The Changing Flora of the New York Metropolitan Region*

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Abstract

We statistically analyzed 100 years of herbarium specimen data for woody plants in the New York metropolitan region in order to measure the floristic changes of this area. Change index values were computed for 224 of the region's 556 woody species to provide a specific measure of whether these species are expanding, contracting, or stable. The results show that, in general, nonnative invasive species are spreading rapidly in the region, while native species are in slight decline.

Keywords: *Chimaphila*, ecological change; Ericaceae; herbarium; invasive plants; *Lonicera*; New York City, urban flora

Introduction

Plant species differ in their ability to adapt to environmental changes brought on by urban development and spread. Yet there are few studies that attempt to quantify the differences in adaptability among species (but see, for example, Dickson et al., 2000). In this study, we use current and historical data on woody plants in the New York metropolitan region to develop a change index measuring the relative degree to which species have expanded or contracted their ranges over the past century. The findings help us gain a better understanding of exactly how the flora of this urban region is changing and should prove useful to those attempting to improve and restore the ecosystems of the region.

It is difficult to quantify changes in the flora of the New York metropolitan region because the region, like other urban areas in the United States, has not been subjected to any long-term plant studies using standard sampling methods. In our study, we used herbarium specimen data from about a dozen herbaria in the northeastern United States. Botanists do not use a standard sampling method when collecting herbarium specimens: Some collect every plant they see, while others collect only the plants they are studying or those that are of particular interest at a site. But although there are a variety of sampling strategies, the strategies themselves have not changed significantly over the past century, and the data should be adequate for carrying out a comparison of the relative changes in the ranges of species.

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Although our technique only analyzes the change in range of a species, it has been shown that there is a relationship between range and abundance of species (Hanski, Kouki & Halkka, 1993; He, Gaston & Wu, 2002). Therefore, an expanding range for a species is a good indication that the species may be increasing in abundance. Likewise, a range contraction is an indicator that a species may be declining in abundance.

Methods

This study is comparable to a study done for plants in Great Britain. We have predominantly used techniques developed by Telfer, Preston, and Rothery (2002), with a few modifications, spelled out in detail here.

The distributional data comes from the New York Metropolitan Flora (NYMF) project database (Moore, Steward, Clemants, Glenn & Ma, 2002; and see http://www.bbg.org/sci/nymf/). This database currently has nearly 250,000 records of plant occurrences from the New York metropolitan region. Each record is geo-coded to five-kilometer-square cells in a grid, with 964 cells total. We will call these cells "blocks." (The names used in this study are those adopted by the NYMF project; see Moore et al., 2002.)

In this study, we used the woody-species data from the NYMF database. The woody-plant data set is the most complete one in the database and has over 145,000 records, representing 556 species. In our analysis, we only used records of woody species based upon herbarium specimens collected between 1901 and 2000. Once we narrowed the data to meet this criterion and eliminated duplicate records, there were 24,795 records remaining for this study. These records were made relatively evenly over the first half of the 20th century, but for the second half of the century, the bulk of the data is from the last decade (the 1990s), when the NYMF project began actively collecting (Figure 1).

The data were partitioned into two cohorts (time periods): the early cohort, containing data from 1901 to 1950, and the later cohort, containing data from 1951 to 2000. Following Telfer, Preston, and Rothery (2002), we only included blocks for which there were occurrences of a species in both cohorts. This reduced the number of blocks used in the analysis to 647. These 647 blocks are distributed throughout the New York metropolitan region (Figure 2). The Telfer, Preston, and Rothery study excluded species with fewer than five occurrences in the early cohort. In our study, we modified the procedure by excluding species with fewer than five occurrences in either the early or late cohort. This reduced the number of species in our study to 224.

The statistical methods for developing the change index are outlined in Telfer, Preston, and Rothery (2002). All statistics were calculated using Systat 10.2 statistical software (SPSS, 2000).

Results and Discussion

Table 1 lists the 224 species studied in this analysis, the raw sampling block counts for each cohort, species provenance (native or introduced), and the change index. Please note that the raw counts for some species show an increase over time, while their change indices show a decrease. This is because there are many more records in the later period (from the 1990s). The statistic essentially corrects for this overabundance of data. This means that a species showing no change in distribution will have a larger raw count in the later period than the earlier, and that some species may show a decrease in distribution while showing an increase in the raw count.

The first, unweighted least-squares regression equation was $y = -1.05 + 0.66x$, with $r^2 = 0.444$. Following two iterations of the weighing procedure, we arrived at a weighted regression equation of $y = -1.00 + 0.68x$, with $r^2 = 0.467$. We believe that the relatively low r^2 is the result of two things. First, unlike in Telfer, Preston, and Rothery (2002), our data were not collected following a uniform procedure. Therefore, we suspect that there is greater statistical error in the data. Second, we believe we are studying a much more rapidly changing flora (an urban flora) than the one in the studies used by Telfer, Preston, and Rothery (a country-wide flora). Therefore, we would expect larger change indices in general.

Figure 3 shows the distribution of change indices in relation to the provenance of the plant species. Because the data for natives are right-skewed, we used a Mann-Whitney U test to determine if the native and nonnative (introduced) species data are significantly different. The Mann-Whitney test statistic was 5054, which is significant ($p = 0.014$). This indicates that the nonnative species are increasing relative to the native species. In general, native species are showing slight decline, and introduced species are showing much greater expansion of their ranges, with only a few species showing any decline.

