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Effects of Anthropogenic Disturbance on Dung Beetle (Coleoptera, Scarabaeinae) Community Structure In The Central Belize Corridor, Belize

Thomas Latha[1], Emmanuel Young[2], Diomar Salazar[3], Rolando Caballero[4]
[1,2,3,4] *(Dept. of Science, University of Belize, Belize)*

Abstract: *In recent years large scale agricultural expansion, accompanied by clearcutting of large tracts of forest has been taking place in the Central Belize Corridor region of Belize. Biological corridors are landscapes that connects habitats, facilitates movement of animals and maintains ecological process connectivity. Dung beetles of the subfamily Scarabaeinae are important indicator species often used to study the effects anthropogenic activities on habitats,as they are sensitive to alteration of habitats. They provide important ecological services byutilizing dung or carrionfor food andfor breeding purposes. They are classified into three functional guilds: rollers, tunnelers and dwellers based on their feeding and breeding strategy. Dung beetles are also classified as large (≥10mm) and small beetles (<10mm) based on their sizes.In the present study, dung beetle species richness, abundance, functional guild composition and beetle size was studied in Big Falls, Belize in the Central Belize corridor region. Dung beetles were collected using 30 pitfall traps baited with either pig dung, human feces or rotten meat in September 2010 (wet season) and March 2012 (dry season). For each collection effort the traps were placed in three transects of five traps eachand collected after 24 hr exposure. A total of 170 beetles belonging to 10 genera and 19 species were collected from Big Falls. Species richness and abundance of dung beetles were low in Big Falls. Tunneler guild and small dung beetles dominated the assemblage. The study revealed that anthropogenic activities such as clearcutting for agriculture, logging and hunting affected mammal abundance and altered the physical characteristics of the forest in the region which in turn negatively affected the dung beetle community structure in the study region.*
Keywords: *anthropogenic disturbance, abundance, beetle size, Central Belize Corridor, dung beetle, functional guild, species richness*

I. Introduction

A Wildlife corridor is a linear landscape element whichserves as a linkage between historically connected habitat/natural areas, and is meant tofacilitate movement between these natural areas [1][2][3]. Wild life corridors enhance gene flow, increase genetic diversity,allow recolonization of extinct patches, and enhance overall metapopulation survival in connected patches[4]. It also allows opportunity for some species to avoid predation, accommodate range shifts due to climate change, provide for a fire escape function and maintain ecological process connectivity[5] [6]. Wildlife corridors arethe most widely advocated method for countering effects of habitat fragmentation [7].

Belize is a Central American country with the highest percent forest cover in the region[8].But recent satellite imagery studies reveal that Belize's forest cover declined from 74.4% in the late 1980's to 61.6% in early 2012[9]. Although the majority of deforestation occurred outside the protected areas(93.6%),such deforestation isolates the protected areas and affect the effectiveness of the protected area systems [10].As a consequence high priority is given to establish and maintain corridors linking the protected areas.

The Central Belize Corridor links two large forest blocks in Belize— the privately managed northern forest block (Rio Bravo Conservation and Management Area (RBCMA), Yalbac, Laguna Seca and Gallon Jug) and the Maya Mountain Massif (MMM) in the south.Itrepresents one of the last viable connections linking the entire Selva Maya Forest of Mexico, Belize and Guatemala. It extends more than 750 km^2 and is comprised of private lands,communities, and protected areas including: the Labouring Creek Jaguar Corridor Wildlife Sanctuary (LCJCWS), the Peccary Hills National Park, the Manatee Forest Reserve on national land, and private protected areas such as Runaway Creek and Monkey Bay[11].

The forests of the corridor supply communities with timber, game meat, pollinators, other forest products, clean fresh water, land for subsistence agriculture, and livelihoods through tourism and commercial agriculture. It's seasonally inundated broad-leaved forests and lowland savannas act as flood control zones. Its broad-leaved forests, especially riparian forests, help maintain the integrity of the Belize River that supplies water to communities and agricultural developments in the corridor area, the Belize River Valley and Belize City. It allows wide-ranging animals, including large catsand white-lipped peccary to travel safely between the RBCMA and the MMM in Belize ensuring their health and long-term survival[11].

