Indigenous and Exotic Dung Beetles (Coleoptera: Scarabaeidae and Geotrupidae) Collected in Florida Cattle Pastures

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ABSTRACT Dung beetles are important to healthy cattle pasture ecosystems as they provide for nutrient recycling, removal of waste products from the soil surface and assist in the reduction of pestiferous flies. Numerous exotic dung beetles have been accidentally or intentionally introduced to the North American continent and several of these have become established. We surveyed for the presence and distribution of dung beetles on four cattle farms in north central Florida over a 3.5-yr period using cattle dung-baited pitfall traps placed at least every 3 wk. In total, 39 species from 20 genera were identified with a total of 62,320 beetles collected in traps. Although none were intentionally released in Florida, six exotic species were present. Significant differences were observed in species captures among the three most sampled farms, with beetle species dominance patterns differing among the farms. The native species, *Onthophagus tuberculifrons* Harold, was the most commonly collected species, and both it and the introduced *Labarrus pseudolividus* Balthasar, had mass emergences. Four of the six most commonly collected species were exotics and included, in order of abundance, *L pseudolividus*, *O. gazella* (F.), *O. taurus* (Schreber), and *Euoniticellus intermedius* (Reiche).

KEY WORDS *Onthophagus tuberculifrons*, *Onthophagus gazella*, *Onthophagus taurus*, *Labarrus pseudolividus*, cattle manure

Dung beetles play a primary role in nutrient recycling in the cattle pasture system and their complexes historically have been closely tied to their native herbivores. In the past 500 yr, as humans have redistributed domesticated livestock to various parts of the planet, dung beetles have, in a few cases, followed these non-native herbivores serendipitously or more recently, been intentionally introduced to these ecosystems in attempts to manipulate bovine dung degradation (Woodruff 1973, Fincher 1986, Tyndale-Biscoe 1990). Despite the classic example of the introduction of dung beetles into Australia in the mid-20th century (Tyndale-Biscoe 1990), other dung beetle introductions have not had such resounding successes.

Dung beetles fall into one of three general categories: rollers, tunnelers, and dwellers (Cambefort and Hanski 1991). Rollers are the smallest group in North America and are not well-represented in dung beetle assemblages from the United States (Cambefort 1991). They mold a ball of dung, roll it away from the dung pat to a more suitable location, and deposit an egg in it. Tunnelers are highly sought after for their behavior of pulling manure from the dung directly into the soil below the dung pat. Dwellers spend much of their life-cycle living within a dung pat. These species also are responsible for aerating dung pats, leading to a dry-down effect. In one way or another, each of these groups facilitates removal of dung from the cattle pasture. Most of the dung beetles imported into Australia and the subset of these introduced into the United States were rollers and tunnelers (Fincher 1986, Tyndale-Biscoe 1990).

Although many recognize the opportunity for improved management of surface dung deposits, including movement into subterranean levels making nutrients more available for plant uptake, reduction of overly rich nutrient run-off from cattle pastures, improved utilization of once fouled grass forages by cattle, and perhaps, improved management of pestiferous flies by removal of their dung resources, others have concerns over the impact of these non-native beetles on native dung beetle species (Woodruff 1973). The State of Florida has not authorized any release of non-native dung beetles; however, releases conducted in nearby states, under USDA and other state approvals (Blume et al. 1973, Blume 1984), have resulted in several new species dispersing into Florida. In 1972, the first intentionally-introduced species to the continental United States, *Onthophagous gazella* (F.), was released in Texas (Blume and Aga 1978). Subsequently, *O. gazella* was released in California, Georgia, Arizona, and Mississippi (Fincher 1981). *Euoniticellus intermedius* (Reiche) was released in Texas and California in the 1970s, and Georgia in 1984 (Fincher 1981, 1986; Montes de Oca and Halffter 1998). Almquist (2001) first reported *E. intermedius* in Florida in 2001, and Wood and Kaufman (2010) reported its further expanded range and prevalence.

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Onthophagus taurus (Schreber), although not known to be intentionally released, was first reported in Florida's panhandle region in 1971 (Fincher and Woodruff 1975, Fincher et al. 1983). The aphodiine, *Labarrus pseudolividus* Balthasar, is believed to have been introduced accidentally into North America several hundred years ago (Woodruff 1973).

