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Front cover: A living jewel, Malcolm's pit viper (*Trimeresurus* (*Parias*) *malcolmi*) is a large and rare pit viper found only on Mount Kinabalu. Photo: Tom Charlton.

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The Sabah Society is a non-governmental organisation founded in 1960 by a group of enthusiasts anxious to record and preserve interesting and important aspects of the history, culture and natural history which might be lost in the increasing surge forward towards modernisation and independence. The objectives they set out remain the same today and are:

i. To stimulate a wider interest in, and knowledge of, the history, natural history and geography of Sabah and the cultures and customs of its people, and
ii. To encourage and assist the recording of knowledge of the history, natural history and geography of Sabah and the preservation of examples of the cultures and customs of its people.

These objectives give the Society a wide base which can accommodate the specific interest of anyone who wishes to share or improve their knowledge of Sabah.

To fulfil our objectives, the Society uses four main activities:

1. Meetings are held at which experts, both local and visiting, are invited to speak on topics relevant to Sabah, or the study of disciplines applicable in Sabah and surrounding areas.
2. Expeditions are organised to places of historical, cultural or of natural history interest, usually over weekends.
3. A journal is published, usually once a year, containing articles written on topics relevant to the objectives.
4. Monographs and books are published as suitable materials and funds become available.

All paying members get a free copy of the Journal as its annual publication depends in part on members' subscriptions. Anyone may submit articles for publication in the Journal, as long as they are relevant to the objectives of The Sabah Society.

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In Search of Sabah's Serpents — Herping the Highlands and Lowlands of Mount Kinabalu

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Borneo; the third largest island in the world and an eco-tourist's paradise, drawing huge numbers of visitors every year in search of wildlife and adventure. Here large areas of primary rainforests, containing some of the highest levels of biodiversity levels in the world, are home to Borneo's most iconic fauna including the pygmy elephant, orang-utan and clouded leopard. However, it was the lure of Borneo's less inviting creatures — its reptiles — that first caught my attention on this beautiful island, and in particular its huge array of snakes.

