CHANGES IN DUNG BEETLES ALONG AN ALTITUDINAL GRADIENT OF TROPICAL FORESTS IN PU HOAT NATURE RESERVE, NGHE AN PROVINCE

Bui Van Bac, Bui Dinh Duc
Vietnam National University of Forestry

https://doi.org/10.55250/jo.vnuf.2022.13.028-034

SUMMARY

Dung beetles are widely used as bio-indicators of habitat changes because they respond quickly to changes in environmental conditions. Altitudinal variation in dung-beetle communities has been studied in various geographical areas. However, there is little known about dung-beetle shifting in tropical forests of Vietnam. This study investigates dung-beetle communities along an altitudinal gradient ranged from 400 to 800 m above sea level (a.s.l.). We collected dung beetles at three transects of three altitudinal classes (altitudinal class 1 = 400 m a.s.l., class 2 = 600 m a.s.l., and class 3 = 800 m a.s.l.) in primary forests of Pu Hoat Nature Reserve, using baited pitfall traps. In total, 28 dung-beetle species of 10 genera were recorded during the course of the study. Of the total recorded species, 25, 22 and 17 species were collected in the altitudinal class 1, class 2, and class 3, respectively. The ANOVA test and Tukey's post-hoc test showed significant differences in species richness, Shannon diversity, and abundance of dung beetles across the altitudinal gradient. Altitudinal class 1 had the highest richness of dung beetles. However, the highest abundance was recorded in the altitudinal class 2. Several dung-beetle species, in response to global warming, have shifted their altitudinal range upward, leading to serious conservation problems such as extinctions of high-elevation species.

Keywords: Altitudinal variation, dung beetles, Pu Hoat Nature Reserve, species diversity.

1. INTRODUCTION

Dung beetles are a diverse and abundant group of insects, belonging to the subfamily Scarabaeinae (Coleoptera: Scarabaeidae). Dung beetles are widely used as bio-indicators of habitat changes because they respond quickly to changes in physical structure of vegetation and perform various ecological functions such as soil fertilization and aeration, increasing nutrient cycling, secondary seed dispersal and biological control agents for gastrointestinal parasites of livestock (Fincher, 1973; Andresen, 2005; Nichols et al., 2008; Audino et al., 2014). Altitude is seen as one of the most important drivers of changes in species richness and composition (Huston, 1994). Changes in dung-beetle communities across different altitudinal classes have been described in Europe, North America, South America, South Africa, Southeast Asia, and Australia (Lobo & Halffter, 2000; Davis et al., 1999; Monteith, 1985; Escobar et al., 2005; Larsen, 2012; Herzog et al., 2013). Previous studies showed a consistent decrease in overall species richness with increasing altitude. However, different functional groups revealed different responses to altitudinal changes. For example, the cool-adapted species of Aphodiini dominate the high altitude, whereas the warm-adapted species of Scarabaeinae dominate the low altitude (Scholtz, 1990). Since dung-beetle communities possess distinct bio-geographical distributions and different evolutionary histories, it has been proposed that altitudinal variation in dung beetle assemblages is supported by unique and historical and geographical variables (Lobo & Halffter, 2000).

Pu Hoat Nature Reserve (NR) is located in Que Phong District (Nghe An Province), covering a total area of 67,934 ha. Pu Hoat is the part of the Western Nghe An Biosphere Reserve, containing various ecosystems and landscapes. This nature reserve hosts more than 750 plant species, 45 mammal species, 131 bird species and eight reptile species (Pu Hoat Nature Reserve, 2013). Recently, Bui Van Bac & Tran Thanh Lam (2021) recorded 54 Scarab beetles. However, the previous studies did not take altitudinal variation in assemblages into account. By analysing the data from three altitudinal transects located along a latitudinal gradient in tropical forests of Pu Hoat NR, we describe the altitudinal changes in species richness, Shannon diversity, and abundance of dung beetles. Further we ask which species could be potential indicators of these altitudinal classes.

