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Abstract. Floyd Bennett Field (FBF), 579 ha in extent, is a division of Gateway National Recreation Area. It is the site of a former airfield, constructed by filling salt marshes with dredged materials. Except for the portion known locally as the "North Forty," all sections of FBF have been cut over to maintain low vegetation. A grassland management plan (GRAMP) for 165 ha was initiated in 1986, to maintain habitats for open-country birds. Over the next few years, encroaching woody vegetation was removed manually and mechanically from the management area. Since then, it has been maintained as a grassland and receives annual mowing, as well as continued manual removal of the larger woody sprouts.

A portion of the GRAMP management area (III) was selected for intensive study of vegetation composition. A grid system was created and vegetation cover was estimated in 127, 1 m × 1 m quadrats. The quadrats were subjected to cluster analysis (CA). Eleven clusters were recognized. These clusters were treated as "plant associations." The following types were distinguished: (native) little bluestem–dewberry grassland, six-weeks fescue annual grassland, a grass marsh, a rush marsh, a switchgrass dry grassland, and a deer-tongue panicgrass grassland; (exotic) mugwort herbland, oriental bittersweet-Japanese honeysuckle vineland, Kentucky bluegrass-mixed grassland, Japanese knotweed tall herbland, and spotted knapweed-common St. Johnswort herbland. The little bluestem–dewberry association accounted for nearly half of all quadrats; six subclusters were recognized. The plant associations determined by CA were compared with plant lists compiled during traverses of all of the map categories in the six GRAMP Areas (I, II, III, IV, V, VI). A table was created to relate the quantitative data of the plant associations to the appropriate map categories. A nonmetric multidimensional scaling ordination (NMDS) was performed on the quadrat data. Finally, the plant associations were compared with those described in the literature of local vegetation studies. The mowing program has been effective in decreasing woody plant cover and has permitted the invasion of a few taxa into monospecific communities, but attendant disturbance of the substrate is likely to cause an increase in exotic plant taxa. As earlier studies noted, mowing has caused the increase in cover of sod-forming grass, and bare ground has virtually disappeared in the managed area. This has negative implications for the maintenance of those grassland bird species that require open ground for nesting.

Keywords: Gateway NRA, grassland, restoration, management, New York City

Introduction

Gateway National Recreation Area (GNRA) is internationally known for the large numbers of nesting and resting birds, especially waterfowl, that it attracts to the great urban center of New York City. Located astride the Lower Bay of New York Harbor, GNRA comprises a number of administrative units. This study deals with the Floyd Bennett Field (FBF) unit, a

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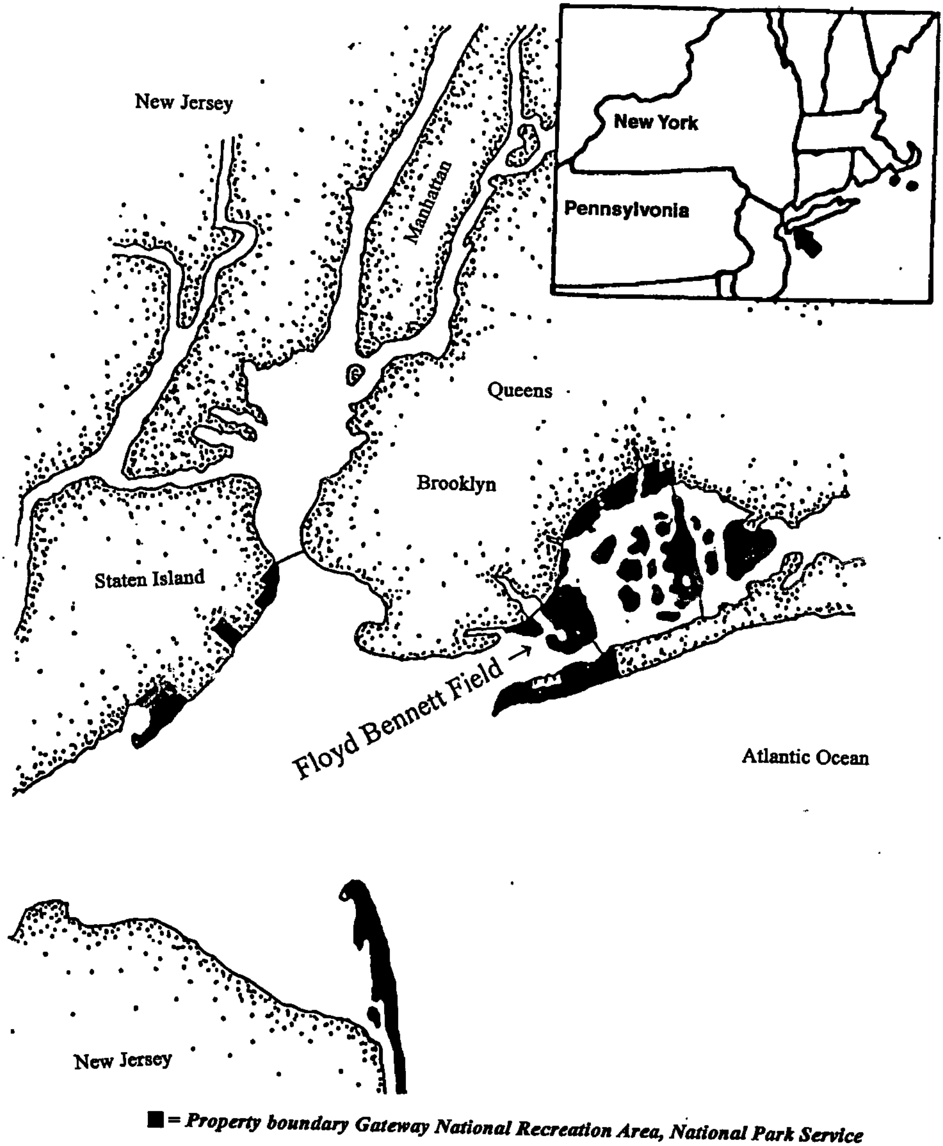

Figure 1. Map of New York City vicinity with Gateway National Recreation Area (NRA) and Floyd Bennett Field indicated.

579 ha site in southern Brooklyn, New York City (Kings County), New York State (figure 1). A part of GNRA since 1974, FBF was formerly managed as a municipal airport and military base. Because of the need to maintain a clear area for airplane traffic, the area around the runways had been mowed regularly, thus creating a grassland habitat. Municipal and federal military airfields contain some of the largest remaining grassland tracts in southern

New England. They are the primary refugia for "area-sensitive" birds such as the upland sandpiper (*Bartramia longicauda*) and grasshopper sparrow (*Ammodramus savannarum*). These bird species, and many others with similar habitat requirements, once nested in the nearby Hempstead Plains, a natural grassland that has lost nearly all of its original 24,000 ha and is now reduced to tracts of 8 and 24 ha, respectively. Today these birds have only a few remaining nesting locations in the northeastern U.S. and face potential extirpation over the next 50 years (Vickery and Dunwiddie, 1997).

In recent decades, FBF has been recognized as a regionally significant habitat for birds that breed and feed in grasslands. From 1984 to 1987, studies of bird–habitat relations were undertaken at FBF (Lent and Litwin, 1989a, b). Breeding birds include the northern harrier (*Circus cyaneus*), short-eared owl (*Asio flammeus*), American kestrel (*Falco sparverius*), barn owl (*Tyto alba*), upland sandpiper (*Bartramia longicauda*), eastern meadowlark (*Sternella magna*), and grasshopper sparrow (*Ammodramus savannarum*). Most of these species are listed as threatened or of special concern in New York State (NYS). Floyd Bennett Field is the only protected site for these birds in New York City (Lent *et al.*, 1997). Lent and Litwin's (1989a, b) studies supported previous National Park Service recommendations that grassland habitats be restored as an aid to increasing populations of the above-mentioned bird species. These recommendations were implemented via the initiation of the Grassland Restoration and Management Program (GRAMP; Cook and Tanacredi, 1990).

Several techniques are available for managing nonarborescent vegetation in forested regions. In England and continental Europe, fire, brush cutting, direct vegetation removal, herbicides, controlled grazing by sheep or cattle, and translocation of desirable vegetation to sites from which they are absent are all used to manage heathlands vegetation (Tiffney, 1997). At FBF, it was decided to continue the practice of regular mowing because of the long experience with that technique, the relatively low cost of continuing to mow (rather than initiate a different type of control), and the relative freedom in setting operational schedules.

According to Vickery and Dunwiddie (1997),

> it is important that we have a better understanding of the evolutionary consequences of management practices on the taxa being managed. This will require a better understanding of the ecological processes that shaped these grassland habitats and taxa. Careful, quantitative research framed around present management practices on grassland habitats provides excellent opportunities to learn more about these grassland ecosystems, and to incorporate these results into improved management practices.

It is toward this end that the present study was undertaken. The objectives were to recognize variation of vegetation in the grassland restoration area, to document composition of the plant communities, and to assess ecological trends. We hope that this knowledge will increase the effectiveness of the management program in maintaining and expanding the populations of native grassland birds, butterflies, and plants in the GRAMP area and provide useful information for other similar management programs. We hypothesized that mowing natural vegetation on mixed marine sediments would produce a number of herbaceous, mainly graminaceous, plant communities, resulting from both the direct cutting of the plant taxa and the occasional localized disturbance of the substrate by the mechanical equipment.

Materials and methods

Management procedures

In winter 1985–1986, efforts began to increase grassland habitat at FBF. These efforts were centered in the management areas, adjacent to the airplane runways, that had been mowed to keep vegetation low and had been the principal breeding site of the grassland-dependent birds at FBF (Areas I–VI in figure 2). The total management area is 140 ha. The restoration process entailed physical removal of aboveground parts of trees, shrubs, and other unwanted plants by cutting and then mowing. Mowing protocols involved the use of a bat-wing "brush-hog" maximower attached to a John Deere tractor, providing a full 12 foot cutting fence. The designated GRAMP Areas (Grassland Management Plots) were mowed every six months, for a period ranging from 10 to 15 years, depending upon the Area. As of the 1999–2000 season, 40 acres (16.2 ha) had been mowed to a grass height of 4 inches (10.2 cm). Mowing protocols are an integral part of the Floyd Bennett Field maintenance schedule. The GRAMP program is managed by representatives of the National Park Service, NYC Audubon Society, American Littoral Society, and Wildlife Conservation Society (Bronx Zoological Park).

