Host Preferences and Habitat Associations of Some Florida Grasshoppers (Orthoptera: Acrididae)

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ABSTRACT Host-plant preferences were assessed by field measurement of grasshopper abundance in relation to measurements of floral community and by laboratory host-plant preferences. Correlations between grasshoppers and plants (biomass and percentage cover) were based on data gathered at 29 study sites in five distinct Florida habitats (including disturbed, freshwater marsh, high pine, oak hammock, and swamp). Relationships among plants in these habitats and 10 abundant grasshopper species were examined to clarify differences in grasshopper assemblages among habitats. The grasshoppers studied were *Aptenopedes sphenarioides* Scudder, *Chortophaga australior* (Rehn and Hebard), *Eritettix obscurus* (Scudder), *Melanoplus bispinosus* Scudder, *Melanoplus querneus* Rehn and Hebard, *Paroxya clavuliger* (Serville), *Schistocerca americana* (Drury), *Schistocerca ceratiola* Hubbell and Walker, and *Spharagemon crepitans* (Saussure). In addition to correlations among individual plants and the abundance of grasshoppers, multiple regression analysis was used to assess how groups of plants were related to grasshopper abundance. These analyses identified grasshopper-plant associations, but some plants were found to be host plants, whereas others were indicators of preferred habitats (indicator plants). Host-plant preferences were determined in the laboratory using five plant-choice tests to help distinguish between host and indicator plants. The 10 grasshopper species examined for laboratory host-plant preferences were the same species scrutinized in the field study. In almost every case, grasshoppers showed specific plant preferences, and the preference studies successfully distinguished between host plants and indicator species. Similar results were obtained whether biomass or percent cover measurements were used to assess the floral community, although percent cover is much easier and faster to determine.

KEY WORDS choice test, habitat selection, host selection, relationship between biomass and plant cover

Habitat use among grasshoppers is dependent on many factors, both biotic and abiotic. Atmospheric factors such as light intensity, temperature, and humidity are extremely influential in habitat selection (Parker 1930). Other influences such as the texture, moisture retention ability, and heat conductance of the soil, as well as food availability, oviposition sites, roosting sites, and the presence or absence of predators and competitors, are also very important (Strohecker 1937, Clark, 1948, Joern 1979). Overall, vegetative structure is the dominant influence on the microclimate and the aforementioned factors (Clark 1948, Dempster 1955, Anderson 1964, Joern 1982). Studies involving the height, density, and shelter provided by foliage, as well as green food and bare ground, indicated that all of these aspects of the overall plant assemblage influenced grasshopper community structure (Clark 1947, Anderson 1964, Joern 1982).

While many individual factors are important to the composition of grasshopper assemblages, they are of secondary importance to the presence of host plants. Grasshoppers are rarely found in habitats where their host plants are not available (Anderson 1964). Grasshoppers tend to aggregate in areas where the preferred host plant is present and achieve maximum biotic potential by feeding on them. In many cases, the life cycle of a grasshopper species is tied closely to the life cycle of its primary host plant, and when the plant disappears, the grasshopper population declines precipitously (Isley 1937). These findings indicate that grasshoppers have evolved and adapted to the seasonal history of preferred host plants and have achieved a temporal and spatial isolation (Mulkern 1967). Therefore, the distributions of grasshoppers are directly correlated with the life cycles of their host plants (Fielding and Brusven 1992).

Friauf (1953) in North America and Kaufmann (1965) in Europe both found that grasshoppers could be classified according to habitat preferences. However, because of their polyphagous nature and mobil-

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ity, these classifications did not always hold true (Blatchley 1920, Friauf 1953, Otte 1981, 1984). Recently, the works of Squitier and Capinera (2002b) and Capinera et al. (2001) have gone a long way to describing the relationships between common Florida habitat types and the grasshopper assemblages found in them. In this study, we attempted to link specific plants or groups of plants within these habitat types to certain grasshoppers to further define the grasshopper/plant relationships within these communities.

Studies involving differential feeding trials have been shown to be very effective in determining food preferences, as well as the degree of selectivity (Mulkern 1967). The grasshoppers of Florida and their food preferences have not been well studied. However, in recent years, some food preference data have been acquired (Capinera 1993, Scherer 1997, Squitier and Capinera 2002a).

The goal of this study was to determine and evaluate the food preferences of several grasshopper species from different Florida habitats using differential feeding trials and host/habitat associations. The grasshoppers studied were among the most abundant in their habitats. The structural characteristics of grasshopper mandibles were also determined for the grasshoppers collected in field studies.

Materials and Methods

Host Plant Preferences. The grasshoppers evaluated in laboratory host preference studies were collected from various habitats, including scrub, oak hammock, disturbed, swamp, and freshwater marsh. The food preferences of *Aptenopedes sphenariodes* Scudder, *Chortophaga australior* (Rehn and Hebard), *Eritettix obscurus* (Scudder), *Melanoplus bispinosus* Scudder, *Melanoplus querneus* Rehn and Hebard, *Paroxya clavuliger* (Serville), *Romalea microptera* (Beauvois), *Schistocerca americana* (Drury), *Schistocerca ceratiola* Hubbell and Walker, and *Spharagemon crepitans* (Scudder) were evaluated. The grasshoppers used in this study were collected in the field using sweep nets and were maintained in the laboratory. They were kept in 0.3 by 0.3 by 0.3-m wire mesh cages at a constant temperature of 32°C and at a relative humidity of 40 ± 10% while being exposed to 14-h days and 10-h nights. Every 2 d, the grasshoppers were supplied with romaine lettuce and bahiagrass, *Paspalum notatum* Fluegge, except *S. ceratiola*, which was provided with fresh sprigs of Florida rosemary, *Ceratiola ericoides* Michx. Fresh water and a dry meal consisting of two parts wheat bran, one part soy powder, and one part whole wheat were also provided.

All of the plants tested were harvested from the habitat in which the grasshoppers were found, allowing for grasshoppers to be accurately tested with flora naturally occurring in their communities. The grasshoppers were given a choice of five plants of roughly equal volume, arranged at equal intervals inside the cages described above. The amount of vegetation for each choice averaged ≈0.90 g for all tests. The combination of plants for each treatment was chosen randomly. The number of grasshoppers released in each testing cage was dependent on the average size of that species. Only adult grasshoppers were used in this study. If a grasshopper species was >32 mm in length (*P. clavuliger*, *R. microptera*, *S. americana*, *S. ceratiola*, and *S. crepitans*), 6 individuals were released into the cage, whereas for grasshoppers <32 mm (*A. sphenarioides*, *C. australior*, *E. obscurus*, *M. bispinosus*, and *M. querneus*), 10 grasshoppers were placed in the cages. Turgidity of the plants was maintained by placing them in cool water immediately on clipping. Sections of the original cuttings were cut and placed in small plastic cups filled with water and sealed with plastic tops containing holes cut in the center. The cups were buried in sand contained in circular plastic tubs, leaving only the plant cuttings exposed above the sand. This allowed grasshoppers that typically feed from the ground to do so rather than climbing to access plant material before feeding. Each trial consisted of five plants, all of different species, arranged equidistant from each other. For each replicate, placement of plants was randomized. Four of the species were common to the habitat type; the fifth species was bahiagrass. The uniform standard by which other preferences could be judged was bahiagrass. This standard was present in each of the primary test trials. Each arrangement of plants was replicated 10 times. A light bulb located to one side was provided for light and heat. and overhead fluorescent lighting helped to even out the lighting. Randomization of plant material eliminated any effect of the light/heat source on feeding.

Grasshoppers were not starved before being tested, limiting the possibility of grasshoppers feeding on nonpreferred plants because of extreme hunger. The experiment was allowed to run until the grasshoppers had consumed >60% of one or more of the five plants. If the grasshoppers had not consumed >60% of any plant after 24 h, the experiment was terminated. A scale of 1–5 as described by Capinera (1993) was used to visually estimate the amount of vegetation consumed, with 1 representing 0–20% consumed, 2 representing 21–40%, 3 representing 41–60%, 4 representing 61–80%, and 5 representing 81–100% consumed. The environmental conditions used during rearing, as described previously, remained the same during experimentation. When enough replications had been run to determine at least five preferences, the five most preferred plants were placed together in secondary choice tests. The plants used in this study, including common names and authors, are listed in Table 1.

The consumption values for each set of plants were analyzed for each grasshopper species using a one-way analysis of variance (ANOVA). The means for each grasshopper species trial were compared using the Student-Newman-Keuls mean separation test (SAS Institute 2001).

