Dung Beetle (Coleoptera: Scarabaeidae) Abundance and Diversity in Alpaca Pastures of Virginia USA[1]

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Abstract Dung-baited pitfall traps were used to conduct a survey of dung beetles (Coleoptera: Scarabaeidae) in alpaca pastures located at Virginia State University, Petersburg, VA, from May to September in 2010 and 2011. Beetles were collected weekly and identified to species. Of the 3,136 beetles collected, 11 species were represented: *Onthophagus taurus* Schreber, *O. pennsylvanicus* Harold, *O. hecate hecate* Panzer, *Copris minutus* Drury, *Phanaeus vindex* MacLeay, *Dichotomius carolinus* L., *Sphaeridium scarabaeoides* L., *Aphodius erraticus* L., *A. fimetarius* L., *A. (Nialaphodius) nigrita* F., and *A. (Labarrus) lividus* Olivier. The most common species found in both years was *O. taurus,* which accounted for 43% and 59% of the populations in 2010 and 2011, respectively. Paracoprid tunneler beetles dominated the collection in both years. Both native and exotic species were abundant, indicating that the introduction of exotic dung beetle species has not been detrimental to native populations. The species abundance and diversity fluctuated throughout the summer, likely related to weather patterns.

Key Words dung beetle, diversity, abundance, richness, alpaca

Blume (1985) documents many dung beetle (Coleoptera: Scarabaeidae) species as being present in Virginia, but the state lacks a thorough collection and checklist of these beneficial insects. Recent collections in North Carolina (Bertone 2004; Lastro 2006) and South Carolina (Harpootlian 2001) have been extensive and have covered many regions and diverse zones. The North Carolina collections were conducted in cattle pastures. The presence and abundance of dung beetle species in grazing systems for alpacas and other camelids is unknown.

Dung beetles are categorized into 3 distinct niches based on their nesting behavior by Halffter and Edmonds (1982). Endocoprid beetles lay their eggs and nest in the dung or just at the soil-dung interface. Paracoprid beetles form brood ball from the dung and bury them in nesting chamber that have been excavated directly underneath the dung source. The telecoprid types also form brood balls for their larvae to consume. They differ from the paracoprid beetles in that a ball of dung is rolled away from the initial dung source and shallowly buried in the soil with a single egg laid on it.

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Fig. 1. Example of a dung-baited pitfall trap used for collecting dung beetles in this study.

A few dung beetle species are species-specific to a dung resource, but the majority of dung beetles are opportunistic feeders of dung. Resource selection and preference of dung type often varies by the needs of dung beetle species. For example, beetles that lay their eggs within the dung will not lay them in wet portions, but in the crust if the dung is overly wet. Gittings and Giller (1998) outline 'findability', physical suitability, and nutritional quality as 3 factors that influence the colonization of dung resources. All of these are greatly affected by the stage of dung decomposition and desiccation.

Olfactometer bioassays indicate dung beetles are attracted to dung volatiles, though the specific compounds have not yet been studied (Dormont et al. 2007). Physical factors of dung attraction were studied by Al-Houty and Al-Musalam (1997) noting a preference for moist horse dung over that of dryer sheep and camel dung by *Scarabaeus cristatus* F. in Kuwait. When comparing cow, horse and sheep dung of the same size, Finn and Giller (2002) found a higher abundance of beetles in sheep dung than the other available dung resources. Dung resource abundance and grazing intensity also have been shown to be factors in the composition of dung beetle communities in semiarid regions of Spain (Lobo et al. 2006). Additional factors that affect the composition of dung beetle assemblages are climate (Errouissi et al. 2004) and soil type (Bertone et al. 2006). Because alpaca dung quality factors such as moisture content, consistency and N content vary from that of cattle dung, preference and resource selection may differ. Therefore, it is important to quantify and describe the

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Table 1. The type of dung beetle species described by both origin (native or exotic to the to North America) and nesting guild (endocoprid or paracoprid).

