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A VEGETATIONAL ANALYSIS OF MILLSTONE POINT, CONNECTICUT

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ABSTRACT: The history and general description of the Millstone Point, Connecticut area are presented. The report documents the initial quantitative study to be used as a reference in future studies. Composition and structure of communities and importance of species are discussed. Communities are compared by strata using coefficients of similarity.

Introduction. As with most of Connecticut, the vegetational composition and structure of Millstone Point has been affected by many historical disturbances: some chronic, some acute. Although presently zoned for industrial development and with several land uses, a parcel encompassing several structurally and compositionally distinct plant communities has been designated a wildlife refuge. In addition to the recreational and aesthetic values of this area, it offers an excellent opportunity to monitor vegetation influenced by several man-induced and natural environmental stresses. The present study was conducted to quantitatively characterize plant communities on Millstone Point and thereby establish a historical frame of reference for future ecological investigations. Faunistic studies were conducted concurrently and will be reported later.

Site Location. Millstone Point is located in the Town of Waterford, Connecticut, New London County, about 2.4 km east of Niantic, and 5.1 km west-southwest of New London. It consists of 400 ha of rocky peninsula that juts into Long Island Sound; it is bounded on the west by Niantic Bay and on the east by Twotree Island Channel.

Geology. An outcrop forms the eastern boundary of Niantic Bay. The relief on Millstone Point is moderate, ranging from sea level to 12 m along the southern portion to 36.6 m on Durfy Hill, north of Rope Ferry Road (Figure 1). Bedrock consists of Monson gneiss, a layered, medium- to coarse-grained rock formation of biotite, horneblende, quartz, and plagioclase feldspar, and Westerly granite, a quartz-biotite-feldspar granite which has penetrated into the adjacent Monson gneiss. Millstone was covered with ice during the Wisconsin stage of glaciation which has resulted in erratic deposition of boulders, rocks, and gravel. Soils have formed in till overlain by glacial outwash deposits. Both till and outwash range from small particle to boulder sizes, but they are largely sand and gravel with a silt binder. Soils are moderately well drained in the upland areas.

Climatology. An atmospheric diffusion condition, strongly influenced by land-sea meteorological interaction, is found at Millstone Point. Mean annual precipitation in this area is 114.3 cm. Mean monthly precipitation is highly variable, with a record low of 0.3 cm to a maximum of 43.4 cm per month. Approximately even distribution occurs over the year. A total annual snowfall of 71 cm falls primarily from December through March. Summer precipitation is

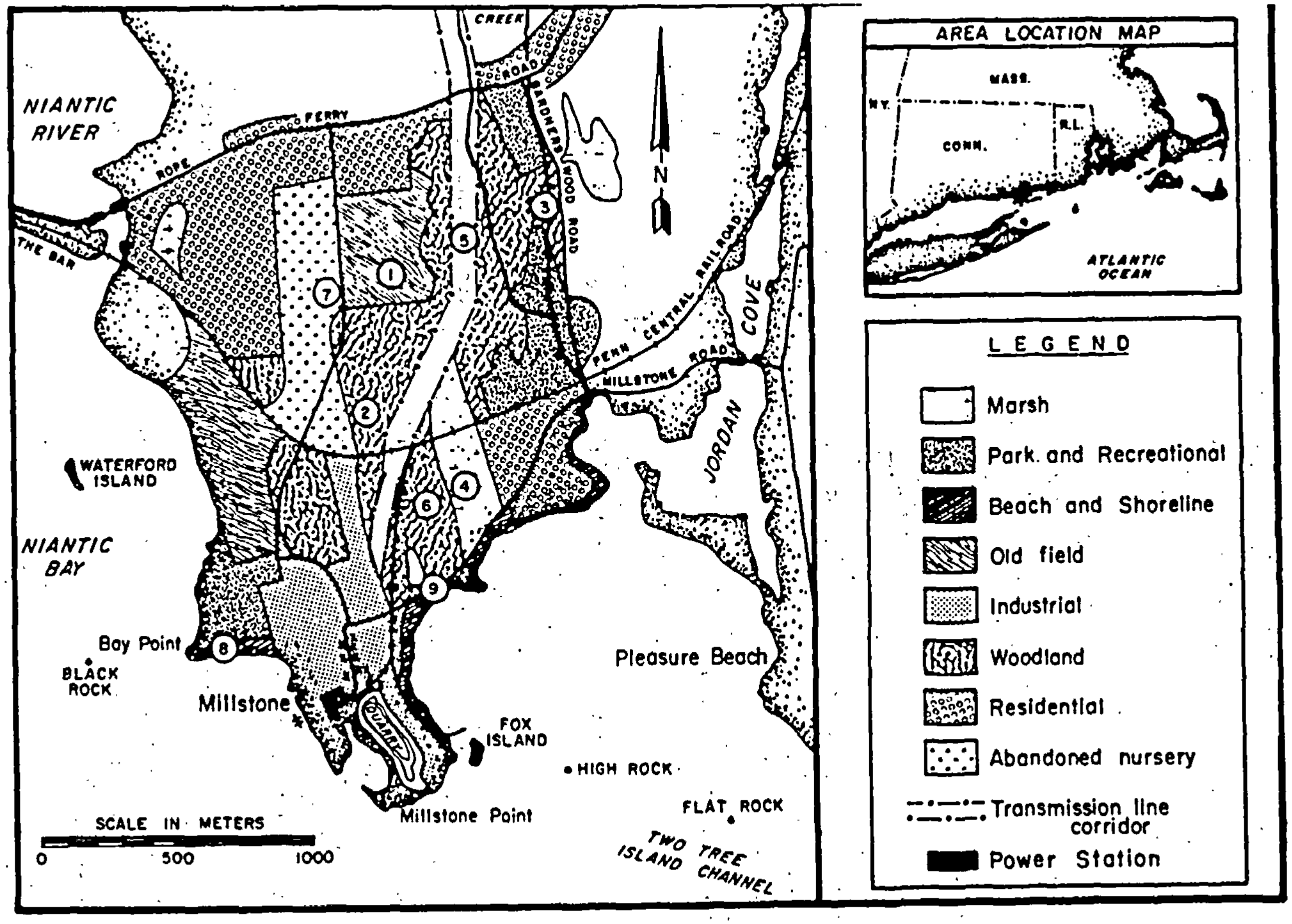

Figure 1. Land-use map of Millstone Point, Connecticut, showing sampling communities: 1, old field; 2, mesic hardwood stand; 3, riparian hardwood stand; 4, marsh; 5, transmission line corridor; 6, xeric hardwood stand; 7, abandoned nursery; 8, beach and recreation area; and 9, beach.

associated mainly with thunderstorms and smaller convective storms. Heavy fog averages 29 days/yr at Bridgeport, Connecticut, generally occurring slightly more frequently during winter and spring. The mean relative humidity at 0100 EST ranges from 67% in June to 84% in July. At 1300 EST the mean relative humidity ranges from 58% to 63%, with the highest recorded during the later portion of the year. Tidal ebb and flow occurs twice daily, with a mean range of 0.82 m (0.98 m in the spring) recorded by the U.S. Coast and Geodetic Survey. Millstone Point is susceptible to high seas and severe storms; five storms have risen water levels to over 1.8 m during the past 33 years. Mean annual surface wind speed is 4.2 m/sec: offshore winds (NW) predominate in winter, and onshore (SW) predominate in summer. Surface water temperatures at Millstone Point range from 1-3 C in January and February to 22-25 C in summer. Mean minimum and maximum air temperatures in July are 18 C and 28.5 C, respectively. The coldest months are January and February, with mean daily minimums of -5.5 C. At Brideport, Connecticut, the record high and low temperatures are 39.5 C and -29 C, respectively. The season between killing frosts is usually from 20 April to 25 October, and the mean length of the frost-free period is normally 188 days.

History, Land Use, and Disturbances. Little specific history is known about Millstone Point prior to the existence of the Nehantic Indians in the area, but they had been there a long time before the land was acquired by white settlers (*Arrowheads to Atoms*, Northeast Utilities Company). Byers (1959) stated that various tribes of Indians probably inhabited the area for over 9000 years before colonization. Sea foods and wildlife were abundant to the Nehantics; they raised corn, lima beans, and pumpkins and gathered nuts and fruits. Fires were used with increasing frequency to facilitate hunting and travel (Day 1953); the coast was probably burned each spring to maintain a shrub cover for wildlife.

By 1672 Englishmen from Massachusetts had settled on Millstone Point, putting the Nehantics on a reservation on Old Black Point. Shortly thereafter the land was largely cleared for agricultural production. Millstones were quarried from the southern tip of Millstone Point beginning in about 1737. The quarry became the largest in Connecticut and one of the largest in the country; Millstone granite was famous for its extreme hardness and variety of distinct colors. Although the Millstone area once had a thriving harbor for fishing smacks and for barges to ship granite, use had greatly declined by the time the 1938 hurricane devastated the area.

Although Millstone Point is presently zoned industrial and has had industrial use for over two centuries, parcels of land are devoted to a mixture of agricultural, commercial, industrial, residential, and recreational uses. The southern part of Millstone Point has been used for power production since 1966, when Northeast Utilities Company began construction. Prior to construction of the Millstone Nuclear Power Station, a 24.3-hectare nursery and a large abandoned quarry with associated structures and materials were the principal features of the site. The U. S. Navy Underwater Systems Center utilizes portions of the quarry pond.

Pleasure boating and fishing are popular in the Niantic River, its bay, and the area southwest of Millstone Point.

Approximately 20.2 hectares of land east of the power station will be maintained as a wildlife management area under Wetlands Act of 1969 (Millstone Point Company 1972); this area includes two ponds, a salt marsh, deciduous uplands between them, and the contiguous shoreline and beach.

Concomitant with colonization, massive deforestation plagued much of the surrounding Connecticut landscape, particularly in the Connecticut River Valley and along the coastal areas. During the post-colonial period, lumbering, agricultural activities, and fires probably occurred continuously, or at least repeatedly, throughout the nineteenth century. Natural phenomena such as insect and disease damage and storms have been prominent environmental stresses on the vegetation. Forests were exploited for cordwood, lumber and charcoal production for over 250 years. By 1800, few mature forests remained. Compositional changes have probably resulted from repeated cuttings which tended to eliminate non-sprouting species, such as hemlock, and thereby favor the sprouting hardwoods (Niering and Goodwin 1962). Agricultural activities in southern New England reached a peak in about 1840, at which time an estimated 70% of Connecticut was cleared for cultivation. By the early 1900s, lumbering practices began to taper off. Due to abandonment of farming and increased industrialization, the state has largely become reforested. Now, 63% of the state is forested, 71-80% of New London County, but the quality of Connecticut lumber is generally poor (Kienholz 1963). Old stone walls traverse most of the present forests and outline the perimeter of formerly cleared agricultural land.

