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SURVEYS OF WILD BEES (HYMENOPTERA: APOIDEA: ANTHOPHILA) IN ORGANIC FARMS OF ALACHUA COUNTY IN NORTH-CENTRAL FLORIDA

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ABSTRACT

Bee surveys were conducted at 5 organic vegetable farms and 1 wildflower farm in Alachua County in north-central Florida. Wild bees were collected passively with colored cups and actively with nets. A total of 4,662 bees was captured belonging to 28 genera and 95 species. *Nomada sulphurata* Smith is a new state record for Florida. The species count also includes 6 *Nomada* and 1 *Triepeolus* morphospecies which likely include undescribed species and additional new Florida records. Of 5 bee families, Apidae was represented by the most species (36), whereas 6 of the 8 most numerous species were Halictidae. A potential new host cleptoparasite association is reported between *Andrena* (*Melandrena*) *barbara* Bouseman and LaBerge and *Nomada imbricata* Smith. The results from these surveys of organic farms are compared to our recently reported surveys of bees in natural areas of Alachua County and with other Florida bee surveys. The most numerous species found on the farms were also numerous in the natural areas, whereas the least numerous species on the farms included many species not found in the natural areas.

Key Words: native bees, bee bowls, pollinator diversity, agricultural ecosystems

RESUMEN

Se realizaron muestreos de abejas en 5 fincas dedicadas a la producción de vegetales orgánicos y en 1 dedicada a la siembra de flores silvestres, en el condado de Alachua, en el norcentro de Florida. Un total de 4,662 individuos fueron capturados, pertenecientes a 28 géneros y 95 especies. La especie *Nomada sulphurata* Smith se registró por primer vez en el estado de Florida. Dentro de la lista de abejas capturadas destacan 6 morfoespecies del género *Nomada* y 1 del género *Triepeolus*, las cuales probablemente incluyen especies no descritas y reportes nuevos para Florida. De 5 familias de abejas, Apidae estuvo representada por la mayor cantidad de especies (36), mientras que 6 de las 8 especies más numerosas fueron Halictidae. Así mismo, se reporta una posible nueva asociación hospedero - cleptoparásito entre *Andrena* (*Melandrena*) *barbara* Bouseman y LaBerge y *Nomada imbricata* Smith. Estos resultados son comparados con resultados recientemente publicados de nuestros muestreos en áreas naturales del condado de Alachua, y con otros muestreos de abejas realizados en Florida. Las especies más numerosas fueron colectadas tanto en fincas como en áreas naturales, mientras que las especies menos abundantes en las fincas incluyeron muchas especies ausentes en las áreas naturales.

Translation of abstract by Laura Ávila.

More than 19,500 described species of bees are known world-wide, about 3,500 of which occur in the continental United States and Canada (Ascher & Pickering 2011). Wild bee populations from natural areas extend into adjacent cultivated land and contribute adventitiously and significantly to agricultural pollination (Kremen et al. 2002, 2004; Klein et al. 2003; Losey & Vaughan 2006; Kohler et al. 2008; Winfree et al. 2008). Honey bee losses have led to greater recognition and appreciation of the pollination services provided by wild bees and of the potential to enhance these services (Winfree et al. 2007a). However, natural bee populations are threatened by the disappearance of natural habitat due to land development and agricultural intensification (Buchmann & Nabhan 1996; Committee on the Status of Pollinators in North America 2007; Kearns et al. 1998; Kremen et al. 2002; Klein et al. 2007; Goulson et al. 2008). To help compensate for this loss, growers are encouraged to enhance bee habitat by providing forage and nesting sites on marginal farmland (Kells et al. 2001; Kremen et al. 2002; Shepherd et al. 2003; Loose et al. 2005; Vaughan et al. 2007).

Bees can be diverse in agricultural systems (Tuell et al. 2009), but the relative contribution of adjacent natural areas and the internal farm environments to the composition of the bee fauna is not sufficiently known. Bee populations are likely to be highly variable across different geographical regions, farming systems, and landscape patterns (Kremen et al 2004; Winfree et al 2008). To establish basic understanding of regional patterns among wild pollinators, surveys from both farms and natural areas are needed from each ecoregion. The relationship between the bee fauna of natural areas and farms in the southeastern US has yet to be well-characterized, and even state-level distributional patterns for bees are inadequately known across most of this region. As an initial step toward characterizing the diversity of bee populations in north-central Florida, we have been conducting a series of surveys in different plant communities and in agricultural landscapes. This report on the bees found in organic farms follows our previous paper on the bees captured in natural areas of Alachua County (Hall & Ascher 2010), permitting a comparison and contrast between these types of land.

Materials and Methods

Details about collecting and preparing the bees are described in Hall & Ascher (2010) and are largely modifications of the methods detailed in *The Very Handy Manual: How to Catch and Identify Bees and Manage a Collection* (Droege 2010). Painted plastic soufflé cups (white, fluorescent yellow, or fluorescent blue), filled with soapy water, were used to capture most of the bees in this study, which were attracted by the color and drowned in the water. For each collection, 24 to 48 cups were hung 10 to 20 cm above the ground vegetation on custom hand-bent wires stuck into the ground, placed about 5 m apart along curved or straight lines, for about 30 hrs. Bees were also collected while foraging on flowers or in flight by net or a hand-held vacuum (http://tech.groups.yahoo.com/group/beemonitoring/files/).

The farms surveyed are widely spaced in the north-central and southwestern parts of Alachua County. Listed in Table 1 are the geographical coordinates and sizes of the farms, the months and years when the collections were taken, and the numbers of collections from each farm. Collections from 3 of the vegetable farms and the wildflower farm (Andrews, Beville, Durando, Zinn) were done largely from Apr through Jun 2007, at the time of most crop flowering. Two farms, from which the most abundant initial bee collections were taken, were each sampled over a 1 yr period, from spring 2006 to spring 2007 (Koenig farm)

Table 1. Farms from which bees were collected.