The first area to be cleared was Area II in 1985–1986, then III in 1986–1987, IV and V in 1987–1988, Area I in 1988–1989, and VI in 1989–1990. Subsequent management included at least annual mowing (during August) but often required manual removal of stump sprouts as well. *Phragmites australis*, *Polygonum cuspidatum*, and *Rubus allegheniensis* were cut throughout the growing season in a special effort to arrest succession and keep vegetation low, thus making the area potentially attractive to endangered and rare grassland bird species. Since September 1990, Gateway management policy has required mowing of the whole GRAMP area twice a year, right before and after the bird-breeding season.

Map analyses

Cover of the various types of vegetation was determined by first identifying different vegetation units by distinguishing the different patterns, textures, tones, and colors on full-color and black-and-white low-altitude aerial photographs of the site taken in 1984 and 1991, respectively. The 1991 photograph was taken immediately after mowing, in November. Vegetation was outlined with India ink (light areas, herbaceous; dark areas, vines and shrubs) on a clear acetate overlay. In addition, ground truthing was established for the 1991 aerial photograph by walking across boundary lines with map in hand and listing dominant species. A final more detailed map was generated utilizing this information. The two vegetation maps appear as figure 2 (premanagement, 1984) and figure 3 (postmanagement, 1991), respectively. Subsequently, a transparent grid system (10 × 10 to the inch [2.54 cm]) was superimposed on the outline map and squares counted for each of the vegetation types, area by area. Percentages of total GRAMP area were calculated by summing the data by vegetation type for all subareas.

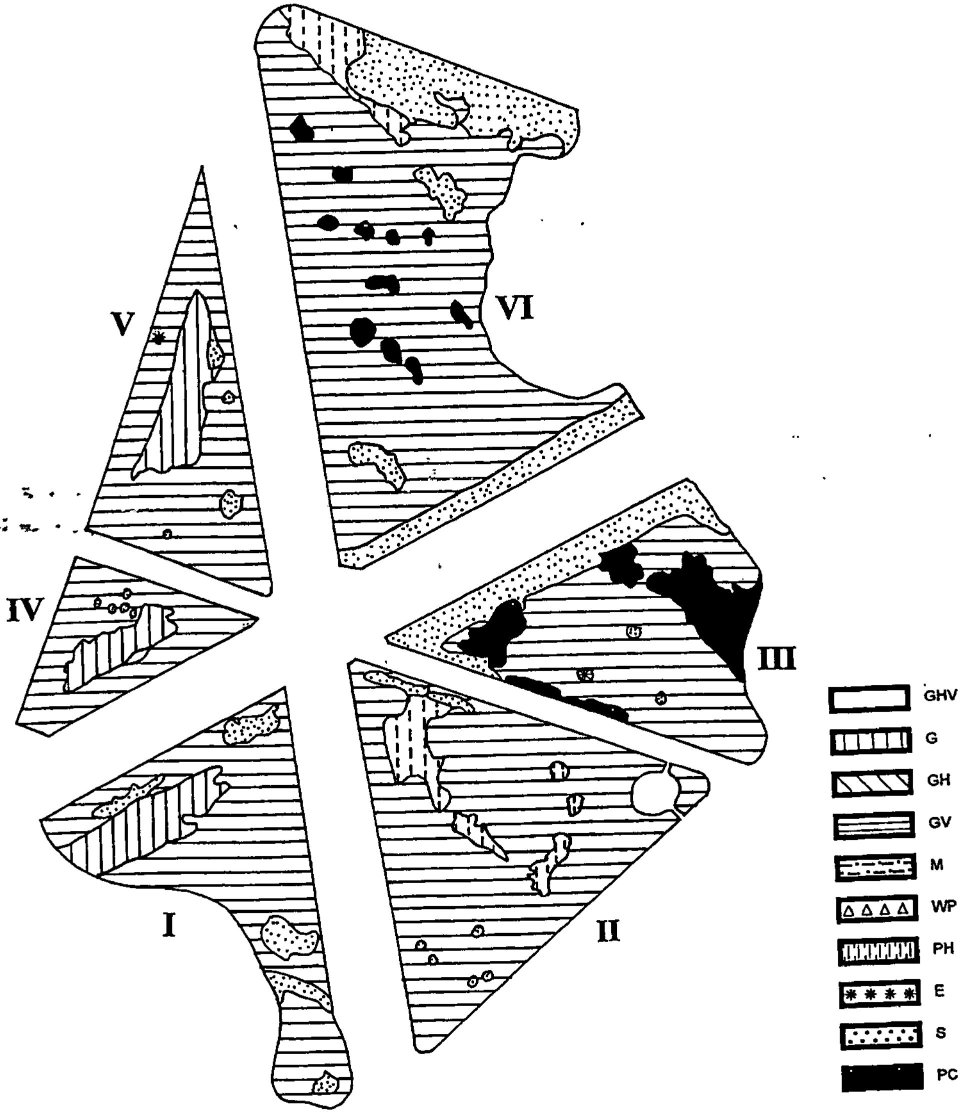

Figure 2. Vegetation map of grassland management area (GRAMP), before management, based on a true color aerial photograph taken in August 1984. (Grassland types) **GHV**, a rich mosaic of grasses, dicot herbs (forbs), shrubs, and small trees; **G**, mainly grasses and other graminoids; **GH**, herbaceous dicots dominate; **GV**, prostrate vines have extensive cover under a sparse grassland; **PC**, a tall herb community of *Polygonum cuspidatum* (Japanese knotweed), pure or with a large variety of grasses, herbs and shrubs. (Marshes) **M**, Graminoid vegetation on wet soils, dominated mainly by rushes (*Juncus* spp.) and grasses; **PH**, reed-dominated communities, pure or with a wide variety of herbs and shrubs. (Shrublands) **S**, a community dominated by shrubs (woody plants that are branched at the base and are less than 6 m tall) such as bayberry (*Myrica pensylvanica*), sumac (*Rhus* spp.), and blackberry (*Rubus allegheniensis*). (Trees) **WP**, a plantation of white pines that was not sampled; **E**, individual specimens of autumn-olive (*Elaeagnus* spp.).

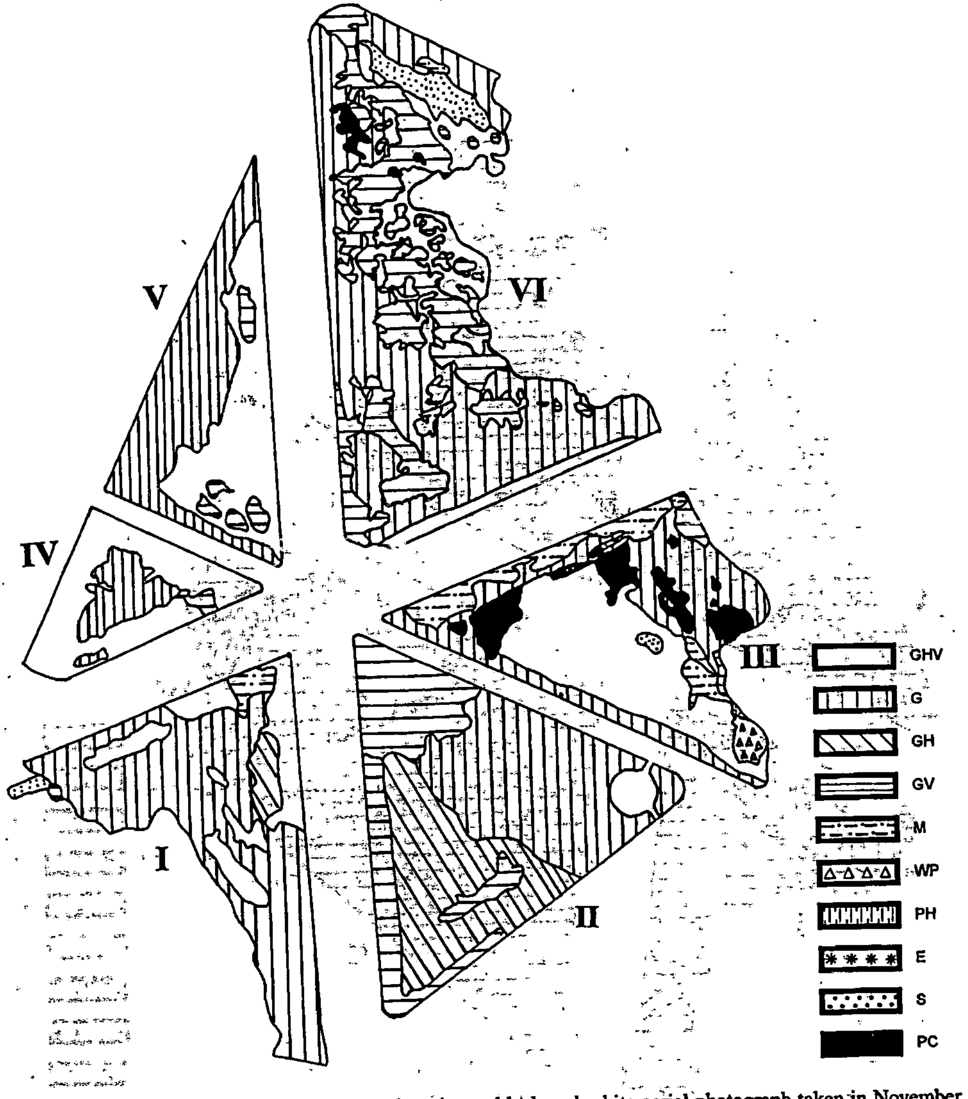

Figure 3. Vegetation map of GRAMP area, based on a black-and-white aerial photograph taken in November 1991.