The entire forest association was changed by the introduction of the chestnut blight prior to 1900. Its earliest record was in 1904, but by 1915 most of the chestnut (*Castanea dentata*) trees were killed in New England (Moss 1973). Scattered stump sprouts are the only remains of this species at Millstone Point. Partial defoliation of trees (probably by gypsy moths) occurred on Millstone Point in 1973, but little damage was observed in 1974.

Heavy winds and storms have been a recurring stress factor throughout the area, with at least 18 severe storms since 1786 (Niering and Goodwin 1962). Two violent storms, one in 1815 and one in 1938, essentially destroyed the oak forests near Stonington, Connecticut, about 19 km east of Millstone Point (Raup 1941). The most recent hurricane, occurring in September 1938, caused heavy damage along the Connecticut River Valley area and in the middle sections of Connecticut to areas beyond the Massachusetts border. Kirk (1939) reported seven days of heavy rainfall associated with this storm; one station reported 45 cm. As a result of the previous heavy rainfall, the storm, consisting of whirling circular winds over 480 km in diameter, moving at a rate of 22-27 m/sec (45 m/sec in some locations), created unprecedented destruction to vegetation (Meyer and Plusnin 1945). Over 100 hemlock near New London, Connecticut, measuring 61-91 cm dbh, were blown down (Avery et al. 1940). Mounds remaining from windthrows landscape the forest floors at Millstone Point.

Vegetation Trends. Following glacial retreat, approximately 15,000 years ago, a park-tundra type vegetation dominated the area. This was followed by *Picea* and *Abies* forests, which in turn gave way to *Pinus*. About 8000 years ago, *Pinus* was succeeded by a forest composed of *Quercus, Betula, Tsuga,* and *Castanea*. Niering and Goodwin (1962) stated that with the exception of *Castanea dentata* trees which have been virtually eliminated from this association, the forests now are similar to those of pre-Indian occupation.

Millstone Point lies in the northern glaciated section of the oak-chestnut forest region (Braun 1950), contiguous northward with the hemlock-white pine northern hardwood region (Nichols 1935). Primary forest types within the section are oak or oak-hickory, oak-chestnut, mixed mesophytic, or hemlock-hardwoods, with several additional local, edaphic, and developmental community types (Braun 1950). Hawley and Hawes (1912) classified the area as sprout-hardwoods region, with secondary forest of *Castanea dentata, Quercus borealis, Q. alba, Q. velutina, Q. prinus,* and *Q. coccinea* originated from sprouts. Bromley (1935) and Lutz (1928) recognized the area as oak region. The Committee of Silviculture, Society of American Foresters (Westveld et al. 1956) classified the area as located in the central hardwoods-hemlock forest zone. Hardwoods in this area are diverse, dominated by *Quercus* spp. and *Carya* spp. (Nichols 1914, Griswold and Ferguson 1957). *Tsuga canadensis* was listed by Lutz (1928) and Niering and Goodwin (1962) as a key conifer species that occurs over extensive areas as scattered individuals or as small local reproductive groups that have expanded in the absence of fire. *Fagus grandifolia, Liriodendron tulipifera, Acer rubrum,* and *A. saccharum* are locally important on lower slopes and in valley bottoms, coves, and swales, whereas *Quercus velutina, Q. coccinea, Q. alba,* and *Q. prinus* are principal dominants of xeric ridges and slopes where the soil is thin (Westveld et al. 1956). *Juniperus virginiana, Prunus serotina,* and *Betula populifolia* are characteristic of abandoned fields and pastures (Niering and Egler 1966).

An old forest near Stonington, Connecticut, was characterized by *Quercus alba* and *Q. velutina* associated with *Carya ovata* and *Acer rubrum* (Nichols 1913). Trees 45-60 cm dbh were common. The forest had been seriously damaged in 1815, presumably by the hurricane of that year. Raup (1941) postulated that its composition prior to 1815 was similar to that prior to destruction by the 1938 hurricane, and that this site had never been agriculturally cultivated. The average tree age in this stand was 123 yr and the oldest was 180 yr. Niering and Goodwin (1962) indicated that the forest may represent one of the original characteristic types on exposed sites along the Sound. A similar forest was described by Taylor (1923) on Long Island at Montauk, 30-40 km southeast of Millstone Point.

Methods. A vegetation cover and land-use survey was conducted on Millstone Point to determine the location and distribution of principal plant communities. Vegetation was mapped and classified according to community type or extant use (Fig. 1). Representative plant communities selected for quantitative analysis were an old field (Community 1), a mesic hardwood stand (Community 2), a riparian hardwood stand (Community 3), a marsh (Community 4), a transmission

line corridor (Community 5), a xeric hardwood stand (Community 6), and a beach (Community 9). Qualitative surveys were made in an abandoned nursery (Community 7) and a beach and recreation area (Community 8). All vegetational strata were sampled in May and October 1973, but only the ground layer was sampled in July 1973. A general qualitative survey of the area was made in October 1974. Voucher specimens will be deposited in the University of Missouri Herbarium (UMO). Nomenclature follows Gleason and Cronquist (1963).

Trees over 10 cm dbh (diameter at breast height) and saplings 2.5-10 cm dbh were sampled by the quarter method (Cottam and Curtis 1956). In each of the three woods, 38-50 points were sampled along parallel transects, each point normally being 15 m beyond the previous. A tree and a sapling were sampled in each quadrant at all points. Tree age estimates were made from increment cores. Relative and absolute values of frequency, density, and dominance (basal area) were calculated for each tree species (Curtis and Cottam 1962). Importance values were computed as the sum of the relative indices (Curtis and McIntosh 1951).

Shrubs and saplings greater than 30.5 cm tall and less than 2.5 cm dbh were sampled by the line-intercept method (Canfield 1941, Bauer 1943). Line-intercepts (15.25 m) were made perpendicular to the transects; 19-35 intercepts were used in the transmission-line corridor and in each of the wooded stands. Absolute and relative frequency and dominance (ground cover) were calculated for each species (Cox 1972).

The quadrat method (Phillips 1959) was used to sample woody plants less than 30.5 cm tall and ground layer vegetation. In forested communities, a circular plot (1 m^2) was centered at quarter points along the transect; 20-30 quadrats were used in each community in each of the three sampling periods. In communities where herbaceous vegetation predominated, 100 circular plots (0.1 m^2) were used each sampling period; sampling plots were distributed along parallel transects at 10-meter intervals. Absolute and relative frequency of each species was calculated.

Kulcyznski's formula (Oosting 1956), used to calculate coefficient of similarity values, is $2w/a+b \times 100$, where a is the sum of all frequency measures in a designated stratum of one community, b is the sum of all frequency measures for a corresponding stratum in another community, and w is the sum of lesser values for only those species common to the two.

Results and Discussion. *Community Descriptions.* Nine communities were found on Millstone Point that had significant distinction to warrant analysis and description.

Old field (Community 1): The old field is located on a gradual southeast-facing slope at an elevation of approximately 24 m above sea level. Although portions of the field are mowed periodically, the area sampled has not been disturbed for approximately six years.

Grasses dominate the community, but pioneer woody species are invading. *Dactylis glomerata* and *Anthoxanthum odoratum* were dominants in May (Table 1). Other significant vernal grasses and forbs included *Poa pratensis*, *Ranunculus*

Table 1. Frequency of species in an old field (Community 1).

Species	May		July		October	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
Dactylis glomerata	67.0	21.8	45.0	13.3	3.0	0.8
Anthoxanthum odoratum	63.0	20.5	36.0	10.7	-	-
Poa pratensis	39.0	12.7	6.0	1.8	87.9	24.0
Plantago lanceolata	34.0	11.1	48.0	14.2	45.5	12.4
Ranunculus bulbosus	22.0	7.2	-	-	-	-
Taraxacum officinale	20.0	6.5	-	-	-	-
Panicum sp.	14.0	4.6	6.0	1.8	81.8	22.3
Rubus sp.	6.0	1.9	4.0	1.2	17.2	4.7
Compositae	5.0	1.6	-	-	-	-
Potentilla canadensis	5.0	1.6	-	-	2.0	0.6
Hieracium aurantiacum	4.0	1.3	-	-	-	-
Trifolium sp.	4.0	1.3	3.0	0.9	-	-
Carex sp.	3.0	1.0	1.0	0.3	6.1	1.7
Gramineae	3.0	1.0	-	-	-	-
Rosa sp.	3.0	1.0	-	-	14.1	3.9
Viburnum dentatum	3.0	1.0	2.0	0.6	1.0	0.3
Achillea millefolium	2.0	0.7	3.0	0.9	2.0	0.6
Fragaria virginiana	2.0	0.7	3.0	0.9	16.2	4.4
Lonicera japonica	2.0	0.7	4.0	1.2	33.3	9.1
Oxalis stricta	2.0	0.7	-	-	3.0	0.8
Convolvulus arvensis	1.0	0.3	-	-	-	-
Prunus serotina	1.0	0.3	-	-	-	-
Rhus radicans	1.0	0.3	6.0	1.8	-	-
Vaccinium corymbosum	1.0	0.3	-	-	-	-

Table 1. continued.

Agrostis stolonifera	-	-	75.0	22.2	-	-
Holcus lanatus	-	-	34.0	10.1	2.0	0.6
Phleum pratense	-	-	29.0	8.6	-	-
Crepis capillaris	-	-	9.0	2.7	-	-
Agropyron repens	-	-	5.0	1.5	-	-
Andropogon virginicus	-	-	5.0	1.5	15.2	4.1
Poa compressa	-	-	4.0	1.2	-	-
Aster sp.	-	-	2.0	0.6	2.0	0.6
Asclepius syriaca	-	-	1.0	0.3	-	-
Daucus carota	-	-	1.0	0.3	-	-
Erigeron strigosus	-	-	1.0	0.3	-	-
Juncus sp.	-	-	1.0	0.3	2.0	0.6
Linaria vulgaris	-	-	1.0	0.3	1.0	0.3
Ranunculus sp.	-	-	1.0	0.3	-	-
Rudbeckia hirta	-	-	1.0	0.3	-	-
Rumex acetosella	-	-	1.0	0.3	1.0	0.3
Paspalum sp.	-	-	-	-	14.1	3.9
Solidago rugosa	-	-	-	-	5.1	1.4
Andropogon scoparius	-	-	-	-	2.0	0.6
Juniperus communis	-	-	-	-	2.0	0.6
Veronica sp.	-	-	-	-	2.0	0.6
Acer rubrum	-	-	-	-	1.0	0.3
Chenopodium sp.	-	-	-	-	1.0	0.3
Lysimachia quadrifolia	-	-	-	-	1.0	0.3
Myrica pensylvanica	-	-	-	-	1.0	0.3
Prunus virginiana	-	-	-	-	1.0	0.3

bulbosus, and *Taraxacum officinale. Platago lanceolata* occurred in various morphological stages in all sampling periods, with an average frequency of 42.5%. The frequency of occurrence of *Agrostis stolonifera, Holcus lanatus,* and *Phleum pratense* increased considerably between May and July; they shared dominance with the two leading grasses sampled in May and *Plantago lanceolata.* In October, the community consisted largely of the vegetative remains of *Poa pratensis* and *Panicum* sp. Seasonal decline of species such as *Potentilla canadensis,* which normally flourish all season, was due largely to early maturation and development of the mid-grasses which created a dense cover and effectively reduced light penetration to underlying species.

