

INDICATOR VALUES AND CHARACTERISTIC SPECIES OF DUNG BEETLES IN TROPICAL FORESTS OF CAT BA NATIONAL PARK, HAI PHONG PROVINCE

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<https://doi.org/10.55250/jo.vnuf.2022.13.062-070>

SUMMARY

Dung beetles (Coleoptera: Scarabaeidae) are considered as an indicator group of habitat modifications. However, little is known about the indicative value of dung beetles for changes in tropical island karst ecosystems of Vietnam. We sampled dung beetles along the gradient of forest disturbances from primary forests to old secondary forests (> 15 years since abandonment), young secondary forests (< 10 years since abandonment) and *Acacia* plantations (< 10 years old) in Cat Ba National Park, Hai Phong Province. Our main aim is to detect dung-beetle species that could be used as potential indicator species of habitat changes. In total, 10 dung-beetle species were identified as potential indicator species of different forest types in Cat Ba National Park based on the indicator value (IndVal) of Dufrene & Legendre (1997). Four species were identified as true specialists in old secondary forests including *Onthophagus phanaeiformis* (Boucomont, 1914), *Sisyphus neglectus* (Gory, 1833), *Copris szechouanicus* (Balthasar, 1958), and *Onthophagus dorsofasciatus* (Fairmaire, 1893). Three species, comprising *Onthophagus* sp1., *Synapsis tridens* (Sharp, 1881), and *Onthophagus trituber* (Wiedemann, 1823) could be considered as the indicator species of primary forests. *Caccobius unicornis* (Fabricius, 1798) and *Onthophagus jeannelianus* (Paulian, 1945) were indicator species of young secondary forests; *Onthophagus luridipennis* (Boheman, 1858) was the indicator of *Acacia* plantations. In the following, we gave an annotated and illustrated checklist of the indicator dung-beetle species that may be broadly useful for habitat monitoring and conservations in Cat Ba National Park.

Keywords: Cat Ba National Park, dung beetles, indicator species, tropical karst ecosystems

1. INTRODUCTION

Dung beetles currently comprise around 7000 described species, belonging to three families: Scarabaeidae, Aphodiidae and Geotrupidae (Coleoptera: Scarabaeoidea) (Hanski & Cambefort 1991). These beetles typically use animal droppings as food and nesting material, and are among the most predominant members of dung insect communities in tropical and warm temperate regions (Davis et al., 2001; Davis et al., 2008). Dung beetles are highly sensitive to changes in the physical structure of habitats, such as vegetation cover (Costa et al., 2017), leaf litter layer (Nichols et al., 2013; Tixier et al., 2015) and soil characteristics (Farias et al. 2015; Beiroz et al., 2017). Therefore, dung beetles are considered as good indicators of a wide range of biodiversity impacts resulting from habitat changes (Nichols et al., 2007; Beiroz et al., 2017). On other hand, since dung beetles depend on vertebrate droppings as essential food and nesting resources, they may better reflect changes in the composition and structure of vertebrate communities (Vulinec 2000; Andresen

& Laurance 2006; Enari et al., 2013). The conversion of tropical forests to anthropogenic land-uses has generated a great variety of natural fragments, resulting in the loss of biodiversity, ecosystem functions and services of different groups of organisms (Bernard et al., 2009; Wood 2017). Dung beetles are increasingly being used in the assessment of the influences of forest transformations on biodiversity (Quintero & Roslin 2005; Vulinec et al., 2006; Gardner et al., 2008; Audino et al., 2014; Beiroz et al., 2017; Davis et al., 2001; Hayes et al., 2009). However, there is still very little known about the indicative value of dung beetles for changes in tropical island karst ecosystems of Vietnam.

Cat Ba National Park (Hai Phong Province) hosts a total area of 17,362.96 ha including both terrestrial ecosystems (10,912.51 ha) and marine ecosystems (6450.45 ha). Cat Ba National Park is the heart of the Cat Ba Biosphere Reserve, possessing a high diversity level with 58 mammals, 205 birds, 47 reptiles, 23 amphibians, and 1,585 plant species being recorded (Abramov & Kruskop 2012). Like many

protected nature areas in Vietnam, much of the natural forest area in Cat Ba National Park is irreversibly destroyed by clear-cutting for arable land, selective logging, and limestone quarrying, leading to the existence of a variety of forest fragments, including areas of primary forests, patches of various secondary forests, and plantations, and meadows. Investigating dung-beetle communities along the forest disturbance gradient in Cat Ba National Park, we aim to quantify and identify dung-beetle species that could be used as potential indicator species of various forest types in this national park.

