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Impact of pasture development on dung beetle (Coleoptera: Scarabaeinae) community structure in Belize, with first report on *Digitonthophagus gazella* (Fabricius, 1787)

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Key words: Scarabaeinae, Dung beetles, Community structure, Pasture, *Digitonthophagus gazelle*.

Abstract

This is the first reported study on dung beetle community structure in a pasture ecosystem of Belize. Belize is a Mesoamerican nation with over 60% forest cover, but over the past three decades Belize's forest cover is being threatened by agricultural development. One of the major cause of forest decline in Belize is pasture development done by clear cutting forests for cattle farming. Scarabaeinae dung beetles are important bioindicator organism, used to study the effects of land use on biodiversity. They are coprophagous beetles sensitive to changes in the environment. Species richness, abundance, guild structure and beetle sizes of scarabaeinae beetles in a pasture ecosystem was studied. Abundance and species richness recorded were very low. Small beetles and tunneler guild dominated the assemblage. *Onthophagus marginicollis*, a small tunneler was the dominant beetle. *Digitonthophagus gazella* an introduced, invasive species in the Neotropics from Africa was recorded for the first time in Belize. The study showed that dung beetle community structure was negatively impacted in the pasture ecosystem.

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Introduction

Expanding livestock production is one of the main drivers of deforestation in Central America. The three largest forest blocks in Central America have shrunk by 23 percent in the past 15 years, almost entirely due to illegal cattle ranching (WCS, 2017). Deforestation for pasture creation has serious consequences on the environment. Pasture provides a very different habitat conditions when compared to forests. Pastures have higher ambient temperatures, larger fluctuations in temperature and humidity, less shade and biodiversity due to the reduction of niches and habitats (Alkemade *et al.,* 2012, Breshears *et al.*, 1998, Ganho and Marinoni, 2003, Martínez-Garza and González-Montagut, 1999). Pastures also affects soil and water quality, increase runoff and sedimentation in rivers (Hubbard *et al.,* 2004), decrease soil carbon stock and is responsible for the large carbon footprint associated with cattle ranching (Ridoutt *et al.,* 2011, Verge *et al.*, 2008).

Belize is a Mesoamerican nation with the highest percent forest cover (CATHALAC, 2011). But recent satellite imagery study revealed that over the past three decades Belize's forest cover declined from 62.8% (3.438 million hectares) in 2010 to 61.6% in early 2012 (3.376 million hectares). Overall some 25,092 ha. (62,003 acres) of forests were cleared from 2010-2012 and another ~33,129 ha. (81,864 acres) of forest was estimated to have suffered from fire / hurricane damage. Cattle ranching was identified as one of the major factor contributing to deforestation in Belize after agriculture, government policies and logging (Garcia-Saqui *et al.*, 2011). In the past few years the cattle industry in Belize has seen a boom with exports of cattle to Mexico (Belize Agriculture Report, 2017). Most of the cattle in Belize is raised in pastures created by clearing forests. The replacement of native flora by large areas of pasture and agriculture habitats could cause environmental disturbances particularly on biodiversity (Wright, 2010). But no reported study exists to evaluate the effects of such forest conversion in Belize.

Scarabaeinae dung beetles are predominantly coprophagous beetles that are some of the most important invertebrate contributors to dung decomposition in both temperate and tropical agricultural grasslands (Gittings *et al.*, 1994, Horgan, 2001, Kaartinen *et al.*, 2013, Lee and Wall, 2006). By feeding on dung, they provide important ecosystem services such as nutrient recycling, soil bioturbation, increases plant growth, secondary seed dispersal, parasite control and reduce greenhouse gas emission from cattle farms (Ardali *et al.*, 2016, Forgie *et al.*, 2018, Piccini *et al.*, 2017, Slade *et al.*, 2016). Dung beetles are broadly categorized into three functional guilds based on their resource utilization. They are rollers (telecoprids), tunnelers (paracoprids) and dwellers (endocoprids) (Cambefort and Hanski, 1991). Rollers, roll dung balls some distance away from the source and bury them in tunnels for feeding and breeding; tunnelers bury dung balls beneath or beside the dung pad and dwellers feed and breed within or in shallow burrows beneath the dung pad (Cambefort and Hanski, 1991).

