THE NEW YORK BOTANICAL GARDEN

HEMLOCK FOREST PROJECT

Part II

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THE NEW YORK BOTANICAL GARDEN

MEMORANDUM

April 8, 1981

TO: V. Sands

FROM: J. McAninch

RE: Hemlock Forest Report

Enclosed please find the end of a project that has grown in size since the day we started. We have attempted to incorporate all the material of any significance from the Hemlock Forest Files into this final report. Unfortunately, most of the work of the past 10 years is incomplete or of little use. I will bring the material with me Friday and you can review the entire set. We have sepearated everything into a few basic types of information which should ease the pain.

In addition to the appendices we have organized the large and extensive data set we generated and will retain such for future reference. I should imagine that as site specific plans are developed the soil, litter, canopy, and vegetation data can be of great importance.

I have several comments I would like to make at the Committee meeting on Friday if you could allow me time. I look forward to seeing you then.

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Concern for the persistence of hemlock (Tsuga canadensis) in the New York Botanical Garden Forest has been evident since the 40-acre grove was set aside by the Lorillard family in 1895. Over the next several years the staff of the Botanical Garden maintained investigations in the forest that included studies of the roots (Harlow, 1900) and seed cycle and seedlings (Lloyd, 1900) of hemlock, the absence of undergrowth in the forest (Gager, 1907) and the effects of soil on hemlock (Robinson, 1909). Later, a cooperative study with the Yale Forestry School, the New York State College of Forestry at Syracuse, and the Department of Forestry of Cornell University sought to evaluate the relationship between hemlock and its environment (Moore, 1923; Moore *et al.*, 1924; Gleason, 1924). This period of great interest in the plight of hemlock in the forest ended with two reports of attempts to plant hemlocks in the hemlock grove (Britton, 1926; 1927). Unfortunately, reports of investigations concerning hemlock or the hemlock grove did not reappear in the Garden Archives until the early 1970's. Aroused by the successful invasion of many hardwood species into the forest and the absence of hemlock regeneration, the Botanical Garden staff initiated a concerted drive to develop a management plan for the 40-acre tract (Irwin, 1979).

The degraded forest condition that promulgated the last decade of activity was strikingly similar to the concerns raised by Britton in 1906: "To further ensure the safety of the forest, it will doubtless be necessary to adopt measures looking toward the restriction of travel through it to well defined lines, by indicating the existing paths and trails; the thin soil and the consequent proximity of the tree roots to the surface cause indiscriminate tramping over them by multitudes to be undesirable. The parks and gardens of the Bronx are already visited by considerable numbers of people, but when these numbers are very largely increased, as they certainly will be, the policing problem, already acute, will become far more serious." Britton appealed to the staff and public at large to appreciate not only the charm of the forest but to recognize the educational features of the small grove.

Today, the place of hemlock in the forest has been seriously challenged by many well-adapted woody invaders. The character of the site has changed significantly due in part to many years of human use and abuse as well as the harsh realities of the surrounding urban environment. Still, there remains a desire to perpetuate hemlock within the forest.

The purpose of this report is to review the life history of hemlock and present the results of intensive studies conducted on 6 selected sites containing hemlock. A set of recommendations will further elaborate upon recommendations described in Part I of this project. Finally, several appendices containing data culled from the Botanical Garden Archives have been included.

Hemlock Life History

Hemlock has commonly been found in cool, moist valleys and ravines in the northern midwest, northeastern North America, and the Appalachian Mountains (Frothingham, 1915; Elias, 1980). This species has been found in pure stands but more commonly in mixed hardwood associations. Common associates have included black birch (Betula lenta), red maple (Acer rubrum), sugar maple (A. saccharum), beech (Fagus grandifolia), hickory (Carya glabra), red oak (Quercus borealis), white oak (Q. alba), black oak (Q. velutina), and white ash (Fraxinus americana) (Frothingham, 1915; Clepper, 1944; Charney, 1980). Hemlocks have been known to reach 500-600 years of age although trees of 200-250 years have been more commonly reported (Clepper, 1944).

Vigorous hemlock stands have been found on a range of soil types although moist, humus-rich, well-drained soils have supported the best stands (Frothingham, 1915; Clepper, 1944). Hemlock has been found on shallow soils where deep layers of organic debris have accumulated (Clepper, 1944; Keatinge, 1967a).

Although seed production has been found to vary between years (Lloyd, 1900), hemlock has been characterized as a prolific seed bearer (Clepper, 1944). Overall reproduction has been reported as poor due to the specific germination requirements of hemlock seed (Lloyd, 1900; Clepper, 1944). Seeds germinated best on lightly shaded sites, void of herbaceous plants, and in the rich litter layers, especially rotting wood (Lloyd, 1900). Too much sun, moisture or dense shade, dry soils and litter composed of hemlock needles have all contributed to germination failures (Lloyd,1900; Frothingham, 1915). The occurrence of hemlock in patches or groves has been attributed to the opportunistic growth that occurred when small areas of the forest canopy adjacent to parent trees have been opened by single tree losses (Clepper, 1944).

Hemlock root systems have been found to be dense and fibrous and occur in laterally spreading, shallow configurations (Lloyd, 1900; Clepper,1944). This characteristic has rendered hemlock susceptible to fire (which kills small seedlings and dries out the humus), wind shake, and increased soil compaction (Britton, 1906; Clepper, 1944).

Once established, seedlings have grown rapidly in open sunlight or maintained suppressed growth under partial or dense shade for periods of 30-70 years (Clepper, 1944; Olson et al., 1959). With a decrease in canopy density, suppressed hemlocks have demonstrated rapid growth over a short period of time (Nienstaedt and Olson, 1955).

Methods and Materials

After collection of the data described in Part I of this project, the pattern of plots containing hemlock was determined (Fig. 1). In an area of hemlock abundance, 6 grids (30 x 30 m) were located and sampled in September, 1980. All woody vegetation within each grid was mapped and the DBH, height, and species recorded for each specimen. Increment cores were taken

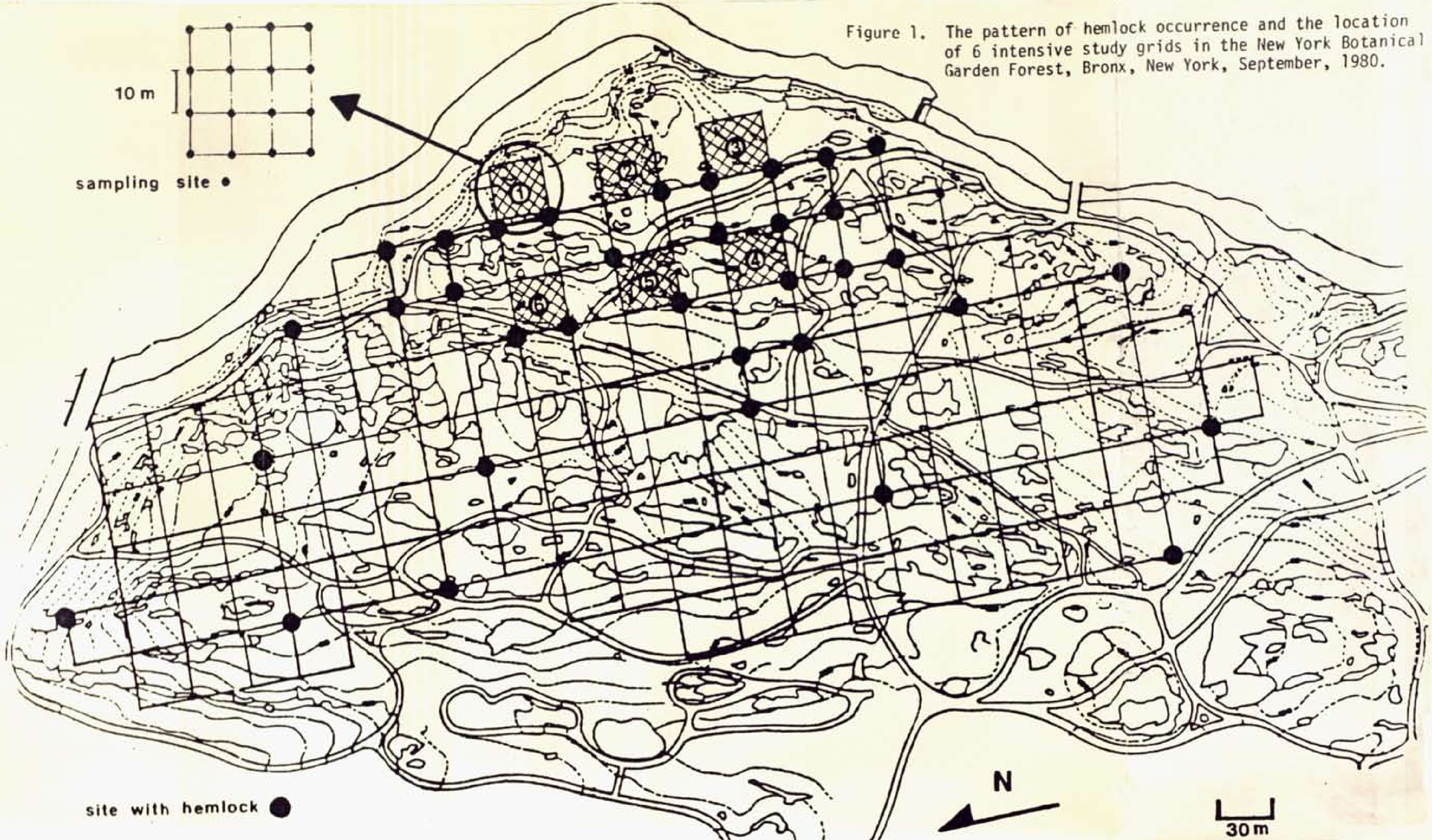


Figure 1. The pattern of hemlock occurrence and the location of 6 intensive study grids in the New York Botanical Garden Forest, Bronx, New York, September, 1980.

from all hemlocks encountered in the 6 study areas. Cores were used to determine age (± 5 yrs) as described by Brace (1966).

All grids were further subdivided into 9 units which resulted in 16 sampling points, each 10 m apart (Fig. 1). A picture of the canopy above each sampling point was recorded with a 35 mm camera placed on the ground surface. All vegetation < 2 m in height was removed from camera range to allow for a clear canopy photograph. After processing, slides were projected onto a point sampling screen containing 54 points. Each point intercept (modified after Chamrad and Box, 1964) was recorded as either dense (opaque) canopy (separated into branch, trunk or leaf), partial canopy (some light penetration) or no canopy (complete light penetration). All points that fell in between the 3 canopy classes were tallied and later divided equally among all 3 groups. The total number of dots in each group was converted to proportionate values.

Leaf litter was collected within a 30 cm-diameter loop at each sampling point. All litter above the mineral soil level was collected. Litter samples were sorted into deciduous leaves, twigs and fruits and coniferous twigs or fruit. All component subsamples were weighed and recorded as a proportion of the total litter sample weight.

Leaf litter depth, soil compaction and soil samples were taken from 4 points located 1 m north, south, east and west of each of the 16 sampling points. Litter depth was measured as described in Part I. Soil compaction was measured using a soil penetrometer (Soiltest CL-700) with a range of 0.00 to 4.50. Soil samples were collected from 0-6 cm and 6-12 cm depths and analyzed for organic matter content and pH as described in Part I.

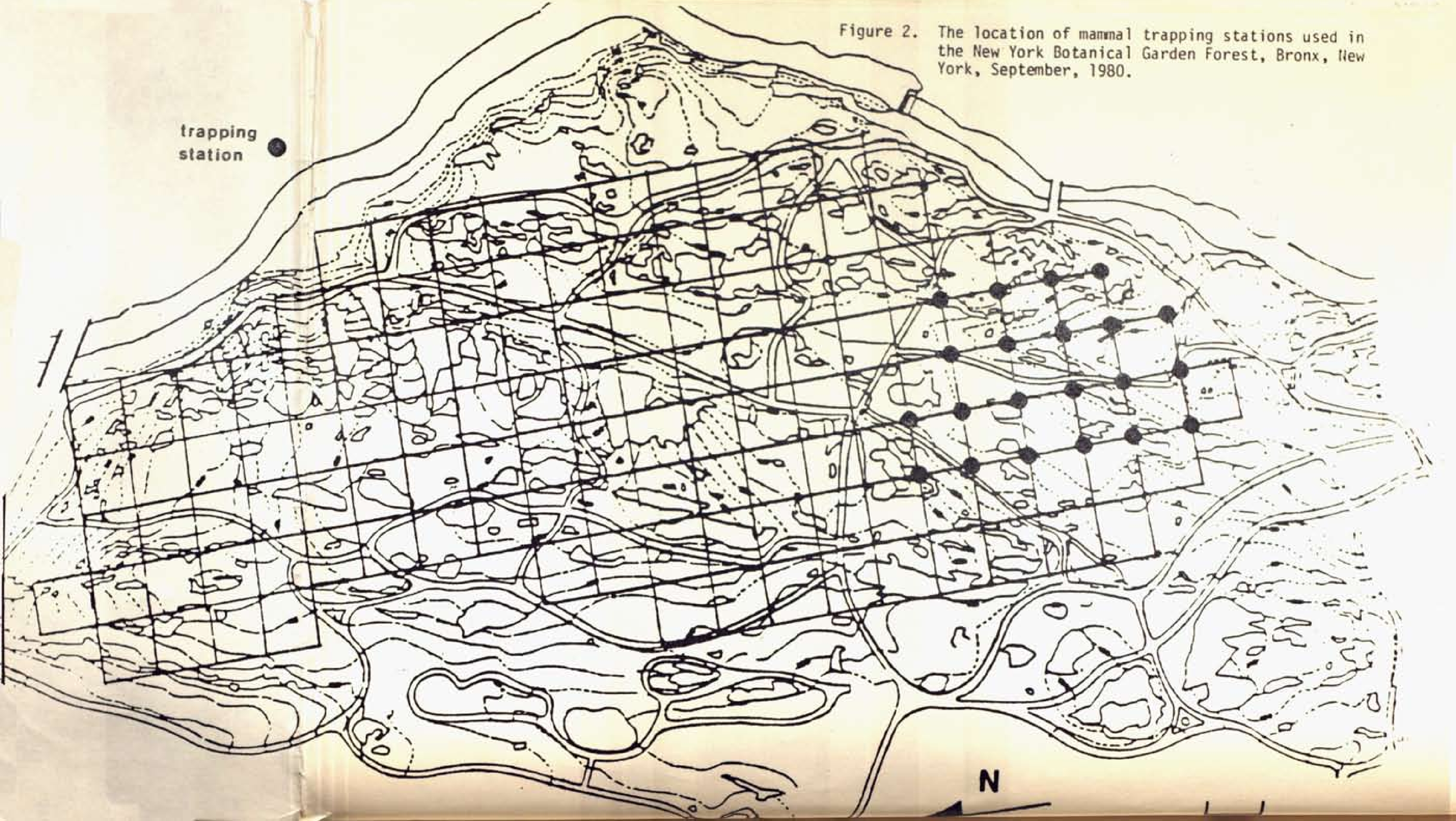
Small mammals were live-trapped and tagged during the period July 28 to August 7, 1980. Trap stations were located 30 m apart on a grid located near the center of the forest (Fig. 2). A 13 x 13 x 41 mm tomahawk trap and a 5 x 6 x 16 mm Sherman live trap were baited with peanut butter and apples and placed at each station. Traps were checked at least twice daily and closed overnight.

