ELEPHANT DUNG BEETLE DIVERSITY IN CHITWAN NATIONAL PARK, NEPAL.

PRADIP TAMANG

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ABSTRACT

Dung beetles are important part of terrestrial ecosystem. The diversity and abundance of dung beetle is affected by the presence of various dung producing animals. They provide several key ecological functions by manipulating the dung during the feeding process. This study is aimed to find out the diversity and abundance of elephant dung beetles in Chitwan National Park,Nepal. It also compares the diversity and abundance in three different blocks namely the Kasara block, the Sauraha block and the Ram-Laxman block within the national park. A total of 193 sample specimen of Elephant dung beetles were collected by using purposive sampling representing 24 morphospecies. The Ram-Laxman block was the most diverse and abundant block. It represented 18 morphospecies from 91 sample specimens collected from this block which represented 47.15% of the total. The Sauraha block was the least diverse and abundant with 13 morphospecies from 27 sample specimen representing 13.98% of the total sample collected. The Kasara block had 15 morphospecies from 75 sample specimen which represented 38.86% of the total. Most of the sample species collected were relatively larger in size (more than 1 cm) but there were a few medium and small sized species as well. The samples collected from each block had beetles of all sizes and color. The difference in species diversity and abundance may be due to the human influence, habitat condition and other environmental factors like sunlight and moisture in the soil.

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1. INTRODUCTION

Introduction:

It is stated, “Organismal diversity encompasses the full taxonomic hierarchy and its components, from individuals upwards to populations, subspecies and species, genera, families, phyla, and beyond to kingdoms and domains.” Therefore organismal diversity includes the most fundamental expressions of biodiversity, such as number of species (Sodhi and Ehrlich, 2010).

Insects are important ecological entity and play diverse ecological role in a well-functioning terrestrial ecosystem. It plays important role in several ecological processes such as nutrient recycle, pollination and seed dispersal and are sensitive towards habitat change (Nichols et al. 2008).

Dung beetles are a small group of insects. They live similar lives in a seemingly homogenous environment. They are mainly associated with moist mammalian herbivore dung but also depend on other sources of dung as well as non-dung food sources (Scholtz et al. 2009). They are dominant organism among the dung feeders with high diversity in tropical forests and Savannas (Davies et al. 2008).

Dung, a highly desirable and nutritious resource attracts thousands of individuals of various species forming an invertebrate dung community. Despite differences in the invertebrate groups attracted towards dung due to geographical location and environmental conditions to which the dung is exposed, same major invertebrate group dominates all dung types and regions. They colonize the dung forming a highly complex community made of dung feeders many of which are dung beetles (Scholtz et al. 2009).

Dung produced by countless organisms both vertebrates or invertebrates; carnivores, herbivore or omnivore attracts dung beetles. However majority of them feed on moist mammalian herbivore dung. The dung may be from either browsing or grazing mammals which produce different types of dung. The herbivore may be ruminant producing fine-textured dung (Gaur, Buffalo), or a non-ruminant producing coarse dung (Elephant). The dung may be excreted as pellet form or in a mass. Even the season in which the dung is produced changes its quality as spring grazing produces high quality dung in comparison to autumn grazing which produces low quality dung (Edwards, 1991; Scholtz et al. 2009).

Dung beetles are the members of Scarabaeidae family and sub-family Scarabaeinae in tropics whereas the Aphodiinae are the sister group in the temperate region. They colonize dung as a very successful member of the group of invertebrates that is attracted towards dung. They have developed astonishing morphological, ecological and behavioral characteristics which allow them to utilize both dung and non-dung products as food resource under various environmental conditions. They have low fecundity and high investment in offspring care which enables them to maintain a healthy population. Even the feeding behavior among adult and larvae dung beetle is unique as they feed on different fraction of food, splitting resources accounting for their evolutionary success (Scholtz et al. 2009).

As a globally distributed insect group with high diversity in tropical forest and savannas, dung beetles ecological importance is paramount. They provide several key ecological functions by manipulating the dung during the feeding process. The ecosystem functions ranges from secondary seed dispersal, nutrient recycling, parasite suppression. They enhance soil fertility by actively relocating nutrient rich organic matter and initiate micro-organismal and chemical changes in the upper soil layers. They prevent loss of Nitrogen through ammonia volatilization. Dung beetles also increase bioturbation by moving large quality of soil to the surface by tunneling activity increasing soil aeration and water porosity (Nichols et al. 2008).

Australia has introduced African dung beetles to control fly population feeding on cattle dung (Scholtz et al. 2009). The feeding and nesting behavior of adult and larval dung beetles serves to control spread of dung-breeding hematophagic and detrivorous flies and other parasites (Nichols et al. 2008).

Dung beetles even help in secondary seed dispersal by burying seed along with the dung or purposefully removing seeds from dung before or after burying dung which is typically a cleaning act. This abandoning of seed on or below the soil surface helps in relocating seeds and thereby helping in plant recruitment (Andersen and Fear, 2005; Nichols et al. 2008).

The elephant dung beetles of Chitwan National Park was collected during the field visit. This national park has a significant number of both domesticated and wild elephants. In this study, the elephant dung beetles from the sites where domesticated elephants were kept was collected. It is a pioneer study in the field of beetles from elephant dungs in Nepal. The main objectives of this study was to:

i. collect and identify the dung beetles found in the elephant dung inside the Chitwan National Park.
ii. examine the diversity of the elephant dung beetles inside the Chitwan National Park.
iii. compare the diversity in between different blocks inside the Chitwan National Park.
iv. observe the abundance of elephant dung beetles and compare it in between different blocks inside the Chitwan National Park.

2. MATERIALS AND METHODS

2.1 Study Site Description:

Chitwan National Park is located at south central part of Nepal in the subtropical lowlands of inner terai. Chitwan National Park was declared the first national park in Nepal. It was established after the introduction of National park and Wildlife act 1973. In 1984, it was designated a UNESCO world heritage site recognizing its unique ecosystem of international importance (Majupuria and Majupuria, 1998). Initially the park area was 544 km^2 but it was extended to its present size of 932 km^2 in 1977 (Smith, 1984). It is situated in the southern part of Chitwan district and shares its boudaries with Parsa wildlife reserve in the east and Balmiki Tiger reserve in the south. It lies between 27°16.56'- 27°42.14' latitudes and 83°50.23'-84°46.25' longitudes. The altitude ranges from 110m to 850m above sea. The park experiences a range of seasonal changes with October through February with average temperature of 25°C and from March to June the temperatures can reach as high as 43°C followed by monsoon season that typically lasts from late June until September with mean annual rainfall of 2150mm. It has rich biodiversity with 68 species of mammals, 544 species of birds, 56 species of herpetofauna and 126 species of fish have been recorded in the park. The park is especially renowned for its protection of One Horned Rhinoceros, Royal Bengal Tiger, Asiatic Elephant and Gharial Crocodile.

(http://www.chitwannationalpark.gov.np).

