Aspen Ecosystem Properties In The Upper Great Lakes

David H. Alban, Donald A. Perala, Martin F. Jurgensen, Michael E. Ostry, and John R. Probst

INTRODUCTION

Strong interest in managing the aspens (*Populus tremuloides* Michx. and *P. grandidentata* Michx.) has recently developed throughout the United States and Canada (Graham *et al.* 1963; Brinkman and Roe 1975; Perala 1977, 1986, 1990; Perala and Russell 1983; Shepperd and Engelby 1983; DeByle and Winokur 1985; Corns 1989; Doucet 1989; Adams 1990; Navratil *et al.* 1990).

Aspens are short-lived, fast-growing trees ubiquitous throughout temperate North America. Quaking aspen is also common in boreal and montane ecosystems. Aspens are found on a broad array of soils, climates, and plant communities. They are disturbance-dependent and typically form dense, uniform, and more-or-less pure stands. Most aspen stands are even-aged because they reproduce immediately after a disturbance, either from seed or from root suckers. Root suckering is by far the most common mode, and they appear whenever the parent trees are killed. Sucker production increases with stocking of the parent stand, and their numbers and vigor diminish with increasing density of the surviving overstory because aspen needs nearly full light. Commonly, longer lived, shade-tolerant species establish in the understory. If a calamity, such as fire, windstorm, or logging kills most of the stand, aspen will dominate most sites. Otherwise, aspen is usually replaced within a single generation by its associates.

Mature stands (50 years of age) typically average 65 to 80 feet tall. Under the best conditions, a few aspens may eventually exceed 100 feet. Growing side-by-side, bigtooth aspen will usually outproduce quaking aspen, especially on sandy soils. Aspen lives longest in cool climates, on calcareous soils, and on good sites. In the East, stands start to break up at 40 to 70 years. In the Rockies, stands sometimes persist to 200 years or so. Commercial rotations range from about 35 years in southern Michigan to about 120 years in the Rockies.

In the upper Great Lakes the aspens have emerged from "weed tree" status to become important commercially within the last few decades. Currently, aspen constitutes about 51 percent of the pulpwood harvested in the region (Blyth and Smith 1988). The large amount of aspen harvested, much of it by the whole-tree method, and the rapid rate of biomass and nutrient accumulation in aspen stands has stirred interest in the impact of aspen management on long-term stand and site productivity, carbon sequestering, and ultimately global climate (Pastor and Bockheim 1984, Ruark and Bockheim 1988, Alban and Perala 1990).

In 1977 we selected four aspen stands in which to study the long-term impact of harvesting, site preparation, and species conversion on stand growth and soil properties. Three stands were in Minnesota and one in the Upper Peninsula of Michigan (fig. 1, table 1). All stands were dominated by mature quaking aspen, but each contained a significant proportion of other tree

---

David H. Alban is a Research Soil Scientist and **Donald A. Perala** is a Principal Silviculturist with the North Central Forest Experiment Station, Grand Rapids, MN.

Martin F. Jurgensen is a Professor of Forest Soils with the School of Forestry and Wood Products, Michigan Technological University, Houghton, MI.

Michael E. Ostry is a Research Plant Pathologist with the North Central Forest Experiment Station, St. Paul, MN.

John R. Probst is a Research Wildlife Biologist with the North Central Forest Experiment Station, Rhinelander, WI.

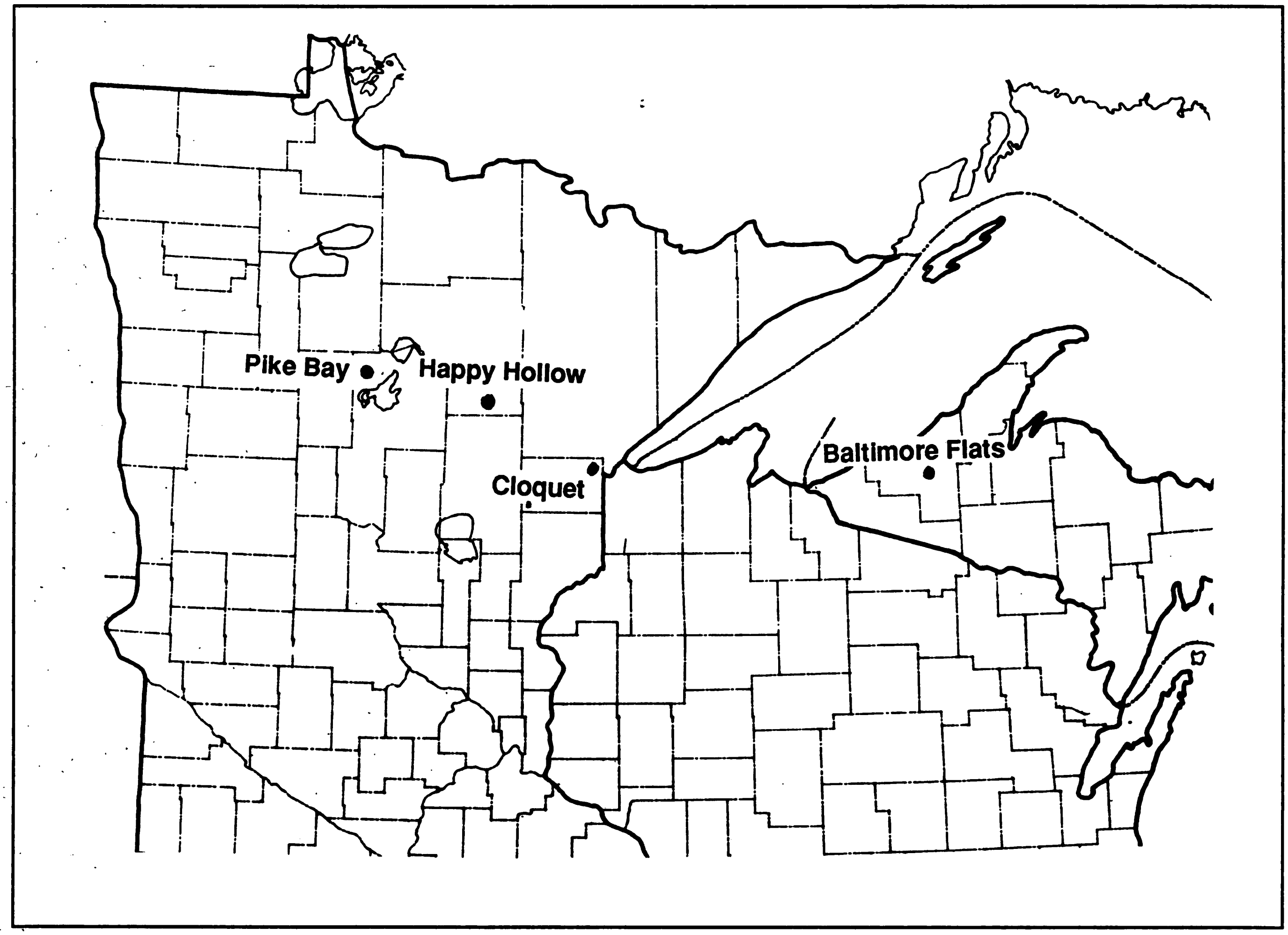


Figure 1.—*Site location.*

Table 1.—*Site locations, size, and ownership*

Site	Area	State/county	Ownership	Latitude/ longitude	Legal description	USGS quadrangle
	Hectares					
Baltimore Flats (BF)	12	Michigan U.P. Ontonagon	Ottawa NF	46° 39'N 89° 13'W	T49N, R39W Sec. NENE18	Rockland
Cloquet (CL)	16	NE Minnesota Carlton	University of MN	46° 43'N 92° 29'W	T49N, R17W Sec. SESE32	Iverson
Happy Hollow (HH)	8	NC Minnesota Itasca	Itasca County	47° 05'N 93° 22'W	T53N, R24W Sec. SW10	Jacobson
Pike Bay (PB)	20	NC Minnesota Cass	Chippewa NF	47° 20'N 94° 30'W	T144N, R30W Sec. NESE6	Pike Bay

species (table 2). The sites were selected to encompass a wide range of soils and therefore a wide range of site quality. Topography was nearly level on the Baltimore Flats (BF), Cloquet (CL), and Pike Bay (PB) sites, and each was dominated by a single soil series (table 3). The Happy Hollow (HH) site was sloping and the soils formed a drainage catena from the excessively drained Zimmerman to the very poorly drained Leafriver soils.

The study sites (Appendix 1) ranged from 8 to 20 ha. Each area, except for HH, was divided into 1-ha plots that ultimately received randomly assigned treatments (except uncut controls were always on the outside of the clearcut area to minimize changes in their microclimatic character). At HH, sample points were simply located on a 40-m spacing. Three harvesting treatments (replicated four or six times) were applied on each treated site: clearcut whole-tree, *i.e.*, extracting the entire aboveground tree from the site; clearcut merchantable bole, extracting only merchantable trees to a 10-cm top; and uncut controls. In addition, sets of shelterwood treatments were installed at CL and PB only. Four of the clearcut plots were converted to *Picea glauca* (Moench) Voss at each treated site.

Soils and vegetation were thoroughly inventoried before harvesting. This inventory provides an uncommonly detailed examination of soil and stand conditions, a baseline to evaluate changes that may occur as the result of either natural processes or man-induced alterations.

CLIMATE

In general, all sites have a continental climate with long, cold winters, warm summers, and moderate amounts of precipitation distributed more or less uniformly throughout the year. The three Minnesota sites are all in a single climate zone, the Michigan site in another, according to the scheme of Rauscher (1984).

Table 2.—*Preharvest vegetation*

		Aspen		Trees/ha		Basal area		Biomass (aboveground)		
Site	Overstory	Age	Site Index	Aspen	Total	Aspen	Total	Trees	Shrubs	Herbs
			m @ 50 yrs			*- - m²/ha - -*		*Mg/ha*	*- - kg/ha - -*	
BF	Aspen n. hardwoods	47	18.1	510	3,192	12.6	24.7	106	821	363
CL	Aspen paper birch	60	17.0	368	701	7.6	19.0	98	4,527	399
HH:Zimmer-man	Aspen balsam fir	51	20.0	525	1,873	11.6	26.9	123	232	123
Redby	Aspen balsam fir	48	21.8	400	2,865	9.8	32.9	144	332	243
Leafriver	Aspen balsam fir black spruce	46	17.6	409	2,131	9.1	28.1	120	1	20
PB	Aspen n. hardwoods	66	24.2	282	1,297	21.6	38.3	256	509	96

Table 3.—*Soils*

Site	Soil type	Description[1]	Taxonomic class[2]
Baltimore Flats	Ontonagon clay (tentative classification)	Baraga Co. MI (Berndt 1988)	Glossic Eutroboralf
Cloquet	Cloquet fine sandy loam	Carlton Co. MN (Lewis 1978)	Typic Dystrochrept
Happy Hollow	Zimmerman, loamy fine sand	Itasca Co. MN (Nyberg 1987)	Alfic Udipsamment
Happy Hollow	Redby, loamy fine sand	Kittson Co. MN (Barron 1979)	Aquic Udipsamment
Happy Hollow	Leafriver, loamy fine sand	Wadena Co. MN (Aldeen, in press)	Histic Humaquept
Pike Bay	Warba silt loam	Itasca Co. MN (Nyberg 1987)	Glossic Eutroboralf

[1]Published soil surveys in which the soils are described.
[2]Taxonomy as explained in Soil Survey Staff (1975).

Long-term climatic data (on computer files) were obtained from the National Oceanic and Atmospheric Administration (NOAA). For the Minnesota sites, NOAA weather stations at Cass Lake, Grand Rapids, and Cloquet were used for the PB, HH, and CL sites, respectively. These weather stations are all northwest of our sites (10, 20, and 2.5 km from PB, HH, and CL, respectively). In Michigan we used the weather station at Kenton, 31 km southeast of the BF site. During the 1980's we collected precipitation on all of our sites. The amounts agreed very closely with NOAA records. Thus, we feel confident in using the precipitation and temperature data from the NOAA stations for the years prior to our data collection.

During the 1951-1980 period, total annual precipitation decreased from east to west (BF site to PB site) from 770 to 640 mm (table 4); however, summer (June-August) precipitation was similar on all four sites (table 5). Total annual precipitation on each site varied by a factor of about 2 (table 5), but summer precipitation varied by up to a factor of 5. Warmer winter temperatures caused the Michigan site to be warmer than the Minnesota sites. Summer temperatures increased slightly from east to west (table 5). Temperatures were much more uniform from year to year, both on a yearly basis and during the summer (table 5).

It appears that during the growing season the four sites have very similar precipitation and temperatures.

GEOLOGY

All four sites are underlain by bedrock of Precambrian age, but their surface characteristics are determined by glacial deposits from the late Wisconsin ice age (table 6). The glacial deposits are at least 30 m thick at each site and the upper layers are the parent materials of very young soils, since the ice last left each area about 10,000 years ago.

Table 4.—*Mean monthly precipitation and temperature*

MONTH	Precipitation (mm) 1951-1980 BF	CL	HH	PB	Temperature (°C) 1951-1980 BF	CL	HH	PB
JAN	28	29	21	21	-11.4	-14.0	-14.7	-17.0
FEB	24	21	16	14	- 9.9	-10.6	-10.8	-13.4
MAR	37	43	32	27	- 4.1	- 4.3	- 4.2	- 6.1
APR	55	53	51	56	4.3	4.3	4.9	3.9
MAY	87	87	80	71	11.2	11.1	12.0	11.2
JUN	100	104	96	100	16.1	16.1	16.9	16.9
JUL	94	111	105	99	18.6	19.3	19.6	19.6
AUG	98	103	86	83	17.4	18.0	18.2	18.3
SEP	92	84	76	68	12.9	12.9	12.9	12.6
OCT	66	56	51	48	7.7	7.2	7.4	6.7
NOV	55	40	31	29	- 0.6	- 1.9	- 2.0	- 3.0
DEC	34	31	24	25	- 7.9	- 9.9	-10.5	-12.4
ANNUAL	770	761	669	639	4.5	4.0	4.1	3.1

Table 5.—*Climatic data*

	Precipitation (mm) (1951-1980)					
	Annual			Summer (Jun-Aug)		
Site	Mean	Range	Std.dev.	Mean	Range	Std.dev.
Baltimore Flats	770	440-990	120	292	90-480	90
Cloquet	761	510-1050	140	318	160-550	90
Happy Hollow	669	460-960	120	287	130-500	90
Pike Bay	639	360-900	140	282	120-490	90

	Temperature (°C) (1951-1980)					
	Annual			Summer (Jun-Aug)		
	Mean	Range	Std.dev.	Mean	Range	Std.dev.
Baltimore Flats	4.5	3.2-5.9	0.68	17.4	16-19	0.94
Cloquet	4.0	2.6-5.3	0.63	17.8	16-19	0.89
Happy Hollow	4.1	2.7-5.3	0.65	18.2	16-20	0.85
Pike Bay	3.1	1.8-4.4	0.73	18.3	17-20	0.88

The Baltimore Flats site is on a nearly level lacustrine plain formed in late Wisconsin time (Valder's phase) about 9,500 years ago. Retreating ice of the Gogebic lobe formed Lake Ontonagon, the source of the lacustrine clay deposits (Black 1969, Hack 1965). The lacustrine deposits on the site are more than 1 m thick, reddish colored, calcareous, stone-free, with about 75 percent clay, and are underlain by a ground moraine.

The Cloquet site is on the gently rolling Cloquet outwash plain (Wright *et al.* 1970). The plain was formed during the Split Rock phase of the Superior lobe that advanced southwest out of the Lake Superior basin about 11,500 years ago. The outwash drift is reddish brown, acid, and high in gravels (deeper soil horizons often contain as much as 40 percent gravel by weight).

Table 6.—*Geology*

Site	Bedrock[1]	Surficial deposits[2]
Baltimore Flats	Jacobville sandstone Precambrian-Cambrian	Lacustrine clay from glacial Lake Ontonagon over ground moraine
Cloquet	Meta sedimentary middle Precambrian	Outwash derived from the Superior lobe; Cloquet outwash plain
Happy Hollow	Meta sedimentary (slates and graywacke) middle Precambrian	Lacustrine sands; Aitkin lacustrine plain
Pike Bay	Granite lower Precambrian	Ground moraine derived from the St. Louis sublobe of the Des Moines lobe; Guthrie till plain

[1]Hack (1965), Ojakangas and Matsch (1982).
[2]Hack (1965), Erickson *et al.* (1971, 1977, 1980), Peterson (1986). All surficial deposits are from the late Wisconsin age.

The Pike Bay site is on the Guthrie till plain, a ground moraine formed by the St. Louis sublobe of the Des Moines lobe that reached its maximum extension about 12,000 years ago (Wright 1972). The St. Louis sublobe advanced from the northwest and deposited grayish-brown, loamy, calcareous, shaley materials with some gravels on rolling topography. Sometime later, perhaps as long as 5,000 years after the retreat of the ice, a thin layer of loess was deposited over much of north-central Minnesota (Grigal *et al.* 1976). At the Pike Bay site, the loess is about 40 cm thick, is silt loam in texture, and forms an abrupt boundary with the underlying glacial till.

As the St. Louis sublobe retreated to the northwest for the last time, Glacial Lakes Aitkin II and Upham II formed at its front. The drainage of Glacial Lake Aitkin exposed the Aitkin lacustrine plain, the environ for the Happy Hollow site. The surficial deposits are fine and very fine noncalcareous sands with almost no gravel. The water table is generally within 3 m of the soil surface.

SOILS

Soil pits were dug 3 m east of subplot 3 within each ha (fig. 2). The pits were about 1 to 1.5 m deep, and bucket augers were used to collect samples to a depth of 2 m. The soils were described by soil scientists from the National Forests or the Soil Conservation Service. Samples were collected from each horizon for laboratory analysis. The profile descriptions that follow and the values in tables 7-10 are average values from the soil pits on each site.

Baltimore Flats

This site is dominated by soils similar to the Ontonagon series, which are very fine, mixed, frigid Glossic Eutroboralfs (Soil Survey Staff 1975). An average soil profile from the site follows:

O_6-0 cm: leaves and other plant material ranging from fresh to well decomposed.

A_0-2 cm: dark reddish-brown (2.5YR 3/4) clay; moderate medium subangular blocky structure; friable; clear wavy boundary.

E_2-10 cm: dark reddish-gray (5YR 4/2) clay; moderate fine subangular blocky structure; firm; clear wavy boundary.

B/E_10-28 cm: red (2.5YR 4/6) and reddish-brown (2.5YR 5/4) clay; moderate medium blocky structure; firm; clear wavy boundary.

Bt1_28-65 cm: red (2.5YR 4/6) clay; moderate fine blocky structure; firm; roots on ped faces; gradual wavy boundary.

Bt2_65-85 cm: reddish-brown (2.5YR 4/4) clay; moderate coarse blocky structure; firm; few roots; gradual wavy boundary.

C1_85-100 cm: reddish-brown (2.5YR 4/4) clay; moderate coarse blocky structure; very firm; very few roots; strong effervescence.

C2_100-200 cm: reddish-brown (2.5YR 4/4) clay; massive structure; no roots; strong effervescence.

The soil is dominated by the very high clay content (table 7); permeability is therefore slow on this site (standing water occurs in slight depressions for several days following all heavy rainfalls). The high clay content restricts root growth to primarily the ped faces. Few roots penetrate beyond 85 cm. The soils are calcareous below 65 cm and Ca and Mg levels and pHs are high deeper in the profile. The A horizon is discontinuous, occurring on about one-half of the area. Where the A is absent, the E horizon lies immediately beneath the forest floor. The site at one time supported large white pines (*Pinus strobus* L.), but only some charred stumps remain. Charcoal in the forest floor and surface mineral horizon further indicate a history of fire that may be partly responsible for the mediocre current growth of aspen.

Cloquet

This site is dominated by the Cloquet soil series, sandy, mixed, frigid Typic Dystrochrepts (Soil Survey Staff 1975). An average profile follows:

O_1-0 cm: leaves and other plant remains only slightly decomposed, and frequently nearly disappearing by the end of the growing season.

