LAND SNAIL CONSERVATION IN BORNEO: LIMESTONE OUTCROPS ACT AS ARKS

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Despite earlier speculations, it now appears that land snail diversity in tropical rainforests is very high. Conservation of these malacofaunas is extremely urgent, because of high extinction rates in these sessile, desiccation-intolerant organisms. In Borneo, conservationists might pay special attention to limestone outcrops. Although these contain far fewer endemics than previously thought, they do act as high-density reservoirs for the regional snail fauna. Targeting relatively undisturbed limestone hills for each region within the island may be an efficient approach for snail conservation.

Key Words: Mollusca Borneo endemism diversity abundance

INTRODUCTION

The humid Tropics are generally considered to have the highest biological diversity in the world. Latitudinal gradients that peak in the Tropics have been recorded in many different taxonomic groups with few exceptions (Rosenzweig 1995). Therefore, it was surprising that land snails should not follow this pattern, as has been tentatively suggested by Solem (1984). Solem argued that the lack of available nutrients, negligible litter, and an abundance of predators, make the tropical rainforest an unfavourable habitat for snails. Instead, he claimed that temperate, stable, moderately moist, and litter-rich forests are the places where land snail diversity reaches its pinnacle. Since then, however, it has been shown that snail diversities in rainforests in tropical Africa (de Winter & Gittenberger 1998; Tattersfield 1996) and Borneo (Schilthuizen & Rutjes, 2001) are in fact among the highest in the world, albeit it at relatively low population densities.

In Borneo, about half of the land snail fauna is composed of small and minute micro-snails with shell diameters of less than 5 mm. Many of these are herbivores and litter-dwelling detritivores, with (in contrast to the African situation) very few carnivores present. The remainder are large-bodied species, including the brightly coloured tree-dwelling snails of the genus *Amphidromus*. Other prominent representatives are the enormous *Bertia brookei*, which reaches a diameter of almost 10 cm, and slugs and semi-slugs of the family Ariophantidae, the charmingly coloured and decorated members of which are mostly found at higher elevations. In terms of biomass, snails probably do not contribute much to the forest ecosystem, but preliminary studies (Schilthuizen, unpublished data) indicate that they might be very suitable to serve as indicator species for forest disturbance, partly because they are easily and exhaustively sampled, with even the most cryptic (e.g., canopy-dwelling) species ending up as empty shells in soil samples.

Borneo is one of the few areas in Southeast-Asia where large tracts of rainforest still exist. This third-largest island in the world is shared by three countries, i.e., Brunei, Malaysia (the states of Sabah and Sarawak), and Indonesia (Kalimantan, the southern two-thirds of the island). Much of the lowland dipterocarp rainforest in Borneo is under severe pressure from various threats, including logging and conversion to plantation forest, and forecasts predict that, under a business-as-usual scenario, Kalimantan (where conservation prospects are especially dire) will have lost all its lowland forest by the year 2010 (Holmes 2000; Jepson *et al.* 2001). Their low tolerance for desiccation, high

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degrees of short-range endemicity and low vagility make that land snails will be severely hit by these losses of habitat. The land snail fauna of the island is probably between 1,000 and 2,000 species and the majority of these are endemic to Borneo. For example, the percentages of Borneo-endemics in the families Hydrocenidae, Diplommatinidae, and Streptaxidae are 94%, 96%, and 93%, respectively (Vermeulen, pers. comm.). The global extinction of a large number of species may thus be feared.

THE RELEVANCE OF LIMESTONE

Although land snails are generally diverse but rare in rainforest on the acidic soils that dominate the island of Borneo, high abundances may be found where forest grows on limestone. This is due to the fact that land snails have high calcium requirements for growth and reproduction (Graveland *et al.* 1994) and thus may reach high population densities on calcareous substrates. Limestone outcrops in many places throughout the island, as it does in many other parts of Southeast-Asia (Figure 1). Sabah and Sarawak (straddling the northwestern one-third of the island of Borneo) hold at least 230 and 70 separate hills, respectively (Wilford 1964; Lim & Kiew 1997; Schilthuizen & Vermeulen unpubl. data). Many of these hills are widely scattered, because they represent single, isolated limestone deposits. Since the late 19th century, Malaysian limestone hills have attracted malacological interest. De Morgan (1885) writes (in Tweedie's [1961] translation), 'these formations are very favourable to the development of molluscs, for I found everywhere where the limestone outcropped a great quantity of shells.' Tweedie himself draws attention to the fact that soil and debris collected from the base of a limestone cliff 'will almost always reveal abundant empty molluscan shells.' These observations have given rise to the idea that limestone hills, although occupying only one percent or so of the land surface, play a major role in supporting snail abundance and diversity (Tweedie 1961). Vermeulen & Whitten (1999) estimate that a patch of limestone habitat will support two to five times more species than a similar patch of non-limestone habitat, and that the number of shells found there is 10-1000 times as high (Figure 2).

