it is recommended that the modified C_m value system be used to define individual plant value and to compute FQI. These modified mean C_m calculations can be modified by plant frequency data on a normalized (relative to frequency of other plants in the lake) or an absolute (relative to the number of surveyed sites) scale, as a "correction" to the modified (C_m) FQI calculations. **These are referred to below as mean C_{m_nf} (modified mean C_m corrected for normalized frequency) and mean C_{m_uf} (modified mean C_m corrected for unbounded frequency)**.

While normalized frequency data provide some indication of which plants are the most frequently found within an aquatic plant community, it does not necessarily provide insights about the absolute frequency. Lakes with a high frequency of multiple plant species might not result in a different (unweighted or normalized) mean C_m value compared to those lakes with the same proportion of these species at an overall much lower level of frequency, even though that in many cases, these lakes would possess more favorable floristic quality. Mean C_m calculations can be 'corrected' for absolute plant frequencies, providing more information about the overall coverage (frequency found at survey sites). While it should be noted that the resulting mean C_m scale corrected for absolute (unbounded) frequency cannot be easily compared to uncorrected FQI calculations or those calculations weighted for normalized frequency, corrections for absolute frequency can be easily generated from projected mean C_m values (as discussed in White Paper 1C) and therefore should be used in analyses of aquatic plant survey data. Using the same approach- correcting mean C_m values corrected for absolute plant frequency- also allows for comparisons between lakes (and programs) and over time.

Section 5.4.2- Comparison of Mean Projected C_m Values Corrected and Uncorrected for Absolute Plant Frequency

Table 5.4.2 compares various measures of mean coefficients of conservatism (C_m) for a subset of the PIRTRAM lakes. Note that Table 5.4.2 does not include all of the lakes (or lake years) projected mean C_m value at the standardized survey site density of 1 site per littoral hectare (pC_{m}_1/ha), and the projected mean C_m value at the same standardized survey site density corrected for unbounded frequency (pC_{m_uf}). These data show that all of the lakes with uncorrected mean C_m values < 0 also have negative frequency-corrected mean C_m values. These include Blydenburgh Lake in 2012 and 2014, Kinderhook Lake in 2007, and Lake Ronkonkoma in 2014- all lakes with more invasive than native plant species. Several other lakes- Ballston Lake in 2006, Collins Lake in 2007, Creamery Pond in 2008, Lake Ronkonkoma in 2010, Snyders Lake in 2002, and Waneta Lake in 2006- exhibited frequency-corrected mean C_m values that were negative. ALL of these lakes were either subject to active management in response to excessive weed growth (*Hydrilla verticillatum* in Creamery Pond, *Myriophyllum spicatum* in Collins Lake, Snyders Lake and Waneta Lake), or otherwise conducted surveys to evaluate perceived excessive weed growth. This suggests that the frequency-corrections of mean C_m values in these lakes provided a more accurate assessment of aquatic plant community conditions than did uncorrected mean C_m values. In contrast, the majority of the lakes presented in Table 5.4.2 with positive mean C_m values, both uncorrected and corrected for plant frequency, were not dominated by invasive species, although there were some exceptions (as discussed in Section 6 below).included in Table 4.3; only a randomly-chosen subset of these data (lake-years) were used to evaluate the influence of plant frequency on mean C_m values. This table includes the uncorrected (projected) mean C_m values and those corrected for plant frequency (pC_{m_uf}).

The range of frequency-corrected mean C_m values presented in Table, from -1.6 in Lake Ronkonkoma to 0.79 in Hards Pond, is much smaller than the range of uncorrected mean C_m values (-3.7 to + 3.1). While some of these smaller differences will be expanded when these values are applied to the FQI equations 1.1 and 1.2, these differences will also be much larger when mean C_m values are corrected for absolute abundance, as discussed in Section 6. However, these frequency-corrected mean C_m data do seem to more closely align with observations about relative invasive species abundance than do uncorrected mean C_m data.

Table 5.4.2- Comparison of Frequency-Corrected Mean C_m Values to Uncorrected Values

Year Lake	Year	Std. Density	Uncorr pCm_ 1/ha	Corr pCm_uf 1/ha
Ballston Lake	2006	48	1.2	-0.14
Big Fresh Pond	2006	13	2.6	0.84
Blydenburgh Lake	2012	40	-1.4	-0.17
Blydenburgh Lake	2014	40	-0.3	-1.06
Cazenovia Lake	2010	225	1.7	0.39
Cazenovia Lake	2013	225	1.8	0.36
Cazenovia Lake	2016	225	1.7	0.33
Cazenovia Lake	2019	225	1.7	0.38
Collins Lake	2007	5	0.5	-0.05
Creamery Pond	2008	4	0.0	-0.13
Creamery Pond	2010	4	0.3	0.18
Creamery Pond	2012	4	0.6	0.18
Hards Pond	2011	12	2.3	0.79
Java Lake	2010	21	1.1	0.20
Kinderhook Lake	2007	109	-0.5	-0.67
Lake Luzerne	2010	24	2.3	0.39
Lake Ronkonkoma	2010	21	1.5	-0.75
Lake Ronkonkoma	2014	21	-3.7	-1.60
Lamoka Lake	2006	160	2.1	0.26
Lamoka Lake	2009	160	2.3	0.40
Morehouse Lake	2010	35	3.1	0.50
Quaker Lake	2010	64	2.1	0.39
Saratoga Lake	2010	657	2.3	0.31
Saratoga Lake	2012	657	2.1	0.17
Snyders Lake	2002	15	0.5	-0.61
Snyders Lake	2005	15	1.0	0.24
Snyders Lake	2008	15	0.8	0.00
Snyders Lake	2011	15	1.2	0.34
Waneta Lake	2006	170	1.4	-0.05
Waneta Lake	2009	170	2.0	0.25

It should also be noted that the frequency-corrected mean C_m values for many lakes (Column 5 in Table 5.4.2) is close to zero, so traditional evaluations of % change can result in very high numbers. For example, if the frequency-corrected mean C_m value of a lake is 0.05, the comparison to a lake with a projected mean C_m of 0.1 represents a 100% difference (= (0.1-0.05)/0.05). This requires a second evaluation criteria. In addition to evaluating the percentage change associated with projecting values, changes less than some low absolute value (such as 0.1 C_m "units" in this analysis) would also be considered within an acceptable range of change. This is discussed further below.

Section 5.5- Estimating Mean Frequency-Corrected C_m From Truncated Surveys

As discussed in Section 4 of White Paper 1D (regarding projected species richness or pSR), and in Section 4 of this White Paper (regarding uncorrected projected coefficients of conservatism, or pC_m), truncated aquatic plant surveys can be used to estimate pSR and pC_m at a standardized survey site density of 1 site per littoral hectare. The use of truncated surveys can save significant resources, thereby allowing more surveys on more waterbodies, or can be used to justify multiple years of surveys on a single waterbody.

Table 4.4.2 in White Paper 1D indicates that 10-15 sites are sufficient to estimate the pSR at 1 site per littoral hectare at an accuracy of more than 95% for small lakes- those with less than 100 hectares of littoral area, although for lakes smaller than 10-15 hectares of littoral area, observed species richness (oSR) values can be computed or measured at the 1 site per littoral hectare survey site density. For larger lakes, Table 4.4.3 in White Paper 1D indicates that a similarly high accuracy of estimating pSR can be achieved with a truncated survey of 25 sites. A similar approach can be used to estimate mean C_m at the same survey site density of 1 site per littoral hectare.

Table 4.4.2 shows that 15 survey sites are sufficient to project mean C_m values in more than half of the surveyed small lakes to an accuracy of 95%, and in more than 75% of the surveyed lakes to an accuracy of 90%. For larger lakes (> 40 hectares of littoral area, Table 4.4.3), 95% accuracy cannot be achieved, by 90% accuracy in estimating mean C_m values can be achieved with 25 survey sites in more than half of the surveyed lakes. The same data show that 80% accuracy can be achieved in more than 75% of the lakes.

Table 5.5.1- First Regression Achieving Various % of Frequency-Corrected pC_m in All Small PIRTRAM Lakes

	First >50%	First >75%	First >90%
%±30%	1-15	5-15	1-25
%±20%	1-15	5-15	1-25
%±10%	1-15	5-15	1-25
%±5%	1-15	5-15	1-25

The same approach can be used to estimated projected mean C_m values corrected for aquatic plant frequency using a relatively small number of survey sites. As discussed above, frequency-corrected mean C_m values can be very close to zero, so percentage differences (between mean C_m projected at 1 site per littoral hectare and mean C_m estimated from regressions of a few survey sites data projected to the same survey site density) in these lakes can appear to be very high. To account for that, "acceptable" estimates meet either a high percentage accuracy criterion or fall within 0.1 C_m units.

Table 5.5.2- First Regression Achieving Various % of Frequency-Corrected pC_m in All Large PIRTRAM Lakes

	First >50%	First >75%	First >90%
%±30%	5-15	5-25	10-25
%±20%	5-15	5-25	15-25
%±10%	5-15	5-25	15-25
%±5%	5-15	5-25	15-25

Appendix 5.5.1 shows summary frequency-corrected C_m data for all lakes, for small and large lakes, and for those lakes with the number of survey sites greater than (or less than) the standardized survey site density of 1 site per littoral hectare. These data only show the percentage of lakes (lake years) that meet the percentage change criteria- for example, the percentage of all PIRTRAM lake years (=16%) for which mean C_m values from a regression of the (mean C_m) data from Sites 1-15, corrected for plant frequency, are within 95% of the mean C_m value projected at a survey site density of 1 site per littoral hectare (also corrected for plant frequency). Appendix 5.5.2 includes all of the lakes in Appendix 5.5.1 that meet the cited criteria AS WELL AS those lakes for which the frequency-corrected regressed mean C_m values fall within 0.1 C_m units of the frequency-corrected mean C_m values at the standardized survey site density.

Table 5.5.1 indicates that 15 sites are sufficient (using regressions of the 1^{st}-15^{th} sites or the 5^{th}-15^{th} survey sites) to estimate the projected mean C_m values corrected for plant frequency to an accuracy of 95% in at least 50-75% of small lakes. 25 sites are needed to afford the same accuracy in more than 90% of the surveyed lakes.

Table 5.5.2 provides the same summary information for large lakes, defined here as having > 40 hectares of littoral area. These data show that 15 sites are sufficient, even in large lakes, to estimate to within 95% the projected frequency-corrected mean C_m values for more than half of the surveyed lakes. However, 25 sites may be needed to achieve the same accuracy in more than 75% of the lakes.

These data, consistent with those presented in Section 4, suggest that 15 survey sites are sufficient to estimate frequency-corrected mean C_m values (used in the FQI equations 1.1 and 1.2 above) at a very high (>95%) accuracy in more than 50-75% of small lakes. These same data indicate that 25 survey sites are needed to achieve a similarly high accuracy in more than 50-75% of large lakes.

Section 6- Weighted C_m and evaluation of plant abundance

Section 6.1- Background Information

As discussed in White Paper 1C Section 3, and in Section 5 of this White Paper, floristic quality indices (FQI) calculated using formulae (Equation 1.1 and 1.2) unweighted for plant frequency run the risk of inaccurate assessments of floristic quality based on those FQI calculations (specifically, corrections to mean C_m values). An even greater risk applies with using mean C_m and FQI values that are not weighted for plant abundance. Weighing mean C_m for plant abundance is more challenging than weighing these mean C_m values for plant frequency, since the latter is essentially a binary choice (“present” or “absent”), while the former can be evaluated in many ways. These are discussed at length in White Paper 1C, Section 9, but are also briefly discussed in Section 6.3 below.

Section 6.2- Monitoring Programs Used to Evaluate FQI and Plant Abundance

Section 5.2 summarizes the limitations of the NYS BioSurvey, ALSC and AWI programs in generated projected mean C_m values weighted for plant frequency, and the same limitations apply to the use of plant abundance-weighted FQI values. The PIRTRAM lakes dataset, however, possess both the granular survey site data and the relative plant abundance data required to generate abundance-weighted projected mean C_m values. As discussed above, there were about 50 lakes were surveyed using the PIRTRAM methodology, some of which were sampled for multiple years. The PIRTRAM dataset is the basis for these evaluations in the balance of Section 6.

It should be noted that although the NYS BioSurvey lakes were assigned a single relative abundance “value” for each plant, these data cannot be compared directly to the relative abundance data generated at individual PIRTRAM survey sites. However, future iterations of this evaluation may bring in the NYS BioSurvey data for comparisons between uncorrected and relative abundance-corrected FQI values.

Section 6.3- Calculating Plant Abundance Corrections to Projected Mean C_m

As noted above, the standard formula for determining projected mean C_m and FQI values does not account for plant abundance. As with plant frequency, plant abundance can be evaluated as a relative (normalized) or absolute (unbounded) factor. The weighting factors associated with plant abundance should also be assigned to the "component" (individual plant) and mean (overall aquatic plant community) C_m values, as with frequency-based factors, since the weighting would influence the quality of the plant community rather than the number of plant species.

Plant abundance was estimated at nearly all of the lakes surveyed in the PIRTRAM aquatic plant dataset, using the previously cited US Army Corps of Engineers and Cornell/SUNY Oneonta relative abundance scales, applied to two-sided rake toss data. These relative abundance assessments are introduced in White Paper 1C, Section 3, culminating in a summary of relative abundance scales in Table 5.3. The same table is reproduced here as Table 6.3.1.

Table 6.3.1: Plant Abundance Categories Used in NYS Plant Surveys

Density Category	Estimated Quantity from Average of 1-2 Rake Tosses	Approximate Biomass	Assigned Score
No plants (Z)	Nothing	0 g/m^2	0
Trace (T)	Fingerful (of plants)	up to 0.1 g/m^2	1
Sparse (S)	Handful	0.1 to 20 g/m^2	5
Medium (M)	Rakeful	20 to 100 g/m^2	25
Dense (D)	Can't Bring In Boat	100 to 400 g/m^2	125

Reference: Kishbaugh, 2020; Johnson, 2008

The approximate biomass associated with each density category was generated from multiple paired rake toss and quadrant biomass sampling conducted at Chautauqua Lake (Johnson, 2008). The assigned score in Table 6.3.1 represents a $\log_5$ scale representing the relationship between a density category and approximate biomass (Kishbaugh, 2020). Other researchers may elect to choose a different scale for defining the weighted distinction between density categories used in the PIRTRAM method and in Table 6.3.1, but it is not anticipated that the results discussed below would change significantly in response to using this alternative weighting scale.