All captured mammals were weighed, sexed, aged, tagged with a #3 monel metal ear tag (National Band and Tag Co.) or toe clipped, examined for external abnormalities and released. Subsequent observations of marked mammals in groups were recorded through September 4, 1980. The number of tagged and untagged individuals as well as the size of each group was noted.

A similar trapping session was conducted on September 17, 18 and 19 on the same grid. All captured mammals were sacrificed via cervical dislocation. All individuals were identified to species, sexed, weighed, grossly examined, and standard measurements were taken. Proximate stomach analyses, kidney fat indices and female reproductive rates were determined.

Maximum linear movement and ranges were determined for all mammals captured at least twice (Stickel, 1954). Minimum population density and population estimates were computed after Lincoln and Baldwin (1929) and Hayne (1949). Indices of relative abundance

Figure 2. The location of mammal trapping stations used in the New York Botanical Garden Forest, Bronx, New York, September, 1980.



were also determined using the method of Pucek (1969). Data from which density and abundance were computed were first adjusted for sprung traps (Nelson and Clark, 1973).

Results

The results concerning hemlock in the Botanical Garden forest will be presented in 2 sections. First, several measures of hemlock occurrence will be derived from data collected on the extensive survey described in Part I. Second, the analyses of hemlock and several ecosystem characteristics on the 6 intensive study sites will be outlined and evaluated.

The distribution of hemlock as determined in the extensive survey (see Fig. 1) was more concentrated along the eastern portion of the forest adjacent to the Bronx River. Elsewhere in the forest individuals were sporadically encountered and were the result of planting attempts or possibly natural regeneration. The overall hemlock density for the forest was 2.1 stems per 100 m^2.

A chi-square goodness of fit test to compare the observed versus expected distribution of hemlock rejected the hypothesis that hemlock occurred at random within the forest ($\chi = 49.13$, $p < .005$). The average crowding experienced by individual hemlock stems within the forest was determined using the index of patchiness of Lloyd (1967). The pattern was not aggregated but was somewhat regular ($I = .36$). This indicated a low intensity pattern of hemlock existed in those areas of the forest where hemlock occurred.

As reported in Part I, the results of 2 x 2 contingency table comparisons of species (Pielou, 1974) indicated no positive, significant relationships existed between hemlock and any of the woody forest species. Weakly significant negative associations occurred between hemlock and black cherry (*Prunus serotina*), sweet cherry (*P. avium*), and hickory (χ^2 = 3.64, 3.52, 2.99, 1 d.f., $p < .10$).

The density of hemlock on the 6 intensive study sites was unexpectedly lower than the density for the entire forest (1.5 stems per 100 m^2). The hemlock densities per 100 m^2 for grids 1 through 6 were 2.7, .4, 1.7, 2.2, 1.5, and .3 respectively. The distribution of hemlock was tested for randomness and, again, hemlock was not found to occur at random (χ^2 = 11.77, $p < .01$). The index of patchiness was derived and indicated the pattern of hemlock on the 6 study sites was similar to the pattern over the entire forest (I = .40).

The results of 2 x 2 contingency table analysis found hemlock did not occur in positive associations with any species. A significant negative association existed between hemlock and red maple (χ^2 = 7.55, 1 d.f., $p < .05$), between hemlock and white ash (χ^2 = 2.52, 1 d.f., $p < .10$) and between hemlock and tulip tree (*Liriodendron tulipifera*) (χ^2 = 2.57, 1 d.f., $p < .10$).

Importance indices derived from volume and frequency data were used to compare each of the 6 study sites (Tables 1-6). In general, hemlocks were found on each study site and predominated the 5-10 m and 10-25 m strata.

On grid 1 few seedlings existed in the 0-1 m strata. Major occupants in this layer and the 1-5 m layer were spicebush (Lindera benzoin) and southern arrow-wood (Viburnum dentatum). Several beech saplings were distributed throughout the 1-5 m strata. The 5-10 m layer was occupied by hemlock and to a lesser extent by red maple, cork tree (Phellodendron amurense), and beech. Hemlock was a dominant constituent of the 10-25 m layer while red maple, black birch, and cork tree were represented in small numbers. The overstory (25-50 m) was occupied by 2 species, red oak and beech.

Grid 2 had no major overstory (25-50 m) but several seedling red maple and black cherry occurred with maple-leaved viburnum (V. acerifolium). Black birch saplings and the shrubs, spicebush and southern arrow-wood, predominated the 1-5 m strata. The major constituent in the 5-10 m layer was red maple which had an importance value nearly 10 times that of black birch, the next most important species. Beech dominated the 10-25 m strata while hemlock was of intermediate importance, and red oak, red maple, white ash, sweetgum (Liquidambar styraciflua) and sassafras (Sassafras albidum) occurred in low numbers.

On Grid 3 the seedling layer was predominated by maple-leaved viburnum, beech, and to a lesser extent white ash and black cherry. Sweet pepperbush (Clethra alnifolia) and southern arrow-wood dominated the 5-10 m layer. Hemlock was a major importance in the 5-10 m strata while red maple and flowering dogwood (Cornus florida) were infrequently encountered. Hemlock was again the most prevalent species in the 10-25 m layer. Black birch was of intermediate importance while red and white oak occurred infrequently.

Table 1. Importance index as derived from volume and frequency by forest strata of woody plants in Grid #1 of the New York Botanical Garden Forest, Bronx, New York, September 1980.

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m³)	Freq (%)	Imp Index	Vol (m³)	Freq (%)	Imp Index	Vol (m³)	Freq (%)	Imp Index	Vol (m³)	Freq (%)	Imp Index	Vol (m³)	Freq (%)	Imp Index
Tsuga canadensis							0.28	27.3	7.64	14.09	55.3	778.66			
Quercus borealis										1.59	2.6	4.18	3.05	50.0	152.50
Quercus alba															
Quercus palustris										1.11	2.6	2.92			
Quercus velutina															
Acer rubrum	*	6.1	0.006				0.18	18.2	3.27	5.49	15.8	86.68			
Acer saccharum															
Fagus grandifolia				0.009	25.0	0.225	0.06	18.2	1.09	2.01	5.3	10.58	3.92	50.0	196.00
Carya glabra															
Liriodendron tulipifera															
Fraxinus americana				0.008	1.3	0.010									
Betula lenta										5.72	5.3	30.11			
Liquidambar styriciflua															
Populus tremuloides															
Nyssa sylvatica															
Ostrya virginiana															
Sassafrass albidum				0.032	1.3	0.042				1.89	2.6	4.97			

Table 1 (cont.)

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Prunus serotina				0.003	7.9	0.024	0.04	9.1	0.36						
Cornus florida	*	6.1	0.006				0.06	9.1	0.55						
Phellodendron amurense							0.11	18.2	2.00	2.33	10.5	24.53			
Aralia spinosa															
Hamamelis virginiana															
Morus alba															
Lindera benzoin	0.001	42.4	0.042	0.007	54.0	0.378									
Viburnum dentatum	0.001	45.5	0.045	0.001	10.5	0.011									
Viburnum acerifolium															
Hydrangea arborescens															
Clethra alnifolia															

* = < 0.001

Table 2. Importance index as derived from volume and frequency by forest strata of woody plants in Grid #2 of the New York Botanical Garden Forest, Bronx, New York, September 1980.

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Tsuga canadensis							0.84	6.0	5.09	1.75	18.2	31.82			
Quercus borealis	*	1.0	0.001							1.42	9.1	12.91			
Quercus alba															
Quercus palustris															
Quercus velutina															
Acer rubrum	0.002	26.8	0.054	0.159	2.0	0.318	2.73	42.4	115.82	1.56	18.2	10.18			
Acer saccharum															
Fagus grandifolia				0.004	2.0	0.008	0.20	3.0	0.61	4.54	18.2	82.55			
Carya glabra															
Liriodendron tulipifera															
Fraxinus americana							0.43	6.0	2.61	1.61	9.1	14.64			
Betula lenta				0.090	21.6	1.944	0.30	36.4	10.91						
Liquidambar styriciflua				0.008	2.9	0.023				1.98	9.1	18.00			
Populus tremuloides							0.01	3.0	0.03						
Nyssa sylvatica															
Ostrya virginiana															
Sassafrass albidum	*	3.1	0.003							0.83	9.1	7.55			

Table 2 (cont.)

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Prunus serotina	0.003	34.0	0.102	0.005	2.9	0.015									
Cornus florida							0.05	3.0	0.15						
Phellodendron amurense	*	6.2	0.006							0.20	9.1	1.82			
Aralia spinosa															
Hamamelis virginiana				0.001	6.9	0.007									
Morus alba															
Lindera benzoin	*	4.1	0.004	0.005	25.5	0.127									
Viburnum dentatum	*	4.1	0.004	0.007	34.3	0.240									
Viburnum acerifolium	0.002	20.6	0.041	*	2.0	0.002									
Hydrangea arborescens															
Clethra alnifolia															

* = < 0.001

Table 3. Importance index as derived from volume and frequency by forest strata of woody plants in Grid #3 of the New York Botanical Garden Forest, Bronx, New York, September 1980.

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Tsuga canadensis							0.98	62.5	61.25	11.14	55.0	612.70			
Quercus borealis				0.021	2.2	0.046				1.33	10.0	13.30			
Quercus alba				0.002	1.1	0.002				5.02	5.0	25.10			
Quercus palustris															
Quercus velutina				0.003	1.1	0.003									
Acer rubrum	*	1.9	0.002				0.23	12.5	2.88	0.57	5.0	2.85			
Acer saccharum															
Fagus grandifolia	0.001	23.1	0.023				0.06	12.5	0.75	0.33	5.0	1.65			
Carya glabra													5.71	100.0	571.00
Liriodendron tulipifera															
Fraxinus americana	*	11.5	0.012												
Betula lenta	*	1.9	0.002							9.58	15.0	143.70			
Liquidambar styriciflua															
Populus tremuloides															
Nyssa sylvatica				0.004	4.4	0.018				0.47	5.0	2.35			
Ostrya virginiana															
Sassafras albidum															

Table 3 (cont.)

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Prunus serotina	0.001	19.2	0.019	0.009	4.4	0.040									
Cornus florida				0.002	9.9	0.020	0.14	12.5	1.75						
Phellodendron amurense															
Aralia spinosa															
Hamamelis virginiana															
Morus alba															
Lindera benzoin				*	3.3	0.003									
Viburnum dentatum				0.006	29.7	0.171									
Viburnum acerifolium	0.003	42.3	0.127												
Hydrangea arborescens															
Clethra alnifolia				0.009	44.0	0.414									

* = < 0.001

Hickory was the only constituent of the 25-50 m strata.

Several species including red maple, white ash, black birch, hop hornbeam (Ostrya virginiana), black cherry, devil's walking stick (Aralia spinosa) and southern arrow-wood were common in the 0-1 m layer of grid 4. The 1-5 m strata was occupied by 9 species of which spicebush and southern arrow-wood were the most prevalent. Hemlock and red maple were the major constituents of the 5-10 m layer. Hemlock had an importance value nearly 12 times greater than black cherry, red maple and black birch in the 10-25 m layer while hemlock and red oak were the only inhabitants of the 25-50 m strata.

Grid 5 had 3 species (black cherry, spicebush, and southern arrow-wood) of nearly equal importance in the 0-1 m layer. Spicebush and to a lesser extent hop hornbeam and southern arrow-wood were prevalent in the 1-5 m layer. Hemlock and red oak dominated the 5-10 m layer while red maple, flowering dogwood, and black birch occurred infrequently. The 10-25 m layer was predominantly hemlock and to a lesser extent red maple. The overstory (25-50 m) was occupied by black oak.

