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RESEARCH ARTICLE

Floristic Quality as an Indicator of Native Species Diversity in Managed Grasslands

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ABSTRACT: We undertook floristic studies of 104 grasslands in the tallgrass prairie region of Kansas to examine differences in the floristic quality of five common grassland management systems. The different grasslands were warm-season prairie hay meadows, warm-season native pastures, cool-season planted hay fields, cool-season planted pastures, and Conservation Reserve Program (CRP) fields. We recorded 383 vascular plant taxa of which 79% were native and 21% were non-native. Species richness at our sites ranged from seven for a cool season pasture to 109 for a warm-season hay meadow. Our results show that warm-season hay meadows exhibit highest species richness (256 taxa) and are habitats for highly conservative native taxa, while degraded grasslands have a higher number of alien taxa (29% in cool season planted hay fields) and lower species richness (136 for cool season hay fields). We computed Floristic Quality Assessment Index (FQI) values, which ranged from 0.3 for a cool-season pasture to 41 for warm-season prairie hay meadows while modified FQI ranged from 0.09 for a cool-season pasture to 4.48 for a warm-season prairie hay meadow. FQI values across management types differed significantly from each other (p=0.000). We conclude that native prairie hay meadows are significant reservoirs of conservative grassland species. In addition, the FQI can be a useful tool for discerning effects of land management on grassland vegetation.

Index terms: Asclepias meadii, coefficient of conservatism, fire, floristic quality assessment, floristics, grasslands, Kansas, prairies

INTRODUCTION

Biodiversity is frequently expressed as a measure of species richness and abundance. Plant communities are often qualitatively described with unquantifiable attributes, which vary depending on the surveyor, type of habitat, etc. The Floristic Quality Assessment Index (FQI), first designed by Swink and Wilhelm (1979), offers a quantitative characterization of plant communities. This index is based upon the degree of conservatism of species, which depends on the specificity a certain plant has toward its habitat. Originally devised for plants in the Chicago region, researchers have demonstrated its use in other regions, such as Missouri (Ladd 1993), Ontario (Oldham et al. 1995), Michigan (Herman et al. 1997, 2001), Wisconsin (Nichols 1998), Illinois (Mathews 2003), Ohio (Andreas et al. 2004), and Florida (Cohen et al. 2004). FQI has been used in a variety of habitats: marshes (Cohen et al. 2004), prairies (Klips 2003), restored wetlands (Mushet et al. 2002), wetlands (Lopez and Fennessy 2002, Matthews 2003), and woodlands (Francis et al. 2000). We demonstrate the use of FQI and modified FQI (Rooney and Rogers 2002) to compare habitat quality in grasslands. We also document the floristic diversity and assess the floristic quality of managed grasslands in northeast Kansas. Five major kinds of grasslands based on vegetation type and management practices were studied: (1) warm-season hay meadows, (2) warm-season pastures, (3) cool-season planted hay fields, (4) cool-season planted pastures, and (5) Conservation Reserve Program (CRP) fields.

Despite several floristic studies and plant inventories conducted in this portion of the Midwestern United States (Barker 1969, Brooks et al. 1977, Brooks and McGregor 1979, Freeman and Hulbert 1985, Freeman and Gibson 1987, Hulett et al. 1988, Kindscher and Wells 1995, Bennett 1996, Kindscher and Teiszen 1998, Freeman 2000, Towne 2002, Freeman et. al. 2003a, 2003b), this is the first study to specifically compare floristic quality analyses and plant species richness across management systems in grasslands. With tallgrass prairie reduced to less than 4% of its original acreage (Tallgrass Legacy Alliance and U.S. Fish and Wildlife Service 2005) and a total loss of 82% in Kansas (Noss et al. 1995), it is imperative to document the existing biodiversity within these prairies and adjacent grasslands that may serve as important habitats for prairie plant species. The study area serves as potential habitat for *Asclepias meadii* Torr. ex Gray and *Platanthera praeclara* Sheviak & Bowles, two species which are federally threatened and primarily occur in tallgrass prairies and hay meadows (U.S. Fish and Wildlife Service 2005).

We undertook this study for the following reasons: (1) to characterize the vegetation of grasslands in the region, (2) to compare floristic quality of grasslands of different management types, (3) to compare species richness across different management types, and (4) to serve as baseline data for our future ecological studies. All study sites were within the Glaciated region of northeast Kansas (Figure 1). The topography consists of flat lands and gentle rolling hills. Farm land in the three counties accounts for an average of about 71% of the total available land (Kansas Agricultural Statistics Service 2003) which is a fragmented mosaic of agricultural fields, second growth woodlands, pastures, and suburban development, along with cool-season hay meadows dominated by brome (*Bromus inermis* Leyss.) and fescue (*Lolium arundinaceum* (Schreb.) S.J. Darbyshire) (Kansas Agricultural Statistics Service 2003). Scattered within this are very few tallgrass prairie remnants in the form of hay meadows and pastures dominated by big bluestem (*Andropogon gerardii* Vitman) and little bluestem (*Schizachyrium scoparium* (Michx.) Nash). Due to this factor, the size of grassland remnants ranged from 2 ha to 65 ha.

The climate of this region is temperate with hot summers and cold winters. Maximum mean summer temperature is about 21°C, and the minimum mean winter temperature is about 0°C. The growing season extends from mid-April until mid-November. Soils in the study area are mainly comprised of silt clay loam. Soils range from shallow to deep, nearly level to gently or moderately sloping, with a slope of 1% to 8%. All soils are moderately drained and suitable for tallgrass prairie grasses, hay fields, and pastures (Dickey et al. 1977a, 1977b; Zavesky and Boatright 1977).

Native hay meadows are dominated by warm-season grasses (C4 photosynthesis pathway) and a wide variety of forbs, and are cut for hay during July or August each year. Warm-season native prairie pastures are also tallgrass prairie remnants but are often degraded due to intensive long-term cattle grazing. Cattle are allowed to graze either all year round or intermittently during the year. Cool-season hay fields are planted with brome grass or a combination of C3 photosynthetic pathway grasses like brome and fescue. Addition of nitrogen fertilizers at a rate of approximately 111 kg per hectare per year increases yield and protein content of cool-season grasses (Brotemarkle and Kilgore 1989). The vegetation in these fields is cut for hay during June or July each year. Cool-season pastures are also planted with a monoculture of brome grass and cattle are allowed to graze during the growing season. Most of these fields are sprayed with a variety of herbicides such as 2,4-D, dicamba, metsulfuron methyl, and picloram (Regehr 2005) whose active ingredients often kill non-target plants in addition to the targeted weeds (U.S. Department of Agriculture 2005). Fields present within the U.S. Department of Agriculture (USDA) Conservation Reserve Program were formerly cropland (Sullivan et al. 2004). These were removed from cultivation and the farmers were paid to reseed them with warm-season native grasses: *Andropogon gerardii* Vitman, *Bouteloua curtipendula* (Michx.) Torr., *Panicum virgatum* L., *Schizachyrium scoparium* (Michx.) Nash, and *Sorghastrum nutans*