The change index in this study is valuable because it provides species-specific information about what is changing in the flora. For instance, nearly all the members of the heath family (Ericaceae) in the region are showing contraction of their ranges. There are probably many reasons why these species appear sensitive to urbanization, but three stand out: 1) most heath family species are acidophilic (Kron & Chase, 1993), and urban soils are generally more basic (Craul, 1992; Scheyer & Hipple, 2005); 2) many Ericaceae species are hydrophytes, and much wetland habitat has been lost over the past century (e.g., New Jersey lost an estimated 39% of its wetlands between 1870 and 1970, with half that loss occurring between 1950 and 1970; see New Jersey Sustainable State Institute, 2004); 3) the overabundance of white-tailed deer (*Odocoileus virginianus*) in suburban regions may impact some species through overgrazing (Department of Environmental Protection, Division of Fish, Game and Wildlife, 1999), though we expect this impact would be broad across many taxa .

The results show that several congeneric species have very different change indices. For example, *Celastrus scandens*, the native American bittersweet, has a change index of –1.15, while *Celastrus orbiculata*, the nonnative Oriental bittersweet, has a change index of +3.24. This wide disparity—indicative of a dramatic decline for the American bittersweet and a dramatic spread by the Oriental bittersweet—reinforces the results of a previously published account of these two species (Steward, Clemants & Moore, 2003).

Nonnative honeysuckles are significantly increasing, while native species are undergoing significant decline. The native *Lonicera dioica* and *L. sempervirens* have change indices of –2.87 and –1.93, respectively, and the nonnative *L. japonica* and *L. morrowii* have change indices of +1.60 and +1.73, respectively (see Figures 4–7). (In the case of *L. japonica* and *L. sempervirens*, the nonnative's growth architecture may be giving it a competitive advantage over its native congener and allowing it to increase its range; see Schweitzer & Larson, 1990; Larson, 2000).

Another nonnative species, *L. maackii*, not included in this study because of its more recent date of introduction (and thus lack of any pre-1950 records), is also rapidly spreading in the region (Figure 8).

Other native-nonnative congeneric species groups also reflect this pattern, such as the following (change index in parentheses): nonnative *Clematis terniflora* (+1.33), native *C. virginiana* (–0.32); nonnative *Morus alba* (+2.41), native *M. rubra* (–1.71); nonnative *Ribes rubrum* (+0.28), native *R. americanum* (–0.41), native *R. hirtellum* (–1.92), and native *R. rotundifolium* (–0.54).

A striking pattern is observed for the New York metropolitan region's two native *Chimaphila* species (which are not being impacted by nonnative congeners), with *C. umbellata* having a change index of –2.51 and *C. maculata* having a change index of –0.29 (Figures 9 and 10). While there have not been any studies aimed at better understanding why *C. umbellata* is declining at a greater rate than *C. maculata*, field botanists have hypothesized that *C. umbellata* may be more significantly affected by deer browsing than *C. maculata*, perhaps as a result of differences in leaf chemistry between the two species (Lamont & Young, 2004). Cowan (1945) reported that *C. umbellata* was casually eaten by deer.

Conclusion

Without question, the flora of the New York metropolitan region is rapidly changing. Most notably, nonnative invasive species are rapidly spreading in the area, while native species are generally in decline. Monitoring programs such as the NYMF project provide a mechanism by which these changes can be quantitatively measured. They may, in the future, be used to identify potentially invasive species before these species spread throughout the range. Also, these programs provide baseline data that future generations can use in comparative analysis to track floristic change.

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Glossary

Acidophilic: Pertaining to plants that thrive in acid soil.

Basic: Alkaline

Change Index: A statistical indication of changes in the distribution of a species. A positive change index indicates that a species is expanding its range, while a negative change indicates that a species is contracting its range.

Congeneric, congener: Belonging to the same genus.

Geo-code: A computerized process that uses coordinates (in our case, cells) to uniquely identify a geographic location from a description.

Hydrophyte: An aquatic plant; one that grows in water or needs a waterlogged habitat.

Least-squares regression equation: A statistical method for a simple linear equation to real data points.

Mann-Whitney U test: A non-parametric test used to compare two independent groups of sampled data.

Figure 1. Number of unique specimens of woody species collected over the past century.

