

REVIEW OF CLAIMS OF SPECIES LOSS IN THE FLORA OF CONCORD, MASSACHUSETTS, ATTRIBUTED TO CLIMATE CHANGE

RAY ANGELO

Harvard University Herbaria
22 Divinity Avenue
Cambridge, Massachusetts 02138-2020
rangelo@oeb.harvard.edu

ABSTRACT

The observations of a previous article (Angelo 2014a) that examined the issue of claimed species loss in the Orchidaceae and Liliaceae of Concord, Massachusetts, are here significantly extended. A comprehensive and detailed review is made of all 192 species claimed to have experienced significant decline in frequency of occurrence in Concord and that were used to determine phenological and phylogenetic correlations in the climate change work of Willis et al. (2008). In addition, I evaluate the methodology and the historical data used by Primack et al. (2009) to determine the species that experienced significant loss and their degree of loss (used by Willis et al.). The recent and comprehensive information used here to make the analysis and evaluation are my recently completed online flora of Concord, Massachusetts (Angelo 2014b), the study of the flora of Middlesex Fells Reservation, Massachusetts (Hamlin et al. 2012), the vascular flora of Worcester County, Massachusetts (Bertin & Rawinski 2012), and the subsequent analysis of the Worcester County native vascular flora by Bertin (2013). The analysis here reveals that only 44 of the 429 Concord species from the Primack et al. (2009) study that are used by Willis et al. (2008) can be claimed with reasonable probability as significantly declining (or to have declined) in frequency of occurrence. Of these 44 species, 24 can be associated with causes for decline other than climate change. Moreover, it is demonstrated that the methodology of Primack et al. (2009) is seriously flawed, that the historical data used for that study are unreliable for the purposes to which they are put, and that the present-day data obtained in that study for uncommon species are also unreliable. Consequently, the dramatic claims by Primack et al. (2009) regarding disappearance of plant species in Concord are unwarranted and the findings in Willis et al. (2008) based upon those claimed disappearances are flawed and unusable.

Primack et al. (2009) surveyed a portion of the flora of Concord, Middlesex County, Massachusetts, between 2003 and 2007, focusing primarily on the protected land of the town. Their findings of species diversity and abundance were compared with the report by Hosmer (1903) for the same general vicinity about 100 years previously. Primack et al. (2009) claim that 24% of 479 native and non-native species seen by Hosmer (1903) could no longer be found and that the losses appeared to be have been sustained mostly in the prior 30-40 years. Willis et al. (2008) utilized data of 429 species from the study of Primack et al. (2008) and phenology data past and present compiled by Miller-Rushing & Primack (2008) to discover correlations between species decline in frequency and historical shifts in average flowering dates. The study found a correlation for species with smaller shifts in flowering dates (comparing recent times and periods in the 19th century) with an apparent decline in frequency of occurrence. In turn such species were found to occur mostly within certain families. The inference drawn was that climate change was responsible for their decline since species that are least able to shift their flowering time due to increasing temperatures are less successful.

In the present study, the methodology and frequency of occurrence data (historical and current) used by Primack et al. (2009) will first be evaluated. Then the group of 192 Concord species (out of 429 species used by Willis et al. 2008) determined by Primack et al. (2009) to have experienced more

than minimal decline in frequency (from 1903 to ca. 2007) will be analyzed using recent information. If the data for changes in frequency of occurrence provided by Primack et al. (2009) are found to be significantly incorrect or unreliable, then the correlations found by Willis et al. (2008) are invalid. Correlations based on the use of faulty data do not confer validity on those data.

Methodology of Primack et. al. (2009)

The concept behind the methodology of Primack et al. (2009) for the species used by Willis et al. (2008) is simple: for each species listed by Hosmer (1903) compare the frequency of occurrence stated by Hosmer (1903) with the frequency of occurrence of the same species in the period 2003-2007. However, multiple, significant problems that are not addressed or disclosed in Primack et al. (2009) are detailed below.

1. Mismatch of study areas

Hosmer's (1903) study area is more than Concord. There is a great difference in the geographical sample area of Hosmer (1903) and Primack et al. (2009). This is clear from the very title of Hosmer's manuscript containing his information. The title is "List of the Wild Flowers (and time of blooming) of Concord, Mass. and vicinity as observed by Alfred W. Hosmer." Hosmer's data include the entire Concord vicinity, not just Concord proper. When Hosmer cites specific locations for species in his list, locations from other townships are included but not typically stated as such. In fact, review of Primack et al.'s (2009) use of Hosmer's records shows that some of those locations (such as Grassy Pond and Stow Swamp) were misconstrued by Primack et al. (2009) to be in Concord instead of in townships outside of Concord, so that the frequency of occurrence assigned to Hosmer's information was increased. These instances are noted in Appendix A below. More importantly, Hosmer's designation of "Common" is not specifically applied only to the plants of Concord but to the Concord vicinity, which includes Lincoln, Bedford, Carlisle, Acton, Sudbury and even non-contiguous Stow (from Hosmer's references to a notable swamp there). One might assert that this is a distinction without a difference, but this is not the case as shown below.

In Willis & Davis (2014) it is implied that, because declines were similarly found when comparing the Primack et al. (2009) survey with data from Henry Thoreau's Journal (1906, all other references to "Journal" are to this) and from Eaton (1974), the much larger Hosmer (1903) sampling area does not significantly change the conclusions. Thoreau in his Journal, however, does not present frequency of occurrence data explicitly, so that such a comparison is not feasible. The frequency of occurrence can be determined crudely in many cases (common vs. uncommon), but only by carefully checking Thoreau's Journal entries for each species, not just using the number of Journal entries for each species. This is due to Thoreau's repeated references to single stations, references to stations outside of Concord, and a great many references that do not cite a specific location. Of the 770 vascular plant species that Thoreau reported or collected in Concord that have been vouchered as occurring in Concord, the frequency of occurrence cannot be even approximately determined for 262 of them, a high percentage. Comparison with Eaton's (1974) information would be a different study and still suffer from the inadequacies identified below.

Plant species are not evenly distributed within the varied habitats of the Concord vicinity, just as the species are not evenly distributed within Concord proper, as the evidence presented below will demonstrate. Striking differences in frequency information occur between Pratt (1878), who limited his work to Concord (with rare exceptions), and that of Hosmer (1903). The difference in sampling areas is the only way to account for these differences. There are even seven instances in just the 192 species reviewed in detail in this article where Pratt (1878) described a species as rare while Hosmer (1903) described it as common, and only two of those seven are alien species (for which a sudden increase would not be unusual). A comparison of all 335 species listed by both Pratt (1878) and Hosmer

(1903) where frequency information is stated or can be determined as either common (including abundant, very common, rather common, common, frequent, and not uncommon) or uncommon (infrequent, uncommon, occasional, scarce, rare) shows that there are 57 instances where Pratt (1878) indicates the species to be uncommon while Hosmer (1903), for the Concord vicinity, indicates the species to be common. In addition there are 36 species not even listed by Pratt (1878) for Concord that are indicated as common by Hosmer (1903), and another 68 species not listed by Pratt (1878) that are described by Hosmer (1903) as uncommon. By contrast, only 17 species are indicated as common by Pratt (1878) and uncommon by Hosmer (1903). So, unless we want to conclude that there was an explosion in abundance for 161 species in Concord between 1878 and 1903, it follows that Hosmer's (1903) frequency information is not entirely representative of Concord proper.

The possibility of less sampling of the flora by Pratt (1878) than by Hosmer (1903) is highly unlikely given that Minot Pratt botanized in Concord for 36 years (1842-1878) while Alfred Hosmer botanized primarily only for 15 years (1888-1903). A familiarity with Pratt's manuscript (1878) reveals that he found a significant number of locations for rare or uncommon plants not found by Thoreau or Alfred Hosmer, each of whom botanized for shorter periods of time. Pratt (1878) lists 587 species in Concord that are vouchered as occurring in Concord (not including 114 species introduced by Minot Pratt himself into Concord) while Hosmer (1903) lists 664 species vouchered as occurring in Concord, including about 10 vouchered Minot Pratt introductions that survived. The main difference between Pratt's and Hosmer's numbers is the advent of new alien species, but some difference also is attributable to the recognition of more species in Hosmer's time that previously were lumped together in Pratt's time. Hosmer's (1903) much larger sample area produces frequencies of occurrence that differ significantly from Concord proper, with many more species found as "common."

Primack et al.'s (2009) study area is less than all of Concord. It is a fundamental principle of measuring population changes to compare the same sample areas. Comparison of the Hosmer (1903) information for the greater Concord vicinity with the much smaller sample area of Primack et al. (2009), focused on the protected areas portion of Concord, would be expected to yield even more incomparable results. This very large differential between sample areas renders invalid the claimed abundance changes of Primack et al. (2009) that were used by Willis et al. (2008).

Primack et al. (2009) purport to measure the effectiveness of conservation efforts by measuring changes in the flora of protected areas of Concord but at the same time announce significant losses for the whole of Concord. There are significant problems with this agenda, the first being that the flora of the protected areas of Concord, as significant as these might be in terms of acreage, is not the flora of the whole of Concord. Numerous stations of uncommon plants are on private, unprotected land, such as in the large sphagnum bog in the southwestern corner of the town, the greater part of Conantum, Ball's Hill, large parts of Punkatasset Hill, an open, sandy plain rapidly disappearing near Second Division Brook, a large part of Fair Haven Hill, Annursnack Hill, and more. The study notes that 35% of the area of the town is actually protected while another 27% is not actually protected but undeveloped and "targeted for conservation efforts." There is no evidence to establish that the flora of the "protected" and "targeted" areas is representative of the flora of the entire town. To measure changes in the protected areas, even including the "targeted" areas" would presume the capability of identifying what was in those areas compared to the historic time of Henry Thoreau or Alfred Hosmer. The historic information for such a comparison is simply unavailable. Pratt (1878) and Hosmer (1903) only occasionally provided plant locations, some of which are not locatable or are located with great difficulty. Thoreau's Journal is also of little assistance since in a great many instances he provided no location for a given plant find or he used his own place name, which in many cases has yet to be determined in terms of modern geographic coordinates. For Primack et al. (2009) to state that 27% of plants seen by Thoreau were not located is not at all surprising in light of the above considerations

(assuming that their count of what Thoreau saw is accurate). For that study further to claim that 36% of the plant species seen by Thoreau persist currently in only one or two populations “vulnerable to extinction” is to conflate the limited exploration and adequacy of that study to what is actually happening to those species in the entire town. The issue of failure to find plant populations is discussed in more detail below.

2. Differing concepts of frequency of occurrence terms

There is an issue with comparing common English terms for frequency of occurrence between two different observers, particularly ones of different eras. This is acknowledged by Primack et al. (2009), but the number of species affected is claimed to be “probably small in comparison to the total number of species in the study” without any justification, particularly with respect to the subset of species for which significant decline is claimed. There is no evidence to indicate exactly what qualified as “common” or “uncommon” in the mind of Alfred Hosmer. Eight stations of a given species spread over seven townships of the Concord vicinity with only one station in Concord proper might qualify as “common” for Hosmer (1903) but would be “rare” for Primack et al. (2009). Or, a species that occurs in abundance in three townships of the Concord vicinity but not in Concord itself might qualify as “common” for Hosmer (1903) but would be extinct for Primack et al. (2009). In addition, Hosmer (1903) did not provide information on the quantities of plants found at any given station. One of the frequency terms utilized by Primack et al. (2009) noted below refers to numbers of plants at a single station. The problem applies even for Eaton (1974), where the sample area is Concord proper. The terms are nowhere defined quantitatively other than by Primack et al. (2009) for their survey, where “common” was defined as three or more populations, “uncommon” as one or two populations, and this latter category subdivided into “infrequent” for two populations, “rare” for one population with more than 10 plants, and “very rare” for one population with 2-10 plants. It was observed when reviewing the source information for Primack et al. (2009) that when Hosmer (1903) simply listed locations rather than provide a frequency description, the definitions that Primack et al. (2009) used for their own finds were applied to these instances in (Hosmer 1903) to yield values of “common” where Hosmer himself did not apply that term. Thus, there were more instances of “common” for Alfred Hosmer’s species than he himself acknowledged.

The increased use of “common” by Hosmer (1903) can be seen statistically. The work of Hosmer (1903) uses “common” in the broad sense (abundant, very common, common, not uncommon) for 61% of the vouchered Concord species (406 out of 664) for which he gives frequency information (and applying the definition of “common” used by Primack et al. 2009). Thoreau’s Journal and herbarium yield 46% (218 out of 478 species) for those vouchered Concord species for which frequency can be reasonably determined, excluding grass-like families not treated by Hosmer (1903) or Pratt (1878). The percentage for Pratt (1878) is 52% (310 out of 587 species), and 49% (443 out of 911 species) for Eaton (1974). The generous use of “common” by Hosmer (1903) together with the added application of this term to additional Hosmer (1903) species where Hosmer (1903) did not use it yields an increased appearance of species decline when Primack et al. (2009) fail to find sufficient populations. Furthermore, small differences in occurrence yield the appearance of larger declines using the definitions of Primack et al. (2009). Under the Primack et al. (2009) concept of frequency, failing to find just three more stations of a species where only one station had been found is the difference between “common” and “rare.” From the above considerations it should be apparent that the attempt to estimate with any reasonable confidence changes in abundance from Alfred Hosmer’s or Thoreau’s time by comparing current estimates to Hosmer’s (1903) information or Thoreau’s very imprecise Journal information is simply not feasible, except for those species that were and are very common and for those that were and have always remained rather rare.

3. Differing experiences of a flora by different botanists, even in the same era

Primack et al. (2009) fail to recognize that different past botanists, skilled and assiduous as they might have been, experienced the same flora differently, oftentimes much differently, such that different evaluations of frequency are reported even for cases where populations of a species haven't changed. For example, in the span of less than a year, with no more than five years of experience in botany, I located three well-separated, healthy populations of *Rhododendron groenlandicum* in Concord. Yet Thoreau, Alfred Hosmer, and Richard Eaton knew it from only the same solitary location in Concord (a location ruined before my time in Concord) and Minot Pratt knew it from only two locations. *Rhododendron groenlandicum* is not an inconspicuous plant and in Concord is close to the southeastern limit of its range, being typically much more common in northern New England. Thus, unless this species somehow tripled in number of stations between the time of Alfred Hosmer and the late 1970s (contrary to the view that northern species are retreating northward due to climate warming), one can confidently presume that there were at least four stations of this native shrub in Concord in the time of Thoreau. The varying frequencies attributed to the various Concord botanists for this species according to Primack et al. (2009) would have been rare, infrequent, and common. Primack et al. (2009) found none of the locations, so that "extinct" would be added to this list. Given the great variance in finding this species by past botanists, the confidence level of a report of its extinction should be low. *Rhododendron groenlandicum* is not an isolated example. In my previous article (Angelo 2014a) I noted much the same results for *Phegopteris connectilis*, and there are other similar examples cited in Appendix A below.

To give a quantitative measure of this, it is revealing to compare the experiences of Thoreau and Minot Pratt, who both botanized in Concord at about the same time and were friends. There are about 374 species vouchered to occur in Concord for which it is possible to discern from Thoreau's Journal whether he found them common or uncommon in Concord and for which Pratt (1878) also provided frequency information. Of these are 58 for which Thoreau did not find the species common while Pratt (1878) found them common. There are 18 species for which Thoreau found the species common but Pratt (1878) did not find them common. Thus, there was disagreement for 76 of 374 species, or 20%. The conclusion should be that any finding that there are many stations of a species in a survey of a given, sizable area is relatively reliable (barring issues of difficulty in identification). Also, findings of relatively few stations of a species are subject to a large margin of error, unless the habitat for the species is known to be rare in the study area (such as sphagnum bogs or serpentine outcrops). Primack et al. (2014) make the point that multiple botanists, including myself, were consulted to ensure an accurate inventory of Concord's flora. But I (and other local botanists) did not make an attempt to correct all the failures to find plants of Primack et al. (2009). I merely provided information on where a limited number of uncommon plants had been found by me in the past. Also, local botanists do not carry in their memory or notes the locations of all occurrences of all common and uncommon species that they have seen over many years of exploration of an area. The amount of time necessary to remedy the notable abundance of failures of Primack et al. (2009) to find species in Concord would be enormous, even if feasible, as discussed below (7. Insulation from falsifiability).

4. Significance of population size

Primack et al. (2009) attach undue significance to numbers of individuals for a given station of a species. Their study defines a separate category of "very rare" for single stations with 10 or fewer plants. This is an arbitrary number. While the number of plants at a lone surviving station in a large area is relevant for the survival of that species in that area, some species are naturally distributed in small quantities in scattered stations. When one of the authors of (Primack et al. 2009) was shown stations of species in Concord at the time of their study that those authors claimed to be "lost" (simply because they failed to locate them), the demonstrations of continued existence of those species in Concord were typically dismissed as insignificant based on the small number of the plants at the station

and upon the fact that more stations were not at once demonstrated. Experienced field botanists know that finding a single population of a species with few individuals does not signify that one has by remarkable chance found the last, dying group of the species in the entire area, regardless of how many hours might have been spent wandering the woodlands, swamps, etc., on the look-out for it. Instead, it is virtually always a sign that there are more populations as small or larger somewhere in the vicinity that have yet to be found. Some species simply do not inhabit the environment in large populations as do *Maianthemum canadense* or *Gaylussacia baccata*. Instead, they disperse themselves in small, sometimes widely separated groups that have long thrived in that mode of distribution.