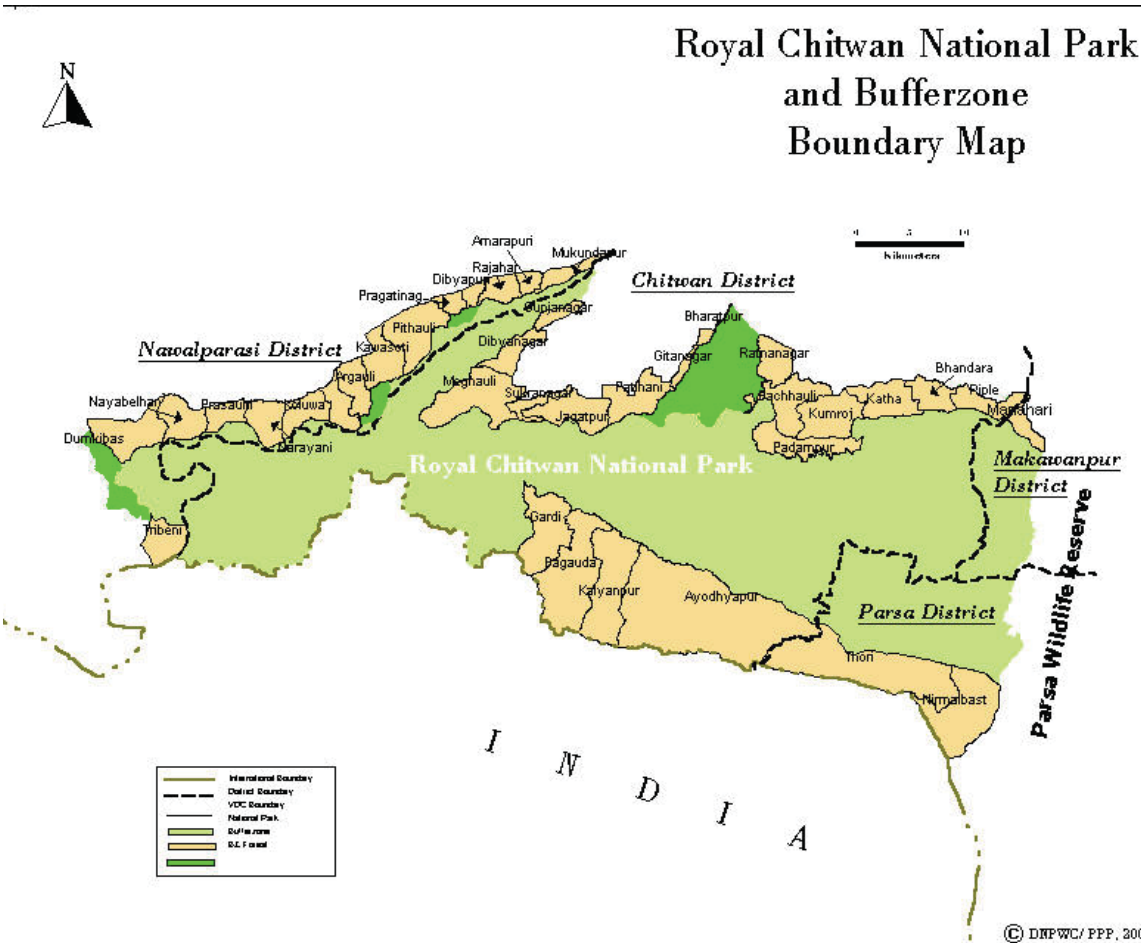

Fig 1: Chitwan National Park and Buffer Zone Bounderdary Map. (Source: Department of National Park and Wildlife Conservation, Babarmahal, Kathmandu.)

2.2 Study species:

Dung beetles are omnipresent component of tropical biotas (Vulinec, 2000). It plays an important part in insect diversity of Afrotropical rainforest.. Dungs produced by mammals and sometimes birds and reptiles provide food and reproductive ground to dung beetles. The diversity and abundance of dung beetles is affected by the presence of various dung producing mammals (Vinod and Sabu, 2007). Dung beetles mostly belong to two subfamilies of Scarabaeidae- Aphodiinae and Scarabaeinae (Gordon et al., 2008). The true dung beetles (Scarabaeoidea) consist of some 7,000 described species of primarily tropical Scarabaeidae (c. 5,000 species) and primarily temperate Aphodiidae (c. 2,000 species) and Geotrupidae (c. 150 species) (Viljanen, 2009).

The main climatic factors affecting the spatial and temporal distribution of dung beetles are temperature and precipitation (Halffter and Edmonds 1982). They are most diverse in moist tropical regions and poorly represented in colder climates or arid regions with most species being restricted to areas where annual precipitation is above 250 mm per year and the annual daily temperature is higher than 15 °C (Halffter and Edmonds 1982).

The variety and abundance of dung beetle is not only dependent on climate and precipitation but also on the availability of different types of dung (Davis and Scholtz, 2001) and the age of soil (Radtke et al, 2007).The young soil supports higher species abundance and biomass than older soil (Radtke et al, 2007). Therefore the geographical distribution of dung beetle is also dependent on the evolution of large mammal and regional composition of large hervibore (Viljanen, 2009).

Evolution of modern dung beetles and its explosive radiation follows the rapid evolution and diversification of mammals. The fossil record of various dung beetles found provide very little in understanding the possible age and evolution of Scarabaeinae (Scholtz et al, 2009). It is generally accepted that ancestral dung beetles probably evolved from detritus feeding organism, where they feed on microbe rich liquid (Hanski and Cambert 1991, Scholtz et al, 2009). However recent phylogenetic reconstruction based on morphology and molecular analysis support the hypothesis that the oldest Gondwana tribes- Canthonini and Dichotomiini are polyphyletic and are representatives of ancestral group found in Africa. Their dispersal from Africa is proposed as a biogeographic and evidence present supports that dung beetle disperse quickly and widely across continents and even in oceans (Sole and Scholtz, 2010).

With evolution of large herbivore mammal and production of large quantity of dung, more dung feeding insects also evolved. The competition for resources from other insects as well as unpredictable and harsh climatic condition destroying the dung led to evolution of functional behavior that helped in exploiting dung for a long period of time (Scholtz et al, 2009).The competition over dung is more pronounced in warmer than in colder climates due to variety of factors like dryness, temperature and number of competitors reducing the usability of dung as food resource (Lumaret et al, 1992). Dung beetles can be, therefore divided into three functional groups: the rollers, the tunnellers and the dwellers or the endocoprophagus (accordingto the terminology of Hanski & Cambefort1991). The rollers roll the dung into balls and conceal them from other in the soil. The tunnellers dig tunnel below the dung heap and burrow the food inside the tunnels. The dwellers live and feed in the dung heap (Lumaret et al, 1992).

Food resource also act as the attractant for pairing up between male and female species along with pheromones. After maturation the female begins nest building and male provisions it with food. Morphological feature such as horn plays important role in mating. The male dung beetle with horn fight and guard the nest and copulate with the female while those without horn has to sneak into the nest in order to copulate with the female. After mating the female lay egg in the nest and the larvae feed on the decomposing nest material. The dung beetle larvae has a hard, biting mouth part to grind the coarse and dry dung and feed on them. They feed and live on food provided by the adult due to which it has high rate of survival and help maintaining the viable population despite their low fecundity rate (Scholtz et al, 2009).

High species diversity of dung beetles results from narrow niches and extreme resource specialization (Larsen et al, 2006). This is helped by diverse morphology and behavior which help them employ various tactics to avoid competition for vertebrate dung which is primary food source and breeding ground (Monaghan et al, 2007). Mostly dung beetles have a broad habitat type such as flood plain forest, grassland but some has specific microhabitats (Larsen et al, 2006). They are attracted to every kind of dung and made no difference in choice for human and non-human dung (Larsen et al, 2006).

Dung beetles are widely used as the focal taxon for the study of biodiversity. Their high diversity and characteristic traits among various species along with many functional roles in the ecosystem help study changes in environment as they respond to it rapidly and the interactions between human disturbances, biodiversity, and ecosystem function. This studies are critical in providing informations to conserve biodiversity and maintain sustainable ecosystem (Larsen and Forsyth 2005).

Dung beetles also play important role in nutrient recycling (Lee et al, 2009) and increase the ability of soil to absorb and hold water (Nielsen, 2007). They play important role as an indicator of healthy ecosystem (Medina et al, 2002). Though dung beetles provide critical ecosystem function, they are threatened by loss in habitat due to landscape conversion and forest fragmentation (Nichols et al, 2007).

Habitat alteration negatively affect distributions of dung beetles. The effects may be direct due to habit change as result of deforestation, forest fragmentation and landscapes change or indirect due to changes in the composition of animals that produce dung (Medina et al, 2002). Deforestation can play important role in loss or extinction of dung beetles as it is the cause of decline in small and large bodied mammals which are the important source of dung in tropical forests (Lee et al, 2009).

2.3 Morphological identification:

All the samples collected during the field visit was placed in 40% alcohol to kill. They were then transferred into 70% alcohol to preserve. The samples were brought to Natural History Museum , Tribhuwan University for identification. All the samples were tagged with a code name. Each sample was photographed and coded.

Phylogenetic appearances is an important feature in identification of the beetles (Krell, 2006). External appearances such as body size, presence and absence of horns (including shape, size and location if present), presence or absence of wings, difference in legs size and length was observed. These morphological characteristics were used as the basis for classification.

Color variation was not used as the distinguishing morphological feature unless other morphological characteristics were dissimilar. Another important morphological characteristic difference in sample species was considered as the roughness or smoothness of the exoskeleton and different kind of impression present on it.

2.4 Study Design:

For the purpose of data collection several field visits were made and samples were collected. The field was visited during the month of October and November of 2014. Purposive sampling was undertaken for sample collection as per the prior knowledge of the availability of domesticated elephant in the national park area. Species abundance distributions are strongly influenced by sampling methods (Larsen et al. 2006).

In the field three different block - Kasara block, Sauraha block and Ram Laxman block was divided representing east, west and south of Chitwan National Park. Each block was divided into different sub-blocks according to availability of elephants. Sauraha block was divided into five sub-blocks as Elephant breeding centre (EBC), Ranger Post Sauraha (RPS), National Trust for Nature Conservation (NTNC) and Icharni. The Ram-Laxman block was divided into three blocks as Dibyapuri, Gideni and Lamichaur. The Kasara block was divided into Bagmara, Kasara and Meghauli. Elephants were present in different army check post and Ranger post within this block for different purposes like patrolling for controlling poachers, census of wild animals especially tiger, One horned rhinoceros etc.