Host Associations. Twenty-nine sites in 10 counties of north-central Florida were surveyed in this study. Most of north-central Florida is a mosaic of flatwoods, high pine, and scrub habitats, with strands of swamp snaking through it. Freshwater marshes and seasonal ponds are not uncommon in these areas. Counties

Table 1. Plants used in choice tests

Scientific names	Common names	Family names
Acer rubrum L.	Red Maple	Aceraeae
Alysicarpus vaginalis L.	Alyce Clover	Leguminosae
Amaranthus spinosus L.	Spiny Amaranth	Amaranthaceae
Ambrosia artemisiifolia L.	Common Ragweed	Compositae
Andropogon virginicus L.	Broomsedge	Gramineae
Aristida beyrichiana Trin. and Rupr.	Wiregrass	Gramineae
Asimina obovata (Willd.)	Flag Pawpaw	Annonaceae
Aster dumosus L.	Bushy Aster	Compositae
Baccharis halimifolia L.	Groundsel Bush	Compositae
Bidens alba L.	Common Beggar Tick	Compositae
Brassica kaber (DC.)	Wild Mustard	Cruciferae
Cenchrus echinatus L.	Southern Sandspur	Gramineae
Centrosema virginianum L.	Climbing Butterfly Pea	Leguminosae
Ceratiola ericoides Michx.	Florida Rosemary	Empetraceae
Chamaecrista fasciculata (Michx.)	Partridge Pea	Leguminosae
Chamaesyce hyssopifolia L.	Hyssop Spurge	Euphorbiaeceae
Chasmanthium laxum L.	Slender Spikegrass	Gramineae
Chenopodium ambrosioides L.	Mexican Tea	Chenopodiaceae
Cladina evansii (Abbayes)	Reindeer Lichen	Cladoniaceae
Clematis reticulata Walter	Vase Vine	Ranunculaceae
Conyza canadensis L.	Horseweed	Compositae
Crotalaria lanceolata E. Meyer	Lanceleaf Crotalaria	Leguminosae
Crotalaria spectabilis Roth.	Showy Crotalaria	Leguminosae
Croton argyranthemus Michx.	Silver Leaf Croton	Euphorbiaeceae
Cynodon dactylon L.	Bermudagrass	Gramineae
Cyperus esculentus L.	Yellow Nutsedge	Cyperaceae
Cyperus odoratus L.	Flat Sedge	Cyperaceae
Cyperus surinamensis Rottb.	Surinam Sedge	Cyperaceae
Desmodium tortuosum (Sw.)	Florida Beggarweed	Leguminosae
Digitaria bicornis (Lam.)	Tropical Crabgrass	Gramineae
Digitaria ciliaris (Retz.)	Southern Crabgrass	Gramineae
Digitaria ischaemum (Schreb.)	Smooth Crabgrass	Gramineae
Diospyros virginiana L.	Persimmon	Ebenaceae
Elephantopus elatus Bertol.	Florida Elephant's Foot	Compositae
Elephantopus nudatus A. Gray	Purple Elephant's Foot	Compositae
Eleusine indica L.	Goosegrass	Gramineae
Erechtites hieraciifolia L.	American Burnweed	Compositae
Eriogonum tomentosum Michx.	Wild Buckwheat	Polygonaceae
Eupatorium capillifolium (Lam.)	Dog Fennel	Compositae
Fatoua villosa (Thunb.)	Hairy Crabweed	Moraceae
Fuirena squarrosa Michx.	Umbrellagrass	Cyperaceae
Gnaphalium pensylvanicum Willd.	Wandering Cudweed	Compositae
Habenaria floribunda Lindl.	Toothpetal False Reinorchid	Orchidaceae
Heterotheca subaxillaris (Lam.)	Camphor Weed	Compositae
Indigofera hirsuta L.	Hairy Indigo	Leguminosae
Lachnanthes caroliniana (Lam.)	Red Root	Haemodoraceae
Lepidium virginicum L.	Pepper Weed	Cruciferae
Licania michauxii Prance	Gopher Apple	Chrysobalanaaceae
Limnobium spongia (Bosc.)	Frog's Bit	Hydrocharitaceae
Ludwigia peruviana L.	Common Primrose Willow	Onagraceae
Oenothera laciniata Hill	Cut Leaved Evening Primrose	Onagraceae
Osmunda cinnamomea L.	Cinnamon Fern	Osmundaceae
Oxalis stricta L.	Yellow Wood Sorrel	Oxalidaceae
Panicum equilaterale Scribn.	no common name	Gramineae
Panicum hemitomon Schult.	Maidencane	Gramineae
Panicum maximum Jacq.	Guineagrass	Gramineae
Panicum virgatum L.	Switchgrass	Gramineae
Paspalum dilatatum Poir.	Dallisgrass	Gramineae
Paspalum notatum Fluegge	Bahiagrass	Gramineae
Pityopsis graminifolia (Michx.)	Silk-Grass	Compositae
Polypremum procumbens L.	Rust Weed	Loganiaceae
Pontederia cordata L.	Pickerel Weed	Pontederiaceae
Quercus geminata Small	Sand Live Oak	Fagaceae
Quercus hemisphaerica Batr.	Laurel Oak	Fagaceae
Quercus laevis Walt.	Turkey Oak	Fagaceae
Quercus myrtifolia Willd.	Myrtle Oak	Fagaceae
Quercus nigra L.	Water Oak	Fagaceae
Rhus copallinum L.	Winged Sumac	Anacardiaceae
Rhynchosia reniformis DC.	Dollar Weed	Leguminosae
Richardia scabra L.	Florida Pusley	Rubiaceae
Rubus cuneifolius Pursh	Sand Blackberry	Rosaceae
Sacciolepis striata L.	American Cupscale	Gramineae
Sagittaria lancifolia L.	Lance Leaf Arrowhead	Alismataceae

Table 1. Continued

Scientific names	Common names	Family names
Salix caroliniana Michx.	Coastal Plain Willow	Salicaceae
Saururus cernuus L.	Lizard's Tail	Saururaceae
Sesbania exaltata (Raf.)	Hemp Sesbania	Leguminosae
Setaria geniculata (Lam.)	Knotroot Foxtail	Gramineae
Sida rhombifolia L.	Arrowleaf Sida	Malvaceae
Smilax auriculata Walter	Wild Bamboo	Liliaceae
Smilax bona-nox L.	Catbrier	Liliaceae
Solanum americanum Mill.	American Black Nightshade	Solanaceae
Solidago canadensis L.	Tall Goldenrod	Compositae
Solidago odora Alt.	Sweet Goldenrod	Compositae
Sorghum bicolor Moench.	Forage Sorghum	Gramineae
Sorghum halepense L.	Johnsongrass	Gramineae
Spermacoce prostrata Aubl.	Slender Buttonweed	Rubiaceae
Stachys floridana Shuttlew.	Florida Betony	Labiatae
Stillingia sylvatica L.	Queen's Delight	Euphorbiaeceae
Typha latifolia L.	Common Cat Tail	Typhaceae
Ulmus alata Michx.	Winged Elm	Ulmaceae
Vaccinium myrsinites Lam.	Shiny Blueberry	Ericaceae
Verbena brasiliensis Vell.	Brazilian Verbena	Verbenaceae
Vitis rotundifolia Michx.	Muscadine Grape	Vitaceae
Xyris elliottii Chapm.	Thin-Leafed Yellow Eyed Grass	Xyridaceae

In each primary trial, bahiagrass was present.

containing at least one sample site were Alachua, Bradford, Clay, Columbia, Gilchrist, Levy, Marion, Putnam, Suwannee, and Union. The sample sites were found in five distinct habitats including disturbed, freshwater marsh, high pine, oak hammock, and swamp. The number of sample sites in each habitat type was as follows: disturbed, 12; freshwater marsh, 4; high pine, 6; oak hammock, 2; swamp, 5. Plant community composition and habitat descriptions follow the descriptions found in Florida Natural Areas Inventory (1990).

Sites were chosen for their uniformity and even distribution of plant material in an effort to avoid areas with large plant aggregations that could skew the results. At each research site, a block of 100 by 100 m was partitioned. Within each block, seven 0.5 by 0.5-m sample units were disbursed at random throughout. These 0.5-m^2 squares were made of 1.25-cm-diameter PVC pipe. Once the square had been placed, each plant within the borders of the square was identified, and its percent cover within the square was determined (Daubenmire 1959). Next, all the plants within the square's perimeter were clipped, separated by species, and placed in paper bags. These plants were later dried to a constant weight in the laboratory and weighed to determine biomass. Overstory vegetation was not included.

Sample size might seem inadequate to characterize an entire plant community; however, variability within sites was not that great. For example, variance between the percent cover of *Aristida beyrichiana* in the six high pine study sites was only 83.4%. Also, in the 12 disturbed habitats, there was a variance of only 110.48% for the percent cover of *Conyza canadensis,* a key component of disturbed habitats in north Florida. A very common grass in swamp habitats is *Chasmanthium laxum,* which had a percent cover variance of only 177.3% within all study sites. In oak hammocks, the variance of the percent cover of *Quercus hemisphaerica* was 90.3% between sites. Therefore, we felt that seven samples were enough to characterize the plant communities and relate them to grasshopper abundance.

Grasshopper diversity was determined by sampling within the 100-m^2 plot at each site. The relative grasshopper abundance was estimated by walking a transect 100 m long by 1 m wide, counting and collecting each grasshopper with a 36-cm-diameter insect net as they flushed (Scherer 1997, Squitier and Capinera 2002b). If there were <40 grasshoppers per transect, three 100-m transects were walked to collect enough grasshoppers for accurate estimations. This transect was positioned randomly within each plot. The net was used as a wand to flush grasshopper in higher vegetation as suggested by Onsager and Henry (1977). However, in most cases the vegetation was low and not very dense.

All grasshoppers and plants were collected from each study site in a single day, with some rearing and identification done later in the laboratory. Each study site was sampled one time. Grasshoppers were collected, and their densities were estimated when the ambient temperature was the highest, between 1200 and 1600 hours. Field collecting and observations were carried out from May 2002 to October 2002.