As with plant frequency corrections, relative abundance measures can be used to corrected component and mean C_m values, as summarized below and in more detail in White Paper 1C, Section 9:

a. *Relative or normalized abundance* refers to a means for evaluating those plants that occur at a higher abundance than other plants, regardless of the absolute abundance. The formula used to calculate normalized weighted abundance mean C_m values is as follows:

Equation 6.3.1: $C_{(m)}\_na$ = *sum of (all sites abundance x C_m value for species) / sum of all sites taxa abundance* where “a” refers to abundance (the other terms are defined in Equation 4.3.1)

b. *Absolute or unbounded abundance* refers to the means for evaluating those plants that are more abundant than other plants, regardless of the relative abundance. The same general method used for evaluating absolute plant frequency is also applied here for evaluating absolute plant abundance, and is described in Equation 5.3.2:

Equation 6.3.2: C_{m_ua} = *sum of (all sites abundance x C_m value for species) / (number of plant species x number of sites)*

The C_{m_na} values generally fall within the same range (scales) as both the traditional C_{ny} and modified C_m values, and therefore the modified FQI values using the modified C_m values corrected for normalized frequency can be evaluated using criteria established for uncorrected C values (as discussed in White Paper 1G). Other criteria are needed to evaluate modified C_m values corrected for unbounded or absolute frequency (C_{m_uf}), since these C values reside on a different scale than can accurately be characterized using uncorrected FQI criteria. These are summarized in Section 5. **However, absolute or unbounded abundance corrections are much more easily applied to projected individual (component) and mean (community) C_m values, as discussed in White Paper 1C, so modified C values corrected for unbounded abundance (C_{m_ua}) are calculated for the PIRTRAM dataset and discussed below.**

Section 6.4- Evaluating Absolute (Unbounded) Abundance Corrections to Mean C_m

Table 6.4.1 shows the mean projected C_m values corrected for absolute plant frequency for most of the PIRTRAM lakes- these values are show in the furthest column to the right under the heading “Corr pCm_ua 1/ha”. These abundance corrections were applied to more lakes than were the frequency corrections; granular survey site data for Chautauqua Lake, Lake Waccabuc, Lake Rippowam, Oscaleta Lake, and some survey years for other PIRTRAM lakes were analyzed for absolute abundance corrections but not for frequency corrections to mean C_m. In addition, abundance data were not available for Lamoka and Waneta Lakes, so projected mean C_m values were corrected (only) for absolute plant frequency in these lakes.

Each of the lakes with negative projected mean C_m values corrected for plant frequency (the fifth column in Table 6.4.1) also exhibited negative projected mean C_m values corrected for plant abundance. However, there were also lakes with negative corrected mean C_m values for plant abundance that had positive corrected mean C_m values for plant frequency- in other words, some lakes did not exhibit “negative” floristic quality based on plant frequency but did exhibit negative floristic quality when considering plant abundance. For example, Creamery Pond in both 2010 and 2012 has low but positive projected mean C_m values when corrected for plant frequency, but highly negative projected mean C_m values when corrected for (absolute) plant abundance. A more detailed discussion about the lakes cited in Table 6.4.1, particularly those with “imbalances” between the uncorrected and (frequency- or abundance-) corrected mean C_m values is provided below.

Table 6.4.1- Comparison of Abundance-Corrected Mean Projected C_m Values to Uncorrected Values

Year Lake	Year	Std. Density	pCm_ 1/ha	Corr pCm_uf 1/ha	Corr pCm_ua 1/ha
Ballston Lake	2006	48	1.2	-0.14	-10.6
Big Fresh Pond	2006	13	2.6	0.84	8.7
Blydenburgh Lake	2012	40	-1.4	-0.17	-86.6
Blydenburgh Lake	2014	40	-0.3	-1.06	-60.6
Cazenovia Lake	2010	225	1.7	0.39	1.9
Cazenovia Lake	2011	225	1.9		0.9
Cazenovia Lake	2012	225	1.8		1.7
Cazenovia Lake	2013	225	1.8	0.36	-1.3
Cazenovia Lake	2014	225	1.7		0.5
Cazenovia Lake	2015	225	1.8		-1.3
Cazenovia Lake	2016	225	1.7	0.33	-3.4
Cazenovia Lake	2017	225	1.7		1.9
Cazenovia Lake	2018	225	1.6		-0.1
Cazenovia Lake	2019	225	1.7	0.38	2.0
Cazenovia Lake	2020	225	1.7		0.6
Cazenovia Lake	2021	225	1.9		1.7
Chautauqua Lake	2015	2060	2.1		0.3
Chautauqua Lake	2017	2060	2.3		0.5
Chautauqua Lake	2019	2060	2.0		0.7
Chautauqua Lake	2021	2060	1.9		0.1
Collins Lake	2007	5	0.5	-0.05	1.8
Creamery Pond	2008	4	0.0	-0.13	-45.1
Creamery Pond	2010	4	0.3	0.18	-27.9
Creamery Pond	2012	4	0.6	0.18	-24.4
Hards Pond	2011	12	2.3	0.79	4.5
Java Lake	2008	21	1.7		3.9
Java Lake	2009	21	2.0		4.6
Java Lake	2010	21	1.1	0.20	3.1
Kinderhook Lake	2006	109	-0.6		-4.6
Kinderhook Lake	2007	109	-0.5	-0.67	-7.8
Lake Luzerne	2009	24	2.3		0.8
Lake Luzerne	2010	24	2.3	0.39	1.6
Lake Rippowam	2008	4	-1.4		-0.7
Lake Rippowam	2016	4	-1.2		-0.6
Lake Rippowam	2018	4	-1.3		4.7
Lake Rippowam	2020	4	-1.4		-6.3
Lake Ronkonkoma	2010	21	1.5	-0.75	-68.2
Lake Ronkonkoma	2014	21	-3.7	-1.60	-25.6

a. Lakes with low uncorrected and frequency corrected C_m but relatively high abundance corrected C_m. This category includes Java Lake, Saratoga Lake, and Collins Lake. Each of these lakes had a mix of native and invasive plants, resulting in depressed uncorrected and frequency corrected mean Cm. However, the dominant plants in these lakes were native; in Java- the most abundant plants, by far, were *Ceratophyllum demersum* and water lilies- these can be considered nuisance plants, but both are native. In Saratoga Lake, the most abundant plants were *Ceratophyllum demersum* and *Najas quadalupensis*, and in Collins Lake, the most abundant plants were *Najas flexilis*, *Potamogeton zosteriformis* and *Elodea canadensis*. For all of these lakes, a relatively high abundance of native plants results in projected abundance-corrected mean C_m values that were higher than expected give the presence of invasive and nuisance native plants.

b. Lakes with relatively stable readings mean C_m values. These include Chautauqua Lake and Lake Waccabuc. Both of these lakes experienced local management (hand pulling *Egeria densa* in Waccabuc) or a relative consistency in management actions (harvesting in large portions of Chautauqua Lake, with herbicides in only a relatively small area of the lake in recent years). This leads to a relative stability in mean C_m values.

Table 6.4.1 (cont)- Comparison of Abundance-Corrected Mean Projected C_m Values to Uncorrected Values

Year Lake	Year	Std. Density	pCm_ 1/ha	Corr pCm_uf 1/ha	Corr pCm_ua 1/ha
Lake Waccabuc	2008	20	1.3		-0.4
Lake Waccabuc	2010	20	1.4		0.2
Lake Waccabuc	2013	20	1.4		0.2
Lake Waccabuc	2014	20	1.7		0.4
Lake Waccabuc	2015	20	1.6		0.4
Lake Waccabuc	2016	20	1.6		0.1
Lake Waccabuc	2017	20	1.7		0.5
Lake Waccabuc	2019	20	1.4		0.5
Lake Waccabuc	2021	20	1.3		-0.1
Lamoka Lake	2006	160	2.1	0.26	
Lamoka Lake	2009	160	2.3	0.40	
Morehouse Lake	2010	35	3.1	0.50	5.2
Oscaleta Lake	2008	8	1.3		0.9
Oscaleta Lake	2016	8	1.5		3.0
Oscaleta Lake	2018	8	1.2		7.6
Oscaleta Lake	2020	8	1.0		10.9
Quaker Lake	2010	64	2.1	0.39	-1.5
Saratoga Lake	2010	657	2.3	0.31	7.3
Saratoga Lake	2011	657	2.1		2.9
Saratoga Lake	2012	657	2.1	0.17	2.9
Snyders Lake	2002	15	0.5	-0.61	-11.9
Snyders Lake	2005	15	1.0	0.24	-3.3
Snyders Lake	2008	15	0.8	0.00	-5.8
Snyders Lake	2011	15	1.2	0.34	5.4
Waneta Lake	2006	170	1.4	-0.05	
Waneta Lake	2009	170	2.0	0.25	

c. Lakes with negative values for all forms of mean C_m (uncorrected and corrected for plant frequency or abundance). These lakes generally have few plant species but a relative high proportion of invasives in high abundance, consistently year to year. These include Blydenburgh Lake, Lake Ronkonkoma, and Kinderhook Lake. All of these lakes were dominated by invasive species in both frequency and abundance, resulting in negative mean C_m values- in some cases, indicative of highly degraded conditions (based on highly negative abundance-corrected mean C_m values (C_{m_ua}).

d. Lakes with more negative abundance-corrected mean C_{m_ua}) than expected given the frequency of plants (and therefore mean C_{m_uf}) values. These include Creamery Pond and Ballston Lake. These lakes have only a few invasive species, and comparatively large numbers of natives), but these invasives dominate the (abundance of) the aquatic plant communities.

e. Lakes with consistently positive mean C_m values, including Big Fresh Pond, Hards Lake, Lake Luzerne and Morehouse Lake, These are lakes dominated by native plants in frequency and abundance, even if some invasives are present.

f. Lakes with highly variable mean C_m values from year to year, including Cazenovia Lake, Lake Rippowam, Oscaleta Lake, and Snyders Lake. These can be summarized as follows:

   a. Cazenovia Lake- Uncorrected mean C_m values were very stable in Cazenovia Lake from 2010 to 2021, and the subset of years for which mean C_m values were corrected for absolute plant frequency (2010, 2013, 2016, 2019) showed a very high stability in mean C_{m_uf} values. However, mean C_m values corrected for absolute abundance (mean C_{m_ua} values) were much more variable- negative in 2013, 2015, 2016, and 2018, and (low but) positive in the other years. In the years with the most negative mean C_{m_ua} values- 2013, 2015 and 2016- *Myriophyllum spicatum* was the most abundant plant in the lake, but in no other year was this invasive plant the most abundant in the lake.
   b. Lake Rippowam- positive mean C_{m_uf} values were calculated in 2018, but negative mean values were calculated in the other survey years (2008, 2016 and 2020) shown in Table 6.4.1. In 2018, *Myriophyllum spicatum* comprised, by abundance, about 6% of the aquatic plant community. In the other surveyed years, *M.spicatum* constituted between 19% and 22% of all plants in the lake. The highest relative percentage of *M.spicatum* (22% by abundance) occurred in 2020, corresponding to the lowest abundance-corrected projected mean C_m values for the lake in Table 6.4.1.
   c. Oscaleta Lake- abundance-corrected projected mean C_m values ranged from 10.9 in 2020 to 0.9 in 2008. The primary difference between these years is the percentage of the aquatic plant community associated with Eurasian watermilfoil, ranging from 7% in 2020 to about 16% in 2008.
   d. Snyders Lake- also exhibited a wide variation in abundance-corrected mean C_m values, ranging from negative values in 2002, 2005 and 2008, and positive values in 2011. This lake was treated on multiple occasions for excessive growth of invasive plants- *Myriophyllum spicatum* in the late 1990ss and *Najas minor* (spot treatment) in the early 2000s. In the years in which abundance-corrected projected mean C_m values were negative, these two invasive plants were among the three most abundant plants in the lake- most often the two most abundant plants. However, in 2011, native plant species comprised all of the five most abundant plants in the lake.

Section 6.5- Estimating Mean Abundance-Corrected C_m From Truncated Surveys

As with uncorrected mean C_m values and those corrected for unbounded plant frequency, mean C_{m_ur}, truncated aquatic plant surveys can be used at a standardized survey site density of 1 site per littoral hectare to accurately estimate mean C_m corrected for absolute plant abundance (C_{m_ua}). As discussed at length in White Paper 1C and in Sections 4 and 5 in this White Paper, the use of truncated surveys can save significant resources, thereby allowing more surveys on more waterbodies, or can be used to justify multiple years of surveys on a single waterbody. However, as seen below, these estimates are not as accurate as those generated for uncorrected mean C_m values or those corrected for plant frequency (mean C_{m_uf}) due to the wide variation in these (abundance-corrected) values across lakes. In addition, while plant frequency can be accurately calculated as a binary choice ("present" or "not present") for individual plants or any combination of sites in a waterbody, plant abundance can only be estimated on a relative scale. Although the plant abundance scales presented in Table 6.3.1 appear to accurately represent the range and relative amount of plants in rake toss collections, these are still estimates that carry some uncertainty and therefore impart some errors.

Table 6.5.1- First Regression Achieving Various % of Abundance-Corrected pC_m in All Small PIRTRAM Lakes

	First >50%	First >75%	First >90%
%±30%	5-15	5-25	5-25
%±20%	5-15	5-25	20-80
%±10%	5-15	20-80	20-80
%±5%	5-25	20-80	none

Table 6.5.1 shows the relationship between the first site regressions for which the estimated mean C_{m_ua} values for various percentages of small lakes fall within ranges of accuracy. This table shows, as an example, that the regression of the estimated corrected mean C_m from the 5th to the 25th survey sites in more than 50% of the small (< 40 hectares littoral area) PIRTRAM lakes will estimate within 95% accuracy the mean C_{m_ua} projected at a survey site density of 1 site per littoral hectare. This indicates that for **small lakes, 15 survey sites are sufficient to estimate the projected standardized mean C_{m_ua} to an accuracy of 90% in at least half of the lakes, but that 25 sites would be needed to improve this accuracy to 95% in more than half of the lakes**, or to achieve 80% accuracy in more than 75% of the lakes, or to achieve 70% accuracy in more than 90% of the lakes.