Farms	Location	Size of farm - ha	Collections Months (# from cups - # from flowers)/ Year[1]
Andrews - Hammock Hollow Herbs	29°27'20"N 82° 8'44"W	2.5	4(1-1), 5(0-1), 6 /07
Beville - Promised Land Organics	29°51'12"N 82°26'29"W	13	4(1-1), 5/07
Durando - Possum Hollow Farm	29°48'22"N 82°27'11"W	5	3(0-1), 4(1-2), 5(1-1) /07
Koenig - Rosie's Organic Farm	29°38'14"N 82°28'10"W	4	5(2-2), 6(1-1), 10 /06; 4(1-2), 5(1-1), 6(1-1) /07; 11(0-1) /08; 3(0-1), 6(0-1), 8(0-1), 10(0-1) /09
Simmons - Bellevue Gardens Organic Farm			
East field	29°32'51"N 82°27'17"W	23	5(1-1), 6, 10(1-1) /07; 3(2-2), 4(1-1), 5(1-1) /08
Melon field	29°33'01"N 82°27'31"W	13	5(1-1), 6(1-1), 10 /07; 3(2-0), 4, 5(1-1) /08
Zinn - Wildflowers of Florida, Inc.	29°54'40"N 82°27'33"W	1.4	9(0-1)/06; 4(1-1), 5(1-1) /07

[1]A single collection was taken from cups in the months whose numbers are not followed by parentheses.

and from spring 2007 to spring 2008 (Simmons farm). At the Simmons farm, collections came from 2 nearby fields. Occasional collections from plants at the Koenig farm continued into fall 2009. In the larger farms (Beville, Simmons), cups were usually placed along the edges of the large fields, whereas in the other smaller farms, cups were placed between small plots.

The farms surveyed for this study each grew a wide variety of crops. The following are the most abundant bee-relevant flowering crops grown on the vegetable farms, including leafy vegetables allowed to bloom, listed approximately in the order of the amount grown: Andrews farm - arugula, cilantro, mustard, squash, cantaloupe; Beville farm - squash, kale, broccoli; Durando farm - bok choy, arugula, Asian mustards, fennel, cilantro, squash, cantaloupe; Koenig farm - cantaloupe, cucumber, squash, watermelon, bean, pepper, and cut-flowers such as sunflower, false Queen Anne's lace, snapdragon, stock, amaranth, calendula, statice; Simmons farm - watermelon, squash, cantaloupe, cucumber, Daikon radish, broccoli, Florida broadleaf mustard. The Zinn farm grew about 30 species of native wildflowers, about 20 of which belonged to the Asteraceae family. In Table 2 are the names and abbreviations of the cultivated crop and ornamental plants and the wild plants from which bees were captured on flowers.

The Durando and Zinn farms were not certified organic, but insecticides were not used. Herbicides were only used on the Zinn farm in small applications. The Andrews farm was largely surrounded by mesic hammock (natural communities defined by the Florida Natural Areas Inventory; www.fnai.org/natcomguide_update.cfm). The Beville farm was adjacent to a pine tree plantation and upland hardwood forest/ mixed woodland. The Durando farm was adjacent to a bottomland forest, near patches of upland hardwood forest/mixed woodland and other farms. The Koenig farm was surrounded by low-density homesites and ruderal areas within remnants of upland hardwood forest/mixed woodland. About half of the Simmons farm was surrounded by upland hardwood forest/mixed woodland and the other half by improved pasture of Bahia Grass (*Paspalum notatum* Flüggé). The Zinn farm was largely surrounded by arable farmland and to 1 side a small adjacent planted pine forest, with patches of upland hardwood forest/ mixed woodland beyond.

RESULTS

For this study, a total of 4,662 bees, belonging to 28 genera and 95 species, was captured in 5 organic vegetable farms and 1 wildflower farm in Alachua County, Florida. The species count includes 6 *Nomada* and 1 *Triepeolus* morphospecies which likely include undescribed species and sexes (see below). The data for the species are in Table 3, which lists the species names and authors, the earliest and latest dates when captured, the farms where captured, and the numbers of females and males captured in cups and on

TABLE 2. PLANTS FROM WHICH BEES WERE COLLECTED.

As -	*Ammi* spp. L. Apiaceae. False Queen Anne's Lace. Introduced. Cultivated.
Ba -	*Bidens alba* (L.) DC. Asteraceae. Beggarticks. Native. Wild.
Bj -	*Brassica juncea* (L.) Czern. Brassicaceae. Florida Broadleaf Mustard, Indian Mustard. Introduced. Cultivated crop.
Bo -	*Brassica oleracea* L. var *italica* Plenck. Brassicaceae. Broccoli. Introduced. Cultivated crop.
Cb -	*Coreopsis basalis* (A. Dietr.) S.F. Blake. Asteraceae. Dye Flower. Native. Wild and cultivated.
Cj -	*Crotalaria juncea* L. Fabaceae. Sunn Hemp. Introduced. Cultivated groundcover.
Cm-	*Corydalis micrantha* (Engelm.ex A.Gray) A.Gray. Fumariaceae. Small Flower Fumewort. Native. Wild.
Co -	*Calendula officinalis*. L. Asteraceae. Pot Marigold. Introduced. Cultivated.
Cr -	*Crateagus* spp. L. Rosaceae. Hawthorn. Native. Wild and cultivated ornamental.
Ef -	*Emilia fosbergii* Nichols. Asteraceae. Tasselflower. Introduced. Wild.
Gp -	*Gaillardia pulchella* Foug. Asteraceae. Firewheel, Blanketflower. Native. Wild and cultivated.
Ha -	*Helianthus annuus* L. Asteraceae. Common Sunflower. Introduced. Cultivated.
Ih -	*Indigofera hirsuta* L. Fabaceae. Hairy Indigo. Introduced. Wild.
Io -	*Ilex opaca* Aiton. Aquifoliaceae. American Holly. Native. Wild and cultivated ornamental.
Mo -	*Misopates orontium* (L.) Raf. Scrophulariaceae. Snapdragon. Introduced. Cultivated.
Nb -	*Nolina britoniana* Nash. Ruscaceae. Britton's Beargrass. Native. Wild.
Pl -	*Phaseolus lunatus* L. Fabaceae. Lima Bean. Introduced. Cultivated crop.
Pv -	*Phaseolus vulgaris*. L. Fabaceae. Bean. Introduced. Cultivated crop.
Ss -	*Sida* spp. L. Malvaceae. Fanpetals. Native. Wild.
Vb -	*Verbena brasiliensis* Vell. Verbenaceae. Brazilian Vervain. Introduced. Wild.

