Habitat Types Effect on Diversity, Distribution and Abundance of Dung Beetles

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Abstract. Dung beetles are ecologically important taxa to study the assessment of habitat modification and disturbance across the globe. This study was aimed to explore community composition, species richness and abundance of dung beetles in response to Gujrat, Punjab, Pakistan. Dung beetle assemblage were sampled from four habitat (natural rangeland, cropland, roadside and housing colonies) during 2014-2016 by placing pitfall traps baited with cattle dung. A total number of 540 specimens representing 17 species belonging to seven genera and four tribes were collected. We calculated species relative abundance in natural habitat (34.8%), cropland habitat (40.4%) and in road side areas (25.2%) was recorded, whereas no specimens were recorded in urban areas. *Aphodius contaminatus* (42.96%) was the most abundant species followed by *Onitis castaneous* (26.29%) and *Onitis singhalensis* (20.74%). Tunnellers (50.58%) and dwellers (49.01%) were dominant in all habitats, whereas rollers were least abundant (1.37%). The values of Shannon-Wiener (H) diversity and evenness (E) showed variations among different habitats i.e. natural habitat (H=1.20; E=0.55), cropland habitat (H=1.41, E=0.32) and roads-side (H=0.80, E=0.37). The study showed that cropland served as a major habitat for dung beetles due to its uniformity and close association with mammalian fauna. The results emphasized that natural habitats within the agro-ecosystem have become isolated and fragmented habitat with lesser stability and low resources thus resulting into less diverse habitat. Roadside areas are in close proximity with cropland and act as corridors for efficient species flow within ecosystem due to cattle movement through these areas.

Keywords: habitat, scarabaeidae, dung beetles, Pakistan

Introduction

Human interventions have caused a higher degree of heterogeneity in agricultural landscape at both spatial and temporal scale and largely affected the species that inhabit these lands (Macdonald and Smith, 1990). Anthropogenic settlements change the plantation structure to monocultures directly or indirectly altering characters of a habitat. Such conditions abolish the establishment of preexisting species in new environment. These physical changes result in habitat loss by converting it into smaller plots of land (Collins *et al*., 2000; Medley *et al*., 1995) leading to more urban gradient.

Natural landscapes have gradually transformed into agro ecosystem, sub urban and finally urban areas resulting a frequent loss in natural habitat within a few decades all over the world (Davis, 1979). Urbanization

results in the decline of biodiversity at a greater rate (Davis, 1979). Species diversity and abundance becomes limited specifically at the urban edges. Urban landscape either eliminates the endemic species completely from its natural habitat by limiting the resources or it may also provide a widespread area for a certain species to flourish (Ott, 1995). Habitat modifications accelerated by humans are going to be expediting in future, hence, leading to more rapid loss of biodiversity. It is essential to assess the sensitivity and response of biotic communities to habitat change for predicting biodiversity loss and designing and proposing conservatory efforts (Sala *et al*., 2000).

Insect population is directly or indirectly affected primarily due to change in habitat as they respond to the change in microclimatic conditions resulting in the modification in the community composition (Gerstmeicr and Lang, 1996; Curry, 1994; Fewkes, 1961; Franz, 1931). Urbanization affects insect population by reduced availability of land due to industrialization and housing,

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environmental pollution (Hafernik, 1992; Davis, 1979) and by isolating the microhabitats (Kindrall and Ahlen, 1992).

Dung beetles are efficient decomposers and play a vital role in nutrient recycling, soil turnover, seed dispersal and as parasitoids of several flies (Nichols *et al*., 2008; Andresen and Levey, 2004; Andersen, 2002a, 2002b, 1999; Horgan, 2001; Halffter and Matthews, 1966). This group acts as an indicator of habitat disintegration, disturbance and diversity richness in tropical forests (Nichols *et al*., 2007; Spector, 2006; Halffter and Arellano, 2002) because these are strongly associated with the mammalian fauna of ecosystem (Spector, 2006).

