

# Vascular Flora of the King Road Landfill in Northwest Ohio

KRISTOPHER D. BARNSWELL AND DARYL F. DWYER<sup>1</sup>, Department of Environmental Sciences, The University of Toledo, Toledo, OH.

**ABSTRACT.** The vascular flora of the King Road Landfill (KRL), located in Sylvania, Ohio, was surveyed during the 2004 growing season to evaluate the development of the plant community and compare it with that of four mature woodlands typical of the native Oak Openings Region: floodplain, sand barren, oak savanna, and deciduous forest. All surveys were made using the U.S. Department of Agriculture's Forest Inventory and Analysis method for phase two plots. Of the 153 plant species identified at the KRL, 60% were native. It was interesting to note that threatened and endangered species (e.g., *Digitaria filiformis*, *Lupinus perennis*, and *Panicum lindheimeri*) also were present. Comparative analysis revealed little similarity with the regional woodlands (Jaccard Index values < 0.5). Two primary factors may have been responsible: (1) 30 years of inactivity at the KRL were insufficient to attain a mature plant community. Indeed, late successional plant species were observed only in the landfill section that had been closed for the longest period of time. (2) The vegetation that surrounded and thus colonized the KRL was not similar to that of the regional woodlands (Jaccard Index values < 0.5). The results of this study were presented to the Ohio Environmental Protection Agency as part of a remedial option for the KRL, which includes creation of a nature preserve at the KRL and an opportunity to direct and study the long-term development of the maturing plant community.

OHIO J SCI 107 (5): 91-103, 2007

## INTRODUCTION

Current regulations for the final closure of municipal solid waste landfills require the use of constructed barriers (US EPA 1993) to prevent the infiltration of precipitation and subsequent formation of leachate. There are numerous landfills that ceased operations prior to 1976 when these requirements were first implemented. Many of these were inadequately capped, have only a thin layer of soil as cover material, and limited post-closure maintenance. These older landfills often develop diverse vegetation on the soil cover (Rebele 1992; Mannik & Smith Group 2002; Kim and others 2004; Martinez-Ruiz and Fernandez-Santos 2005), which suggests that they may serve as habitat for plant species that are native to the regions in which they are located.

In this paper, we include the results of a survey of the vascular flora which developed for the King Road Landfill (KRL) in Sylvania, Ohio, during the 30 years since the landfill ceased operations. The purpose was to determine whether the KRL was developing a plant community typical of the endangered and unique Oak Openings Region (OOR) of northwest Ohio. Of the numerous landfills that ceased operations prior to 1976 in this region, none have been studied for this purpose.

The Nature Conservancy lists the OOR as one of America's Last Great Places (Grigore 2004); unfortunately, only a small percentage of this regional, habitat remains (Green Ribbon Initiative 2002). Floristic surveys that have been completed for the OOR (Moseley 1928; Easterly 1969, 1972, 1973, 1979; Brewer and Vankat 2001, 2004; Neher and others 2004; Walters unpublished) list a diversity of vascular plant species that compares favorably with the diversity found in any land area of equal size in Ohio (Walters, personal communication 2005). In the study presented here, it was determined that the plant species composition at the KRL differed considerably from that of the woodland communities that are typical for the OOR as they exist in the Oak Openings Metropark (OOMP). However, the landfill contained several threatened and endangered plant species, which suggests that the KRL may serve as an important site for their preservation.

## DESCRIPTION OF FIELD SITES

The KRL is located in Sylvania, Ohio, a suburb west of Toledo; the main entrance is located 41°40'47" North and 83°43'22" West. The landfill contains 104 acres; municipal solid waste was deposited onto 80 acres, which were divided into five sequentially used land parcels. Solid waste deposition began in 1954 with the land parcel located on the easternmost part of the landfill and progressed westward over time until 1976 (Fig. 1), when landfill operations ceased. The solid waste was covered with sandy soil obtained from a borrow pit located in the northwest section of the landfill site. Only a small, central area of the KRL was seeded with grass; the remaining vegetation occurred naturally (Michael Momenee, personal communication 2005).

The OOMP ([www.metroparkstoledo.com/metroparks](http://www.metroparkstoledo.com/metroparks)) was established in 1938; it is located nine miles southwest of Toledo at 41°32'48" North and 83°50'41" West. The OOMP contains 3,700 acres with six different plant communities representative of the OOR (John Jaeger, personal communication 2005): floodplain, sand barren, oak savanna, deciduous forest, and dry and wet prairies. The plant communities that contain predominantly woody species (i.e., floodplain, sand barren, oak savanna, and deciduous forest) were chosen for comparison to the KRL, because the landfill is dominated by woody vegetation (Mannik & Smith Group 2002). The floodplain area is frequently under water; controlled burnings are used in the oak savanna to control the growth of understory vegetation (John Jaeger, personal communication 2005).

## SURVEY METHOD

Plant surveys were made for the KRL and OOMP from April through August in 2004, using the modified Forest Inventory and Analysis (FIA) for phase 2 plots (USDA Forest Service 2000). At the KRL, two study sites were selected within each of the five landfill parcels, the SE corner of the landfill, and the adjacent Ten-Mile Creek floodplain. Two locations adjacent to the landfill were surveyed to gain insight into the species of plants present, that could have provided a source of seeds for re-vegetation of the landfill itself: the SE region of the KRL that had not received solid waste and the floodplain of Ten Mile Creek that is located across the street from the northwest corner of the KRL (Fig. 1). At OOMP, two survey sites were selected within each of the four

<sup>1</sup>Address correspondence to Daryl F. Dwyer, Department of Environmental Sciences, 2801 W. Bancroft St., The University of Toledo, Toledo, OH 43606. Telephone: 419-530-2661. Email: [daryl.dwyer@utoledo.edu](mailto:daryl.dwyer@utoledo.edu)

