Influence of Plant Parameters on Occurrence and Abundance of Arthropods in Residential Turfgrass

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ABSTRACT The effect of taxa [common Bermuda grass, *Cynodon dactylon* (L.); centipedegrass, *Eremochloa ophiuroides* Munro Hack; St. Augustinegrass, *Stenotaphrum secundatum* [Walt.] Kuntze; and zoysiagrass, *Zoysia* spp.], density, height, and weed density on abundance of natural enemies, and their potential prey were evaluated in residential turf. Total predatory Heteroptera were most abundant in St. Augustinegrass and zoysiagrass and included Anthocoridae, Lasiochilidae, Geocoridae, and Miridae. Anthocoridae and Lasiochilidae were most common in St. Augustinegrass, and their abundance correlated positively with species of Blissidae and Delphacidae. Chinch bugs were present in all turf taxa, but were 23–47 times more abundant in St. Augustinegrass. Anthocorids/lasiochilids were more numerous on taller grasses, as were Blissidae, Delphacidae, Cicadellidae, and Cercopidae. Geocoridae and Miridae were most common in zoysiagrass and were collected in higher numbers with increasing weed density. However, no predatory Heteroptera were affected by grass density. Other beneficial insects such as staphylinids and parasitic Hymenoptera were captured most often in St. Augustinegrass and zoysiagrass. These differences in abundance could be in response to primary or alternate prey, or reflect the influence of turf microenvironmental characteristics. In this study, Simpson's diversity index for predatory Heteroptera showed the greatest diversity and evenness in centipedegrass, whereas the herbivores and detritivores were most diverse in St. Augustinegrass lawns. These results demonstrate the complex role of plant taxa in structuring arthropod communities in turf. An increased understanding of how turf species and cultivars help shape pest and beneficial arthropod communities will enhance predictive abilities and further pest management objectives.

KEY WORDS predatory Heteroptera, turfgrass, arthropod diversity, insect–plant interactions

The turfgrass ecosystem supports a diverse arthropod community (Potter and Braman 1991). Species diversity and seasonal abundance of select groups of turfgrass inhabitants have been studied in detail, e.g., Collembola (Rochefort et al. 2005), Carabidae, and Staphylinidae (Braman and Pendley 1993a,b; Rochefort et al. 2006). Evaluation of pesticide use, mowing and fertilization has illustrated a resilient beneficial arthropod community that is influenced by cultural practices offering opportunities for modifying pest management practices (Cockfield and Potter 1983; Vavrek and Niemczyk 1990; Terry et al. 1993; Braman and Pendley 1993a; Kunkel et al. 1999, 2001; Byrne and Bruns 2005; Carstens et al. 2007).

One of the best opportunities to manage turfgrass pests is by deploying pest-resistant plants. Many advances in identifying resistant germplasm and/or potential underlying mechanisms of resistance to turfgrass pests have been made (for review, see Reinert et al. 2004). Furthermore, the influences of pest-resistant grasses on predators and parasitoids and the role of these grasses in mediating pest response to insecticides have been explored (Braman et al. 2003, 2004a,b). Focused studies on beneficial arthropods in particular grass species such as buffalograss, *Buchloë dactyloides* (Nuttall) (Heng-Moss et al. 1998), have led to a better understanding of potential natural enemies of pests that routinely affect those grasses.

Frank and Shrewsbury (2004)) and Braman et al. (2002) demonstrated that conservation plantings could be important tools in enhancing conservation biological control. Thatch thickness is positively correlated with abundance of hairy chinch bug, *Blissus leucopterus hirsutus* Montandon, in cool-season turf (Davis and Smitley 1990a,b). Infested lawns in that study also had significantly less Kentucky bluegrass, *Poa pratensis* L., versus fine fescue, *Festuca rubra* L., than uninfested lawns. Predators (Geocoridae, Nabidae, Formicidae, Reduviidae, Carabidae, and spiders) also were significantly positively correlated with thatch thickness in that study.