For example, Pratt (1878) noted for *Asclepias amplexicaulis* that it was sparingly scattered in all quarters of Concord, while Thoreau did not notice it in Concord until 1852, about 10 years before his death. In my time in Concord in the 1970s/80s I observed this same sparse distribution pattern. In 2007 on a brief visit to Concord I found a modest amount of this plant along a road where I had seen it about 30 years before. Upon directing one of the authors of the Primack et al. (2009) paper to this location (since in the 4-5 years of that study they had found none) this station was dismissed at once as insignificant due to the smallness of the population (about 20 plants). This reflects an ignorance of the ecological and historical context of this species in Concord. It is likewise with *Asclepias exaltata* for which Pratt (1878) noted its occurrence only in the northerly part of the town and that there were not more than three or four plants in all. I found *A. exaltata* in my time in Concord at six locations, but never with more than a few plants at each location. *Asclepias amplexicaulis* and *Asclepias exaltata*, unlike their vigorously vegetatively reproducing sister species, *Asclepias syriaca*, never occur in Concord in great quantities, illustrating clearly that species in Concord within the same genus can march to different drummers. Failure to recognize this ecological fact and the reproductive nature of individual species is to misread the Concord flora, or any flora, such as at Middlesex Fells. While increase or decrease in numbers of a particular population at a particular site might be of interest, we simply do not have that level of detailed information from past botanists in Concord for a significant spectrum of the flora. The peculiar view adopted by Primack et al. (2014) is that happening to find one population with a relatively small number of individuals invariably portends the extinction of the species in the near future, a view that is without foundation. New stations for a species, for instance, will start small. If the view is simply that it is more likely to become extinct, this too is unsubstantiated, particularly given the fact that all stations of the plant are not known. If a species is known with certainty, due usually to rarity of habitat, to occur only in few numbers at a very few sites, then those would, of course, be more vulnerable to extinction. But the key point is knowing with certainty how many stations there really are and the natural distribution pattern for the species.

5. Inadequacy of exploration — under-sampling

This is might be the most significant problem with the study by Primack et al. (2009). That study does not take into account the possibility of inadequacy of their survey for the variety of reasons identified in my previous article (lack of access, lack of skill at locating particular species, limited exploration). Primack et al. (2009) were unable to find 70 of Hosmer's (1903) 322 native Concord species used by Willis et al. (2008), including *Myrica gale*, *Clintonia borealis*, and *Andromeda polifolia*, known to be currently in the town. Earlier indications of inadequate sampling are found in Drayton & Primack (1996) where, for example, among the species claimed as "lost" were the showy, wetland species, *Lobelia cardinalis*, *Ilex verticillata*, and *Lysimachia terrestris*, all of which Hamlin et al. (2012) found to be common and not at all "lost" or hard to find. One of the clearest signs that the study by Primack et al. (2009) has significantly underreported the occurrence of species in Concord is the reporting of some currently common, easy-to-recognize, native species as "infrequent" (only two stations) in Concord. These include *Mitchella repens* (currently plentiful and common throughout Concord), *Houstonia caerulea* (more than seven locations, several of these in abundance), *Sassafras albidum* (currently more than 12 stations) *Anemone quinquefolia* (abundant with many more than four

stations), *Chimaphila umbellata* (more than four stations), *Gaultheria procumbens* (plentiful with many more than four stations), *Apios americana* (plentiful with many more than four stations), *Lobelia inflata* (plentiful with many stations), and *Sium suave* (plentiful with many more than four stations), as reported by Cherrie Corey (2014 pers. comm.) and Cole Winstanley (2014 pers. comm.). See Appendix A for details for some of these. All of these but one are currently common in both Worcester County (Bertin pers. comm.) and at Middlesex Fells (Hamlin et al. 2012). That one, *Houstonia caerulea* (not common at Middlesex Fells), however, is widespread and abundant in Concord as noted above. For a study of Concord purporting to be intensive (for at least four years) to fail significantly in finding these nine, well-known, common species, corroborated as currently common in studies of locales near Concord as well as by local Concord resident naturalists, implies that the findings of the Primack et al. (2009) study for other common species and especially uncommon species cannot be relied upon.

It is not for this article to determine the reasons for the failure just noted. The limitation of Primack et al. (2009) in their explorations of Concord primarily to “protected areas” could be a contributing factor, although the finds of Cherrie Corey and Cole Winstanley noted above are mostly on protected lands. Even in exploring such areas there is no means available to evaluate how thorough the authors were in exploring those areas. Lack of access to important privately owned tracts of land might also be a factor. The skill of the authors of the Primack et al. (2009) study in recognizing and finding plants could be a major factor.

Additional indication of underreporting of species abundance by Primack et al. (2009) is the fact that 57 of 171 species (adjusted from 192 to remove unusable taxa as detailed below) claimed by that study to have significantly declined in abundance have not declined or are only minimally declined in frequency in the recent studies of Worcester County (Bertin & Rawinski 2012) and the Middlesex Fells Reservation (Hamlin et al. 2012), as detailed in the Appendix A. The finding of Primack et al. (2009) that significant numbers of species declined only between the time of Eaton (1974) and Primack et al. (2009) rather than between older botanical surveys is not at all surprising if the Primack et al. (2009) findings are significantly inadequate, as is indicated above. Also, the finding of Primack et al. (2009) that species reported by Eaton (1974) as uncommon to one degree or another were the ones mostly found by them to have become “locally extinct” is consistent with the greater likelihood that their inadequate survey would be less likely to find uncommon species (since they even had difficulty finding species that have remained common through time).

Primack et al. (2014) make the argument that a comparison is not feasible between two floral studies of a given area, as between Drayton & Primack (1996) and Hamlin et al. (2012), or between the latter and Deane (1896), because comparable numbers of investigators did not spend comparable numbers of hours. This assumes not only that effectiveness of study is directly proportional to hours spent between different individuals but also that Primack et al. (2014) have accurate information on the number of hours spent by Hosmer (1903) botanizing in Concord proper and on the number of hours expended by those botanists known to have provided the information used by Deane (1896). Even with this knowledge, the point of Primack et al. (2014) renders comparison between all studies unreliable (including between Hosmer 1903 and Primack et al. 2009), as no two of them will have spent comparable time, assuming such time is equally effective. Thus, the findings of thorough multiple studies over time and in neighboring areas is essentially the only way to obtain a reasonable understanding of what changes are actually occurring for each species.

6. Alien species

The inclusion of alien species in presenting claims of species loss is questionable. The disappearance of alien species in any area has much more to do with changes in cultivation practices (agricultural, ornamental, seeding projects) and industry (presence or absence of textile mills, extent of railroads, etc.) than it does with broader environmental changes. This can be seen in the species-by-species review of the 192 species (native and alien) of claimed significant decline used by Willis et al. (2008). The case of *ASPARAGUS OFFICINALIS* is particularly dramatic with the frequency of occurrence tracking clearly the great expansion of asparagus farming in Concord right after the time of Thoreau followed by the significant decrease in this farming in the 20th century. Bertin and Parise (2014) appropriately analyze abundance changes of non-native species in Worcester County, Massachusetts separately from native species (Bertin 2013).

With regard to discerning effects of climate change, including alien species is unwarranted and misleading. Such species have not adapted to the local environment over hundreds or thousands of years as native species have. The fact that they can be introduced into and multiply so quickly in Concord demonstrates that they are sensitive to factors that do not affect the native species correspondingly. These species by their nature tend to be very adaptable to new environments and changes in the environment. Jonathan Lenoir, lead author of a study cited by Willis et al. (2008), has expressed agreement (2014 pers. comm.) with this, stating “for non-native plants it is very hard to disentangle the pure effect of climate warming from the niche-filling effect of the alien in its non-native range after human introduction.” Bertin & Parise (2014) have concluded that their study provides “some of the strongest quantitative evidence of the important link between human modification of the landscape and the success of nonnative plant species for any region of North America.” and that “Residential land use is a key correlate of the occurrence of nonnative species.” Bertin and Parise (2014) considered a variety of factors that could account for the patterns of increase and decrease of nonnative species without finding climate change as a key factor. Among the 429 species used by Willis et al. (2008), 107 were nonnative species, predominantly from Eurasia, of which only 102 are actually usable (see discussion below). Of these 102 nonnative species, 38 species were claimed to be declining in the data used by Willis et al. (2008) and were used to find correlations of decline attributed to climate change.

Of the 171 species (adjusted from 192 to remove unusable taxa, as explained below) claimed by Primack et al. (2009) to have *significantly* declined in frequency of occurrence in Concord and used by Willis et al. (2008), 27 are alien species, or slightly more than 15%. This is not unusually high, but it is a significant number. It would be best for studying species decline to limit the study to native species, removing the modest but significant alien component of the species studied. To be sure, it is of interest to monitor changes in nonnative species in the flora (as Bertin and Parise 2014 do), but the results should not be mixed with those of the native species (as do Primack et al. 2009 and Willis et al. 2008).

7. Insulation from falsifiability

The nature of the study of Primack et al. (2009) is such that, for practical purposes, it is not possible to prove definitively that the claims of significant species loss are either false or significantly in error. Consider what it would require to change significantly the finding of loss for just one species. Suppose that Hosmer (1903) claimed that a particular Concord species was frequent and that Primack et al. (2009) were unable to find any stations for the species. First, it is not possible to prove that Hosmer (1903) was in error or to what degree, other than by indirect means as reasoned earlier, but which Primack et al. (2009) can simply choose not to accept. Secondly, to prove that the failure to find the species in the modern era was significantly in error would require spending time and effort to search a large area for a species that is possibly uncommon, in order to locate two or three stations. Even if

that effort were successful, the authors are likely to dismiss the stations as insignificant if a sufficient number of individuals is not found at each station or if there is only sparse flowering among the individuals found (as one of those authors has been done). Lastly, even if the authors accept the fact that they are in error for that one species, the argument will be that the results of their study are unaffected since the remainder of the many losses claimed still have not been disproven. In effect to prove the study significantly in error the entire study would need to be redone. This effectively insulates the findings of that study from falsifiability for practical purposes, other than by a combination of direct and indirect means as is done here. A case where such a study was redone was for Middlesex Fells, in which one of the authors of Primack et al. (2009) was also involved in the original study there. The redone study (Hamlin et al. 2012) did in fact find the results of the earlier study (Drayton & Primack 1996) to be significantly in error with respect to the current state of the flora. Even so, Primack et al. (2014) have attempted to argue that those recent findings do not change the claims of losses in their original study in Drayton and Primack (1996).

Review of the 192 Concord species claimed to have significantly declined by Primack et al. (2009) and used by Willis et al. (2008)

A means is used here to conduct a check on the Concord species declines reported by Primack et al. (2009) and used by Willis et al. (2008) in a manner that avoids the insulation-from-falsifiability barrier of the former study (discussed above). The 192 species among the 429 Concord species used by Willis et al. (2008) showing more than minimal decline were considered one by one in their ecological, historical and regional context: first, to determine if they were actually listed by Hosmer (1903), free of taxonomic issues, and possessing usable frequency of occurrence information by Hosmer (1903); second, to determine if there truly is a decline and to what degree; and third, to determine whether or not any possible or likely decline might be related to climate change (avoiding decline linked to other causes or decline that is only local). By removing species whose decline cannot be measured and those for which any decline would not be related to climate change, a residue of species suitable for investigation is obtained. The number of these is much less than the 192 species of claimed significant decline used by Willis et al. (2008). Species of minimal decline (a decrease of only -1 using the method of Willis et al. 2008 as explained below) are not considered here, as the margin of error (for actual decline) is too significant, either on the Hosmer (1903) or Primack et al. (2009) side or both. There were 92 such species of claimed minimal decline that were not reviewed one by one. To demonstrate the unlikelihood that consideration of these would likely yield many additional species worthy of consideration, a check was made to see how many of these are reported as currently “common” in both Worcester County (using Bertin & Rawinski 2012) and in the Middlesex Fells Reservation (Hamlin et al. 2012). It was found that there were 48 species meeting these conditions alone. Applying the other checks (taxonomic, observations of current frequency, other causes, etc., as are applied to the 192 species with significant decline) on the remaining 44 species of minimal decline (including 8 nonnative species) would most likely reduce these to relatively few, if any, and, in any case, would be of minimal significance. They would be of minimal significance since minimal decline as used by Willis et al. (2008) is essentially the difference in finding only one less station for a species currently than historically — easily within the margin for error.

1. Assumptions of Willis et al. (2008)

Willis et al. (2008) attempt to link correlations of Concord species declines as determined by Primack et al. (2009) with the lack of responsiveness in flowering times in some species to changes in average temperature in the environment (phenologically challenged species). The phenologically challenged species were in turn phylogenetically correlated (suggesting phylogenetic conservatism for this shared trait). Finding such correlations suggests the operation of climate change in species declines. This attempt is not possible if the underlying species losses claimed are not real or are not reliable. If the species losses are not distributed as claimed or not as pronounced as claimed, then any

correlation found is not significant. The attempt is also not credible if many species losses can be determined with reasonable likelihood to be attributable to causes other than climate change and/or to have occurred before climate change is likely to have been significant. For reference, the set of 429 Concord species used by Willis et al (2008) is listed in Appendix B along with the degree of change in frequency of occurrence for each species used in that study which was derived (as explained below) from Primack et al. (2009). Of the 429 species used by Willis et al. (2008), 265 species (62%) are in the families noted in that study as implicated phylogenetically for having phenologically challenged constituents. Thus, if Primack et al. (2009) were generally inadequate in finding plant species, then species declines are overreported and those purported declines would more likely show up in these families, giving the appearance of a correlation of losses with families having more phenologically challenged species.

Willis et al. (2008) assigned number values not only to the frequency of occurrence in Concord claimed by Primack et al. (2009) but also to the frequency of occurrence in the greater Concord vicinity reported by Hosmer (1903). This implies a degree of accuracy in the reports of Hosmer (1903) and Primack et al. (2009) that is neither warranted nor justifiable. As discussed and illustrated above, neither of these two sources is particularly reliable. The work of Hosmer (1903) tended to find more species as “common” than did Pratt (1878) before him and Eaton (1974) after him. Of the 402 Concord species (not just those used by Willis et al. 2008) reported on by all three of these botanists, Hosmer (1903) reported 316 species as common or frequent, Pratt (1878) reported 276 species, and Eaton (1974) reported 257 species. This parallels a similar comparison made earlier. The near agreement between Pratt (1878) and Eaton (1974) with fewer common species reported by Eaton would be expected. The excessive use of “common” by Hosmer (1903) is in accord with the discussion above — Hosmer’s much larger sample area and perhaps more generous concept of “common.” Thus, there is a built-in bias toward “common” in the Hosmer (1903) data.

Willis et al. (2008) assigned to Hosmer’s (1903) and Primack et al. ’s (2009) frequency information the number values 6 for “very common,” 5 for “common,” 4 for “frequent,” 3 for “infrequent,” 2 for “rare,” 1 for “very rare,” and 0 for absent in the flora, where “very common” means found throughout the area, “common” defined as more than three stations, “frequent” as three stations, “infrequent” as two stations, “rare” as one station with more than ten plants, and “very rare” as one station with ten or fewer plants. By creating two categories for rare occurrence in effect magnifies the amount of decline for species that cannot be located at all. The assignment of such quantitative measures to the approximate qualitative terms of Hosmer (1903) is artificial and unrealistic given the considerable variation in evaluating frequency of occurrence not only between different botanists but also from species to species. As noted above and in my previous article (Angelo 2014a), no one botanist or small group of investigators can assess the frequency of occurrence of any given species with the accuracy presumed (allowing for some inaccuracy) by Willis et al. (2008), particularly for those species that are not common or occur in small numbers at each station. It was noted above that Primack et al. (2009) even had difficulty correctly assessing the frequency for common species. With the inapplicability of and overreporting of “common” in the Hosmer (1903) information combined with the undersampling of the Concord flora by Primack et al. (2009) compared to previous Concord botanists, it is understandable that significant declines were reported by Primack et al. (2009). The assumption built-in to the study of Willis et al. (2008) is that the approximate estimates of Hosmer’s (1903) frequency of occurrence of species in the Concord vicinity are sufficiently accurate measurements for Concord proper and that the findings or lack of findings of Primack et al. (2009) are also sufficiently accurate.