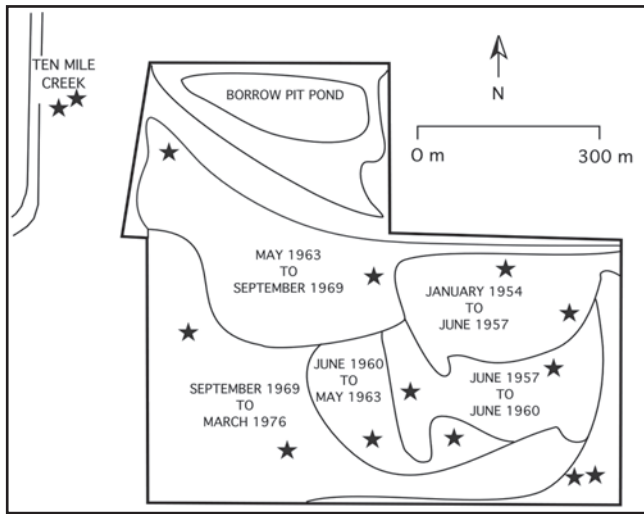


FIGURE 1. Time periods for the areas of operation at the King Road Landfill. Courtesy of The Mannik & Smith Group. Modified by James Coss.

woodland communities. Locations for the study sites were selected randomly, surface roads at the KRL and walking/hiking trails at the OOMP were intentionally avoided. Each site contained four individual plots (167 m<sup>2</sup>) in which all vascular plants were identified; plant nomenclature followed Cooperrider et al. (2001); plant characteristics were obtained from the PLANTS Database (USDA, NRCS 2004).

During the survey, the observed plant species were placed into one of two groups: (1) woody species with a diameter at breast height (dbh) ≥ 2.5 cm, and (2) understory species, including herbaceous plants and woody plants with a dbh < 2.5 cm. The

mean number of individual woody species per survey site was calculated and extrapolated to obtain the number of individuals per hectare (Table 1). Understory species were reported as ground cover percentages (Table 2), due to the difficulty in separating and counting individual plants. The scale crafted by Daubenmire (1959) was used for this purpose, in which coverage estimates are placed within one of six ranges (0 – 5%, 5 – 25%, 25 – 50%, 50 – 75%, 75 – 95%, and 95 – 100%). The ground coverage for each plant species was then reported as the midpoint value for each range (i.e., 2.5%, 15%, 37.5%, 62.5%, 85%, and 97.5%). The degree of similarity in plant species composition between sites was calculated using the Jaccard Index (Real and Vargas 1996); values ≥ 0.5 demonstrate significant similarity (Abella et al. 2001).

### RESULTS

A complete list of all plant species observed at the KRL and the OOMP is presented in Tables 1 and 2. Both tables were designed to allow for easy comparisons of plant species between sites. For example, black locust, *Robinia pseudoacacia*, which is intolerant of shade, can be observed at all sites at the KRL, but, as might be expected, not in the heavily forested woodland communities of the OOMP and the heavily wooded floodplain of Ten Mile Creek (Table 1).

Vascular plants native to Ohio accounted for 60% of the 153 species identified at the KRL. The most frequently observed woody species (Table 1) included: *Populus deltoides*, *R. pseudoacacia*, and *Ulmus pumila*. The most frequently observed understory species (Table 2) included: *Ambrosia artemisiifolia*, *Daucus carota*, *Melilotus albus*, *Parthenocissus quinquefolia*, *Toxicodendron radicans*, and *Verbascum thapsus*. The majority of these species are commonly associated with early stages of succession (e.g., *Alliaria petiolata*,

Table 1

Densities of woody plant species (dbh ≥ 2.5 cm) per hectare at the KRL and OOMP.

Name	KRL Waste Disposal Parcels					KRL Surroundings		OOMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
<i>Acer negundo</i> (box elder)*	23	75	--	15	8	82	247	64	--	--	--
<i>Acer rubrum</i> (red maple)*	--	--	--	--	--	--	--	--	30	30	503
<i>Acer saccharinum</i> (silver maple)*	--	15	--	--	--	--	142	8	--	--	--
<i>Aesculus glabra</i> (Ohio buckeye)*	--	--	--	--	--	--	142	--	--	--	--
<i>Ailanthus altissima</i> (tree of heaven)	--	8	75	--	45	8	--	--	--	--	--
<i>Catalpa bignonioides</i> (common catalpa)	--	--	--	--	--	8	--	--	--	--	--
<i>Catalpa speciosa</i> (northern catalpa)	--	--	8	--	8	--	--	--	--	--	--
<i>Celtis occidentalis</i> (hackberry)*	8	8	--	--	--	--	23	30	--	--	--
<i>Cornus amomum</i> (pale dogwood)*	15	--	--	--	--	15	--	--	--	--	--
<i>Cornus drummondii</i> (roughleaf dogwood)*	--	--	--	--	223	15	--	--	--	--	--

Table 1 (cont.)

Densities of woody plant species ( $dbh \geq 2.5$  cm) per hectare at the KRL and OOMP:

Name	KRL Waste Disposal Parcels					KRL Surroundings		OORMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
	<i>Cornus racemosa</i> (gray dogwood)*	--	90	--	--	--	--	45	82	--	--
<i>Fraxinus americana</i> (white ash)*	--	--	--	--	--	--	--	60	--	--	--
<i>Fraxinus pennsylvanica</i> var. <i>pennsylvanica</i> (green ash)*	23	52	--	--	8	--	52	--	--	--	--
<i>Fraxinus pennsylvanica</i> var. <i>subintegerrima</i> (red ash)*	60	--	--	23	8	30	15	--	--	--	--
<i>Fraxinus quadrangulata</i> (blue ash)*	--	--	--	--	--	8	--	--	--	--	--
<i>Gleditsia triacanthos</i> (honey locust)*	8	--	--	8	--	15	--	--	--	--	--
<i>Hamamelis virginiana</i> (witch hazel)*	--	--	--	--	8	15	--	--	--	--	97
<i>Juglans nigra</i> (black walnut)*	--	23	--	--	--	8	--	30	--	--	--
<i>Juniperus virginiana</i> (eastern red cedar)*	--	--	--	--	--	8	--	--	--	--	--
<i>Lindera benzoin</i> (spice bush)*	--	--	--	--	--	--	15	--	--	--	8
<i>Morus alba</i> (white mulberry)	45	--	8	15	--	82	--	15	--	--	--
<i>Prunus avium</i> (sweet cherry)	--	--	--	--	--	8	--	--	--	--	--
<i>Prunus serotina</i> (black cherry)*	--	37	8	15	15	82	--	--	--	52	52
<i>Prunus virginiana</i> (choke cherry)*	8	--	--	--	--	23	--	--	37	--	--
<i>Populus deltoides</i> (eastern cottonwood)*	45	217	105	105	225	52	--	--	--	--	--
<i>Quercus alba</i> (white oak)*	--	--	--	--	--	--	--	--	37	187	240
<i>Quercus bicolor</i> (swamp white oak)*	--	--	--	--	--	--	--	30	--	--	--
<i>Quercus rubra</i> (red oak)*	--	--	--	--	--	--	--	--	217	--	--
<i>Quercus velutina</i> (black oak)*	--	--	--	--	15	30	--	8	--	75	90
<i>Rhamnus cathartica</i> (common buckthorn)	8	15	--	--	8	8	--	--	--	--	--
<i>Rhus typhina</i> (staghorn sumac)*	--	52	--	15	--	--	--	--	--	--	--
<i>Robinia pseudoacacia</i> (black locust)	607	359	67	270	300	187	--	--	--	--	--
<i>Salix nigra</i> (black willow)*	--	--	--	--	--	--	--	8	--	--	--
<i>Sassafras albidum</i> (sassafras)*	--	--	--	--	--	45	--	--	82	97	37
<i>Tilia americana</i> (American basswood)*	--	--	--	--	--	--	30	--	--	--	--
<i>Ulmus americana</i> (American elm)*	15	23	--	--	--	--	127	75	--	--	--
<i>Ulmus pumila</i> (Chinese elm)	981	344	314	23	23	374	--	--	--	--	--
<i>Ulmus rubra</i> (slippery elm)*	45	--	--	--	--	8	--	--	--	--	--

\* Denotes plant species native to Ohio.

Table 2

Ground cover percentage of the understory plant species identified in the vegetation surveys.

Name	KRL Waste Disposal Parcels					KRL Surroundings		OOMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
<i>Acalypha virginica</i> var. <i>rhomboidea</i> (three-seed mercury)*	--	--	--	2.5	--	15.0	--	--	--	--	--
<i>Achillea millefolium</i> (yarrow)*	2.5	--	2.5	--	2.5	--	--	--	--	2.5	--
<i>Agastache nepetoides</i> (yellow giant hyssop)*	--	--	--	--	2.5	--	--	--	--	--	--
<i>Agrostis gigantea</i> (redtop)	15.0	--	2.5	2.5	2.5	--	--	--	--	2.5	--
<i>Agrostis stolonifera</i> var. <i>palustris</i> (creeping bent grass)	15.0	--	--	--	--	--	--	--	--	--	--
<i>Alliaria petiolata</i> (garlic mustard)	2.5	15.0	15.0	15.0	2.5	15.0	15.0	2.5	--	--	2.5
<i>Alopecurus pratensis</i> (meadow foxtail)	15.0	--	--	--	--	--	--	--	--	--	--
<i>Ambrosia artemisiifolia</i> (annual ragweed)*	2.5	2.5	15.0	2.5	2.5	2.5	2.5	--	2.5	--	--
<i>Ambrosia trifida</i> (great ragweed)*	--	--	--	2.5	--	2.5	--	--	--	--	--
<i>Amelanchier arborea</i> (downy serviceberry)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Aralia nudicaulis</i> (wild sarsaparilla)*	--	2.5	--	--	--	--	--	--	--	--	2.5
<i>Arenaria serpyllifolia</i> (thyme-leave sandwort)	--	--	--	2.5	2.5	2.5	--	--	--	--	--
<i>Arisaema dracontium</i> (green dragon)*	--	--	--	--	--	--	2.5	2.5	--	--	--
<i>Arisaema triphyllum</i> (jack-in-the-pulpit)*	--	--	--	--	--	--	2.5	--	--	--	2.5
<i>Asarum canadense</i> (wild ginger)*	--	--	--	--	--	--	15.0	--	--	--	--
<i>Asclepias exaltata</i> (poke milkweed)*	--	--	--	--	2.5	2.5	--	--	--	--	--
<i>Asclepias incarnata</i> (swamp milkweed)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Asclepias syriaca</i> (common milkweed)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Asclepias tuberosa</i> (butterfly milkweed)*	--	--	--	2.5	--	--	--	--	--	2.5	--
<i>Asclepias verticillata</i> (whorled milkweed)*	2.5	--	15.0	--	--	--	--	--	--	--	--
<i>Aster lanceolatus</i> var. <i>simplex</i> (panicled aster)*	--	2.5	--	--	--	--	15.0	2.5	--	--	--
<i>Aster macrophyllus</i> (large-leaved aster)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Athyrium filix-femina</i> (lady fern)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Barbarea vulgaris</i> (yellow rocket)	15.0	15.0	--	--	15.0	--	--	--	--	--	--
<i>Betula pumila</i> (bog birch)* <sup>†</sup>	--	--	--	--	--	--	--	2.5	--	--	--
<i>Boehmeria cylindrica</i> (false nettle)*	2.5	--	2.5	--	--	--	2.5	--	--	--	--
<i>Bromus inermis</i> (smooth brome)	--	2.5	2.5	2.5	2.5	--	--	--	--	--	--
<i>Bromus japonicus</i> (Japanese brome)	15.0	--	15.0	15.0	--	2.5	--	--	--	--	--
<i>Bromus latiglumis</i> (ear-leaved brome)*	--	--	--	--	--	--	2.5	--	--	--	2.5



Table 2 (cont.)

Ground cover percentage of the understory plant species identified in the vegetation surveys.