Grid 6 had species in the 0-1 m layer with spicebush being the most common. Spicebush and southern arrow-wood were the most prevalent in the 1-5 m strata. Hemlock, red maple and sugar maple were the only inhabitants of the 5-10 m layer. In the 10-25 m layer sugar maple was the dominant species followed by red maple, white ash, sassafras, and hemlock. The overstory layer was occupied equally by the tulip tree and white ash.

Table 4. Importance index as derived from volume and frequency by forest strata of woody plants in Grid #4 of the New York Botanical Garden Forest, Bronx, New York, September 1980.

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Tsuga canadensis							0.20	28.6	5.71	16.90	51.6	872.26	7.62	66.7	508.00
Quercus borealis				0.027	0.4	0.011							10.25	33.3	341.67
Quercus alba															
Quercus palustris															
Quercus velutina															
Acer rubrum	*	7.3	0.007				0.10	42.9	4.29	3.01	9.7	29.13			
Acer saccharum															
Fagus grandifolia															
Carya glabra										0.19	3.2	0.61			
Liriodendron tulipifera										0.59	3.2	1.90			
Fraxinus americana	*	10.9	0.011				0.01	14.3	0.14						
Betula lenta	0.001	23.6	0.24	0.002	0.4	0.001				1.57	6.5	10.13			
Liquidambar styriciflua															
Populus tremuloides															
Nyssa sylvatica															
Ostrya virginiana	*	10.9	0.011	0.001	0.4	*				0.61	3.2	1.97			
Sassafrass albidum										0.96	3.2	3.10			

* = < 0.001

Table 4 (cont.)

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Prunus serotina	0.001	20.0	0.020	0.013	1.6	0.021	—	—	—	3.16	19.4	61.16	—	—	—
Cornus florida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phellodendron amurense	—	—	—	0.004	0.4	0.002	0.01	14.3	0.14	—	—	—	—	—	—
Aralia spinosa	0.001	16.4	0.016	—	—	—	—	—	—	—	—	—	—	—	—
Hamamelis virginiana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Morus alba	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lindera benzoin	—	—	—	0.019	38.7	0.723	—	—	—	—	—	—	—	—	—
Viburnum dentatum	*	10.9	0.011	0.033	49.6	1.649	—	—	—	—	—	—	—	—	—
Viburnum acerifolium	—	—	—	0.002	5.9	0.012	—	—	—	—	—	—	—	—	—
Hydrangea arborescens	—	—	—	0.002	2.7	0.005	—	—	—	—	—	—	—	—	—
Clethra alnifolia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* = < 0.001

Table 5. Importance index as derived from volume and frequency by forest strata of woody plants in Grid #5 of the New York Botanical Garden Forest, Bronx, New York, September 1980.

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Tsuga canadensis				0.045	1.7	0.077	2.91	12.2	35.50	11.52	40.0	460.80			
Quercus borealis							2.02	14.6	29.56						
Quercus alba															
Quercus palustris															
Quercus velutina													9.46	100.0	946.00
Acer rubrum				0.025	0.8	0.020	0.94	7.3	6.88	4.98	40.0	199.20			
Acer saccharum															
Fagus grandifolia							0.03	4.9	0.15						
Carya glabra															
Liriodendron tulipifera															
Fraxinus americana							0.01	2.4	0.02						
Betula lenta				0.001	0.8	0.001	0.47	4.9	2.29	1.14	13.3	15.20			
Liquidambar styriciflua				0.008	0.8	0.006									
Populus tremuloides															
Nyssa sylvatica															
Ostrya virginiana				0.006	18.3	0.092	0.01	36.5	0.37						
Sassafrass albidum				0.013	1.7	0.002	0.13	2.4	0.32						

Table 5 (cont.)

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Prunus serotina	0.001	39.1	0.039	0.014	0.8	0.011	0.11	4.9	0.54	0.25	6.7	1.67	—	—	—
Cornus florida	—	—	—	—	—	—	0.50	9.8	4.88	—	—	—	—	—	—
Phellodendron amurense	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aralia spinosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hamamelis virginiana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Morus alba	—	—	—	*	2.5	0.003	—	—	—	—	—	—	—	—	—
Lindera benzoin	0.001	30.4	0.030	0.012	55.0	0.648	—	—	—	—	—	—	—	—	—
Viburnum dentatum	0.001	30.4	0.030	0.004	17.5	0.070	—	—	—	—	—	—	—	—	—
Viburnum acerifolium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hydrangea arborescens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Clethra alnifolia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* = < 0.001

Table 6. Importance index as derived from volume and frequency by forest strata of woody plants in Grid #6 of the New York Botanical Garden Forest, Bronx, New York, September 1980.

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Tsuga canadensis				0.021	0.3	0.006	0.11	25.0	2.75	2.88	4.5	13.09			
Quercus borealis										0.51	4.5	2.32			
Quercus alba															
Quercus palustris															
Quercus velutina															
Acer rubrum				0.004	0.3	0.001	0.05	25.0	1.25	3.43	18.2	62.36			
Acer saccharum				0.002	2.0	0.004	0.03	50.0	1.50	4.68	31.8	148.91			
Fagus grandifolia															
Carya glabra															
Liriodendron tulipifera													37.24	83.3	103.33
Fraxinus americana	0.001	11.8	0.012							3.42	9.1	31.09	6.29	16.7	104.83
Betula lenta										1.05	9.1	9.55			
Liquidambar styriciflua															
Populus tremuloides															
Nyssa sylvatica															
Ostrya virginiana															
Sassafrass albidum	0.001	20.4	0.020							1.60	9.1	14.55			

Table 6 (cont.)

Strata	0-1m			1-5m			5-10m			10-25m			25-50m		
Species	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Prunus serotina	*	6.5	0.005	0.001	0.3	*									
Cornus florida				0.003	0.7	0.002				0.22	4.5	1.00			
Phellodendron amurense	*	4.3	0.004	0.012	0.7	0.008				0.66	9.1	6.00			
Aralia spinosa															
Hamamelis virginiana															
Morus alba															
Lindera benzoin	0.003	39.8	0.119	0.032	65.3	2.090									
Viburnum dentatum	0.001	17.2	0.017	0.014	30.3	0.424									
Viburnum acerifolium															
Hydrangea arborescens															
Clethra alnifolia															

* = < 0.001

The age distribution of hemlock derived from trees cored and aged on the 6 study sites (N = 68) was very irregular (Fig. 3). Trees ranged in age from 29 to 174 years. A large cluster of individuals was found in the 30 to 50 year range which was evidence that either natural hemlock regeneration or planting had occurred during the period 1930-1950. Due to the disjunct nature of the age distribution no life table data was generated.

The linear relationships between hemlock age and DBH ($y = 2.04x + 7.39$, $r^2 = .40$, $p > .10$) and hemlock age and height ($y = 2.23x + 25.12$, $r^2 = .14$, $p > .25$) were not statistically significant. These regression relationships were evidence that a portion of the hemlocks sampled were in various stages of growth suppression.

The results of soil, litter, and canopy data analysis indicated the wide variations encountered across the entire forest (see Part I) were evident within each of the 6 sample grids (Tables 7-12). High coefficients of variation and wide 95 percent confidence intervals were characteristic of all parameters except both soil pH measures. The results of the analysis of variance (ANOVA) found only soil organic matter at the 6-12 cm depth was significantly different between grids (Table 13). Large variations existed within grids for each parameter and greatly reduced the significance of any between grid differences.

Soil pH for each grid at each soil level had mean values similar to the mean for the entire forest of 4.11 (see Part I). The pH range over all grids was 3.78 to 6.06 and no significant regression relationships were found between soil levels.

Table 7. A summary of the soil, litter and canopy data for Grid #1 in the New York Botanical Garden Forest, Bronx, New York, September, 1980.

	Soil pH		Organic Matter		Soil	Leaf Litter			Canopy (Percent)		
	0-6cm	6-12cm	0-6cm	6-12cm	Compaction	Total Depth	Percent Deciduous	Percent Coniferous	Dense	Partial	None
Mean	3.98	4.00	25.55	15.18	2.23	3.4	64.9	35.1	53.7	29.7	17.3
Standard Deviation	0.16	0.19	9.14	5.04	1.16	1.4	25.9	25.9	19.7	24.8	10.5
Minimum Value	3.78	3.83	14.47	8.88	0.43	1.1	4.3	6.0	5.6	2.8	5.6
Maximum Value	4.29	4.27	45.43	26.14	3.58	5.5	94.0	95.7	80.6	87.0	36.1
Lower Confidence Limit (=0.025)	3.67	3.63	7.64	5.30	0.04	0.7	14.2	15.6	15.1	18.8	3.3
Upper Confidence Limit (=0.975)	4.29	4.37	43.46	25.06	4.50	6.1	115.6	85.8	92.2	78.2	37.9
Coefficient of Variation	0.04	0.05	0.36	0.33	0.52	0.4	0.4	0.7	0.4	0.8	0.6

Table 8. A summary of the soil, litter and canopy data for Grid #2 in the New York Botanical Garden Forest, Bronx, New York, September, 1980.

	Soil pH		Organic Matter		Soil	Leaf Litter			Canopy (Percent)		
	0-6cm	6-12cm	0-6cm	6-12cm	Compaction	Total Depth	Percent Deciduous	Percent Coniferous	Dense	Partial	None
Mean	4.10	4.07	32.08	21.03	1.39	4.3	94.7	5.3	41.1	43.8	15.1
Standard Deviation	0.15	0.12	14.73	11.87	0.77	2.4	6.7	6.7	19.4	25.0	8.4
Minimum Value	3.79	3.88	17.04	11.09	0.46	0.3	77.4	0.0	11.1	13.9	5.6
Maximum Value	4.36	4.32	48.61	51.37	2.80	9.0	100.0	22.6	68.5	80.6	33.3
Lower Confidence Limit (=0.025)	3.81	3.83	3.21	2.24	0.12	0.5	81.6	7.8	3.1	5.1	1.3
Upper Confidence Limit (=0.975)	4.39	4.31	60.95	44.30	2.90	9.1	107.8	18.4	79.0	92.7	31.6
Coefficient of Variation	0.37	0.29	0.46	0.56	0.55	0.6	0.1	1.3	0.5	0.6	0.6

Table 9. A summary of the soil, litter and canopy data for Grid #3 in the New York Botanical Garden Forest, Bronx, New York, September, 1980.

	Soil pH		Organic Matter		Soil	Leaf Litter			Canopy (Percent)		
	0-6cm	6-12cm	0-6cm	6-12cm	Compaction	Total Depth	Percent Deciduous	Percent Coniferous	Dense	Partial	None
Mean	4.11	4.04	28.59	17.02	2.27	5.2	84.8	15.2	31.6	50.1	18.9
Standard Deviation	0.18	0.08	10.09	4.86	1.20	2.7	14.3	14.3	15.1	26.8	22.2
Minimum Value	3.87	3.92	9.73	7.11	0.81	2.0	49.9	0.1	10.2	5.6	2.8
Maximum Value	4.53	4.21	42.40	24.14	4.50	10.9	99.9	50.2	69.4	75.0	75.0
Lower Confidence Limit (=0.025)	3.76	3.88	8.81	7.49	0.08	0.2	56.7	12.9	2.1	2.4	24.5
Upper Confidence Limit (=0.975)	4.46	4.20	48.37	26.55	4.62	10.5	112.9	43.3	61.2	102.5	62.4
Coefficient of Variation	0.44	0.20	0.35	0.29	0.53	0.5	0.2	0.9	0.5	0.5	1.2

Table 10. A summary of the soil, litter and canopy data for Grid #4 in the New York Botanical Garden Forest, Bronx, New York, September, 1980.

	Soil pH		Organic Matter		Soil	Leaf Litter			Canopy (Percent)		
	0-6cm	6-12cm	0-6cm	6-12cm	Compaction	Total Depth	Percent Deciduous	Percent Coniferous	Dense	Partial	None
Mean	4.14	4.09	37.84	31.25	2.28	4.1	80.2	19.8	59.0	16.6	24.5
Standard Deviation	0.15	0.14	14.41	11.02	0.95	1.9	24.7	24.7	22.7	25.4	12.0
Minimum Value	3.94	3.85	20.57	13.30	1.05	0.5	9.7	0.1	21.3	0.0	8.3
Maximum Value	4.39	4.33	77.48	53.80	4.06	8.0	99.9	54.1	88.0	63.0	53.7
Lower Confidence Limit (=0.025)	3.85	3.82	9.60	9.65	0.42	0.3	31.8	28.7	14.4	33.3	0.9
Upper Confidence Limit (=0.975)	4.43	4.36	66.08	52.85	4.14	7.8	128.7	68.2	103.5	66.4	48.1
Coefficient of Variation	0.04	0.03	0.59	0.35	0.42	0.5	0.3	1.3	0.4	1.5	0.5

Table 11. A summary of the soil, litter and canopy data for Grid #5 in the New York Botanical Garden Forest, Bronx, New York, September, 1980.