Note: Authorities from Wunderlin & Hansen (2003).

TABLE 3. BEES CAUGHT IN ORGANIC FARMS OF ALACHUA COUNTY FLORIDA, 2006-2009.

				Farms[2]						Individuals collected: In cups		Individuals collected: Netted on flowers[3] or in flight (Net)				
	Species[1]	Early date of collection	Late date of collection	Andrews	Beville	Durando	Koenig	Simmon	Zinn	Females	Males	Females	Males	AC[4]	NA[5]	Totals
	Colletidae															
1	*Colletes brimleyi* Mitchell	24-III	28-III				•					1Io	8Io	•	•	9
2	*Colletes mandibularis* Smith	8-V	8-V				•					3As		•	•	3
3	*Colletes nudus* Robertson	14-VI	14-VI				•				1			•		1
4	*Colletes thoracicus* Smith	24-III	3-IV				•					1Io	5Io	•		6
5	*Hylaeus* (*Prosopis*) *modestus modestus* Say	2-IV	2-IV				•						1Io	••	•	1
	Halictidae															
6	*Augochlora* (*Augochlora*) *pura pura* (Say)	23-VI	23-VI						•			1Cb		••	•	1
7	*Augochlorella aurata* (Smith)	12-III	12-X	•		•	•	•	•	18		1		•	•	19
8	*Augochloropsis* (*Paraugochloropsis*) *anonyma* (Cockerell)	3-IV	25-V		•		•		•	8				•	•	8
9	*Augochloropsis* (*Paraugochloropsis*) *metallica* (Fabricius)	12-III	8-V				•	•		2		1Io		•	•	3
10	*Agapostemon* (*Agapostemon*) *splendens* (Lepeletier)	12-III	12-X	•	•	•	•	•	•	136	13	1Bo 1Gp 1Ha 2Io 3Mo 3Net	1Gp 1Ss 1Net	•	•	163
11	*Sphecodes atlantis* Mitchell	12-III	12-X				•	•		7	5			•	•	12
12	*Sphecodes coronus* Mitchell	3-IV	3-IV				•			1				•		1
13	*Sphecodes fattigi* Mitchell	8-V	8-V					•		1				•••		1
14	*Sphecodes mandibularis* Cresson	18-V	18-V					•		1				•		1
15	*Halictus* (*Odontalictus*) *poeyi* Lepeletier	12-III	12-X	•	•	•	•	•	•	242	11	1As 10Ba 14Cb 1Co 23Gp 16Ha 4Pv 2Ss 9Net	1Cb 1Gp 1Pv 1Net	•	•	337
16	*Lasioglossum* (*Dialictus*) *apopkense* (Robertson)	25-V	19-VI					•	•	3				•	•	3
17	*Lasioglossum* (*Dialictus*) *callidum* (Sandhouse)[6]	1-V	14-VI				•			3				•••		3
18	*Lasioglossum* (*Dialictus*) *floridanum* (Robertson)[7]	2-V	19-VI					•		3				•		3
19	*Lasioglossum* (*Dialictus*) *macoupinense* (Robertson)	8-V	8-V					•			1			•	•	1
20	*Lasioglossum* (*Dialictus*) *nymphale* (Smith)	12-III	12-X	•	•	•	•	•		936	2			•	•	938

TABLE 3. (CONTINUED) BEES CAUGHT IN ORGANIC FARMS OF ALACHUA COUNTY FLORIDA, 2006-2009.