Name	KRL Waste Disposal Parcels					KRL Surroundings		OOMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
	<i>Dipsacus fullonum</i> (common teasel)	2.5	--	--	--	--	--	--	--	--	--
<i>Echinochloa muricata</i> var. <i>microstachya</i> (barnyard grass)*	--	--	2.5	--	--	--	--	--	--	--	--
<i>Elaeagnus angustifolia</i> (Russian olive)	--	--	2.5	--	2.5	--	--	--	--	2.5	--
<i>Elymus repens</i> (quack grass)	--	2.5	2.5	15.0	15.0	--	--	--	--	--	--
<i>Elymus trachycaulus</i> (bearded wheat grass)* <sup>T</sup>	--	--	2.5	--	2.5	--	--	--	--	--	--
<i>Elymus virginicus</i> (Virginia wildrye)*	--	--	15.0	15.0	--	--	2.5	2.5	--	--	--
<i>Equisetum arvense</i> (horsetail)*	--	--	--	--	--	--	--	2.5	--	--	--
<i>Erigeron annuus</i> (daisy fleabane)*	15.0	2.5	15.0	2.5	2.5	15.0	--	--	--	--	--
<i>Erigeron pulchellus</i> var. <i>pulchellus</i> (robin's plantain)*	2.5	--	2.5	2.5	2.5	2.5	--	--	2.5	2.5	--
<i>Eupatorium altissimum</i> (tall boneset)*	2.5	--	15.0	2.5	2.5	2.5	--	--	--	--	--
<i>Euphorbia corollata</i> (flowering spurge)*	--	--	--	--	--	--	--	--	2.5	2.5	--
<i>Euphorbia cyparissias</i> (cypress spurge)	--	--	2.5	2.5	--	--	--	--	--	--	--
<i>Euphorbia nutans</i> (spotted spurge)*	--	--	--	2.5	--	--	--	--	--	--	--
<i>Euthamia graminifolia</i> (grass-leaved goldenrod)*	--	2.5	2.5	--	--	--	--	--	--	2.5	--
<i>Euthamia tenuifolia</i> var. <i>tenuifolia</i> (lance-leaved goldenrod)*	2.5	--	2.5	--	--	--	--	--	--	--	--
<i>Festuca ovina</i> (sheep fescue)	--	--	--	--	--	--	--	--	2.5	2.5	--
<i>Festuca subverticillata</i> (nodding fescue)*	--	--	--	--	--	--	--	2.5	--	--	--
<i>Fragaria vesca</i> (woodland strawberry)*	--	--	--	--	--	2.5	--	--	--	--	--
<i>Galium asprellum</i> (rough bedstraw)*	--	--	--	--	--	--	--	2.5	--	--	--
<i>Galium circaezans</i> (wild licorice)*	--	--	--	--	--	2.5	--	--	--	2.5	--
<i>Gaultheria procumbens</i> (wintergreen)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Geranium maculatum</i> (wild geranium)*	--	2.5	--	2.5	2.5	2.5	--	--	--	--	--
<i>Geum canadense</i> (white avens)*	2.5	2.5	--	--	2.5	2.5	2.5	15.0	--	--	--
<i>Glechoma hederacea</i> (ground ivy)	--	--	--	--	2.5	--	--	--	--	--	--
<i>Hackelia virginiana</i> (Virginia stickseed)*	--	--	--	--	2.5	--	--	--	--	--	--
<i>Helianthemum canadense</i> (rockrose)* <sup>PT</sup>	--	--	--	--	--	--	--	--	25.0	--	--
<i>Helianthus divaricatus</i> (woodland sunflower)*	2.5	--	--	--	--	2.5	--	--	--	--	--
<i>Heliopsis helianthoides</i> (smooth ox-eye)*	--	--	--	--	--	--	--	2.5	--	--	--

Table 2 (cont.)

Ground cover percentage of the understory plant species identified in the vegetation surveys.

Name	KRL Waste Disposal Parcels					KRL Surroundings		OOMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
<i>Hibiscus trionum</i> (flower-of-an-hour)	--	--	2.5	--	--	--	--	--	--	--	--
<i>Hieracium caespitosum</i> (meadow hawkweed)	--	--	--	--	2.5	--	--	--	--	--	--
<i>Hypericum perforatum</i> (common St. Johnswort)	--	2.5	2.5	2.5	2.5	2.5	--	--	--	--	--
<i>Hypericum prolificum</i> (shrubby St. Johnswort)*	--	--	--	--	--	--	--	--	--	2.5	--
<i>Impatiens capensis</i> (spotted touch-me-not)*	--	--	--	--	2.5	--	15.0	2.5	--	--	--
<i>Impatiens pallida</i> (pale touch-me-not)*	--	--	--	--	--	--	--	2.5	--	--	--
<i>Juncus articulatus</i> (jointed rush)*	--	--	--	--	--	--	--	--	--	2.5	--
<i>Juncus effusus</i> (common rush)*	2.5	--	--	--	--	--	--	--	--	2.5	--
<i>Juncus torreyi</i> (Torrey's rush)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Krigia virginica</i> (dwarf dandelion)* <sup>T</sup>	--	--	--	--	--	--	--	--	2.5	2.5	--
<i>Laportea canadensis</i> (wood nettle)*	--	--	--	--	--	--	37.5	37.5	--	--	--
<i>Leersia virginica</i> (white grass)*	--	--	--	--	--	--	2.5	15.0	--	--	--
<i>Leonurus cardiaca</i> (motherwort)	--	2.5	--	2.5	2.5	2.5	--	--	--	--	--
<i>Lepidium campestre</i> (field pepperweed)	2.5	2.5	2.5	--	2.5	--	--	--	--	--	--
<i>Lespedeza capitata</i> (bush-clover)*	--	--	--	--	--	--	--	--	2.5	2.5	--
<i>Ligustrum vulgare</i> (common privet)	2.5	2.5	--	--	2.5	--	--	--	--	--	--
<i>Lithospermum officinale</i> (European gromwell)	2.5	2.5	2.5	2.5	--	2.5	--	2.5	--	--	--
<i>Lolium arundinaceum</i> (tall fescue)	2.5	--	2.5	2.5	15.0	--	--	--	--	--	--
<i>Lolium perenne</i> (perennial rye grass)	--	--	2.5	15.0	2.5	--	--	--	--	--	--
<i>Lonicera maackii</i> (amur honeysuckle)	2.5	2.5	--	--	--	--	--	--	--	--	--
<i>Lonicera tatarica</i> (tartarian honeysuckle)	15.0	2.5	2.5	15.0	2.5	15.0	2.5	--	--	--	--
<i>Lupinus perennis</i> (wild lupine)* <sup>PT</sup>	--	--	--	--	--	2.5	--	--	2.5	--	--
<i>Lycopus americanus</i> (cut-leaved water-horehound)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Lysimachia ciliata</i> (fringed loosestrife)*	--	--	--	--	--	--	2.5	--	--	--	--
<i>Lysimachia nummularia</i> (moneywort)	--	--	--	--	--	--	37.5	2.5	--	--	--
<i>Lysimachia quadrifolia</i> (whorled loosestrife)*	--	--	--	--	--	--	2.5	--	--	2.5	--
<i>Lythrum alatum</i> (winged loosestrife)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Medeola virginiana</i> (indian cucumber root)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Medicago lupulina</i> (black medick)	--	2.5	2.5	2.5	2.5	2.5	--	--	--	--	--

Table 2 (cont.)