	Soil pH		Organic Matter		Soil	Leaf Litter			Canopy (Percent)		
	0-6cm	6-12cm	0-6cm	6-12cm	Compaction	Total Depth	Percent Deciduous	Percent Coniferous	Dense	Partial	None
Mean	3.87	4.17	28.17	24.13	1.75	4.1	76.3	23.7	50.3	22.4	27.3
Standard Deviation	0.28	0.21	13.74	10.46	0.78	2.8	24.0	24.0	13.7	13.1	19.2
Minimum Value	3.80	3.95	13.33	12.82	0.63	0.6	28.2	0.00	26.9	5.6	6.5
Maximum Value	4.75	4.76	51.28	46.85	3.15	3.2	100.0	71.9	70.4	47.2	62.0
Lower Confidence Limit (=0.025)	3.32	3.76	1.24	3.63	0.22	1.4	29.3	23.3	23.5	3.3	10.3
Upper Confidence Limit (=0.975)	4.42	4.58	55.10	44.63	3.28	9.6	123.3	70.7	77.1	48.1	64.9
Coefficient of Variation	0.72	0.50	0.49	0.43	0.45	0.7	0.3	1.0	0.3	0.6	0.7

Table 12. A summary of the soil, litter and canopy data for Grid #6 in the New York Botanical Garden Forest, Bronx, New York, September, 1980.

	Soil pH		Organic Matter		Soil	Leaf Litter			Canopy (Percent)		
	0-6cm	6-12cm	0-6cm	6-12cm	Compaction	Total Depth	Percent Deciduous	Percent Coniferous	Dense	Partial	None
Mean	4.47	4.35	31.29	22.91	1.51	3.0	84.2	15.8	56.0	30.8	13.3
Standard Deviation	0.58	0.58	22.39	12.56	0.88	1.6	14.1	14.1	21.2	22.2	6.0
Minimum Value	4.05	3.83	5.27	6.93	0.50	0.0	44.4	0.0	13.9	0.9	3.7
Maximum Value	5.97	6.06	90.12	50.98	3.56	5.4	100.0	55.6	86.1	77.8	24.1
Lower Confidence Limit (=0.025)	3.33	3.21	12.59	1.71	0.21	0.2	56.5	11.8	14.4	12.7	1.6
Upper Confidence Limit (=0.975)	5.61	5.49	75.17	47.53	3.23	6.2	111.8	43.5	97.6	74.3	24.9
Coefficient of Variation	0.13	0.13	0.72	0.55	0.58	0.6	0.2	0.9	0.4	0.7	0.5

Figure 3. The age distribution of the hemlock population sampled on 6 intensive grids in the New York Botanical Garden Forest, Bronx, New York, September, 1980.

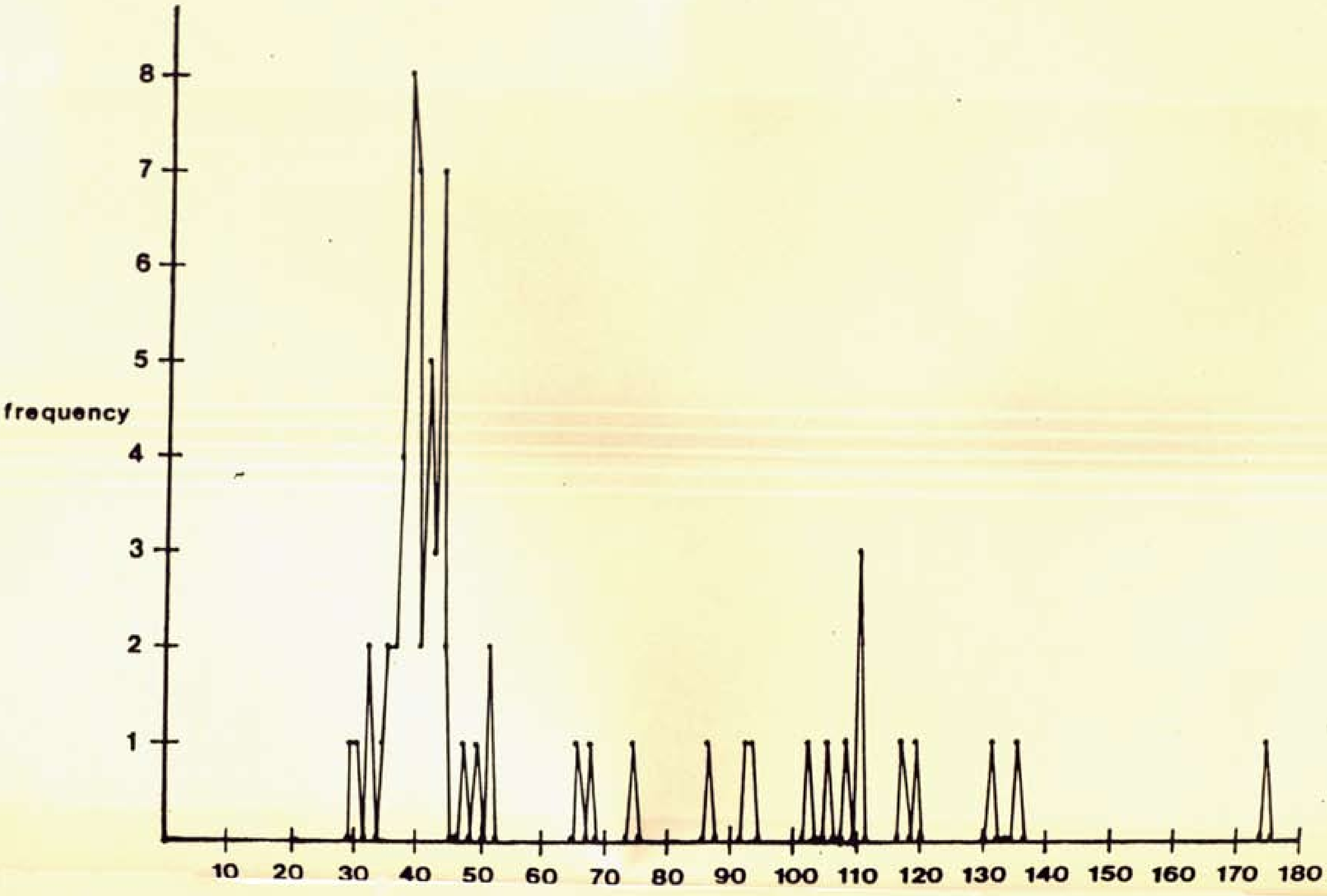


Table 13. ANOVA for each soil, litter, and canopy parameter for 6 grids sampled in the New York Botanical Garden Forest, Bronx, New York, September 1980.

Parameter	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Soil pH (0-6cm)	Between grids	5	4.0	.80	
	Within grid	15	23.2	1.55	.52
	Total	20	27.2		
Soil pH (6-12cm)	Between grids	5	1.7	.34	
	Within grids	15	23.2	.65	.52
	Total	20	24.9		
Soil Organic Matter (0-6cm)	Between grids	5	1624.4	324.9	
	Within grids	15	30063.8	2004.3	.16
	Total	20	31688.2		
Soil Organic Matter (6-12cm)	Between grids	5	11528.8	2305.8	
	Within grids	15	9120.5	608.0	3.79**
	Total	20	20649.3		
Soil Compaction	Between grids	5	15.1	3.02	
	Within grids	15	86.4	5.76	.53
	Total	20	101.5		
Total Litter Depth	Between grids	5	45.6	9.12	
	Within grids	15	447.7	29.85	.31
	Total	20	493.3		
Percent Deciduous Litter	Between grids	5	8582.8	1716.6	
	Within grids	15	45880.8	3058.7	.56
	Total	20	54463.6		
Percent Coniferous Litter	Between grids	5	7834.6	1566.9	
	Within grids	15	34551.6	2303.4	.68
	Total	20	42386.2		
Percent Dense Canopy	Between grids	5	9262.8	1852.6	
	Within grids	15	31775.8	2118.4	.87
	Total	20	41038.6		
Percent Partial Canopy	Between grids	5	11937.1	2387.4	
	Within grids	15	48327.8	3221.9	.74
	Total	20	60264.9		
Percent No Canopy	Between grids	5	2527.9	505.6	
	Within grids	15	18222.7	1214.8	.42
	Total	20	20750.6		

**p < .025

Percent soil organic matter generally decreased within increased soil depth although no significant relationship was found. The comparison of grid means from the ANOVA tests found only grids 1 and 3, and grids 2 and 6 were not significantly different in organic matter at the 6-12 cm depth.

Soil compaction ranged from 0.43 to 4.50 across all grids. The wide variation encountered was found within grids as well as between grids.

Litter depth and composition varied widely between grids and within grids. Mean litter depth for the 6 grids ranged from 3.0 cm to 5.2 cm. Over all the grids deciduous matter made up a mean of 64.9 percent to 95.7 percent of the total litter sampled.

Percent canopy coverage also varied widely within grids and between grids. The relationships between any pair of canopy parameters as well as the pattern of canopy patterns were not significant.

Overall, no pairwise relationships were significant when all soil, litter and canopy values were regressed against each other. In addition, no significant correlations were found between hemlock density and any parameter on each grid.

Three mammals, the eastern chipmunk (*Tamias striatus*), the grey squirrel (*Sciurus carolinensis*) and the Norway rat (*Rattus norweigius*) were captured in the 2 mammal sampling periods. During period 1 (July, 1980), 372 total trap nights were expended to capture 15 chipmunks and 53 squirrels. In the second period (September, 1980), 9 chipmunks, 36 squirrels and 1 Norway rat were captured over 373 total trap nights. Unexpectedly, no smaller rodents were captured.

No significant differences existed between periods for chipmunk abundance or density (Table 14). The sex ratio favored females in both sample populations. The abundance and density estimates determined for the chipmunk population in sample period 1 were considered to be more accurate than the estimates from period 2. Period 1 trapping extended over 7 days while period 2 lasted for 3 days. A high percent (> 80) of the sample population was marked by day 3 of period 1 (Fig. 4) which indicated a consistently high proportion of the individuals in the population were being sampled. The comparison of the capture frequencies for males and females for both periods combined found no significant differences in trappability (Table 15).

The movements of chipmunks tagged during period 1 were evaluated using the distance between successive captures and home range estimates (for individuals captured at least 3 times). No significant differences were found between male and female chipmunks for either distance between successive captures (Table 16) or home range size (Table 17). Wide variation existed within the sexes for each parameter.

Variation was minimal in several body measurements and in total weight for the combined chipmunk population in period 2 (Table 18). Kidney fat weight was low for all individuals. The 95 percent confidence interval for kidney fat weight was 5 times the standard deviation (.03 g) and was due to wide variation

Table 14. The relative abundance, density and sex ratio of the eastern chipmunk population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Sample Period	Relative Abundance[a]	Density (per ha)	Sex Ratio Female-Male
1	5.51	9.4	2:1
2	2.85	14.3	3:5:1

[a]Captures per 100 trap nights

Table 15. Capture frequencies for the eastern chipmunk population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

		Capture Frequency					
Sex	N	1	2	3	4	5	6
M	5	1	1	1	1	1	0
F	10	5	0	2	2	0	1

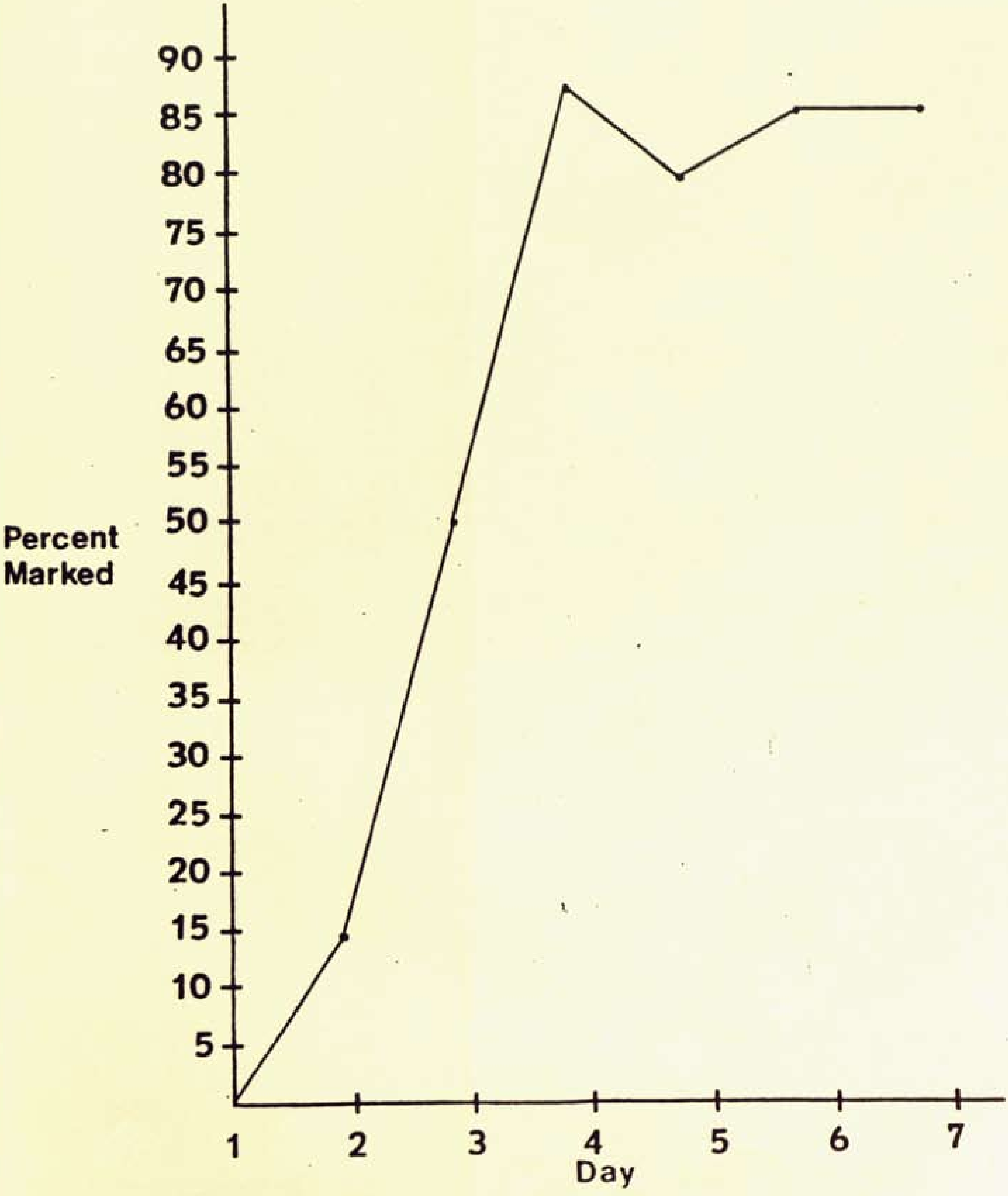
Table 16. The distance between successive captures for the eastern chipmunk population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Sex	N	Mean (m)	Standard Deviation	Range	95 Percent Conf. Interval	t value
M	4	33	29.4	0-72	25.0-91.0	
F	8	57	44.7	0-144	30.6-144.6	.93, 10 d.f.

