

## Population dynamics and conservation assessment of two recently described *Synopsis* beetles in tropical karst ecosystems of Northern Vietnam

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### Động thái quần thể và đánh giá bảo tồn hai loài bọ hung *Synopsis* mới được mô tả trong hệ sinh thái karst nhiệt đới ở miền Bắc Việt Nam

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#### ABSTRACT

The genus *Synopsis* Bates, 1868, comprises 24 species of large-bodied dung beetles, many of which are rare and highly specialised to the karst ecosystems of Southeast Asia. In Vietnam, seven *Synopsis* species have been documented, including the two recently described: *Synopsis puluongensis* Bui & Bonkowski, 2018, and *Synopsis horaki* Zidek & Pokorný, 2010. This study evaluated the population status, habitat preferences, and conservation needs of these two species across five karst ecosystems in Northern Vietnam from June 2023 to March 2024. Using baited pitfall traps and flight interception traps, we confirmed their rarity, highly specific habitat requirements, and dependence on undisturbed environments. Although *S. puluongensis* demonstrates a restricted range, small population size, and fewer than five known locations, the current study highlights insufficient data, particularly from other adjacent and similar ecosystems, to conclusively determine its status. As a result, it may be more appropriately assessed as Data Deficient (DD). Similarly, *S. horaki* was newly recorded in Phia Oac–Phia Den National Park, but its population remains poorly understood due to insufficient data and incomplete surveys. Habitat degradation caused by deforestation, limestone quarrying, and agricultural expansion poses significant threats to both species. Conservation efforts should prioritise protecting primary karst forests, expanding protected areas, restoring degraded habitats, and promoting sustainable land use practices. Further research into the ecological roles and distribution of *Synopsis* species is essential for their long-term conservation and the preservation of biodiversity in tropical karst ecosystems.

#### TÓM TẮT

Giống *Synopsis* Bates, 1868 gồm 24 loài bọ hung lớn, nhiều loài hiếm và thích nghi đặc biệt với hệ sinh thái núi đá vôi Đông Nam Á. Tại Việt Nam, ghi nhận bảy loài, trong đó có hai loài được mô tả mới gần đây: *Synopsis puluongensis* Bui & Bonkowski, 2018 và *Synopsis horaki* Zidek & Pokorný, 2010. Nghiên cứu từ 6/2023 đến 3/2024 tại năm hệ sinh thái núi đá vôi miền Bắc đã đánh giá tình trạng quần thể, sinh cảnh và yêu cầu bảo tồn của hai loài này, sử dụng bẫy hố mồi nhử và bẫy chặn bay. Loài *S. puluongensis* có phạm vi phân bố hẹp, quần thể nhỏ và chỉ hiện diện tại dưới năm địa điểm khảo sát, nhưng dữ liệu chưa đủ để xác định tình trạng bảo tồn, xếp loại Thiếu Dữ Liệu (DD). Loài *S. horaki* được ghi nhận mới tại Vườn Quốc gia Phia Oắc–Phia Đén, song dữ liệu còn hạn chế. Phá rừng, khai thác đá vôi và mở rộng nông nghiệp là các mối đe dọa chính đối với cả hai loài. Do đó, cần ưu tiên bảo vệ rừng nguyên sinh, mở rộng khu bảo tồn, phục hồi sinh cảnh suy thoái và thúc đẩy quản lý đất bền vững. Các nghiên cứu sâu hơn về vai trò sinh thái và phân bố loài là cần thiết để bảo tồn lâu dài và duy trì đa dạng sinh học trong hệ sinh thái núi đá vôi.

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## 1. INTRODUCTION

The genus *Synapsis*, consisting of 24 large-bodied dung beetle species, is crucial to tropical forest ecosystems due to its significant role in nutrient cycling and secondary seed dispersal [1]. By burying dung, *Synapsis* beetles not only improve soil nutrient availability but also mitigate parasite loads that adversely affect vertebrate populations. These activities indirectly promote forest regeneration by facilitating the dispersal and germination of seeds from digested fruits [2]. The ecological significance of these processes highlights the role of large-bodied dung beetles, such as *Synapsis* species, as critical bioindicators of ecosystem health, forest integrity, and functional biodiversity [3].