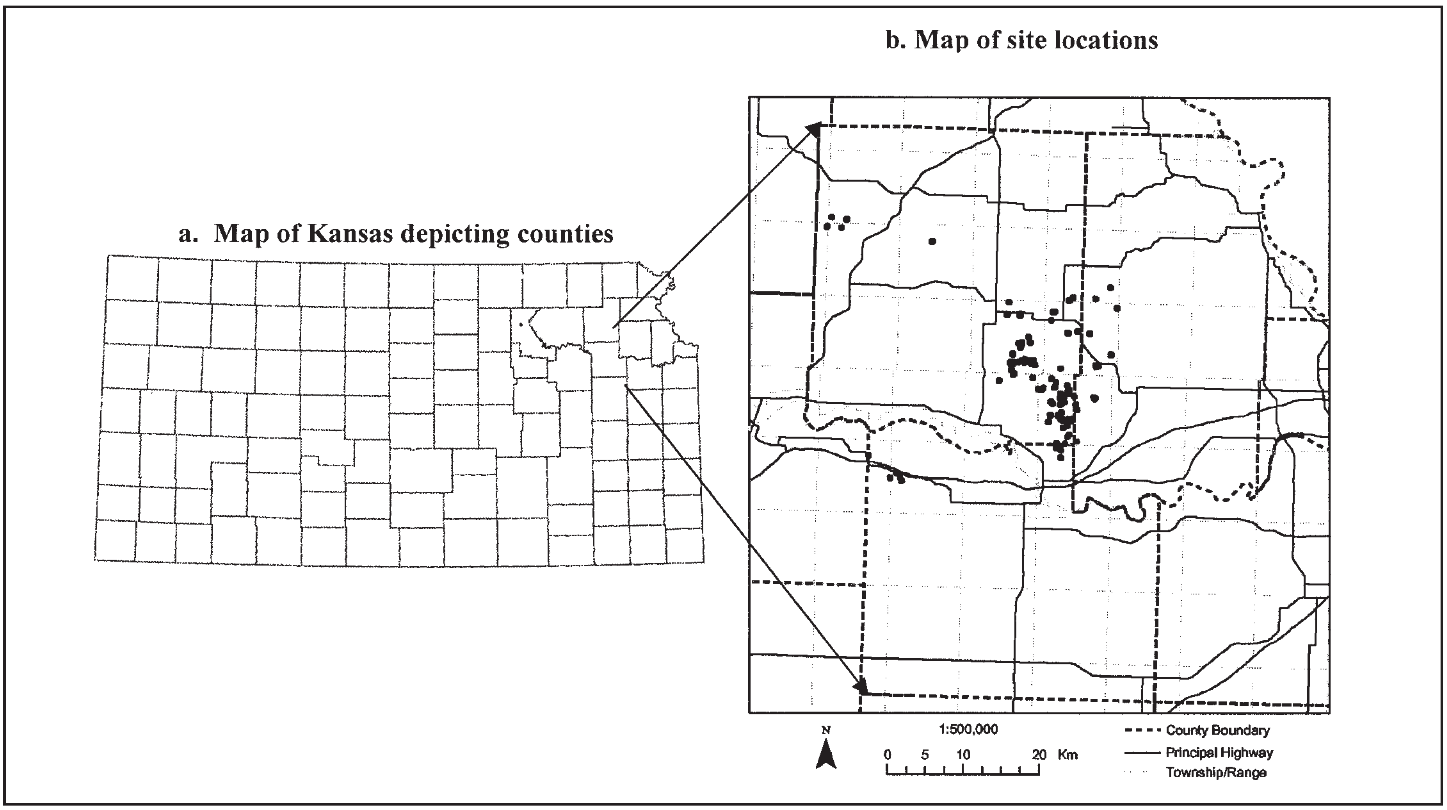

Figure 1. a) Map of Kansas depicting counties, b) map of site locations. Dots indicate location of fields sampled in Douglas, Jefferson, and Leavenworth counties.

(L.) Nash. This practice reduces soil erosion, improves water quality, and enhances wildlife habitat (Sullivan et al. 2004). Landowners enrolled in the Conservation Reserve Program are required to manage their fields with some form of management practice once every 10 years. This includes burning, interseeding, cutting for hay, grazing, and light disking.

Historically, fire has been an important factor in shaping the nature of the vegetation in tallgrass prairies. Since tallgrass prairies prevalent in eastern Kansas are capable of supporting woody vegetation, fire has been the main cause of limiting their growth (Bragg 1995). Suppression of fire can cause a substantial increase in woody growth leading to elimination of prairie plants (Gehring and Bragg 1992). It is fairly easy to eliminate *Juniperus virginiana* L., a common woody invader in prairies with the use of fire. However, other common invaders such as *Cornus drummondii* C.A. Mey., species of *Fraxinus* L., species of *Ulmus* L., and species of *Quercus* L. are difficult to remove with fire as they easily resprout from roots (Bragg 1995). Fire in the tallgrass prairie ecosystem also affects herbaceous vegetation in various ways depending on time of fire (Bragg 1995). Controlled spring burning is practiced as a form of management for elimination of woody plants, increase in productivity, increase in forb species, and the production of seedlings. Fire is often used along with grazing in an effort to maintain long-term diversity in these grasslands (Bragg 1995).

METHODS

We studied 104 privately owned grasslands and sampled at least 20 grasslands of each type: warm-season hay meadows (C4H), warm-season pastures (C4G), cool-season planted hay fields (C3H), cool-season planted pastures (C3G), and CRP fields.

Driving surveys within the region or Natural Resource Conservation Service (NRCS) digital aerial photography identified all grasslands. In addition, the Kansas Natural Heritage Inventory had previously identified several tallgrass prairie remnants. Grasslands within similar soil series were selected to maintain uniformity in geographic features. Contacting landowners and briefly interviewing about management practices ascertained management types. All sites were sampled once in the summer of 2004 between May 26 and July 28 in order to determine the greatest number of species in the sampled plots. Hay meadows needed to be sampled in early summer to ensure correct identification of taxa before the sites were cut for hay, which starts in early July for the cool-season fields and in late July for warm-season hay meadows. We set up three 20-m x 20-m plots (400 m^2), each spaced 20 m apart along a 100 m transect. Each of these plots had two subplots of 10 m x 10 m (100 m^2) and 1 m x 1 m (1 m^2) nested within the largest plot. All nested subplots were situated at one corner of the 20-m x 20-m plot. Each transect was situated at least 40 m away from the periphery of the field and on an upland location at any given site to ensure uniformity of locations and to avoid unusual circumstances which could confound data. Any kind of disturbance in fields or presence of wet habitats, depressions, etc., was noted. Species lists were made for all plots by field identification of plants. Representative specimens were brought back to the Kansas Biological Survey and keyed using Steyermark (1972), Bare (1979), Great Plains Flora Association (1986), and Yatskievych (1996). Problematic specimens were identified at the R.L. McGregor Herbarium at the University of Kansas. Taxa were determined to be native or alien to North America using Kartesz and Meacham (2004). Nomenclature follows Kartesz and Meacham (2004).

A complete species list (Table 1) based on plot sampling was compiled for each site within each management type. Coefficients of conservatism (C of C) were assigned to each species. The coefficient of conservatism ranges from 0-10, with higher values, such as *Asclepias meadii* with a C of C value of 10, indicating plants with higher fidelity to specific habitats. Plants with higher fidelity occupy a small ecological niche, cannot tolerate disturbance within surroundings, are habitat specific, and tend to perish easily with changes in habitat. Low C of C plants are tolerant of many different conditions, and are typically weedy generalists. Exotic taxa are all assigned a 0. Invasive natives are likewise assigned a 0. Plants with a C of C of 1-3 occur in a variety of habitats. Those with a C of C of 4-6 are associated with a specific plant community but tolerate moderate disturbance, while those with scores of 7-8 are associated with a community of advanced successional stage. High fidelity plants have scores of 9-10.

