Institute of Biodiversity and Environmental Conservation

The Distribution and Ecology of Land Snails (Mollusca: Gastropoda) in Limestone Habitats of Western Sarawak

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Species inventories and ecological studies are fundamental tools for assessing the conservation of limestone-associated species such as land snails. Unfortunately, previous inventories of land snail species in the Bau-Serian limestone area lack a systematic checklist with corresponding illustrations for each species. This study aims to investigate the species composition of land snails in the Bau limestone hill clusters in Sarawak, to measure the estimated species richness and sampling effectiveness between live-caught snails and empty snail shells, and finally to investigate the relationships between land snail species and microhabitats. To fill this knowledge gap, systematic and random sampling for land snails were carried out at eight limestone outcrops. All specimens were sorted, identified to species level, and catalogued. Sampling effectiveness between live snails and empty snail shells was determined using cluster-scale completeness ratios for 135 plots. Species completeness analyses were conducted to extrapolate species richness and inventory for different spatial scales. Cluster analyses were conducted to determine the relationship between the species community and assemblages based on the presence, absence, and abundance data of 17 live-caught land snail species. Associations between land snail species and microhabitats sampled were described using the bipartite weighted network. A total of 122 land snail species, of which 18 are new to science, from 58 genera and 24 families, with photographs of each species. The inventory revealed high completeness of sampling for both empty shells and live-taken snails (> 90%) but species diversity is very low for live snails compared to empty snail shells at hill and cluster scales suggesting that some species may have expired locally. Cluster analysis showed that the land snails assemblages do not correspond to different microhabitats, but rather to locality. The limestone area in Bau has a very high degree of endemism due to the low dispersal ability of the land snails. The soil sample appears to have very high species richness, but the species composition contains species from different niches and microhabitats. As the limestone hills in Sarawak are threatened by various habitat degradation activities, further inventories are needed to assess the species richness of land snails in limestone hill clusters to identify and conserve high-priority areas for snail conservation in Sarawak.

Keywords: Limestone forest, land snail, inventory, sampling effectiveness, ecology

Taburan dan Ekologi Siput Darat (Mollusca: Gastropoda) dalam Habitat Batu Kapur di Barat Sarawak

ABSTRAK

Inventori spesies dan kajian ekologi adalah alat asas untuk menilai pemuliharaan spesies yang berkaitan dengan batu kapur seperti siput darat. Malangnya, inventori sebelumnya spesies siput darat di kawasan batu kapur Bau-Serian tidak mempunyai senarai semak yang sistematik dengan ilustrasi yang sepadan untuk setiap spesies. Kajian ini bertujuan untuk menyiasat komposisi spesies siput darat di gugusan bukit batu kapur Bau di Sarawak, untuk mengukur anggaran kekayaan spesies dan keberkesanan pensampelan antara siput yang ditangkap hidup dan cengkerang kosong, dan akhirnya untuk menyiasat hubungan antara spesies siput darat dan mikrohabitat. Bagi mengisi jurang pengetahuan ini, persampelan sistematik dan rawak bagi siput darat telah dijalankan di lapan singkapan batu kapur. Semua spesimen telah diisih, dikenal pasti kepada peringkat spesies dan dikatalogkan. Keberkesanan pensampelan antara siput hidup dan cengkerang kosong ditentukan menggunakan nisbah kesempurnaan skala kelompok untuk 135 petak. Analisis kesempurnaan spesies telah dijalankan untuk mengekstrapolasi kekayaan spesies dan inventori untuk skala spatial yang berbeza. Analisis kluster telah dijalankan untuk menentukan hubungan antara komuniti spesies dan himpunan berdasarkan data kehadiran, ketiadaan dan kelimpahan 17 spesies siput darat yang hidup. Hubungan antara spesies siput darat dan mikrohabitat diterangkan menggunakan rangkaian berwajaran dwipartit. Sebanyak 122 spesies siput darat direkod, di mana 18 adalah spesies baharu, daripada 58 genera dan 24 keluarga, dengan gambar bagi setiap spesies. Inventori menunjukkan kesempurnaan pensampelan yang tinggi untuk kedua-dua cengkerang kosong dan siput hidup (>90%) tetapi kepelbagaian spesies adalah sangat rendah untuk siput hidup *berbanding dengan cangkerang kosong di skala bukit dan kluster yang menunjukkan bahawa sesetengah spesies mungkin telah pupus di kawasan tersebut. Analisis kluster menunjukkan bahawa himpunan siput darat tidak sepadan dengan mikrohabitat yang berbeza, tetapi lebih kepada lokaliti. Kawasan batu kapur di Bau mempunyai tahap endemisme yang sangat tinggi kerana keupayaan penyebaran siput darat yang rendah. Sampel tanah kelihatan mempunyai kekayaan spesies yang sangat tinggi, tetapi komposisi siput mengandungi spesies daripada relung dan mikrohabitat yang berbeza. Memandangkan bukit batu kapur di Sarawak diancam oleh pelbagai aktiviti degradasi habitat, inventori selanjutnya diperlukan untuk menilai kekayaan spesies siput darat dalam gugusan bukit batu kapur untuk mengenal pasti dan memulihara kawasan keutamaan tinggi untuk pemuliharaan siput di Sarawak.*

Kata kunci: *Hutan batu kapur, siput darat, inventori, keberkesanan pensampelan, ekologi*