2. RESEARCH METHODS

2.1. Dung beetle sampling and identification

We investigated dung-beetle communities along an altitudinal gradient ranged from 400 to 800 m above sea level (a.s.l.). Three transects of three altitudinal classes (i.e., the altitudinal class 1 = 400 m a.s.l., class 2 = 600 m a.s.l., and class 3 = 800 m a.s.l.) were deployed to collect dung beetles in primary forests of Pu Hoat NR in Nam Giai commune in 2020. We used baited pitfall traps for dung-beetle sampling. In total, 20 traps were placed at each altitudinal class. The traps were placed at intervals of at least 200 m to minimize trap interference. Each trap consisted of a plastic bucket buried to its rim in the soil, filled with 0.5 L 70% ethanol, and baited with 300 gram of fresh cow dung. All trapped dung beetles were removed from the traps after 72 h of trap exposure and were preserved in ethanol until examination in the laboratory (Bui et al., 2020).

Dung beetles were identified based on the identification keys of Balthasar (1963), Barbero et al. (2009), Bui et al. (2018), Bui & Bonkowski (2018), Ochi & Kon (2007), Paulian (1945), the list of Vietnamese dung beetles documented by Kabakov & Napolov (1999), and through comparison with the reference collections of Vietnamese dung beetles in Bui et al. (2020).

2.2. Data analysis

We used R software v.3.5.1 (R Core Team, 2018) to carry out statistical analyses. Species accumulation curves were computed to assess the completeness of dung-beetle sampling across the three altitudinal classes. Both the analysis of variance (ANOVA) and Tukey's post-hoc test were used to test for differences in species richness, abundance, and Shannon's diversity index among the altitudinal classes.

The Shannon Diversity Index is calculated as: $H = -\Sigma pi * \ln(pi)$. Where: Σ: A Greek symbol that means "sum"; ln: Natural log; pi: the proportion of the entire community made up of species i. The higher the value of H reveals the higher the diversity of species in a particular community. Whereas, the lower the value of H revleas the lower the diversity. A value of H = 0 indicates a community that only has one species.

We used the value indicator (IndVal) according to Dufrêne & Legendre (1997) to identify possible indicator species for each altitudinal class, combining specificity of a given species in a given altitudinal class with its fidelity within that class. Species with a high specificity and high fidelity within a class are considered to achieve the highest indicator value. Those species with significant IndVals of greater than 70% were regarded as characteristic indicator species for the altitudinal class. This analysis was performed in R software using the indicspecies package v. 1.7.6 (Caceres & Jansen, 2016) with 9999 permutations.

We generated Venn diagram, using the VennDiagram package v. 1.6.18 (Hanbo, 2017) to indicate the number of dung-beetle species common to altitudinal classes.

3. RESULTS AND DISCUSSION

3.1. Changes in species composition of dung beetles along an altitudinal gradient

In total, 28 dung-beetle species of 10 genera were recorded along an altitudinal gradient (from 400 m to 800 m a.s.l.) in tropical forests of Pu Hoat NR in Nam Giai commune. The genus *Onthophagus* Latreille, 1802 dominated the dung-beetle communities in the study sites with 12 recorded species, followed by genera: *Copris* Geoffroy, 1762 (six species), *Aphodius* Illiger, 1798 (two species), *Liatongus* Reitter, 1892 (two species). Six genera, comprising *Caccobius* Thomson, 1859, *Catharsius* Hope, 1837, *Paragymnopleurus* Shipp, 1897, *Sinodrepanus* Simonis, 1985, *Sisyphus* Latreille, 1807 and *Synapsis* Bates, 1868 had one species each. Tunnellers represented 86% of all the recorded species (24 species), rollers and dwellers represented 7% (2 species) each (Table 1).

Table1. Species composition of dung beetles across three altitudinal classes in Pu Hoat Nature Reserve. Class 1 (400 m a.s.l), class 2 (600 m a.s.l), and class 3 (800 m a.s.l); 0 – unrecorded; 1 – recorded)