Likewise, Table 6.5.2 shows that **in large (>40 hectares littoral area) lakes, 40 survey sites are needed to ensure 90% accuracy in half of the lakes, and 60 survey sites would be needed to assure 80% accuracy in 75% of the lakes**. 90-95% accuracy cannot be achieved in more than 75% of the lakes using truncated surveys, likely consistent with the much higher variability found in estimating mean C_m values corrected for absolute plant abundance.

Table 6.5.2- First Regression Achieving Various % of Abundance-Corrected pC_m in All Large PIRTRAM Lakes

	First >50%	First >75%	First >90%
%±30%	15-40	10-60	25-80
%±20%	15-40	25-60	none
%±10%	20-40	none	none
%±5%	20-80	none	none

These data suggest that 90% accuracy is sufficient to accept the results from truncated (reduced site) aquatic plant surveys, 15 sites in small lakes and 40 sites in large lakes are sufficient to accurately estimate abundance-corrected mean C_m values in half of the surveyed lakes. Likewise, if a reduction in accuracy to 80% is acceptable, abundance-corrected mean C_m values in more than 75% of surveyed lakes could be accurately estimated with 25 sites in small lakes and 60 sites in large lakes, recognizing that for lakes with less than 25 hectares of littoral area, these abundance-corrected mean C_m values can be calculated directly rather than projected.

Section 6.6- Summary of Truncated Survey Results for Evaluating C_m

Table 6.6.1 summarizes the percent accuracy in estimating the standardized mean C_m values from 15 site and 25 site regressions (that is, estimating the projected mean C_m values using only those data from regressions from the mean C_m data at each survey site for up to 15 and 25 sites) in various percentages of small lakes. This table includes summary data for evaluating uncorrected mean C_m and mean C_m values corrected for absolute frequency and absolute abundance. These data show that a 15 site survey is sufficient to achieve an accuracy of at least 90%-95% for more than half of the surveyed small lakes regardless of whether these mean C_m values are uncorrected or corrected for frequency or abundance. This accuracy drops to at least 80-95% if at least 75% of the small lakes are held to this standard, and may require 25 survey sites if the same accuracy is desired for at least 75%-90% of small lakes. As discussed above, for small lakes with less than 15-25 hectares of littoral area, mean C_m values can be calculated from the 15-25 survey sites rather than projected from regressions of these surveys. For small lakes with littoral areas greater than 15-25 hectares (up to 40 hectares), projected mean C_m values should be estimated from these regressions.

Table 6.6.1- % Accuracy in Corrected and Uncorrected C_m Values Achieved in Small PIRTRAM Lakes with 15 to 25 Survey Sites

	Uncorrected		Freq. Corrected		Abund. Corrected	
	15 Sites	25 Sites	15 Sites	25 Sites	15 Sites	25 Sites
>50% Small Lakes	>95%	>95%	>95%	>95%	>90%	>95%
>75% Small Lakes	>90%	>90%	>95%	>95%	>80%	>80%
>90% Small Lakes	>70%	>80%	<70%	>95%	<70%	>70%

Table 6.6.2- % Accuracy in Corrected and Uncorrected C_m Values Achieved in Large PIRTRAM Lakes with 25 to 60(-80) Survey Sites

	Uncorrected			Freq. Corrected			Abund. Corrected		
	25 Sites	40 Sites	60-80 sites	25 Sites	40 Sites	60-80 Sites	25 Sites	40 Sites	60-80 Sites
>50% Large Lakes	>90%	>90%	>90% ^	>95%	>95%	>95% ^	<70%	>90%	>95% +
>75% Large Lakes	>80%	>80%	>80% ^	>95%	>95%	>95% ^	<70%	<70%	>80% ^
>90% Large Lakes	<70%	>70%	>70% ^	>95%	>95%	>95% ^	<70%	<70%	>70% +

^ Accuracy achieved in 60 sites
+ Accuracy achieved in 80 sites

For large lakes, Table 6.6.2 provides a similar summary of the percent accuracy in 25 and 40 site surveys in estimating uncorrected and corrected mean C_m values. These data show that 25 sites are sufficient to evaluate frequency-corrected mean C_m values at a very high accuracy, while 40 sites are required to achieve more than 90% accuracy in more than half of the large surveyed lakes for uncorrected or abundance-corrected mean C_m values. Truncated surveys- using 25 or 40 sites- cannot achieve a similarly high accuracy in more than 75%-90% of lakes, but more than 95% accuracy can be achieved in 80 survey sites in more than half of the large lakes for abundance-corrected mean C_m values, or more than 80% accuracy can be achieved using 60 survey sites in more than 75% of abundance-corrected mean C_m values in large lakes.

As discussed at length in Section 6, abundance-corrected mean C_m values appear to be the most accurate means for evaluating coefficients of conservatism in New York state lakes. The data summarized in Table 6.6.2 indicate that **for small lakes, 15 survey sites appear to be sufficient to achieve more than 90% accuracy in estimating abundance-corrected mean C_m values in more than half of small surveyed lakes, and 25 survey sites may be sufficient to achieve an accuracy of more than 80% in more than 75% of lakes, or an accuracy of more than 70% in more than 90% of small surveyed lakes. For large lakes, 40 survey sites may be sufficient to achieve an accuracy (in estimating abundance-corrected mean C_m values) of more than 90% in more than 50% of large surveyed lakes, 60 survey sites may be needed to achieve an accuracy of more than 80% in more than 75% of large lakes, and 80 survey sites may be needed to achieve an accuracy of more than 70% in more than 90% or large lakes**.

There may be many differences in how monitoring programs define relative abundance. For example, some programs use single rake toss data to define relative abundance. Some programs use multiple tosses and average the ordinal relative abundance (a 1 in the first throw and 4 are the third throw are "averaged" as a 2.5, although the weighted average would be 63 (=(125+1)/2), while the unweighted average would be 56 (= 5^((4+1/2)). A more extreme example is two tosses of 4 and 0 = unweighted of (4-0)/2 = 2 and relative abundance of 5 (conversion of ordinal 2), or weighted = (125+0)/2 = 62.5. Some monitoring programs usedweighted averages.

These differences may be important in evaluating data from multiple programs which use different methods to get to a single value for each site and each lake. This was apparent when evaluating PRISM surveys, some of which conducted simple averages of ordinal values and some of which reported individual toss data. Most of the PIRTRAM lakes reported both two tosses and a single relative abundance ordinal value for the compilation of the two tosses, but not clear how the single value was computed (unweighted averages, weighted averages, etc.)

Ultimately, lake managers can use this information to determine the number of survey sites needed to achieve sufficiently high accuracy in estimating abundance-corrected mean C_m values in surveyed lakes, in an attempt to balance the number of (and effort associated with) survey sites with the accuracy needed to achieve sufficient confidence in evaluating floristic quality. If these managers would prefer to use frequency-corrected or uncorrected mean C_m values in FQI equations, Table 6.6.2 can also be used to determine the number of survey sites appropriate to achieve an acceptable accuracy. It should again be noted that, for lakes with littoral areas less than 25-40 (or 60) hectares, conducting surveys with the number of sites equivalent to the standardized survey site density of 1 site per littoral hectare (so, for example, 20 sites in a 20 ha littoral lake) allows for computation of "observed" mean C_m rather than "projected" mean C_m values.

Section 7: Potential C Value Metrics- What is a Good C_m Value?

Section 7.1- Evaluating Uncorrected Mean C_m Values

Floristic quality values associated with high and low quality lakes is discussed at length in White Paper 1G in the context of evaluating floristic quality indices (FQIs), using multiple criteria established in other settings. A similar metric system has not yet been developed for evaluating mean C values. One of the potential FQI metrics has been established in the state of Florida. Botanists from that state have designed broad categories of aquatic plant community values, as summarized in Table 7.1.1. (Fore et al, 2007). These plant sensitivity categories can be compared to the C_m value system established in Section 3 above. Based on these C_m value definitions "sensitive" plants cited in Table 7.1.1 could be assigned a C_m value of 5 (corresponding to protected plants, consistent with the designations used in many other states). "Tolerant" plants could be assigned a C_m value of 1, consistent with observations of nuisance native plants. All other "native" plants could be considered "intolerant" and assigned a C_m value of 3. All exotic plants, including all invasive species, could be assigned a C_m value of -3, corresponding to the midpoint in the modified C_m value system between exotic but not invasive (C_m = -1) and exotic and highly invasive (C_m = -5). It should be noted that most exotic plants are actually (already) assigned a C_m value of -3, as discussed above.

Table 7.1.1- Typical Aquatic Plant Community Designations

Aquatic Plant Community Designation	Description
Outstanding	67% "sensitive", 0% "tolerant", 90% "native", 0% "invasive"
Excellent	20% "sensitive", 20% "tolerant", 85% "native", 0% "invasive"
Fair	15% "sensitive", 35% "tolerant", 70% "native", 10% "invasive"
Poor	0% "sensitive", 50% "tolerant", 60% "native", 25% "invasive"
Very Poor	0% "sensitive", 40% "tolerant", 40% "native", 40% "invasive"

From Fore, L.S. et al, 2007

Table 7.1.2- Mean C_m Values Associated with Aquatic Plant Community Designations

	Outstanding	Excellent	Fair	Poor	Very Poor
Mean C_m	> 4.0	2.6-4.0	1.4-2.6	0.0-1.4	-0.8 – 0.0

Table 7.1.2 shows uncorrected mean C_m values required to meet the criteria associated with the "Outstanding", "Excellent", "Fair", "Poor", and "Very Poor" floristic quality designations. "Outstanding" floristic quality requires a predominance of protected plant species, which are likely not found in any New York state lakes. "Excellent" conditions are associated with lakes dominated by benign native plant species, which convey many important ecosystem functions to lakes. Lakes with excellent floristic quality can include some nuisance native plants (with C_m < 3), but invasive plants are generally not found in these lakes. "Fair" floristic quality is associated primarily nuisance native plants, and "poor" floristic quality is associated primarily with a mix of nuisance native and exotic plants. "Very poor" conditions are limited to those lakes with at least several exotic plants, including those that behave invasively. It should be noted that the

designations cited in Table 7.1.2 do NOT include corrections for the frequency or abundance of plants, but instead only evaluates the presence of plants, whether they are common or uncommon in lakes. It should also be noted that there is only a small spread in mean C_m values between "outstanding" and "very poor"- only about 5 C_m "units" (4.0 to -0.8), but this is similar to the spread in mean C_m values using the traditional New York C_{ny} system (Figures 4.3.2.1 through 4.3.2.3).

Table 7.1.3- % PIRTRAM Lakes Meeting C_m Evaluation Criteria from Table 7.1.2

	C_m Evaluation using Table 7.1.2 Criteria				
	Outst.	Exc.	Fair	Poor	V.Poor
% Lakes Using C_m	0%	10%	48%	24%	19%

Legend- Outst = Outstanding, Exc = Excellent; Cm = modified C value system

When these criteria are applied to the PIRTRAM lakes with granular survey site data (and therefore a sufficient database to compute projected mean C_m values), the majority of these lakes can be characterized as having "fair" to "very poor" floristic quality. These data are presented in Table 7.1.3, for 21 PIRTRAM lakes. "Excellent" floristic quality is limited to those lakes- Morehouse Lake and Big Fresh Pond- with no exotic plants. Even those lakes (Lake Luzerne) with a very high diversity of moderate- to high-floristic quality plants cannot completely offset the small number of invasive plant species, resulting in essentially every lake with any invasive plants to be characterized as "fair" (or worse). While this may be intuitively satisfying- befitting the focus of agencies and lake communities on the impact of invasive species for aquatic plant communities- this does not account for the frequency or abundance of plants. Therefore, lakes with only a few specimen of invasive plants and many specimen of native plants may be characterized the same as lakes with many invasive plant specimen and few native plant specimen (recognizing that this example may in fact not be realistic due to the actual plant dynamics in lakes with ANY invasive species).

Table 7.1.4- % Lakes in Each NYS Monitoring Program Meeting C_m Evaluation Criteria Using Table 7.1.2

	C_m Evaluation using Table 7.1.2 Criteria				
Program	Outst.	Exc.	Fair	Poor	V.Poor
NYS BioSurvey-all	0%	61%	39%	0%	0%
BioSurv Adks	0%	80%	20%	0%	0%
BioSurv non Adks	0%	51%	49%	0%	0%
AWI	0%	26%	71%	3%	0%
PIRTRAM	0%	10%	48%	24%	19%

Legend- Outst = Outstanding, Exc = Excellent; Cm = modified C value system

In addition, while the preponderance of "fair" to "very poor" lakes among the PIRTRAM dataset may seem instinctively correct since these lakes were included in PIRTRAM surveys in response to existing or perceived future management, a comparison to historical data suggests that the use of uncorrected mean C_m values may not accurately characterize floristic quality in New York state lakes. Only the PIRTRAM dataset among the New York state aquatic plant survey programs has the granular survey site data to calculate a mean C_m value projected to a standardized survey site density of 1 site per littoral hectare. However, the strong relationship between observed mean C_m

at all survey sites and the projected mean C_m at this standardized survey site density (Figures 4.3.1 and 4.3.2) suggests that observed mean C_m can be used to evaluate mean C_m criteria.