Correlation analysis between some of the abundant grasshopper species (the same 10 species used in host plant preference studies) and plants were determined followed by multiple regression analysis to assess the relationship between grasshopper abundance and specific plants (MINITAB Statistical Software 2000).

Results and Discussion

In this study, 37 grasshopper species were collected from five habitats. During the course of sampling, 111 plant species were identified and collected. Both the percentage cover and biomass of the plants collected

Table 2. Correlation coefficient (*r*) between grasshopper density and abundance (biomass and percentage cover) of individual plant species

Aptenopedes sphenarioides	Cover (%)	Plant	*Sparganium americanum*	*Cyperus compressus*	*Eupatorium capillifolium*	*Andropogon virginicus*
		r	0.734	0.675	0.661	0.640
	Biomass (g)	Plant	*Sparganium americanum*	*Andropogon virginicus*	*Cyperus compressus*	*Panicum hemitomon*
		r	0.746	0.685	0.675	0.566
Chortophaga australior	Cover (%)	Plant	*Lepidium virginicum*	*Spermacoce prostrata*	*Oxalis stricta*	*Cenchrus echinatus*
		r	0.732	0.689	0.679	0.639
	Biomass (g)	Plant	*Lepidium virginicum*	*Conyza canadensis*	*Spermacoce prostrata*	*Cenchrus echinatus*
		r	0.737	0.689	0.627	0.585
Eritettix obscurus	Cover (%)	Plant	*Arisitida beyrichiana*	*Stillingia sylvatica*	*Ceratiola ericoides*	*Licania michauxii*
		r	0.936	0.847	0.802	0.732
	Biomass (g)	Plant	*Arisitida beyrichiana*	*Ceratiola ericoides*	*Quercus laevis*	*Licania michauxii*
		r	0.902	0.799	0.790	0.774
Melanoplus bispinosus	Cover (%)	Plant	*Conyza canadensis*	*Amaranthus spinosus*	*Richardia scabra*	*Digitaria bicornis*
		r	0.787	0.745	0.647	0.567
	Biomass (g)	Plant	*Conyza canadensis*	*Amaranthus spinosus*	*Spermacoce prostrata*	*Richardia scabra*
		r	0.810	0.682	0.655	0.637
Melanoplus querneus	Cover (%)	Plant	*Panicum equilaterale*	*Crataegus flava*	*Ulmus alata*	*Clematis reticulata*
		r	0.927	0.899	0.893	0.832
	Biomass (g)	Plant	*Panicum equilaterale*	*Ulmus alata*	*Dichondra carolinensis*	*Clematis reticulata*
		r	0.912	0.901	0.834	0.832
Paroxya clavuliger	Cover (%)	Plant	*Cyperus odoratus*	*Fuirena squarrosa*	*Limnobium spongia*	*Typha latifolia*
		r	0.918	0.918	0.918	0.918
	Biomass (g)	Plant	*Cyperus odoratus*	*Fuirena squarrosa*	*Limnobium spongia*	*Typha latifolia*
		r	0.918	0.918	0.918	0.918
Romalea microptera	Cover (%)	Plant	*Clematis reticulata*	*Crataegus flava*	*Ulmus alata*	*Smilax bona-ox*
		r	0.872	0.825	0.872	0.766
	Biomass (g)	Plant	*Clematis reticulata*	*Ulmus alata*	*Dichondra carolinensis*	*Smilax bona-ox*
		r	0.872	0.836	0.799	0.750
Schistocerca americana	Cover (%)	Plant	*Amaranthus spinosus*	*Sorghum bicolor*	*Wahlenbergia marginata*	*Oenothera laciniata*
		r	0.625	0.588	0.58	0.568
	Biomass (g)	Plant	*Sorghum halepense*	*Amaranthus spinosus*	*Sorghum bicolor*	*Chenopodium ambroioides*
		r	0.654	0.622	0.588	0.540
Schistocerca ceratiola	Cover (%)	Plant	*Stillingia sylvatica*	*Lupinus villosus*	*Ceratiola ericoides*	*Smilax auriculata*
		r	0.887	0.819	0.817	0.809
	Biomass (g)	Plant	*Stillingia sylvatica*	*Lupinus villosus*	*Smilax auriculata*	*Vaccinium myrsinites*
		r	0.828	0.819	0.815	0.812
Spharagemon crepitans	Cover (%)	Plant	*Quercus geminata*	*Cladina evansii*	*Quercus hemisphaerica*	*Quercus myrtifolia*
		r	0.993	0.909	0.878	0.611
	Biomass (g)	Plant	*Quercus geminata*	*Quercus hemisphaerica*	*Cladina evanasii*	*Quercus myrtifolia*
		r	0.996	0.953	0.900	0.611

Shown are the four plant species with the most significant ($P < 0.05$) Pearson correlation coefficients.

Table 3. Plant species most significant in multiple regression equation of grasshopper abundance, with t value, r, and R^2

Aptenopedes sphenarioides		Plant	*Sparganium americanum*	*Panicum hemitomon*	*Erechtites hieraciifolia*	*Aristitida beyrichiana*
	Cover (%)	t	5.61	5.93	3.14	3.89
		r	0.734	0.574	0.425	0.080
		R^2	53.86	80.39	85.93	91.37
		Plant	*Eupatorium capillifolium*	*Smilax auriculata*	*Panicum hemitomon*	
	Biomass (g)	t	5.46	−3.27	2.82	
		r	0.448	0.065	0.566	
		R^2	69.61	83.91	90.65	
Chortophaga australior		Plant	*Lepidium virginicum*	*Cechrus echinatus*	*Oxalis stricta*	*Ambrosia artemisiifolia*
	Cover (%)	t	5.59	5.72	−3.47	3.98
		r	0.732	0.639	0.679	0.142
		R^2	53.64	79.47	86.14	91.65
		Plant	*Lepidium virginicum*	*Oxalis stricta*	*Oenothera laciniata*	*Indigofera hirsuta*
	Biomass (g)	t	3.80	3.70	2.68	2.53
		r	0.737	0.578	0.579	0.154
		R^2	56.77	81.78	89.87	94.37
Eritettix obscurus		Plant	*Aristida beyrichiana*	*Pinus palustris*		
	Cover (%)	t	13.78	13.68		
		r	0.936	0.587		
		R^2	87.56	98.48		
		Plant	*Ceratiola ericoides*	*Pinus palustris*		
	Biomass (g)	t	2.17	4.63		
		r	0.799	0.587		
		R^2	54.08	94.36		
Melanoplus bispinosus		Plant	*Conyza canadensis*	*Brassica kaber*	*Polypremum procumbens*	*Cenchrus echinatus*
	Cover (%)	t	6.62	−4.18	4.51	5.00
		r	0.787	−0.005	0.275	0.511
		R^2	61.89	77.20	87.42	93.83
		Plant	*Digitaria bicornis*	*Rubus cuneifolius*	*Aster dumosus*	*Erechtites hieraciifolia*
	Biomass (g)	t	2.82	−2.74	−2.68	−3.66
		r	0.57	−0.069	0.041	−0.120
		R^2	49.91	75.86	89.00	97.02
Melanoplus querneus		Plant	*Panicum equilaterale*	*Ximenia americana*		
	Cover (%)	t	12.83	22.36		
		r	0.927	0.317		
		R^2	85.91	99.3		
		Plant	*Rubus cuneifolius*			
	Biomass (g)	t	7.57			
		r	−0.098			
		R^2	98.28			
Paroxya clavuliger		Plant	*Typha latifolia*	*Xyris elliottii*		
	Cover (%)	t	12.01	35.74		
		r	0.918	0.360		
		R^2	84.24	99.69		
		Plant	*Eupatorium capillifolium*	*Fuirena squarrosa*	*Sacciolepis striata*	
	Biomass (g)	t	3.67	4.32	3.14	
		r	0.849	0.918	0.918	
		R^2	56.43	91.88	97.89	

Table 3. Continued

Romalea microptera		Plant	*Clematis reticulata*	*Chasmanthium laxum*		
	Cover (%)	*t*	9.27	8.76		
		r	0.872	0.540		
		R^2	76.09	93.95		
		Plant	*Panicum equilaterale*	*Liquidambar styraciflua*		
	Biomass (g)	*t*	4.76	47.79		
		r	0.694	0.138		
		R^2	87.82	99.99		
Schistocerca americana		Plant	*Amaranthus spinosus*	*Chenopodium ambrosioides*	*Sesbania exaltata*	*Digitaria bicornis*
	Cover (%)	*t*	4.08	4.80	4.87	−5.42
		r	0.625	0.541	0.292	0.103
		R^2	39.08	68.27	84.03	92.99
		Plant	*Sorghum halepense*	*Chenopodium ambrosioides*	*Cynodon dactylon*	*Cenchrus echinatus*
	Biomass (g)	*t*	4.41	5.61	6.12	3.79
		r	0.375	0.301	0.136	0.352
		R^2	42.79	74.70	90.11	93.92
Schistocerca ceratiola		Plant	*Stillingia sylvatica*	*Rhus copallinum*		
	Cover (%)	*t*	10.00	−30.18		
		r	0.887	−0.065		
		R^2	78.75	99.41		
		Plant	*Aristida beyrichiana*	*Ceratiola ericoides*		
	Biomass (g)	*t*	8.29	32.34		
		r	0.565	0.632		
		R^2	86.42	99.32		
Spharagemon crepitans		Plant	*Quercus geminata*	*Quercus hemesphaerica*		
	Cover (%)	*t*	45.24	−17.24		
		r	0.993	0.878		
		R^2	98.70	99.90		
		Plant	*Quercus geminata*			
	Biomass (g)	*t*	7.14			
		r	0.996			
		R^2	98.07			

at each study site were determined to further define the structure of the plant community. By collecting from a number of locations and habitats, significant correlations ($P < 0.05$) between 10 common grasshopper species and plants were determined (Table 2). Multiple regression analysis was used to further describe the relationship between the plants and these 10 grasshoppers (Table 3). The 10 grasshoppers chosen for study were *A. sphenarioides* Scudder, *C. australior* (Rehn and Hebard), *E. obscurus* (Scudder), *M. bispinosus* Scudder, *M. querneus* Rehn and Hebard, *P. clavuliger* (Serville), *R. microptera* (Beauvois), *S. americana* (Drury), *S. ceratiola* Hubbell and Walker, and *S. crepitans* (Saussure). Many of these grasshoppers can be found in more than one habitat type; however, they are usually dominant in at least one specific habitat type (Squitier and Capinera 2002b).

