**International Journal of Entomology Research**
**www.entomologyjournals.com**
**ISSN: 2455-4758**
**Received: 10-12-2022, Accepted: 26-12-2022, Published: 13-01-2023**
**Volume 8, Issue 1, 2023, Page No. 47-51**

# Impact of anthropogenic disturbance on beetle diversity, with special reference to ground beetles (Coleoptera - Carabidae) and dung beetles (Coleoptera - Scarabaeidae): A review

**Rahul Yadav, Farha Naz, Sweety Nalwaya, Kanan Saxena***
Department of Zoology, Government Meera Girls College, Udaipur, Rajasthan, India

**Abstract**
Anthropogenic disturbances can change environmental characteristics at different scales. Beetles are good indicators of various kinds of disturbances such as habitat fragmentation, edge of habitat, urbanization, climate change and pollution and also show fluctuation in their diversity according to the disturbance. Mainly dung beetle species are used for the study of forest edge. Due to their comparative facility of collection and identification, ground beetles are studied for urbanization effect. Many studies suggest an increasing beetle abundance with an increasing degree of disturbance, while the species richness, species evenness, and the diversity were found to decrease. Throughout fragmentation researches, habitat fragmentation effect was mainly observed in forests. Plummeted species richness, abundance and evenness of beetles was observed in isolated and smaller forest fragments. Small forest fragments house generalist species abundantly while large forest fragments are favoured by forest specialist species. Some species are very sensitive to edge and pollution, and also have threat to extinction, so conservation of such species is also necessary. The present study is based upon more than 40 worldwide publications from 2005 to 2021. In this study, we review the anthropogenic effects only on dung and ground beetles, as there is no sufficient study on other beetles (coleoptera). In India very limited research has been done on anthropogenic effect on beetles' diversity. Finally, we propose further research to help us better understand the effect of anthropogenic impact on beetle diversity.

**Keywords:** anthropogenic disturbance, beetles, diversity, edge, habitat fragmentation

## Introduction

Insects are found in every type of habitat on land, in water and air, from equator to the arctic and from sea level to the snowfield of mountains (Belamkar & Jadesh, 2012) [4] and also show a big difference in their trophic level status, size, life history, seasonality, movement and requirements for habitats (Nazir *et al*., 2014) [30]. Insects with other invertebrates make up more than 75% of all described species diversity worldwide (Adjaloo at. al, 2012) [1]. Most successful insect order Coleoptera alone shows about 38% (3,87,100 species) of insect species of the world (Zhang, 2011). The insect fauna of India is vast. In India, Coleoptera is most dominant insect order comprising of about 15,500 species (Varshney, 1988) [45]. The essential biological parameters of an ecosystem are the diversity, dimensions and population size of the species. The vegetation, climate and the interactions among them determine the diversity, distribution abundance and richness of insect species (Torres & Madi-Ravazzi, 2006) [41].

Various anthropogenic disturbances like habitat fragmentation, habitat loss, habitat destruction, edge effect, pollution, climate change and others, directly or indirectly affect the beetle's diversity. Habitat edge (transitional zones between adjoining ecosystems) increase by worldwide fragmentation and loss of natural habitats (Ewers & Didham, 2008) [10]. Fragmentation, a landscape level occurrence, reduces quality and size of the habitat, and increases isolation by creating significantly different ecological limits. (Fahrig, 2003) [11]. Probably, habitat fragmentation contributes to dwindling number of species in the terrain and might lead to threat of local extinctions.

Urbanization also affects beetles' diversity. Works on urban-rural gradients illuminate the effects of urbanisation on biotic communities (Niemela *et al*., 2000) [31]. Gradients along populated cities to rural environments are observed globally, reflecting almost identical anthropogenic composition and processes. (Niemela, 2000) [31]. On other hand, increased pollutant or pollution (by human activity) also affect the animal diversity. Habitat pollution puts organisms to a big threat as the organisms are exposed to direct or indirect association with polluted environment (Touceda-Gonzalez *et al*., 2017) [43].

## Anthropogenic effects on ground and dung beetles

### A. Effect of habitat fragmentation on beetle diversity

Habitat fragmentation effect was mainly observed in forests indicating that large forest fragments are favoured by forest specialist species, while smaller forest fragments are preferred by generalist species due to ease of crossing the edge. Fragmentation studies show that dung beetle abundance, evenness and species richness declined in smaller forest fragments, because small fragments have smaller habitat area so species do not show longer connectivity to adjacent habitat.