Species	Functional groups	Class1	Class2	Class3
1. *Aphodius elegans* Allibert, 1848	Dwellers	0	0	1
2. *Aphodius mirificus* (Balthasar, 1932)	Dwellers	1	0	1
3. *Caccobius unicornis* (Fabricius, 1798)	Tunnellers	1	1	1
4. *Catharsius molossus* Linnaeus, 1758	Tunnellers	1	1	1
5. *Copris carinicus* Gillet, 1910	Tunnellers	0	1	1
6. *Copris confucius* Harold, 1877	Tunnellers	1	1	1
7. *Copris magicus* Harold, 1881	Tunnellers	0	1	0
8. *Copris numa* Lansberge, 1886	Tunnellers	1	1	0
9. *Copris reflexus* Fabricius, 1787	Tunnellers	1	1	0
10. *Copris szechouanicus* Baltharsar, 1958	Tunnellers	1	1	1
11. *Liatongus gagatinus* (Hope, 1831)	Tunnellers	1	1	0
12. *Liatongus vertagus* (Fabricius, 1798)	Tunnellers	1	1	1
13. *Onthophagus dorsofasciatus* Fairmaire, 1893	Tunnellers	1	1	1
14. *Onthophagus luridipennis* Boheman, 1858	Tunnellers	1	0	0
15. *Onthophagus papulatus* Boucomont, 1914	Tunnellers	1	1	0
16. *Onthophagus phanaeiformis* Boucomont, 1914	Tunnellers	1	1	0
17. *Onthophagus rectecornutus* Lansberge, 1883	Tunnellers	1	1	0
18. *Onthophagus proletarius* Harold, 1875	Tunnellers	1	1	1
19. *Onthophagus sycophanta* Fairmaire, 1887	Tunnellers	1	0	0
20. *Onthophagus taurinus W*hite, 1844	Tunnellers	1	1	0
21. *Onthophagus thanwaakhomus* Masumoto, 1992	Tunnellers	1	1	1
22. *Onthophagus tragus* (Fabricius, 1792)	Tunnellers	1	1	1
23. *Onthophagus trituber (Wiedemann,* 1823)	Tunnellers	1	1	1
24. *Onthophagus vaulogeri* Boucomont, 1923	Tunnellers	1	1	1
25. *Paragymnopleurus brahminus* (Waterhouse, 1890)	Rollers	1	0	1
26. *Sinodrepanus similis Simonis, 1985*	Tunnellers	1	1	1
27. *Sisyphus neglectus* Gory, 1833	Rollers	1	0	0
28. *Synapsis tridens* Sharp, 1881	Tunnellers	1	1	1

Species overlap was surprisingly low between the three altitudinal classes, with 13 common species being occurred in all classes from 28 species in total (Figure 1), suggesting that each altitudinal class harbours unique subsets of dung-beetle communities. According to IndVal, four dung-beetle species were significantly associated with one altitudinal class (IndVal > 70%, $p<0.05$). Of which, two species comprising *Paragymnopleurus brahminus* and *Sisyphus neglectus* were indicator species of altitudinal class 1 (400 m a.s.l.). *Copris magicus* were significantly associated with altitudinal class 2 (600 m a.s.l.), while *Aphodius elegans* were the indicator species of altitudinal class 3 (800 m a.s.l.) (Table 2).

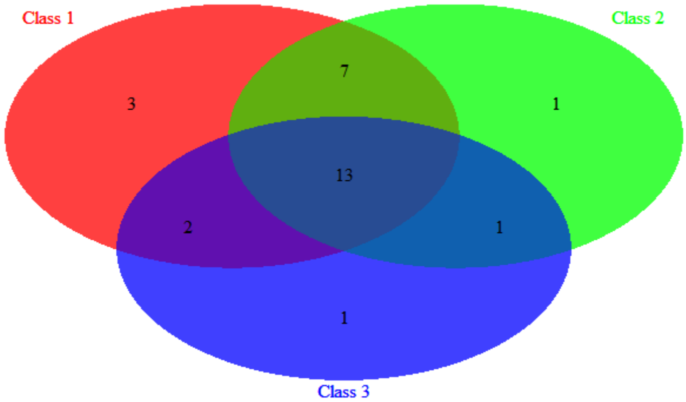

Figure 1. Venn diagrams showing the number of dung beetles occurring in uniquely and in common in the altitudinal classes (class1: 400 m a.s.l.; class 2 = 600 m a.s.l.; class 3 = 800 m a.s.l.) in tropical forests of Pu Hoat Nature Reserve

Table 2. Dung-beetle species preferences for different altitudinal classes as indicated by the indicator value test. Species were ordered according to the value of IndVal, *p* values less than 0.05 were considered significant