An assumption by Willis et al. (2008) is that an apparent strong correlation of species declines in those plant groups containing phenologically challenged species likely means that declines in these groups are related to climate change. Simply because correlations with other measurable factors are

not found does not automatically mean that other factors are not operating in any decline, as is acknowledged by Willis et al. (2014). Multiple other factors (habitat destruction/degradation, local water pollution, competition from new alien species) accounting for significant decline in different groups operating in different degrees would lessen or even alter the apparent correlation found for phenologically challenged species. A reasonable description of some of these other factors was given by Primack et al. (2009), to account for the losses they claimed, without assigning primary cause to climate change. A far more extensive and detailed discussion of multiple causes of abundance changes is given by Bertin (2013) in his analysis of changes in the native flora of Worcester County, Massachusetts. While it was found by Bertin (2013) that northern native species declined relative to southern species, as would be expected due to warming average temperatures, this was only one of multiple other likely or possible causes of frequency of occurrence changes. Declines were found by Bertin (2013) to be significant in a much smaller number of taxonomic groups than claimed by Willis et al. (2009), even though Bertin (2013) studied the entire flora of the study area, unlike Willis et al. (2008). Moreover, declines in some of these groups noted by Bertin (2013), such as in *Ribes* and *Crataegus*, can be understood to be due to causes other than phenology or climate change. The correlation detected in Willis et al. (2008) should not blind one to the effects of other causes or to dismiss those other causes as insufficiently significant when in fact they can be the more important cause of most declines.

2. Timeline of climate change effects

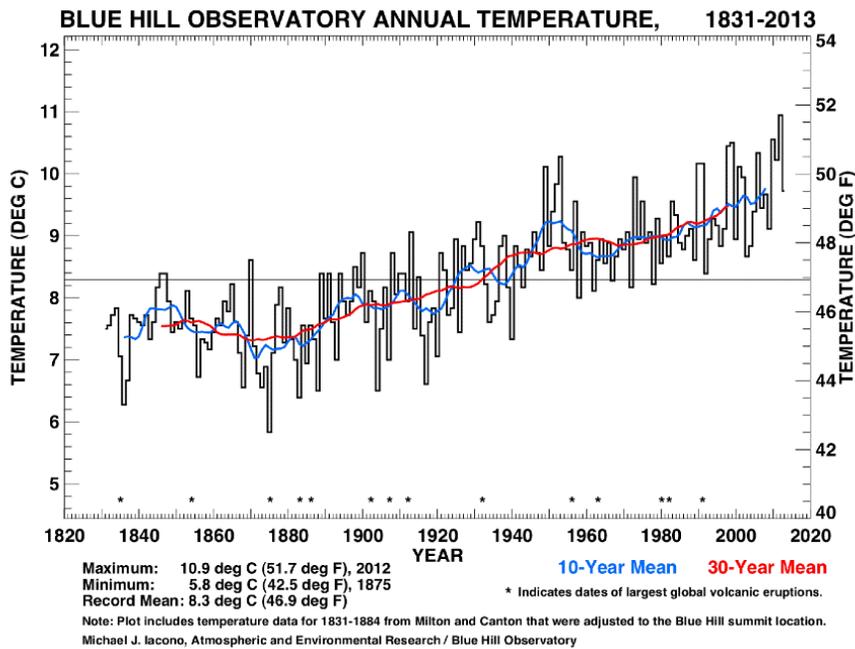
If climate warming is causing some species to decline in frequency of occurrence, there are questions as to the magnitude of warming necessary to create an observable effect, how much decline ensues for a given amount of warming, how rapidly the effect occurs, and over what historical periods would this effect be expected to be detectable. For the most part the answers to these questions are not known, at least definitively. It is reasonable to assume that warming would affect different species variably in a more or less continuous spectrum of sensitivities.

Three studies are cited by Willis et al. (2008) to support the effect of climate change on plant species occurrence. One (Sturm et al. 2001) shows that shrub abundance increased in the Arctic between ca. 1949 to 2000, which is to be expected at the northern range limit of species with climate warming. Another study (Beckage et al. 2008) found that there was a shift in abundance at the margins of the northern hardwood-boreal forest ecotone distributed altitudinally in the Green Mountains of Vermont between 1964 and 2005. Northern hardwoods increased significantly in dominance in the lower portion of the ecotone, while the boreal forest correspondingly declined within this lower portion. This would be equivalent to a northward shift latitudinally at the northern range limit of the more southerly hardwood species, again to be expected with climate warming. The third study (Lenoir et al. 2008) was a large-scale study in France that demonstrated an upward altitudinal shift in the optimum elevation for many forest species for the periods 1905 to 1985 and 1986 to 2005, with the shift being larger for species restricted to mountain habitats and for “grassy” (i.e., herbaceous) species, which are characterized by faster population turnover.

The findings of the above three studies indicate observable effects of climate change in the decades immediately preceding 2005. The findings of the third study suggest that there would be an analogous shift in optimum latitude for plant species such that some native species would increase while others would decrease in frequency of occurrence. The compression of this effect altitudinally compared to latitudinally is likely to make the latter effect more difficult to document. Since more native plant species occur in North America as latitude decreases, a general shift northward in the optimum latitude in the distributions of species should imply that more native species would increase in abundance in Concord than decrease, contrary to the findings of Primack et al. (2009). No attempt was made in this third study (Lenoir et al. 2008) to relate declines in frequency of occurrence to flowering time changes, and no widespread, unexplained declines were reported. Even though increase

in average annual temperature in recent decades has been widely established, the effect on plant populations is by no means consistent. For example, a very recent study of 296 plant species using an extensive network of occurrence records over a 40-year period demonstrated that most (63%) plant species migrated downward in elevation toward increased warmth and precipitation in a climactically diverse section of western North America (Harsch & HilleRisLambers 2014).

To see what changes in average temperatures have occurred in Concord from the time of Thoreau to the present, the most applicable records for the longest period of time would be those of the Blue Hill Observatory in Milton, Massachusetts, 33.3 kilometers (20.7 miles) southeast of Concord. Blue Hill Observatory is the home of the oldest continuous weather record in North America. It is located 17.8 kilometers (11 miles) south-southwest of Boston, while Concord is 25.7 kilometers (16 miles) northwest of Boston. As the Blue Hills Observatory is situated a little closer to Boston than to Concord and in a direction from Boston where there has been dense, urban development, it would be expected that the average temperatures would be moderately higher than in Concord due to the influence of the Boston heat island, especially in the 20th century when this heat island would have developed most significantly. In other words the recorded average temperature increases at the Blue Hill Observatory would be accentuated to some degree compared to Concord. However, for the purposes of this discussion, only the relative increase in mean average over historical periods is of interest, not the absolute increase.



A chart of historic Blue Hill Observatory annual temperatures is given above. From this chart the following can be determined:

Changes in 10 year mean average annual temperature (10YR-AVG) at Blue Hill Observatory, Massachusetts

Period	Starting 10YR-AVG	Ending 10YR-AVG	Change
1878-1903	7.2 C	7.8 C	+0.6 C
1878-1974	7.2 C	8.8 C	+1.6 C
1974-2004	8.8 C	9.4 C	+0.6 C

The dates chosen correspond approximately to the dates of the floras of Pratt (1878) and Hosmer (1903) and the study of Primack et al. (2009).

The comment by Primack et al. (2009) that most of the claimed disappearance of species since Thoreau's time (died 1862) seems to have occurred in the 30 to 40 years prior to that study (1964 to 2004) appears to be at odds with the fact that the increase in 10-year mean average annual temperature at the Blue Hill Observatory from 1878 to 1974 was 1.6 C, while the increase from 1974 to 2004 was only .6 C. From the above numbers one would expect that if climate warming were responsible for significant declines in species, the preponderance of such decline would be expected prior to 1974 and not after it. To test whether in fact there was an apparent significant decline in frequency of occurrence in Concord from 1878 to 1974, it is only necessary to compare the frequency (common vs. uncommon) for native Concord species reported by Pratt (1878) for the same native species as reported by Eaton (1974). There are 416 vouchered native Concord species (including species not used by Willis et al. 2008) where "common" (including frequent, very common, abundant) or "uncommon" (including infrequent, occasional, rare, extinct) is indicated by both Pratt (1878) and Eaton (1974). Of these, 60 native species are reported by Pratt (1878) to be common that Eaton (1974) reports as uncommon, that is, ones that have decreased in frequency. There are 36 native species reported by Pratt (1878) as uncommon, but reported as common by Eaton (1974), that is, ones that have increased in frequency of occurrence. For the remaining 320 native Concord species there was no significant difference in frequency of occurrence reported by Pratt (1878) and Eaton (1974). Thus, there is only a slight margin of net species showing decline (24 out 416 native species). This is not the striking evidence of species declines one would expect for a 1.6 C increase in average annual temperature compared to a 0.6 C increase (for a period where change has been observed), if climate warming was causing significant losses in native species.

A similar comparison can be made between Pratt (1878) and Hosmer (1903), assuming, only for the sake of illustration, that Hosmer's greater study area is sufficiently representative of Concord. There are 355 native species for which Pratt (1878) and Hosmer (1903) both indicate common or uncommon. Of these, only 16 species are reported as common by Pratt (1878) and uncommon by Hosmer (1903). Yet there are 48 native species reported by Pratt (1878) as uncommon but that are reported as common by Hosmer (1903). This would represent a significant net *increase* (32 native species out 352) in species of increasing in abundance from 1878 to 1903 when the 10 year average mean temperature at Blue Hill Observatory *increased* by an .6 C, contrary to the claim of Primack et al. (2009) that there is species decline over time and the claim of Willis et al. (2008) that there is significant decline due to climate change. The more likely explanation is that the Hosmer (1903) frequency data are not representative of Concord proper as noted earlier. To repeat, Minot Pratt botanized in Concord for a much longer period (36 years) than Alfred Hosmer (15 years), and Minot Pratt limited his flora to Concord proper, while Alfred Hosmer did not. In preparing my online flora (Angelo 2014b) it was apparent in comparing Pratt (1878) and Hosmer (1903) that Pratt knew the Concord flora better than Hosmer, finding more locations of rare or uncommon plants that Hosmer (1903) did not find, but that I found in the 1970s/80s.

In light of the preceding, any claim that there was a dramatic decline of species in Concord from 1974 to 2004 is contrary to evidence and would be more indicative of the inadequacy of the survey of Primack et al. (2009) than of a significant decline in that period due to climate change. The evidence used below of recent studies in nearby areas will point to more limited species declines that might be related to climate change.

3. Use of recent studies to discern widespread species decline

If a species has suffered significant decline due to climate change, it would not do so just in Concord, Massachusetts, but also in areas close by. This would be true whether climate change might cause a decline throughout the range of the species or just at the margins of its distribution. It is therefore valuable to have current information from recent, careful studies in Worcester County,

Massachusetts (Bertin & Rawinski 2012; Bertin 2013) and Middlesex Fells Reservation, Massachusetts (Hamlin et al. 2012), to gauge what is actually happening in areas relatively close to Concord. Worcester County is a county in central Massachusetts that is adjacent to Middlesex County, where Concord is located. Its center is approximately at the northeast border of the town of Paxton, which is about 45 kilometers (28 miles) west southwest of Concord. The Middlesex Fells Reservation extends over several towns and cities in Middlesex County, primarily Medford and Stoneham. It is located about 29 kilometers (18 miles) due east of Concord. The location of these two areas bracket Concord geographically very well. The recent floristic studies of these two areas close to and on either side of Concord at approximately the same altitude and latitude offer an excellent opportunity to evaluate what is actually happening in terms of changes of species frequency of occurrence and indications of the reasons for some change.

Worcester County has an area of 3,919 square kilometers (1,513 square miles) with elevations ranging from 48 meters (157 feet) to 611 meters (2006 feet). Like Concord, it has a significant river flora with multiple rivers, including the sources of both the Assabet and Sudbury Rivers, which join in Concord to form the Concord River. The variety of habitats and topography within the county are as varied or more varied than in Concord, including an urban area (city of Worcester). It retains more of the open, dry expanses of land, agricultural lands, and unspoiled sphagnum bogs than does Concord.

The Middlesex Fells Reservation has an area of 10.4 square kilometers (4.0 square miles) with elevations ranging from 19.8 meters (65 feet) to 96.6 meters (317 feet). It has no rivers and no kettle-hole sphagnum bogs, thus lacking, in these respects and perhaps others, the habitat diversity of Concord. It is surrounded by a highly developed urban/suburban environment, being much closer to Boston, but within its borders it presently is relatively protected from further development, unlike Concord.

For comparison, Concord has an area of 67.08 square kilometers (25.9 square miles) with elevations ranging from about 35.4 meters (116 feet) to 110 meters (361 feet). Concord has two rivers that join to form one and has the remnants of several sphagnum bogs. It also has several areas with some calcite and small pockets of limestone in the otherwise acidic soil. While there is significant development in the town, there are many areas that are currently protected from development.

Thus, Concord represents in different ways a transition from the more urban-influenced Middlesex Fells to the less developed Worcester County. The recent flora of Worcester County (Bertin & Rawinski 2012) contains designation of current frequency of occurrence for each species as well as indication of cases where there is decline or increase in a species when compared to records prior to 1980 or in some cases relative to the last historic date of collection. Bertin (2013) analyzed over 67,000 recent observations of native plant species in Worcester County supported by over 6,700 recent herbarium collections and compared them to information obtained from approximately 36,000 historical herbarium specimens. Using that information, each native species was given a change index number between +1.0 and -1.0, where the number represents the difference between the number of townships with post-1980 observations/collections and the number of townships with pre-1980 herbarium records divided by the total number of townships where the species has been recorded. Robert Bertin, the author of the study, has stated that other than for the city of Worcester itself, just about all recent records date from 1998 or later, with the majority from 2003 or later (Bertin pers. comm 2014). Thus, a good record for current status and state of flux is provided by this flora. Likewise, the careful work in the recent Middlesex Fells Reservation by Hamlin et al. (2012) provides the current status (observations of multiple investigators from 2003 to 2011) and compares it with a detailed flora published in 1896 (Deane 1896).

Application of the results of the two recent studies on either side of Concord, combined with direct recent observations of Concord residents and consideration of ecological and historical context, permit a reliable approximation of the status of the 192 species in Concord (adjusted to 171 usable species, as explained below) claimed to be significantly declining. In effect, the review below, using the recent neighboring floristic studies screens out the local effects due to causes of decline particular to Concord or metropolitan Boston or due to the inadequate sampling by Primack et al. (2009).

4. Results and significance

Each plant species has its own story — its own ecological and historical context, its own biological behavior. Before applying a statistical broad-brush to the floral inhabitants or former inhabitants of a local community, it is worthwhile to review to the extent possible, directly or indirectly, what is happening for each species. It is also necessary to consider whether some species should be removed from consideration on other grounds (taxonomic, absence of data, etc.) as explained below. This is to limit consideration to those species that might be responding significantly through their frequency of occurrence to climate change and not more seriously affected by other factors, whether known or unknown. The number of usable species with claimed significant decline is 171 of the 192 such species used by Willis et al. (2008), since 21 species must be removed from consideration based on the problems discussed in the first three categories below.

This species-by-species review of 192 species with claimed significant decline used by Willis et al. (2008) is given in detail in Appendix A below. As a result of this review the species were placed into one of 11 categories. The categories are reviewed here so that the reasoning for each category can be understood.

1. Not listed by Hosmer (1903) under any name. Four species among the 192 Concord species with significant decline listed in the unpublished spreadsheet provided by Willis are not to be found in Hosmer (1903) under the name in the spreadsheet or under any equivalent older name or synonym. The reason for this is unknown but most likely due to an imperfect attempt to convert one of Hosmer's (1903) names to a modern equivalent. *Lechea tenuifolia*, for example, was a perfectly distinct species in Alfred Hosmer's time and in fact has been documented from Concord. But Hosmer (1903) does not list it, so that it is not possible to derive a change in frequency in this species based on Hosmer (1903).

2. Taxonomic problems. Eight species were found to be listed in Hosmer (1903) using names that at that time comprised what are currently two or more species found in Concord, even though the particular name used by Hosmer (1903) might correspond to a particular modern name. Since a study trying to measure change in frequency must be comparing equivalent taxonomic entities to yield meaningful results, these instances must be removed from consideration. In one case, *MENTHA PIPERITA*, the taxon is now considered to be a hybrid (with non-native parents), so that its biology would make it an unsuitable taxon for a study of change in frequency of occurrence.

3. No frequency information provided by Hosmer (1903). For nine species listed by Hosmer (1903) and used by Willis et al. (2009) and Primack et al. (2009), Hosmer (1903) provided no information whatsoever other than flowering dates, or he provided merely habitat information which Primack et al. (2009) presumed without justification to be a statement of frequency of occurrence — typically interpreted as “common.” When Hosmer annotated a species only with “River,” “Swamps,” “Roadsides,” “Brooks,” etc., without providing frequency information, frequency for Concord was presumed to be “common” by Primack et al. (2009). For example, “River” could refer to one or more of the towns Concord, Lincoln, Sudbury, Bedford, Carlisle, or even Acton or Maynard without knowing which ones or how many stations there are, or in which towns. As with Pratt (1878), Hosmer

(1903) sometimes chose to list only the habitat of a species without committing to any particular frequency of occurrence. Such instances are not usable to measure frequency of occurrence change.