2. RESEARCH METHODOLOGY

2.1. Dung-beetle sampling and identification

We sampled dung beetles in a standardized manner across a gradient of forest disturbance from primary forests to old secondary forests (> 15 years since abandonment), young secondary forests (< 10 years since abandonment) and *Acacia* plantation (< 10 years old), using baited pitfall traps, over two collection trips between September 2020 and April 2021. In total 20 traps were placed at each forest type.

Traps were deployed at intervals of at least 200 m to minimize trap interference. We placed traps for 72 h at each site during each collection trip. We checked the traps at 6:00 am and 6:00 pm every day, collecting the trapped dung beetles, but also releasing other animals (e.g., snakes, lizards, frogs, and spiders) that had accidentally fallen in the traps. The dung beetle collections were then pooled to obtain a single sample per trap for analysis. Each pitfall trap consisted of a plastic bucket, 22 cm in diameter and 16 cm depth, buried to its rim in the soil. Traps were filled with 70% ethanol, and baited with 300 g of a fresh pig-buffalo dung (1:1 vol. ratio) mixture (Bui et al., 2022).

Dung-beetle species 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 and Napolov (1999), and through comparison with the reference collections of Vietnamese dung beetles in Bui et al., (2020).

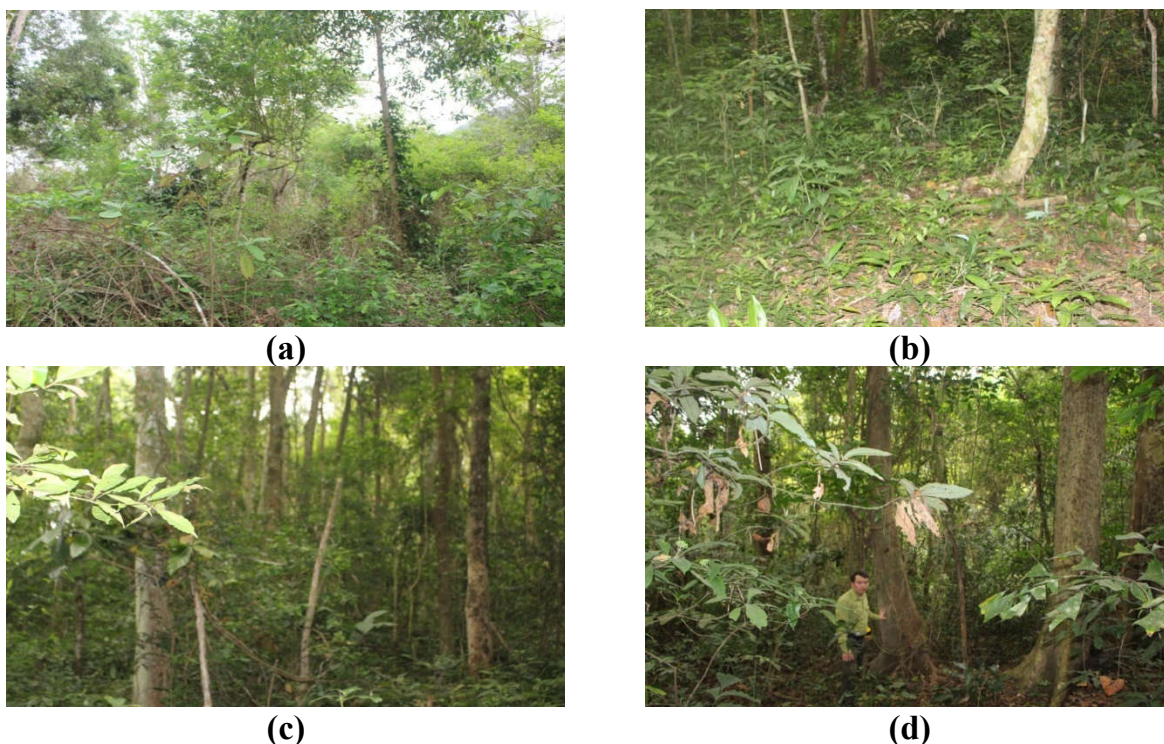


Figure 1. Trapping sites at the four examined forest types in Cat Ba National Park (*Acacia* plantation site (a), young secondary-forest site (b), old secondary-forest site (c), and primary-forest site (d))