Ground cover percentage of the understory plant species identified in the vegetation surveys.

Name	KRL Waste Disposal Parcels					KRL Surroundings		OOMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
	<i>Melilotus albus</i> (white sweet clover)	2.5	15.0	15.0	15.0	2.5	15.0	--	--	--	--
<i>Melilotus officinalis</i> (yellow sweet clover)	2.5	15.0	2.5	2.5	15.0	2.5	--	--	--	--	--
<i>Monarda fistulosa</i> (wild bergamot)*	--	2.5	--	--	--	2.5	--	--	--	--	--
<i>Muhlenbergia schreberi</i> (nimblewill)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Nepeta cataria</i> (catnip)	--	15.0	15.0	2.5	15.0	2.5	--	--	--	--	--
<i>Oenothera biennis</i> var. <i>biennis</i> (common evening primrose)*	--	--	2.5	2.5	--	--	--	--	2.5	2.5	--
<i>Osmunda cinnamomea</i> (cinnamon fern)*	--	--	--	--	--	--	--	--	--	--	15.0
<i>Osmunda regalis</i> var. <i>spectabilis</i> (royal fern)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Oxalis stricta</i> (common yellow wood-sorrel)*	15.0	2.5	2.5	2.5	15.0	2.5	--	--	--	--	--
<i>Panicum acuminatum</i> var. <i>fasciculatum</i> (old-field panic grass)*	--	--	--	--	--	2.5	--	--	--	--	--
<i>Panicum acuminatum</i> var. <i>lindheimeri</i> (Lindheimer's panic grass)* <sup>E</sup>	2.5	--	--	--	--	--	--	--	15.0	2.5	--
<i>Panicum clandestinum</i> (deer's tongue grass)*	2.5	--	2.5	--	--	2.5	--	--	--	--	--
<i>Panicum columbianum</i> (American panic grass)*	15.0	2.5	2.5	--	--	2.5	--	--	2.5	15.0	--
<i>Panicum latifolium</i> (broad-leaved panic grass)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Panicum oligosanthes</i> var. <i>scribnerianum</i> (Scribner's rosette grass)*	--	--	2.5	--	--	--	--	--	2.5	2.5	--
<i>Paronychia canadensis</i> (forked chickweed)*	--	--	2.5	--	--	--	--	--	--	--	--
<i>Parthenocissus quinquefolia</i> (Virginia creeper)	15.0	37.5	2.5	15.0	37.5	37.5	15.0	15.0	--	--	2.5
<i>Penstemon digitalis</i> (bearded foxglove)*	--	--	2.5	--	--	--	--	--	--	--	--
<i>Phleum pratense</i> (Timothy)	2.5	--	--	--	--	2.5	--	--	--	--	--
<i>Photinia floribunda</i> (chokeberry)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Physalis heterophylla</i> (clammy ground cherry)*	--	--	--	2.5	--	--	--	--	--	--	--
<i>Phytolacca americana</i> (American pokeweed)*	2.5	2.5	--	--	--	--	--	--	--	--	--
<i>Pilea pumila</i> (clearweed)*	--	--	--	--	--	--	2.5	15.0	--	--	--
<i>Pinus strobes</i> (white pine)*	--	--	2.5	--	--	--	--	--	2.5	--	--
<i>Plantago lanceolata</i> (English plantain)	--	2.5	--	2.5	2.5	--	--	--	--	--	--
<i>Plantago major</i> (common plantain)	--	2.5	--	2.5	2.5	--	--	--	--	--	--
<i>Poa compressa</i> (Canada blue grass)	--	--	15.0	15.0	15.0	2.5	--	--	2.5	2.5	--



Table 2 (cont.)

Ground cover percentage of the understory plant species identified in the vegetation surveys.

Name	KRL Waste Disposal Parcels					KRL Surroundings		OOMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
<i>Poa pratensis</i> (Kentucky blue grass)	--	--	2.5	15.0	2.5	--	--	--	--	2.5	--
<i>Polygala polygama</i> (racemed milkwort)* <sup>T</sup>	--	--	--	--	--	--	--	--	2.5	2.5	--
<i>Polygonatum biflorum</i> (smooth solomon's seal)*	--	--	--	--	--	--	--	--	2.5	--	2.5
<i>Polygonum convolvulus</i> (black bindweed)	2.5	2.5	2.5	2.5	--	2.5	--	--	--	--	--
<i>Polygonum pennsylvanicum</i> (Pennsylvania smartweed)*	--	--	2.5	--	--	--	--	2.5	--	--	--
<i>Polygonum persicaria</i> (lady's thumb)	--	--	--	--	--	--	--	2.5	--	--	--
<i>Polygonum virginianum</i> (jumpseed)*	--	2.5	--	--	--	--	2.5	2.5	--	--	--
<i>Potentilla recta</i> (sulphur cinquefoil)	2.5	2.5	--	2.5	2.5	--	--	--	--	--	--
<i>Prenanthes alba</i> (white lettuce)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Prunus americana</i> (American plum)*	--	2.5	--	--	--	2.5	--	--	--	--	--
<i>Previdium aquilinum</i> (bracken fern)*	--	--	--	--	--	--	--	--	15.0	37.5	2.5
<i>Ranunculus hispidus</i> .var <i>hispidus</i> (hispid buttercup)*	--	--	--	--	--	--	2.5	--	--	--	--
<i>Ranunculus hispidus</i> var. <i>nitidus</i> (swamp buttercup)*	--	--	--	--	--	--	2.5	--	--	2.5	--
<i>Rhus copallina</i> var. <i>latifolia</i> (dwarf sumac)*	--	--	--	--	--	--	--	--	2.5	--	--
<i>Rubus allegheniensis</i> (Allegheny blackberry)*	--	--	--	--	--	--	--	--	2.5	--	--
<i>Rubus flagellaris</i> (northern dewberry)*	--	2.5	--	2.5	2.5	2.5	--	--	2.5	15.0	2.5
<i>Rubus hispidus</i> (bristly dewberry)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Rubus occidentalis</i> (black raspberry)*	2.5	15.0	2.5	15.0	15.0	2.5	--	--	--	--	--
<i>Rubus pensilvanicus</i> (Pennsylvania blackberry)*	--	--	--	--	--	2.5	--	--	--	--	--
<i>Rudbeckia laciniata</i> var. <i>laciniata</i> (cut-leaf coneflower)*	--	--	--	--	--	--	--	2.5	--	--	--
<i>Rumex acetosella</i> (red sorrel)	--	--	--	--	--	--	--	--	2.5	--	--
<i>Rumex crispus</i> (curly dock)	2.5	2.5	2.5	2.5	2.5	2.5	--	--	--	--	--
<i>Rumex obtusifolius</i> (bitter dock)	--	--	--	--	2.5	--	--	--	--	--	--
<i>Salix discolor</i> (pussy willow)*	--	--	--	--	--	--	--	--	2.5	--	--
<i>Salix humilis</i> var. <i>tristis</i> (prairie willow)*	--	--	2.5	--	--	--	--	--	--	--	--
<i>Saponaria officinalis</i> (bouncing bet)	--	--	2.5	--	2.5	--	--	--	--	--	--
<i>Scirpus atrovirens</i> (dark-green bulrush)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Scirpus pendulus</i> (rufous bulrush)*	2.5	--	--	--	2.5	--	--	--	--	--	--
<i>Setaria glauca</i> (yellow foxtail)	--	2.5	2.5	2.5	--	--	--	--	--	--	--