A stone fence, overgrown with vines and shrubs, circumscribes the old field which is bordered by a mixed hardwood stand on the east. Many woody species had invaded the perimeter and were scattered in the old field; among these pioneers were *Rubus* sp., *Lonicera japonica, Rosa* sp., *Viburnum dentatum, Rhus radicans,* and *Juniperus communis.*

Any man-induced disturbances such as mowing will curtail natural community development, but in protected areas woody pioneers such as *Juniperus communis* and native perennials such as *Andropogon virginicus* and *A. scoparius,* which were scattered on the lower side of the old field, will become increasingly important. *Dactylis glomerata, Anthoxanthum odoratum, Agrostis stolonifera, Panicum* sp., *Holcus lanatus,* and *Phleum pratense* will probably continue to dominate in areas that are mowed periodically.

Mesic Hardwood Stand (Community 2): Several factors have had continual or intermittent influence on the mesic hardwood stand. The Penn Central Railroad and a gravel access road to the transmission line corridor bisect the woods. Most of the stand is within 1.8 km of Long Island Sound; thus, vegetation is submitted periodically to salt-spray. Several stone fences that traverse the woods indicate that the land was previously cleared for agricultural production. The elevation ranges from 6 m to 18 m above sea level, and the topography is mostly flat. Natural drainage has been partially blocked along the southern edge of the stand by New Millstone Road, and a small intermittent stream and natural depressions throughout the community perpetuate moist soil.

Two tree species dominated the stand, and three other species had common occurrences. The mesophytic *Acer rubrum* dominated in depressions, whereas *Quercus velutina,* a xerophyte, dominated the rises and upper slopes. *Acer rubrum* contributed 45.8% of the stand basal area and *Quercus velutina* 25.3%. The two species occurred with equivalent frequencies. *Betula lenta, Quercus alba,* and *Nyssa sylvatica* were common associates (Table 2).

Most trees were young, small (2.5 - 40.0 cm dbh), and derived from sprouts, but several large and relatively old trees were found (Table 3). Selected increment borings of large trees revealed the age of a 51.6-cm dbh *Nyssa sylvatica* to be 110 yr and a 41.7-cm dbh *Carya tomentosa* to be 123 yr.

Acer rubrum, Betula lenta, Carya tomentosa, and *Nyssa sylvatica* were dominant saplings (Table 4). *Hamamelis virginiana* and *Amelanchier arborea* were abundant

Table 2. Frequency, importance value, and basal area of trees in three forest stands on Millstone Point.

Species	Community	Frequency (%)			Importance Value			Basal Area (m^2/ha)		
		2	3	6	2	3	6	2	3	6
Acer rubrum		66.7	60.5	22.0	103.6	86.1	28.1	16.8	20.3	3.3
Quercus velutina		66.7	20.0	66.0	80.8	29.3	98.0	9.3	5.8	8.5
Betula lenta		26.7	28.9	30.0	23.3	25.1	30.5	2.2	3.1	2.2
Quercus borealis		17.7	13.2	4.0	22.3	22.6	4.2	2.8	4.8	0.3
Quercus alba		24.4	7.9	26.0	17.9	9.4	32.0	0.9	1.9	2.7
Nyssa sylvatica		20.0	13.2		17.7	12.1		1.5	0.9	
Quercus coccinea		11.1	7.9	28.0	9.5	7.7	29.4	0.9	1.0	1.7
Carya tomentosa		11.1	15.8	10.0	8.7	14.9	10.2	0.6	1.5	0.7
Quercus palustris		6.7	5.3	28.0	7.1	3.8	28.7	0.9	0.2	1.5
Fagus grandifolia		4.4	42.1	8.0	3.1	55.4	10.6	0.1	7.8	1.0
Carya glabra		2.2	5.3		2.4	3.9		0.4	0.3	
Betula lutea		2.2			1.9			0.2		
Sassafras albidum		2.2	2.6	2.0	1.5	2.0	1.5	<0.1	0.1	0.1
Prunus serotina			13.2	8.0		9.6	22.7		0.3	4.3
Fraxinus pennsylvanica			13.2			10.5			1.1	
Amelanchier arborea			7.9			5.8			0.4	
Pyrus sp.			2.6			1.8			<0.1	
Hamamelis virginiana				2.0			2.4			0.3
Populus grandidentata				2.0			1.6			0.1
Totals					299.8	300	299.9	36.7	49.6	26.7

Table 3. Structure of three woods on Millstone Point, listing density (stems/ha) of species

Species	Size classes (cm dbh) 2.5-10.1	10.2-17.5	17.6-25.0	25.1-32.5	32.6-40.0	40.1-47.5	47.6-55.0	>55.1	Totals
	Mesic Hardwoods (Community 2)								
Acer rubrum	107.9	110.2	61.3	20.5	12.4	4.2	8.2	20.8	345.5
Quercus velutina	25.9	48.9	118.4	48.9		4.2			246.3
Betula lenta	75.6	28.7	8.2	8.2	8.2				128.9
Nyssa sylvatica	72.1	24.5	16.3		4.2				117.1
Carya tomentosa	75.6	12.4		8.2					96.2
Quercus borealis	10.1	16.3	8.2	28.7	4.2				67.5
Quercus alba	13.1	32.6	12.4						58.1
Hamamelis virginiana	55.6								55.6
Prunus serotina	36.1								36.1
Betula lutea	25.9		4.2						30.1
Lindera benzoin	25.9								25.9
Fagus grandifolia	13.1	8.2							21.3
Quercus coccinea		4.2	4.2	12.4					20.8
Carya glabra	16.5				4.2				20.7
Amelanchier arborea	19.5								19.5
Quercus palustris			8.2	8.2					16.4
Viburnum dentatum	6.4								6.4
Sassafras albidum		4.2							4.2
Carpinus caroliniana	3.5								3.5
Crataegus sp.	3.5								3.5
Vaccinium corymbosum	3.5								3.5
Totals	589.8	290.2	241.4	135.0	33.2	8.4	8.2	20.8	1327.0

Table 3. continued.

	Riparian Woods (Community 3)								
Fagus grandifolia	88.9	39.8	29.9	20.0	20.0		3.2	6.7	208.5
Acer rubrum	70.1	26.7	39.8	6.7	6.7	6.7	3.2	23.3	113.1
Quercus velutina	29.6	9.9	9.9	3.2	3.2	6.7		9.9	72.4
Quercus borealis	13.6		13.3	3.2	6.7	6.7	6.7	3.2	53.4
Carya tomentosa	21.7	9.9	6.7	6.7	6.7				51.7
Betula lenta	10.6	3.2	9.9	9.9	9.9	6.7			50.2
Nyssa sylvatica	16.1	20.0	3.2		3.2				42.5
Prunus serotina	21.7	20.0							41.7
Quercus alba	21.7	6.7			3.2			3.2	34.8
Fraxinus pennsylvanica	10.6	6.7	3.2	3.2			3.2		26.9
Lindera benzoin	24.2								24.2
Amelanchier arborea	10.6	6.7			3.2				20.5
Carya glabra	10.6	3.2							17.0
Sassafras albidum	13.6		3.2						16.8
Hamamelis virginiana	16.1								16.1
Alnus serrulata	13.6								13.6
Quercus coccinea			3.2	3.2	6.7				13.1
Clethra alnifolia	8.2								8.2
Quercus palustris			6.7						6.7
Pyrus sp.		3.2							3.2
Carpinus caroliniana	3.0								3.0
Kalmia latifolia	3.0								3.0
Vaccinium corymbosum	3.0								3.0
Totals	410.5	156.0	129.0	59.3	69.5	26.8	16.3	46.3	913.7

Table 3. Continued.

Species	Size classes (cm dbh) 2.5-10.1	10.2-17.5	17.6-25.0	25.1-32.5	32.6-40.0	40.1-47.5	47.6-55.0	>55.0	Totals
Xeric Hardwoods (Community 6)									
Quercus velutina	147.0	203.6	69.2	24.5	4.0	8.2			456.5
Acer rubrum	136.4	32.6	4.0	4.0	4.0		4.0	4.0	189.0
Quercus alba	69.9	57.1	20.3	4.0	4.0	4.0			159.3
Quercus coccinea	35.1	61.0	28.4						124.5
Betula lenta	35.1	40.8	20.3	8.2	4.0				108.4
Prunus serotina	80.6	12.1	4.0	4.0				4.0	104.7
Quercus palustris	14.1	73.1	16.3						103.5
Carya tomentosa	52.4	16.3	12.1						80.8
Fagus grandifolia	48.9	8.2	16.3	4.0					77.4
Amelanchier arborea	35.1								35.1
Quercus borealis	10.4	4.0	8.2						22.5
Sassafras albidum	17.5	4.0							21.5
Carya glabra	3.5	4.0							7.5
Rhododendron nudiflorum	6.9								6.9
Hamamelis virginiana				4.0					4.0
Populus grandidentata		4.0							4.0
Pyrus sp.	3.5								3.5
Nyssa sylvatica	3.5								3.5
Totals	699.9	520.8	199.1	52.7	16.0	12.1	4.0	8.0	1512.6

Table 4. Frequency of saplings and large shrubs in three forest stands on Millstone Point.