	Species[1]	Early date of collection	Late date of collection	Farms[2]						Individuals collected: In cups		Individuals collected: Netted on flowers[3] or in flight (Net)		AC[4]	NA[5]	Totals
				Andrews	Beville	Durando	Koenig	Simmon	Zinn	Females	Males	Females	Males			
21	*Lasioglossum* (*Dialictus*) *pectorale* (Smith)	12-III	12-X	•	•	•	•	•	•	385	1	4Io		•	•	390
22	*Lasioglossum* (*Dialictus*) *puteulanum* Gibbs	12-III	12-X	•	•	•	•	•	•	1762	19	1Bo 1Cb 1Mo 1Pv 1Ss		••	•	1786
23	*Lasioglossum* (*Dialictus*) *reticulatum* (Robertson)	12-III	12-X	•	•	•	•	•	•	131	1	1Bo 1Io 6Mo 1Nb		•	•	141
24	*Lasioglossum* (*Dialictus*) *robertsonellum* Michener	18-V	19-VI		•			•		4				•	•	4
25	*Lasioglossum* (*Dialictus*) *tamiamense* (Mitchell)	27-IV	12-X	•				•		2				•••		2
26	*Lasioglossum* (*Evylaeus*) *nelumbonis* (Robertson)	12-III	25-V	•	•		•	•		9				•	•	9
27	*Lasioglossum* (*Hemihalictus*) *lustrans* (Cockerell)	3-IV	25-VI		•		•			5	10			•		15
28	*Lasioglossum* (*Lasioglossum*) *fuscipenne* (Smith)	24-III	23-IV			•	•					1Cb 3Io	1Io	•		5
	Andrenidae															
29	*Andrena* (*Archiandrena*) *banksi* Malloch	12-III	3-IV			•	•	•		1		3Cr 3Io	18Io	•	•	25
30	*Andrena* (*Larandrena*) *miserabilis* Cresson	12-III	3-IV			•	•	•		17	26	4Cr 58Io	1Cr 5Io	•	•	111
31	*Andrena* (*Melandrena*) *barbara* Bouseman and LaBerge	12-III	3-IV			•	•	•		14	2	11Io	6Bj 1Cr 14Io	••	•	48
32	*Andrena* (*Melandrena*) *confederata* Viereck	12-III	24-IV			•	•	•	•	1		3Io	11Cr 14Io	•	•	29
33	*Andrena* (*Melandrena*) *obscuripennis* Smith	3-IV	3-IV				•				1			•		1
34	*Andrena* (*Scrapteropsis*) *atlantica* Mitchell	24-III	3-IV				•					1Io	13Io	•	•	14
35	*Andrena* (*Scrapteropsis*) *ilicis* Mitchell	28-III	3-IV				•					4Io	1Io	•		5
36	*Andrena* (*Scrapteropsis*) *imitatrix* Cresson	12-III	28-III			•	•					1Cr 5Io	2Io	•	•	8
37	*Andrena* (*Tylandrena*) *perplexa* Smith	12-III	3-IV				•	•		3				•		3
38	*Perdita* (*Cockerellia*) *bequaerti bequaerti* Viereck	18-IV	14-VI			•	•	•		11	2	1Cb 1Co 18Ha	9Ha	•••		42
39	*Perdita* (*Hexaperdita*) *bishoppi bishoppi* Cockerell	12-X	12-X					•		1				•	•	1
40	*Perdita* (*Hexaperdita*) *nubila* Timberlake	3-IV	12-X				•	•		4	2			•	•	6
	Megachilidae															
41	*Anthidiellum* (*Loyolanthidium*) *perplexum* (Smith)	1-V	1-V					•		1				••	•	1
42	*Stelis* (*Dolichostelis*) *louisae* Cockerell	25-V	25-V						•			1Gp		•	•	1

TABLE 3. (CONTINUED) BEES CAUGHT IN ORGANIC FARMS OF ALACHUA COUNTY FLORIDA, 2006-2009.

				Farms[2]						Individuals collected						
										In cups		Netted on flowers[3] or in flight (Net)				
	Species[1]	Early date of collection	Late date of collection	Andrews	Beville	Durando	Koenig	Simmon	Zinn	Females	Males	Females	Males	AC[4]	NA[5]	Totals
43	*Osmia* (*Helicosmia*) *georgica* Cresson	23-IV	23-IV			•						1Cb		•••		1
44	*Osmia* (*Melanosmia*) *atriventris* Cresson	12-III	12-III					•			1			••	•	1
45	*Osmia* (*Melanosmia*) *sandhouseae* Mitchell	24-IV	24-IV						•		1			••	•	1
46	*Megachile* (*Acentron*) *albitarsis* Cresson	20-V	12-X	•			•	•		1		1Ba 1Bo 1Ih	1Ba	•	•	5
47	*Megachile* (*Callomegachile*) *sculpturalis* Smith	1-VII	1-VII				•					2Cj		••	•	2
48	*Megachile* (*Chelostomoides*) *campanulae* (Robertson)	24-V	24-V			•						2Et		••	•	2
49	*Megachile* (*Chelostomoides*) *exilis parexilis* Cresson	8-V	1-VII				•	•				1Ha 2Pl	1Pl 2Vb	•••		6
50	*Megachile* (*Chelostomoides*) *georgica* Cresson	3-VI	3-VI				•					2Net		•	•	2
51	*Megachile* (*Leptorachis*) *petulans* Cresson	23-IV	29-VI	•			•	•	•	2	1	1Ba 3Gp	3Gp 3Ha 1Pl 1Vb	•	•	15
52	*Megachile* (*Litomegachile*) *brevis pseudobrevis* Say[8]	12-III	12-X					•		3	2			••	•	5
53	*Megachile* (*Litomegachile*) *mendica mendica* Cresson	12-III	12-X				•	•		1		3Cj 2Ih 1Pl	1Ba 2Ha 1Vb	••	•	11
54	*Megachile* (*Litomegachile*) *texana* Cresson	1-V	29-VI				•				1	1Bo	2Pl	•	•	4
55	*Megachile* (*Megachiloides*) *rubi* Mitchell	23-IV	23-IV			•						1Cb		•	•	1
56	*Megachile* (*Sayapis*) *policaris* Say	23-IV	25-V						•			3Gp	1Gp	•	•	4
57	*Megachile* (*Xanthosarus*) *addenda* Cresson	2-V	8-V				•	•		3	1	1Ha		•	•	5
58	*Coelioxys* (*Boreocoelioxys*) *sayi* Robertson	25-VI	25-VI				•						1Ba	•	•	1
59	*Coelioxys* (*Coelioxys*) *immaculata* Cockerell	8-V	8-V					•			1			•		1
	Apidae															
60	*Xylocopa* (*Xylocopoides*) *virginica virginica* L.[9]	19-VIII	19-VIII				•					1Cj		•	•	1
61	*Ceratina* (*Ceratinula*) *cockerelli* Smith	28-III	13-VI				•	•		2				•	•	2
62	*Ceratina* (*Zadontomerus*) *dupla floridana* Mitchell[10]	12-III	14-VI				•	•	•	6				•	•	6
63	*Nomada fervida* Smith	26-IV	13-VI	•			•					4Net	1Ba 2Ha 3Net	•	•	10
64	*Nomada* aff. *florilega* Lovell and Cockerell[11]	3-IV	3-IV				•					1Io				1
65	*Nomada fragariae* Mitchell	12-III	24-III			•	•					1Io	2Cr	•		3
66	*Nomada* aff. *illinoensis*/*sayi* Robertson[11]	12-III	3-IV				•	•		1		26Io	22Io			49

TABLE 3. (CONTINUED) BEES CAUGHT IN ORGANIC FARMS OF ALACHUA COUNTY FLORIDA, 2006-2009.

