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The relationship between nectar sources and regal fritillary (Speyeria idalia Drury) butterfly populations.

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THE RELATIONSHIP BETWEEN NECTAR SOURCES AND REGAL FRITILLARY (*Speyeria idalia* Drury) BUTTERFLY POPULATIONS

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by

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THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

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ABSTRACT

I investigated the relationship between nectar source diversity and regal fritillary (*Speyeria idalia* Drury) butterfly populations at ten native tallgrass prairie sites in eastern Nebraska. Walking-transect surveys were used to establish regal fritillary population-density indices in 1996 and 1997. Flowering-plant surveys were also conducted, coincident with the butterfly surveys, and were used to develop blossom-diversity, density, and abundance indices. Spearman rank correlation was used to examine relationships between regal fritillary density indices and plant survey variables. Two significant, positive correlations were identified between (1) 1996 population-density indices and 1996 blossom-diversity indices for known nectaring sources of the regal fritillary ($n = 10$, $r = 0.903$, $P < 0.000$) and between (2) 1997 population-density indices and 1996 blossom-diversity indices for known nectaring sources of the regal fritillary ($n = 10$, $r = 0.770$, $P = 0.009$). No significant relationship was found between 1997 population-density indices and 1997 blossom-diversity indices for known nectaring sources of the regal fritillary ($n = 10$, $r = -0.006$, $P = 0.987$). In addition, there were significant, positive correlations between site-size and 1996 population-density indices ($n = 10$, $r = 0.695$, $P = 0.026$) and between site-size and blossom-diversity indices for known nectaring sources of the regal fritillary in 1996 ($n = 10$, $r = 0.726$, $P = 0.018$), and in 1997 ($n = 10$, $r = 0.646$, $P = 0.044$). I used intraclass correlation to see if there was greater variation in population-density indices between sites or years. The calculated intraclass correlation coefficient of 0.648 ($P = 0.012$) suggests that differences in population-density indices are more attributed to differences in site characteristics (*e.g.*, nectar source diversity and site size) than to differences between years. Approximately half of all nectar visits were to *Asclepias* spp. This study showed that positive relationships do exist between regal fritillary densities and nectar source diversity, although this relationship may vary from year to year. Further, large site size appears to be beneficial to regal fritillary populations.

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INTRODUCTION

The historic tallgrass prairie once covered more than 570,000 km^2 of central North America (Howe, 1994). Since European settlement, up to 99% is estimated to have been lost through conversion to other land uses, primarily agriculture (Howe, 1994). The resulting high agricultural productivity of the prairie states contributes to the well-being of the nation, but conservation of remaining tallgrass prairie is also beneficial. Benefits include historic (Weaver, 1954), aesthetic (Mlot, 1990), economic (Williams and Diebel, 1996), and ecological values (Mlot, 1990; Samson and Knopf, 1994; Steinauer and Collins, 1996), all inherent within the wealth of biodiversity of the remaining native tallgrass prairies. This biodiversity, however, is being threatened through further fragmentation and management.

Most of the remaining tallgrass prairie is relegated to small, isolated fragments (Panzer, 1988; Steinauer and Collins, 1996). Since fragmented ecosystems often suffer a loss of biological diversity (Wilcove, 1987), prairie-dependent species remain threatened even if the physical loss of extant prairie habitat is halted. The task of conserving these threatened species is a complex one because each species has specific habitat requirements and the effect of fragmentation, especially as it applies to individual species, is at best, not fully understood. While ecologists and conservation biologists continue to study the effects of prairie fragmentation on native biota, it is important to act now to protect those species known to be declining or otherwise threatened.

Until recently, prairie conservation issues have dealt primarily with plants (Opler, 1981). However, well over half of the species present on native tallgrass prairies are insects (Mlot, 1990). Thus, assessing the effect of conservation efforts on insects, as well as plants and other biota, is critical to obtaining an accurate measure of effects on the total biodiversity. Recent studies on

insects and other invertebrates have been directed toward this end (Opler, 1981; Panzer, 1988; Moffat and McPhillips, 1993; Panzer *et al.*, 1995; Arenz and Joern, 1996; Swengel, 1996).

One invertebrate that has declined in number, and that has been recognized as a species of concern, is the regal fritillary butterfly (*Speyeria idalia* Drury, Lepidoptera: Nymphalidae: Argynninae) (Bliss and Schweitzer, 1987; Opler, 1992). The regal fritillary is considered one of the most important indicator species of native tallgrass prairie (Hammond and McCorkle, 1983), having been classified both as a remnant dependent species (Panzer *et al.*, 1995) and as a specialist (Swengel, 1996). With the decline in the amount of tallgrass prairie, this species also has declined throughout much of its range, presently being most abundant in isolated tallgrass prairie fragments west of the Mississippi River (Opler, 1981; Bliss and Schweitzer, 1987; Opler, 1992). The state of Nebraska is considered to be the last stronghold for this species (Nebraska Natural Heritage Program Element Ranking, 1996). As a result of its overall decline, the regal fritillary is a candidate for the federal list of endangered and threatened species (Swengel, 1996). This status, and its role as an indicator species, makes the regal fritillary well-suited for in-depth study since careful management of this species may help safeguard native tallgrass prairie biodiversity as a whole (Moffat and McPhillips, 1993; Arenz and Joern, 1996).

Although the regal fritillary is a focus species in prairie conservation efforts, only a limited amount of information on its population biology is available. The regal fritillary is a univoltine species that overwinters as a first-instar larva (Opler, 1992). Larvae feed specifically on violets (*Viola* spp.) when they emerge in the spring (Bliss and Schweitzer, 1987). Although the prairie violet (*V. pedatifida* G. Don) and bird's foot violet (*V. pedata* L.) have been specifically listed (Hammond and McCorkle, 1983; Opler, 1992), it is certain that other violet species are utilized (Opler and Krizek, 1984; Bliss and Schweitzer, 1987, S. Spomer, pers. comm.). Despite their strong affinity for violets, however, this larval foodplant does not seem to be an essential parameter in determining habitat suitability (Bliss and Schweitzer, 1987), nor does it seem to account for the decline of the species (Ferge, 1990). This conclusion is noteworthy since the

distribution and abundance of nutritional resources, including both larval foodplants and adult liquid sustenance, have been reputed to be the most influential factors affecting butterfly populations (Ehrlich, 1984). If nutrition is the primary factor affecting butterfly populations, and the larval food source is not responsible for the decline of the regal fritillary, then the adult food source is the implied regulating factor. This conclusion is consistent with that of Opler and Krizek (1984) who noted that the scarcity of adult foraging habitats often regulates butterfly densities. Specifically regarding the regal fritillary, it has been suggested that the primary factor leading to the decline of the species is the loss of large contiguous tracts of prairie that support plant species with a diverse group of nectar sources on which to forage (Ferge, 1990). The purpose of my study was to investigate this relationship between nectar source diversity and regal fritillary populations. This purpose was accomplished by examining potential relationships between regal fritillary populations and nectar source diversity, abundance and density at ten remnant tallgrass prairies in eastern Nebraska.

METHODS

Sites.--Ten native tallgrass prairies were chosen for the study, all of which were located in eastern Nebraska (Fig. 1) within the tallgrass prairie region (Küchler, 1964; 1985). Criteria used to select sites included accessibility, size, and knowledge of existing regal fritillary populations (Table 1). Due to a limited number of sites from which to select, there was variation between sites in management history and in current management practices (Table 2).

The climate of the study region is continental, with hot summers (25°C) and cold winters (5°C). Temperatures vary considerably both daily and seasonally. Annual precipitation ranges from 690-760 mm with most occurring from April to September. In general, the sun shines 70-75% of day-time hours during the summer months. Most sites were characterized by silty soils, although some were loamy or clayey. Soils were primarily Mollisols with an occasional Entisol. All

Fig. 1. Location of tallgrass prairie study sites in Nebraska. County names are shown adjacent to county maps. Sites are as follows: 1 = Bauermeister, 2 = Fricke, 3 = Larkspur, 4 = Madigan, 5 = Nine-mile, 6 = Schneekloth N., 7 = Schneekloth S., 8 = Shanahan, 9 = Stolley and 10 = Twin Lakes. Schneekloth N. and S. are represented by one dot.

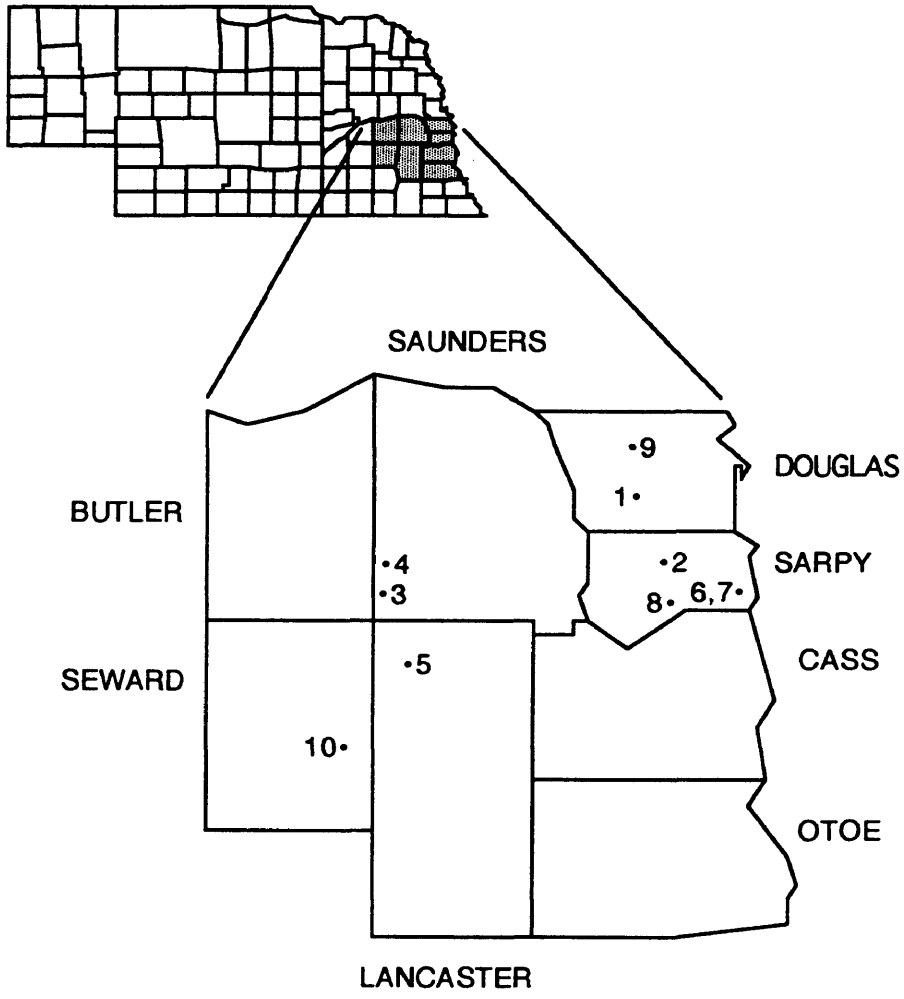

SAUNDERS
DOUGLAS
BUTLER
SARPY
CASS
SEWARD
OTOE
LANCASTER
•9
1•
•4
•3
•2
8• 6,7•
•5
10•

Table 1. Tallgrass prairie study sites and their corresponding ownership, size, and location.