Table 7.1.5- Mean C_{ny} Values Associated with Aquatic Plant Community Designations

	Outstanding	Excellent	Fair	Poor	Very Poor
Mean C_{ny}	> 6.0	4.3-6.0	2.9-4.3	1.6-2.9	0.8-1.6

Table 7.1.4 shows the percentage of lakes in two of the other monitoring programs cited in White Paper 1A (the NYS BioSurvey and AWI) meeting each of the mean C_m criteria developed in Table 7.1.2 (the ALSC data do not include species-level identifications and therefore cannot be interrogated for mean C_m values). Although the data from the NYS BioSurvey and AWI programs can "only" be used to evaluate observed mean C_m values at the survey site density for each program lake, the data in Table 7.1.4 indicate a very high percentage of "Excellent" and "Fair" condition lakes in the NYS BioSurvey and AWI datasets. While these historical (NYS BioSurvey) and present-day Adirondack (AWI) lakes presumably exhibit more favorable floristic quality than contemporary lakes in the rest of lakes, the contrast seems to be unexpectedly high. Specifically, the lack of poor and very poor lakes in the non-Adirondack portion of the state at the time of the NYS BioSurvey, when many of these lakes were already highly developed, may underestimate the impact of this development. It is more likely that these unexpectedly favorable floristic quality assessments reflect the lack of invasive species at the time of the NYS BioSurvey (as discussed at length in White Paper 1E). In other words, while the findings in Table 4.4.3 COULD be accurate, it is more likely that correcting the mean C_m values in the PIRTRAM surveys for frequency and relative abundance (or the criteria cited in Table 7.1.2 may not accurately characterize floristic quality in New York state lakes).

Section 3 of this White Paper discusses the value of a modified C_m value system relative to the traditional New York C_{ny} system. The metrics proposed in this section for evaluating uncorrected mean C_m values can be checked against the C_{ny} system. The recommended use of a modified C_m value system is further advanced by a detailed evaluation of C_m relative to C_{ny} in the context of evaluating Table 7.1.1 above. Table 7.1.5 shows the mean C_{ny} values associated with the Florida aquatic plant community designations; this can be contrasted with the mean C_m values cited in Table 7.1.2. Both systems share a similar range from "Very Poor"- to "Outstanding" – from -0.8 to 4.0 in the C_m system and from 0.8 to 6.0 in the C_{ny} system. The mean C_m system shifts downward due to the assignment of negative C values to exotic plant species, while the mean C_{ny} system shifts upward due to the assignment of high C values (>5) to highly sensitive plants.

Table 7.1.6- % Lakes in Each NYS Monitoring Program Meeting C_{ny} Evaluation Criteria Using Table 7.1.5

	C_m Evaluation using Table 7.1.5 Criteria				
Program	Outst.	Exc.	Fair	Poor	V.Poor
NYS BioSurvey-Adk	2%	95%	3%	0%	0%
NYS BioSurvey-nAdk	0%	91%	9%	0%	0%
AWI	7%	93%	0%	0%	0%
PIRTRAM	0%	31%	52%	17%	0%

Legend- Outst = Outstanding, Exc = Excellent; Cm = modified C value system; Adk = limited to Adirondack Park; nAdk- limited to lakes outside the Adirondack Park

However, larger differences are apparent when assigning lakes from three of the major NYS aquatic plant monitoring programs cited in White Paper 1A to these aquatic plant community designations based on mean C values. Table 7.1.6 summarizes the percentage of lakes in the NYS BioSurvey, AWI and PIRTRAM programs that fit the aquatic plant designations ("Outstanding", "Excellent",…) in Table 7.1.1 using the criteria cited in Tables 7.1.2 and 7.1.5. The results from Table 7.1.6 regarding the use of the traditional C_{ny} system can be compared directly to the results from Table 7.1.4 regarding the use of the modified C_m system.

Both the C_{ny} and C_m systems indicate a loss in floristic quality, via mean C values, over time, particularly in lakes outside of the Adirondack Park. It is reasonable to assume that the higher percentage of "poor" and "very poor" quality lakes in PIRTRAM is indicative of a need to manage aquatic plant communities, consistent with higher degrees of large scale or entire lake management in lakes outside the Adirondacks (where most of the PIRTRAM lakes reside). These differences, however, are much larger using the C_m system compared to the C_{ny} system.

The lack of significant difference between the Adirondack and non-Adirondack lakes at the time of the NYS BioSurveys in the 1920s and 1939s using the C_{ny} system seems to bely the sense that developmental pressures, the presence of AIS, and heavy lake use was much greater outside the Adirondacks, even at that time. However, there is a strong difference in the NYS BioSurvey lakes within and outside the Adirondacks using the C_m system.

discussed above, it is reasonable to presume that the lakes of the 1920-30s (via the NYS BioSurvey) exhibited better floristic quality to those surveyed in recent years (Adirondack AWI lakes in the 2010s and non-Adirondack PIRTRAM lakes in the 1990s-2010s). However, the C_{ny} system suggests that more than 95% of these historically surveyed and present Adirondack lakes would be considered to have "excellent" or better floristic quality. This seems to be unrealistically high, even if the same criteria found only about 30% of the non-Adirondack PIRTRAM lakes to meet the same criteria. However, if the C_m system were deployed instead, the percentage of "excellent" or better NYS BioSurvey lakes dropped from 95% to between 80% (Adirondack lakes) and 50% (non Adirondack lakes), to 25% for AWI lakes and about 10% of the PIRTRAM lakes. It is likely that few of the NYS BioSurvey lakes were managed for excessive aquatic plant growth, consistent with a high percentage of lakes with "excellent" or better floristic quality.

The same modified C_m criteria identified no historical (NYS BioSurvey) or AWI lakes as having "poor" or "very poor" floristic quality, but more than 40% of the PIRTRAM lakes having poor or very poor floristic quality. Since the PIRTRAM studies generally include lakes that were either managed or surveyed in anticipation of future management, it is likely that these lakes are more likely to have fair to poor floristic quality. The modified C_m system found that about 90% of the PIRTRAM lakes had fair to poor (or very poor) floristic quality, compared to about 65% of the PIRTRAM lakes with similar assessments using the traditional C_{ny} system (and fewer than 20% of the lakes with poor or very poor assessments). In other words, it appears that the modified C_m system results in mean C values that appear to be more consistent with the frequency of aquatic plant management of these waterbodies. This again suggests that the modified C_m value system may be superior to the traditional C_{ny} system in evaluating floristic quality.

Additional insights about the most appropriate percentage of lakes meeting the FQI Criteria cited above can be drawn from the water quality realm. As part of the instructions for states to develop numeric nutrient criteria (NNC), the US EPA recommended that states define reference waterbodies- those with minimal impacts associated with excessive nutrient levels. It is reasonable to define "reference" conditions as "excellent" or "outstanding", the same floristic quality descriptions used in the Florida plant community designations in Table 7.1.1. US EPA further recommended that a representative measure of "reference" conditions- a water quality threshold (total phosphorus, or TP levels) that accounts for outlier data- can be defined as the 75th percentile of the reference waterbody dataset. These thresholds were found to be roughly equivalent to the 25th percentile condition (TP levels) of the entire lakes' population. Therefore, in the absence of well-defined reference conditions, EPA recommended that reference conditions can be defined as the 25th percentile of the entire dataset.

Shifting the focus back to floristic quality, reference waterbodies (those with minimal impacts due to excessive plant growth) have not been defined in New York state, although the NYS BioSurvey lakes were surveyed at a time (about 100 years ago) prior to the onset of significant impacts to aquatic plant communities due to lakefront development, year-round lake use, and AIS introduction. The traditional C_{ny} system summarized in Table 7.1.6 indicates that more than 95% of all NYS BioSurvey lakes can be described as "excellent" or "outstanding", roughly corresponding to reference waterbodies. This appears to be too high, since even if the NYS BioSurvey lakes from the 1920s-30s would be considered "minimally impacted" by excessive plants, only about 75% of these lakes should be considered "excellent". However, the modified C_m system (Table 7.1.4) finds that between 50% and 80% of the NYS BioSurvey lakes exhibited "excellent" floristic quality, consistent with the roughly 75% threshold discussed above for defining reference condition. In addition, about 25% of the AWI dataset exhibited "excellent" floristic quality, perhaps as expected if the AWI dataset represents the larger population of non-reference Adirondack lakes. The lower percentage of "excellent" PIRTRAM lakes also appears to be consistent with the expectation that these managed lakes should generally not be considered "reference". In short, **the use of the US EPA reference waterbody and reference condition paradigm applied to the data in Table 7.1.2 further suggests that the modified C_m system is a more accurate system than the traditional C_{ny} system for evaluating aquatic plant**

communities. However, the reference condition approach has limited applicability to present-day PIRTRAM lakes, since nearly all of these lakes have been highly developed and likely indicate little if any evidence of "unimpacted" conditions.

The data presented in Sections 5 and 6 of this White Paper also suggest that uncorrected mean C_m values are less likely to accurately characterize floristic quality, particularly those with marginal to poor quality, than are those values corrected for plant frequency or abundance. Potential metrics for evaluating corrected mean C_m values are briefly discussed below.

Section 7.2- Evaluating Mean C_m Values Corrected for Absolute Frequency

Although the mean C_m values corrected for relative plant frequency (or abundance) will generally fall on the same scale as uncorrected mean C_m values, mean C_m values corrected for absolute plant frequency fall on a different scale. This is seen in the lake examples provided in White Paper 1C, Section 4. In addition, measures of absolute rather than relative frequency lend themselves much better to projecting mean C_m values to a standardized survey site density, as discussed briefly in White Paper 1C. Therefore, the same mean C_m criteria outlined in Table 7.1.2 cannot be used to characterize lakes based on projected mean C_m values corrected for absolute frequency.

However, if the typical aquatic plant community designations in Table 7.1.1 are applied to both the presence AND the frequency of aquatic plants, classification categories similar to those cited in Table 7.1.2 for uncorrected mean C_m values can also be developed for mean C_m values corrected for the absolute frequency of plants. For example, a "Fair" aquatic plant community distribution (as cited in Table 7.1.1) of 15% sensitive plants, 35% tolerant plants, 70% native plants, and 10% invasive plants can be applied to both individual plant species AND collective (frequency of) plants. Absolute plant frequency assessments also require knowledge of the percentage of surveyed sites for which plants are found. Fortunately, nearly all aquatic plant surveys in PIRTRAM lakes include at least some plants at nearly all survey sites. It can also be assumed that a high frequency of plants are directly correlated with floristic quality- a higher frequency of valuable plants (with higher C_m values) is associated with better floristic quality, particularly when invasive plants (assigned a negative C_m value) are associated with poor floristic quality and will bring down the mean C_m values. Note that this does not imply that a higher abundance (rather than a higher frequency) of plants is more favorable; this issue is discussed in Section 7.3.

Table 7.2.1- Frequency-Corrected Mean C_m Values Associated with Aquatic Plant Community Designations

	Outstanding	Excellent	Fair	Poor	Very Poor
Mean C_m (C_{m_uf})	> 2.4	0.8-2.4	0.3-0.8	0.1-0.3	-0.3 – 0.1 (< 0.1)

Table 7.2.1 shows the ranges of frequency-corrected mean C_m values corresponding to the aquatic plant community designation categories cited in Table 7.1.1. These values can be compared to the uncorrected mean C_m values shown in Table 7.1.2. The frequency-corrected data are in a tighter range (approximately 3 units)

than the uncorrected values (a range of approximately 5 units). However, as noted above, mean C_m values corrected for frequency are more likely to accurately characteristic floristic quality in lakes, as discussed at length in Section 5.

Table 7.2.2- % PIRTRAM Lakes Meeting C_m Evaluation Criteria from Table 7.1.2 (C_m) and Table 7.2.1 (C_{m_uf})

	C_m Evaluation using Criteria Above				
	Outst.	Exc.	Fair	Poor	V.Poor
% Lakes Using C_{m_uf}	0%	6%	35%	12%	47%
% Lakes Using C_m	0%	10%	48%	24%	19%

Legend- Outst = Outstanding, Exc = Excellent; Cm = modified C value system

Table 7.2.2 shows the percentage of PIRTRAM lakes (NOT lake-years) that meet the frequency-corrected mean C_m criteria presented in Table 7.2.1, and compares this to the uncorrected mean C_m data from Table 7.1.3. These data reflect the averages for each of the surveyed lakes, but as seen below, may vary slightly from year to year. The frequency corrections generally shift the lake floristic assessments from more favorable to less favorable. As seen below, when assessments at individual lakes (and especially individual lake-years) are compared, frequency corrections appear to more accurately characterize floristic quality.

Table 7.2.3 compares the assessment of select (30 lake years, as discussed in Section 5 above) PIRTRAM lakes using the criteria in Table 7.1.2 with uncorrected mean C_m values, with the assessments using the criteria in Table 7.2.1 for mean C_m values corrected for absolute plant frequency. While most of the lakes (nearly 2/3) exhibited similar assessments using either assessment criteria, there were some differences. These are discussed briefly below:

Table 7.2.3 Comparison of Uncorrected and Frequency-Corrected Mean C_m Assessments for Select PIRTRAM Lakes

Year Lake	Year	Assess Uncorr	Assess Corr pCm_uf
Ballston Lake	2006	Poor	Poor
Big Fresh Pond	2006	Excellent	Fair
Blydenburgh Lake	2012	Very Poor	Poor
Blydenburgh Lake	2014	Very Poor	Very Poor
Cazenovia Lake	2010	Fair	Fair
Cazenovia Lake	2013	Fair	Fair
Cazenovia Lake	2016	Fair	Fair
Cazenovia Lake	2019	Fair	Fair
Collins Lake	2007	Poor	Poor
Creamery Pond	2008	Very Poor	Poor
Creamery Pond	2010	Poor	Fair
Creamery Pond	2012	Poor	Fair
Hards Pond	2011	Fair	Fair
Java Lake	2010	Poor	Fair
Kinderhook Lake	2007	Very Poor	Very Poor
Lake Luzerne	2010	Fair	Fair
Lake Ronkonkoma	2010	Fair	Very Poor
Lake Ronkonkoma	2014	Very Poor	Very Poor
Lamoka Lake	2006	Fair	Fair
Lamoka Lake	2009	Fair	Fair
Morehouse Lake	2010	Excellent	Fair
Quaker Lake	2010	Fair	Fair
Saratoga Lake	2010	Fair	Fair
Saratoga Lake	2012	Fair	Fair
Snyders Lake	2002	Poor	Very Poor
Snyders Lake	2005	Poor	Fair
Snyders Lake	2008	Poor	Poor
Snyders Lake	2011	Poor	Fair
Waneta Lake	2006	Poor	Poor
Waneta Lake	2009	Fair	Fair