Host Plant Preferences. Virtually all grasshopper species showed some degree of preference among the plants presented in each five-choice test (Table 4).

The species examined from freshwater marsh habitats were *A. sphenariodes* and *P. clavuliger.* Freshwater marshes are usually wet, treeless areas in which emergent grasses and forbs dominate.

Aptenopedes sphenariodes showed a definite preference for *Elephantopus elatus* followed by *Erechtites hieraciifolia, Pityopsis graminifolia, Fuirena squarrosa,* and *P. notatum. A. sphenarioides* can be found in most of Florida's habitat types; however, they seem to be most abundant in freshwater marshes and lakeside habitats (Squitier and Capinera 2002b). In the case of *A. sphenarioides,* the obviously forbivorous mandibles are at odds with their mixed feeding behavior (Smith and Capinera 2005). While *A. sphenarioides* preferred *E. elatus,* they did feed on some grasses as well, including *P. notatum,* and especially *F. squarrosa. E. elatus* is uncommon in freshwater marshes, where the related *Elephantopus nudatus* is much more common, but *E. elatus* can be found on the dry sandy outskirts of these areas. *F. squarrosa* is an emergent sedge very common in the marsh itself, often forming a dense mat in the more shallow areas. *P. notatum* can be found at the very edge of the waterline and all along the banks of these areas.

Paroxya clavuliger showed a preference for *Limnobium spongia* followed by *F. squarrosa, Sagittaria lancifolia, Sesbania exaltata,* and *P. notatum. P. clavuliger* is known to feed on *Typha latifolia* (Scherer 1997, Squitier and Capinera 2002a) but did not seem so inclined in this study. Again, this species displayed forbivorous-type mandibles (Smith and Capinera 2005), but did choose to feed on *F. squarrosa* in one test. Overall, however, *P. clavuliger* seemed to prefer forbs, particularly *L. spongia,* a very common emergent plant in freshwater marshes.

The three species examined from disturbed habitats were *C. australior, M. bispinosus,* and *S. americana.* Disturbed habitats have a very large and diverse floral complement. These habitats are typically found in roadside areas or fallow fields in the first stage of ecological succession. Annual and perennial grasses and forbs dominate these areas.

Chortophaga australior showed a preference for *Eleusine indica* followed by *Digitaria ciliaris, P. notatum, Amaranthus spinosus,* and *Cenchrus echinatus. C. australior* showed an almost universal preference in choice tests for commonly occurring grasses, particularly *E. indica,* with the exception of *A. spinosus,* which is a common forb. Their mandible morphology suggests a mixed diet (Smith and Capinera 2005), which is reinforced by the data obtained in choice tests.

Melanoplus bispinosus showed a preference for *Richardia scabra* followed by *P. notatum, Gnaphalium pensylvanicum, Brassica kaber,* and *Digitaria bicornis. M. bispinosus* also preferred a mixture of grasses and forbs in choice tests, namely *R. scabra* and *P. notatum,* both very common in this habitat. Once again, these findings are supported by their herbivorous mouthpart morphology (Smith and Capinera 2005).

Schistocerca americana was the most extensively studied species in this report. *S. americana* showed a preference for *Digitaria ischemum* and *Chamaesyce hyssopifolia,* followed by *S. exaltata, Smilax bona-nox, Cyperus esculentus, C. echinatus, Chamaecrista fasciculata, Panicum maximum, Panicum hemitomon,* and *P. notatum. S. americana* is one of the few grasshoppers examined in this study for which there is some feeding data recorded. These grasshoppers can be found in almost every habitat in Florida (Squitier and Capinera 2002b), and they display herbivorous mandibles (Smith and Capinera 2005). Capinera (1993) found that, while *S. americana* fed readily on *P. notatum,* they quickly moved to feed on other, more preferred plants, including crabgrass (*Digitaria* spp.), and later in the season, to spurge (*Chamaesyce* spp.). Scherer (1997) also found that *S. americana* showed an inclination to feed on *P. notatum.* In this study, both *D. ischemum* and *C. hyssopifolia* were preferred host plants. As found by Capinera (1993), when faced with obviously nonpreferred plants, *S. americana* would feed freely on *P. notatum.* Throughout the growing season, both *P. notatum* and most *Digitaria* species are common in disturbed areas. Later in the season, *C. hyssopifolia* becomes a dominant forb.

Eritettix obscurus and *S. ceratiola* were collected from high pine habitats. This type of habitat is dominated by an overstory of *Pinus palustris* or *Quercus laevis* and a very open understory supporting a large number of grasses, primarily *A. beyrichiana.* This ecosystem is common throughout central and north central Florida, and *E. obscurus* is one of the most dominant grasshoppers found there.

Eritettix obscurus fed exclusively on *P. notatum* and *A. beyrichiana,* with a clear preference for *A. beyrichiana.* As Blatchley (1920) noted, these grasshoppers live on or within clumps of wiregrass, and choice tests showed this to be a major food source. *E. obscurus* definitely preferred *A. beyrichiana,* and to a lesser degree, *P. notatum.* These preferences coincide with other studies of Gomphocerinae in which they seemed to be mostly graminivorous (Isley 1944, Gangwere 1965, Joern 1983). The fact that their mandibles

