EVALUATING THE IMPORTANCE OF ROADSIDE HABITAT FOR NATIVE INSECT POLLINATORS

BDK-75

Final Report

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The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

Metric Conversion Table

SI* (MODERN METRIC) Conversion Factors

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		AREA		
in^2	squareinches	645.2	square millimeters	mm^2
ft^2	squarefeet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL

MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				

lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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16. Abstract

The effect of roadway margin vegetation mowing frequency on native insect pollinator diversity, butterfly mortality resulting from vehicular collisions, and floral resource abundance and species richness was investigated in Alachua County, Florida. Three vegetation mowing treatments were implemented: no mowing, mowing every 3 weeks, and mowing every 6 weeks. Results showed that mowing treatment had a profound effect on all floral resource variables evaluated. By contrast, there were there was no significant correlations between either butterfly mortality or insect diversity and abundance and any of the floral resource variables measured. Additional detailed results and management implications are discussed.

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Executive Summary

Populations of managed and wild insect pollinators have suffered declines in recent years prompting calls for proactive strategies designed to help increase the sustainability of the valuable ecosystem service they deliver to both natural and agricultural systems. While much recent attention has been placed on resource provision in agricultural systems, it is clear that effective pollinator conservation must comprehensively be incorporated into the broader environment, with overall efforts involving landscapes well beyond the farm boundary. Roadsides offer many potential resources for pollinators. They can support a wide variety of flower-rich forage habitat for access to pollen and nectar; and unlike agricultural landscapes, remain unplowed, therefore providing potential nesting sites for ground nesting bees. These same areas can offer food and cover for other beneficial insect predators and parasitoids, colorful butterflies and moths, and other wildlife including songbirds.

Our study examined how roadway margin mowing frequency affected butterfly mortality resulting from vehicular collisions, native insect pollinator diversity, and the diversity and abundance of herbaceous flowering plants that provide forage. Three vegetation mowing treatments were implemented: no mowing, mowing every 3 weeks, and mowing every 6 weeks. The mowing treatments were administered by the Florida Department of Transportation along six highways in north-central Florida over a two year period. Repeated treatment blocks were distributed between all sites. Each block consisted of a 600-m strip of margin parallel to one side of the road's outer edge. The three abovementioned vegetation treatments were randomly assigned to 200-m sections within each block. Data in the form of live butterfly counts, butterflies found dead near the road's edge, insect pollinator counts and floral resource counts were gathered from all blocks.

We found that mowing treatment had a profound effect on all floral resource variables evaluated. Results of pairwise comparisons indicated that the every six week mowing treatment had significantly more blooms per sample and also great floral area coverage than the other two treatments. There was also evidence indicating that mowing prolonged bloom duration in several high value forage species. By contrast, there were there was no significant correlations between either butterfly mortality or insect diversity and abundance and any of the floral resource variables measured. However, habitat utilization, migratory tendency and adult size all had a significant effect on relative butterfly mortality.

From a management perspective, a slight reduction in regular mowing frequency could provide a significant benefit for native insect pollinators by increasing the floral resources available throughout the year, especially if implemented over a larger landscape scale. Similarly, butterflies such as the monarch that are associated with large southward migrations in the fall would potentially benefit from an abundant and diverse source of available nectar during that time.

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1. Introduction

Plant pollination provided by insects is an ecosystem service that is essential to agricultural productivity, human economic security, global food webs, and protection of biodiversity. Recent evidence has pointed to substantial losses of pollinators in many regions of the globe from anthropogenic sources, with the strongest data coming from Europe and North America. Loss of pollinator diversity can have significant spillover impacts to natural communities and agricultural productivity including decreased crop yields, higher commodity prices, increased vulnerability of some plant species to extinction, and ecosystem disruption.

Habitat degradation and loss are leading factors driving the downward trend of pollinator populations. While much recent attention has been placed on alternative management approaches in agricultural systems, it is clear that effective pollinator conservation must comprehensively be incorporated into the broader environment, with overall efforts involving landscapes well beyond the farm boundary.

Luckily, most insects require or can tolerate smaller remnants of available habitat to thrive compared to larger organisms. Roadsides, utility easements and canal margins, often overlooked as waste areas and seldom mentioned in the larger conservation conversation, offer many potential resources for pollinators. Given that bee (and overall insect pollinator) diversity can be high in intermittently disturbed areas with early-successional plant communities, such landscape elements may be particularly important. They can support a wide variety of flower-rich forage habitat for access to pollen and nectar; and unlike agricultural landscapes, remain unplowed, therefore providing potential nesting sites for ground nesting bees. These same areas offer food (nectar, pollen, host plants and/or prey) and cover for other beneficial insects such as predators and parasitoids, colorful butterflies and moths, and other wildlife including songbirds.

In Florida, such roadways run adjacent to or transect virtually all economically important agricultural lands that support the production of numerous commodities from watermelon and squash to strawberries and blueberries. Numerous recent initiatives have targeted pollinator-friendly augmentation (planting of wildflowers or other flowering plants) on farm lands to potentially enhance insect pollinator availability to an adjacent target crop. Such additions can remove land from production, present additional costs to the grower for establishment and maintenance, are inefficient for certain crops such a watermelon that must be rotated on a multiple year cycle, may not provide critical nesting habitat, and are often met with skepticism by growers. Roadways represent a significant area of already available land that is regularly maintained and which provides a diversity of both forage vegetation and potentially high quality nesting habitat. Such landscapes may provide an even more critical impact for the conservation and maintenance of insect pollinator populations than any smaller scale (and potentially much more costly) agricultural enhancement. The Florida Department of Transportation (FDOT) is responsible for management and care of approximately 81,000 hectares; ½ of one percent of the entire land area of Florida. Unlike a contiguous parcel of this size, state highway roadsides are a network of living edges, touching and linking nearly every natural and agricultural resource in the state. The impact of roadside management decisions extends far beyond the road’s edge, often for several hundred yards, and impacts nearly twenty times that amount of the surrounding environment.

By investigating how roadside vegetation management helps support and benefit pollinator populations, the proposed project directly supported FDOT’s overall mission of enhancing economic prosperity and preserving the quality of the state’s environment and communities. It further strengthened alliances with the Florida Department of Agriculture and Consumer Services by assisting Florida's farmers and agricultural industries and helping to conserve and protect the state's agricultural and natural resources.

The overall goal of the following research studies is to reduce the invertebrate knowledge gap in road ecology by testing whether simple changes in roadside management can impact pollinators utilizing roadside margins in Alachua County, Florida. More specifically, how mowing frequency affects the diversity and abundance of mobile native insect pollinators and herbaceous flowering plants that provide host, pollen and nectar resources.

2. SCOPE OF WORK

2.1 Study A. Floral Resource and Insect Pollinator Abundance in FDOT-Managed Roadside Margins

2.1.1. Research Sites

Six highway sites were selected (Figure 1), each with a high degree of similarity to minimize the effects of confounding variables. The managed roadside margins at each site, comprised of grasses and forbs, spanned an average width of 13 m from the road's edge to the dominant established woody vegetation. The designed explanatory variable was the mowing treatment, which had three levels: no mowing (no-mow) during the course of the study, mowing every 6 weeks (6-week), and mowing every 3 weeks (3-week, standard practice by FDOT in and around the Gainesville area). In total, there were 17 mowing treatment blocks. The mowing treatments were administered by FDOT from March 14, 2012 to November 1, 2014 to cover the peak of the growing season in north-central Florida. Treatment blocks were distributed between all sites. Each treatment block consisted of a 600-m strip of margin parallel to one side of the road's outer edge (i.e., the center medians were not used). The three abovementioned vegetation treatments were randomly assigned to 200-m sections within each block. There was a 100-m buffer between each block that served to aid in spatial and visual separation of the blocks. The first 3 m along the road's immediate edge, i.e. safety strip, was mowed independently from the treatments. This is the width considered necessary to allow space for a vehicle to safely pull off the paved surface of the road. Its mowing frequency will likely depend on the growth rate of the vegetation, which will need to be maintained at a fairly short height. The remaining margin that goes back to the established woody vegetation received the mowing treatments.