				Farms[2]						Individuals collected						
										In cups		Netted on flowers[3] or in flight (Net)				
	Species[1]	Early date of collection	Late date of collection	Andrews	Beville	Durando	Koenig	Simmon	Zinn	Females	Males	Females	Males	AC[4]	NA[5]	Totals
67	*Nomada imbricata* Smith[12]	24-III	28-III				•					1Io	4Io	•••		5
68	*Nomada* aff. *lehighensis* Cockerell[11]	2-IV	2-IV				•					1Io				1
69	*Nomada* "MR-2"[11]	24-III	3-IV				•					2Io				2
70	*Nomada* aff. *pygmaea* Cresson[11]	24-III	24-III				•					1Io				1
71	*Nomada rubicunda* Olivier	12-III	12-III					•		1				•••		1
72	*Nomada* cf. *sphaerogaster* Cockerell[11]	24-III	28-III				•						12Io			12
73	*Nomada sulphurata* Smith[13]	24-III	24-III				•					1Io		•••		1
74	*Nomada vegana* Cockerell[14]	24-IV	31-V	•	•	•		•			2	1Et 2Vb	1Bo 1Ss 1Vb 1Net	•••		9
75	*Triepeolus* cf. *lunatus* (Say)[11]	2-V	25-VI				•	•					1Ba 1Vb			2
76	*Triepeolus lunatus concolor* (Robertson)	2-V	8-V					•				1Vb	2Vb	•		3
	Triepeolus lunatus lunatus (Say)	8-V	8-V									2Vb				2
77	*Triepeolus remigatus* (Fabricius)	25-V	1-VII	•	•				•	4		1Ha	1Gp 1Ha	•		7
78	*Triepeolus rufithorax* Graenicher	2-V	8-V					•					2Vb	•		2
79	*Epeolus bifasciatus* Cresson	8-V	8-V					•					4Vb	••	•	4
80	*Epeolus glabratus* Cresson	13-VI	25-VI				•			1		1Ba	3Ba	••	•	5
81	*Melitoma taurea* (Say)	20-V	3-VI				•				2			•	•	2
82	*Melissodes* (*Apomelissodes*) *apicata* Lovell and Cockerell	18-IV	18-IV					•			1			•	•	1
83	*Melissodes* (*Eumelissodes*) *boltoniae* Robertson	21-IX	12-X				•	•	•	1	3		1Net	•	•	5
84	*Melissodes* (*Melissodes*) *bimaculata bimaculata* (Lepeletier)	20-V	12-X		•	•	•	•		28	15	1Pl 1Ss	3Ha 1Pl	•	•	49
85	*Melissodes* (*Melissodes*) *communis communis* Cresson	18-IV	25-VI	•	•	•	•	•	•	75	133	2Gp	1Bo 11Gp 1Ha	•	•	223
86	*Melissodes* (*Melissodes*) *tepaneca* Cresson	8-V	13-VI				•	•		3				••	•	3
87	*Svastra* (*Epimelissodes*) *aegis* (LaBerge)	31-V	1-VII	•			•	•				5Ha	2Ha	••	•	7
88	*Svastra* (*Epimelissodes*) *petulca petulca* (Cresson)	24-V	24-V			•						1Pv		•••		1
89	*Xenoglossa* (*Eoxenoglossa*) *kansensis* Cockerell[15]	2-V	2-V					•		5	3			••	•	8
90	*Habropoda laboriosa* (Fabricius)	11-III	12-III					•		1		1Cm		•	•	2
91	*Bombus* (*Cullumanobombus*) *fraternus* (Smith)	8-V	8-V				•					1As		•		1

TABLE 3. (CONTINUED) BEES CAUGHT IN ORGANIC FARMS OF ALACHUA COUNTY FLORIDA, 2006-2009.

				Farms[2]						Individuals collected						
										In cups		Netted on flowers[3] or in flight (Net)				
	Species[1]	Early date of collection	Late date of collection	Andrews	Beville	Durando	Koenig	Simmon	Zinn	Females	Males	Females	Males	AC[4]	NA[5]	Totals
92	*Bombus* (*Cullumanobombus*) *griseocollis* (DeGeer)[16]	3-IV	3-IV				•			1				•	•	1
93	*Bombus* (*Pyrobombus*) *impatiens* Cresson[16]	20-V	20-V				•				1			•	•	1
94	*Bombus* (*Thoracobombus*) *pensylvanicus* (DeGeer)[16]	25-VI	25-VI				•			1				•	•	1
95	*Apis* (*Apis*) *mellifera* L.[17]													•	•	
	TOTAL															4662

[1]Species are listed in phylogenetic sequence by family-group, genus-group taxa, and alphabetically within the least inclusive applicable genus-group taxon.
[2]Farms listed in Table 1.
[3]Abbreviations for plant species in Table 2.
[4]AC: Alachua County records - • reported for county or found "throughout" Florida according to Pascarella (2008); •• new records from the natural areas by Hall & Ascher 2010; ••• new records from this study; blank - morphospecies not marked.
[5]NA: Reported from Alachua County natural areas by Hall & Ascher 2010.
[6]*Lasioglossum callidum* - the valid name for *Dialictus versatus sensu* Mitchell, in part (Gibbs, 2010). Florida records of *L. versatum* pertain to *L. callidum* rather than to true *L. versatum* (Robertson), a senior synonym of *L. rohweri* (Ellis) as determined by Gibbs (2010).
[7]*Lasioglossum floridanum* - a subspecies of *L. pilosum* (Smith) prior to Gibbs (2010). Florida records of *L. pilosum* pertain to *L. floridanum* rather than to *L. pilosum sensu stricto*, a species confirmed to occur south only to North Carolina.
[8]*Megachile brevis pseudobrevis* likely to be elevated soon to specific rank (C. Sheffield cf. Hall & Ascher 2010).
[9]More *Xylocopa* observed foraging but not captured or counted, see text.
[10]*Ceratina dupla floridana* likely to be elevated soon to specific rank (C. Sheffield *cf*. Hall & Ascher 2010).
[11]Possible new Florida and Alachua County record.
[12]*Nomada imbricata* Smith was recorded (Pascarella 2008) under the junior synonym *N. bishoppi* Cockerell.
[13]New Florida record.
[14]*Nomada vegana* Cockerell was recorded (Pascarella 2008) under the senior synonym *N. modesta* Cresson, unavailable due to primary homonymy with the European *N. modesta* Herrich-Schäffer.
[15]*Xenoglossa kansensis* - captured after those reported previously (Hall 2010).
[16]More *Bombus* observed foraging but not captured or counted, see text.
[17]*Apis mellifera* caught in cups, not saved or counted, see text.

