

# Exploring the predation of large land snails using preyed shell remains from rock anvil sites in a tropical limestone rainforest in Malaysia

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## Abstract

The study of prey-predator interactions between land snails and birds offers important insights into evolutionary and ecological relationships. Here we report a case study of rock anvils presumably used by the birds *Myophonus caeruleus* and *Enicurus ruficapillus* in a cave cavity of a limestone hill in Malaysia. The preyed shell remains of four land snails namely, *Hemiplecta* sp., *Cyclophorus perdix perdix*, *Amphidromus atricallosus perakensis* and *Cyclophorus semisulcatus*, were found around rock anvils in the nine plots. Finally, we discussed the potential and limitations of using shell remains of preyed land snails for behavioural, ecological, and evolutionary studies between land snails and their predators.

## Keywords

Karst, Cyclophoridae, Camaenidae, Ariophantidae, Muscicapidae

## Introduction

Land snails play a significant role in the terrestrial ecosystem as an important food source for many organisms, including birds and mammals (<xref class="hide" type="bibr" rid="7805053" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805071" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805466" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805398" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805198" data-deleted="false">Cited item deleted!</xref>). However, very little is known about these ecological interactions in tropical terrestrial ecosystems of Southeast Asia, as there are very few systematic in-situ studies on land snail predation in the region, and almost none for macro land snails of shell sizes larger than 10 mm (<xref class="hide" type="bibr" rid="7805062" data-deleted="false">Cited item deleted!</xref>)

type="bibr" rid="7805325" data-deleted="false">Cited item deleted!</xref>). Elsewhere, only a few in-situ studies of tropical land snail predation by vertebrates have been undertaken (<xref class="hide" type="bibr" rid="7805244" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805557" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805280" data-deleted="false">Cited item deleted!</xref>). There are a few reasons why these field studies are rare for macro land snails in tropical terrestrial ecosystems in Southeast Asia. First, the density of large sized land snails in tropical rainforests is generally low, except in forests on calcareous habitats such as limestone karst ecosystems (<xref class="hide" type="bibr" rid="7805475" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805308" data-deleted="false">Cited item deleted!</xref>). Second, the shelled remains of the preyed snails could only persist for a very short time in the acidic conditions of non-limestone forests compared to limestone forests (<xref class="hide" type="bibr" rid="7805439" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805457" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805421" data-deleted="false">Cited item deleted!</xref>). Thirdly, direct observation or field experiment on the interaction of land snails and their predators is difficult given the structural complexity of forest stands and herbaceous vegetation and the diversity of predators in tropical regions, apart from chance observations (e.g., <xref class="hide" type="bibr" rid="7805225" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805334" data-deleted="false">Cited item deleted!</xref>).

Interactions between land snails and birds offer important insights into evolutionary and ecological relationships (<xref class="hide" type="bibr" rid="7805595" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805587" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805566" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805161" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805170" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805353" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805216" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805380" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805039" data-deleted="false">Cited item deleted!</xref>). Birds are the best known and commonly observed shell-breaking predators of land snails. Selective predation by birds is one of the main mechanisms responsible for variation in shell polymorphism (<xref class="hide" type="bibr" rid="7805280" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805466" data-deleted="false">Cited item deleted!</xref>). They remove, break or crush the shells with their hard parts, such as teeth or claws and beaks (<xref class="hide" type="bibr" rid="7805430" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805466" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805604" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805280" data-deleted="false">Cited item deleted!<xref class="hide" type="bibr" rid="7805235" data-deleted="false">Cited item deleted!</xref>).

Although birds can swallow smaller land snails along with their tissue and shell, when eating larger snail tissue, birds must carry the snail to the nearest solid object such as rocks, empty bottles or stumps of felled trees to break its shell (<xref class="hide" type="bibr" rid="7805412" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805152" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805448" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805466" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805613" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805493" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805557" data-deleted="false">Cited item deleted!</xref> <xref class="hide" type="bibr" rid="7805298" data-deleted="false">Cited item deleted!</xref>). However, none of these observations come from a tropical region. Therefore, rock anvils in limestone habitats are an ideal natural laboratory for studying large land snails and specific predators, especially birds, due to the high number of living snail populations, good preservation of preyed shells and availability of rock anvils in the open cave next to the forest ().

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## **Ethics and security**

The surveys were conducted with the permission of the Forestry Department, Pahang, Malaysia (PHN.PHG.(PEM)118/146 BHG.10(S3); PHDK 80/1/23 Jld.11(42); JH/100 Jld. 22(4)).

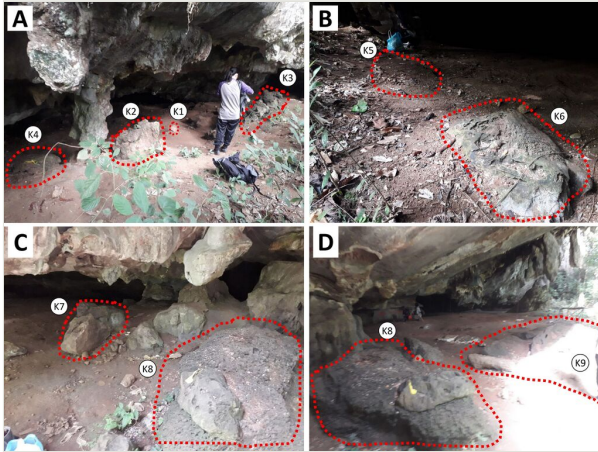


Figure 1.