Species	Community	Frequency (%) 2	3	6	Relative Frequency (%) 2	3	6
Acer rubrum		46.7	44.7	50.0	17.6	15.5	17.1
Betula lenta		37.8	10.5		14.3	3.6	6.8
Carya tomentosa		31.1	13.2	26.0	11.8	4.5	8.9
Nyssa sylvatica		28.9	15.8	2.0	10.9	5.5	0.7
Hamamelis virginiana		15.6	10.5		5.9	3.6	
Prunus serotina		22.2	18.4	34.0	8.4	6.4	11.6
Betula lutea		15.6		20.0	5.9		
Quercus velutina		11.1	26.3	50.0	4.2	9.1	17.1
Amelanchier arborea		13.3	10.5	16.0	5.0	3.6	5.5
Lindera benzoin		6.7	15.8		2.5	5.5	
Carya glabra		8.9	7.9	2.0	3.4	2.7	0.7
Fagus grandifolia		6.7	36.8	20.0	2.5	12.7	6.8
Quercus alba		6.7	15.8	32.0	2.5	5.5	11.0
Quercus borealis		4.4	13.2	6.0	1.7	4.5	2.1
Viburnum dentatum		2.2			0.8		
Carpinus caroliniana		2.2	2.6		0.8	0.9	
Crataegus sp.		2.2			0.8		
Vaccinium corymbosum		2.2	2.6		0.8	0.9	
Sassafras albidum			13.2	6.0		4.5	2.1
Alnus serrulata			10.5			3.6	
Fraxinus pennsylvanica			10.5			3.6	
Clethra alnifolia			7.9			2.7	
Kalmia latifolia			2.6			0.9	
Quercus coccinea				16.0			5.5
Quercus palustris				6.0			2.1
Rhododendron nudiflorum				4.0			1.4
Pyrus sp.				2.0			0.7

understory components. Shade-intolerant tree species such as *Prunus serotina* were present near openings and along the borders of the stand.

The open perimeters also favored development of a dense shrub stratum (Table 5). *Viburnum dentatum, Clethra alnifolia,* and *Lindera benzoin* were dominant shrubs with ground cover values of 11.0%, 9.7% and 9.8%, respectively. Tree seedlings were scattered and scarce.

Species composition in the ground layer was nearly 50% greater in July than in May or October; a delayed coastal spring and heavy frosts in early fall caused a short growing season. *Maianthemum canadense* and *Thelypteris noveboracensis* were abundant in the May and July samples, but by October above-ground vegetation of the former had disappeared, and the latter was greatly reduced in frequency (Table 6). The intermittent stream provided suitable microhabitats for mesophytes such as *Symplocarpus foetidus, Polygonatum canaliculatum,* and ferns.

Riparian Hardwood Stand (Community 3): The riparian hardwood stand is a narrow woods located between Gardners Wood Road to the east and an open recreational area to the west (Fig. 1). A small stream longitudinally traverses the woods and periodically floods the lower areas. Well-developed, untilled soil, relative inaccessibility, and unsuitability for agricultural use have favored

Table 5. Frequency and ground cover of species in the shrub stratum of three forest stands and a transmission line corridor on Millstone Point.

Species	Community	Frequency (%)				Relative Frequency				Ground Cover (%)			
		2	3	5	6	2	3	5	6	2	3	5	6
Tree Seedlings													
Prunus serotina		5.0	5.3		20.7	50.0	7.1		22.2	0.4	0.5		2.8
Nyssa sylvatica		5.0	5.3		13.8	50.0	7.1		14.8	0.2	0.4		0.5
Hamamelis virginiana		5.0		5.7		2.2		2.2		0.4		0.2	
Fagus grandifolia			31.6		3.4		42.9		3.7		8.0		0.3
Betula lenta			10.5				14.3				0.7		
Quercus sp.			5.3	14.3	17.2		7.1	22.7	18.5		0.5	0.3	0.9
Carya glabra			5.3		3.4		7.1		3.7		0.3		0.1
Sassafras albidum			5.3		6.9		7.1		7.4		0.2		0.1
Amelanchier arborea			5.3		3.4		7.1		3.7		0.1		0.1
Betula populifolia				22.9				36.4				0.6	
Betula lutea				11.4				18.2				0.4	
Quercus borealis				5.7				9.1				0.5	
Ostrya virginiana				2.9				4.5				0.5	
Acer rubrum				5.7	10.3			9.1	11.1			0.1	0.5
Quercus alba					6.9				7.4				0.6
Quercus velutina					3.4				3.7				0.6
Quercus coccinea					3.4				3.7				0.1
Totals										1.0	10.7	2.6	6.6

Table 5. continued.

Shrubs												
Viburnum dentatum	85.0	42.1	11.4	27.6	37.8	24.2	4.3	18.6	11.0	3.2	0.4	3.0
Clethra alnifolia	40.0	42.1	8.6	6.9	17.8	24.2	3.3	4.7	9.7	11.6	0.9	2.5
Lindera benzoin	25.0	15.8			11.1	9.1			9.8	2.6		
Smilax rotundifolia	35.0	31.6	17.1	6.9	15.6	18.2	6.5	4.7	1.7	7.2	1.1	0.2
Vaccinium corymbosum	25.0		34.3	3.4	11.1		13.0	2.3	2.4		2.5	0.1
Rubus sp.	5.0		22.9		2.2		8.7		2.0		7.7	
Ilex verticillata	5.0				2.2				0.3			
Rhododendron nudiflorum		15.8	11.4	6.9		9.1	4.3	4.7		6.6	0.5	0.6
Viburnum acerifolium		21.1	2.9			12.1	1.1			1.7	0.1	
Kalmia latifolia		5.3	28.6			3.0	10.9			0.8	3.1	
Rubus allegheniensis			68.6				26.1				8.4	
Rosa sp.			11.4	6.9			4.3	4.7			1.4	0.1
Smilax glauca			8.6				3.3				1.4	
Rhus typhina			11.4				4.3				0.4	
Spiraea tomentosa			11.4				4.3				0.3	
Myrica pensylvanica			2.9				1.1				0.3	
Rhus copalina			2.9				1.1				0.2	
Myrica asplenifolia			2.9				1.1				0.1	
Gaylussacia baccata				72.4				48.8				14.4
Vaccinium sp.				17.2				11.6				2.0
Totals									36.9	33.7	28.8	22.9

Table 6. Frequency of species in the ground layer of a mesic hardwood stand (Community 2).

Species	May		July		October	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
Maianthemum canadense	80.0	19.5	83.3	19.4	-	-
Viburnum dentatum	65.0	15.9	53.3	12.4	28.0	13.2
Thelypteris noveboracensis	55.0	13.4	20.0	4.7	32.0	15.1
Uvularia sessilifolia	30.0	7.3	6.7	1.6	-	-
Prunus serotina	20.0	4.9	13.3	3.1	8.0	3.8
Dennstaedtia punctilobula	15.0	3.7	16.7	3.9	-	-
Symplocarpus foetidus	15.0	3.7	10.0	2.3	4.0	1.9
Polygonatum canaliculatum	10.0	2.4	-	-	-	-
Arisaema triphyllum	10.0	2.4	10.0	2.3	-	-
Aster sp.	10.0	2.4	16.7	3.9	-	-
Clethra alnifolia	10.0	2.4	23.3	5.4	24.0	11.3
Gramineae spp.	10.0	2.4	-	-	4.0	1.9
Impatiens biflora	10.0	2.4	10.0	2.3	8.0	3.8
Lycopodium obscurum	10.0	2.4	6.7	1.6	4.0	1.9
Ranunculus sp.	10.0	2.4	-	-	-	-
Vaccinium corymbosum	10.0	2.4	-	-	-	-
Acer rubrum	5.0	1.2	10.0	2.3	4.0	1.9
Aralia nudicaulis	5.0	1.2	-	-	-	-
Arenaria lateriflora	5.0	1.2	-	-	-	-
Dryopteris spinulosa	5.0	1.2	-	-	-	-
Geranium maculatum	5.0	1.2	6.7	1.6	-	-
Lonicera japonica	5.0	1.2	6.7	1.6	8.0	3.8
Lysimachia quadrifolia	5.0	1.2	3.3	0.8	-	-
Thalictrum sp.	5.0	1.2	-	-	-	-

Table 6. continued.

Smilax rotundifolia	-	-	23.3	5.4	4.0	1.9
Rhus radicans	-	-	20.0	4.7	-	-
Osmunda cinnamomea	-	-	13.3	3.1	20.0	9.4
Rubus flagellaris	-	-	13.3	3.1	12.0	5.7
Medeola virginiana	-	-	6.7	1.6	-	-
Myrica pensylvanica	-	-	6.7	1.6	-	-
Osmunda regalis	-	-	6.7	1.6	-	-
Pteridium aquilinum	-	-	6.7	1.6	4.0	1.9
Viburnum acerifolium	-	-	6.7	1.6	4.0	1.9
Athyrium filix-femina	-	-	3.3	0.8	12.0	5.7
Chimaphila maculata	-	-	3.3	0.8	-	-
Gaylussacia baccata	-	-	3.3	0.8	-	-
Hypericum punctatum	-	-	3.3	0.8	-	-
Lindera benzoin	-	-	3.3	0.8	8.0	3.8
Lycopodium complanatum	-	-	3.3	0.8	-	-
Monotropa hypopithys	-	-	3.3	0.8	-	-
Onoclea sensibilis	-	-	3.3	0.8	4.0	1.9
Rhododendron nudiflorum	-	-	3.3	0.8	-	-
Carya sp.	-	-	-	-	4.0	1.9
Mitchella repens	-	-	-	-	4.0	1.9
Quercus sp.	-	-	-	-	4.0	1.9
Sassafras albidum	-	-	-	-	4.0	1.9
Viola sp.	-	-	-	-	4.0	1.9

continued development of the riparian woods. Increment borings from several species revealed the community age to be approximately 125 yr, although there were indications of selected cuttings in the last century.

The composition of the upper canopy was diverse, but the density of stems was low. *Acer rubrum* dominated the riparian woods and *Fagus grandifolia* was a leading associate. The former had a higher importance value than the latter, but *Fagus grandifolia* had a slightly higher density than *A. rubrum*. *Acer rubrum* contributed 40.9% of the community basal area, and *F. grandifolia* contributed 15.7%. *Quercus velutina*, *Q. borealis*, and *Betula lenta* were common associates, and *Carya tomentosa*, *Nyssa sylvatica*, *Fraxinus pennsylvanica*, *Prunus serotina*, and *Q. alba* had lesser importance (Table 2). Although small stems were more numerous than large ones, the abundance of large stems was far greater than that found in other woods of Millstone Point (Table 3).

The composition and diversity of sapling were similar to those of trees (Table 4); this reflected the stability and maturity of the community as well as variability of abiotic factors. *Fagus grandifolia* saplings were nearly as prevalent as *Acer rubrum* saplings, and the former appeared to be increasing in abundance. *Quercus velutina* saplings were prominent on rises. Microhabitats (e.g., depressions, stream sides, slopes, and ridges) were variable, and both upland and lowland species flourished. Due to favorable growth conditions, shrubs grew large and contributed to the total diversity of the understory. Strong light penetration along the forest borders permitted reproduction of shade-intolerant pioneer species such as *Prunus serotina*.