Habitat fragmentation is the one of the major anthropogenic disturbances that influences the size and quality of habitat. Forest specialist species of ground beetles were favoured by the large forest fragments, while generalist species and species frequently associated with forest (forest generalists) dominated the smaller forests (Gaublomme *et al*., 2008) [14]. Lesser number of beetle species were present in smaller and isolated fragments, but forest fragments with less diverse tree species and lower number of shade-tolerant species presented considerably diminished dung beetle species. Large fragment in the Atlantic Forest appears to consist of a sort of unique habitat for particular group of dung beetle species, as well as integrity of their communities (Filgueiras *et al*., 2011) [13].

Barragan *et al*., (2011) [2] studied habitat alteration and recorded decline in dung beetle diversity in two of the three Mexican biosphere reserves. Spatial effects appear as factors shaping communities at larger extent, while environmental heterogeneity is significant at smaller scales. Large scale rise in dung beetle diversity might result from presence of geographical barriers and habitat fragmentation which limits the dispersal ability of beetle species.

Four dominant beetle families responded differently to forest fragmentation and forest types. Staphylinidae and Curculionidae were influenced by forest types, while Carabidae was impacted by forest fragmentation. Chrysomelidae was not influenced (Kwon *et al*., 2021) [21]. Highest abundance values were observed in the forest fragments, but dung and carrion beetle biomass was highest in the meadows. Highest number of species were prevalent in the forest fragments and forest meadow edges. (Diaz *et al*., 2010) [6].

Beiroz *et al*. (2018) [3] demonstrated that dung beetles' responses to disturbance may not provide similar information on similar indices. They highlighted that taxonomic and functional diversity both consistently reduced in plantations compared to undisturbed native forests. Amongst anthropogenically disrupted landscapes, natural habitats, apparently, serve for the conservation of vulnerable species and also as refuge for the lost and depleted dung beetle fauna (Jain & Mittal, 2012) [19]. Due to considerable loss of habitat and fragmentation, one-fifth of the beetle fauna might diminish. The species dependent on the largest patches of habitat and those that specialize in using disturbed habitat in linear-remnants are vulnerable to extinction after habitat fragmentation (Driscoll & Weir, 2005) [7].

Major natural disturbance agents were Bark beetles in western North American forests. However, recent bark beetle population outbreaks have exceeded the frequencies, impacts, and ranges documented during the previous 125 years. Fundamental regime shifts may take place if key thresholds are exceeded due to reduced habitat heterogeneity and increase in climate change. (Raffa *et al*., 2008) [38].

## B. Edge effect on beetle diversity

Dung beetles species of the forest were distinctly vulnerable to edge effects. Number of species (richness) was higher in the forest than the edge because dung beetles prefer forest interior as compared to edge and food availability is also higher in interior for a particular dung beetle species.

Forest edges formed by natural or anthropogenic processes, affect the abundance and dispersal power of ground beetles of different habitat. Open-habitat species could not penetrate into natural forest edges which prevent their movement into the forest interiors, while forest specialist species infiltrated and attained abundances corresponding to forest interiors (Magura & Lovei, 2020) [25]. There seem to be very few edge-specialist carabids, and open land edges of forests act as effective barriers for forest or open habitat species. Although, generalist species cross the edge easily, and species from the surrounding open habitat invade the edges of forest fragments. (Niemela *et al*., 2006) [33]. Forest edges predominantly harbour generalist ground beetle species In large forest patches, forest specialist species were common, or else they vanished due to habitat depletion (Gaublomme *et al*. 2008) [14].

The edge effect patterns cannot be generalized on carabid beetle communities. Phillips *et al*., (2006) [37] found that boreal forest edges created by salvage logging had no carabid species restricted to this area. The diversity of carabid and staphylinid beetles is maintained by the forest edges. (Tothmeresz *et al*., 2014) [42]. The number and species richness of Staphylinidae were remarkably lesser in the grassland area than in the interior of the forest and forest edge. Ground beetle species from both neighbouring habitats are maintained by natural forest edges, which also conserve species characteristic of and those restricted to the edge. Diverse functional traits are found in species living at natural edges. The functional and phylogenetic diversity is enhanced as these species belong to heterogeneous lineages. (Magura, 2017) [24]. Carabid beetle abundance and richness registered greatest near the forest edge and meadow. Forest edge functions as a barrier for the species that occur only in the forest or in meadow as these species did not cross forest edge to enter into the other habitat (Ohwaki el al., 2015) [36]. Across forest-meadow ecotones, the age and structure of vegetation determines the spatial distribution pattern of carabid beetles (Brigic *et al*., 2014) [5].