4. Hosmer (1903) frequency information conflicts with Pratt (1878), and with Thoreau. Primack et al. (2009) stated that “Minot Pratt’s observations overlap those of Thoreau and Hosmer, ...” If that is in fact the case, then the findings of Pratt (1878) for the most part should not differ greatly from those of Hosmer (1903). Yet in fact, there are 23 species of the 192 species of claimed significant decline for which this is the case. It is not to be expected that between 1878 and 1903 there would be an increase in species frequency of occurrence when there was warming in that period by 0.6 C in the 10 year mean of the average annual temperature at Blue Hill Observatory, as noted above. However, for 23 species that Hosmer (1903) listed as “rather common,” “common,” or, in one case, “not uncommon,” Pratt (1878) either did not list the species in Concord at all, or listed it as “rare,” “not common,” at only one or two locations, or in some other manner inconsistent with it being “common.” Additional support from Thoreau’s Journal is provided in Appendix A to support Pratt’s (1878) finding rather than Hosmer’s (1903) characterization. The explanation for these discrepancies is evident from the discussion earlier in this paper, i.e., that Hosmer (1903) applied a generous concept of “common” to the much wider Concord vicinity rather than to Concord proper. Thus, it is incorrect to use his frequency of occurrence information in all cases and certainly not for the 23 species in this category.

5. Species inappropriate for study. Included in this category are seven species that are either garden escapes, agricultural plants or, in one case, a plant introduced into Concord by Minot Pratt. The story of the rise and decline of *ASPARAGUS OFFICINALIS* included here is given to illustrate how the increase and decrease of species such of these would have nothing to do with climate change. Similarly, none of the other species here belong in a study claiming to relate species decline to climate change.

6. Not declining, or local to Concord if so. The 57 species included in this group are primarily ones for which the frequency of occurrence for the species is either not declining in Middlesex Fells Reservation and Worcester County or is actually increasing in these locations. While this does not directly establish what the species has been doing in Concord, it means that any decline in Concord would be local to the immediate Concord vicinity and not related to the much more widespread effect of climate change. Most likely these species are not declining and Primack et al. (2009) underreported the recent frequency of occurrence in Concord. For some of the species in this group the evidence from Middlesex Fells Reservation and Worcester County is corroborated by recent observations of Concord residents. One species, *LEONURUS CARDIACA* (a once in-favor but now out-of-favor garden plant), in this group could equally well be placed in category 4. None of these species should be used to establish a correlation of “decline” with the absence of significant, historical shifts in flowering time.

7. Possibly declining, but locally if so. The 40 species in this group are ones that are not declining (in some cases they are increasing) in Worcester County but are declining in Middlesex Fells Reservation or were never recorded at the Reservation. In addition, for these species the information from Eaton (1974) generally does not show a significant decrease from the information of Pratt (1878) or Hosmer (1903). Thus any decline in Concord would be local and relatively recent (after 1974). For *Clintonia borealis*, one of my recent observations in Concord is noted and additional information is provided in Appendix A and the Literature Cited to show how significant recent deer-browsing is likely to be the cause for any for this particular species. Also, there is an urbanization gradient that proceeds from Middlesex Fells Reservation through Concord to Worcester County. This gradient has grown through the period under consideration (ca. 1860 to ca. 2004) such that it is to be expected that plant species most affected by urbanization/suburbanization would suffer most in Middlesex Fells

Reservation and least in Worcester County. Species of this type would more likely be found in this group. Whatever the reasons for local declines, such declines would not be due to climate change.

8. Probably declining, but locally if so. The five species in this category are ones for which there is some clear indication in decline outside of Concord, but not in both Worcester County and Middlesex Fells, and for which specific causes other than climate change are not reasonably certain.

9. Declined due to specific causes. The decline of the three species in this category is easily attributable to specific causes as described in Appendix A, not related to climate change.

10. Declining, likely due to causes other than climate warming and/or only locally. The reasons for placement of 16 species in this category are explained in Appendix A. Some of these were disappearing or disappeared well before climate warming would have been significantly operating. Four of the species are not declining in Worcester County.

11. Declining for uncertain reasons. Included here are 20 species that appear to be declining regionally for reasons not known with certainty.

To summarize the results:

- 51 species not usable or not appropriate for study (categories 1 to 5)
- 57 species not declining in frequency of occurrence or only locally so (category 6)
- 40 species possibly declining in frequency of occurrence, but locally if so (category 7)
- 5 species probably declining in frequency of occurrence, but locally if so (category 8)
- 19 species declined or declining, but not due to climate change (categories 9 and 10)
- 20 species declining in frequency of occurrence for unknown reasons (category 11)
- 192 total (used by Willis et al. (2009) that are claimed as significantly declined)

Thus, instead of 192 species, there are only 20 species to consider whose decline might be significantly related to climate change. The reason (or reasons) for decline of these 20 species in Concord and adjacent regions is an open question. Also, it is not claimed here that climate change has had no role in the decline in Concord of other species, only that climate change would not be the predominant cause. For the purposes of making correlations among the 20 species with responsiveness of flowering time to changes in average temperature, the sample size would appear to be too small. More interesting would be to examine what changes might be occurring at the northern and southern limits of the range of the 20 species, and even in the center (latitudinally) of their range of distribution. Another question is why certain native species, such as *Hibiscus moscheutos*, *Vernonia noveboracensis*, and *Viola brittoniana*, at the northern limit of their range in Concord do not appear to be increasing or decreasing in abundance.

In summary this article shows that the Concord species declines reported by Primack et al. (2009) are unreliable, and in any event they are significantly fewer than the number reported. Because of the unreliability and much smaller number of these claimed declines, the conclusions of Willis et al. (2008) are unjustifiable. This finding in fact helps account for a result differing from that of Willis et al. (2008) found by Bertin (pers. comm. 2014) in a new, forthcoming, detailed analysis of phenology and abundance changes for 186 species over the past 60 years using more than 25,000 herbarium specimens and personal observations. While measurable shifts in flowering times were found for some species over this period, Bertin found no significant correlation, negative or positive, between shift or lack of shift in flowering time and change in abundance. This finding by Bertin is consistent with what is reported here, that the Willis et al. 2008 result is not reliable.

The emerging picture is that only about 44 species among the 429 species selected by Willis et al. (2008) can be determined as probably or definitely declining significantly, but that climate change would not be the predominant cause for 24 of them. Of the remaining 20 for which the cause (or causes) of decline is an open question, 16 species are among the families containing phenologically challenged species. This is more than the 12 species or so that would be estimated by chance (62% noted above), but this is a small sample size. While climate change is likely to be having some effect on the Concord flora, it apparently is not the cause of a dramatic disappearance of species claimed by Primack et al. (2009), even if species of certain groups might be more affected than others as claimed by Willis et al. (2008).

ACKNOWLEDGEMENTS

I thank especially Concordians and naturalists Cherrie Corey and Cole Winstanley for sharing their excellent and growing knowledge of Concord's flora. David Boufford kindly reviewed this article in multiple drafts. James Hinds (a former resident of Concord) also generously provided careful review. I thank Walter Kittredge and Cherrie Corey for reviewing the first draft of this article. Robert Bertin provided useful comments and helpful unpublished data from his Worcester County flora analysis. Lastly, I thank my wife, Erika Sonder, for her support and comments on this article.

LITERATURE CITED

- Angelo, R. 2014a. Observations relative to claims of disappearance of Liliaceae and Orchidaceae in Concord, Massachusetts, USA. *Phytoneuron* 2014–43: 1–8.
- Angelo, R. 2014b. Vascular Flora of Concord, Massachusetts. First posted 30 December 2012; last revised 31 July 2014. <<http://ray-a.com/ConcordMassFlora.pdf>>
- Beckage, B., B. Osborne, C. Pucko, D.G. Gavin, T. Siccama, and T. Perkins. 2008. An upward shift of forest ecotone during 40 years of warming in the Green Mountains of Vermont, USA. *Proc. Natl. Acad. Sci.* 105: 4197–4202.
- Balgooyen, C.P. and Waller D.M. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. *Natural Areas J.* 15: 308–318.
- Bertin, R.I. and C.M. Parise. 2014. Patterns and changes in the nonnative flora of Worcester County, Massachusetts. *Amer. Midl. Nat.* 172: 37–60.
- Bertin, R.I. and T.J. Rawinski. 2012. Vascular Flora of Worcester County, Massachusetts. Special Publication of the New England Botanical Club, Cambridge, Massachusetts.
- Bertin, R.I. 2013. Changes in the native flora of Worcester County, Massachusetts. *J. Torrey Bot. Soc.* 140: 414–452.
- Dame, L.L. and F.S. Collins. 1888. Flora of Middlesex County, Massachusetts. Middlesex Institute, Malden, Massachusetts.
- Deane, W., ed. 1896. Flora of the Blue Hills, Middlesex Fells, Stony Brook, and Beaver Brook Reservations of the Metropolitan Parks Commission, Massachusetts. C.M. Barrows & Co. Boston.
- Drayton, B. and R.B. Primack. 1996. Plant species lost in an isolated conservation area in metropolitan Boston from 1894 to 1993. *Conserv. Biol.* 10: 30–39.
- Eaton, R.J. 1974. A Flora of Concord. Special Publication, No. 4, The Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.
- Fernald, M.L. 1950. Gray's Manual of Botany, 8th ed. D. Van Nostrand Company, New York.
- Gray, A., S. Watson, and J.M. Coulter. 1889. Manual of the Botany of the Northern United States, 6th ed. American Book Company, New York.
- Hamlin, B.T., W.T. Kittredge, D.P. Lubin and E.B. Wright. 2012. Changes in the vascular flora of the Middlesex Fells Reservation, Middlesex County, Massachusetts. *Rhodora* 114: 229–308.

- Hamlin, B.T. and W.T. Kittredge. 2013. An update on the Middlesex Fells flora. *Rhodora* 115: 191–196.
- Hamlin, B.T. and W.T. Kittredge. 2014. Further discoveries in the Middlesex Fells. *Rhodora* 116: 224–227.
- Harsch, M. and J. HilleRisLambers. 2014. Species distributions shift downwards across western North America. *Global Change Biology*, DOI: 10.1111/gcb.12697.
- Hosmer, A.W. 1903. List of the Wild Flowers (and time of blooming) of Concord, Mass. and vicinity as observed by Alfred W. Hosmer. Vol. I 1878-1898, Vol. II 1899-1903. Manuscript at Concord Free Public Library, Concord, Massachusetts.
- Lamont, E.E. and S.M. Young. 2004. Noteworthy plants reported from the Torrey Range 2002-2003. *J. Torrey Bot. Soc.* 131: 394–402.
- Lenoir, J., J.C. Gégout, P.A. Marquet, P. deRuffay, and H. Brisse. A significant upward shift in plant species optimum elevation during the 20th century. *Science* 320: 1768–1771.
- Miller-Rushing, A.J. and Primack, R.B. 2008. Global warming and flowering times in Thoreau's Concord: A community perspective. *Ecology* 89: 332–341.
- Pratt, M. 1878. Plants of Concord, Natural and Introduced. Manuscript at Concord Free Public Library, Concord, Massachusetts.
- Primack, R.B., A.J. Miller-Rushing and K. Dharaneeswaran. 2009. Changes in the flora of Thoreau's Concord. *Biol. Conserv.* 142: 500–508.
- Primack, R.B., A.J. Miller-Rushing, and B. Drayton. 2014. Reply to Angelo: Declines in species in Thoreau's Concord and the Middlesex Fells Reservations, Massachusetts, USA. *Phytologia* 2014-60: 1–5.
- Sturm, M., C. Racine and K. Tape. 2001. Climate change: Increasing shrub abundance in the Arctic. *Nature* 411: 546–547.
- Thoreau, H.D. 1906. The Writings of Henry David Thoreau, Journal, Bradford Torrey, ed., vols. I–XIV. Houghton Mifflin and Company, Boston.
- Waller, D.M. and W.S. Alverson. 1997. The white-tailed deer: A keystone herbivore. *Wildlife Soc. Bull.* 25: 217–226.
- Willis, C.G., B. Ruhfel, R.B. Primack, A.J. Miller-Rushing, and C.C. Davis. 2008. Phylogenetic patterns of species loss in Thoreau's woods are driven by climate change. *Proc. Natl. Acad. Sci.* 105: 17029–17033. <<http://www.pnas.org/content/early/2008/10/24/0806446105.full.pdf>>
- Willis, C.G. and C.C. Davis. 2014. Reply to Angelo: Climate Change and species loss in Thoreau's woods (Concord, Massachusetts USA). *Phytoneuron* 2014-59: 1–4.

APPENDIX A

Review of the 192 Concord species used by Willis et al. (2008) claimed by Primack et al. (2009) to have experienced significant decline since 1903 (Hosmer 1903)

Explanation:

Nomenclature is that of my online Concord flora (Angelo 2014b). Where there is a difference, scientific names used in an unpublished spreadsheet used for (Willis et al. 2008), kindly provided by Willis, are given in parentheses.

Names in upper case are not native to Concord.

“MdsxFls: occasional => rare” means at Middlesex Fells Reservation occasional in 1895 and rare in 2012 according to Hamlin et al. (2012) as updated through July 2014 (Hamlin & Kittredge 2013, Hamlin & Kittredge 2014, Hamlin pers. comm. 2014) .

“MdsxFls: none => none” means at Middlesex Fells Reservation not found in 1895 and not found in 2012 though elsewhere recorded or reported at the Reservation according to Hamlin et al. (2012).

“MdsxFIs no records” means never recorded as found at Middlesex Fells Reservation according to Hamlin et al. (2012).

“WorCo: fairly common not declining (-0.200)” means reported as fairly common in Worcester County in 2012 with no indication of decline, using (Bertin & Rawinski 2012) and the change index (explained previously) for Worcester County, Massachusetts defined in (Bertin 2013) and (Bertin & Parise 2014), where here values between -0.250 and 0.250 are considered not declining.

1. NOT LISTED BY HOSMER (1903) UNDER ANY NAME (4 species)

Lechea tenuifolia: This species is not listed by Hosmer (1903). This name was available to him in Gray’s Manual of Botany 6th ed. (Gray et al. 1889) if he had wanted to use it. Hosmer (1903) lists *Lechea minor* and *Lechea thymifolia* both of which would translate into the modern *Lechea intermedia*. *Lechea minor* in the modern sense has not been recorded from Middlesex County. The only other *Lechea* listed by Hosmer (2013) is *Lechea major* which is currently known as *Lechea mucronata*.

MENTHA ARVENSIS: Hosmer (1903) does not list this under any name.

MONARDA BRADBURIANA: Hosmer (1903) does not list this. If *MONARDA FISTULOSA* is intended by Primack et al. (2009), then this is a Minot Pratt introduction and not suitable for study.

MONARDA MEDIA: Hosmer (1903) and Pratt (1878) do not list this from Concord. Thoreau does not refer to it in his Journal and collected no herbarium specimen of it.

2. TAXONOMIC PROBLEMS (8 species)

Agrimonia gryposepala: Hosmer’s (1903) use of this name includes *Agrimonia gryposepala* and *Agrimonia stricta*. Thus, his frequency information is not usable.

Antennaria plantaginifolia: Hosmer’s (1903) use of this name includes *Antennaria plantaginifolia*, *Antennaria howellii* subsp. *neodioica*, *Antennaria neglecta*, *Antennaria parlinii* var. *parlinii*, and almost certainly *Antennaria parlinii* var. *fallax*. Thus, his frequency information is not usable.

Galium trifidum: Hosmer’s (1903) use of this name includes *Galium trifidum*, *Galium palustre*, and *Galium tinctorium*. Thus, his frequency information is not usable.

Gentiana andrewsii: Hosmer’s (1903) use of this name includes *Gentiana andrewsii* and *Gentiana clausa*. Thus, his frequency information is not usable.

MENTHA PIPERITA: This is a hybrid (*MENTHA AQUATICA* X *MENTHA SPICATA*) and not a proper taxon for a study of this type.

Rosa carolina: Hosmer’s (1903) use of this name includes *Rosa carolina* and *Rosa virginiana*. Thus, his frequency information is not usable.

Rosa virginiana: This name is not used by Hosmer (1903) as he would have included it in *Rosa carolina* as noted above. Which of Hosmer’s (1903) names Willis et al. (2008) or Primack et al. (2009) translated into this name is unclear. *Rosa virginiana* is not declining (or only in Concord if so) in any event. MdsxFIs: frequent => frequent. WorCo: fairly common not declining (-0.160).

Viola blanda: Hosmer's (1903) use of this name includes *Viola blanda* and *Viola macloskeyi*. Thus, his frequency information is not usable.

3. NO FREQUENCY INFORMATION PROVIDED BY HOSMER (1903) (9 species)

Asclepias exaltata: Hosmer (1903) lists this as "Swamps." Pratt (1878) lists this as rare with only three to four plants in total located in a certain sector of Concord. Thoreau refers to this only twice in his Journal only one of which is to occurrence in Concord. Hence, there is very minimal occurrence in Concord to begin with. MdsxFIs: rare => occasional. WorCo: common not declining (0.026).