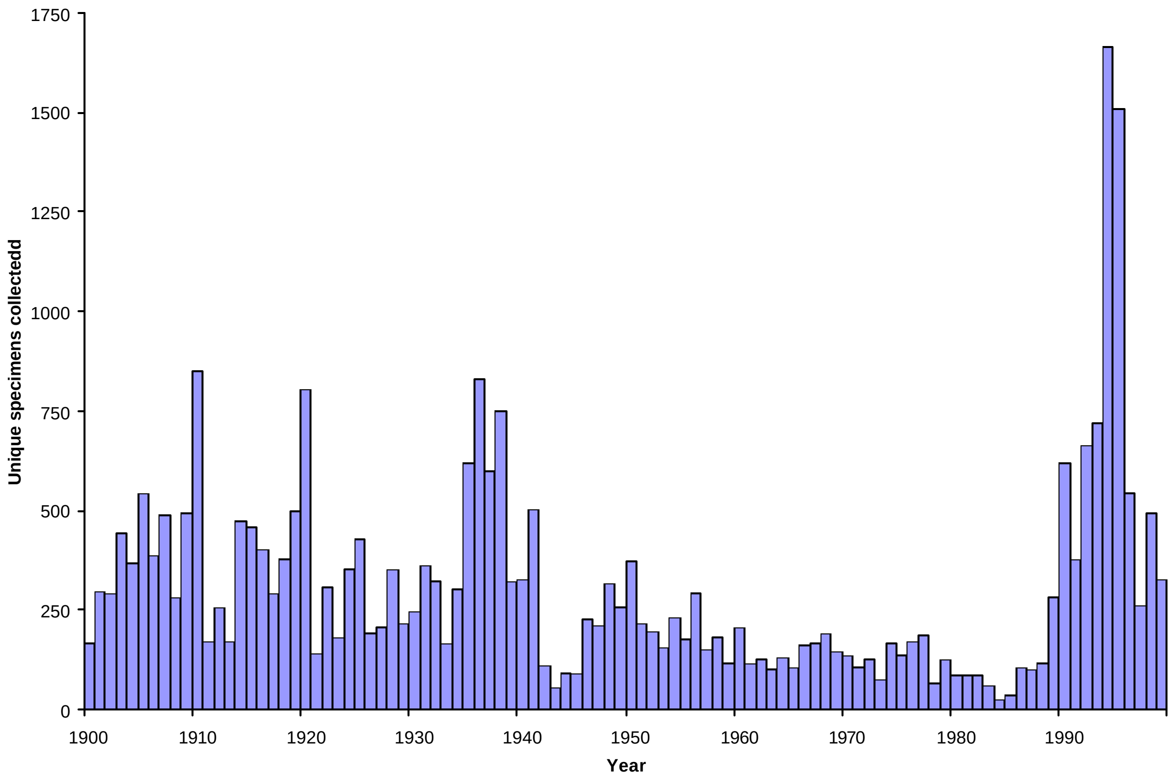


Figure 2. Distribution of blocks used in this study.

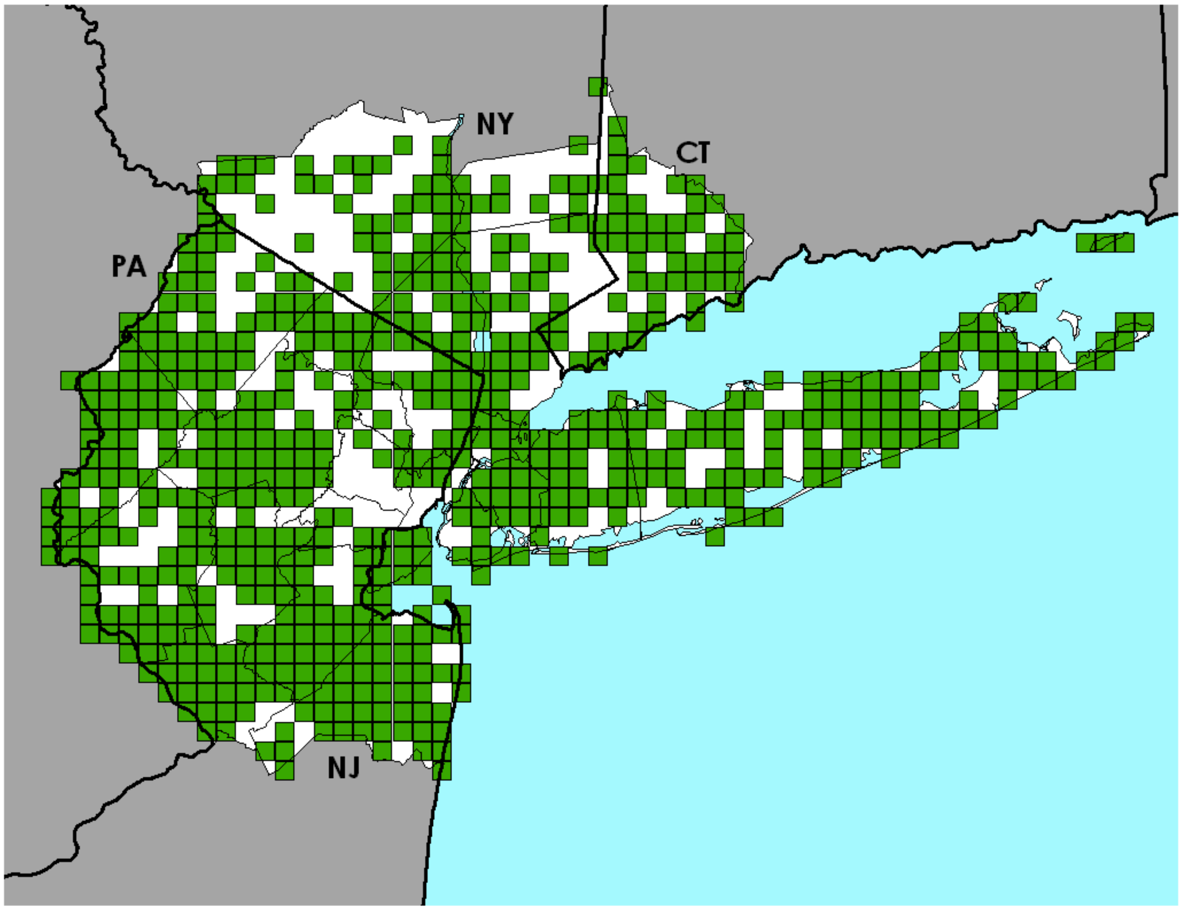


Figure 3. A dual histogram of the change indices for introduced (nonnative) and native species. These graphs show the distribution of change index values for the 226 species studied.