Although grass species and cultivar are known to affect occurrence and abundance of common pest insects such as southern chinch bug, *Blissus insularis*

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Barber; twolined spittlebug, *Prosapia bicincta* (Say); and fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Brandenburg and Villani 1995), plant-related factors that may influence natural enemies in turf are not well understood. Grassy lawns are the most common urban plantings, but residential properties are heterogeneous, even in local contiguous communities. Earlier field plot studies provided insights into the role of turfgrass taxa in structuring beneficial arthropod communities (Braman et al. 2000, 2002, 2003, 2004a). We undertook this study to determine to what extent warm-season turfgrass taxa and other turf parameters may influence the abundance of predaceous Heteroptera and other foliar-dwelling natural enemies and their potential prey in residential turfgrass.

Materials and Methods

Study Sites for Survey. Twenty University of Georgia employees volunteered their lawns for our study within Spalding County. Three monthly visits to the 20 sites were conducted between 25 May and 26 July 2005. All samples were collected between 1000 and 1200 hours and between 1400 and 1700 hours. Lawns were maintained by the homeowners, not by commercial landscape professionals. No insecticides were applied, but two homeowners made one application of atrazine and imazapyr herbicides to control weeds. Four warm-season turfgrass species were surveyed, including two common Bermuda grass, *Cynodon dactylon* (L.); nine centipedegrass, *Eremochloa ophiuroides* Munro Hack; six St. Augustinegrass, *Stenotaphrum secundatum* [Walt.] Kuntze; and three zoysiagrass, *Zoysia* spp., lawns.

Arthropod Sampling. Vacuum and sweep samples were collected from each lawn on three dates in May, June, and July, 2005. Samples were collected from a 9.2- by 9.2-m area, further subdivided into quadrants of 4.6 by 4.6 m. Vacuum samples consisted of 20 suctions of 10-s duration using a 'Vortis' vacuum sampler (Burkhard Manufacturing Co., Ltd., Herefordshire, England) from each quadrant. The Vortis vacuum sampler opening area was 0.02 m^2; thus, 0.4 m^2 were sampled per quadrant with air throughput of 10.5 m^3/min. Samples were cleaned, labeled, and stored in ethanol (70%). Subsequently, arthropods were sorted, identified, and counted. Sweep samples were collected using a standard beating net (Wards, Rochester, NY) by taking 25 sweeps along the diagonal of the 9.2- by 9.2-m area delineated at each residence. Sweep samples were transferred to plastic bags, frozen, cleaned, sorted, and stored in 70% ethanol for processing.

Plant Parameters Evaluated. Grass taxa, density, height, and weed taxa and density were recorded from each lawn on each date. Grass density was assessed using a plastic strip 8.5 cm in length, 6.5 cm in width, and 1 mm in thickness, with a 2.5-cm^2 opening in the center. This plastic strip was randomly dropped in a plot and the number of grass blades passing through the 2.5-cm^2 area was recorded. Four density readings were averaged for each lawn and sampling date. Weed species were noted and density assessed by counting the number of weeds on a diagonal transect across the 9.2- by 9.2-m plot or number of all weeds per 13.0 m.

Statistical Analysis. Data were transformed by taking the square root of the insect count plus 0.5. The MIXED procedure in SAS (SAS Institute 2003) was used to perform a mixed model analysis of covariance. Turfgrass species and sample date were fixed, classification effects; grass density, grass height, and weed density were continuous effects; and homeowner lawn was treated as a random effect. Differences in least square means were determined by pairwise *t*-tests and letter grouping were assigned accordingly. Relationships among various groups of insects were assessed using the correlation procedure of SAS. Only taxa with adequate numbers for meaningful comparison were analyzed.

Diversity of arthropod families inhabiting the different turf species was compared using Simpson's diversity index (D) (Magurran 1988, Siemann et al. 1997). Arthropods were grouped into five categories: heteropteran predators, other turf predators, herbivores and detritivores, others, and the total. Heteropteran predators included Anthocoridae/Lasiochilidae, Geocoridae, Miridae, Nabidae, Reduviidae, and predaceous Pentatomidae that were collected. The category other turf predators included all Araneae, Staphylinidae, Formicidae, Chrysopidae, Anisolabididae, and Phlaeothripidae. The herbivores and detritivores category was composed of Blissidae, Alydididae, Scutelleridae, Cicadellidae, Delphacidae, Membracidae, Aphididae, Cercopidae, Thripidae, Curculionidae, Elateridae, Sminthuridae, combined Entomobryidae and Isotomidae, and Oribatidae. The category others included Hymenoptera, Diptera, Orthoptera, Coleoptera, Lepidoptera, and Psocoptera. Separate diversity indices were calculated for the three monthly sample dates.