Geologically and ecologically, Florida represents a unique environment for soil-inhabiting organisms, specifically, having high water table levels and soil profiles predisposed to nutrient run-off or leaching, as well as the presence of other invasive parasitic and predatory insect species. This represents unique challenges, particularly to species that burrow deeply into the soil. Florida is home to over one million beef cattle and several hundred thousand dairy cattle. These animal systems are maintained under different grazing regimes; however, the pasture systems in Florida are quite similar. Nutrient run-off is of great concern to Florida. Lastro (2006) documented that *O. taurus* dung-burying activity resulted in greater forage production than in unincorporated dung treatments, and that increased plant growth was similar to enhancement by urea fertilizer. The role of dung beetles in the reduction of pestiferous flies has been controversial or difficult to document (Bornemissza 1970, Blume et al. 1973, Wallace and Tyndale-Biscoe 1983, Roth 1989).

Although these beetles are recognized as present in Florida, to date no study has been published on their abundance and overall presence on Florida's cattle pastures. The objective of this study was to identify the species of dung beetles, their relative abundance and distribution on several cattle pastures in north central Florida as represented in dung-baited pitfall traps placed over multiple years.

Materials and Methods

Beginning in June 2005 and continuing until December 2008, a study of the diversity and seasonal abundance of beetles in the superfamily Scarabaeoidea, specifically those associated with the processing of animal manure in managed cattle pastures, was conducted at four cattle farms in north central Florida. The sites selected were two beef cattle farms and two dairies in the vicinity of Gainesville, FL.

The beef cattle farm designated as Beef 1 was located in south central Alachua County. This site was low and near an old lake bed and has very deep, poorly drained, very slowly permeable soils classified as Emeralda and Surrency Series with upper layers of fine sand and sandy loam above layers of sandy clay and sandy clay loam (USDA 2004, 2011). The water table was within 25 cm of the surface and free water was persistent to permanent during years of normal rainfall. The improved pasture was planted in bahiagrass (*Paspalum notatum* Flugge). Approximately 550 cow-calf pairs were on 970 ha, with 150 heifers or cow-calf equivalents nearest the trapping site during the study.

The second beef farm (Beef 2) was the Santa Fe River Ranch, a University of Florida beef cattle facility, located in northwestern Alachua County. The soils at this site fall into three series, two of which are very similar. Both the Millhopper and Lochloosa Series are sand or fine sand over sandy loam to sandy clay loam. The drainage characteristics of those soils range from moderately well-drained and moderately permeable to somewhat poorly drained and slowly permeable. The Millhopper soils are on upland areas of central and southern Florida. The Lochloosa soils are on nearly level to sloping landscapes in the Coastal Plain. The third soil series, Chipley, consists of very deep, somewhat poorly drained, very rapid or rapidly permeable sandy or fine sandy soils (USDA 2004, 2011). It occurs on uplands in the Southern Coastal Plain. The farm contained 647 ha of bahiagrass pasture and supports 300 head of Angus-Brangus cow-calf pairs.

The dairy farm designated as Dairy 1 was located near the middle of the eastern edge of Gilchrist County, just west of Alachua County. The entire site consisted of soil classified as Penney Series (USDA 2004, 2011). It was a very deep, excessively drained, and rapidly permeable fine sandy soil located on uplands. The forages on the farm consisted chiefly of a sparse growth of pineland threeawn, indiangrass, creeping bluestem, and panicums. The pasture at the beginning of the study (19 July 2005) consisted of bahiagrass with patches of Bermuda grass (*Cynodon dactylon* L.). There was a milking herd of ≈400 Holstein cows. Management of the dairy transferred to a leaser in July 2007. Thereafter the pasture was disked and replanted with alternative forage crops that included millet, *Pennisetum americanum* (L.), for spring and summer and winter rye, *Secale cereale* L., for fall and winter. Cattle were absent from the property during pasture renovation, from May 2007 to mid-July 2007. Pitfall traps were set three times between those dates. By 17 July 2007, 250 heifers occupied an enclosure 150 m from our traps. Farm management directed that traps be removed in late September to accommodate installation of an overhead irrigation system. Traps were reinstalled 24 January 2008 in a central area of the rotational grazing enclosure array that held 555 milking cows. Cattle were no further away than 1,200 m at any time.