Dung beetles show habitat specificity and their community structure is affected by types of vegetation, soil and other environmental variables (Cambefort and Hanski, 1991, Hill, 1996, Osberg *et al.*, 1994). Due to their sensitivity to environmental changes, and the important ecological services they render, dung beetles are considered well-suited as bioindicator organisms to study the effects of land use on biodiversity and ecosystem functions (Audino *et al.*, 2014, Favila and Halffter, 1997, Halffter and Favila, 1993, Howden and Nealis, 1975, Klein, 1989, Tonelli *et al.*, 2017).

In the present study dung beetle community structure attributes such as species richness, abundance, guild structure and beetle size in a pasture ecosystem was investigated. This is the first such study done in a pasture ecosystem of Belize. Earlier studies on dung beetle community structure was done in forest ecosystems of Belize (Latha *et al.*, 2016 a & b, 2018). Such studies helps to understand the consequence of forest conversion into pastures, on biodiversity of ecologically important species. We predict that the dung beetle community structure will be negatively impacted in the pasture ecosystem.

Materials and methods

Study site

The study site, Tiger Run farm Ltd. is located 63 miles along George Price Highway in Cayo District (17.0984° N, 88.9414° W) of Belize at an elevation of 78 (msl) (Fig. 1). The farm at present has 650 acre of pasture with 1,900 to 2,000 heads of cattle. The pasture was created by clearing broadleaf forest and is dominated by *Panicum maximum* Jacq (Mombasa grass) and scattered trees such as *Ceiba pentrada* (L.) Gaertner (Ceiba). The cattle in the farm is grass fed and rotated frequently in a system of small pastures. The farm also has 170 acres of Valencia oranges and 150 acres of corn/bean cultivated in rotation.

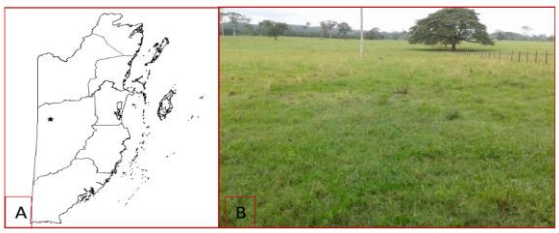

Fig. 1. (A) Location of Tiger Run Farm Ltd. in Belize (B) Pasture ecosystem of Tiger Run Farm Ltd., Belize.

Collection Methodology

Dung beetles were collected using dung baited pitfall traps during 2016-17 period. A total of four collections were made, two each for the wet (June to January) and dry seasons (February to May). Each collection involved placing ten pit fall traps baited with pig dung, an omnivore dung and a good attractant for dung beetles (Marsh *et al.*, 2013). Traps were placed along a transect, 30 m apart, in the pasture ecosystem. Traps consisted of plastic tubs (20x8cm) buried to its rim in soil holding a mixture of mild detergent and salt to drown and preserve the dung beetles. A plastic sheet (33x40cm) supported by 30 cm sticks were set over each trap to prevent desiccation on warm days and flooding on rainy days. The traps were emptied into fine nylon gauze (0.5 mm mesh size) after 24 hour exposure to concentrate the catches from the traps. An ethanol filled wash bottle was used to wash the catch into labeled bottles. Collected beetles were preserved in 70% alcohol and identified to species level using verified taxonomic keys. Dung beetles < 10mm were labeled as small and ≥ 10mm were labeled as large beetles. The beetle species were also designated into their functional guilds (tunneler, roller and dweller) (Cambefort and Hanski, 1991).