Florisitic composition of managed vegetation in Area III

Area III is an approximately triangular field (figures 2, 3). Roughly, the western two-thirds of this area—the managed grassland portion—was used in our study. Twenty-five stakes were placed at 20 meter intervals along the southeast side, which is bordered by the central runway of the former airfield. Using a plane table, alidade, rod, and Brunton compass, we sighted lines perpendicular to this baseline. Additional stakes were then placed at 40 meter intervals along each of the 25 lines and also at the opposite ends of the lines. Each stake marked the location of a 1×1 m quadrat. Vegetation was sampled using a 1 m × 1 m quadrat frame placed to the north of each stake, so that the center of one side rested against the stake. Species within the frame were identified and the percentage cover of each was estimated. Nomenclature follows Mitchell and Tucker (1997). A voucher specimen was taken for each species for which data were recorded.

Data processing

The Bray–Curtis index of dissimilarity, based on the cover of taxa, was used to compare all quadrats (Legendre and Legendre, 1998). For a cluster analysis of the quadrats, a dendrogram was generated by the UPGMA method (Legendre and Legendre, 1998; see also Pielou, 1984), in which the least dissimilar quadrats were hierarchically linked (figure 4). We used the dendrogram to group quadrats having similar flora and vegetation (those having the least dissimilar Bray–Curtis indices). For each species, we calculated the mean percentage cover in each grouping, and the frequency (percent of quadrats in which the species occurred). Cluster analysis was performed on the species with respect to the quadrats, again using the

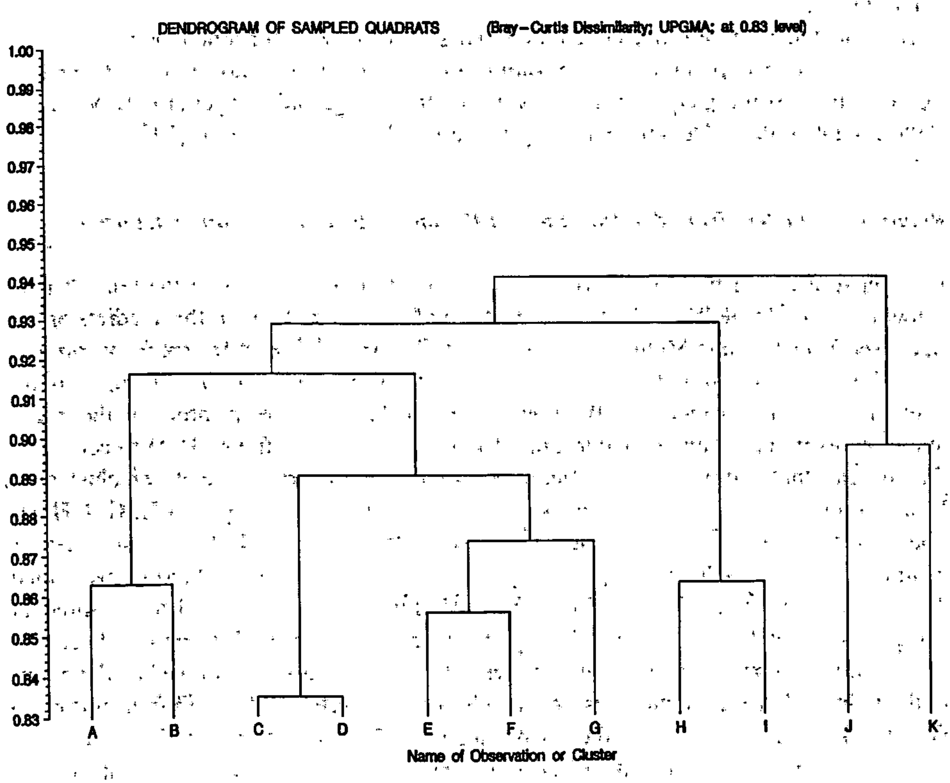

Figure 4: Dendrogram of Bray–Curtis dissimilarity values for Area III quadrats, linked by UPGMA method. Dendrogram has been truncated at the 0.83 level of dissimilarity for clarity.

Bray–Curtis index of dissimilarity. Results of the analysis of the species groups gave no information as useful as the analysis of quadrats and were not reported.

Ordination is a technique for arranging samples (of vegetation, in this case) in relation to a multidimensional (species, in this case) space. In this way, intrinsic patterns hidden in the data may become apparent. This technique orders data so that environmental gradients can be inferred. We chose nonmetric multidimensional scaling (NMDS) for ordination of our quadrats (Legendre and Legendre, 1998); we computed using SAS 6.12 (SAS Institute, 1997). In this indirect ordination technique, the dissimilarity between every pair of quadrats is estimated (in our case by the Bray–Curtis formula), and then the points representing the quadrats are plotted in such a way as to make the distance between every pair of points as nearly as possible equal to their dissimilarity. The number of axes of the coordinate frame in which the points are plotted depends on the number of dimensions that faithfully reproduce the distances. "Badness of fit" (SAS Institute, 1997) measures the "stress" of the ordination. Minchin (1987) showed that NMDS ordination is usually more robust than other popular methods. The values of the coordinates are of no intrinsic interest; they merely achieve the desired spacing between points. Minchin's (pers. comm., 2000) unpublished research on variants of NMDS shows that there is usually little difference in the results of global and local NMDS. Therefore he recommends the simpler global form, which takes much less computation.

To relate the array of groups to environmental factors, we determined the habitat preferences of plants occupying extreme positions on the ordination (clusters F, C, D, and B in figure 5), by consulting Gleason and Cronquist (1991), Page and Weaver (1974), Muenscher (1980), United States Department of Agriculture (1971) and Uva *et al.* (1997).

Relation of clusters from dendrogram to 1991 map legend vegetation categories

In order to evaluate the relation of the eleven dendrogram clusters to the ten 1991 map categories, we proceeded as follows. A diagram of the locations of all the quadrats on their lines (see Materials and Methods section: *Floristic Composition of Managed Vegetation in Area III*) was drawn onto a clear acetate 8.5 × 11 inch sheet. This overlay was superimposed over the 1991 map (figure 3). We now turned to the computer printout of the quadrat assignments in the complete dendrogram (shortened version is figure 4). For each cluster, the quadrats that compose it were identified. Next, each quadrat in the eleven clusters was located on the clear overlay, and the map category of vegetation (e.g., **GVH**, **G**, **GH**, etc.) noted for the quadrat. The map categories were tallied for each cluster and summed. For example, cluster E included 63 quadrats, but 69 assignments to map categories were made. This was due to the location of a few of those quadrats at the transition of two or three map categories (vegetation types), and these were assigned to both or all categories because of uncertainty as to predominant vegetation type. The map categories followed by the number of their cluster E assigned quadrats (in parentheses) were **GHV** (33), **GHV**/transitions (13), **G** (14), **G**/transitions (2), and other map categories (7). Considering another case, cluster D has 14 assigned quadrats and 14 designations. These are related to map categories as follows: **PC** (4), **PC**/transitions (6), others (4). We then inferred the relation between each of the eleven dendrogram clusters and ten map legend categories (vegetation types).

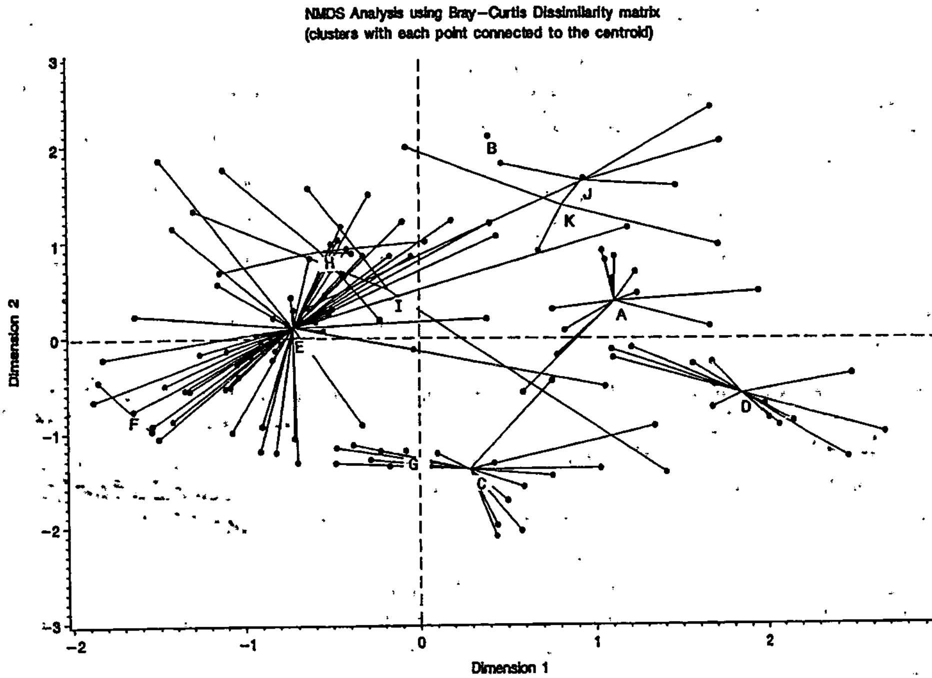

Figure 5. NMDS (nonmetric multidimensional scaling) ordination of eleven clusters of quadrats in Area III, based on Bray–Curtis dissimilarity values. Clusters with each point (quadrat) connected to the centroid of the cluster. Cluster labels correspond to clusters in figure 4.