Species	Altitudinal classes	IndVal	*p* value
Paragymnopleurus brahminus	Class 1 (400 m a.s.l.)	82.6	< 0.001
Sisyphus neglectus	Class 1 (400 m a.s.l.)	79.2	< 0.001
Copris magicus	Class 2 (600 m a.s.l.)	77.2	0.013
Aphodius elegans	Class 3 (800 m a.s.l.)	71.2	0.022

3.2. Changes in taxonomic diversity of dung beetles along an altitudinal gradient

Of the total recorded species, 25, 22 and 17 species were collected in altitudinal class 1 (400 m a.s.l), class 2 (600 m a.s.l), and class 3 (800 m a.s.l), respectively. The species accumulation curves for the three altitudinal classes appeared to approach an asymptote, reflecting the high completeness of sampling method (Figure 2). Sampling efficiency according to the Chao1 estimator was very high in all altitudinal classes (> 95%).

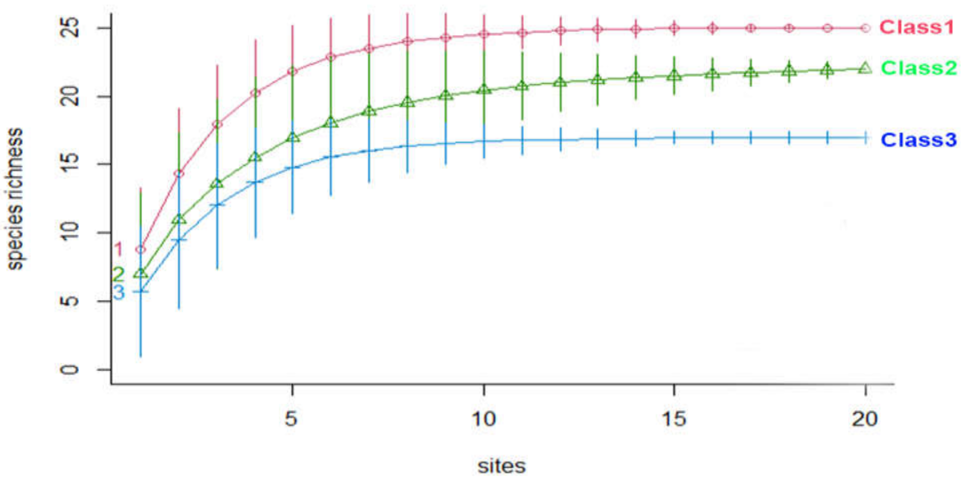

Figure 2. Species accumulation curves of dung-beetle communities in the three altitudinal classes in tropical forests of Pu Hoat Nature Reserve (class 1 = 400 m a.s.l; class 2 = 600 m a.s.l; class 3 = 800 a.s.l.)

The ANOVA results showed significant differences in species richness of dung beetles across the altitudinal gradient (ANOVA: $F_{richness\ [2,57]} = 9.7$, $p < 0.001$). According to Tukey's post-hoc test, the altitudinal class 1 had the highest richness of dung beetles, while the altitudinal class 3 had the lowest richness. Similarity, Shannon's diversity index showed a highest level in the altitudinal class 1. In contrast, the ANOVA test and Tukey's post-hoc test indicated that the altitudinal class 2 had the highest abundance of dung beetles (ANOVA: $F_{abundance\ [2,57]} = 10.8$, $p < 0.001$) (Figure 3).