	Origin		Nesting Guild	
Species	**Native**	**Exotic**	**Endocoprid**	**Paracoprid**
A. erraticus		Europe	X	
A. fimetarius		Europe	X	
A. lividus		Europe	X	
A. nigrita		Europe	X	
C. minutus	X			X
D. carolinus	X			X
O. h. hecate	X			X
O. pennsylvanicus	X			X
O. taurus		Europe, Asia		X
P. vindex	X			X
S. scarabaeoides		Europe	X	

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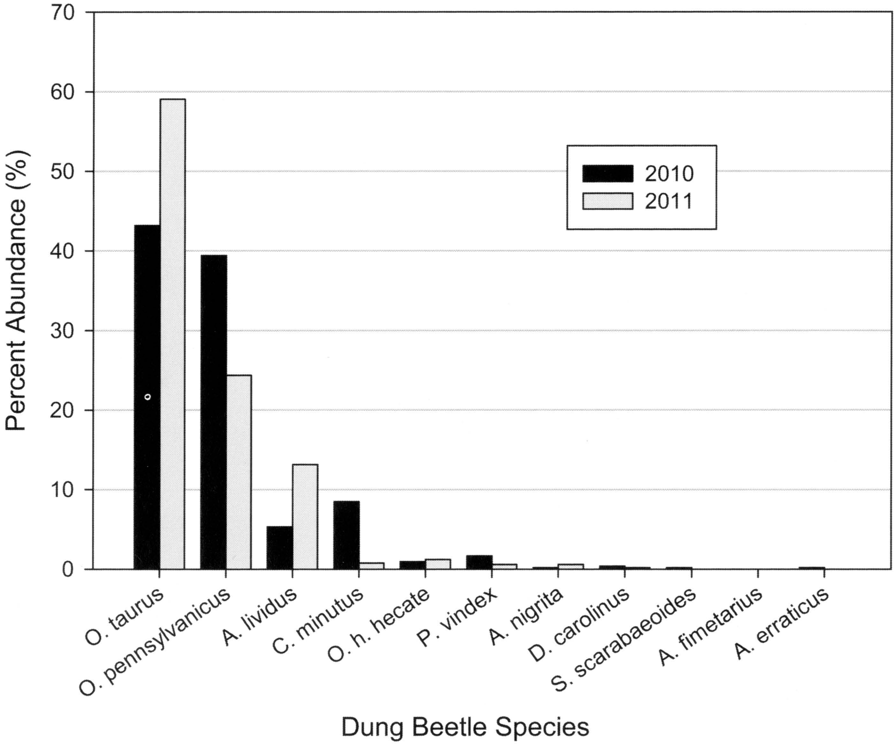

Fig. 2. The relative abundance of each dung beetle species collected in 2010 and 2011, represented as a percentage of the total number of beetles collected each year.

abundance and community composition of dung beetles found in alpaca pastures in the midAtlantic region of the U.S.

Materials and Methods

Dung-baited pitfall traps, as described by Bertone (2004) (Fig. 1), were used to collect samples of dung beetles for this study. Alpaca dung was collected fresh and homogenized by hand mixing weekly from May through August in 2010 and 2011to bait the pitfall traps. The site of dung collection and beetle trapping was the alpaca unit of Virginia State University's (VSU) Randolph Farm, located outside of Petersburg, VA (Latitude N 37°13' 30.1149", Longitude W 77°25' 42.7267", Elevation 32 m). Soil texture in the collection area ranged from fine sandy loam to loam. Slopes within the pasture areas ranged from 0 - 12%. Ground cover in the pastures consisted mostly of bermudagrass (*Cynodon dactylon* L.) and tall fescue (*Festuca arundinacea* Schreber). A total of 8 - 16 traps were placed along the fence line of the alpaca paddocks. Number of traps varied by date in 2011 due to damage from alpacas, so relative abundance is used to present the results. Traps were baited midday and remained in the

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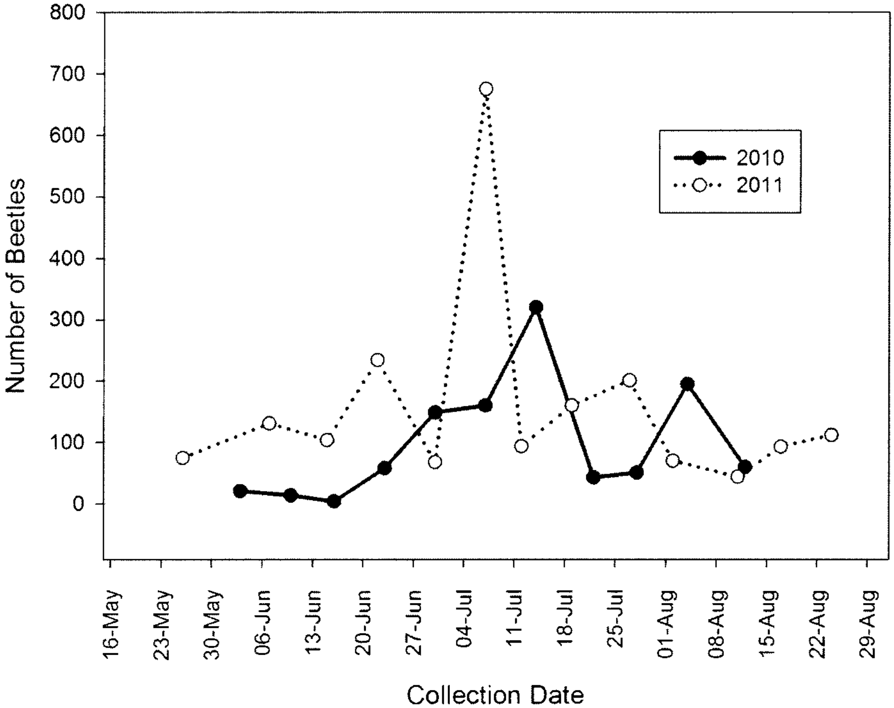