Differences in locality and habitat conditions give rise to a different type of community composition of dung beetles. Diversity of dung beetles is greater in forest as compared to grassland (Edwards *et al*., 2017; Frank *et al*., 2017). They respond negatively to habitat changes, fragmentation and isolation of forest patches and intensive land use (Shahabuddin *et al*., 2010; Gardner *et al*., 2008; Nichols *et al*., 2007; Halffter *et al*., 1992) but the effect of urbanization is still not very clear (Radtke *et al*., 2008; Carpaneto *et al*., 2005; Wallace and Richardson, 2005).

The present study was conducted to evaluate the impact of habitat change on dung beetle diversity due to urbanization in an agricultural area in semi-arid regions of Pakistan where intensive industrialization and massive constructions have altered the natural habitats of insect fauna. The impact of habitat loss on dung beetles is necessary to understand in order to have an insight into bio-indication, decomposition activities and to design a conservation strategy for dung beetles. This study was designed to evaluate community structure of dung beetles in four different habitats and to assess their response towards habitat disturbance.

Material and Methods

Experimental details and sampling. *Study area.* The study was conducted in the vicinity of Gujrat city during July 2014 - June 2016 representing different habitats with variable human intervention. The sampling units are located at the northern boundary of Punjab province between latitude 32.57, 38 °N and longitude 74.07, 89 °E, 224 meters above the sea level. The Punjab province is fed by five major rivers and comprises an agrarian economy province of Pakistan.

The study area has two major rivers, the river Chenab and the river Jhelum making the area suitable for agricultural activities. The maximum temperature is 45 °C during summers that does not prolong due to the proximity of mountains of Azad Kashmir and below 2 °C during the winter season. On the basis of crops produced, Gujrat is divided into two categories, irrigated and rain-fed regions. Overall the climate of Gujrat is moderate and the soil is suitable for cultivation of a variety of crops. But massive increase in population and the establishment of vast industrial units have replaced the croplands.

The study area was divided into four main sites; natural habitat comprised of undisturbed semi-forest area (rangeland), croplands with seasonal crops, roads and construction sites, and the urban area including gardens and lawns in housing colonies (Fig. 1).

A preliminary survey was conducted to locate the appropriate sampling sites in these areas. Each of the sites was further sub-divided into five sampling units as described in Table 1.

Sampling. Pitfall traps baited with cattle dung were used for sampling. A total of 12 traps were placed fortnightly during the whole study period. Five traps per sampling site were placed with a distance of 10 m in a square with the fifth trap in the center of the square