Site	Ownership	Size (ha)	Location	
			Latitude and Longitude	Township and Range
Bauermeister	City of Omaha	12	41°13' N, 96°11' W	Nebraska, Douglas Co. T14N, R11E, Sec. 3
Fricke	Private	6	41°10' N, 96°01' W	Nebraska, Sarpy Co. T14N, R12E, Sec. 24
Larkspur	Nebraska Game and Parks Commission	20	41°05' N, 96°53' W	Nebraska, Saunders Co. T13N, R5E, Sec. 19
Madigan	University of Nebraska - Lincoln	12	41°10' N, 96°52' W	Nebraska, Saunders Co. T14N, R5E, Sec. 20
Nine-mile	University of Nebraska - Lincoln	97	40°52' N, 96°49' W	Nebraska, Lancaster Co. T10N, R5E, Sec. 1 and 2
Schneekloth N	Private	5	41°05' N, 95°53' W	Nebraska, Sarpy Co. T13N, R13E, Sec. 16
Schneekloth S	Private	6	41°05' N, 95°53' W	Nebraska, Sarpy Co. T13N, R13E, Sec. 16
Shanahan	Private	2	41°04' N, 96°02' W	Nebraska, Sarpy Co. T13N, R12E, Sec. 23
Stolley	City of Omaha	10	41°16' N, 96°11' W	Nebraska, Douglas Co. T15N, R11E, Sec. 15
Twin Lakes	Nebraska Game and Parks Commission	48	40°50' N, 96°57' W	Nebraska, Seward Co. T10N, R4E, Sec. 14

Table 2. Past and present management of tallgrass prairie study sites.

Site	Management Practices
Bauermeister	Hayed in late August for many years prior to 1984. From 1984-1993, the site was neither burned nor hayed. In 1994, approximately one half of the prairie was burned in late April or early May. In 1996, approximately half of the prairie was burned on 1 May; approximately one-fourth was mowed that same winter. In 1997, approximately one-third of the prairie was burned on 6 May.
Fricke	Historically hayed once a year in mid- to late August and burned in its entirety in spring. In 1996 and 1997, the prairie was not burned.
Larkspur	Historically hayed once a year. Since the mid-1970's the prairie has been occasionally hayed, but mostly rested. It has never been burned. It was last hayed in 1996 (see notes on Table 3).
Madigan	Management history prior to 1975 is unknown. The prairie may have been hayed but has presumably never been burned. Since 1975 it has been hayed annually in late August or in September.
Nine-mile	Historically hayed occasionally and lightly grazed by cattle. Since 1979, managed mostly with spring-time burning. In 1995, over half of the prairie was burned. No burning was done in 1996. In 1997 approximately one-third of the prairie was burned on 23 May.
Schneekloth N.	Hayed twice a year prior to 1995. On 23 April 1995 portions of the prairie were burned. It was hayed once that fall. On 6 May 1996, approximately 10% of the prairie was burned. It was hayed that fall with the exception of a patch to be burned the following spring. On 5 May 1997, approximately one-third of the prairie was burned.
Schneekloth S.	Approximately 20% burned on 1 June 1997. Otherwise, the management is the same as Schneekloth N.
Shanahan	Historically hayed once a year and occasionally grazed in fall and winter. Since 1988, usually hayed once in mid- to late-August (see notes on Table 3). In 1993, the entire prairie was burned. Since then, only portions have been burned. In 1996, approximately 5% was burned in the first week of May. None of the prairie was burned in 1997.
Stolley	Hayed in July for at least 20 years prior to 1980 and not since then. Since 1983, only portions of the prairie have been burned at any one time. The last known burn date is 4 May 1994.
Twin Lakes	Management history is vague but likely consisted of occasional haying and light grazing. Since the mid-1970's, the prairie has been occasionally hayed, but mostly rested. It has been burned twice, both times completely. The last known burning date was in April 1987. It was last hayed in 1996 (see notes on Table 3).

sites included some topographic variability thus providing conditions for a mix of upland and lowland tallgrass prairie species. Climate and soil details are from Elder *et al.* (1965), Quandt (1974), Bartlett (1975), and Brown *et al.* (1980).

Butterfly population survey.--Regal fritillary density indices were determined from data collected by walking along a preestablished survey transect on each prairie. Survey transects traversed all major regions of each prairie and, therefore, transect length varied with the size of the site (Thomas, 1983). Surveys were conducted approximately weekly at each prairie for a total of eight weeks, beginning after adults were first observed in the region (Table 3). Along each survey transect, I counted each regal fritillary seen within an area 5 m in front and 5 m to either side of me (Thomas, 1983; Gall, 1985; P. Hammond, pers. comm.). In addition to presence, I recorded the activity (*e.g.*, flying, sunning, nectaring) of the butterfly at the time it was counted. I attempted to avoid double-counting butterflies, such as those that followed me. Generally, surveys were conducted from 1000-1530 hrs on sunny (less than 50% cloud cover) days, with temperatures above 21° C. These survey criteria were modified under certain conditions. Specifically, when the temperature exceeded 27° C, either surveying occurred with a cloud cover up to 75% or surveying time was extended to 0930-1600 hrs, providing that cloud cover remained less than 50%. Surveying criteria were based on those described by Gall (1985).

Population density indices were developed from transect survey data, based on methods described by Thomas (1983). Counts from weekly transect surveys were summed across the entire surveying period for each site and divided by the transect length at that site. This index allowed for site-to-site comparisons of relative populations densities within a given year.

Plant survey.--Flowering-plant surveys were conducted coincident with the butterfly surveys that they preceded or followed (Table 3). These surveys consisted of evaluating plants that were flowering (forbs only) in 20, 1 m^2 plots distributed evenly along each butterfly transect

Table 3. Tallgrass prairie study sites and corresponding (a) butterfly/flower survey intervals for 1996 and 1997 and (b) violet survey dates for 1997.

Site	Survey Dates			
	1996	1997		
	Butterfly/Flower Survey	Butterfly/Flower Survey	Violet Survey	
			Date 1	Date 2
Bauermeister	24 June - 15 August	19 June - 16 August	1 May	21 May
Fricke	22 June - 14 August	20 June - 16 August	6 May	23 May
Larkspur[a]	20 June - 13 August	17 June - 13 August	5 May	29 May
Madigan	20 June - 13 August	17 June - 13 August	5 May	29 May
Nine-mile	19 June - 12 August	21 June - 20 August	4 May	22 May
Schneekloth N.	21 June - 14 August	20 June - 18 August	2 May	23 May
Schneekloth S.	21 June - 14 August	20 June - 18 August	2 May	23 May
Shanahan[b]	25 June - 20 August	18 June - 15 August	6 May	28 May
Stolley	24 June - 15 August	19 June - 15 August	1 May	21 May
Twin Lakes[c]	25 June - 21 August	18 June - 15 August	6 May	24 May

[a] In 1996, parts of the prairie were mowed. On 22 July, some of the perimeter of the prairie had been mowed. Three of 20 plots fell within the mowed area and thus contained no flowering forbs. On 29 July, more of the prairie had been mowed. Eleven of 20 plots fell within the mowed area and thus contained no flowering forbs. There were no additional changes to the prairie when surveyed on 6 August but 10 of 20 plots fell within previously mowed areas and contained no flowering forbs. By 13 August, the remainder of the prairie had been mowed. All plots fell in mowed areas and thus no flowering forbs were recorded.

[b] In 1996, the prairie had been completely mowed when surveyed on 9 August, thus no flowering forbs were present in any of the plots on that date or on the following and final survey date, 20 August.

[c] In 1996, part of the prairie had been mowed when surveyed on 21 August. Four of 20 plots fell within the mowed areas and thus contained no flowering forbs.

route from a randomized starting point. Within each plot, the number of currently-flowering plants was recorded by species. In addition, for every plant counted, I also estimated the number of blossoms present on each inflorescence. Blossom numbers were categorized as: a) 1, b) 2-5, c) 6-10, d) 11-20, and e) > 20 blossoms. Midpoint values of each category (*e.g.*, 1, 4, 8, 16, and 32) were used to estimate the absolute number of blossoms occurring, by species, on dates of butterfly counts. In the family Asteraceae, a flowering head was counted as a single blossom. Similarly, red clover (*Trifolium pratense* L.) spikes, composed of a variable number of individual flowers, were also counted as individual blossoms provided that some of the spike was flowering.

In the spring of 1997, each site was also surveyed twice for violets (*Viola* spp.), the only known food of regal fritillary larvae (Table 3). These surveys consisted of counting the number of violet clumps occurring in 40, 1 m^2 plots that were distributed evenly along the butterfly transect route from a randomized starting point. A violet clump, as defined here, is any number of violet leaves arising from the same point at soil level. The total number of violet clumps recorded at a site constituted a violet density index and, when multiplied by site size, constituted a violet abundance index.

Data analysis.--The plant species list obtained from weekly plant surveys was used to form a site master-plant-species list that contained all species recorded at that particular site as well as the total number of blossoms contributed by each species. Blossoms, considered here to represent the nectar source for the regal fritillary, were summed across all species to calculate a blossom density index for each site. The blossom density index was multiplied by site size to form a blossom abundance index. In addition, those plants that were known to be nectar sources of the regal fritillary, as indicated either by the literature (Bliss and Schweitzer, 1987; Nagel *et al.*, 1991; Bray, 1994) or by personal observation, were extracted from the site's master-plant-species list and used to calculate additional blossom density and blossom abundance indices. Finally, Shannon-Wiener diversity indices (H'), based on the number of blossoms contributed by species,

were calculated for each site (Zar, 1996). Two different blossom diversity indices were calculated for each site, one included all species recorded from that site and the other included only known regal fritillary nectar sources.