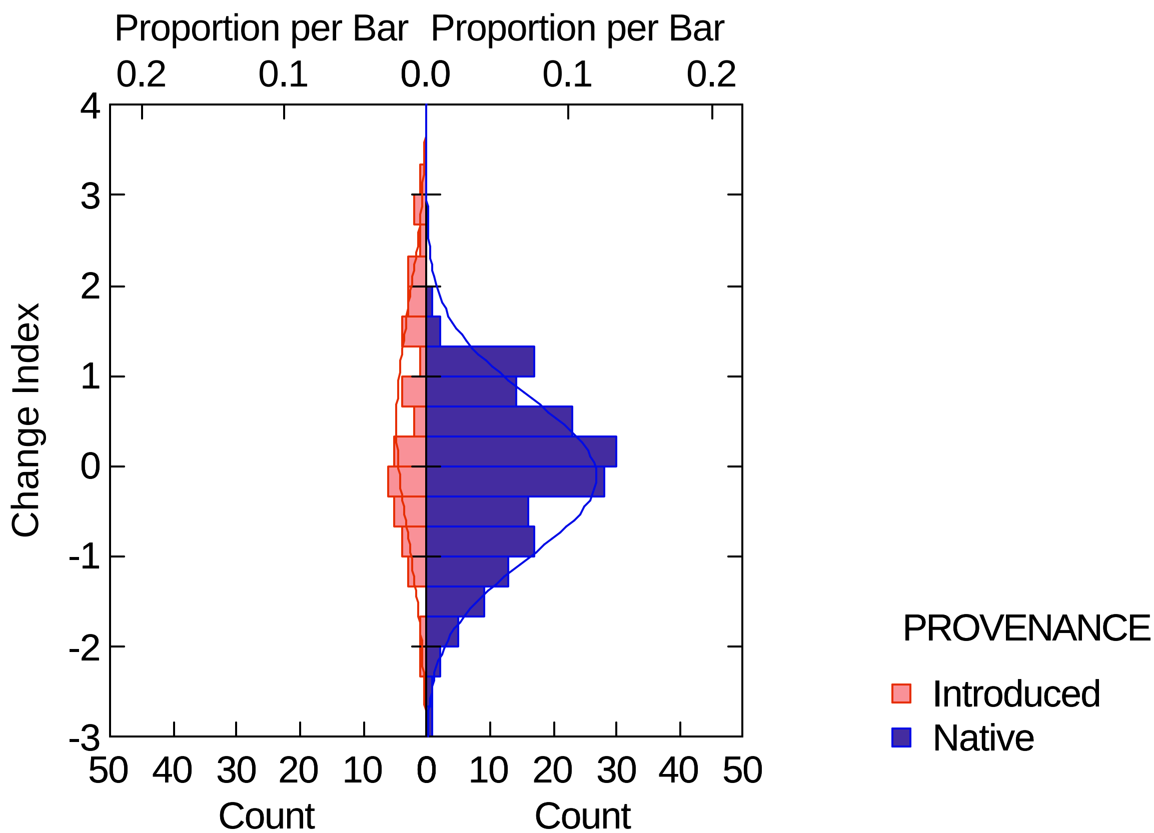
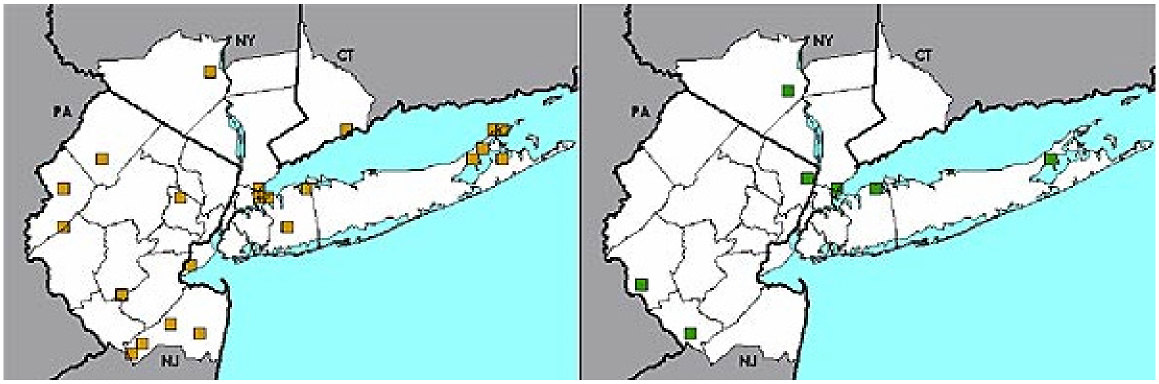


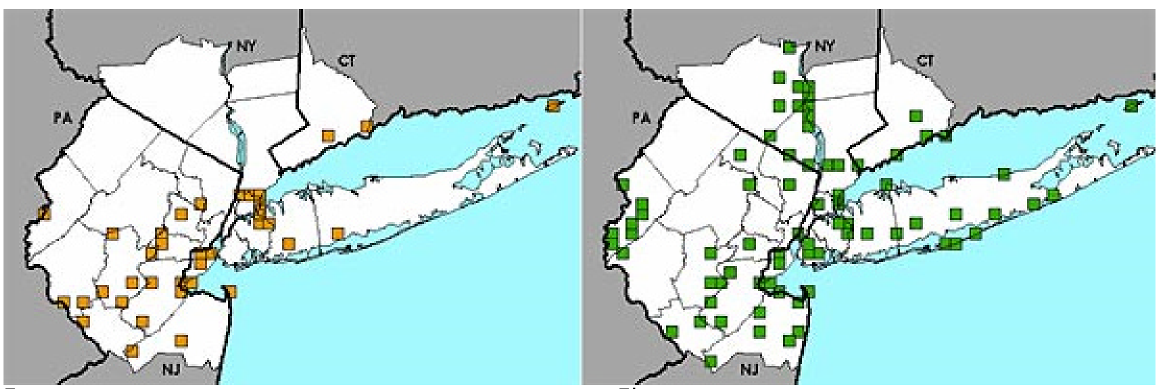
Figure 4. Range map of *Lonicera sempervirens* for the New York metropolitan area. (Native, Change Index = –1.93)