In each block and the sub-block the elephants were kept in different conditions. In Sauraha block, the elephants were kept like domestic animals. They were kept under the shed and were tied to poles so that they could not move freely. A lot of tourists visited this place to watch elephants, so had a lot of anthropogenic disturbances. The dung excreted by elephants was collected every morning and burnt to destroy. The researcher had to reach to the site early in morning before the dungs were disposed and destroyed to collect beetle samples from the freshly excreted dung.

The elephants in the other two blocks- the Ram-Laxman and the Kasara block were kept in semi wild condition inside the national park. Mostly they were kept freely inside an enclosed territory made of wire. Electricity was passed through these wires especially during night time to prevent the elephants from escaping and other wild animals from entering. In theses sites also the dungs was collected and dumped to destroy using fire. Each site was visited and samples were collected before the dungs were destroyed. This two blocks had less human disturbance in terms of the people visiting theses sites as they were deep inside the park.

The elephants in all the blocks were mostly fed on food brought from forest along with rice grains and other non forest products. Samples were collected directly by visiting those sites and kept in 40% alcohol. The sample were collected as many as possible. The dung beetle was collected from the dung that was 12-48 hrs old. The 12 hrs old elephant dung is referred as fresh and 48 hrs is old and dung older than 48 hrs is considered very old dung where no dung beetle was found. The researcher also tried to collect samples from diverse group as far as possible looking at the morphology of the beetle.The samples were first kept in 40% alcohol to kill and then preserved in 70% alcohol. Several photographs of each and all sample was taken and used as the main tool for identification as samples collected was not allowed to bring at the university lab due to legal reasons. although all the sample collected is stored in Natural History Museum, Tribhuwan University, Kathmandu.

2.5 Environmental Disturbances:

Dung beetles are sensitive towards different kind of disturbances and their composition and abundance are affected in varying degree. Species richness, abundance and biomass is usually reduced as result of habitat fragmentation, hunting and other interference [Larsen and Forsyth, 2005]. Each sample collection site was disturbed by human presence as the elephant was kept under human supervision. Dungs were removed and collected in a particular area and were burnt to keep the stable clean for the elephants. The elephants in Sauraha block was entirely kept as domestic elephants whereas in the other two blocks- the Ram-Laxman and the Kasara, they were kept in semi wild condition inside the national park. So, in Sauraha block, there was no forest in the immediate surrounding whereas in other two blocks the elephants were kept inside the forest or sheds made just adjacent to the forest.The dung in these blocks was usually moist as they were under shades of tree but in some area like Sauraha they were kept in open and was dry due to the exposure of sun. In Sauraha block, the researcher was unable to collect many specimen because the dung was removed and destroyed so early due to many tourist visiting this area.

2.6 Data analysis and presentation:

The sample collected during the field visit was well documented. First photographs of each sample was taken and each sample preserved in 70% alcohol was stored in the laboratory of Natural History Museum, Tribhuwan University, Kathmandu. The morphospecies identification was done using photographs as the researcher was unable to bring the collected samples to Norway due to legal reasons in Nepal. The samples are safely stored in the lab of Natural History Museum, Tribhuwan University, Kathmandu, Nepal. The result of this analysis is presented in tables, charts, graphs to give clear and concise idea of the result obtained from the analysis of data.

3. RESULTS

3. Results:

A total of 193 sample specimens were collected during the study period. They represented 24 different morphospecies. The morphospecies are named as Species A, B, C, D respectively. The number of specimen collected for each morphospecies is different and ranges from 1-30. Some of the morphospecies were present in all blocks of the study area. Among the 24 morphospecies, 6 morphospecies namely Species F, Species G, Species K, Species O, Species U and Species W were present in all blocks.

The most represented morphospecies in terms of its presence in all blocks was Species G. It was present in 8 sub-blocks among all the 11 sub-blocks. The most abundant morphospecies was Species U, representing 15.55% of the total number of species. The least abundant morphospecies were Species H, Species V and Species X representing 0.51% of total species respectively.

The elephant dung beetles collected were of various sizes and colours. Most of the elephant dung beetles were large in size but some were medium and smaller in sizes also. The color of these elephant dung beetles was mostly dark. Some of the elephant dung beetles also had bright colors. They were either red, brown or had shades of both. One of the elephant dung beetle also had shades of green on its back.

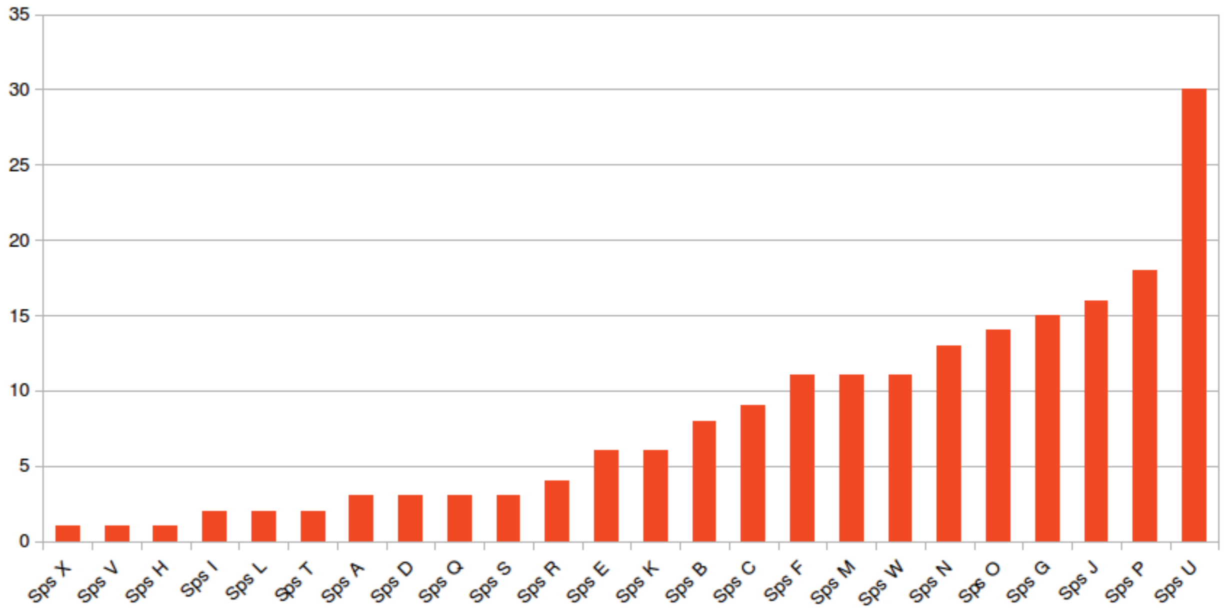

Fig 2: Graph showing distribution of Morphospecies in ascending order.

Table 1: Table showing Number of Species Distribution

	LOCATION										
	SAURAHA BLOCK					RAM LAXMAN BLOCK			KASARA BLOCK		
Name of Species	EBC	RPS	NTNC	RCA	ICHARNI	DIBYAPURI	GIDENI	LAMICHAUR	BAGMARA	KASARA	MEGHAULI
Species A								1			2
Species B								1	1		6
Species C								7		2	
Species D								3			
Species E							3	1			2
Species F			2	2			4		2	1	
Species G		1	2	2			3	4	1	1	1
Species H		1									
Species I	1									1	
Species J						5			10	1	
Species K		1	1			3				1	
Species L							2				
Species M							4		1	4	2
Species N			1	1					2	7	2
Species O			1				5	1	3	2	2
Species P						9	3	6			
Species Q		1	1				1				
Species R							4				
Species S	1					1		1			
Species T			1		1						
Species U		1	2			14	3		2	8	
Species V										1	
Species W		1	1					2		5	2
Species X		1									

Table 2: Table showing Distribution of Species

	LOCATION										
	SAURAHA BLOCK					RAM LAXMAN BLOCK			KASARA BLOCK		
Name of Species	EBC	RPS	NTNC	RCA	ICHARNI	DIBYAPURI	GIDENI	LAMICHAUR	BAGMARA	KASARA	MEGHAULI
Species A											X
Species B								X	X		X
Species C								X		X	
Species D								X			
Species E							X	X			X
Species F			X	X			X		X	X	
Species G		X	X	X			X	X	X	X	X
Species H		X									
Species I	X									X	
Species J						X			X	X	
Species K		X	X			X				X	
Species L							X				
Species M							X		X	X	X
Species N			X	X					X	X	X
Species O			X				X	X	X	X	X
Species P						X	X	X			
Species Q		X	X				X				
Species R							X				
Species S	X					X		X			
Species T			X		X						
Species U		X	X			X	X		X	X	
Species V										X	
Species W		X	X					X		X	X
Species X		X									

The Ram-Laxman block located at the south of Chitwan National Park was the area with most species abundance. It had 91 morphospecies present from the total of 193 which is 47.15% of the total species present. This block was also area with most diverse morphospecies with representation from all morphospecies found during this study except Species H, Species I, Species N and Species W. The morphospecies like Species D, Species L, Species P,and Species R were only present in this block. Among the sub blocks of the Ram-Laxman block, Dibyapuri and Gideni sub-block was the site with most abundant species with 32 morphospecies present in each where as Lamichaur was the least abundant with 27 morphospecies present. Both Dibyapuri and Gideni had 35.16% of the total number of morphospecies present in Ram-Laxman block. The Lamichaur sub-block had 29.67% of the total morphospecies present.The Gideni and Lamichaur sub-block was the most diverse site representing 10 morphospecies each whereas Dibyapuri was the least diverse representing only 5 morphospecies in Ram-laxman Block. Among all the morphospecies, Species R found in Gideni sub-block was the most unique morphospecies.