Non-parametric Spearman rank correlation (Zar, 1996) was used to assess the relationships between regal fritillary population-density indices and the nectar source variables from the 10 study sites. In addition, site size and violet indices were included in the correlation analysis. A correlation table that included all variables was computed using SAS (SAS User's Guide, 1985a).

During both butterfly and plant surveys, regal fritillary nectaring activities and the plant species on which they occurred, were documented. Each individual butterfly-plant interaction observed was treated as a separate observation. If more than one individual was nectaring on the same plant, each was counted as a separate interaction. Contingency table analysis was used to test for independence of nectar source usage by year (SAS User's Guide, 1985a).

RESULTS

Summary of data collected.--Regal fritillary population-density indices ranged from 0.016 - 0.133 in 1996, and from 0.013 - 0.128 in 1997 (Table 4). Results from the Wilcoxon paired-sample test (Zar, 1996) indicate that population-density indices were larger in 1996 than in 1997 ($n = 10$, $P = 0.05$). At each site, population density peaked during the first half of July (Appendix Tables 1 and 2).

For combined years and sites, a total of 72 plant species was recorded to be flowering, including 24 species that are known as regal fritillary nectar sources (Appendix Table 3). No flower species was found at all 10 sites in either 1996 or 1997, although each site did contain at least 4 species known as nectar sources for the regal fritillary (Table 5, Appendix Tables 4-23). Results from Wilcoxon paired-sample tests showed no significant differences, between years, for the

Table 4. Regal fritillary (*Speyeria idalia*) transect survey data for 1996 and 1997.

Site	Total number of individuals observed by site		Transect Length (m)	Population Density Index	
	1996	1997		1996	1997
Bauermeister	54	24	1860	0.029	0.013
Fricke	32	33	1980	0.016	0.017
Larkspur	195	173	2310	0.084	0.075
Madigan	230	271	2110	0.109	0.128
Nine-mile	594	197	4460	0.133	0.044
Schneekloth N.	79	67	1890	0.042	0.035
Schneekloth S.	40	41	2280	0.018	0.018
Shanahan	40	29	840	0.048	0.035
Stolley	101	87	1910	0.053	0.046
Twin Lakes	296	184	3220	0.092	0.057

Table 5. Known nectar sources of the regal fritillary (*Speyeria idalia*) that were recorded during plant surveys. 1996 = species recorded in 1996; 1997 = species recorded in 1997. Species occurring both years are indicated by the word "both". A dash (-) indicates no data. Sites are as follows: 1 = Bauermeister, 2 = Fricke, 3 = Larkspur, 4 = Madigan, 5 = Nine-mile, 6 = Schneekloth N., 7 = Schneekloth S., 8 = Shanahan, 9 = Stolley and 10 = Twin Lakes. Authorship follows Great Plains Flora Association (1986).

Species	Occurrence of documented nectar sources of the regal fritillary (*Speyeria idalia*), by site (1-10)									
	1	2	3	4	5	6	7	8	9	10
Achillea millifoleum L.	-	1997	both	both	1996	-	-	both	1996	both
Allium canadense L.	-	1997	-	-	-	-	-	-	-	1996
Asclepias syriaca L.	1996	-	-	1996	both	-	1997	-	both	both
Asclepias verticillata L.	both	-	1996	-	both	-	-	-	-	both
Carduus nutans L.	-	-	1997	-	-	-	1996	-	-	1997
Cirsium flodmanii (Rydb.) Arthur	-	-	1997	-	-	-	-	-	-	-
Cirsium sp.	-	-	-	-	-	-	-	-	-	both
Coreopsis palmata Nutt.	both	-	-	-	-	1996	-	-	-	-
Dalea purpurea Vent.	1996	-	both	1996	1996	1996	-	both	-	-
Dianthus armeria L.	-	-	both	-	-	-	-	-	-	-
Echinacea angustifolia DC.	-	-	1997	-	-	-	-	1996	-	-
Euphorbia corollata L.	both	both	-	-	-	both	both	1996	both	-
Heliopsis helianthoides (L.) Sweet var. *scabra* (Dun.) Fern.	both	both	-	1996	-	1996	both	-	both	-
Hypericum perforatum L.	-	-	-	-	-	-	-	-	-	1996
Monarda fistulosa L.	both	-	-	1996	-	-	-	-	-	-

Table 5. Known nectar sources of the regal fritillary (*Speyeria idalia*) that were recorded during plant surveys. Continued.

Species	Occurrence of documented nectar sources of the regal fritillary (*Speyeria idalia*), by site (1-10)									
	1	2	3	4	5	6	7	8	9	10
Phlox pilosa L.	both	both	-	-	-	both	both	1997	both	-
Silphium integrifolium Michx.	-	both	-	1997	-	both	both	-	1997	-
Silphium laciniatum L.	-	1996	-	-	-	-	-	-	-	-
Solidago missouriensis Nutt.	both	-	-	both	both	-	1997	-	both	1997
Symphoricarpos orbiculatus Moench	-	-	both	-	-	-	-	-	-	-
Trifolium pratense L.	both	both	1997	1997	-	both	both	1997	-	-
Verbena hastata L.	-	-	-	-	1997	-	-	-	-	-
Verbena stricta Vent.	-	-	1996	-	1996	-	-	-	-	-
Vernonia sp.	-	-	both	-	1996	both	-	-	1997	both

following indices: blossom-density and known-source-blossom-density (Table 6), blossom-abundance and known-source-blossom-abundance (Table 7), and blossom-diversity (Table 8). However, known-source-blossom-diversity indices (Table 8) were significantly larger in 1996 than in 1997 (Wilcoxon paired-sample test, $n = 10$, $0.025 > P > 0.01$).

Correlation data.--Both positive and negative correlations between regal fritillary density indices and the several plant survey variables were found to be significant ($P \leq 0.05$). Of these, biologically meaningful, significant, positive correlations were found between (1) 1996 regal fritillary population-density indices and 1996 known-source-blossom-diversity indices ($n = 10$, $r = 0.903$, $P < 0.000$), and (2) 1997 population-density indices and 1996 known-source-blossom-diversity indices ($n = 10$, $r = 0.770$, $P = 0.009$) (Table 9). However, there was no significant relationship between 1997 population-density indices and 1997 known-source-blossom-diversity indices ($n = 10$, $r = -0.006$, $P = 0.987$). Because of the differing correlation results between population-density indices and known-source-blossom-diversity indices in 1996 and 1997, a *post-hoc* test was performed to see if the greater variation in population-density indices was due to sites or years. I used intraclass correlation, which incorporates an ANOVA, to perform this test (Zar, 1996). All ANOVA variables were calculated using SAS (SAS User's Guide, 1985b). The *intraclass correlation coefficient* is calculated as:

$$r_I = (\text{groups MS} - \text{error MS}) / (\text{groups MS} + \text{error MS})$$

If r_I is positive, there is more variability between groups than within groups; if r_I is negative, there is more variability within groups than between groups. The intraclass correlation procedure assumes random sampling from a bivariate, normal distribution and equal population variances (Zar, 1996). In this study, the test was used even though only the assumption of equal population variances was met because the ANOVA test is considered robust and because the results were

Table 6. Blossom-density indices for 1996 and 1997.

Site	All nectar sources		Known regal fritillary nectar sources	
	1996	1997	1996	1997
Bauermeister	24630	9932	20080	8845
Fricke	16663	8491	3381	4868
Larkspur	1406	4306	1299	1201
Madigan	7186	1590	2154	359
Nine-mile	9815	1752	2901	1340
Schneekloth N.	7811	7638	4885	4071
Schneekloth S.	7687	4154	6212	3221
Shanahan	3386	8560	317	1294
Stolley	5643	4250	3793	3901
Twin Lakes	1403	3380	237	781

Table 7. Blossom-abundance indices for 1996 and 1997.

Site	All nectar sources		Known regal fritillary nectar sources	
	1996	1997	1996	1997
Bauermeister	295560	119184	240960	106140
Fricke	99978	50946	20286	29208
Larkspur	28120	86120	25980	24020
Madigan	86232	19080	25848	4308
Nine-mile	952055	169944	281397	129980
Schneekloth N.	39055	38190	24425	20355
Schneekloth S.	46122	24924	37272	19326
Shanahan	5079	12840	476	1941
Stolley	56430	42500	37930	39010
Twin Lakes	67344	162240	11376	37488

Table 8. Shannon-Wiener blossom-diversity indices for 1996 and 1997.

Site	All nectar sources		Known regal fritillary nectar sources	
	1996	1997	1996	1997
Bauermeister	0.582	0.543	0.423	0.376
Fricke	0.713	0.722	0.332	0.335
Larkspur	0.543	0.821	0.431	0.347
Madigan	0.744	0.654	0.621	0.153
Nine-mile	0.778	0.714	0.491	0.468
Schneekloth N.	0.699	0.605	0.342	0.159
Schneekloth S.	0.488	0.592	0.259	0.328
Shanahan	0.755	0.503	0.378	0.258
Stolley	0.624	0.597	0.470	0.444
Twin Lakes	0.607	0.413	0.565	0.398

Table 9. Spearman rank correlations between regal fritillary population-density indices and site size (column variables) and plant survey variables (row variables). The top number in each matrix pair is the correlation coefficient (r) and the bottom number is the P value. PDI = Population Density Index, VDI = Violet Density Index, VAI = Violet Abundance Index, BDeI = Blossom Density Index, BAI = Blossom Abundance Index, KSBDeI = Known Source Blossom Density Index, KSBAI = Known Source Blossom Abundance Index, BDiI = Blossom Diversity Index, and KSBDiI = Known Source Blossom Diversity Index.

Plant survey variables	Site Size	PDI 1996	PDI 1997
PDI 1996	*0.695 0.026		
PDI 1997	0.482 0.159	*0.818 0.004	
VDI 1997	-0.431 0.213	-0.213 0.555	-0.024 0.947
VAI 1997	‡0.683 0.030	0.576 0.082	0.503 0.138
BDeI 1996	-0.128 0.724	-0.455 0.187	*-0.697 0.025
BDeI 1997	-0.561 0.092	†-0.709 0.022	*-0.709 0.022
BAI 1996	0.555 0.096	0.152 0.676	-0.188 0.603
BAI 1997	‡0.793 0.006	0.285 0.425	0.006 0.987
KSBDeI 1996	-0.280 0.433	-0.600 0.067	-0.624 0.054
KSBDeI 1997	-0.384 0.273	†-0.745 0.013	*-0.830 0.003
KSBAI 1996	0.470 0.171	0.164 0.652	-0.079 0.829
KSBAI 1997	‡0.640 0.046	0.176 0.627	-0.139 0.701
BDiI 1996	-0.061 0.867	0.394 0.260	0.103 0.777
BDiI 1997	0.195 0.589	0.103 0.777	0.236 0.511

Table 9. Spearman rank correlation table. Continued.