1. **Lakes with assessments improving** when mean C_m is corrected for absolute plant frequency. This represented a small number of the lakes (lake-years) cited in Table 7.2.3, and included Blydenburgh Lake in 2012, Creamery Pond in all three survey years, Java Lake in 2010, and Snyders Lake in 2005 and 2011. Each of these lakes have invasive species, and in some cases these plants have been actively managed. However, Blydenburgh Lake in 2012 and Creamery Pond in 2008 improved from “Very Poor” to “Poor”, still indicating significant floristic quality issues. Some of the other lakes were discussed in Section 6 in this White Paper, and include lakes with a high frequency of native plants relative to a high number of invasive species (*Ceratophyllum demersum* in Blydenburgh Lake, *Ceratophyllum demersum* and *Wolffia* sp in Creamery Pond, *Ceratophyllum demersum* and *Elodea canadensis* in Java Lake, and *Elodea canadensis* in Snyders Lake in 2011). Snyders Lake in 2005 had several invasive species, but similarly low densities of all plants, including many native plant species. **For most (and perhaps all) of these lakes, frequency corrections appear to result in more accurate floristic quality assessments.**

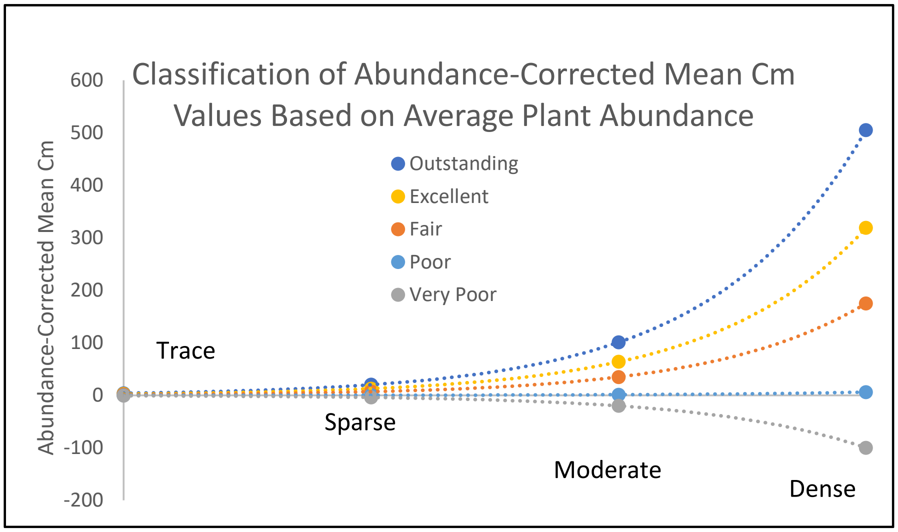
2. **Lakes with assessments degrading** when mean C_m is corrected for absolute plant abundance. This includes Big Fresh Pond in 2006, Lake Ronkonkoma in 2010, Morehouse Lake in 2010, and Snyders Lake in 2002. Big Fresh Pond and Morehouse Lake had no invasive species (and thus had an “Excellent” uncorrected mean C_m assessment), but had a paucity of plants in many locations, resulting in a degraded assessment when mean C_m values were corrected for plant frequency. Lake Ronkonkoma in 2010 was dominated by a high frequency of *Hydrilla verticillata* (comprising more than 75% of all plants), although overall frequency of all plants was low. Likewise, Snyders Lake in 2002 was dominated by *Myriophyllum spicatum* and *Najas minor*

(comprising more than 80% of all plants), although, as with Lake Ronkonkoma, overall plant frequency was low. **For all of these lakes, it appears that frequency corrections result in more accurate assessments.**

Section 7.3- Evaluating Mean C_m Values Corrected for Absolute Abundance

The challenges cited above in generating metrics for frequency-corrected mean C_m values are even more pronounced for abundance-corrected mean C_m values. This results from the lack of agreement on "how much is too much?". Section 7.2 discusses how the frequency of a particular plant species, defined as the number of survey sites with at least the presence of that species, is closely related to floristic quality- the more survey sites occupied by the plant species, the higher the floristic quality. However, it is not clear if "more is better" as it relates to plant abundance. Dense growth of most plants would often result in impediments to recreational uses, although this is less of a concern with low-lying native plants. Likewise, trace growth of many plants would be insufficient to support some ecological functions of plant communities, although trace growth of nuisance native or invasive plant species might be preferred.

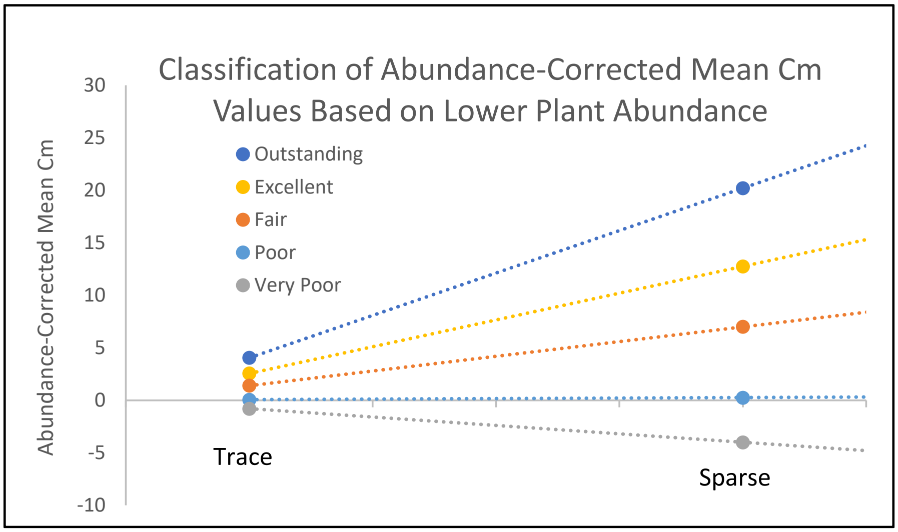
Figure 7.3.1- Abundance Corrected Mean C_m Values for Each Table 7.1.1 Aquatic Plant Designation Relative to Average Plant Abundance



This is illustrated in Figure 7.3.1. If the typical aquatic plant community designations in Table 7.1.1 (indicating the percentage of plant types associated with the quality of the plant community) are applied to a standardized plant abundance, there is an increasing divergence in mean C_m values for each community designation. For example, as seen in Figure 7.3.1, For example, if the typical abundance of all plants in a lake is "moderate", the abundance-corrected mean C_m values range from -20 (in "Very Poor" quality lakes) to 101 (in "Outstanding" quality lakes). This figure shows a very strong correlation between plant abundance and abundance-corrected mean C_m values that can be used to establish floristic quality criteria. Unless the "ideal" plant abundance is known, criteria thresholds cannot be established.

It is also likely that the "larger" plant abundance categories in Figure 7.3.1 are realistically not achieved in lakes- it is unlikely that the average abundance of ALL plants in a lake is either dense or moderate, even though many historical programs provide a blanket lakewide assessment of dense or moderate for all plants. Even a designation of "sparse" as a lakewide assessment, which provides much tighter but still clear distinctions among the plant assessment categories (Figure 7.3.2- a truncated version of Figure 7.3.1 showing only "trace" and "sparse" values), may not be a realistic designation. While the average abundance for some or even many plants might be "sparse" (typical of a plant found at trace levels at 25% of sites, sparse levels at 25% of sites, and moderate levels in 15% of sites), most plants are not found at that overall abundance. In reality, the "average" plant in each category, particularly protected (C_m = +5), beneficial (C_m = +3), and nuisance native (C_m = +1) plants, may not even be found at an average of "trace" across the entire lake, although higher abundances are often associated with invasive species. These issues greatly complicate the process for developing abundance-corrected mean C_m criteria.

Figure 7.3.2- Abundance Corrected Mean C_m Values for Each Table 7.1.1 Aquatic Plant Designation Relative to Lower Plant Abundance



Given the uncertainties associated with estimating the most accurate relative abundance for "outstanding" relative to "excellent" plant communities, it may be appropriate to fold these into a single "good" category, particularly since there is almost certainly a gap between "fair" and "excellent". It is likely that "good" falls between "excellent" and "fair" and therefore draws from both categories. Likewise, given these uncertainties, there may be little value in trying to distinguish between "poor" and "very poor" since, intuitively, it is likely that any lakes with frequency or abundance levels of invasive plants sufficiently high to dominate a plant community should almost certainly be defined as having (at least) "poor" floristic quality. It is also reasonable to say that lakes not dominated (in frequency or abundance) by exotic plants are likely to exhibit either “fair” or “good” floristic quality. Therefore, it appears that the most important question is how to best distinguish “fair” and “good” lakes.

Table 7.3.1- “Average” Abundance for All Plants with Cited C_m Value Meeting Aquatic Plant Designation

New Aquatic Plant Designation	Average Abundance for Average C_m Values			
	$C_m = 5$	$C_m = 3$	$C_m = 1$	$C_m = -3$
Good	0.50	5.00	0.25	0.10
Fair	0.10	1.00	2.24	2.24
Poor	0.10	0.50	2.24	11.18

Legend-
$C_m = 5$ = protected plants; $C_m = 3$ = beneficial native plants; $C_m = 1$ = nuisance native plants; $C_m = -3$ = exotic and invasive plants

All average abundance values on $\log_5$ scale (1 = trace, 5 = sparse,..)

A more accurate way to assign plant abundance levels to each of the aquatic plant designation categories in Table 7.1.1 is to acknowledge that plant abundance of poor quality plants increase as floristic quality decreases, and generally the plant abundance of good quality plants increase as floristic quality increases. However, protected plants, conferred the highest C_m designation ($C_m = +5$) are less common even in high quality lakes. Table 7.3.1 assigns “expected” average plant abundance values for each of the “updated” (good, fair, poor) aquatic plant community designations for each of the plants assigned the cited C_m values ($C_m = +5$ for protected plants, $C_m = +3$ for beneficial or benign native plants, $C_m = +1$ for nuisance native plants, and $C_m = -3$ for all exotic plant species, including highly invasive plants. The values equal to or below 1 correspond to a percentage of “trace” (relative abundance = 1) abundance, so for example, this table suggests that “good” floristic quality lakes would have an average abundance of 0.25 of nuisance native plants ($C_m = 1$). In that case, a typical distribution of ALL nuisance native plants, not just any single nuisance species, in 100 survey sites could be, for example 1 sites of moderate growth (abundance = 1 x 25 = 25) or 5 sites of sparse growth (abundance = 5 x 5 = 25), or 25 sites of trace growth (abundance = 25 x 1 = 25), or any combination thereof. Note that some individual species may be (much) more common than the average cited in this table, but the average of all plants described as protected, beneficial, nuisance, or exotic would be estimated by this table.

This table also shows values above 1 for some plants and aquatic plant designation. The value of 5 for beneficial native plants ($C_m = +3$) in “good” lakes corresponds to “sparse” communities, while a value of 2.24 or for nuisance native plants ($C_m = +1$) in “fair” and “poor” lakes corresponds to a weighted average abundance between trace (relative abundance = 1) and sparse (relative abundance = 5), or $5^{1.5}$. Likewise, the value of 11.18 for exotic plants ($C_m = -3$) represents a weighted average abundance that falls between sparse (relative abundance = 5) and moderate (relative abundance = 25), or $5^{2.5}$. Although the estimated plant abundance values in Table 7.3.1 allows for developing abundance-corrected mean C_m thresholds for each of these aquatic plant designations, as seen below, and although these thresholds appear to be well aligned with the intuitive aquatic plant designations for the PIRTRAM lakes, **this represents a first attempt to assign expected plant abundance values for each plant type for each aquatic**

plant designation. Additional work is needed to assign the most appropriate expected plant abundance levels for each aquatic plant community designation, and to improve the accuracy of the mean C_m thresholds noted below.

Table 7.3.2- Percentage of Each Plant Type Associated with Modified Aquatic Plant Community Designations (from modified Table 7.1.1)

	C_m Values			
	Cm5-Protected	Cm3-Beneficial	Cm1-Nuisance	Cm-3 - Exotic
Good	15%	50%	25%	10%
Fair	5%	30%	40%	25%
Poor	0%	25%	40%	35%

To convert these values into thresholds for each of the aquatic plant community designations cited above also requires redefining the expected percentages of each plant type in "good", "fair" and "poor" lakes, using Table 7.1.1 as the basis for these assignments. These percentages generally correspond to the more expansive aquatic plant community designations in Table 7.1.1, with "good" generally falling between the Table 7.1.1 designations of "excellent" and "fair" (with all values above these thresholds also consistent with "good" communities. Likewise, "poor" and "very poor" are collapsed into a single designation of "poor", with all values outside of these thresholds also falling into the "poor" category. These converted percentages of each plant type for "Good", "Fair" and "Poor" lakes are provided in Table 7.3.2.

Table 7.3.3- Abundance-Corrected Mean C_m Values Associated with Modified Aquatic Plant Community Designations

	Good	Fair	Poor
Mean C_m (C_{m_ua})	> 8	0-8	< 0

The results from Tables 7.3.1 and 7.3.2 can be combined to generate abundance-corrected mean C_m (or mean C_{m_ua}) thresholds for these modified aquatic plant community designations. These are presented in Table 7.3.3- NOTE THAT THESE RESIDE ON A DIFFERENT SCALE THAN THOSE DEVELOPED FOR UNCORRECTED MEAN C_m OR THOSE CORRECTED FOR ABSOLUTE PLANT FREQUENCY. These data suggest that "good" plant communities are associated with abundance corrected mean C_m values above 8, while "poor" communities are associated with low positive to negative corrected mean C_m values (and "fair" designations fall between these thresholds). Although not included in Table 7.3.3, these data indicate that a threshold between "poor" and "very poor" could be assigned an abundance-corrected mean C_m value of -10, but there might be little value in distinguishing between these designations. Table 7.3.3 also includes a lower "fair" threshold of 1.3 (rather than 0), allowing for "poor" designations in some lakes with positive abundance-corrected mean C_m values. This apparent break from intuition (the assumption that lakes dominated by invasives will have a negative mean C_m value) may be due to corralling all exotic plants into a single C_m = -3 assignment, even though many lakes dominated by invasives plants are dominated by *Myriophyllum spicatum* or *Hydrilla verticillata*, both of which are properly assigned a mean C_m value of -5. For this reason, as discussed at the end of this chapter, the final recommended mean C_m thresholds (drawn from

Table 7.2.1 and 7.3.2) for each aquatic plant community designation will anchor the threshold between “fair” and “poor” at a mean C_m value of 0.