Table 2 (cont.)

Ground cover percentage of the understory plant species identified in the vegetation surveys.

Name	KRL Waste Disposal Parcels					KRL Surroundings		OOMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
	<i>Setaria viridis</i> (green foxtail)	--	--	2.5	2.5	--	2.5	--	--	--	--
<i>Silene latifolia</i> (white campion)	--	2.5	2.5	2.5	2.5	--	--	--	--	--	--
<i>Silene vulgaris</i> (bladder campion)*	--	--	2.5	--	--	--	--	--	--	--	--
<i>Smilacina racemosa</i> (false spikenard)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Smilax hispida</i> (bristly greenbrier)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Smilax rotundifolia</i> (common greenbrier)*	--	--	--	--	--	--	--	--	2.5	--	2.5
<i>Solanum carolinense</i> (horsenettle)	2.5	2.5	--	2.5	--	--	--	--	--	--	--
<i>Solidago canadensis</i> var. <i>canadensis</i> (Canada goldenrod)*	2.5	2.5	2.5	2.5	--	--	--	--	--	--	--
<i>Spiraea alba</i> var. <i>alba</i> (meadow-sweet)*	--	--	--	--	--	--	--	--	--	2.5	--
<i>Stachys aspera</i> (hyssop hedge nettle)*	--	--	--	--	--	--	--	2.5	--	--	--
<i>Stachys tenuifolia</i> (common hedge nettle)*	--	--	--	--	--	--	--	2.5	--	--	--
<i>Symplocarpus foetidus</i> (skunk cabbage)*	--	--	--	--	--	--	--	15.0	--	--	2.5
<i>Taraxacum officinale</i> (common dandelion)	--	2.5	--	--	2.5	--	--	--	--	--	--
<i>Thalictrum thalictroides</i> (rue anemone)*	--	--	--	--	--	2.5	--	2.5	--	--	--
<i>Thlaspi arvense</i> (field pennycress)	--	--	--	--	--	2.5	--	--	--	2.5	--
<i>Toxicodendron radicans</i> (poison ivy)*	15.0	15.0	2.5	2.5	2.5	37.5	2.5	2.5	--	--	--
<i>Tragopogon dubius</i> (yellow salsify)	--	2.5	2.5	2.5	2.5	--	--	--	--	--	--
<i>Trifolium pratense</i> (red clover)	--	--	2.5	--	2.5	--	--	--	--	--	--
<i>Trifolium repens</i> (white clover)	--	--	--	2.5	--	--	--	--	--	--	--
<i>Typha latifolia</i> (broad-leaf cattail)*	2.5	--	--	--	--	--	--	--	--	--	--
<i>Urtica dioica</i> var. <i>procera</i> (tall nettle)*	--	--	--	2.5	--	--	--	2.5	--	--	--
<i>Vaccinium pallidum</i> (blue-ridge blueberry)*	--	--	--	--	--	--	--	--	--	2.5	--
<i>Vaccinium vacillans</i> (early Low-bush blueberry)*	--	--	--	--	--	--	--	--	--	--	2.5
<i>Verbascum blattaria</i> (moth mullein)	--	2.5	--	--	2.5	--	--	--	--	--	--
<i>Verbascum thapsus</i> (common mullein)	2.5	2.5	2.5	2.5	2.5	2.5	--	--	--	2.5	--
<i>Verbena urticifolia</i> (white vervain)*	2.5	2.5	--	--	--	--	--	2.5	--	--	--
<i>Veronica arvensis</i> (corn speedwell)	--	--	2.5	2.5	--	--	--	--	--	--	--
<i>Viola pubescens</i> (common yellow violet)*	--	--	--	--	--	--	2.5	--	--	--	--

Table 2 (cont.)

Ground cover percentage of the understory plant species identified in the vegetation surveys.

Name	KRL Waste Disposal Parcels					KRL Surroundings		OOMP Woodland Communities			
	1969- 1976	1963- 1969	1960- 1963	1957- 1960	1954- 1957	SE Corner	Ten-Mile Creek	Flood- plain	Sand Barren	Savanna	Deciduous Forest
<i>Viola sagittata</i> (arrow-leaved violet)*	--	--	--	--	--	--	--	--	--	2.5	--
<i>Vitis aestivalis</i> (summer grape)*	2.5	15.0	15.0	15.0	15.0	15.0	2.5	--	--	2.5	--
<i>Zanthoxylum americanum</i> (prickly-ash)*	2.5	--	--	--	--	--	--	--	--	--	--

Plant species listed in Table 1 are not included.