4a 4b

(Native, Change Index = –1.93)
4a. Specimens collected between 1901 and 1950
4b. Specimens collected between 1951 and 2000

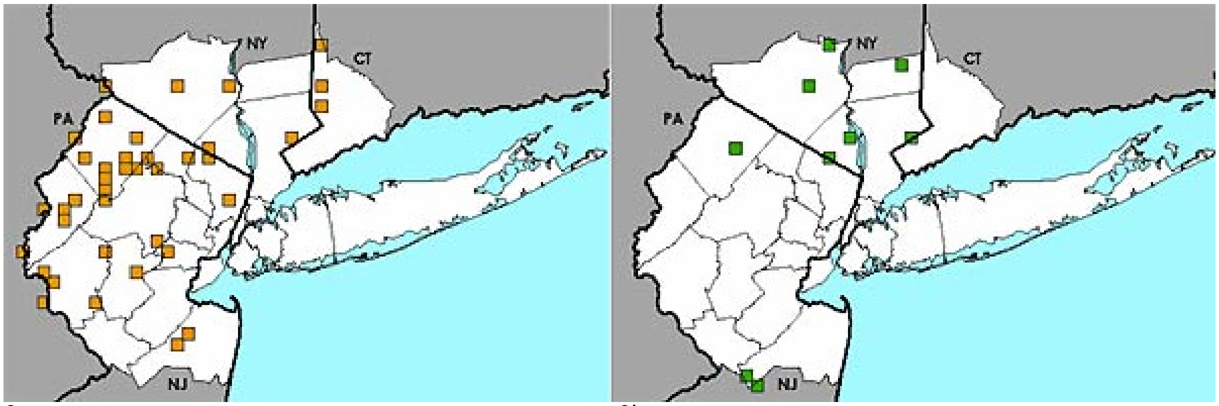
Figure 5. Range map of *Lonicera japonica* for the New York metropolitan area. (Introduced, Change Index = +1.60)



5a 5b

(Introduced, Change Index = +1.60)
5a. Specimens collected between 1901 and 1950
5b. Specimens collected between 1951 and 2000

Figure 6. Range map of *Lonicera dioica* for the New York metropolitan area.



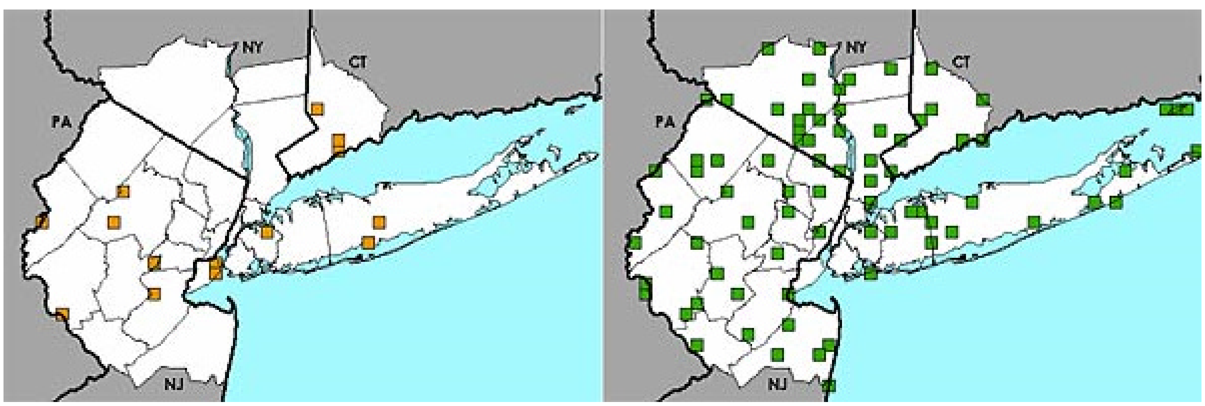
6a 6b

(Native, Change Index = –2.87)

6a. Specimens collected between 1901 and 1950

6b. Specimens collected between 1951 and 2000

Figure 7. Range map of *Lonicera morrowii* for the New York metropolitan area.



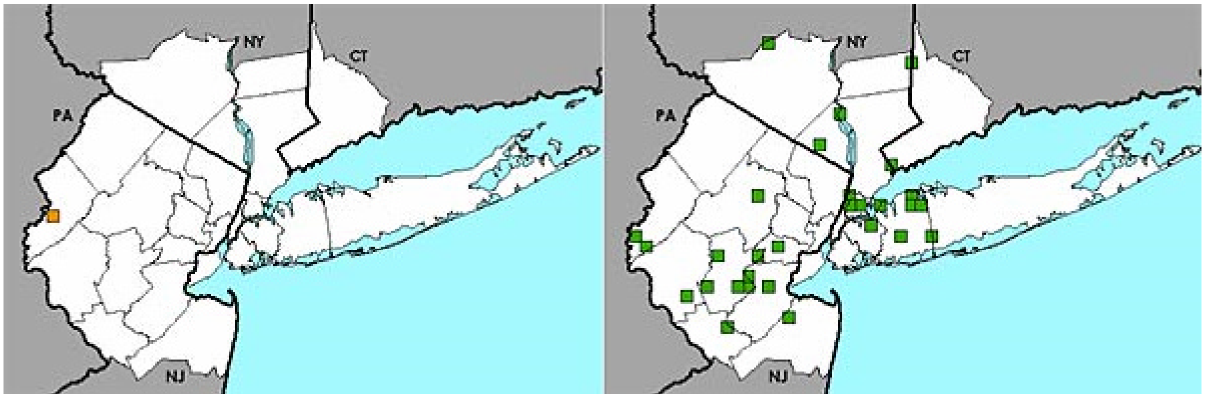
7a 7b

(Native, Change Index = –2.73)