Karst ecosystems, which are extensively distributed in Northern Vietnam, are characterised by rugged limestone formations, unique hydrological patterns, and shallow, nutrient-poor soil profiles. These ecosystems have developed over millions of years, resulting in a mosaic of microhabitats that support a high degree of endemism and specialised ecological interactions among flora and fauna [4]. Species inhabiting karst environments are often highly adapted to resource-scarce conditions, making them particularly sensitive to environmental perturbations. However, the intrinsic fragility of these ecosystems, combined with their slow rates of soil formation and vegetation recovery, renders them highly susceptible to anthropogenic disturbances. Activities such as limestone quarrying for construction materials, deforestation, and agricultural expansion have caused severe habitat loss and fragmentation, jeopardising the survival of species that depend on these fragile environments [5].

Despite their ecological importance and biodiversity value, karst ecosystems are significantly underrepresented in conservation frameworks within Southeast Asia. This lack of recognition in conservation planning is particularly alarming given the accelerating pace of habitat degradation, which highlights

the necessity for targeted research to inform effective conservation strategies and management practices.

The *Synapsis* beetles of Southeast Asia, including Vietnam, have historically received limited research attention. Of the seven *Synapsis* species documented in Vietnam, several are associated with karst environments and exhibit notable variation in abundance and habitat preferences [1]. The recent discoveries of *Synapsis puluongensis* in the Pu Luong Nature Reserve and *Synapsis horaki* in Phia Oac – Phia Den National Park have highlighted the ecological vulnerabilities of karst-restricted *Synapsis* species [1, 6]. As representatives of the specialised and often endemic fauna of karst ecosystems, these species exemplify the intricate dependencies between biodiversity and habitat integrity in limestone landscapes.

The survival of *Synapsis* beetles is intrinsically linked to the availability of large mammal dung, their primary resource for reproduction and sustenance. Consequently, the pressures exerted on large mammal populations, including hunting and habitat encroachment, indirectly threaten *Synapsis* populations by reducing the availability of this critical resource. These compounded threats underscore the interconnectedness of karst ecosystems and the urgent need to address the broader drivers of biodiversity loss.

Although prior research has underscored the ecological roles of *Synapsis* beetles, significant knowledge gaps remain regarding their population dynamics, habitat preferences, and conservation needs, particularly in the context of karst ecosystems. Most existing studies have focused on their roles in broader forest ecosystems, without adequately addressing the specific dependencies and challenges of karst-adapted species [7]. Furthermore, limited data exist on the influence of environmental factors, such as forest cover, anthropogenic disturbance, and dung availability, on their distribution and abundance. This lack of understanding hampers the formulation of conservation

strategies tailored to the unique ecological requirements of karst-dependent species.

To address these gaps, the present study investigates the population dynamics, distribution, and conservation status of *Synapsis puluongensis* and *Synapsis horaki* within the karst landscapes of northern Vietnam. Specifically, this research aims to: (1) assess population densities and spatial patterns of *Synapsis* species across karst and non-karst sites, clarifying their habitat preferences and levels of specialisation; (2) evaluate the conservation status of *Synapsis* species, with an emphasis on rare and newly described taxa, using IUCN Red List criteria; and (3) identify key ecological drivers influencing the abundance and distribution of *Synapsis* beetles, including forest cover, large mammal presence, and anthropogenic disturbance. By bridging these critical knowledge gaps, this study seeks to provide a foundation for developing targeted conservation strategies that align with the ecological dependencies and vulnerabilities of *Synapsis* beetles in karst ecosystems.

## **2. RESEARCH METHODS**

### **2.1. Study areas**

Fieldwork was conducted across six spatially separated areas in Northern Vietnam, with five of these areas selected to encompass a range of tropical karst habitats. Tropical karsts are an exceptionally unique and important landscape element in Southeast Asia, covering an area of approximately 400,000 km<sup>2</sup>. Limestone karst systems are also a prominent landscape feature in Vietnam, spanning a total area of 60,000 km<sup>2</sup>, primarily in Northern and central regions. The five distinct karst ecosystems selected for sampling included Cat Ba National Park (NP), Phia Oac–Phia Den NP, Huu Lien Nature Reserve (NR), Ngoc Son–Ngo Luong NR, and Pu Luong NR. Phia Oac–Phia Den NP and Huu Lien NR contain tropical karst ecosystems representing a significant portion of the karst landscape in the Northeast Red River region, while Pu Luong and Ngoc Son–Ngo Luong NRs host characteristic karst ecosystems of the