Data Analysis

For data analyses both wet and dry season collections were pooled (n=40 samples). A species accumulation curve was constructed to evaluate sampling efficiency (Gotelli and Colwell, 2001) using Estimate S (Version. 9.1.0). The data was tested for normality using Kolmogorov-Smirnov and Shapiro-Wilk test. Since the data significantly deviated from a normal distribution, non-parametric test, Kruskal-Wallis was used to compare variation in abundance between species and guild. Differences with a p-value <0.05 was compared using Mann-Whitney U test. Abundance in beetle sizes were compared using Mann-Whitney U test. All statistical analysis were done using SPSS 21. A species abundance curve was plotted to display relative species abundance. These graphs are useful to explore attributes of the assemblage, such as species richness (number of points), evenness (slope) and number of rare species (tail of the curve).

Results

A total of 26 beetles belonging to five genera and eight species were collected from the pasture ecosystem (Table 1). Species Accumulation curve did not reach an asymptote and is continuously rising. This shows the possibility of finding more species with additional sampling effort (Fig. 2). Dung beetle species abundance varied significantly ($H=24.33$, $df=7$, $p=.001$). Tunnelers were the most abundant guild (80.76%) followed by rollers (15.4%) and dwellers (3.8%) (Fig. 3). The abundance of functional guild varied significantly ($H=11.397$, $df=2$, $p=.003$). Pairwise comparison using Mann Whitney U test revealed that there was significant difference in abundance between tunneler and roller ($p=.002$) but not between roller and dweller ($p=1.000$) and tunneler and dweller ($p=.084$). Small beetles accounted for 96.2% and large beetles 3.8% of the assemblage (Fig. 4). The abundance of small and large beetles varied significantly ($p=.000$).

Table 1. Dung beetles collected from pasture ecosystem of Belize during the 2016-17 study period; size (S=small, L=large); guild (R=roller, T=tunneler, D=dweller).

Species	Size	Guild	Total
Canthon cyanellus	S	R	1
Canthon sp1	S	R	1
Digitonthophagus gazella	S	T	2
Eurysternus mexicanus	L	D	1
Onthophagus batesi	S	T	4
Onthophagus marginicollis	S	T	15
Pseudocanthon sp1	S	R	1
Pseudocanthon perplexus	S	R	1

Species abundance curve showed a steep slope with *Onthophagus marginicollis* as the most abundant species (57.7%) followed by *O. batesi* (15.4%) and *Digitonthophagus gazella* (7.6%). *Canthon cyanellus, C. sp1, Eurysternus mexicanus, Pseudocanthon sp1* and *P. perplexus* were all singleton species (Fig. 5).

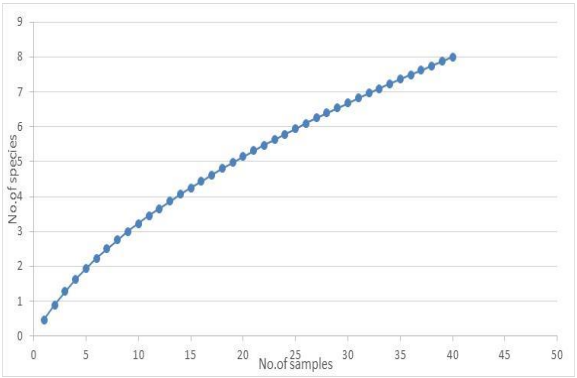

Fig. 2. Species Accumulation curve for dung beetles collected from the pasture ecosystem of Belize for the 2016-17 study period.

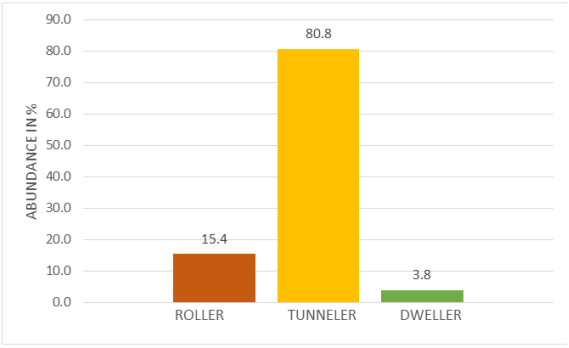

Fig. 3. Dung beetle guild distribution in the pasture ecosystem of Belize for the 2016-17 study periods.