Geum aleppicum: Hosmer (1903) lists this (as *Geum strictum*) without comment. MdsxFIs: no records. WorCo: uncommon not declining (-0.200). Cole Winstanley (2014 pers. comm.) recently photographed this near Elm Brook. Cherrie Corey (2014 pers. comm.) reports this recently at Great Meadows occurring each year reliably in good quantity all along the Dike Trail and also found near the Ripley building.

LILIUM LANCIFOLIUM: Hosmer (1903) lists this simply as "Escaped." Also, this occasional garden escape is not appropriate for study. MdsxFIs: no records. WorCo: uncommon decreasing (-0.27)

Persicaria punctata (*Polygonum punctatum*): Hosmer (1903) lists this only as "River." MdsxFIs: rare => rare. WorCo: common increasing (0.681).

Platanthera clavellata: Hosmer (1903) lists this (as *Habenaria tridentata*) with no frequency information. MdsxFIs: no records. WorCo: fairly common not declining (-0.120).

Rumex brittanica (*Rumex orbiculatus*): Hosmer (1903) lists this only as "Brooks." MdsxFIs: no records. WorCo: fairly common increasing (0.429).

Sagittaria filiformis (*Sagittaria subulata*): Hosmer (1903) lists this only as "River." MdsxFIs: no records. WorCo: rare increasing (0.333), all records from the county are after 1973.

Utricularia purpurea: Hosmer (1903) lists this only as "River." MdsxFIs: rare => none. WorCo: common increasing (0.353).

Vaccinium oxycoccus: Hosmer (1903) lists this only as "Cold swamps." MdsxFIs: no records. WorCo: fairly common not declining (0.100).

4. HOSMER (1903) FREQUENCY INFORMATION CONFLICTS WITH PRATT (1878) AND WITH THOREAU (23 species)

ANAGALLIS ARVENSIS: Hosmer (1903) lists this as common. Not listed at all by Pratt (1878). No specimen in Thoreau herbarium, and only two references in Thoreau Journal neither of which are to occurrence in Concord. Middlesex County Flora (Dame & Collins 1888) has this as rare, found in only two towns, not Concord. MdsxFIs: no records. WorCo: rare, first record in 1933.

Angelica atropurpurea: Hosmer (1903) lists this as common. Pratt (1878) lists only two locations for it, Thoreau's Journal refers to it mostly or entirely at two locales in the town. Middlesex County Flora (Dame & Collins 1888) has this as generally distributed, but scarce. MdsxFIs: no records. WorCo: fairly common not declining (-0.143).

Apocynum cannabinum: Hosmer (1903) lists it as common. Pratt (1878) lists this as rare, Middlesex County Flora (Dame & Collins 1888) has this as not common. MdsxFIs: rare => rare. WorCo: common increasing (0.560).

ARMORACIA RUSTICANA: Hosmer (1903) lists this as rather common. Pratt (1878) does not list this at all. Thoreau refers to it only four times in his Journal with no definite reference to wild occurrence and no specimen of it in his herbarium. MdsxFIs: no records. WorCo: rare declining (-0.64).

Asclepias purpurascens: Hosmer (1903) lists this as common. Pratt (1878) lists it as rare. No specimen in Thoreau herbarium and only one Journal reference to it in Concord, which itself is likely a mistaken identification. MdsxFIs: no records. WorCo: presumed extirpated formerly sporadic, last record 1954.

Chenopodium simplex: Hosmer (1903) lists this as common. Pratt (1878) however lists it as not common. Thoreau mentions it only four times in his Journal. MdsxFIs: rare => occasional. WorCo: uncommon increasing (0.286).

Circaea alpina: Hosmer (1903) lists this as common. Pratt (1878) lists it from only two locations in Concord. Thoreau refers to it only about nine times in his Journal, but the inadequacy of the manuals he used make his identifications questionable, especially since he refers to the more common *Circaea canadensis* only seven times. MdsxFIs: no records. WorCo: fairly common not declining (0.235).

Crotalaria sagittalis: Hosmer (1903) lists this as rather common. Pratt (1878) lists it as rare. Thoreau notes it at a few sites in Concord and late in his life (October 3, 1858) comments in his Journal "One year I find it on the Great Fields and think it rare; the next I find it in a new and unexpected place. It flits about like a flock of sparrows, from field to field." MdsxFIs: no records. WorCo: rare increasing, first record in the 2000s.

FAGOPYRUM ESCULENTUM: Hosmer (1903) is the only one to list this escape from cultivation as common. Thoreau refers to it only twice in his Journal. Pratt (1878) lists it without commenting on its frequency. Eaton (1974) refers to it only as occasional, rarely persistent after cultivation. Also, any decrease in frequency would be most likely associated with decrease in its cultivation. MdsxFIs: rare => none. WorCo: uncommon not declining (-0.23).

Goodyera tessellata: Hosmer (1903) lists this as rather common. Pratt (1878) lists it as rare. There are only six references to it in Thoreau's Journal with only two locales mentioned and no specimen in his herbarium. MdsxFIs: no records. WorCo: fairly common not declining (-0.222).

HYLOTELEPHIUM TELEPHIUM (HYLOTELEPHIUM TELEPHIOIDES, in error): Hosmer (1903) lists this as common. Pratt (1878) notes it at only one location. There are nine references (one in error) to this in Thoreau's Journal with only one location specified in multiple references. MdsxFIs: occasional => occasional. WorCo: common increasing (0.30).

Iris prismatica: Hosmer (1903) lists this as common. Pratt (1878) lists it as not as common as *Iris versicolor* which he lists as common. There are only eight references to this in Thoreau's Journal in which no more than two Concord locations are specified. MdsxFIs: no records. WorCo: presumed extirpated, only record from 1937.

Myosotis verna: Hosmer (1903) lists this as common. Pratt (1878) lists it from just two locales. Thoreau refers to it only seven times in his Journal, all apparently at Conantum where he found it in several places. Eaton (1974) lists this as uncommon. MdsxFIs: frequent => rare. WorCo: rare declining (-0.333).

Prenanthes serpentaria: Hosmer (1903) lists this as common. Pratt (1878) lists only one location for it. Only five references to it in Thoreau's Journal and only two Concord locations noted. MdsxFIs: rare => rare. WorCo: presumably extirpated, last record 1935.

Pycnanthemum incanum: Hosmer (1903) lists this as rather common. Pratt (1878) lists only two locations. Thoreau only refers to it seven times in his Journal with only two Concord locations noted. MdsxFIs: none => rare. WorCo: uncommon increasing, all records after 1987.

Pycnanthemum muticum: Hosmer (1903) lists this as common. Pratt (1878) does not list it at all. Thoreau refers to it only seven times in his Journal noting apparently three Concord locations. MdsxFIs: no records. WorCo: uncommon decreasing (-0.300).

Pyrola chlorantha: Hosmer (1903) lists this as common. Pratt (1878) lists just two locations. Thoreau refers to it only six times in his journal noting just two Concord locations. MdsxFIs: rare => none. WorCo: uncommon declining (-.333).

RIBES RUBRUM: Hosmer (1903) lists this as common. Pratt (1878) does not list it at all. Thoreau's Journal has no references to it in the wild and no specimen is in his herbarium. Also, any decline would likely be due to purposeful eradication of *Ribes* spp. to prevent pine blister rust in the 20th century. MdsxFIs: rare => rare. WorCo: common not declining (0.06).

Sericocarpus linifolius: Hosmer (1903) lists this as common. Pratt (1878) does not list it at all. No references to it in Thoreau's Journal. MdsxFIs: rare => rare. WorCo: uncommon not declining (0.091).

SILENE ARMERIA: Hosmer (1903) lists this as rather common. Pratt (1878) lists it as only occasionally wild. Thoreau refers to it only three times in his Journal and no specimen in his herbarium. MdsxFIs: none => occasional. WorCo: fairly common not declining (0.15).

Solidago uliginosa: Hosmer (1903) lists this as common. Pratt (1878) lists it simply as in swamps in the north part of town with no indication that it is common. There is only one reference to this in Thoreau's Journal. MdsxFIs: rare => rare. WorCo: common not declining (0.091).

Tephrosia virginiana: Hosmer (1903) lists this as not uncommon. Pratt (1878) lists this as rather rare. Thoreau's Journal does not refer to more than perhaps three Concord locations for it. MdsxFIs: no records. WorCo: uncommon not declining (0.111).

Vernonia noveboracensis: Hosmer (1903) lists this as common. Pratt (1878) lists this as rather rare. Thoreau's Journal refers to this only at Flint's Bridge and along the Assabet River "here and there." MdsxFIs: no records. WorCo: rare declining (-0.429).

5. SPECIES INAPPROPRIATE FOR STUDY (7 species)

ASPARAGUS OFFICINALIS: Eaton (1974) notes this to be common as single plants apparently spread by birds. Thoreau refers to it only four times in his Journal and collected no specimen in his herbarium. Its history in Concord is easily explained by the advent and subsequent decline of

asparagus farming in Concord after Thoreau (see quote below). MdsxFIs: no records. WorCo: common not declining (0.07).

“It was about this time that the production of asparagus exploded. Between 1876 and 1879 ground planted to asparagus doubled. In the early asparagus years in the late 1870s the largest producers were mostly on Sudbury Road led by George Wheeler, Judge French and Charles Hubbard. Bob Gross called Concord ‘the asparagus capital of the Guilded [sic] Age’. By the 1880s Concord produced 75,000 bunches of asparagus, half the Massachusetts crop. The Middlesex County Asparagus Growers Association later registered the Old North Bridge brand of asparagus.” --
<<http://www.concordma.com/magazine/autumn07/19centuryfarming.html>>

Even in my time in the 1970s/80s there was Asparagus Farm on Bedford Street. But this farm is gone and asparagus farming, while still conducted in Concord, is very much reduced.

CAMPANULA ROTUNDIFOLIA: This was introduced to Concord by Minot Pratt. No Journal reference to this or herbarium collection by Thoreau in Concord.

MALVA NEGLECTA: Only four references to this in Thoreau’s Journal. However, Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. This is a weed of lawns, barnyards and cultivated fields. MdsxFIs: occasional => rare. WorCo: fairly common not declining (-0.03).

PASTINACA SATIVA: This is an agricultural plant. The historical information is inconsistent. Hosmer (1903) lists this as common. Pratt (1878) lists one locale “and other places.” Thoreau refers to it about eight times in his Journal with one locale in an orchard and almost none of the others with specific locale. MdsxFIs: occasional => none. WorCo: fairly common not declining (0.08).

PERSICARIA ORIENTALIS (POLYGONUM ORIENTALE): Pratt (1878) lists this as often cultivated, but occasionally found spontaneous. Hosmer (1903) lists this from dumps and apparently one Concord location (but possibly in Lincoln). This is an occasional garden escape. MdsxFIs: no records. WorCo: presumed extirpated and never established, last record 1945.

PORTULACA OLERACEA: Thoreau refers to it only eleven times in his Journal. Pratt (1878) lists it without commenting on frequency. Hosmer (1903) lists it as very common. Eaton (1974) lists it as common, often abundant. This is a garden, yard and cultivated land weed that increased significantly since Thoreau’s time. MdsxFIs: common => frequent. WorCo: common increasing (0.62).

SPERGULA ARVENSIS: There are just seven references to this in Thoreau’s Journal with no more than 3-4 locales of wild occurrence in Concord implied. Pratt (1878) lists it without providing frequency information. Hosmer (1903) lists this as common. Eaton (1974) lists it as uncommon. This weed is associated with cultivated fields. MdsxFIs: no records. WorCo: uncommon declining (-0.57).

6. NOT DECLINING, OR LOCAL TO CONCORD IF SO (57 species)

Allium canadense: MdsxFIs: rare => frequent. WorCo: uncommon not declining (-0.048). Hosmer (1903) lists this as common. Pratt (1878) lists this from only two sites. Thoreau refers to it only about ten times in his Journal mentioning only three Concord locations specifically.

Anemone quinquefolia: MdsxFIs: common => common. WorCo: common not declining (0.105). Cherrie Corey (2014 pers. comm.) reports this to be currently one of the most abundant spring flowers in Concord with many more than four stations.

Apios americana: MdsxFIs: frequent => common. WorCo: common not declining (0.091). Cherrie Corey (2014 pers. comm.) reports this to be currently plentiful in Concord with many more than four stations.

Aralia hispida: MdsxFIs: common => common. WorCo: common not declining (0.237).

Aureolaria flava: MdsxFI: none => occasional. WorCo: fairly common not declining (-.0161).

Aureolaria pedicularia: MdsxFIs: frequent => common. WorCo: common not declining (0.241).

BERBERIS VULGARIS: MdsxFIs: common => common. WorCo: common not declining (0.11).

Chimaphila umbellata: MdsxFIs: frequent => common. WorCo: common not declining (-0.034). Cherrie Corey (2014 pers. comm.) reports more than four stations of this currently in Concord. Cole Winstanley (2014 pers. comm.) reports more than six stations in the Estabrook Woods alone.

Chrysosplenium americanum: MdsxFIs: frequent => frequent. WorCo: common increasing (0.333).

Comandra umbellata: MdsxFIs: common => common. WorCo: common not declining (0.026).

Comptonia peregrina: MdsxFIs: common => common. WorCo: common not declining (0.026).

Cornus alternifolia: MdsxFIs: common => common. WorCo: common not declining (0.242). Cherrie Corey (2014 pers. comm.) reports this to be currently common in Concord.

Cornus rugosa: MdsxFIs: rare => rare. WorCo: fairly common not declining (0.243). Eaton (1974) reported this as infrequent. Yet I found it in five locations in the 1970s/80s. In 2014 Cherrie Corey (2014 pers. comm.) found this in two locations different from my locations.

Epilobium coloratum: MdsxFIs: none => rare. WorCo: common not declining (0.088).

Eubotrys racemosa: MdsxFIs: frequent => frequent. WorCo: fairly not declining (0.231).

Hosmer (1903) lists this as uncommon. Pratt (1878) does not list this from Concord. Thoreau refers to it about nine times in his Journal, but all references to it in Concord are from one site. The site where Thoreau saw it, a *Chamaecyparis* swamp, was significantly ruined about 1940 according to Eaton (1974). Hosmer's (1903) information is inadequate to determine how many stations he knew it from in Concord. I found this in the 1980s at a site not known to Thoreau or Minot Pratt.

Eupatorium perfoliatum: MdsxFIs: common => common. WorCo: common not declining (0.113).

Euphorbia maculata (*Chamaesyce nutans*): MdsxFIs: rare => frequent. WorCo: common increasing (0.341). Cherrie Corey (2014 pers. comm.) reports this to be currently very common in Concord.

Eurybia macrophylla: MdsxFIs: occasional => common. WorCo: common not declining (0.024). Cherrie Corey (2014 pers. comm.) reports this to be currently common in Concord.

Gaultheria procumbens: MdsxFIs: common => common. WorCo: common not declining (0.044). Cherrie Corey (2014 pers. comm.) reports this currently plentiful with many more than four stations, robust at Moore's Swamp, for example.

Goodyera pubescens: Cherrie Corey (2014 pers. comm.) has seen and photographed this in more than four locales in Concord in recent years. Cole Winstanley (2014 pers. comm.) has observed more than four stations in Estabrook Woods alone. MdsxFIs: occasional => none. WorCo: common not declining (0.143).

Gratiola aurea: MdsxFIs: frequent => frequent. WorCo: common not declining (0.176).

Hieracium scabrum: MdsxFIs: frequent => common. WorCo: common not declining (0.183).

Houstonia caerulea (moist fields, pastures): Hosmer (1903) lists this as very common. Eaton (1974) lists it as common. I found this common in the 1980s. In recent years Cherrie Corey (2014 pers. comm.) has found large numbers of these in many places in Sleepy Hollow Cemetery, a patch every year at Great Meadows, abundant at a cul-de-sac near Route 2, patches at the former landfill by Route 2, small patches near Walden Pond, patches along a Park Service Trail near Meriam's Corner, and other places not noted -- finding one or two new locations each year. Cole Winstanley (pers. comm. 2014) notes two additional locations and is aware of others not noted by him since it is so common. Any decline in this in Concord is minimal. MdsxFIs: common => rare. WorCo: common not declining (0.053).

Hypoxis hirsuta: MdsxFIs: common => common. WorCo: common not declining (-0.054). Cherrie Corey (2014 pers. comm.) reports it to be currently plentiful at the lime quarries in the Estabrook Woods. Cole Winstanley (2014 pers. comm.) reports this recently along a trail in the northern part of Estabrook Woods.

Ilex verticillata: MdsxFIs: common => common. WorCo: common not declining (0.132). Cherrie Corey (2014 pers. comm.) reports this to be currently very common in Concord. Cole Winstanley (2014 pers. comm.) reports from many wooded swamps, at least in the Estabrook and Wright woods. Bryan Hamlin (pers. comm. 2014) reports this as one of the common species missed by Drayton & Primack (1996) in their Middlesex Fells study.

Kalmia latifolia: MdsxFIs: none => frequent. WorCo: abundant not declining (0.028).