Table 4. Plant Consumption in five-choice trials by grasshoppers

Grasshopper species	Plant species and associated mean consumption values ± SD				
Aptenopedes sphenarioides	*Paspalum notatum*	3.7 ± 0.7a	*Andropogon virginicus*	1.1 ± 0.3b	*Aristida beyrichiana*
	Paspalum notatum	1.6 ± 0.5b	*Fuirena squarrosa*	3.5 ± 0.5a	*Limnobium spongia*
	Paspalum notatum	1.1 ± 0.3b	*Ceratiola ericoides*	1.0 ± 0.0b	*Pityopsis graminifolia*
	Paspalum notatum	1.2 ± 0.4b	*Centrosema virginianum*	1.0 ± 0.0b	*Croton argyranthemus*
	Paspalum notatum	1.1 ± 0.3c	*Erechtites hieraciifolia*	4.4 ± 0.5a	*Lachnanthes caroliniana*
	Paspalum notatum[a]	1.0 ± 0.0c	*Elephantopus elatus*	4.1 ± 0.6a	*Erechtites hieraciifolia*
Chortophaga australior	*Paspalum notatum*	1.3 ± 0.5b	*Amaranthus spinosus*	4.4 ± 0.7a	*Eupatorium capillifolium*
	Paspalum notatum	3.8 ± 0.4a	*Cynodon dactylon*	1.2 ± 0.4b	*Sida rhombifolia*
	Paspalum notatum	4.6 ± 0.5a	*Conyza canadensis*	1.0 ± 0.0b	*Gnaphalium pensylvanicum*
	Paspalum notatum	4.4 ± 0.5a	*Andropogon virginicus*	1.2 ± 0.4b	*Aristida beyrichiana*
	Paspalum notatum	1.3 ± 0.5b	*Alysicarpus vaginalis*	1.5 ± 0.5b	*Cenchrus echinatus*
	Paspalum notatum	1.8 ± 0.6b	*Chamaecrista fasciculata*	1.1 ± 0.3c	*Chenopodium ambrosioides*
	Paspalum notatum	1.0 ± 0.0b	*Bidens alba*	1.2 ± 0.4b	*Desmodium tortuosum*
	Paspalum notatum[a]	1.2 ± 0.4c	*Amaranthus spinosus*	1.1 ± 0.3c	*Cenchrus echinatus*
Eritettix obscurus	*Paspalum notatum*	1.3 ± 0.5b	*Andropogon virginicus*	1.0 ± 0.0b	*Aristida beyrichiana*
	Paspalum notatum	4.0 ± 0.7a	*Ceratiola ericoides*	1.0 ± 0.0b	*Quercus geminata*
	Paspalum notatum	3.7 ± 0.5a	*Centrosema virginianum*	1.0 ± 0.0b	*Croton argyranthemus*
Melanoplus bispinosus	*Paspalum notatum*	4.2 ± 0.6a	*Panicum maximum*	1.5 ± 0.5b	*Smilax bona-nox*
	Paspalum notatum	3.2 ± 0.8b	*Brassica kaber*	3.8 ± 0.8a	*Conyza canadensis*
	Paspalum notatum	1.6 ± 0.7b	*Amaranthus spinosus*	1.0 ± 0.0c	*Eupatorium capillifolium*
	Paspalum notatum	2.4 ± 0.8b	*Bidens alba*	1.1 ± 0.3d	*Desmodium tortuosum*
	Paspalum notatum	3.4 ± 0.7a	*Cynodon dactylon*	1.4 ± 0.5b	*Sida rhombifolia*
	Paspalum notatum	3.3 ± 0.9a	*Ambrosia artemisiifolia*	1.3 ± 0.7b	*Aster dumosus*
	Paspalum notatum[a]	1.8 ± 0.9b	*Brassica kaber*	1.4 ± 0.5b	*Digitaria bicornis*
Melaonplus querneus	*Paspalum notatum*	1.8 ± 0.8b	*Chasmanthium laxum*	1.0 ± 0.0c	*Panicum equilaterale*
	Paspalum notatum	1.1 ± 0.3c	*Aster durmosus*	3.8 ± 0.6a	*Clematis reticulata*
	Paspalum notatum	1.0 ± 0.0c	*Habenaria floribunda*	4.1 ± 0.6a	*Osmunda cinnamomea*
	Aster dumosus[a]	1.0 ± 0.0d	*Clematis reticulata*	1.3 ± 0.5c,d	*Habenaria floribunda*
Paroxya clavuliger	*Paspalum notatum*	1.1 ± 0.3b	*Pontederia cordata*	1.1 ± 0.3b	*Sagittaria lancifolia*
	Paspalum notatum	4.1 ± 0.7a	*Ambrosia artemisiifolia*	1.0 ± 0.0c	*Baccharis halimifolia*
	Paspalum notatum	2.2 ± 0.6b	*Cyperus surinamensis*	1.4 ± 0.5c	*Eupatorium capillifolium*
	Paspalum notatum	1.3 ± 0.5b	*Cyperus odoratus*	1.2 ± 0.4b	*Fuirena squarrosa*
	Paspalum notatum[a]	1.0 ± 0.0d	*Fuirena squarrosa*	2.2 ± 0.6b	*Limnobium spongia*
Romalea microptera	*Paspalum notatum*	1.4 ± 0.7b	*Chasmanthium laxum*	1.2 ± 0.4b	*Panicum equilaterale*
	Paspalum notatum	1.9 ± 0.7c	*Acer rubrum*	1.0 ± 0.0d	*Aster dumosus*
	Paspalum notatum	1.0 ± 0.0b	*Fuirena squarrosa*	1.4 ± 0.5b	*Limnobium spongia*
	Paspalum notatum	1.1 ± 0.3c	*Habenaria floribunda*	3.4 ± 0.7a	*Osmunda cinnamomea*
	Aster dumosus[a]	1.0 ± 0.0c	*Habenaria floribunda*	1.9 ± 1.1b	*Quercus nigra*
Schistocerca americana	*Paspalum notatum*	3.3 ± 1.2a	*Diospyros virginiana*	1.0 ± 0.0b	*Smilax bona-nox*
	Paspalum notatum	3.8 ± 0.6a	*Pontederia cordata*	1.1 ± 0.3c	*Sagittaria lancifolia*
	Paspalum notatum	4.2 ± 0.4a	*Aster dumosus*	1.0 ± 0.0b	*Chenopodium ambrosioides*
	Paspalum notatum	3.4 ± 1.0a	*Amaranthus spinosus*	1.0 ± 0.0c	*Eupatorium capillifolium*
	Paspalum notatum	3.6 ± 1.3b	*Cyperus surinamensis*	1.4 ± 0.5c	*Sacciolepis striata*
	Paspalum notatum	4.8 ± 0.4a	*Lepidium virginicum*	1.0 ± 0.0c	*Oxalis stricta*
	Paspalum notatum	1.8 ± 0.4c	*Crotalaria lanceolata*	1.2 ± 0.4d	*Cyperus esculentus*
	Paspalum notatum	1.5 ± 0.7b	*Chamaecrista fasciculata*	5.0 ± 0.0a	*Erechtites hieraciifolia*
	Paspalum notatum	1.3 ± 0.5b	*Alysicarpus vaginalis*	1.5 ± 1.0b	*Cenchrus echinatus*
	Paspalum notatum	2.4 ± 0.5b	*Crotalaria spectabilis*	1.5 ± 0.5c	*Lachnanthes caroliniana*
	Paspalum notatum	1.4 ± 0.7c	*Fatoua villosa*	1.1 ± 0.3c	*Panicum maximum*
	Paspalum notatum[a]	1.3 ± 0.5c	*Cyperus esculentus*	1.3 ± 0.5c	*Digitaria ischaemum*
	Cenchrus echinatus[a]	2.1 ± 0.6b	*Chamaecrista fasciculata*	1.7 ± 0.7b,c	*Chamaesyce hyssopifolia*
Schistocerca ceratiola	*Paspalum notatum*	1.0 ± 0.0b	*Aristida beyrichiana*	1.0 ± 0.0b	*Asimina obovata*
	Paspalum notatum	1.0 ± 0.0a	*Andropogon virginicus*	1.0 ± 0.0a	*Licania michauxii*
	Paspalum notatum	1.0 ± 0.0a	*Centrosema virginianum*	1.0 ± 0.0a	*Elephantopus elatus*
Spharagemon crepitans	*Paspalum notatum*	1.6 ± 0.7b	*Andropogon virginicus*	1.1 ± 0.3c	*Panicum hemitomon*
	Paspalum notatum	1.9 ± 0.7b	*Centrosema virginianum*	2.7 ± 0.7a	*Cladina evansii*

apparently evolved for grass feeding reinforces these findings (Smith and Capinera 2005).

Schistocerca ceratiola refused all plants except *C. ericoides,* lending credence to the long-suspected theory that they are completely monophagous (Capinera et al. 2001). They rejected all other plants presented to them. *C. ericoides* is found only in extremely xeric sandhill ecosystems such as scrub and high pine. While not usually a dominant plant in these areas, it can be quite common under the right conditions. Because *C. ericoides* is the only plant on which *S. ceratiola* feeds, their forb-feeding mandibles seem appropriate (Smith and Capinera 2004).

From swamp habitats, *M. querneus* and *R. microptera* were examined. Swamp habitats are usually found along rivers and streams and contain standing water at least annually. Trees that typify these areas are cypress, palms, maples, and sweetgums. Vines, epiphytes, and tall grasses are also features of swamps.

While grasshopper diversity is quite low in these areas, *M. querneus* is very common within them in northern Florida and southern Georgia. *M. querneus*