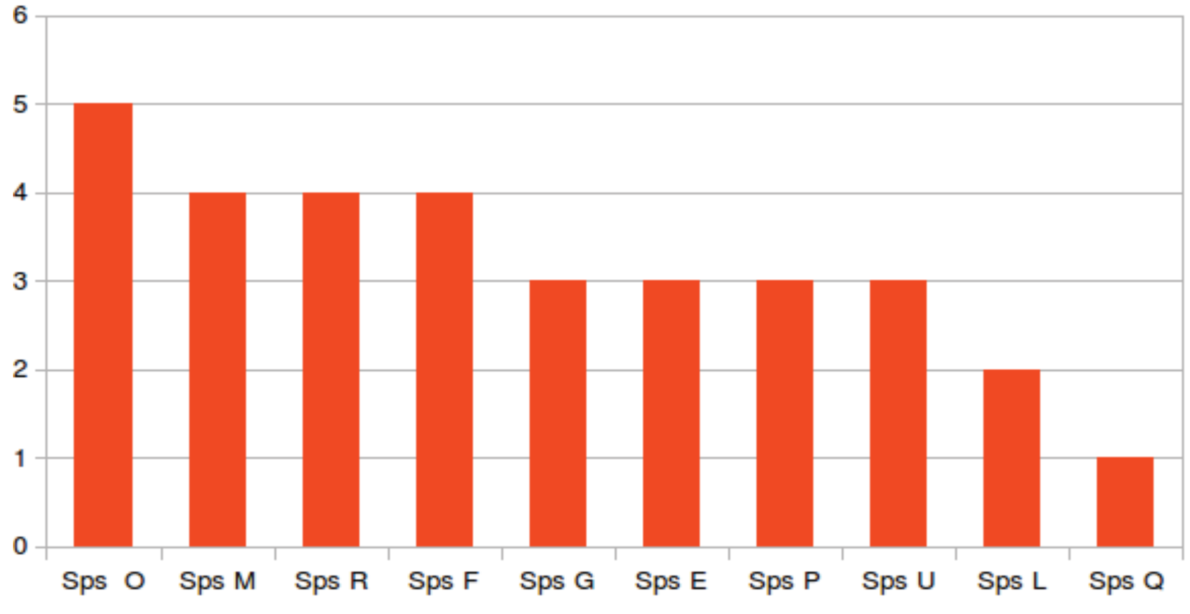

Fig 3 : Species Distribution of sub-block Gideni

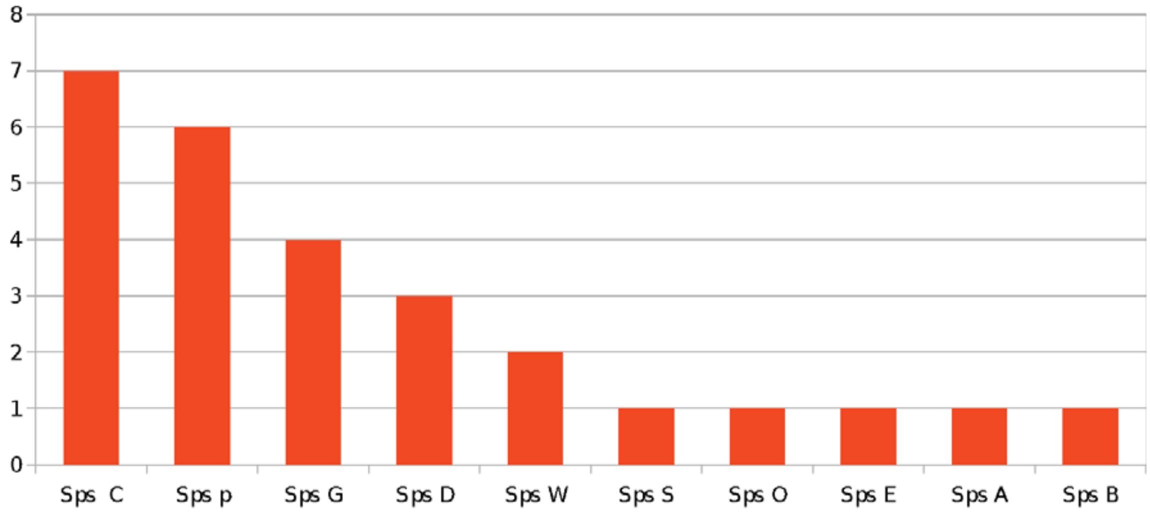

Fig 4 : Species Distribution of sub-block Lamichaur

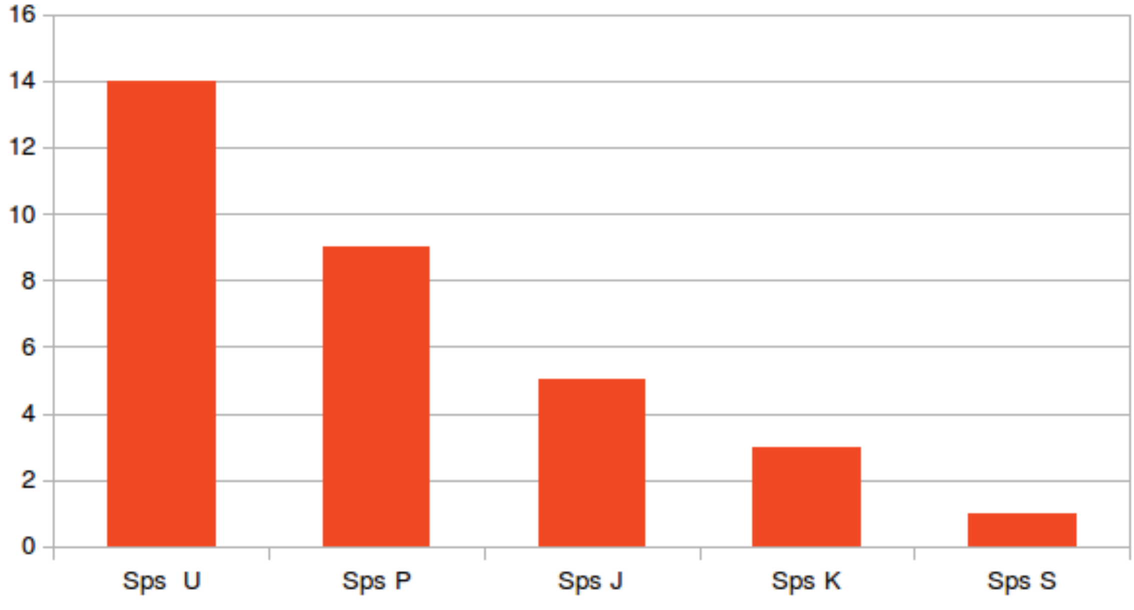

Fig 5: Species Distribution of sub-block Dibyapuri

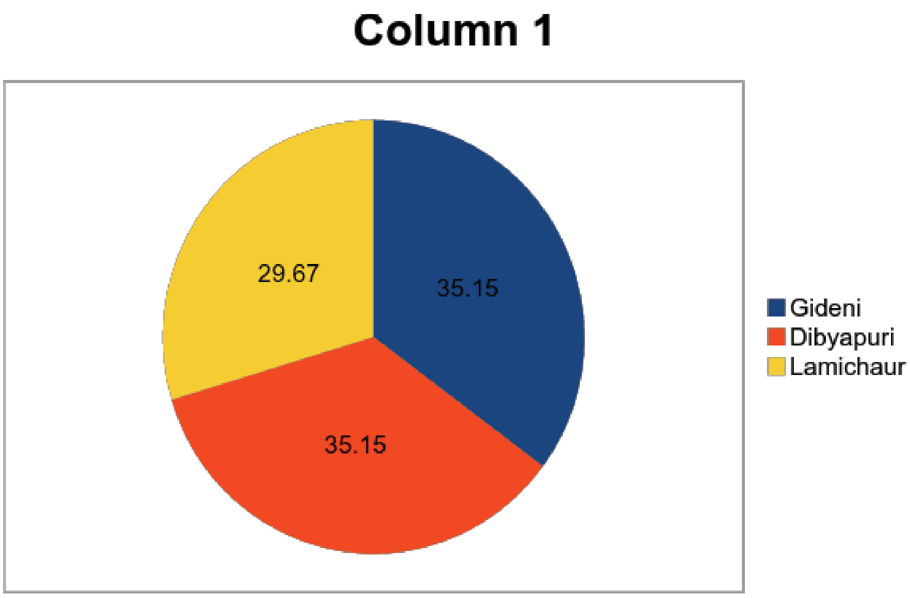

Fig 6: Percentage Distribution of Species present in Ram-Laxman Block.