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LIST OF ABBREVIATIONS

*	Land snail specimens in ME Collection not collected in the present survey
C1	Bau Limestone Hill Clusters
C1H1	part of mykarst-336 Gunung Doya (= Bukit Sokwang)
C1H2	mykarst-329 Gunung Kapor
C1H3	mykarst-333 Gunung Lobang Angin
CGS	Centre for Graduate Studies
IBEC	Institute of Biodiversity and Environmental Conservation
ITBC	Institute for Tropical Biology and Conservation
ME	Mohammad Effendi Private Collection
MZU	Zoological Museum of Universiti Malaysia Sarawak
S1	Site 1
S2	Site 2
S3	Site 3
UMS	Universiti Malaysia Sabah
UNIMAS	Universiti Malaysia Sarawak

CHAPTER 1

INTRODUCTION

1.1 Study Background

Borneo is recognized as one of the world's biodiversity hotspots (Myers et al., 2000). A diverse number species of flora and fauna are found in various types of Malaysian forests, which comprise lowland forests, montane forests, and mangrove forests. In addition to these commonly known forest types, there are also small areas of swamp forest, heath forest, and forest on limestone. Although the total area for several hundreds of limestone hills in Borneo represents less than 0.1% of the land of Peninsular Malaysia (Liew et al., 2021a), the forest on limestone hills supports a significant portion of biodiversity.

The ecological and evolutionary processes that govern the biodiversity patterns and richness of these fragmented, isolated, and majority small patches of limestone forests are similar to the process that acts on oceanic islands' biodiversity. These limestone hills constitute Carbon Carbonate ($CaCO_3$) and thus the forest on or around the hills grows on alkali soil (high pH). This patchy alkali forest is surrounded by forest that grows on more acidic soils (low pH). The surrounding acidic forest acts as an effective barrier for organism dispersal, especially for some plants and snails because many of these organisms are adapted specifically to live in high-pH limestone forests (Berry, 1963; Vermeulen & Whitten, 1998).

Hence, limestone forest resembles islands, harbouring a large number of endemic species, each with unique evolutionary history in this isolated limestone forest (Schilthuizen, 2004; Clements et al., 2006). This biodiversity importance of limestone forests is often overlooked because of the general impression that it has often had very thin and patchy forest cover due to the thin soil and has no charismatic vertebrate fauna. The biodiversity of the majority of the limestone hills is still under exploration. To illustrate this, a search in the literature reveals that 22 out of 66 new animal species (33%) that were described in the year 2014 from Peninsular Malaysia were collected from limestone forests (Bursey et al., 2014a; 2014b; Dang et al., 2014; Grismer et al., 2014a; 2014b; 2014c; 2014d; 2014e; 2014f; 2014g; Jaloszynski, 2014; Liew et al., 2014; Matzui et al., 2014; Mutafchiev et al., 2014; Ng & Schubart, 2014; Ng et al., 2014; Ochi & Kon, 2014; Onn et al., 2014a; 2014b; 2014c; Schawaller, 2014; Siriboon et al., 2014; Sutcharit et al., 2014; Tanasevitch, 2014; Takaoka et al., 2014a; 2014b; 2014c; Takeuchi, 2014; Turillazzi et al., 2014; Vermeulen & Marzuki, 2014; Victoria & Lin, 2014; Ya'cob et al., 2014; Yoshizawa et al., 2015).

Bornean limestone forests are under threat of degradation of the surrounding forest and irreversible destruction due to quarrying activities (Vermeulen, 1994; Schilthuizen et al., 2005). *Plectostoma scaphilum* (van Benthem-Jutting, 1952), a Diplommatinid snail from Bukit Panching, Kuantan, Pahang has been declared extinct due to habitat destruction (Liew et al., 2014; Liew, 2015). In Borneo, there are at least two karst-dependent species that were probably extinct due to habitat destruction (Vermeulen, 1994; Schilthuizen, 2004). Hence, it is important to protect these hills that support these high-endemic species. However, it is not feasible to protect all limestone hills of Borneo. Thus, certain criteria need to be applied to prioritize the conservation and protection of some of those important limestone forests.

The most conventional criteria in prioritization of conservation areas are to protect the areas with high biodiversity and a high number of endemic species. Although now always been explained explicitly, the high biodiversity and endemic species reflected the unique and rich evolutionary history of the area. Each of the several hundred limestone hills in Borneo has different physical and geographical characteristics in terms of the degree of isolation, size, and geological history (Hutchison, 2005; Hall, 1998; 2009). Understanding the community ecology and biological evolutionary history of these limestone hills/clusters could help us to prioritize the conservation efforts to protect these small, neglected, and vulnerable limestone hills that have high biodiversity values.

However, it is not possible to study all different taxa groups of organisms to obtain a picture of the evolutionary history of limestone hills. Because of these, calcicole organisms that obligate to limestone hills are a promising surrogate species for other taxa to understand the general biological evolutionary history of limestone hills. In this case, the land snail is known to be a suitable model to understand the role of history and selection in the origins of biodiversity (Davison, 2002).

1.2 Problem Statement

Inventory and ecological studies are crucial for the conservation of limestone-associated species such as land snails to maintain the biodiversity balance in the limestone forest. Species inventories were reported by Vermeulen and Junau (2007) in the Bau-Serian limestone range yielding 148 species. However, these reports lack a systematic checklist with proper illustrations for every species in addition to the provisional species identities in previous reports cannot be used to compare with recently collected specimens.

The land snails in the tropical forest were formerly claimed to be neither abundant nor diverse compared to the temperate forest (Solem, 1984). His statement about the abundance and diversity of the land snails in tropical forests is not completely wrong since the abundance and diversity of land snails in the tropical forests are concentrated only in limestone forests and high altitude forests. The possible reasons behind his claim due to lack