\* denotes plant species native to Ohio;

<sup>E</sup> denotes plant species endangered;

<sup>T</sup> denotes plant species threatened;

<sup>PT</sup> denotes potentially threatened (status determined by the Ohio Biological Survey).

*Dianthus armeria*, *Lonicera tatarica*, and *U. pumila*). Two late successional species (*Hamamelis virginiana* and *Quercus velutina*) were observed less frequently and only in the section of the KRL that was the first taken out of use (1957) and has remained dormant for the longest period of time. Several threatened and endangered plant species also were observed as understory plants (Table 2).

The vegetation of the Ten-Mile Creek floodplain contained plant species commonly found in wet habitat, including *Acer* spp., *Aesculus glabra*, *Cornus racemosa*, and *Ulmus americana* (Table 1), *Asarum canadense*, *Impatiens capensis*, *Laportea canadensis*, and *Lysimachia nummularia* (Table 2).

Prior to this study, the SE corner of the KRL and the Ten Mile Creek floodplain were believed to have been relatively non-disturbed. However, we observed a number of plant species commonly associated with earlier stages of succession (e.g., *R. pseudoacacia*, *Sassafras albidum*, and *U. pumila*) (Table 1). In addition, many understory species were invasive (Table 2). By analyzing Tables 1 and 2, it was apparent that neither site had significantly contributed to the flora of the KRL. In addition, Jaccard Index values that were used to compare the species composition for these sites with those for the KRL were relatively low (< 0.4, Table 3).

Plant species in the floodplain, sand barren, oak savanna, and deciduous forest communities of the OOMP were primarily native (86% of the species) and later successional species (e.g., *H. virginiana* and *Quercus* spp.). Of the woody plant species, *Quercus* spp. were the most common (Table 1); the composition of understory species varied widely between each community (Table 2).

Although many plant species present in the regional woodland communities of the OOMP were observed at the KRL, the Jaccard Index values (Table 3) suggested poor similarity in species composition. The greatest degree of similarity (Jaccard Index value (0.15) was for the KRL land parcel operated from 1960-1963 and the oak savanna community, where fire is regularly used to control understory vegetation; both sites contained many plant species common to earlier stages of succession.

## DISCUSSION

When undertaking this study, one goal was to assess whether the KRL was developing a mature woodland community with plant species that are typical for the OOR. The data suggest that this has not occurred by this point in time. One reason may be that the landfill is in early stages of community development, during which plant species that are invasive (Johnson and others 2006) and those with short life spans (Odum 1969; Hudson 1980) would be expected to predominate. Indeed, species with these characteristics (e.g., *L. tatarica*, *U. pumila*, *R. pseudoacacia*) occurred throughout the KRL, while later successional species (e.g., *H. virginiana* and *Q. velutina*) common to northwest Ohio were found only in the oldest landfill parcel.

Other factors that could influence the occurrence of plant species at the KRL include: (1) the mound-shaped topography of the landfill which is not similar to the topography of its surroundings, creating different drainage characteristics; (2) the solid waste of the landfill was covered with soil excavated from a borrow pit, which would exclude plant species that require richer topsoil; and (3) the plant species in the sites surrounding the KRL are themselves not representative of an OOR woodland community. This last factor could play an important role, because plant colonization of an area requires an available seed source (Donath and others 2003; Foster and Tilman 2003), which is typically from nearby vegetation (Robinson and others 1992; Robinson and Handel 2000) and the existing soil (Egler 1954).

As noted previously, there has been an extensive diminution of native green space for the OOR. The data in this study suggest that older landfills such as the KRL might serve as habitat for native plant species. The most intuitive approach would be to seed and plant native species (Handel and others 1997; Dickinson 2000; Montalvo and others 2002; Rawlinson and others 2004; Matesanz and others 2006). The remedial option presented to the Ohio Environmental Protection Agency for the KRL notes that this could be accomplished by creating clusters of preferred species, which would then spread throughout the landfill site (Yarranton

Table 3

*Jaccard index values for the similarity in plant species composition between survey sites.*

Survey Site	KRL Surroundings		OOR Woodland Communities			
	SE Corner	Ten-Mile Creek	Floodplain	Sand Barren	Savanna	Deciduous Forest
1954-1957	0.38	0.08	0.07	0.08	0.13	0.09
1957-1960	0.35	0.11	0.09	0.08	0.12	0.04
1960-1963	0.30	0.09	0.08	0.09	0.15	0.04
1963-1969	0.33	0.15	0.14	0.05	0.07	0.05
1969-1976	0.31	0.14	0.13	0.10	0.12	0.06
SE Corner	--	--	0.12	0.12	0.14	0.11
Ten-Mile Creek	--	--	0.32	0.01	0.04	0.07

Values  $\geq 0.5$  indicate similarity between survey sites.

and Morrison 1974; Robinson and Handel 2000). As part of this option, researchers from the University of Toledo would help to select appropriate plant species, design the remedial approach and undertake long-term monitoring of the resultant cover. Attempts would be made to limit the growth of invasive plant species that could threaten the persistence of native species (Priour-Richard and Lavorel 2000; Thomson 2005).

This remedial option could be used to protect the threatened and endangered plant species present at the KRL (Table 2) and create habitat for other ecologically important organisms. *Lupinus perennis* (Table 2) is a prime example of a potentially threatened plant species that also serves as a host for the larvae of the Karner blue butterfly (*Lycæides melissa samuelis*), itself a nationally endangered species (Grundel and others 1998). In addition, plant species that are presumed extirpated, such as *Digitaria filiformis* (Table 2), may find the conditions of the KRL very suitable.

**ACKNOWLEDGEMENTS.** The U.S. Department of Agriculture (grant #2002-06143) and the Ohio State University Research Foundation (grant #743441) provided research funding. The authors thank the Ohio Environmental Protection Agency and Lucas County for their assistance; Toledo Area Metroparks for access to the OOMP; John Jaeger and Tim Walters for advice in identifying plant species; Tom Hays of Worster, Goldberg, & Hays and Michael Momenee of the Mannik & Smith Group for information and assistance at the KRL. This is contribution number 2008-001 of the University of Toledo Lake Erie Center.