The study was modeled as an unbalanced split-plot design. The high plot level, the sites, had no treatment structure. Although the three sites were not selected at random, it was assumed that if numerous such sites existed, those selected would have been representative of such sites. The small plot level, the eight blocks, had a randomized complete block design. The random independent variables were site and block.

Figure 1. Google Maps images of all FDOT-managed study sites in Alachua County, Florida. Orange line shows approximate location of roadside margin sampled (containing research treatment blocks) at each site. The managed roadside margins at each site, comprised of grasses and forbs, spanned an average width of 13 m from the road’s edge to the dominant established woody vegetation. The mowing treatments were administered by FDOT). Eight blocks were distributed between the three sites. Each block consisted of a 600-m strip of margin parallel to one side of the road’s outer edge (i.e., the center medians were not used).

2.1.2. Floral Sampling

Floral abundance and species richness were assessed monthly (Figures 2-5). Only herbaceous flowering plants were evaluated. Flowers from grasses (Poaceae) or woody plants were not counted. Each treatment block was divided into 30 equal sized units. During each sampling period, 10 units were randomly selected. In each unit, a 1-m^2 PVC quadrat was haphazardly placed. Floral resource abundance was determined by counting the number of flowers and/or inflorescences within each quadrat. If flowers were less than 1 mm in diameter and part of a larger inflorescence (ca. 2.5 cm or less in diameter), the inflorescence was counted as a single flower. Tall flowers that were folded over by the quadrat and appeared to be in the 1-m^2 sampling area were not counted if they were rooted outside the area. When large numbers of small flowers were present, counts were made in clusters and estimated to the nearest five flowers. Species were identified visually in the field when possible. Any unknown species were later identified from collected specimens and photographs. Only flowers that were visibly open and thus likely receptive to pollinators were counted. Additionally, the percent bloom cover (a proxy for visibility to mobile pollinators) in each quadrat was estimated by multiplying the # of blooms x mean blossom width. All vegetation surveys were initiated at all sites in mid-February of each year and continued on a regular basis throughout the course of the growing season until no later than 15 November. All field data was collected on individual field forms and then added to a database at a later time back in the lab. Significant effort was placed on plant identification. All flowers were identified to species level. Unknown species were photographed or vouchered for later identification.

Figure 2. Research site along State Road 27 north of Newberry, Alachua County, Florida. May 2013 showing no mow section and extensive wildflowers in bloom.

Figure 3. Research site along State Road 27 north of High Springs, Alachua County, Florida. August 2013 showing 3 week mow section.

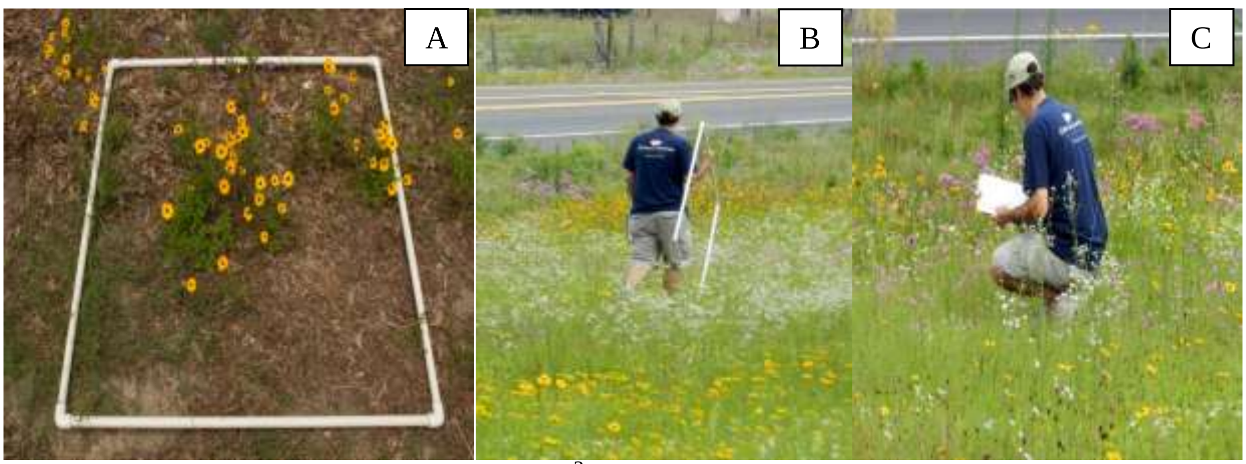

Figure 4. Floral sampling: A. Standard 1-m^2 PVC quadrat showing sampling technique; B. Principal investigator in roadside margin walking to randomly assigned unit for sampling; C. Principal investigator recording wildflower bloom data in the field.

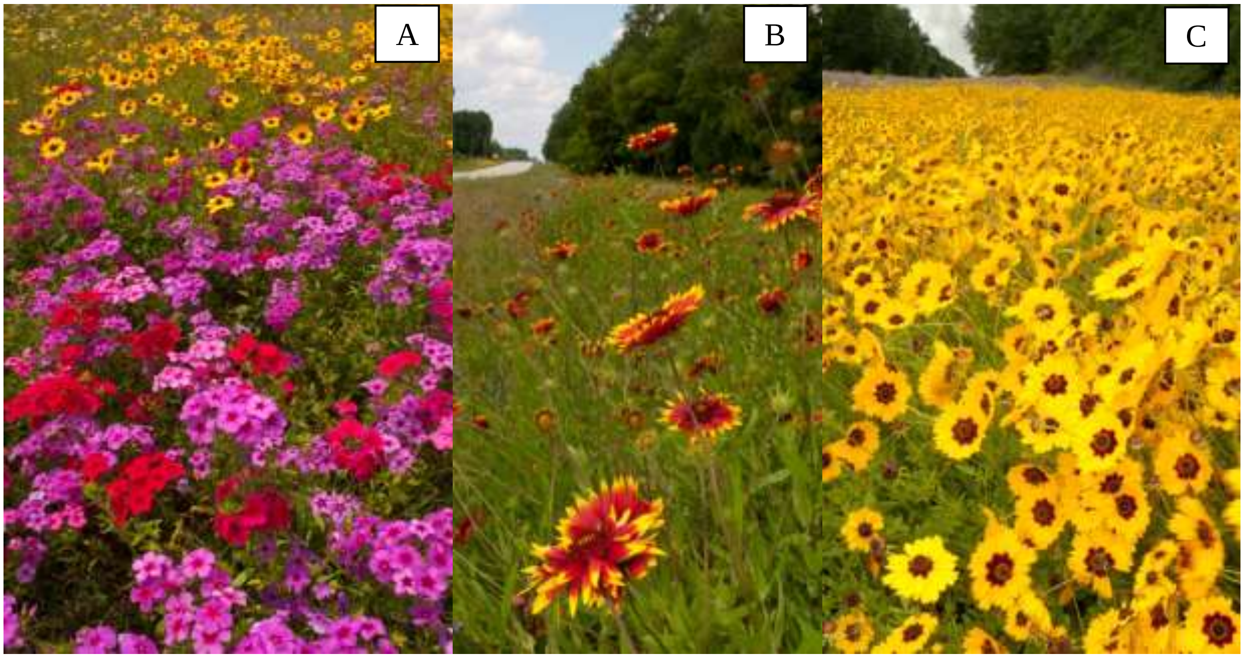

Figure 5. Images of wildflower diversity and density along several roadside treatment units. A. *Phlox drummondii*; B. *Gaillardia pulchella*; C. *Coreopsis basalis*.

A split-plot analysis was used on the floral resource data. Species that were known to be favorable nectar sources for butterflies were analyzed as a separate group. Thus there were four groups of floral resource variables: floral density of all species (floral density), floral density of known forage species (forage density), total floral species richness (floral richness), and richness of forage species (forage richness). Density data were $y' = \ln(y + 1)$ transformed and fit to the split-plot model with a normal distribution. Floral richness data did not need to be transformed to meet the normality assumptions. Nectar richness data could not be transformed to meet the normality assumptions, so they were left untransformed and fit using a Poisson distribution. Analyses were conducted using SAS version 9.2 for Windows (SAS Institute Inc., Cary, North Carolina, USA). Significance was considered for P-values less than or equal to 0.05.