Coefficients of conservatism were obtained from Freeman and Morse (2002) and the FQI was calculated according to the following formula from Swink and Wilhelm (1994). $I=R/\sqrt{N}$, where I= floristic quality assessment index, R= sum of coefficients of conservatism for all plants recorded in the area, and N= number of different native species recorded. Species that did not have coefficients assigned to them, such as all non-native taxa, were not considered in the equation. The modified floristic quality assessment index for each community type was also calculated as modified FQI=C, where C is the mean coefficient of conservatism (Rooney and Rogers 2002). Species richness and percent exotic species were also computed for each site. We conducted a one-way ANOVA using SPSS (SPSS 12.0) and used the Tukey's post-hoc test to conduct pair-wise comparisons among different management types.

RESULTS

We observed 383 species represented by 223 genera and 66 families (Table1). Of these, 301 (79%) were native while 82 (21%) taxa were non-native. Of the non-native taxa, approximately 1% (four) is considered invasive noxious weeds: these were *Carduus nutans*, *Cirsium arvense*, *Convolulus arvensis*, and *Lespedeza cuneata* (Kansas Department of Agriculture 2005). Families represented by the most number of species were: Asteraceae (64), Poaceae (55), Fabaceae (34), Cyperaceae (23), and Rosaceae (15). The largest genus was *Carex* with 15 species followed by *Asclepias* with 10 species.

Two taxa, unusual elsewhere in the three-county region, were abundant at our sites.

Table 1. List of species observed at all study sites. C is the coefficient of conservatism, an asterisk indicates that a species is alien to North America and numbers in columns indicate the number of fields each species occurred in. Management types are abbreviated as follows: C4H = warm-season hay meadow, C4G = warm-season pasture, C3H = cool-season hay meadow, C3G = cool-season pasture and CRP = Conservation Reserve Program field. Nomenclature follows Kartesz and Meacham, 2004.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Abutilon theophrasti	*	0	0	0	2	5
Acalypha rhomboidea	1	0	0	0	0	1
Acalypha virginica	0	6	9	0	2	12
Acer negundo	1	0	0	0	1	1
Acer saccharinum	2	1	1	0	0	0
Achillea millefolium	1	19	14	5	4	3
Ageratina altissima var. *altissima*	1	2	0	0	0	4
Agrimonia parviflora	4	0	3	0	0	0
Agrostis hyemalis	2	7	4	1	0	6
Agrostis stolonifera	*	9	13	0	4	1
Allium canadense	2	2	0	0	0	0
Allium stellatum	6	1	0	0	0	0
Allium vineale	*	11	1	6	0	4
Amaranthus retroflexus	*	0	0	0	1	0
Amaranthus rudis	0	0	0	0	0	3
Ambrosia artemisiifolia	0	11	14	6	15	17
Ambrosia psilostachya	3	3	6	0	0	1
Ambrosia trifida	0	0	1	1	0	2
Amorpha canescens	7	14	8	0	0	1
Ampelopsis cordata	2	0	0	1	0	0
Anagallis arvensis	*	0	0	0	0	1
Andropogon gerardii	4	20	19	2	3	20
Andropogon virginicus	0	2	6	0	2	2
Antennaria neglecta	2	17	8	2	2	7
Apocynum cannabinum	0	20	9	10	11	18
Arctium minus	*	0	0	0	1	0
Arenaria serpyllifolia	*	11	3	4	1	2
Aristida oligantha	0	1	1	4	0	4
Arnoglossum plantagineum	6	6	1	0	0	0
Artemisia ludoviciana	2	2	7	0	1	6
Asclepias amplexicaulis	7	9	3	0	1	1
Asclepias hirtella	7	2	1	1	2	1
Asclepias meadii	10	3	0	0	0	0
Asclepias stenophylla	7	1	0	0	0	0
Asclepias sullivantii	5	1	0	0	0	0
Asclepias syriaca	1	2	9	8	4	7
Asclepias tuberosa	6	10	3	1	1	0

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Asclepias verticillata	1	14	13	6	4	10
Asclepias viridiflora	6	8	4	0	6	1
Asclepias viridis	1	15	18	13	21	14
Baptisia alba var. *macrophylla*	5	8	15	0	4	0
Baptisia bracteata	6	15	11	0	0	0
Barbarea vulgaris	*	8	4	5	3	0
Bouteloua curtipendula	5	6	13	0	0	18
Brickellia eupatorioides	2	10	4	8	3	6
Bromus inermis	*	13	20	21	22	5
Bromus japonicus	*	15	19	12	18	5
Callirhoe alcaeoides	6	1	0	0	0	0
Calylophus serrulatus	5	1	0	1	0	0
Camelina microcarpa	*	0	2	5	2	0
Campsis radicans	*	0	0	0	1	0
Cannabis sativa	*	0	1	0	1	0
Capsella bursa-pastoris	*	0	0	1	0	0
Carduus nutans	*	7	9	4	4	1
Carex annectens	5	1	0	0	0	0
Carex austrina	2	3	12	9	10	1
Carex bicknellii	8	4	1	0	0	1
Carex blanda	1	1	3	2	2	0
Carex brevior	5	13	13	9	10	4
Carex bushii	4	7	8	6	3	1
Carex davisii	4	0	1	0	1	0
Carex emoryi	5	0	0	2	0	0
Carex frankii	4	0	0	0	1	0
Carex gravida	4	2	11	5	7	1
Carex hirsutella	5	1	3	0	2	0
Carex leavenworthii	2	1	4	5	5	0
Carex meadii	7	15	4	2	1	0
Carex mesochorea	5	5	4	5	5	1
Carex molesta	4	1	0	0	2	0
Chamaecrista fasciculata	2	2	3	0	0	11
Ceanothus americanus	9	7	1	0	0	0
Ceanothus herbaceus	8	8	1	0	0	0
Celastrus scandens	4	0	1	0	0	0
Cerastium brachypetalum	*	4	1	0	1	0

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Cerastium fontanum	*	3	5	4	4	0
Cercis canadensis	2	2	0	0	0	1
Chaerophyllum tainturieri	2	0	0	1	0	0
Chenopodium album	0	0	1	0	0	1
Chloris verticillata	0	0	3	0	2	0
Chamaesyce maculata	0	2	12	1	12	10
Chamaesyce nutans	0	0	7	4	1	6
Cirsium altissimum	2	3	11	0	0	12
Cirsium arvense	*	0	1	0	1	0
Cirsium undulatum	4	2	0	0	0	3
Cirsium vulgare	*	1	3	1	5	2
Comandra umbellata	6	11	0	0	0	0
Conium maculatum	*	0	1	0	0	0
Convolvulus arvensis	*	0	1	9	11	5
Conyza canadensis	0	6	10	3	7	9
Coreopsis palmata	7	6	1	0	0	0
Cornus drummondii	1	6	9	0	1	15
Crataegus mollis	4	1	0	0	1	0
Croton capitatus	1	1	9	1	6	0
Croton glandulosus	1	0	0	0	0	1
Croton monanthogynus	1	2	2	1	5	2
Cynanchum laeve	0	0	5	3	6	7
Cynodon dactylon	*	0	1	0	0	0
Cyperus acuminatus	0	1	0	0	0	1
Cyperus echinatus	3	1	2	0	1	0
Cyperus lupulinus	3	6	13	0	11	2
Cyperus strigosus	4	0	0	0	0	2
Dactylis glomerata	*	8	6	10	10	0
Dalea candida	7	14	5	0	0	1
Dalea purpurea	7	17	7	1	1	3
Dasistoma macrophylla	4	0	1	0	0	0
Datura stramonium	*	1	2	0	1	0
Daucus carota	*	2	1	0	0	0
Delphinium carolinianum ssp. *virescens*	6	1	0	0	0	0
Desmanthus illinoensis	2	4	3	2	0	11
Desmodium cuspidatum	6	0	0	0	0	1