The Kasara block representing the eastern part of Chitwan National Park was medium in terms of species abundance among the three blocks. It had 76 morphospecies present which is 39.93% of the total morphospecies present. Among the 24 morphospecies identified, it had 15 different morphospecies present among its three sub-blocks. The 9 morphospecies missing from this block were Species D, Species L, Species P, Species H, Species Q, Species R, Species S, Species T and Species X. Among the sub-blocks of Kasara block, the sub-block Kasara centre was the most abundant with 34 morphospecies present which represented 45.33% of the total number of morphospecies found in this block. The sub-blocks Bagmara and Meghauli had 22 and 19 morphospecies each representing 29.33% and 25.33% of the total morphospecies present in this block respectively. In terms of diversity Kasara center was again the most diverse among the sub-blocks of this block with 12 different morphospecies whereas both Bagmara and Meghauli were equally diversified representing 8 different morphospecies.

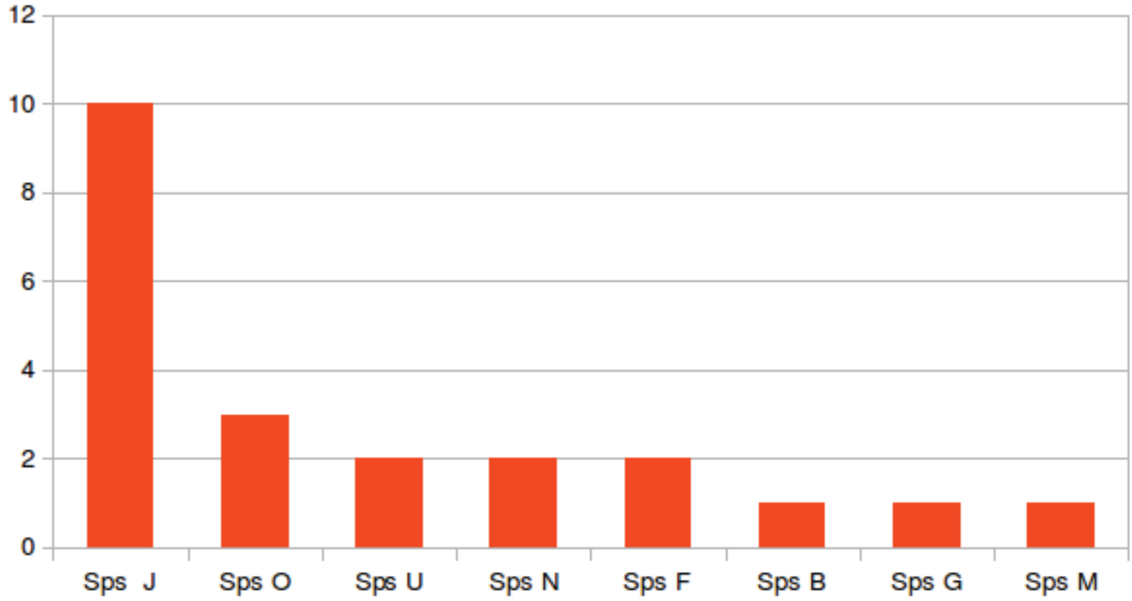

Fig 7: Species Distribution of sub-block Bagmara

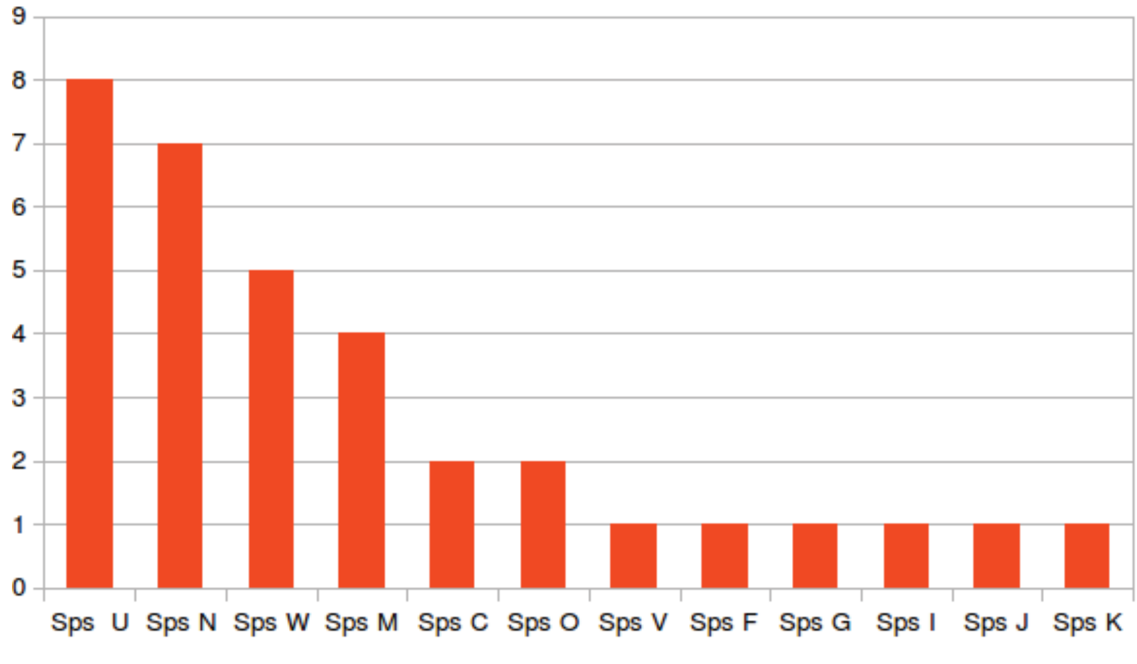

Fig 8: Species Distribution of sub-block Kasara center.