Pitfall traps were placed at the second dairy farm, Dairy 2, for a 31-wk period when Dairy 1 was in transition, with trapping dates of 16 May to 18 December 2007 that encompassed 11 trap dates, all 3–4 wk apart. Dairy 2 was located near the middle of the western edge of Alachua County, ≈2.1 km southeast of Dairy 1. The three soil types at this location included two series, Pedro and Jonesville, which have varying depths of sand and sandy loam over limestone (USDA 2004, 2011). Pedro consists of shallow, well-drained, moderately rapidly permeable sand and sandy loam over limestone. The soils are on nearly level to gently sloping landscapes in the Coastal Plain. The limestone was within 15–51 cm of the surface. Jonesville series consists of moderately deep, well-drained soils that formed in sandy and loamy marine sediments over limestone. These soils occur on ridges and gently undulating uplands. The depth of the limestone was between 66 and 150 cm. The third soil type was Arredondo, which consists of well-drained soils that are rapidly permeable in the thick sandy surface and subsurface layers and moderate to very slowly permeable in the sandy loam subsoil, 177–228 cm beneath the surface (USDA 2004, 2011). The pasture was bahiagrass, although there was considerable *Amaranthus* spp. near the side of the pasture where traps were placed. This was a small dairy operation with ≈250 milking cows, mostly Holstein and a few Brown Swiss.

Beetles were captured using the dung-baited pitfall trap design and method described in Bertone et al. (2005). Briefly, fresh cow dung was collected from multiple mature cows from each study site. Portions of dung, measured out using a 55-ml ice cream scoop, were packaged into stapled pouches of 21-cm^2 paper towel. The dung pouches were frozen (−20°C) until needed. The pitfall trap consisted of a no. 4 mesh hardware cloth platform for bait attachment, anchored to and positioned above a 9-cm-diameter funnel, which extended into a 9 cm diameter, screened-bottom, PVC canister. Each trap position in the field was equipped with a 35 cm length of 10.6-cm-diameter PVC pipe into which the trap fit, allowing the top of the funnel to rest at ground level. When the traps were deployed, a dung pouch was clipped to the platform over the funnel. Traps were placed along fence lines and spaced at least 20 m apart in open or lightly tree-lined areas. Ten traps were set at each study site every trapping date and exposed for 24 h, after which live beetles were placed into holding containers, returned to the lab, frozen, identified, and enumerated. Identification was done using the keys of Woodruff (1973) and Gordon and Skelley (2007) with verification performed on some specimens by Michael C. Thomas and Paul E. Skelley of the Florida Department of Agriculture and Consumer Services, Gainesville, FL. Voucher specimens have been deposited in the Florida State Collection of Arthropods, FL Department of Agriculture and Consumer Services–Division of Plant Industry.

This study spanned ≈3.5 yr, from 17 June 2005 to 9 December 2008. The trapping schedule was year round, mostly at 3-wk intervals (73% of the schedule). Occasionally, 1-wk (16%), 2-wk (5%), and 4-wk (4%) trapping intervals were necessary to accommodate weather and farm practices and preferences. Trapping was interrupted at Beef 1 for a 12-wk interval in the fall of 2006 and trapping ended, at the owner's request, 9 wk earlier than at the other sites. Trapping at Dairy 1 was interrupted for a 19-wk interval in late 2007, as described earlier. Dairy 2 was used for a period of 31 wk to compensate for the loss of trapping data from Dairy 1.

A χ^2 analysis was conducted and probability values were calculated on the 10 most commonly collected beetle species. Comparisons were made between the three farms that were sampled most often and only dates where farms were sampled within 1 wk of each other were used to determine the relative beetle presence on each farm.

Table 1. Dung beetle diversity and abundance at four cattle farms in north central Florida as measured with dung-baited pitfall traps

Farm	No. sampling dates	No. genera	No. species	No. beetles
Beef 1	60	14	26	8,611
Beef 2	66	17	30	19,591
Dairy 1	66	18	30	32,594
Dairy 2	11	10	14	1,524

Farms sampled between June 2005 and Dec. 2008. Dairy 2 sampled from 16 May to 18 December 2007.

Overall, 39 species from 20 genera were collected. Ten traps per farm per sample date.