Results

Map analyses of GRAMP area: changes in vegetation cover from 1984 to 1991, based on comparison of aerial photographs

Premanagement vegetation of grassland management (GRAMP) area

Pre-GRAMP vegetation was reconstructed from personal observations, reports, maps, and photographs (Grady and Rogers, 1984). Rogers *et al.* (1984) described the vegetation as four-layered, including a sparse moss/lichen carpet, a layer of forbs and grasses reaching about 1.5 m, a herb/shrub layer reaching about 5 m, and a sparse upper layer of young trees. They noted that fires occurred yearly, but these were sporadic. Only a few species dominated the landscape—dense stands of bayberry (*Myrica pensylvanica*) and reeds (*Phragmites australis*) covered 50% of the premanaged GRAMP area, and grassland, dominated by little bluestem (*Schizachyrium scoparium*) and other grasses, covered about 25%. The August 1984 true-color aerial photograph (1 inch = 200 ft) shows mowed or cleared patches, adjacent to the runways, that were to become the GRAMP-managed grassland. The light green color and the uniform texture of the herbaceous vegetation contrast with the dark green color and irregular texture of the bayberry shrublands and mixed low woodlands that still surround the GRAMP area. It is likely that the present boundaries of the GRAMP area were

Table 1. Changes in percentage cover in entire GRAMP area, from 1984 to 1991 (From aerial photographs).

All GRAMP areas	Grasslands				Rushes (M) and reeds (Ph)		Japanese knotweed	Shrubland[1]				Woodland (mainly *Prunus serotina*)
	GHV	GH	G	GV	M	Ph	(PC)	Ru	Myr	Rh	S	
1984 total %	77.9	—	5.1	—	—	2.7	4.5	—	7.4	0.2	1.4	0.6
1991 total %	20.8	11.3	46.7	11.3	2.6	—	5.1	0.2	1.4	—	—	0.4
1984 entire category %	83.0				2.7		4.5	9.0				0.6
1991 entire category %	90.1				2.6		5.1	1.6				0.4

[1]Ru = *Rubus* spp.; Myr = *Myrica pensylvanica*; Rh = *Rhus* spp.; S = other shrubs.

strongly influenced by the earlier management of the site as an airfield, which created a low mainly herbaceous vegetation in an effort to provide good visibility to pilots. Within this vegetation, the occasional trees and the many shrubs were removed.

In figure 2, a vegetation map based on the 1984 aerial photograph, major categories of vegetation were used for the purpose of mapping (grassland, marshes, shrublands); some trees were also marked. Because certain species were described as forming nearly pure expanses on the landscape in 1984, it was possible to map these species separately. Hence the names *Phragmites australis*, *Polygonum cuspidatum*, and *Elaeagnus* are used in the legend. Percentages of ground cover in the 1984 aerial photograph are given in Table 1.

Postmanagement vegetation of the grassland management (GRAMP) area

The legend for the 1991 vegetation map, figure 3, is expanded in Table 2. Map categories are based on the potential life forms of the dominant species. Table 1 presents numerical data based on the measurement of vegetation cover in both the 1984 and 1991 maps. In 1984, various (upland) grassland types comprised 83.0% of total cover; relatively small areas of marshes and reed (*Phragmites*, a tall grass on wet sites), and *Polygonum cuspidatum* (Japanese knotweed, a tall herb from a thick perennial base) were also recorded. Shrubland types comprised only 9.0%; trees only 0.6%. Most of the area covered by grassland was a rich mixture of herbs, grasses, vines, and shrubs (designated GHV). Among the herbs, goldenrods (*Solidago* spp.) probably played a major role (judging from their present abundant sprouting from extensive rhizomes), with a thick understory of prostrate vines, mainly *Rubus flagellaris*. There were numerous shrubs scattered throughout this mixed herbland; it is likely that bayberry, *Myrica pensylvanica*, was most abundant. *Rubus allegheniensis* (blackberry) probably was also well developed, as indicated by the numerous stump sprouts that can still be seen in traversing the GRAMP area. Although grasses were interspersed throughout the grassland, the area actually dominated only by grasses, designated **G** in Table 1, was not large. Most of the 9% shrubland cover in the 1984 GRAMP area consisted of nearly uniform stands of bayberry. These stands appear to have been planted to border the runways and make them inaccessible to lateral ground traffic.

For the 1991 map, a subjective list of common species in the map categories was established by traversing all the GRAMP Areas. Comparing the 1991 map data with that

Table 2. Comparison of 1991 map legend vegetation categories with Area III groups from cluster analysis.

1991 map vegetation category	Clusters from dendrogram (no. quadrats of occurrence/total quadrats in cluster) (quadrats on/near two map vegetation types are counted twice for occurrence)
Grassland (herbaceous types)	
G Grasses dominant	C(15/17), J(4/5), D(6/14), A(2/12), H(4/5), K(4/4), I(3/3), F(1/2), G(1/1)
GH Forbs (dicot herbs) dominant	[Not present in Area C]
GV Vines (woody and herbaceous) dominant	A(1/12)
GHV Grassland with mixture of forbs, vines, shrubs	E(46/63), C(2/17), F(1/2), D(3/14)
PC Tall herbland of Japanese knotweed (*Polygonum cuspidatum*)	D(10/14), J(2/5), E(16/63), K(2/4), I(1/3)
Marshes	
M Grass and rush marshes	A(10/12), B(1/1), E(10/63), H(2/5), I(1/3), D(1/14), F(1/2), K(2/4)
PH Reed marsh	E(2/63), H(1/5)
Shrubland	
S Bayberry, blackberry, sumac, black cherry, ailanthus, or autumn-olive	E(3/63)

of 1984 (Table 1), we find that nearly pure grasslands (G) now account for almost half of the total vegetation, up from only 5.6 percent. The GHV category, the rich mixture of grasses (*Schizachyrium scoparium* is the dominant, with many other species of Poaceae), herbs (*Aster* spp., *Solidago* spp., *Potentilla*, *Gnaphalium*, *Rumex acetosella*), vines (*Rubus flagellaris*) and shrubs (*Myrica pensylvanica*, *Rubus allegheniensis*, *Rhus copallina*), plus mosses and lichens on the surface, was formerly predominant on the GRAMP landscape. It has been reduced from 78% (1984 map) to only about 23% of the total grassland category. Shrubs and vines persist in this grassland vegetation but are kept low by mowing. In the 1991 ground survey, we were able to recognize two new grassland types. One, designated **GH**, now includes 11.3% of all grassland cover. It includes open fields that are dominated by forbs such as *Artemisia vulgaris*, *Aster* spp., and *Solidago* spp.

The other new grassland type (GV), also accounting for 11.3 percent of grassland cover, is dominated by *Rubus flagellaris*, a trailing woody vine, with a sparse overstory of *Schizachyrium scoparium*. As already noted, shrubland (mainly *Myrica pensylvanica*, *Rhus copallina*, *Rubus allegheniensis*, *Prunus serotina*) has been drastically reduced, by design. Bayberry (*M. pensylvanica*) remains the dominant among the sparse shrubs. Total areas of the other three principal categories remain about equally small.

Within the category rushes and reeds, *Phragmites* has all but disappeared with continued mowing. This category shows a change in physiognomy, from *Phragmites* domination to the present condition of a mixture of *Phragmites* stems, *Panicum* spp., and *Rubus flagellaris*. Other wetland herbs (designated **M** category), principally rushes (*Juncus* spp.), have increased correspondingly. Associates of the rushes are Cyperaceae, especially *Carex* spp., and Poaceae (grasses) such as *Agrostis* spp., *Schizachyrium*, *Festuca* spp., *Panicum*, *Poa*, and *Phragmites*). Cover of Japanese knotweed (PC category, *Polygonum cuspidatum*) appears to have remained similar, but this is misleading. It formed dense thickets in 1984, whereas in 1991 it had much lower cover. All trees have been removed from the GRAMP area.

Quadrat analyses of present postmanagement GRAMP vegetation

Figure 4 gives the results of a cluster analysis of Bray–Curtis dissimilarity values for the 127, 1 m × 1 m quadrats in Area III (figure 3). At a dissimilarity value of 0.83, the cluster analysis identified 11 clusters; at 0.70, 22 clusters; at 0.60, 34 clusters. Distance on the vertical axis is arbitrary. It was decided to recognize the clusters (groups of closely similar quadrats) at the 0.83 level, because at the lower levels of dissimilarity the clusters did not represent communities recognizable in the field but rather fragments of those communities. Almost half of the quadrats fell into a single cluster (E). Appendix 1 shows percentage cover data, by dendrogram cluster, for all taxa in the 127 quadrats.

Descriptions of plant communities identified by cluster analysis

In this section, we list the clusters in alphabetical order and characterize each cluster as a plant community. In the following descriptions, a dash (–) separates dominants in the same stratum or life form (e.g., *Schizachyrium scoparium-Panicum*); a slash (/) separates dominants of different strata (e.g., shrubs/herbs). The names grassland, herbland, vineland, and shrubland denote associations dominated by grasslike (graminoid) plants, dicotyledonous herbs, vines, and shrubs, respectively.

Cluster A (mugwort herbland)
Cluster A comprises 11 quadrats. The aggressive, exotic herb, mugwort (*Artemisia vulgaris*) is the dominant, with nearly 50% of all plant cover. A rich mixture of life forms occurs with mugwort. Other herbs, graminoids, vines, and shrubs compose the remaining plant cover, in nearly equal proportions.

Cluster B (oriental bittersweet-Japanese honeysuckle vineland)
Cluster B comprises only one quadrat, near the northern edge of the field. The vines oriental bittersweet (*Celastrus orbiculata*) and Japanese honeysuckle (*Lonicera japonica*) dominate, accompanied by dewberry (*Rubus flagellaris*) and climbing false buckwheat (*Polygonum scandens*). These vines compose 80% of plant cover. The remaining cover is provided by *Polygonum lapathifolium* and *Artemisia vulgaris*.

Cluster C (Kentucky bluegrass-mixed grassland)
Cluster C comprises 17 quadrats. The first dominant is Kentucky bluegrass (*Poa pratensis*), with 40% cover. Little bluestem (*Schizachyrium scoparium*) and some other grasses bring the total cover of Poaceae to nearly 70% of the community. Japanese knotweed (*Polygonum cuspidatum*), with over 16% cover, is the only other important species.