Table 4. Continued

Plant species and associated mean consumption values ± SD				*F*	*P*	df
Licania michauxii	1.0 ± 0.0b	*Rhus copallinum*	1.0 ± 0.0b	94.43	0.0001	4,45
Ludwigia peruviana	1.0 ± 0.0c	*Sacciolepis striata*	1.0 ± 0.0c	107.6	0.0001	4,45
Stillingia sylvatica	1.0 ± 0.0b	*Vaccinium myrsinites*	1.0 ± 0.0b	93.33	0.0001	4,45
Elephantopus elatus	3.6 ± 0.8a	*Eriogonum tomentosum*	1.0 ± 0.0b	73.58	0.0001	4,45
Panicum hemitomon	1.0 ± 0.0c	*Xyris elliottii*	1.2 ± 0.4c	127.5	0.0001	4,45
Fuirena squarrosa	1.2 ± 0.4c	*Pityopsis graminifolia*	1.8 ± 0.6b	42.54	0.0001	4,45
Richardia scabra	1.1 ± 0.3b	*Sorghum bicolor*	1.6 ± 0.7b	77.68	0.0001	4,45
Solanum americanum	1.1 ± 0.3b	*Verbena brasiliensis*	1.1 ± 0.3b	131.7	0.0001	4,45
Rubus cuneifolius	1.0 ± 0.0b	*Spermacoce prostrata*	1.0 ± 0.0b	250.2	0.0001	4,45
Licania michauxii	1.0 ± 0.0b	*Rhus copallinum*	1.0 ± 0.0b	253.4	0.0001	4,45
Chamaesyce hyssopifolia	1.1 ± 0.3b	*Indigofera hirsuta*	1.0 ± 0.0b	52.95	0.0001	4,45
Eleusine indica	4.2 ± 0.4a	*Paspalum dilatatum*	1.5 ± 0.5b	90.37	0.0001	4,45
Digitaria ciliaris	3.7 ± 0.4a	*Sorghum halepense*	1.5 ± 0.5b	72.52	0.0001	4,45
Digitaria ciliaris	1.7 ± 0.7b	*Eleusine indica*	4.2 ± 0.6a	71.88	0.0001	4,45
Licania michauxii	1.0 ± 0.0b	*Rhus copallinum*	1.0 ± 0.0b	116.2	0.0001	4,45
Quercus laevis	1.0 ± 0.0b	*Stillingia sylvatica*	1.0 ± 0.0b	202.5	0.0001	4,45
Pityopsis graminifolia	1.0 ± 0.0b	*Rhynchosia reniformis*	1.0 ± 0.0b	312.4	0.0001	4,45
Solidago canadensis	1.0 ± 0.0b	*Vitis rotundifolia*	1.2 ± 0.4b	87.19	0.0001	4,45
Rubus cuneifolius	1.0 ± 0.0c	*Sorghum halepense*	1.2 ± 0.4c	64.27	0.0001	4,45
Richardia scabra	4.7 ± 0.5a	*Sorghum bicolor*	1.3 ± 0.7c	105.2	0.0001	4,45
Digitaria bicornis	3.0 ± 0.7a	*Spermacoce prostrata*	1.0 ± 0.0d	18.96	0.0001	4,45
Solanum americanum	1.0 ± 0.0b	*Verbena brasiliensis*	1.5 ± 0.7b	39.74	0.0001	4,45
Gnaphalium pensylvanicum	2.6 ± 1.1a	*Oenothera laciniata*	1.3 ± 0.7b	10.84	0.0001	4,45
Gnaphalium pensylvanicum	1.6 ± 0.8b	*Richardia scabra*	4.0 ± 0.8a	24.37	0.0001	4,45
Smilax bona-nox	4.4 ± 0.5a	*Ulmus alata*	1.4 ± 0.7b,c	73.74	0.0001	4,45
Liquidambar styraciflua	1.5 ± 0.7c	*Vitis rotundifolia*	1.6 ± 0.5c	30.08	0.0001	4,45
Panicum virgatum	1.0 ± 0.0c	*Quercus nigra*	3.2 ± 0.8b	116.9	0.0001	4,45
Quercus nigra	1.7 ± 0.7c	*Smilax bona-nox*	3.2 ± 0.6b	74.57	0.0001	4,45
Salix caroliniana	1.0 ± 0.0b	*Typha latifolia*	1.4 ± 0.5b	97.29	0.0001	4,45
Elephantopus nudatus	1.6 ± 0.5b	*Setaria geniculata*	1.2 ± 0.4b,c	88.08	0.0001	4,45
Saururus cernuus	1.0 ± 0.0c	*Sesbania exaltata*	4.3 ± 0.8a	71.48	0.0001	4,45
Limnobium spongia	3.6 ± 1.1a	*Sacciolepis striata*	1.0 ± 0.0b	37.76	0.0001	4,45
Sagittaria lancifolia	1.6 ± 0.7c	*Sesbania exaltata*	1.1 ± 0.3d	62.01	0.0001	4,45
Smilax bona-nox	4.4 ± 0.5a	*Ulmus alata*	1.1 ± 0.3b	83.72	0.0001	4,45
Clematis reticulata	1.3 ± 0.5c,d	*Vitis rotundifolia*	2.6 ± 0.8b	25.39	0.0001	4,45
Sagittaria lancifolia	3.9 ± 0.3a	*Sesbania exalta*	1.5 ± 1.0b	56.56	0.0001	4,45
Panicum virgatum	1.1 ± 0.3c	*Quercus nigra*	2.6 ± 1.1b	32.61	0.0001	4,45
Sagittaria lancifolia	3.9 ± 0.9a	*Smilax bona-nox*	1.0 ± 0.0c	29.59	0.0001	4,45
Solidago canadensis	1.0 ± 0.0b	*Vitis rotundifolia*	1.0 ± 0.0b	33.28	0.0001	4,45
Salix caroliniana	1.2 ± 0.4c	*Typha latifolia*	1.9 ± 0.7b	56.25	0.0001	4,45
Conyza canadensis	1.0 ± 0.0b	*Oenothera laciniata*	1.1 ± 0.3b	263	0.0001	4,45
Richardia scabra	1.4 ± 0.7c	*Sorghum bicolor*	2.5 ± 1.4b	16.07	0.0001	4,45
Saururus cernuus	1.0 ± 0.0c	*Sesbania exaltata*	4.8 ± 0.4a	74.05	0.0001	4,45
Sida rhombifolia	1.0 ± 0.0c	*Solidago odora*	1.0 ± 0.0c	202.7	0.0001	4,45
Digitaria ischaemum	4.8 ± 0.4a	*Gnaphalium pensylvanicum*	1.0 ± 0.0d	109.9	0.0001	4,45
Heterotheca subaxillaris	1.0 ± 0.0c	*Rhynchosia reniformis*	1.0 ± 0.0c	305	0.0001	4,45
Chamaesyce hyssopifolia	3.5 ± 0.7a	*Indigofera hirsuta*	1.3 ± 0.7b	24.18	0.0001	4,45
Panicum hemitomon	3.6 ± 0.5a	*Polypremum procumbens*	1.0 ± 0.0d	75.82	0.0001	4,45
Spermacoce prostrata	2.6 ± 0.8b	*Stachys floridana*	1.0 ± 0.0c	54.06	0.0001	4,45
Sesbania exaltata	2.7 ± 0.7b	*Smilax bona-nox*	1.5 ± 0.5c	64.56	0.0001	4,45
Panicum hemitomon	1.1 ± 0.3c	*Panicum maximum*	1.4 ± 0.5c	53.05	0.0001	4,45
Ceratiola ericoides	4.4 ± 0.5a	*Croton argyranthemus*	1.0 ± 0.0b	433.5	0.0001	4,45
Pityopsis graminifolia	1.2 ± 0.4a	*Quercus laevis*	1.0 ± 0.0a	2.43	0.0611	4,45
Eriogonum tomentosum	1.0 ± 0.0a	*Rhynchosia reniformis*	1.2 ± 0.4a	2.25	0.0785	4,45
Quercus hemisphaerica	1.0 ± 0.0c	*Quercus myrtifolia*	1.0 ± 0.0c	25.23	0.0001	4,45
Elephantopus elatus	1.0 ± 0.0c	*Smilax auriculata*	1.0 ± 0.0c	29.35	0.0001	4,45

[a] Indicates a secondary test trial of preferred plants.
Consumption was rated on a 1–5 scale (see text for details). Also shown are statistics associated with each row of data.
Consumption values within the same row followed by the same letter are not significantly different by SNK, $P = 0.05$.

showed a preference for *Habenaria floribunda*, followed by *S. bona-nox*, *Quercus nigra*, *Clematis reticulata*, and *Aster dumosus*. *R. microptera* showed a preference for *Sagittaria lancifolia*, followed by *H. floribunda*, *Q. nigra*, *S. bona-nox*, and *A. dumosus*. These grasshoppers displayed forbivorous mandibles (Smith and Capinera 2005). *M. querneus* seemed to prefer *S. bona-nox* and *H. floribunda* above all else. *S. bona-nox* is common in swamps, although *H. floribunda* is not. However, wet shaded areas, usually swamps, are the only areas in Florida these orchids can be found.

Romalea microptera is another well-studied grasshopper species and can be found in a number of moist habitats. This species displays the classic forbivorous mandible structure (Smith and Capinera 2005). In choice tests, *R. microptera* only palpated grasses cursorily before moving on to other more palatable plants.

R. microptera has been documented to prefer *Sagittaria* (Squitier and Capinera 2002a) and *Smilax* (Scherer 1997). Once again, these findings are consistent with this study, in which *R. microptera* showed an overall preference for *S. lancifolia* and to a lesser degree *S. bona-nox. S. lancifolia* is an emergent plant found in open, sunny environments in seasonal ponds or roadside ditches. *S. bona-nox*, however, is one of the most common vines in moist habitats with a fairly dense overstory.

Spharagemon crepitans was the only species tested from oak hammock. While not necessarily a scrub habitat, oak hammocks are considered to be climax communities of sandhill and scrub ecosystems (Soil and Water Conservation Service 1989). Oak hammocks, both the overstory and understory, are dominated by various species of *Quercus.* Some grasses appear sparsely, with occasional vines, but most of the understory is open, bare sand. These areas are home to one of Florida's most secretive grasshoppers, *S. crepitans. S. crepitans* had particularly low consumption values. While true host plant preferences could not be determined conclusively, these grasshoppers fed on *P. hemitomon* and *C. virginianum,* showing a mixed diet of grasses and forbs consistent with their mixed feeding mandibles (Smith and Capinera 2005). Neither of these plants is particularly common in oak hammocks; however, *S. crepitans* was disinclined to feed on any of the dominant *Quercus* species presented.

Most of the grasshoppers examined in this study have poorly understood host plant preferences. For many, this study is the first documentation of their feeding behavior. With the exceptions of *S. ceratiola,* which seems to be entirely monophagous, and *E. obscurus,* which seems to be oligophagous, all grasshoppers examined in this study were polyphagous. However, even the polyphagous species displayed preferences.

As a whole, the order Orthoptera is considered to be polyphagous in nature. However, many studies carried out in the laboratory involving the presentation of several food types to grasshoppers, as well as field observations, have proven that grasshoppers are quite selective when given a number of choices (Mulkern 1967). Joern (1986) stated that, while most forbivorous grasshoppers are monophagous or polyphagous, most graminivorous grasshoppers are oligophagous.