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Desmodium glutinosum	3	0	0	0	0	3
Desmodium illinoense	5	18	17	4	2	14
Desmodium paniculatum	4	1	5	1	0	3
Desmodium sessilifolium	7	13	11	1	0	3
Dianthus armeria	*	18	14	9	4	1
Dichanthelium acuminatum	3	20	12	2	3	1
Dichanthelium clandestinum	5	0	1	0	1	0
Dichanthelium linearifolium	7	4	0	0	0	0
Dichanthelium oligosanthes	4	19	17	2	4	0
Dichanthelium sphaerocarpon	5	2	0	0	0	0
Digitaria cognata var. *cognata*	3	4	11	0	1	2
Digitaria ischaemum	*	0	4	0	2	1
Dipsacus fullonum	*	0	0	0	0	1
Echinacea pallida	7	14	1	0	0	0
Echinochloa crus-galli	*	0	1	0	0	0
Echinochloa muricata	0	0	1	0	2	0
Eleocharis compressa	6	0	1	0	0	0
Eleusine indica	*	0	0	0	1	0
Elymus canadensis	5	3	4	0	1	3
Elymus villosus	5	0	0	0	0	1
Elymus virginicus	3	2	8	0	0	5
Eragrostis spectabilis	3	0	1	0	1	0
Erechtites hieracifolia	1	0	1	0	0	3
Erigeron annuus	0	4	3	4	1	9
Erigeron strigosus	4	19	16	8	5	12
Eriochloa contracta .	0	0	0	0	0	1
Eryngium yuccifolium	7	7	1	0	0	0
Eupatorium altissimum	2	2	1	0	0	10
Eupatorium serotinum	2	0	0	0	0	1
Euphorbia corollata	5	13	3	1	1	3
Euphorbia dentata	0	1	6	2	2	0
Euphorbia marginata	0	0	7	0	1	0
Euthamia gymnospermoides	3	6	6	0	1	4
Fimbristylis puberula	8	10	0	0	0	0
Fragaria virginiana	2	14	15	2	1	3
Fraxinus pennsylvanica	0	1	0	0	0	0
Gaillardia pulchella	4	0	0	0	0	2

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Galium aparine	0	0	1	9	1	4
Galium obtusum	5	1	0	0	0	0
Galium virgatum	5	4	0	1	0	0
Gaura longiflora	2	1	1	0	0	0
Gaura parviflora	1	3	4	0	0	5
Gentiana puberulenta	8	7	1	0	0	0
Geranium carolinianum	0	1	0	2	0	7
Geum canadense	1	0	0	0	0	3
Glandularia canadensis	3	0	1	0	0	0
Gleditsia triacanthos	0	3	10	7	13	2
Grindelia lanceolata var. *lanceolata*	3	0	1	0	0	0
Grindelia squarrosa	0	0	1	0	0	0
Gymnocladus dioica	4	0	0	0	0	2
Hedeoma hispidum	1	6	1	5	3	1
Helianthus annuus	0	0	6	0	3	10
Helianthus grosseserratus	4	2	3	0	0	1
Helianthus maximilianii	3	1	0	0	0	3
Helianthus rigidus	5	3	0	0	0	3
Helianthus tuberosus	2	0	1	0	0	0
Hesperostipa spartea	8	4	0	0	0	0
Hibiscus trionum	*	0	0	1	0	2
Hieracium longipilum	5	16	3	0	0	0
Hordeum jubatum	1	0	2	0	2	0
Hordeum pusillum	0	0	3	4	6	1
Houstonia pusilla	1	1	0	0	0	0
Hypericum perforatum	*	8	5	1	2	1
Hypericum punctatum	6	5	4	0	0	1
Hypoxis hirsuta	5	1	0	0	0	0
Ipomoea hederacea	*	0	0	0	0	1
Ipomoea lacunosa	0	0	0	0	0	5
Iva annua	0	0	1	0	0	0
Juglans nigra	3	2	0	0	1	0
Juncus interior	2	3	6	0	2	3
Juncus tenuis	0	8	10	3	11	3
Juncus torreyi	2	0	0	0	0	1
Juniperus virginiana	1	11	6	5	3	4

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Koeleria macrantha	6	16	12	0	0	3
Kummerowia stipulacea	*	6	14	3	14	9
Kummerowia striata	*	0	2	0	0	0
Lactuca ludoviciana	3	6	2	2	0	4
Lactuca saligna	*	3	2	0	3	5
Lactuca serriola	*	3	4	3	4	4
Leersia virginica	3	0	0	0	0	1
Lepidium campestre	*	0	0	1	0	0
Lepidium densiflorum	0	10	9	16	9	12
Lespedeza capitata	6	16	6	1	0	6
Lespedeza cuneata	*	0	8	0	0	5
Lespedeza violacea	5	10	3	0	1	3
Lespedeza virginica	5	0	2	0	0	3
Leucanthemum vulgare	*	10	6	3	0	3
Leucospora multifida	0	0	0	0	0	1
Liatris aspera	6	6	2	0	0	0
Liatris pycnostachya	7	3	0	0	1	1
Linum sulcatum	6	12	4	0	0	0
Lithospermum arvense	*	0	0	2	0	0
Lithospermum canescens	7	9	3	0	0	0
Lithospermum incisum	5	8	7	2	0	0
Lobelia spicata	6	18	6	0	0	0
Lolium arundinaceum	*	15	19	16	18	2
Lolium pratense	*	0	0	1	0	0
Lotus corniculatus	*	0	0	0	0	2
Lythrum alatum	4	0	1	0	0	0
Maclura pomifera	*	3	12	2	14	1
Malva neglecta	*	0	0	0	1	0
Medicago lupulina	*	17	17	5	8	5
Medicago sativa	*	2	0	0	0	0
Melilotus albus	*	3	6	0	1	7
Melilotus officinalis	*	6	9	5	7	8
Menispermum canadense	4	0	0	0	1	1
Microthlaspi perfoliatum	*	5	2	5	1	0
Mimosa nuttallii	6	7	5	0	0	1
Mirabilis albida	5	2	2	0	0	0
Mirabilis nyctaginea	0	2	0	0	0	0