The shrub stratum was dense; seedlings and shrubs created a 44.4% cover (Table 5). *Fagus grandifolia* was the most prominent tree seedling intercepted, and *Clethra alnifolia* dominated the shrub species. Other important shrubs included *Viburnum dentatum*, *V. acerifolium*, *Smilax rotundifolia*, *Rhododendron nudiflorum*, *Lindera benzoin*, and *Kalmia latifolia*.

Maianthemum canadense was the most abundant spring herb that persisted in vegetative form through the July sample period (Table 7). *Symplocarpus foetidus*, *Caltha palustris*, *Osmunda cinnamomea*, and *Impatients biflora* commonly occurred in low, damp areas. *Polygonatum biflorum*, *Aster* sp., and *Thelypteris noveboracensis* occupied well-drained areas on upper slopes. An abundance of *Clethra alnifolia* seedlings was indicated from July and October data. *Smilax rotundifolia* showed a seasonal increase in relative frequency from 1.5% to 16.2%.

Marsh (Community 4): This sea-level community lies along the eastern edge of Millstone Point and is connected to Long Island Sound by a culvert under Old Millstone Road. As have most salt marshes along the coast, this marsh has been trenched to control mosquito breeding. Portions are shallow open pools which will eventually fill with invading salt-tolerant emergents. The community is classified as a shallow coastal marsh, 0.6-1.5 m (2-5 ft) deep (Hill and Shearin 1970). Coastal marsh vegetation is controlled primarily by salinity and water depth.

Few species (13 in May and October, 18 in July) were found in the marsh and they were generally unique to the community type. In May, vegetation was

Table 7. Frequency of species in the ground layer of a riparian hardwood stand (Community 3).

Species	May		July		October	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
Maianthemum canadense	55.0	16.2	40.0	10.3	-	-
Polygonatum biflorum	40.0	11.8	-	-	-	-
Aster sp.	30.0	8.8	10.0	2.6	-	-
Thelypteris noveboracensis	30.0	8.8	30.0	7.8	25.0	13.5
Ranunculus sp.	25.0	7.4	-	-	-	-
Gramineae spp.	20.0	5.9	6.6	1.7	10.0	5.4
Amelanchier arborea	15.0	4.4	-	-	-	-
Clethra alnifolia	15.0	4.4	60.0	15.5	35.0	18.9
Fagus grandifolia	10.0	2.9	6.6	1.7	-	-
Polygonatum canaliculatum	10.0	2.9	-	-	-	-
Rhododendron nudiflorum	10.0	2.9	-	-	-	-
Smilacina racemosa	10.0	2.9	20.0	5.2	-	-
Symplocarpus foetidus	10.0	2.9	20.0	5.2	-	-
Viburnum dentatum	10.0	2.9	30.0	7.8	10.0	5.4
Caltha palustris	5.0	1.5	-	-	-	-
Dryopteris spinulosa	5.0	1.5	-	-	-	-
Onoclea sensibilis	5.0	1.5	6.6	1.7	-	-
Parthenocissus quinquefolia	5.0	1.5	3.3	0.9	-	-
Polystichum acrostichoides	5.0	1.5	3.3	0.9	-	-
Rhus radicans	5.0	1.5	6.6	1.7	5.0	2.7
Rubus sp.	5.0	1.5	3.3	0.9	5.0	2.7

Table 7. continued.

Smilax rotundifolia	5.0	1.5	23.3	6.0	30.0	16.2
Viburnum acerifolium	5.0	1.5	6.6	1.7	15.0	8.1
Viola sp.	5.0	1.5	3.3	0.9	5.0	2.7
Osmunda cinnamomea	-	-	23.3	6.0	-	-
Carex sp.	-	-	13.3	3.4	10.0	5.4
Impatiens biflora	-	-	13.3	3.4	-	-
Lindera benzoin	-	-	10.0	2.6	5.0	2.7
Medeola virginiana	-	-	10.0	2.6	-	-
Arisaema triphyllum	-	-	6.6	1.7	-	-
Lonicera japonica	-	-	6.6	1.7	-	-
Acer rubrum	-	-	3.3	0.9	-	-
Boehmeria cylindrica	-	-	3.3	0.9	-	-
Dennstaedtia punctilobula	-	-	3.3	0.9	-	-
Lysimachia quadrifolia	-	-	3.3	0.9	-	-
Monotropa uniflora	-	-	3.3	0.9	-	-
Quercus alba	-	-	3.3	0.9	-	-
Thalictrum sp.	-	-	3.3	0.9	-	-
Compositae spp.	-	-	-	-	5.0	2.7
Nyssa sylvatica	-	-	-	-	5.0	2.7
Prunus serotina	-	-	-	-	5.0	2.7
Quercus sp.	-	-	-	-	5.0	2.7
Smilax glauca	-	-	-	-	10.0	5.4

largely dormant, but unidentifiable grass sprouts occurred with an 85% frequency (Table 8). In July, *Spartina patens* was the most abundant grass; its frequency of occurrence increased by October. *Spartina alterniflora* also occurred with notable frequency in October, although it was not observed in the two previous sampling periods. Seasonally, *Distichlis spicata* increased in frequency, but its relative frequency in the community did not vary greatly. *Scirpus* sp. was locally abundant in all sampling periods in drier areas along the west border of the community. *Spartina patens, S. alterniflora, Distichlis spicata, Salicornia bigelovii,* and *Solidago sempervirens* predominated over the greatest extent of the marsh. In October, these species composed almost 80% of the relative frequency. Although *Phragmites communis* and shrubs are not common to salt marshes (Hill and Shearin 1970), they grew on spoil banks adjacent to the channelized stream and into the edges of the marshes. Other less abundant species characteristic of the marsh included *Juncus gerardi* and *Pluchea purpurascens* which occurred throughout the marsh. *Panicum virgatum* was found on higher areas only a few centimeters above the high tide line.

Transmission Line Corridor (Community 5): The transmission line corridor is a distinct man-induced habitat type on Millstone Point. The topography is undulating with several steep hills, the soil is gravelly to rocky, and a shallow drainage ditch extends the length of the site. The 152-meter-wide cleared strip roughly bisects the upland hardwood stands (Communities 2 and 6). It was cleared during the summer and fall of 1968, used as a land-fill area for refuse in 1973, and topsoil was moved locally in 1974. Vegetation will be maintained in an early stage of succession; woody vegetation will be controlled periodically when it becomes a hazard to transmission service.

High species diversity in the corridor (92 species) reflects the presence of a wide variety of aggressive weed species and herbaceous and woody pioneers adapted to disturbed conditions, as well as the species residual from the former hardwood forest (Tables 5 and 9). Species common to disturbed habitats were most abundant. *Betula populifolia* was the dominant tree species occurring primarily as seedlings and small saplings (Table 5). Most other seedlings originated from rootstocks or as disseminules from adjacent hardwood forests. The combined relative frequency of *Quercus* spp. and *Betula lutea* was 50%. *Rubus allegheniensis,* an early successional shrub, strongly dominated the shrub stratum; however, residual forest species such as *Kalmia latifolia* and *Vaccinium corymbosum* were also abundant. The total shrub cover was 28.8% (Table 5).

Considerable variation was noted in the composition of the ground layer. Approximately 48 species were sampled in May, 60 in July, and 44 in October. Grasses, sedges, rushes, and spike rushes were generally prominent seasonally. *Carex* and *Juncus* were sampled in all three periods. Several woody species, such as *Rubus allegheniensis,* were persistent throughout the sampling year, whereas others, such as *R. flagellaris,* increased only from July to October. Some of the more prominent herbaceous species that were mature during the May study included *Eleocharis* sp., *Potentilla simplex, Maianthemum canadense,* and *Osmunda cinnamomea* (Table 9). During the summer, *Lysimachia quadrifolia, Panicum*

Table 8. Frequency of species in a marsh (Community 4).

Species	May		July		October	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
Gramineae spp.	85.0	52.1	-	-	13.3	6.3
Scirpus sp.	19.0	11.7	18.0	7.1	9.3	4.4
Distichlis spicata	17.0	10.4	28.0	11.0	29.3	13.9
Solidago sempervirens	17.0	10.4	32.0	12.6	12.0	5.7
Carex sp.	6.0	3.7	2.0	0.8	-	-
Labiatae spp.	5.0	3.1	6.0	2.4	-	-
Phragmites communis	5.0	3.1	36.0	14.2	8.0	3.8
Poa pratensis	2.0	1.2	8.0	3.1	-	-
Rhus radicans	2.0	1.2	2.0	0.8	1.3	0.6
Rosa sp.	2.0	1.2	-	-	1.3	0.6
Ammophila breviligulata	1.0	0.6	-	-	-	-
Convolvulus arvensis	1.0	0.6	-	-	-	-
Vaccinium corymbosum	1.0	0.6	-	-	-	-
Spartina patens	-	-	58.0	22.8	74.7	35.4
Salicornia bigelovii	-	-	20.0	7.9	32.0	15.2
Festuca sp.	-	-	14.0	5.5	-	-
Juncus gerardi	-	-	10.0	3.9	1.3	0.6
Juncus sp.	-	-	6.0	2.4	-	-
Panicum virgatum	-	-	4.0	1.6	-	-
Rumex acetosella	-	-	4.0	1.6	-	-
Equisetum arvense	-	-	2.0	0.8	-	-
Geum sp.	-	-	2.0	0.8	-	-
Sparganium sp.	-	-	2.0	0.8	-	-
Spartina alterniflora	-	-	-	-	20.0	9.5
Pluchea purpurascens	-	-	-	-	6.7	3.2
Atriplex sp.	-	-	-	-	1.3	0.6

Table 9. Frequency of species in the ground layer of a transmission line corridor (Community 5).