7a. Specimens collected between 1901 and 1950

7b. Specimens collected between 1951 and 2000

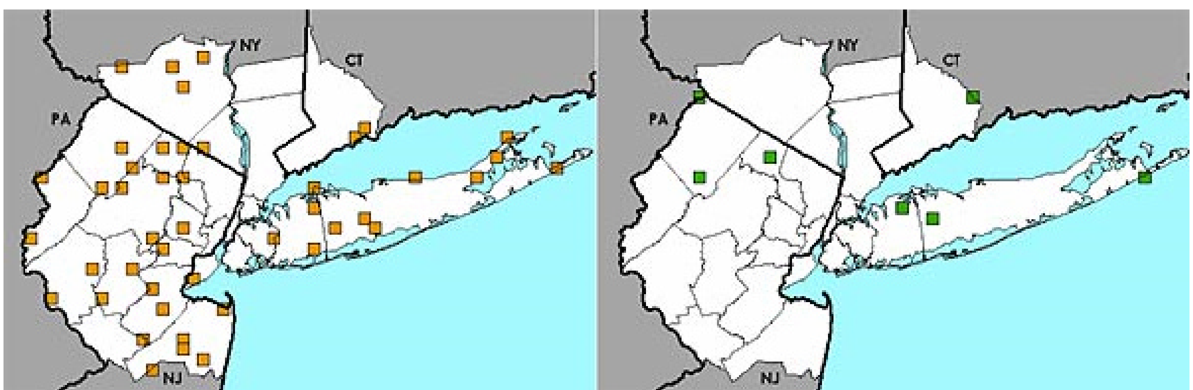
Figure 8. Range map of *Lonicera maackiii* for the New York metropolitan area.



8a	8b

(Introduced, no change index, too few collections in early period)
8a. Specimens collected between 1901 and 1950
8b. Specimens collected between 1951 and 2000

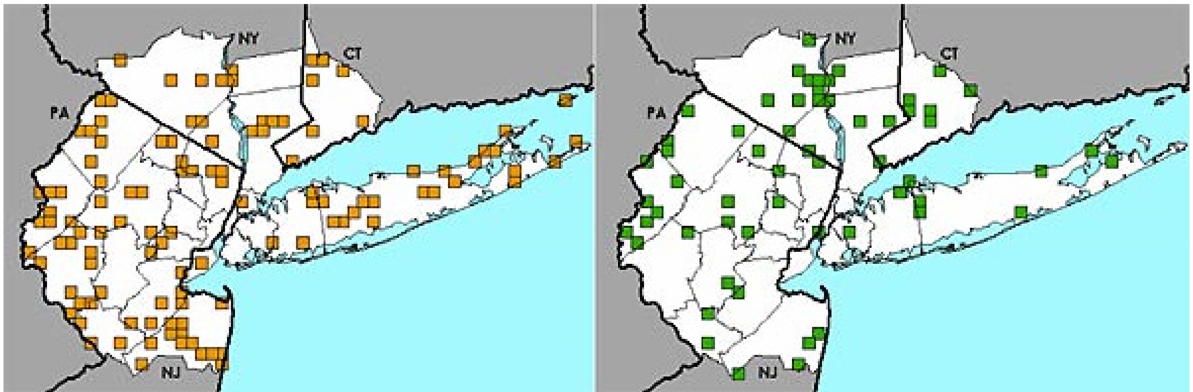
Figure 9. Range map of *Chimaphila umbellata* for the New York metropolitan area.



9a	9b

(Native, Change Index = –2.51)
9a. Specimens collected between 1901 and 1950
9b. Specimens collected between 1951 and 2000

Figure 10. Range map of *Chimaphila maculata* for the New York metropolitan area.



10a	10b

(Native, Change Index = –0.29)
10a. Specimens collected between 1901 and 1950
10b. Specimens collected between 1951 and 2000

Table 1. The change index for each species in the study along with the raw data and the provenance of each species. (Names follow Moore et al., 2002.)

Species name	Provenance	1901–1950 raw count	1951–2000 raw count	Change Index
Acer negundo	Native	22	65	1.86
Acer pensylvanicum	Native	18	23	0.20
Acer platanoides	Introduced	22	58	1.64
Acer pseudoplatanus	Introduced	13	23	0.57
Acer rubrum	Native	93	117	1.26
Acer saccharinum	Native	22	39	0.91
Acer saccharum	Native	45	69	1.12
Acer spicatum	Native	26	11	–1.48
Aesculus hippocastanum	Introduced	6	8	–0.37
Ailanthus altissima	Introduced	16	54	1.88
Akebia quinata	Introduced	6	6	–0.84
Alnus incana	Native	17	20	0.03
Alnus serrulata	Native	85	67	0.26
Amelanchier arborea	Native	29	43	0.76
Amelanchier canadensis	Native	47	90	1.59
Amelanchier stolonifera	Native	15	16	–0.22
Amorpha fruticosa	Native	22	37	0.81
Ampelopsis brevipedunculata	Introduced	8	40	2.12
Aralia spinosa	Introduced	6	34	2.14
Arctostaphylos uva-ursi	Native	43	13	–1.81
Aronia arbutifolia	Native	71	59	0.25
Aronia melanocarpa	Native	39	21	–0.86
Baccharis halimifolia	Native	37	39	0.30
Berberis thunbergii	Introduced	25	65	1.71
Berberis vulgaris	Introduced	17	12	–0.84
Betula alleghaniensis	Native	34	21	–0.69
Betula lenta	Native	69	64	0.44
Betula nigra	Native	30	21	–0.55
Betula papyrifera	Native	12	7	–1.35
Betula populifolia	Native	82	74	0.50
Broussonetia papyrifera	Introduced	15	10	–1.01