Cluster D (Japanese knotweed tall herbland)

Cluster D comprises 14 quadrats. It is dominated by Japanese knotweed (*Polygonum cuspidatum*), which has over 55% of plant cover. When other herbaceous dicots are counted, the total cover by herbs is nearly 73%. Grasses and vines are also present.

Cluster E (Schizachyrium scoparium/Rubus flagellaris grassland)

Cluster E, comprising 63 quadrats, is by far the largest of the plant communities. There are two major dominants, little bluestem (*Schizachyrium scoparium*) and dewberry (*Rubus flagellaris*). A few other grasses are present and some shrubs and herbs. Few nonnative taxa are found, mainly dicot herbs. This community appears to be of the type that formed the matrix of the pre-GRAMP vegetation on the site.

At the 0.80 level cluster E divides into two unequal groups. The smaller subcluster (E1) is dominated by bayberry (*Myrica pensylvanica*), with rough-stemmed goldenrod (*Solidago rugosa*), dewberry, and little bluestem. The larger subcluster divides at the 0.72 level into five subclusters. The three largest and/or most distinctive of these subclusters are characterized as follows: E2) [*Schizachyrium scoparium* grassland] accounting for about half of the group E quadrats; *Schizachyrium scoparium* dominates with a sparse understory of *Rubus flagellaris*; a few of the quadrats also contain a dense growth of sucker sprouts from *Prunus serotina* (black cherry) stumps; E3) [*Rubus flagellaris* vineland] a tangle of *Rubus flagellaris*, a prostrate vine, characterizes this community type, which includes several other native plants; a sparse to moderate overstory of *Schizachyrium scoparium* is present in most but not all of the quadrats; this subgroup is similar to the preceding in floristic composition but with the roles of the two dominants reversed; it accounts for approximately a third of E quadrats; E4) (gray birch shrubland) in the two stands that compose this subcluster, *Betula populifolia* (gray birch) is sprouting from stumps that remain after cutting and mowing; a mixture of mainly native shrubs, grasses, and forbs forms an understory; as with the *Myrica*-dominated subcluster, the cessation of mowing would allow this subarea to revert to dense shrubland; in this case, *Betula* trunks would emerge above a low canopy of *Prunus serotina* and *Rhus copallina*.

Cluster F (six-weeks fescue (Vulpia octoflora) annual grassland)

Cluster F comprises only two quadrats. The dominant plant taxa are the native annual grass *Vulpia octoflora* (35% cover) and a mixture of goldenrod species (*Solidago* spp., 24% cover). Little bluestem and silvery cinquefoil (*Potentilla argentea*), a low trailing herb, are the only other dominants. Because *Vulpia* and *Potentilla* often occur on otherwise bare soils, this community may represent vegetation on a recently disturbed site.

Cluster G (spotted knapweed-common St. Johnswort herbland)

Cluster G comprises only one quadrat, at the beginning of a line and near a large paved surface. Here the dominants are a few exotic herbs with relatively low cover. The leading dominant is spotted knapweed (*Centaurea maculosa*) with 33% cover. The second dominant is common St. Johnswort (*Hypericum perforatum*) with 26% cover. Overall, herbs comprise 75% cover, while grasses provide only about 16% cover. Exotic species are the dominants here.

Cluster H (rush marsh)
Cluster H comprises 5 quadrats. The dominants are graminoids with 63% cover. Rushes (*Juncus* spp.), with over 40% cover, provide the largest portion of the cover. Herbs account for 20% of plant cover. Shrubs and vines are also present. This community is composed of plants that are found in moist sites (*Juncus effusus, Phragmites australis, Sambucus canadensis*) and may represent a wetland community that was present in the pre-GRAMP landscape.

Cluster I (grass marsh)
Cluster I comprises 3 quadrats. It is dominated by unidentified Poaceae (46%), of which silver hair grass (*Corynephorus canescens*) and/or weeping love grass (*Eragrostis curvula*) are probably major components, and by the wetland graminoids *Juncus* spp. and *Carex silicea*. Graminoids comprise 77% of plant cover. Other plants of these moist soils are Japanese knotweed and elder (*Sambucus canadensis*). A mixture of goldenrod species accounts for 7% of plant cover.

Cluster J (switchgrass grassland)
Cluster J comprises 5 quadrats. Switchgrass (*Panicum virgatum*) is the major dominant, with 72% cover. The tall herb, white boneset (*Eupatorium album*), is the second dominant with 10% of plant cover. Other grasses are present but provide little cover, as is also the case for other herbs. The shrubs, shining sumac (*Rhus copallina*) and bayberry (*Myrica pensylvanica*), provide over 8% cover. This community of perennial bunchgrass represents mainly native vegetation on well-drained sites. Switchgrass provides abundant plant cover on coastal sandy flatlands and behind sand dunes.

Cluster K (deer-tongue panicgrass (Panicum clandestinum) grassland)
Cluster K comprises 4 quadrats. The dominant plant is the native *Panicum clandestinum* (deer-tongue panicgrass), with 44% plant cover. Other graminoids, mainly grasses, contribute to the community for a total of 61% graminoid cover. Herbs comprise over 17% plant cover, and the trailing woody vine, dewberry, provides 11% cover.

Relation of clusters from dendrogram to 1991 map legend vegetation categories

Table 2 relates the 1991 map categories to Area III clusters. Cluster C is almost completely assigned to map category **G**, grassland with no understory of vines. This is also true of the smaller clusters G, H, I, J, and K. All of these clusters are dominated by graminoid vegetation, with the exception of cluster G (weedy herbs). Cluster E, grassland of little bluestem, dewberry, herbs and shrubs, is the largest, with more than two-thirds of its quadrats assigned to map category **GHV** (rich mixed grassland). Cluster D has most of its quadrats (10 of 14) assigned to **PC** Japanese knotweed. Japanese knotweed community is the assignment for cluster D. Cluster A has 10 of its 12 quadrats assigned to **M**, grass and rush marshes. Cluster A is described as a mugwort community with a rich mixture of life forms. Mugwort is often seen on moist disturbed sites throughout Long Island. Cluster B, a single quadrat, is also assigned to **M**, incorrectly. Cluster B is the vineland of oriental bittersweet and

Japanese honeysuckle. While there is a lack of complete agreement between clusters and 1991 map categories, there is a general correspondence within the graminoid life form and in the denser stands of Japanese knotweed.

Ordination of Area III quadrats

Figure 5, a two-dimensional ordination, is presented as a simple display of the clusters. It shows the results of an NMDS ordination of Bray–Curtis dissimilarity values (stress = 0.214; SAS Institute, 1997). The stress value is a measure of the extent to which the rank order of dissimilarity disagrees with the rank order of distances between points. Eleven clusters are identified. The quadrats are points connected to the centroid of each cluster. Apparent overlaps are the result of displaying a multidimensional analysis in only two axes. The stress value of 0.214 is considered somewhat high. Thus the interpretation of our two-dimensional ordination plot is likely to be somewhat inaccurate.

The dense aggregation of quadrats at the left (centered on dimension 1: −1; dimension 2; 0) of the figure represents mainly cluster E (*Schizachyrium scoparium* and *Rubus flagellaris*). Clusters F, H, and I are also located there. At the center right (centered on dimension 1: +0.3; dimension 2: −1.5) is cluster C; cluster G is also located there. At extreme right is cluster D (centered on dimension 1: +1.8; dimension 2: −0.5). Cluster A is at middle right (centered on dimension 1: +1.1; dimension 2: +0.3). Clusters B, J, and K are small clusters located approximately in the quadrant where dimension 1 is +1.0 and dimension 2 ranges from −1.0 to 2.0. Thus the largest clusters, E, C, D, and A, are readily distinguishable in the two-dimensional ordination.

By analyzing the data in a three-dimensional NMDS ordination of Bray–Curtis dissimilarity values, we are able to reach a more acceptable stress value (stress = 0.159; SAS Institute, 1997). In the optimal view, the dense aggregation of quadrats at the front left of the figure represents mainly cluster E (*Schizachyrium scoparium* and *Rubus flagellaris*). Clusters F, H, and I are also located there. At the extreme right (in the front) is cluster D. At center-right is cluster A. At the front of the figure, immediately to the right of cluster E, is cluster C. The clusters, therefore, hold approximately the same relative positions as in figure 5. The display, however, suffers from an overly complex array of lines and quadrat labels, which are especially unreadable in cluster E. It was not included as a figure but is available to readers upon request.

In the following paragraphs, the positions of the clusters in figure 5 (two-dimensional ordination) are discussed with respect to their floristic composition. We then speculate on the ecological nature of the two ordination axes, based on the known ecological preferences and tolerances of component species.

Cluster F occurs in the extreme negative position of dimension 1 in the two-dimensional ordination (figure 5). This cluster comprises two quadrats in which *Vulpia octoflora* is the first dominant (34.7% cover), *Solidago* spp. is second (24.4% cover), *Schizachyrium scoparium* is third dominant (18.2% cover), and *Potentilla argentea* is fourth (12.1%). *Rhus copallina* and *Prunus serotina* are present in small amounts. Only seven taxa occur in this cluster, which appears to represent disturbed, nutrient-poor sites that may have been produced by scraping away topsoil in mowing, following cutting of the woody plants. *Vulpia* is said to occupy dry or sterile soils (Muenscher, 1980). *Solanum carolinense*, a plant "that thrives on sandy or gravelly soils" (Uva *et al.*, 1997), waste places, and cultivated fields, is also present.

Cluster D occurs on the extreme positive end of dimension 1 (figure 5), and nearly equidistant as cluster F from the center at 0. Nineteen taxa compose total plant cover for cluster D. The leading dominant is *Polygonum cuspidatum* (55.4%). Commonly known as Japanese knotweed, this species usually dominates "rich, damp sites," especially along rivers (Page and Weaver, 1974), and "waste places and neglected gardens" (Muenscher, 1980). *Bromus tectorum* (8.55%), a distant second, occurs in fields, pastures, roadsides, and waste places, often on dry sandy or gravelly soil. *Artemisia vulgaris* (4.70%) is a weed of turfgrass, nurseries, waste places, fields, and pastures. We propose that dimension 1 is a gradient of soil moisture, with moisture increasing from the negative portion of the axis to the positive.