This corridor is subject to intense human pressure from communities living in and around the corridor. Activities such as clear cutting for agricultural expansion, legal and illegal logging, community expansion, forest fires, unsustainable hunting are affecting the flora and fauna in the region[11].

In the present study, dung beetlesof the subfamily Scarabaeinae were used as a focal taxon to study the effects of anthropogenic disturbance in the Central Belize Corridor region.Dung beetles are an important biological indicator and area model taxon to study effects of habitat modification. They are an ideal indicator group as they are ubiquitous; easy to collect using standard sampling methods;their taxonomy is well known; and they show distinct response to natural habitat gradient and land use changes[12].Dung beetlesthrough their feeding and breeding activities which involves dung burial, perform very important ecological services.They enrich soil through nutrient recycling;control pests by destroying eggs and larvae of parasitic flies found in mammalian dung; contribute to forest regeneration through secondary seed dispersal[13]. Based on their feeding and breeding strategies they are classified primarily into three functional guilds— tunnelers, rollers and dwellers. Tunnelers (paracoprids) bury balls of dung beneath the dung pat to feed and breed. Rollers (telecoprids) roll the dung balls considerable distance away from the dung pat to bury. Dwellers (endocoprids) neither roll nor burrow, they simply live in manure[14]. Dung beetles also exhibit size differences. Dominance of small (<10mm) and large beetle (≥ 10mm)populations in a habitat is influenced by physical factors of the environment, habitat types and land use changes [15].The objective of the present study was to investigate if dung beetle species richness, abundance, functional guild composition and beetle size wereaffected by anthropogenic activitiesin the Central Belize Corridor region. We predict that dung beetle community structure will be negatively affected byanthropogenic disturbance.

II. Materials And Methods

2.1. Study site

The study site Big Falls is a private land encompassing an area of 37,000 acres and covers 20% of the Central Belize Corridor. It is located 17°25'59.99"N -88°33'0.01"W, at an elevation of 22 msl in the Cayo Districtof Belize.Part of the forest in the region had been cleared for agriculture, primarily rice (~10, 000 acres). Free-range cattle ranching is also practiced by the proprietors of the land.

The forest in the region constitutes broken ridge forest (lowland broadleaf forest).Recent studies on mammal diversity of the regionrevealed the presence of about 20 mammal species which include coati (*Nasua narica*), grison (*Galictis vittata caraster*), jaguar (*Panthera onca*), jaguarundi (*Puma yagouaroundi*), kinkajou (*Potos flavus*), margay (*Leopardus wiedii*), ocelot (*Leopardus pardalis*), paca (*Cuniculus paca*), puma (*Puma concolor*), tapir (*Tapirus* bairdii), tayra (*Eira Barbara*)[16].

The forest in the region is subjected to intense human pressure. Besides agriculture, the forest is degraded by logging and natural disasters such as hurricanes.Hurricane Richard which passed through the region in October 2010 destroyed a large number of trees.The forest isalso the source of sustenance for residents,of some sixteen villages, living in and around the corridor that use the forest to hunt, obtain firewood and graze their cattle (free- range cattle ranching). Predation of cattle by wild cats and crop raiding by wild animals have increased human wildlife conflict in the region [16].