2.1.3. Pollinator Sampling

The project focused on sampling the species richness and abundance of native insect pollinators (i.e. bees, wasps, butterflies, etc.) in roadway margins (Figure 6). Pollinators were sampled passively using pan traps of 4 different colors (white, blue, red and yellow). Pan traps (colorful bowls filled with soapy water) are useful for pollinator surveys as they help eliminate collector bias, are relatively inexpensive, are easily replicated, and can be used over a long period of time at multiple sites simultaneously. This method is particularly effective at collecting numerous species of bees, but is also effective for various flower-visiting flies, skipper butterflies, and a wide range of other insect taxa. Due to the number of site surveys, such passive sampling was the only viable method (vs. adding hand netting). Sets (one of each color) of pan traps were deployed every two weeks during the study concurrently with the floral sampling. All traps remained in the field for 24 hr. At the end of the sampling period, pan trap contents were strained, washed, identified (to the lowest taxonomic level possible; most to family), and then pinned or preserved in alcohol. The date, block number, treatment, and pan color in which it was collected were recorded for each insect sample. All pertinent information was then entered in a Excel database for later analysis.

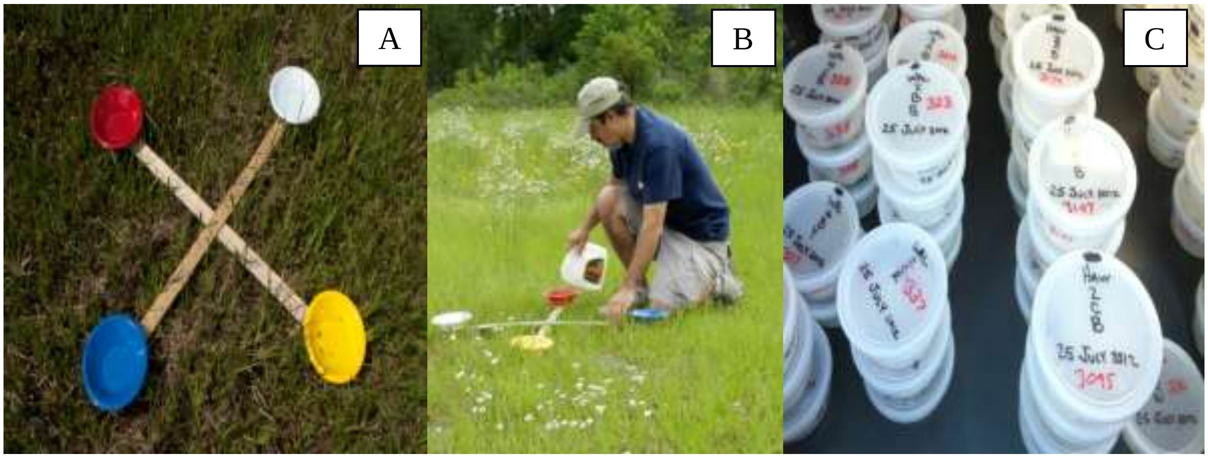

Figure 6. Insect pollinator sampling and specimen organization. A. Typical pan trap set-up showing four different color bowls for passive insect collection; B. Jaret Daniels in a roadside margin filling pan traps with soapy water; and C. Specimen jars with insects in alcohol prior to identification. Each jar has separate code/data system which pertains to roadside location, pan trap color and date of initial collection.

2.2 Study B. Floral Resource and Butterfly Abundance in FDOT-Managed Roadside Margins

We were able to leverage additional research from the FDOT-funded project. Specifically, we piggybacked a one year pilot study on the front end to test whether or not simple changes in roadside management in Alachua County can impact butterfly mortality.

2.2.1. Research Sites

Three highway sites were selected within a 19 km radius of Gainesville, Florida (Alachua County). All sites had a high degree of similarity to minimize the effects of confounding environmental variables. Each highway had the same posted speed limit (105 km/h), a similar traffic volume (averaging 11,000 vehicles/d), and all were four-lane highways with a vegetated center median (Florida Department of Transportation 2009). The managed roadside margins at each site, comprised of grasses and forbs, spanned an average width of 8 m from the road's edge to the established woody vegetation. The latter was primarily pine and mixed hardwood forest, although some sections of the State Route 20 site were adjacent to patches of cypress wetland. The woody vegetation extended back at least 600 m from the road at each site. These sites are fairly representative of rural highways in north central Florida.

The overall research design and vegetation mowing treatments followed those mentioned in Study A. Eight blocks were distributed between the three sites. Each block consisted of a 600-m strip of margin parallel to one side of the road's outer edge (i.e., the center medians were not used). All blocks within each site were located on the same side of the road. There was a 100-m buffer between each block that served to aid in spatial and visual separation of the blocks. Site 1

(Highway 441) contained two blocks, Site 2 (State Route 24) contained four blocks, and Site 3 (State Route 20) contained two blocks. Site 2 had the longest stretch of continuous margin and it was divided into four blocks to maximize replication of the treatments.

The mowing treatments were administered by the FDOT. A John Deere Ztrack mower (Model 797, Deere & Company, Moline, Illinois, USA) was used to administer the mowing treatments. It had three spinning blades that spanned a total width of 1.8 m. The height of the mower's blades was set at 14 cm.

The mowing treatments began on 6 Apr 2011 and ended on 2 Nov 2011, covering the peak growing season for north central Florida. All sites were intended to be mowed on the same day of each week according to treatment level specifications; however, weather-related issues or logistical problems led to some sites being mowed the next day or the previous day. The FDOT provided documentation forms with each mowing cycle to verify that all treatments were administered correctly.

2.2.2. Floral Sampling

Data in the form of herbaceous flowering plant abundance and species richness was gathered from all treatment blocks. Floral sampling gathered was done on the day before each mowing treatment. Data were gathered within five randomly placed 1-m^2 quadrats per 100-m treatment section. Each 100-m treatment section was divided into 80 cells and five cells were randomly selected for quadrat placement on each sampling day in each section. Because each cell was ca. 10 m^2, the observer dropped the quadrat into the cell without looking directly at the ground to minimize sampling bias. Floral resource abundance was determined by counting the number of flowers and/or inflorescences within each quadrat. If flowers were less than 1 mm in diameter and part of a larger inflorescence (ca. 2.5 cm or less in diameter), the inflorescence was counted as a single flower. Tall flowers that were folded over by the quadrat and appeared to be in the 1-m^2 sampling area were not counted if they were rooted outside the area. When large numbers of small flowers were present, counts were made in clusters and estimated to the nearest five flowers. Species were identified visually in the field when possible. Any unknown species were later identified from collected specimens and photographs. Only flowers that were visibly open and thus likely receptive to pollinators were counted. Flowers from grasses (Poaceae) and woody species were not counted.

2.2.3. Butterfly Sampling

Data in the form of live butterfly counts and butterflies found dead near the road's edge were primarily gathered from the blocks between 0900 and 1400 hrs. Persistent rain, cloudy skies combined with forecasted maximum daytime temperatures below 18 ˚C, and/or winds over 32 km/h warranted a rescheduling of data collection. To account for any spillover effects from adjacent treatments within each block, data collection was restricted to the middle 100 m of each 200-m treatment section. The order in which the three sites were visited alternated between the six permutations of the three sites: 1-2-3, 3-2-1, 2-1-3, 3-1-2, 1-3-2, and 2-3-1. The permutation orders were repeated as necessary. This method of alternating orders aimed to minimize temporal sampling bias compounded by travel time between sites. Blocks within sites were always visited in the same order.

Road-killed butterflies found near the road's edge within each treatment section were removed, counted, and identified once weekly. The first 1 m of paved surface at the road's edge and the first adjoining 1 m of clear zone were examined carefully by two observers with overlapping fields of vision. Walking was done against the flow of traffic for safety concerns because both observers were very close to moving traffic. Data from the first collection (week 0) were discarded as they potentially included dead butterflies that had been accumulating before the treatments were administered. Dead butterflies seen outside the 2-m-wide viewing zone were removed but not counted. Intact butterfly corpses and butterfly wings were collected with forceps and placed in labeled glassine envelopes for temporary storage. Wings or wing fragments were still counted as an individual.