Table 7.—*Soil properties (Baltimore Flats site, Ontonagon soil)*

Horizon	Depth	Particle size: Clay	Silt	Sand	Db	pH	Organic[1] carbon	Nitrogen[2]	Cations[3]: Ca	Mg	K
	cm	*Percent*			*g/cc*		*Percent*	*ppm*	*ppm*		
O	6-0	—	—	—	0.16	5.6	31.0	11,300	16,370	4,402	4,044
A	0-2	60	17	23	0.75	5.5	13.5	8,420	4,980	602	466
E	2-10	59	22	19	1.16	5.3	1.5	1,060	1,460	294	166
B/E	10-28	71	16	13	1.33	5.4	0.8	628	2,150	454	195
Bt1	28-65	77	13	10	1.39	6.2	0.5	290	3,690	694	184
Bt2	65-85	73	14	13	1.50	8.2	—	173	9,470	697	135
C1	85-100	72	15	13	1.41	8.2	—	150	9,520	665	118
C2	100-200	75	15	10	—	8.3	—	152	10,080	669	123

[1]Organic carbon by induction furnace.
[2]Kjeldahl nitrogen.
[3]In mineral horizons, exchangeable cations were extracted with 1N NH_4OAC. In the organic horizons cations are the total in a wet digested sample.

A_0-6 cm: black (10YR 2/1) fine sandy loam; moderate fine granular structure; many earthworm casts; very friable; clear smooth boundary.

Bw1_6-24 cm: dark-brown (7.5YR 4/4) fine sandy loam; moderate very fine subangular blocky structure; very friable, gradual smooth boundary.

Bw2_24-58 cm: brown (7.5YR 5/4) fine sandy loam; moderate very fine subangular blocky structure; very friable; 5 percent coarse fragments by weight; abrupt smooth boundary.

2Bw_58-75 cm: reddish-brown (5YR 4/3) gravelly loamy sand; weak medium subangular blocky structure; about 50 percent coarse fragments by weight; abrupt smooth boundary.

2C_75-110 cm: reddish-brown (5YR 4/3) gravelly coarse sand; massive; loose; about 50 percent coarse fragments by weight; abrupt smooth boundary.

3C_110-165 cm: reddish-brown (5YR 4/3) sand; massive; loose; few roots.

This soil has a rich A horizon caused by intense mixing by earthworms. The earthworm activity results in only a very slight forest floor accumulation. The 2 soil material that begins at 58 cm is dominated by a large amount of gravel up to 10 cm in diameter (table 8). The coarse material does not seem to restrict root growth, but has very low moisture storage capacity. The soil is noncalcareous throughout and has very low levels of exchangeable cations in the deeper soil horizons.

Happy Hollow

This site is sloping with various depths to a water table, resulting in three soils of varying drainage class:

Zimmerman, excessively drained, coarse-loamy mixed, frigid Alfic Udipsamment (45 percent of the area).

Redby, somewhat poorly drained, coarse-loamy mixed, frigid Aquic Udipsamment (35 percent of the area).

Leafriver, very poorly drained, coarse-loamy mixed, frigid Histic Humaquept (20 percent of the area).

Table 8.—*Soil properties (Cloquet site, Cloquet soil)*

Horizon	Depth	Particle size: Clay	Silt	Sand	Gravel >2 mm	Db	pH	Organic[1] carbon	Nitrogen[2]	Cations[3]: Ca	Mg	K
	cm	% (<2 mm soil)			%	g/cc		%	ppm	- - ppm - -		
O	1-0	—	—	—	—	0.33	5.1	18.8	4,988	7,740	1,860	1,780
A	0-6	16	39	45	3	0.97	4.9	5.5	2,480	1,454	182	131
Bw1	6-24	12	37	51	11	1.15	5.1	0.72	405	390	42	51
Bw2	24-58	8	23	69	9	1.24	5.3	0.34	211	352	41	44
2Bw	58-75	8	10	82	68	1.20	5.6	0.24	144	685	102	78
2C	75-110	4	2	94	31	1.20	5.6	0.14	79	466	71	40
3C	110-165	4	1	95	12	—	5.8	0.09	47	476	61	38

[1]Organic carbon by induction furnace.
[2]Kjeldahl nitrogen.
[3]In mineral horizons, exchangeable cations were extracted with 1N NH_4OAC. In the organic horizons cations are the total ir a wet digested sample.

Average profiles follow:

Zimmerman loamy fine sand

O_3-0 cm: organic litter.

E_0-10 cm: grayish-brown (10YR 5/2) loamy fine sand; weak very fine granular structure; very friable; clear wavy boundary.

Bw_10-24 cm: yellowish-brown (10YR 5/4) loamy fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary.

BC_24-50 cm: pale-brown (10YR 6/3) loamy fine sand; weak coarse subangular structure; very friable; gradual wavy boundary.

C1_50-96 cm: light yellowish-brown (2.5YR 6/3) fine sand; massive; very friable; a few yellowish-brown (10YR 5/4) lamella beginning at about 80 cm; gradual wavy boundary.

C2_96-146 cm: light yellowish-brown (2.5YR 6/3) fine sand; few medium and fine faint yellowish-brown (10YR 5/4) mottles; massive; very friable; very few roots.

Redby loamy fine sand

O_5-0 cm: organic litter ranging from fresh to well decomposed.

E_0-9 cm: grayish-brown (10YR 5/2) loamy fine sand; weak fine subangular blocky structure; very friable; clear wavy boundary.

Bw_9-25 cm: brown (7.5YR 4/4) loamy fine sand; weak medium subangular blocky structure; very friable; clear wavy boundary.

Bg_25-57 cm: pale-brown (10YR 5/3) loamy fine sand; few fine yellowish-brown (10YR 5/8) mottles; weak coarse subangular blocky structure; very friable; gradual wavy boundary.

BCg_57-100 cm: light brownish-gray (2.5YR 6/2) fine sand; many large prominent yellowish-brown (10YR 5/8) and common medium prominent yellowish-red (5YR 4/8) mottles; weak coarse subangular blocky structure; very friable; few roots; gradual wavy boundary.

Cg_100-150 cm: olive-gray (5YR 5/2) fine sand; common medium distinct yellowish-brown (10YR 5/4) and few fine prominent yellowish-red (5YR 5/8) mottles; massive; very friable; very few roots.

Leafriver loamy fine sand

Oa_7-0 cm: black (10YR 2/1) well decomposed organic materials.

A_0-8 cm: black (5YR 2/1) loamy fine sand; few fine prominent yellowish-red (5YR 5/8) mottles; weak coarse subangular blocky structure; very friable; abrupt smooth boundary.

Bg1_8-18 cm: olive-gray (5YR 5/2) loamy fine sand; common medium prominent yellowish-brown (10YR 5/6) mottles; weak coarse subangular blocky structure; very friable; roots common, clear smooth boundary.

Bg2_18-48 cm: light brownish-gray (2.5YR 6/2) fine sand; common medium prominent yellowish-brown (10YR 5/6) mottles; massive; very friable; clear smooth boundary.

Bg3_48-85 cm: gray (5YR 5/1) fine sand; common medium prominent yellowish-brown (10YR 5/6) mottles; massive; very friable; few roots; clear smooth boundary.

Cg_85-160 cm: gray (5YR 6/1) fine sand; common medium prominent yellowish-brown (10YR 5/6) and few fine prominent yellowish-red (5YR 5/8) mottles; massive; very friable; no roots; calcium carbonate nodules.

Soil texture is fine sand to loamy fine sand at Happy Hollow (table 9). Generally, fine sand and very fine sand each constitute about 40-45 percent of the soil and nearly all the rest is medium sand. Soil nutrients, particularly Mg and K, tend to be lower than at the other sites.

Table 9.—*Soil properties (Happy Hollow site)*

Horizon	Depth	Particle size: Clay	Silt	Sand	Db	pH	Organic[1] carbon	Nitrogen[2]	Cations[3]: Ca	Mg	K
	cm	- - - *%* - - -			*g/cc*		- *%* -	- *ppm* -	- - - *ppm* - - -		
					Zimmerman loamy fine sand						
O	3-0	—	—	—	0.26	5.2	21.8	9,158	9,090	1,590	1,960
E	0-10	7	17	76	1.08	4.7	0.81	396	161	23	24
Bw	10-24	6	12	82	1.25	5.2	0.69	324	222	27	30
BC	24-50	5	8	87	1.33	5.4	0.29	158	154	22	21
C1	50-96	4	7	89	1.51	5.6	0.15	85	180	22	16
C2	96-146	4	7	89	—	5.4	0.12	63	265	38	19
					Redby loamy fine sand						
O	5-0	—	—	—	0.19	4.3	29.9	9,220	6,220	1,310	1,654
E	0-9	6	18	76	0.99	4.4	0.78	278	155	18	17
Bw	9-25	5	13	82	1.31	4.8	0.71	402	100	13	26
Bg	25-57	5	9	86	1.55	5.0	0.38	144	96	16	13
BCg	57-100	4	8	88	1.69	4.6	0.23	83	160	38	9
Cg	100-150	4	5	91	—	4.7	0.18	69	312	72	14
					Leafriver loamy fine sand						
Oa	7-0	—	—	—	0.19	4.7	26.0	10,500	8,290	1,920	1,51[illegible]
A	0-8	6	14	80	1.04	5.2	3.70	218	2,070	282	1[illegible]
Bg1	8-18	4	6	90	1.36	5.5	0.36	194	278	55	[illegible]
Bg2	18-48	4	7	89	1.60	5.5	—	98	204	36	[illegible]
Bg3	48-85	3	7	90	1.55	6.4	—	63	410	92	1[illegible]
Cg	85-160	—	—	—	—	7.2	—	—	805	275	1[illegible]

[1]Organic carbon by induction furnace.
[2]Kjeldahl nitrogen.
[3]In mineral horizons, exchangeable cations were extracted with 1N NH_4OAC. In the organic horizons cations are the tot: a wet digested sample.

Drainage improves from Leafriver to Redby to Zimmerman. Forest floor thickness decreases as drainage improves and depth to mottles increases (near the surface for Leafriver to 25 cm for Redby to 96 cm for Zimmerman). The surface mineral horizon for the Leafriver soil is a dark A horizon, whereas it is an eluviated E horizon for the other soils; however, an A horizon occurs sporadically in the Redby and Zimmerman soils. The better drained soils are acid throughout the profile, whereas the Leafriver soil has higher pHs and becomes calcareous at about 85 cm.

Aspen site index is greatest on the intermediate-drainage Redby soil (table 2), as is total stand basal area and biomass. Species composition changes with drainage, with red and jack pine most common on the well drained Zimmermai and black spruce most common on the very poorly drained Leafriver soil.

Pike Bay

This site is dominated by the Warba soil serie: fine-loamy, mixed, frigid Glossic Eutroboralfs (Soil Survey Staff 1975). An average profile description follows:

O_6-0 cm: leaves and other plant materials ranging from fresh to well decomposed.

A_0-1 cm: black (10YR 2.5/1) silt loam; weak medium granular structure; very friable; abrupt smooth boundary.

E1_1-12 cm: gray (10YR 6/1) silt loam; weak medium platy structure; very friable; clear smooth boundary.

E2_12-40 cm: light brownish-gray (10YR 6/2) silt loam; weak medium platy structure; friable; clear smooth boundary.

B/E_40-60 cm: dark brown (10YR 4/3) loam; moderate medium subangular blocky structure; firm; penetrated by tongues of light brownish-gray silt loam (E2); clear wavy boundary.

Bt1_60-81 cm: dark-brown (10YR 4/3) clay loam; moderate medium subangular blocky structure; firm; clay films on ped faces; about 3 percent coarse fragments by weight; gradual smooth boundary.

Bt2_81-96 cm: dark-brown (10YR 4/3) sandy clay loam; weak coarse subangular blocky structure; firm; clay films on ped faces; about 5 percent coarse fragments by weight; gradual smooth boundary.

C_96-185 cm: light olive-brown (2.5YR 5/3) sandy clay loam; massive; friable; few roots; effervesces strongly; about 10 percent coarse fragments by weight.

The Warba soil is the most productive soil in this study. The site has white pine stumps up to 5 feet in diameter and a rich mixture of large-diameter northern hardwoods, indicating a fertile site. The soil has a silt loam cap of loess overlying glacial till that varies from loam to clay loam to sandy clay loam (table 10). This till has little gravel. The soil becomes calcareous at 96 cm, with a corresponding large increase in the calcium concentration.

LITTERFALL

Total aboveground litterfall was collected in 0.4-m^2 traps for 1 or 2 years prior to harvesting on each of the study sites. Annual litterfall ranged from about 2,600 to 3,800 kg/ha (table 11); this is similar to other aspen values from the Lake States (Crow 1974, Cooper 1981, Perala and Alban 1982) and similar to world values for angiosperms at the latitude of the Lake States (Bray and Gorham 1964).

Table 10.—*Soil properties (Pike Bay site, Warba soil)*

Horizon	Depth	Particle size: Clay	Particle size: Silt	Particle size: Sand	Gravel >2 mm	Db	pH	Organic[1] carbon	Nitrogen[2]	Cations[3]: Ca	Cations[3]: Mg	Cations[3]: K
	cm	*% (<2 mm soil)*			*%*	*g/cc*		*%*	*ppm*		*- - ppm - -*	
O	6-0	—	—	—	—	0.19	5.6	19.8	10,100	14,700	2,460	2,640
A	0-1	24	64	12	0	0.97	5.3	8.5	5,220	3,918	365	223
E1	1-12	9	68	23	0	1.23	5.4	.88	656	618	83	65
E2	12-40	9	65	26	0	1.39	5.6	.26	219	397	63	47
B/E	40-60	23	36	41	1	1.45	5.6	.26	228	1,340	349	119
Bt1	60-81	30	27	43	3	1.50	5.8	.26	258	1,945	494	175
Bt2	81-96	27	23	50	5	1.50	6.6	.25	228	2,052	530	141
C	96-185	26	25	49	10	1.55	7.8	—	334	5,008	548	135

[1]Organic carbon by induction furnace.
[2]Kjeldahl nitrogen.
[3]In mineral horizons, exchangeable cations were extracted with 1N NH_4OAC. In the organic horizons cations are the total in a wet digested sample.

Table 11.—*Aboveground litterfall*

Site/Year	Litterfall kg/ha/yr	SD	Traps	Litterfall components Leaves	Needles	Branches	Misc.
			Number	*Percent*			
BF 1978	3,776	934	20	80	1	18	1
1979	3,122	607	20	65	2	31	2
Mean	3,449	726	20	72	2	24	2
CL 1978	2,935	806	22	82	5	11	2
PB 1981	3,673	532	39	87	1	10	2
1983	3,276	586	38	—	—	—	—
Mean	3,467	459	37	87	1	10	2
HH 1982							
Zimmerman soil	2,798	751	14	—	—	—	—
Redby soil	2,906	551	13	—	—	—	—
Leafriver soil	2,621	620	6	—	—	—	—
Mean	2,809	643	33	42	39	18	1

At the BF, CL, and PB sites, leaves make up 65 to 87 percent of the total litterfall, and about 70 percent of total litterfall occurs from mid-September to mid-October. At the HH site, leaves make up a much smaller proportion of total litterfall because of the greater abundance of conifers in the stands. Hence, needles make up a larger percentage of the litterfall (table 11), and litterfall is spread more evenly throughout the year (only 55 percent occurs between mid-September and mid-October).

It is interesting that litterfall does not differ much from one site to another or among the three soils at the HH site, even though site quality and tree growth differ markedly over the range of sites.

VEGETATION

The study sites had a complex vegetative assemblage that challenged inventory and summary. We stratified our vegetation sampling into three layers rather than vegetational classes: the *tree* layer, the *shrub* layer, and the *herb* layer. In the tree layer (stems >2.5 cm DBH) we recorded trees (and a few exceptionally large shrubs) by species and DBH on four permanent 0.05-ha circular measurement plots per treatment plot (fig. 2). We determined biomass and nutrients of 5 to 20 of these trees per species per site. We felled the trees, removed the limbs, and sectioned the boles

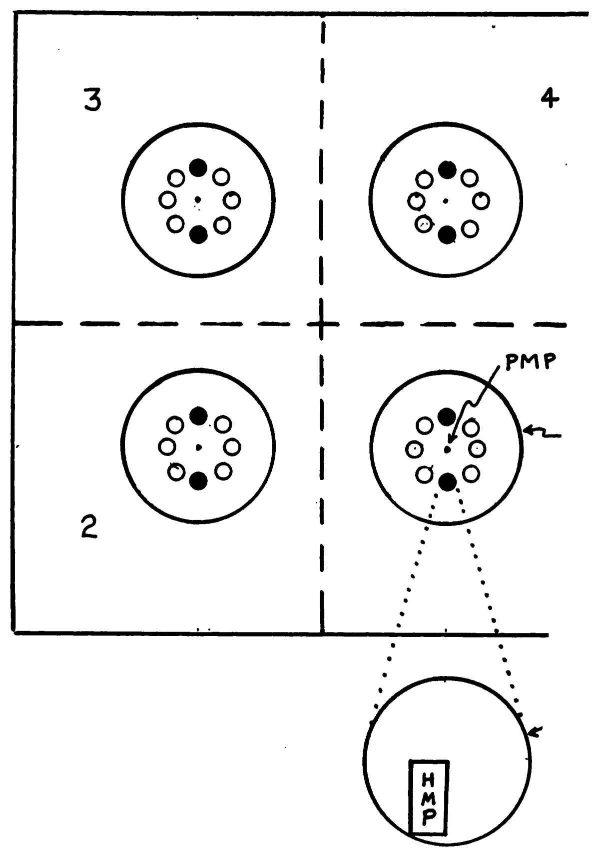


Figure 2.—*The sampling scheme for eacl treatment plot. TMP = tree measureme SMP = shrub measurement plot, HMP = measurement plot, PMP = permanent n ment point. Shaded SMPs denote initic samples. Open SMPs were used in su years.*

into 1-m bolts. Bolts and limbs were weighed in the field; subsamples were taken for laboratory processing. The trees were separated into bolewood, bole bark, foliage, live branches, and dead branches.

Shrubs and herbs were sampled on each treatment plot at eight systematic sample points located 5 m north and south of the tree-plot centers (fig. 2). The herb layer (herbs and woody seedlings less than 15 cm tall) was clipped from 0.5-m^2 plots and bagged. The shrub layer (woody plants >15 cm tall but <2.5 cm DBH) was recorded by species and by caliper to the nearest odd mm at 15 cm on 4-m^2 plots. We collected up to 30 sample shrubs per species per site, including excavated roots >5 mm caliper, for laboratory analyses to represent the range of sizes encountered. In the laboratory, shrubs were separated into root, leaf, and perennial aboveground (wood and bark of stem and branches) tissues.

Vegetation samples were ovendried (75°C), weighed, and prepared for chemical analyses. Allometric tree and shrub biomass equations of the general form:

$$W = aD^b \qquad (1)$$

were developed from the sample data to estimate component ovendry weight (W) from diameter or caliper (D). These equations were applied to plot measurement data to estimate biomass in the woody standing crop. Values for the herb layer were estimated directly by expanding the laboratory data from clipped plots.

The plot field data were reduced to summaries by layer (Appendices 2-4) that included species frequency, population density (woody species only), dominance (basal area or cover percent), relative values of these, and the mean of these relative values, the importance value (Ohmann and Ream 1971).

An independent vegetation survey established synecological coordinate values (Bakuzis and Hansen 1959) for each study site (table 12). The coordinate values for nutrients and moisture (fig. 3) are consistent with measured productivity of

Table 12.—*Synecological values (Bakuzis and Hansen 1959)*

Site	Coordinates			
	Moisture	**Nutrient**	**Heat**	**Light**
BF	2.44	2.83	2.55	2.50
CL	2.16	2.26	2.23	3.12
HHZ	2.48	2.07	1.72	2.79
HHR	2.78	2.06	1.69	2.63
HHL	3.22	2.11	1.75	2.64
PB	2.56	3.14	2.70	2.24

these sites. The nutrient values for HH vary little but the moisture values vary as expected over the drainage catena.

The BF site was classified as the Tsuga-Acer-Mitchella Habitat Type according to the system of Coffman *et al.* (1983). None of the other sites have been classified according to any formal system.

A total of 122 species, plus undifferentiated grasses and sedges, were identified on the four study sites. Ten of these species occurred on all six soils and an additional three species occurred on all four sites (Appendices 2-4). Fifty-nine species occurred on only one soil.

All soils had nearly the same number of tree species, but differed widely in numbers of shrubs and herbs (table 13). Total number of species ranged from 24 at HHL to 68 at PB. CL, HHZ, and HHR were much alike in vegetational species, and quite dissimilar to BF and PB.