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Monarda fistulosa	3	3	5	2	0	1
Morus alba	*	3	5	3	0	2
Morus rubra	5	0	2	2	0	0
Muhlenbergia sp.		1	0	0	0	0
Myosotis verna	2	1	0	0	0	0
Nepeta cataria	*	0	2	0	0	0
Oenothera biennis	0	0	0	1	0	0
Oenothera speciosa	2	1	0	0	0	0
Oenothera villosa	0	1	1	1	0	0
Oligoneuron rigidum	3	8	2	1	0	1
Onosmodium bejariense	4	0	2	0	0	0
Oxalis dillenii	0	18	16	13	20	19
Oxalis violacea	4	3	1	1	0	2
Panicum capillare	0	1	5	0	1	1
Panicum virgatum	4	13	15	0	0	20
Paronychia fastigiata	5	0	0	0	0	1
Parthenocissus quinquefolia	1	1	0	0	1	2
Pascopyrum smithii	2	0	0	0	0	1
Paspalum setaceum	2	8	16	0	13	2
Pedicularis canadensis	7	4	0	0	0	0
Penstemon tubaeflorus	3	2	0	0	0	0
Phleum pratense	*	13	15	11	19	0
Phlox pilosa	7	8	0	0	0	0
Physalis hederifolia	7	1	1	0	1	1
Physalis heterophylla	4	5	12	2	6	3
Physalis longifolia	2	5	6	8	9	10
Physalis pumila	4	12	9	8	5	7
Physalis virginiana	6	8	6	0	0	0
Phytolacca americana	0	0	2	0	0	0
Plantago aristata	2	3	3	0	2	0
Plantago lanceolata	*	0	0	1	0	0
Plantago major	*	0	2	0	2	0
Plantago patagonica	1	0	1	0	0	0
Plantago virginica	1	18	7	3	3	7
Poa compressa	*	5	8	0	6	0
Poa pratensis	*	16	19	20	20	7
Polygala incarnata	*	3	0	0	0	0

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Polygala verticillata	8	9	0	1	0	3
Polygonum amphibium	3	0	0	1	0	1
Polygonum arenastrum	2	1	1	1	3	0
Polygonum lapathifolium	2	1	0	0	0	0
Polygonum pensylvanicum	*	0	0	0	0	1
Polygonum punctatum	2	0	0	0	1	0
Polygonum scandens	3	0	0	0	0	1
Polygonum virginianum	2	0	0	0	0	1
Polytaenia nuttallii	6	1	0	0	0	0
Populus deltoides	0	0	0	0	0	1
Potentilla arguta	6	2	0	0	0	0
Potentilla recta	*	17	2	7	0	0
Potentilla simplex	3	1	0	0	0	0
Prunella vulgaris	*	4	4	0	0	0
Prunus americana	3	1	3	0	1	3
Prunus mahaleb	*	0	0	0	0	1
Prunus serotina	3	2	0	0	0	0
Prunus virginiana	2	0	1	0	0	0
Pediomelum esculentum	7	6	1	0	0	0
Pseudognaphalium obtusifolium	0	0	3	0	1	4
Psoralidium tenuiflorum	3	5	2	0	0	0
Pycnanthemum tenuifolium	4	8	4	0	0	2
Pyrrhopappus carolinianus	1	0	2	0	0	3
Quercus rubra	6	0	1	0	0	0
Quercus velutina	5	0	0	0	0	1
Ratibida columnifera	4	2	0	0	0	1
Ratibida pinnata	3	7	3	0	0	0
Rhus copallina	3	2	0	0	0	0
Rhus glabra	1	2	1	0	1	5
Robinia pseudoacacia	0	0	1	0	0	1
Rorippa palustris	2	0	0	0	0	1
Rorippa sylvestris	*	0	0	0	1	0
Rosa arkansana	4	14	8	0	2	0
Rosa multiflora	*	1	1	0	1	1
Rubus alumnus	4	2	4	3	2	5
Rubus flagellaris	5	4	6	0	0	4
Rudbeckia hirta	2	18	14	2	2	2

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Rudbeckia subtomentosa	6	1	1	0	0	0
Rudbeckia triloba	4	0	1	0	0	0
Ruellia humilis	3	19	18	4	4	0
Rumex altissimus	0	1	0	2	6	5
Rumex crispus	*	2	6	12	5	8
Rumex obtusifolius	*	0	0	0	0	1
Salix amygdaloides	3	0	0	0	0	1
Salix humilis	7	1	0	0	0	0
Salix nigra	2	0	0	1	0	0
Salvia azurea	4	17	2	2	0	2
Sambucus nigra	2	0	0	0	0	1
Sanicula odorata	2	0	0	0	0	1
Schizachyrium scoparium	5	19	14	1	1	20
Schedonnardus paniculatus	3	0	0	0	1	0
Scirpus pendulus	3	3	2	1	1	0
Scleria triglomerata	8	12	2	0	0	0
Scutellaria parvula	5	3	0	0	0	0
Setaria faberi	*	0	1	0	0	5
Setaria parviflora	3	1	4	0	0	0
Setaria pumila	*	0	8	0	1	6
Setaria viridis	*	0	0	0	1	0
Sida spinosa	*	0	0	0	0	3
Silene antirrhina	0	6	0	11	2	5
Silene stellata	5	0	1	0	1	0
Silphium integrifolium	3	5	2	1	0	0
Silphium laciniatum	4	16	3	1	0	0
Sisymbrium officinale	*	0	0	0	1	0
Sisyrinchium campestre	6	14	1	0	0	0
Smilax tamnoides	2	1	0	1	3	0
Solanum carolinense	1	18	19	18	21	17
Solanum ptycanthum	1	0	1	0	0	0
Solanum rostratum	0	0	1	0	2	0
Solidago canadensis	1	13	10	5	1	20
Solidago missouriensis	5	12	3	1	0	7
Solidago nemoralis	2	9	1	0	1	6
Solidago speciosa	7	1	1	0	0	0
Sorghastrum nutans	5	17	18	2	0	18

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Spartina pectinata	4	2	2	0	1	0
Spermolepis inermis	3	3	0	0	0	0
Spiranthes vernalis	8	1	6	0	0	1
Sporobolus compositus	3	20	18	3	5	14
Sporobolus cryptandrus	0	0	2	0	1	0
Sporobolus heterolepis	8	5	3	0	0	2
Sporobolus vaginiflorus	0	0	0	0	0	1
Stellaria media	*	0	0	1	0	0
Strophostyles helvula	3	0	0	0	0	1
Strophostyles leiosperma	3	2	5	0	0	7
Symphiotrichum ericoides	5	18	7	1	1	0
Symphiotrichum laeve	7	1	0	0	0	0
Symphiotrichum oblongifolium	5	2	1	0	0	1
Symphiotrichum oolentangiense	8	15	8	0	0	0
Symphiotrichum pilosum	0	16	16	5	4	9
Symphiotrichum praealtum	3	9	4	2	1	6
Symphoricarpos orbiculatus	1	8	13	2	11	8
Taraxacum officinale	*	1	8	2	10	2
Teucrium canadense	1	1	3	0	1	2
Thlaspi arvense	*	2	2	8	1	3
Torilis arvensis	*	4	8	0	5	7
Toxicodendron radicans	0	5	7	0	1	7
Tradescantia bracteata	5	5	0	0	0	0
Tradescantia ohiensis	5	2	1	0	0	0
Tragia betonicifolia	5	4	3	0	3	0
Tragopogon dubius	*	17	9	5	5	3
Tridens flavus	1	11	15	3	12	4
Trifolium pratense	*	15	15	8	9	1
Trifolium repens	*	5	13	2	12	1
Triodanis leptocarpa	3	6	0	0	0	0
Triodanis perfoliata	2	5	0	0	0	3
Tripsacum dactyloides	3	16	8	3	2	2
Ulmus americana	2	0	1	0	1	1
Ulmus rubra	3	16	7	3	5	16
Valerianella radiata	2	1	0	0	0	0
Verbascum blattaria	*	0	2	0	5	0
Verbascum thapsus	*	0	5	1	4	0

continued

Table 1. Continued.