Southwest Red River region. The karst ecosystems of Phia Oac–Phia Den NP, Pu Luong NR, and Ngoc Son–Ngo Luong NR span an elevation range of 800–2,000 m above sea level (a.s.l.), while the karst ecosystems of Huu Lien NR are located at elevations ranging from 200–400 m a.s.l. Cat Ba NP contains island karst ecosystems, while the other research locations are situated on the mainland of Vietnam. All study areas are influenced by a tropical monsoon climate, with average annual rainfall ranging from 1,500 to 1,700 mm and average annual temperatures of 20°C–22°C.

The non-karst ecosystem selected for investigating *Synapsis* species was the Dong Chau–Khe Nuoc Trong Nature Reserve (17.9832° N, 106.3763° E). Located in Quang Binh province, Dong Chau–Khe Nuoc Trong NR consists of primary and secondary forests with relatively high biodiversity. Although it is less impacted than other reserves, the region remains vulnerable to illegal logging and encroachment from nearby agricultural fields, with major forested areas limited to elevations above 200 m.

### **2.2. Dung beetle sampling**

To examine *Synapsis* communities, we conducted structured sampling across two defined localities (core and buffer) within each of the six study areas from 2022 to 2024. Sampling took place during peak beetle activity periods in summer (June–August) and spring (March–May), ensuring comprehensive seasonal data collection.

Five 2×2 km sampling squares were systematically established within each locality to cover a variety of habitats. In each locality, we deployed 100 baited pitfall traps at regular intervals of at least 100 m, capturing a representative sample of *Synapsis* species. Pitfall traps, each consisting of a plastic container (22 cm diameter, 16 cm depth), were filled with 70% ethanol to preserve specimens. A mixture of fresh pig and buffalo dung was used as bait to attract *Synapsis* beetles, given their preference for large mammalian dung as a food source. To prevent incidental capture of

small mammals, each pitfall trap was covered with a 25 × 25 cm metal mesh (2 × 2 cm openings), allowing *Synapsis* beetles access while excluding larger organisms. Traps were checked daily during the trapping period, with all captured dung beetles collected and any non-target species promptly released.

In addition to pitfall traps, five flight interception traps were set up within each locality to record flying *Synapsis* individuals. These traps consisted of a plastic sheet (1.5 m in height) stretched between two trees, positioned 1 m above ground level. Trays filled with 70% ethanol were positioned below each sheet to capture beetles colliding with the barrier. Flight interception traps were checked twice daily (morning and late afternoon), with *Synapsis* species recorded and any non-target species released.

### 2.3. Dung-beetle identification and IUCN Red List assessment

*Synapsis* species were identified using the identification keys provided by Bui & Bonkowski (2018) [1] and through comparison with the reference collection of Vietnamese dung beetles in Bui et al. (2020) [8].

The conservation status of each *Synapsis* species was assessed following IUCN Red List criteria, focusing on key metrics: Area of Occupancy (AOO), population size and number of mature individuals, and habitat quality and associated threats. AOO was calculated as the total area within each study site where *Synapsis* species were recorded, using a spatial resolution of 4 km<sup>2</sup> grid cells [9]. Population size and the number of mature individuals were estimated based on individual species counts derived from pitfall and flight trap data, with extrapolations applied based on observed densities and habitat extent. Habitat quality and threats, including the presence of large mammals and anthropogenic pressures such as quarrying and logging, were assessed based on canopy cover, disturbance level, and evidence of human activities.

The population trend assessment for the

two *Synapsis* species is based on a comparison of population density between the current investigation and the findings of Bui & Bonkowski (2018). This analysis examines any observed reductions in population size or habitat extent over the past five years.