Live butterflies seen in the treatment sections were also counted and identified on the same day every 2 weeks. Butterflies were mostly identified on the wing or while perched on exposed vegetation, but efforts were made to net and photograph individuals that were difficult to identify. If a netting attempt failed, the individual was documented at the most specific taxonomic level of certainty. Considering how narrow the margins were, a linear transect parallel to the road and spanning the width of the margin (~ 8 m) was suitable to document the species of butterflies present. Sampling with this basic protocol was intended to document relative abundance of each species for comparative purposes and to determine whether road-killed butterflies were representative of those seen flying in the margins.

3. FINDINGS

3.1. Study A. Floral Resource and Insect Pollinator Abundance in FDOT-Managed Roadside Margins

3.1.1. Insect Pollinators

All insect specimens collected in the sampled roadside areas during 2012 and 2013 were processed, identified, preserved and databased for analysis. The resulting dataset was massive and comprised over 110,000 individual specimens representing 11 orders and 147 families (Table 1). Taxonomic identification was completed to the lowest possible level possible. As larger scale diversity was most critical to this study, we include family-level data. While finer scale data was recorded (to genus or morphospecies), it was not included in this analysis. The most abundant insect orders (in reference to the total number of specimens represented in the samples) were Diptera, Hymenoptera, Coleoptera, and Lepidoptera. This was not surprising as they generally represent large, mobile and flower-visiting insects – principle pollinating groups that would be readily captured in the targeted sampling method utilized.

Table 1. Insect families recorded in roadside margins.

Order	Family
DIPTERA	**DOLICHOPODIDAE**
	DROSOPHILIDAE
	BIBIONIDAE
	PHORIDAE
	TIPULIDAE
	EMPIDIDAE
	SARCOPHAGIDAE
	ASILIDAE
	BOMBYLIIDAE
	CALLIPHORIDAE
	CECIDOMYIIDAE
	CERATOPOGONIDAE
	CHIRONOMIDAE
	CHLOROPIDAE
	CULICIDAE
	DIXIDAE
	DRYOMYZIDAE
	EPHYDRIDAE
	FANNIIDAE
	HELEOMYZIDAE
	LAUXANIIDAE
	MUSCIDAE
	MYCETOPHILIDAE
	PSYCHODIDAE
	SCATHOPHAGIDAE
	SCATOPSIDAE
	SCIARIDAE
	SIMULIIDAE
	STRATIOMYIDAE
	SYRPHIDAE

	TACHINIDAE
	THAUMALEIDAE
HYMENOPTERA	**HALICTIDAE**
	FORMICIDAE
	CRABRONIDAE
	APIDAE
	POMPILIDAE
	ANDRENIDAE
	BRACONIDAE
	CHALCIDIDAE
	CHRYSIDIDAE
	CYNIPIDAE
	DIAPRIIDAE
	ENCYRTIDAE
	EUPELMIDAE
	EURYTOMIDAE
	EVANIIDAE
	ICHNEUMONIDAE
	LEUCOSPIDAE
	MEGACHILIDAE
	MUTILLIDAE
	PAMPHILIIDAE
	PLATYGASTRIDAE
	SCOLIIDAE
	SIRICIDAE
	SPHECIDAE
	TIPHIIDAE
	TORYMIDAE
	VESPIDAE
HEMIPTERA	CICADELLIDAE
	CERCOPIDAE
	REDUVIIDAE
	DELPHACIDAE
	MEMBRACIDAE
	ACANTHOSOMATIDAE
	ALYDIDAE
	BELOSTOMATIDAE
	BERYTIDAE
	DICTYOPHARIDAE
	LARGIDAE
	LYGAEIDAE
	MIRIDAE
	NABIDAE
	PENTATOMIDAE
	PHYLLOXERIDAE
	RHYPAROCHROMIDAE
	THYREOCORIDAE
LEPIDOPTERA	**GEOMETRIDAE**
	PYRALIDAE
	PTEROPHORIDAE
	TORTRICIDAE
	HESPERIIDAE
	TINEIDAE
	EREBIDAE
	PIERIDAE
	GELECHIIDAE

	NYMPHALIDAE
	COLEOPHORIDAE
	YPONOMEUTIDAE
	SPHINGIDAE
	ZYGANIDAE
	LYCAENIDAE
	NEPTICULIDAE
	NOTODONTIDAE
	NOCTUIDAE
	PSYCHIDAE
	GRACILLARIIDAE
	CRAMBIDAE
	PAPILIONIDAE
	PTEROPHORIDAE
	PYRALIDAE
COLEOPTERA	**CHRYSOMELIDAE**
	MORDELLIDAE
	BUPRESTIDAE
	SCARABAEIDAE
	STAPHYLINIDAE
	ANTHICIDAE
	BIPHYLLIDAE
	BRUCHIDAE
	BOSTRICHIDAE
	CANTHARIDAE
	CARABIDAE
	CERAMBYCIDAE
	COCCINELLIDAE
	CURCULIONIDAE
	DYTISCIDAE
	HYDROPHILIDAE
	LATRIDIIDAE
	ELATERIDAE
	MELOIDAE
	MYCETOPHAGIDAE
	NITIDULIDAE
	PHALACRIDAE
	LEOIDIDAE
	ENDOMYCHIDAE
	PTILODACTYLIDAE
	SCIRTIDAE
	SPHINDIDAE
	TENEBRIONIDAE
	THROSCIDAE
ORTHOPTERA	ACRIDIDAE
	TETTIGONIIDAE
	GRYLLIDAE
	TETRIGIDAE
	TRIDACTYLIDAE
	GRYLLOTALPIDAE
	RHAPHIDOHORIDAE
BLATTODEA	BLATTELLIDAE
DERMAPTERA	FORFICULIDAE
ISOPTERA	RHINOTERMITIDAE
ODONATA	COENAGRIONIDAE
	LIBELLULIDAE

THYSANAPTERA	THRIPIDAE MEROTHRIPIDAE PHLAEOTHRIPIDAE

Bolded families are known principle pollinators. Most abundant groups were in Orders Diptera, Hymenoptera, and Coleoptera.

There were there was no significant correlations (e.g. p=0.94, mowing treatment) between insect abundance and mowing treatment or for any of the floral resource variables measured. Figure 7, for example, reflects overall abundance of all insects sampled per visit based on mowing treatment. A refined analysis was completed based on the inclusion of only known principle pollinating groups and yielded similar non-significant results. Lastly, a third analysis was completed in which the dipteran family Dolichopidae was excluded. This was done due to the overwhelming number of specimens recorded in all pan trap samples (Figure 8).

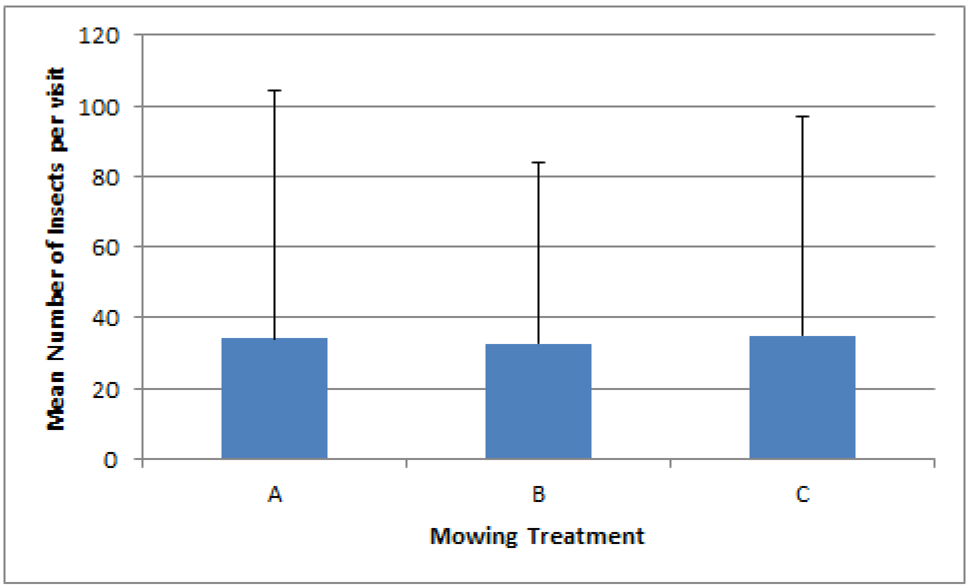

Figure 7. Mean number of total insects collected in pan trap samples per visit based on mowing treatment: no mow (C), every 6 weeks (A), and every 3 weeks (B).