LEONURUS CARDIACA: MdsxFIs: occasional => frequent. WorCo: common not declining (0.23). Hosmer (1903) lists this as common, but there are only three references to it in Thoreau's Journal and Pratt (1878) does not comment on frequency.

Lespedeza hirta: MdsxFIs: frequent => common. WorCo: common not declining (0.195).

Lilium canadense: MdsxFIs: frequent => frequent. WorCo: common not declining (0.039).

Ludwigia palustris: MdsxFIs: common => common. WorCo: common not declining (0.124).

Mitchella repens: MdsxFIs: common => common. WorCo: common not declining (0.176). Cherrie Corey (2014 pers. comm.) and Cole Winstanley (2014 pers. comm.) both report this currently plentiful, easily with many more than five locations, generally in mixed pine-oak forest throughout Concord.

Monotropa hypopitys: MdsxFIs: frequent => frequent. WorCo: uncommon increasing (0.371). Hosmer (1903) lists this as common. Pratt (1878) lists this as rare. Thoreau notes it in his Journal at six locations in Concord. Cherrie Corey (2014 pers. comm.) reports seeing this recently in the Spencer Brook Valley and since 2008 southwest of Gowing's Swamp and in the Estabrook Woods.

Myrica gale: MdsxFIs: occasional => none. WorCo: common not declining (0.140). The frequency information used by Willis et al. (2008) from Primack et al. (2009) was its complete absence from Concord. In 2007 I verified it (and directed the lead author of the latter study to it) plentiful at a roadside location that I knew from the 1970s, and that was the only location for it cited by Pratt (1878). Cherrie Corey (2014 pers. comm.) reports two different healthy populations of it there and 4-5 distinct populations at Great Meadows. Eaton (1974) lists it as common.

Nymphoides cordata: MdsxFIs: no records. WorCo: fairly common not declining (0.063).

Penthorum sedoides: MdsxFIs: occasional => occasional. WorCo: common increasing (0.265). Eaton (1974) indicates that this is scarce, formerly common, and possibly a casualty of river pollution. Decline in Concord and not elsewhere is consistent with river pollution particular to Concord.

Persicaria sagittata (*Polygonum sagittatum*): MdsxFIs: common => common. WorCo: common not declining (0.062). Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. Cherrie Corey (2014 pers. comm.) reports this to be currently pervasive at Great Meadows also generally in the floodplain of the Concord River.

Polygonatum pubescens: MdsxFIs: common => common. WorCo: common not declining (0.132).

Proserpinaca palustris: MdsxFIs: occasional => frequent. WorCo: common, not declining (0.088).

Prunella vulgaris: MdsxFIs: common => common. WorCo: common not declining.

Prunus virginiana: MdsxFIs: common => common. WorCo: common not declining (0.054).

Sassafras albidum: MdsxFIs: frequent => common. WorCo: common not declining (0.118). Currently widespread in Concord according to Cherrie Corey (2014 pers. comm.) and Cole Winstanley (2014 pers. comm.) who between them know of at least 12 stations for it.

Scorzoneroides autumnalis (*Leontodon autumnalis*): MdsxFIs: common => common. WorCo: common not declining (0.24).

Silene antirrhina: MdsxFIs: occasional => occasional. WorCo: common increasing (0.409).

Sium suave: MdsxFIs: common => common. WorCo: common not declining (0.194). Cherrie Corey (2014 pers. comm.) reports this currently plentiful in Concord with many more than four stations.

Smilax herbacea: MdsxFIs: frequent => common. WorCo: common not declining (0.107). Cherrie Corey (2014 pers. comm.) reports this to be currently common in Concord. Cole Winstanley (2014 pers. comm.) reports more than seven stations, more than six in Estabrook Woods alone.

Solidago bicolor: MdsxFIs: common => common. WorCo: common not declining (-0.018).

Sparganium eurycarpum: MdsxFIs: no records. WorCo: uncommon increasing (0.500). Hosmer (1903) lists this as common. Pratt (1878) lists it without commenting on frequency. There are only four references to this in Thoreau's Journal. Eaton (1974) lists it as common along the banks of the polluted river. The most likely explanation is that it was uncommon in Thoreau's time, later became more common in the Concord vicinity due to manufacturing pollution in the rivers in the late 19th century and later sewage pollution in Concord in the 1930s, and is likely uncommon again due to

improvement of the river water quality in recent decades. Cherrie Corey (2014 pers. comm.) reports this to be increasing at Great Meadows over the past eight years.

Symphyotrichum novae-angliae: MdsxFls: none => rare. WorCo: common not declining (0.135). Thoreau never saw this in Concord. There are three references to it in his Journal, none of which refer to Concord. Late in his life (September 16, 1859) he notes in his Journal finding it in neighboring Acton and commenting "I must call it a plant of this vicinity, then." Pratt (1878) lists it as abundant at one locality in Concord and rare in other parts of the town. Hosmer (1903) simply lists this at three localities in Concord. Eaton lists it as common, rapidly increasing in abundance. Cherrie Corey (2014 pers. comm.) reports this currently to be in at least four locations in Concord.

Symphyotrichum puniceum: MdsxFls: frequent => frequent. WorCo: common not declining (0.196).

Symphyotrichum undulatum: MdsxFls: common => common. WorCo: common not declining (0.013).

Triadenum virginicum: MdsxFls: frequent => common. WorCo: common increasing (0.582). Cherrie Corey (2014 pers. comm.) reports this as currently common in Concord.

TRIFOLIUM CAMPESTRE: MdsxFls: none => frequent. WorCo: fairly common increasing (0.71).

Utricularia gibba: MdsxFls: rare => rare. WorCo: common increasing (0.408). Hosmer (1903) lists this at only one possible Concord locality, Fairhaven Bay, but that bay has a Lincoln side as well as a Concord side divided about equally. Hosmer's reference to this at Grassy Pond is a well-known locality in Acton, Massachusetts. Pratt (1878) does not list this species for Concord. There are no references to it in Thoreau's Journal and no specimen in his herbarium. Edward Hoar collected a specimen in Bateman's Pond only in 1875. Eaton lists it as common, abundant in the Great Meadows impoundments created well after Thoreau's time. The record shows that this was essentially absent from Concord in Thoreau's and Pratt's time and increased significantly in abundance after Hosmer's time.

Utricularia radiata (Utricularia inflata): MdsxFls: none => occasional. WorCo: common not declining (0.129).

Veratrum viride: MdsxFls: frequent => occasional. WorCo: common increasing (0.429). Currently common in Concord. Cherrie Corey (2014 pers. comm.) has found this growing abundantly in many wet seeps in the Estabrook Woods, especially in the upper Saw Mill Brook area and the drainage from Mink Pond and frequent throughout the upper Spencer Brook valley (in 2014). I found this in a different location in the southwest part of Concord on a brief visit in 2007.

Verbena urticifolia: MdsxFls: frequent => common. WorCo: common not declining (0.122). Cherrie Corey (2014 pers. comm.) reports this to be currently common in Concord.

Viburnum lentago: MdsxFls: frequent => frequent. WorCo: common not declining (0.118).

7. POSSIBLY DECLINING, BUT LOCALLY IF SO (40 species)

Baptisia tinctoria: Pratt (1878) and Eaton (1974) list this as common. Hosmer (1903) lists it as very common. MdsxFls: common => frequent. WorCo: common not declining (0.022).

Bidens cernua: Hosmer (1903) and Eaton (1974) list this as common. Cherrie Corey (2014 pers. common.) reports this to be currently common in Concord. MdsxFs: frequent => rare. WorCo: common not declining (0.013).

Campanula aparinoides: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as frequent. MdsxFs: occasional => none. WorCo: fairly common not declining (-0.182).

Cardamine pensylvanica: Hosmer (1903) and Eaton (1974) list this as common. Cherrie Corey (2014 pers. comm.) reports this becoming a noxious weed at roadsides, fields and lawns throughout Concord. MdsxFs: common => frequent. WorCo: common not declining (0.200).

CIRSIUM VULGARE: Hosmer (1903) and Eaton (1974) list this as common. MdsxFs: common => frequent. WorCo: fairly common increasing (0.44), first collected in 1901.

Clematis virginiana: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as uncommon. Cherrie Corey (2014 pers. comm.) and Cole Winstanley (2014 pers. comm.) have three stations for this currently in Concord. Primack et al. (2009) found this at a different location than the other three, so that under the definition of “common” adopted for that study and by Willis et al. (2008) this qualifies currently as “common.” MdsxFs: frequent => rare. WorCo: common not declining (0.084).

Clintonia borealis: Pratt (1878) simply notes it in Walden Woods and elsewhere. Eaton (1974) lists it as frequent. One Concord population was found unexpectedly by me during a brief visit in 2007. Deer browsing is most likely the reason for any decline in this species. Waller & Alverson (1997) found this species to be particularly vulnerable among other Liliaceae to deer browsing in Wisconsin, in one instance having extirpated it from a large island there. Also, Balgooyen & Waller (1995) have shown that this species in particular can be used as a good indicator of deer browsing activity. MdsxFs: no records. WorCo: common not declining (-0.012).

Cornus racemosa: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. Cherrie Corey (2014 pers. comm.) reports this to be currently in at least four locations in Concord. MdsxFs: common => frequent. WorCo: common not declining (0.200).

Drosera intermedia: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. MdsxFs: frequent => none. WorCo: common increasing (0.373).

Gnaphalium uliginosum: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. MdsxFs: common => frequent. WorCo: common not declining (0.07).

Hedeoma pulegioides (dry rocky woods, fields and old pastures): Eaton (1974) lists this as infrequent, but abundant in the Conantum vicinity. MdsxFs: common => occasional. WorCo: fairly common not declining (-0.189).

Hieracium venosum: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. MdsxFs: common => frequent. WorCo: fairly common not declining (0.095).

Hyloidesmum nudiflorum (*Desmodium nudiflorum*): Hosmer (1903) lists this as common. Pratt (1878) lists it for two locales and sparsely in other places. Thoreau refers to this only five times in his Journal and notes it at only one Concord locale. Eaton (1974) listed this as rare. In the 1970s/80s I found this in five locations including one of those listed by Pratt (1878) and the one noted by Thoreau.

The great variation in ability of botanists to find this is notable. MdsxFls: frequent => occasional. WorCo: fairly common not declining (0.158).

Hypericum canadense: Pratt (1878) lists this as rather common. Hosmer (1903) lists it as very common. Eaton (1974) lists this as frequent. MdsxFls: common => frequent. WorCo: common not declining (0.158).

Hypericum gentianoides: Hosmer (1903) lists this as very common. Eaton (1974) lists it as common. MdsxFls: common => frequent. WorCo: common not declining (0.234).

Kalmia polifolia: Thoreau in his Journal indicates that he found this in four Concord bogs, two of which were later ruined in the first half of the 20th century. Pratt (1878) lists this as rare found in only a few cold bogs. Hosmer (1903) simply lists this from three bogs -- two in Concord and the other mostly in Lincoln. Eaton (1974) lists this as occasional, at four stations (three of Thoreau's and one not cited by the others). In the 1970s/80s I found this in five Concord bogs. If two bogs where Thoreau saw it had not been ruined before my time, I would have seen it in seven bogs. On the surface the evidence suggests that this species increased in frequency between historic times and even between my time and Eaton. Observer reports are variable. It is known to survive in at least one of the bogs in recent years, but unless the other four bogs where I saw it are searched by a competent botanist and the bogs observed for degradation, this species cannot be determined to have declined. Any decline is most likely due to degradation of bogs and would be local in any case. MdsxFls: no records. WorCo: uncommon not declining (0.040).

Lechea intermedia: Hosmer (1903) lists this under two separate names as common. Eaton (1974) lists it as common. MdsxFls: frequent => occasional. WorCo: common not declining (0.157).

Lechea mucronata: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. MdsxFls: common => rare. WorCo: common increasing (0.375). Cherrie Corey (2014 pers. comm.) reports this to be currently common in Concord.

Lobelia inflata: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. Cherrie Corey (2014 pers. comm.) reports this to be currently at many stations in Concord, sporadic in waste areas. MdsxFls: common => frequent. WorCo: common not declining (0.073).

Lobelia spicata: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. MdsxFls: frequent => none. WorCo: fairly common not declining (0.069).

Lycopus americanus: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists this as frequent. MdsxFls: common => frequent. WorCo: common not declining (0.146).

Micranthes pensylvanica (*Saxifraga pensylvanica*): Pratt (1878) lists this as common. Hosmer (1903) lists it as very common. Eaton (1974) lists it as frequent. MdsxFls: frequent => none. WorCo: common, not declining (0.033).

NEPETA CATARIA: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as uncommon. MdsxFls: occasional => rare. WorCo: fairly common not declining (-0.14).

Packera aurea: Pratt (1878) lists this as common. Hosmer (1903) lists it as very common. Eaton (1974) lists it as frequent. MdsxFls: common => occasional. WorCo: common not declining (0.157).

Platanthera grandiflora: Thoreau refers to this 11 times in his journal, but all Concord occurrences are at one location. Pratt (1878) lists this as rare, but adds that it is occasionally found in boggy places. Hosmer (1903) lists this as rather uncommon and notes only one Concord locality. Whether Hosmer knew any other localities in Concord is unknown. Eaton (1974) lists it as occasional. I confirmed this in Concord in 2007 in about the same quantity (seven plants or more) where I had seen it in the 1970s, but was unable to check on the two other locations where I had seen it more sparsely, one of these being Thoreau's location. MdsxFIs: no records. WorCo: fairly common declining (-.300).

Polygala paucifolia: Pratt (1878) lists this as abundant in the south part of town. Hosmer (1903) lists it as common. Eaton (1974) lists it as frequent, often abundant in large colonies. MdsxFIs: no records. WorCo: common not declining (0.034).

Polygala sanguinea: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. MdsxFIs: frequent => occasional. WorCo: common not declining (-0.011).

Sagittaria latifolia: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. MdsxFIs: frequent => occasional. WorCo: common increasing (0.277).

Sarracenia purpurea: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as rather common. Any decline most likely due to habitat destruction/degradation which would occur more frequently in the more developed urban and suburban metropolitan Boston area. MdsxFIs: frequent => none. WorCo: fairly common not declining (-0.040).

Sericocarpus asteroides: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as frequent. MdsxFIs: common => frequent. WorCo: common not declining (-0.050).

SISYMBRIUM OFFICINALE: Hosmer (1903) and Eaton (1974) list this as common. MdsxFIs: common => occasional. WorCo: common not declining (0.11).

Spiraea tomentosa: Pratt (1878) lists this as abundant. Hosmer (1903) and Eaton (1974) list it as very common. Cherrie Corey (2014 pers. comm.) reports this to be currently common in Concord. MdsxFIs: common => frequent. WorCo: common not declining (0.034).

Spiranthes cernua: Pratt (1878), Hosmer (1903) and Eaton (1974) list this as common. MdsxFIs: common => occasional. WorCo: common not declining (-0.026).

Symphyotrichum patens: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as frequent. MdsxFIs: common => rare. WorCo: fairly common increasing (0.391).

Trillium cernuum: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as uncommon. MdsxFIs: frequent => occasional. WorCo: common not declining (-0.026).

Trillium undulatum: Hosmer (1903) lists this only from Minot Pratt's property and Stow swamp (in Stow, Massachusetts). The station at Pratt's would be an introduction since Pratt (1878) lists this as rare, found at only one location elsewhere in the Concord. Thoreau himself never saw this in Concord, although his sister did and collected a specimen. Disappearance from Concord of what was likely just one small station is possible, but would most likely be due to habitat destruction or picking and is local in any case. MdsxFIs: no records. WorCo: common not declining (-0.059).

Urtica dioica subsp. *gracilis*: Pratt (1878) lists this as not uncommon. Hosmer (1903) and Eaton (1974) list this as common. Thoreau refers to this only five times in his Journal. MdsxFIs: common => rare. WorCo: common not declining.

Utricularia cornuta: Hosmer (1903) lists this as “Bateman’s Pond. Banks of river.” Pratt (1878) notes this simply on the shores of Bateman’s Pond. Thoreau refers to this only eight times in his Journal and only notes it at Fairhaven Bay (Sudbury River) about half of which is in Lincoln. The only definite Concord location is Bateman’s Pond (as confirmed by Eaton) so that Primack et al. (2009) assigning Hosmer’s (1903) frequency of occurrence as “frequent” is unjustified. If this is currently absent from Bateman’s Pond, the significance would be minimal and likely due to water quality issues at Bateman’s Pond which is now private school property. MdsxFIs: no records. WorCo: fairly common increasing (0.333).

Veronica scutellata: Hosmer (1903) and Eaton (1974) list this as common. MdsxFIs: common => occasional. WorCo: common not declining (0.014).

Viola labradorica: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as uncommon. Middlesex County Flora (1888) lists this as widely distributed but not common. Thoreau refers to it 11 times in his Journal suggesting he found it infrequent or uncommon. MdsxFIs: rare => none. WorCo: common not declining (-0.071).