Species	May		July		October	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
Aster spp.	87.5	12.5	38.7	10.7	-	-
Eleocharis sp.	62.5	8.9	-	-	-	-
Rubus alleghenienses	60.0	8.6	22.7	6.3	36.0	5.4
Lysimachia quadrifolia	55.0	7.9	34.7	9.6	-	-
Potentilla simplex	50.0	7.1	13.3	3.7	8.0	1.2
Maianthemum canadense	40.0	5.7	1.3	0.4	-	-
Carex spp.	35.0	5.0	21.3	5.9	60.0	9.0
Osmunda cinnamomea	32.5	4.6	8.0	2.2	-	-
Gramineae spp.	25.0	3.6	-	-	52.0	7.8
Juncus sp.	25.0	3.6	17.3	4.8	40.0	6.0
Potentilla canadensis	20.0	2.9	9.3	2.6	12.0	1.8
Lonicera japonica	17.5	2.5	1.3	0.4	4.0	0.6
Digitaria sp.	15.0	2.1	-	-	4.0	0.6
Anthoxanthum odoratum	12.5	1.8	4.0	1.1	-	-
Aralia nudicaulis	10.0	1.4	-	-	-	-
Impatiens biflora	10.0	1.4	6.7	1.9	-	-
Phragmites communis	10.0	1.4	-	-	4.0	0.6
Symplocarpus foetidus	10.0	1.4	1.3	0.4	-	-
Arenaria lateriflora	7.5	1.1	-	-	-	-
Arisaema triphyllum	7.5	1.1	-	-	-	-
Cerastium vulgatum	7.5	1.1	-	-	-	-
Rumex acetosella	7.5	1.1	2.7	0.7	12.0	1.8
Smilax rotundifolia	7.5	1.1	5.3	1.5	16.0	2.4
Betula lutea	5.0	0.7	2.7	0.7	4.0	0.6

Table 9. continued

Equisetum arvense	5.0	0.7	1.3	0.4	-	-
Frageria virginiana	5.0	0.7	2.7	0.7	16.0	2.4
Geranium maculatum	5.0	0.7	-	-	-	-
Labiatae spp.	5.0	0.7	-	-	-	-
Polygonatum canaliculatum	5.0	0.7	-	-	-	-
Thalictrum sp.	5.0	0.7	-	-	-	-
Viola lanceolata	5.0	0.7	-	-	-	-
Acer rubrum	2.5	0.4	2.7	0.7	-	-
Betula populifolia	2.5	0.4	4.0	1.1	8.0	1.2
Convolvulus arvensis	2.5	0.4	-	-	4.0	0.6
Geum sp.	2.5	0.4	-	-	-	-
Hamamelis virginiana	2.5	0.4	1.3	0.4	-	-
Onoclea sensibilis	2.5	0.4	-	-	-	-
Oxalis stricta	2.5	0.4	6.7	1.9	-	-
Poa pratensis	2.5	0.4	1.3	0.4	-	-
Prunus serotina	2.5	0.4	2.7	0.7	-	-
Quercus sp.	2.5	0.4	-	-	-	-
Ranunculus sp.	2.5	0.4	-	-	-	-
Rosa sp.	2.5	0.4	1.3	0.4	4.0	0.6
Scrophularia lanceolata	2.5	0.4	-	-	-	-
Uvularia grandiflora	2.5	0.4	-	-	-	-
Vaccinium corymbosum	2.5	0.4	2.7	0.7	16.0	2.4
Viburnum acerifolium	2.5	0.4	-	-	4.0	0.6
Viburnum dentatum	2.5	0.4	1.3	0.4	12.0	1.8
Rubus flagellaris	-	-	22.7	6.3	44.0	6.6
Panicum auburne	-	-	21.3	5.9	-	-

Table 9. continued.

Species	May		July		October	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
Solidago sp.	-	-	16.0	4.4	-	-
Kalmia latifolia	-	-	8.0	2.2	16.0	2.4
Agrostis stolonifera	-	-	6.7	1.9	32.0	4.8
Clethra alnifolia	-	-	6.7	1.9	16.0	2.4
Ipomoea sp.	-	-	5.3	1.5	-	-
Linaria vulgaris	-	-	5.3	1.5	12.0	1.8
Baptisia tinctoria	-	-	4.0	1.1	-	-
Galium triflorum	-	-	4.0	1.1	-	-
Panicum boscii	-	-	4.0	1.1	-	-
Achillea millefolium	-	-	2.7	0.7	-	-
Lyonia ligustrina	-	-	2.7	0.7	-	-
Mimulus ringens	-	-	2.7	0.7	-	-
Pteridium aquilinum	-	-	2.7	0.7	-	-
Sassafras albidum	-	-	2.7	0.7	-	-
Viola fimbriatula	-	-	2.7	0.7	-	-
Amelanchier laevis	-	-	1.3	0.4	-	-
Apios americana	-	-	1.3	0.4	-	-
Berberis vulgaris	-	-	1.3	0.4	-	-
Compositae spp.	-	-	1.3	0.4	-	-
Holcus lanatus	-	-	1.3	0.4	-	-
Lindera benzoin	-	-	1.3	0.4	-	-
Lycopus americanus	-	-	1.3	0.4	-	-
Phytolacca americana	-	-	1.3	0.4	-	-

Table 9 . Continued.

Polygonum sp.	-	-	1.3	0.4	-	-
Quercus borealis	-	-	1.3	0.4	-	-
Rhododendron nudiflorum	-	-	1.3	0.4	4.0	0.6
Smilax glauca	-	-	1.3	0.4	4.0	0.6
Spiraea tomentosa	-	-	1.3	0.4	8.0	1.2
Thelypteris noveboracensis	-	-	1.3	0.4	-	-
Verbena sp.	-	-	1.3	0.4	8.0	1.2
Vitis sp.	-	-	1.3	0.4	-	-
Solidago rugosa	-	-	-	-	88.0	13.2
Panicum spp.	-	-	-	-	52.0	7.8
Andropogon virginicus	-	-	-	-	20.0	3.0
Lycopodium obscurum	-	-	-	-	8.0	1.2
Cyperus sp.	-	-	-	-	4.0	0.6
Dennstaedtia punctilobula	-	-	-	-	4.0	0.6
Epilobium sp.	-	-	-	-	4.0	0.6
Eupatorium perfoliatum	-	-	-	-	4.0	0.6
Hypericum sp.	-	-	-	-	4.0	0.6
Juniperus virginiana	-	-	-	-	4.0	0.6
Myrica pensylvanica	-	-	-	-	4.0	0.6
Polygonum arifolium	-	-	-	-	4.0	0.6
Typha latifolia	-	-	-	-	4.0	0.6
Viola sp.	-	-	-	-	4.0	0.6

auburne, and *Agrostis stolonifera* flourished, whereas *Solidago rugosa* and *Andropogon virginicus* matured by autumn.

Xeric Hardwood Stand (Community 6): This stand probably has a greater history of disturbances than any other wooded area on Millstone Point. It is suitable for many land uses. Access is readily available from land or sea; it is near shore and lacks the wet depressions found in other woods. The land rises to a north-south ridge, sloping eastward into the marsh and westward into the pond. Thus, topography, in combination with the sandy to rocky soil, creates a well-drained forest floor. Stone fences that traverse the woods indicated previous agricultural land use. Proximity to Long Island Sound and evidence of salt residue on the abaxial surfaces of tree leaves indicate that this woods has a greater subjection to salt spray than other woods. Residual earth mounds created by windthrows of past severe storms were prominent throughout the sampling area. The various disturbance factors have probably contributed synergetically to the physiognomy of the community forming a distinct hiatus with other wooded stands.

Biotic symptoms of past stresses on the ecosystem are the open upper canopy, dense understory, small total basal area, and predominance of small trees. Only 81.1% canopy cover was calculated, but light penetration through the upper canopy augmented the development of a dense understory. Sapling and large-stemmed shrub density was higher than in other stands on Millstone Point. However, the lower shrub cover was less than in other woods. Basal area of trees was lowest of the three stands measured. Sixty-four percent of the trees were small, 10.2-17.5 cm dbh (Table 3), but increment cores taken from the largest trees, such as a 113-yr *Fagus grandifolia* (45.7 cm dbh), indicated that a few trees had survived over a century of disturbances.

In the overstory there was a strong stand dominance by one species as indicated by the importance and frequency values; basal area values stressed the importance of several associate species to the over-all community structure. *Quercus velutina,* the stand dominant, had an importance value of 98.0 (Table 2), which is greater than three times that of the nearest associate. However, only 31.8% of the community basal area was contributed by *Q. velutina. Quercus alba, Q. coccinea, Q. palustris, Betula lenta,* and *Acer rubrum* were the most common associates; 42.7% of the stand basal area was contributed by these species. *Prunus serotina, Fagus grandifolia, Carya tomentosa,* and *Quercus borealis* had lesser significance. *Quercus* species contributed 55.1% of the stand basal area.

The general reproductive success of important overstory species was reflected in the sapling stratum. *Quercus velutina* and *Acer rubrum* were codominants (Tables 4 and 5). *Sassafras albidum* and *Amelanchier arborea* were prominent understory components. *Prunus serotina* and *Quercus* sp. dominated the shrub stratum, and *Nyssa sylvatica* and *Acer rubrum* were common associates.

Gaylussacia baccata was the primary shrub species, contributing 63.0% of the shrub ground cover. *Viburnum dentatum, Vaccinium* spp., and *Clethra alnifolia* also contributed notably to a total shrub and tree seedling cover of 29.5%.

Thick litter and dense upper shrub-sapling cover precluded the development of a diverse herbaceous ground layer (Table 10). *Maianthemum canadense* was exceptionally dense during the spring and summ - surveys, and *Athyrium*

filix-femina was locally prominent during summer and fall. *Gaylussacia baccata* occurred with high frequencies in all sample periods. Other prominent woody stems found in the ground layer were *Prunus serotina*, *Viburnum dentatum*, *Quercus* spp., *Rhus radicans*, *Acer rubrum*, *Vaccinium corymbosum*, and *Rubus* sp.

Table 10. Frequency of species in the ground layer of a xeric hardwood stand (Community 6).

Species	May		July		October	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
Maianthemum canadense	88.0	26.5	97.1	22.1	-	-
Gaylussacia baccata	40.0	12.0	54.3	12.3	52.0	24.1
Prunus serotina	36.0	10.8	31.4	7.1	4.0	1.9
Viburnum dentatum	28.0	8.4	28.6	6.5	8.0	3.7
Quercus sp.	28.0	8.4	-	-	20.0	9.3
Rhus radicans	20.0	6.0	11.4	2.6	-	-
Gramineae spp.	20.0	6.0	2.9	0.6	12.0	5.6
Lysimachia quadrifolia	12.0	3.6	8.6	1.9	-	-
Rosa sp.	12.0	3.6	-	-	-	-
Osmunda cinnamomea	12.0	3.6	5.7	1.3	-	-
Acer rubrum	8.0	2.4	20.0	4.5	4.0	1.9
Aster sp.	8.0	2.4	14.3	3.2	4.0	1.9
Vaccinium corymbosum	8.0	2.4	17.1	3.9	32.0	14.8
Parthenocissus quinquefolia	4.0	1.2	-	-	-	-
Pteridium aquilinum	4.0	1.2	8.6	1.9	-	-
Rubus sp.	4.0	1.2	2.9	0.6	16.0	7.4
Athyrium filix-femina	-	-	20.0	4.5	24.0	11.1
Quercus borealis	-	-	20.0	4.5	-	-
Carex sp.	-	-	17.1	3.9	-	-
Monotropa uniflora	-	-	11.4	2.6	-	-
Smilax rotundifolia	-	-	11.4	2.6	4.0	1.9
Trientalis borealis	-	-	11.4	2.6	-	-
Clethra alnifolia	-	-	8.6	1.9	8.0	3.7
Rhododendron nudiflorum	-	-	5.7	1.3	-	-
Smilax glauca	-	-	5.7	1.3	8.0	3.7
Chimaphila maculata	-	-	2.9	0.6	4.0	1.9
Danthonia sp.	-	-	2.9	0.6	-	-

Table 10. continued.