Table 1. Description of sampling sites in Gujrat, Punjab, Pakistan

| Habitat type	Habitat description
Natural habitat (NH 1-5)	Natural habitat comprised of semi forest area, about 20 km away from Gujrat city in the north. Five sampling units were selected and named after the surrounding villages as Kakrali, Sabor, Miana Chak, Dolat Nagar and Rehmania Pul
Cropland (AH 1-5)	Cropland habitats were selected as Ikhlas Garh, Ghuman, Kotli Kohala, Sook Kalan and Mangowal. Crops and the adjacent areas containing cattle were examined.
Road side area (RSA 1-5)	Five roads surrounding Gujrat city were sampled as, Bhimber road, Jalal pur Jattan to Kharian road, University-Gandra road and Kunjah road
Housing colonies (HC 1-5)	Housing colonies named as Model town, Shalimar town, Service More, Haryawala Chowk and Shaheen Chowk in Gujrat city were selected and gardens and lawns of houses were taken as sampling units
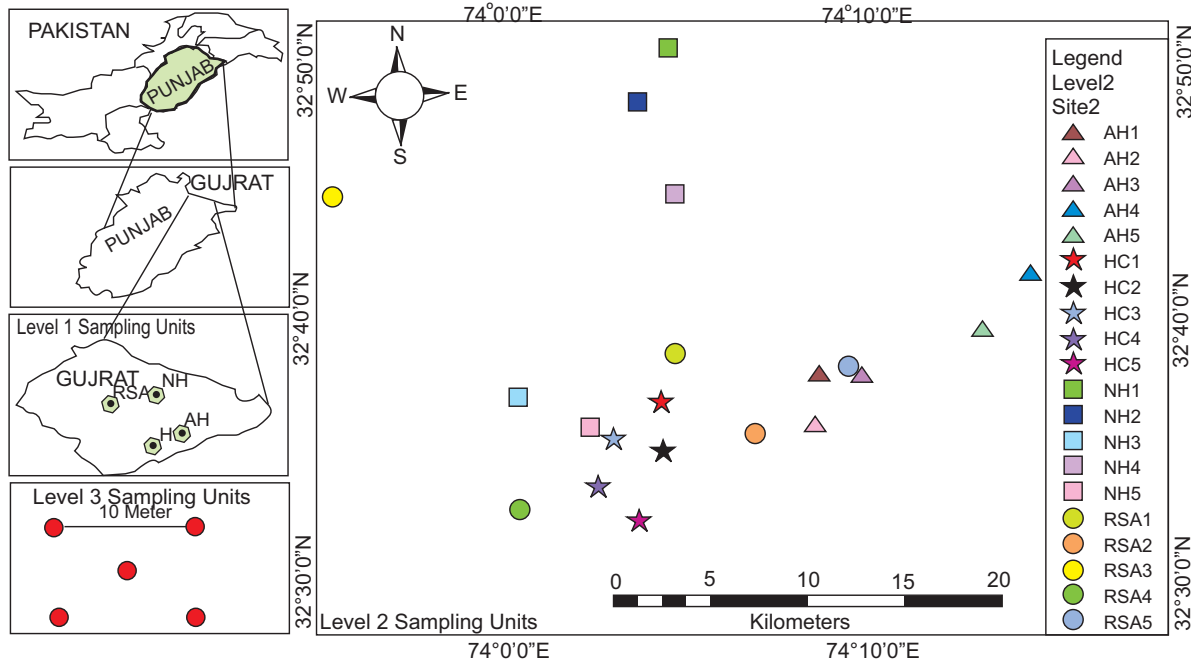
Fig. 1. Map of sampling sites in Gujrat, Punjab, Pakistan.

(Fig. 1). Pitfall traps consisted of 200 mL transparent plastic cups with a diameter of 8 cm containing 50 mL salt water mixed with detergent to reduce surface tension (Larsen and Forsyth, 2005). The traps were placed in the soil, while their rims were in the level with the soil surface. Traps were covered with plastic net with three holes of suitable size and 10 g fresh cattle dung wrapped in a plastic bag was placed on it.

Data collection. Beetles were collected after every 4 d and dung was refreshed as it loses its attractiveness after 48 h. Collected specimens were immediately shifted to killing jars which were made by using KCN. The specimens were preserved in 70% alcohol and then identified to the species level by examining through a binocular microscope and using identification keys by Balthasar (1963) and Arrow (1931) then tagged. Specimens were then divided into their functional guild comprising of tunnelers, dwellers and rollers to evaluate their functional and spatial guild composition. All the collected species were then dry pinned in wooden collection boxes containing naphthalene tablets to avoid fungal attacks and deposited to the zoological museum in the Department of Zoology, University of Gujrat.

Data analysis. Species accumulation curves and species richness estimators were estimated by EstimateS. Diversity (Magurran, 2004) was estimated using Shannon–Weaver diversity index (Shannon and Weaver,

1949), evenness with Simpson's evenness index (Simpson, 1949), richness with Margalef's species richness index (d) and Berger-Parker index for species dominance. Analysis of variance for differences in habitats, sites and species was performed by three-way ANOVA test.

Results and Discussion

Species composition. A total number of 540 specimens were collected during a two-year study period (July, 2014 - June, 2016). From the 300 baited traps, a total of 186, 218 and 136 individuals were captured from natural forest, cropland and road sides, respectively (Table 2). It represented 17 species belonging to seven genera and four tribes. The percentage composition of species abundance in natural habitat (34.8%), cropland habitat (40.4%) and in road side areas (25.2%), whereas no specimens were recorded in urban areas.