Campsis radicans	Introduced	10	15	0.13
Carpinus caroliniana	Native	53	66	0.83
Carya cordiformis	Native	20	40	1.06
Carya glabra	Native	42	46	0.44
Carya ovalis	Native	15	12	–0.70
Carya ovata	Native	28	43	0.80
Carya tomentosa	Native	50	51	0.42
Castanea dentata	Native	63	50	0.10
Catalpa bignonioides	Introduced	10	24	0.94
Ceanothus americanus	Native	61	25	–1.10
Celastrus orbiculata	Introduced	8	71	3.24
Celastrus scandens	Native	81	30	–1.15
Celtis occidentalis	Native	68	56	0.21
Cephalanthus occidentalis	Native	53	63	0.74
Chamaecyparis thyoides	Native	27	20	–0.51
Chamaedaphne calyculata	Native	49	23	–0.98
Chimaphila maculata	Native	107	59	–0.29
Chimaphila umbellata	Native	39	8	–2.51
Clematis terniflora	Introduced	8	26	1.33
Clematis virginiana	Native	36	27	–0.32
Clethra alnifolia	Native	101	63	–0.08
Comptonia peregrina	Native	63	46	–0.05
Cornus alternifolia	Native	41	34	–0.07
Cornus amomum	Native	75	75	0.64
Cornus florida	Native	87	83	0.65
Cornus foemina	Native	77	64	0.30
Cornus rugosa	Native	31	18	–0.85
Cornus sericea	Native	12	21	0.50
Corylus americana	Native	60	56	0.37
Corylus cornuta	Native	21	16	–0.60
Crataegus crusgalli	Native	17	14	–0.58
Crataegus pruinosa	Native	21	13	–0.95
Diervilla lonicera	Native	38	19	–1.00
Diospyros virginiana	Native	20	16	–0.54

Dirca palustris	Native	8	6	–1.15
Elaeagnus umbellata	Introduced	12	53	2.18
Epigaea repens	Native	67	26	–1.16
Euonymus europaea	Introduced	19	12	–0.97
Fagus grandifolia	Native	42	71	1.26
Fraxinus americana	Native	50	63	0.82
Fraxinus nigra	Native	21	27	0.31
Fraxinus pennsylvanica	Native	45	46	0.36
Gaultheria procumbens	Native	41	24	–0.69
Gaylussacia baccata	Native	102	65	–0.04
Gaylussacia frondosa	Native	59	28	–0.86
Hamamelis virginiana	Native	66	73	0.75
Hibiscus syriacus	Introduced	7	10	–0.16
Hudsonia ericoides	Native	30	8	–2.19
Hudsonia tomentosa	Native	60	26	–1.01
Hydrangea arborescens	Native	16	8	–1.45
Ilex glabra	Native	32	15	–1.20
Ilex laevigata	Native	24	17	–0.65
Ilex opaca	Native	16	26	0.55
Ilex verticillata	Native	78	69	0.43
Iva frutescens	Native	34	33	0.10
Juglans cinerea	Native	21	23	0.03
Juglans nigra	Native	21	47	1.30
Juniperus communis	Native	19	10	–1.28
Juniperus virginiana	Native	74	57	0.14
Kalmia angustifolia	Native	64	35	–0.57
Kalmia latifolia	Native	67	49	–0.02
Larix laricina	Native	14	11	–0.77
Leucothoe racemosa	Native	76	39	–0.59
Ligustrum vulgare	Introduced	13	14	–0.28
Lindera benzoin	Native	73	97	1.18
Liquidambar styraciflua	Native	42	35	–0.05
Liriodendron tulipifera	Native	32	61	1.29
Lonicera dioica	Native	35	6	–2.87

Lonicera japonica	Introduced	33	73	1.60
Lonicera morrowii	Introduced	14	77	2.73
Lonicera sempervirens	Native	20	7	–1.93
Lycium barbarum	Introduced	13	10	–0.85
Lyonia ligustrina	Native	104	54	–0.41
Lyonia mariana	Native	68	33	–0.75
Magnolia virginiana	Native	18	16	–0.42
Malus coronaria	Native	8	8	–0.68
Malus pumila	Introduced	13	22	0.49
Menispermum canadense	Native	48	42	0.12
Morus alba	Introduced	20	81	2.41
Morus rubra	Native	20	8	–1.71
Myrica gale	Native	34	13	–1.52
Myrica pensylvanica	Native	112	63	–0.22
Nemopanthus mucronatus	Native	25	10	–1.60
Nyssa sylvatica	Native	62	75	0.88
Ostrya virginiana	Native	46	39	0.03
Parthenocissus quinquefolia	Native	58	84	1.19
Parthenocissus vitacea	Native	7	7	–0.75
Paulownia tomentosa	Introduced	8	18	0.69
Philadelphus coronarius	Introduced	10	16	0.24
Physocarpus opulifolius	Native	25	17	–0.70
Picea rubens	Native	10	8	–0.92
Pinus echinata	Native	8	6	–1.15
Pinus rigida	Native	44	34	–0.16
Pinus strobus	Native	33	33	0.13
Pinus virginiana	Native	20	7	–1.93
Platanus occidentalis	Native	13	32	1.16
Populus alba	Introduced	11	13	–0.22
Populus deltoides	Native	16	42	1.41
Populus grandidentata	Native	73	54	0.05
Populus tremuloides	Native	56	43	–0.03
Potentilla fruticosa	Native	28	12	–1.42
Prunus avium	Introduced	23	42	0.99