Results

Dung beetles in Scarabaeidae, subfamilies Scarabaeinae and Aphodiinae, and Geotrupidae were recovered. Thirty-nine species from 20 genera were identified with 62,320 beetles collected in traps, in total (Table 1). Six exotic species were represented in these collections and included *Aphodius fimetarius* (L.), *Calamosternus granarius* (L.), *E. intermedius, L. pseudolividus, O. gazella,* and *O. taurus.* By farm, Dairy 1 generated the largest numbers of beetles, 32,594, from 66 sample dates (mean of 494 per sample date) (Table 1). The fewest per sample date were collected at Beef 1, located south of Gainesville, with 8,611 beetles from 60 collection dates (mean of 144 per sample date). Species diversity was greatest at the Beef 2 and Dairy 1 sites, each documenting 30 species from 17 and 18 genera, respectively (Table 1).

Individual farm dung beetle diversity and abundance data are presented in Table 2. The five most commonly collected beetles, which accounted for 87% of all beetles captured, were *O. tuberculifrons* Harold (53.4%), *L. pseudolividus* (13.6%), *O. gazella* (11.9%), *O. taurus* (6.1%), and *O. pennsylvanicus* Harold (2.5%). However, these results were skewed heavily toward individual sites. For example, *O. tuberculifrons* predominated at two of the sites (Beef 2 and Dairy 1), with few collected at the other two sites. At the Beef 1 site, 50.3% of the beetles collected were *L. pseudolividus,* whereas at the Dairy 2 site, *O. gazella* (40.5%) and *O. taurus* (33.6%) predominated.

Four species were collected solely at the Beef 1 site [*Ataenius imbricatus* (Melsheimer), *A. picinus* Harold, *A. spretulus* (Haldeman), and *Pseudocanthon perplexus* (LeConte)], whereas three species were collected only at the Beef 2 site [*A. cylindrus* Horn, *Canthon v. viridis* (Beauvois), and *Oscarinus crassulus* (Horn)] (Table 2). An additional four species were collected only at the Dairy 1 site [*Canthon probus* (Germar), *Mycotrupes gaigei* Olson and Hubbell, *Os. windsori* (Cartright), and *Parataenius simulator* (Harold)].

Analysis of primary species presence between the three farm sites clearly shows that beetle abundance on farms, as well as the overall beetle captures, were not equivalent for the 10 most commonly collected species (Table 3). This analysis also documents that beetle populations at the three farm sites varied significantly for both native and introduced species, in

Table 2. Number (percent of total) of dung beetles trapped at four north central Florida cattle farms between June 2005 and December 2008