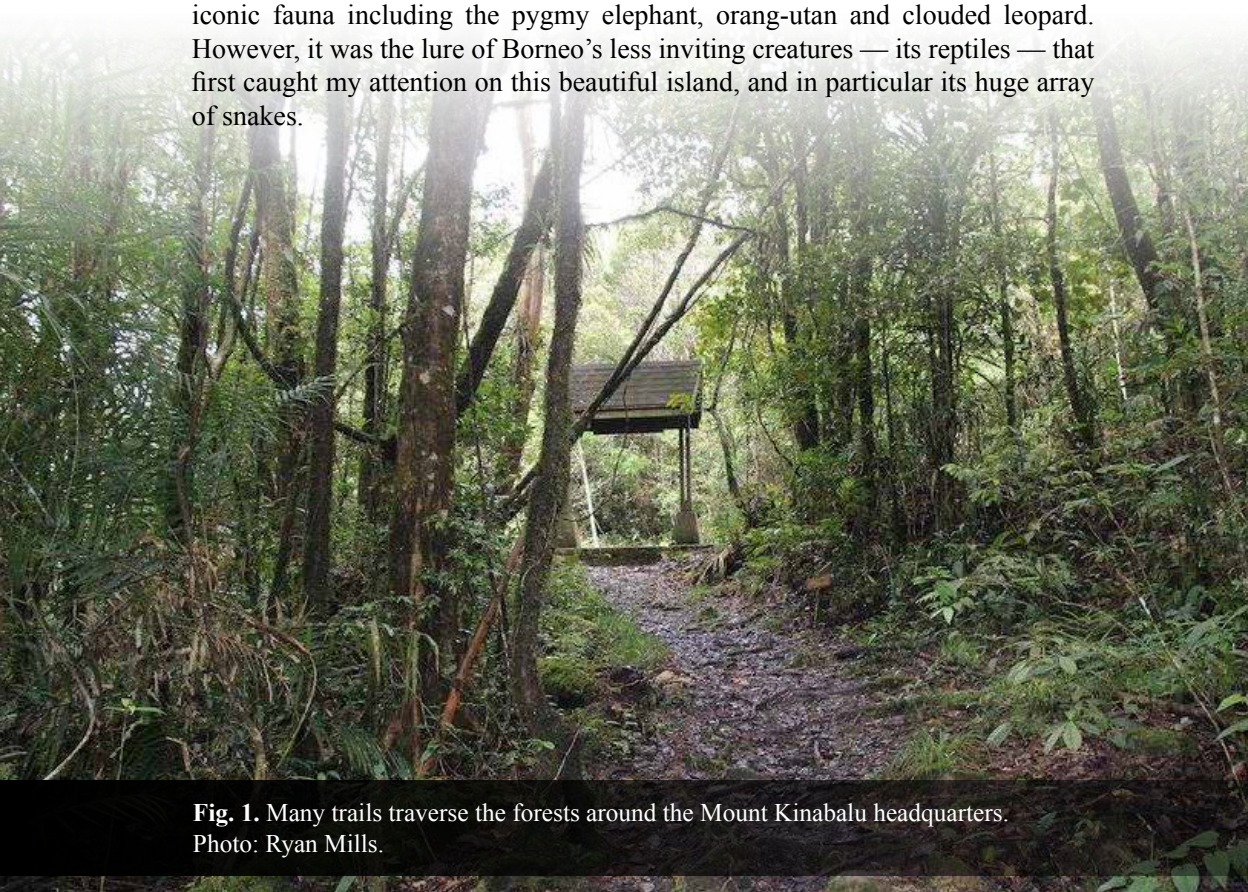

Fig. 1. Many trails traverse the forests around the Mount Kinabalu headquarters. Photo: Ryan Mills.

I made my first visit out to Borneo in April 2004, and since then have returned several times for the purpose of finding and photographing its reptiles and amphibians; a task known as 'herping'. My latest trip was made in December 2016. This would only last for a period of nine days of which we would spend the majority of our time around Mount Kinabalu, and two wildlife photographers and good friends of mine from the UK, Ryan Mills and Tom Williams, would be joining me.

Despite being home to a large number of snake species, Borneo is a difficult place to herp in comparison to elsewhere within southeast Asia, and here diversity definitely does equal density. Long days and nights of searching can often be a fruitless task. For this reason, careful planning before the start of the trip was essential, researching and familiarising ourselves with the habits and habitats of the snakes that we wanted to photograph on the trip. This time around our target species were to be the Malcolm's pit viper (*Trimeresurus* (*Parias*) *malcolmi*), the Kinabalu krait (*Bungarus flaviceps baluensis*), and the Sumatran pit viper (*Trimeresurus* (*Parias*) *sumatranus*). Three rare and elusive species, two of which are endemics to the island of Borneo.

Ryan, Tom and myself met a Heathrow airport early on 5 December, and our small team made the 12-hour flight from London to Kuala Lumpur, and from there took

Fig. 2. Close-up of head of Malcolm's pit viper (*Trimeresurus* (*Parias*) *malcolmi*). Photo: Tom Charlton.

a short flight over to Sabah. After arriving in Kota Kinabalu around midday on 6 December, we collected our hire car and made the three-hour journey up to the first location of our trip, the headquarters of Mount Kinabalu, where we were to spend two nights. Mount Kinabalu is home to amazing fauna and flora, including the world's largest pitcher plant (*Nepenthes rajah*), and some species calling this mountain home can be found nowhere else on earth. The mountain has the highest peak of Borneo, with its summit reaching 4095 metres above sea level, with the National Park headquarters itself sitting at around 1565 metres asl. This high elevation makes for a difficult environment for cold-blooded reptiles to exist, and many species occur in much lower population densities in comparison to reptiles of the warmer lowland forests. For this reason, we knew we were going to have to put plenty of time and effort into our searching if we were to find the species we wanted to photograph. Despite the beautiful weather of Kota Kinabalu, as we neared the park HQ the clouds appeared and light rain began to fall.

We decided to stay just outside the National Park at the Panataran guesthouse, which offered convenient, comfortable accommodation and served good food. After checking-in, we paid for our entrance tickets into the National Park, grabbed some dinner and then prepared ourselves with wet-weather gear ready to head out in search of snakes shortly after dark. Light rain quickly turned into a downpour as we walked up the road leading to the Timpohon gates, scanning the road-side vegetation with our torches for snakes.

The first snake of the trip was found around one hour into our first night walk. A tiny Schmidt's reed snake (*Calamaria schmidti*) was slowly making its way along the tarmac on the verge of the road. Although diminutive in size, these are very attractive little snakes, covered in black glossy scales that glow an oily iridescence under torchlight. They spend much of the daytime hidden under fallen leaf litter and other forest floor debris, emerging at night to feed on earthworms. One of the smallest snakes occurring on the island of Borneo, we were happy with our first find and hoping that things would only get bigger from here on in! After walking in the rain for four and half hours, tired from our travels over the previous day, we decided to call it a night and headed back to our beds for some much-needed rest.