Correlation of Grasshopper Abundance with Measures of Plant Community Structure. The grasshoppers examined from disturbed habitats were *C. australior, M. bispinosus,* and *S. americana. C. australior* showed the strongest positive correlation with *Lepidium virginiana.* This plant is a very common winter annual in almost every type of disturbed habitat (i.e., roadside, fallow fields, pastures, and old fields). Choice tests have shown that this is not a host plant of *C. australior;* therefore, we consider *L. virginiana* to be an indicator species, correlated with plants and habitats preferred by *C. australior.* Another plant that showed a high positive correlation with *C. australior* was *C. echinatus.* This grass is a common summer annual in disturbed habitats, usually dry sandy areas, and is a preferred host plant of *C. australior.*

Melanoplus bispinosus showed the strongest positive correlation with *C. canadensis. C. canadensis* is a very common forb in the summer and fall in almost every type of open disturbed habitat throughout northern Florida. *M. bispinosus* showed no inclination to feed on *C. canadensis* in choice tests, so this plant is considered to be an indicator species. *R. scabra,* a common summer annual and a known host plant of *M. bispinosus,* was also highly correlated with the abundance of this grasshopper.

Schistocerca americana was highly correlated with both *A. spinosus* and *Sorghum halepense,* both common plants throughout the growing season. *Schistocerca americana* did not feed on *A. spinosus* in choice tests, and *S. halepense* was not tested. Another plant highly correlated with the occurrence of *S. americana* was *Sorghum bicolor,* a very close relative of *S. halepense.* While not a preferred food plant in choice tests, *S. americana* did feed on *S. bicolor* to some degree.

The grasshopper species examined from freshwater marsh habitats were *A. sphenarioides* and *P. clavuliger. A. sphenarioides* abundance showed the strongest positive correlation with *S. americanum. S. americanum* is a common emergent reed in freshwater marshes and lakeside habitats and is usually seen in late spring and throughout the summer. This plant was not offered in choice tests; consequently, determinations as to its palatability could not be determined. Therefore, *S. americanum* was considered to be a possible indicator plant. Interestingly, *Andropogon virginicus* was also highly correlated with *A. sphenarioides. A. virginicus* does not occur in freshwater marshes but is a common perennial in disturbed and sandy woodland habitats. This seeming discrepancy can be explained by the tendency of *A. sphenarioides* to inhabit at least 10 distinct Florida habitats (Squitier and Capinera 2002b). Although *A. sphenarioides* is usually most abundant in freshwater marshes and other hydric habitats, it does occur in many other habitats. This explains why they can be associated with plants outside of their preferred habitats.

Paroxya clavuliger abundance showed the strongest positive correlation with *Cyperus odoratus. C. odoratus* is a common sedge on the edges of, or within, freshwater marshes and roadside ditches where water level fluctuations occur regularly. This plant can be considered an indicator species, because in choice tests, *P. clavuliger* did not consume it. However, other highly correlated plants found almost exclusively in freshwater marshes such as *F. squarrosa, L. spongia,* and *T. latifolia* are known host plants of *P. clavuliger* (Squitier and Capinera 2002a).

The grasshopper species examined from high pine habitats were *E. obscurus* and *S. ceratiola.* Because of their restricted host range, both of these grasshoppers are somewhat anomalous among the Acrididae. The plant most highly correlated with *E. obscurus* was *A. beyrichiana,* which was one of only two plants that *E. obscurus* consumed during choice tests. In high pine habitats, *A. beyrichiana* is virtually ubiquitous year round but is not found in many other habitats. The fact that *E. obscurus* lives within, and feeds on, clumps of *A. beyrichiana* gives this grasshopper a very limited habitat range. Therefore, *A. beyrichiana* is an excellent indicator plant as well as a host plant for *E. obscurus.*

Schistocerca ceratiola, however, has an even more limited range in that it can only be found on, or in very close proximity to, *C. ericoides.* Therefore, whereas *S. ceratiola* may not be a dominant grasshopper in every high pine habitat in central Florida, in most cases where there is a large aggregation of *C. ericoides,* this grasshopper is abundant. The plant with the strongest positive correlation to *S. ceratiola* was *Stillingia sylvatica,* which, while not an abundant perennial, can only be found in high pine and sandhill communities. This plant is a major indicator for this habitat therefore is highly correlated with this specialized grasshopper. Naturally, *S. ceratiola* was also highly correlated with *C. ericoides,* and in choice tests, *C. ericoides* seemed to be the only plant *S. ceratiola* would consume. Therefore, *C. ericoides* can be considered both a host plant and an indicator plant for *S. ceratiola.*

Spharagemon crepitans was the only grasshopper examined from oak hammocks. Although this grasshopper will occasionally show up in high pine or scrub habitats, it usually is abundant only in oak hammocks. These habitats have a very low understory and are almost completely dominated by *Quercus geminata, Q. hemisphaerica,* and *Q. incana.* The lichen *Cladina evansii* is also very common on the soil surface in these areas. Therefore, it was inevitable that these plants were the most highly correlated with *S. crepitans* numbers. In choice tests, *S. crepitans* did not feed heavily on any of the plants presented to it, including *Q. geminata* and *C. evansii;* therefore, no host plant determinations could be made. Consequently, high concentrations of *Quercus* in the presence of *C. evansii* seemed to be the best indicator for these grasshoppers.

The grasshopper species examined from swamp habitats were *M. querneus* and *R. microptera. M. querneus* abundance showed the highest positive correlation with *Panicum equilaterale.* This grass is not commonly associated with swamp habitats; however, in north central Florida, many riverside swamps are actually found in quite sandy areas where *P. equilaterale* occurs. While not a host plant, this grass acts as an excellent indicator species for *M. querneus,* which seems to prefer higher sandy swamps, especially those associated with the Santa Fe River and its tributaries. *M. querneus* definitely showed a preference in choice tests for *C. reticulata,* which was also highly correlated with this grasshopper. *C. reticulata,* like *P. equilaterale,* occurs in higher, sandy swamps associated with fast moving rivers.

Romalea microptera was also highly correlated with *C. reticulata* and, whereas *Romalea* did show a slight preference for this plant in choice tests, overall, this plant was considered to be an indicator plant rather than a host plant. However, *S. bona-nox,* which was also highly correlated with *R. microptera,* was readily fed on in choice tests and subsequently can be considered both an indicator as well as a host plant. *S. bona-nox* is a very common vine in swamps, as well as other low wet areas with a thick canopy.

These aforementioned correlations were made between one grasshopper species and each plant occurring in their habitats. The grasshopper/plant correlations were remarkably similar when using either plant cover or biomass as a sampling method for estimating plant abundance. This is very significant considering the difference in time and effort involved in the two sampling techniques. Estimating the coverage of plants was done visually and, in most cases, very quickly. Contrasted with the clipping, bagging, drying, and weighing of plant material involved in determining biomass, it is obvious that using plant cover as an estimating technique for floral composition is more expedient and less strenuous for the researcher.

Multiple Regression Analysis of Grasshopper Abundance with Measures of Plant Community Structure. *Aptenopedes sphenarioides* is a common grasshopper found throughout Florida, as well as southern Georgia and Alabama. It can be found in numerous habitats. However, it is usually only abundant in lakeside and marsh ecosystems (Squitier and Capinera 2002b). Multiple regression analyses of *A. sphenarioides* abundance in relation to plant cover suggested that *S. americanum, P. hemitomon, E. hieraciifolia,* and *A. beyrichiana* were the most important, whereas *E. capillifolium, Smilax auriculata,* and *P. hemitomon* were the most important, when considering plant biomass. These six plants explain most of the variability, with *P. hemitomon* occurring in both the percent cover and biomass analyses. Of these plants, only *E. hieraciifolia* is a known host plant, whereas both *A. beyrichiana* and *P. hemitomon* were rejected in choice tests. Also, because *A. sphenarioides* occurs in so many different habitats, the plants associated with it may be dominant in habitats other than freshwater marshes. *E. capillifolium, E. hieraciifolia,* and *P. hemitomon* can be found in disturbed habitats, as well as more hydric marsh habitats, whereas *A. beyrichiana* and *S. auriculata* are usually found in dry habitats associated with upland ecosystems. However, *S. americanum* is only found in wet marsh-like habitats. Therefore, in wet habitats, the presence of *S. americanum, E. capillifolium, E. hieraciifolia,* and *P. hemitomon* should point to the presence of *A. sphenarioides.* In drier, sandy habitats, the presence of *A. beyrichiana* and *S. auriculata* should strongly indicate the presence of *A. sphenarioides.*

Chortophaga australior is a common grasshopper throughout Florida and adjacent southern states. Although this grasshopper may occur in wooded areas, it is much more numerous in open, often disturbed, habitats (Squitier and Capinera 2002b). Multiple regression analyses of *C. australior* abundance in relation to plant cover revealed that *L. virginicum, C. echinatus, Oxalis stricta,* and *Ambrosia artemisiifolia* were most important, whereas *L. virginicum, O. stricta, Oenothera laciniata,* and *Indigofera hirsuta* were the most important when considering plant biomass. These six plants accounted for most of the grasshopper variability, with *L. virginicum* and *O. stricta* occurring in both the cover and biomass analysis. Of these plants, only *C. echinatus* is a known host plant, and *I. hirsuta* was rejected in choice tests. All of the plants associated with *C. australior* can be found in disturbed habitats and were considered indicator species, especially when found together.