The data indicated that three species were most common, two common, three less common and 8 were least common. Maximum number of species belonged to Scarabeinae representing the genera, Catharsius (5 species), Onitis (6 species), Heliocopris (1 species), Onthophagus (1 species) and Gymnopleurus (2 species) and there species belonged to family Aphodiinae named as *A. contaminatus*, *A. fossor* and *O. cinctus* (Oniticellini). Among three major species *A. contaminatus*

(Aphodiinae) dominated the cropland while *O. castaneous* and *O. singhalensis* (Scarabaeinae) showed a higher abundance in natural habitat but were also common in agricultural habitat.

The abundance data collected by natural habitat revealed that six species named *A. contaminatus*, *O. castaneous*, *O. singhalensis*, *C. molessus*, *H. bucephalus* and *O. cinctus* were found in the habitat with variable numbers significantly different from each other. In cropland habitat, 13 species were captured showing different abundance and represented by the *A. contaminatus*, *O. castaneous*, *O. singhalensis*, *O. cinctus*, *O. excavatus*, *A. fossor*, *G. bicallosus*, *O. subopacus*, *O. philemon*, *O. falcatus*, *C. granulates*, *C. pithecius* and *O. gazella*. The data from roadside habitat revealed the presence of six species with an abundance of *A. contaminatus*, *O. castaneous*, *O. singhalensis*, *O. excavatus*, *C. platypus* and *C. sagax*.

Functional guild. The captured species were differentiated into their functional guild. Out of seventeen species collected, thirteen species were Paracoprid (Tunnelers), three were Endocoprid (Dwellers) and one species belonged to Telocoprid (Rollers) guild (Table 2).

Tunnelers were the dominant group representing a species composition of about 50% and were found in three habitats (natural habitat, cropland and roadside areas). Dwellers shared about 48% of the total abundance inhabited under natural habitat and cropland, whereas only one species was found in the road-side area and it was collected from all three habitats. However, Rollers were the rare guild comprising only 1.4% of the total reported species and were collected from the cropland only. Large-sized individuals were found in natural habitat, whereas small-sized were common with the large-sized specimens in cropland and roadside habitats.

Species richness and abundance. Species richness was expressed in terms of Shannon-Weiner diversity index for the three habitats natural, cropland and road-side areas where different species were captured. There were no species reported from housing colonies. However, the dung beetle species were collected from village-based residential areas characterized by the presence of cattle. Diversity and evenness values were calculated for natural habitat (H=1.20; E=0.55), cropland habitat (H=1.41, E=0.32) and roads-side (H=0.80, E=0.37).

Simpson's index for natural, cropland and road-side area was 0.64, 0.65 and 0.40, respectively. Margalef's richness index was 0.96 for natural habitat, 2.23 for cropland habitat and 1.02 for roadside habitat. The

Table 2. Habitat-wise relative abundance of species captured from Gujrat, Punjab, Pakistan during 2014-2016

Species name	Functional guild	Habitat-wise abundance (%)				Species abundance (no.)	Relative abundance (%)
		Natural habitats	Croplands	Road side areas	Housing colonies		
Aphodius contaminatus	Dwellers	6.034483	49.56897	44.39655	0	232	45.49
Onitis castaneous	Tunnelers	46.47887	38.02817	15.49296	0	142	23.92
Onitis singhalensis	Tunnelers	78.57143	19.64286	1.785714	0	112	20.00
Oniticellus cinctus	Dwellers	78.94737	21.05263	0	0	19	3.72
Onitis excavatus	Tunnelers	0	57.14286	42.85714	0	14	2.74
Aphodius fossor	Dwellers	0	100	0	0	7	1.37
Catharsius molessus	Tunnelers	100	0	0	0	2	0.392
Catharsius platypus	Tunnelers	0	0	100	0	2	0.392
Gymnopleurus bicallosus	Rollers	0	100	0	0	2	0.392
Onitis philemon	Tunnelers	0	100	0	0	1	0.196
Onitis subopacus	Tunnelers	0	100	0	0	1	0.196
Onitis falcatus	Tunnelers	0	100	0	0	1	0.196
Catharsius sagax	Tunnelers	0	0	100	0	1	0.196
Catharsius granulatus	Tunnelers	0	100	0	0	1	0.196
Heliocopris bucephalus	Tunnelers	100	0	0	0	1	0.196
Catharsius pithecius	Tunnelers	0	100	0	0	1	0.196
Onthophagus gazella	Tunnelers	0	100	0	0	1	0.196

results demonstrated higher species richness in cropland habitat. Berger-Parker index for species dominance was 0.47 for natural, 0.53 for croplands and 0.76 for roadside habitat. Indices showed that cropland area was more diverse than the other two habitats (Table 3).