We spent the following daytime walking some of the light trails close to the headquarters. Snakes are difficult enough to spot at night, and even more so during the day when many species remain stationary and camouflaged. We took it easy during our daytime hikes, wanting to reserve our efforts for the evening when our main target species for this particular area, the Malcolm's pit viper, would most likely be active.

Again the rain came shortly before dark as we prepared to head out on our second night of trekking. This time we left the road early on, walking on the Pandanus trail; a steep, muddy track that proved difficult to ascend in the wet conditions. As we walked up to the start of the trail another reed snake was spotted, this time

Fig. 3. Mount Kinabalu, the focal point of the renowned Kinabalu Park in northern Borneo. Photo: Antony van der Ent.

Fig. 4 A living jewel, Malcolm's pit viper (*Trimeresurus* (*Parias*) *malcolmi*) is a large and rare pit viper found only on Mount Kinabalu. Photo: Tom Charlton.

Fig. 5 (above). Mossy frog (*Philautus macroscelis*). **Fig. 6** (below). Kinabalu slender toad (*Ansonia hanitschi*). Photo: Tom Charlton.

Fig. 7. First snake of the trip — the diminutive Schmidt's reed snake (*Calamaria schmidti*). Photo: Tom Charlton.

a Griswold's reed snake (*Calamaria griswoldi*). Usually displaying bright yellow stripes along the dorsal, this particular specimen was a drab brown colour, but still a great snake to find and photograph. We slowly made our way along the trail for almost three hours, finding numerous dragon lizards, geckos, frogs and some truly spectacular invertebrates, but no snakes to reward our efforts. Once we had reached the end of the trail and got back on the road at 11pm, Ryan decided to head down to the guesthouse whilst Tom and I opted to walk for another hour, carrying on up the Timpohon road. As the rain continued to fall without signs of stopping, Tom eagerly walked ahead and out of sight. It was just after he disappeared that I heard the call — "*I've got a Malcolm's up here!*". Legs tired and burning, I quickly closed the gap between Tom and I, and rounded the corner to find him pointing his torch at the bottom of a bank of mud and ferns, where a huge adult female Malcolm's pit viper was coiled under his torchlight. This snake, with black body colouration and covered in luminous green specks, was more spectacular in the flesh than any photo could ever do justice. We had found

Fig. 8. Kinabalu angle-toed gecko (*Cyrtodactylus baluensis*). Photo: Tom Charlton.

our top target on only the second night of the trip! The crown jewel of Kinabalu herpetofauna and arguably Borneo's most spectacular snake, Malcolm's pit viper is a rare species endemic to Mount Kinabalu and very seldom encountered. Ryan received an excited phone call, and he hurried back up the hill to find us. We set about photographing this magnificent snake, using an umbrella to save our camera gear from the pouring rain and trying our best to disturb the snake as little as possible. After some time it began to move off and we watched as it disappeared up the bank, its body colouration allowing it to blend in perfectly with the surrounding vegetation.

We made our way down the hill, still euphoric due to our rare find, when Ryan shouted the words every herper wants to hear — "*SNAKE!"*. Up ahead, a small, thick-set dark snake was stretched out in the middle of the road, likely washed out of its refuge from the heavy downpour. As we got a little closer, we realised we had found another of the mountain's rarest snakes, Chasen's mountain viper (*Garthius chaseni*). A stout, brown terrestrial snake, rather dull to look at in comparison to the Malcolm's pit viper, Chasen's mountain viper is however an even rarer find with only a few specimens spotted on the mountain each year. We couldn't believe our luck! Again, we followed the snake as it made its way across the road and onto the verge, where we were able to take photographs of this incredibly rare serpent. Funnily enough, in spite of our success, we had failed to find one of the more common species of snake found around the park headquarters — the Sabah pit viper (*Trimeresurus* (*Popeia*) *sabahi*) — which is often seen by visitors to the park on low-lying branches and ferns. I had, however, photographed this species on previous trips to Borneo.

We left the Mount Kinabalu headquarters the following morning and made the one-hour drive down to the Poring Hot Springs, situated at the mountain's foothills, and stopped off in Ranau on the way for lunch. After organising accommodation in Poring, we made quick use of one of the hot spring baths to relax before the night's walk. On my previous visits to this area, the gates of Poring Hot Springs remained open in the evening, allowing night walks to spot some of the amazing nocturnal fauna this warm lowland region has to offer. Unfortunately, this time round we were told the gates closed shortly after 6pm and night walks were no longer allowed. With our time in Borneo very limited, we sought permission for a pass into the park that evening, even if it was necessary to be accompanied by a park ranger, but was told that nothing could be arranged for us and so we had to quickly make other plans before dark.