Species	Beef 1	Beef 2	Dairy 1	Dairy 2
Aphodius fimetarius (L.)[a]	3 (0.03)	1 (0.01)	10 (0.03)	
Ataenius cylindrus Horn		12 (0.06)		
A. erratus Fall	35 (0.41)		1 (0.00)	
A. imbricatus (Melsheimer)	2 (0.02)			
A. picinus Harold	2 (0.02)			
A. platensis (Blanchard)	3 (0.03)	3 (0.02)	4 (0.01)	
A. spretulus (Haldeman)	2 (0.02)			
Ateuchus lecontei (Harold)	9 (0.10)	66 (0.33)	102 (0.31)	4 (0.26)
Blackburneus aegrotus (Horn)	3 (0.03)	13 (0.07)	65 (0.20)	
B. rubeolus (Beauvois)	346 (4.02)	115 (0.58)	813 (2.49)	16 (1.05)
Calamosternus granarius (L.)[a]	1 (0.01)	9 (0.05)	51 (0.16)	
Canthon depressipennis LeConte	1 (0.01)	51 (0.26)	141 (0.43)	
C. pilularius (L.)	29 (0.34)	128 (0.65)	443 (1.36)	9 (0.59)
C. probus (Germar)			1 (0.00)	
C. vigilans LeConte	1 (0.01)	5 (0.03)		
C. v. viridis (Beauvois)		3 (0.02)		
Copris minutus (Drury)	3 (0.03)	111 (0.56)	545 (1.67)	16 (1.05)
Dichotomius carolinus (L.)		4 (0.02)	4 (0.01)	1 (0.07)
Euoniticellus intermedius (Reiche)[a]	16 (0.19)	1,025 (5.18)	328 (1.01)	56 (3.67)
Geotrupes egeriei Germar	3 (0.03)	100 (0.50)	14 (0.04)	
Irrasinus stupidus (Horn)		16 (0.08)	214 (0.66)	
Labarrus pseudolividus Balthasar[a]	4,343 (50.44)	389 (1.96)	3,604 (11.06)	111 (7.28)
Melanocanthon bispinatus (Robinson)		2 (0.01)	4 (0.01)	
Melanocanthon granulifer (Schmidt)		2 (0.01)	20 (0.06)	1 (0.07)
Mycotrupes gaigei Olson and Hubbell			352 (1.08)	
Onthophagus concinnus Laporte		30 (0.15)	9 (0.03)	
O. gazella (F.)[a]	2,015 (23.40)	1,921 (9.70)	2,798 (8.58)	685 (44.95)
O. hecate blatchleyi Brown	725 (8.42)	421 (2.13)	212 (0.65)	8 (0.52)
O. oklahomensis Brown	4 (0.05)	168 (0.85)	282 (0.87)	1 (0.07)
O. pennsylvanicus Harold	207 (2.40)	1,279 (6.46)	53 (0.16)	
O. taurus (Schreber)[a]	792 (9.20)	344 (1.67)	2,294 (7.04)	568 (37.27)
O. tuberculifrons Harold	25 (0.29)	13,274 (67.03)	19,917 (61.11)	40 (2.62)
Oscarinus crassulus (Horn)		1 (0.01)		
Os. windsori (Cartright)			3 (0.01)	
Parataenius simulator (Harold)			5 (0.02)	
Phanaeus igneus MacLeay		138 (0.70)	248 (0.76)	
P. vindex MacLeay	37 (0.43)	162 (0.82)	57 (0.17)	8 (0.52)
Pseudagolius bicolor (Say)	1 (0.01)	9 (0.05)		
Pseudocanthon perplexus (LeConte)	3 (0.03)			
Total	8,611	19,591	32,594	1,524

$N = 10$ traps per farm. Dairy 2 sampled 16 May to 18 December 2007.
[a] Introduced species.

that significant differences were observed between farms with each species. Furthermore, these differences were not because of an individual farm having an over representation of all types of beetles, as each farm had either the most or second most individuals of a species based on six or seven of the 10 species.

Two major peaks in activity were observed with *L. pseudolividus*. The first occurred on 5 June 2007 at the Beef 1 site where 3,548 beetles were collected from 10 traps and the second on 08 October 2008 at the Dairy 1 site where 2,056 beetles were collected (Fig. 1a). Additionally, several large emergences were observed with *O. tuberculifrons*, including 5 June 2007 (5,673 beetles from 10 traps); 08 October 2008 (3,197); and 09 December 2008 (5,655) at the Dairy 1 site; and a collection of 2,522 beetles on 16 September 2008 at the

Table 3. Comparison of selected dung beetles captured at three cattle farms

Species	Total beetles per farm			χ^2	*P* value
	Beef 1	Beef 2	Dairy 1		
Blackburneus rubeolus (Beauvois)	223	100	772	12.71	$P = 0.0004$
Canthon pilularius (L.)	27	99	421	8.68	$P = 0.0013$
Copris minutus (Drury)	2	40	531	16.49	$P < 0.0001$
Euoniticellus intermedius (Reiche)	7	362	220	6.21	$P = 0.0333$
Labarrus pseudolividus Balthasar	4,203	368	3,395	54.39	$P < 0.0001$
Onthophagus gazella (F.)	1,866	1,506	2,592	5.18	$P < 0.0001$
O. hecate (Panzer)	598	280	187	4.42	$P = 0.0098$
O. pennsylvanicus Harold	194	886	52	20.39	$P < 0.0001$
O. taurus (Schreber)	664	1,870	265	27.10	$P < 0.0001$
O. tuberculifrons Harold	14	7,905	13,617	234.35	$P < 0.0001$
Total	7,929	12,405	24,732	214.50	$P < 0.0001$

df = 2, $N = 47$ within-week dung beetle trapping events between 2005 and 2008. At each site, 10 pitfall traps were utilized.