Cluster B occupies the greatest positive position on dimension 2. It comprises only one stand, which is dominated by vines: *Celastrus orbiculata* (33.3%), *Lonicera japonica* (33.3%), and *Rubus flagellaris* (6.7%). *Celastrus orbiculata* forms "tangles and thickets" in "landscapes, roadsides and other uncultivated areas" (Uva *et al.*, 1997). *Lonicera japonica* is a "weed of perennial crops in orchards... plantations, nurseries and landscapes" (Uva *et al.*, 1997); also gardens and waste places. Mowing, followed by ploughing and harrowing, is the suggested method to eradicate *Lonicera* (Muenscher, 1980). This implies that the habitat of cluster B is little disturbed by the mowing regime that strongly affects most of the quadrats.

Cluster C occupies the most negative position on dimension 2. It is composed of 29 species, of which grasses dominate, especially *Poa pratensis* (40.5%), *Schizachyrium scoparium* (17.1%), and *Panicum virgatum* (6.9%). *Polygonum cuspidatum* (16.2%) is the third dominant. Grasses at FBF are dependant upon a regular regimen of mowing to avoid being overgrown by shrubs, vines, and trees. Dimension 2 likely represents a gradient of disturbance intensity, i.e., mowing.

Discussion

Evaluation of management techniques for vegetation at Floyd Bennett Field

Previous quantitative vegetation studies at Floyd Bennett Field

Following the nomenclature of Norton *et al.* (1984), Lent and Litwin (1989a) listed the "covertypes" found on FBF before the implementation of GRAMP, together with percentages of the total area occupied by each covertype. Upland, terrestrial covertypes comprising >1% of the total area were *Phragmites* (20.60%), runways (18.25%), mixed grassland (15.00%), developed land (13.80%), mixed open shrubs/grass (5.36%), bayberry/mixed shrubs (5.06%), mowed grasslands or lawn (4.64%), and mixed grasses/shrubs (1.80%).

Grady and Rogers (1984) applied the Mueller–Dombois and Ellenberg (1974) life-form system of vegetation classification to Floyd Bennett Field. They constructed a large-scale (1:2400) base map using aerial photographs overlaid with the Universal Transverse Mercator Coordinate system, recorded dominant life forms on the map after field reconnaissance, and took photographs of representative mapping units. Photographs of vegetation in the North Forty area, taken in 1983, are also available, accompanied by a vegetation map of the area (Solecki, 1984).

Other vegetation studies at FBF include Hartig and Rogers (1984), on the fire ecology of *Phragmites australis* (tall reed grass), and Rogers *et al.* (1984), on the growth of *Myrica pensylvanica* (bayberry). In the latter study, the authors conservatively estimate that without human intervention, bayberry would replace all grasslands in 35 years or less. Lent and Litwin (1989b) show that between 1984, when management began, and 1987, "shrub" cover was reduced fourfold; from 85.5 to 22.5%, reflecting the systematic removal of this life form. Cover of "bareground" decreased tenfold during the same period, from 25.5 to 2.4%, "bunchgrass" decreased by nearly half, from 49.7 to 29.9%; "sodgrass" tripled from 4.2 to 13.2%, forbs doubled from 10.8 to 20.7%, "herb species" increased from 9.5 to 13.4%, and "litter" from 4.8 to 6.5%.

Present study of vegetation change under GRAMP management

As has been noted previously, the physical structure of the GRAMP area has changed from 1984 to the present, in that tree and shrub life forms have been removed. The marked changes in vegetation structure noted by Lent and Litwin (1989b) between pre- and postmanagement eras are described above. Bare ground, reported to have decreased from 25 to less than 3% after management began, was not an important feature in any of our GRAMP quadrats and was not recorded in our samples.

It is not surprising that after 15 years of annual mowing and manual removal of shrubs, the presently existing major plant communities are herbaceous, and shrub-dominated types are absent. Of the eleven clusters recognized as plant communities, five are grassland types on well-drained soils (C, E, F, J, K), two (H, I) are graminoid-dominated marshes of moist soils. Of the remaining four types, three are herb-dominated (A, D, G), and one (B) is vine-dominated. Thus management practices designed to increase areas dominated by grasses have been successful. Before 1985, GRAMP area grassland was richly mixed with forbs, shrubs, and small trees; now it is a much simpler vegetation dominated mainly by native *Schizachyrium scoparium* but including native *Panicum* spp. and a number of exotic grasses (e.g., *Eragrostis curvula*, *Poa* spp., and *Festuca* spp.). Frequent associates of the grasses are the prostrate vine *Rubus flagellaris*, *Solidago* spp. (goldenrods), the annual herb *Linaria canadensis*, many native perennial herbs, and many exotic forbs.

Referring to Table 2, while there is a lack of complete agreement between clusters and 1991 map categories, there is general correspondence within the graminoid life form and in the denser stands of Japanese knotweed. In examining the possible causes for the lack of a complete agreement of cluster to map category, we find a small degree of imprecision in superimposing sample grid points onto the map. This may be due to changes in scale as a result of size reduction during xeroxing. Some quadrats appear to occur at or near a line drawn to separate different grassland types; these are counted twice and assigned to both types. Location of some of the more distant quadrats may be imprecise because of poor weather conditions during that phase of the survey. Inconsistencies may also be due to the fact that the 1991 aerial photo was taken immediately after a mowing, although the area was traversed after some regrowth.

Mowing on an annual basis appears to be diminishing the percentage cover of tall grasses and herbs such as *Phragmites* and *Polygonum cuspidatum*, resulting in a locally more mixed community. Mowing also appears to be diminishing the dominance of wetland plants on the moist sites. Reduced cover by wetland plants may be due to increased evaporation of water from exposed soils, as a consequence of removing all but a few inches of plant height above the soil level.

The results of our study support our hypothesis that mowing produces a variety of herbaceous communities, mainly graminaceous. Further, mowing and the local, occasional, consequent mechanical damage to plants at and below the soil level may be responsible for the presence of some communities dominated by exotic grasses and herbs. Exotic plants, and native plants tolerant of disturbance, are present as dominants in a number of the mainly graminoid communities, including the exotic Kentucky bluegrass (a key component of residential lawns and the dominant in cluster C), and the two natives, path rush (*Juncus tenuis*, H) and deer-tongue panic grass (*Panicum clandestinum*, K). *Vulpia octoflora* grassland (F) appears to develop after mowing machines scrape away topsoil. *Artemisia vulgaris* herbland (A) occurs along the edges of paved roads; *Centaurea-Hypericum-Saponaria* herbland (G), although of uncertain origin, most likely develops under disturbed conditions.

Exotic and disturbance-tolerant native plants are present, possibly as a consequence of both mowing and manual removal of woody plants. Perhaps, under continued mowing, native grasses, herbs, and shrubs will spread to reduce or eliminate these exotic types, as manual removal of shrubs and small trees is discontinued. Nevertheless, it is also possible that stoloniferous and rhizomatous exotic grasses such as Kentucky bluegrass (*Poa pratensis*) and Canada bluegrass (*Poa compressa*), and quackgrass (*Agropyron repens*), may enter or spread in cover, successfully competing against the native flora because of their tolerance to mowing. It is also possible that mowing with massive vehicles will continue to scrape the soil and remove vegetation, creating a permanent habitat for exotic herbs and grasses of disturbed soils.

Rudnicky *et al.* (1997) tested prescribed fire as an alternative habitat management technique for nesting grassland birds at FBF. Two fields were burned, one in April 1993 and one in August 1993. They found that the August-burned field continued to have more open ground (bare soil) than the April-burned site, which soon resembled the mowed area due to the presence of continuous plant cover. Woody plants showed lower rates of growth, and greater mortality, in the August-burned field.

Comparisons of managed (GRAMP) vegetation with local plant communities

Reschke (1990) describes the ecological communities of New York State. Under "VI. Terrestrial System, A. Open Uplands" she notes the following communities that share many dominants with GRAMP vegetation; "7. Maritime grassland," "8. Hempstead Plains grassland," "22. Successional old field." Under "D. Terrestrial Cultural" she lists the following similar types, with only a general indication of dominant plants: "12. Mowed Lawn," "13. Mowed roadside/pathway," "22. Brushy cleared land." (Reschke uses the word "lawn" to include all vegetation that is periodically mowed and dominated by grasses.) Clearly all GRAMP vegetation must be classified within the latter three categories, since it is maintained by management practices such as mowing and cutting. Because a few years have elapsed since shrubs and trees were removed, "Brushy cleared land" in the GRAMP area has been converted to "Mowed 'lawn'" (*sensu* Reschke) and "Mowed roadside/pathway" by regular mowing. Nevertheless, the substrate upon which the managed vegetation grows is derived from local sublittoral dredge spoils, consisting mainly of sand, muck, and shells. Such substrates, naturally deposited, are the normal habitats for native maritime herbaceous and woody vegetation.

An inspection of Reschke's lists of dominant plants for "Maritime grassland," "Successional old field," and "Hempstead Plains grassland" suggests that although the GRAMP area vegetation must be classified in Reschke's (1990) system as "Mowed 'lawn'" and "Mowed roadside/pathway," there are strong floristic similarities to "Maritime grassland" and "Successional old field," with lesser similarities to "Hempstead Plains grassland." Contrary to Reschke (1990), we suggest the term "Mowed grassland" be used for GRAMP-managed vegetation.

Grassland plant taxa under GRAMP management

Mehrhoff (1997) lists 28 common native grassland plant species for eastern North America. Of these, six are present in our samples: *Aster* spp., *Euthamia graminifolia*, *Solidago canadensis*, *S. juncea*, *S. rugosa*, *Carex pensylvanica*, and *Schizachyrium scoparium*. Mehrhoff (1997) also lists 12 plants that are "rare or restricted in New England grasslands." None of these rare plants was recorded in our sampled quadrats. One of the rare species (*Pityopsis falcata*) is common in the unmanaged grasslands immediately north of our study site (Byer, 1997). A second (*Asclepias tuberosa*) was collected from a trailside at nearby Jamaica Bay Wildlife Refuge (Byer, 1997).