Table 7.3.4- % PIRTRAM Lakes Meeting C_m Criteria from Table 7.1.2 (C_m), Table 7.2.1 (C_{m_uf}), and Table 7.3.3 (C_{m_ua})

	C_m Evaluation using Criteria Above				
	Outst.	Exc.	Fair	Poor	V.Poor
% Lakes Using C_{m_ua}	5% (Good)		53%	42% (Poor)	
% Lakes Using C_{m_uf}	0%	6%	35%	12%	47%
% Lakes Using C_m	0%	10%	48%	24%	19%

Legend- Outst = Outstanding, Exc = Excellent; Cm = modified C value system

IT IS IMPORTANT TO NOTE THAT WHILE THE CRITERIA OUTLINED IN THIS WHITE PAPER CAN PROVIDE INFORMATION ABOUT FLORISTIC QUALITY (BASED ON THE QUALITY AND QUANTITY OF THE INDIVIDUAL PLANTS), ADDITIONAL MEANS FOR EVALUATING FLORISTIC QUALITY INVOLVES USING PROJECTED SPECIES RICHNESS AND MEAN C VALUES TO GENERATE FLORISTIC QUALITY INDICES, OR FQIs. THESE ARE DISCUSSED AT LENGTH IN WHITE PAPER 1G.

Table 7.3.4 compares the assessments for uncorrected mean C_m values, and those corrected for absolute plant frequency (C_{m_uf}) and corrected for absolute plant abundance (C_{m_ua}). The percentage of high quality lakes (Outstanding, Excellent or Good) decreases as the mean C_m values move from uncorrected to corrected, while the percentage of low quality lakes (Fair, Poor, or Very Poor) increase. This also seems intuitively accurate, since the PIRTRAM lakes were surveyed either in response to or in anticipation of plant management actions. The data presented in Section 7.2 above suggest that the frequency corrections to the mean C_m values appear to improve the accuracy of the floristic characterization. The assessment differences between the frequency corrections and the abundance corrections in Table 7.3.4 may reflect a relatively higher frequency than abundance of some invasive plants (i.e. found in patches rather than beds). However, it is possible that frequency corrections are more accurate than abundance corrections for some of these lakes, particularly since the relative abundance estimates (using a $\log_5$ scale, as discussed above) may be less accurate for some lakes.

Table 7.3.5 provides a summary assessment of the uncorrected and corrected mean C_m values for the PIRTRAM lakes, using the criteria outlined in Table 7.1.2 (uncorrected C_m), Table 7.2.1 (frequency-corrected C_{m_uf}), and Table 7.3.3 (abundance-corrected C_{m_ua}). As discussed earlier, mean C_m values were not computed for each surveyed year for each PIRTRAM lake, although each surveyed lake included randomly chosen survey years for assessments. These data show a general shift from more favorable to less favorable assessments as mean C_m values are corrected for plant frequency or abundance, consistent with the observations summarized in Table 7.3.4. The assessments in most lakes or most lake-years was similar from uncorrected to corrected assessments, although a few lakes exhibited some differences as the mean C_m values were corrected for frequency or abundance. Some of the lakes with significant differences in assessments are discussed below:

Table 7.3.5. Comparison of Plant Community Assessments in Uncorrected and Corrected Mean C_m Values in PIRTRAM Lakes

Year Lake	Year	Assess Uncorr	Assess Corr pCm_uf	Assess Corr pCm_ua
Ballston Lake	2006	Poor	Poor	Poor
Big Fresh Pond	2006	Excellent	Fair	Good
Blydenburgh Lake	2012	Very Poor	Poor	Poor
Blydenburgh Lake	2014	Very Poor	Very Poor	Poor
Cazenovia Lake	2010	Fair	Fair	Fair
Cazenovia Lake	2011	Fair		Fair
Cazenovia Lake	2012	Fair		Fair
Cazenovia Lake	2013	Fair	Fair	Poor
Cazenovia Lake	2014	Fair		Fair
Cazenovia Lake	2015	Fair		Poor
Cazenovia Lake	2016	Fair	Fair	Poor
Cazenovia Lake	2017	Fair		Fair
Cazenovia Lake	2018	Fair		Poor
Cazenovia Lake	2019	Fair	Fair	Fair
Cazenovia Lake	2020	Fair		Fair
Cazenovia Lake	2021	Fair		Fair
Chautauqua Lake	2015	Fair		Fair
Chautauqua Lake	2017	Fair		Fair
Chautauqua Lake	2019	Fair		Fair
Chautauqua Lake	2021	Fair		Fair
Collins Lake	2007	Poor	Poor	Fair
Creamery Pond	2008	Very Poor	Poor	Poor
Creamery Pond	2010	Poor	Fair	Poor
Creamery Pond	2012	Poor	Fair	Poor
Hards Pond	2011	Fair	Fair	Good
Java Lake	2008	Fair		Fair
Java Lake	2009	Fair		Good
Java Lake	2010	Poor	Fair	Fair
Kinderhook Lake	2006	Very Poor		Poor
Kinderhook Lake	2007	Very Poor	Very Poor	Poor
Lake Luzerne	2009	Fair		Fair
Lake Luzerne	2010	Fair	Fair	Fair
Lake Rippowam	2008	Very Poor		Poor
Lake Rippowam	2016	Very Poor		Poor
Lake Rippowam	2018	Very Poor		Good
Lake Rippowam	2020	Very Poor		Poor
Lake Ronkonkoma	2010	Fair	Very Poor	Poor
Lake Ronkonkoma	2014	Very Poor	Very Poor	Poor

a. Big Fresh Pond 2006 and Morehouse Lake 2010. Both of these lakes have no invasive species, and exhibited less favorable assessments as frequency- or abundance-corrected mean C_m values were evaluated. These less favorable assessments were due to relatively low abundance and especially frequency of native plants, indicating sub-optimal distribution of aquatic plants. Overall frequency and abundance of plants in these lakes was low.

b. Cazenovia Lake. Plant assessments were fairly stable regardless of whether mean C_m values were uncorrected or corrected for plant frequency or abundance. However, the least favorable assessments occurred in 2013, 2015, 2016 and 2018; in most of these years, *Myriophyllum spicatum* was the most abundant plant in the lake (more than 27% of the overall abundance; in no other year was Eurasian milfoil more than 22% of the plant community by abundance).

c. Lake Rippowam 2018. The abundance-corrected assessments were much more favorable than the uncorrected assessments for Lake Rippowam in 2018. The overall aquatic plant community included primarily nuisance and invasive plants, but native plants were the most abundant plants in the lake.

d. Lake Ronkonkoma 2010. The lake had a mix of native and invasive plants in 2010, resulting in a “fair” uncorrected assessment, but the plant abundance was dominated by *Hydrilla verticillata* (representing more than 99% of the overall abundance in the lake).
e. Oscaleta Lake 2018 and 2020. The lake included a mix of native, nuisance and invasive plants, leading to relatively poor assessments, but (by far) the most abundant plants in the lake are native.
f. Snyders Lake 2011. As with Oscaleta Lake, Snyders Lake in 2011 includes multiple invasive, nuisance and native plants, but *Elodea canadensis* comprises nearly 50% of the overall plant abundance (this plant was more than 70% of the plant community in 2010, but this year was not assessed in Table 7.3.5.

Table 7.3.5 (cont). Comparison of Plant Community Assessments in Uncorrected and Corrected Mean C_m Values in PIRTRAM Lakes

Year Lake	Year	Assess Uncorr	Assess Corr pCm_uf	Assess Corr pCm_ua
Lake Waccabuc	2008	Poor		Poor
Lake Waccabuc	2010	Fair		Fair
Lake Waccabuc	2013	Poor		Fair
Lake Waccabuc	2014	Fair		Fair
Lake Waccabuc	2015	Fair		Fair
Lake Waccabuc	2016	Fair		Fair
Lake Waccabuc	2017	Fair		Fair
Lake Waccabuc	2019	Fair		Fair
Lake Waccabuc	2021	Poor		Poor
Lamoka Lake	2006	Fair	Fair	
Lamoka Lake	2009	Fair	Fair	
Morehouse Lake	2010	Excellent	Fair	Good
Oscaleta Lake	2008	Poor		Fair
Oscaleta Lake	2016	Fair		Fair
Oscaleta Lake	2018	Poor		Good
Oscaleta Lake	2020	Poor		Good
Quaker Lake	2010	Fair	Fair	Poor
Saratoga Lake	2010	Fair	Fair	Good
Saratoga Lake	2011	Fair		Fair
Saratoga Lake	2012	Fair	Fair	Fair
Snyders Lake	2002	Poor	Very Poor	Poor
Snyders Lake	2005	Poor	Fair	Poor
Snyders Lake	2008	Poor	Poor	Poor
Snyders Lake	2011	Poor	Fair	Good
Waneta Lake	2006	Poor	Poor	
Waneta Lake	2009	Fair	Fair	

These summaries indicate that most of the discrepancies in aquatic plant community assessments between uncorrected and either frequency-corrected or abundance-corrected mean C_m values can be explained by circumstances associated with conditions at individual lakes. The data presented in Table 7.3.4 indicate that these corrections are likely to result in less favorable aquatic plant assessments relative to those assessments generated from uncorrected mean C_m values, but that these corrections are more likely to improve the aquatic plant community assessments derived from aquatic plant survey data. While additional data may be needed to determine if abundance-derived corrections are preferred to frequency-derived corrections, the data presented in Section 7 suggest that abundance-derived corrections appear to be more accurate. **Therefore, it is recommended that mean C_m values needed for FQI equations should be corrected for absolute plant abundance, using the relative abundance scales summarized in Table 6.3.1.**

Section 8- Recommendations to Improve Evaluations Based on Coefficients of Conservatism (C values)

This White Paper summarizes the use of coefficients of conservatism (C values) in large groups of New York state lakes, and provides several recommendations to improve the calculation and use of individual plant and collective mean C values. These include the following, discussed at length in Sections 1 through 7; some of these recommendations are also included in White Papers 1D and 1G.

1. C values provide a consistent means to evaluate the quality of individual plant species within an aquatic plant community, and with some measures of the quantity of these plant species (species richness), can accurately evaluate plant communities through calculated floristic quality indices (FQI). However, the existing (New York) C value system suffers from some problems inherent in most aquatic plant surveys. The modified FQI system, or mFQI, should adopt modified C values (C_m), rather than New York-specific C values (C_{ny}) to assign each native plant into one of three C_m categories (protected plants- $C_m = 5$; benign plants- $C_m = 3$; nuisance plants- $C_m = 1$), and each exotic plant into one of three different C_m categories (benign exotic plants- $C_m = -1$; regional or moderately invasive plants- $C_m = -3$; highly invasive plants- $C_m = -5$).
2. mFQI calculations suffer from inconsistencies in the number of survey sites since species richness (one component of mFQI) increases as survey sites increase (mean C_m values, on the other hand, reach an asymptotic value after a relatively small number of survey sites, although these mean C_m values continue to vary slightly). These mFQI values, or more specifically the component species richness and C values, should be evaluated at a standardized survey site density of 1 site per littoral hectare, to compare lakes across programs or individual lakes over time. However, standardized values require granular survey site data showing the frequency and/or relative abundance of each plant at each site to generate regressions showing changes in mean C_m values at any survey site density. This is achieved by using subsampling methods outlined in White Paper 1C.
3. C values, and associated mFQI values, should be corrected for the frequency and abundance of plants within a surveyed area to improve the accuracy of floristic quality evaluations.
4. These corrections can be generated for both normalized (relative) and absolute (unbounded) measures of frequency or abundance, but absolute or unbounded corrections can be most easily applied to subsampled data and therefore should be used for calculating mean C_m values in surveyed lakes.
5. Mean C_m values can be converted into assessment "scores" although there is little information in the literature to support the development of a scoring system, particularly for frequency- or abundance-corrected mean C_m values. The Florida aquatic plant community designations offer one method for establishing mean C_m thresholds for each designation, and these thresholds appear to be aligned with observed conditions in these lakes. Absent other methods, this method is recommended for use in assigning mean C_m scores for surveyed lakes.

6. Although the data summarized in this White Paper identifies slightly different thresholds

Table 8.1- Recommended Mean C_m Thresholds and Aquatic Plant Community Designations Based on Uncorrected and Corrected Values

	Outstanding	Excellent	Fair	Poor	Very Poor
Mean C_m (uncorrected)	> 4.0	2.6-4.0	1.4-2.6	0.0-1.4	< 0
Mean C_{m_uf} (freq corr)	> 2.4	0.8-2.4	0.3-0.8	0-0.3	< 0
Mean C_{m_uf} (abund corr)	> 8.0 (Good)		0.0-8.0	< 0 (Poor)	

delineating the differences between "fair" and "poor" floristic quality, it is intuitively satisfying to define the difference between "fair" and "poor" for abundance-corrected mean C_m values as falling at a mean C_m value of 0, consistent with the conceptual idea that lakes dominated (as defined by absolute plant abundance) by invasives as being poor. Likewise, the difference between "poor" and "very poor" lakes should also be defined at this boundary for uncorrected or frequency-corrected mean C_m values, since it is possible that some lakes with a high frequency of invasive plants may still have a low abundance of these plants.

Table 8.1 reflects these small changes in the data thresholds outlined in Tables 7.1.2, 7.2.1 and 7.3.3 to support these broad concepts. An evaluation of the most appropriate mean C_m score for individual lake years also seems to support this suggested change.