Fig. 3. The abundance of dung beetles collected throughout each collection period.

field for approximately 24 h to attract both day and night flying species. All beetles for each collection date found in the traps were placed in plastic bags and frozen before being identified to species using a key developed by Harpootlian (2001) and counted. Specimens are vouchered in Department of Entomology Insect Collection at Virginia Tech, Blacksburg.

Shannon's diversity index (Krebs 1989) was used as an indicator of dung beetle diversity for each week of collection. This was calculated using the following formula:

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i),$$

where H' = Diversity index; S = Number of species (species richness); p_i = Relative abundance (n_i / N) of species i; n_i = Abundance of species i; and N = Total number of individuals collected. The formula used for relative abundance (p_i) is included in the equation for the diversity index. When appropriate, the abundance of beetles in 2011 has been converted to beetles per 8 traps to make the numbers comparable to 2010 where 8 traps were consistently used every week.

The Renkonen index was used to calculate the percent similarity in the dung community between years. The formula for this is:

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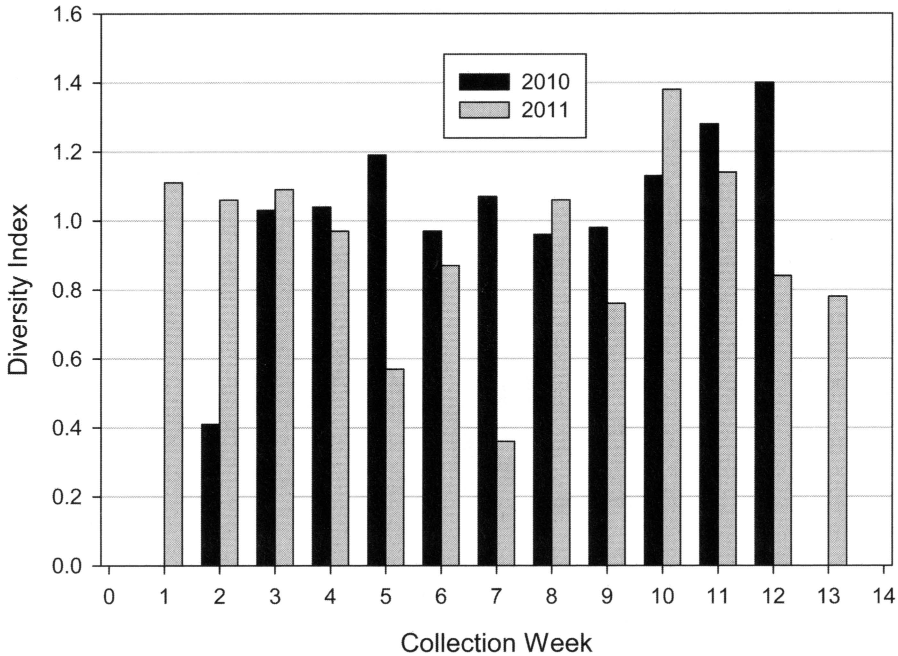

Fig. 4. The dung beetle species diversity represented by Shannon's diversity index shown by collection week for both years. Week 1 starts on May 27 and week 13 ends August 25.

$$P = \sum \min(p_{1i,}\ p_{2i}),$$

where P = Percentage similarity between samples 1 and 2; p_{1i} = Percentage of species i in 2010 community; and p_{2i} = Percentage of species i in 2011 community. The Renkonen index is commonly used and is not greatly affected by the sample size or species diversity (Krebs 1989). Correlations of diversity index with weather factors were analyzed using JMP (SAS Institute 2007).