Plant survey variables	Site Size	PDI 1996	PDI 1997
KSBDil 1996	*0.726	*0.903	*0.770
	0.018	0.000	0.009
KSBDil 1997	*0.646	0.285	-0.006
	0.044	0.425	0.987

* significant ($P \leq 0.05$); † = significant ($P \leq 0.05$), but not biologically meaningful; ‡ = significant ($P \leq 0.05$), but confounded because one variable inherently incorporates the other

highly significant. The calculated intraclass correlation coefficient of 0.648 (P = 0.012, Table 10) suggests that differences in population-density indices are more attributed to differences in site characteristics (*e.g.*, nectar source diversity and site size) than to differences between years.

In addition to the significant, positive correlations, there were five significant, negative correlations (Table 9). Of these five, only those between (1) 1997 population-density indices and 1996 blossom-density indices, (2) 1997 population-density indices and 1997 blossom-density indices, and (3) 1997 population-density indices and 1997 known-source-blossom-density indices, appear to be biologically meaningful. It is worth noting that there were no significant correlations between population-density indices and either violet-density indices or violet-abundance indices (Table 9, Appendix Table 24).

Significant relationships were also identified between site-size and several of the variables evaluated (Table 9). These include significant positive correlations with 1996 population-density indices (n = 10, r = 0.695, P = 0.026) and with both 1996 and 1997 known-source-blossom-diversity indices (n = 10, r = 0.726, P = 0.018 and n = 10, r = 0.646, P = 0.044, respectively). Finally, there were also significant positive correlations between site-size and various abundance indices, although these correlations are confounded because site size is directly incorporated into the calculation of the abundance indices (Table 9).

Nectaring activities.--Regal fritillaries were observed nectaring at 21 different species of plants during 1996 and 1997 (Tables 11 and 12). Common milkweed (*Asclepias syriaca* L.) was clearly the most visited plant, followed by wild bergamot (*Monarda fistulosa* L.) (Tables 11 and 12). Sixty of the 63 nectaring visits on common milkweed occurred prior to 18 July. All of the 53 nectaring observations on wild bergamot occurred after 18 July.

I performed contingency table analysis to test for independence of nectar-source use by year by dividing regal fritillary nectar visits into two groups, the milkweeds (*Asclepias* spp.) and all other species (Fig. 2). The milkweeds were clearly the most visited group of plants in this study

Table 10. Summary of ANOVA statistics used in calculating the *intraclass correlation coefficient*.

Source of variation	df	SS	MS	F Value	P
Between years (group)	9	0.02131545	0.00236838	4.68	0.0122
Within years (error)	10	0.00506350	0.00050635		
Total	19	0.02637895			

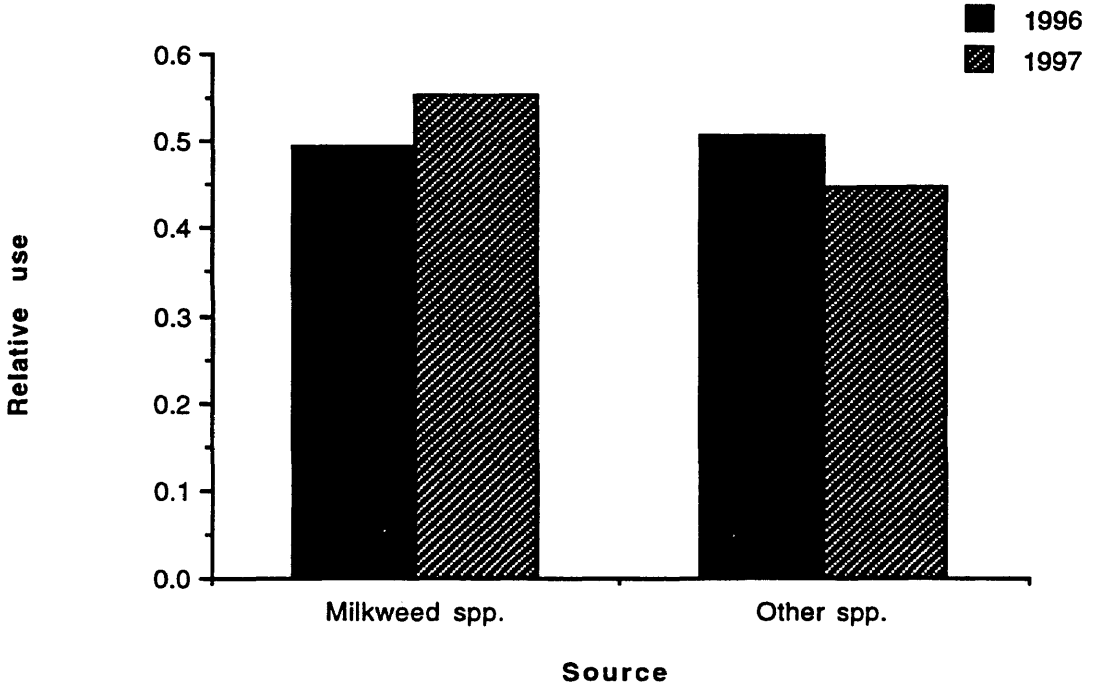
Table 11. Number of regal fritillary (*Speyeria idalia*) nectaring observations occurring in 1996, by site. Dashes (-) indicate no data. Sites are as follows: 1 = Bauermeister, 2 = Fricke, 3 = Larkspur, 4 = Madigan, 5 = Nine-mile, 6 = Schneekloth N., 7 = Schneekloth S., 8 = Shanahan, 9 = Stolley and 10 = Twin Lakes. Authorship follows Great Plains Flora Association (1986).

Species	Number of nectaring observations in 1996 by sites (1-10)										Total by species
	1	2	3	4	5	6	7	8	9	10	
Achillea millefolium L.	-	-	-	-	2	-	-	-	-	2	4
Asclepias incarnata L.	-	-	-	-	5	-	-	-	-	-	5
Asclepias sullivantii Engelm. ex Gray	-	-	-	-	-	-	-	-	-	7	7
Asclepias syriaca L.	1	-	3	12	9	-	-	-	4	10	39
Asclepias tuberosa L.	-	1	-	-	7	4	-	9	-	2	23
Asclepias verticillata L.	-	-	5	-	20	-	-	-	-	-	25
Carduus nutans L.	1	-	2	-	-	-	1	1	-	-	5
Cirsium flodmanii (Rydb.) Arthur	-	-	1	-	-	-	-	-	-	-	1
Cirsium vulgare (Savi) Ten.	-	-	-	-	-	-	-	-	-	4	4
Cirsium spp.	-	-	-	3	-	-	-	-	-	-	3
Dianthus armeria L.	-	-	1	-	-	-	-	-	-	-	1
Echinacea angustifolia DC.	-	-	-	1	-	-	-	2	-	-	3
Heliopsis helianthoides (L.) Sweet var. *scabra* (Dun.) Fern.	5	-	-	-	-	1	-	-	7	-	13
Liatris pycnostachya Michx.	-	1	-	-	-	-	-	-	-	-	1
Monarda fistulosa L.	7	-	-	21	4	5	-	-	3	-	40
Silphium integrifolium Michx.	-	-	-	-	-	6	-	-	-	-	6
Silphium laciniatum L.	-	1	-	-	-	-	-	-	-	-	1
Trifolium pratense L.	-	7	-	-	-	1	1	-	-	-	9
Vernonia sp.	1	4	-	-	-	-	-	-	-	6	11
Total by site	**15**	**14**	**12**	**37**	**47**	**17**	**2**	**12**	**14**	**31**	
										Grand total	**201**

Table 12. Number of regal fritillary (*Speyeria idalia*) nectaring observations occurring in 1997, by site. Dashes (-) indicate no data. Sites are as follows: 1 = Bauermeister, 2 = Fricke, 3 = Larkspur, 4 = Madigan, 5 = Nine-mile, 6 = Schneekloth N., 7 = Schneekloth S., 8 = Shanahan, 9 = Stolley and 10 = Twin Lakes. Authorship follows Great Plains Flora Association (1986).

Species	Number of nectaring observations in 1997 by site (1-10)										Total by species
	1	2	3	4	5	6	7	8	9	10	
Asclepias incarnata L.	-	-	-	-	2	-	-	-	-	-	2
Asclepias sullivantii Engelm. ex Gray	-	2	-	-	-	-	-	-	-	29	31
Asclepias syriaca L.	-	-	-	14	3	-	1	-	4	3	25
Asclepias tuberosa L.	-	-	-	4	8	6	-	1	-	5	24
Asclepias verticillata L.	-	-	-	-	8	-	-	-	-	-	8
Carduus nutans L.	-	1	3	1	-	-	-	1	-	2	8
Cirsium flodmanii (Rydb.) Arthur	-	-	11	-	-	-	-	-	-	1	12
Cirsium spp.	-	-	-	12	1	-	-	-	-	-	13
Dianthus armeria L.	-	-	1	-	-	-	-	-	-	-	1
Echinacea angustifolia DC.	-	-	-	3	-	-	-	-	-	-	3
Euphorbia corollata L.	2	-	-	-	-	-	-	-	-	-	2
Heliopsis helianthoides (L.) Sweet var. *scabra* (Dun.) Fern.	-	-	-	-	-	-	-	-	1	-	1
Hypericum perforatum L.	-	-	1	-	-	-	-	-	-	-	1
Liatris pycnostachya Michx.	-	2	-	-	-	-	-	-	-	-	2
Monarda fistulosa L.	-	-	-	6	-	10	-	-	-	-	16
Silphium integrifolium Michx.	-	2	-	2	-	-	1	-	-	-	5
Trifolium pratense L.	-	-	1	3	-	-	2	-	-	-	6
Vernonia sp.	-	-	-	-	-	2	1	-	-	-	3
Total by site	**2**	**7**	**17**	**45**	**22**	**18**	**5**	**2**	**5**	**40**	
									Grand total		**163**

Fig. 2. Regal fritillary (*Speyeria idalia*) relative nectar source use of two major plant groups in 1996 and 1997.


1996
1997
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Relative use
Milkweed spp.
Other spp.
Source

and thus were considered separately for this test. Results from 2 x 2 contingency table analysis employing the *Fisher exact test* showed that relative use of these two groups is not significantly different between years (P = 0.399).