Dung beetle species found in Savanna also preferred edge habitat rather than being edge specialists, signifying benefits of advantages in edges. Road edge displayed diverse aggregation but did not show any universal species (Feer, 2008) [12].

Roller dung beetle abundance was high in the forest and low in ecotone, showing no marked difference. A representative of forest assemblage was the ecotone dung beetle assemblage. The roller guild of dung beetles did not prefer the ecotone habitat even though it was close to the forest and also the agriculture field. (Latha & Thomas, 2020) [23]. Dung beetle diversity and abundance decreases from forest to sun-grown coffee and an intense turnover of species was observed at the forest-coffee edge. Sun grown coffee matrix forms a barrier against forest species suggesting a complicated forest-coffee ecotone (Villada-Bedoya *et al*., 2017) [46].

## C. Effect of urbanization on beetle diversity

Beetle diversity and species richness (Dung and Ground) increase along a gradient from urban to rural area, as urbanisation leads to change in environment and habitat characteristics. Urbanisation also reduces the habitat availability, so generally there is lower species diversity and richness in this area.

Anthropogenic disturbance in urban habitat fragments is indicated by many carabid beetles, which act as potent biological indicators (McGregor & Wahl, 2020). More urbanized sites were reported to have few forest specialist species and increased generalist ground beetle species (Gaublomme *et al*., 2008) [14]. Habitat and environmental characteristics alteration followed by urbanization result in cluster of randomly colonized ground beetle species from the surrounding matrix, forbidding appropriate functioning of the ecosystem (Magura *et al*., 2018) [27].

Abundance and species diversity of carabid beetles decreased along an urbanization gradient. Additionally, the highly disturbed urban sites characteristically had some dominant species, in contrast to the suburban and rural areas. Besides, large sized carabid beetles decreased proportionately towards the city centres (Niemela & Kotze, 2009) [32].

Salomao *et al*., (2019) [40] provided evidence that dung beetles (specific functional groups) were affected by urbanization. Urbanization had varied effects for each group as different functional groups utilize different strategies to use habitats and resources. They noticed that dung beetles were prone to urbanization and urban areas play a significant role in conserving biodiversity and maintenance of ecosystem.

Density and diversity of beetles, particularly of unique species, decreases from city centres to rural environs. Ladybird beetle population increased with urbanization in California but decreased in Michigan as urbanization increased. Thus, urban context may be considered a major contributor to biodiversity in habitats and is significant in urban ecosystems for perpetuating agricultural methods (Egerer *et al*., 2018) [9].

Vegetated or Green roofs harbour diverse beetle communities despite their emplacement in urban topography. Wingless species are absent in such places suggesting the requirement to bridge the association of green roofs and ground level habitats (Kyro *et al*., 2018) [22].

Ground beetles in urban green spaces are affected considerably by urbanization at all levels of biological organization (Magura & Lovei, 2021) [26].

### D. Effect of climate change and pollution on beetle diversity

Mainly beetle diversity and richness were higher in cooler area and lower in warmer area. Within an area, diversity was lower in summer as compared to winter. So, climate and temperature also affect the beetles' diversity. It is also seen that the beetle diversity is higher in moderate polluted habitat and lower in high and low polluted habitat (according to moderate habitat disturbance hypothesis).

Abundance and diversity of beetles living on the forest floor declined in warmer climate (Harris *et al*., 2019) [17].

The uncontaminated areas showed varying body-size of carabid beetles. Carabid assemblages in massive polluted locales show community disassembly. Worsening pollution is the major cause of extinction of vulnerable large sized beetles having greater competitive potential. Smaller sized and generalist species that are less sensitive replace the sensitive large sized species of beetles. The unstable interface amongst species in communities lead to co-occurrence of species on heavily polluted sites (Kedzior *et al*., 2018) [20].