Results and Discussion

Species collected. Eleven species of dung beetles were collected from late-May through late-August in 2010 and 2011 (Table 1). The species collected were *Onthophagus taurus* Schreber, *O. pennsylvanicus* Harold, *O. hecate hecate* Panzer, *Copris minutus* Drury, *Phanaeus vindex* MacLeay, *Dichotomius carolinus* L., *Sphaeridium scarabae-oides* L., *Aphodius erraticus* L., *A. fimetarius* L., *A. (Nialaphodius) nigrita* F., and *A. (Labarrus) lividus* Olivier. All of the species in this community are of the Scarabaeidae family with the exception of *S. scarabaeoides,* which represents the Hydrophilidae family. Previous studies have not included the Hydrophilidae family, as Scarabaeidae is considered to contain the "true" dung beetles. Recent North Carolina dung beetle collections (Bertone, 2004; Lastro, 2006) have included the Geotrupidae family, but no

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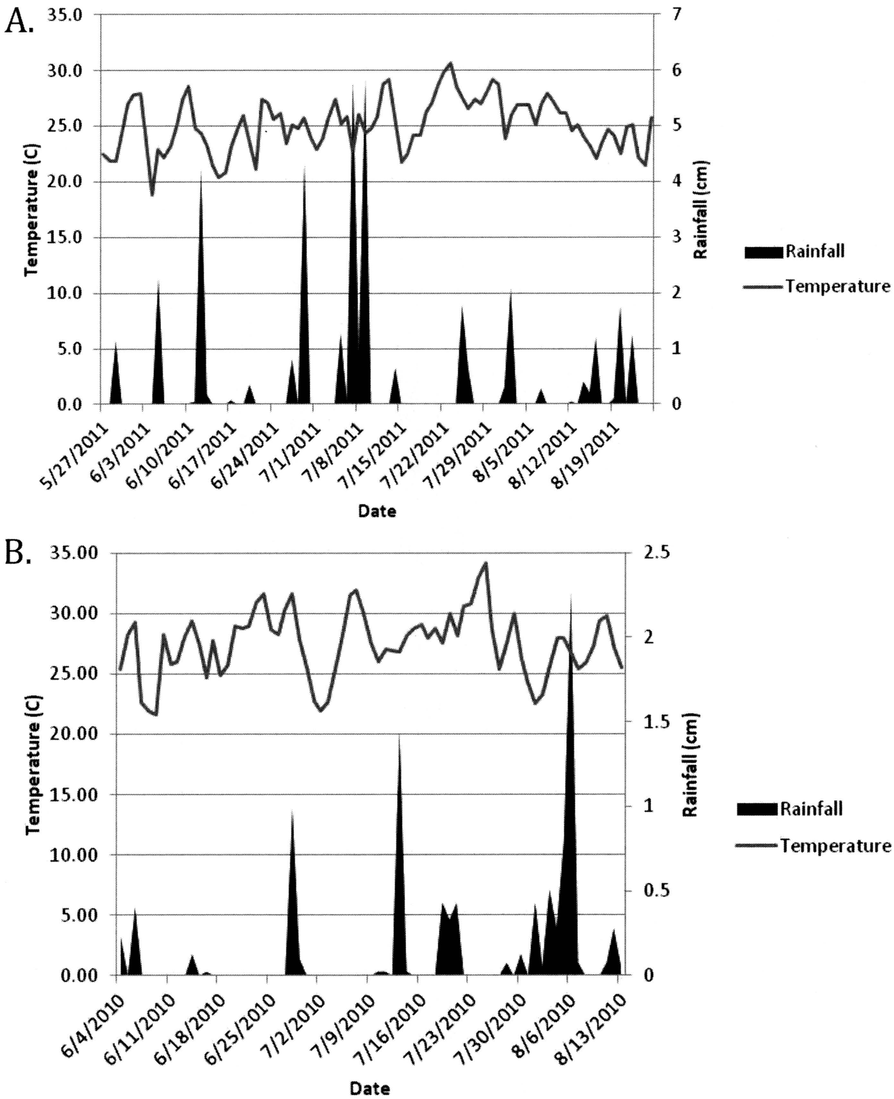

Fig. 5. The daily rainfall and daily average temperatures are shown for the 2010 (A) and 2011 (B) collection periods.

species of that family were collected in this study. The species in the present collection also have been collected in North Carolina (Bertone 2004; Lastro 2006) or in South Carolina (Harpootlian 2001).