I examined the relationship between the number of nectaring observations made at a site and site-size to see if my data were biased. No significant relationship was noted between site-size and nectaring observations in either 1996 (Spearman rank correlation, n = 10, r = 0.555, P = 0.096) or 1997 (n = 10, r = 0.540, P = 0.107). Not unexpectedly, nectaring observations were significantly correlated with regal fritillary population-density indices in both years. Spearman rank correlation for nectaring observations and population-density indices was 0.634 (n = 10, P = 0.049) in 1996 and 0.720 (n = 10, P = 0.019) in 1997.

DISCUSSION

Butterfly resources.--Results of this study indicate that positive relationships exist between regal fritillary populations and the diversity of their nectar sources but that this relationship is variable, at least from year-to-year. Whether this is a cause-effect relationship, however, has yet to be shown. Britten and Riley (1994), who noted similar results in a similar study on the Uncompahgre fritillary (*Boloria acrocnema* Gall & Sperling), suggest that this relationship is probably the result of ecological correlations rather than a direct relationship between nectar sources and the butterfly. They speculate that habitat characteristics that make an area suitable for a high diversity of flowering plants may also make the area suitable for the Uncompahgre fritillary. This type of ecological correlation may explain the relationship between nectar source diversity and regal fritillary population densities observed in this study as well.

There may be, however, a more functional relationship between nectar sources and the regal fritillary. This functional relationship relates to the reality that, in butterflies, as in all organisms, incoming resources must be allocated to reproduction, maintenance, storage, and

acquisition of more resources (Boggs and Ross, 1993). For the adult stage of a holometabalous insect, a primary purpose is reproduction (Opler and Krizek, 1984). Nutrients needed for reproduction, and other adult activities, may come from several sources, including larval reserves set aside at metamorphosis, adult feeding and, in females, nutrients contributed by males during spermataphore formation (May, 1992; Boggs, 1997). The Mormon fritillary (*Speyeria mormonia* Edwards), a species related to the regal fritillary, provides an example of the importance of nutrients to fitness. In this species, no eggs are mature at adult emergence so that nutrients obtained during adult feeding may be allocated to all eggs (Boggs, 1997). When female Mormon fritillary are semistarved, fecundity declines in direct proportion to the decrease in adult food, from which Boggs and Ross (1993) concluded that adult life span is conserved at the expense of reproduction under adult resource stress. Although no studies have addressed resource allocation in the regal fritillary, it is reasonable to assume that it is similar to that in the Mormon fritillary in this regard, especially since other aspects of their biology are similar (C. Boggs, pers. comm.). Therefore, in the regal fritillary, as in the Mormon fritillary, fecundity may decline if adult food is limited. Considering this potential importance of adult resources to the regal fritillary, the positive relationship between regal fritillary densities and diversity of their known nectar sources, as found in this study, is not surprising. Further, a diversity of nectar sources should ensure that some resources may always be available. Factors including plant phenology, variation in plant response to climate and management, inter-year variation in nectar production in-, or between-species, and nectar consumption by competing nectarivores, all point to the importance of diversity in adult resources.

Blossom diversity indices.--In 1996, there was a significant, positive correlation between regal fritillary population-density indices and known-source-blossom-diversity indices. This relationship may reflect the past as much as the present in that sites that frequently have a high diversity of known-nectar sources of the regal fritillary may regularly be able to support high densities of the butterfly. The significant positive correlation observed between 1997 population-

density indices and 1996 known-source-blossom-diversity indices supports this possibility. However, the relationship between 1997 population densities and 1996 known-source diversity also may reflect the relationship between adult resources and fecundity, as already discussed.

In contrast to 1996, no significant correlation was found between 1997 population-density indices and 1997 known-source-blossom-diversity indices. Such year-to-year variation is not surprising in field-based studies and only serves to point out that these are complex interactions that do not appear to have a single or simple explanation. One aspect of complexities is the differential response of plants and animals to management. For example, burning on 23 May 1997 undoubtedly resulted in direct larval mortality that contributed to the approximately 66% decrease in regal fritillary population-density indices between 1996 and 1997 at Nine-mile Prairie. While this spring burning had a direct impact on the butterflies through larval mortality, nectar sources were not eliminated but rather only set back, so that, by the end of the flowering season the known-source-blossom-diversity index of 1997 occurred at a level similar to that of 1996. In this instance, the substantial decline in regal fritillary occurrence at one site in one year may have affected overall correlation results. Other, less apparent differences in management also may have contributed to different results for 1996 and 1997 since not all prairies were managed exactly the same way in any year.

Characteristics of the sampling protocol may provide one other possible explanation for differences between 1996 and 1997 correlations between population-density indices and known-source-blossom-diversity indices. If sampling did not equally assess all nectar sources at all sites, this would most likely affect subsequent analyses. For instance, the site with the highest regal fritillary population-density index in 1997, Madigan Prairie, had a noticeably patchy distribution of nectar sources that were largely missed by the systematic distribution of plots in plant surveys that year (personal observation). The discrepancy between the high regal fritillary population-density index and the very low, known-source-blossom-diversity index that occurred

at Madigan Prairie in 1997, most likely reflects this artifact of sampling which, in turn, affected overall correlation results.

Blossom density indices.--The significant, negative correlations between butterfly population-density indices and blossom-density indices are unexpected in light of the apparent importance of adult resources. Sites with high blossom density indices, however, tended to be dominated by one or two species, usually red clover or flowering spurge (*Euphorbia corollata* L.) (Appendix Tables 4-23), species that both occurred widely and that produced large numbers of blossoms. Although both of these species are known nectar sources of the regal fritillary, they do not seem to be favored. During the two years of study, regal fritillaries were observed nectaring on red clover 15 of 364 times, and only 2 of 364 times on flowering spurge (Tables 11 and 12). If these species are not regularly used by the regal fritillary, high densities of these species may not be useful to the butterfly. Thus, total blossom indices may not be the best parameter to measure in studies with relatively selective foragers.

Site size.--The significant, positive correlation between regal fritillary population-density indices and site-size in 1996 may suggest that large site-size is beneficial to regal fritillary populations. Opler (1981), for example, mentioned that large sites: (1) help maintain minimum population sizes in unfavorable years or catastrophes, (2) prevent loss of genetic variability, (3) help ensure the inclusion of necessary biotic and physical resources, and (4) allow a margin of error for management mistakes. The absence of a similar relationship in 1997, as occurred between population-density indices and site-size in 1996, may reflect the deleterious effects of spring burning at Nine-mile Prairie, the largest prairie in the study.

In addition to the relationship with regal fritillary density indices, this study also noted a significant, positive relationship between site-size and known-source-blossom-diversity indices, but for both 1996 and 1997. This result suggests a positive relationship between size and plant

species diversity, consistent with results found in other studies (*e. g.*, MacArthur and Wilson, 1967; Pianka, 1988). To the extent that a large site-size helps ensure a diversity of plant species favorable to the regal fritillary, then, site-size has the potential to provide conditions suitable for regal fritillary population maintenance.

Conclusion.--Overall, this study found a positive relationship between regal fritillary population densities and the diversity of their known nectar sources, although this relationship may exhibit annual variation. Further, a positive relationship was noted between site-size and regal fritillary densities suggesting that some aspect of site-size, perhaps a diversity of nectar sources, may benefit regal fritillary populations. While a diversity of nectar sources may be important to the overall maintenance of regal fritillary populations, milkweed species seem to be the preferred nectar source, at least during the two years of this study.

The general results of this study strengthen arguments favoring both the maintenance of high biodiversity in remaining tallgrass prairie remnants and the importance of preserving large sites. While the focus of this study was the regal fritillary, there are certainly other species that may similarly benefit from the continued maintenance of tallgrass prairie biodiversity. Future studies that address the importance of diversity as it relates to invertebrate populations are critical to a complete understanding of the tallgrass prairie ecosystem.

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APPENDIX

Appendix Table 1. Counts from regal fritillary (*Speyeria idalia*) transect surveys in 1996. Only survey dates are included. Dashes (-) indicate no data. Sites are as follows: 1 = Bauermeister, 2 = Fricke, 3 = Larkspur, 4 = Madigan, 5 = Nine-mile, 6 = Schneekloth N., 7 = Schneekloth S., 8 = Shanahan, 9 = Stolley and 10 = Twin Lakes.

	Sites									
Date	1	2	3	4	5	6	7	8	9	10
19 June	-	-	-	-	2	-	-	-	-	-
20 June	-	-	0	2	-	-	-	-	-	-
21 June	-	-	-	-	-	0	0	-	-	-
22 June	-	0	-	-	-	-	-	-	-	-
24 June	0	-	-	-	-	-	-	-	0	-
25 June	-	-	-	-	-	-	-	6	-	9
26 June	-	-	-	-	46	-	-	-	-	-
27 June	-	-	2	36	-	-	-	-	-	-
28 June	-	-	-	-	-	5	5	-	-	-
29 June	-	4	-	-	-	-	-	-	-	-
1 July	2	-	-	-	-	-	-	-	2	-
2 July	-	-	-	-	-	-	-	13	-	88
3 July	-	-	-	-	142	-	-	-	-	-
4 July	-	-	40	59	-	-	-	-	-	-
5 July	-	6	-	-	-	22	7	-	-	-
8 July	10	-	-	-	-	-	-	-	26	-
9 July	-	-	-	-	-	-	-	9	-	81
10 July	-	-	-	-	127	-	-	-	-	-
11 July	-	-	70	-	-	-	-	-	-	-
12 July	-	14	-	-	-	16	7	-	-	-
13 July	-	-	-	43	-	-	-	-	-	-
15 July	21	-	-	-	-	-	-	-	40	-
17 July	-	-	-	-	-	-	-	3	-	63
18 July	-	-	-	-	149	-	-	-	-	-
23 July	-	-	46	30	-	-	-	-	-	-
24 July	-	0	-	-	-	8	9	-	-	-
25 July	5	-	-	-	-	-	-	5	18	-
27 July	-	-	-	-	54	-	-	-	-	19
29 July	-	-	26	20	-	-	-	-	-	-
30 July	-	4	-	-	-	7	6	-	-	-
2 August	6	-	-	-	-	-	-	4	6	-
5 August	-	-	-	-	44	-	-	-	-	-
6 August	-	-	11	24	-	-	-	-	-	15
7 August	-	3	-	-	-	8	0	-	-	-
8 August	7	-	-	-	-	-	-	-	4	-
9 August	-	-	-	-	-	-	-	0	-	12
12 August	-	-	-	-	30	-	-	-	-	-
13 August	-	-	0	16	-	-	-	-	-	-
14 August	-	1	-	-	-	13	6	-	-	-
15 August	3	-	-	-	-	-	-	-	5	-
20 August	-	-	-	-	-	-	-	0	-	-
21 August	-	-	-	-	-	-	-	-	-	9

Appendix Table 2. Counts from regal fritillary (*Speyeria idalia*) transect surveys in 1997. Only survey dates are included. Dashes (-) indicate no data. Sites are as follows: 1 = Bauermeister, 2 = Fricke, 3 = Larkspur, 4 = Madigan, 5 = Nine-mile, 6 = Schneekloth N., 7 = Schneekloth S., 8 = Shanahan, 9 = Stolley and 10 = Twin Lakes.