Proportion of families (total individuals per family, i) relative to the sum of the total numbers of individuals from all families (p_i) were calculated and squared. The squared proportions for all the families were summed and the reciprocal was calculated.

$$D = \frac{1}{\sum_{i=1}^{S} p_i^2}$$

Simpson's D is proportional to equitability for taxon richness (S) (sum of families from each category, where at least one individual from each family is collected). Therefore, if equitability increases, richness also increases for a particular community. Simpson's equitability (E_D) otherwise called evenness can be calculated by taking the total of the maximum possible families assumed to be present in a turfgrass system. Equitability (E_D) values fall between 0 and 1 and maximum evenness occurs if the value is 1 for the following:

Table 1. Influence of date and turfgrass parameters on arthropod abundance in vacuum samples

Arthropod taxon[a]	Grass taxa			Date			Grass ht			Grass density			Weed density		
	F	df	*P*	*F*	df	*P*	*F*	df	*P*	*F*	df	*P*	*F*	df	*P*
Heteroptera	6.2	3	<0.001	2.9	2	NS	8.2	1	0.005	3.9	1	NS	1.6	1	NS
Pre. Heteroptera	4.4	3	0.002	3.3	2	0.04	3.2	1	NS	1.8	1	NS	5.6	1	0.01
Anthocoridae	7.7	3	<0.001	2.0	2	NS	18.1	1	<0.001	2.9	1	NS	0.0	1	NS
Geocoridae	4.9	3	<0.001	9.3	2	<0.001	1.6	1	NS	0.5	1	NS	10.3	1	0.001
Miridae	5.6	3	<0.001	2.0	2	NS	0.4	1	NS	0.0	1	NS	5.1	1	0.03
Blissidae	9.2	3	<0.001	9.2	2	<0.001	16.3	1	<0.001	4.7	1	0.03	0.7	1	NS
Cicadellidae	1.1	3	NS	9.3	2	<0.001	24.8	1	<0.001	2.2	1	NS	9.9	1	0.001
Delphacidae	10.7	3	<0.001	1.4	2	NS	42.0	1	<0.001	3.6	1	NS	0.1	1	NS
Aphididae	1.5	3	NS	15.9	2	<0.001	2.1	1	NS	1.3	1	NS	0.9	1	NS
Cercopidae	3.4	3	0.01	3.4	2	0.01	29.3	1	<0.001	2.2	1	NS	0.2	1	NS
Diptera	2.0	3	NS	16.9	2	<0.001	5.4	1	0.02	2.4	1	NS	5.3	1	0.02
Hymenoptera	4.3	3	0.003	2.3	2	NS	15.3	1	<0.001	0.2	1	NS	1.7	1	NS
Formicidae	2.4	3	NS	0.6	2	NS	11.0	1	0.001	11.0	1	0.001	0.0	1	NS
Coleoptera	4.4	3	0.002	6.4	2	0.002	1.9	1	NS	0.0	1	NS	4.8	1	0.03
StaphylinidaeA	0.9	3	0.05	11.9	2	<0.001	6.1	1	0.01	0.6	1	NS	0.1	1	NS
StaphylinidaeL	4.6	3	0.001	11.4	2	<0.001	4.1	1	0.04	0.1	1	NS	0.2	1	NS
Cicadellidae	1.1	3	NS	9.3	2	<0.001	24.8	1	<0.001	2.2	1	NS	9.9	1	0.001
Sminthuridae	3.2	3	0.02	8.5	2	<0.001	0.4	1	NS	10.9	1	0.001	2.6	1	NS
Other Collembola	2.9	3	0.03	6.4	2	0.002	3.2	1	NS	1.7	1	NS	0.0	1	NS
Phlaeothripidae	1.5	3	NS	0.0	2	NS	2.2	1	NS	1.3	1	NS	5.2	1	0.02
Thripidae	1.4	3	NS	13.8	2	<0.001	0.0	1	NS	6.7	1	0.01	4.2	1	0.04
Acari	1.4	3	NS	3.1	2	0.05	5.8	1	0.02	0.1	1	NS	4.4	1	0.04
Araneae	2.4	3	0.05	0.6	2	NS	15.5	1	<0.001	3.9	1	0.05	1.5	1	NS

[a] Pre. Heteroptera, predatory Heteroptera; A, adult; L, larvae.

$$E_D = \frac{D}{S}$$

The diversity and evenness indices were calculated for each category and analyses comparing diversity and evenness among grass taxa were conducted using PROC GLM procedure of SAS (SAS Institute 2003).