Approximately one-third of the plant taxa sampled in our study are exotic. It is not certain whether exotics show an increase over the pre-GRAMP condition. However, soil disturbance due to mowing with heavy machines and extensive uprooting of trees and shrubs can be expected to provide habitats suitable for exotic herbs. If development of typical northeastern U.S. native grassland is an objective, the present management program is not ideal. Maintenance of delicate native wet meadows by winter treatment using a push-mower has proved to be successful (Lindberg, 1997).

Related grassland management studies

Dunwiddie *et al.* (1997), studying management of coastal grasslands on Nantucket Island, Massachusetts, noted that in 1983 the dominant plants were *Schizachyrium scoparium*, *Festuca ovina*, and *Rubus hispidus*. In the next 11 years, a management regime of burning and mowing was initiated. After six treatments in 11 years, the following changes were noted: (1) untreated grassland shifted from grasses and forbs to heathland shrubs (*Gaylussacia baccata* and *Vaccinium angustifolium*), shrub cover increased from 39 to 65%, and shrub frequency increased from 184 to 257%, over the 11 years; (2) August-burned plots showed a 62% increase in herbaceous species. (3) August-mowed plots showed an 83% increase in herbaceous species; (4) shrubs declined in both August-burned and August-mowed plots, especially bayberry (*Myrica*), which declined eightfold; (5) April-burned plots showed only a 40% increase in nonwoody species; cover and frequency of shrubs remained the same; Niering and Dreyer (1989), however, reported that 12 years of spring burns resulted in *Gaylussacia baccata* increasing in cover and frequency; and (6) forbs remained unchanged under all regimes, but declined in the untreated plots.

Ecological importance of grasslands in the northeast

Larger regional airports in the northeastern U.S. have been recognized as the last refuges of a number of Coastal Plain plant species and some threatened or endangered birds (Mehrhoff, 1997). It is therefore important to evaluate the effectiveness of the grassland management program at FBF, in maintaining or increasing grassland biota. To this end, it is appropriate to discuss the historical (and likely prehistorical) role of grasslands in the landscapes of the northeast.

Precolonial grasslands

Native grasslands have been a feature of the northeastern United States since precolonial times. Examples of such grasslands include sandplain grasslands, such as the 24,000 ha Hempstead Plains on central Long Island. Many authors also include ericaceous upland heathlands, such as Epping Plain, Maine, which was 2–3 miles in diameter, and those on Martha's Vineyard and Nantucket Island, in their discussion of native grasslands. Other nonforested areas in the northeast are "pine grassland barrens," natural dune grasslands, and mountain balds (Vickery and Dunwiddie, 1997). Native Americans set fires in south coastal New England, to clear land for agriculture and for unimpeded travel through forests. Pine grassland barrens on Pineo Ridge, in Washington Co., Maine, have existed for 900 years and may have been kept open by those fires.

In northeastern North America, essentially all native grassland plants are adapted to fire, with either extensive fibrous roots and protected buds like little bluestem (*Schizachyrium scoparium*) or large corms such as northern blazing star (*Liatris scariosa* var. *novae-angliae*) and butterfly weed (*Asclepias tuberosa*). Fire is said to stimulate their flowering, reduce seed predation, and provide a suitable substrate for germination. Other plants endemic to northeastern grasslands are bushy rockrose (*Helianthemum dumosum*), sandplain agalinis (*Agalinis acuta*), sickle-leaved golden aster (*Pityopsis falcata*), and Nantucket shadbush (*Amelanchier nantucketensis*) (Vickery and Dunwiddie, 1997). None of the endemic grassland plants of the northeast has established populations at Floyd Bennett Field.

Colonial-era grasslands

Agricultural grasslands are the result of land clearing and plowing by European settlers. Pastures were planted with exotic grasses and forbs for forage and hay for farm animals and were maintained by agricultural activity (Vickery and Dunwiddie, 1997). By the late 18th and early 19th centuries, 60% of forests in New England had been cleared for cropland and pastures. Foraging by farm animals prevented forests from becoming reestablished, and grazing maintained heathlands; the effects persist up to the present day. Nevertheless, in the past 60 years the size of hayfields and pastures in New England and New York has declined by approximately 60% (Vickery and Dunwiddie, 1997). Remaining grasslands are fragmented and isolated.

Bird-breeding and grassland management
If bare ground is a requirement for successful breeding of some grassland birds, as suggested by reviews of the recent literature (Rudnicky *et al.*, 1997; Rudnicky and Patterson, 1994; Lent and Litwin, 1996), then the GRAMP mowing regimen is inadequate. Most of our quadrats in the GRAMP area are well vegetated, and the prospects are for denser vegetation. Observations of grasslands that were maintained for over 15 years of annual mowing (see Lanyon, 1981) support the view that density of vegetation cover increases with this treatment. Rudnicky *et al.* (1997) conclude, "summer burns may be more beneficial to maintaining bird-nesting habitat at FBF than spring burns or mowing."

Managed grasslands: global perspectives

Breymeyer (1990) presents a global perspective on managed grasslands. For the present study, flora and vegetation in the Northern Hemisphere hold the greatest interest. Titlyanova *et al.* (1990) described Northern Hemisphere grasslands as separable into two types, meadows and steppes. Steppe is a zonal type of climax ecosystem. In North America, steppe is called prairie. Those authors describe meadows as primarily hydromorphic, often having a secondary origin, and classifiable as a stage in long-term succession. Ellenberg (1988) notes that natural meadows also develop on very stony dry ground and on blowing sand.

In Central Europe, Ellenberg (1988) states that, with the exception of reed and sedge marshes and salt marshes, there would be no grasslands without man's management practices. The first types of managed grasslands were "litter meadows" or "straw meadows," cut late in the year when they had already ripened to straw; these were usually in wet sites. He further states that meadows on drier sites ("hay meadows" or "fodder meadows") are comparatively young ($\leq$1000 years old). These are maintained by twice-a-season mowing. Cattle graze the land permanently from April to October, allowing the dung to return nutrients to the ecosystem. Time enough has elapsed so that "many good character species" have developed. Fodder meadows survived up until about 1960, when "rotational grazing" (grazing after raking with mowing) was instituted along with other modern farming methods. Large masses of animals graze small patches and then move on to the next. In the plant community that develops under this practice, only clover and grasses persist, almost entirely eliminating weeds, and the community is "very poor floristically." Ellenberg states that under a regime of once- or twice-a-season mowing, meadows become dominated by hemicryptophytes, especially tall grasses. The more frequently the stand is mown, the more numerous the lower growing grasses and herbs become. Regularly cut lawns and playing fields consist entirely of short grasses, creeping white clover, and a few rosette plants. Tussock-forming grasses develop under a regime of autumn cutting (litter meadows, in alpine foothills), which allows the plants to set seed and to transfer photosynthate to storage organs at or below soil level.

Diamond (1998) dates European farming to slightly before 5000 B.C. Natural grassland has only been extensively modified in North America over the past 100–200 years

(Ellenberg, 1988). Ellenberg (1988) also summarizes the many effects of the urban environment on vegetation in general (longer growing season, introduction of exotic flora, dust, sulfur dioxide, etc.).

Studies of the extensive areas of managed grassland in South Africa are also instructive (Acocks, 1988; Edwards and Tainton, 1990). Ranchers have traditionally raised beef cattle by allowing them to forage on natural vegetation. Native grasses (mainly members of the Andropogoneae) proved unsuitable for continuous grazing of European domesticated animals. Continuous selective grazing led to the denudation of lush vegetation along watercourses and to desertification of natural grasslands and savannas, with attendant problems for biodiversity (replacement of native grasses by unwanted species of Paniceae, Stipeae, Eragrosteae, and Sporoboleae), erosion, and water conservation (Acocks, 1988; Edwards and Tainton, 1990). Instead, and especially in order to raise dairy cows, farmers had to plow, sow, and manage intensively European grasses (e.g., *Dactylis glomerata*, *Festuca arundinacea*, and *Lolium multiflorum*).

Conclusions

A number of conclusions pertinent to the management process can be derived from the results of our study. Half the samples fell into the *Schizachyrium scoparium/Rubus flagellaris* grassland type (cluster E), a community dominated by native plants. We may tentatively conclude that the management of vegetation by mowing, on natural marine substrates, does not prevent the continuance of a landscape dominated by native plants. Nevertheless, the presence of many exotic taxa, approximately one-third of the flora, can be taken as a sign that the present techniques of management, i.e., mowing with heavy machines and manual removal of shrubs and trees, is conducive to the survival of exotics. There is uncertainty in predicting the long-term consequences of a regular regimen of mowing the woody plants *Myrica pensylvanica*, *Prunus serotina*, and *Betula populifolia*, which continue to coexist in our samples with *Schizachyrium scoparium* and *Rubus*. It is possible that those woody plants will spread laterally underground and eventually result in a low shrubland. Manual removal of shrubs may become necessary and more difficult with continued mowing. Were the periodic mowings to cease, however, the remaining tree and shrub crowns and roots would expand rapidly.

Bulldozing sprouting stumps of woody plants would create bare and disturbed soil that would encourage the germination and survival of "weedy" species; e.g., annual and biennial herbs such as *Ambrosia* (ragweed) and annual grasses such as *Vulpia*. Since woody species can adequately be controlled by manual removal and summer burns, this highly disruptive treatment need not be considered. Given the ongoing success of current management techniques in creating habitat for open ground nesting birds, the use of herbicides is definitely to be discouraged, because of their negative and unpredictable impacts upon the environment and on humans.

Rudnicky *et.al.* (1997) state, "Summer burns may be more beneficial to maintaining bird-nesting habitat at FBF than spring burns or mowing." In order to ascertain if fire can be used to maintain open grasslands in which extensive bare ground is present, a new long-term program of management is indicated (Rudnicky and Patterson, 1994).