The statistical analysis of the data showed significant results for species abundance in all habitats (Table 4). The species accumulation curve calculated by EstimateS was asymptote showing the tendency towards more coverage of species in selected study area (Fig. 2). Species richness estimators including Mao tau, Chao 1 and 2, Abundance-based Coverage Estimator and Incidence-based Coverage Estimator were plotted. Chao 1 and Chao 2 were steeper, indicating the presence of more unique and doubletons species in the data while ACE was climbing gradually with a diverse trend of abundance (Fig. 3).

The study was designed to explore the effect of habitat modification on dung beetle. Diversity indices including Shannon-Weiner index, Simpson's index, Margalef's species richness index and Berger-Parker dominance index revealed that the species richness was not significantly different in each habitat. But data indicated variation in the abundance of different habitats. Cropland

Table 3. Species diversity indices calculated for different type of habitats of Gujrat, Punjab, Pakistan

Indices	Natural habitat	Croplands	Road side areas
Taxa_S	6	13	6
Individuals186	218	136	
Dominance_D	0.3621	0.3527	0.6022
Simpson_1-D	0.6379	0.6473	0.3978
Shannon_H1.	196	1.411	0.8031
Evenness_e^H/S	0.5513	0.3153	0.3721
Margalef	0.9568	2.229	1.018
Berger-Parker	0.4731	0.5275	0.7574

Table 4. Species diversity indices calculated for different type of habitats of Gujrat, Punjab, Pakistan

Source	Type III sum of squares	Df	Mean square	F	Significance
Model	488a	23	21.2	109	0
Habitat	3.36	2	1.67	8.59	0
Sites	0.48	4	0.12	0.62	0.65
Species	389	16	24.3	125	0
Error	592	3037	0.19		
Total	1080	3060			

a. R squared = .45 (Adjusted R squared = .45)

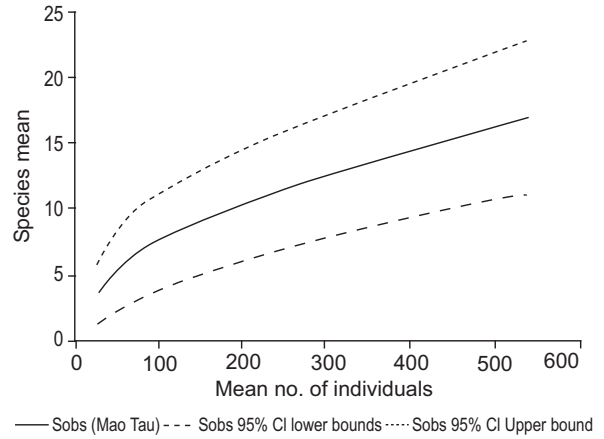— Sobs (Mao Tau) - - - Sobs 95% CI lower bounds ····· Sobs 95% CI Upper bound

Fig 2.   Asymptote species accumulation curve (Sobs Mau-Tau) based on the number of individuals at 95 % confidence level.

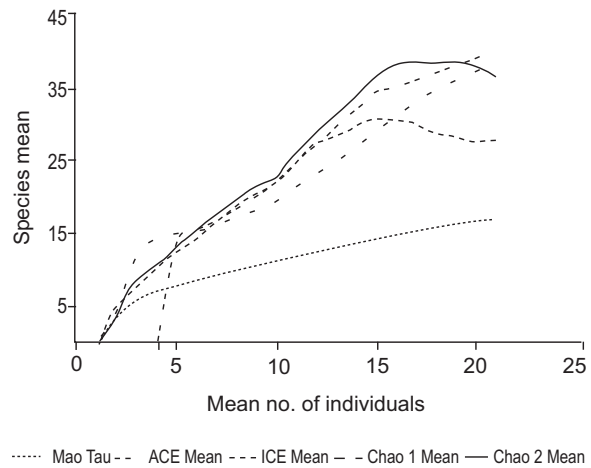····· Mao Tau - - ACE Mean - - - ICE Mean — Chao 1 Mean — Chao 2 Mean