Vegetation on all sites was dominated by mature aspen, with *Betula papyrifera* Marsh. a common associate at CL, *Abies balsamea* (L.) Mill. at HH, and northern hardwoods (*Acer saccharum* Marsh., *Tilia americana* L., and *Fraxinus* spp.) common on the other sites (Appendix 2). *Corylus cornuta* Marsh. and *Diervilla lonicera* Mill. were the dominant shrubs on the drier sites (CL and

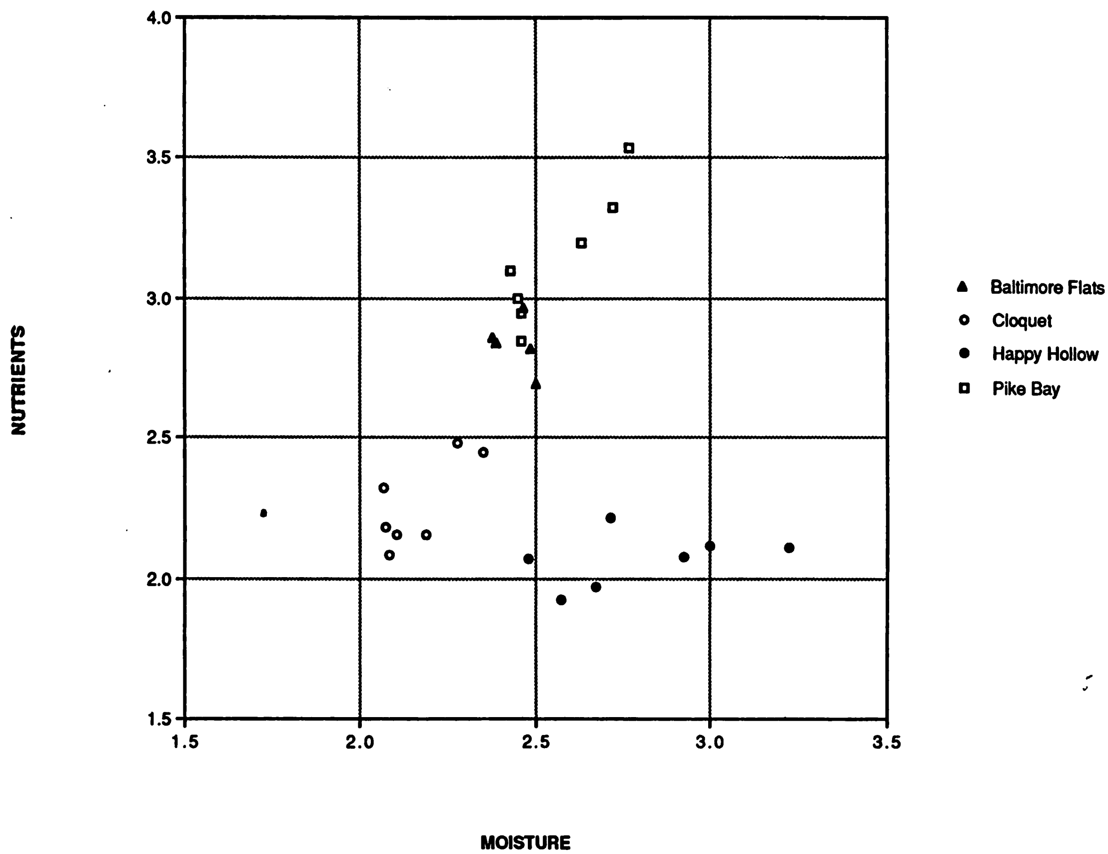


Figure 3.—*Moisture-nutrients coordinates.*

HHZ); otherwise, the shrub component was so variable and diverse as to defy generalization (Appendix 3). Either *Aralia nudicaulis* L. or *Aster macrophyllus* L. dominated the herb component, except at PB (Appendix 4). There the herb component was highly diverse and only weakly dominated by *Uvularia grandiflora* Sm. Note that *A. saccharum* dominated all vegetation layers at this site.

The amount of biomass in the boles amounted to about 75 to 80 percent of the total (Appendix 5). Foliage amounted to only about 1 to 5 percent.

NITROGEN DYNAMICS

Of the many elements essential for tree growth, nitrogen (N) is required in greater amounts than any other mineral nutrient, and is usually the most limiting in eastern forest soils (Stone 1973).

Nitrogen is unique among the soil macro-nut ents because it is present almost entirely as organic forms. No inorganic soil reserve is normally present to alleviate losses of N due forest management practices. Timber harve and site preparation techniques required to regenerate aspen can impact soil organic ma levels, and consequently the soil microflora in the cycling of soil N. Of particular import is the addition of atmospheric N to the soil b fixing microorganisms, and the mineralizati organic N to NH_4 and NO_3.

A few species of symbiotic N-fixing plants oc curred on the sites:

Alnus crispa	CL
Amphicarpa bracteata	PB
Lathyrus ochroleucus	CL
Melilotus alba	BF
Trifolium repens	BF
Vicia americana	CL

Table 13.—*Matrix of the number of species present on each site (the highlighted diagonal), the number of species in common (below diagonal)*[1], *and indices of similarity (above diagonal). For example, BF has 14 tree species, 7 of these in common with HHL, and is 50 percent similar to HHL in tree species.*

	BF	CL	HHZ	HHR	HHL	PB
			Trees			
BF	$\boxed{14}$	43	41	43	50	67
CL	6	$\boxed{14}$	83	79	64	67
HHZ	6	12	$\boxed{15}$	97	83	73
HHR	6	11	14	$\boxed{14}$	86	71
HHL	7	9	12	12	$\boxed{14}$	80
PB	10	10	11	11	12	$\boxed{16}$
			Shrubs			
BF	$\boxed{11}$	61	50	25	0	56
CL	7	$\boxed{12}$	59	35	0	69
HHZ	4	5	$\boxed{5}$	60	0	53
HHR	2	3	3	$\boxed{5}$	0	32
HHL	0	0	0	0	$\boxed{0}$	0
PB	7	9	5	3	0	$\boxed{14}$
			Herbs			
BF	$\boxed{41}$	41	37	42	27	41
CL	15	$\boxed{33}$	70	56	37	48
HHZ	12	20	$\boxed{24}$	80	53	45
HHR	13	15	18	$\boxed{21}$	58	41
HHL	7	8	9	9	$\boxed{10}$	25
PB	16	17	14	12	6	$\boxed{38}$

[1]Index of similarity = $\left(\frac{2w}{(a+b)}\right) \times 100$, where "w" is the specie count in common, "a" is the specie count on one site, and "b" is the count on the other. Values of complete identity = 100, completely different = 0. (Modified after Sorenson (1948); reviewed by Chambers and Brown 1983).

The low frequency of occurrence of these plants, however (Appendices 3, 4), indicates that they contribute little to nitrogen accretion at this stage of stand development.

Soil samples were taken periodically from the forest floor and at various depths in the mineral soil to determine N-fixation rates and NH_4 and NO_3 concentrations. Nitrogen fixation rates were measured using the acetylene reduction technique (Hardy *et al.* 1973). Ammonium and NO_3 concentrations were determined by specific ion electrodes.

Available soil N levels did not reflect site productivity (table 14). Available N levels in the mineral soil were lowest at BF, and were similar at CL and PB. The low concentrations of available N in the forest floor at CL were due to the lack of an O_a layer in this soil. High moisture contents in the mineral soil at BF were associated with low available soil N.

Nitrogen fixation rates were highest in the organic layers and decreased with depth in the mineral soil on all three sites (table 15). This was expected, because nearly all N-fixing microorganisms require organic substrates as energy sources. Because of their high bulk density, however, the amount of N fixed by the mineral

Table 14.—*Available soil N concentrations (NH4 and NO3)*[1]

Site and soil strata	NO3	NH4
	- - - *ppm* - - -	
Baltimore Flats		
Forest Floor	13.2	51.5
Mineral Soil		
0-5 cm	5.0	3.5
20-30 cm	4.6	1.7
Cloquet		
Forest Floor	8.2	4.1
Mineral Soil		
0-5 cm	7.4	6.4
20-30 cm	5.2	4.5
90-100 cm	4.1	2.4
Pike Bay		
Forest Floor	12.4	53.1
Mineral Soil		
0-5 cm	6.8	6.9
20-30 cm	4.4	4.0
90-100 cm	5.3	2.8

[1]Sampled in May, June, and July 1978.

Table 15.—*Nitrogen additions from nonsymbio soil nitrogen fixation*

	N fixation rate	N fixe
	ng N/g/24h	*kg/ha/*
Baltimore Flats		
Forest Floor	74.8	1.43
Mineral Soil		
0-5 cm	20.0	1.74
5-25 cm	6.2	2.53
		5.70
Cloquet		
Forest Floor	41.2	.49
Mineral Soil		
0-5	11.0	.82
5-25 cm	3.7	1.44
		2.75
Pike Bay		
Forest Floor	54.7	.78
Mineral Soil		
0-5 cm	9.8	.88
5-25 cm	2.1	.89
		2.55

soil was greater than that fixed in the forest floor (table 15).

Nitrogen fixation inputs in 1978 were similar on both the CL and PB sites, but the contribution of the forest floor to the total was much different. The incorporation of organic materials into the surface mineral horizons by earthworms at CL reduced N-fixing activity in the forest floor, but increased it deeper in the soil. In contrast to CL and PB, nitrogen additions were more than twice as high in the more poorly drained BF site. Nearly all nonsymbiotic N-fixing bacteria are either facultative or strict anaerobes, and their activity would be favored in a soil with higher moisture contents.

Nitrogen inputs from nonsymbiotic N fixation on these sites (table 15) appear to be somewhat less than that from precipitation, but would be appreciable over a rotation (Pastor and Bockheim 1984, Verry and Timmons 1982).

INSECTS AND DISEASE

Aspen are damaged by many diseases and pests throughout the rotation of a stand. (few of these insects and diseases, however, seriously injure or kill trees (Batzer 1972, / son 1972, Ostry *et al.* 1989). There are a r ber of insects and diseases that affect juve aspen; however, the greatest damage and \ loss occurs in the older age classes (Ostry

Although defoliating insects and foliage dis are not usually important, growth of affect trees can be reduced, and defoliated asper be predisposed to other damaging agents. Lake States, the forest tent caterpillar (*Malacosoma disstria*), has the greatest im any forest insect on aspen in the north-ce United States. Periodic outbreaks of this can defoliate aspen over large areas for se consecutive years. Leaf diseases caused l *Marssonina, Septoria, Ciborinia, Melamps*

Venturia are widespread throughout the range of aspen. Except for shoot blight caused by *Venturia macularis* in young sucker stands, these diseases are of minor importance (Perala 1984, Ostry In prep.).

The greatest impact on aspen is the reduction in volume and quality caused by canker and decay fungi. *Phellinus tremulae*, the cause of white trunk rot, is the predominant decay organism that affects aspen in the Lake States. The most common canker disease resulting in stem breakage and tree death is Hypoxylon canker caused by the fungus *Hypoxylon mammatum*. Susceptibility of aspen to *H. mammatum* varies by clone (Capony and Barnes 1974) and may be influenced by many stand factors (Anderson and Martin 1981). White trunk rot and Hypoxylon canker often limit the rotation age of aspen in the Lake States. Cankers caused by *Nectria galligena* or *Ceratocytis fimbriata* can also be prevalent on aspen, lowering wood quality and weakening stems. The perennial cankers caused by these fungi, however, cannot easily be distinguished from each other in the field.

Wood-boring insects can degrade wood, provide entry courts for fungi and bacteria, and weaken trees, subjecting them to wind breakage. The most damaging wood borer is the poplar borer, *Saperda calcarata*, which extensively tunnels in the cambium of infested trees. A number of wood-boring insects and insects that oviposit on aspen have been found important in providing wounds that increase infection of aspen by *H. mammatum* (Ostry and Anderson 1990).

In July 1977, the prevalence of white trunk rot, Hypoxylon canker, and "Nectria" canker was recorded for all aspen on the permanent tree measurement plots at the BF, CL, and PB sites. The presence of fruit bodies (conks) of *Phellinus* was used to identify trees with white trunk rot. Since the volume of wood affected by hidden decay (early stage of decay or trees with no external symptoms) can equal that with visible symptoms, the actual incidence of white trunk rot may be considerably greater than recorded. Hypoxylon cankers that were potentially lethal (lower bole cankers) or top cankers that would reduce the merchantable volume of affected trees were recorded. Any other serious damage by biotic or abiotic agents and the DBH of all aspen were recorded.

The prevalence of white trunk rot and cankers was generally low throughout the study sites (table 16). Aspen was affected by white trunk rot most frequently at the PB site. "Nectria" canker was present on a relatively large number of trees at CL, but on few trees at the other sites. Hypoxylon canker was present on more trees at BF than at CL or PB. Typically, the prevalence of Hypoxylon canker is greater in pole-sized stands than in the older age classes.

Table 16.—*Preharvest prevalence of white trunk rot and cankers of aspen in 1977*

Site	Percentage of aspen affected		
	White trunk rot	Hypoxylon canker	"Nectria" canker
BF	7	4	<1
CL	3	1	11
PB	38	<1	1

White trunk rot and bacterial wetwood significantly increase as aspen matures. In addition, the thin bark of aspen is easily wounded by biotic and abiotic agents, and these wounds provide an increasing number of entry points for many fungi and bacteria that further degrade aspen in older age classes.

WILDLIFE

Traditionally, the forest ecosystems in the Lake States were most valued for their yields of timber, white-tailed deer, and ruffed grouse, as well as for furbearers and minor game species. Nongame species were simply accepted as inherent to the ecosystem (Yahner 1989). In the 1970's, concerns about endangered species and other sensitive wildlife led to the protection of nest sites for bald eagles and ospreys. The National Forest Management Act of 1976 required the USDA Forest Service to maintain biological diversity, which broadened management considerations to all vertebrate and plant species. State mandates and initiatives are evolving rapidly to supplement Federal laws (*e.g.*, Millsap 1990, Zumeta 1991).

Characteristic wildlife of regenerating and juvenile aspen stands include the song sparrow, white-throated sparrow, mourning warbler, and chestnut-sided warbler (Back 1979, Niemi and Hanowski 1984, Probst *et al.* 1991), as well as game and nongame species that use edges or a variety of habitat ages, such as white-tailed deer, black bear, ruffed grouse, American woodcock, red-tailed hawk, and veery.

As regenerating aspen stands grow into sapling and small-pole stands, they have a higher proportion of species that are more specific to mature forests, including many Neotropical migrant birds or woodland raptors. Common among these are the ovenbird, least flycatcher, red-eyed vireo, and veery (Probst *et al.* 1991). Pole stands support few unique species, but provide habitat for ruffed grouse, black and white warblers, and American redstarts (Probst 1979, Thompson and Fritzell 1990). Habitat characteristics associated with overmature aspen are important to many plants and animals. Large, dead trees are used by both mammals and birds. Decadent, declining aspen stands that have a sparse canopy provide raptor perches as well as habitat for songbirds like the northern oriole, warbling vireo, blue-gray gnatcatcher, and wood pewee. The developing understory should have vegetation structure and associated fauna similar to stands regenerating after wholesale disturbance. Coarse woody debris is important to invertebrates, herpetofauna, black bears, and ground-foraging birds. Small mammal populations are sensitive to stand disturbance (Probst and Rakstad 1987), and rise or fall, depending on the amount of woody material remaining.

Small mammals were trapped in late September and October at PB and BF (1977, 1978, 1979) and at CL (1977). Trap stations were spaced at 15-m intervals along transect lines located 50 m apart. This grid provided 12 stations pe are. Two snap-traps baited with peanu were placed at each station and were ch and rebaited for 5 consecutive days.

Bird censuses were conducted at PB in 1978, and 1980; at BF in 1977, 1978, and at CL in 1977 and 1978. Bird den estimated using a modification of the s mapping techniques as described by P (1979). Six or seven census visits wer each study plot between May 20 and J The number of species included partia ries. The number of singing males of species was determined by using data total number recorded each trip (non-species) or the number of discrete loc where a species was found (territorial The number of males of non-singing s estimated by assuming an even sex r halving the average number of indivic counted each trip. Species that forag within the study areas but nested els estimated by averaging the number c seen on each census trip. The estim for each singing territorial species w by summing the number of territoria the estimated fractions of territories pletely contained within each censu Breeding bird densities were express number of males per 40 ha.

The total number of mammals trap dramatically from east to west with times as many at PB as at BF (table site, one species was two or three ti common than its nearest competito mouse was most numerous at both PB sites, but the most common spe was the red-backed vole.

Total bird numbers differed little b but individual species varied great site (table 17). The great-crested fl the brown-headed cowbird were m common at BF than at the other s chestnut-sided warbler and the m bler were present in abundant nu but absent from the other sites. T the highest counts (least flycatche vireo) were much more common a the other sites (table 17).

Table 17.—*Small mammal (number per 1,000 trap-station nights) and breeding bird populations (number per 40 ha) in unharvested aspen stands in northern Minnesota and Michigan's Upper Peninsula*

Species	Baltimore Flats	Cloquet	Pike Bay
Masked Shrew (*Sorex cinereus*)	0.3	17	0
Short-tailed Shrew (*Blarina brevicauda*)	16.3	7	0.3
Deer Mouse (*Peromyscus maniculatus*)	54	13	195
White-footed Mouse (*Peromyscus leucopus*)	1.3	80	104
Red-backed Vole (*Clethrionomys gapperi*)	3.3	147	89
Sum Mammals	75	264	388
Ruffed Grouse (*Bonasa umbellus*)	2.0	+	-
Broad-winged Hawk (*Buteo platypterus*)	-	+	+
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	+	1.5	+
Pileated Woodpecker (*Dryocopus pileatus*)	-	+	+
Common Flicker (*Colaptes auratus*)	+	1.3	-
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	-	-	2.7
Downy Woodpecker (*Dendrocopus pubescens*)	-	+	+
Hairy Woodpecker (*Dendrocopus villosus*)	4.0	2.0	1.3
Great-crested Flycatcher (*Myiarchus crinitus*)	13.0	1.5	1.7
Eastern Wood-pewee (*Contopus virens*)	-	4.5	6.7
Least Flycatcher (*Empidonax minimus*)	11.0	16.0	46.7
Blue Jay (*Cyanocitta cristata*)	+	1.3	0.3
Black-capped Chickadee (*Parus atricapillus*)	4.0	4.0	1.3
White-breasted Nuthatch (*Sitta carolinensis*)	-	-	1.0
Red-breasted Nuthatch (*Sitta canadensis*)	-	6.0	-
Robin (*Turdis migratorius*)	-	2.0	0.3
Veery (*Hylocichla fuscescens*)	4.0	10.0	6.7
Hermit Thrush (*Hylocichla guttata*)	1.3		-
Red-eyed Vireo (*Vireo olivaceus*)	27.0	19.5	39.7
Yellow-throated Vireo (*Vireo flavifrons*)	-	-	1.7
Parula Warbler (*Parula americana*)		-	0.7
Black-throated Green Warbler (*Dendroica virens*)	4.0	-	3.1
Chestnut-sided Warbler (*Dendroica pensylvanica*)	-	20.5	-
Blackburnian Warbler (*Dendroica fusca*)	+	1.3	+
Black-and-white Warbler (*Mniotilta varia*)	2.0	-	-
Ovenbird (*Seiurus aurocapillus*)	6.0	17.7	17.3
Mourning Warbler (*Oporornis philadelphia*)	-	10.5	-
Canada Warbler (*Wilsonia canadensis*)	2.0	-	-
Brown-headed Cowbird (*Molothrus ater*)	26.0	1.0	0.6
Scarlet Tanager (*Piranga olivacea*)	+	1.7	2.7
Purple Finch (*Carpodacus purpureus*)	+	+	1.0
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	8.0	3.0	+
Chipping Sparrow (*Spizella passerina*)	+	0.7	+
Sum Birds	114	126	133

ACKNOWLEDGMENTS

J. Bondioli, D. Benson, Dr. A. Hallgren, and D. Lauber provided the BF, CL, and HH study sites. Dr. V. Kurmis and Dr. R. Leary determined the synecological coordinates for all sites. J. Jordan classified the Habitat Type of the BF site. G. Goltz, J. Jordan, P. Nyberg, and R. Lewis formally described the soil pits. For their assistance, cooperation, and enthusiasm for the research conducted here, we are grateful.

LITERATURE CITED

Adams, Roy D., ed. 1990. **Aspen symposium '89 proceedings**; 1989 July 25-27; Duluth, MN. Gen. Tech. Rep. NC-140. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 348 p.

Alban, D.H.; Perala, D.A. 1990. **Impact of aspen timber harvesting on soils**. In: Gessel, S.P.; Lacate, D.S.; Weetman, G.F.; Powers, R.F., eds. Sustained productivity of forest soils: Proceedings of the 7th North American forest soils conference; Vancouver, BC: University of British Columbia: 377-391.

Aldeen, D. 1991. **Soil survey of Wadena County, Minnesota**. U.S. Department of Agriculture, Soil Conservation Service. (In press.)