### LITERATURE CITED

- Abella SR, Jaeger JF, Gehring, DH, Jacks RG, Menard KS, High KA. 2001. Restoring historic plant communities in the Oak Openings Region of northwest Ohio. *Ecol Rest* 19(3): 155-160.
- Bradshaw A. 1997. Restoration of mined lands - using natural processes. *Ecol Eng* 8: 255-269.
- Brewer LG, Vankat JL. 2001. Vegetation of the Oak Openings of northwestern Ohio at the time of Euro-American settlement. Map + text. Columbus (OH): Ohio Biological Survey.
- Brewer LG, Vankat JL. 2004. Description of vegetation of the Oak Openings of northwestern Ohio at the time of Euro-American settlement. *Ohio J Sci* 104 (4): 76-85.
- Cooperrider TS, Cusick AW, Kartesz JT. 2001. Seventh catalog of the vascular plants of Ohio. The Ohio State University Press, Columbus, Ohio.
- Daubenmire R. 1959. A canopy-coverage method of vegetational analysis. *Northwest Sci.* 33, 43-64.
- Dickinson NM. 2000. Strategies for sustainable woodland on contaminated soils. *Chemosphere* 41: 259-263.
- Donath TW, Holzel N, Otte A. 2003. The impact of site conditions and seed dispersal on restoration success in alluvial meadows. *App Veg Sci* 6: 13-22.
- Easterly NW. 1969. The oaks of the Oak Openings. *Castanea* 34: 335-351.
- Easterly NW. 1972. The compositae of the Oak Openings. *Ohio J Sci* 72(1): 11-21.
- Easterly NW. 1973. A list of the grasses and grasslike plants of the Oak Openings, Lucas County, Ohio. *Ohio J Sci* 73(5): 272-296.
- Easterly NW. 1979. Rare and infrequent plant species in the Oak Openings of northwestern Ohio. *Ohio J Sci* 79(2): 51-55.
- Egler FE. 1954. Vegetation science concepts. I. Initial floristic composition - a factor in old vegetation development. *Vegetatio* 4: 412-417.
- Foster BL, Tilman D. 2003. Seed limitation and the regulation of community structure in oak savanna grassland. *J Ecol* 91: 999-1007.
- Green Ribbon Initiative. 2002. The Green Ribbon Initiative. <http://www.oakopen.org>
- Grigore M. 2004. Living in the Oak Openings: a homeowner's guide to one of the world's last great places. Nature Conservancy, Toledo, Ohio.
- Grundel R, Pavlovic NB, Sulzman CL. 1998. Habitat use by the endangered Karner blue butterfly in oak woodlands: the influence of canopy cover. *Biol Conserv* 85: 47-53.
- Handel SN, Robinson GR, Parsons WFJ, Mattei JH. 1997. Restoration of woody plants to capped landfills: root dynamics in an engineered soil. *Rest Ecol* 5: 178-186.
- Hudson MA. 1980. Patterns of species diversity in an old field ecosystem. *Bull Ecol Soc Am* 61: 110.
- Johnson VS, Litvaitis JA, Lee TD, Frey SD. 2006. The role of spatial and temporal scale in colonization and spread of invasive shrubs in early successional habitats. *For Ecol Manage* 228: 124-134.
- Kim KD, Lee EJ, Cho KH. 2004. The plant community of Nanjido, a representative nonsanitary landfill in South Korea: implications for restoration alternatives. *Water Air Soil Pollut* 154: 167-185.
- Mannik & Smith Group. 2002. King Road Landfill Feasibility Study. Draft Alternative No. 11 Vegetative Final Cover and Engineered Controls. Prepared for: Lucas County Sanitary Engineer, December 2002, Holland, OH, 16p.

- Martinez-Ruiz C, Fernandez-Santos, B. 2005. Natural revegetation on topsoiled mining-spoils according to the exposure. *Acta Oecol* 28: 231-238.
- Matesanz S, Valladares F, Tena D, Costa-Tenorio M, Bote D. 2006. Early dynamics of plant communities on revegetated motorway slopes from southern Spain: is hydroseeding always needed? *Rest Ecol* 14(2): 297-307.
- Montalvo AM, McMillan PA, Allen EB. 2002. The relative importance of seeding method, soil ripping, and soil variables on seeding success. *Rest Ecol* 10(1): 52-67.
- Moseley EL. 1928. Flora of the Oak Openings. *Proc Ohio Academ Sci* 8 (special paper number 20), 79-134.
- Neher DA, Walters T, Tramer E, Weicht TR, Veluci RM, Saiya-Cork K, Will-Wolf S, Toppin J, Traub J, Johansen JR. 2004. Biological soil crust and plant communities in a sand savanna of northwestern Ohio. *J Torr Bio Soc* 130(4): 244-252.
- Odum EP. 1969. The strategy of ecosystem development. *Science* 164: 262-270.
- Prieur-Richard AH, Lavorel S. 2000. Invasions: the perspective of diverse plant communities. *Aust Ecol* 25: 1-7.
- Rawlinson H, Dickinson N, Nolan P, Putwain P. 2004. Woodland establishment on closed old-style landfill sites in N.W. England. *For Ecol Manage* 202: 265-280.
- Real R, Vargas JM. 1996. The probabilistic basis of Jaccard's index of similarity. *Syst Biol* 45(3): 380-385.
- Rebele F. 1992. Colonization and early succession on anthropogenic soils. *J Veg Sci* 3(2): 201-208
- Robinson GR, Handel SN, Schmalhofer VR. 1992. Survival, reproduction, and recruitment of woody plants after 14 years on a restored landfill. *Environ Manage* 16: 265-271.
- Robinson GR, Handel SN. 2000. Directing spatial patterns of recruitment during an experimental urban woodland reclamation. *Ecol Appl* 10(1): 174-188.
- Thomson D. 2005. Measuring the effects of invasive species on the demography of a rare endemic plant. *Biol Invas* 7: 615-624.
- USDA Forest Service. 2000. Forest inventory analysis national core field guide. Vol. 1., Field data collection procedure for phase 2 plots, Version 1.4. USDA Forest Service, Internal report. On file at USDA Forest Service, Washington Office, Forest Inventory and Analysis, Washington, DC.