2.2. Data analysis

Statistical analyses were carried out in R software v.3.5.1 (R Core Team 2018). An indicator value analysis (IndVal) was carried out, using the *indicspecies* package v. 1.7.6 (Caceres & Jansen 2016) in order to identify the characteristic species of specific forest types (Dufrene & Legendre 1997). This method combines measures of specificity and fidelity and provides an indicator value (IndVal) for each species, as a percentage, as follows (Dufrene & Legendre 1997):

$$\text{IndVal}_{ij} = A_{ij} \times B_{ij} \times 100$$

Specificity measure:

$$A_{ij} = N_{\text{individuals}_{ij}} / N_{\text{individuals}_i}$$

(where $N_{\text{individuals}_{ij}}$ is the mean number of species i across sites of group j , and $N_{\text{individuals}_i}$ is the sum of the mean numbers of individuals of species i over all groups;

Fidelity measure: $B_{ij} = N_{\text{sites}_{ij}} / N_{\text{sites}_j}$

(where $N_{\text{sites}_{ij}}$ is the number of sites in cluster (habitat) j where species i is present, and N_{sites_j} is the total number of sites in that cluster.

Each species has a percentage IndVal with an associated measure of significance, with high and significant percentages designating good indicator species. Those species with significant IndVals of greater than 70% were regarded as characteristic indicator species for the habitat. While detector species have IndVal values between 45 and 70%.

3. RESULTS AND DISCUSSIONS

3.1. Indicator and detector species

A total of 34 taxa of dung beetles were collected, with 30, 27, 21, and 18 species being found in primary forests, old secondary forests, young secondary forests and *Acacia* plantations, respectively, during the two dedicated surveys in 2021.

The dung beetles were distributed across 11 genera: *Onthophagus* Latreille, 1802 (20 taxa), *Copris* Geoffroy, 1762 (four species), *Aphodius* Illiger, 1798 (two species). Eight genera: *Synapsis* Bates, 1868, *Catharsius* Hope, 1837, *Eodrepanus* Barbero, Palestrini, and Roggero, 2009, *Paragymnopleurus* Shipp,

1897, *Sinodrepanus* Simonis, 1985, *Sisyphus* Latreille, 1807, *Liatongus* Reitter, 1892 and *Caccobius* Thomson, 1859, had one representative species each.

Of the 34 collected taxa, 26 taxa were identified to species level; eight taxa could not be named reliably to species but were assigned to the two genera *Onthophagus* and *Aphodius*. In the case of these genera, we assigned taxa to morphospecies. Although, such taxonomic classification does not affect our analyses, further taxonomic work, including in some cases generic revisions, would be required to name species with confidence.

The results of analysis of indicator species (Dufrene and Legendre, 1997) of dung-beetle characteristic of primary forests, old secondary forests, young secondary forests and *Acacia* plantations are showed in Table 1. Fifteen (15) species (44% of the total) with significant ($p < 0.05$) IndVal values were identified for each forest type: 10 indicator species with IndVal values higher than 70%, five detector species (IndVal value between 45 and 70%) and 19 species with IndVal values lower than 45%.

We used the IndVal values calculated according to Dufrene & Legendre (1997) to identify indicator species as those “characteristic” of a particular habitat (i.e. with high specificity and fidelity to the habitat and thus a high percentage IndVal). In total, 10 indicator species with IndVal values higher than 70% were recorded. *Onthophagus phanaeiformis*, *Sisyphus neglectus*, *Copris szechouanicus*, and *Onthophagus dorsofasciatus*, were identified as true specialists in old secondary forests. *Onthophagus* sp1. *Synapsis tridens* and *Onthophagus trituber* could be considered the indicator species of primary forests. *Caccobius unicornis* and *Onthophagus jeannelianus* were indicator species of young secondary forests; *Onthophagus luridipennis* was the indicator of *Acacia* plantations.