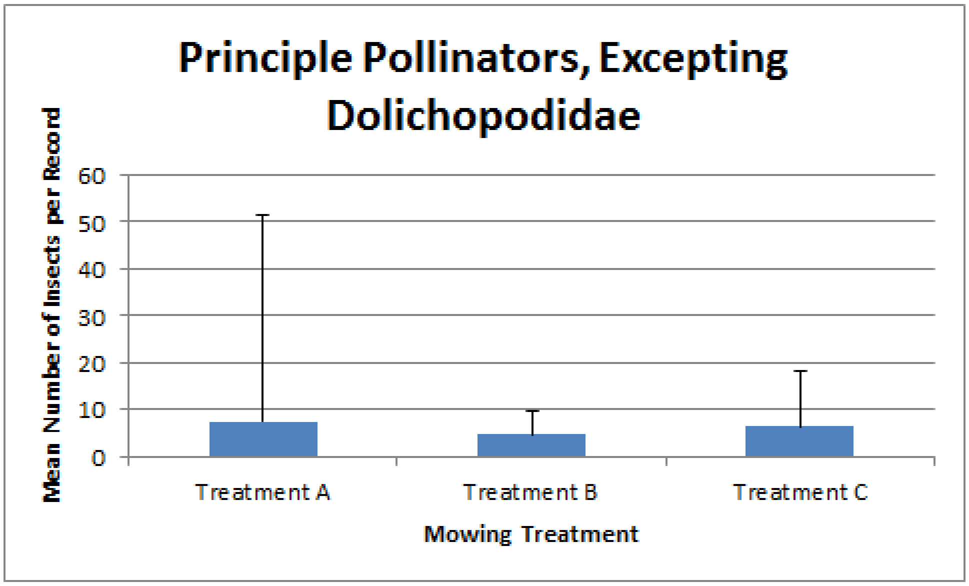

Figure 8. Mean number of total insects classified as principle pollinators (excluding Dolichopidae) collected in pan trap samples per visit based on mowing treatment: every 6 weeks (A), every 3 weeks (B), and no mow (C).

The lack of a significant relationship with treatment is not necessarily surprising owing to the relatively small treatment block size and the fact that most of the principle pollinating taxa are capable of foraging for pollen and nectar over a much broader area (> 2 km for some large bees). Nonetheless, as more insects were collected in the 6 week mowing treatment blocks, which indicated that if floral resources were present, pollinators were attracted to them. If we extrapolate this potential effect over a broader geographic area however, the impact of reduced floral resource availability due to frequent roadside mowing at a landscape scale could be quite impactful.

3.1.2. Floral Resources

There were 133 herbaceous flowering plant species identified in 42 families found along the sampled roadside margins (Table 2). Species were characterized based on their known attractiveness to insect pollinators.

Table 2. Identified roadside margin flowering plant species.

Family	Nectar Species and Author	Pollinator Status
Acanthaceae	***Dyschoriste oblongifolia* (Michx.)Kuntze**	N
	***Ruellia caroliniensis* (J.F.Gmel.)Steud.**	N
Alliaceae	*Allium canadense* L.	P
Amaranthaceae	*Alternanthera philoxeroides* (Mart.)Griseb.	Y
Alismataceae	*Sagittaria lancifolia* L.	Y
Apiaceae	*Chaerophyllum tainturieri* Hook.	Y
	Eryngium baldwinii Sprengel	Y
Apocnaceae	***Asclepias humistrata* Walter**	E
	***Asclepias tuberosa* L.**	E
Araliaceae	*Hydrocotyle umbellata* L.	N
Asteraceae	*Ambrosia artemisiifolia* L.	Y
	Acmella oppositifolia (Lamarck) R. K. Jansen	N

	Berlandiera subacaulis (Nutt.)Nutt.	Y
	Bidens alba (L.) de Candolle	E
	Bidens mitis (Michx.)Sherff	Y
	Calyptocarpus vialis Less.	N
	Chrysopsis mariana (L.)Elliott	Y
	Conyza canadensis (L.)Cronquist	N
	Coreopsis basalis (A.Dietr.)S.F.Blake	E
	Coreopsis lanceolata L.	E
	Coreopsis leavenworthii Torr. & A.Gray	E
	Croptilon divaricatum (Nutt.)Raf.	Y
	Erigeron annuus (L.) Persoon	Y
	Erigeron quercifolius Poir.	Y
	Erigeron strigosus Muhlenberg ex Willdenow	Y
	Eupatorium album L.	Y
	Eupatorium capillifolium (Lam.)Small ex Porter & Britton	N
	Gaillardia pulchella Foug.	Y
	Heterotheca subaxillaris (Lam.)Britton & Rusby	Y
	Hymenopappus scabiosaeus L'Hér.	Y
	Krigia cespitosa (Raf.)K.L.Chambers	Y
	Kummerowia striata (Thunb.)Schindl.	N
	Lactuca graminifolia Michx.	Y
	Mikania scandens (L.) Willdenow	E
	Pectis prostrata Cav.	N
	Pluchea rosea (Miller) Pruski	Y
	***Ptilimnium capillaceum* (Michx.)Raf.**	Y
	Pyrrhopappus carolinianus (Walter)DC.	Y
	Solidago fistulosa Mill.	E
	Solidago odora Aiton	E
	Sonchus asper (L.)Hill	N
	Symphyotrichum pilosum (Willd.)G.L.Nesom	N
	Symphyotrichum simmondsii (Small) G. L. Nesom	N
	Youngia japonica (L.)DC.	N
Boraginaceae	*Heliotropium amplexicaule* Vahl	E
	Lithospermum caroliniense (J.F.Gmel.)MacMill.	N
Brassicaceae	***Lepidium virginicum* L**	Y
	Raphanus raphanistrum L.	N
Campanulaceae	*Campanula floridana* S.Watson ex A.Gray	Y
	Lobelia feayana A. Gray	Y
	Triodanis biflora (Ruiz & Pavon) Greene	N
	Triodanis perfoliata (L.)Nieuwl.	N
	Wahlenbergia marginata (Thunb.)A.DC.	N
Caprifoliaceae	*Valerianella radiata* (L.)Dufr.	Y
Caryophyllaceae	*Arenaria serpyllifolia* L.	N
	Stellaria media (L.)Vill.	N
Chrysobalanaceae	***Licania michauxii*** Prance	Y
Clusiaceae	*Hypericum mutilum* L.	Y
Commelinaceae	*Commelina erecta* L.	N
	Tradescantia ohiensis Rafinesque	Y
Convolvulaceae	*Ipomoea cordatotriloba* Dennst.	N
	Stylisma abdita Myint	N
	Stylisma patens (Desr.)Myint	N
Cyperaceae	*Rhynchospora colorata* (L.)H.Pfeiff.	Y
Cucurbitaceae	*Melothria pendula* L.	N
Euphorbiaceae	*Chamaesyce hyssopifolia (*L.)Small	N
	Cnidoscolus stimulosus (Michx.)Engelm. & A.Gray	N
	Croton glandulosus L. var. *septentrionalis* Müll.Arg	N