Species Name	C	C4H	C4G	C3H	C3G	CRP
Verbena simplex	2	1	0	0	0	1
Verbena stricta	1	3	14	2	11	4
Verbena urticifolia	2	1	4	0	2	4
Vernonia baldwinii	2	20	18	12	17	8
Veronica peregrina	0	3	2	13	6	6
Viola nephrophylla	2	0	2	0	0	3
Viola pedatifida	6	18	8	0	1	0
Viola bicolor	0	0	0	0	1	0
Viola sororia	2	1	1	0	0	1
Vitis riparia	2	1	0	0	0	1
Xanthium strumarium	0	0	3	1	1	0
Zanthoxylum americanum	3	0	0	0	1	0
Zizia aurea	5	0	1	0	0	0

These were *Carex hirsutella (*listed as rare in Kansas (Kartesz and Meacham 2005), and found in cool-season hay fields, warm-season pastures, and one warm-season hay meadow) and *Paronychia fastigiata,* present in a CRP field. We also found several species with high coefficients of conservatism. *Asclepias meadii* (occurring in three warm-season hay meadows) and *Ceanothus americanus* (occurring in eight warm-season hay meadows and one native pasture) were our most conservative species with C of C of 10 and 9 respectively.

Species richness at our sites ranged from seven for a cool season pasture to 109 for a warm-season hay meadow. Species richness was significantly higher in warm-season hay meadows as well as warm-season pastures (Figure 2a). FQI ranged from 0.3 for a cool-season pasture to 41 for warm-season hay meadows, while modified FQI ranged from 0.09 for a cool-season pasture to 4.48 for a warm-season hay meadow. FQI of warm-season pastures and warm-season hay meadows were significantly different from each other (p=0.000) as well as from all other management types (Figure 2b). Trends within modified FQI showed almost identical patterns to FQI values (Figure 2c).

Warm-season hay meadows are classic

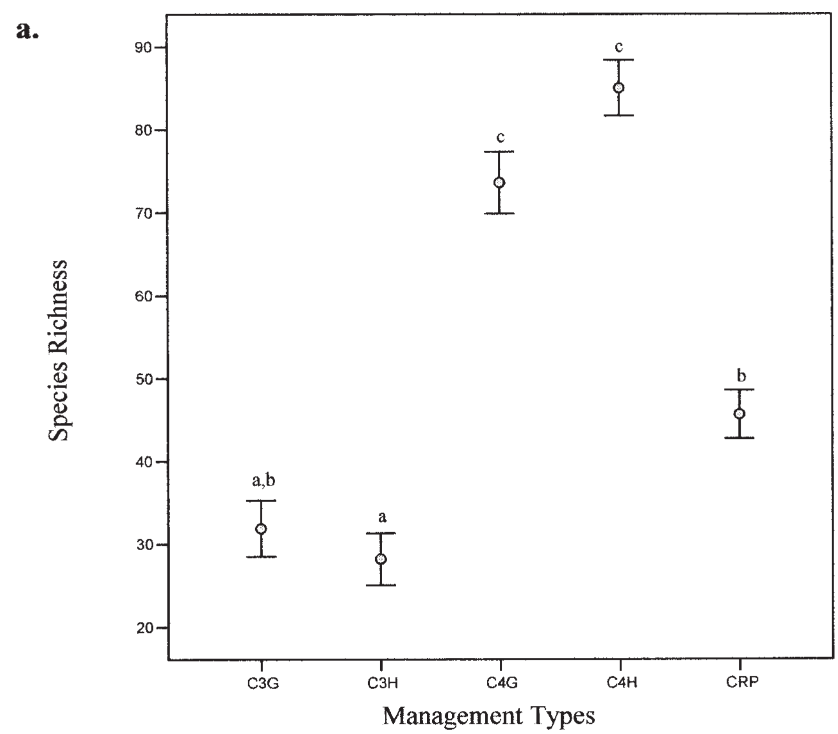

Figure 2. Graphs showing a) species richness per site across different management regimes, b) FQI across different management regimes, c) modified FQI across different management regimes, d) percent exotic species across different management regimes. Error bars indicate standard error of the means, dark circles indicate means, and means are significantly different (α = 0.05) if they do not share common letters. Management types are abbreviated as follows: C3G = cool-season pasture, C3H = cool-season hay field, C4G = warm-season native pasture, C4H = warm-season prairie hay meadow, and CRP = Conservation Reserve Program field.