Table 1. Dung beetles species with significant values of IndVal ($p < 0.05$) sensitive to the habitat conditions and forest types in Cat Ba National Park. Species with IndVal values higher than 70% (in bold and with asterisk) were considered indicator species. Species with IndVal values between 45% and 70% (in bold and without asterisk) were considered detector species

Species	IndVal			
	PF	OSF	YSF	AP
<i>Aphodius</i> sp1.	47.2	31.4	12.1	8.3
<i>Aphodius mirificus</i> (Balthasar, 1932)	23.4	21.1	-	11.5
<i>Caccobius unicornis</i> (Fabricius, 1798)	0.85	1.21	77.4 (*)	18.2
<i>Catharsius molossus</i> (Linnaeus, 1758)	16.2	21.6	1.89	-
<i>Copris magicus</i> (Harold, 1881)	-	3.7	-	-
<i>Copris reflexus</i> (Fabricius, 1787)	16.7	15.9	-	1.01
<i>Copris sinicus</i> (Hope, 1842)	2.31	5.4	6.2	-
<i>Copris szechouanicus</i> (Balthasar, 1958)	19.2	83.3 (*)	20.2	13.4
<i>Eodrepanus striatulus</i> (Paulian, 1945)	50.6	20.4	7.8	6.6
<i>Liatongus gagatinus</i> (Hope, 1831)	1.3	1.3	2.4	-
<i>Onthophagus crassicollis</i> (Boucomont, 1913)	0.8	0.8	11.3	2.9
<i>Onthophagus deflexicollis</i> (Lansberge, 1883)	1.8	2.2	6.7	-
<i>Onthophagus dorsofasciatus</i> (Fairmaire, 1893)	45.2	80.1 (*)	41.6	20.5
<i>Onthophagus jeannelianus</i> (Paulian, 1945)	2.1	3.4	74.2 (*)	8.9
<i>Onthophagus luridipennis</i> (Boheman, 1858)	0.6	-	26.3	75.6 (*)
<i>Onthophagus orientalis</i> (Harold, 1868)	16.3	46.5	43.1	20.8
<i>Onthophagus papulatus</i> (Boucomont, 1914)	5.7	1.1	8.7	2.3
<i>Onthophagus phanaeiformis</i> (Boucomont, 1914)	4.6	78.3 (*)	-	-
<i>Onthophagus rectecornutus</i> (Lansberge, 1883)	11.4	6.8	5.5	4.1
<i>Onthophagus</i> sp 1.	90.9 (*)	-	-	-
<i>Onthophagus</i> sp2.	1.3	7.4	-	-
<i>Onthophagus</i> sp3.	-	-	-	3.8
<i>Onthophagus</i> sp4.	-	-	21.5	-
<i>Onthophagus</i> sp5.	2.2	1.3	-	-
<i>Onthophagus</i> sp6.	20.2	3.4	24.1	6.8
<i>Onthophagus</i> sp7.	10.1	8.5	29.5	14.6
<i>Onthophagus strandi</i> (Balthasar, 1935)	6.7	9.8	65.1	51.6
<i>Onthophagus sycophanta</i> (Fairmaire, 1887)	46.7	-	-	-
<i>Onthophagus tricornis</i> (Wiedemann, 1823)	92.7 (*)	32.4	-	-
<i>Onthophagus trituber</i> (Wiedemann, 1823)	43.2	-	-	-
<i>Paragymnopleurus brahminus</i> (Waterhouse, 1890)	23.2	17.3	8.9	1.2
<i>Sinodrepanus similis</i> (Simonis, 1985)	-	23.1	-	-
<i>Sisyphus neglectus</i> (Gory, 1833)	1.3	91.2 (*)	1.2	-
<i>Synapsis tridens</i> (Sharp, 1881)	89.6 (*)	-	-	-

Note: Primary forests (PF), old secondary forests (OSF), young secondary forests (YSF) and Acacia plantations (AP)

Dung beetle species characteristic of primary forests and old secondary forests were predicted to be indicative of a change in habitat state from intact forests to disturbed forests. Primary forests and old secondary forests are restricted and threatened habitat types that, under disturbance conditions in the area, are being replaced by anthropogenic habitats such as secondary forests and plantations forests. Differences in vegetation structure between the

forests habitats are thought to contribute most to the differences in dung beetle assemblages between them.