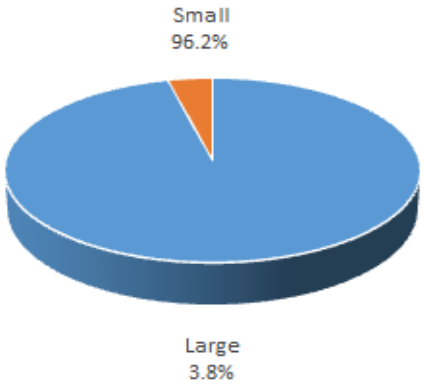

Fig. 4. Dung beetle size distribution in the pasture ecosystem of Belize for the 2016-17 study period.

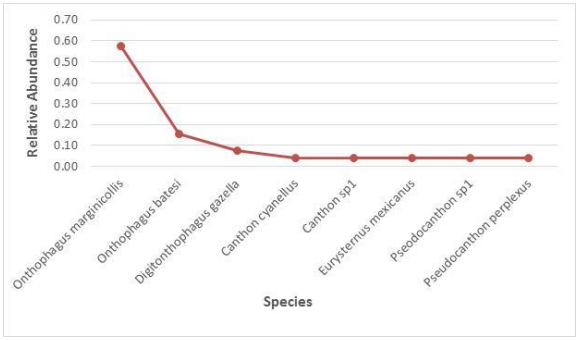

Fig. 5. Species Abundance curve for the pasture ecosystem of Belize for the 2016-17 study period.

Discussion

Conventional cattle ranching in treeless pastures affects biodiversity and ecosystem functions (Alkemade *et al.,* 2012). Dung beetle species richness and abundance was negatively affected in the pasture ecosystem of Tiger Run Farm Ltd., Belize. Species richness and abundance was very low compared to earlier studies done in the forest habitats of Belize (Latha *et al*., 2016 a, b). A total of 169 beetles belonging to nine genera and 15 species were collected from an isolated forest fragment of Guanacaste National Park and a total of 170 beetles belonging to 10 genera and 19 species were collected from a lowland broadleaf forest in Central Belize Corridor during 2010-12 study period (Latha *et al*., 2016 a, b).

Dung beetles are sensitive to habitat modifications related to vegetation cover. Replacement of native forest by pasture entails a drastic reduction in richness and species composition of dung beetles (Braga *et al*., 2013, Korasaki *et al*., 2013, Louzada and

Carvelho e Silva, 2009, Scheffler, 2005, Silva *et al.*, 2014). The removal of native vegetation for pasture, generates a sudden change in microclimate variables such as temperature, humidity and light intensity. Drop in humidity and increase in light intensity and temperature leads to faster drying of food resource (Klein, 1989). This reduces the time during which the food resource is available to beetles and increases adult and larval mortality (Galante *et al.*, 1995, Horgan, 2007, Klein, 1989, Silva *et al.*, 2014). In addition, management activities such as the use of veterinary substances as practiced in the study site affects dung quality and can also alter dung beetle assemblages in terms of composition, abundance, and biomass on traditional farms (Numa *et al.,* 2012). Constant trampling of the dung and vegetative cover by cattle in the pasture habitat of a cattle farm also affects dung beetles negatively (Jameson, 1989).