Ground beetles were significantly higher in extremely polluted habitat than in lesser polluted ones. These findings may suggest that ground beetles in heavily polluted environs have the potential for entomoremediation of the habitat (Tozser, 2019) [44].

### E. Other anthropogenic effects on beetle diversity

Dung beetles' habitat preference depends on biotic factors such as forest cover and mammalian diversity as well as abiotic factors like temperature (Goh *et al*., 2019) [15]. To provide rich diversity of beetles in agricultural land, it is paramount to manage biodiversity with moderate intensity. The entire agricultural landscape should be managed to support abundance of carabids besides management of isolated fields. (Mayr *et al*. 2007) [28].

Edwards *et al*., (2017) [8] found tunnelling and larger species to respond more than other functional groups impacted by the micro-habitat variation.

Noriega *et al*., (2021) [35] studies strengthen the evidence that human activities have negative impacts on the diversity and structure of dung beetle assemblages.

Dung beetle response to management of livestock is different for varied biomes. Presumably, dung beetles were preadapted to the environmental conditions in dry ecosystem inflicted by cattle ranching while this effect was significantly greater in the wet ecosystems (Guerra Alonso *et al*., 2020) [16].

Lower alpha diversity in parks and campus than in residential plots and remnant forest patches represents differential responses of beetles to habitat disruption (Ramalingam & Rajan, 2017) [39].

Disturbed vegetation sites had higher diversity and species richness than most of the undisturbed sites. The species of family Elateridae were consistent with disturbance, though the correlations were weak (Heusi-Silveira *et al*., 2012) [18].

## Conclusion

We can conclude that ground beetle abundance increases with an increasing degree of disturbance, while the species evenness, richness and the diversity declined. Habitat fragmentation effect is observed mainly in forest and it is seen that forest specialist species are favoured by large forest fragments and smaller forest fragments have generalist species (because generalist species easily cross the edge). Fragmentation studies show that smaller forest fragments have reduced dung beetle abundance, evenness and species richness. Isolated fragments had reduced abundance and richness, though this reaction is dependent on matrix quality. Studies suggest that significantly higher species richness was present in the forest edges maintained by natural processes as compared to the forest interiors, while forest edges with persistent anthropogenic disturbance had low species count. Forest species of dung beetles were clearly vulnerable to edge effects. Beetle abundance and biomass declined markedly from forest to edge. Edges harbour less species richness than the forest. In some cases, beetle diversity also fluctuates according to environmental heterogenicity and moderate habitat disturbance hypothesis. There is a rise in density and richness of carabid beetles from urban to the rural environment. Moreover, a few dominant species are characteristic of urban environments, and more species are from the suburban and rural sites. Increased pollution may lead to extinction of sensitive forest specialist species by generalist species with more competitive ability, and therefore, conservation of these type of species is also necessary. Climatic warming reduces the abundance and diversity of beetles. Some studies also correlate this effect by change of beetle diversity (decline) from winter to summer. So, various anthropogenic disturbances cause decrease in beetle diversity by different gradient, some cause more and some less, and some effects cause extinction of species.

## References

1. Adjaloo MK, Oduro W, Mochiah MB. Spatial distribution of insect assemblage in cocoa farms in relation to natural forest. J. Appl. Biosc.,2012:54:3870-3879.
2. Barragan F, Moreno CE, Escobar F, Halffter G, Navarrete D. Negative impacts of human land use on dung beetle functional diversity. PloS one,2011:6(3):e17976.