Lonicera japonica	-	-	-	-	2.9	0.6	-	-	-	-	-	-	-	-
Luzula campestris	-	-	-	-	2.9	0.6	-	-	-	-	-	-	-	-
Lycopodium complanatum	-	-	-	-	2.9	0.6	-	-	-	-	-	-	-	-
Lycopodium obscurum	-	-	-	-	2.9	0.6	-	-	-	-	-	-	-	-
Medeola virginiana	-	-	-	-	2.9	0.6	-	-	-	-	-	-	-	-
Quercus alba	-	-	-	-	2.9	0.6	8.0	3.7	-	-	-	-	-	-
Smilacina racemosa	-	-	-	-	2.9	0.6	-	-	-	-	-	-	-	-
Solidago flexicaulis	-	-	-	-	-	-	4.0	1.9	-	-	-	-	-	-
Thelypteris noveboracensis	-	-	-	-	-	-	4.0	1.9	-	-	-	-	-	-

Abandoned Nursery (Community 7): The abandoned nursery occupies considerable acreage at Millstone Point. This area is occasionally marshy and less than ideal for horticultural species. Many cultivated shrubs and trees are still present; some are being salvaged. Common cultivated trees included *Acer palmatum* var. *atropurpureum*, *Cornus florida*, *C. florida* var. *rubra*, *Malus floribunda*, *Prunus*

cerasifera var. *pissardii*, *P. yedoensis*, *P. yedoensis* var. *flore-plena*, and *Sorbus americana*. Trees and shrubs usually cultivated for arbors, hedges, and borders common to the nursery were *Juniperus chinensis* var. *pfitzeriana*, *J. communis*, *J. virginiana*, *Taxus cuspidata*, *Berberis thunbergi*, *B. vulgaris*, and *Thuja occidentalis*. Other cultivated shrubs included *Andromeda glaucophylla*, *Ilex opaca*, *Philadelphus coronarias*, *Pieris japonica*, and *Rhododendron* spp.

Portions of the nursery are in various successional stages, and pioneer species are invading from the fencerows and neighboring plant communities. Because part of the area was only recently abandoned, annual plants such as *Ambrosia artemisiifolia* were present. *Plantago lanceolata*, *P. rugelli*, *Cirsium vulgare*, *Polygonum persicaria*, *Rumex crispus*, and *Solanum dulcamara* were examples of pioneer species that invaded areas adjacent to cultivated plots and along the dirt access roads. In other open areas, *Agrostis stolonifera*, *Anthoxanthum odoratum*, *Holcus lanatus*, *Phleum pratense*, *Agropyron repens*, *Aster* spp., *Solidago graminifolia*, *S. rugosa*, *Galium aparine*, *Ipomoea* sp., and *Erigeron strigosus* were common. Woody species such as *Viburnum dentatum* and *Rosa* sp. also occurred in open areas; these species indicated more advanced stages of succession. *Juncus* spp., *Carex* spp., *Impatiens biflora*, *Asclepias incarnata*, *Dennstaedtia punctilobula*, and *Cicuta maculata* were present in mesic microhabitats. *Acer negundo*, *A. rubrum*, *Prunus serotina*, and a variety of shrubs and vines inhabited fencerows and borders. *Rhus radicans*, *Parthenocissus quinquefolia*, *Rosa* sp., *Rubus allegheniensis*, and *Smilax rotundifolia* were most abundant. Shrubs and vines that occurred less frequently were *Aronia arbutifolia*, *Rubus flagellaris*, *Spiraea tomentosa*, *Vaccinium corymbosum*, *Viburnum dentatum*, and *Vitis* sp.

Cultivated species are normally not strong competitors; thus, a climax hardwood forest community will probably successionally develop. Some nursery plants may persist for several decades, depending upon their natural affinity to the community type.

Beach and Recreation Area (Community 8): This area, developed by Northeast Utilities Company as a public recreational area, is a narrow strip of sandy beach with contiguous rock outcroppings, and a picnic area.

Pioneer species, such as *Ammophila breviligulata*, *Lathyrus japonicus*, and *Artemisia caudata*, that represent the first stage of vegetational zonation, occurred at the edge of the beach. Where these hardy plants were established in the sand, a firmer base was provided for species such as *Rhus radicans*, *Solidago sempervirens*, *Oenothera biennis*, *Rosa* sp., and *Myrica pensylvanica*. Herbs in inland areas of more advanced successional stages included *Hypericum perforatum*, *Asclepius tuberosa*, *Panicum boscii*, *Agrostis stolonifera*, *Anthoxanthum odoratum*, *Achillea millefolium*, and *Ipomoea* sp. Common shrubs and vines were *Rubus phoenicolasius*, *R. occidentalis*, *Rhus copalina*, *R. typhina*, *Parthenocissus quinquefolia*, *Gaylussacia baccata*, and *Lonicera japonica*.

Although the picnic area is mostly managed lawn with cultivated trees and shrubs, natural vegetation in various stages of succession occurs on the perimeter. *Pyrus* sp., *Prunus avium*, *P. serotina*, *Amelanchier arborea*, *Salix* sp., *Betula populifolia*, and *Juniperus virginiana* were common trees. *Lonicera japonica* and *Rhus*

radicans formed a dense ground cover under thickets of *Rhus typhina* and *R. copalina* in the periphery of the visitors' center and picnic area. *Celastrus scandens* was a common climbing vine. *Sambucus canadensis* and *Viburnum dentatum* occurred in more successionally advanced areas further inland. A mixture of weeds that reflect disturbances inherent to borders between recreational and natural areas included *Solidago* spp., *Poa pratensis*, *Dactylis glomerata*, *Rumex acetosella*, *Agrostis stolonifera*, *Ambrosia artemisiifolia*, and *Hypericum perforatum*. On open inland areas, *Agropyron repens*, *Asclepius syriaca*, *A. tuberosa*, *Aster* sp., *Chrysanthemum leucanthemum*, *Lactuca* sp., *Panicum boscii*, *Phleum pratense*, *Phytolacca americana*, *Plantago lanceolata*, *Polygonum scandens*, *Rumex acetosella*, *Smilacina racemosa*, and *Solanum dulcamara* occurred. *Spartina alterniflora* and *Juncus* sp. inhabited moist areas. *Sedum* sp. grew in scarce clumps in the cracks of extensive granitic outcroppings on Bay Point. Vegetation in this area was largely limited by the solid rock stratum and salt spray.

Beach (Community 9): The beach is a moderately sparse grassland of medium height with large areas of bare sand. Few species survive the harsh environment, but diversity increases with increasing distance inland.

Succession occurs slowly in areas close to the sea. The first vegetation zones are subject to greater wave and tide influences, more concentrated salt sprays, more critical soil moisture, wider ranges in soil and ambient air temperatures, stronger winds, and more illusive plant anchorage than locations further inland. Where the sandy beach soil is enriched by an accumulation of organic litter, it provides a more favorable environment for secondary invaders.

Nine species were recorded on the beach in May, eighteen in July, and twenty-four in October (Table 11). *Ammophila breviligulata* was the most abundant species in all sample periods (mean relative frequency of 47.2%) and formed the first vegetation successional zone. Several species occurred throughout the beachgrass zone. *Linaria vulgaris* flourished in the spring and summer but its frequency declined by fall. *Oenothera biennis* was first sampled in the summer, and it was the second most abundant species sampled in summer and fall. The occurrence of *Solidago sempervirens* and *Datura stramonium* among the *Ammophila breviligulata* clumps in both summer and fall is also notable. *Rosa* sp. shrubs, *Rhus radicans*, *Parthenocissus quinquefolia*, and *Convolvulus arvensis* generally occurred inland from the beachgrass zone.

Intercommunity Comparisons. *Diversity.* Of the 32 non-cultivated tree species sampled in this study, 19 occurred in the upper canopy (4 were considered understory or shade-intolerant pioneers), 21 occurred in the understory, 17 were encountered in the shrub intercepts, and 17 were sampled in the ground layer. Of the 32 shrub species encountered, 6 were sampled in the understory, 20 occurred in shrub intercepts, and 22 occurred in the ground layer. Approximately 140 herbaceous species were sampled; 12 were ferns or lower vascular plant species.

Of the wooded stands, the riparian woods exhibited the greatest species diversity. Sixteen tree species were recorded in the riparian woods, whereas only 13 were recorded in each of the other hardwood stands. Similarly, the greatest number of species (20) was recorded in the understory of the riparian woods, 18 in

Species	May		July		October	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
Ammophila breviligulata	96.0	69.2	100.0	30.5	82.0	41.8
Linaria vulgaris	16.0	11.5	16.0	4.9	2.0	1.0
Rhus radicans	6.7	4.8	16.0	4.9	14.0	7.1
Poa pratensis	5.3	3.9	-	-	-	-
Rumex acetosella	5.3	3.9	-	-	-	-
Parthenocissus quinquefolia	4.0	2.9	20.0	6.1	2.0	1.0
Convolvulus arvensis	2.7	1.9	20.0	6.1	2.0	1.0
Achillea millefolium	1.3	1.0	4.0	1.2	2.0	1.0
Oxalis stricta	1.3	1.0	-	-	-	-
Oenothera biennis	-	-	52.0	15.9	20.0	10.2
Lactuca sp.	-	-	20.0	6.1	4.0	2.0
Agropyron repens	-	-	16.0	4.9	-	-
Rosa sp.	-	-	12.0	3.7	2.0	1.0
Solidago sempervirens	-	-	12.0	3.7	10.0	5.1
Datura stramonium	-	-	8.0	2.4	10.0	5.1
Daucus carota	-	-	8.0	2.4	-	-
Ipomoea sp.	-	-	8.0	2.4	-	-
Cirsium arvense	-	-	4.0	1.2	10.0	5.1
Cyperus strigosus	-	-	4.0	1.2	-	-
Labiatae sp.	-	-	4.0	1.2	-	-
Solanum dulcamara	-	-	4.0	1.2	2.0	1.0
Elymus virginicus	-	-	-	-	6.0	3.1
Spartina alterniflora	-	-	-	-	6.0	3.1
Euphorbia polygonifolia	-	-	-	-	4.0	2.0
Rubus sp.	-	-	-	-	4.0	2.0
Ambrosia artemisiifolia	-	-	-	-	2.0	1.0
Atriplex glabriuscula	-	-	-	-	2.0	1.0
Digitaria sp.	-	-	-	-	2.0	1.0
Panicum sp.	-	-	-	-	2.0	1.0
Quercus borealis	-	-	-	-	2.0	1.0
Umbelliferae sp.	-	-	-	-	2.0	1.0
Viburnum dentatum	-	-	-	-	2.0	1.0

the mesic hardwood stand, and 16 in the xeric hardwood stand. More species of small saplings were recorded in the shrub stratum of the xeric hardwood stand (11) than in the mesic hardwood stand (2), riparian woods (8), or transmission line corridor (6). The greatest number of shrub species was observed in the transmission line corridor (17); 6-8 shrub species were found in each of the wooded stands. More species were found in the ground layer of the transmission line corridor (60 in July, mean of 50 for 3 samples) than in any other community. The marsh and beach communities exhibited the least mean diversity (15 and 17 species, respectively). The mean number of species in the three sampling periods in the ground layer of the old field (27) approximated that of the mesic hardwood stand, which was greater than found in the riparian woods (24) or the xeric hardwood stand (21). Nearly twice as many species were recorded in the ground layer of the xeric hardwood stand in the summer as in the spring and fall sampling periods. This seasonal pattern was observed in most communities.