Anderson, G.W. 1972. **Diseases**. In: Aspen symposium proceedings. Gen. Tech. Rep. NC-1. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 74-82.

Anderson, G.W.; Martin, M.P. 1981. **Factors related to incidence of Hypoxylon cankers in aspen and survival of cankered trees**. Forest Science. 27: 461-476.

Back, G. 1979. **Avian communities and management guidelines of the aspen-birch forest**. In: Proceedings, Symposium on management of north central and northeastern forests for nongame birds. Gen. Tech. Rep. NC-51. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 67-79.

Bakuzis, E.V.; Hansen, H.L. 1959. **A prov assessment of species synecological r ments in Minnesota forests**. Minnesot Forestry Notes 84. 2 p.

Barron, D.D. 1979. **Soil survey of Kittso County, Minnesota**. U.S. Department c Agriculture, Soil Conservation Service.

Batzer, H.O. 1972. **Insects**. In: Aspen syr sium proceedings. Gen. Tech. Rep. NC- Paul, MN: U.S. Department of Agricultu Forest Service, North Central Forest Ex ment Station: 83-87.

Berndt, L.W. 1988. **Soil survey of Barag County area, Michigan**. U.S. Departm Agriculture, Soil Conservation Service.

Black, R.F. 1969. **Valderan glaciation i ern upper Michigan**. In: Proceedings, conference. Ann Arbor, MI: Internation Association Great Lakes Research: 11

Blyth, J.E.; Smith, W.B. 1988. **Pulpwoo duction in the north-central region county, 1986**. Resour. Bull. NC-106. MN: U.S. Department of Agriculture, F Service, North Central Forest Experim Station. 26 p.

Bray, J.R.; Gorham, E. 1964. **Litter pr in forests of the world**. Advanced Ec Research. 2: 101-157.

Brinkman, Kenneth A.; Roe, Eugene I. **Quaking aspen: silvics and manage the Lake States**. Agric. Handb. 486. ton, DC: U.S. Department of Agricult

Capony, J.A.; Barnes, B.V. 1974. **Clon tion in the incidence of Hypoxylon on trembling aspen**. Canadian Jour Botany. 52: 1475-1481.

Chambers, J.C.; Brown, R.W. 1983. **M vegetation sampling and analysis c etated mined lands**. Gen. Tech. Rep Ogden, UT: U.S. Department of Agric Forest Service, Intermountain Forest Range Experiment Station. 57 p.

Coffman, M.S., Alyanak, E.; Kotar, J.; Ferris, J.E. 1983. **Field guide, habitat classification system for Upper Peninsula of Michigan and northeast Wisconsin**. Houghton, MI: CROFS; Department of Forestry, Michigan Technological University (paged in sections).

Cooper, A.W. 1981. **Aboveground biomass accumulation and net primary production during the first 70 years of succession in *Populus grandidentata* stands on poor sites in northern lower Michigan**. In: West, D.C.; Shugart, H.H.; Botkin, D.B., eds. Forest successions. New York: Springer-Verlag: 339-360.

Corns, I.G.W. 1989. **Ecosystems with potential for aspen management**. Forestry Chronicle. 65: 16-22.

Crow, T. W. 1974. **Temporal and spatial patterns of pretreatment litter production in site 1 and the control area**. In: Rudolph, T.D., ed. The Enterprise, Wisconsin, Radiation Forest: preirradiation ecological studies. Washington, DC: Technical Information Center, U.S. Atomic Energy Commission: 105-113.

Davidson, R.W.; Atkins, R.C.; Fry, R.D.; Racey, G.D.; Weingartner, D.H. 1989. **A silvicultural guide for the Poplar Working Group in Ontario**. Ontario Ministry of Natural Resources, Toronto. Science and Technology Series; vol. 5: 67 p.

DeByle, Norbert V.; Winokur, Robert P., eds. 1985. **Aspen: ecology and management in the western United States**. Gen. Tech. Rep. RM-119. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 283 p.

Doucet, R. 1989. **Regeneration silviculture of aspen**. Forestry Chronicle. 65(1): 23-27.

Erickson, R.B.; Harms, G.F.; Rust, R.H. 1971. **Minnesota soil atlas, Hibbing sheet**. Misc. Rep. 110. St. Paul, MN: University of Minnesota, Agricultural Experiment Station. 47 p.

Erickson, R.A.; Rust, R.H.; Harms, G.F. 1980. **Minnesota soil atlas, Bemidji sheet**. Misc. Rep. 168. St. Paul, MN: University of Minnesota, Agricultural Experiment Station. 74 p.

Erickson, R.A.; Rust R.H.; Harms, G.F.; Hanson, L.D. 1977. **Minnesota soil atlas, Duluth sheet**. Misc. Rep. 148. St. Paul, MN: University of Minnesota, Agricultural Experiment Station. 51 p.

Graham, S.A.; Harrison, R.P., Jr.; Westell, C.E., Jr. 1963. **Aspens: phoenix trees of the Great Lakes region**. Ann Arbor, MI: University of Michigan Press. 272 p.

Grigal, D.F.; Severson, R.C.; Goltz, G.E. 1976. **Evidence of eolian activity in north-central Minnesota 8,000 to 5,000 years ago**. Geological Society of America Bulletin. 87: 1251-1254.

Hack, J.T. 1965. **Postglacial drainage evolution and stream geometry in the Ontonagon area, Michigan**. Geological Survey Professional Paper 504-B. 40 p.

Hardy, R.W.F.; Burns, R.D.; Holsten, R.D. 1973. **Application of the acetylene-ethylene assay for measurement of nitrogen fixation**. Soil Biology and Biochemistry. 5: 47-81.

Lewis, R.C. 1978. **Soil survey of Carlton County, Minnesota**. U.S. Department of Agriculture, Soil Conservation Service. 77 p.

Millsap, B.A. 1990. **Setting priorities for the conservation of fish and wildlife species in Florida**. Wildlife Monographs. 111: 1-57.

Navratil, S.; Bella, I.E.; Peterson, E.B. 1990. **Silviculture and management of aspen in Canada: the western Canada scene**. In: Adams, R.D., ed. Aspen symposium '89 proceedings; 1989 July 25-27; Duluth, MN. Gen. Tech. Rep. NC-140. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 39-60.

Niemi, G.J.; Hanowski, J.M. 1984. **Relationship of breeding birds to habitat characteristics in logged areas**. Journal of Wildlife Management. 48: 438-443.

Nyberg, P.R. 1987. **Soil survey of Itasca County, Minnesota**. U.S. Department of Agriculture, Soil Conservation Service. 197 p.

Ohmann, L.F.; Ream, R.R. 1971. **Wilderness ecology: a method of sampling and summarizing data for plant community classification**. Res. Pap. NC-49. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 14 p.

Ojakangas, R.W.; Matsch, C.L. 1982. **Minnesota's geology**. St. Paul, MN: University of Minnesota Press. 255 p.

Ostry, M.E. 1986. **Aspen management minimizes disease impact**. In: Proceedings, Integrated pest management symposium for northern forests. Madison, WI: University of Wisconsin Cooperative Extension Service: 191-199.

Ostry, M.E.; Anderson, N.A. 1990. **Disease resistance in a wild system: Hypoxylon canker of aspen**. In: Adams, R.D., ed. Aspen symposium '89 proceedings; 1989 July 25-27; Duluth, MN. Gen. Tech. Rep. NC-140. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 237-241.

Ostry, M.E.; Wilson, L.F.; McNabb, H.S., Jr.; Moore, L.M. 1989. **A guide to insect, disease, and animal pests of poplars**. Agric. Handb. 677. Washington, DC: U.S. Department of Agriculture, Forest Service. 118 p.

Pastor, J.; Bockheim, J.G. 1984. **Distribution and cycling of nutrients in an aspen-mixed hardwood-spodosol ecosystem in northern Wisconsin**. Ecology. 65: 339-353.

Perala, D.A. 1977. **Manager's handbook for aspen in the north central States**. Gen. Tech. Rep. NC-36. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 30 p.

Perala, D.A. 1984. **How endemic injuries affect early growth of aspen suckers**. Canadian Journal of Forest Research. 14: 755-762.

Perala, D.A. 1986. **Aspen management**. In: Proceedings, Integrated pest management symposium for northern forests; 1986 March 24-27; Madison, WI: University of Wisconsin Cooperative Extension Service: 87-97.

Perala, D.A. 1990. ***Populus tremuloides* Mi quaking aspen**. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North Americ Hardwoods. Agric. Handb. 654. Washingtc DC: U.S. Department of Agriculture, Fores Service: 555-569.

Perala, D.A.; Alban, D.H. 1982. **Biomass, n ent distribution, and litterfall in *Popul Pinus*, and *Picea* stands on two differe soils in Minnesota**. Plant-Soil. 64: 177-1

Perala, D.A.; Russell, J. 1983. **Aspen**. In: E R.M., tech. comp. Silvicultural systems f major forest types of the United States. A Handb. 445. Washington, DC: U.S. Depa of Agriculture, Forest Service: 113-115.

Peterson, W.L. 1986. **Late Wisconsin gla history of northwestern Wisconsin an western upper Michigan**. Bull. 1652. V ington, DC: U.S. Geological Survey. 14

Probst, J.R. 1979. **Oak forest bird comn ties**. In: Proceedings, Symposium on m ment of north central and northeastern for nongame birds; 1979 January 23-2 Minneapolis, MN. Gen. Tech. Rep. NC- Paul, MN: U.S. Department of Agricult Forest Service, North Central Forest E ment Station: 80-88.

Probst, J.R.; Rakstad, D.S. 1987. **Small mal communities in three aspen st classes**. Canadian Field Naturalist. 1 368.

Probst, J.R.; Rakstad, D.S.; Rugg, D.J. **Breeding bird communities in rege and mature broadleaf forests in th Lake States**. Forest Ecology and Ma In Press.

Rauscher, H.M. 1984. **Homogeneous climatic zones of the Lake States**. NC-240. St. Paul, MN: U.S. Departm Agriculture, Forest Service, North C Forest Experiment Station. 39 p.

Ruark, G.A.; Bockheim, J.C. 1988. **B primary production, and nutrient tion for an age sequence of *Popu tremuloides* ecosystems**. Canadi Forest Research. 18: 433-443.

Shepperd, W.D.; Engelby, O. 1983. **Rocky Mountain aspen**. In: Burns, R.M., tech. comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture, Forest Service: 77-79.

Soil Survey Staff. 1975. **Soil taxonomy**. Agric. Handb. 436. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. 754 p.

Sorenson, T. 1948. **A method for establishing groups of equal magnitude in plant sociology based on similarity of species content**. Akta K. Danske Vidensk. Selsk. Biol. Skr. J. 5: 1-34.

Stone, E.L. 1973. **Regional objectives in forest fertilization, current and potential**. In: Leaf, A.L.; Leonard, R.E., eds. Forest fertilization. Gen. Tech. Rep. NE-3. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 10-18.

Thompson, F.R.; Fritzell, E.K. 1990. **Bird densities and diversity in clearcut and mature oak-hickory forests**. Res. Pap. NC-293. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

Verry, E.S.; Timmons, D.R. 1982. **Waterborne nutrient flow through an upland-peatland watershed in Minnesota**. Ecology. 63: 1456-1467.

Wright, H.E., Jr. 1972. **Quaternary history of Minnesota**. In: Sims, P.K.; Wory, G.B., eds. Geology of Minnesota: a centennial volume. St. Paul, MN: Minnesota Geological Society: 515-547.

Wright, H.E., Jr.; Mattson, L.A.; Thomas, J.A. 1970. **Geology of the Cloquet quadrangle, Carlton County, Minnesota**. GM-3. St. Paul, MN: Minnesota Geological Survey GM-3. 30 p.

Yahner, R.H. 1989. **Forest management and featured species of wildlife: effects on coexisting species**. In: Finley, J.; Brittingham, M., eds. Proceedings, Symposium on timber management and its effects on wildlife. University Park, PA: Pennsylvania State University, School of Forest Resources: 146-161.

Zumeta, D.C. 1991. **Protecting biological diversity: a major challenge for Minnesota forestry in the 1990s**. Journal of Minnesota Academy of Science. 56: 24-33.

APPENDIX 1.—STUDY SITE LAYOUT

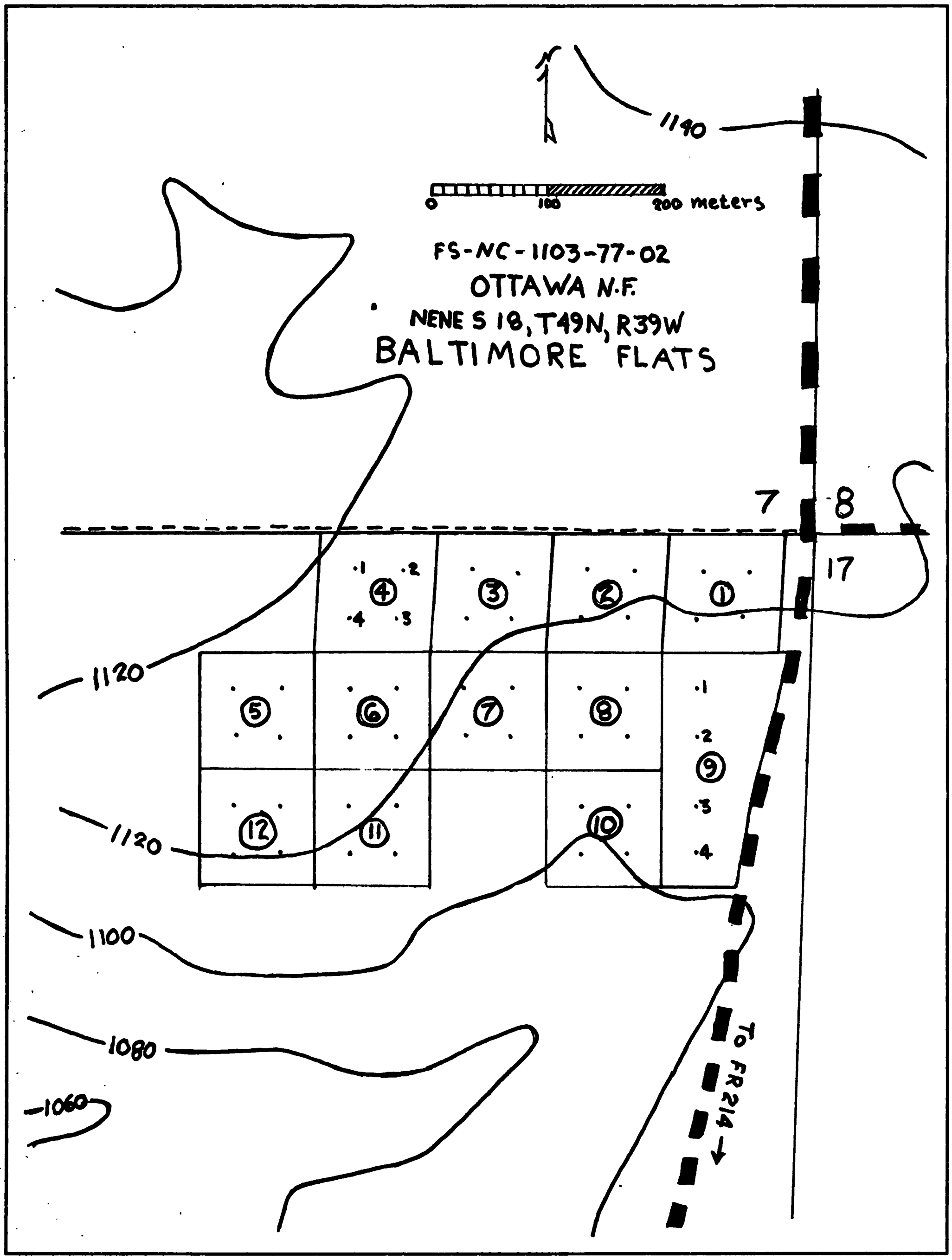
This appendix contains study site maps and treatment plot identification.

Treatment	BF	CL	PB
Clearcut, whole tree	<u>3</u>,6,7,<u>11</u>	<u>7</u>,8,<u>10</u>,16	<u>1</u>,3,5,11, 12,<u>17</u>
Clearcut, merchantable bole	1,2,<u>8</u>,<u>10</u>	<u>2</u>,4,6,<u>9</u>	<u>4</u>,8,9,13, <u>15</u>,16
Shelterwood cut, whole tree	none	1,11	10,14
Shelterwood cut, merchantable bole	none	3,5	6,7

Treatment plots converted after harvesting to *Picea glauca* (Moench) Voss are underlined. Contour interval is in feet.