Sampling plots in Phg 77 Bukit Mengapur, Pahang, Malaysia (3°44'47.0" N, 102°50'17.9" E). (A) Plots K1, K2, K3 and K4; (b) Plots K5 and K6; (C) Plots K7 and K8; (D) Plots K8 and K9

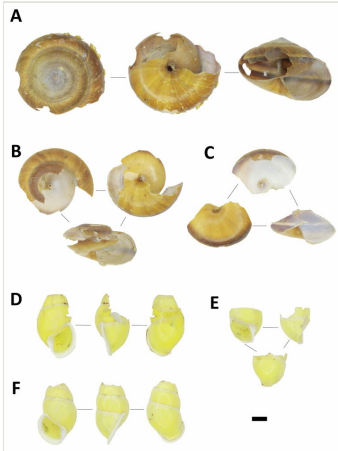


Figure 2.

Shells damaged by predators, collected from rock anvils. (A)-(C) *Hemiplecta* sp. (Ariophantidae), BORMOL 14979; (D)-(F) *Amphidromus atricallosus perakensis* (Camaenidae), BORMOL 14996. Scale = 1 cm.

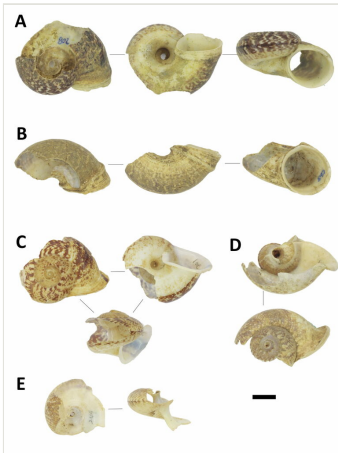


Figure 3.

Shells damaged by predators, collected from rock anvils. (A)-(B) *Cyclophorus semisulcatus* (Cyclophoridae), BORMOL 14807; (C)-(E) *Cyclophorus perdix perdix* (Cyclophoridae), BORMOL 14978. Scale = 1 cm.

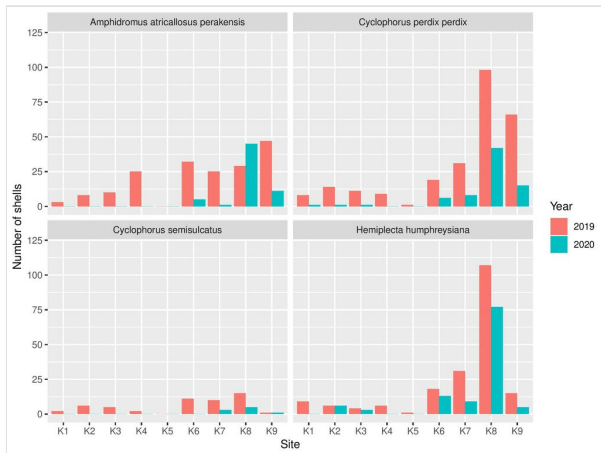


Figure 4.

Two bird species were recorded with the camera traps set up on plots 7, 8 and 9 in Phg 77 Bukit Mengapur, Pahang, Malaysia (3°44'47.0" N, 102°50'17.9" E). (A) Blue-whistling Thrush, *Myophonus caeruleus*, recorded with the camera trap on 04/03/2020 at 6.22 pm; (B) Red Chestnut-naped forktail, *Enicurus ruficapillus*, recorded with the camera trap on 06/03/2020 at 8.16 am.

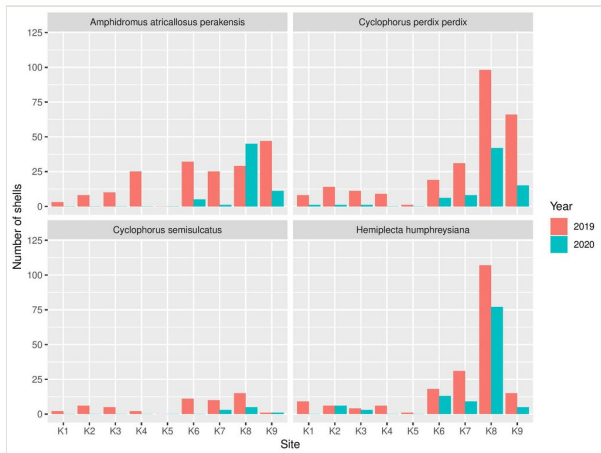


Figure 5.

The number of shells of the four land snail species collected from the nine plots of rock anvils in Phg 77 Bukit Mengapur, Pahang, in 2019 and 2020 (3°44'47.0" N, 102°50'17.9" E). The shells collected in 2019 were accumulated at the plots before the first sampling on 13/01/2019, while the shells collected in 2020 represent the shells brought to the plots by predators between 13/01/2019 and 07/03/2020.