Table 17. The home range of the eastern chipmunk population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Sex	N	Mean (m^2)	Standard Deviation	Range	95 Percent Conf. Interval	t value
M	4	1575	1100	0-2700	581-3731	
F	8	2138	1300	0-4500	411-4686	.55, 10 d.f.

Figure 4. The cumulative proportion of marked eastern chipmunks captured in period 1 in the New York Botanical Garden Forest, Bronx, New York, July, 1980.



between individuals. The relationship between total weight and kidney fat weight was not significant.

Of the 7 female chipmunks captured in period 2, only 2 had recent pregnancies. The litter sizes were 5 and 6 and were determined by counting placental scars.

No significant differences were found between periods for squirrel abundance or density (Table 19). The sex ratio favored males in period 1 while both sexes were equally encountered in period 2. The estimates of abundance and density for period 1 were considered to be biased downward as a high proportion of squirrels were not marked until the end of the period (Fig. 5). In addition the comparison of capture frequencies for males and females indicated males were less trappable than females (Table 20).

Wide variation in movement patterns were found for both sexes. Significant differences were found between males and females for the distance between successive captures (Table 21). Although movements were shorter for males, the significant difference was due, in part, to the fact that no individual male was captured more than 3 times. The mean home range for males was less than that for females and this difference was not statistically significant (Table 22).

Small variations were evident for all body measurements and total weight for the squirrels collected in period 2 (Table 23). As with the chipmunks, the squirrel kidney fat 95 percent confidence interval was nearly 5 times the standard deviation. The relationship between kidney fat weight and total weight was not statistically significant.

Table 18. Summary of physical data for the eastern chipmunk population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Parameter[a]	N	Mean	Standard Deviation	Range	95 Percent Conf. Interval
total weight	9	99.9	6.9	89.9-109.8	86.4-113.4
total length	8	24.4	0.9	22.6-25.4	22.6-26.2
hind foot length	9	3.5	0.1	3.3-3.6	3.3-3.7
tail length	8	9.2	0.7	8.1-9.8	7.8-10.6
ear length	9	1.7	0.1	1.6-1.9	1.5-1.9
kidney fat weight	9	0.09	0.03	0.04-0.15	0.03-0.15

[a]Weights in grams and measurements in centimeters.

Table 19. The relative abundance, density and sex ratio of the grey squirrel population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Sample Period	Relative Abundance[a]	Density (per ha)	Sex Ratio Female-Male
1	16.61	44.9	.77:1
2	10.47	51.9	1:1

[a]Captures per 100 trap nights

Table 20. Capture frequencies for the gray squirrel population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Sex	N	Capture Frequency 1	2	3	4	5	6
M	30	21	9	0	0	0	0
F	23	10	6	4	2	2	1

Figure 5. The cumulative proportion of marked grey squirrels captured in period 1 in the New York Botanical Garden Forest, Bronx, New York, July, 1980.

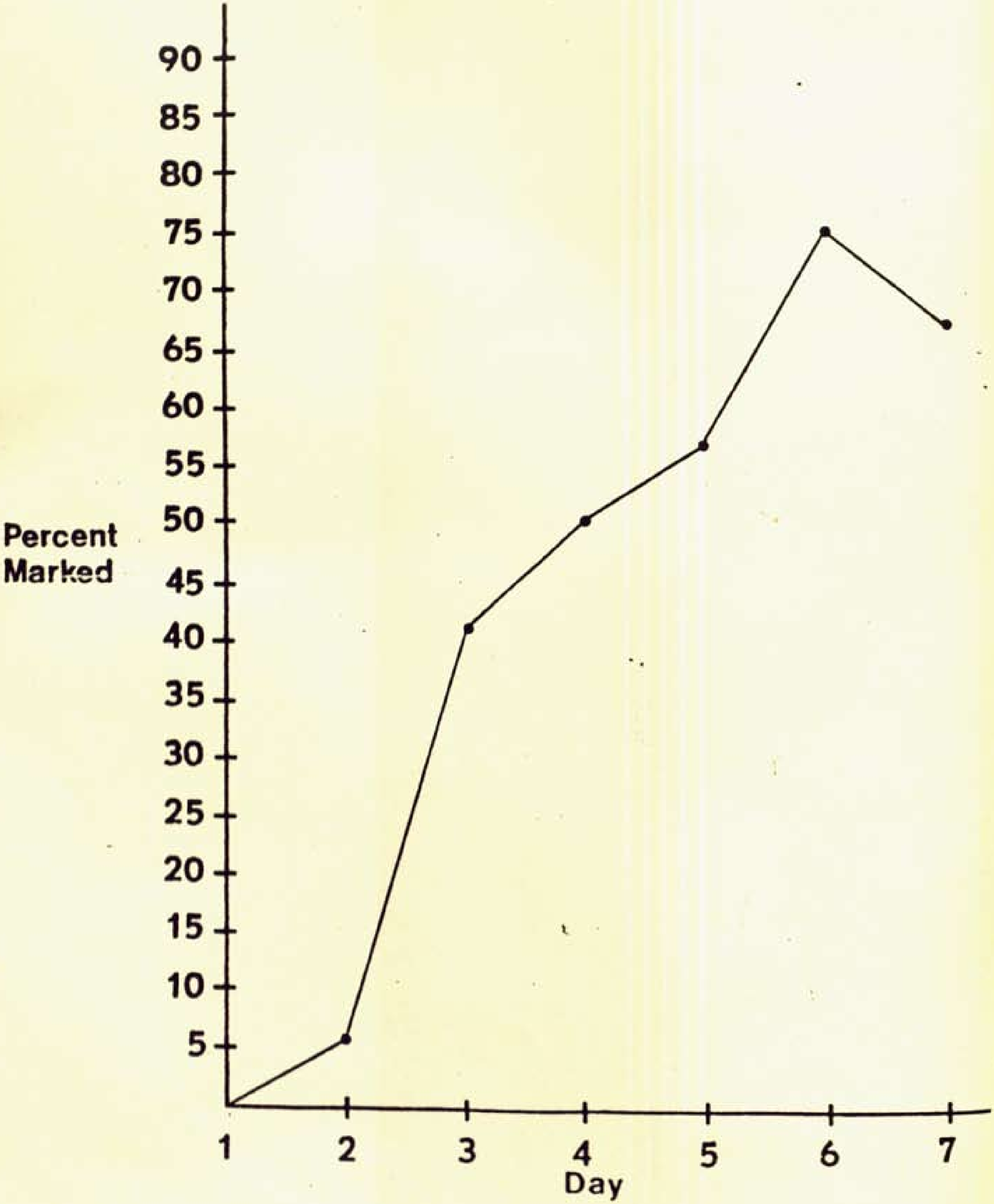


Table 21. The distance between successive captures for the grey squirrel population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Sex	N	Mean (m)	Standard Deviation	Range	95 Percent Conf. Interval	t value
M	15	54.7	39.6	0-151	22.9-132.3	
F	16	93.1	58.9	30-200	22.3-208.5	2.19, 29 d.f.*

* - $p < .05$

Table 22. The home range of the grey squirrel population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Sex	N	Mean (m^2)	Standard Deviation	Range	95 Percent Conf. Interval	t value
M	15	2217	1133.9	0-3600	5.7-4439.1	
F	16	2816	966.1	1800-4950	922-4709.1	1.64, 29 d.f.

Table 23. Summary of physical data for the grey squirrel population sampled in the New York Botanical Garden Forest, Bronx, New York, July-September, 1980.

Parameter[a]	N	Mean	Standard Deviation	Range	95 Percent Conf. Interval
total weight	18	568.2	42.7	499.9-680.1	484.5-651.9
total length	17	47.4	2.3	42.0-51.5	42.9-51.9
hind foot length	18	6.7	0.2	6.3-7.0	6.3-7.1
tail length	17	21.8	1.7	17.8-24.2	18.5-25.1
ear length	18	2.9	0.2	2.6-3.1	2.5-3.3
kidney fat weight	18	0.41	0.14	0.20-0.70	0.14-0.68

[a]Weights in grams and measurements in centimeters.

Of the 19 female squirrels collected, 17 showed evidence of a past or developing litter. The mean litter size was 2.9 and the range was from 1 to 4.

Proximate food habits were determined by inspection of the stomach contents of squirrels collected in period 2. In all cases nearly all recognizable fragments were identified as the endosperm of nuts, especially peanuts.

Discussion

The pattern of hemlock throughout the forest as well as on the 6 sample grids was not random, yet regular and of a low intensity. No positive associations were discovered on either the extensive or intensive studies. Several negative associations occurred with mid- to overstory species (tulip tree, white ash, red maple, and hickory) and two relatively shade-intolerant species (black and sweet cherry). Many species of varying importance were competing with hemlock on each of the 6 grids. Hemlock importance was inconsistent and attained high values only in the 10-25 m strata. These data were very dissimilar to that reported by Charney (1980). Hemlock was 70 percent of the seedling and sapling layer and occurred in association with oaks and maples.

The age distribution generated from hemlocks on the 6 grids was void of specimens less than 29 years of age. In addition, single individuals occurred sporadically in the range 50 to 174 years.

In summary, hemlocks generally were found as mid-story, 30 to 50 year-old specimens growing among a great variety of competing woody forest species. The lack of an aggregated pattern of occurrence indicated individual hemlocks were dropping out of the population and not being replaced by surrounding seedlings characteristic of hemlock regeneration (Lloyd, 1900; Clepper, 1944). Evidence of suppressed growth on hemlock was found and attributed to the dense overstory of tulip tree, red and black oak, and beech.

The New York Botanical Garden Forest appeared to be in a state of transition over the entire tract as well as on the smaller intensive study sites. Intense competition for space has resulted in disjunct temporal patterns in some species, remnant populations of a few species, and a highly variable guild of newly established species. A principal component of the aforementioned condition has been the extreme heterogeneity in soil, litter and canopy parameters found over the entire forest as well as on small areas within the forest. The potential for hemlock to emerge as a forest dominant has been jeopardized by these factors.

Although soil pH, organic matter and compaction were variable, the mean values were evidence that acidic, dry and compacted soils were most common. Leaf litter was composed mostly of deciduous matter and was inconsistent in depth. Canopy density varied widely and has likely created many areas of too much or too little shade. In general, the lack of soil nutrient release, low soil moisture and pH, variable soil organic matter, variable litter depth and composition, and undue soil compaction wrought by human disturbance has seriously challenged the present hemlock population. The presence of discolored needles and hemlock scale (Wallner, 1965) have been verified and are indications of decreased vigor in many specimens (Decker, 1969; Shotland, 1975).

Attempts to replant hemlock have not been successful. The planting in the mid-1920's (Britton, 1926; 1927) has resulted in only a very few remaining individuals. Records of 2 plantings in 1975 indicated few seedlings survived for even a few weeks. In the first case 14 of 34 seedlings established in the forest remained after 2 weeks (Bridges, 1975). In the latter example 10 of 17 seedlings were alive after 7 weeks (Sharkey and Thomas, 1975). By late 1975 few of the newly planted seedlings remained. Human abuse, the nature of the edaphic, litter, and canopy conditions described above, and the competition of a tolerant guild of pioneer species have contributed to these unsuccessful plantings.

The potential for natural regeneration has also been seriously decreased by all the aforementioned forest conditions. In addition an evaluation of hemlock seed production, seed viability and fertility, and seed predation has not been undertaken. Hemlock cones were recovered in the litter on 50 of 96 sampling stations over the 6 sample grids. Since hemlock cones have been shown to release seeds prior to cone drop (Frothingham, 1915), the recovery of cones in the litter layer provided evidence of cone and possibly seed production.

The potential for vertebrate predation on hemlock seed is high. Birds have been the most numerous and troublesome consumers of pine and hemlock seeds (Mann and Derr, 1955). Lists of bird sightings in the New York Botanical Garden Forest have included many seed-eating and in particular ground-feeding species (Appendix 4).

Small mammals have been thought to be heavy predators on hemlock seed as well as other tree fruits. Unexpectedly, the white-footed mouse (Peromyscus leucopus), a usual forest inhabitant, was not recovered during the trapping sessions. This species has been the greatest threat to conifer seeds, especially in managed timber stands (Howard et al., 1968).