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

1. Regional agreement on which plants should be included in each modified C value category, with a particular focus on the lakes that should be characterized as "nuisance native" (C_m = 1). The present list includes those native plants that are periodically the subject of plant management actions in New York state, and generally thrive in lakes with compromised water quality (due to an ability to grow prolifically in turbid water, organic sediments, and both shallow and deep water). While such a list can be generated from a combination of aquatic plant permit applications and feedback from local lake professionals, the "nuisance native" plant list may differ from state to state. Since it is likely that both a significant overlap in nuisance native plants exist across states and there are few nuisance native plants that are unique to a specific (northeastern US) state, a common list could be developed. This could be done in consultation with both state permit managers and regional lake professionals, such as those involved with the Northeast Aquatic Plant Management Society.
2. There may be a need to evaluate whether additional plants should be included in the "most sensitive"/ "protected" category (C_m = 5). At present, the proposed C_m = 5 designation is limited to the few RTE plants defined in NYS, assigning "favored" status to those plants cited on the NYS Rare Plant list and thereby conferred special protection. One consequence of this is the finding that few lakes fit the definition of "outstanding", which is anchored to a high percentage of protected plants. However, other plants might

have very high ecological value that warrants inclusion on the protected category list. This would ultimately increase FQI values, perhaps appropriately, but would results in more plants that require identification expertise, create a new non-regulatory category for plants not otherwise afforded special protection, and might cloud the distinction between C_m and C_{ny} values.

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Appendix 2.1: NYS C_{ny} and Modified C_m Values for NYS Aquatic Plants

Scientific Name	*Common Name*	*Type*	*C_{ny}*	*C_m*
Alisma gramineum	narrowleaf water plantain	f	8.5	3
Armoracia aquatica	lake cress	s	9	3
Azolla caroliniana	Carolina mosquitofern	f	3	1
Brasenia schreberi	watershield	f	5	3
Brassicacae sp	lake cress	e	9	3
Butomus umbellatus	flowering rush	e	0	-1
Cabomba caroliniana	fanwort	s	0	-3
Calla palustris	water arum	e	7.5	3
Calla sp	water arum	e	7.5	3
Callitriche hermaphroditica	northern water-starwort	s	7	5
Callitriche heterophylla	twoheaded water-starwort	s	5	3
Callitriche palustris	vernal water-starwort	s	3	3
Callitriche stagnalis	pond water-starwort	s	0	-1
Callitriche verne	vernal water-starwort	s	5	3
Callitriche sp	water-starwort	s	5	3
Carex aquatilis	water sedge	e	7	3
Carex comosa	longhair sedge	e	4.5	3
Carex chordorrhiza	creeping sedge	e	9	5
Carex lasiocarpa	woollyfruit sedge	e	7.5	3
Carex limosa	mud sedge	e	9	3
Carex rostrata	rosy sedge	e	4	3
Carex vesicaria	blister sedge	e	7	3
Carex sp	sedge	e	7	3
Ceratophyllum demersum	coontail	s	2.5	1
Ceratophyllum echinatum	spiny hornwort	s	4	5
Ceratophyllum sp	coontail	s	2.5	3
Chara vulgaris	muskgrass	s	5	3
Chara sp	muskgrass	s	5	3
Decodon verticillatus	swamp loosestrife	e	7.5	3
Drepanocladus sp	unnamed aquatic moss	s	5	3
Dulichium arundinaceum	three-way sedge	e	6	3
Egeria densa	Brazilian elodea	s	0	-3
Eichornia crassipes	water hyacinth	e	0	-3
Elatine americana	American waterwort	s	10	5
Elatine minima	small waterwort	s	6	3
Elatine triandra	three stamen waterwort	s	8	3
Elatine sp	waterwort	s	8	3
Eleocharis acicularis	needle spikerush	s	4	3
Eleocharis elliptica	elliptic spikerush	s	5	3
Eleocharis engelmannii	Engelmann's spikerush	s	6	5
Eleocharis erythropoda	bald spikerush	s	5	3
Eleocharis intermedia	matted spikerush	s	7.5	3
Eleocharis obtusa	blunt spikerush	s	3.5	3
Eleocharis ovata	ovate spikerush	s	6	5

Scientific Name	Common Name	Type	C_{ny}	C_m
Eleocharis palustris	common spikerush	s	5	3
Eleocharis quadrangulata	squarestem spikerush	s	8.5	3
Eleocharis robbinsii	Robbins spikerush	s	8	5
Eleocharis rostellata	beaked spikerush	s	9	3
Elodea sp.	waterweed	s	3	3
Elodea bifoliata	twoleaf waterweed	s	0	-1
Elodea canadensis	common waterweed	s	3	3
Elodea nuttallii	Nuttall's pondweed	s	3.5	3
Equisetum fluviatile	water horsetail	s	5.5	3
Eriocaulon aquaticum	sevenangle pipewort	s	7	3
Eriocaulon septangulare	pipewort	s	7	3
Eriocaulon sp	pipewort	s	7	3
Fontinalis sp.	unnamed water moss	s	5	3
Glyceria borealis	small floating mannagrass	e	6.5	3
Glyceria striata	fowl mannagrass	e	3.5	3
Graminea sp	mannagrass	e	7	3
Hippuris vulgaris	common mare's tail	s	9	5
Hottonia inflata	American featherfoil	f	9	5
Hydrocharis morsus-ranae	European frogbit	f	0	-5
Hydrocotyle americanum	American marshpennywort	f	3.5	3
Hydrocotyle ranunculoides	floating marshpennywort	f	5	5
Hydrocotyle umbellata	manyflower marshpennywort	f	5	5
Hydrilla verticillatum	hydrilla	f	0	-5
Hypericum adpressum	creeping St. Johns wort	s	9.5	5
Hypericum boreale	northern St. Johns wort	s	3	3
Hypericum ellipticum	pale St. Johns wort	s	3	3
Hypericum sp	St. Johns wort	s	6	3
Iris sp	iris	e	6	3
Isoetes echinospora	spiny spored quillwort	s	7	3
Isoetes engelmannii	Appalachian quillwort	s	7	3
Isoetes lacustris	lake quillwort	s	9	5
Isoetes riparia	shore quillwort	s	9	3
Isoetes sp	quillwort	s	8	3
Juncus acuminatus	tapertip rush	e	4.5	3
Juncus arcticus	arctic rush	e	4	3
Juncus articulatus	jointleaf rush	e	3	3
Juncus effusus	lamp rush	e	2	3
Juncus filiformis	thread rush	e	5.5	3
Juncus nodosus	knotted rush	e	4.5	3
Juncus pelocarpus	brownfruit rush	e	6	3
Juncus sp	rush	e	5	3
Lemna minor	lesser duckweed	f	2	3
Lemna perpusilla	minute duckweed	f	5.5	5
Lemna trisulca	star duckweed	f	5	3
Lemna valdiviana	valdivia duckweed	f	5.5	5
Lemna sp	duckweed	f	2	3

Scientific Name	Common Name	Type	C_{ny}	C_m
Limnobia spongia	American spongeplant	f	5	3
Limosella aquatica	water mudwort	s	10	3
Limosella australis	Welsh mudwort	s	10	3
Lipocarpha micrantha	smallflower halfchaff sedge	e	8.5	3
Littorella sp	shoreweed	s	8	3
Lobelia dortmanna	water lobelia	s	7	3
Lobelia sp	lobelia	s	7	3
Ludwigia palustris	marsh seedbox	f	3	3
Ludwigia peploides	water primrose	f	0	-5
Ludwigia sphaerocarpa	globefruit primrose-willow	f	9.5	5
Lysimachia nummularia	creeping jenny	e		3
Lysimachia quadrifolia	fourflower yellow loosestrife	e	3.5	5
Lysimachia terrestris	earth loosestrife	e	4.5	3
Lysimachia sp	loosestrife	e	4	3
Lythrum lineare	wand lythrm	e	9.5	5
Lythrum salicaria	purple loosestrife	e	0	-5
Marsalia quadrifolia	European fourleaf clover	f	0	-1
Megalodonta beckii	water marigold	s	7.5	5
Myrica sp	sweetgale	e	8	3
Myriophyllum alterniflorum	alternateflower watermilfoil	s	10	5
Myriophyllum aquaticum	parrotfeather	s	0	-3
Myriophyllum farwellii	Farwell's watermilfoil	s	8	5
Myriophyllum heterophyllum	variable watermilfoil	s	0	-5
Myriophyllum humile	low watermilfoil	s	5	3
Myriophyllum pinnatum	cutleaf watermilfoil	s	8	5
Myriophyllum sibiricum	Northern watermilfoil	s	4	3
Myriophyllum spicatum	Eurasian watermilfoil	s	0	-5
Myriophyllum tenellum	leafless watermilfoil	s	6.5	3
Myriophyllum verticillatum	whorlleaf watermilfoil	s	4.5	3
Myriophyllum sp	watermilfoil	s		3
Najas flexilis	slender naiad	s	4	3
Najas marina	spiny naiad	s	9.5	5
Najas minor	brittle naiad	s	0	-1
Najas gracillima	slender waternymph	s	6	3
Najas guadalupensis	southern naiad	s	5.5	1
Najas quadalupensis var muenscheri	Muenscher's waternymph	s	9.5	5
Najas quadalupensis var olivacea	Guadalupe waternymph	s	8.5	5
Najas sp	naiad	s	6	3
Nelumbo lutea	American lotus	f	8	1
Nelumbo nucifera	sacred lotus	f	0	-1
Neobeckii aquatica	lakecress	s	9	3
Nitella flexilis	stonewort	s	5	3
Nitellopsis obtusa	starry stonewort	s	0	-5
Nuphar advena	yellow pond lily	f	7	1
Nuphar microphylla	yellow pond lily	f	7	3

Scientific Name	Common Name	Type	C_{ny}	C_m
Nuphar rubrodisca	yellow pond lily	f	7	3
Nuphar sp	yellow waterlily	f	7	1
Nuphar variegata	variegated yellow waterlily	f	7	1
Nymphaea odorata	fragrant white wateriliy	f	4.5	1
Nymphaea tuberosa	American water waterlily	f	4.5	1
Nymphaea sp	white waterlily	f	4.5	1
Nymphoides cordata	little floating heart	f	7	3
Nymphoides peltata	yellow floating heart	f	7	-3
Peltandra virginica	green arrow arum	e	6	3
Phalaris arundinacea	reed canarygrass	e	1	1
Phragmites australis	phragmites	e	0	-5
Poaceae sp	bluegrass	e	7	3
Podostemum ceratophyllum	hornleaf riverweed	s	9	5
Polygonum amphibium	longroot smartweed	f	6	3
Pontederia cordata	pickerelweed	e	5.5	3
Potamogeton alpinus	alpine pondweed	s	7	5
Potamogeton amplifolius	large leaf pondweed	s	4.5	1
Potamogeton berchtoldii	Berchtold's pondweed	s	4	3
Potamogeton bicupulatus	snailseed pondweed	s	4.5	3
Potamogeton confervoides	Tuckerman's pondweed	s	9	3
Potamogeton crispus	curly-leafed pondweed	s	0	-3
Potamogeton diversifolius	waterthread pondweed	s	7	5
Potomogeton epihydrus	ribbonleaf pondweed	s	4	3
Potamogeton foliosus	leafy pondweed	s	3.5	1
Potamogeton friesii	Fries' pondweed	s	5	3
Potamogeton gramineus	variable pondweed	s	5	3
Potamogeton hillii	Hill's pondweed	s	8	5
Potamogeton illinoensis	Ilinois pondweed	s	5.5	3
Potamogeton natans	floating brownleaf pondweed	s	4	3
Potamogeton nodosus	long leaf pondweed	s	4	3
Potamogeton oakesianus	Oakes' pondweed	s	5	3
Potamogeton obtusifolius	bluntleaf pondweed	s	5	3
Potamogeton perfoliatus	clasping leaf pondweed	s	4	3
Potamogeton praelongus	whitestem pondweed	s	4.5	3
Potamogeton pulcher	spotted pondweed	s	7	5
Potamogeton pusillus	small pondweed	s	4	3
Potamogeton richardsonii	Richardson's pondweed	s	4.5	3
Potamogeton robbinsii	Robbins pondweed	s	4.5	3
Potamogeton spirillus	spiral pondweed	s	4.5	3
Potamogeton strictifolius	narrowleaf pondweed	s	9	5
Potamogeton tennesseensis	Tennessee pondweed	s	3.5	3
Potamogeton veseyi	Vasey's pondweed	s	5	3
Potamogeton zosteriformis	flat-stemmed pondweed	s	5	3
Potamogeton sp (narrow)	unID narrowleafed pondweed	s	7	3
Potamogeton sp (wide)	unID wideleafed pondweed	s	4	3
Proserpinacea palustris	marsh mermaidweed	s	6	3

Scientific Name	Common Name	Type	C_{ny}	C_m
Proserpinacea pectinatus	combleaf mermaidweed	s	9	5
Ranunculus aquatilis	white water crowfoot	s	5	3
Ranunculus flabellaris	yellow buttercup	s	6	3
Ranunculus longirosteris	long beak buttercup	s	5	3
Ranunculus reptans	creeping buttercup	s	6	3
Ranunculus trichophyllus	threadleaf crowfoot	s	5	3
Riccia fluitans	unnamed liverwort	f	5	3
Rorippa nasturtium-aquaticum	onerow yellow cress	e	4	3
Ruppia maritima	widgeongrass	e	8.5	3
Sagittaria graminea	grassy arrowhead	e	7	3
Sagittaria latifolia	broadleaf arrowhead	e	4	3
Sagittaria rigida	sessiefruit arrowhead	e	4.5	3
Sagittaria sp	arrowhead	e	5	3
Sagittaria subulata	awl-leaf arrowhead	e	9	5
Sagittaria teres	slender arrowhead	e	9.5	3
Scirpus acutus	hardstem bulrush	e	7	3
Scirpus americanus	chairmaker's burush	e	7.5	3
Scirpus ancistrocaetus	barbed bristle bulrush	e	10	5
Scirpus fluviatilis	low bulrush	e	5	3
Scirpus georgianus	Georgia bulrush	e	3	5
Scirpus longii	Long's bulrush	e	8	5
Scirpus rubrotinctus (microcarpus)	panicled bulrush	e	5	3
Scirpus subterminalis	swaying bulrush	e	6.5	3
Scirpus torreyi	Torrey's bulrush	e	6	3
Scirpus validus	softstem bulrush	e	5	3
Scirpus sp	bulrush	e	6	3
Sium suave	hemlock water parsnip	e	4	3
Sparganium americanum	American bur reed	e	5	3
Sparganium androcladum	branched bur reed	e	5	3
Sparganium angustifolium	narrowleaf bur reed	s	6.5	3
Sparganium chlorocarpum (emersum)	European bur reed	e	6	3
Sparganium eurycarpum	broadfruit bur reed	e	5	3
Sparganium fluctuans	floating bur reed	e	6.5	5
Sparganium minimum (natans)	small bur reed	e	8	5
Sparganium sp	bur reed	s	6	3
Sphagmum sp	sphagmum moss	s	5	3
Spirodela polyrhiza	large duckweed	f	3	3
Stuckenia filiformis	fineleaf pondweed	s	8	5
Stuckenia pectinata	Sago pondweed	s	5.5	3
Stuckenia vaginata	sheathed pondweed	s	8	3
Subularia aquatica var americana	American waterawlwort	s	9.5	-5
Trapa natans	waterchestnut	f	0	-3
Typha angustifolius	narrowleaf cattail	e	0	-5
Typha latifolia	broadleaf cattail	e	2.5	1
Unknown		s	5	3
Utricularia cornuta	horned bladderwort	s	8	3