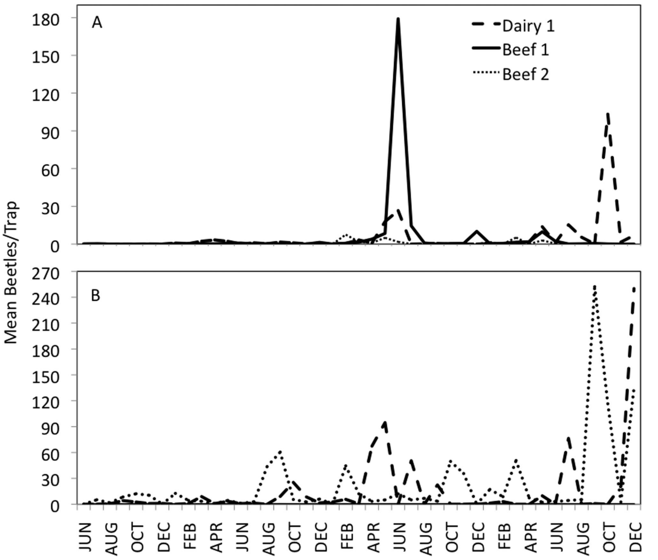

Fig. 1. Mean monthly collection of *L. psuedolividus* Balthasar (A) and *O. tuberculifrons* Harold (B) from three cattle farms in north central Florida between 2005 and 2008. Beetles collected using 10 cattle dung-baited pitfall traps placed for 24 h. Most months represent means of two or more collection dates.

Beef 2 site (Fig. 1b). In all aforementioned situations, the percentage of beetles captured 3 wk before or after the large collection was <3% for *L. psuedolividus* and 28% or less for *O. tuberculifrons.*

Ten scarabs generally not considered dung utilizers, and not counted among the species described above, typically were collected in small numbers during this study. These included two Trogidae: *Trox variolatus* Melsheimer, *Omorgus suberosus* F.; one Hybosoridae: *Hybosorus illigeri* Reiche; and seven Scarabaeidae: *Cyclocephala parallela* Casey, *Dycinetus morator* (F.), *Euetheola humilis* (LeConte), *Euphoria sepulchralis* (F.), *Ligyrus (Tomarus) neglectus* (LeConte), *Martineziana dutertrei* (Chalumeau), and *Strategus anteaus* (Drury).

Discussion

No single farm provided >18 genera or 30 species of the 20 genera and 39 species collected overall. Of the three most sampled farms, the northern and western farms had the greatest diversity. Both of these farms also had the driest soils. Of the species collected at one or the other beef cattle farm, only those represented in very small numbers (<30 specimens) were found to be different. A similar pattern existed between the Dairy 1 site and the two beef cattle farms, with the exception of *Mycotrupes gaigei* Olson and Hubbell, where 352 specimens were collected only at the Dairy 1 site. Woodruff (1973) reports a rather narrow distribution of this species as occurring from the Georgia line in eastern Madison and western Hamilton counties southward into Pasco and Pinellas counties. The Dairy 1 site falls in this zone, whereas the other two collection sites do not. In total, 11 species were collected at only one of the four sites sampled, with no unique collections at the Dairy 2 site, which had limited sampling dates.

The prominence of introduced dung beetles attracted to cow dung in Florida's cattle pastures is evident in that four of the six most commonly collected species were exotics. Furthermore, none of these exotics were intentionally introduced to Florida. As discussed in Wood and Kaufman (2010), *E. intermedius* was collected often at two of the current sites after being first discovered in Suwannee County, FL in 2001 (Almquist 2001), with subsequent 2001 collections by Almquist in Gainesville, FL. However, *E. intermedius* numbers have risen considerably and it can be found in large numbers in the same pasture on the University of Florida's Gainesville campus, particularly during October (P. E. Kaufman, personal communication). However, only 16 *E. intermedius* were collected at the Beef 1 site during the 3.5 yr of this study. This is somewhat puzzling, as the farm is only 10 km south of the University of Florida's campus pasture.

The Beef 1 site also provided the fewest number of dung beetle individuals of the three primarily sampled sites. However, much of the difference in the total beetle captures was because of the extremely low numbers of the native *O. tuberculifrons* collected at the Beef 1 site (25 specimens, versus 13,274 and 19,917 at the Beef 2 and Dairy 1 sites). *Onthophagus tuberculifrons* was considered the most common dung beetle in Florida by Woodruff (1973), and based on our surveillance in north central Florida this remains the case. Woodruff (1973) reported that it is most common from sandy soils, but little is known about the immature stages. Given the striking difference in *O. tuberculifrons* abundance between sampled sites and that the Beef 1 site had the highest water table with a limited drainage soil structure, this beetle may not be important in similar lowland cattle pastures that are common across Florida.