	Sites									
Date	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
17 June	-	-	0	24	-	-	-	-	-	-
18 June	-	-	-	-	-	-	-	0	-	0
19 June	0	-	-	-	-	-	-	-	0	-
20 June	-	2	-	-	-	6	0	-	-	-
21 June	-	-	-	-	1	-	-	-	-	-
23 June	-	-	16	37	-	-	-	-	-	-
25 June	-	-	-	-	-	-	-	5	-	12
26 June	5	-	-	-	-	-	-	-	3	-
27 June	-	14	-	-	-	12	3	-	-	-
28 June	-	-	-	-	20	-	-	-	-	-
30 June	-	-	-	-	-	-	-	22	-	49
1 July	-	-	-	114	-	-	-	-	-	-
2 July	-	-	46	-	-	-	-	-	43	-
4 July	7	-	-	-	-	12	9	-	-	-
5 July	-	2	-	-	-	-	-	-	-	-
7 July	-	-	-	-	65	-	-	-	-	-
14 July	-	-	79	46	-	-	-	-	-	-
15 July	-	-	-	-	-	-	-	2	-	79
16 July	10	-	-	-	-	-	-	-	28	-
17 July	-	9	-	-	-	11	7	-	-	-
18 July	-	-	-	-	52	-	-	-	-	-
21 July	-	-	26	17	-	-	-	-	-	-
22 July	-	-	-	-	-	-	-	0	-	34
23 July	0	-	-	-	-	-	-	-	3	-
24 July	-	4	-	-	-	12	5	-	-	-
25 July	-	-	-	-	27	-	-	-	-	-
29 July	-	-	2	16	-	-	-	-	-	-
30 July	-	-	-	-	-	-	-	0	-	4
31 July	1	1	-	-	-	-	-	-	4	-
2 August	-	-	-	-	21	2	9	-	-	-
4 August	-	-	3	6	-	-	-	-	-	-
5 August	-	-	-	-	-	-	-	0	-	4
6 August	1	-	-	-	-	-	-	-	5	-
7 August	-	0	-	-	-	-	7	-	-	-
8 August	-	-	-	-	3	4	-	-	-	-
13 August	-	-	1	11	-	-	-	-	-	-
15 August	-	-	-	-	-	-	-	0	1	2
16 August	0	1	-	-	-	-	-	-	-	-
18 August	-	-	-	-	-	8	1	-	-	-
20 August	-	-	-	-	8	-	-	-	-	-

Appendix Table 3. Summary of vegetative data collected in 1996 and 1997. For each plant, the number on the left of the slash corresponds to the number of times, out of 8 possible times, that a species was recorded in 1996 and the number on the right includes similar results for data collected in 1997. A dash (-) indicates no data. Plants marked with an asterisk (*) are known nectar sources of the regal fritillary (*Speyeriai idalia*). Sites are as follows: 1 = Bauermeister, 2 = Fricke, 3 = Larkspur, 4 = Madigan, 5 = Nine-mile, 6 = Schneekloth N., 7 = Schneekloth S., 8 = Shanahan, 9 = Stolley and 10 = Twin Lakes.. Authorship follows Great Plains Flora Association (1986).

Species	Number of weeks species occurred in plant surveys in 1996 / 1997, by site (1-10)									
	1	2	3	4	5	6	7	8	9	10
**Achillea millifoleum* L.	-	0/2	4/3	2/1	2/0	-	-	3/3	2/0	2/2
**Allium canadense* L.	-	0/1	-	-	-	-	-	-	-	1/0
Amorpha canescens Pursh	3/4	-	1/2	3/4	3/4	3/5	2/4	4/5	3/2	2/1
Anemone canadensis L.	-	2/2	-	-	-	-	1/0	-	-	-
Apocynum cannabinum L.	1/0	-	-	-	-	-	-	2/3	0/1	-
**Asclepias syriaca* L.	1/0	-	-	1/0	2/1	-	0/1	-	3/2	1/2
**Asclepias verticillata* L.	2/1	-	2/0	-	6/5	-	-	-	-	1/1
Atragalus canadensis L.	0/2	-	-	4/4	-	1/0	-	-	-	-
Baptisia lactea (Raf.) Thieret	-	-	-	-	-	-	-	-	0/1	-
Cacalia plantaginea (Raf.) Shinners	-	-	-	-	-	-	-	1/0	-	-
Callirhoe involucrata (T. & G.) A. Gray	-	-	-	-	2/0	-	-	-	-	-
Calylophus serrulatus (Nutt.) Raven	-	-	-	3/3	-	-	-	-	-	-
**Carduus nutans* L.	-	-	0/1	-	-	-	2/0	-	-	0/1
Ceanothus americanus L. var. *pitcheri* T. & G.	-	-	-	-	-	-	0/1	3/0	-	-
**Cirsium flodmanii* (Rydb.) Arthur	-	-	0/1	-	-	-	-	-	-	-

Appendix Table 3. Summary of vegetative data collected in 1996 and 1997. Continued.

Species	Number of weeks species occurred in plant surveys in 1996 / 1997, by site (1-10)									
	1	2	3	4	5	6	7	8	9	10
**Cirsium* sp.	-	-	-	-	-	-	-	-	-	1 / 1
Comandra umbellata (L.) Nutt.	-	-	-	0 / 1	-	-	-	-	-	-
Convolvulus arvensis L.	-	-	-	-	2 / 0	1 / 0	2 / 0	-	2 / 0	1 / 1
**Coreopsis palmata* Nutt.	2 / 2	-	-	-	-	1 / 0	-	-	-	-
Dalea candida Michx. *ex* Willd.	0 / 1	-	0 / 1	4 / 4	4 / 0	4 / 5	3 / 2	4 / 4	-	-
**Dalea purpurea* Vent.	1 / 0	-	3 / 2	5 / 0	1 / 0	1 / 0	-	3 / 3	-	-
Delphinium virescens Nutt.	-	-	-	1 / 0	-	-	-	-	-	-
Desmodium illinoense A. Gray	1 / 1	-	-	1 / 0	0 / 1	-	-	-	-	-
**Dianthus armeria* L.	-	-	2 / 2	-	-	-	-	-	-	-
**Echinacea angustifolia* DC.	-	-	0 / 1	-	-	-	-	1 / 0	-	-
Erigeron strigosus Muhl. *ex* Willd.	0 / 1	0 / 2	1 / 0	7 / 5	3 / 1	5 / 8	2 / 7	6 / 8	0 / 2	0 / 1
**Euphorbia corollata* L.	5 / 5	2 / 1	-	-	-	5 / 5	4 / 3	2 / 0	4 / 5	-
Euphorbia marginata Pursh	-	-	-	-	-	-	-	-	-	0 / 1
Gaura longiflora Spach	-	-	-	-	1 / 3	-	-	-	-	-
Helianthus grosseserratus Martens	-	5 / 1	-	-	-	-	-	-	-	-
Helianthus rigidus (Cass.) Desf.	-	-	-	-	1 / 2	-	-	-	-	1 / 0
**Heliopsis helianthoides* (L.) Sweet var. *scabra* (Dun.) Fern.	4 / 3	4 / 2	-	1 / 0	-	2 / 0	4 / 4	-	6 / 5	-

Appendix Table 3. Summary of vegetative data collected in 1996 and 1997. Continued.

Species	Number of weeks species occurred in plant surveys in 1996 / 1997, by site (1-10)									
	1	2	3	4	5	6	7	8	9	10
Hieracium longipilum Torr.	-	-	-	1 / 1	-	-	-	-	-	1 / 2
**Hypericum perforatum* L.	-	-	-	-	-	-	-	-	-	1 / 0
Linum sulcatum Ridd.	-	-	0 / 2	2 / 0	4 / 0	-	-	4 / 4	-	1 / 2
Lithospermum canescens (Michx.) Lehm.	-	-	0 / 1	-	-	-	-	-	-	-
Lysimachia ciliata L.	-	3 / 5	-	-	-	-	-	-	-	-
Medicago lupulina L.	-	1 / 1	0 / 6	-	-	-	-	-	-	1 / 0
Melilotus alba Medic.	-	5 / 4	-	-	2 / 1	-	-	-	-	-
Melilotus officinalis (L.) Pall.	-	7 / 2	0 / 1	-	1 / 0	-	-	-	-	-
Mirabilis nyctaginea (Michx.) MacM.	-	-	-	-	-	-	0 / 1	-	1 / 1	-
**Monarda fistulosa* L.	3 / 2	-	-	1 / 0	-	-	-	-	-	-
Nepeta cataria L.	-	-	-	-	0 / 1	-	-	-	-	-
Oenothera biennis L.	-	-	-	-	1 / 0	-	-	-	-	-
Oxalis stricta L.	-	-	-	-	-	-	-	-	1 / 0	-
Oxalis violacea L.	-	-	-	-	0 / 1	-	-	-	-	-
**Phlox pilosa* L.	2 / 2	2 / 2	-	-	-	2 / 3	3 / 3	0 / 1	2 / 2	-
Physalis sp.	2 / 0	-	1 / 2	0 / 1	2 / 2	-	-	-	0 / 1	-
Polygonum bicome Raf.	-	-	-	-	-	-	-	-	0 / 1	-

Appendix Table 3. Summary of vegetative data collected in 1996 and 1997. Continued.