3.2. Annotated and illustrated checklist of indicator dung-beetle species in Cat Ba

The following list includes photographs of 10 indicator dung-beetle species identified during the dedicated dung-beetle surveys, together with their distribution in Vietnam and Cat Ba.

Onthophagus phanaeiformis

Vietnam records:

Ha Noi, Cao Bang, Hoa Binh, Thanh Hoa, Nghe An, Gia Lai, Kon Tum (Kabakov & Napolov, 1999; Bui et al., 2020; Bui Van Bac, 2020b; Bui Van Bac & Tran Thanh Lam, 2021).

Cat Ba NP records:

Recorded at primary forests and old secondary forests in April/May 2021.



(Scale bar: 1 mm)

Onthophagus dorsofasciatus

Vietnam records:

Lao Cai, Lang Son, Cao Bang, Tuyen Quang, Thanh Hoa, Nghe An (Kabakov & Napolov, 1999; Bui et al., 2020; Bui Van Bac, 2020b; Bui Van Bac & Tran Thanh Lam, 2021).

Cat Ba NP records:

Recorded at primary forests, old secondary forests, young secondary forests and *Acacia* plantations in April/May 2021.



(Scale bar: 1 mm)

Onthophagus trituber

Vietnam records:

Thai Nguyen, Tuyen Quang, Ha Giang, Vinh Phuc, Lao Cai, Cao Bang, Hoa Binh, Son La, Lai Chau, Thanh Hoa, Nghe An, Dong Nai (Kabakov & Napolov, 1999; Bui et al., 2020; Bui Van Bac, 2020a,b; Bui Van Bac & Tran Thanh Lam, 2021).

Cat Ba NP records:

Recorded at primary forests in April/May 2021



(Scale bar: 1 mm)

Onthophagus jeannelianus

Vietnam records:

Cao Bang (Bui Van Bac, 2020b).

Cat Ba NP records:

Recorded at primary forests, old secondary forests, young secondary forests and *Acacia* plantations in April/May 2021.



(Scale bar: 1 mm)

Onthophagus luridipennis

Vietnam records:

Ha Noi, Lang Son, Vinh Phuc, Cao Bang, Yen Bai, Ha Giang, Tuyen Quang, Thai Nguyen, Quang Ninh, Hai Phong, Hoa Binh, Son La, Lai Chau, Dien Bien, Thanh Hoa, Nghe An, Quang Binh, Quang Tri, Gia Lai, Kon Tum, Binh Thuan, Dong Nai, Binh Duong, Binh Phuoc (Kabakov & Napolov, 1999; Bui et al., 2020; Bui Van Bac, 2020a,b; Bui Van Bac & Tran Thanh Lam, 2021).

Cat Ba NP records:

Recorded at primary forests, young secondary forests and *Acacia* plantations in April/May 2021.



(Scale bar: 1 mm)

Onthophagus sp1.

Vietnam records: unknown

Cat Ba NP records:

Recorded at primary forests in April/May 2021.



(Scale bar: 1 mm)

Sisyphus neglectus

Vietnam records:

Ha Giang, Tuyen Quang, Nghe An (Kabakov & Napolov, 1999; Bui Van Bac & Tran Thanh Lam, 2021).

Cat Ba NP records:

Recorded at primary forests and old secondary forests in April/May 2021.



(Scale bar: 1 mm)

Copris szechouanicus

Vietnam records:

Thanh Hoa, Nghe An, Cao Bang (Kabakov & Napolov, 1999; Bui et al., 2018; Bui et al., 2020; Bui Van Bac, 2020b; Bui Van Bac & Tran Thanh Lam, 2021).

Cat Ba NP records:

Recorded at primary forests, old secondary forests, young secondary forests and *Acacia* plantations in April/May 2021.



(Scale bar: 1 mm)

Synapsis tridens

Vietnam records:

Lao Cai, Lai Chau, Cao Bang, Thanh Hoa, Nghe An (Kabakov & Napolov, 1999; Bui et al., 2018; Bui & Bonkowski, 2018; Bui et al., 2020; Bui Van Bac, 2020a,b; Bui Van Bac & Tran Thanh Lam, 2021).