The number of species present in pastures is also affected by the composition of the original vegetation, the time the pastures take to form, their isolation, grass composition, stability and environmental complexity (Almeida *et al.*, 2011). Conversion of forests to pastures creates a greater shift in physical and biotic characteristics than conversion of open habitats such as cerrado to pasture (Silva *et al.*, 2014). This is due to the fact that species of open areas are adapted to use pastures as habitat and cattle dung as a food resource (Horgan, 2007, Laurance *et al.*, 2011, Silva *et al.*, 2014). On the other hand, forest specialist species are unable to use pasture as habitat and cattle dung as food resources and nesting material (Díaz *et al.*, 2010, Spector and Ayzama, 2003). Hence conversion of forest to pasture decrease species richness and abundance in the region as most interior forest species cannot tolerate the conditions offered by deforested areas (Davis *et al.*, 2001, Escobar, 2000, Horgan, 2007, Silva *et al.,* 2014). Large deforested areas also breaks connectivity between remaining forest fragments and serve as a barrier for the dispersal of forest dung beetles (Hernández *et al.*, 2003).

Pastures are simple and homogeneous habitats with low diversity of food resources (Laurance *et al.*, 2011). Bovine feces are the dominant food source and as such coprophagous species with preference to bovine dung are dominant in pasture habitats (Silva *et al.*, 2014). The invasive species, *Digitonthophagus gazella,* present in the study site is such a coprophagous species. It is better adapted to the microclimatic conditions of the pasture and manage to use bovine feces as a source of food and for nesting. Since the anthropic introduction of the African dung beetle *D. gazella* in 1970 in Texas, to assist in the removal of cattle feces (Blume and Aga 1978, Fincher *et al.,* 1983), its dispersion has been documented in Mexico, Central America, South America and the Caribbean (Noriega *et al.*, 2017). This is the first record of *D. gazella* in Belize. Species such as *Canthon cyanellus, Eurysternus mexicanus, Onthophagus batesi, O. marginicollis, Pseudocanthon perplexus* collected from the pasture habitat were earlier collected from forest habitats of Belize (Latha *et al.,* 2016 a, b, 2018) so these species can be considered as generalist with respect to habitat preference.

Small bodied beetles dominated the assemblage. Large bodied dung beetles are more susceptible to habitat disturbance (Gardner *et al.*, 2008). Though small beetles remove large amounts of dung from agriculture systems; they build smaller tunnels than do large beetles, therefore excavating less soil (Braga *et al.,* 2013) and bury less seeds than do large beetles (Feer, 1999). This negatively affects the ecosystem functions these beetles render in a habitat. Tunneler guild dominated the pasture assemblage, such dominance of tunneler guild in habitats of Neotropics is a common occurrence (Halffter *et al.*, 1992). Their tunneling behavior gives these beetles a competitive advantage over roller and dweller guilds as they are able to relocate the dung beneath the soil rapidly before it desiccates and is trampled upon. The rank abundance curve showed a steep curve with dominance of *O. marginicollis*. Such distribution of abundance, characterized by the occurrence of few species with high abundance and a long tail of singleton species is a common phenomenon in many communities (Verbek, 2011) but it may be more pronounced in open and disturbed habitats (Estrada *et al.*, 1998, Scheffler, 2005, Latha *et al.,* 2016 a and b).

The present study showed that conversion of forest into cattle pasture in Belize negatively affected dung beetle community structure. To minimize the effects of such pasture creation on biodiversity, it is recommended to retain small isolated patches of native trees and shrubs in the pasture to maintain some of the diversity of the original landscape which can act as refuge for dung beetles of forest ecosystem (Horgan, 2007).

Conclusion

Clear cutting for pasture development should be discouraged in Belize and a shift to silvopastoral ecosystem with rotational grazing of cattle in pastures with forage grasses, herbs, shrubs and trees should be encouraged. This improves production efficiency in cattle farms, carbon sequestration, conservation of biodiversity, and improves ecosystem functions in landscape dominated by cattle. Since this is the first study on pasture dung beetles of Belize, it is recommended that further studies be undertaken to study the effects of pasture development on dung beetle community structure and the influence of landscape matrix, to fully understand the consequence of forest conversion into pastures for cattle ranching in Belize.

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