Several studies have examined the structure of dung beetle communities and how they respond not only to the influence of habitat type, but also to the impact of various disturbances to their habitat, including forest canopy changes, landscape type, vegetation, dung type, and pesticide use (Fincher et al. 1970, Doube and Macqueen 1991, Fincher 1992, Masis and Marquis 2009, Davis et al. 2010). However, especially for tunneling species, soil structure differences (Lumaret 1983, Lumaret and Kirk 1991) and water table depth (Brussaard 1985) greatly influence beetle assemblages, with soil moisture levels appreciably impacting larval survival and thus, adult population levels. Given the importance of soils to tunneling dung beetle biology and behavior, it is a critical parameter to understand in a state such as Florida with its variable soils and fluctuating water table. Bertone et al. (2005), working in North Carolina, collected few *O. tuberculifrons* on North Carolina's coastal plain, an area dominated by sandy soils, with no beetles of this species collected in the clay soil-dominated piedmont region. Doube (1983) documented that 23 of 71 African dung beetles collected showed soil type preferences. Given the general proximity, the similar pasture habitat and the simultaneous sampling parameters and timing between samplings used in the current study, the ecological preferences for soil type and the impact of soil moisture likely are the cause of the widely divergent collections of *O. tuberculifrons* we observed.

Within species comparisons documented that collections from one of the farms differed in abundance from the other two for each of the 10 most commonly collected species. In addition to the previously described variation with *O. tuberculifrons*, most within-species abundance differences were considerable; with no single farm dominating the rank-within-catch comparisons across the 10 species. In addition, although the Beef 1 site was the wettest site sampled and the deleterious impacts this may have had on *O. tuberculifrons* capture as discussed earlier, the Beef 1 site ranked first or second in abundance of the other four common *Onthophagus* species, illustrating the care needed in generalizing expected behaviors across a genus.

As observed and discussed in Fiene et al. (2011), *L. pseudolividus* showed very large peaks in abundance. Although our total specimen collections were less than reported by these authors, our exposure time was only 24 h versus the 7-d period used in Fiene et al. (2011). We documented several large emergences of *O. tuberculifrons* at two of our three sample sites and these emergences overlapped with both large *L. pseudolividus* emergences on those sampling dates (with the third site *O. tuberculifrons* emergence preceded by one 3-wk sample period). Such serendipity seems unlikely, whereas either climactic conditions, farm management practices, or both probably played an important role. Rainfall has been shown with several species to drive adult activity (Halffter and Matthews 1966), but in examining nearby reported precipitation in the current study, no patterns were observed.

There were 11 species that were collected at only one site over the 3.5-yr project. Such collections are not uncommon and typically occur with beetles that do not prefer the dung type offered in traps or are species that are low in number in a given area. In addition, these beetles may have flown in from nearby nonpasture areas, may have been interested in the moisture source provided by our baits, particularly in dry times, or may have been accidental interceptions in the pitfall traps.

Livestock producer interest in dung beetles continues to persevere with many producers asking our Extension program about rearing or purchasing beetles for release on their farms. However, many producers are unaware that, in most cases, they already have a complementary assemblage of dung beetles on their farms and that their herd management practices greatly influence the effectiveness of these beetles. This study provides evidence that each of these farms exhibited dynamic and unique dung beetle diversity. Because of the habitat that dung beetles occupy, there is a risk associated with indiscriminant transportation of wild-collected beetles from one farm to another, particularly outside of local areas. Before such an endeavor is undertaken, further research should be conducted to determine the pathogens and parasites that these beetles harbor or vector.

This study offers a profile of dung beetle activity of much longer duration than others published in the United States and documents that variations between sites can be substantial. Four of the six most commonly collected beetles were introduced species suggesting that either a niche was available for these species on cattle farms in Florida or that these species displaced the more generalist and perhaps adaptive native species. Given that cattle are not native to North America, it is not surprising that these introduced species, largely selected because of their affinity to cattle dung, are thriving. Although the data may not exist to answer some of these questions, the impact of this relatively new assemblage on pestiferous flies, such as the horn fly, should be undertaken.

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