Of the species collected, *O. pennsylvanicus, O. h. hecate, C. minutus, D. carolinus, S. scarabaeoides,* and *P. vindex* are native whereas the others are exotic and have origins in Europe, Africa, or Asia (Table 1). Native species represented 51% of the

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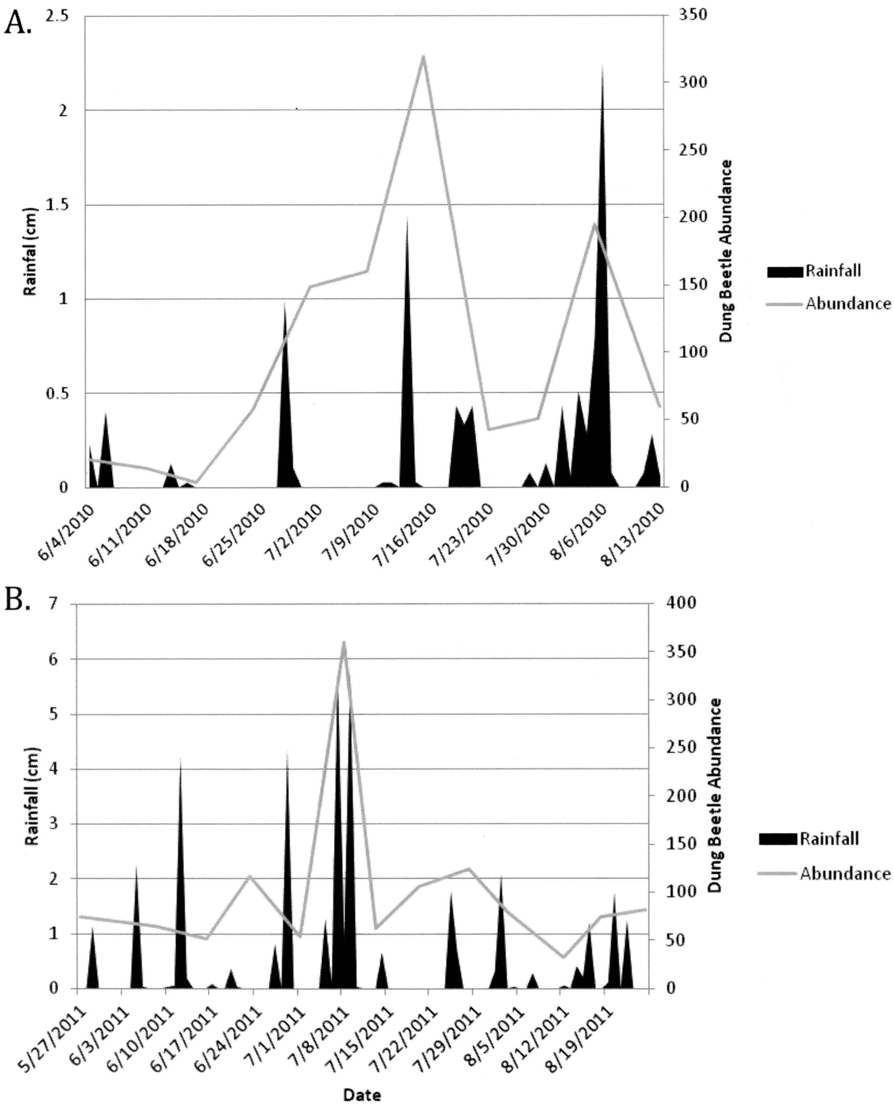

Fig. 6. The abundance of dung beetles collected is shown along with daily rainfall throughout the 2010 (A) 2011 (B) collection periods.

population in 2010, and 27% in 2011. These data indicate that nonnative and native dung beetle species are interacting and sharing dung resources in alpaca pastures. Because both nonnative and native beetles were abundant, we conclude that the activity of the nonnative species has no detrimental effect on the reproduction and life cycle of the native species found in this study. Therefore, these nonnative dung beetles are exotic, but do not appear to be invasive.