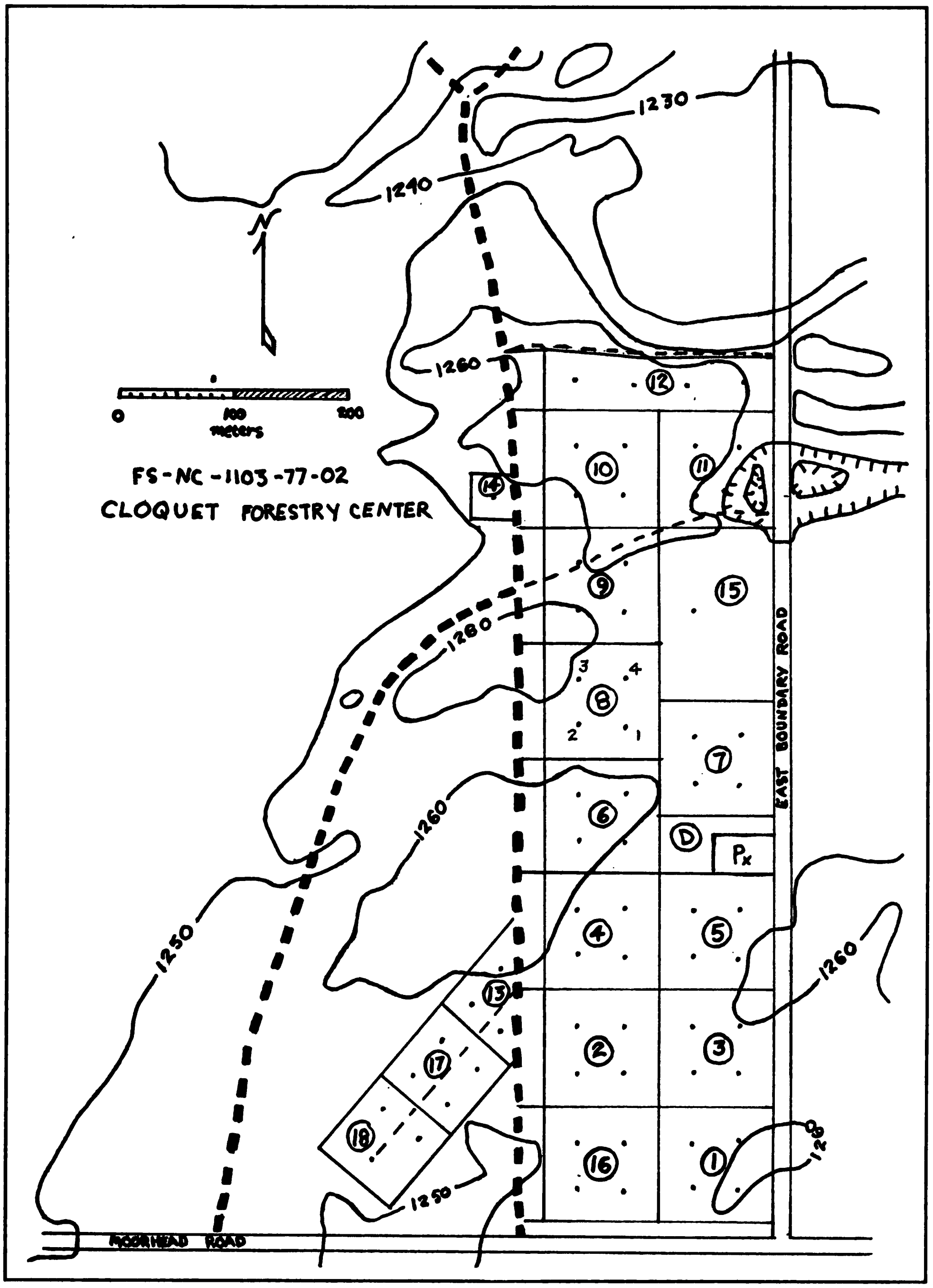
APPENDIX 1.—STUDY SITE LAYOUT

a. Baltimore Flats



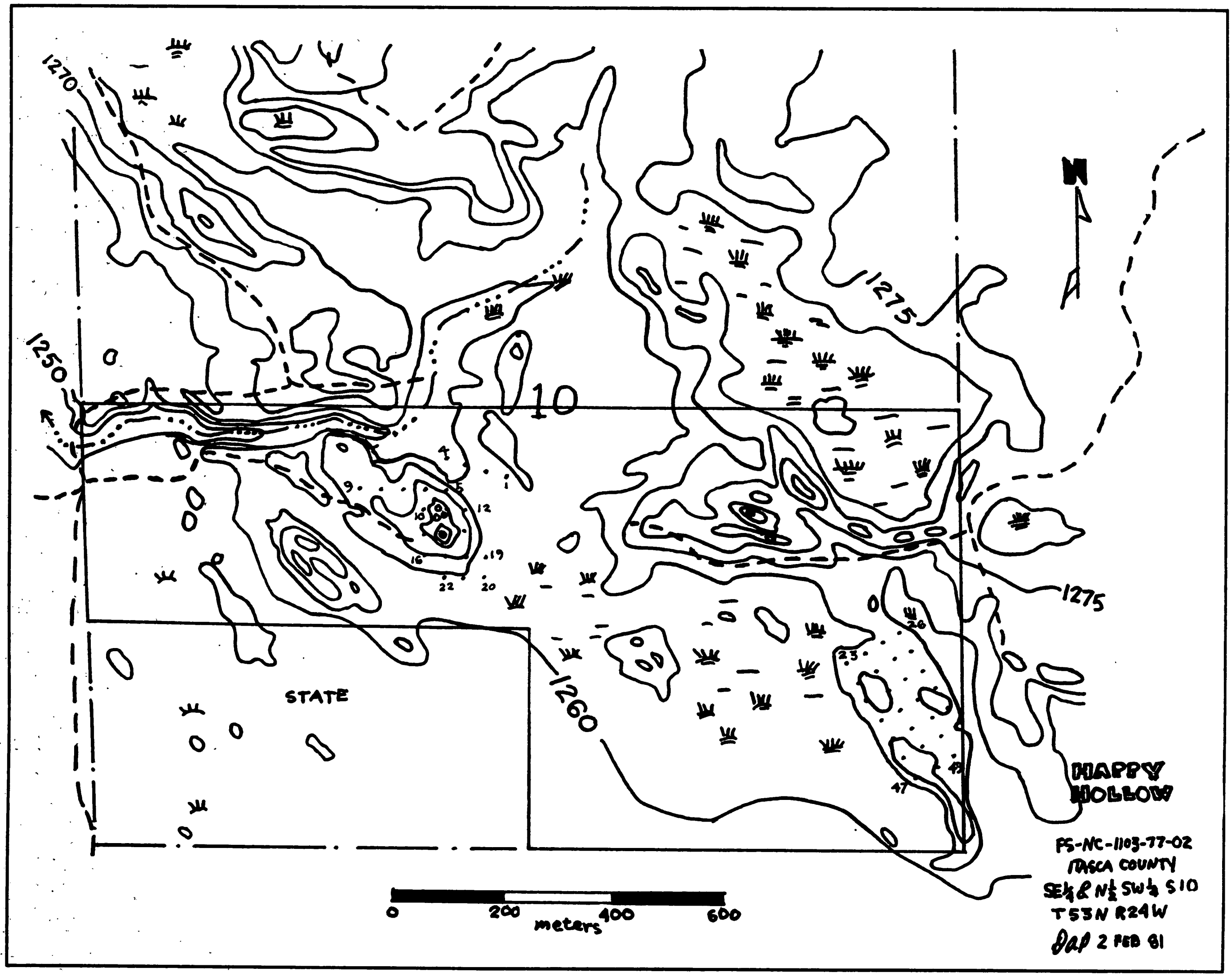
APPENDIX 1.—STUDY SITE LAYOUT

b. Cloquet



APPENDIX 1.—STUDY SITE LAYOUT

c. Happy Hollow



APPENDIX 1.—STUDY SITE LAYOUT

d. Pike Bay

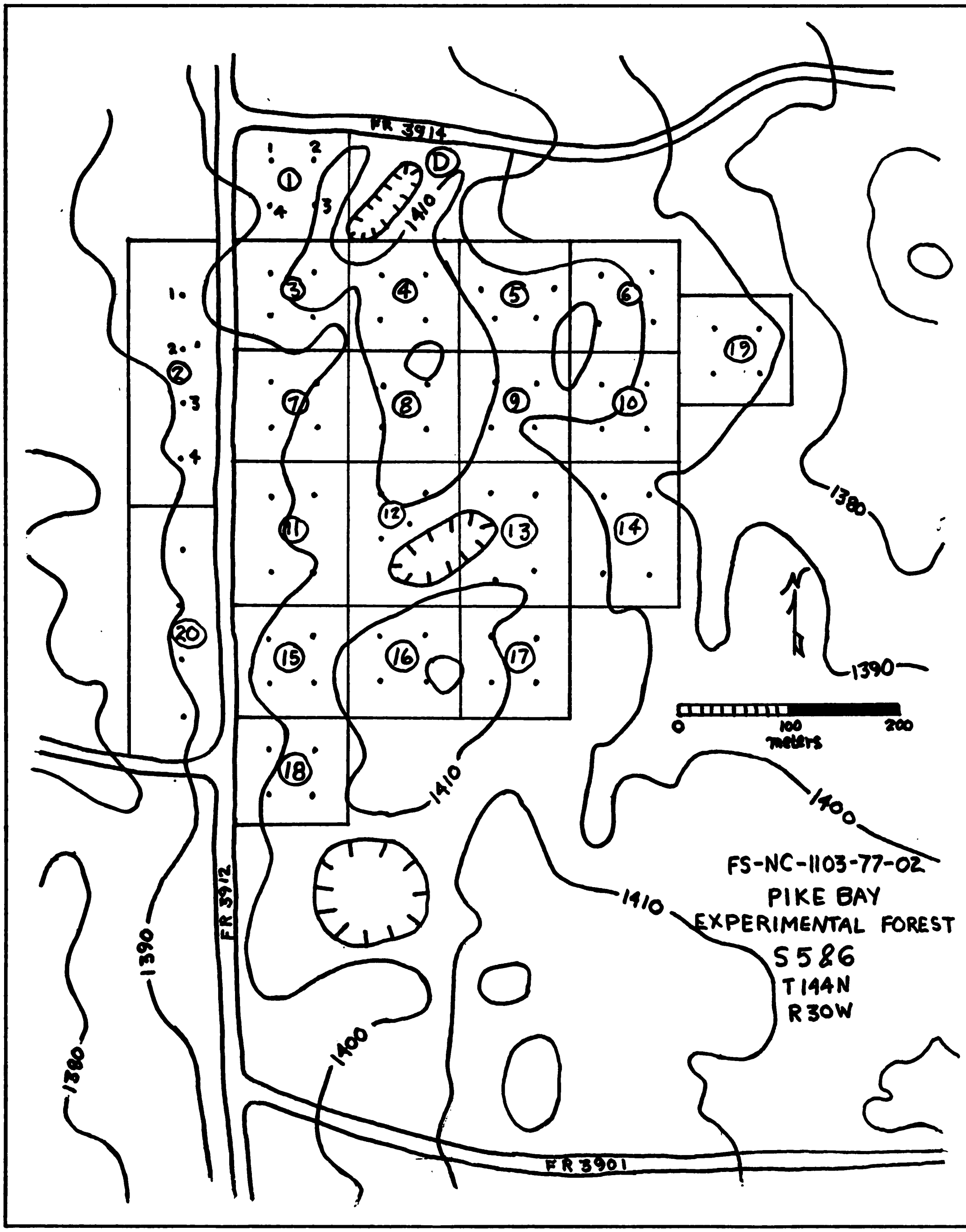


Table 17.—*Small mammal (number per 1,000 trap-station nights) and breeding bird populations (number per 40 ha) in unharvested aspen stands in northern Minnesota and Michigan's Upper Peninsula*

Species	Baltimore Flats	Cloquet	Pike Bay
Masked Shrew (*Sorex cinereus*)	0.3	17	0
Short-tailed Shrew (*Blarina brevicauda*)	16.3	7	0.3
Deer Mouse (*Peromyscus maniculatus*)	54	13	195
White-footed Mouse (*Peromyscus leucopus*)	1.3	80	104
Red-backed Vole (*Clethrionomys gapperi*)	3.3	147	89
Sum Mammals	75	264	388
Ruffed Grouse (*Bonasa umbellus*)	2.0	+	-
Broad-winged Hawk (*Buteo platypterus*)	-	+	+
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	+	1.5	+
Pileated Woodpecker (*Dryocopus pileatus*)	-	+	+
Common Flicker (*Colaptes auratus*)	+	1.3	-
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	-	-	2.7
Downy Woodpecker (*Dendrocopus pubescens*)	-	+	+
Hairy Woodpecker (*Dendrocopus villosus*)	4.0	2.0	1.3
Great-crested Flycatcher (*Myiarchus crinitus*)	13.0	1.5	1.7
Eastern Wood-pewee (*Contopus virens*)	-	4.5	6.7
Least Flycatcher (*Empidonax minimus*)	11.0	16.0	46.7
Blue Jay (*Cyanocitta cristata*)	+	1.3	0.3
Black-capped Chickadee (*Parus atricapillus*)	4.0	4.0	1.3
White-breasted Nuthatch (*Sitta carolinensis*)	-	-	1.0
Red-breasted Nuthatch (*Sitta canadensis*)	-	6.0	-
Robin (*Turdis migratorius*)	-	2.0	0.3
Veery (*Hylocichla fuscescens*)	4.0	10.0	6.7
Hermit Thrush (*Hylocichla guttata*)	1.3		-
Red-eyed Vireo (*Vireo olivaceus*)	27.0	19.5	39.7
Yellow-throated Vireo (*Vireo flavifrons*)	-	-	1.7
Parula Warbler (*Parula americana*)		-	0.7
Black-throated Green Warbler (*Dendroica virens*)	4.0	-	3.1
Chestnut-sided Warbler (*Dendroica pensylvanica*)	-	20.5	-
Blackburnian Warbler (*Dendroica fusca*)	+	1.3	+
Black-and-white Warbler (*Mniotilta varia*)	2.0	-	-
Ovenbird (*Seiurus aurocapillus*)	6.0	17.7	17.3
Mourning Warbler (*Oporornis philadelphia*)	-	10.5	-
Canada Warbler (*Wilsonia canadensis*)	2.0	-	-
Brown-headed Cowbird (*Molothrus ater*)	26.0	1.0	0.6
Scarlet Tanager (*Piranga olivacea*)	+	1.7	2.7
Purple Finch (*Carpodacus purpureus*)	+	+	1.0
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	8.0	3.0	+
Chipping Sparrow (*Spizella passerina*)	+	0.7	+
Sum Birds	114	126	133

ACKNOWLEDGMENTS

J. Bondioli, D. Benson, Dr. A. Hallgren, and D. Lauber provided the BF, CL, and HH study sites. Dr. V. Kurmis and Dr. R. Leary determined the synecological coordinates for all sites. J. Jordan classified the Habitat Type of the BF site. G. Goltz, J. Jordan, P. Nyberg, and R. Lewis formally described the soil pits. For their assistance, cooperation, and enthusiasm for the research conducted here, we are grateful.

LITERATURE CITED

Adams, Roy D., ed. 1990. **Aspen symposium '89 proceedings**; 1989 July 25-27; Duluth, MN. Gen. Tech. Rep. NC-140. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 348 p.

Alban, D.H.; Perala, D.A. 1990. **Impact of aspen timber harvesting on soils**. In: Gessel, S.P.; Lacate, D.S.; Weetman, G.F.; Powers, R.F., eds. Sustained productivity of forest soils: Proceedings of the 7th North American forest soils conference; Vancouver, BC: University of British Columbia: 377-391.

Aldeen, D. 1991. **Soil survey of Wadena County, Minnesota**. U.S. Department of Agriculture, Soil Conservation Service. (In press.)

Anderson, G.W. 1972. **Diseases**. In: Aspen symposium proceedings. Gen. Tech. Rep. NC-1. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 74-82.

Anderson, G.W.; Martin, M.P. 1981. **Factors related to incidence of Hypoxylon cankers in aspen and survival of cankered trees**. Forest Science. 27: 461-476.

Back, G. 1979. **Avian communities and management guidelines of the aspen-birch forest**. In: Proceedings, Symposium on management of north central and northeastern forests for nongame birds. Gen. Tech. Rep. NC-51. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 67-79.

Bakuzis, E.V.; Hansen, H.L. 1959. **A prov assessment of species synecological r ments in Minnesota forests**. Minnesot Forestry Notes 84. 2 p.

Barron, D.D. 1979. **Soil survey of Kittso County, Minnesota**. U.S. Department c Agriculture, Soil Conservation Service.

Batzer, H.O. 1972. **Insects**. In: Aspen syı sium proceedings. Gen. Tech. Rep. NC- Paul, MN: U.S. Department of Agricultu Forest Service, North Central Forest Ex ment Station: 83-87.

Berndt, L.W. 1988. **Soil survey of Barag County area, Michigan**. U.S. Departm Agriculture, Soil Conservation Service.

Black, R.F. 1969. **Valderan glaciation i ern upper Michigan**. In: Proceedings, conference. Ann Arbor, MI: Internation Association Great Lakes Research: 11

Blyth, J.E.; Smith, W.B. 1988. **Pulpwoo duction in the north-central region county, 1986**. Resour. Bull. NC-106. MN: U.S. Department of Agriculture, F Service, North Central Forest Experim Station. 26 p.

Bray, J.R.; Gorham, E. 1964. **Litter prc in forests of the world**. Advanced Ec Research. 2: 101-157.

Brinkman, Kenneth A.; Roe, Eugene I. **Quaking aspen: silvics and manage the Lake States**. Agric. Handb. 486. ton, DC: U.S. Department of Agricult

Capony, J.A.; Barnes, B.V. 1974. **Clon tion in the incidence of Hypoxylon on trembling aspen**. Canadian Jour Botany. 52: 1475-1481.

Chambers, J.C.; Brown, R.W. 1983. **M vegetation sampling and analysis c etated mined lands**. Gen. Tech. Rep Ogden, UT: U.S. Department of Agric Forest Service, Intermountain Forest Range Experiment Station. 57 p.

Coffman, M.S., Alyanak, E.; Kotar, J.; Ferris, J.E. 1983. **Field guide, habitat classification system for Upper Peninsula of Michigan and northeast Wisconsin**. Houghton, MI: CROFS; Department of Forestry, Michigan Technological University (paged in sections).

Cooper, A.W. 1981. **Aboveground biomass accumulation and net primary production during the first 70 years of succession in *Populus grandidentata* stands on poor sites in northern lower Michigan**. In: West, D.C.; Shugart, H.H.; Botkin, D.B., eds. Forest successions. New York: Springer-Verlag: 339-360.

Corns, I.G.W. 1989. **Ecosystems with potential for aspen management**. Forestry Chronicle. 65: 16-22.

Crow, T. W. 1974. **Temporal and spatial patterns of pretreatment litter production in site 1 and the control area**. In: Rudolph, T.D., ed. The Enterprise, Wisconsin, Radiation Forest: preirradiation ecological studies. Washington, DC: Technical Information Center, U.S. Atomic Energy Commission: 105-113.

Davidson, R.W.; Atkins, R.C.; Fry, R.D.; Racey, G.D.; Weingartner, D.H. 1989. **A silvicultural guide for the Poplar Working Group in Ontario**. Ontario Ministry of Natural Resources, Toronto. Science and Technology Series; vol. 5: 67 p.

DeByle, Norbert V.; Winokur, Robert P., eds. 1985. **Aspen: ecology and management in the western United States**. Gen. Tech. Rep. RM-119. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 283 p.

Doucet, R. 1989. **Regeneration silviculture of aspen**. Forestry Chronicle. 65(1): 23-27.

Erickson, R.B.; Harms, G.F.; Rust, R.H. 1971. **Minnesota soil atlas, Hibbing sheet**. Misc. Rep. 110. St. Paul, MN: University of Minnesota, Agricultural Experiment Station. 47 p.

Erickson, R.A.; Rust, R.H.; Harms, G.F. 1980. **Minnesota soil atlas, Bemidji sheet**. Misc. Rep. 168. St. Paul, MN: University of Minnesota, Agricultural Experiment Station. 74 p.

Erickson, R.A.; Rust R.H.; Harms, G.F.; Hanson, L.D. 1977. **Minnesota soil atlas, Duluth sheet**. Misc. Rep. 148. St. Paul, MN: University of Minnesota, Agricultural Experiment Station. 51 p.

Graham, S.A.; Harrison, R.P., Jr.; Westell, C.E., Jr. 1963. **Aspens: phoenix trees of the Great Lakes region**. Ann Arbor, MI: University of Michigan Press. 272 p.

Grigal, D.F.; Severson, R.C.; Goltz, G.E. 1976. **Evidence of eolian activity in north-central Minnesota 8,000 to 5,000 years ago**. Geological Society of America Bulletin. 87: 1251-1254.

Hack, J.T. 1965. **Postglacial drainage evolution and stream geometry in the Ontonagon area, Michigan**. Geological Survey Professional Paper 504-B. 40 p.

Hardy, R.W.F.; Burns, R.D.; Holsten, R.D. 1973. **Application of the acetylene-ethylene assay for measurement of nitrogen fixation**. Soil Biology and Biochemistry. 5: 47-81.

Lewis, R.C. 1978. **Soil survey of Carlton County, Minnesota**. U.S. Department of Agriculture, Soil Conservation Service. 77 p.

Millsap, B.A. 1990. **Setting priorities for the conservation of fish and wildlife species in Florida**. Wildlife Monographs. 111: 1-57.

Navratil, S.; Bella, I.E.; Peterson, E.B. 1990. **Silviculture and management of aspen in Canada: the western Canada scene**. In: Adams, R.D., ed. Aspen symposium '89 proceedings; 1989 July 25-27; Duluth, MN. Gen. Tech. Rep. NC-140. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 39-60.

Niemi, G.J.; Hanowski, J.M. 1984. **Relationship of breeding birds to habitat characteristics in logged areas**. Journal of Wildlife Management. 48: 438-443.

Nyberg, P.R. 1987. **Soil survey of Itasca County, Minnesota**. U.S. Department of Agriculture, Soil Conservation Service. 197 p.

Ohmann, L.F.; Ream, R.R. 1971. **Wilderness ecology: a method of sampling and summarizing data for plant community classification**. Res. Pap. NC-49. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 14 p.

Ojakangas, R.W.; Matsch, C.L. 1982. **Minnesota's geology**. St. Paul, MN: University of Minnesota Press. 255 p.

Ostry, M.E. 1986. **Aspen management minimizes disease impact**. In: Proceedings, Integrated pest management symposium for northern forests. Madison, WI: University of Wisconsin Cooperative Extension Service: 191-199.

Ostry, M.E.; Anderson, N.A. 1990. **Disease resistance in a wild system: Hypoxylon canker of aspen**. In: Adams, R.D., ed. Aspen symposium '89 proceedings; 1989 July 25-27; Duluth, MN. Gen. Tech. Rep. NC-140. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 237-241.

Ostry, M.E.; Wilson, L.F.; McNabb, H.S., Jr.; Moore, L.M. 1989. **A guide to insect, disease, and animal pests of poplars**. Agric. Handb. 677. Washington, DC: U.S. Department of Agriculture, Forest Service. 118 p.

Pastor, J.; Bockheim, J.G. 1984. **Distribution and cycling of nutrients in an aspen-mixed hardwood-spodosol ecosystem in northern Wisconsin**. Ecology. 65: 339-353.

Perala, D.A. 1977. **Manager's handbook for aspen in the north central States**. Gen. Tech. Rep. NC-36. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 30 p.

Perala, D.A. 1984. **How endemic injuries affect early growth of aspen suckers**. Canadian Journal of Forest Research. 14: 755-762.

Perala, D.A. 1986. **Aspen management**. In: Proceedings, Integrated pest management symposium for northern forests; 1986 March 24-27; Madison, WI: University of Wisconsin Cooperative Extension Service: 87-97.

Perala, D.A. 1990. ***Populus tremuloides* Mi quaking aspen**. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North Americ Hardwoods. Agric. Handb. 654. Washingtc DC: U.S. Department of Agriculture, Fores Service: 555-569.

Perala, D.A.; Alban, D.H. 1982. **Biomass, n ent distribution, and litterfall in *Popul Pinus*, and *Picea* stands on two differe soils in Minnesota**. Plant-Soil. 64: 177-1

Perala, D.A.; Russell, J. 1983. **Aspen**. In: E R.M., tech. comp. Silvicultural systems f major forest types of the United States. A Handb. 445. Washington, DC: U.S. Depa of Agriculture, Forest Service: 113-115.