each of the plant species. As with our previous report (Hall & Ascher 2010), we have cited species with updated names and taxonomic status relative to previously published studies. As listed in the endnotes of Table 3, 4 other species found in the farms had been previously recorded from Florida under different names.

Five percent of the species were in the family Colletidae, 24% in Halictidae, 13% in Andrenidae, 20% in Megachilidae, and 38% in Apidae. Ninety percent of individuals were female; 10% male. Eight species with 100 or more individuals collected accounted for 88% of the total number of bees: *Lasioglossum* (*Dialictus*) *puteulanum* Gibbs 1,786 (1,767F 19M); *L.* (*D.*) *nymphale* (Smith) 938 (936F 2M); *L.* (*D.*) *pectorale* (Smith) 390 (389F 1M); *Halictus* (*Odontalictus*) *poeyi* Lepeletier 337 (322F 15M); *Melissodes* (*Melissodes*) *communis communis* Cresson 223 (77F 146M); *Agapostemon* (*Agapostemon*) *splendens* (Lepeletier) 163 (147F 16M); *L.* (*D.*) *reticulatum* (Robertson) 141 (140F 1M); and *Andrena* (*Larandrena*) *miserabilis* Cresson 111 (79F 32M). Eighty-eight percent of the bees were caught in cups, 11% captured with nets from identified flowers, and less than 1% over unidentified flowers or the ground. Thirty-seven percent of the species were caught only in cups, 37% only with nets, and 26% in both cups and with nets. Forty-nine percent (47) of the species were represented by only 1 to 3 bees (1 bee - 31%, 2 bees - 9%, 3 bees - 9%). Seventy-one percent of the species caught only in cups and 63% of the species caught only with nets were represented by 1 to 3 bees.

A large proportion of *Andrena* and nearly all *Nomada* and *Colletes* were captured with nets. Results from this study are further biased favoring the numbers of *Andrena* and *Nomada*, because of concentrated collecting from a few trees of American Holly, *Ilex opaca* Aiton, at the Koenig farm. Bees were collected from *Ilex opaca* in natural areas (Hall & Ascher 2010), but these trees did not attract the abundance of bees seen on the trees in this farm. One specimen reported here as *Nomada* "MR-2", found in the spring of 2007, was identified as a likely new species based on morphology and DNA analyses (M. Rightmyer, S. Droege; personal communication) but remains undescribed. This find encouraged subsequent intense collecting on the same trees the following 2 yrs. Five other *Nomada* morphospecies captured subsequently, all belonging to the *ruficornis* species group and therefore probable cleptoparasites of *Andrena*, were determined by S. Droege (personal communication) to have affinities with eastern North American species: *N.* aff. *florilega* Lovell and Cockerell, *N.* aff. *illinoensis*/*sayi*, *N.* aff. *lehighensis* Cockerell, *Nomada* aff. *pygmaea* Cresson, and *N.* cf. *sphaerogaster* Cockerell (Fig. 1). The latter may be the undiscovered male of this

Fig. 1. *Nomada* cf. *sphaerogaster* male. See colored photograph online in supplementary material at InfoLink3.

rare species reported only from New Jersey and Wisconsin. Names should be available for these morphospecies upon completion of revisionary studies now in progress (S. Droege, M. Rightmyer, S. Brady, personal communication). All may prove to be new state and county records, in addition to *Nomada sulphurata* (Smith) recorded here for the first time from Florida and Alachua County. Two male specimens key to *T. lunatus lunatus* (Say), which was treated as conspecific with *T. lunatus* by Rightmyer (2008). We treat these specimens as a different morphospecies, listed as *Triepeolus* cf. *lunatus* (Say), as they do not appear to be conspecific with typical *T. lunatus*.

Twenty-five cleptoparasitic species (26% of the total number of species; 3% of the total number of individuals) were captured: 4 *Sphecodes*; 1 *Stelis*; 2 *Coelioxys*; 12 *Nomada* (includes the 6 morphospecies); 4 *Triepeolus* (includes the 1 morphospecies); and 2 *Epeolus*. This percentage is high relative to the latitudinal gradient of cleptoparasite composition of bee populations, in which larger proportions are found in more northern regions (Wcislo 1987). However, the percentages of parasitic species reported for Florida as a whole and for Archbold Biological Station were similarly high, at 24% and 27% respectively (Wcislo 1987; Deyrup et al. 2002). The concentrated collecting of *Nomada* from American Holly, mentioned above, contributed to this high percentage. At 1 location in Alachua County, but outside the study area, a *Nomada imbricata* Smith female was captured in 2010 and 8 females were captured in 2011 while attempting to enter ground nests of *Andrena* (*Melandrena*) *barbara* Bouseman and LaBerge. No other *Nomada* species were seen. These observations suggest, but do not conclusively establish, a new host-cleptoparasite relationship between these 2 species, which were also found in the organic farms. In Ithaca, New York, where *A. barbara* does not occur, *N. imbricata* has been observed entering nests of *Andrena* (*Melandrena*) *dunningi* Cockerell (novel unpublished observation by JSA), a species not recorded from Florida.