3. Beiroz W, Sayer E, Slade EM, Audino L, Braga RF, Louzada J *et al*. Spatial and temporal shifts in functional and taxonomic diversity of dung beetles in a human-modified tropical forest landscape. Ecological Indicators,2018:95:518-526.
4. Belamkar NV, Jadesh M. A preliminary study on abundance and diversity of insect fauna in Gulbarga District, Karnataka, India. International Journal of Science and Research,2012:3(12):1670-1675.
5. Brigic A, Starcevic M, Hrasovec B, Elek Z. Old Forest edges may promote the distribution of forest species in carabid assemblages (Coleoptera: Carabidae) in Croatian forests. European journal of entomology,2014:*111*(5):715-725.
6. Diaz A, Galante E, Favila ME. The effect of the landscape matrix on the distribution of dung and carrion beetles in a fragmented tropical rain forest. Journal of Insect Science, 2010, 10(1).
7. Driscoll DA, Weir TOM. Beetle responses to habitat fragmentation depend on ecological traits, habitat condition, and remnant size. Conservation Biology,2005:19(1):182-194.
8. Edwards FA, Finan J, Graham LK, Larsen TH, Wilcove DS, Hsu WW *et al*. The impact of logging roads on dung beetle assemblages in a tropical rainforest reserve. Biological conservation,2017:205:85-92.
9. Egerer M, Li K, Ong TWY. Context matters: contrasting ladybird beetle responses to urban environments across two US regions. Sustainability,2018:10(6):1829.
10. Ewers RM, Didham RK. Pervasive impact of large-scale edge effects on a beetle community. Proceedings of the National Academy of Sciences of the United States of America,2008:105:5426-5429.
11. Fahrig L. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology Evolution and Systematics,2003:34:487-515.
12. Feer F. Responses of dung beetle assemblages to characteristics of rain forest edges. *Ecotropica*,2008:14:49-62.
13. Filgueiras BK, Iannuzzi L, Leal IR. Habitat fragmentation alters the structure of dung beetle communities in the Atlantic Forest. Biological Conservation,2011:144(1):362-369.
14. Gaublomme E, Hendrickx F, Dhuyvetter H, Desender K. The effects of forest patch size and matrix type on changes in carabid beetle assemblages in an urbanized landscape. Biological conservation,2008:141(10):2585-2596.
15. Goh TG, Loo JS, Farahin-Mustafa N, Sakinah-Myassin N, Hashim R. The habitat preference of dung beetle species associated with elephant dung of the Malay Peninsula. Raffles Bulletin of Zoology, 2019, *67*.
16. Guerra Alonso CB, Zurita GA, Bellocq MI. Dung beetles response to livestock management in three different regional contexts. Scientific reports,2020:10(1):1-10.
17. Harris JE, Rodenhouse NL, Holmes RT. Decline in beetle abundance and diversity in an intact temperate forest linked to climate warming. Biological Conservation,2019:240:108219.
18. Heusi-Silveira M, Lopes BC, Ide S, Castellani TT, Hernández MI. Beetle (Insecta, Coleoptera) assemblage in a Southern Brazilian restinga: effects of anthropogenic disturbance and vegetation complexity. Studies on Neotropical Fauna and Environment,2012:47(3):203-214.
19. Jain R, Mittal IC. Diversity, faunal composition and conservation assessment of dung beetles (Coleoptera: Scarabaeidae) in two reserve forests of Haryana (India). *Entomologie Faunistique-Faunistic Entomology*, 2012.
20. Kedzior R, Kosewska A, Skalski T. Co-occurrence pattern of ground beetle (Coleoptera, Carabidae) assemblages along pollution gradient in scotch pine forest. Community Ecology,2018:19(2):148-155.
21. Kwon TS, Jung JK, Park YS. Influences of forest type and fragmentation by a road on beetle communities in the Gwangneung forest, South Korea. Korean Journal of Ecology and Environment,2021:54(1):61-70.
22. Kyro K, Brenneisen S, Kotze DJ, Szallies A, Gerner M, Lehvavirta S. Local habitat characteristics have a stronger effect than the surrounding urban landscape on beetle communities on green roofs. Urban Forestry & Urban Greening,2018:29:122-130.
23. Latha T, Thomas SK. Edge effect on roller dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) in the moist South Western Ghats. J. Entomol. Zool. Stud.,2020:8,1044-1047.
24. Magura T. Ignoring functional and phylogenetic features masks the edge influence on ground beetle diversity across forest-grassland gradient. Forest Ecology and Management,2017:384:371-377.
25. Magura T, Lovei GL. The permeability of natural versus anthropogenic forest edges modulates the abundance of ground beetles of different dispersal power and habitat affinity. Diversity,2020:12(9):320.
26. Magura T, Lovei GL. Consequences of urban living: Urbanization and ground beetles. Current Landscape Ecology Reports,2021:6(1):9-21.
27. Magura T, Lovei GL, Tothmeresz B. Conversion from environmental filtering to randomness as assembly rule of ground beetle assemblages along an urbanization gradient. Scientific reports,2018:8(1):1-9.
28. Mayr S, Wolters V, Dauber J. Ground beetles (Coleoptera: Carabidae) in anthropogenic grasslands in Germany: effects of management, habitat and landscape on diversity and community. Wiadomos ci Entomologiczne,2007:26:169-184.
29. McGregor R, Wahl V. Beetles in the city: ground beetles (Coleoptera: Carabidae) in Coquitlam, British Columbia as indicators of human disturbance. Journal of the Entomological Society of British Columbia,2020:117:20-30.
30. Nazir S, Sharif F, Arshad M, Khan A. Diversity Analysis of Insects of the Thorn Forest Community at Harappa Archaeological Site, Pakistan. Pak. J. Zool.,2014:46(4):1091-1099.
31. Niemela J. Biodiversity monitoring for decision-making. Annales Zoologici Fennici,2000:37:307-317.
32. Niemela J, Kotze DJ. Carabid beetle assemblages along urban to rural gradients: A review. Landscape and Urban Planning,2009:92(2):65-71.
33. Niemela J, Koivula M, Kotze DJ. The effects of forestry on carabid beetles (Coleoptera: Carabidae) in boreal forests. In Beetle Conservation Springer, Dordrecht, 2006, 5-18.
34. Niemela J, Kotze J, Ashworth A, Brandmayr P, Desender K, New T. The search for common