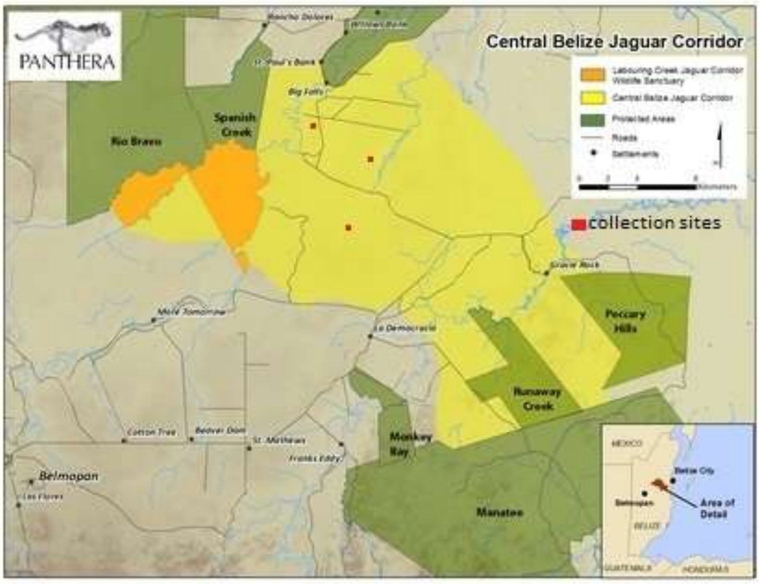

Fig 1. The study site Big Falls in the Central Belize Corridor, Belize

2.2. Specimen collection

Dung beetles were collected in September 2010and March 2012. Fifteen baited pitfall traps were used during each collection effort to trapthe dung beetles. The traps were placed in three transects separated by a distance of 300 m. Each transect consisted of five traps placed 30m apart.The traps consisted of plastic tubs (20x8cm) buried to the rim in soil and holding a mixture of mild detergent and salt or coolant to preserve the dung beetles. A plastic sheet (33x40cm) supported by 30 cm sticks were set over each trap to restrict desiccation on warm days and flooding on rainy days. Pig dung, human feces or rotten meat were used as bait in the different traps to maximize the chances of trapping the beetlesas most species of scarabaeinae utilize different types of dung or rotting material [17]. Traps were collected after 24 hours. The beetles were transported in labeled vials to the laboratory at the University of Belize and identified to species level. Dung beetles were separated based on their size into small (<10mm) and large (≥ 10mm) beetles and into their functional guild as roller, tunneler and dweller species.

2.3. Data Analysis

Species richness is a fundamental measurement of community and regional diversity, and is an important parameter used for planning conservation strategies [18]. Dung beetle species richness estimation was done to compare observed species richness (S_{obs}) to estimated species richness using nonparametric species richness estimators such as Chao 1, ACE, first and second order Jacknife methods.These nonparametric species richness estimators use the abundance-based data to estimate the total number of species. Chao 1 estimator is based on the principal that if rare species (singleton) continue to be discovered while a community is being sampled there is likelihood of more rare species being found. Until all species have been recovered at least twice (doubletons), there is likely no more species to be found. ACE use the same approach but use species which occur 1-10 times in the sample.The jackknife method reduces the bias of an estimator by removing subsets of the data and recalculating the estimator with the reduced sample [18]. Abundance-based jackknife estimators are based on the number of singletons (species represented by exactly one individual) and doubletons (species represented by exactly two individuals)[19].The species richness estimation was calculated using EstimateS v.9. A species accumulation curve was drawn to determine sampling effort and the possibility of finding additional species. A species (or higher taxon) accumulation curve records the total number of species revealed, during the process of data collection [18]. A species abundance distribution curve was drawn to describe the abundance (number of individuals observed) of each species encountered within the community. One Way Anova was used to determine the difference in abundance between large (≥10mm) and small beetles(<10mm) and functional guild (roller, tunneler and dweller). All statistical analyses were done using SPSS 21 (IBM SPSS Statistics for Windows 2012).

III. Results

A total of 170 beetles belonging to 10 genera and 19 species were collected from Big Falls (TABLE 1). The number of species observed was between 74% and 82% of the species richness values generated by Chao 1, ACE, Jackknife 1 and Jacknife 2 estimators (TABLE 2).The species richness estimation values and the species accumulation curve (Fig. 2) indicate that the expected number of species had been collected.