## 3. RESULTS

### 3.1 Species observations and distribution patterns of *Synapsis* species in karst ecosystems

From 2022 to 2024, surveys across five karst ecosystems and one non-karst ecosystem in northern and central Vietnam recorded the presence of two recently described *Synapsis* species: *Synapsis puluongensis* and *S. horaki*. Both species were found to be rare and highly dependent on karst habitats, with their distributions limited to specific limestone formations. Detailed analyses of their spatial patterns, population densities, and habitat preferences highlight their vulnerability to habitat disturbance, underscoring the need for targeted conservation efforts.

#### a. *Synapsis puluongensis*

Initially described in 2018 within Pu Luong Nature Reserve, *S. puluongensis* was scarce, with only six (6) individuals observed at its discovery site (20°28'54"N, 105°14'31"E; 20°28'55"N, 105°14'29"E; 20°28'54"N, 105°14'29"E; and 20°28'56"N, 105°14'28"E) [1]. Our follow-up surveys revealed an expanded range, recording 53 individuals at 29 sites, including 18 new sites in Ngoc Son – Ngo Luong Nature Reserve. Only two (2) individuals were observed at the original site, reflecting a substantial population decline of nearly 70% for this species in its known habitat. Similarly, the newly recorded sites revealed very low numbers, with most locations averaging just 1–2 individuals, indicating a limited population density within suitable habitats.

Habitat preferences and environmental correlates: The species predominantly occupied regions with over 80% canopy cover and proximity to water sources, typically within 200 m. The preference for dense, moist

environments indicates vulnerability to habitat disturbance, including deforestation and reduced canopy cover, which could

impact the microclimatic conditions required by *S. puluongensis*.

**Table 1. Coordinates of recorded sites of *Synopsis puluongensis***

Sites	Latitude	Longitude	Locations	Comments
1	20.48167	105.2419	Puluong Nature Reserve	Original site
2	20.48194	105.2414	Puluong Nature Reserve	Original site
3	20.48167	105.2414	Puluong Nature Reserve	Original site
4	20.48222	105.2411	Puluong Nature Reserve	Original site
5	20.47089	105.2407	Puluong Nature Reserve	New site
6	20.4737	105.2367	Puluong Nature Reserve	New site
7	20.46429	105.2509	Puluong Nature Reserve	New site
8	20.48072	105.2187	Puluong Nature Reserve	New site
9	20.49006	105.2059	Puluong Nature Reserve	New site
10	20.49963	105.1917	Puluong Nature Reserve	New site
11	20.46401	105.2496	Puluong Nature Reserve	New site
12	20.47778	105.2544	Ngoc Son – Ngo Luong Nature Reserve	New site
13	20.47191	105.2513	Ngoc Son – Ngo Luong Nature Reserve	New site
14	20.48408	105.2448	Ngoc Son – Ngo Luong Nature Reserve	New site
15	20.47346	105.2497	Ngoc Son – Ngo Luong Nature Reserve	New site
16	20.45979	105.2675	Ngoc Son – Ngo Luong Nature Reserve	New site
17	20.45721	105.2656	Ngoc Son – Ngo Luong Nature Reserve	New site
18	20.4696	105.2546	Ngoc Son – Ngo Luong Nature Reserve	New site
19	20.48362	105.2478	Ngoc Son – Ngo Luong Nature Reserve	New site
20	20.45306	105.2698	Ngoc Son – Ngo Luong Nature Reserve	New site
21	20.45714	105.2835	Ngoc Son – Ngo Luong Nature Reserve	New site
22	20.47625	105.2476	Ngoc Son – Ngo Luong Nature Reserve	New site
23	20.45612	105.2814	Ngoc Son – Ngo Luong Nature Reserve	New site
24	20.45191	105.2673	Ngoc Son – Ngo Luong Nature Reserve	New site
25	20.45032	105.3019	Ngoc Son – Ngo Luong Nature Reserve	New site
26	20.45126	105.2817	Ngoc Son – Ngo Luong Nature Reserve	New site
27	20.43501	105.3137	Ngoc Son – Ngo Luong Nature Reserve	New site
28	20.42907	105.3292	Ngoc Son – Ngo Luong Nature Reserve	New site
29	20.43719	105.3341	Ngoc Son – Ngo Luong Nature Reserve	New site