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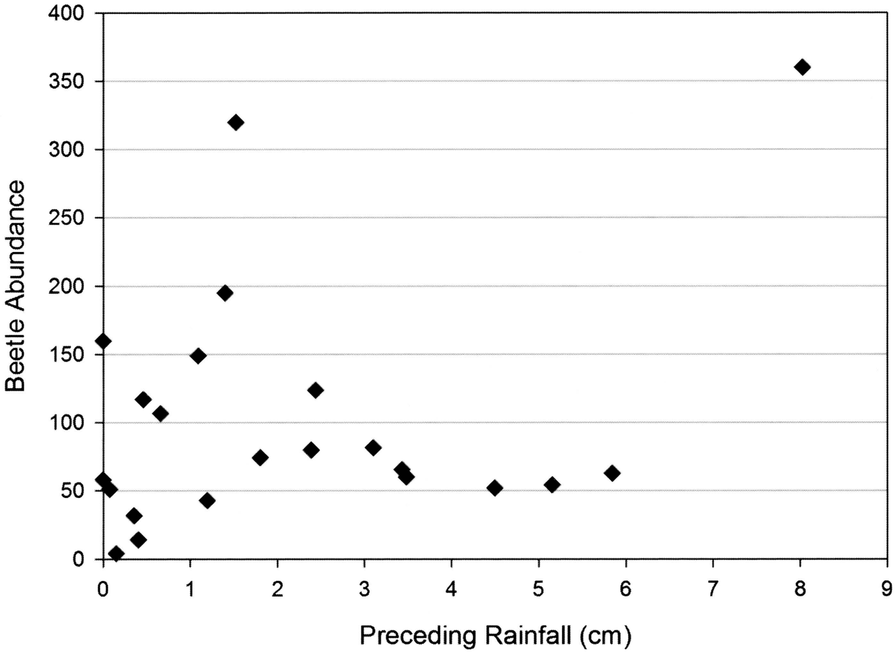

Fig. 7. The relationship between preceding rainfall since the last collection date and the number of beetles collected on the corresponding collection date.

Endocoprid species collected were *S. scarabaeoides, A. erraticus, A. fimetarius, A. nigrita,* and *A. lividus.* The remaining species were all of the paracoprid nesting guild, including *O. taurus, O. pennsylvanicus, O. h. hecate, C. minutus, P. vindex,* and *D. carolinus* (Table 1). All native species collected were paracoprid beetles. The paracoprid species were generally larger beetles compared with the endocoprid. No telecoprid beetles were collected and have only been minor species in recent collections in North Carolina (Bertone 2004, Lastro 2006). Paracoprid beetles were dominant in both years, representing 94% of the population in 2010 and 86% in 2011. The tunneling behavior of paracoprid dung beetles results in improvements in soil structure (Mittal 1993) and soil nutrient levels (Bertone et al. 2006), which can contribute to enhanced forage growth (Lastro 2006). One of the tunneling species found in this study, *O. taurus,* can bury 36.8 g (dry weight) dung with a single mating pair (Hunt and Simmons 2002).

Species abundance. A total of 1075 beetles was collected in 2010, and 2061 beetles were collected in 2011. Species that comprise over 5% of the population are considered to be dominant (Howden and Scholtz 1986). The most abundant species in both years was *O. taurus,* which accounted for 43% of the population in 2010 and 59% in 2011. *Onthophagus pennsylvanicus* was the second most abundant in both years with 39% and 24% of the population in 2010 and 2011, respectively. In 2010, *C. minutus* was a dominant species at 9% of the population, but was not dominant in 2011. *Anolis lividus* was a dominant species in both years and comprised 5% and

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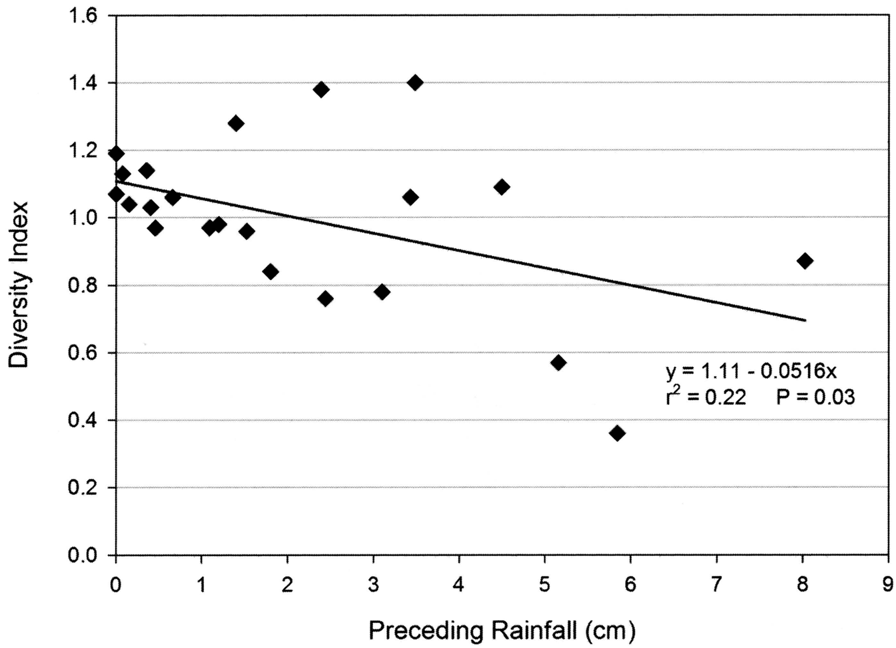