anthropogenic impacts on biodiversity: a global network. Journal of Insect Conservation,2000:4:3-9.
35. Noriega JA, March-Salas M, Castillo S, García QH, Hortal J, Santos AM. Human perturbations reduce dung beetle diversity and dung removal ecosystem function. Biotropica,2021:53(3):753-766.
36. Ohwaki A, Kaneko Y, Ikeda H. Seasonal variability in the response of ground beetles (Coleoptera: Carabidae) to a forest edge in a heterogeneous agricultural landscape in Japan. European Journal of Entomology, 2015:112(1):135.
37. Phillips ID, Cobb TP, Spence JR, Brigham RM. Salvage logging, edge effects, and carabid beetles: connections to conservation and sustainable forest management. Environmental Entomology, 2006:35(4):950-957.
38. Raffa KF, Aukema BH, Bentz BJ, Carroll AL, Hicke J A, Turner MG *et al*. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions. Bioscience,2008:58(6):501-517.
39. Ramalingam RAVI, Rajan PD. Effects of various urban land-uses on the epigeic beetle communities in Bangalore city, India. Tropical Ecology,2017:58(2):295-305.
40. Salomao RP, Alvarado F, Baena-Díaz, F, Favila ME, Iannuzzi L, Liberal CN *et al*. Urbanization effects on dung beetle assemblages in a tropical city. Ecological Indicators,2019:*103*:665-675.
41. Torres FR, Madi-Ravazzi L. Seasonal variation in natural populations of Drosophila spp. (Diptera) in two woodlands in the State of Sao Paulo, Brazil. Iheringia, Serie Zoologia,2006:96:437-444.
42. Tothmeresz B, Nagy DD, Mizser S, Bogyo D, Magura T. Edge effects on ground-dwelling beetles (Carabidae and Staphylinidae) in oak forest-forest edge-grassland habitats in Hungary. European Journal of Entomology,2014:111(5).
43. Touceda-Gonzalez M, Prieto-Fernandez A, Renella G, Giognoni L, Sessitsch S, Brader, G *et al*. Microbial community structure and activity in trace elementcontaminated soils phytomanaged by Gentle Remediation Options (GRO). Environ Pollut,2017:231:237-251. https://doi.org/10.1016/j. envpol.2017.07.097
44. Tozser D, Magura T, Simon E, Mizser S, Papp D, Tothmeresz B. Pollution intensity-dependent metal accumulation in ground beetles: a meta-analysis. Environmental Science and Pollution Research,2019:26(31):32092-32102.
45. Varshney RK. Faunal Diversity in India, Insecta, Zoological Survey of India, 1988, 146-157.
46. Villada-Bedoya S, Cultid-Medina CA, Escobar F, Guevara R, Zurita G. Edge effects on dung beetle assemblages in an Andean mosaic of forest and coffee plantations. Biotropica,2017;49(2):195-205.
47. Zhang ZQ. Animal biodiversity: An introduction to higher level classification and taxonomic richness. Zootaxa., 2011, 7-12.