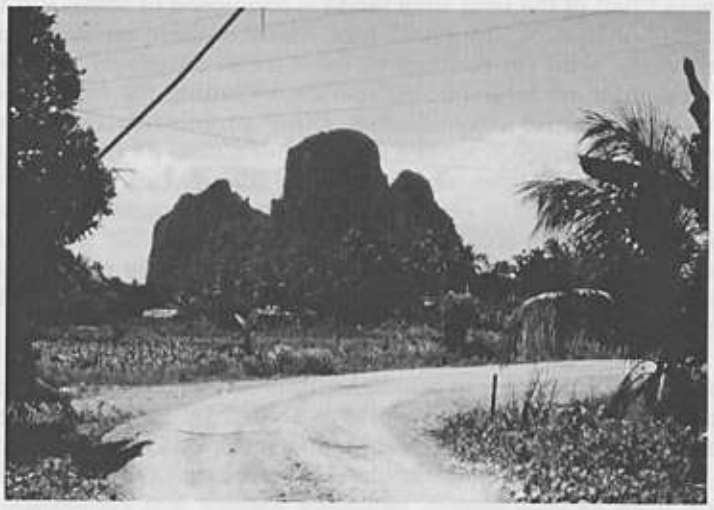

Figure 1 Gua Cheras, near Kuantan, Peninsular Malaysia. Strongly weathered limestone outcrops like these can be found in abundance in Borneo.

Figure 2 Soil samples from limestone hills yield large numbers of shells from sometimes more than 100 species. This is a fraction of the result of soil sampling in Gua Pungiton, Sabah, Malaysian Borneo.

Besides higher diversity and abundance of land snails, endemism has also been claimed as a feature of limestone. Tweedie (1961) and Vermeulen & Whitten (1999) report that certain land snail taxa, e.g., the families Streptaxidae, Hydrocenidae and Diplommatinidae are all obligate calcicoles, that is, they occur only on limestone. Virtually all Bornean records from these families derive from limestone hills, and many species have been recorded from a single locality only, suggesting high degrees of short-range endemism. For example, Vermeulen & Whitten (1999) state that at least six species from these families are endemic to Gunung Sarang, a small (0.2 square kilometre) limestone hill in Sarawak, whereas Gunung Subis, also in Sarawak, contains no less than 50 such endemics on its 15 square kilometres. As a consequence, cases of extinction have also been reported. The limestone hills on the offshore island of Labuan, for example, were removed for the construction of an airstrip, and *Opisthostoma otostoma* Boettger, 1893 and *O. decrespignyi* (H. Adams, 1865), which occurred only there, are presumed lost (Vermeulen 1994).

A REEVALUATION OF LIMESTONE

Given the high degrees of diversity, abundance, and endemism in their malacofauna, it appears that limestone hills are land snail hotspots and should have a high priority in conservation in Borneo. However, new data indicate that their role in supporting Borneo's malacofauna must be reevaluated. A recent study in Sabah suggests that the differences in snail population density on limestone are not that large after all (Schilthuizen *et al.* 2002a). Plots were demarcated on limestone hills and on neighbouring non-limestone substratum, and a standardised sampling of the malacofauna was carried out. The data showed that population densities on the limestone are between two and ten times as high as on non-limestone. The perceived higher diversities on limestone were also not as clear as previously suspected. Randomisations showed that total predicted diversity on limestone was just 14% higher.

Endemism on limestone hills may also not be as pronounced as previously thought. Because collecting there is efficient, malacological studies in Borneo had until recently always concentrated on limestone hills. With the exception of a few well-visited sites, such as Mount Kinabalu, limestone areas were the source for almost all knowledge on the malacofauna of Borneo. However, over the past ten years, several malacologists have begun sorting soil samples from other areas. As a result, more and more species, previously regarded as restricted to limestone, have been found elsewhere. Vermeulen (1996) reports finding *Diplommatina whiteheadi* E.A. Smith, 1898 in the Crocker Range. Subsequently, almost 100 five-litre samples of soil from non-limestone areas in several regions of Sabah yielded specimens of *Georissa saulae* van Benthem Jutting, 1966; *G. gomantongensis* E.A. Smith, 1893; *Diplommatina centralis* Vermeulen, 1993; *D. soror* Vermeulen, 1993; *D. sykesi* Fulton, 1901; *D. whiteheadi* E.A. Smith, 1898; *D. electa* Fulton, 1905; *D. rubicunda* (Von Martens, 1864); *D. cyrtorhitis* Vermeulen, 1993; *D. isseli* Godwin Austen, 1889; *D. strongyla* Vermeulen, 1993; *Opisthostoma* (s. str.) *brachyacrum lambii* (Vermeulen, 1991); *Arinia stenotrochus* Vermeulen, 1996; *A. turgida* Vermeulen, 1996; *A. brevispira orientalis* Vermeulen, 1996 and *A. paricostata* Vermeulen 1996 (Schilthuizen & Rutjes 2001; Schilthuizen *et al.* 2002a,b; Schilthuizen, unpublished data). All these species had previously only been recorded from limestone and/or were considered obligate calcicoles.