White Paper 1F-
Evaluation of Coefficients of Conservatism in NYS Lakes

Scientific Name	Common Name	Type	C_{ny}	C_m
Utricularia geminiscapa	hiddenfruit bladderwort	s	7	3
Utricularia gibba	humped bladderwort	s	6	3
Utricularia inflata	swollen bladderwort	s	4	3
Utricularia intermedia	flatleaf bladderwort	s	5.5	3
Utricularia juncea	southern bladderwort	s	7.5	5
Utricularia minor	lesser bladderwort	s	7	3
Utricularia olivacea	piedmont bladderwort	s	0	3
Utricularia purpurea	purple bladderwort	s	6	1
Utricularia radiata	little floating bladderwort	s	6	5
Utricularia resupinata	lavender bladderwort	s	6.5	3
Utricularia striata	striped bladderwort	s	8	5
Utricularia subulata	zigzag bladderwort	s	8	5
Utricularia vulgaris	common bladderwort	s	5	1
Utricularia sp	bladderwort	s	6	3
Vallisneria americana	eelgrass	s	4.5	3
Wolffia borealis	northern watermeal	f	4	1
Wolffia brasiliensis (papulifera)	Braziian watermeal	f	4	1
Wolffia columbiana	Columbian watermeal	f	3	1
Wolffia gladiata	Florida mudmidget	f	0	1
Wolffia sp	watermeal	f	3	1
Zanichellia palustris	horned pondweed	s	8	3
Zizania aquatica	annual wildrice	e	7.5	3
Zizania palustris	northern wildrice	e	6.5	5
Zosterella dubia	water stargrass	s	5.5	3

Legend:
Type = type of aquatic plant, as encountered in typical NYS aquatic plant surveys
s = submergent
f = floating leaf
e = emergent
C_{ny} = coefficients of conservatism for New York state, average from two state contact botanists (Fried et al, 2012)
C_m = simplified coefficient of conservatism using -5 to 5 scale (Kishbaugh, 2020)

Appendix 4.5.1: % Accuracy of Mean C_m Estimates At Survey Site Densities

All Lakes	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	64	64	52	52	52	52	45	45	45	45	45
%±30%	61%	88%	81%	90%	92%	92%	84%	91%	93%	96%	93%
%±20%	41%	81%	69%	85%	92%	88%	69%	84%	89%	87%	87%
%±10%	25%	63%	35%	67%	69%	73%	40%	67%	64%	71%	69%
%±5%	16%	44%	19%	44%	44%	52%	29%	47%	53%	56%	49%

Small Lakes	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	35	35	25	25	25	25	22	22	22	22	22
%±30%	68%	92%	89%	96%	100%	96%	86%	100%	100%	100%	95%
%±20%	46%	89%	81%	93%	100%	93%	86%	91%	95%	86%	86%
%±10%	27%	78%	48%	89%	78%	85%	64%	86%	82%	82%	82%
%±5%	16%	59%	26%	63%	67%	70%	45%	68%	68%	68%	59%

Large Lakes	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	27	27	25	25	25	25	23	23	23	23	23
%±30%	52%	81%	72%	84%	84%	88%	83%	83%	87%	91%	91%
%±20%	33%	70%	56%	76%	84%	84%	52%	78%	83%	87%	87%
%±10%	22%	41%	20%	44%	60%	60%	17%	48%	48%	61%	57%
%±5%	15%	22%	12%	24%	20%	32%	13%	26%	39%	43%	39%

Lakes w/Std < Sites	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	41	41	36	36	36	36	34	34	34	34	34
%±30%	71%	98%	89%	100%	100%	97%	91%	100%	100%	100%	97%
%±20%	46%	90%	78%	97%	100%	94%	79%	94%	97%	91%	91%
%±10%	24%	68%	39%	75%	72%	81%	44%	74%	71%	74%	74%
%±5%	12%	44%	19%	50%	44%	56%	32%	50%	56%	62%	56%

Lakes w/Std > Sites	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	23	23	16	16	16	16	11	11	11	11	11
%±30%	43%	70%	63%	69%	75%	81%	64%	64%	73%	82%	82%
%±20%	30%	65%	50%	56%	75%	75%	36%	55%	64%	73%	73%
%±10%	26%	52%	25%	50%	63%	56%	27%	45%	45%	64%	55%
%±5%	22%	43%	19%	31%	44%	44%	18%	36%	45%	36%	27%

Legend- %±30%(20%,10%,5%) = estimated pC_m from regression within 30%, 20%, 10% and 5% of projected pC_m at 1 site/littoral hectare; S1-15 = regression of estimated C_m at sites 1-15 projected to 1 site per littoral hectare

All = all PIRTRAM lakes; Small Lakes = littoral area < 40 ha; Large Lakes = littoral acre > 40 ha;
Lakes w/Std < Sites = # Survey Sites > 1 site/littoral hectare (so pC_m is calculated rather than projected)
Lakes w/Std > Sites = # Survey Sites < 1 site/littoral hectare (so pC_m is projected rather than calculated)

Appendix 5.5.1: % Accuracy of Frequency-Corrected Mean C_m Estimates At Survey Site Densities, Using % Differences Only

All Lakes	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	30	30	21	21	21	21	14	14	14	14	11
%±30%	43%	77%	52%	86%	81%	71%	57%	79%	79%	86%	91%
%±20%	30%	50%	38%	71%	62%	67%	50%	71%	71%	86%	73%
%±10%	17%	27%	29%	62%	48%	48%	36%	50%	71%	64%	55%
%±5%	13%	17%	19%	29%	24%	14%	21%	29%	29%	21%	27%

Small Lakes	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	15	15	7	7	7	7	4	4	4	4	1
%±30%	53%	88%	78%	100%	89%	67%	100%	75%	75%	100%	100%
%±20%	35%	59%	56%	78%	56%	56%	100%	75%	75%	100%	100%
%±10%	18%	35%	44%	78%	44%	56%	75%	75%	75%	75%	100%
%±5%	12%	24%	33%	33%	22%	11%	50%	50%	25%	0%	0%

Large Lakes	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	13	13	12	12	12	12	10	10	10	10	10
%±30%	31%	62%	33%	75%	75%	75%	40%	80%	80%	80%	90%
%±20%	23%	38%	25%	67%	67%	75%	30%	70%	70%	80%	70%
%±10%	15%	15%	17%	50%	50%	42%	20%	40%	70%	60%	50%
%±5%	15%	8%	8%	25%	25%	17%	10%	20%	30%	30%	30%

Lakes w/Std < Sites	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	15	15	10	10	10	10	8	8	8	8	5
%±30%	60%	87%	50%	90%	90%	80%	63%	88%	88%	100%	100%
%±20%	40%	47%	40%	70%	70%	80%	50%	75%	75%	100%	100%
%±10%	20%	27%	30%	50%	50%	60%	38%	38%	75%	75%	80%
%±5%	13%	13%	20%	30%	20%	10%	25%	25%	13%	13%	20%

Lakes w/Std > Sites	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40
N	15	15	11	11	11	11	6	6	6	6	6
%±30%	27%	67%	55%	82%	73%	64%	50%	67%	67%	67%	83%
%±20%	20%	53%	36%	73%	55%	55%	50%	67%	67%	67%	50%
%±10%	13%	27%	27%	73%	45%	36%	33%	67%	67%	50%	33%
%±5%	13%	20%	18%	27%	27%	18%	17%	33%	50%	33%	33%

Legend- %±30%(20%,10%,5%) = estimated frequency-corrected pC_m from regression within 30%, 20%, 10% and 5% of projected pC_m at 1 site/littoral hectare; S1-15 = regression of estimated frequency-corrected C_m at sites 1-15 projected to 1 site per littoral hectare

All = all PIRTRAM lakes; Small Lakes = littoral area < 40 ha; Large Lakes = littoral acre > 40 ha;
Lakes w/Std < Sites = # Survey Sites > 1 site/littoral hectare (so pC_m is calculated rather than projected)
Lakes w/Std > Sites = # Survey Sites < 1 site/littoral hectare (so pC_m is projected rather than calculated)

Appendix 5.5.2: % Accuracy of Abundance-Corrected Mean C_m Estimates At Survey Site Densities, Using % Differences and Absolute (ΔC_m<0.1)

All Lakes	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40	S1-60	S5-60	S10-60	S15-60	S20-60	S25-60	S20-80	S25-80	S40-80
N	59	59	47	47	47	47	40	40	40	40	40	18	18	18	18	18	18	31	31	18
%±30%	31%	59%	40%	64%	70%	66%	43%	68%	80%	70%	75%	28%	56%	83%	78%	72%	83%	84%	74%	78%
%±20%	25%	46%	26%	53%	60%	55%	28%	55%	68%	60%	58%	17%	39%	67%	67%	67%	72%	84%	68%	67%
%±10%	15%	27%	21%	30%	45%	38%	23%	35%	50%	43%	53%	6%	22%	33%	28%	39%	44%	55%	42%	50%
%±5%	14%	19%	19%	21%	26%	23%	20%	20%	30%	18%	28%	0%	0%	28%	28%	39%	22%	26%	26%	33%

Small Lake	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40	S1-60	S5-60	S10-60	S15-60	S20-60	S25-60	S20-80	S25-80	S40-80
N	33	33	23	23	23	23	20	20	20	20	20	0	0	0	0	0	0	11	11	0
%±30%	49%	89%	64%	92%	92%	80%	70%	95%	95%	80%	85%							82%	64%	
%±20%	40%	74%	48%	80%	76%	68%	55%	80%	85%	65%	60%							82%	64%	
%±10%	23%	43%	40%	48%	60%	48%	45%	55%	70%	45%	55%							55%	27%	
%±5%	20%	29%	36%	32%	36%	32%	40%	35%	45%	15%	25%							0%	9%	

Large Lake	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40	S1-60	S5-60	S10-60	S15-60	S20-60	S25-60	S20-80	S25-80	S40-80
N	24	24	22	22	22	22	20	20	20	20	20	18	18	18	18	18	18	20	20	18
%±30%	4%	17%	14%	32%	45%	50%	15%	40%	65%	60%	65%	28%	56%	83%	78%	72%	83%	85%	80%	78%
%±20%	4%	4%	0%	23%	41%	41%	0%	30%	50%	55%	55%	17%	39%	67%	67%	67%	72%	85%	70%	67%
%±10%	4%	4%	0%	9%	27%	27%	0%	15%	30%	40%	50%	6%	22%	33%	28%	39%	44%	55%	50%	50%
%±5%	4%	4%	0%	9%	14%	14%	0%	5%	15%	20%	30%	0%	0%	28%	28%	39%	22%	40%	35%	33%

Lakes w/Std < Sites	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40	S1-60	S5-60	S10-60	S15-60	S20-60	S25-60	S20-80	S25-80	S40-80
N	41	41	36	36	36	36	34	34	34	34	34	12	12	12	12	12	12	25	25	12
%±30%	37%	63%	44%	67%	75%	67%	44%	74%	88%	74%	82%	17%	58%	100%	92%	83%	100%	88%	76%	83%
%±20%	34%	46%	31%	53%	67%	61%	32%	59%	74%	65%	65%	0%	42%	83%	75%	75%	83%	88%	72%	75%
%±10%	22%	29%	28%	28%	50%	42%	26%	38%	56%	47%	59%	0%	25%	42%	42%	58%	50%	68%	44%	58%
%±5%	20%	20%	25%	19%	31%	28%	24%	21%	35%	21%	29%	0%	0%	33%	42%	58%	25%	32%	28%	42%

Lakes w/Std > Sites	S1-15	S5-15	S1-25	S5-25	S10-25	S15-25	S1-40	S5-40	S10-40	S15-40	S20-40	S1-60	S5-60	S10-60	S15-60	S20-60	S25-60	S20-80	S25-80	S40-80
N	18	18	11	11	11	11	6	6	6	6	6	6	6	6	6	6	6	6	6	6
%±30%	17%	50%	27%	55%	55%	64%	33%	33%	33%	50%	33%	50%	50%	50%	50%	50%	50%	67%	67%	67%
%±20%	6%	44%	9%	55%	36%	36%	0%	33%	33%	33%	17%	50%	33%	33%	50%	50%	50%	67%	50%	50%
%±10%	0%	22%	0%	36%	27%	27%	0%	17%	17%	17%	17%	17%	17%	17%	0%	0%	33%	0%	33%	33%
%±5%	0%	17%	0%	27%	9%	9%	0%	17%	0%	0%	17%	0%	0%	17%	0%	0%	17%	0%	17%	17%

Legend- %±30%(20%,10%,5%) = estimated abundance-corrected pC_m from regression within 30%, 20%, 10% and 5% of projected pC_m at 1 site/littoral hectare OR ΔC_m <0.1); S1-15 = regression of estimated abundance-corrected C_m at sites 1-15 projected to 1 site per littoral hectare

All = all PIRTRAM lakes; Small Lakes = littoral area < 40 ha; Large Lakes = littoral acre > 40 ha;
Lakes w/Std < Sites = # Survey Sites > 1 site/littoral hectare (so pC_m is calculated rather than projected)
Lakes w/Std > Sites = # Survey Sites < 1 site/littoral hectare (so pC_m is projected rather than calculated)