Of the 2 abundant mammal species in the forest, chipmunks were the least likely seed predator. Chipmunks were found in moderate densities and in good condition. The mean weight of chipmunks in this study (99.9 g) were within the range of 90 to 100 g reported by Brenner and Lyle (1975). Litter sizes were comparable to those reported by Uhlig (1955). The food habits of chipmunks have included fungi, Coleoptera, Lepidoptera larvae, acorns, roots, fruit, leaves, flowers, beech and hickory nuts and small seeds (Allen, 1938; Wrazen and Svendsen, 1978). The presence of small seeds of any kind was unusual in these studies and contributed to the conclusion that chipmunks had no negative impact on hemlock seeds or seedlings in this study.

Grey squirrel densities in the forest (Table 19) were much higher than densities reported by Flyger (1955) (15 per ha), Flyger (1974) (12-14 per ha), and Thompson (1978b) (1-8 per ha). Home ranges, due to the high density, were much smaller than in a semiurban population studied by Thompson (1978a). The condition and weights of squirrels were lower than reported by Uhlig (1955).

Litter sizes were similar to those determined by Thompson (1978a). The diet of squirrels has included maple and oak flowers (spring), and maple samaras, oak, hickory and beech nuts (Barber, 1954; Davison, 1964; Nixon et al., 1968; Thompson and Thompson, 1980).

In this study squirrels were consuming handouts (especially peanuts) almost exclusively. Opportunistic feeding occurred on bulbs and freshly planted flowers in the Native Plant and Rock Garden. In the spring squirrels have been observed to feed upon green hemlock cones in the forest (Shotland, 1975). On several occasions in this study squirrels were observed to be aggressive, ravenous feeders. Several instances of squirrels unfolding the small mammal traps to consume the bait were recorded. In summary, grey squirrels were not felt to have a direct impact on hemlock during the study period. In other seasons, particularly late winter and early spring, seed and/or seedling consumption may occur.

The damage potential to hemlock as well as the current damage in the maintained gardens would decrease if the squirrel density were reduced. That task would be difficult as squirrels have a higher birth rate than death rate in urban populations (Thompson, 1978a). The population in this study has the potential to increase by 1.5 times annually, based on a longevity of 5 years (Thompson, 1978a) and the litter size of 2.9 per pregnant female. In addition to resident squirrel production, reduction strategies would have to account for immigration from dense populations throughout the Bronx Park.

The position of hemlock in the New YOrk Botanical Garden Forest is tenable, at best. The future of hemlock will be determined by the reproduction of the current population and the survival of seedlings, both artificial and natural. The variable presence of many guilds of species is evidence of the harsh realities of the urban environment and past management policies. The selection of management strategies must be based upon what currently exists and be carefully monitored to determine the direction and timetable of change of the edaphic and biotic elements in the forest. The limits of the ecosystem must be recognized and accepted as the foundation for the management of the forest. In short, the perpetuation of hemlock and the restoration of the forest ecosystem within the heavily urbanized Bronx environment may be the greatest challenge the Garden research, interpretation and management staff have encountered.

Recommendations

In addition to research recommendations 1, 2 and 3 described in Part I of this report, we recommend that 2 additional research needs be addressed.

1. The cycle of hemlock reproduction should be studied. Seed production, viability, fertility and predation rates should be evaluated in the stand of hemlock existing in the east-central portion of the forest bordering the river. The potential for natural hemlock regeneration will be determined by this study and the companion study on nutrient cycling and soil recovery.

2. At periodic intervals surveys of the users of the New York Botanical Garden Forest should be conducted. The survey completed by Lipp (1974) provided many insights into the New York Botanical Garden visitor population (Appendix II). In general the average visitor to the New York Botanical Garden resided in the Bronx, was at least 20 years of age, white, had attained a high school education (and more likely had a college education), and came with friends, family or alone. Most visitors arrived by car, subway, bus or walked, had visited either once or twice, or more than 12 times, and stayed in the Garden for 2-4 hours. Nearly two-thirds of the visitors were not familiar with the Garden programs nor did they participate in the programs. Nine of 10 persons became aware of the Garden through parents, relatives, friends, as a child, by living in the Bronx, or by accident. Most visitors came to pursue Garden activities or for personal convenience. Nearly 9 of 10 said their visit was favorable as was the Garden and/or the convenience activities they experienced. Nearly 80 percent felt the Garden needed improved facilities, activities, and visitor control. Finally in a survey conducted only in the forest, 9 of 10 persons were in the forest for social, recreational, or general garden appreciation pursuits. Only 11 percent were interested in the forest and a portion of this group were interested in the Bronx River. In summary, the success of any forest

management program will be contingent upon substantial changes in the habits and attitudes of the present visitor population.

In Part I of this report, Recommendation 4 provided several foundations for the selection of a forest management option while Recommendation 5 detailed 2 visitor management plans. With these recommendations as prerequisites, 1, 2, or any combination of the following, management options can be selected for the forest.

1. Let events proceed, emphasizing and monitoring the conditions within the forest. Control of the public will be essential to the presentation of the forest story and the evolution of the edaphic and biotic elements of the system. This passive approach to management would allow research to monitor any changes, have great educational value and involve increased security. As the energy required to directly influence any edaphic or biotic conditions would be negligible, this option should have minimal support costs.

2. Manage the forest for native northeastern forest species wherever they occur. This would involve protecting areas with the best vigor and stand composition. In addition, the removal of exotic species, stabilization of the forest floor by controlling access and improving soil conditions in selected areas would be beneficial. The changes in the forest ecosystem would provide a basis for research as well as an exciting public interpretation story.

Depending upon the size of the managed areas, external energy in the form of manpower and equipment will be needed to maintain and encourage the desired stand composition. Security and staff costs will be greater than for option 1.

3. The option to maintain and encourage hemlock as a dominant member of the forest. Careful selection of areas for soil rejuvenation as well as for studies of artificial and natural hemlock regeneration will be of critical importance. Data from the present study should be used to locate sites with the proper balance of soil pH, organic matter, litter depth and composition and canopy coverage values. This option will develop an exciting story line with a historical base for New Yorkers. Accomplishing this option will require extensive publicity, intensive people control and protection of sensitive sites. Monitoring studies will be necessary to evaluate progress and plan future work. This option, because a single species will be emphasized, will be the most expensive and most difficult to accomplish.

Regardless of the option selected, the steps in the forest management process must be well conceived and guided by the characteristics of each site. The bounds or limits of the forest ecosystem should be well understood. A firm direction and a timetable for recovery under any management option should be developed from the monitoring efforts. All energy inputs should be carefully calculated so the management options selected can be financially maintained and thereby fully realized. Finally the true story of the plight of the New York Botanical Garden Forest needs to be told to the public. With public understanding, concern and respect, the research and management options selected can produce benefits to a large cross-section of our urbanized society.

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Appendix I. A preliminary evaluation of a proposed management plan for the New York Botanical Garden Forest.

The proposed management plan under consideration by the Hemlock Forest Committee would involve the division of the forest into 3 areas (Fig. 1). This proposal would require that forest management plans for areas A, B, C be developed and integrated into an overall forest management strategy.

Data from the 151 plots used in the forest survey were subdivided and grouped according to their occurrence in the 3 areas. A preliminary analysis of spatial and temporal woody vegetation patterns was completed and will be discussed. All methods were as presented in Part I and II of this report.

Results and Discussion

The total number of stems, frequency of occurrence and relative density of the woody species found on each area was determined. Area A contained several species that occurred frequently throughout the site (Table 1). These included black cherry, sweet cherry, hickory, white ash, cork tree, black oak, red oak, and spicebush. Only spicebush was found in high densities while the remaining species occurred sporadically as individuals. No significant relationships resulted from the comparison of species occurrence by 2 x 2 contingency tables.

Hemlock, and to a lesser extent, red maple, spicebush, and white ash dominated Area B(Table 2). The low density of all but spicebush indicated most species were scattered throughout the unit. The results of contingency table comparisons of species found hemlock had a significant negative association with red maple (χ^2 - 3.90, 1 d.f., $p < .05$).

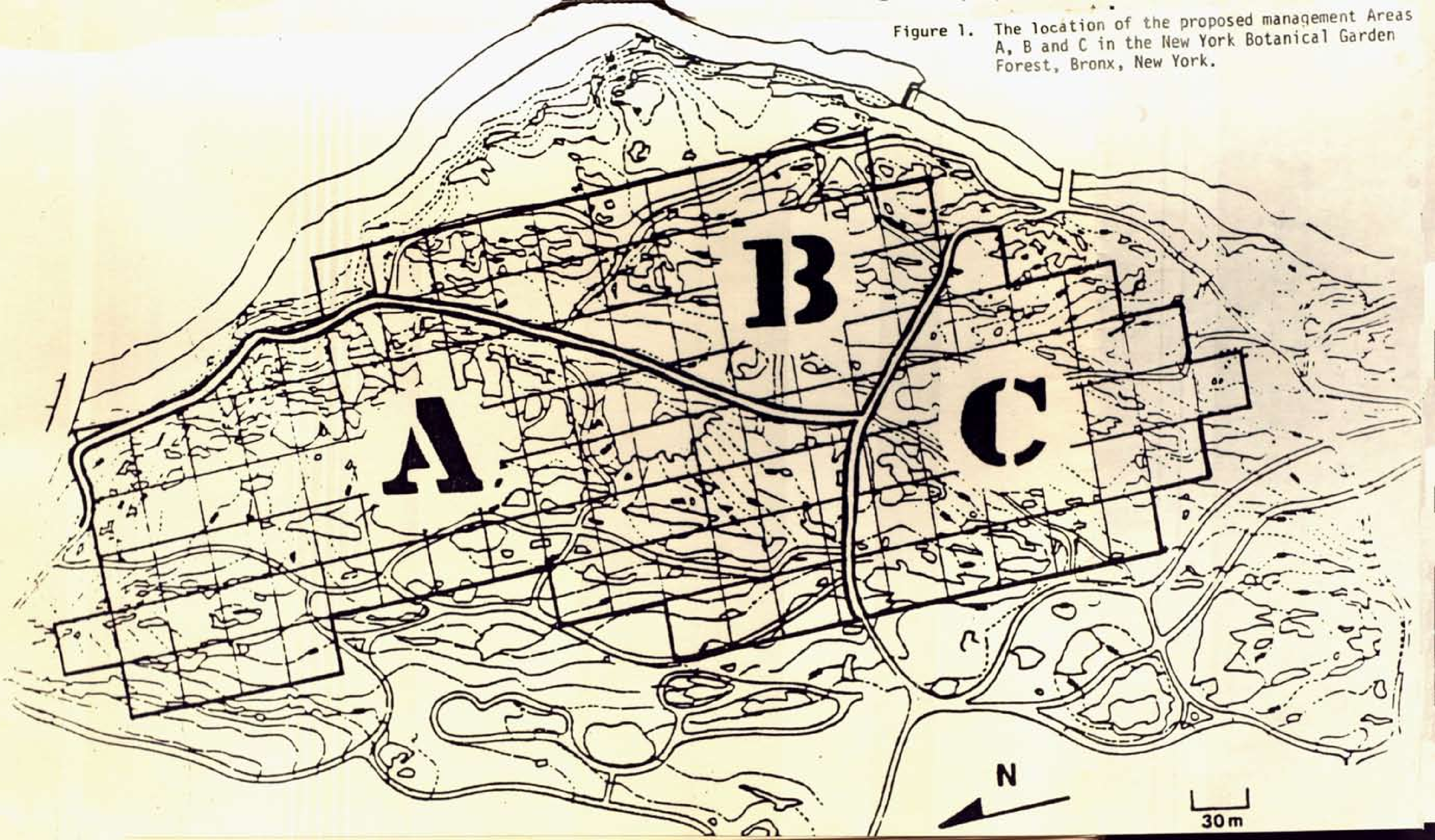

Figure 1. The location of the proposed management Areas A, B and C in the New York Botanical Garden Forest, Bronx, New York.

Table 1. The total number of stems, frequency of occurrence and relative density of woody species found on Area A in the New York Botanical Garden Forest, Bronx, New York, September 1980.

Species	Total Number of Stems	Frequency of Occurrence (%)	Relative Density (m^2)
Tsuga canadensis	9	7	0.6
Quercus borealis	16	12	1.1
Quercus alba	4	5	0.3
Quercus palustris	0	0	0.0
Quercus velutina	12	11	0.8
Acer rubrum	9	5	0.6
Acer saccharum	9	7	0.6
Fagus grandifolia	4	4	0.3
Carya glabra	14	15	1.0
Liriodendron tulipifera	3	4	0.2
Fraxinus americana	12	13	0.8
Betula lenta	3	3	0.2
Liquidambar styraciflua	1	1	0.1
Ulmus americana	7	5	0.5
Ostrya virginiana	3	3	0.2
Carpinus caroliniana	0	0	0.0
Sassafras albidum	1	1	0.1
Prunus serotina	141	39	9.6
Prunus avium	56	27	3.8
Cornus florida	8	8	0.5
Phellodendron amurense	21	17	1.4
Aralia spinosa	32	5	2.2
Ailanthus altissima	14	3	1.0
Lindera benzoin	288	31	19.6
Viburnum dentatum	74	11	5.0
Viburnum acerifolium	46	4	3.1
Morus alba	0	0	0.0
Magnolia stellata	0	0	0.0
Crataegus sp.	1	1	0.1
Malus sp.	0	0	0.0

Table 2. The total number of stems, frequency of occurrence and relative density of woody species found on Area B in the New York Botanical Garden Forest, Bronx, New York, September 1980.