8. PROBABLY DECLINING, BUT LOCALLY IF SO (5 species)

CIRSIUM ARVENSE (fields, pastures, waste ground): Pratt (1878) lists this as frequent. Hosmer (1903) lists it as very common. Eaton (1974) reports it to be very scarce. MdsxFIs: frequent => rare. WorCo: fairly common, not declining (0.11).

Helianthus divaricatus (roadsides, dry thickets and open woods): Pratt (1878) lists this as not uncommon. Hosmer (1903) lists it as common. Eaton (1974) lists this as uncommon. MdsxFIs: rare => occasional. WorCo: fairly common declining (-0.373).

Lilium philadelphicum (dry, open, usually deciduous woods and clearings): Pratt (1878) lists this as frequent. Hosmer (1903) lists it as rather common. Eaton (1974) lists this as infrequent but scarce. This is a species probably declining due to disappearance of habitat and to deer browsing, but it is not yet declining in Worcester County. MdsxFIs: frequent => none. WorCo: common not declining (-0.104).

Oenothera perennis (fields, clearings): Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as frequent. MdsxFIs: common => none. WorCo: common not declining (-0.031).

Symphotrichum laeve (dry open ground): Pratt (1878) and Hosmer (1903) list this as common. Eaton lists it as uncommon. MdsxFIs: common => none. WorCo: common not declining (-0.133).

9. SPECIES DECLINE DUE TO SPECIFIC CAUSES (3 species)

Andromeda polifolia: Decline in Concord attributable to habitat destruction. Hosmer (1903) lists this only from two specific sphagnum bogs in Concord. One of these bogs was ruined in the first part of the 20th century. Dr. Harold Hemond of MIT (2014 pers. comm.) has seen it at the remaining bog in the past few years in quantities many more than 10 plants. Cherrie Corey (2014 pers. comm.) has seen a hundred or more plants at this bog in recent years. MdsxFIs: no records. WorCo: rare declining (-0.333).

Celastrus scandens: The dramatic disappearance of this species in eastern Massachusetts and elsewhere can be directly associated with its replacement by the similar alien *CELASTRUS ORBICULATUS* beginning at least by about 1950. Fernald (1950) does not include New England in the range of *CELASTRUS ORBICULATUS*, but Bertin & Rawinski (2012) report the first herbarium collection of it in Worcester County in 1942 and notes that hybridization between the two species is likely contributing to the decline of the native species. I saw a few massive individuals of *CELASTRUS ORBICULATUS* in Concord's Estabrook Woods in the late 1970s that must have been there at least since 1950. Eaton (1974) in error reported *Celastrus scandens* to be "Frequent" without any listing of *CELASTRUS ORBICULATUS* when in fact I found in the late 1970s that *CELASTRUS ORBICULATUS* was ubiquitous and that *Celastrus scandens* was nowhere to be found. So, the replacement in Concord of the native species by the Asian one must have occurred rapidly between 1950 and about 1970. MdsxFIs: frequent => none. WorCo: uncommon declining (-0.400).

Ribes hirtellum: Decline due to purposeful extirpation to prevent pine blister rust. MdsxFIs: occasional => occasional. WorCo: fairly common declining (-0.333).

10. DECLINING, LIKELY FOR REASONS OTHER THAN CLIMATE CHANGE AND/OR ONLY LOCALLY (16 species)

ACORUS CALAMUS (*Acorus americanus*, in error): Eaton (1974) lists this as very scarce when formerly common citing water pollution as the likely cause. MdsxFIs: common => rare. WorCo: fairly common not declining (0.06).

Arethusa bulbosa: This was disappearing well before 1950. Fernald (1950) notes it as "rapidly becoming extinct .. s.[outh] of Nfld [Newfoundland] and Canada." Lamont & Young (2004) note the complete disappearance by 1940 of a population formerly growing in great abundance on Long Island, NY in 1877. MdsxFIs: no records. WorCo: rare declining (-0.750).

Brasenia schreberi: Eaton (1974) indicates the decline in Concord is due to water pollution of the rivers: "Formerly common to abundant, now scarce except in unpolluted waters." MdsxFIs: occasional => rare. WorCo: common increasing (0.333).

Calopogon tuberosus: Eaton (1974) notes: "progressive elimination of undisturbed habitat has reduced this formerly scarce orchid to the status of a rarity." MdsxFIs: no records. WorCo: uncommon declining (-0.636).

Castilleja coccinea: Hosmer (1903) lists this only at Hayward's Swamp on the side of Annursnack Hill, the only place Thoreau found it. Primack et al. (2009) designating the Hosmer (1903) frequency of occurrence as "frequent" is based on misconstruing Hosmer's note (following his listing it only at Hayward Swamp), "Form with yellow bracts not uncommon.," as meaning not uncommon in Concord when in fact he means not uncommon within the population at Hayward's Swamp. Alfred Hosmer is the last person known to have seen this in Concord which was in 1902. Its disappearance from this last Concord site occurred well before any climate change effects. MdsxFIs: no records. WorCo: presumed extirpated, last record in 1939, formerly sporadic. Now considered historical in Massachusetts.

Lupinus perennis (dry sandy banks, open gravelly places): Eaton (1974) lists this as scarce, becoming rare. MdsxFIs: no records. WorCo: fairly common not declining (-0.152). On Massachusetts watch list.

Menyanthes trifoliata: Hosmer (1903) lists this as common. Pratt (1878) notes only two Concord locations and elsewhere not specified. Four Concord locations are noted in Thoreau's Journal. Eaton (1974) lists it as rare. Three locations where it formerly grew in Concord were ruined well before the 1970s. MdsxFIs: no records. WorCo: uncommon not declining (-0.231).

Micranthes virginensis (Saxifraga virginensis): Pratt (1878) lists this as on rocks everywhere. Hosmer (1903) lists it as very common. Eaton (1974) lists it as infrequent. I found it in the 1980s to be scarce. Cherrie Corey (2014 pers. comm.) reports this still to be at the lime quarries in the Estabrook Woods and at Martha's Point in Concord. This species would be declining in metropolitan Boston due to disappearance of open rocky habitat. MdsxFIs: common => rare. WorCo: fairly common not declining (0.055).

Platanthera orbiculata: Pratt (1878) records that he introduced this to Concord except for three plants he found, that he did not introduce. Most or all of the Hosmer (1903) report of this in Concord would be survivors of Minot Pratt's introduction. Thoreau's Journal and herbarium do not record him ever finding this in Concord. Eaton (1974) lists this as rare, status unknown. As this appears to have been disappearing by 1939 in Worcester County, the probable disappearance of only three native plants in Concord would have no relevance to climate change. MdsxFIs: no records. WorCo: presumably extirpated, last record 1939. On Massachusetts watch list.

Platanthera psycodes: Pratt (1878) lists this as common in moist meadows. Hosmer (1903) calls it rather common, but then notes it at only two Concord localities (not in meadows) as if this was significant. Eaton (1974) lists it as uncommon, perhaps rare. The history of reference to it in Concord is consistent knowing that this orchid is a plant of river meadows and swampy open woods and that the Concord rivers (and their adjacent meadows) became polluted after Alfred Hosmer's time, particularly in the 1930s. Hosmer (1903) noted the two Concord locations because they were not by the rivers where the orchid was most plentiful. The three locations in the Estabrook Woods where I found it in the 1970s/80s include the only two specific locations cited by Hosmer. As I found that this plant occurs only in very small numbers where it does occur in the woods, it is not surprising that Primack et al. (2009) managed to find only one of the three locations. The evidence indicates decline in Concord, but most of it local (river pollution). MdsxFIs: rare => rare. WorCo: fairly common declining (-0.394).

Pogonia ophioglossoides: Hosmer (1903) lists it as common. Pratt (1878) lists it as abundant. Eaton (1974) attributes the decline in this species due to destruction of its habitats (as he had observed it from the 1920s to the 1960s). MdsxFIs: no records. WorCo: fairly common not declining (-0.167).

Prenanthes alba: MdsxFIs: no records. WorCo: presumably extirpated, formerly uncommon, last record 1946.

Ranunculus aquatilis var. *diffusus (Ranunculus trichophyllus)*: There are only three references to this in Thoreau's Journal, all from one site where he noted the plant new to him in 1854. Pratt (1878) lists it as common. Hosmer (1903) lists it from three Concord locales. Eaton (1974) lists it as uncommon. Experience of past Concord botanists is inconsistent. MdsxFIs: rare => none. WorCo: none -- records there from eight townships with last record for it in 1946, presumed to be extirpated.

Rhododendron canadense: Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as occasional. The decline in this would be due largely to destruction/degradation of bogs in Concord and pollution of the river meadows in the early part of the 20th century as noted above for other species. MdsxFIs: occasional => none. WorCo: fairly common not declining (-0.200).

ROSA RUBIGINOSA (ROSA EGLANTERIA): Pratt (1878) and Hosmer (1903) list this as common. The Middlesex County Flora (Dame & Collins 1888) lists this as occasional and not very common under each of its two previous names. Thus, it appears not to have been so popular outside of Concord. Eaton (1974) lists it as infrequent. I found it to be scarce in the 1970s/1980s. The decline in this escape from cultivation is most likely due to decline in its popularity as a yard shrub. MdsxFIs: occasional => none. WorCo: rare declining (-0.83).

Silene caroliniana: A declining species, but declining well before 1950. Hosmer (1903) lists it as very common. Eaton (1974) lists it as occasional. MdsxFIs: no records. WorCo: reports this perhaps extirpated in Worcester County with records from four townships the last being in 1932.

11. DECLINING FOR UNCERTAIN REASONS (20 species)

Anaphalis margaritacea (dry fields, clearings): Pratt (1878) lists this as abundant. Hosmer (1903) lists it as common. Eaton (1974) lists it as frequent. MdsxFIs: frequent => occasional. WorCo: fairly common declining (-0.290).

Anemone virginiana (dry or rocky open woods): Eaton (1974) reports this uncommon, but widespread. MdsxFIs: frequent => rare. WorCo: fairly common declining (-0.309).

ANTHEMIS COTULA (waste ground, roadsides): MdsxFIs: occasional => none. WorCo: fairly common declining (-0.28).

Ceanothus americanus (dry open woods and thickets): Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists it as frequent. I found it occasional in the 1980s. MdsxFIs: common => occasional. WorCo: fairly common declining (-0.255).

Chamerion angustifolium (“*Epilobium anagallidifolium*,” in error) (recent clearings, recently burned woodlands, thickets): Eaton lists this as common. MdsxFIs: common => none. WorCo: fairly common declining (-0.500).

Cirsium pumilum (dry open soil): Eaton (1974) says it is rare. MdsxFIs: frequent => none. WorCo: uncommon declining (-0.514).

Corallorhiza maculata: Hosmer (1903) notes this from two Concord locations and states that it is not uncommon. Pratt (1878) does not list this at all. There are ten references (one of them outside Concord) to this in Thoreau’s Journal with only three Concord localities noted. The historic record is somewhat consistent if Thoreau found three Concord stations, Pratt (1878) none and Hosmer (1903) two, with Hosmer’s (1903) reference as “not uncommon” being to the greater Concord vicinity. Eaton (1974) lists it as scarce. This was never common or frequent in Concord. MdsxFIs: occasional => none. WorCo: uncommon declining (-0.267).

Eurybia radula (bogs, sphagnum swamps and sphagnum shores): Eaton (1974) reports this as rare. On Massachusetts watch list. Endangered or protected in Kentucky, Maryland, New York, and elsewhere. MdsxFIs: no records. WorCo: uncommon (-0.143, based on few records).

Gentianopsis crinita (brook meadows, ditch banks, wet thickets): Eaton (1974) lists this as occasional and transient. MdsxFIs: rare (1897) => none. WorCo: fairly common declining (-0.368).

Geum rivale (wet peaty meadows and bogs): Although there are only four references to this in Thoreau's Journal, it is an apparently recently declining species. Eaton (1974) lists this as common. MdsxFls: occasional => none. WorCo: uncommon declining (-0.379).

Lysimachia hybrida (river meadows, swamps, shores): MdsxFls: no records. WorCo: uncommon declining (-0.615).

Moneses uniflora: Pratt (1878) and Thoreau never found this in Concord or in neighboring towns. Hosmer (1903) lists just two Concord locations for this. Eaton (1974) lists this as rare, at two locales different than those of Hosmer (1903). This scarce, hard-to-see species is a poor taxon to gauge frequency of occurrence as the historical record shows. MdsxFls: rare => none. WorCo: uncommon declining (-0.583).

Pedicularis canadensis (dry open woods and clearings): MdsxFls: frequent => rare. WorCo: uncommon declining (-0.696).

Polygala verticillata (dry or moist open sterile habitats): MdsxFls: no records. WorCo: fairly common (-0.273). On Massachusetts watch list.

Ranunculus flabellaris (streams, ponds): Pratt (1878) lists this as rather rare, in contrast to Hosmer (1903) (common), Eaton (1974) (rather common), and apparently Thoreau. MdsxFls: frequent => rare. WorCo: uncommon declining (-0.455).

Ranunculus flammula var. *ovalis* (shores): Pratt (1878) and Hosmer (1903) list this as common. Eaton (1974) lists this as uncommon. MdsxFls: no records. WorCo: no records. On the Massachusetts watch list.

Sanicula marilandica (open commonly dry woods and thickets): MdsxFls: common => occasional. WorCo: fairly common declining (-0.280).

Spiranthes lacera var. *lacera* (fields, peaty meadows): MdsxFls: frequent => none. WorCo: uncommon declining (-0.677).

Thalictrum thalictroides (open woods usually in dry circumneutral soil): MdsxFls: frequent => rare. WorCo: fairly common declining (-0.263).

Viola pubescens (rich, usually deciduous woods): Hosmer (1903) lists this as rather common noting two localities in Concord. Pratt (1878) lists the area of the town it is found and one locality. Eaton (1974) lists it as rare. MdsxFls: rare => none. WorCo: fairly common declining (-0.362).

APPENDIX B

Listing by family of the 429 species used by Willis et al. (2008)

Species names are those used by Willis et al. (2008) in an unpublished spreadsheet used for their work kindly provided by Willis. Family names and the genera included under those families are those used in my online Concord flora (Angelo 2014b).

* - families cited by Willis et. al. (2008) as experiencing most loss

() - number of species in family

Integer beside each species is the amount of frequency change using frequency integers assigned by Willis et al. (2008) to Hosmer (1903) and to Primack et al. (2009) from data provided by the latter.

Species names in upper case are not native to Concord. Information in {} indicates origin of non-native species.

Non-native species =107; 43 species reported to be declining from data of Primack et al. (2009)

Native species = 322; 241 species reported to be declining from data of Primack et al. (2009)

Total species = 429; 284 species reported to be declining from data of Primack et al. (2009)

ACORACEAE (1)

Acorus americanus -3 {Concord species is *A. calamus* from Europe}

ADOXACEAE (5)

Sambucus nigra -1

Viburnum acerifolium 0

Viburnum lentago -2

Viburnum nudum 0

Viburnum recognitum 0

ALISMATACEAE (2)

Sagittaria latifolia -2

Sagittaria subulata -4

ANACARDIACEAE (5)

Rhus copallinum -1

Rhus glabra -1

Rhus typhina +1

Toxicodendron radicans -1

Toxicodendron vernix -1

APIACEAE (7)

Angelica atropurpurea -5

Cicuta bulbifera 0

Cicuta maculata -1

DAUCUS CAROTA -1 {from Eurasia}

PASTINACA SATIVA -2 {from Eurasia}

Sanicula marilandica -2

Sium suave -2

APOCYNACEAE (8)

Apocynum androsaemifolium -1

Apocynum cannabinum -5

Asclepias exaltata -3

Asclepias incarnata 0

Asclepias purpurascens -5

Asclepias syriaca -1

CYNANCHUM LOUISEAE +4 {from Europe}

VINCA MINOR +2 {from Eurasia}

AQUIFOLIACEAE (2)

Ilex mucronata 0

Ilex verticillata -2

ARACEAE (4)

Arisaema triphyllum -1
Calla palustris -1
Peltandra virginica 0
Symplocarpus foetidus 0

ARALIACEAE (2)

Aralia hispida -2
Aralia nudicaulis 0

ASTERACEAE* (59)

Achillea millefolium -1
Ambrosia artemisiifolia 0
Anaphalis margaritacea -2
Antennaria plantaginifolia -3
ANTHEMIS COTULA -3 {from Eurasia}
Bidens cernua -4
Bidens frondosa 0
CICHORIUM INTYBUS -1 {from Eurasia}
CIRSIUM ARVENSE -4 {from Eurasia}
Cirsium pumilum -5
CIRSIUM VULGARE -2 {from Eurasia}
Conyza canadensis -1
Doellingeria umbellata 0
Erechtites hieraciifolia -1
Erigeron annuus 0
Erigeron philadelphicus -1
Erigeron pulchellus -1
Eupatoriadelphus dubius 0
Eupatorium perfoliatum -2
Eurybia macrophylla -5
Eurybia radula -5
Gnaphalium uliginosum -2
Helianthus divaricatus -5
HIERACIUM AURANTIACUM +1 {from Europe}
Hieracium canadense -1
Hieracium paniculatum -1
Hieracium scabrum -2
Hieracium venosum -2
Ionactis linariifolius 0
Krigia virginica -1
Lactuca canadensis -1
Leontodon autumnalis -2
LEUCANTHEMUM VULGARE -1 {from Eurasia}
Mikania scandens 0
Oclemena acuminata -1
Packera aurea -3
Prenanthes alba -5
Prenanthes serpentaria -5
Pseudognaphalium obtusifolium 0