Fig. 8. The relationship between preceding rainfall since the last collection date and the number of beetles collected on the corresponding collection date.

13% of the population in 2010 and 2011, respectively. All other species were minor (Fig. 2).

Dung beetle abundance fluctuated throughout the summer. The highest abundance was recorded in early to midJuly in both 2010 and 2011 (Fig. 3). The abundance of the 2 most common species, *O. taurus* and *O. pennsylvanicus,* also peaked during this collection period. *Onthophagus h. hecate* individuals were not present until the beginning of July in either year. They have been seen as early as March in North Carolina collections (Bertone 2004).

Individuals of the minor species were generally collected seasonally. *Aphodius fimetarius* and *A. erraticus* individuals were collected only in midJune in 2010 and 2011. *Sphaeridium scarabaeoides* were collected only in midJuly, and the 2 *A. nigrita* beetles collected in 2010 were the same times they were collected in 2011.

Similarity. Despite the larger number of beetles collected in 2011, one species (*A. erraticus*) collected in 2010 was not represented in 2011. However, this was a minor species in 2010, and the percent similarity or Renkonen index in the dung beetle community between the 2 years was 75.6%. The high percent similarity indicates that the composition of the communities and their dominance structures did not vary greatly between years.

Shannon's diversity index. Species diversity includes species richness and relative abundance. By including relative abundance, calculations for species diversity account for both richness and evenness of the population. Shannon's diversity index is a commonly used index, and has been used in this study. In biological systems, this

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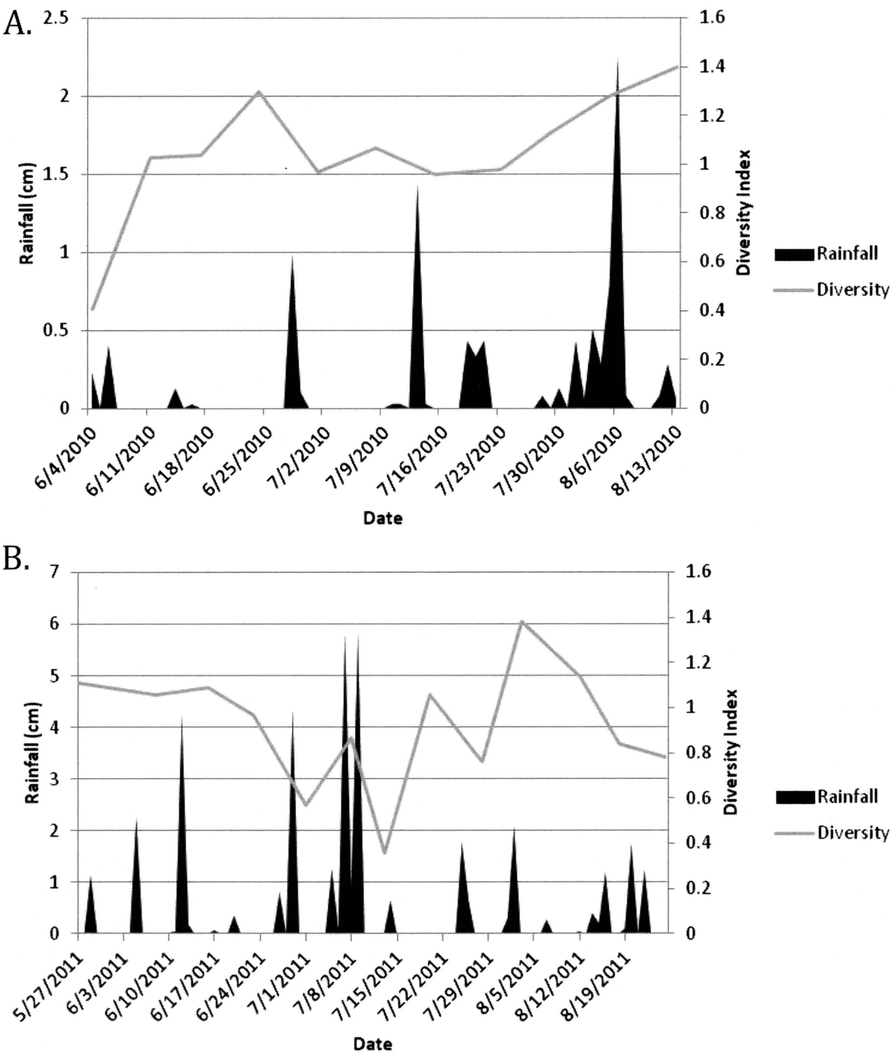