Cat Ba NP records:

Recorded at primary forests in April/May 2021



(Scale bar: 1 mm)

Caccobius unicornis

Vietnam records:

Ha Noi, Lao Cai, Quang Ninh, Ha Giang, Thai Nguyen, Tuyen Quang, Thanh Hoa, Nghe An, Quang Binh, Quang Tri, Dong Nai, Phu Quoc (Kabakov & Napolov, 1999; Bui et al., 2020; Bui Van Bac & Tran Thanh Lam, 2021).

Cat Ba NP records:

Recorded at primary forests, old secondary forests, young secondary forests and *Acacia* plantations in April/May 2021.



(Scale bar: 1 mm)

4. CONCLUSION

We identified 10 dung-beetle species as potential indicator species of different forest types in Cat Ba National Park. We provided annotated and illustrated checklist of these indicator dung-beetle species. The checklist contains a detailed photographic guide, hence it may be broadly useful for both specialists and non-specialists in the identification of these indicator 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

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GIÁ TRỊ CHỈ THỊ SINH HỌC VÀ CÁC LOÀI BỌ HUNG ĐẶC TRƯNG TRONG RỪNG NHIỆT ĐỚI TẠI VƯỜN QUỐC GIA CÁT BÀ

Bùi Văn Bắc

Trường Đại học Lâm nghiệp

TÓM TẮT

Bọ hung ăn phân (Coleoptera: Scarabaeidae) được biết đến là nhóm sinh vật chỉ thị sinh học quan trọng cho sự thay đổi sinh cảnh. Tuy nhiên, cho đến nay giá trị chỉ thị sinh học của chúng tại các khu rừng nhiệt đới trên đảo ở Việt Nam còn ít được biết đến. Nghiên cứu đã tiến hành điều tra quần xã bọ hung theo các mức độ xáo trộn khác nhau của hệ sinh thái rừng tại Vườn Quốc gia (VQG) Cát Bà, Thành phố Hải Phòng: từ rừng nguyên sinh đến rừng thứ sinh lâu năm (rừng đã phục hồi trên 15 năm), rừng thứ sinh mới phục hồi (dưới 10 năm) và rừng trồng keo (dưới 10 năm). Mục đích chính của nghiên cứu là xác định được các loài bọ hung chỉ thị cho kiểu rừng chính tại khu vực. Dựa vào kết quả định lượng về giá trị chỉ thị (IndVal) của Dufrêne & Legendre (1997), 10 loài bọ hung đã được xác định là loài chỉ thị tiềm năng cho các kiểu rừng khác nhau ở VQG Cát Bà. Trong đó, bốn loài đặc trưng (chỉ thị) cho các khu rừng thứ sinh lâu năm, bao gồm *Onthophagus phanaeiformis* (Boucomont, 1914), *Sisyphus neglectus* (Gory, 1833), *Copris szechouanicus* (Balthasar, 1958) và *Onthophagus dorsofasciatus* (Fairmaire, 1893). Ba loài: *Onthophagus* sp.1., *Synopsis tridens* (Sharp, 1881) và *Onthophagus trituber* (Wiedemann, 1823) được coi là loài chỉ thị của rừng nguyên sinh. *Caccobius unicornis* (Fabricius, 1798) và *Onthophagus jeannelianus* (Paulian, 1945) là loài chỉ thị của rừng thứ sinh mới phục hồi; *Onthophagus luridipennis* (Boheman, 1858) là loài chỉ thị cho rừng trồng keo. Ngoài ra, nghiên cứu cung cấp thông tin về đặc điểm phân bố cùng với các bức ảnh đặc tả về các loài chỉ thị, qua đó giúp việc nhận dạng chúng dễ dàng, thuận lợi cho việc quan trắc và quản lý hệ sinh thái rừng nhiệt đới tại VQG Cát Bà.

Từ khóa: Bọ hung, loài chỉ thị, hệ sinh thái núi đá vôi, Vườn Quốc gia Cát Bà.

Received : 25/02/2022

Revised : 31/3/2022

Accepted : 12/4/2022