**b. *Synopsis horaki***

Previously, this species was known solely from the holotype specimen collected in Tam Dao National Park (Vinh Phuc province). Our survey has revealed a limited population, with only four individuals recorded in Phia Oac – Phia Den National Park (coordinates: 22°34'3.6"N, 105°53'3.3"E; 22°34'1.4"N, 105°53'3.3"E; 22°34'3.1"N, 105°53'4.7"E; 22°34'3.1"N, 105°53'4.4"E). The precise coordinates of these sightings indicate a narrow distribution, highlighting the urgent

need for ongoing monitoring and targeted conservation efforts. The discovery of this species in Phia Oac – Phia Den National Park extends its known range, but the small population size within karst ecosystems underscores its potential vulnerability. To accurately assess the conservation status of this species, it is essential to expand surveys to additional locations, particularly by resurveying the original ecosystems in Tam Dao National Park and its surrounding areas.

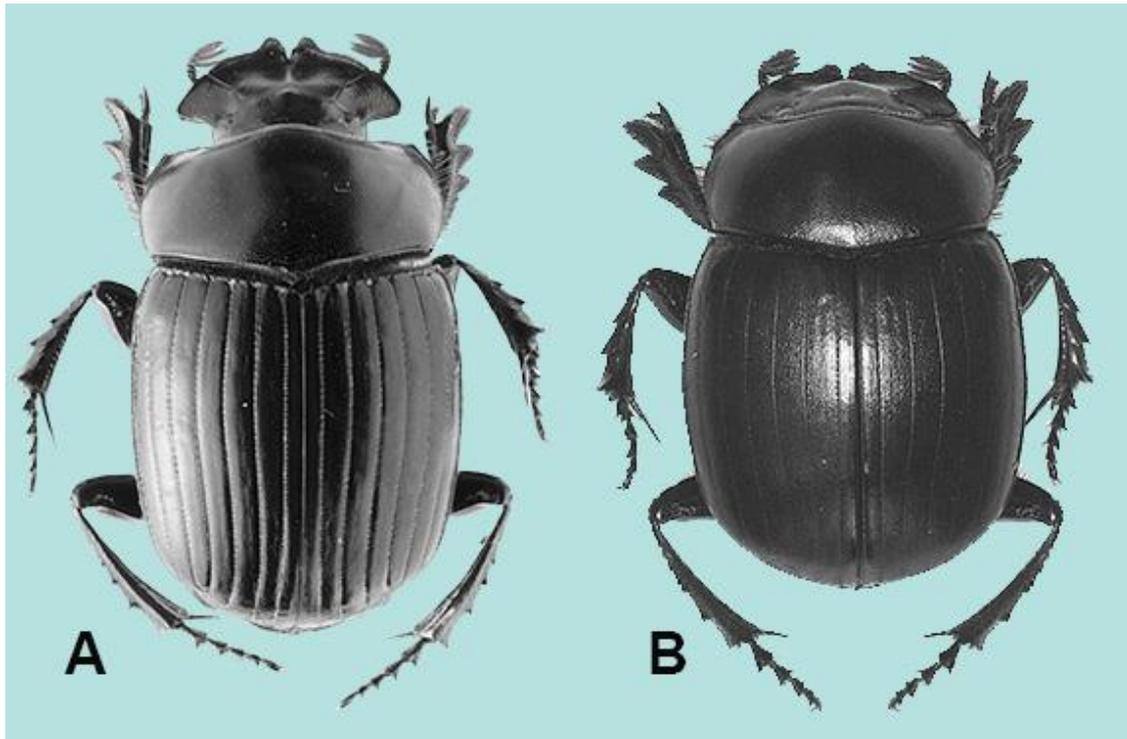


Figure 1. Habitus of *Synapsis puluongensis* (A) and *Synapsis horaki* (B)

### 3.2. Conservation assessment of *Synapsis* species in Vietnam's tropical karst ecosystems

To evaluate the conservation status of *Synapsis* species recorded during the study, we employed the IUCN Red List criteria, focusing on critical parameters such as area of

occupancy (AOO), population density, and key threats across diverse habitats. The findings highlighted the precarious status of these species, particularly those reliant on undisturbed karst habitats (Figure 2, Table 2).