Species	Number of weeks species occurred in plant surveys in 1996 / 1997, by site (1-10)									
	1	2	3	4	5	6	7	8	9	10
Potentilla arguta Pursh	5 / 4	-	-	3 / 1	-	-	-	-	-	-
Potentilla recta L.	-	-	3 / 1	-	-	2 / 2	-	-	-	-
Psoralia argophylla Pursh	-	1 / 1	-	1 / 2	3 / 1	-	-	-	0 / 2	-
Psoralea tenuiflora Pursh	-	-	-	-	3 / 3	-	-	-	-	3 / 6
Ratibida pinnata (Vent.) Barnh.	5 / 4	5 / 5	-	-	-	-	1 / 0	-	-	-
Rosa sp.	-	-	-	1 / 2	0 / 1	0 / 1	1 / 1	-	2 / 2	0 / 1
Rudbeckia hirta L.	7 / 6	3 / 3	-	1 / 1	-	-	-	2 / 7	1 / 3	-
**Silphium integrifolium* Michx.	-	2 / 4	-	0 / 1	-	3 / 3	4 / 3	-	0 / 3	-
**Silphium laciniatum* L.	-	2 / 0	-	-	-	-	-	-	-	-
Sisymbrium loeselii L.	-	-	-	-	-	-	1 / 0	-	-	-
**Solidago missouriensis* Nutt.	4 / 3	-	-	2 / 3	2 / 1	-	0 / 1	-	2 / 4	0 / 3
**Symphoricarpos orbiculatus* Moench	-	-	3 / 1	-	-	-	-	-	-	-
Taraxacum officinale Weber	-	-	-	-	1 / 0	-	-	-	-	-
Teucrium canadense L.	-	-	0 / 1	-	-	-	1 / 1	-	2 / 2	-
Thalictrum dasycarpum Fisch. & Ave-Lall.	-	2 / 0	-	-	-	1 / 1	-	-	-	-
Tradescantia sp.	-	-	-	-	-	-	-	2 / 0	-	-
Tragopogon dubius Scop.	-	-	0 / 1	2 / 0	-	-	-	-	-	-

Appendix Table 3. Summary of vegetative data collected in 1996 and 1997. Continued.

Species	Number of weeks species occurred in plant surveys in 1996 / 1997, by site (1-10)									
	1	2	3	4	5	6	7	8	9	10
**Trifolium pratense* L.	0/2	8/8	0/3	0/1	-	6/7	8/8	0/3	-	-
Triodanis perfoliata (L.) Nieuw.	-	-	-	-	-	-	-	2/0	-	-
**Verbena hastata* L.	-	-	-	-	0/2	-	-	-	-	-
**Verbena stricta* Vent.	-	-	1/0	-	2/0	-	-	-	-	-
**Vernonia* sp.	-	-	1/1	-	1/0	2/2	-	-	0/1	1/2
Zizia aurea (L.) Koch.	-	0/1	-	-	-	0/1	-	-	-	-

Appendix Table 4. Plant species list for Bauermeister Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Amorpha canescens	Leadplant	4216
Apocynum cannabinum	Indian Hemp Dogbane	12
*Asclepias syriaca**	Common Milkweed	96
*Asclepias verticillata**	Whorled Milkweed	97
*Coreopsis palmata**	Finger Coreopsis	41
*Dalea purpurea**	Purple Prairie Clover	32
Desmodium illinoense	Illinois Tickclover	32
*Euphorbia corollata**	Flowering Spurge	13268
*Heliopsis helianthoides**	False Sunflower	110
*Monarda fistulosa**	Wild Bergamot	1932
*Phlox pilosa**	Prairie Phlox	172
Physalis sp.	Ground Cherry sp.	8
Potentilla arguta	Tall Cinquefoil	98
Ratibida pinnata	Grayhead Prairie Coneflower	74
Rudbeckia hirta	Brown-eyed Susan	110
*Solidago missouriensis**	Prairie Goldenrod	4332
	Total blossoms =	**24630**

Appendix Table 5. Plant species list for Bauermeister Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Amorpha canescens	Leadplant	632
*Asclepias verticillata**	Whorled Milkweed	16
Astragalus canadensis	Canada Milk-vetch	160
*Coreopsis palmata**	Finger Coreopsis	103
Dalea candida	White Prairie Clover	16
Desmodium illinoense	Illinois Tickclover	4
Erigeron strigosus	Daisy Fleabane	16
*Euphorbia corollata**	Flowering Spurge	4916
*Heliopsis helianthoides**	False Sunflower	49
*Monarda fistulosa**	Wild Bergamot	80
*Phlox pilosa**	Prairie Phlox	67
Potentilla arguta	Tall Cinquefoil	11
Ratibida pinnata	Grayhead Prairie Coneflower	204
Rudbeckia hirta	Brown-eyed Susan	44
*Solidago missouriensis**	Prairie Goldenrod	3612
*Trifolium pratense**	Red Clover	2
	Total blossoms =	**9932**

Appendix Table 6. Plant species list for Fricke Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Anemone canadensis	Meadow Anemone	44
*Euphorbia corollata**	Flowering Spurge	247
Helianthus grosseserratus	Sawtooth Sunflower	9
*Heliopsis helianthoides**	False Sunflower	172
Lysimachia ciliata	Fringed Loosestrife	576
Medicago lupulina	Black Medic	880
Melilotus alba	White Sweetclover	3376
Melilotus officinalis	Yellow Sweetclover	7652
*Phlox pilosa**	Prairie Phlox	225
Psoralea argophylla	Silver-leaf Scurfpea	176
Ratibida pinnata	Grayhead Prairie Coneflower	303
Rudbeckia hirta	Brown-eyed Susan	10
*Silphium integrifolium**	Rosinweed	24
*Silphium laciniatum**	Compass Plant	17
Thalictrum dasycarpum	Purple Meadow Rue	256
*Trifolium pratense**	Red Clover	2696
	Total blossoms =	**16663**

Appendix Table 7. Plant species list for Fricke Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	624
*Allium canadense**	Wild Onion	4
Anemone canadensis	Meadow Anemone	45
Erigeron strigosus	Daisy Fleabane	36
*Euphorbia corollata**	Flowering Spurge	8
Helianthus grosseserratus	Sawtooth Sunflower	2
*Heliopsis helianthoides**	False Sunflower	53
Lysimachia ciliata	Fringed Loosestrife	59
Medicago lupulina	Black Medic	32
Melilotus alba	White Sweetclover	1780
Melilotus officinalis	Yellow Sweetclover	1296
*Phlox pilosa**	Prairie Phlox	404
Psoralea argophylla	Silver-leaf Scurfpea	48
Ratibida pinnata	Grayhead Prairie Coneflower	263
Rudbeckia hirta	Brown-eyed Susan	30
*Silphium integrifolium**	Rosinweed	33
*Trifolium pratense**	Red Clover	3742
Zizia aurea	Golden Alexander	32
	Total blossoms =	**8491**

Appendix Table 8. Plant species list for Larkspur Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	856
Amorpha canescens	Leadplant	48
*Asclepias verticillata**	Whorled Milkweed	17
*Dalea purpurea**	Purple Prairie Clover	308
*Dianthus armeria**	Deptford Pink	44
Euphorbia marginata	Snow-on-the-mountain	1
Physalis virginiana	Virginia Ground Cherry	3
Potentilla recta	Sulphur Cinquefoil	55
*Symphoricarpos orbiculatus**	Buckbrush	53
*Verbena stricta**	Hoary Vervain	17
Vernonia sp.*	Ironweed sp.	4
	Total blossoms =	**1406**

Appendix Table 9. Plant species list for Larkspur Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	760
Amorpha canescens	Leadplant	1164
*Carduus nutans**	Musk Thistle	1
*Cirsium flodmanii**	Flodman's Thistle	1
Dalea candida	White Prairie Clover	564
*Dalea purpurea**	Purple Prairie Clover	404
*Dianthus armeria**	Deptford Pink	3
*Echinacea angustifolia**	Purple Coneflower	1
Linum sulcatum	Grooved Flax	2
Lithospermum canescens	Hoary Puccoon	8
Medicago lupulina	Black Medic	827
Melilotus officinalis	Yellow Sweetclover	380
Physalis sp.	Ground Cherry sp.	19
Potentilla recta	Sulphur Cinquefoil	8
*Symphoricarpos orbiculatus**	Buckbrush	4
Teucrium canadense	American Germander	132
Tragopogon dubius	Goat's Beard	1
*Trifolium pratense**	Red Clover	25
Vernonia sp.*	Ironweed sp.	2
	Total blossoms =	**4306**

Appendix Table 10. Plant species list for Madigan Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millifoleum**	Yarrow	320
Amorpha canescens	Leadplant	3656
*Asclepias syriaca**	Common Milkweed	64
Astragalus canadensis	Canada Milk-vetch	440
Calylophus serrulatus	Plains Yellow Primrose	33
Dalea candida	White Prairie Clover	560
*Dalea purpurea**	Purple Prairie Clover	792
Delphinium virescens	Prairie Larkspur	32
Desmodium illinoense	Illinois Tickclover	12
Erigeron strigosus	Daisy Fleabane	275
*Heliopsis helianthoides**	False Sunflower	22
Hieracium longipilum	Hawkweed	4
Linum sulcatum	Grooved Flax	3
*Monarda fistulosa**	Wild Bergamont	680
Potentilla arguta	Tall Cinquefoil	10
Psoralia argophylla	Silver-leaf Scurfpea	2
Rosa sp.	Rose sp.	1
Rudbeckia hirta	Brown-eyed Susan	2
*Solidago missouriensis**	Prairie Goldenrod	276
Tragopogon dubius	Goat's Beard	2
	Total blossoms =	**7186**

Appendix Table 11. Plant species list for Madigan Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millifoleum**	Yarrow	32
Amorpha canescens	Leadplant	92
Astragalus canadensis	Canada Milk-vetch	784
Calylophus serrulatus	Plains Yellow Primrose	14
Comandra umbellata	Bastard Toad-flax	2
Dalea candida	White Prairie Clover	172
Erigeron strigosus	Daisy Fleabane	150
Hieracium longipilum	Hawkweed	1
Physalis sp.	Ground Cherry sp.	1
Potentilla arguta	Tall Cinquefoil	1
Psoralia argophylla	Silver-leaf Scurfpea	10
Rosa sp.	Rose sp.	3
Rudbeckia hirta	Brown-eyed Susan	1
*Silphium integrifolium**	Rosinweed	1
*Solidago missouriensis**	Prairie Goldenrod	324
*Trifolium pratense**	Red Clover	2
	Total blossoms =	**1590**