Table 1. Dung beetle species collected from Big Falls, Belize during the study period 2010-2012.
***Size (S= small, L= large beetles); $Functional guild (T=tunneler, R=roller, D=dweller)**

Species	Size*	Functional Guild$	Total	%
Ateuchus laetitiae	S	T	24	15
Canthidium ardens	S	R	2	1
Canthon cyanellus	S	R	27	17
Canthon euryscelis	S	R	4	2
Copris laeviceps	L	T	22	14
Coprophanaeus telamon corythus	L	T	1	1
Deltochilum lobipes	L	R	25	16
Deltochilum pseudoparile	L	R	9	6
Deltochilum scabriusculum	L	R	1	1
Eurysternus caribaeus	L	D	10	6
Onthophagus coscineus	S	T	13	8
Onthophagus crinitus	S	T	1	1
Onthophagus incensus	S	T	2	1
Onthophagus luismargaritorum	S	T	2	1
Onthophagus marginicollis	S	T	1	1
Onthophagus yucatanus	S	T	19	12
Phanaeus endymion	L	T	3	2
Uroxys bidentis	S	T	1	1
Uroxys micros	S	T	3	2

Table 2. Estimated species richness and percentage difference between actual (S_{obs})and estimated species richness values of dung beetles collected from Big Falls, Belize during the study period 2010-2012.

Abundance	S_{obs}	Chao1	ACE	Jacknife1	Jacknife2
170	19	23.14	25.59	25.77	29.6
%		82.10	74.24	73.72	64.1

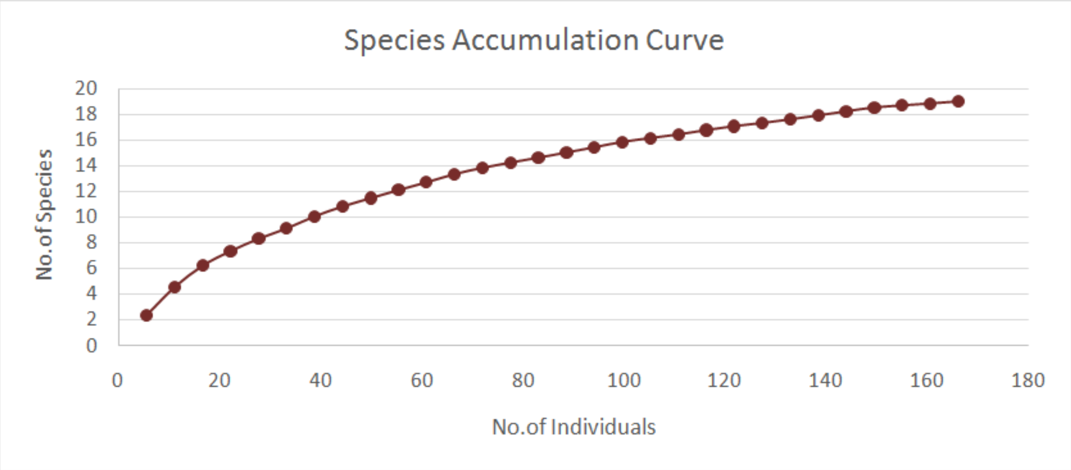

Fig. 2. Species Accumulation Curve (Mao Tao) of dung beetles collected from Big Falls, Belize during the study period 2010-2012.

The species abundance curve showed few abundant species and many rare species. *Ateuchus laetitiae, Canthon cyanellus, Copris laeviceps, Deltochilum lobipes, Onthophagus yucatanus* were the abundant species. *Coprophanaeus telamon corythus, Deltochilum scabriusculum, Onthophagus crinitus, O. marginicollis, Uroxys bidentis* were the rare species represented by one individual each (Fig. 3.).