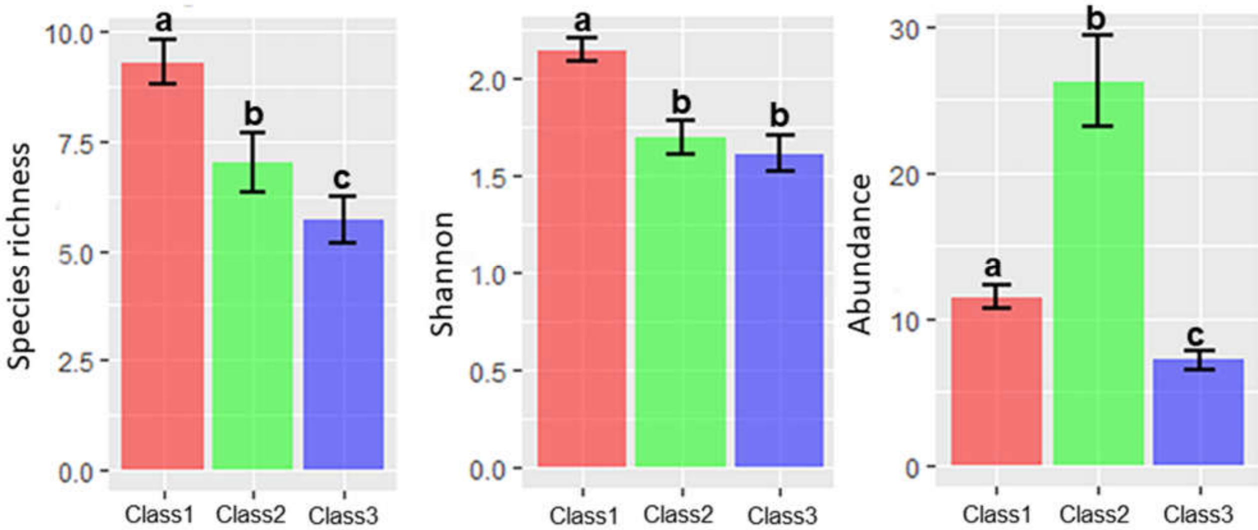

Figure 3. Bar graph illustrating the means and standard errors (error bars) of species richness, Shannon's diversity index, and abundance in three altitudinal classes in tropical forests of Pu Hoat Nature Reserve. Different letters indicate statistically significant differences at *p* < 0.05. Bars with no letters in common are significantly different (*p* < 0.05)

This study provides one of the first examples of how dung-beetle change along an altitudinal gradient in tropical forests of Vietnam. Our study indicates that dung-beetle richness decreased with increasing altitude, consistent with previous studies by Larsen (2012) and Herzog et al. (2013). However, in contrast to richness, abundance showed a highest level in the altitudinal class of 600 m a.s.l. There are numerous factors mask the influence of habitat structure on species occurrence. It is well known that the occurrence of dung beetles strictly depends on food resources, historical factors, climate and habitat compositions (Lumaret et al., 1992). Vegetation parameters seem to be an influential factor in explaining the variation in dung-beetle richness among the altitudinal classes. Plants affect dung beetles directly through regulating microclimatic conditions, but also indirectly through providing habitats for vertebrate fauna, the main supplier of food for dung beetles. Richness of dung beetles decreased with decreasing temperature, as dung-beetle communities included of many warm-adapted species (Lobo & Halffter, 2000). The effects of climatic change on dung beetle communities should be receive further attention, as dung beetles are widely seen as good indicators for habitat changes.

However, our results revealed a highest abundance of dung beetles in the altitudinal class 2 (600 m a.s.l.). Particularly, this altitudinal class contained larger populations of large-bodied dung beetles. This may be explained by the fact that large-bodied dung beetles are constrained to use the droppings of large herbivores due to larger food requirements for their brood masses during the breeding season (Hanski & Cambefort, 1991). However, large herbivores are relatively rare on the altitudinal class 1 (m a.s.l.), as these animals are often disturbed by anthropogenic activities such as illegal logging and hunting at this altitudinal class. Small-bodied dung beetle species that are typically diverse among tropical dung-beetle communities, in contrast to large-bodied dung beetles, are less dependent on large dung patches of mammals. These small dung beetles use various dung resources from small animals such as lizards, rodents, and birds in the altitudinal class 1.

4. CONCLUSION

Changes in the taxonomic diversity of dung beetles along the altitudinal gradient of tropical forests in Vietnam have been clearly described for the first time. Although species richness declined with increasing altitude, abundance did not show this pattern. Mean species richness showed the peak at low elevations (400 m a.s.l.), while mean abundance had the peak at middle elevations (600 m a.s.l.). In response to global warming, several dung-beetle species may shift their altitudinal range upward, leading to conservation problems such as extinctions of high-elevation species.

Acknowledgment

The results of this research are among outputs of the project: Examining the insect diversity and reviewing solutions for insect conservation in Pu Hoat Nature Reserve according to the Decision 118/QĐ-SNN.QLKTKHCN dated on 06/3/2020 of the Nghe An Department of Agriculture and Rural Development.

REFERENCES

1. Andresen, E. 2005. Effects of season and vegetation type on community organization of dung beetles in a tropical dry forest. Biotropica, 37: 291–300.