Fig. 9. The dung beetle species diversity represented by Shannon's diversity index is shown along with daily rainfall throughout the 2010 (A) 2011 (B) collection seasons.

index can be as low as 0, but generally never exceeds 5. The higher the index value, the greater the diversity of the community sampled (Krebs 1989). The overall diversity index (H') in 2010 was 1.27 and 1.09 in 2011, indicating that species diversity was greater in 2010 than in 2011 during the summer.

The highest species abundance and richness on any collection date was 7 species on 15 July in 2010 and 8 species on 8 July in 2011 (Fig. 3). Although the abundance and richness were the greatest on these dates, the relative species abundance, or

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evenness, was not necessarily higher (Fig. 4). Interestingly, the greatest species diversity in both years was recorded within a week of each other. The maximum diversity index was 1.40 and 1.38 in the first and second years, respectively, and occurred within the first 2 weeks of August. Other than peaking around the same time in the season, the trends in species diversity were not similar between the 2 collection years. Diversity in 2010 generally increased from May through August, whereas no discernable trends were seen in 2011.

Impact of weather on abundance and diversity. Total rainfall during the 2010 collection period was 9.6 cm, which was much lower than the 38.2 cm recorded in 2011. Also, daily temperatures were 2.0°C higher on average in 2010 than in 2011 [Figs. 5 (A,B)]. Peaks in abundance tended to decrease after rainfall events [Fig. 6 (A,B)]. Whereas the highest peak in 2011 (360 beetles per 8 traps) occurred following the highest weekly rain accumulation, a heavy rainfall the following week resulted in a relatively low abundance (62.7 beetles per 8 traps). Also, the amount of preceding rainfall did not significantly correlate with dung beetle abundance ($P = 0.15$) (Fig. 7). This suggests that there are likely other factors, such as temperature and reproductive cycles, involved in dung beetle emergence. A probable explanation is that a large cohort of adults emerged with the first heavy rainfall, leaving few pupae in the soil when the next rainfall event occurred shortly after the first. Both *O. taurus* and *O. pennsylvanicus* adults peaked in abundance after heavy rainfall, but a closer look at the environmental cues that trigger emergence peaks in these species is needed to confirm our hypothesis that emergence was solely due to rainfall.

Dung beetle species diversity was negatively correlated with preceding rainfall, but the relationship was not strong ($P = 0.03$, $r^2 = 0.22$) (Fig. 8). Peaks in species diversity do not appear to coincide with rainfall events [Fig. 9 (A,B)]. Whereas the species richness tended to be positively correlated with rainfall, the relative abundance did not exhibit high evenness with preceding rainfall.

Previous studies have reported variations in dung beetle activity due to rainfall, drought, and temperature. Lumaret et al. (1992) reported a peak in emergence after the first heavy fall rain. This response may be similar to the peaks seen in the current study where abundance was highest following a relatively high rainfall event. The 2011 data more likely reflect the expected seasonal life cycling of dung beetles because rainfall was more abundant and evenly distributed throughout the season. Higher temperatures and less rainfall with longer drought periods likely contributed to the lower overall abundance of beetles in 2010.

Conclusions. This study has demonstrated that diverse and abundant dung beetle communities occur in alpaca pastures in the midAtlantic region of the United States. Dung beetle communities are valuable components in healthy pasture ecosystems. Understanding their distribution, seasonal abundance, and species diversity are all key aspects in helping researchers develop management recommendations that preserve and build strong and active dung beetle populations.

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