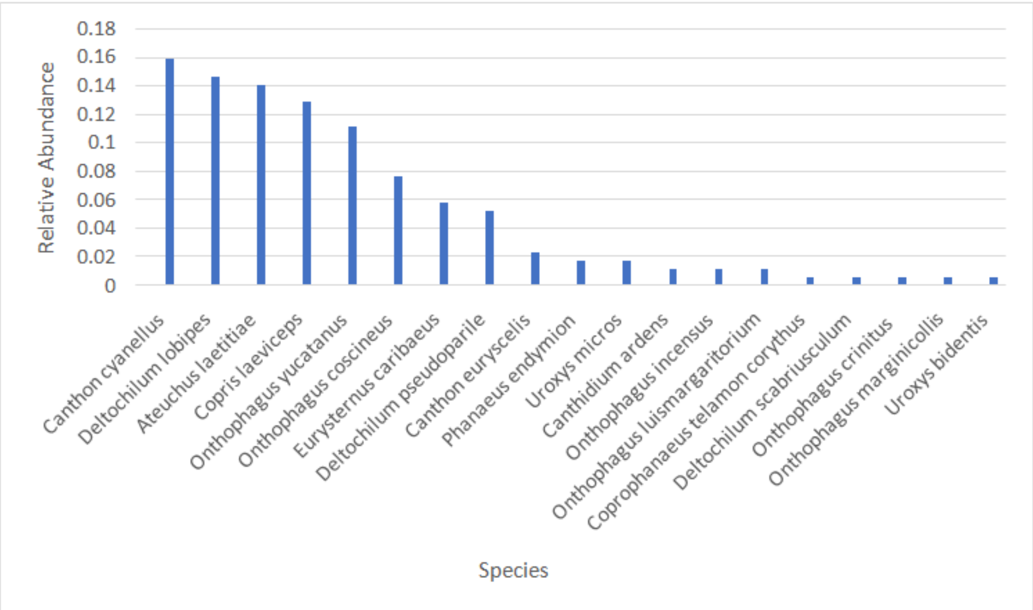

Fig. 3. Species abundance distribution of dung beetles collected from Big Falls, Belize during the study period 2010-2012.

Small beetles accounted for 58% and large beetle 42% of the assemblage (Fig. 4.). Small and large beetles did not show significant difference in their abundance ($F=.367$ $df=1$ $p>0.05$). Tunnelers made up 58% of the assemblage, rollers 40% and dwellers made up 6% of the assemblage (Fig. 5.). Functional guild abundance did not show significant difference ($F=.654$ $df=2$ $p>0.05$). The dominant tunnelers were *Ateuchus laetitiae* (14.9%), *Copris laeviceps* (13.7%), *Onthophagus yucatanus* (11.8%). The dominant rollers were *Canthon cyanellus* (16.8%) and*Deltochilum lobipes* (15.5%).

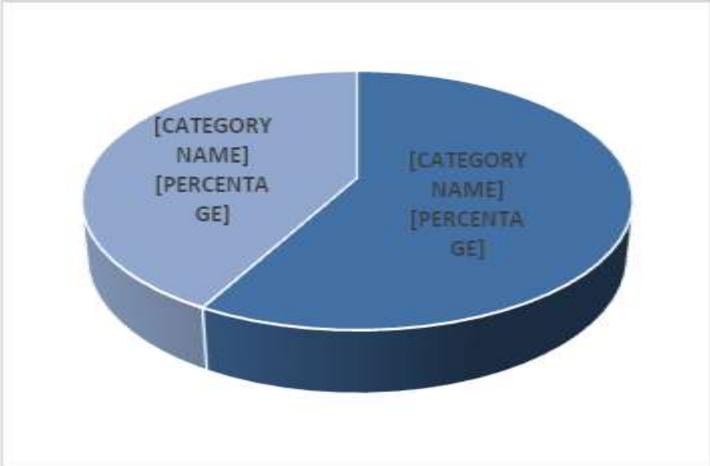

Fig. 4. Proportion of small and large beetles collected from Big Falls, Belize during the study period 2010-2012.

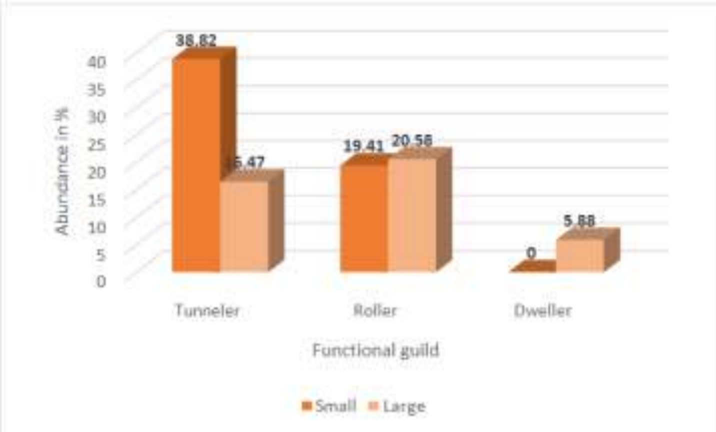

Fig.5. Functional guild composition of dung beetles of Big Falls, Belize during the study period 2010-2012**.**