Audino, L. D., Louzada, J. & Comita, L. 2014. Dung beetles as indicators of tropical forest restoration success: Is it possible to recover species and functional diversity? Biol Conserv., 169: 248–257.

2. Balthasar, V. 1963. Monographie der Scarabaeidae und Aphodiidae der Palaearktischen und Orientalischen Region. Coleoptera: Lamellicornia. Band 1. Allgemeiner Teil, Systematischer Teil: 1. Scarabaeinae, 2. Coprinae (Pinotini, Coprini). Verlag der Tschechoslowakischen Akademie der Wissenschaften, Prag.

3. Barbero, E., Palestrini, C. & Roggero, A. 2009. Systematics and phylogeny of *Eodrepanus*, a new *Drepanocerine* genus, with comments on biogeographical data. Journal of Natural History, 43: 1835–1878.

4. Bui, V. B. & Bonkowski, M. 2018. *Synapsis puluongensis* sp. nov. and new data on the poorly known species *Synapsis horaki* (Coleoptera: Scarabaeidae) from Vietnam with a key to Vietnamese species. Acta Entomologica Musei Nationalis Pragae, 58: 407–418.

5. Bui, V. B. & Tran, T. L. 2021. Species composition of Scarab beetles (Coleoptera: Scarabaeidae) including three endangered species from Pu Hoat Nature Reserve, Nghe An. Journal of Forestry Science and Technology, 6: 92–100.

6. Bui, V. B., Dumack, K. & Bonkowski, M. 2018. Two new species and one new record for the genus *Copris* (Coleoptera: Scarabaeidae: Scarabaeinae) from Vietnam with a key to Vietnamese species. European Journal of Entomology, 115: 167–191.

7. Bui, V. B., Ziegler, T. & Bonkowski, M. 2020. Morphological traits reflect dung beetle response to land use changes in tropical karst ecosystems of Vietnam. Ecological Indicators, 108: 1–9.

8. Caceres, M. D. & Jansen, F. 2016. Indicspecies: Relationship between species and groups of sites. R package version 1.7.6.

9. Davis, A. L. V., Scholtz, C. H. & Chown, S. L. 1999. Species turnover, community boundaries and biogeographical composition of dung beetle assemblages across an altitudinal gradient in South Africa. Journal of Biogeography, 26: 1039–1055.

10. Dufrene, M. & Legendre, P. 1997. Species assemblages and indicator species, the need for a flexible asymmetrical approach. Ecological Monographs, 67: 345–366.

11. Escobar, F., Lobo, J. M. & Halffter, G. 2005. Altitudinal variation of dung beetle (Scarabaeidae: Scarabaeinae) assemblages in the Colombian Andes. Glob Ecol Biogeogr.,14: 327–337.

12. Fincher, G. T. 1973. Dung beetles as biological control agents for gastrointestinal parasites of livestock. The journal of parasitology, 59(2): 396–399.

13. Hanbo, C. 2017. VennDiagram: Generate High-Resolution Venn and Euler Plots. R package version 1.6.18.

14. Hanski, I. & Cambefort, Y. 1991. Dung beetle ecology. Princeton University Press. Princeton.

15. Herzog, S. K., Hamel-Leigue, A. C., Larsen, T. H., Mann, D. J., Soria-Auza, R. W., Gill, B. D. 2013. Elevational distribution and conservation biogeography of phanaeine dung beetles (Coleoptera: Scarabaeinae) in Bolivia. PLoS One, 8 (e64963): 1–11.

16. Huston, M. A. 1994. Biology diversity. The coexistence of species on changing landscapes. Cambridge University Press, Cambridge.

17. Kabakov, O. N. & Napolov, A. 1999. Fauna and ecology of Lamellicornia of subfamily Scarabaeinae

(Scarabaeidae, Coleoptera) of Vietnam and some parts of adjacent countries: South China, Laos and Thailand. Latvijas Entomologs, 37: 58–96.

18. Larsen, T. H. 2012. Upslope range shifts of Andean dung beetles in response to deforestation: compounding and confounding effects of microclimatic change. Biotropica, 44: 82–89.

19. Lobo, J. M. & Halffter, G. 2000. Biogeographical and ecological factors affecting the altitudinal variation of mountainous communities of coprophagous beetles (Coleoptera: Scarabaeoidea): a comparative study. Ann Entomol Soc Am., 93: 115–126.