Peterson, W.L. 1986. **Late Wisconsin gla history of northwestern Wisconsin an western upper Michigan**. Bull. 1652. V ington, DC: U.S. Geological Survey. 14

Probst, J.R. 1979. **Oak forest bird comn ties**. In: Proceedings, Symposium on m ment of north central and northeasterr for nongame birds; 1979 January 23-2 Minneapolis, MN. Gen. Tech. Rep. NC- Paul, MN: U.S. Department of Agricult Forest Service, North Central Forest E ment Station: 80-88.

Probst, J.R.; Rakstad, D.S. 1987. **Small mal communities in three aspen st classes**. Canadian Field Naturalist. 1(368.

Probst, J.R.; Rakstad, D.S.; Rugg, D.J. **Breeding bird communities in rege and mature broadleaf forests in th Lake States**. Forest Ecology and Ma In Press.

Rauscher, H.M. 1984. **Homogeneous climatic zones of the Lake States**. NC-240. St. Paul, MN: U.S. Departn Agriculture, Forest Service, North C Forest Experiment Station. 39 p.

Ruark, G.A.; Bockheim, J.C. 1988. **B primary production, and nutrient tion for an age sequence of *Popu tremuloides* ecosystems**. Canadi Forest Research. 18: 433-443.

Shepperd, W.D.; Engelby, O. 1983. **Rocky Mountain aspen**. In: Burns, R.M., tech. comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture, Forest Service: 77-79.

Soil Survey Staff. 1975. **Soil taxonomy**. Agric. Handb. 436. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. 754 p.

Sorenson, T. 1948. **A method for establishing groups of equal magnitude in plant sociology based on similarity of species content**. Akta K. Danske Vidensk. Selsk. Biol. Skr. J. 5: 1-34.

Stone, E.L. 1973. **Regional objectives in forest fertilization, current and potential**. In: Leaf, A.L.; Leonard, R.E., eds. Forest fertilization. Gen. Tech. Rep. NE-3. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 10-18.

Thompson, F.R.; Fritzell, E.K. 1990. **Bird densities and diversity in clearcut and mature oak-hickory forests**. Res. Pap. NC-293. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

Verry, E.S.; Timmons, D.R. 1982. **Waterborne nutrient flow through an upland-peatland watershed in Minnesota**. Ecology. 63: 1456-1467.

Wright, H.E., Jr. 1972. **Quaternary history of Minnesota**. In: Sims, P.K.; Wory, G.B., eds. Geology of Minnesota: a centennial volume. St. Paul, MN: Minnesota Geological Society: 515-547.

Wright, H.E., Jr.; Mattson, L.A.; Thomas, J.A. 1970. **Geology of the Cloquet quadrangle, Carlton County, Minnesota**. GM-3. St. Paul, MN: Minnesota Geological Survey GM-3. 30 p.

Yahner, R.H. 1989. **Forest management and featured species of wildlife: effects on coexisting species**. In: Finley, J.; Brittingham, M., eds. Proceedings, Symposium on timber management and its effects on wildlife. University Park, PA: Pennsylvania State University, School of Forest Resources: 146-161.

Zumeta, D.C. 1991. **Protecting biological diversity: a major challenge for Minnesota forestry in the 1990s**. Journal of Minnesota Academy of Science. 56: 24-33.

APPENDIX 1.—STUDY SITE LAYOUT

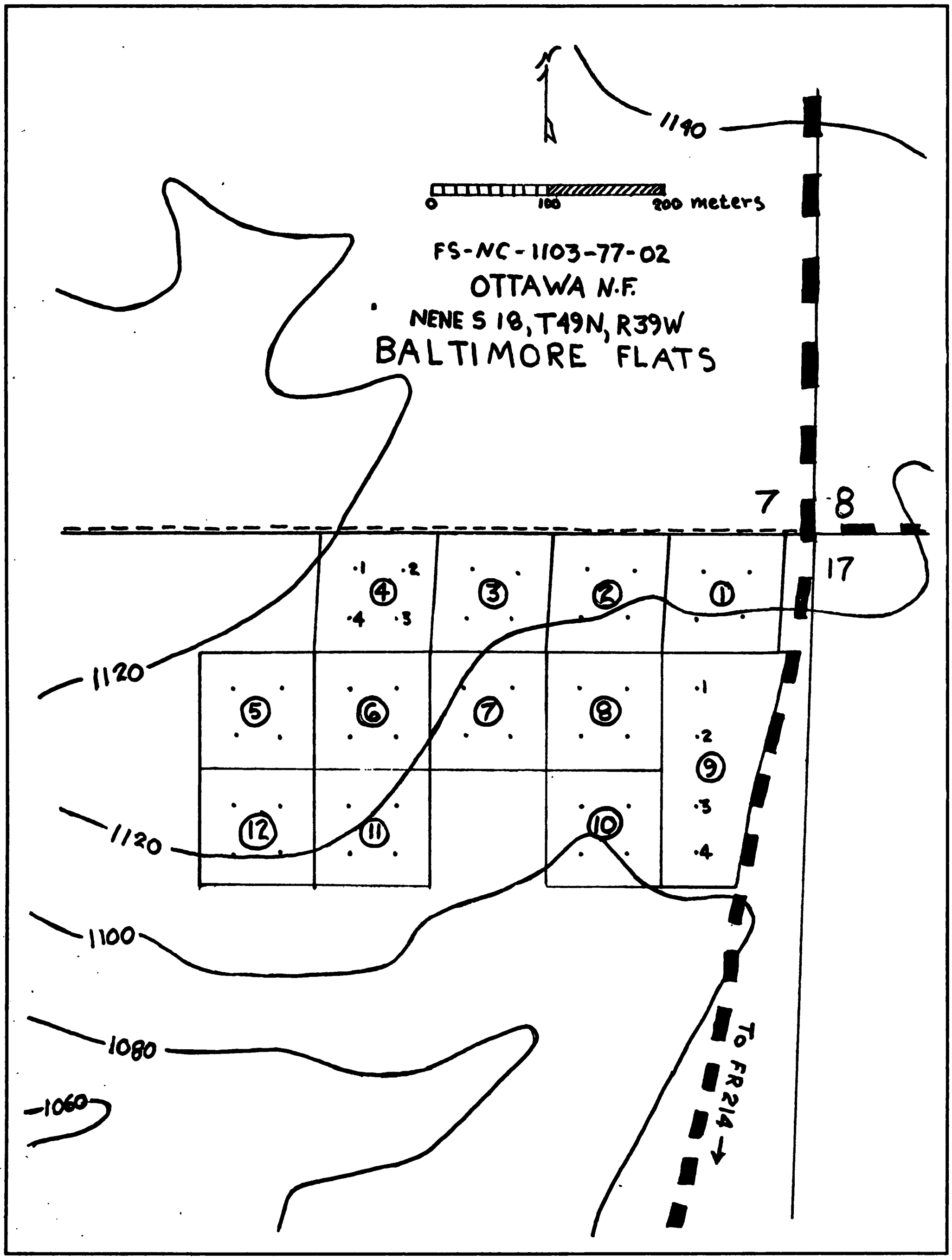
This appendix contains study site maps and treatment plot identification.

Treatment	BF	CL	PB
Clearcut, whole tree	3,6,7,11	7,8,10,16	1,3,5,11, 12,17
Clearcut, merchantable bole	1,2,8,10	2,4,6,9	4,8,9,13, 15,16
Shelterwood cut, whole tree	none	1,11	10,14
Shelterwood cut, merchantable bole	none	3,5	6,7

Treatment plots converted after harvesting to *Picea glauca* (Moench) Voss are underlined. Contour interval is in feet.

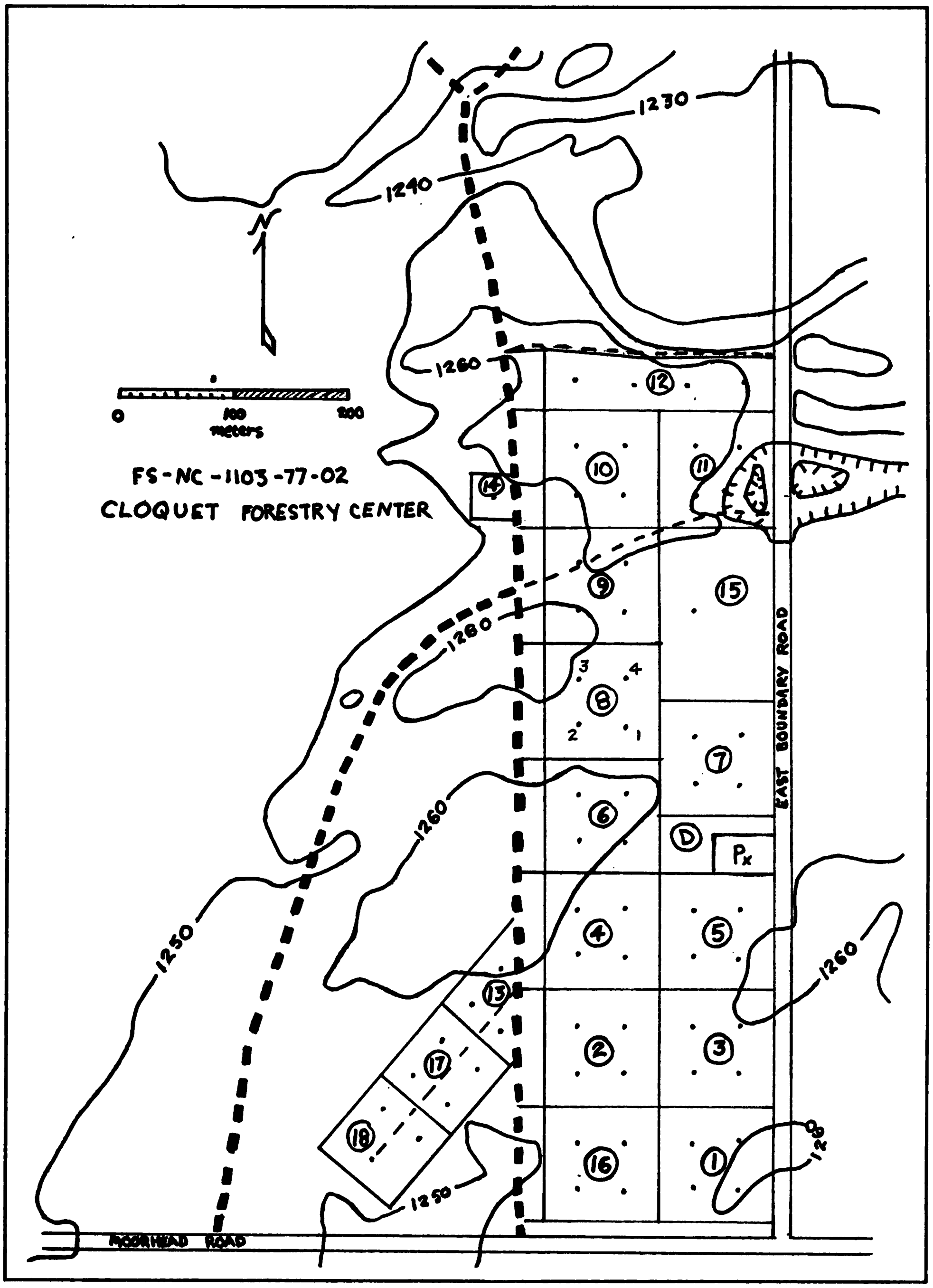
APPENDIX 1.—STUDY SITE LAYOUT

a. Baltimore Flats



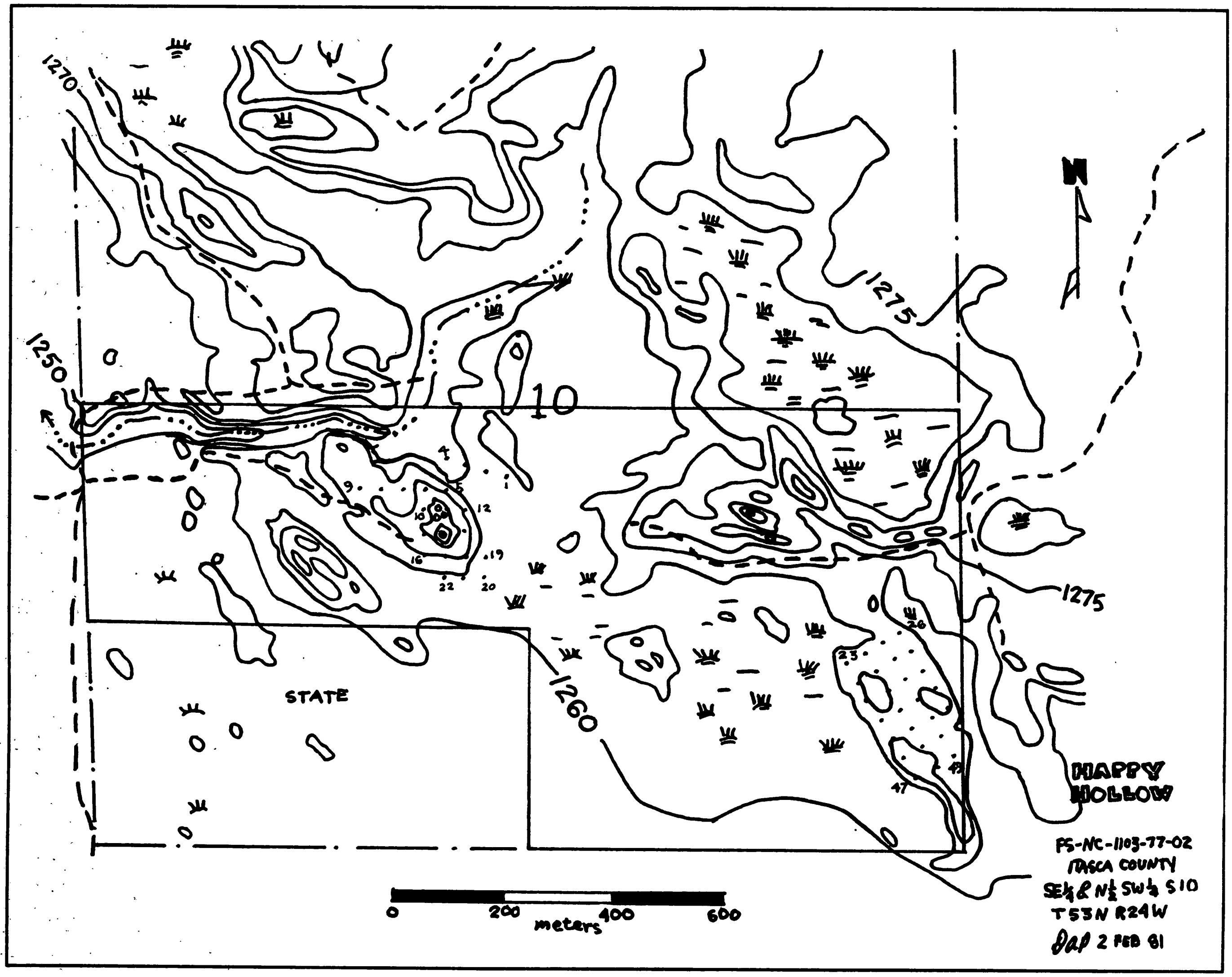
APPENDIX 1.—STUDY SITE LAYOUT

b. Cloquet



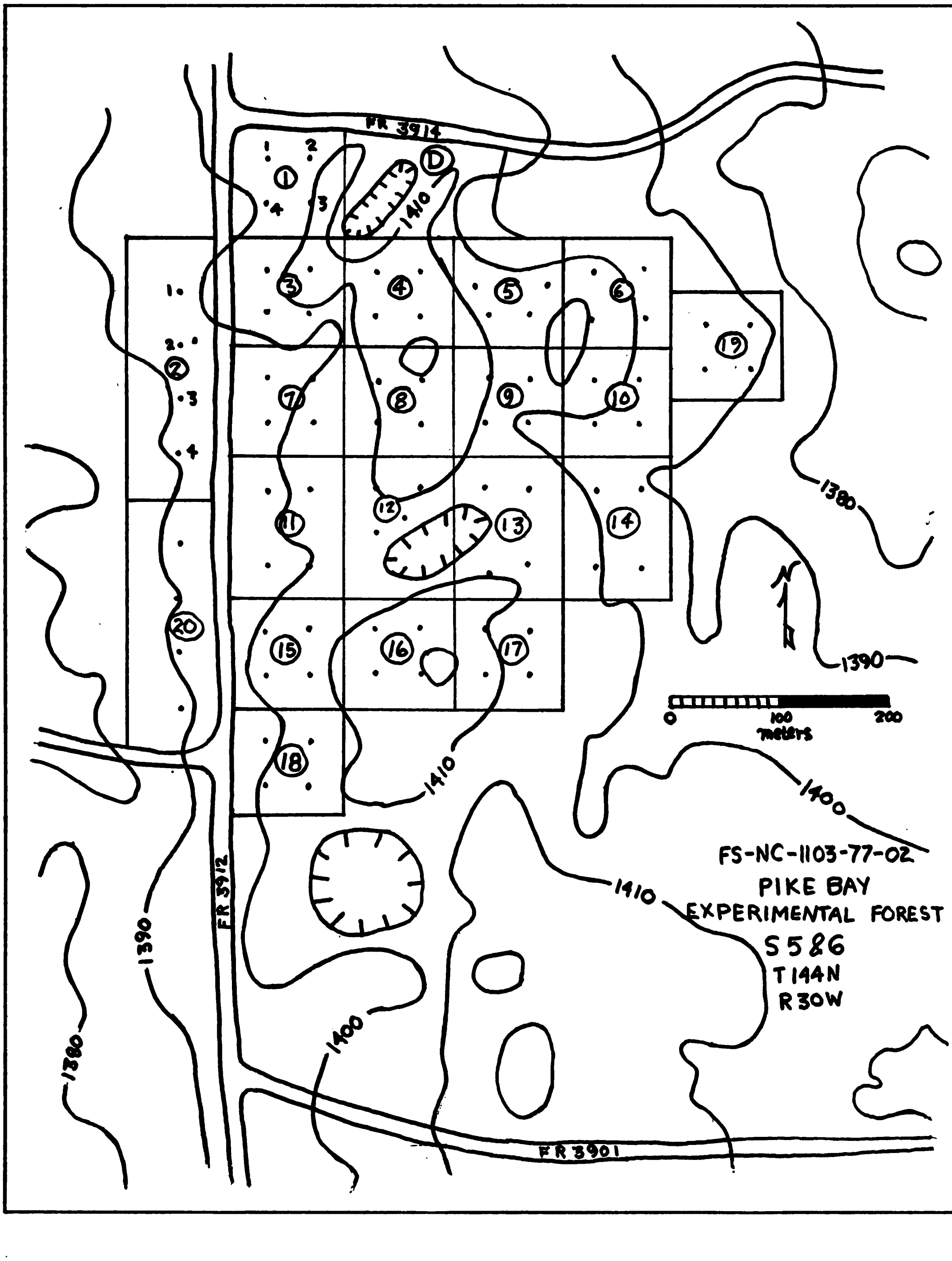
APPENDIX 1.—STUDY SITE LAYOUT

c. Happy Hollow



APPENDIX 1.—STUDY SITE LAYOUT

d. Pike Bay



APPENDIX 2.—THE TREE LAYER

SPECIES	CODE	SITE	FREQ	STEMS	BASAL AREA	REL FREQ	REL DENS	REL DOM	IMPOR VALUE
			%	Per ha	m^2/ha	--------- Percent --------			
Abies balsamea (L.) Mill.	178	BF	46	72	0.9	6.7	2.3	3.7	4.2
		CL	21	12	0.1	5.1	1.6	0.5	2.4
		HHZ	100	1,024	8.8	17.8	54.7	32.7	35.1
		HHR	100	1,961	14.0	16.7	68.5	42.5	42.5
		HHL	100	862	8.6	19.6	40.5	30.5	30.2
		PB	13	6	0.2	1.7	0.4	0.5	0.9
Acer rubrum L.	2	BF	92	366	1.2	13.3	11.5	4.8	9.9
		CL	65	63	1.1	16.1	9.0	5.6	10.3
		HHZ	33	36	0.3	5.9	1.9	1.3	3.1
		HHR	47	58	0.7	7.8	2.0	2.0	4.0
		HHL	33	22	0.6	6.5	1.0	2.0	3.2
		PB	65	49	1.1	8.7	3.7	2.9	5.1
Acer saccharum Marsh.	4	BF	98	1,536	5.5	14.2	48.1	22.1	28.1
		CL	3	1	<.1	0.8	0.2	<.1	0.3
		PB	100	642	7.2	13.4	49.5	18.7	27.2
Betula alleghaniensis Britt.	20	BF	6	1	<.1	0.9	<.1	0.1	0.3
		PB	70	44	0.9	9.4	3.4	2.4	5.0
Betula papyrifera Marsh.	21	BF	8	2	<.1	1.2	0.1	0.1	0.4
		CL	71	183	6.1	17.7	26.1	32.2	25.3
		HHZ	81	130	2.6	14.4	6.9	9.7	10.3
		HHR	94	136	2.7	15.7	4.8	8.1	9.5
		HHL	67	84	2.6	13.0	4.0	9.1	8.7
		PB	78	54	1.2	10.4	4.2	3.1	5.9
Carpinus caroliniana Walt.	22	BF	2	5	<.1	0.3	0.2	<.1	0.2
Fraxinus americana L.	164	BF	73	145	0.6	10.6	4.6	2.5	5.9
Fraxinus nigra Marsh.	165	HHL	33	62	0.5	6.5	2.9	1.9	3.8
		PB	19	19	0.5	2.5	1.5	1.3	1.7
Fraxinus pennsylvanica Marsh.	166	CL	2	0	<.1	0.4	<.1	<.1	0.1
Ostrya virginiana (Mill.) K.Koch	26	BF	73	82	0.3	10.6	2.6	1.2	4.8
		PB	83	87	0.4	11.1	6.7	0.9	6.2