Fig 3.   Species richness estimates, species richness estimators including Mao tau, Chao 1 and 2, Abundance-based coverage estimator and incidence-based coverage estimator.

habitat showed maximum abundance. Magurran (2004) reported that abundance was independent of species richness that is similar to our work.

Maximum species diversity was observed in cropland habitat and no species was found in the housing colonies. These results were quite opposite to the expectations. In most studies natural habitats were observed with maximum number of species (Estrada and Coates-Estrada, 2002). Natural habitats are least disturbed habitats but anthropogenic activities have transformed them into disturbed isolated patches.

The land use change of natural habitat has resulted in a stable agro-ecosystem. Cropland has emerged as a dominant habitat in cultivated area. Janzen (1983) reported that forest has become more fragmented and disturbed but urbanized habitat are more stable, dominant and old in terms of species composition. Similar, observations were recorded in other regions (Gardner *et al*., 2008; Larsen *et al*., 2005; Scheffler, 2005; Vulinec, 2002; Klein, 1989).

It revealed that urbanization changed the species composition in all habitats. Community structure changes with change in habitat. Hill (1996) reported that changes in dung beetle assemblage structure occur over tens of meters. In our study the distances between sampling units were 10-12 Km. Scarabaeinae was most abundant in all habitats with Aphodius dominating cropland and roadside habitats. Spector and Ayzama (2003) reported variation in species structure for just a few meter distances.

Species dominance varied from one habitat to another. *A. contaminatus* was dominant in cropland and roadside habitat. In natural habitat *O. singhalensis* and *O. castaneous* were the dominant species, but also frequently found in cropland and roadside habitats. The community structure varied from abundant to rare species in all habitats. Dung beetle abundance is characterized by the availability of the resources in a habitat (Horgan, 2005).

The dung beetle assemblage and colonization patterns are generally observed as a few dominant, some common and a large number of rare species due to temporary nature of resources in a habitat (Doube, 1983). The results indicated a greater number of rare and unique species (Hanski and Cambefort, 2014).

Species evenness revealed a gradient of disturbance as this value was greater in natural habitat and lesser in cropland and roadside habitat. Evenness is inversely proportional to species diversity and dominance. The greater values of evenness indicate the greater dominance and species diversity.

Guild structure exhibited dominance of tunnelers over dwellers and rollers in natural habitat. This type of dominance is a typical assemblage of dung beetles reported from different regions of the world (Sabu *et al*., 2007, 2006; Vinod and Sabu, 2007; Andresen, 2005; Cambefort and Walter, 1991). Dwellers dominated the cropland and roadside habitat. Similar results were reported by Vinod (2009) due to greater availability of

dung pat. It has been observed that dominance of dwellers in croplands with little mammalian diversity replaces other guilds i.e., Tunnelers and rollers. The presence of both large- and small-sized individuals revealed the stability of habitats especially croplands which has emerged as successful man-managed habitats. Dung beetles have adapted to these monocultures fragmented agricultural belts as a safe micro-habitat. The study revealed the diversity and distribution pattern of the basic fauna of dung beetles in the selected areas and behavioural changes exhibited by the said species with the degree of change in habitat and the interactions of dung beetles within and between species and with other components of ecosystem. It has also assessed the potential of dung beetle to resist and respond to habitat modification. It was concluded that cropland has been developed as a safe and stable man-managed habitat. Agro-ecosystem supports species diversity and richness more than isolated fragmented natural habitats due to uniform vegetation and managed faunistic patterns. In addition to this, roadside habitats act as corridors for species flow within agricultural area and also well adapted to dung beetles due to availability of resources.

Conflict of Interest. The authors declare no conflict of interest.

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