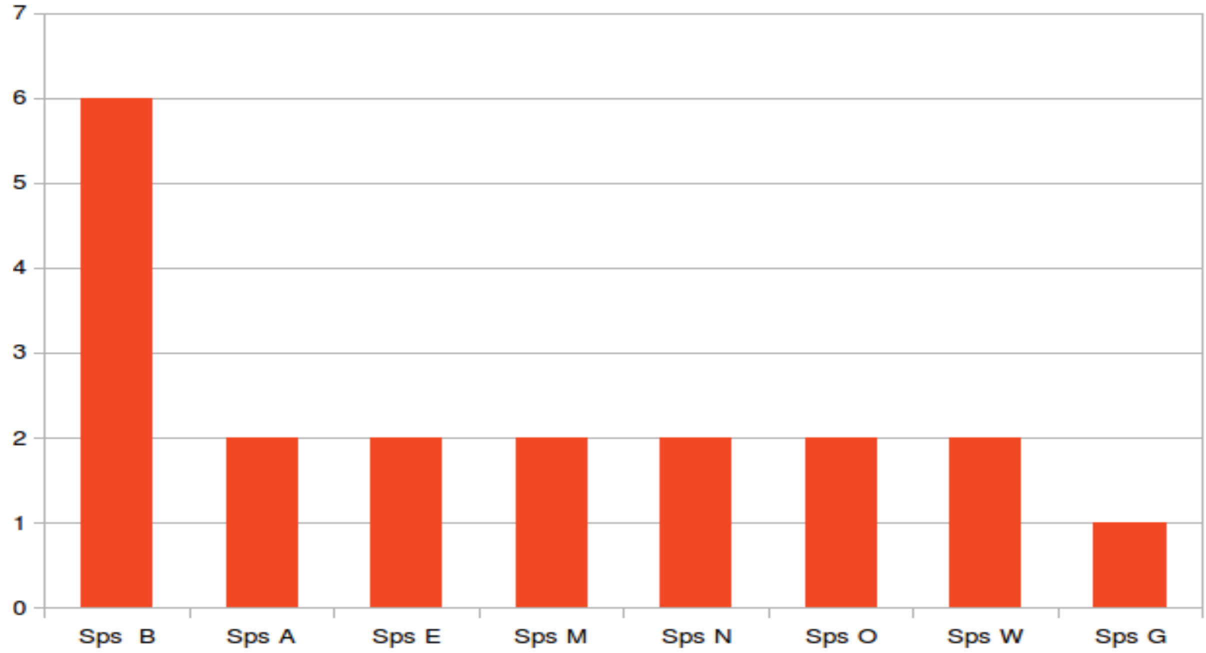

Fig 9: Species Distribution of sub-block Meghauli

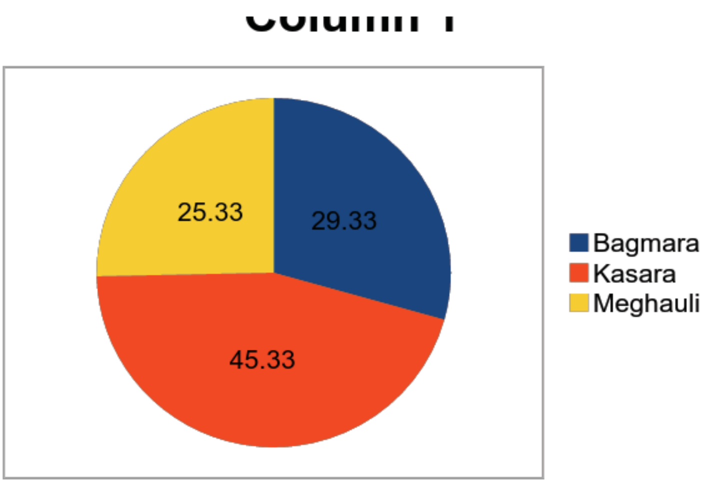

Fig 10: Percentage Distribution of Species present in Kasara Block

The Sauraha block represented the western part of Chitwan National Park.This block was the least abundant of all the blocks having 13.98% of total species collected. 27 Morphospecies were collected from this area representing 13 different morphospecies. Among them, the Species X and H were only found in the sub-block RPS of Sauraha Block. Among the five sub-blocks, NTNC sub-block had the most number of morphospecies making it the most abundant and diverse among the sub-blocks of Sauraha Block. It had 12 morphospecies present representing 9 different kinds. The least abundant and diverse sub-blocks were EBC and Icharni with 2 and 1 morphospecies representing 7.4% and 3.7% of the total morphospecies collected in this block. The sub-block RPS and RCA almost equally abundant with 7 and 5 morphospecies representing 25.92% and 18.51% of the total number respectively but RPS was more diverse representing 7 different morphospecies against 5 different morphospecies of RCA.

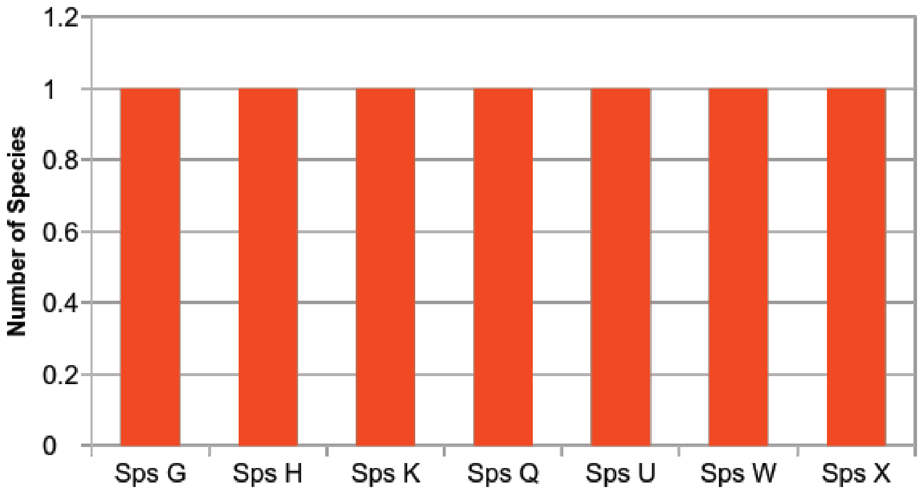

Fig 11: Species Distribution of sub-block Ranger Post Sauraha (RPS)

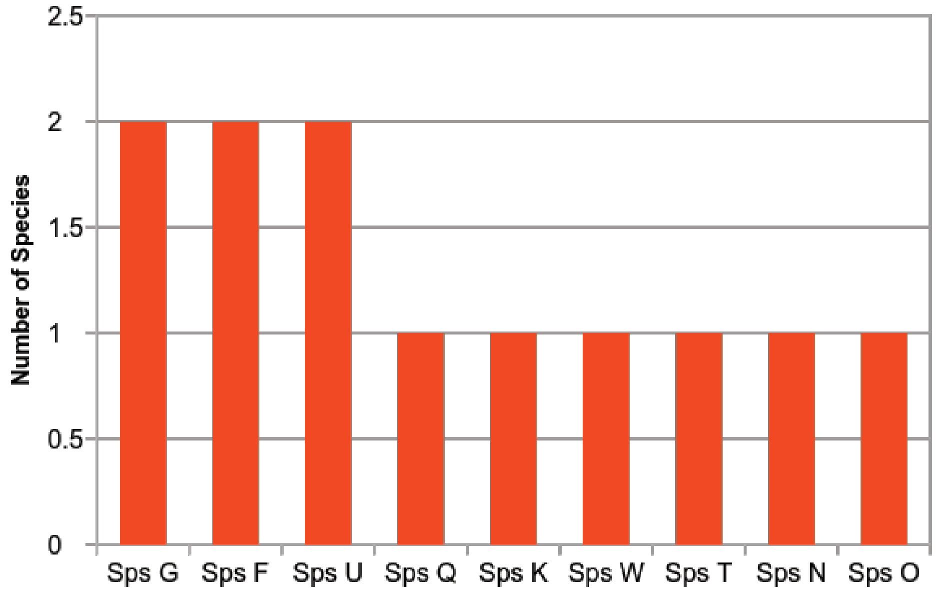

Fig 12: Species Distribution of sub-block National Trust for Nature Conservation (NTNC).

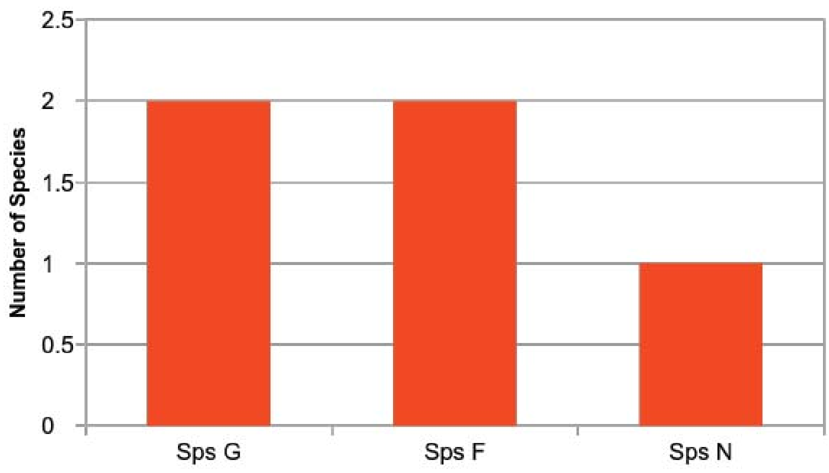

Fig 13: Species Distribution of sub-block Rhino Camp Area (RCA).

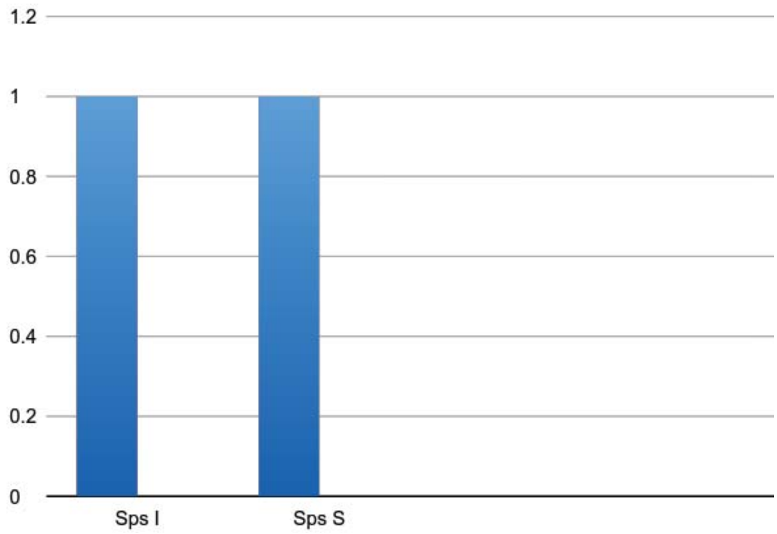

Fig 14: Species Distribution of sub-block Elephant Breeding Center (EBC).