	Croton michauxii G.L.Webster	N
	Poinsettia cyathophora (Murray)Bartling	Y
Fabaceae	*Alysicarpus ovalifolius* (Schumach. & Thonn.)J.Leónard	N
	Aeschynomene viscidula Michaux	N
	***Chamaecrista fasciculata* (Michaux) Greene**	E
	***Desmodium incanum* de Candolle**	N
	***Desmodium triflorum* (L.)DC.**	N
	Galactia elliottii Nutt.	N
	Galactia erecta (Walter)Vail	N
	***Indigofera hirsuta* L.**	N
	***Indigofera miniata* Ortega**	N
	***Indigofera spicata* Forssk.**	N
	Medicago lupulina L.	N
	Melilotus albus Medicus	N
	Melilotus indicus (L.)All.	N
	Melilotus officinalis Lam.	Y
	Mimosa strigillosa Torr. & A.Gray	Y
	Trifolium repens L.	E
	Vicia sativa L.	N
Gentianaceae	*Sabatia angularis* (L.) Pursh	N
Geraniaceae	*Geranium carolinianum* L.	Y
Iridaceae	*Sisyrinchium angustifolium* Miller	N
	Sisyrinchium rosulatum E. P. Bicknell	N
Linaceae	*Linum floridanum* (Planch.)Trel.	
Linderniaceae	*Cantinoa mutabilis (*Rich.)Harley & J.F.B.Pastore	N
	Lindernia crustacea (L.)F.Muell.	N
Lamiaceae	*Clinopodium brownei* (Sw.)Kuntze	N
	Hyptis alata (Rafinesque) Shinners	E
	Lamium amplexicaule L.	Y
	Monarda punctata L.	E
	Salvia lyrata L.	E
	Stachys floridana Shuttleworth ex Bentham	Y
	Trichostema dichotomum L.	Y
Lythraceae	*Cuphea carthagenensis* (Jacq.)J.F.Macbr.	N
	Lythrum alatum Pursh var. *lanceolatum* (Elliott)Torr. & A.Gray ex Rothr.	N
Malvaceae	***Sida ulmifolia* Mill.**	N
Nytctaginaceae	*Boerhavia diffusa* L.	N
Onagraceae	*Ludwigia octovalvis* P. H. Raven	N
	Oenothera simulans (Small)W.L.Wagner & Hoch	N
	Oenothera laciniata Hill	N
Paperaceae	*Argemone albiflora* Hornem.	N
Oxalidaceae	*Oxalis corniculata* L.	N
Plantaginaceae	***Bacopa caroliniana* (Walter) B. L. Robinson**	N
	***Bacopa monnieri* (L.) Pennell**	N
	***Plantago lanceolata* L.**	N
	Veronica arvensis L.	N
Polygalaceae	*Asemeia violacea* (Aubl.)J.F.B.Pastore & J.R.Abbott	N
Polygonaceae	*Polygonella gracilis* Meisn.	N
	Polygonum hydropiperoides Michx.	N
	Rumex hastatulus Baldwin	N
Portulacaceae	*Portulaca pilosa* L.	N
Rubiaceae	*Diodia teres* Walter	N
	Diodia virginiana L.	N
	Galium tinctorium L.	N
	Richardia brasiliensis Gomes	Y

	Spermacoce remota Lamarck	E
Solanaceae	*Physalis pubescens* L.	N
Tetrachondraceae	*Polypremum procumbens* L.	N
	Piriqueta cistoides (L.)Griseb. subsp. *caroliniana* (Walter)Arbo	N
Verbenaceae	*Glandularia aristigera* (S.Moore)Tronc.	Y
	***Phyla nodiflora* (L.) Greene**	E
	Verbena brasiliensis Vellozo	E
	Verbena officinalis subsp.*halei* Barber	Y
	Verbena scabra Vahl	Y
Xyridaceae	*Xyris ambigua* Beyrich ex Kunth	N

Species rated as not typically utilized by insect pollinators (N), typically utilized by insect pollinators (Y), or exceptional pollinator-friendly species (E). Species in bold represent known larval host plants for specific Florida butterflies.

Total floral abundance (Figure 9) and number of blooms per record (=sample) (Figure 10) were evaluated based on mowing treatment.

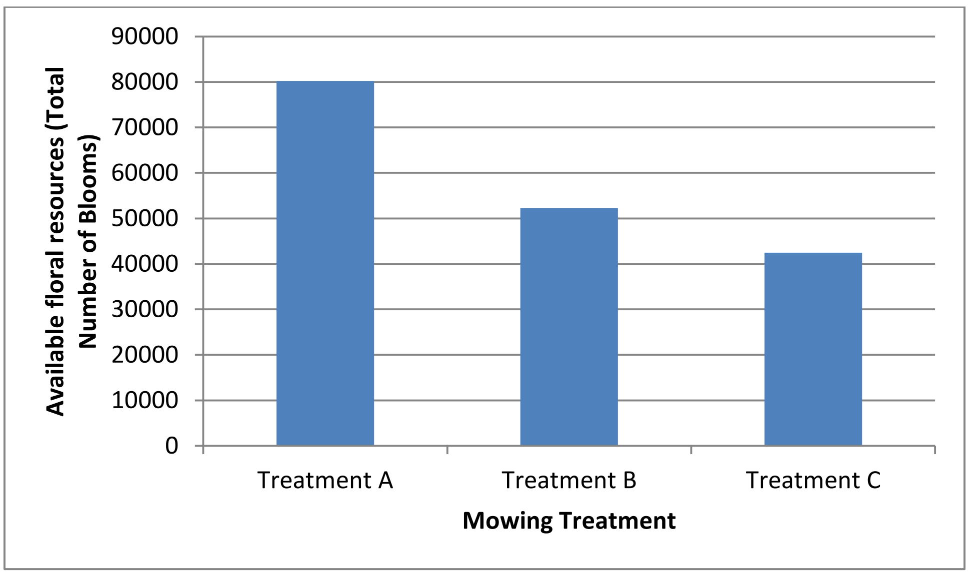

Figure 9. Total number of blooms based on mowing treatment: every 6 weeks (A), every 3 weeks (B), and no mow (C).

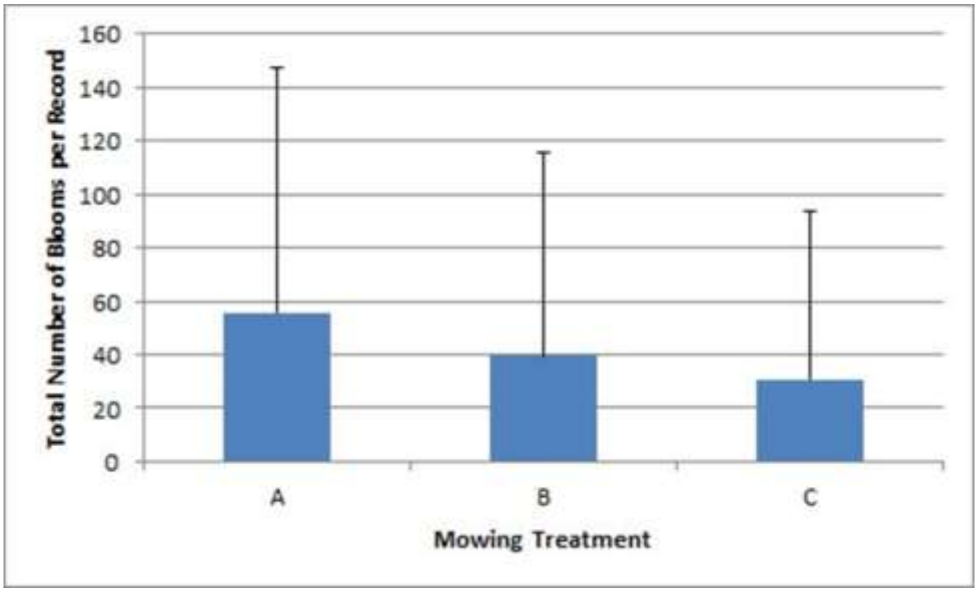

Figure 10. Total number of blooms per sample (record) based on mowing treatment: every 6 weeks (A), every 3 weeks (B), and no mow (C).

The mowing treatment had a significant effect on each of the four floral resource variables (Table 3). The results of pairwise comparisons indicated all mowing treatments evaluated were significantly different from each other (A vs B, p=0.0010053; A vs C, p= 0.0010053; B vs C p=0.0103320). The every 6 week mowing treatment had significantly more blooms per sample and also great floral area coverage than the other two treatments. Somewhat surprisingly, the no mow treatment had significantly fewer blooms per sample and a lower floral area coverage than the other two treatments. These results are likely due to more frequent re-bloom after mowing treatment - promoting the production of new flowers on a more frequent schedule akin to regular pruning. There is also evidence suggesting the density of nectar species changed over time as would be expected with flowering plant phenology. Additionally, the 6 and 3 week mowing treatments prolonged bloom period of several genera (e.g. *Coreopsis, Tradescantia, Hyptis*).