Eritettix obscurus is found only in peninsular Florida and inhabits upland ecosystems such as high pine and scrub habitats, where it can be quite numerous (Squitier and Capinera 2002b). Multiple regression analyses of *E. obscurus* abundance in relation to plant cover indicated that *A. beyrichiana* and *Pinus palustris* were the most significant plants, whereas *C. ericoides* and *P. palustris* were the most important when considering plant biomass. These three plants explain most of the variability, with *P. palustris* present in both the cover and biomass analysis. Of these plants, *A. beyrichiana* is the only plant that *E. obscurus* consumed in choice tests, and *C. ericoides* was rejected outright. Because *C. ericoides* often occurs alongside *A. beyrichiana,* taken together, these plants are excellent indicators for the presence of *E. obscurus.* The association of *P. palustris* with *E. obscurus* is to be expected, given that *P. palustris* and *Q. laevis* are the dominant trees in high pine habitats.

Melanoplus bispinosus is commonly found in Florida north of Lake Okeechobee and its range extends to other southern states and as far west as Texas and Oklahoma. Although sometimes found in wooded habitats, this grasshopper is usually associated with disturbed, open habitats (Squitier and Capinera 2002b). Multiple regression analyses of *M. bispinosus* in relation to plant cover suggested that *C. canadensis, B. kaber, Polypremum procumbens,* and *C. echinatus* were the most important determinants of abundance, whereas *D. bicornis, Rubus cuneifolius, A. dumosus,* and *E. hieraciifolia* were the most important when considering biomass. These eight plants explain most of the variability, with none of them occurring in both the cover and biomass analysis. *M. bispinosus* showed a preference for *B. kaber* and *D. bicornis* in choice tests, while rejecting *C. canadensis* and *R. cuneifolius.* All of these plants can be found in disturbed habitats, and taken together, are excellent indicators for *M. bispinosus.*

Melanoplus querneus can be found in swamps and hardwood hammocks throughout north Florida and parts of southern Georgia and Alabama. This grasshopper prefers woodland habitats, particularly near rivers or streams (Squitier and Capinera 2002b). Multiple regression analyses of *M. querneus* abundance in relation to plant cover suggested that *P. equilaterale* and *Ximenia americana* were the most important, whereas *R. cuneifolius* was the most important when considering plant biomass. These three plants explain most of the variability in *M. querneus* abundance, with none occurring in the analyses of both plant cover and biomass. In choice tests, *M. querneus* did not show any preference for *P. equilaterale,* and neither *X. americana* nor *R. cuneifolius* were offered in choice tests. *X. americana* is usually associated with sandy environments; however, as explained earlier, many swamp habitats associated with alluvial systems in north Florida and southern Georgia are quite sandy and have a high elevation in relation to surrounding areas. *R. cuneifolius* is also found in sandy habitats, but can also be found in wetter swamp habitats as well as more disturbed areas. However, *R. cuneifolius* showed a strong negative correlation with *M. querneus* but did explain most of the variability in the regression equation when considering plant biomass, so this plant was not considered an indicator plant. While not preferred food plants, the presence of *X. americana* and *P. equilaterale* together is a good indication that *M. querneus* will be present.

Paroxya clavuliger occurs throughout Florida as well as most of the eastern United States. It is usually found in wet areas like freshwater and saltwater marshes as well as in lakeside habitats (Squitier and Capinera 2002b). Multiple regression analyses of *P. clavuliger* abundance in relation to plant cover suggested that *T. latifolia* and *Xyris elliottii* were the most important, whereas *E. capillifolium, F. squarrosa,* and *Sacciolepis striata* were the most important when considering plant biomass. These five plants account for most of the variability, but none occur in both the plant cover and biomass analyses. Of these plants, only *F. squarrosa* was found to be a host plant in choice tests. However, Squitier and Capinera (2002a) found that *P. clavuliger* showed a preference for *T. latifolia* in choice tests. *E. capillifolium* was not considered to be a very good indicator species because it shows up in so many different habitats. However, *S. striata* and *X. elliottii* are usually found in open lakeside or marsh habitats, making them very good indicator species, and the probability of finding *P. clavuliger* increases considerably when *F. squarrosa* and *T. latifolia* are found in the same area.

Romalea microptera is found throughout Florida and the southern United States and as far west as eastern Texas. It seems to be most common in low, wet areas such as swamps and roadside ditches (Squitier and Capinera 2002b). However, these grasshoppers disperse quite readily during their nymphal instars. Multiple regression analyses of *R. microptera* abundance in relation to plant cover revealed that *C. reticulata* and *C. laxum* were the most important, whereas *P. equilaterale* and *Liquidambar styraciflua* were the most important when considering plant biomass. Of these plants, *C. reticulata* was the only one that *R. microptera* preferred in choice tests. Although *R. microptera* usually fed on other plants presented to it, it did feed at least intermittently on *C. reticulata. R. microptera* was often found in areas with large numbers of *M. querneus;* therefore, while not a host plant, *P. equilaterale* was highly associated with *R. microptera. L. styraciflua* and *C. laxum* are almost always found in swamps or on the banks of streams and rivers. All of these plants are fairly habitat specific, and finding more than one of them together is an excellent indication that *R. microptera* can be found there as well.

Schistocerca americana is found from Florida to southern Canada and throughout the midwestern

United States. It can be found in almost every habitat type in Florida but is most abundant in disturbed habitats and pastures (Squitier and Capinera 2002b). Multiple regression analyses of *S. americana* abundance in relation to plant cover suggested that *A. spinosus*, *Chenopodium ambrosioides*, *S. exaltata*, and *D. bicornis* were the most important, whereas *S. halepense*, *C. ambrosioides*, *Cynodon dactylon*, and *C. echinatus* were the most important when considering plant biomass. These seven plants account for most of the variability, with *C. ambrosioides* occurring in both the plant cover and biomass analysis. In choice tests, *S. americana* showed a preference for *S. exaltata*, and although not a preferred host plant, these grasshoppers did feed on *C. echinatus*. Also, in choice tests, *S. americana* rejected *A. spinosus* and *C. ambrosioides*. *D. bicornis* was not offered in choice tests; however, a close relative, *Digitaria ischemum*, was one of the most preferred plants, and Capinera (1993) found that *S. americana* fed on several *Digitaria* species. All of these plants can be found in disturbed habitats and can act as indicator species.

Schistocerca ceratiola has an extremely limited geographic range. It occurs only in central Florida. *S. ceratiola* is found only in high sandy habitats where *C. ericioides* occurs (Squitier and Capinera 2002b). Multiple regression analyses of *S. ceratiola* in relation to plant cover suggested that *S. sylvatica* and *Rhus copallinum* were the most important, whereas *A. beyrichiana* and *C. ericoides* were the most important when considering plant biomass. These four plants explain most of the variability in *S. ceratiola* abundance, with none of the plants occurring in the analyses of both plant cover and biomass. *C. ericoides* is the only known host plant of *S. ceratiola*. In fact, in choice tests, when *C. ericoides* was not offered *S. ceratiola*, the grasshoppers would often die of starvation before the termination of the test trial. So, although *A. beyrichiana* was rejected in choice tests, it often occurs in areas where *C. ericoides* is found. *S. sylvatica* and *R. copallinum* are also found in dry sandy habitats in close association with *C. ericoides*. However, *C. ericoides* is the only plant that can act as a true indicator species for *S. ceratiola* because it not only feeds on, but lives within, *C. ericoides* bushes.

Spharagemon crepitans can be found throughout Florida and extreme southern Georgia. Very shady oak hammocks seem to be the only place these grasshoppers occur in large numbers (Squitier and Capinera 2002b). Multiple regression analyses of *S. crepitans* abundance in relation to plant cover indicated that *Q. geminata* and *Q. hemisphaerica* were the most important, whereas *Q. geminata* was the most important when considering plant biomass. These two plants explain most of the variability in *S. crepitans* numbers, with *Q. geminata* occurring in both types of analysis. Neither *Q. geminata* nor *Q. hemisphaerica* were consumed in choice tests. However, when these two oaks are found in quantity, they act as very good indicators for the presence of *S. crepitans*.

Correlations made using multiple regression analysis linked groups of plants to specific grasshoppers. In this case, a plant highly correlated with a grasshopper was also highly correlated with other plants occurring in the presence of the same grasshopper. Therefore, a plant that may have been nonpreferred in choice tests was, in fact, highly correlated because of it being a characteristic of the preferred habitat. In this instance, the results varied greatly when either plant cover or plant biomass was sampled. These findings indicate that on a one-on-one basis between a plant and a grasshopper either sampling technique was sufficient to determine correlations. However, when linking multiple plants to specific grasshoppers and complicating the overall model, the effectiveness of these techniques differs greatly.

Results from this study suggest that within preferred habitats the abundance of certain grasshoppers can be associated with certain plants. This relationship is sometimes based on nonpreferred host plants, although these plants are integral to the overall habitat choice. These grasshopper/plant associations help to explain the grasshopper's habitat preference by recognizing elements of plant communities that are linked (autocorrelated) to their abundance. For 10 grasshopper species and five habitats, the most important host plants and indicator plants were determined. This allows us to make more accurate predictions as to the presence or absence of certain grasshoppers within habitat types and provide insight into possible food plants. It also helps explain why not all examples of a particular habitat contain a completely predictable assemblage of grasshoppers.

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