RUDBECKIA HIRTA -1 {from the Great Plains}
Sericocarpus asteroides -2
Sericocarpus linifolius -5
Solidago bicolor -2
Solidago caesia 0
Solidago canadensis 0
Solidago juncea 0
Solidago nemoralis -1
Solidago odora +2
Solidago rugosa 0
Solidago uliginosa -5
SONCHUS ASPER +3 {from Eurasia, Africa}
Symphyotrichum laeve -5
Symphyotrichum novaeangliae -3
Symphyotrichum patens -5
Symphyotrichum puniceum -2
Symphyotrichum undulatum -5
TANACETUM VULGARE -1 {from Eurasia}
TARAXACUM OFFICINALE -1 {from Eurasia}
Vernonia noveboracensis -3

BALSAMINACEAE* (1)

Impatiens capensis 0

BERBERIDACEAE (2)

BERBERIS VULGARIS -2 {from Eurasia}
PODOPHYLLUM PELTATUM +1 {from southern and midwestern US}

BORAGINACEAE (5)

ECHIUUM VULGARE 0 {from Eurasia}
Myosotis arvensis +1
Myosotis laxa +1
MYOSOTIS SCORPIOIDES -1 {from Eurasia}
Myosotis verna -2

BRASSICACEAE (12)

ARMORACIA RUSTICANA -4 {from Europe}
BARBAREA VULGARIS 0 {from Eurasia}
CAPSELLA BURSAPASTORIS 0 {from Eurasia}
Cardamine bulbosa 0
CARDAMINE DIPHYLLA 0 {from western & northern New England}
Cardamine pensylvanica -2
CARDAMINE PRATENSIS +1 {from western New England & Eurasia}
DRABA VERNA +2 {from Eurasia}
LEPIDIUM CAMPESTRE +3 {from Eurasia}
Lepidium virginicum -1
RAPHANUS RAPHANISTRUM -1 {from Eurasia}
SISYMBRIUM OFFICINALE -2 {from Eurasia}

CABOMBACEAE (1)

Brasenia schreberi -2

CAMPANULACEAE* (7)

Campanula aparinoides -2

CAMPANULA RAPUNCULOIDES -1 {from Eurasia}

CAMPANULA ROTUNDIFOLIA -2 {from northern & western New England}

Lobelia cardinalis 0

Lobelia inflata -2

Lobelia spicata -5

Triodanis perfoliata -1

CAPRIFOLIACEAE (1)

Triosteum aurantiacum -1

CARYOPHYLLACEAE* (14)

CERASTIUM FONTANUM +4 {from Eurasia}

DIANTHUS ARMERIA 0 {from Eurasia}

Moehringia lateriflora 0

SAGINA PROCUMBENS +1 {from Eurasia}

SAPONARIA OFFICINALIS 0 {from Eurasia}

SCLERANTHUS ANNUUS -1 {from Eurasia}

Silene antirrhina -3

SILENE ARMERIA -5 {from Eurasia}

Silene caroliniana -3

SILENE VULGARIS +2 {from Eurasia}

SPERGULA ARVENSIS -2 {from Eurasia}

SPERGULARIA RUBRA -1 {from Eurasia}

STELLARIA GRAMINEA +1 {from Eurasia}

STELLARIA MEDIA -1 {from Eurasia}

CELASTRACEAE* (1)

Celastrus scandens -5

CHENOPODIACEAE (2)

CHENOPODIUM ALBUM 0 {from Eurasia}

Chenopodium simplex -5

CISTACEAE* (4)

Helianthemum canadense -1

Lechea intermedia -2

Lechea mucronata -5

Lechea tenuifolia -3

COMANDRACEAE (1)

Comandra umbellata -3

COMMELINACEAE (1)

Tradescantia virginiana 0

CONVOLVULACEAE (3)

Calystegia sepium -1*Cuscuta gronovii* -1*IPOMOEA PURPUREA* 0 {from the neotropics}

CORNACEAE* (4)

Cornus alternifolia -2*Cornus canadensis* -1*Cornus racemosa* -3*Cornus rugosa* -3

CRASSULACEAE* (2)

HYLOTELEPHIUM TELEPHIODES -3 {the Concord species is *HYLOTELEPHIUM TELEPHIUM*
from Eurasia}*Sedum acre* +2 {from Eurasia}

CUCURBITACEAE (1)

ECHINOCYSTIS LOBATA +1 {from northern & western New England}

DIERVILLACEAE (1)

Diervilla lonicera -1

DROSERACEAE (2)

Drosera intermedia -2*Drosera rotundifolia* +1

ERICACEAE* (25)

Andromeda polifolia -3*Chamaedaphne calyculata* -1*Chimaphila maculata* +1*Chimaphila umbellata* -2*Epigaea repens* -1*Eubotrys racemosa* -3*Gaultheria procumbens* -2*Gaylussacia baccata* 0*Gaylussacia frondosa* 0*Kalmia angustifolia* 0*Kalmia latifolia* -2*Kalmia polifolia* -2*Lyonia ligustrina* 0*Moneses uniflora* -3*Monotropa hypopithys* -2*Monotropa uniflora* 0*Pyrola chlorantha* -5*Pyrola elliptica* 0*Rhododendron canadense* -2*Rhododendron viscosum* -1*Vaccinium angustifolium* 0*Vaccinium corymbosum* 0*Vaccinium macrocarpon* -1

Vaccinium oxycoccus -4
Vaccinium pallidum 0

EUPHORBIACEAE* (3)

Acalypha rhomboidea -1
Chamaesyce nutans -6
EUPHORBIA CYPARISSIAS -1 {from Eurasia}

FABACEAE (23)

Amphicarpaea bracteata 0
Apios americana -2
Baptisia tinctoria -2
CHAMAECRISTA FASCICULATA +2 {from southeastern New England}
Crotalaria sagittalis -5
Desmodium nudiflorum -2
Desmodium paniculatum 0
Lespedeza capitata -1
Lespedeza frutescens +1
Lespedeza hirta -3
Lespedeza virginica -1
Lupinus perennis -5
MELILOTUS OFFICINALIS +2 {from Eurasia}
ROBINIA PSEUDOACACIA -1 {from central & southeastern US}
SECURIGERA VARIA +2 {from Eurasia}
Tephrosia virginiana -4
TRIFOLIUM ARVENSE 0 {from Eurasia, Africa}
TRIFOLIUM AUREUM 0 {from Eurasia}
TRIFOLIUM CAMPESTRE -2 {from Eurasia, Africa}
TRIFOLIUM HYBRIDUM 0 {from Eurasia}
TRIFOLIUM PRATENSE 0 {from Eurasia}
TRIFOLIUM REPENS 0 {from Eurasia}
VICIA CRACCA 0 {from Eurasia}

GENTIANACEAE (2)

Gentiana andrewsii -5
Gentianopsis crinita -5

GERANIACEAE (2)

Geranium maculatum -1
GERANIUM ROBERTIANUM 0 {from central, western & northern New England}

GROSSULARIACEAE* (2)

Ribes hirtellum -5
RIBES RUBRUM -4 {from Europe}

HALORAGACEAE* (1)

Proserpinaca palustris -3

HAMAMELIDACEAE* (1)

Hamamelis virginiana -1

HYPERICACEAE* (4)

Hypericum canadense -2
Hypericum gentianoides -3
HYPERICUM PERFORATUM -1 {from Eurasia}
Triadenum virginicum -2

IRIDACEAE (4)

Iris prismatica -3
IRIS PSEUDACORUS +1 {from Eurasia}
Iris versicolor -1
Sisyrinchium angustifolium -1

LAMIACEAE* (18)

GALEOPSIS TETRAHIT 0 {from Europe}
GLECHOMA HEDERACEA 0 {from Eurasia}
Hedeoma pulegioides -5
LEONURUS CARDIACA -2 {from Eurasia}
Lycopus americanus -2
Lycopus virginicus -1
MENTHA ARVENSIS -3 {from Eurasia}
MENTHA PIPERITA -5 {hybrid with parents from Eurasia, Africa}
MONARDA BRADBURIANA -5 {from the Midwest & southern US, not known in Concord}
MONARDA MEDIA -3 {from the Midwest & southern US }
NEPETA CATARIA -3 {from Eurasia}
Prunella vulgaris -2
Pycnanthemum incanum -5
Pycnanthemum muticum -5
Scutellaria galericulata -1
Scutellaria lateriflora 0
THYMUS PULEGIOIDES 0 {from Europe}
Trichostema dichotomum -1

LAURACEAE (2)

Lindera benzoin +2
Sassafras albidum -2

LENTIBULARIACEAE* (5)

Utricularia cornuta -4
Utricularia gibba -2
Utricularia inflata -5
Utricularia macrorrhiza -1
Utricularia purpurea -4

LILIACEAE* (19)

Allium canadense -2
ASPARAGUS OFFICINALIS -4 {from Eurasia}
Clintonia borealis -5
CONVALLARIA MAJALIS 0 {from Eurasia}
HEMEROCALLIS FULVA +1 {from Asia}
Hypoxis hirsuta -2

Lilium canadense -4
LILIUM LANCIFOLIUM -3 {from Asia}
Lilium philadelphicum -5
Maianthemum canadense +1
Maianthemum racemosum -1
Medeola virginiana 0
ORNITHOGALUM UMBELLATUM +1 {from Eurasia}
POLYGONATUM BIFLORUM 0 {from southwestern New England}
Polygonatum pubescens -2
Trillium cernuum -4
Trillium undulatum -3
Uvularia sessilifolia -1
Veratrum viride -3

LYTHRACEAE (2)

Decodon verticillatus +1
LYTHRUM SALICARIA +2 {from Eurasia}

MALVACEAE (2)

Hibiscus moscheutos -1
MALVA NEGLECTA -2 {from Eurasia}

MELASTOMATACEAE (1)

Rhexia virginica -1

MENYANTHACEAE (2)

Menyanthes trifoliata -5
Nymphoides cordata -3

MOLLUGINACEAE (1)

Mollugo verticillata -1

MYRICACEAE (3)

Comptonia peregrina -2
Morella pensylvanica -1
Myrica gale -5

MYRSINACEAE* (6)

ANAGALLIS ARVENSIS -5 {from Eurasia}
Lysimachia hybrida -2
LYSIMACHIA NUMMULARIA +2 {from Eurasia}
Lysimachia quadrifolia 0
Lysimachia thyrsoflora -1
Trientalis borealis -1

NELUMBONACEAE (1)

NELUMBO LUTEA 0 {from Connecticut southward}

ONAGRACEAE* (8)

Circaea alpina -2

Circaea lutetiana 0
Epilobium anagallidifolium -5
Epilobium coloratum -2
Ludwigia alternifolia 0
Ludwigia palustris -2
Oenothera biennis -1
Oenothera perennis -3

ORCHIDACEAE* (14)

Arethusa bulbosa -5
Calopogon tuberosus -5
Corallorhiza maculata -5
Cypripedium acaule 0
Goodyera pubescens -2
Goodyera tessellata -5
Platanthera clavellata -5
Platanthera grandiflora -2
Platanthera lacera 0
Platanthera orbiculata -4
Platanthera psychodes -4
Pogonia ophioglossoides -3
Spiranthes cernua -4
Spiranthes lacera -5

OROBANCHACEAE* (7)

Agalinis paupercula -1
Aureolaria flava -2
Aureolaria pedicularia -2
Castilleja coccinea -4
Melampyrum lineare -1
Orobanche uniflora 0
Pedicularis canadensis -5

OXALIDACEAE* (1)

Oxalis stricta -1

PAPAVERACEAE (3)

CHELIDONIUM MAJUS 0 {from Eurasia}
Corydalis sempervirens -1
Sanguinaria canadensis +1

PENTHORACEAE* (1)

Penthorum sedoides -4

PHRYMACEAE* (1)

Mimulus ringens -1

PHYTOLACCACEAE (1)

Phytolacca americana 0

PLANTAGINACEAE (11)

Chelone glabra -1
Gratiola aurea -4
LINARIA VULGARIS 0 {from Eurasia}
Nuttallanthus canadensis -1
PLANTAGO ARISTATA +1 {from central US}
PLANTAGO LANCEOLATA 0 {from Eurasia}
PLANTAGO MAJOR 0 {from Eurasia}
VERONICA OFFICINALIS 0 {from Eurasia}
Veronica peregrina 0
Veronica scutellata -2
VERONICA SERPYLLIFOLIA 0 {from Eurasia}

POLYGALACEAE (3)

Polygala paucifolia -2
Polygala sanguinea -2
Polygala verticillata -5

POLYGONACEAE (17)

FAGOPYRUM ESCULENTUM -4 {from cultivation, originally from Asia}
Polygonella articulata +1
Polygonum arifolium +1
POLYGONUM AVICULARE 0 {probably from Eurasia}
POLYGONUM CUSPIDATUM +3 {from Asia}
POLYGONUM HYDROPIPER +1 {from Eurasia, Australia}
Polygonum hydropiperoides 0
Polygonum lapathifolium +2
POLYGONUM ORIENTALE -3 {from Asia, Australia}
Polygonum pensylvanicum +3
POLYGONUM PERSICARIA 0 {from Asia}
Polygonum punctatum -4
Polygonum sagittatum -2
RUMEX ACETOSELLA 0 {from Eurasia}
RUMEX CRISPUS 0 {from Eurasia}
RUMEX OBTUSIFOLIUS -1 {from Eurasia}
Rumex orbiculatus -4

PONTEDERIACEAE (1)

Pontederia cordata 0

PORTULACACEAE (2)

CLAYTONIA VIRGINICA +1 {from western Massachusetts, Connecticut}
PORTULACA OLERACEA -3 {probably from Eurasia}

RANUNCULACEAE* (18)

Actaea pachypoda 0
Anemone quinquefolia -2
Anemone virginiana -5
Aquilegia canadensis -1
AQUILEGIA VULGARIS +1 {from Europe}

Caltha palustris -1
Clematis virginica -4
Coptis trifolia 0
Ranunculus abortivus -1
RANUNCULUS ACRIS -1 {from Eurasia}
RANUNCULUS BULBOSUS 0 {from Eurasia}
Ranunculus flabellaris -5
Ranunculus flammula -5
Ranunculus trichophyllus -4
Thalictrum dioicum -1
Thalictrum pubescens -1
Thalictrum thalictroides -2
XANTHORHIZA SIMPLICISSIMA 0 {from mid-Atlantic to southeastern US}

RHAMNACEAE (1)

Ceanothus americanus -2

ROSACEAE* (19)

Agrimonia gryposepala -2
Amelanchier canadense 0
Fragaria virginiana -1
Geum aleppicum -5
Geum canadense -1
Geum rivale -5
Photinia melanocarpa -1
POTENTILLA ARGENTEA 0 {from Eurasia}
Potentilla canadensis 0
Potentilla norvegica 0
POTENTILLA RECTA +3 {from Eurasia}
Prunus americana 0
Prunus serotina 0
Prunus virginiana -2
Rosa carolina -3
ROSA EGLANTERIA -5 {from Eurasia}
Rosa virginiana -2
Spiraea alba -1
Spiraea tomentosa -2

RUBIACEAE* (7)

Cephalanthus occidentalis 0
Galium asprellum 0
Galium circaezans 0
Galium trifidum -5
Galium triflorum 0
Houstonia caerulea -3
Mitchella repens -3

SAPINDACEAE (1)

Acer pensylvanicum +1

SARRACENIACEAE* (1)

Sarracenia purpurea -3

SAXIFRAGACEAE* (3)

Chrysosplenium americanum -2

Saxifraga pensylvanica -6

Saxifraga virginiana -3

SCROPHULARIACEAE (1)

VERBASCUM THAPSUS 0 {from Eurasia}

SMILACACEAE* (2)

Smilax herbacea -2

Smilax rotundifolia 0

SOLANACEAE (1)

SOLANUM DULCAMARA 0 {from Eurasia}

SPARGANIACEAE (1)

Sparganium eurycarpum -2

URTICACEAE (2)

Boehmeria cylindrica -1

Urtica dioica -5

VERBENACEAE (2)

Verbena hastata -1

Verbena urticifolia -2

VIOLACEAE* (7)

Viola blanda -5

Viola cucullata 0

Viola labradorica -5

Viola lanceolata 0

Viola pedata -1

Viola pubescens -2

Viola sororia 0

VITACEAE (3)

Ampelopsis brevipedunculata (*Parthenocissus quinquefolia* intended & thus duplicated) -1

Parthenocissus quinquefolia -1

Vitis labrusca 0

XYRIDACEAE (1)

Xyris torta -1