Table 3. Responses of the four floral resource variables to mowing treatment (no mowing, mowing every 6 weeks, and mowing every 3 weeks).

Response	**Treatment**
Density, all species	1.1102e-16*
Density, nectar species	1.0052e-11*
Species richness, all species	0.001052 *
Species richness, nectar species	0.010310 *

The p-values are listed in each column. * Significant at p<0.05.

3.1.3. Summary

- Roadsides harbor a high diversity of herbaceous flowering plant species and known nectar resources for a high diversity of insect families, including many taxa that provide key ecosystem services such as pollination or natural pest control. The resulting diversity and abundance of beneficial insects could have valuable spill-over effects for the maintenance and productivity of adjacent conservation and agricultural lands.

- A total of133 herbaceous flowering plant species in 42 families were found recorded from the sampled roadside margins over the course of the study.

- The frequency of roadside mowing in North-Central Florida had a significant effect on the density, richness and % bloom cover of floral resources in surveyed roadside margins over the course of two field seasons.

- All mowing treatments were significantly different, with the 6 week treatment resulting in significantly more floral resources than the other two treatments. The no mow treatment had the lowest recorded floral resources. Evidence also suggests that regular but reduced frequency mowing could prolong the bloom period for several high-value flowering species. Reduced mowing might also enable seed set in some fast growing species – instead of frequent mowing that could potential retard seed set and ultimately cause an overall reduction or attrition of some flowering plant species through time.

- More than 110,000 individual specimens representing 11 orders and 147 families were collected over the course of the study.

- The most abundant insect orders were Diptera, Hymenoptera, Coleoptera, and Lepidoptera. This includes key pollinating groups such as bees, wasps, flies, beetles and butterflies.

- There were no significant correlations between insect abundance and mowing treatment or for any of the floral resource variables measured.

3.1.4. Management Implications

Results from this study strongly suggest that a slight reduction in FDOT vegetation mowing frequency could provide a significant benefit for native insect pollinators by increasing the quantity and diversity of important forage resources available throughout the year, especially if implemented over a larger landscape scale. Such changes could potentially enhance the overall productivity and sustainability of the valuable ecosystem service they deliver to both natural and agricultural systems.

3.2. Study B. Floral Resource and Butterfly Abundance in FDOT-Managed Roadside Margins

3.2.1. Butterflies

There were a total of 258 live butterflies recorded and 187 dead butterflies collected. This translates to an overall relative mortality of 0.420. With 2.4 km of roadside sampled repeatedly over the course of 27 weeks, there were approximately four live butterflies per km per week. There were approximately three dead butterflies per km per week. These values only apply to one side of the road. As with live counts, the total dead butterfly count of 187 individuals was likely an underestimate of the total road-killed per week. Although each sampling period in our study theoretically included a week of accumulating mortality, it is likely that the residency time of the corpses was less than a week. Red imported fire ants *Solenopsis invicta* (Buren) (Hymenoptera: Formicidae) were abundant in the margins and ants were observed dismembering recently disabled butterflies that were still alive (i.e., less than 1 h post-injury).

There were 30 butterfly taxa identified in five families (Table 4). The numbers of live and dead butterflies, regardless of mowing treatments, differed depending on the species (Table 1). Live and dead butterfly counts increased greatly after mid-late August. This was expected for two main reasons: 1. Many butterfly populations (those that are multivoltine – have multiple generations per year) typically build up through the first half of the growing season and reach near peak numbers toward the middle or end of summer. 2. Migratory taxa begin to move southward into peninsular Florida.

Table 4. Identified roadside margin butterfly species and their attributes.

Species and Author	Habitat	Migrate	Size	Dead	Live
Hesperiidae					
Copaeodes minima Edwards 1870	O	N	S	0	22
Erynnis horatius Scudder & Burgess 1870	W	N	M	3	10
Hylephila phyleus Drury 1773	O	Y	S	4	2
Polites vibex Geyer 1832	O	Y	S	1	3
Pyrgus oileus/albescens Linnaeus 1767/Plötz, 1884	O	N	S	1	25
Urbanus proteus	O	Y	M	1	0
Unknown Hesperiidae, likely Hesperiinae	-	-	-	0	16
Lycaenidae					
Calycopis cecrops Fabricius 1793	W	N	S	0	3
Hemiargus ceraunus Fabricius 1793	O	N	S	0	17
Strymon melinus Hübner 1818	O	N	S	0	3
Nymphalidae					
Agraulis vanillae Linnaeus 1758	O	Y	L	63	36
Danaus gilippus Cramer 1775	O	Y	L	2	0
Danaus plexippus Linnaeus 1758	O	Y	L	5	3
Junonia coenia Hübner 1822	O	Y	M	1	22
Limenitis archippus Cramer 1775	W	N	L	4	1
L. arthemis astyanax Fabricius 1775	W	N	L	1	0
Phyciodes phaon/tharos Edwards 1864/Drury 1773	O	N	S	0	21
Vanessa virginiensis Drury 1773	O	N	M	1	3

Papilionidae					
Battus philenor Linnaeus 1771	W	N	L	2	1
Eurytides marcellus Cramer 1777	W	N	L	4	3
Papilio glaucus Linnaeus 1758	W	N	L	6	0
Papilio palamedes Drury 1773	W	N	L	14	0
Papilio polyxenes Fabricius 1775	W	N	L	3	2
Papilio troilus Linnaeus 1758	W	N	L	4	0
Pieridae					
Abaeis nicippe Cramer 1779	O	N	M	25	8
Colias eurytheme Boisduval 1832	O	N	M	1	1
Eurema daira Godart 1819	O	Y	S	2	22
Nathalis iole Biosduval 1836	O	N	S	0	3
Phoebus sennae Linnaeus 1758	O	Y	L	37	18
Pontia protodice Boisduval & Le Conte 1830	O	N	M	2	13

The species authors are cited in Pelham (2008). The Habitat column indicates whether each species tends to occupy open (O) habitats or wooded (W) habitats. The Migrate column indicates whether (Y=yes) or not (N=no) a given species tends to migrate in Florida. The Habitat and Migrate classes were based on Scott (1986). The Size column is based on average wing span for each species: S < 20 mm, 21 mm < M < 45 mm, and L >46 mm. The genera *Pyrgus* and *Phyciodes* each contained two species with very subtle wing pattern differences. Because not all individuals could be captured for proper identification, the species were lumped into their respective genera. Similarly, unidentified individuals within Hesperiidae were grouped together. They all appeared to have morphological features characteristic of the Hesperiinae. Known migratory species are highlighted in bold.

There were no significant correlations between butterfly mortality and any of the floral resource variables measured. Such inconclusive results are possibly due to the sparse butterfly data at each sampling interval or a lack of any true correlation. Habitat utilization did have a significant effect on the relative mortality of butterflies (df = 1; P < 0.001). Wooded-habitat butterflies had a higher relative mortality (0.67) compared to open-habitat butterflies (0.375). The migratory tendency had a significant effect on relative mortality (df = 1; P < 0.001), with migratory butterfly species experiencing higher relative mortalities (0.596) compared to non-migratory species (0.224). Although there were roughly equal numbers of combined live and dead migratory and non-migratory individuals (231 migratory and 214 non-migratory), the significantly higher overall relative mortality of migratory species was likely due to the fact that those species crossed the road more frequently. The two most abundant migratory species in our study, *Agraulis vanillae* (L) (Lepidoptera: Nymphalidae) and *Phoebis sennae* (L) (Lepidoptera: Pieridae). The non-migratory species in our study likely spent more time in the margins and traveled shorter distances, thereby reducing their susceptibility to roadkill. Size also had a significant effect on relative mortality (df = 2; P < 0.001), with larger butterflies have the highest relative mortalities. Butterfly size likely introduced a sampling bias to our study, because large butterflies were more likely to be seen than small butterflies. It was less likely to spot a dead small butterfly than a live and moving one. This likely resulted in the lower than expected relative mortality for small butterflies.

3.2.2. Floral Resources

Approximately 12,700 flowers and inflorescences were recorded with an average of 11.8 flowers/ m^2 across the nine sampling periods (13 May through 1 Nov). There were 72 flower species identified in 32 families (Tables 5 and 6).