Collections from flowers were further biased against some conspicuous species. *Bombus* and *Xylocopa* species were not collected from flowers, with the exception of 1 specimen of each genus. *B.* (*Cullumanobombus*) *griseocollis* (DeGeer), *B.* (*Pyrobombus*) *bimaculatus* Cresson, *B.* (*Pyrobombus*) *impatiens* Cresson, *B.* (*Thoracobombus*) *pensylvanicus* (DeGeer), *X. virginica* L. and *X. micans* Lepeletier are commonly seen in different parts of the county, and queens and workers of *Bombus* were captured for an earlier project. However, the few *Bombus* reported here were caught in cups. The exception was 1 *B.* (*Cullumanobombus*) *fraternus* Smith queen, the only individual of this species we have seen so far in our surveys.

Only 2 non-native species, *Megachile* (*Callomegachile*) *sculpturalis* Smith and *Apis mellifera* L., were caught. Honey bees were seen consistently in the cups, but only in small numbers, even at 2 farms (Koenig and Andrews) where managed colonies were located nearby. They were not counted nor saved.

Indicated in Table 3 are the 61 species found also in our recent surveys of bees in natural areas of Alachua County (Hall & Ascher 2010). Thirty-four species found in the present farm study had not been captured from the natural areas, and 51 species found in the natural areas were not found in the farms (111 species were reported in the earlier publication, but, in the page proofs, *Eucera* (*Synhalonia*) *rosae* (Robertson) was added to the end of the list for a total of 112 species). From the natural areas and farms surveys combined, a total of 146 species has been captured (138 described, plus 1 morphospecies from the natural areas and 7 from the farms).

One hundred forty bee species had been previously reported from Alachua County or throughout Florida, according to Pascarella (2008), although the presence of 3 in Florida is questionable and 2 have been placed in synonomy with other species. Of the remaining 135 species, 61 were found in the farms (indicated in Table 3), 45 of which were among 73 previous county records from the natural areas (Hall & Ascher 2010). Sixteen species from the farms were among the 39 new county records from the natural areas (corrected from 37 in our earlier report - the addition of *Eucera rosae* and 1 miscount). Eleven additional identified species from the farms, not including the 7 morphospecies, are new county records (indicated in Table 3). A total of 185 described species and at least 8 morphospecies has now been reported from Alachua County.

Previously, we compared the bee species captured in Alachua County natural areas with those from the other major bee surveys in Florida (Hall & Ascher 2010). Pascarella et al. (2000) recorded species they had captured in the Everglades National Park along with those that Graenicher (1930) and others had found in the Everglades and in Dade and Monroe Counties outside the Park. Deyrup et al. (2002) list the bee species and their floral hosts found at Archbold Biological Station on the Lake Wales Ridge, Highlands County, south-central Florida. Together, they had reported a total of 142 species of which we had found 42 species in both the Alachua County natural areas and organic farms surveys. Nine additional species were found only in the farms surveys (51 total), whereas an additional 25 species were found only in the natural areas surveys (67 total), indicating a greater similarity of the south Florida natural areas to the Alachua County natural areas, despite differences in native vegetation, than to the farms.

Discussion

This study of the bee diversity in organic farms in north-central Florida follows the same approach as our previous surveys of the bee fauna in natural areas (Hall & Ascher 2010). The goals of the surveys were to find as many of the species present as possible and to estimate their abundance. Replicable quantitative surveys were not intended. The systematic and consistent use of cups was the primary means to collect bees, supplemented by opportunistic and less consistent use of nets. On some farms, collections were conducted over longer periods of time, and net-collecting was concentrated on certain plants. Although some bees were captured on crop flowers, documenting visitation to these was not a focus of the study.

The bee sampling from our surveys from both Alachua County natural areas (Hall & Ascher 2010) and organic farms has been generally characterized by a few species caught in large numbers and far more species represented by a few individuals. This tendency was more extreme among the bees captured in the farms. Eighty-eight percent of the bees collected were represented by only 8 species. The single most abundant species collected, *Lasioglossum puteulanum*, accounted for 42% of the bees. In contrast to the large numbers of these few species, 49% of the species from farms were represented by only 1 to 3 bees, suggesting that further sampling would reveal many additional species. The farms and natural areas were most similar with respect to the abundant species, as the 7 most abundant species from the farms were among the 10 most abundant species from natural areas, although not in the same order. The difference in species composition between the farms and natural areas was largely among those represented by 3 bees or fewer, accounting for 22 (65%) of the 34 species caught only in the farms. Considering only the bees caught with cups, the average number of individuals per cup sampling from the farms was about 4 times that from the natural areas, that is, about twice as many bees caught with half as many collections.

Collections at the Koenig and Simmons farms extended over a year or longer, whereas collections at the other farms were limited to the spring of 1 yr. Furthermore, at the Simmons farm, bees came from 2 fields (Table 1; data pooled for Table 3), thus twice as many cups were used per collection compared to collections from the other farms. Consequently, the largest total numbers of bees were collected from the Simmons farm (about 3,000) and the Koenig farm (about 1,000) (data not shown), as well as the largest number of bees belonging to each of the 8 most abundant species. With 1 exception, the 8 most abundant species were found on all the farms but differed widely in the numbers of each (*Lasioglossum nymphale*, the second most numerous species overall, was not caught at the Zinn farm). The greater number of bees from the Simmons farm can be largely attributed to *L. nymphale* (about 900) and *L. puteulanum* (about 1,400), whereas, for example, a total of only 22 *L. nymphale* was caught from the other farms (data not shown). The largest number of species was collected from the Koenig farm (65, including the 6 *Nomada* and 1 *Triepeolus* morphospecies) followed by the Simmons farm (51, including the 1 *Triepeolus* morphospecies). The numbers of species collected from the 4 less-intensively sampled farms were considerably fewer and were comparable (Andrews 16; Beville 14; Durando 22; Zinn 18) as were the numbers of bee individuals, ranging from about 75 to 130. More frequent and intense collecting from flowers at the Koenig farm, such as from the American Holly, likely contributed to its greater recorded species richness. Cut-flowers for marketing grown on the Koenig farm, in addition to a large variety of vegetables, may have also contributed to the diversity of attracted bees. However, samples from Zinn's wildflower farm were not particularly numerous or diverse. This farm was largely surrounded by tilled fields of conventional farms, perhaps the least favorable bee habitat.