Results

In total, 333,278 arthropods were identified primarily at the family level, of which 24,699 and 308,579 were captured in sweep and vacuum samples, respectively. Arthropods in vacuum samples represented 92% of the total individuals collected. The order Hemiptera accounted for 12% of the total arthropods. Of the total number of hemipterans collected, 73% were captured in vacuum samples. Most of the heteropterans (92.3%) were found in vacuum samples, in which 86.6% were nymphs and 13.4% were adults. In contrast, of the ≈8% of total heteropterans captured in sweep samples, 80.7% were adults. Predatory heteropterans were most common in vacuum (89%) rather than sweep samples. Arthropods were consistently better represented in vacuum samples, so subsequent analysis focused on arthropods obtained by this method.

Influence of Turfgrass Species on Arthropod Abundance. Abundance of most hemipterans was significantly influenced by turfgrass taxa, except Cicadellidae and Aphididae (Table 1). Among other arthropod groups quantified, only collembolans, thrips, mites, and dipterans did not vary with turfgrass taxa. Hemipterans were found in all turfgrass taxa and were most abundant in St. Augustinegrass (Tables 1 and 2). Hemipteran families included Alydidae, Anthocoridae, Aphididae, Blissidae, Cercopidae, Cicadellidae, Delphacidae, Geocoridae, Miridae, Nabidae, Pentatomidae, Reduviidae, and Tingidae. Those families sufficiently abundant for further analysis included combined Anthocoridae and Lasiochilidae, Blissidae, Cercopidae, Cicadellidae, Delphacidae, Geocoridae, and Miridae. Among the phytophagous families, Blissidae, represented by the southern chinch bug, *Blissus insularis* Barber, was present in all four turf taxa, but was 23–47 times more abundant in St. Augustinegrass (Table 2). Cicadellidae were statistically similar in abundance among the turf types. Cercopidae were more often collected in centipedegrass and St. Augustinegrass. Delphacidae were most common in St. Augustinegrass. Total predatory Heteroptera consisted of Anthocoridae, Lasiochilidae, Geocoridae, Miridae, Nabidae, Pentatomidae, and Reduviidae and were most often collected in St. Augustinegrass and zoysiagrass. Anthocoridae and Lasiochilidae combined, Miridae, and Geocoridae were collected in sufficient numbers for further analysis at the family level. The anthocorids/lasiochilids, *Orius insidosus* (Say) and *Lasiochilus palidulus* Reuter, were most common in St. Augustinegrass (Table 2). Although previously placed in the family Anthocoridae, Schuh and Stys (1991) elevated the subfamily Lasiochilinae to family status, which seems to be gaining general acceptance (Schuh and Slater 1995). Anthocorid/lasiochilid abundance correlated positively and significantly with Blissidae ($r = 0.7$, $P < 0.001$) and Delphacidae ($r = 0.9$, $P < 0.001$). The geocorids *Geocoris uliginosus* Say, *Geocoris punctipes* Say, and *Isthmocoris piceus* (Say) were most common in zoysiagrass as adults, whereas nymphs were equally as common in centipedegrass. The predaceous mirid species identified as *Spanagonicus albofasciatus* (Reuter), was also most commonly collected in zoysiagrass. Among other beneficial arthropods, spiders were most common in St. Augustine-

Table 2. Mean ± SE number of arthropods per 0.4-m^2 vacuum sample from 20 residential lawns, Spalding Co., GA