Table 2. Summary of primary criteria used to evaluate if a *Synapsis* species belongs in a threatened category

Species	Examined Areas	Number of locations recorded	Population size	Population reduction	IUCN Classification
<i>Synapsis puluongensis</i>	240 km <sup>2</sup>	<5	53	< 70%	Data Deficient (DD)
<i>S. horaki</i>	NA	<5	NA	NA	Data Deficient (DD)

## 4. DISCUSSION

### *Habitat dependence and key threats*

Our surveys across multiple karst ecosystems revealed that *Synapsis* species are highly dependent on the availability of undisturbed habitats and the presence of large-bodied mammals for dung resources. These mammals, such as Delacour's langur, Cao-vit gibbon, and Tonkin snub-nosed monkey, are critically endangered, with their populations declining due to habitat destruction from limestone quarrying,

deforestation, and slash-and-burn agriculture [10-12]. The reliance of *Synapsis* beetles on these mammals makes them especially vulnerable to ecosystem changes, as degraded forests often lack the ecological components necessary for their survival.

### *Population Assessment of Synapsis puluongensis*

Initially described in Pu Luong Nature Reserve in 2018, *Synapsis puluongensis* was found to have a restricted distribution and low population density [1]. Follow-up surveys

expanded its known range to Ngoc Son – Ngo Luong Nature Reserve, recording 53 individuals across 29 sites. Despite this, the population size remains critically low, with densities averaging 1–2 individuals per site. Furthermore, the species is highly dependent on specific habitats, favoring areas with dense canopy cover (>80%) and proximity to water sources (<200 m).

While these findings suggest the species could meet the criteria for Endangered (EN) under the IUCN Red List, the limited survey

scope (~240 km<sup>2</sup> of six reserves) and insufficient evidence for trends in population decline prevent a definitive assessment. Given these gaps, *Synapsis puluongensis* should be classified as Data Deficient (DD) until further research expands knowledge of its distribution, Extent of Occurrence (EOO), population trends, and threats. This classification aligns with the precautionary principle and highlights the need for additional data to accurately evaluate its conservation status.

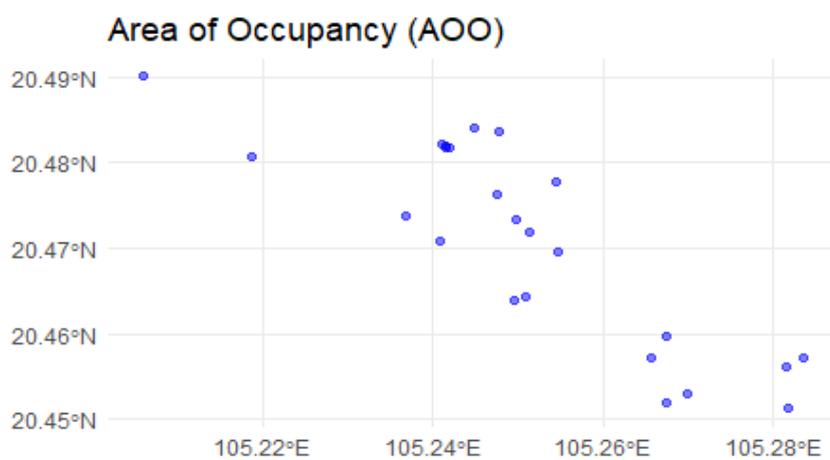


Figure 2. Area of occupancy (AOO) of *Synapsis puluongensis*

**Population assessment of *Synapsis horaki***

The dung beetle *Synapsis horaki* was historically known only from a single holotype specimen collected in Tam Dao National Park, Vietnam [6]. During our study, the species was newly recorded in Phia Oac–Phia Den National Park, where four individuals were observed. This marks a significant range extension and suggests that the species may inhabit multiple locations in northern Vietnam. However, the small population size recorded highlights its rarity and possible ecological vulnerability, particularly in light of its association with karst ecosystems.

To refine our understanding of *S. horaki*'s distribution, we conducted targeted surveys in four additional tropical karst ecosystems: Cat Ba National Park, Huu Lien Nature Reserve, Ngoc Son–Ngo Luong Nature Reserve, and Pu Luong Nature Reserve. Despite extensive sampling efforts, no individuals of *S. horaki*

were detected in these areas. This absence raises important questions about the species' habitat preferences and distribution limits. Given the lack of evidence supporting its confinement to karst environments, we propose expanding surveys to include non-karst areas surrounding Tam Dao National Park. These regions may provide additional suitable habitats that have yet to be investigated.