20. Lumaret, J. P., Kadiri, N. & Bertrand, M. 1992. Changes in resources: consequences from the dynamics of dung beetle communities. J. Appl. Ecol., 29: 349–356.

21. Monteith, G. B. 1985. Altitudinal transect studies at Cape Tribulation, North Queensland VII. Coleoptera and Hemiptera (Insecta). Queensland Naturalist, 26: 70–80.

22. Nichols, E., Spector, S., Louzada, J., Larsen, T., Amezquita, S. & Favila, M. E. 2008. Ecological functions and ecosystem services provided by Scarabaeinae dung beetles. Biol Conserv., 141: 1461–1474.

23. Ochi, T. & Kon, M. 2017. Notes on the coprophagous scarab-beetles (Coleoptera, Scarabaeidae) from Southeast Asia. XXVIII. A new genus and three new subgenera of the genus Parascatonomus. Giornale Italiano di Entomologia, 14: 775–792.

24. Paulian, R. 1945. Faune de l'Empire Français III. Coléoptère Scarabéides de l'Indochine. Première partie. Paris, Libraire Larose.

25. Pu Hoat Nature Reserve, 2013. Planning for conservation and sustainable development of special-use forests of Pu Hoat Nature Reserve in the period of 2013-2020. Pu Hoat, Que Phong. Nghe An.

26. R Core Team. 2018. R: A Language and environment for statistical computing. R Foundation for Statistical Computing.

27. Scholtz, C. H. 1990. Phylogenetic trends in the Scarabaeoidea (Coleoptera). Journal of Natural History, 24: 1027–1066.

THAY ĐỔI TRONG QUẦN XÃ BỌ HUNG ĂN PHÂN THEO ĐỘ CAO Ở RỪNG NHIỆT ĐỚI THUỘC KHU BẢO TỒN THIÊN NHIÊN PÙ HOẠT, TỈNH NGHỆ AN

Bùi Văn Bắc, Bùi Đình Đức

Trường Đại học Lâm nghiệp

TÓM TẮT

Bọ hung ăn phân được sử dụng rộng rãi làm chỉ thị sinh học cho những thay đổi của sinh cảnh vì chúng phản ứng nhanh với những thay đổi của điều kiện môi trường. Thay đổi trong quần xã bọ hung ăn phân theo độ cao đã được nghiên cứu ở các khu vực địa lý khác nhau trên thế giới. Tuy nhiên, sự thay đổi này ở rừng nhiệt đới của Việt Nam còn ít được biết đến. Nghiên cứu tiến hành điều tra các quần xã bọ hung theo các độ cao khác nhau, biến động từ 400 m đến 800 m so với mực nước biển. Nghiên cứu đã thu thập bọ hung bằng bẫy hố có mồi nhử theo ba tuyến điều tra ở ba lớp độ cao: lớp 1 = 400 m, lớp 2 = 600 m, và lớp 3 = 800 m trong các cánh rừng tự nhiên của Khu Bảo tồn thiên nhiên Pù Hoạt trong năm 2020. Tổng cộng, 28 loài bọ hung ăn phân thuộc 10 giống đã được ghi nhận. Trong đó, 25, 22 và 17 loài được ghi nhận lần lượt ở các lớp độ cao 1, 2 và 3. Phân tích phương sai (ANOVA) và kiểm định Tukeys cho thấy sự khác biệt có ý nghĩa thống kê về số lượng loài, mức độ đa dạng và phong phú của bọ hung theo các lớp độ cao. Lớp độ cao 1 có nhiều loài bọ hung được ghi nhận nhất. Tuy nhiên, mức độ phong phú quần thể được tìm thấy ở độ cao 2. Nhiều loài bọ hung, để đối phó với sự nóng lên của trái đất, đã dịch chuyển phạm vi phân bố lên đai cao, dẫn đến các vấn đề trong bảo tồn như sự tuyệt chủng của các loài sống ở độ cao lớn.

Từ khóa: bọ hung ăn phân, đa dạng loài, độ cao, Khu Bảo tồn thiên nhiên Pù Hoạt.

Received	**: 11/3/2022**
Revised	**: 13/4/2022**
Accepted	**: 28/4/2022**