Table 5. Identified roadside margin herbaceous flowering plant species (wildflowers) known to be regularly utilized as nectar sources by Florida butterflies.

Family	Nectar Species and Author	Native
Alismataceae	*Sagittaria lancifolia* Linnaeus 1759	N
Apiaceae	*Eryngium baldwinii* Sprengel 1825	N
Asteraceae	*Acmella oppositifolia* (Lamarck) R. K. Jansen 1985	N
	Bidens alba (Linnaeus) de Candolle 1836	N
	Erigeron annuus (Linnaeus) Persoon 1807	N
	Erigeron strigosus Muhlenberg ex Willdenow 1803	N
	Eupatorium album Linnaeus 1767	N
	Mikania scandens (Linnaeus) Willdenow 1803	N
	Pluchea rosea (Miller) Pruski 2005	N
	Symphyotrichum simmondsii (Small) G. L. Nesom 1995	N
Brassicaceae	*Lepidium virginicum* Linnaeus 1753	N
Campanulaceae	*Lobelia feayana* A. Gray 1877	N
	Triodanis biflora (Ruiz & Pavon) Greene 1894	N
Clusiaceae	*Hypericum mutilum* Linnaeus 1753	N
Commelinaceae	*Tradescantia ohiensis* Rafinesque 1814	N
Fabaceae	*Aeschynomene viscidula* Michaux 1803	N
	Chamaecrista fasciculata (Michaux) Greene *1897*	N
	Desmodium incanum de Candolle 1825	
	Medicago lupulina Linnaeus 1753	
	Melilotus albus Medicus 1787	
	Trifolium repens Linnaeus 1753	
Gentianaceae	*Sabatia angularis* (Linnaeus) Pursh 1814	N
Iridaceae	*Sisyrinchium angustifolium* Miller 1769	N
	Sisyrinchium rosulatum E. P. Bicknell 1899	
Lamiaceae	*Hyptis alata* (Rafinesque) Shinners 1962	N
	Stachys floridana Shuttleworth ex Bentham 1848	N
Onagraceae	*Ludwigia octovalvis* P. H. Raven 1962	
	Oenothera laciniata Hill 1767	N
Oxalidaceae	*Oxalis corniculata* Linaeus 1753	N
Plantaginaceae	*Bacopa caroliniana* (Walter) B. L. Robinson 1908	N
	Bacopa monnieri (Linnaeus) Pennell 1946	N
Portulacaceae	*Portulaca pilosa* Linnaeus 1753	N
Rubiaceae	*Diodia virginiana* Linnaeus 1753	N
	Richardia brasiliensis Gomes 1801	
	Spermacoce remota Lamarck 1792	N
Tetrachondraceae	*Polypremum procumbens* Linnaeus 1753	N
Verbenaceae	*Phyla nodiflora* (Linnaeus) Greene 1899	N
	Verbena brasiliensis Vellozo 1829	
	Verbena officinalis subsp. *halei* Barber 1982	N
	Verbena scabra Vahl 1798	N
Xyridaceae	*Xyris ambigua* Beyrich ex Kunth 1843	N

The species authors and the native classification (N= native to Florida) are cited in Wunderlin and Hansen (2008).

Table 6. Identified roadside margin flowering plant species not known to be regularly used as nectar sources by Florida butterflies, but which may influence foraging behavior.

Family	**Species and Author**	**Native**
Apiaceae	*Ptilimnium capillaceum* (Michaux) Rafinesque 1830	N
Araliaceae	*Hydrocotyle verticillata* Thunberg 1798	N
Asteraceae	*Conyza canadensis* (Linnaeus) Cronquist 1943	N
	Cotula coronopifolia Linnaeus	
	Boltonia diffusa Elliott 1823	N
	Eupatorium capillifolium (Lamarck) Small ex Porter & Britton 1894	N
	Eclipta prostrata(Linnaeus) 1771	N
	Pectis prostrata Cavanilles 1797	N
Campanulaceae	*Wahlenbergia marginata* (Thunberg) Alph. de Candolle 1830	
Clusiaceae	*Hypericum gentianoides* (Linnaeus) Britton et al. 1888	N
Cyperaceae	*Rhynchospora colorata* (Linnaeus) H. Pfeiffer 1935	N
Eriocaulaceae	*Eriocaulon compressum* Lamarck 1789	N
Euphorbiaceae	*Chamaesyce hypericifolia* (Linnaeus) Millspaugh 1909	N
Fabaceae	*Desmodium triflorum* Linnaeus) de Candolle 1825	
	Kummerowia striata (Thunberg) Schindler 1912	
Hydroleaceae	*Hydrolea quadrivalvis* Walter 1788	N
Lamiaceae	*Clinopodium brownei* (Swartz) Kuntze 1891	N
Loganiaceae	*Mitreola petiolata* (J. F. Gmelin) Torrey and Gray 1841	N
Lythraceae	*Cuphea carthagenensis* (Jacquin) J. F. Macbride 1930	
Malvaceae	*Melochia corchorifolia* Linneaus 1753	
Melastomataceae	*Rhexia mariana* Linnaeus 1753	N
Molluginaceae	*Mollugo verticillata* Linnaeus 1753	
Onagraceae	*Gaura angustifolia* Michaux 1803	N
	Ludwigia octovalvis (Jacquin) P. H. Raven 1962	N
Plantaginaceae	*Gratiola pilosa* Michaux 1803	N
	Lindernia grandiflora Nuttall 1818	N
	Mecardonia acuminata (Walter) Small 1903	N
Polygalaceae	*Polygala lutea* Linnaeus 1753	N
	Polygala leptocaulis Vellozo 1829	N
Polygonaceae	*Polygonum punctatum* Elliott 1817	N
Urticaceae	*Boehmeria cylindrica* (Linnaeus) Swartz 1788	N

The mowing treatment had a significant effect on each of the four floral resource variables (Table 7). The results of pairwise comparisons indicated the no-mow treatment and 6-week treatments were not significantly different from each other. They both had significantly greater densities and numbers of species compared to the 3-week treatment. There is also evidence suggesting the density of nectar species changed over time as would be expected with flowering plant phenology.

Table 7. Responses of the four floral resource variables to mowing treatment (no mowing, mowing every 6 weeks, and mowing every 3 weeks).

Response	Treatment
Density, all species	0.0330 *
Density, nectar species	0.0331 *
Species richness, all species	0.0036 *
Species richness, nectar species	0.0029 *

The p-values are listed in each column. * Significant at $p<0.05$.

3.2.3. Summary

- There were a total of 72 herbaceous flowering plant species in 32 families recorded over the course of the study.

- The frequency of roadside mowing in Alachua County has a profound effect on floral composition and diversity in the margins over the course of just one field season.

- Mowing treatment had a significant effect on each of the four flower resource variables evaluated: floral density of all species (floral density), floral density of nectar species (nectar density), total floral species richness (floral richness), and species richness of floral nectar species (nectar richness).

- The no-mow treatment and 6-week treatment were not significantly different from each other. They both had significantly greater floral densities and numbers of species per square meter of road margin compared to the 3-week treatment.

- Although not statistically significant, the 6-week treatment appeared to yield the greatest number of herbaceous flowering plant species.

- There were a total of 30 butterfly in five families recorded over the course of the study.

- There were no significant correlations between butterfly mortality and any of the floral resource variables measured. Nonetheless, graphical trends suggest that seasonal abundance of live butterflies was affected by changes in roadside vegetation management. Frequent mowing appeared to limit butterfly numbers particularly later in the season from August onward when population numbers of resident species build up and when several migratory species begin moving back into the Florida peninsula from locations farther north.

- Habitat utilization, migratory status and adult size all had a significant effect on mortality.

- Although there were roughly equal numbers of combined live and dead migratory and non-migratory individuals (231 migratory and 214 non-migratory), the significantly higher overall relative mortality of migratory species was likely due to the fact that those species crossed the road more frequently.

3.2.4. Management Implications

FDOT adjust their mowing frequency to approximately every 6 weeks or less, especially later in the season (August to October) when overall resident and migrant butterfly numbers increase to help maximize floral resource availability and minimize roadway mortality resulting from vehicle-organism collisions. Such minor changes would also potentially benefit numerous other highly mobile native insect pollinators.

References

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