Percentage cover for sampled taxa summarized by dendogram cluster (at 0.83 level)

Species	J	E	C	D	A	H	K	I	F	B	G
1 *Achillea millefolium*	—	0.34	0.19	—	—	—	0.24	—	3.05	—	—
2 *Agrostidae* spp.	—	0.08	—	—	—	—	—	—	—	—	—
3 *Agrostis* spp.	—	—	—	—	0.30	—	—	—	—	—	—
4 *Allium vineale*	—	0.14	1.15	—	—	—	7.25	—	2.91	—	—
5 *Ampelopsis brevipedunculata*	—	—	—	0.06	—	—	—	—	—	—	—
6 *Andropogon scoparius*	2.38	33.4	17.1	—	—	3.13	—	—	18.2	—	13.2
7 *Apocynum cannabinum*	3.64	0.37	—	0.98	0.08	4.84	2.05	—	—	—	2.63
8 *Artemisia vulgaris*	—	0.25	0.69	4.69	48.2	—	—	—	—	6.67	—
9 *Asclepias syriaca*	—	0.10	0.11	—	2.01	—	—	—	—	—	—
10 *Aster* spp.	—	—	—	—	0.48	—	—	—	—	—	—
11 *Baccharis halimifolia*	—	—	—	—	0.32	—	—	—	—	—	—
12 *Barbarea vulgaris*	—	—	—	—	0.34	—	—	—	—	—	—
13 *Betula populifolia*	—	1.91	—	—	—	—	—	—	—	—	—
14 *Bromus japonicus*	—	—	—	0.43	0.61	—	—	—	—	—	—
15 *Bromus tectorum*	—	—	—	8.55	3.27	—	—	—	—	—	—
16 *Calystegia sepium*	—	—	—	2.14	—	—	—	—	—	—	—
17 *Carex pensylvanica*	—	0.47	—	—	—	—	—	—	—	—	—
18 *Carex siliea*	—	0.08	—	—	0.32	0.45	—	5.81	—	—	—
19 *Celastrus orbiculata*	—	—	—	0.85	1.59	—	—	—	—	33.3	—
20 *Centaurea maculosa*	—	—	0.07	—	—	—	—	—	—	—	32.9
21 *Cirsium arvense*	—	—	—	—	1.27	—	—	—	—	—	—
22 *Cirsium vulgare*	—	—	—	2.12	1.85	—	0.46	—	—	—	—
23 *Daucus carota*	—	0.07	2.35	—	0.31	—	—	—	—	—	6.58
24 *Erigeron* spp. (?)	—	0.43	0.62	0.29	—	—	1.88	0.77	—	—	—
25 *Eupatorium album*	0.57	—	—	—	0.31	—	—	—	—	—	—
26 *Eupatorium hyssopifolium*	—	0.52	1.11	0.13	0.32	4.44	—	—	—	—	—
27 *Eupatorium rugosum*	—	—	—	—	—	—	—	0.39	—	—	—
28 *Euthamia graminifolia*	—	0.32	—	0.30	1.31	—	0.20	3.83	—	—	—
29 *Euthamia tenuifolia*	—	0.32	0.30	—	—	4.24	—	—	—	—	—
30 *Festuca rubra*	—	0.33	—	—	—	—	—	—	—	—	—
31 *Gnaphalium obtusifolium*	—	—	—	0.06	—	—	—	—	—	—	—
32 *Holcus lanatus*	—	—	—	—	0.07	—	—	—	—	—	—
33 *Hypericum perforatum*	—	0.42	—	—	—	—	2.91	—	—	—	26.3
34 *Juncus effusus*	—	0.26	—	—	0.32	13.6	2.31	15.5	—	—	—

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Species	J	E	C	D	A	H	K	I	F	B	G
35 *Juncus secundus*	—	0.58	—	—	—	—	—	—	—	—	—
36 *Juncus tenuis*	—	1.71	—	—	2.71	27.8	—	9.60	—	—	—
37 *Lactuca canadensis*	—	0.01	—	—	—	—	—	—	—	—	—
38 *Lactuca serriola*	—	0.04	—	0.27	0.31	—	11.7	—	—	—	—
39 *Lepidium campestre*	—	0.03	—	—	—	—	1.21	—	—	—	—
40 *Lepidium virginicum*	—	0.16	—	—	—	—	—	—	—	—	—
41 *Lespedeza* spp.	—	0.66	0.66	—	—	—	0.41	—	—	—	—
42 *Leucanthemum vulgare*	—	—	—	—	1.31	—	—	—	—	—	—
43 *Linaria canadensis*	—	3.02	—	—	—	—	—	—	—	—	—
44 *Linaria vulgaris*	9.68	0.36	—	—	0.08	—	—	—	—	—	—
45 *Lolium perenne*	—	0.63	—	1.07	0.30	—	—	—	—	—	—
46 *Lonicera japonica*	—	—	—	—	—	—	—	—	—	—	—
47 *Lotus corniculata*	—	—	0.66	—	—	—	—	—	—	33.3	—
48 *Lycopus americanus*	—	—	—	—	—	0.22	—	—	—	—	—
49 *Myrica pensylvanica*	4.55	4.95	—	0.21	1.11	—	2.36	—	—	—	—
50 *Oenothera biennis*	—	—	—	—	—	0.40	—	—	—	—	—
51 *Oxalis stricta*	—	0.03	0.47	0.05	0.10	—	0.39	—	0.49	—	—
52 *Panicum clandestinum*	—	0.20	—	0.06	—	—	43.7	—	—	—	—
53 *Panicum lanuginosum*	0.20	1.97	1.81	0.58	—	15.7	—	—	—	—	—
54 *Panicum virgatum*	1.00	0.66	6.88	0.86	—	—	—	—	—	—	—
55 *Parthenocissus quinquefolia*	—	0.83	0.03	—	2.59	2.53	—	—	—	—	—
56 *Phragmites australis*	—	0.08	—	—	—	2.75	—	—	—	—	—
57 *Plantago* spp.	—	0.16	—	—	—	—	—	—	—	—	—
58 *Poa pratensis*	—	2.78	40.5	1.34	7.44	0.13	1.02	—	—	—	2.63
59 *Poa* spp.	71.6	0.84	1.65	0.65	0.81	—	7.21	—	—	—	—
60 *Poaceae* spp.	—	0.99	—	0.32	0.07	—	—	46.1	—	—	—
61 *Polygonum cuspidatum*	—	—	16.2	55.4	—	—	—	7.69	—	—	6.58
62 *Polygonum lapathifolium*	—	—	—	—	—	—	—	—	—	13.3	—
63 *Polygonum scandens*	—	0.21	—	—	—	0.51	0.23	—	—	6.67	—
64 *Polygonum* spp.	—	0.15	—	—	—	0.63	—	—	—	—	—
65 *Polytrichum* spp.	—	0.13	—	—	—	—	—	1.94	—	—	—
66 *Potentilla argentea*	—	0.34	1.57	—	—	—	—	—	12.1	—	—
67 *Potentilla canadensis*	—	—	—	—	—	0.13	—	—	—	—	—
68 *Potentilla recta*	—	—	0.38	—	0.10	—	—	—	—	—	—
69 *Potentilla simplex*	—	—	—	—	0.06	—	—	—	—	—	—
70 *Prunus serotina*	0.40	2.93	—	—	0.85	—	—	—	1.22	—	—

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	Species	J	E	C	D	A	H	K	I	F	B	G
71	*Rhus copallinum*	—	0.84	0.59	1.40	0.30	—	0.48	—	1.46	—	6.58
72	*Rosa multiflora*	—	0.05	—	—	—	—	—	—	—	—	—
73	*Rubus allegheniensis*	—	0.92	1.41	—	—	1.27	—	—	—	—	—
74	*Rubus flagellaris*	3.64	26.5	1.86	4.81	7.85	5.43	11.0	1.92	—	6.67	2.63
75	*Rubus laciniatus*	—	0.12	—	—	—	—	—	—	—	—	—
76	*Rumex acetosella*	—	0.93	0.11	1.58	—	1.11	—	1.28	—	—	—
77	*Rumex crispus*	—	—	—	—	0.49	0.23	—	—	—	—	—
78	*Sambucus canadensis*	—	0.22	—	1.61	2.78	5.19	—	1.54	—	—	—
79	*Saponaria officinalis*	—	—	—	—	0.60	—	—	—	—	—	—
	Schizachyrium scoparium (see Andropogon scoparius)											
80	*Silene latifolia*	—	—	—	0.34	—	—	—	—	—	—	—
81	*Solanum carolinense*	—	0.09	0.46	1.61	0.04	—	0.67	—	1.46	—	—
82	*Solanum dulcamara*	—	0.09	—	0.18	—	—	—	—	—	—	—
83	*Solidago canadensis*	—	0.17	0.06	0.85	0.71	—	0.39	—	—	—	—
84	*Solidago juncea*	0.40	1.17	0.50	—	0.31	—	—	—	—	—	—
85	*Solidago rugosa*	—	3.57	—	6.21	3.97	5.17	0.97	1.28	—	—	—
86	*Solidago sempervirens*	—	0.15	—	—	—	—	—	—	—	—	—
87	*Solidago speciosa*	—	0.06	—	—	—	—	—	—	—	—	—
88	*Solidago* spp.	1.00	0.70	—	—	0.08	0.13	0.58	2.31	24.4	—	—
89	*Spiraea tomentosa*	—	0.02	—	—	—	—	—	—	—	—	—
90	*Toxicodendron radicans*	—	—	—	—	0.51	—	—	—	—	—	—
91	*Tragopogon porrifolius*	—	—	0.49	—	—	—	—	—	—	—	—
92	*Unident.* spp.	—	—	—	—	1.24	—	0.39	—	—	—	—
93	*Verbascum thapsis*	0.91	0.24	—	—	—	—	—	—	—	—	—
94	*Vulpia octoflora*	—	—	—	—	—	—	—	—	34.7	—	—

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