Prunus maritima	Native	46	32	–0.32
Prunus pensylvanica	Native	14	12	–0.62
Prunus pumila	Native	18	9	–1.39
Prunus serotina	Native	74	101	1.25
Prunus virginiana	Native	39	31	–0.18
Ptelea trifoliata	Native	8	10	–0.31
Pyrus communis	Introduced	6	10	0.00
Quercus alba	Native	57	77	1.04
Quercus bicolor	Native	49	46	0.26
Quercus coccinea	Native	40	49	0.62
Quercus ilicifolia	Native	70	42	–0.35
Quercus marilandica	Native	32	25	–0.32
Quercus montana	Native	48	53	0.54
Quercus muhlenbergii	Native	6	9	–0.17
Quercus palustris	Native	31	53	1.07
Quercus phellos	Native	11	15	0.02
Quercus prinoides	Native	51	26	–0.81
Quercus rubra	Native	50	78	1.23
Quercus stellata	Native	36	26	–0.39
Quercus velutina	Native	60	76	0.95
Rhamnus cathartica	Introduced	16	22	0.26
Rhamnus frangula	Introduced	10	32	1.45
Rhododendron maximum	Native	28	28	0.04
Rhododendron periclymenoides	Native	94	56	–0.21
Rhododendron viscosum	Native	105	59	–0.26
Rhus copallinum	Native	55	51	0.30
Rhus glabra	Native	72	65	0.42
Rhus hirta	Native	44	48	0.46
Ribes americanum	Native	23	19	–0.41
Ribes hirtellum	Native	24	8	–1.92
Ribes rotundifolium	Native	20	16	–0.54
Ribes rubrum	Introduced	18	24	0.28
Robinia hispida	Introduced	10	12	–0.25
Robinia pseudo-acacia	Introduced	21	60	1.76

Robinia viscosa	Introduced	19	6	–2.13
Rosa carolina	Native	105	58	–0.29
Rosa eglanteria	Introduced	16	7	–1.67
Rosa multiflora	Introduced	14	79	2.79
Rosa palustris	Native	50	45	0.19
Rosa rugosa	Introduced	11	14	–0.09
Rosa virginiana	Native	38	16	–1.30
Rubus allegheniensis	Native	67	43	–0.25
Rubus flagellaris	Native	49	34	–0.29
Rubus hispidus	Native	48	35	–0.21
Rubus laciniatus	Introduced	13	15	–0.16
Rubus occidentalis	Native	46	37	–0.06
Rubus odoratus	Native	48	19	–1.29
Rubus pensilvanicus	Native	34	29	–0.13
Rubus phoenicolasius	Introduced	35	62	1.22
Salix alba	Introduced	16	13	–0.64
Salix bebbiana	Native	31	12	–1.54
Salix discolor	Native	74	83	0.86
Salix eriocephala	Native	43	41	0.21
Salix fragilis	Introduced	12	11	–0.60
Salix humilis	Native	84	19	–2.01
Salix nigra	Native	42	63	1.03
Salix purpurea	Introduced	15	10	–1.01
Salix sericea	Native	54	24	–1.02
Sambucus canadensis	Native	74	79	0.76
Sambucus racemosa	Native	29	15	–1.08
Sassafras albidum	Native	66	97	1.31
Smilax glauca	Native	69	44	–0.25
Smilax rotundifolia	Native	59	67	0.73
Solanum dulcamara	Introduced	67	78	0.86
Spiraea alba	Native	64	51	0.12
Spiraea tomentosa	Native	63	33	–0.65
Staphylea trifolia	Native	48	50	0.43
Symphoricarpos orbiculatus	Introduced	9	9	–0.61

Tilia americana	Native	35	57	1.06
Toxicodendron radicans	Native	45	54	0.65
Toxicodendron vernix	Native	30	31	0.13
Tsuga canadensis	Native	34	40	0.44
Ulmus americana	Native	36	59	1.09
Ulmus rubra	Native	35	41	0.45
Vaccinium angustifolium	Native	72	29	–1.05
Vaccinium corymbosum	Native	159	87	–0.11
Vaccinium macrocarpon	Native	66	21	–1.51
Vaccinium pallidum	Native	104	70	0.08
Vaccinium stamineum	Native	64	46	–0.07
Viburnum acerifolium	Native	108	82	0.33
Viburnum dentatum	Native	101	92	0.65
Viburnum lentago	Native	38	39	0.26
Viburnum nudum	Native	57	30	–0.70
Viburnum opulus	Native	16	22	0.26
Viburnum prunifolium	Native	74	85	0.90
Viburnum rafinesquianum	Native	19	14	–0.71
Vitis aestivalis	Native	82	66	0.28
Vitis labrusca	Native	81	69	0.38
Vitis riparia	Native	25	31	0.35
Vitis vulpina	Introduced	19	17	–0.38
Zanthoxylum americanum	Native	12	20	0.42