Species	Total Number of Stems	Frequency of Occurrence (%)	Relative Density (m^2)
Tsuga canadensis	41	56	4.9
Quercus borealis	3	5	0.4
Quercus alba	1	2	0.1
Quercus palustris	2	5	0.2
Quercus velutina	0	0	0.0
Acer rubrum	25	28	3.0
Acer saccharum	4	7	0.5
Fagus grandifolia	6	7	0.7
Carya glabra	0	0	0.0
Liriodendron tulipifera	3	7	0.4
Fraxinus americana	9	12	1.1
Betula lenta	3	7	0.4
Liquidambar styraciflua	0	0	0.0
Ulmus americana	0	0	0.0
Ostrya virginiana	0	0	0.0
Carpinus caroliniana	3	2	0.4
Sassafras albidum	23	7	2.7
Prunus serotina	5	9	0.6
Prunus avium	1	2	0.1
Cornus florida	4	7	0.5
Phellodendron amurense	2	2	0.2
Aralia spinosa	0	0	0.0
Ailanthus altissima	1	2	0.1
Lindera benzoin	115	26	13.6
Viburnum dentatum	8	7	0.9
Viburnum acerifolium	18	2	2.1
Morus alba	1	2	0.1
Magnolia stellata	1	2	0.1
Crataegus sp.	0	0	0.0
Malus sp.	0	0	0.0

Table 3. The total number of stems, frequency of occurrence and relative density of woody species found on Area C in the New York Botanical Garden Forest, Bronx, New York, September 1980.

Species	Total Number of Stems	Frequency of Occurrence (%)	Relative Density (m^2)
Tsuga canadensis	12	13	1.6
Quercus borealis	4	8	0.5
Quercus alba	0	0	0.0
Quercus palustris	0	0	0.0
Quercus velutina	5	8	0.7
Acer rubrum	7	10	0.9
Acer saccharum	3	8	0.4
Fagus grandifolia	36	13	4.7
Carya glabra	1	3	0.1
Liriodendron tulipifera	0	0	0.0
Fraxinus americana	5	8	0.7
Betula lenta	0	0	0.0
Liquidambar styraciflua	26	23	3.4
Ulmus americana	3	5	0.4
Ostrya virginiana	0	0	0.0
Carpinus caroliniana	1	3	0.1
Sassafras albidum	2	3	5.1
Prunus serotina	29	23	3.8
Prunus avium	0	0	0.0
Cornus florida	4	8	0.5
Phellodendron amurense	8	15	1.0
Aralia spinosa	2	3	0.3
Ailanthus altissima	13	5	1.7
Lindera benzoin	293	46	38.3
Viburnum dentatum	110	10	14.4
Viburnum acerifolium	0	0	0.0
Morus alba	0	0	0.0
Magnolia stellata	0	0	0.0
Crataegus sp.	0	0	0.0
Malus sp.	17	3	2.2

Area C was similar to Area A (Table 3) as many species occurred frequently throughout the area. These included hemlock, red maple, beech, sweetgum, black cherry, cork tree, spicebush, and southern arrow-wood. Only spicebush and southern arrow-wood were found in high densities. No significant vegetation associations were identified by the contingency table comparisons.

Temporal pattern for each species was evaluated by inspection of the frequency distribution across DBH classes. Area A was comprised of many species with individuals occurring most frequently as seedlings or saplings (Table 4). Spicebush, southern arrow-wood, maple-leaved viburnum, tree-of-heaven, devil's walking stick, sweet cherry and black cherry were well established in the lower strata. Hemlock and tulip tree were seldom found and were overstory specimens in every case. Many species had disjunct distributions while red oak, red maple and hickory demonstrated a declining frequency of occurrence with increasing DBH. The species composition changed between DBH classes and was very heterogeneous within DBH classes.

Area B was dominated by older aged hemlocks (Table 5). No seedlings or saplings of hemlock, red oak, or black oak were found. Many species occurred as rare individuals in disjunct DBH class distributions. Only red maple was found across several DBH classes. In the lower forest strata spicebush and to a lesser extent maple-leaved viburnum and sassafras were prevalent.

Species heterogeneity similar to that encountered on Area A

Table 4. Percent and total number of stems (N) by DBH classes of woody plants found on Area A in the New York Botanical Garden Forest, Bronx, New York, September 1980.

DBH (cm)	0-1		1-5		5-10		10-20		20-40		>40	
Species	%	N	%	N	%	N	%	N	%	N	%	N
Tsuga canadensis			11	1			33	3	22	2	33	3
Quercus borealis	25	4	31	5	6	1	13	2	6	1	19	3
Quercus alba	25	1	25	1	25	1			25	1		
Quercus palustris												
Quercus velutina			42	5	8	1	17	2	17	2	17	2
Acer rubrum	44	4	22	2	11	1	11	1	11	1		
Acer saccharum			56	5	22	2	11	1	11	1		
Fagus grandifolia	25	1	75	3								
Carya glabra	14	2	36	5	7	1	36	5	7	1		
Liriodendron tulipifera											100	3
Fraxinus americana	8	1	50	6	8	1			25	3	8	1
Betula lenta			67	2					33	1		
Liquidambar styraciflua			100	1								
Ulmus americana			71	5					29	2		
Ostrya virginiana			33	1			67	2				
Carpinus caroliniana												
Sassafras albidum							100	1				
Prunus serotina	50	71	41	58	6	9	2	3				
Prunus avium	23	13	57	32	18	10	2	1				
Cornus florida			12	1			88	7				
Phellodendron amurense	10	2	43	9	19	4	24	5	5	1		
Aralia spinosa	94	30	6	2								
Ailanthus altissima	71	10			29	4						
Lindera benzoin	27	78	73	210								
Viburnum dentatum	28	21	72	53								
Viburnum acerifolium	100	46										
Morus alba												
Magnolia stellata												
Crataegus sp.	100	1										
Malus sp.												

Table 5. Percent and total number of stems (N) by DBH classes of woody plants found on Area B in the New York Botanical Garden Forest, Bronx, New York, September 1980.

DBH (cm)	0-1		1-5		5-10		10-20		20-40		>40	
Species	%	N	%	N	%	N	%	N	%	N	%	N
Tsuga canadensis					7	3	41	17	34	14	17	7
Quercus borealis							33	1	67	2		
Quercus alba									100	1		
Quercus palustris							50	1	50	1		
Quercus velutina												
Acer rubrum	20	5	36	9	8	2	32	8	4	1		
Acer saccharum			75	3			25	1				
Fagus grandifolia	33	2	50	3					17	1		
Carya glabra												
Liriodendron tulipifera											100	3
Fraxinus americana	67	6	11	1					22	2		
Betula lenta									67	2	33	1
Liquidambar styraciflua												
Ulmus americana												
Ostrya virginiana												
Carpinus caroliniana			33	1	33	1	33	1				
Sassafras albidum	100	23										
Prunus serotina	20	1	60	3	20	1						
Prunus avium									100	1		
Cornus florida					75	3	25	1				
Phellodendron amurense			50	1	50	1						
Aralia spinosa												
Ailanthus altissima	100	1										
Lindera benzoin	29	33	68	78	3	4						
Viburnum dentatum			100	8								
Viburnum acerifolium	100	18										
Morus alba			100	1								
Magnolia stellata					100	1						
Crataegus sp.												
Malus sp.												

Table 6. Percent and total number of stems (N) by DBH classes of woody plants found on Area C in the New York Botanical Garden Forest, Bronx, New York, September 1980.

DBH (cm)	0-1		1-5		5-10		10-20		20-40		>40	
Species	%	N	%	N	%	N	%	N	%	N	%	N
Tsuga canadensis			67	8	17	2			17	2		
Quercus borealis	25	1	25	1					50	2		
Quercus alba												
Quercus palustris												
Quercus velutina					20	1	40	2	20	1	20	1
Acer rubrum	29	2			14	1	43	3	14	1		
Acer saccharum	33	1			33	1			33	1		
Fagus grandifolia	53	19	17	6	19	7	3	1	3	1	6	2
Carya glabra									100	1		
Liriodendron tulipifera												
Fraxinus americana			60	3	20	1	20	1				
Betula lenta												
Liquidambar styraciflua	58	15	19	5	4	1	8	2	4	1	8	2
Ulmus americana			33	1			67	2				
Ostrya virginiana												
Carpinus caroliniana							100	1				
Sassafras albidum	50	1			50	1						
Prunus serotina	31	9	55	16	10	3	3	1				
Prunus avium												
Cornus florida	25	1			50	2	25	1				
Phellodendron amurense	13	1	38	3	38	3	13	1				
Aralia spinosa	100	2										
Ailanthus altissima	92	12	8	1								
Lindera benzoin	43	127	45	133	11	33						
Viburnum dentatum	92	101	8	9								
Viburnum acerifolium												
Morus alba												
Magnolia stellata												
Crataegus sp.												
Malus sp.	100	17										

was found on Area C (Table 6). The seedling and sapling layer was occupied by several species with beech, sweetgum, spice-bush and southern arrow-wood being the most frequently encountered. Beech, sweetgum, black cherry and cork tree were well established populations with individuals occurring in a continuous DBH class distribution.

Recommendations

Area A

This area was the most variable in species composition and spacial and temporal pattern. Thus, any management plan with specific species group concerns as an objective would be expensive and very difficult to attain. Perhaps this area could be unmanaged and protected as having value as a comparison to Areas B and C. Competition should be allowed to continue and the various species adaptations investigated by researchers and interpreted to the public. In addition, the location of this area at the west portion of the forest could give Area B a buffer from visitor pressure arising from the museum building area.

Area B

This area would be the best choice for attempts to manage for hemlock. Hemlock was relatively dense on the area and few competitors were present. Although the soil and litter will require restoration, the cool, moist air from the Bronx River should be an aid to hemlock growth and reproduction. The area could be separated into subunits for experimentation with soil and litter manipulation strategies. Nutrient cycling and hemlock reproduction studies should be the key elements in determining the potential for hemlock recovery. In addition, the educational benefits of all activities should be exploited through extensive on-site interpretation.

This management option will demand increased security and staff commitment to continued hemlock studies. To retain an ecological basis for the recovery, few if any unnatural additions or activies should occur. The manipulations of soil and litter should be mechanical and designed to restore the flow of nutrients presently stagnated in various sectors of the forest ecosystem. If monitoring efforts find little or no recovery over a period of 2 to 3 years, more disruptive measures or unnatural inputs should be considered.

Area C

This area would provide an intermediate management opportunity in comparison to those plans proposed for Areas A and B. The presence of beech, red maple, hemlock, sweetgum, red oak, white ash and sugar maple suggests the possibility of managing the area as a mixed hemlock-hardwood association. Exotic species could be removed to eliminate unwanted competition. No soil or litter rejuvenation would be anticipated since many seedlings and saplings of most of the species mentioned above are present. Protection from people would still be paramount and should be developed in conjunction with a public interpretation program. The results of monitoring these areas should provide information intermediate to the uncontrolled strategy proposal for Area A and the very specific plan for hemlock recovery on Area B.

Appendix II. An analysis of the New York Botanical Garden visitor population

TABLE 1. Place of residence of New York Botanical Garden visitor population in percentiles

Political Unit	Spring	Summer	Fall	Average
New York City				
Bronx	69	62	61	64
Manhattan	11	11	12	11
Queens	5	4	5	5
Brooklyn	2	2	2	2
Staten Island	<1	0	0	0
TOTAL	87	79	80	82
Proximate Area				
Westchester	4	6	10	7
Long Island	1	1	1	1
Upstate New York	1	3	1	2
New Jersey	3	4	3	3
Connecticut	1	1	1	1
TOTAL	10	15	16	14
Distant Area				
Other U.S. state	2	4	3	3
Foreign country	<1	2	1	1
TOTAL	2	6	4	4
TOTAL INTERVIEWED	646	1874	665	1062

TABLE 2. Age structure of the New York Botanical Garden Visitor Population

Age Category	Spring	Summer	Fall	Average
>55	29	31	30	30
30-54	38	38	39	38
20-29	26	21	23	23
15-19	4	7	4	5
0-14	2	2	2	2
TOTAL INTERVIEWED	650	1867	649	

TABLE 3. Sex ratio of the New York Botanical Garden Visitor Population

Sex	Spring	Summer	Fall	Average
Male	54	52	55	54
Female	46	48	45	46
TOTAL INTERVIEWED	644	1879	663	

TABLE 4. Ethnic composition of the New York Botanical Garden Visitor Population

Ethnic Group	Spring	Summer	Fall	Average
Black	9	7	5	7
White	66	74	90	77
Oriental	7	4	2	4
Hispanic	18	15	3	12
TOTAL INTERVIEWED	679	1877	661	

TABLE 5. Social composition of the New York Botanical visitor population

Category	Spring	Summer	Fall	Average
Alone	28	19	20	22
Family Group	48	51	44	48
Group of Friends	22	28	32	27
Group of Family & Friends	--	--	3	1
Organized Group	2	2	1	2
TOTAL INTERVIEWED	653	1877	661	

TABLE 6. Family structure of the New York Botanical Garden Visitor population

Couple	43
Couple & Offspring	19
1 Parent & Offspring	25
Extended Family	13
TOTAL INTERVIEWED	263

(Note: Spring population only)

TABLE 7. Educational level of adult New York Botanical Garden visitor population

Education	Spring	Summer	Fall	Average
< Secondary School	7[a]	7[a]	4[a]	6[a]
Secondary School Education or Degree	30[a]	28[a]	29[a]	29[a]
College Education or Degree	39	39	48	42
> College Degree	21[b]	17	12	17
TOTAL INTERVIEWED	644	1877	662	

[a]This percentage has been corrected for the percentage of sample in 0-13 age category and 0-17 age category.

[b]71% graduate school degrees; 29% were yet in graduate school.