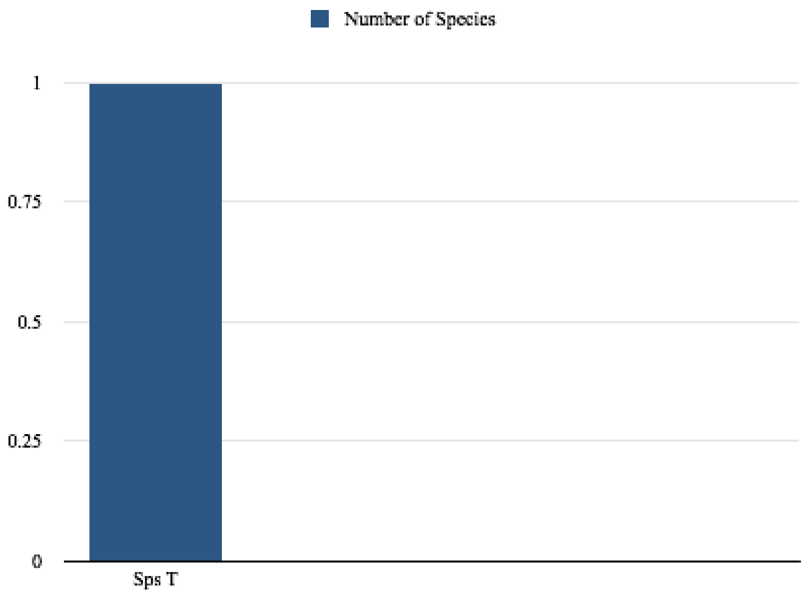

Fig 15: Species Distribution of sub-block Icharni

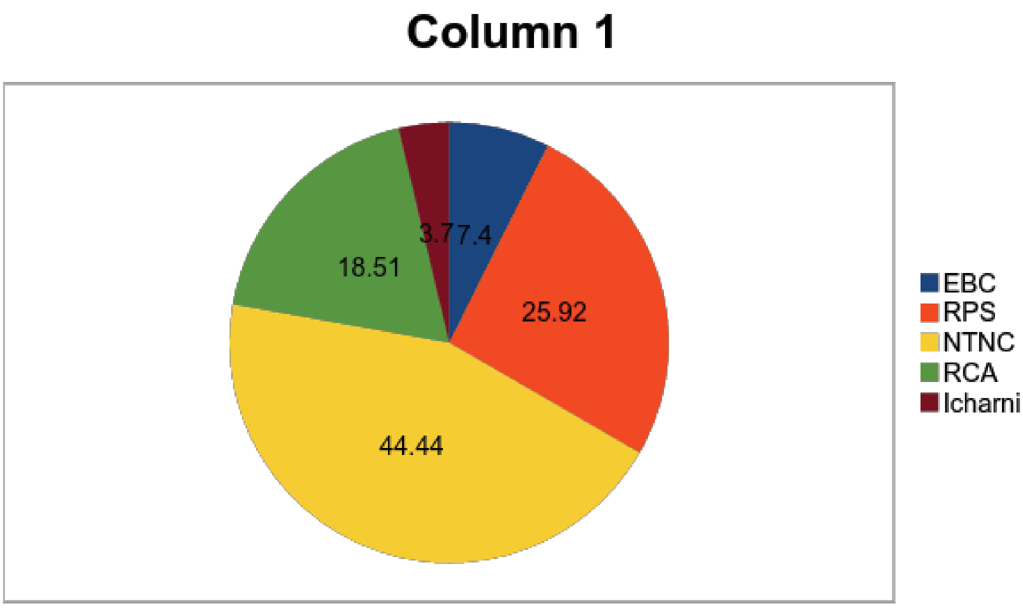

Fig 16: Percentage Distribution of Specie present in Sauraha Block.

4. DISCUSSIONS

4. Results and Discussions:

This study found that there is 24 different morphospecies of elephant dung beetle in Chitwan National Park. This was determined from the 193 sample specimen collected from the park. Most of them were relatively large in size (more than 1 cm) but there were a few medium and small sized species as well. The samples collected from each block had beetles of all sizes and color. Most of the elephant dung beetles had dark color but some of them had red and brown colors (Species T, Species Q, species S, Species U). One of the mosphospecies (Species V) even had shade of green on its back. Although it is possible that same species can have different colors. A study done on *Gymnopleurus humanus* proposed both genetic and climatic explanations about color morphing without any concrete conclusions. Although a strong correlation between color variation and environmental factors was made (Davis et al. 2008). In this study color was not made an identifying characteristics if other morphological characteristics were identical.

Though the dung beetles showed uniformity in size across all blocks within the Chitwan National Park, their were variations among other morphological traits. Each block had diverse range of dung beetles. One morphospecies (Species R) collected from Dibyapuri sub-block of Ram-laxman block was unique in its morphological structure. Some of the morphospecies were only present in one block and absent in other. The morphospecies R was present only in sub-block Dibyapuri of Ram-Laxman block.Also Species L, Species D and Species P were only found in Ram-Laxman block. Similarly, Species T, Species H and Species X was present only in Sauraha block whereas Species V was found only in Kasara block. In between the blocks within the Chitwan National Park, Ram Laxman block is the most diverse block with 18 of the 24 morphospecies present while Sauraha and Kasara blocks were less diverse with 13 and 15 morphospecies present respectively.

A community is considered diverse if it has higher species richness and evenness than the one dominated by a few species (GC et al. 2009). This confirms our prediction that species of elephant dung beetles were diverse across the blocks.

The difference in species diversity may be due to the human influence, habitat condition and other environmental factors like sunlight and moisture in soil. Though all the habitat from where the elephant dung beetles were collected was influenced and disturbed by humans. The Sauraha block was the most disturbed because of the influx of tourists. Elsewhere human activity were mainly from the staffs who were in charge of taking care of the elephants. Also the elephants shelter in Sauraha block was not in (or adjacent to) the forest like in other two blocks. In both Ram-Laxman and Kasara blocks either the elephants were kept inside the forest with wire fencing a huge area allowing free movements of elephants or kept in shelter made adjacent to forest. So, these places had more humidity and were moist in the soil due to the absence of direct sunlight most of the time.

A study done with three paracoprid dung beetles by Sowig (1995) on influence of soil type and soil moisture on micro-habitat selection found that there was no discrimination in selection of dung for first 24 hrs but as time passed 50% of all species that depended specifically on soil moisture and soil type left and the larvae’s survival in the brood chamber was entirely influenced by soil moisture.

This result corresponds with the finding that insects are key to maintaining ecosystem functions but knowledge of impact on them due to human activity is limited. It is equally true for dung beetles which provide multiple ecosystem services but face conservation threat from human induced destruction of their habitat (Nichols et al. 2007).

The correlations of dung beetle to climatic area occur at all three of the considered taxonomic levels, whereas correlations to numbers of dung types are primarily restricted to higher taxonomic level. The regions with low numbers of dung types have greater numbers of genera concentrated into few tribes than regions with higher numbers of dung types (Davis and Scholtz, 2001). The areas enriched with large herbivore mammals with significant biomass contain more species of dung beetle than those that have comparatively poor mammalian faunas (Davis, 2000).

Dung beetle are primarily associated with mammalian dung and are indicators of their abundance and diversity (Vulinec, 2000). Chown et al. (1995) found higher likelihood of very high density of the dung beetle *Circellium bacchus* with high elephant densities.

Elephant dung is heterogenous in nature with both fibrous and fine dung particles in it. The heterogenous nature of elephant dung help them to attract both fine and coarse dung feeders as well as generalist type. A study in the moist forest of South Western Ghats in India showed that elephant dung with both its fluid and fibrous dung particle was able to attract more taxonomically diverse and even dung beetle in comparison to gaur dung which is moist and non-pelleted (Gaur is a ruminant). This study showed that tunnelers are the dominant functional group followed by dwellers and rollers in terms of species richness and abundance (Vinod and Sabu, 2007).

In other study done by Sabu et al. (2006) in the deciduous forest of Western Ghats of India, they described the association between the diversity, guild structure and succession of dung beetles with Indian elephant dung. They found 21 dung beetle species belonging to 3 major functional guilds. The dweller and tunneler were more abundant in comparison to rollers.

A study conducted by Verdu et al. (2007) in managed landscapes, dung beetle communities are complex in structure due to interactions among livestock grazing, vegetation composition and human interference. Several species both tolerant and intolerant to grazing were found to be present including species indifferent to grazing. Areas with low grazing intensity had fewer species than areas with high grazing intensity. Fewer species in low grazing intensity resulted due to limiting of the resources due to competitive interactions whereas high grazing intensity caused mortality due to the inability of the dung beetles to resist disturbance. As a result dung beetles were found to be less diverse in disturbed landscape due to grazing (Verdu et al. 2007).

A study conducted by Teresa, (2009) found that increase in forest disturbances and change in other factor associated with dung beetle distribution shows decrease in ecological responsibility of dung beetles like removal of dung. It also changes dung beetle diversity and reduces their ability to perform ecosystem services.