The species' current classification as Data Deficient (DD) under IUCN Red List criteria reflects the paucity of data on its population trends, distribution, and habitat requirements. To address this gap, further surveys are urgently needed, particularly in the original ecosystems of Tam Dao National Park and adjacent non-karst landscapes. Such efforts will not only clarify its conservation status but also provide valuable insights into its ecological adaptability and potential resilience in the face

of habitat change.

The absence of *S. horaki* in multiple surveyed karst ecosystems, coupled with its detection in only one additional location, underscores the importance of habitat protection and targeted conservation measures. The species' apparent rarity makes it particularly vulnerable to habitat degradation, deforestation, and other anthropogenic pressures. Conservation strategies should prioritise the protection of forested landscapes, both within and outside karst ecosystems, and incorporate long-term monitoring programs to track population trends and habitat integrity.

In conclusion, the discovery of *S. horaki* in Phia Oac–Phia Den National Park represents an important step in understanding the distribution of this poorly known species. However, much remains unknown about its ecology and conservation needs. Expanding surveys to non-karst areas and integrating habitat protection initiatives will be critical to ensuring the survival of this rare dung beetle and preserving the ecological functions it supports.

#### **Conservation recommendations**

The conservation of *Synapsis* species requires a comprehensive approach that addresses habitat protection, community engagement, regular monitoring, and further research. One of the most critical actions is the preservation of primary forests, both in karst and non-karst ecosystems. These undisturbed habitats provide the stability necessary for *Synapsis* species to thrive. Preventing deforestation and mitigating habitat degradation through stronger enforcement against illegal logging and agricultural encroachment are essential steps to safeguard these vital ecosystems.

Equally important is the involvement of local communities in conservation efforts. Collaborating with communities living near key habitats can reduce harmful practices such as slash-and-burn agriculture and the overexploitation of dung beetles, which often

unintentionally harm *Synapsis* populations. Educational campaigns highlighting the ecological importance of these beetles can help foster a sense of shared responsibility for their protection and promote sustainable land-use practices.

Regular monitoring of *Synapsis* populations is indispensable for understanding their population trends and habitat conditions. Establishing systematic surveys, particularly for species classified as Endangered (EN) or Data Deficient (DD) will provide critical data for conservation planning. Monitoring efforts should focus on species such as *S. puluogensis* and *S. horaki*, whose small population sizes and restricted distributions make them particularly vulnerable. Additionally, habitat restoration initiatives, such as reforestation and the rehabilitation of secondary forests, are necessary to expand the range of suitable environments for these beetles. The creation of new protected areas and the expansion of existing ones in regions identified as potential habitats will further strengthen conservation efforts.

Further research is also vital to understanding the ecological roles, habitat preferences, and dispersal capacities of *Synapsis* species. Studies exploring their dependency on specific ecosystems, genetic diversity, and potential resilience to environmental changes can provide valuable insights for targeted conservation strategies. Research into their interactions with other species and their contributions to ecosystem functions, such as nutrient cycling, will enhance our ability to design effective management plans.

By implementing these measures, we can ensure the survival of *Synapsis* species and protect the ecological integrity of tropical forest ecosystems. A collaborative effort involving researchers, conservationists, policymakers, and local communities is essential to achieving these goals and preserving biodiversity for future generations.

#### **5. CONCLUSION**

This study underscores the urgent need for conservation efforts to protect *Synapsis*

beetles, which are highly dependent on undisturbed tropical forest habitats. *Synapsis puluongensis*, with its restricted distribution, low population density, and reliance on specific habitats, has been provisionally classified as Data Deficient (DD) due to insufficient data on its full Extent of Occurrence (EOO), Area of Occupancy (AOO), population trends, and threats. Similarly, *Synapsis horaki* remains classified as Data Deficient (DD) pending further surveys to clarify its status. The reliance of *Synapsis* species on intact primary forests highlights the critical importance of preserving these ecosystems. Immediate actions, including habitat protection, long-term monitoring, and expanded surveys, are essential to ensure the survival of these rare and ecologically significant beetle species.

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