The results from our surveys reflect different outcomes of the sampling methods. Bee species were not equally attracted to the colored cups, as others have also observed (Cane et al. 2000; Roulston et al. 2007; Wilson et al. 2008). Although bees captured in cups do not necessarily represent the relative abundance of different species at each location, capture rates of an individual species may provide a reasonably objective measure of relative abundance at different locations. Collections with cups resulted in particularly long series of certain species. Other species were better captured on flowers, so supplemental net-collecting provided a more comprehensive species list than did the cups alone, although net collections captured fewer individuals of some species (particularly small *Lasioglossum*). Very small bees, representing the large proportion of those found in this study, are probably less effective than larger bees as pollinators of many plants, including crops (Kremen et al. 2002). However, their abundance may compensate for size to some extent.

To what extent farm environments and surrounding landscapes are responsible for the composition of the bee fauna of farms has been the subject of many studies (e.g. Westphal et al. 2003; Kremen et al. 2004; Ricketts 2004; Shuler et al. 2005; Chacoff & Aizen 2006; Greenleaf & Kremen 2006; Ockinger & Smith 2007; Winfree et al. 2007b, 2008; Ricketts et al. 2008). Further research is needed on the natural sources of bee pollinators and on the factors that attract and maintain species with the anatomy and behavior to be effective crop pollinators. Factors influencing bee diversity could include availability of appropriate supplemental forage and of nest sites, spatial relationships among these resources, and land use heterogeneity (Steffan-Dewenter et al. 2002; Chacoff & Aizen 2006; Kim et al. 2006; Kleijn & van Langevelde 2006; Pontin et al 2006; Carvell et al. 2007; Brosi et al. 2008; Kohler et al. 2008; Rundlof & Smith 2008; Julier & Roulston 2009).

Although our surveys are preliminary steps toward addressing such issues, possible confounding factors that might explain differences in our bee collections are worth mentioning. As described in the Methods section, the different farms studied in Alachua County had notably different surrounding landscapes which were not necessarily representative of the surveyed natural areas (Hall & Ascher 2010). The Andrews and Simmons farms were immediately adjacent to large natural areas similar to those surveyed, and the latter was between 1.5 and 2.0 km from the Kanapaha Prairie sites, actually surveyed in our earlier study. However, the other farms were distant from any other surveyed natural area. The bee fauna of the farms may have included both truly resident species nesting within the farms and foragers entering from surrounding natural areas. The many bee species we found in natural areas but not in the farms, and vice versa, indicates that either the landscapes surrounding the farms, if the main source of bees, are distinct from the surveyed natural areas, the blooms within farms selectively attract different species, or the farm environment, at least partly or perhaps largely, defines a resident bee fauna. Wildflowers in disturbed marginal or fallow farmland may be as important as crop flowers in attracting bees, which may be better sustained than in the wild, particularly in irrigated farms. Many flowers on which bees were caught in this study were not of cultivated plants. Nevertheless, there was a large variety among the food crops, which is characteristic of small organic farms, and cultivated cutflowers. Both the variety of crops and the absence of pesticides would likely contribute to the diversity of attracted bees.

The organic farms of Alachua County have a bee fauna of richness similar to that documented for natural areas, and bees found on the farms include notable native species not found in the natural areas. These results contrast with those from other regions, especially central California. The California chaparral and other habitats are highly favorable for bees (Messinger & Griswold 2002) and support far greater numbers of bee species than those reported from farms in the same broad region (Kremen et al 2002, 2004). Some natural sites in Florida may be either too wet (e.g. seasonally flooded) or too heavily forested to provide sufficient sunny areas for herbaceous flowers and associated bee species (Deyrup et al. 2002). Farms may be providing open areas and concentrated floral resources that attract nesting and/or foraging bee species at a greater diversity and abundance than some natural areas, as was found in a study of bees in farms and forests of New Jersey (Winfree et al. 2007b). Compared to areas such as California, farming in north-central Florida is more similar to that in New Jersey and Pennsylvania (Winfree et al. 2007b, 2008), generally with smaller field sizes, greater crop and weed diversity, and patches of nearby natural habitat, which may be more compatible for maintaining native bee diversity.

Although the most abundant species found on the farms overlapped extensively with those found in natural areas, the least abundant species did not. Additional collecting may reveal that more of these species are present in both types of land. Nevertheless, farm conditions in north-central Florida appear to support the presence of a diverse and interesting bee fauna and may provide particularly favorable habitat for certain species, such as the reported morphospecies, that are rare in collections, taxonomically poorly known, or in at least 1 case potentially new to science. Studies of farms contribute to basic knowledge of the native bee fauna and are not merely recording a subset of species documented from the nearby natural sites (surveyed by Hall and Ascher 2010). Conversely, other bee species surely require nesting and foraging resources more or less restricted to specific natural habitats. The 51 species found in our surveys of Alachua County natural areas and not found in the farms include, for example, *Lithurgus* (*Lithurgopsis*) *gibbosus* Smith, an oligolege of pricklypear cactus, *Opuntia* (Hurd 1979), not a desirable plant on farmland, and *Hylaeus* (*Prosopis*) *schwarzii* Cockerell, a wetland-associated species (Graenicher 1930). Thus, comparative studies of bees in different Florida landscapes are revealing differences in habitat use by bees, potentially of conservation significance. However, species-level patterns can be better assessed after more comprehensive information is available about the taxonomy, distribution, abundance, and life history of regional bees.

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