Not only was their the difference in diversity but also in terms of the abundance. Each block had different number of dung beetles. The Ram-Laxman block was the most abundant with 91 sample specimens which represented 47.15% of the total. The Sauraha block was the least abundant with 27 sample specimen representing 13.98% of the total sample collected. The Kasara block had 75 sample specimen which represented 38.86% of the total. In terms of the abundance of individual morphospecies, Species U was the most abundant with 15.55% of the total where as Species X, SpeciesV and Species H was the least abundant with just 0.51% of the total. The decrease in abundance in elephant dung beetle in Sauraha block can be attributed to human disturbance and environmental factors like more sunlight due to absence of forest cover which modifies the habitat.

Highly modified habitat with little or no tree cover affect species abundance distributions with hyper abundance of small bodied species over large bodied. This kind of species distribution in fact affect ecosystem functions as small bodied species are less capable to transport dung and disperse seeds (Nichols et al. 2007).

Similar finding was made by Hanski and Krikken, (1991) which showed the abundance of small rollers (Sisyphus) in elephant dung pats and low presence of large rollers (Gymnopleurus) in pitfall traps. Although they suggested that previous published study showed association of larger dung beetles and with bigger dung pats (Sabu et al. 2006) which supports the finding of this study.

A study was conducted in Chobe National Park, Botswana to study species richness and abundance across a range of food type comprising of various dungs and carrion. It showed that most abundant species were attracted to all bait types but mostly they were attracted to specific dung type or carrion. Dung attracted majority of fauna in terms of richness and abundance. There was similarity in species richness in traps baited with pig, cattle, and elephant dung but was relatively lower in those baited with sheep dung and carrion. The abundance was relatively greater in pig dung than in all other bait types (Tshikae et al. 2008).

High abundance of dung beetles is associated with elephant dungs. It may be due to the reliability and abundance of food source that the elephant dung provides. Species richness and abundance of the Scarabaeidae were especially high under sunny conditions. This coincided with a higher germination success of plants in elephant droppings under sunny conditions than in the shade. Aslo the study showed that colonization of dung was high 1-2 days of dropping in contrast to the findings of Sabu et al. (2006) for Indian elephant (Elephas maximus L.) which was 3 days. The earlier colonization of dung was assumed to be due to its dryness as a result of its exposure to sun (Theuerkauf et al. 2009). Thus, the abundance of dung beetles is correlated to less human interference, more intact habitat and favorable environmental conditions, thereby supporting the prediction and finding of this study.

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APPENDIX

This section contains pictures of the plot sites and the morphospecies collected during the field visit.

Species A

Number of specimen: 3

Location: Lamichaur and Meghauli

Species B

Number of Specimen: 7

Location: Bagmara and Meghauli.

Species C

Number of Specimen: 9

Location: Lamichaur and Kasara

Species D

Number of Specimen: 3

Location: Lamichaur.

Species E

Number of Specimen: 6

Location: Gideni, Lamichaur, Meghauli.

Species F

Number of Specimen: 11

Location: NTNC, RCA, Gideni, Bagmara, Kasara center.

Species G

Number of Specimen: 15

Location: RPS, NTNC, RCA, Gideni, Lamichaur, Bagmara, Kasara, Meghauli.

Species H

Number of Specimen: 1

Location: Ranger Post Sauraha (RPS).

Species I

Number of Specimen: 2

Location: EBC, Kasara.

Species J

Number of Specimen: 16

Location: Dibyapuri, Bagmara, Kasara.

Species K

Numberof Specimen: 6

Location: RPS, NTNC, Dibyapuri, Kasara center.

Species L

Number of Specimen: 2

Location: Gideni.

Species M

Number of Specimen: 11

Location: Gideni, Bagmara, Kasara center, Meghauli.

Species N

Number of Specimen: 13

Location: NTNC, RCA, Bagmara, Kasara, Meghauli.

Species O

Number of Specimen: 14

Location: NTNC, Gideni, Lamichaur, Bagmara, Kasara center, Meghauli.

Species P

Number of Specimen: 18

Location: Dibyapuri, Gideni, Lamichaur.

Species Q

Number of Specimen: 3

Location: RPS, NTNC, Gideni.

Species R

Number of Specimen: 4

Location: Gideni.

Species S

Number of Species: 3

Location: EBC, Dibyapuri, Lamichaur.

Species T

Number of Specimen: 3

Location: Icharni, NTNC

Species U

Number of Specimen: 30

Location: NTNC, Gideni, Bagmara, Kasara, Dibyapuri.

Species V

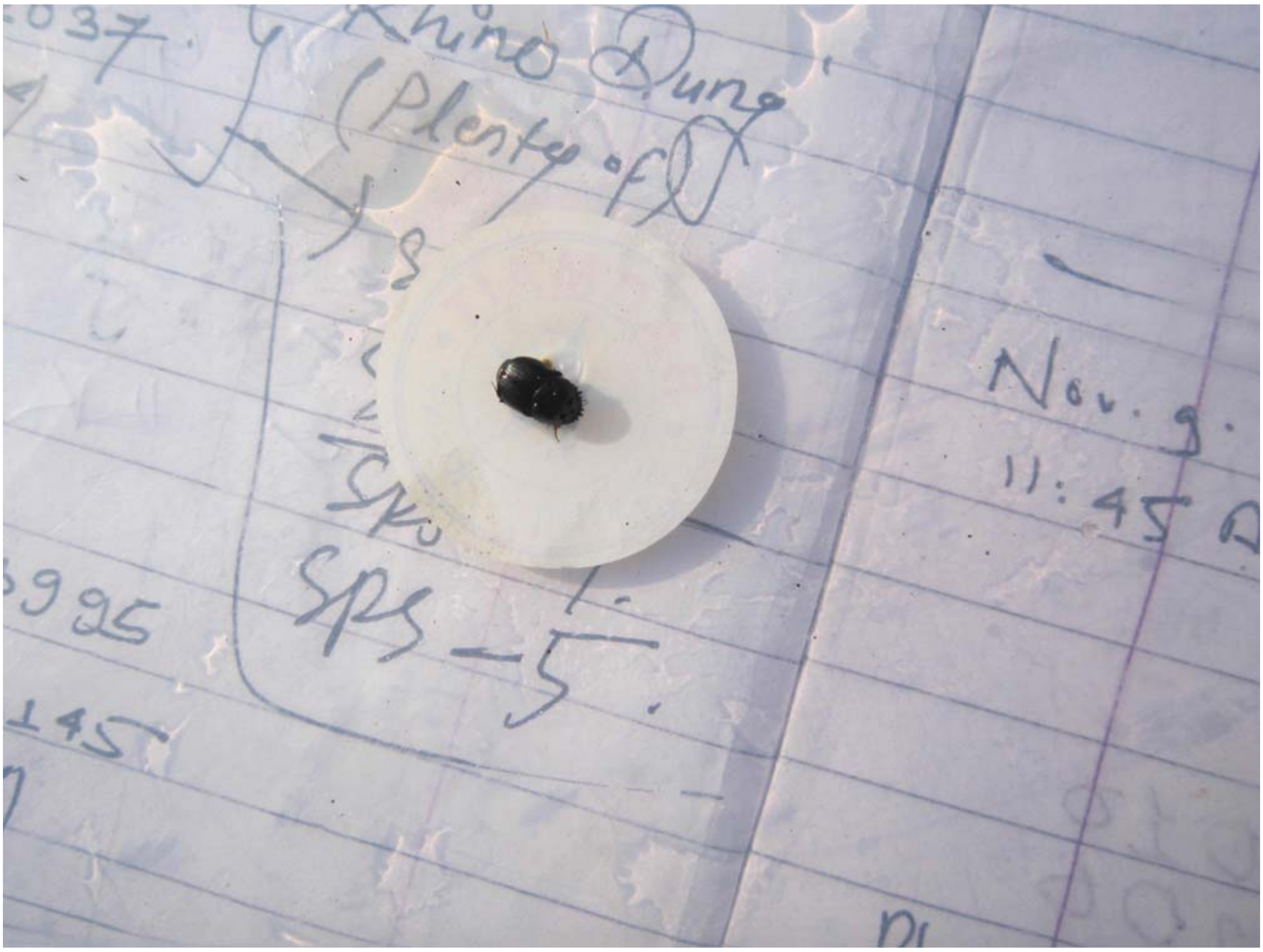
Number of Specimen: 1

Location: Kasara.

Species W

Number of Specimen: 11

Location: NTNC, RPS, Lamichaur, Kasara, Meghauli.



Name X

Number of Specimen: 1

Location: Ranger Post Sauraha (RPS).

APPENDIX II

This section shows pictures of how elephant are kept at different sites within the Chitwan National Park.