(Appendix 2 continued)

(Appendix 2 continued)

SPECIES	CODE	SITE	FREQ	STEMS	BASAL AREA	REL FREQ	REL DENS	REL DOM	IMPO VALU
			%	*Per ha*	m^2/ha	- - - - - - - - -	- - - - *Percent*	- - - - - - - -	
Picea glauca	181	BF	10	2	<.1	1.5	0.1	0.2	0.[illegible]
(Moench) Voss		CL	13	3	0.1	3.1	0.4	0.5	1.4
		HHZ	38	14	0.4	6.8	0.8	1.4	3.[illegible]
		HHR	41	14	0.7	6.9	0.5	2.0	3.[illegible]
		HHL	44	13	0.4	8.7	0.6	1.3	3.5
		PB	20	7	0.3	2.7	0.5	0.7	1.3
Picea mariana	180	CL	3	1	<.1	0.8	0.1	0.1	0.3
(Mill.) B.S.P.		HHZ	24	35	0.3	4.2	1.9	1.2	2.4
		HHR	59	192	1.8	9.8	6.7	5.4	7.3
		HHL	33	642	5.6	6.5	30.1	19.8	18.8
Pinus banksiana	182	CL	24	15	0.9	5.9	2.1	4.7	4.2
Lamb.		HHZ	29	19	0.3	5.1	1.0	1.1	2.4
Pinus resinosa	183	CL	33	40	2.6	8.3	5.7	13.9	9.3
Ait.		HHZ	43	59	1.9	7.6	3.2	6.9	5.9
		HHR	18	6	0.5	2.9	0.2	1.6	1.6
Pinus strobus L.	184	CL	6	3	0.1	1.6	0.4	0.7	0.9
		HHZ	19	5	0.4	3.4	0.3	1.4	1.7
		HHR	41	11	1.4	6.9	0.4	4.4	3.9
		PB	4	1	0.3	0.5	0.1	0.8	0.5
Populus	232	CL	8	3	0.1	2.0	0.5	0.3	0.9
balsamifera L.		HHZ	10	2	<.1	1.7	0.1	0.1	0.6
		HHR	12	2	0.2	2.0	0.1	0.6	0.9
		HHL	11	9	0.2	2.2	0.4	0.8	1.1
		PB	6	2	0.1	0.8	0.2	0.3	0.4
Populus	233	CL	32	50	1.0	7.9	7.2	5.3	6.8
grandidentata		HHZ	29	48	0.3	5.1	2.5	1.2	2.9
Michx.		HHR	12	2	<.1	2.0	0.1	0.1	0.7
		HHL	11	7	0.1	2.2	0.3	0.3	0.9
		PB	43	36	2.8	5.7	2.8	7.3	5.3
Populus	234	BF	100	510	12.6	14.5	16.0	50.9	27.1
tremuloides		CL	100	318	6.6	24.8	45.3	34.8	35.0
Michx.		HHZ	100	477	11.2	17.8	25.5	41.8	28.4
		HHR	100	398	9.8	16.7	13.9	29.7	20.1
		HHL	100	402	9.1	19.6	18.9	32.2	23.5
		PB	93	247	18.8	12.4	19.0	49.2	26.9

(Appendix 2 cont

(Appendix 2 continued)

SPECIES	CODE	SITE	FREQ	STEMS	BASAL AREA	REL FREQ	REL DENS	REL DOM	IMPOR VALUE
			%	*Per ha*	*m²/ha*		--------- *Percent*	--------	
Prunus serotina Ehrh.	218	BF	19	4	<.1	2.7	0.1	0.1	1.0
Quercus macrocarpa Michx.	99	HHZ	33	7	<.1	5.9	0.4	<.1	2.1
		HHR	18	7	0.1	2.9	0.2	0.4	1.2
		HHL	33	11	0.2	6.5	0.5	0.7	2.6
		PB	11	3	0.2	1.5	0.2	0.5	0.8
Quercus rubra L.	97	CL	22	8	0.2	5.5	1.2	1.3	2.7
		HHZ	5	4	<.1	0.8	0.2	0.1	0.4
		HHR	6	1	<.1	1.0	<.1	<.1	0.3
		HHL	11	2	<.1	2.2	0.1	<.1	0.8
		PB	31	11	0.7	4.2	0.8	1.8	2.3
Salix bebbiana Sarg.	236	BF	4	2	<.1	0.6	0.1	<.1	0.2
Thuja occidentalis L.	60	HHZ	14	13	0.3	2.5	0.7	1.1	1.4
		HHR	41	71	1.0	6.9	2.5	3.0	4.1
		HHL	11	4	0.3	2.2	0.2	1.0	1.1
Tilia americana L.	248	BF	100	427	3.0	14.5	13.4	12.3	13.4
		HHZ	5	1	<.1	0.8	0.1	<.1	0.3
		HHR	12	6	0.1	2.0	0.2	0.2	0.8
		HHL	11	4	0.1	2.2	0.2	0.4	0.9
		PB	84	67	2.3	11.2	5.1	6.0	7.4
Ulmus americana L.	250	BF	56	39	0.5	8.2	1.2	2.0	3.8
		HHL	11	4	<.1	2.2	0.2	0.1	0.8
		PB	28	13	0.5	3.7	1.0	1.3	2.0
TOTALS	500	BF	688	3,192	24.7	100	100	100	100
		CL	404	701	19.0	100	100	100	100
		HHZ	562	1,873	26.9	100	100	100	100
		HHR	600	2,865	32.9	100	100	100	100
		HHL	511	2,131	28.1	100	100	100	100
		PB	745	1,297	38.3	100	100	100	100

APPENDIX 3.—THE SHRUB LAYER

SPECIES	CODE	SITE	FREQ	STEMS	BASAL AREA	REL FREQ	REL DENS	REL DOM	IM VA
			%	*Per ha*	*m²/ha*	*- - - - - - - - - Percent*		*- - - - - - -*	
Abies balsamea (L.) Mill.	178	BF	6	521	0.02	2.21	2.11	1.74	
		HHZ	5	125	0.02	5.26	0.45	5.01	
		HHR	19	1,154	0.23	23.81	11.32	57.13	
		PB	1	47	<.01	0.29	0.07	0.12	
Acer rubrum L.	2	BF	32	2,943	0.18	11.44	11.95	18.26	
		CL	3	139	<.01	1.32	0.15	0.05	
		HHR	4	577	0.01	4.76	5.66	1.60	
		PB	16	1,016	0.01	3.76	1.62	0.69	
Acer saccharum Marsh.	4	BF	38	3,724	0.24	13.28	15.12	23.56	
		PB	98	36,954	0.58	22.54	59.05	44.27	
Acer spicatum Lam.	5	BF	5	599	0.02	1.85	2.43	1.52	
		CL	4	794	0.06	1.64	0.88	0.98	
		HHZ	5	375	<.01	5.26	1.36	0.60	
		PB	43	5,250	0.08	9.97	8.39	5.78	
Alnus crispa (Ait.) Pursh	18	CL	2	516	0.03	0.66	0.57	0.55	
Amelanchier spp. Medic.	211	BF	17	599	0.01	5.90	2.43	1.28	
		CL	20	1,845	0.09	8.22	2.04	1.54	
		PB	3	109	<.01	0.72	0.17	0.09	
Betula alleghaniensis Britt.	20	PB	1	16	<.01	0.14	0.02	0.02	
Betula papyrifera Marsh.	21	HHR	4	192	<.01	4.76	1.89	0.93	
Carpinus caroliniana Walt.	22	BF	1	26	<.01	0.37	0.11	0.02	
Cornus alternifolia L. f.	55	BF	1	52	<.01	0.37	0.21	0.10	
		PB	6	547	<.01	1.30	0.87	0.34	
Cornus rugosa Lam.	57	CL	6	833	0.07	2.30	0.92	1.15	

(Appendix 3

SPECIES	CODE	SITE	FREQ	STEMS	BASAL AREA	REL FREQ	REL DENS	REL DOM	IMPOR VALUE
			%	*Per ha*	*m²/ha*	---------	*Percent*	--------	
Cornus stolonifera Michx.	58	PB	1	47	<.01	0.29	0.07	0.03	0.1
Corylus cornuta Marsh.	25	BF	49	4,479	0.11	17.34	18.18	11.31	15.6
		CL	96	68,016	5.36	39.80	75.34	90.31	68.5
		HHZ	25	7,875	0.28	26.32	28.51	63.18	39.3
		HHR	8	1,250	0.11	9.52	12.26	26.61	16.1
		PB	24	2,327	0.07	5.49	3.72	4.81	4.7
Diervilla lonicera Mill.	29	CL	44	14,087	0.15	18.42	15.60	2.55	12.2
		HHZ	15	17,375	0.12	15.79	62.90	27.85	35.5
		HHR	23	5,288	0.04	28.57	51.89	9.52	30.0
		PB	1	16	<.01	0.14	0.02	0.01	0.1
Dirca palustris L.	247	PB	23	984	0.17	5.06	1.57	13.28	6.6
Fraxinus americana L.	164	BF	9	599	0.03	3.32	2.43	3.06	2.9
Fraxinus nigra Marsh.	165	BF	6	312	0.05	2.21	1.27	4.74	2.7
		PB	9	516	0.01	2.17	0.82	0.49	1.2
Fraxinus pennsylvanica Marsh.	166	PB	4	297	0.01	0.87	0.47	1.13	0.8
Ledum groenlandicum Oeder	83	HHR	8	1,250	0.01	9.52	12.26	3.37	8.4
Lonicera canadensis Bartr.	31	BF	7	365	0.01	2.58	1.48	0.50	1.5
		CL[1]	7	397	0.01	2.96	0.44	0.15	1.2
		PB[1]	10	797	0.01	2.31	1.27	0.84	1.5
Ostrya virginiana (Mill.) K.Koch	26	BF	13	990	0.07	4.43	4.02	7.06	5.2
		PB	33	2,234	0.07	7.37	3.57	5.21	5.4
Picea glauca (Moench) Voss	181	PB	1	16	<.01	0.14	0.02	0.34	0.2
Pinus strobus L.	184	PB	1	16	<.01	0.14	0.02	0.01	0.1

(Appendix 3 continued)

SPECIES	CODE	SITE	FREQ	STEMS	BASAL AREA	REL FREQ	REL DENS	REL DOM	IMP VA
			%	*Per ha*	m^2/ha	Percent			
Populus balsamifera L.	232	CL	1	60	<.01	0.33	0.07	0.01	
Populus grandidentata Michx.	233	CL	6	278	0.01	2.30	0.31	0.11	
		PB	2	219	<.01	0.43	0.35	0.37	
Populus tremuloides Michx.	234	BF	50	4,818	0.06	17.71	19.56	6.01	
		CL	34	1,885	0.08	14.14	2.09	1.41	
		HHZ	25	1,000	0.01	26.32	3.62	1.96	
		HHR	12	385	<.01	14.29	3.77	0.67	
		HHL	17	417	<.01	100.00	100.00	100.00	1
		PB	62	5,344	0.17	14.02	8.54	12.98	
Prunus serotina Ehrh.	218	BF	2	78	<.01	0.74	0.32	0.05	
Prunus virginiana L.	219	BF	8	339	<.01	2.95	1.37	0.37	
		CL	14	1,131	0.04	5.92	1.25	0.65	
		HHZ	5	125	<.01	5.26	0.45	0.20	
		PB	26	1,875	0.03	6.07	3.00	1.95	
Quercus macrocarpa Michx.	99	PB	1	16	<.01	0.14	0.02	0.01	
Quercus rubra L.	97	CL	1	20	<.01	0.33	0.02	0.00	
		PB	27	1,016	0.01	6.21	1.62	0.57	
Ribes triste Pall.	241	BF[2]	5	1,302	0.02	1.85	5.29	2.00	
		CL	1	20	<.01	0.33	0.02	<.01	
		HHZ[3]	15	750	0.01	15.79	2.71	1.20	
		HHR[3]	4	96	<.01	4.76	0.94	0.11	
		PB[2]	15	1,297	0.01	3.47	2.07	0.70	
Rubus pubescens Raf.	223	BF	3	208	<.01	1.11	0.85	0.24	
Rubus parviflorus Nutt.	222	BF	1	104	<.01	0.37	0.42	0.07	
Salix bebbiana Sarg.	235	BF	4	182	0.01	1.48	0.74	0.81	
		CL[4]	2	238	0.03	0.99	0.26	0.50	

(Appendix

(Appendix 3 continued)

SPECIES	CODE	SITE	FREQ	STEMS	BASAL AREA	REL FREQ	REL DENS	REL DOM	IMPOR VALUE
			%	*Per ha*	*m^2/ha*	- - - - - - - - - *Percent*			- - - - - - - -
Tilia americana	248	BF	18	2,057	0.14	6.27	8.35	13.70	9.4
L.		PB	19	875	0.06	4.34	1.40	4.38	3.4
Ulmus americana	250	BF	6	339	0.04	2.21	1.37	3.59	2.4
L.		PB	10	656	0.02	2.31	1.05	1.38	1.6
Viburnum rafinesquianum Schult.	34	PB	1	47	<.01	0.14	0.07	0.08	0.1
Viburnum trilobum	35	CL	1	20	<.01	0.33	0.02	<.01	0.1
Marsh.		PB	1	47	<.01	0.14	0.07	0.06	0.1
TOTALS		BF	282	24,635	1.01	100	100	100	100
		CL	241	90,278	5.94	100	100	100	100
		HHZ	95	27,625	0.44	100	100	100	100
		HHR	81	10,192	0.41	100	100	100	100
		HHL	17	417	<.01	100	100	100	100
		PB	432	62,578	1.30	100	100	100	100

[1]Also *L. hirsuta* Eat.
[2]Also *R. cynosbati* L.
[3]Also *R. glandulosum* Grauer
[4]Also *S. humilis* Marsh.

APPENDIX 4.—THE HERB LAYER

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPO[RTANCE] VAL[UE]
			Percent				
Abies balsamea (L.) Mill.	178	BF	5	0.2	0.7	0.2	
		HHZ	35	1.1	5.2	3.2	
		HHR	31	0.9	5.0	1.4	
		HHL	17	0.5	4.8	3.4	
		PB	1	<.1	0.1	0.1	
Acer rubrum L.	2	BF	33	1.5	4.2	1.9	
		CL	33	1.1	5.1	1.4	
		HHZ	15	0.5	2.2	1.5	
		HHR	12	0.3	1.9	0.5	
		PB	6	0.3	1.0	0.7	
Acer saccharum Marsh.	4	BF	27	0.9	3.4	1.2	
		PB	90	6.1	15.1	16.2	
Acer spicatum Lam.	5	BF	4	0.1	0.5	0.2	
		CL	1	<.1	0.1	<.1	
		HHR	4	0.1	0.6	0.2	
		PB	2	0.1	0.3	0.2	
Actaea rubra (Ait.) Willd.	199	BF	1	<.1	0.1	<.1	
		PB	3	0.1	0.4	0.2	
Amelanchier spp. Medic.	211	BF	2	0.1	0.3	0.1	
		CL	2	0.1	0.4	0.1	
Amphicarpa bracteata (L.) Fern.	90	PB	8	0.3	1.3	0.8	
Anemone canadensis L.	201	PB	1	<.1	0.1	<.1	
Anemone quinquefolia L.	202	HHZ	10	0.3	1.5	0.9	
		CL	9	0.3	1.3	0.3	
		PB	2	0.1	0.3	0.2	
Apocynum androsaemifolium L.	10	BF	2	0.1	0.3	0.1	
		CL	2	0.2	0.2	0.2	
Aquilegia canadensis L.	203	BF	1	<.1	0.1	<.1	
Aralia racemosa L.	12	PB	1	0.3	0.2	0.9	

(Apper[ndix 4 continued])

(Appendix 4 continued)

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPORTANCE VALUE
			- - - - - - - - - -	- - - - - - - - - - Percent	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -
Aralia nudicaulis L.	13	BF	28	3.2	3.6	4.0	3.8
		CL	70	13.1	10.7	16.7	13.6
		HHZ	25	5.6	3.7	16.4	10.1
		HHR	35	3.8	5.7	6.0	5.8
		PB	27	3.3	4.5	8.9	6.7
Asarum canadense L.	14	PB	6	0.4	0.9	1.1	1.0
Asclepias tuberosa L.	15	CL	2	<.1	0.2	0.1	0.1
Aster macrophyllus L.	42	BF	82	28.2	10.5	35.5	23.2
		CL	87	22.8	13.4	28.9	21.0
		HHZ	30	2.1	4.5	6.2	5.3
		HHR	35	11.0	5.7	17.4	11.0
		PB	18	0.8	3.0	2.1	2.6
Aster lateriflorus (L.) Britt.	40	BF	3	0.1	0.4	0.1	0.3
Athyrium filix-femina (L.) Roth	194	BF	4	0.4	0.5	0.5	0.5
Betula alleghaniensis Britt.	20	PB	1	<.1	0.1	<.1	0.1
Betula papyrifera Marsh.	21	HHR	8	0.2	1.3	0.3	0.8
Botrychium virginianum (L.) Sw.	171	BF	2	0.1	0.3	0.1	0.2
		PB	1	0.1	0.1	0.3	0.2
Carex spp. L.	61	BF	43	5.8	5.4	7.2	6.3
		CL	80	11.9	12.3	15.1	13.7
		HHR	4	0.1	0.6	0.2	0.4
		PB	35	3.5	5.9	9.3	7.6
Carex/Gramineae spp.	75	CL	9	1.9	1.3	2.4	1.8
Caulophyllum thalictroides (L.) Michx.	27	PB	1	<.1	0.1	<.1	0.1
Cirsium arvense (L.) Scop.	44	BF	2	0.1	0.3	0.1	0.2

(Appendix 4 continued)

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPO VA
			Percent				
Clintonia borealis (Ait.) Raf.	137	BF	2	0.2	0.3	0.3	
		CL	26	2.5	4.0	3.2	
		HHZ	40	2.4	6.0	7.0	
		HHR	38	2.5	6.2	4.0	
		HHL	50	1.5	14.2	10.3	
		PB	13	0.5	2.2	1.3	
Coptis groenlandica (Oeder) Fern.	204	HHZ	5	0.2	0.7	0.6	
		HHR	19	0.6	3.1	0.9	
		HHL	17	2.5	4.8	17.2	
Cornus alternifolia L. f.	55	PB	2	0.1	0.3	0.2	
Cornus canadensis L.	56	BF	1	<.1	0.1	<.1	
		CL	1	<.1	0.1	<.1	
		HHZ	30	0.9	4.5	2.6	
		HHR	65	13.9	10.5	22.0	
		HHL	33	3.0	9.4	20.7	
Cornus rugosa Lam.	57	CL	1	<.1	0.1	<.1	
Corylus cornuta Marsh.	25	BF	4	0.1	0.5	0.2	
		CL	21	0.6	3.2	0.8	
		HHZ	10	0.3	1.5	0.9	
		HHR	4	0.1	0.6	0.2	
Diervilla lonicera Mill.	29	CL	15	0.6	2.3	0.7	
		HHZ	25	0.8	3.7	2.3	
		HHR	12	0.8	1.9	1.3	
		PB	1	<.1	0.2	0.1	
Dirca palustris L.	247	PB	1	<.1	0.1	<.1	
Dryopteris spinulosa (O.F.Muell.) Watt	195	BF	1	<.1	0.1	<.1	
		HHL	17	0.5	4.8	3.4	
		PB[1]	11	1.1	1.8	3.0	
Epigaea repens L.	81	PB	1	<.1	0.1	<.1	
Equisetum sylvaticum L.	76	BF	3	0.1	0.4	0.1	
		HHR	4	0.1	0.6	0.2	
		PB	12	0.5	2.1	1.2	