TABLE 8. Mode of transportation of the New York Botanical Garden visitor population

Category	Spring	Summer	Fall	Average
Car	40	51	46	46
Walk	38	28	34	33
Subway and/or Bus	16	19	18	18
Taxi	3	1	1	2
Bicycle	3	1	1	2
TOTAL INTERVIEWED	643	1876	659	

TABLE 9. Frequency of past attendance of the New York Botanical Garden visitor population

Category	Spring	Summer	Fall	Average
1st visit	23	38	26	29
2-3	15	18	17	17
4-6	10	12	15	12
7-12	12	7	9	9
Over 12	40	25	33	33
TOTAL INTERVIEWED	682	1973	662	

TABLE 10. Frequency of attendance of the New York Botanical Garden visitors with over 20 visits

21-29	19
30-39	7
40-49	43
100-199	21
200-299	6
Over 300	4
TOTAL INTERVIEWED	234

(Note: Spring population only)

TABLE 11. Length of visit

Category	Summer	Fall	Average
About 1/2 hour	1	6	4
One hour	11	13	12
Two hours	31	31	31
Three hours	28	31	30
One-half day	22	13	18
Full day	7	5	6
TOTAL INTERVIEWED	532	144	

TABLE 12. Manner in which visitors became aware of the New York Botanical Garde

Active:		
(Education, Tourist Information, Mass Media)	11	
Passive:		(Note: Spring population only)
(Live in Bronx, Childhood, Parents/Relatives, Friends, Accidentally)	89	
TOTAL INTERVIEWED	684	

TABLE 13. Familiarity with the New York Botanical Garden programs

Category	Spring	Summer	Fall	Average
Yes	49	33	34	39
No	41	67	66	58
TOTAL INTERVIEWED	148	491	137	

TABLE 14. Participation in the New York Botanical Garden programs

Category	Spring	Summer	Fall	Average
Yes	18	11	16	15
No	82	89	84	85
TOTAL INTERVIEWED	146	489	139	

TABLE 15. Reasons for visiting the New York Botanical Garden

	Spring	Summer	Fall	Average
Biological/Ecological Pursuits (to appreciate nature, identify plants, lectures, study herb garden)	11	15	11	12
General Garden activities and exhibits (see floral displays, take photographs, paint)	55	60	65	60
Convenience (place to take children, to socialize, to walk dog)	29	25	24	26
TOTAL INTERVIEWED	687	1878	663	

TABLE 16. Reaction to New York Botanical Garden visit

Category	Summer	Fall	Average
Favorable	83	92	87
Unfavorable	3	2	3
Mixed feelings	14	6	10
TOTAL INTERVIEWED	493	139	

TABLE 17. Responses to the question -"What do you like best about the Garden?"

Response Category	Spring	Summer	Fall	Average
Natural Areas (primitive woods, nature sites)	19	11	21	17
Garden Exhibits (floral displays, educational facilities, Conservatory, Rock Garden)	39	53	54	49
Convenience (atmosphere, oasis within city, close to home)	42	36	25	34
TOTAL INTERVIEWED	661	583	139	

TABLE 18. Visitor opinion of the New York Botanical Garden facilities and program

Category	Spring	Summer	Fall	Average
Improve Garden Facilities & Activities (better security, more signs, stronger educational effort, improve maintenance, better transportation within Garden)	42	59	69	57
Improve Control of Visitor Activities (too much refuse, music, noise, etc.; restrict car & motor-cycle use; incompatible recreational practices - base-ball, swimming, etc. - too many dogs)	18	22	20	20
No Improvement Necessary or No Opinion	40	19	11	23
TOTAL INTERVIEWED	1325	942	221	

TABLE 19. Reason for visitor use of the New York Botanical Garden Forest

Category	Weekly Average
	Summer
Biological/Ecological	
(observing nature, looking at falls)	11
General Garden Activities and Exhibits	
(walking on/off trail, photographing)	31
Social/Recreational	
(swimming, dog walking, eating, sunning, music, reading)	58
TOTAL INTERVIEWED	498

Source

Lipp, F. J. 1974. The New York Botanical Garden audience survey. Unpubl. report, New York Bot. Garden Library, Hemlock Forest File. 12 pp.

Shotland, S. 1975. New York Botanical Garden Hemlock Forest Study. Unpubl. report, New York Bot. Garden Library, Hemlock Forest File. Not complete.

Appendix III. Verified species list of woody and herbaceous plants in the New York Botanical Garden Forest as reported by Shotland, 1974 (Source A), this study (Source B), or by both studies (Source C)

WOODY PLANTS

Source	Latin Name	Common Name
A	Acer platanoides	Norway maple
C	Acer rubrum	red maple
C	Acer saccharum	sugar maple
B	Ailanthus altissima	tree of heaven
C	Aralia spinosa	devil's walking stick
C	Betula lenta	sweet birch
A	Betula populifolia	gray birch
C	Carpinus caroliniana	American hornbeam
B	Carya glabra	pignut hickory
C	Celastrus scandens	climbing bittersweet
B	Clethra alnifolia	sweet pepperbush
C	Cornus florida	flowering dogwood
C	Crataegus sp.	hawthorn
C	Fagus grandifolia	American beech
C	Fraxinus americana	white ash
C	Hamamelis virginiana	witch hazel
B	Hydrangea arborescens	hydrangea
C	Lindera benzoin	spicebush
C	Liquidambar styraciflua	sweetgum
C	Liriodendron tulipifera	tulip tree
C	Lonicera japonica	Japanese honeysuckle
A	Magnolia acuminata	cucumber magnolia
B	Magnolia stellata	star magnolia
B	Malus sp.	crabapple
B	Morus alba	white mulberry
C	Nyssa sylvatica	black tupelo
C	Ostrya virginiana	eastern hop hornbeam
A	Paulownia tomentosa	royal paulownia
C	Phellodendron amurense	Amur cork tree
A	Phytolacca americana	pokeberry
A	Platanus occidentalis	American sycamore
A	Populus grandidentata	big tooth aspen
C	Populus tremuloides	trembling aspen
B	Prunus avium	mazzard cherry
C	Prunus serotina	black cherry
C	Quercus alba	white oak
C	Quercus borealis	red oak
C	Quercus palustris	pin oak
C	Quercus velutina	black oak
B	Rhododendron sp.	azalea
A	Rhus sp.	staghorn sumac

Source	Latin Name	Common Name
B	Rubus allegheniensis	mountain blackberry
A	Sambucus canadensis	American elder
C	Sassafras albidum	sassafras
A	Smilax sp.	greenbrier
A	Sorbus americana	American mountain-ash
C	Tsuga canadensis	eastern hemlock
B	Ulmus americana	American elm
C	Viburnum acerifolium	maple-leaved viburnum
C	Viburnum dentatum	southern arrow-wood

HERBACEOUS PLANTS

Source	Latin Name	Common Name
A	Ambrosia trifida	great ragweed
C	Aster divaricatus	white woodland aster
A	Cirsium horridulum	thistle
B	Commelina virginica	dayflower
B	Glechoma hederacea	run-away-robin
A	Impatiens biflora	jewelweed
A	Lysimachia quadrifolia	whorled loosestrife
C	Maianthemum canadense	Canada mayflower
A	Oxalis stricta	yellow wood sorrel
A	Panicum sp.	panic grass
B	Panicum clandestinum	panic grass
C	Parthenocissus quinquefolia	Virginia creeper
B	Poa sp.	meadow grass
B	Polygonatum biflorum	Solomon's-seal
C	Polygonum scandens	knotweed
A	Polygonum sp.	knotweed
C	Smilacena racemosa	false Solomon's-seal
A	Solanum dulcamara	deadly nightshade
A	Solidago sp.	goldenrod
A	Tovara virginiana	jumpseed
B	Urtica dioica	stinging nettle

Source

Shotland, S. 1975. New York Botanical Garden Hemlock Forest Study. Unpubl. report, New York Bot. Garden Library, Hemlock Forest File. Not complete.

This Study.

Appendix IV. Species list of birds and mammals in the New York Botanical Garden Forest.

BIRDS

Common Loon
Grebe, Horned
Pied-billed
Heron, Great Blue
Green
Little Blue
Egret, Cattle
Great
Snowy
Heron, Black-crowned Night
Yellow-crowned Night
Bittern, American
Least
Swan, Mute
Goose, Canada
Brant
Snow
Duck, Mallard
Black
Gadwall
Pintail
Teal, Green-winged
Blue-winged
Duck, Shoveler
American Widgeon
Wood
Redhead
Ring-necked
Canvasback
Scaup, Lesser
Common Goldeneye
Bufflehead
Ruddy
Hooded Merganser
Common Merganser
Turkey Vulture
Goshawk
Hawk, Sharp-shinned
Cooper's
Red-tailed
Red-shouldered
Broad-winged
Rough-legged
Bald Eagle
Hawk, Marsh (Harrier)
Osprey
Falcon, Peregrine
Hawk, Pigeon (Merlin)
Sparrow (Kestrel)

Grouse, Ruffed
Bobwhite
Pheasant, Ring-necked
Rail, King
Clapper
Virginia
Plover, Semipalmated
Killdeer
Plover, Black-bellied
Woodcock, American
Snipe, Common
Sandpiper, Spotted
Solitary
Yellowlegs, Greater
Lesser
Sandpiper, Least
Semipalmated
Gull, Great Black-backed
Herring
Ring-billed
Laughing
Dovekie
Dove, Rock (Domestic Pigeon)
Mourning
Cuckoo, Yellow-billed
Black-billed
Barn Owl
Owl, Screech
Great Horned
Barred
Long-eared
Short-eared
Saw-whet
Common Nighthawk
Whip-poor-will
Chimney Swift
Ruby-throated Hummingbird
Belted Kingfisher
Common Flicker
Woodpecker, Pileated
Red-bellied
Red-headed
Yellow-bellied Sapsucker
Woodpecker, Hairy
Downy
Black-back Three-toe
Eastern Kingbird
Western Kingbird
Flycatcher, Great Crested

Appendix IV (cont.)

Eastern Phoebe
Flycatcher, Yellow-bellied
Acadian
Least
Eastern Wood Pewee
Flycatcher, Olive-sided
Lark, Horned
Swallow, Tree
Bank
Rough-winged
Barn
Cliff
Blue Jay
Common Crow
Fish Crow
Black-capped Chickadee
Boreal Chickadee (Brown-capped)
Tufted Titmouse
Nuthatch, White-breasted
Red-breasted
Brown Creeper
Wren, House
Winter
Carolina
Long-billed Marsh
Mockingbird
Catbird
Brown Thrasher
Robin
Thrush, Wood
Hermit
Swainson's
Grey-cheeked
Veery
Eastern Bluebird
Blue-grey Gnatcatcher
Golden-crowned Kinglet
Ruby-crowned Kinglet
Cedar Waxwing
Northern Shrike
Starling
Vireo, White-eyed
Yellow-throated
Solitary
Red-eyed
Philadelphia
Warbling

Warbler, Black & White
Prothonotary
Swainson's
Worm-eating
Golden-winged
Blue-winged
Brewster's } Hybrids
Lawrence's
Tennessee
Orange-crowned
Nashville
Parula
Yellow
Magnolia
Cape May
Black-throated Blue
Myrtle
Townsend
Black-throated Green
Cerulean
Blackburnian
Yellow-throated
Chestnut-sided
Bay-breasted
Blackpoll
Pine
Prairie
Western Palm
Yellow Palm
Northern Water-thrush
Ovenbird
Louisiana Water-thrush
Warbler, Kentucky
Connecticut
Mourning
Yellow-throat
Yellow-breasted Chat
Warbler, Hooded
Wilson's
Canada
American Redstart
House Sparrow
Bobolink
Eastern Meadow Lark
Red-winged Blackbird
Orchard Oriole
Northern Oriole

Appendix IV (cont.)

Rusty Blackbird
Common Grackle
Brown-headed Cowbird
Tanager, Scarlet
Summer
Cardinal
Grosbeak, Rose-breasted
Blue
Indigo Bunting
Grosbeak, Evening
Purple Finch
House Finch
Grosbeak, Pine
Common Redpoll
Pine Siskin
American Goldfinch
Red Crossbill
White-winged Crossbill
Sparrow, Savannah
Common Junco
Sparrow, Tree
Chipping
Field
White-crowned
White-throated
Fox
Lincoln's
Swamp
Song
Snow Bunting

BIRDS (Supplement)

Duck, Tufted
Coot, American
Godwit, Marbled
Sandpiper, Stilt
Dowitcher, Short-billed
Sandpiper, Pectoral
Gull, Iceland (Kumlien's)
Pipit, Water
Towhee, Rufous-sided
Sparrow, Vesper

Parakeet, Rose-ringed (exotic)

MAMMALS

Verified

Shorttail Shrew
Eastern Chipmunk
Grey Squirrel
White-footed Mouse
Muskrat
Norway Rat
Eastern Cottontail

Appendix IV (cont.)

Possible

Opossum
Shrew, Masked
    Smoky
    Least
Mole, Starnose
    Eastern
Bat, Little Brown Myotis
    Keen Myotis
    Small-footed Myotis
    Silver-haired
    Eastern Pipistrel
    Big Brown
    Red
    Hoary
Raccoon
Weasel, Shorttail
    Longtail
    Mink
Otter, River
Skunk, Striped
Woodchuck
Squirrel, Red
    Southern Flying
Mouse, Deer
Vole, Meadow
Jumping Mouse, Meadow
    Woodland

Source

Knight, F. W. 1972. Birds: An unexpected dimension of the New York Botanical Garden. Garden J. 22(2):44.

Hait, S. 1980. Personal communication.

This Study.