Nevertheless, one important group of land snails has until now never been found anywhere else but on limestone. This is the subgenus *Opisthostoma* (*Plectostoma*), with 44 Bornean species (Vermeulen 1994). The subgenus exhibits a staggering diversity in shell shape, including various kinds of aperture orientations, radial ribs, apertural decorations and teeth (Figure 3). Endemism is high and on a single limestone hill usually just one or two species are found sympatrically. They are, however, extremely common, occurring in large numbers on the limestone rock faces, where they indubitably form the major component of the snail fauna. Away from limestone, however, not a single individual has ever been found. Schilthuizen *et al.* (2002a) found 472 individuals of *Opisthostoma* (*Plectostoma*) *lissopleuron* Vermeulen, 1994 in six standard plots on limestone, and zero in five plots on adjoining sandstone, sometimes less than 200 m away

Figure 3 Opisthostoma perspectivum Vermeulen, 1994 endemic to Batu Punggul in Sabah, Malaysian Borneo. Drawing by J.J. Vermeulen.

from the nearest limestone. Not surprisingly, it is this subgenus that exhibits the highest degree of endemism, with most species restricted to either a single hill, or a few hills in each other's close proximity. So, obligate calcicoly, whereas not true for the majority of taxa previously thus considered, does apply to this particular (and peculiar) subgenus.

CONCLUSIONS

The terrestrial malacofauna of Borneo presumably amounts to roughly 1,500 species. Most of these live in lowland rainforest, which supports, contrary to earlier speculations, a very rich snail diversity. With almost all of Borneo's lowland dipterocarp rainforests threatened with imminent disappearance, the mollusks' fate should be feared for, since most species are not expected to survive under the hot and dry conditions succeeding forest conversion.

The novel insights into the role of limestone outcrops in supporting malacofauna allow for a more focused approach to designing management plans for land snails in Borneo. Conserving limestone hills should focus less of the endemic species occurring there, and more on their role as "arks". Limestone outcrops may contain certain endemic species of *Opisthostoma* (*Plectostoma*), but more importantly, they may contain large populations of the other snail species living in the area. A relatively small limestone hill spared from the forest degradation that affects its surroundings, may thus serve as a reservoir for the local snail fauna, from which the degraded forests may be restocked during future ecosystem reassembly.

In principle, limestone hills in Borneo are good candidates for conservation. Due to their rugged surface they are unsuitable for logging and plantation operations. Also, the fact that they often have caves from which swiftlet nests are harvested, has helped in their protection. Several limestone hills survive in relatively good condition in areas that have otherwise been completely converted to, for example, oil palm plantation.

Given the strong regional differentiation in snail fauna, mollusk conservation efforts could be aimed towards preserving a few large, good-quality limestone hills in each region. For example, a fairly uniform snail fauna (the "Lahad Datu - Segama fauna"; Schilthuizen & Vermeulen 2002) can be found in an area within a roughly 50 km radius around the town of Lahad Datu in eastern Sabah. This area has been severely affected by oil palm plantation. Many limestone outcrops in this area are small and oil palm has been planted right up to the foot of them. This has led to desiccation, fire, and strong degradation of the vegetation on these hills, with presumed concomitant depauperation of the malacofauna. However, a large (3 square kilometre) limestone hill in the Tabin Wildlife Reserve is still in good condition, surrounded by a large area of moderately logged forest. And although this outcrop contains no species endemic to it, it supports good populations of most of the characteristic snail species of the Lahad Datu - Segama fauna. Therefore, conservation of the regional snail fauna may be accomplished by highlighting the relevance of this particular outcrop (Schilthuizen & Vermeulen 2002).

For Sabah, sufficient data may already be available for delineating regional faunas and highlighting suitable limestone outcrops. For other parts of the island, especially Kalimantan, more data need to be gathered before such an approach may be adopted.

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