Appendix Table 12. Plant species list for Nine-mile Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	260
Amorpha canescens	Leadplant	3824
*Asclepias syriaca**	Common Milkweed	100
*Asclepias verticillata**	Whorled Milkweed	857
Callirhoe involucrata	Purple Poppymallow	10
Convolvulus arvensis	Field Bindweed	4
Dalea candida	White Prairie Clover	328
*Dalea purpurea**	Purple Prairie Clover	16
Erigeron strigosus	Daisy Fleabane	70
Gaura longiflora	Large-flowered Gaura	4
Helianthus rigidus	Rigid Sunflower	2
Linum sulcatum	Grooved Flax	6
Melilotus alba	White Sweetclover	596
Melilotus officinalis	Yellow Sweetclover	40
Oenothera biennis	Common Evening Primrose	6
Physalis sp.	Ground Cherry sp.	3
Psoralea argophylla	Silver-leaf Scurfpea	82
Psoralea tenuiflora	Wild Alfalfa	1937
*Solidago missouriensis**	Prairie Goldenrod	1616
Taraxacum officinale	Dandelion	2
*Verbena stricta**	Hoary Vervain	36
Vernonia sp.*	Ironweed sp.	16
	Total blossoms =	**9815**

Appendix Table 13. Plant species list for Nine-mile Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Amorpha canescens	Leadplant	296
*Asclepias syriaca**	Common Milkweed	24
*Asclepias verticillata**	Whorled Milkweed	672
Desmodium illinoense	Illinois Tickclover	12
Erigeron strigosus	Daisy Fleabane	12
Gaura longiflora	Large-flowered Gaura	20
Helianthus rigidus	Stiff Sunflower	8
Linum sulcatum	Grooved Flax	1
Nepeta cataria	Catnip	12
Oxalis violacea	Violet Wood Sorrel	3
Physalis sp.	Ground Cherry sp.	15
Psoralea argophylla	Silver-leaf Scurfpea	1
Psoralea tenuiflora	Wild Alfalfa	31
Rosa sp.	Rose sp.	1
*Solidago missouriensis**	Prairie Goldenrod	216
*Verbena hastata**	Blue Vervain	428
	Total blossoms =	**1752**

Appendix Table 14. Plant species list for Schneekloth N. Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Amorpha canescens	Leadplant	1312
Astragalus canadensis	Canada Milk-vetch	16
Convolvulus sp.	Hedge Bindweed	1
*Coreopsis palmata**	Finger Coreopsis	1
Dalea candida	White Prairie Clover	1028
*Dalea purpurea**	Purple Prairie Clover	128
Erigeron strigosus	Daisy Fleabane	433
*Euphorbia corollata**	Flowering Spurge	3391
*Heliopsis helianthoides**	False Sunflower	9
*Phlox pilosa**	Prairie Phlox	32
Potentilla recta	Sulphur Cinquefoil	48
*Silphium integrifolium**	Rosinweed	12
Thalictrum dasycarpum	Purple Meadow Rue	88
*Trifolium pratense**	Red Clover	1287
Vernonia sp.*	Ironweed sp.	25
	Total blossoms =	**7811**

Appendix Table 15. Plant species list for Schneekloth N. Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Amorpha canescens	Leadplant	2112
Dalea candida	White Prairie Clover	452
Erigeron strigosus	Daisy Fleabane	832
*Euphorbia corollata**	Flowering Spurge	3733
*Phlox pilosa**	Prairie Phlox	221
Potentilla recta	Sulphur Cinquefoil	14
Rosa sp.	Rose sp.	1
*Silphium integrifolium**	Rosinweed	13
Thalictrum dasycarpum	Purple Meadow Rue	12
*Trifolium pratense**	Red Clover	69
Vernonia sp.*	Ironweed sp.	35
Zizia aurea	Golden Alexander	144
	Total blossoms =	**7638**

Appendix Table 16. Plant species list for Schneekloth S. Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Amorpha canescens	Leadplant	860
Anemone canadensis	Meadow Anemone	1
*Carduus nutans**	Musk Thistle	2
Convolvulus sp.	Field Bindweed	2
Dalea candida	White Prairie Clover	584
Erigeron strigosus	Daisy Fleabane	9
*Euphorbia corollata**	Flowering Spurge	5014
*Heliopsis helianthoides**	False Sunflower	77
*Phlox pilosa**	Prairie Phlox	68
Ratibida pinnata	Grayhead Prairie Coneflower	6
Rosa arkansana	Prairie Wild Rose	1
*Silphium integrifolium**	Rosinweed	20
Sisymbrium loeselii	Tall Hedge Mustard	8
Teucrium canadense	American Germander	4
*Trifolium pratense**	Red Clover	1031
	Total blossoms =	**7687**

Appendix Table 17. Plant species list for Schneekloth S. Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Amorpha canescens	Leadplant	561
*Asclepias syriaca**	Common Milkweed	64
Ceanothus americanus	New Jersey Tea	40
Dalea candida	White Prairie Clover	56
Erigeron strigosus	Daisy Fleabane	250
*Euphorbia corollata**	Flowering Spurge	2547
*Heliopsis helianthoides**	False Sunflower	50
Mirabilis nyctaginea	Wild Four-o'clock	9
*Phlox pilosa**	Prairie Phlox	94
Rosa sp.	Rose sp.	3
*Silphium integrifolium**	Rosinweed	5
*Solidago missouriensis**	Prairie Goldenrod	32
Teucrium canadense	American Germander	14
*Trifolium pratense**	Red Clover	429
	Total blossoms =	**4154**

Appendix Table 18. Plant species list for Shanahan Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	132
Amorpha canescens	Leadplant	816
Apocynum cannabinum	Indian Hemp Dogbane	11
Cacalia plantaginea	Indian Plantain	32
Ceanothus americanus	New Jersey Tea	1120
Dalea candida	White Prairie Clover	444
*Dalea purpurea**	Purple Prairie Clover	168
*Echinacea angustifolia**	Purple Coneflower	1
Erigeron strigosus	Daisy Fleabane	582
*Euphorbia corollata**	Flowering Spurge	16
Linum sulcatum	Grooved Flax	27
Rudbeckia hirta	Brown-eyed Susan	8
Tradescantia sp.	Spiderwort sp.	2
Triodanis perfoliata	Venus' Looking Glass	27
	Total blossoms =	**3386**

Appendix Table 19. Plant species list for Shanahan Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	960
Amorpha canescens	Leadplant	194
Apocynum cannabinum	Indian Hemp Dogbane	100
Dalea candida	White Prairie Clover	317
*Dalea purpurea**	Purple Prairie Clover	329
Erigeron strigosus	Daisy Fleabane	5693
Linum sulcatum	Grooved Flax	9
*Phlox pilosa**	Prairie Phlox	2
Rudbeckia hirta	Brown-eyed Susan	953
*Trifolium pratense**	Red Clover	3
	Total blossoms =	**8560**

Appendix Table 20. Plant species list for Stolley Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	288
Amorpha canescens	Leadplant	1772
*Asclepias syriaca**	Common Milkweed	98
Convolvulus sp.	Field Bindweed	2
*Euphorbia corollata**	Flowering Spurge	2425
*Heliopsis helianthoides**	False Sunflower	801
Mirabilis nyctaginea	Wild Four-o'clock	24
Oxalis stricta	Yellow Wood Sorrel	5
*Phlox pilosa**	Prairie Phlox	85
Rosa sp.	Rose sp.	14
Rudbeckia hirta	Brown-eyed Susan	1
*Solidago missouriensis**	Prairie Goldenrod	96
Teucrium canadense	American Germander	32
	Total blossoms =	**5643**

Appendix Table 21. Plant species list for Stolley Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
Amorpha canescens	Leadplant	108
Apocynum cannabinum	Indian Hemp Dogbane	40
*Asclepias syriaca**	Common Milkweed	88
Baptisia lactea	White Wild Indigo	8
Erigeron strigosus	Daisy Fleabane	25
*Euphorbia corollata**	Flowering Spurge	2237
*Heliopsis helianthoides**	False Sunflower	169
Mirabilis nyctaginea	Wild Four-o'clock	18
*Phlox pilosa**	Prairie Phlox	94
Physalis sp.	Ground Cherry sp.	1
Polygonum bicome	Pink Smartweed	104
Psoralea argophylla	Silver-leaf Scurf Pea	6
Rosa sp.	Rose sp.	6
Rudbeckia hirta	Brown-eyed Susan	9
*Silphium laciniatum**	Rosinweed	9
*Solidago missouriensis**	Prairie Goldenrod	1296
Teucrium canadense	American Germander	24
Vernonia sp.*	Ironweed sp.	8
	Total blossoms =	**4250**

Appendix Table 22. Plant species list for Twin Lakes Prairie, 1996. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	112
*Allium canadense**	Wild Onion	16
Amorpha canescens	Leadplant	520
*Asclepias syriaca**	Common Milkweed	64
*Asclepias verticillata**	Whorled Milkweed	4
Cirsium sp.*	Thistle sp.	1
Convolvulus arvensis	Field Bindweed	3
Helianthus rigidus	Stiff Sunflower	1
Hieracium longipilum	Hawkweed	8
Hypericum perforatum	Common St. John's-wort	1
Linum sulcatum	Grooved Flax	1
Medicago lupulina	Black Medic	36
Psoralea tenuiflora	Wild Alfalfa	597
Vernonia sp.*	Ironweed sp.	39
	Total blossoms =	**1403**

Appendix Table 23. Plant species list for Twin Lakes Prairie, 1997. All species detected during plant surveys are included with estimated number of blossoms. Known nectar sources of the regal fritillary (*Speyeria idalia*) are marked with an asterisk (*).

Scientific name	Common name	Blossoms
*Achillea millefolium**	Yarrow	128
Amorpha canescens	Leadplant	104
*Asclepias syriaca**	Common Milkweed	49
*Asclepias verticillata**	Whorled Milkweed	16
*Carduus nutans**	Musk Thistle	13
Cirsium sp.*	Thistle sp.	1
Convolvulus sp.	Bindweed sp.	5
Erigeron strigosus	Daisy Fleabane	20
Euphorbia marginata	Snow-on-the-mountain	2
Hieracium longipilum	Hawkweed	4
Linum sulcatum	Grooved Flax	2
Psoralea tenuiflora	Wild Alfalfa	2460
Rosa sp.	Rose sp.	2
*Solidago missouriensis**	Prairie Goldenrod	564
Vernonia sp.*	Ironweed sp.	10
	Total blossoms =	**3380**

Appendix Table 24. Number of violet clumps recorded at tallgrass prairie study sites, on each of two survey dates (Table 3).

Site	Number of violet (*Viola* spp.) clumps	
	Date 1	Date 2
Bauermeister	0	8
Fricke	26	30
Larkspur	25	20
Madigan	30	15
Nine-mile	3	13
Schneekloth N.	2	27
Schneekloth S.	0	19
Shanahan	12	38
Stolley	1	4
Twin Lakes	3	7