IV. Discussion

The present study shows that habitat disturbance did affect dung beetle community structure in the study region. Species richness and abundance of dung beetles were low in Big Falls. There are several factors that contributed to the low abundance and species richness of dung beetles in the study region. Studies have shown that abundance of mammals, whose dung is the main food source for dung beetles, is an important factor that affects dung beetle species richness and abundance[20]. Though recent mammal inventory studies in the region recorded the presence of puma, jaguar, margay, jaguarundi, ocelot, tapir, coati, kinkajou, tayra, grison andpaca;studies have shown that mammal abundance in the region is low and their population is negatively impacted by multiple factors[16]. Unsustainable hunting and clear cutting for agriculture was identified as the main threat to mammal fauna living in the Central Belize Corridor [11].Other factors include increasedhuman-wildlife conflicts due to crop raiding by peccary, agouti, coati which increase confrontation between small farmers and the animals;attacks on livestock by jaguars especially in farms adjacent to protected areas and farms were livestock is allowed to roam freely in the forest results in jaguars being killed by hunters/farmers [16] [11] .Road kills of animals crossing the highway and seasonal flooding of the study region in the wet season are alsoimportant factors that affected the mammal population[16]. In addition natural disasters like hurricaneswhich occurred during the study period destroyed large number of trees which are habitats for the arboreal mammals.This made them potential prey for predators and hunters. Forest fires in the summer caused by deadwood from the hurricane also killed many mammals [16].

Vegetation cover affects physical factorsof the environment such as sunlight penetration, temperature and humiditywhich inturn affectdung beetle community structure[21][22][23][24][25].Logging, clear cutting for agriculture and natural disasters like hurricanes that destroyed trees in the study region affected physical factors such as temperature, sunlight penetration and humidity which in turn negatively affected dung beetle species richness and abundance. Increased sunlight penetration and temperature led to the dominance of dung beetle species such as *Canthon cyanellus*, *Copris laeviceps*,*Deltochilum lobipes*,*Ateuchus laetitiae*, *Onthophagus* *yucatanus*which are tolerant to such conditions and adapted to survive in open and disturbed habitats. These species were also collected from the isolated fragmented forest of Guanacaste National Park [26] which makes them species that are common in the region and that are tolerant to habitat disturbances. The forest in the study region is also subjected to heavy rains and regular flooding in the wet season. This would be detrimental to the dung beetles as their dung source would be washed away in the heavy rains and their tunnels inundated by flood.

Tunneler guild dominance as observed in the study region is a characteristic of neotropical forests and is related to their superior competitive nature[25][27].Tunneler dominance was also observed in previous study in a fragmented forest of Belize [26]. Small beetle dominance in the study area can be linked to habitat disturbance observed in the study region. Studies have shown that large bodied beetles are more susceptible to habitat disturbance than small bodied beetles[22][28]. Large beetles require more food resources,large dung pats[29] and are affected by decline in dung availability [30][20]. They also have low fecundity[31]. Forest fragmentation [22][32], conversion to agriculture [33][28], and deforestation[34] are all found to affect large dung beetles by altering physical factors like temperature and sunlight exposure and declining dung diversity and availability.

V. Conclusion

The present study revealed that anthropogenic activities in the Central Belize Corridor region has affected the community structure of dung beetles by negatively altering the vegetation, physical characteristics and mammalian composition of the habitat. Biological corridors help mitigate the effects of habitat fragmentation. The recent spate of large scale agricultural expansion,accompanied by the clearing of large tracts of forest in the Central Belize Corridor region, can further fragment the forest leading to more species loss, and an altered faunal composition thataffects ecosystem functioning. This also curtails dispersal of large vertebrates through the country and the region. Therefore establishment and protection of the integrity of wildlife corridors should be an important part of wildlife conservation strategy in Belize.

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