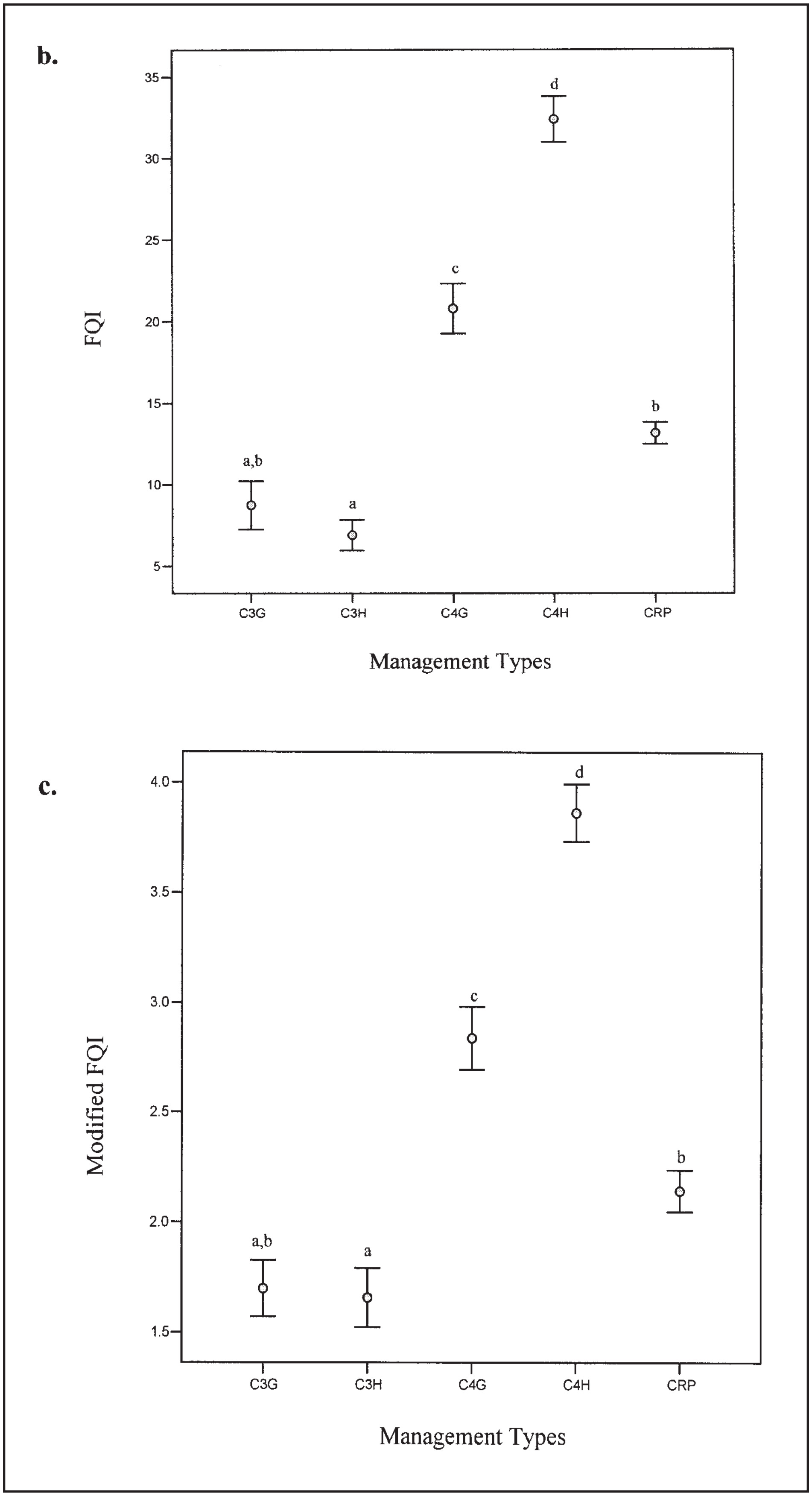

Figure 2. Continued.

tallgrass native prairie remnants and were characterized by *Andropogon gerardii, Panicum virgatum*, *Schizachyrium scoparium*, *Sporobolus heterolepis,* and *Tripsacum dactyloides*. Other dominant species included *Amorpha canescens*, *Asclepias tuberosa, Ceanothus americanus, Echinacea pallida, Phlox pilosa, Salvia azurea,* and several species of *Liatris* and *Silphium*. Warm-season hay meadows were our most diverse sites with species richness ranging from 55 to 109 and a high percentage of conservative, native species. Only 16% of the total species found at these sites were non-native, while 33 species had C of C of seven or above. FQI values for these sites ranged from 17 to 41.

Only two of the 20 warm-season hay meadows we surveyed had been managed by conducting any controlled burns at least once in the past few decades. This management with fire was sporadic and infrequent and did not seem to affect species richness and composition within these two meadows. Species richness for these sites (84 and 82) was very close to the average species richness (85) for this management type. FQIs were slightly higher (37 and 33) from the average value of 32; modified FQIs were similar to the average, as were number of native taxa.

Warm-season pastures had a species richness ranging from 39 to 96 taxa, while 21 taxa had C of C of seven or greater. These ranged from highly degraded fields (FQI=5) to moderately high quality native prairie remnants (FQI= 30). One warm-season pasture within this study has been burned every year since the year 2000. It was burned periodically for several years prior to 2000. This site had higher than average species richness and number of native species at 94 and 75 respectively, while their FQI and modified FQIs were similar to average values for all warm-season pastures.

Cool-season hay fields showed a dominance of non-native grasses such as *Bromus inermis, Bromus japonicus,* and *Lolium arundinaceum*. Interspersed within these grasses were several other aliens and ruderals such as *Achillea millefolium, Cerastium fontanum, Kummerowia stipulacea,*

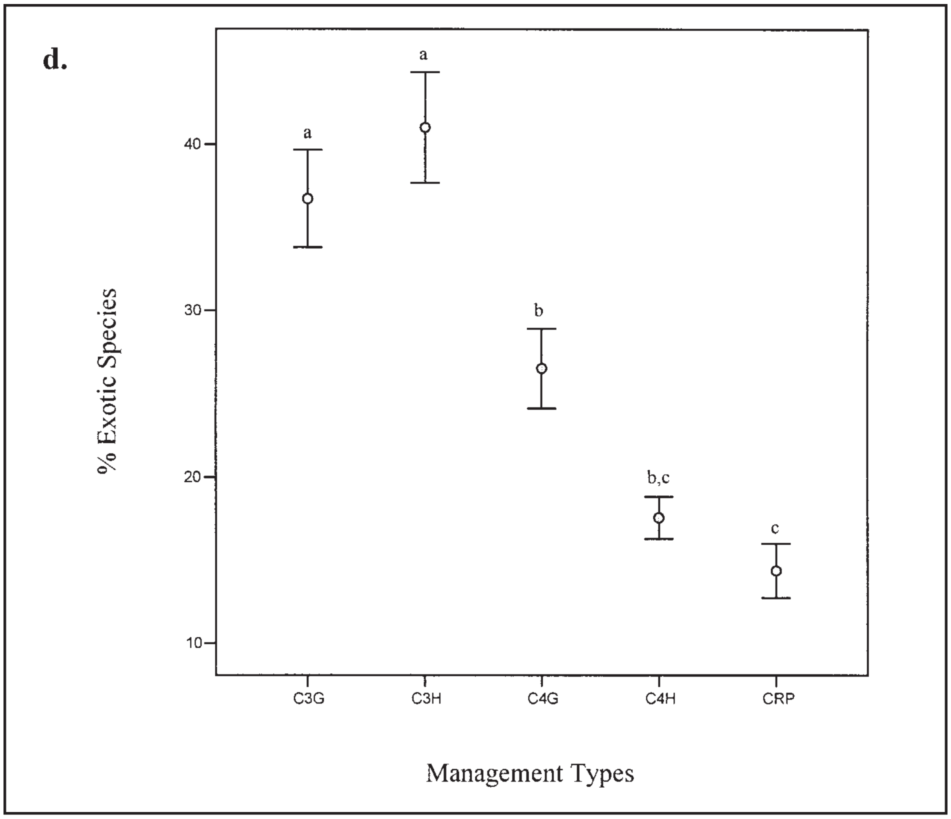

Figure 2. Continued.

Medicago lupulina, Solanum carolinense, Trifolium pratense, and *Verbena stricta.* Species richness within cool-season hay fields ranged from 10 to 66 with some fields containing up to 70% alien taxa, while FQI ranged from 2 to 19. The percentage of exotic species found within cool-season hay fields was higher than for other management regimes, with the mean significantly different from warm season and CRP fields. We found four conservative taxa in cool-season hay fields: *Asclepias hirtella*, *Carex meadii*, *Desmodium sessilifolium*, and *Dalea purpurea*. None of the cool-season hay meadows we studied were burned in the recent past.

Species richness within cool-season pastures ranged from 7 to 57 and included several non-native taxa – a distribution similar to the cool-season hay fields. Several alien taxa and those with lower C of C dominated this landscape. However, we observed six conservative taxa with C of C of seven: *Asclepias amplexicaulis*, *A. hirtella, Carex meadii*, *Dalea purpurea*, *Liatris pycnostachya*, and *Physalis hederifolia*. Cool-season pastures considered in this study were also not subjected to burning practices.

Fields enrolled in CRP had a dominant cover of planted native grasses such as *Andropogon gerardii, Bouteloua curtipendula*, *Panicum capillare*, *Schizachyrium scoparium*, and *Sorghastrum nutans*. We found 12 taxa with C values of seven or greater in these fields. These included *Amorpha canescens, Asclepias amplexicaulis, Carex bicknellii, Spiranthes vernalis,* and *Sporobolus heterolepis*. Species richness and floristic quality of these fields were moderate with means of 45 for species richness and 13 for FQI (Table 2). Most of the CRP fields in our study had not been burned in the past decade except for three fields, all owned by the same person, and these three had been burned once in the past decade. However, species richness, FQI, modified FQI, and number of native species for each of these fields did not vary greatly from the average.