Arthropods	Bermudagrass	Centipedegrass	St. Augustinegrass	Zoysiagrass
Hemiptera total	48.3 ± 28.6b	79.1 ± 20.4b	226.9 ± 109.7a	56.5 ± 24.2b
Heteroptera	2.5 ± 1.2b	1.6 ± 0.2b	23.8 ± 17.9a	18.6 ± 12.3a
Predatory Heteroptera	2.2 ± 1.1b	1.1 ± 0.2b	7.8 ± 5.2a	17.9 ± 11.7a
Anthocoridae	0.2 ± 0.1b	0.2 ± 0.1b	7.0 ± 5.2a	0.1 ± 0.1b
Geocoridae	0.2 ± 0.1c	0.7 ± 0.2b	0.3 ± 0.1c	1.0 ± 0.1a
Miridae	1.6 ± 1.1b	0.2 ± 0.1b	0.3 ± 0.1b	16.1 ± 11.0a
Blissidae	0.3 ± 0.1b	0.4 ± 0.1b	15.8 ± 12.7a	0.7 ± 0.5b
Cicadellidae	43.9 ± 28.2a	72.5 ± 19.4a	80.1 ± 52.9a	33.1 ± 13.1a
Delphacidae	1.0 ± 0.7b	7.9 ± 3.6b	108.3 ± 49.2a	6.6 ± 5.0b
Cercopidae	0.1 ± 0.1b	0.4 ± 0.2a	0.4 ± 0.2a	0.1 ± 0.1b
Sminthuridae	324.8 ± 122.9a	164.2 ± 34.2a	242.0 ± 71.5a	247.9 ± 93.9a
Other Collembola	667.9 ± 118.4a	420.2 ± 60.2a	493.0 ± 81.8a	547.6 ± 116.3a
Staphylinidae adult	0.4 ± 0.3c	1.2 ± 0.7b	3.5 ± 0.8a	2.2 ± 1.0ab
Staphylinidae larva	0.6 ± 0.4b	2.6 ± 0.9b	5.7 ± 4.2a	2.5 ± 0.9b
Formicidae	7.2 ± 2.0a	10.4 ± 22.5a	10.7 ± 1.5a	11.2 ± 2.0a
Parasitic Hymenoptera	8.9 ± 2.2b	9.7 ± 2.2b	21.5 ± 8.9a	13.2 ± 2.5a
Araneae	15.6 ± 2.2b	19.9 ± 3.3b	32.7 ± 9.4a	15.2 ± 2.9b
Thripidae	9.2 ± 6.3a	14.8 ± 9.3a	15.6 ± 8.9a	13.6 ± 6.8a
Phlaeothripidae	0.3 ± 0.1a	1.6 ± 1.1a	3.0 ± 1.5a	3.1 ± 2.1a
Diptera	11.2 ± 2.8a	20.2 ± 3.4a	27.3 ± 4.8a	17.3 ± 5.3a
Acari	107.2 ± 64.3b	346.9 ± 43.0a	498.5 ± 80.2a	324.2 ± 94.0a
Other Coleoptera	1.4 ± 0.5b	2.9 ± 0.5ab	4.0 ± 0.8a	3.2 ± 0.6a

Means followed by the same letter are not significantly different ($P > 0.05$; Fisher's LSD).

grass, whereas parasitic Hymenoptera and staphylinids were captured more often in St. Augustinegrass and zoysiagrass than in Bermuda grass or centipedegrass lawns.

Grass Density and Height as Determinants of Arthropod Abundance. Grass density was a less important factor affecting arthropod abundance than grass height (Table 1). None of the predatory heteropterans were influenced by grass density, but blissid and delphacid adults, spiders, thrips, and sminthurid collembolans were more abundant in denser grass. Cicadellidae, Delphacidae, Cercopidae, Diptera, Hymenoptera, Staphylinidae, Acari, and Araneae were more abundant in taller grass. In addition, anthocorid/lasiochilid nymphs and adults were significantly more common in taller turf, as were nymphal and adult chinch bugs. Geocorids, mirids, thrips, and collembolans were not affected by grass height.

Effect of Weed Density on Occurrence and Abundance of Turf Arthropods. The major broadleaf weed species observed included yellow woodsorrel (*Oxalis* spp.), plantain (*Plantago* spp.), common lespedeza [*Lespedeza sericea* (Thunb.) H. & A], ground ivy (*Glechoma hederacea* L.), dandelion (*Taraxacum officinale* Weber), hop clover (*Trifolium dubium* Sibth.), violet (*Viola* spp.), chickweed [*Drymaria cordata* (L.) Willd. ex Roem. and Schult.], white clover (*Trifolium repens* L.), hawksbeard [*Youngia japonica* (L.) DC.], and grassy weeds such as annual bluegrass (*Poa annua* L.), Bermuda grass (*Cynodon dactylon* L.), and southern crabgrass (*Digitaria ciliaris* (Retz) Koel. Anthocorids/lasiochilids, delphacids, aphids, cercopids, collembolans, staphylinids, spiders, formicids, and parasitic hymenopterans were independent of weed density. Geocorids and mirids, thrips, mites, leafhoppers, and flies were positively affected by weed density (Table 1).