Density: Trees were denser in the xeric hardwood (812.7 stems/ha) than in the mesic hardwood stand (737.2 stems/ha) or in the riparian woods (503.2 stems/ha). However, more large-stemmed trees, greater than 32.6 cm dbh, were recorded in the riparian woods than in the other stands (Table 3). The sapling structure (2.5-10.1 cm dbh) closely resembled that of the upper canopy in each of the three woods. *Quercus velutina* had the greatest mean density (258.4 stems/ha) and *Acer rubrum* had the second highest (215.8 stems/ha). The third most common associate was *Betula lenta,* which had a mean density in the three stands of 95.8 stems/ha.

Basal Area: A greater basal area of trees was measured in the riparian woods (49.6m^2/ha) than in the mesic hardwood (36.7 m^2/ha) or xeric hardwood stand (26.7 m^2/ha; Table 2). *Acer rubrum* had the highest mean basal area in the three wooded stands (12.4 m^2/ha). Associate species were *Quercus velutina, Fagus grandifolia, Q. borealis,* and *Betula lenta* with mean basal areas of 7.9, 3.0, 2.6, and 2.5 m^2/ha, respectively.

Coefficients of Similarity: Calculation of the degrees of similarity for the vegetation communities revealed a tremendous range of values, from a low of 2.4% similarity between two ground layers to a high of 71.2% similarity between two canopies (Fig. 2). Percentage similarity was generally greater between upper strata than between lower strata. In the ground layer, 62% of the comparisons revealed less than 10% similarity between communities, whereas all similarity values from shrub strata comparisons were greater than 20% and all sapling and tree similarity values were greater than 50%.

The percent similarity was greater in all strata in forested than in nonforested communities. The second-highest coefficients were calculated between forested communities and the transmission line corridor. All indices of herbaceous communities were less than 10%. In woods, the percent similarity between ground layers ranged from 36.6% to 50.7%, shrub strata 20.3% to 57.8%, understory 57.3% to 61.9%, and upper canopy 50.0% to 71.2%. The mesic hardwood stand and riparian woods shared the greatest percent similarity, mean

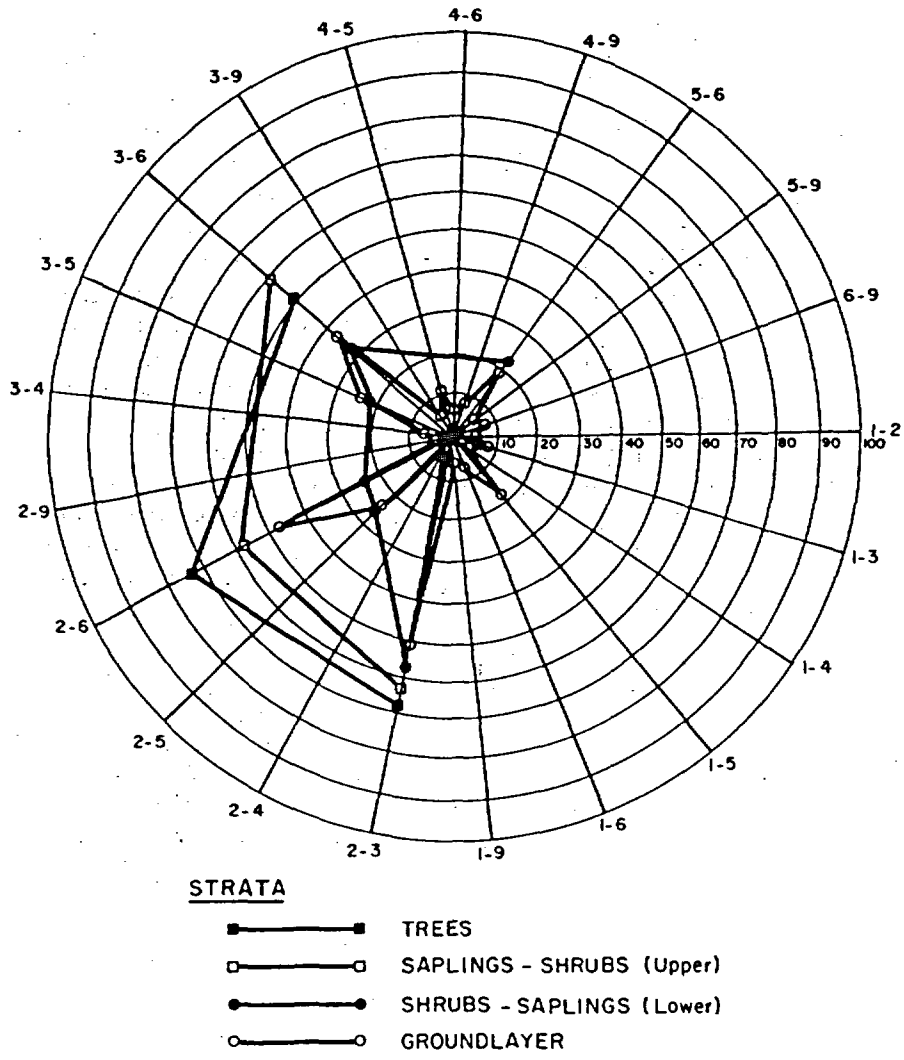

Figure 2. Phytograph of community coefficients indicating the degree of similarity between communities. The coefficients are based on frequencies of species by respective strata. Each radius indicates the degree or percentage of similarity between the two numbered communities.

of all strata 59.3%, whereas that shared by the mesic hardwood and xeric hardwood stands was 48.8%, and by the riparian woods and xeric hardwood stands was 44.7%.

Whereas large indices indicate high degrees of similarity, small indices indicate high degrees of uniqueness. The old field, marsh, and beach were the most distinct communities on Millstone Point; species common to any one of these communities were generally not found in any other community.

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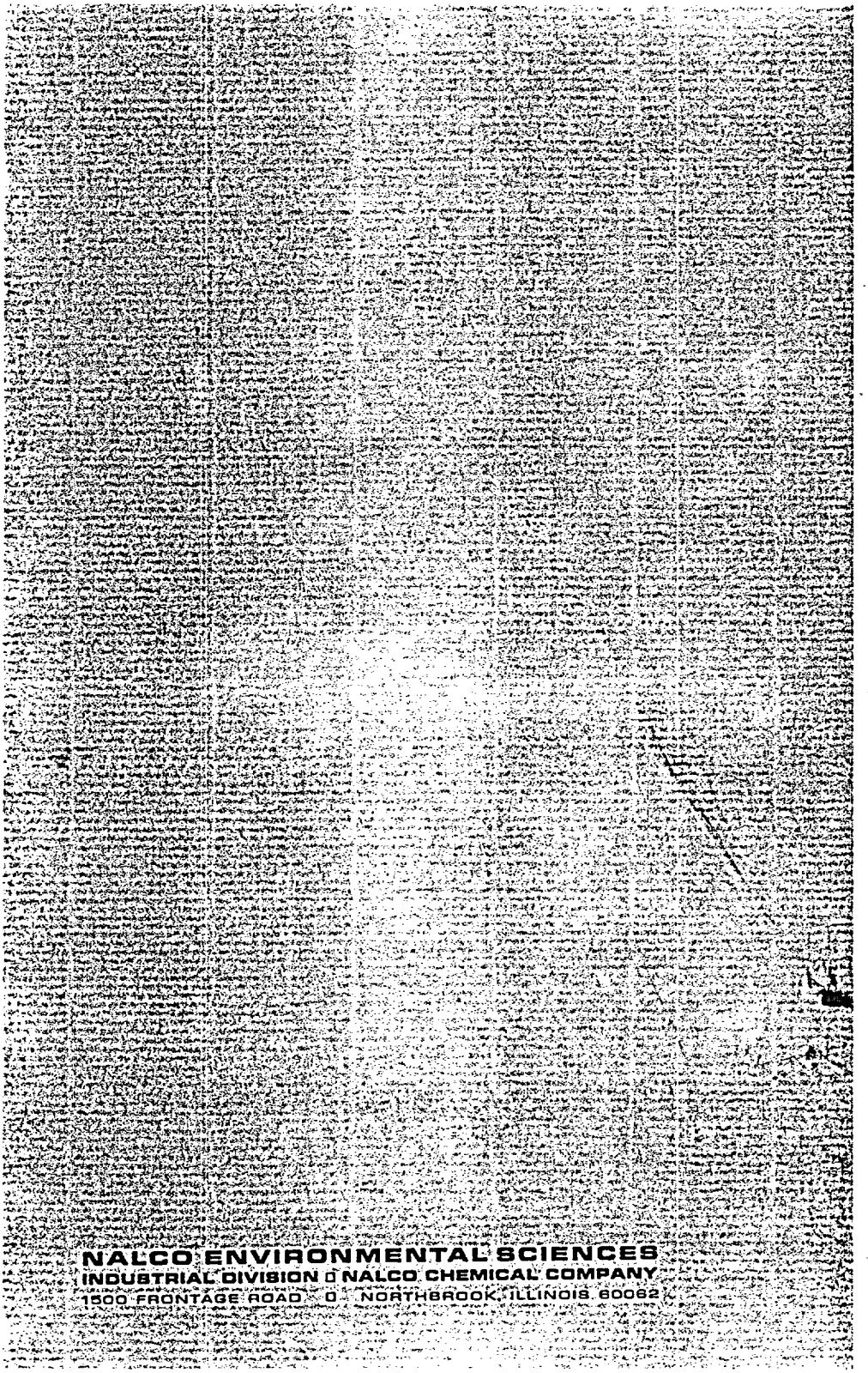

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