DISCUSSION

The warm-season hay meadows we surveyed are the remaining islands of high quality habitat in this landscape. They support several high fidelity taxa, exhibit greatest species richness, have the highest FQI, and have low exotic species number. These are valuable patches of floristically diverse habitats, which are otherwise rare in northeast Kansas. The Kansas Natural Heritage Program has not documented any other tracts of grasslands with comparable floristic diversity in the Glaciated region of Kansas and can confirm the uniqueness of these prairie remnants (K. Kindscher, Kansas Biological Survey, pers. comm.). Overall, these meadows support a rich, taxonomically diverse flora in comparison to any other grassland type within our study.

Three of these warm-season hay meadows also support the federally threatened *Asclepias meadii*, known to be extant only in Kansas, Missouri, Iowa, and Illinois and

Table 2. Average and total richness and FQI values for all sites within specific management regimes. Management types are abbreviated as follows: C4H = warm-season hay meadow, C4G = warm-season pasture, C3H = cool-season hay meadow, C3G = cool-season pasture and CRP = Conservation Reserve Program field.

	C3G	C3H	C4G	C4H	CRP
Avg. Species Richness	33	31	73	85	45
Avg. FQI	9	8	21	32	13
Modified FQI	1.68	1.7	2.8	3.86	2.14
Avg. Native Species	22	20	55	70	39
Total Richness	177	136	255	256	215

believed to be extirpated from Wisconsin and Indiana (Environmental Protection Agency 2003). In Kansas, *Asclepias meadii* is known to occur only in native prairie remnants indicating that this is the sole type of habitat for the sustenance of this species in Kansas (C. Freeman, Kansas Natural Heritage Inventory, pers. comm.). Habitat loss and fragmentation are the two main causes of the decline in population of this species (U.S. Fish and Wildlife Service 2003). Preservation of prairie remnants is imperative for the survival of *Asclepias meadii*. Another species *Platanthera praeclara,* the western prairie white fringed orchid, is federally threatened (U.S. Fish and Wildlife Service 2005), and is restricted to prairies (C. Freeman, Kansas Natural Heritage Inventory, pers. comm.). Although we did not encounter this species at any of our study sites, we recognize the importance of native prairie hay meadows as potential habitat. These unique habitat patches may be managed to more effectively conserve native flora. Native prairie hay meadows are cut for hay early each summer before many species either flower or set seed. This limits seed formation and dispersal of native grassland vegetation within the existing field and other suitable habitat patches. Based on our findings, we suggest incentives for landowners to cut vegetation within these meadows for hay on alternate years in an effort to allow the possibility of increased seed formation. We also recommend mixed management of these meadows by resting the field for one year, followed by cutting for hay preceding an early spring burn the following year. This practice will benefit biodiversity by enriching floristic quality of the existing meadow and possibly surrounding habitats (Bragg 1995). Alternatively, cutting for hay much later during the growing season is another technique that could be employed for permitting seed formation and dispersal. These practices will not be financially economical or lucrative to landowners, and we suggest substantial monetary incentives to encourage these types of management.

We sampled a wide array of native pastures ranging from poor quality sites with several alien taxa to high quality sites with several conservative taxa. Heavy grazing in native grasslands can be the cause of accelerated weed invasion (Daubenmire 1940, Hobbs and Huenneke 1992, Fleischner 1994). This can lead to higher species richness. Some of these warm-season pastures can be home to rare and endangered species as at three of our sites, which support several individuals of *Carex hirsutella*. If managed by reducing grazing intensity and removing invasives, there is potential for restoring some of these pastures, which may be able to support taxa that are more conservative and site-specific. Some warm-season pastures are considerably degraded, perhaps due to overgrazing, over seeding with cool-season grasses, and herbicide use, while others are of higher quality. Others show high species richness and a low number of exotic species.

Cool-season hay meadows are seeded with *Bromus inermis* or with a combination of *Bromus inermis* and *Lolium arundinaceum*. These fields are fertilized abundantly (ca. 156 kg of nitrogen per hectare per year; Brotemarkle and Kilgore 1989), which encourages growth of a single species but consequently reduces floristic diversity. This explains the low diversity and single species dominance within these fields (Foster et. al 2004). However, our results show that cool-season hay fields have the capacity to support conservative taxa, illustrating the possible suitability of habitat within an apparently unsuitable and unlikely matrix. Cool-season pastures are also often seeded with *Bromus inermis* but show more species diversity than hay fields due to the presence of weedy taxa. These fields demonstrate the capacity to support high fidelity taxa, which have a relatively small ecological niche.

Conservation Reserve Program fields could serve as important habitat for conservative species, and are an invaluable resource for native seeds. Although the seeds planted in CRP fields are not necessarily obtained from local sources, their regional nativity makes them crucial for habitat quality improvement. These fields are planted with native grasses and support several conservative taxa. Plant communities are often colonized by species present in neighboring habitat patches (Foster and Tilman 2003); therefore, seed dispersal by plants from these fields may facilitate the spread of native grassland species.

Overall, burning did not have a major effect on species composition within these fields. Since all the warm-season hay meadows we surveyed are privately owned and managed and produce annual crops of hay, burning is seldom practiced as a management technique. This is true for most prairie remnants in northeast Kansas. Very few prairies, both hay meadows and pastures, in northeast Kansas are under an easement or managed by state or county officials and subsequently managed to maintain biodiversity. Such prairies are subjected to periodic burns, while those that are privately owned serve as a hay source for cattle and horses and burning is not viewed as economically beneficial to landowners.

Floristic Quality Assessment using FQI has been suggested as being a problematic indicator of the quality of a habitat, and modified FQI has been suggested to have advantages over FQI (Rooney and Rogers 2002). However, our results depict identical significant differences in FQI values for fields across different management types and the corresponding modified FQI values for these fields. We realize that the original value of FQI introduces the number of native species into the equation, which depends upon the size of the site sampled, while the modified FQI eliminates this bias (Rooney and Rogers 2002). However, we sampled areas of identical size, thus eliminating size bias. Our FQI and modified FQI results have a similar overall trend, but do have some subtle differences wherein high values of modified FQI for a particular site do not necessarily correspond with high values of FQI for the same site. This is demonstrated by three of the cool-season pastures we sampled which showed relatively high values of modified FQI (>2), while FQI values were relatively low (<7). This was due to the very low number of native species that had average coefficients of conservatism around 2. FQI values for these sites indicate the true nature of the poor quality of these pastures. These three pastures had one or two species each with C of C greater than 4, but the predominant vegetation within each individual field was that of non-native grasses and ruderal species. However, interpreting values of modified FQI alone in this case would lead to the idea that these sites are of higher superior floristic quality than they actually are.

Based on our studies of 104 sites, we conclude that to get the most appropriate picture of the condition of a particular site, it is helpful to calculate both FQI and modified FQI values. Our data show that warm-season hay fields and warm-season pastures are the most floristically diverse and are very high quality habitats. However, they will need to be managed to maintain this biodiversity. These fields are the few remaining reservoirs of diverse native prairies and rare species, including *Asclepias meadii,* and need to be protected and properly managed in perpetuity.

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