Diversity and Evenness Indices for Arthropod Groups in Residential Turf. Simpson's diversity and evenness indices were significantly different among grass taxa for all arthropod categories (Table 3). Data are presented as original means ± SE. Greatest diver-

Table 3. Analysis of variance of Simpson's Diversity and Evenness indices among arthropods by turfgrass taxa from residential lawns sampled during May–July, 2005 in Spalding Co., GA

Category	Grass genotype			Sampling date		
	df	*F value*	*P* value	df	*F value*	*P* value
Simpson's diversity index (D)						
Heteropteran predators	3	3.98	0.04	2	12.53	0.001
Other turf predators	3	4.14	0.04	2	0.33	NS
Herbivores and detritivores	3	4.19	0.04	2	1.59	NS
Other orders	3	9.35	0.004	2	7.56	0.01
Total	3	4.57	0.03	2	1.80	NS
Simpson's equitability (evenness; E_D)						
Heteropteran predators	3	4.03	0.04	2	13.11	0.001
Other turf predators	3	3.90	0.04	2	0.93	NS
Herbivores and detritivores	3	3.88	0.04	2	1.65	NS
Other orders	3	4.13	0.04	2	20.31	<0.001
Total	3	4.57	0.03	2	1.23	NS

sity and evenness of arthropods were found in St. Augustinegrass (4.31 ± 1.29 and 0.17 ± 0.05, respectively). Sampling date was significant for predatory Heteroptera and others categories in this study. The predatory Heteroptera category showed the highest Simpson's diversity index in centipedegrass (2.49 ± 0.91) compared with the other three turfgrass taxa. The category other turf predators showed higher diversity in St. Augustinegrass (2.12 ± 0.32) and zoysiagrass (1.85 ± 0.23). Herbivores and detritivores were diverse in St. Augustinegrass (3.72 ± 0.97) compared with other turfgrasses. Diversity of predatory Heteroptera was higher on the second sampling date (2.99 ± 0.33) compared with the first and third sampling dates (Table 3).

Evenness for predatory Heteroptera was also highest on centipedegrass (0.41 ± 0.15). Other turf predators were patchier on Bermuda grass (0.24 ± 0.03) and more evenly distributed on the other turfgrasses. Herbivores and detritivores were most evenly distributed on St. Augustinegrass (0.26 ± 0.07) and least on Bermuda grass (0.17 ± 0.03). Evenness of other arthropod families collected from the samples was higher on zoysiagrass than other turfgrass taxa.

Discussion

Our study showed that the generalist predators in Heteroptera had colonized all warm-season turfgrass types but were not equally abundant among turfgrass taxa in residential settings. Abundance of total predatory Heteroptera followed the pattern zoysiagrass ≥ St. Augustinegrass > Bermuda grass ≥ centipedegrass. Mirids and geocorids were most abundant in zoysiagrass, and anthocorids/lasiochilids were most common in St. Augustinegrass in this study. In previous field plot studies, where zoysiagrass, Bermuda grass, and seashore paspalum (*Paspalum vaginatum* Schwartz) were compared, all predatory heteropterans (Miridae, Anthocoridae, and Geocoridae) were more abundant on seashore paspalum and Bermuda grass than on zoysiagrasses (Braman et al. 2003). In the previous study, predatory Heteroptera strongly correlated with Cicadellidae that were also significantly more numerous in paspalum and Bermuda grass than in zoysiagrass plots. Perhaps the grass taxa are more a determinant of predator abundance as host for primary or alternative prey rather than for any physiological or architectural property of the grasses themselves, although all the heteropteran groups in this study engage in some phytophagy. Geocoridae have shown nutritional flexibility when availability of prey density declines, feeding instead on plant parts such as pods, leaves, seeds and nectars (Eubanks and Denno 1999, Dunbar 1971). *G. punctipes* are considered foliage dwellers in vegetables and field crops (Eubanks and Denno 1999, Cosper et al. 1983) and on turfgrass (Dunbar 1971), but *G. uliginosus* is predominantly a ground dweller in turf (Braman et al. 2003). Carstens et al. (2007) determined that bigeyed bugs were more numerous in the chinch bug-susceptible buffalograss '378′ compared with the more resistant 'Prestige'. They speculated that higher numbers of bigeyed bugs reflected number of chinch bugs on the susceptible cultivar. In their study, higher numbers of bigeyed bugs also were found at higher nitrogen levels, again, possibly a reflection of higher prey numbers. Lower mowing heights in their study decreased chinch bugs and slightly increased bigeyed bug numbers.