(Appendix 4

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPORTANCE VALUE
			Percent				
Epilobium angustifolium L.	168	PB	1	<.1	0.1	<.1	0.1
Fragaria virginiana Duchesne	212	BF	50	4.7	6.4	6.0	6.2
		CL	21	0.7	3.2	0.9	2.0
		HHZ	10	0.3	1.5	0.9	1.2
		HHR	19	0.6	3.1	0.9	2.0
Fraxinus americana L.	164	BF	4	0.1	0.5	0.2	0.3
Fraxinus nigra Marsh.	165	BF	4	0.1	0.5	0.2	0.3
		PB	4	0.1	0.7	0.4	0.5
Fraxinus pennsylvanica Marsh.	166	PB	3	0.1	0.4	0.2	0.3
Galium triflorum Michx.	229	CL	2	0.1	0.4	0.1	0.2
		PB	3	0.1	0.4	0.2	0.3
Gaultheria procumbens L.	82	CL	3	0.1	0.5	0.1	0.3
		HHZ	5	0.1	0.7	0.3	0.5
Geranium robertianum L.	100	BF	4	0.3	0.5	0.3	0.4
Gramineae	112	BF	64	3.4	8.1	4.3	6.2
		CL	4	0.6	0.6	0.8	0.7
		HHZ	95	1.4	14.2	4.1	9.1
		HHR	31	0.9	5.0	1.4	3.2
		HHL	17	0.5	4.8	3.4	4.1
		PB	28	1.5	4.7	4.0	4.4
Hepatica americana (DC.) Ker.	205	BF	32	1.2	4.1	1.6	2.8
		CL	4	0.3	0.6	0.4	0.5
		HHZ	25	0.8	3.7	2.3	3.0
		HHR	27	0.8	4.4	1.3	2.8
		PB	8	0.2	1.3	0.6	0.9
Impatiens biflora Walt.	16	PB	1	<.1	0.1	<.1	0.1
Iris versicolor L.	122	PB	1	<.1	0.1	<.1	0.1
Lathyrus ochroleucus Hook.	91	CL	1	<.1	0.1	<.1	<.1

(Appendix 4 continued)

(Appendix 4 continued)

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPOR VAL
			Percent				
Linnaea borealis L.	30	HHZ	20	1.2	3.0	3.5	[illegible]
		HHR	23	1.2	3.7	1.9	[illegible]
Lonicera canadensis Bartr.	31	BF	6	0.2	0.8	0.2	[illegible]
		CL[2]	4	0.4	0.6	0.5	
		PB[2]	3	0.1	0.5	0.2	
Lycopodium clavatum L.	153	CL	2	0.2	0.2	0.2	
		HHZ	20	3.6	3.0	10.6	
		HHR	27	7.2	4.4	11.4	
		HHL	17	0.5	4.8	3.4	
Lycopodium complanatum L.	154	HHR	4	1.5	0.6	2.4	
Lycopodium obscurum L.	155	CL	8	0.7	1.2	0.8	
		HHZ	30	1.5	4.5	4.4	
		HHR	8	2.0	1.3	3.2	
		PB	1	<.1	0.2	0.1	
Lycopodium annotinum L.	152	CL	6	0.4	0.8	0.5	
		HHZ	5	0.2	0.7	0.7	
		PB	3	0.2	0.4	0.4	
Maianthemum canadense Desf.	138	BF	55	2.2	7.0	2.8	
		CL	63	3.0	9.6	3.8	
		HHZ	70	3.3	10.4	9.7	
		HHR	69	6.7	11.2	10.6	
		HHL	83	2.5	23.6	17.2	
		PB	51	1.9	8.5	5.2	
Melilotus alba Desr.	92	BF	1	<.1	0.1	<.1	
Mentha arvensis L.	128	BF	19	0.8	2.4	1.0	
Mitchella repens L.	230	BF	17	1.4	2.1	1.8	
Mitella nuda L.	240	PB	1	<.1	0.1	<.1	
Osmunda claytoniana L.	172	PB	1	0.1	0.2	0.3	
Ostrya virginiana (Mill.) K.Koch	26	BF	1	<.1	0.1	<.1	
		PB	5	0.2	0.8	0.6	
Petasites palmatus (Ait.) Gray	50	HHL	17	0.5	4.8	3.4	

(Appendi

(Appendix 4 continued)

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPORTANCE VALUE
			Percent				
Pinus strobus L.	184	HHR	4	0.1	0.6	0.2	0.4
Polygonatum biflorum (Walt.) Ell.	140	BF	1	<.1	0.1	<.1	0.1
Polygonatum pubescens (Willd.) Pursh	139	BF	6	0.2	0.8	0.2	0.5
Polygonum cilinode Michx.	186	CL	1	<.1	0.1	<.1	0.1
Populus tremuloides Michx.	234	BF	9	0.4	1.2	0.5	0.9
		CL	2	<.1	0.2	0.1	0.1
		HHZ	10	0.3	1.5	0.9	1.2
		HHR	8	0.2	1.3	0.3	0.8
		PB	1	<.1	0.1	<.1	0.1
Potentilla palustris (L.) Scop.	214	PB	1	<.1	0.2	0.1	0.2
Prenanthes alba L.	51	BF	4	0.1	0.5	0.2	0.3
Prunella vulgaris L.	129	BF	3	0.1	0.4	0.1	0.3
Prunus virginiana L.	219	BF	2	0.1	0.3	0.1	0.2
		CL	4	0.2	0.6	0.3	0.4
		PB	6	0.2	1.0	0.5	0.8
Pteridium aquilinum (L.) Kuhn	196	BF	22	5.7	2.8	7.2	5.0
		CL	29	8.0	4.5	10.2	7.3
		HHZ	10	2.1	1.5	6.2	3.8
		HHR	8	1.2	1.3	1.9	1.6
		HHL	17	0.5	4.8	3.4	4.1
		PB	1	<.1	0.1	<.1	0.1
Pyrola elliptica Nutt.	84	BF	2	0.1	0.3	0.1	0.2
Pyrola secunda L.	271	CL	13	0.4	1.9	0.5	1.2
		HHZ	15	0.5	2.2	1.5	1.8
		HHR	19	0.6	3.1	0.9	2.0
Pyrola virens Schweigg.	86	BF	1	<.1	0.1	<.1	0.1
Quercus macrocarpa Michx.	99	PB	1	<.1	0.1	<.1	0.1

(Appendix 4 continued)

(Appendix 4 continued)

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPO[illegible] VAL[illegible]
			Percent				
Quercus rubra L.	97	BF	1	<.1	0.1	<.1	[illegible]
		CL	1	<.1	0.1	<.1	[illegible]
		PB	7	0.2	1.2	0.6	[illegible]
Rhus radicans L.	9	BF	3	0.5	0.4	0.6	[illegible]
Ribes triste Pall.	241	BF[3]	5	0.2	0.7	0.2	[illegible]
		HHZ[4]	5	0.2	0.7	0.6	[illegible]
		HHR[4]	8	0.2	1.3	0.3	[illegible]
		PB[3]	8	0.3	1.4	0.9	[illegible]
Rosa acicularis Lindl.	220	CL	2	<.1	0.2	0.1	[illegible]
		HHZ	10	0.3	1.5	0.9	[illegible]
Rubus pubescens Raf.	223	BF	23	1.5	2.9	1.8	[illegible]
		CL	25	1.5	3.8	1.9	[illegible]
		HHZ	20	0.6	3.0	1.8	[illegible]
		HHR	4	0.1	0.6	0.2	[illegible]
		HHL	17	0.5	4.8	3.4	[illegible]
		PB	23	0.8	3.9	2.7	[illegible]
Rubus parviflorus Nutt.	222	BF	1	<.1	0.1	<.1	[illegible]
		CL	1	0.1	0.1	0.2	[illegible]
Rubus idaeus var. (Michx.) Maxim.	224	CL	2	0.3	0.2	0.3	[illegible]
Salix bebbiana Sarg.	236	BF	5	0.2	0.7	0.2	[illegible]
Sanicula marilandica L.	258	BF	9	0.3	1.2	0.4	[illegible]
Smilacina racemosa (L.) Desf.	141	CL	5	0.3	0.7	0.3	[illegible]
		PB	16	0.9	2.6	2.5	[illegible]
Smilacina stellata L.	142	CL	6	0.4	0.9	0.6	[illegible]
Solidago canadensis L.	53	BF	13	0.9	1.6	1.1	[illegible]
		CL[5]	3	0.1	0.5	0.1	[illegible]
		HHR	8	1.2	1.3	1.9	[illegible]
Streptopus amplexifolius (L.) DC.	145	BF	1	0.2	0.1	0.2	[illegible]

(Appendix 4 c[illegible]

(Appendix 4 continued)

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPORTANCE VALUE
			----------	----------	Percent	----------	----------
Streptopus roseus Michx.	146	BF	20	0.9	2.5	1.1	1.8
		CL	55	4.3	8.4	5.4	6.8
		HHZ	15	0.5	2.2	1.5	1.8
		PB	37	2.5	6.2	6.6	6.4
Taraxacum officinale Weber	54	BF	1	<.1	0.1	<.1	0.9
		HHR	4	0.1	0.6	0.2	0.4
Thalictrum dioicum L.	209	CL	1	0.1	0.1	0.2	0.1
		PB	6	0.4	1.0	1.2	1.1
Tilia americana L.	248	BF	1	<.1	0.1	<.1	0.1
		PB	1	<.1	0.1	<.1	0.1
Trientalis borealis Raf.	198	BF	3	0.2	0.4	0.3	0.3
		CL	5	0.1	0.7	0.2	0.4
		HHZ	20	0.6	3.0	1.8	2.4
		HHR	19	0.6	3.1	0.9	2.0
		HHL	33	1.0	9.4	6.9	8.1
		PB	19	0.6	3.1	1.5	2.3
Trifolium repens L.	93	BF	1	0.2	0.1	0.2	0.2
Trillium grandiflorum (Michx.) Salisb.	147	BF	8	0.4	1.1	0.5	0.8
		PB	4	0.2	0.6	0.5	0.6
Ulmus americana L.	250	BF	4	0.1	0.5	0.2	0.3
		PB	1	<.1	0.1	<.1	0.1
Urtica dioica L.	261	PB	1	0.1	0.1	0.3	0.2
Uvularia grandiflora Sm.	149	PB	48	5.4	8.1	14.3	11.2
Uvularia perfoliata L.	150	PB	3	0.6	0.4	1.6	1.0
Uvularia sessifolia L.	151	CL	4	0.1	0.6	0.2	0.3
		HHZ	10	0.3	1.5	0.9	1.2
		HHR	8	0.2	1.3	0.3	0.8
		PB	57	2.7	9.5	7.2	8.4
Vaccinum angustifolium Ait.	88	CL	14	0.9	2.1	1.1	1.5
		HHZ	50	2.1	7.5	6.2	6.8
		HHR	38	3.4	6.2	5.2	5.8
		HHL	17	0.5	4.8	3.4	4.1

(Appendix 4 continued)

(Appendix 4 continued)

SPECIES	CODE	SITE	FREQUENCY	AVERAGE COVER	RELATIVE FREQUENCY	RELATIVE COVER	IMPOR VALU
			-----	-----	Percent	-----	-----
Vicia americana Muhl.	95	CL	6	0.2	0.9	0.2	[illegible]
Viola pubescens Ait.	262	BF	48	2.5	6.1	3.2	[illegible]
		CL	4	0.1	0.6	0.2	[illegible]
		PB	4	0.1	0.7	0.4	
Waldsteinia fragarioides (Michx.) Tratt.	226	BF	75	8.9	9.6	11.3	1
Unknown		BF	1	<.1	0.1	<.1	
		CL	1	<.1	0.1	<.1	
		PB	3	0.2	0.4	0.4	
TOTALS		BF	784	79.4	100	100	1
		CL	654	78.8	100	100	1
		HHZ	670	34.1	100	100	[illegible]
		HHR	617	63.2	100	100	[illegible]
		HHL	352	14.5	100	100	
		PB	597	37.4	100	100	

[1]Also *D. disjuncta* (Ledeb.) C.V.Mort.
[2]Also *L. hirsuta* Eat.
[3]Also *R. cynosbati* L.
[4]Also *R. glandulosum* Grauer
[5]Also *S. flexicaulis* L.

APPENDIX 5.—TREE LAYER BIOMASS (Mg/ha)

SPECIES	CODE	SITE	FOLIAGE	LIVE BRANCHES	DEAD BRANCHES	BOLE BARK	BOLE WOOD	ABOVE-GROUND TOTAL[1]
Abies balsamea (L.) Mill.	178	BF	0.52	0.8	0.08	0.3	1.5	3.3
		CL	0.08	0.1	0.00	0.0	0.2	0.4
		HHZ	3.06	7.3	1.50	2.8	16.8	33.3
		HHR	4.77	11.5	2.35	4.3	26.2	52.5
		HHL	3.04	7.1	1.48	2.8	16.6	32.6
		PB	0.03	0.1	0.05	0.1	0.5	0.8
Acer rubrum L.	2	BF	0.21	0.8	0.09	0.6	3.3	5.0
		CL	0.15	0.9	0.09	0.5	3.6	5.5
		HHZ	0.04	0.3	0.04	0.2	1.0	1.6
		HHR	0.09	0.7	0.09	0.3	2.1	3.3
		HHL	0.09	0.6	0.08	0.3	1.8	2.9
		PB	0.09	0.8	0.08	0.7	4.8	6.4
Acer saccharum Marsh.	4	BF	1.35	3.3	0.49	3.0	17.0	25.3
		CL	<.01	<.1	<.01	<.1	<.1	<.1
		PB	0.93	10.7	0.60	5.8	30.6	48.6
Betula alleghaniensis Britt.	20	BF	<.01	<.1	<.01	<.1	0.1	0.1
		PB	0.07	1.4	0.03	0.8	5.4	7.1
Betula papyrifera Marsh.	21	BF	<.01	<.1	<.01	<.1	0.1	0.1
		CL	0.83	8.7	0.73	3.3	23.1	36.7
		HHZ	0.36	2.6	0.13	1.8	8.9	14.0
		HHR	0.42	2.9	0.14	1.8	9.1	14.6
		HHL	0.46	3.0	0.14	1.7	8.9	14.4
		PB	0.08	1.3	0.02	0.8	5.6	7.7
Carpinus caroliniana Walt.	22	BF	<.01	<.1	<.01	<.1	<.1	<.1
Fraxinus americana L.	164	BF	0.04	0.5	0.06	0.3	1.4	2.4
Fraxinus nigra Marsh.	165	HHL	0.09	0.4	0.03	0.3	1.7	2.5
		PB	0.05	0.5	0.06	0.2	1.9	2.8
Fraxinus pennsylvanica Marsh.	166	CL	<.01	<.1	<.01	<.1	<.1	<.1
Ostrya virginiana (Mill.) K.Koch	26	BF	0.07	0.3	0.02	0.1	0.7	1.2
		PB	0.04	0.2	0.04	0.1	1.1	1.5

(Appendix 5 continued)

(Appendix 5 continued)

SPECIES	CODE	SITE	FOLIAGE	LIVE BRANCHES	DEAD BRANCHES	BOLE BARK	BOLE WOOD
Picea glauca (Moench) Voss	181	BF	0.01	<.1	0.01	<.1	0.1
		CL	0.10	0.2	<.01	<.1	0.2
		HHZ	0.16	0.3	0.09	0.1	0.9
		HHR	0.30	0.4	0.16	0.2	1.6
		HHL	0.16	0.2	0.09	0.1	0.8
		PB	0.04	0.1	0.10	0.1	0.9
Picea mariana (Mill.) B.S.P.	180	CL	0.01	<.1	<.01	<.1	<.1
		HHZ	0.10	0.2	0.07	0.1	0.7
		HHR	0.58	1.0	0.35	0.6	3.8
		HHL	1.84	3.0	0.93	1.8	11.8
Pinus banksiana Lamb.	182	CL	0.16	0.5	0.31	0.3	3.2
		HHZ	0.06	0.1	0.11	0.1	0.8
Pinus resinosa Ait.	183	CL	0.69	2.3	0.27	0.7	8.7
		HHZ	0.53	1.5	0.19	0.5	5.9
		HHR	0.14	0.4	0.05	0.1	1.5
Pinus strobus L.	184	CL	0.02	0.1	0.01	<.1	0.6
		HHZ	0.09	0.3	0.04	0.1	1.3
		HHR	0.33	1.3	0.16	0.4	5.1
		PB	0.07	0.2	0.03	<.1	0.9
Populus balsamifera L.	232	CL	<.01	<.1	<.01	<.1	0.2
		HHZ	<.01	<.1	<.01	<.1	0.1
		HHR	0.03	0.2	0.05	0.2	0.8
		HHL	0.02	0.1	0.03	0.1	0.7
		PB	<.01	0.1	<.01	0.1	0.5
Populus grandidentata Michx.	233	CL	0.07	0.6	0.11	0.7	3.3
		HHZ	0.03	0.1	0.03	0.2	0.7
		HHR	<.01	<.1	<.10	<.1	<.1
		HHL	0.01	<.1	0.01	0.1	0.2
		PB	0.14	2.0	0.26	2.6	12.4
Populus tremuloides Michx.	234	BF	1.09	7.8	1.60	8.3	40.3
		CL	0.43	3.4	0.49	5.2	20.8
		HHZ	1.03	7.8	1.08	9.4	38.1
		HHR	0.89	6.9	0.95	8.2	33.4
		HHL	0.85	5.8	0.82	7.2	29.0
		PB	1.04	15.7	1.99	20.3	96.0
Prunus serotina Ehrh.	218	BF	<.01	<.1	<.01	<.1	<.1

(Appendix

(Appendix 5 continued)

SPECIES	CODE	SITE	FOLIAGE	LIVE BRANCHES	DEAD BRANCHES	BOLE BARK	BOLE WOOD	ABOVE-GROUND TOTAL[1]
Quercus macrocarpa Michx.	99	HHZ	<.01	<.1	<.01	<.1	<.1	<.1
		HHR	0.01	0.1	0.02	0.1	0.3	0.5
		HHL	0.02	0.2	0.03	0.1	0.5	0.8
		PB	0.02	0.4	0.07	0.2	1.2	1.7
Quercus rubra L.	97	CL	0.02	0.3	0.06	0.2	1.0	1.5
		HHZ	<.01	<.1	0.01	<.1	0.1	0.2
		HHR	<.01	<.1	<.01	<.1	<.1	<.1
		HHL	<.01	<.1	<.01	<.1	<.1	<.1
		PB	0.07	1.0	0.18	0.6	3.7	5.4
Salix bebbiana Sarg.	236	BF	<.01	<.1	<.01	<.1	<.1	<.1
Thuja occidentalis L.	60	HHZ	0.08	0.1	0.02	0.1	0.3	0.7
		HHR	0.31	0.4	0.10	0.2	1.2	2.3
		HHL	0.05	0.2	0.02	0.1	0.3	0.6
Tilia americana L.	248	BF	0.22	1.1	0.57	1.3	4.2	6.9
		HHZ	<.01	<.1	<.01	<.1	<.1	<.1
		HHR	<.01	<.1	0.01	<.1	0.1	0.2
		HHL	0.01	<.1	0.01	<.1	0.2	0.3
		PB	0.18	2.0	0.04	1.7	6.9	10.8
Ulmus americana L.	250	BF	0.03	0.2	0.04	0.3	2.0	2.5
		HHL	<.01	<.1	<.01	<.1	0.1	0.1
		PB	0.02	0.2	0.02	0.4	2.8	3.3
TOTALS	500	BF	3.54	15.0	2.97	14.2	70.1	105.7
		CL	2.58	17.1	2.08	11.0	64.8	98.0
		HHZ	5.57	20.8	3.32	15.3	75.4	122.8
		HHR	7.88	25.9	4.43	16.3	85.3	143.9
		HHL	6.64	20.7	3.67	14.5	72.5	120.4
		PB	2.94	37.5	3.69	35.6	180.0	256.4

[1]Estimated by nonlinear regression of above-ground total d.b.h. and may differ from the sum components.

☆U.S. GOVERNMENT PRINTING OFFICE: 1992 - 655-550/40310