Our study showed that geocorids and mirids, primarily *S. albofasciatus,* not only were most abundant in zoysiagrass lawns, they were more common in "weedy" lawns. On soybean, *Glycine max* (L.) Merr., this mirid fed mainly on the lepidopteran pests *Heliothis zea* (Boddie) and *Pseudoplusia includens* Walker (Neal et al. 1972). Some studies have suggested that mirid nymphs often feed on spider mite eggs and adults, bollworm eggs and larvae, lygus bug eggs, and all stages of banded whitefly (Butler 1965, Butler and Stoner 1965) and on weed species in cotton-growing areas (Stoner and Bottger 1965). The diet of *S. albofasciatus* has not been explored in turfgrass. Stoner and Bottger (1965) also indicate phytophagous tendencies of mirids when in high numbers on cotton and reported that pest control measures may be necessary during seedling stages of cotton.

Few studies have been conducted with anthocorids in turf grasses, although Reinert (1978) suggested their potential as predators of southern chinch bugs in Florida. Chinch bugs are serious turf pests in the southern United States, especially on St. Augustinegrass. Planthoppers, also common on St. Augustinegrass in our study, are often considered more a nuisance in residential turf than potential pest species (Potter and Braman 1991), although they have been reported as pests of St. Augustinegrass on Florida sod farms (Cherry et al. 2006). Anthocorids/lasiochilids as natural enemies of chinch bugs merit further study based on observed correlations. Vacuum sampling in St. Augustinegrass cultivar trials and insecticide study plots also have consistently demonstrated anthocorids and lasiochilids, especially *L. palidulus,* in close association with southern chinch bug (S.K.B., unpublished).

Arthropod fauna in St. Augustinegrass lawns were influenced by grass height, which varied from 3.8 to 12.9 cm. We found that minute pirate bugs, chinch bugs and planthoppers (Delphacidae) increased with grass height in St. Augustinegrass. The increase in minute pirate bugs may be in response to chinch bugs or planthoppers, or increase in mowing height may help by providing favorable microclimatic conditions for predators in turf. Smitley et al. (1998) also found greater diversity in ground-dwelling predatory beetles in golf rough (tall grass) regions than in green (shorter grass). Delphacids on golf courses in Japan were abundant and most common in longer grass (Yasuda et al. 2008). Mowing frequency varied from lawn to lawn and also might have affected the arthropod abundance in turfgrass.

Mirids increased with increasing weed density in lawns. They might have benefited from weeds in zoysiagrass, as supplemental nutritional resources or because of the presence of alternate prey items. Also, most of the lawns (60%) were exposed to partial sunlight, increasing the possibility of high moisture retention in certain turf locations that may in turn indirectly favor soil dwelling fauna such as collembolans (Frank and Shrewsbury 2004) and mites. Braman et al. (2000) also observed increased arthropod numbers in shaded turf with higher moisture content than areas fully exposed to sunlight. Collembolan density was also higher where there were larger patches of weed flora in some residential lawns. Frank and Shrewsbury (2004) suggested the likelihood that vegetation near the turfgrass could supply pollen to the turf area and directly benefit the collembolans. They considered the possibility of Collembola and leafhoppers as potential prey items for ground-dwelling, generalist predators in turf.

In conclusion, our study indicated the occurrence and abundance of predatory heteropterans were strongly influenced by turfgrass taxa as were other arthropods in residential turf. Several predator taxa were associated with abundance patterns of potential prey populations. More studies are needed to understand how the turfgrass environment, including resistance characteristics, helps structure the arthropod community and predatory efficiency on turf pests. Occurrence and abundance of anthocorids and lasiochilids suggest a fruitful area for further study as potential natural enemies of common pests in turf.

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