We found a track to walk for a few kilometres through agricultural land, finding many frogs along the way. The hot, sticky conditions of Poring were in stark contrast to the cool climate of the Mount Kinabalu headquarters we had been experiencing on the previous few nights. Eventually, we made our way into a large area of bamboo thickets and began searching for our limbless quarry. After an hour, we spotted a huge female Borneo keeled pit viper (*Tropidolaemus*

subannulatus) coiled up next to a large clump of bamboo around 5 ft off the ground. This large species of viper, whose bite is dangerous but generally not considered life-threatening, is one of Borneo's more commonly encountered venomous snakes. I've seen many of these during my previous trips to Borneo, however this was without doubt the largest to date, and from looking at her girth she was very likely pregnant.

The following day, in an attempt to find somewhere more suitable for night hikes, we organised new accommodation at Lupa Masa, a rainforest camp situated just outside the boundaries of Kinabalu National Park. This had to be arranged 24 hours in advance for them to prepare for our stay, and so we were to remain in Poring town for one more night. Again, the following evening we headed out just after dark, finding another muddy track to follow. Just 30 minutes into the walk, we left the track to check out the verges of a small banana plantation. Almost immediately I came across our second target species of the trip, the Kinabalu krait (*Bungarus flaviceps baluensis*), crossing the path a few metres in front of me. This subspecies of the red-headed krait is a truly unbelievable-looking snake, its varied colours and patterns spread down the length of its body giving the appearance of two different snake species rolled into one. This particular

Fig. 9. Head of the Chasen's mountain viper (*Garthius chaseni*). Photo: Tom Charlton.

Fig. 10. A very unexpected find, a Chasen's mountain viper (*Garthius chaseni*) that we found crossing the road during heavy rain.. Photo: Tom Charlton.

specimen was around 120 cm long, though they are capable of reaching nearly 200 cm. One of the most venomous species of snake within southeast Asia, the Kinabalu krait has a potent neurotoxic venom which works quickly to shut down its victim's respiratory system. However, like all snakes, kraits are defensive rather than aggressive and this snake showed no signs of agitation, even as we approached. As it began to enter tall grass, we carefully moved it to a more open patch of ground using a snake hook, and took some photos before leaving the snake to carry on its hunt for prey. A specialist reptilian-feeder, the krait's diet is made up almost exclusively of other snakes.

The next morning, we packed up our belongings and prepared to head to Lupa Masa. Accessing this spectacular eco camp requires leaving your car behind in town and making a 30–40 minute walk along tracks and trails, crossing streams and bamboo bridges deep into the forest. Lupa Masa is located in a hot and

Fig. 11. The huge female Borneo keeled pit viper (*Tropidolaemus subannulatus*) that we encountered in a bamboo forest close to Poring. Photo: Tom Charlton.

humid patch of primary rainforest, and is home to many spectacular snakes, lizards and frogs, as well as a variety of invertebrate, bird and mammal species. We'd spend the next three nights here to find and photograph as many as we could, walking the trails through the forest day and night, and returning to camp only for food and rest. Over the three nights and many hours spent walking the forest trails, we were able to find a second Kinabalu krait, two blunt-headed slug snakes (*Aplopeltura boa*), a sunbeam snake (*Xenopeltis unicolor*), plus species of numerous amazing frogs and lizards, most notable being the impressive Malayan horned frog (*Megophrys nasuta*).

On our last night at Lupa Masa, we headed out just before dark to walk the main trail leading into camp. Whilst we tend to trek as a group, that night we decided to split up in order to cover as much ground as possible, in a last attempt to turn up our remaining target species. Further up the trail, Ryan made his way off the track and

Fig. 12. Kinabalu krait (*Bungarus flaviceps baluensis*). A rare subspecies of the red-headed krait that is endemic to the island of Borneo. Photo: Tom Charlton.

Fig. 13. Green mountain dragon (*Phoxophrys cephalum*). Photo: Tom Charlton.

Fig. 14 (above). The blunt-headed slug snake (*Aplopeltura boa*) feeds exclusively on slugs and snails. **Fig. 15** (below). Malayan horned frog (*Megophrys nasuta*). Photos: Tom Charlton.

Fig. 16 (above). Female Borneo anglehead lizard (*Gonocephalus borneensis*). **Fig. 17** (below). Sunbeam snake (*Xenopeltis unicolor*). Photos: Tom Charlton.

into a thicker part of the forest. As he walked past a tree sapling, he spotted a subadult male Sumatran pit viper (*Trimeresurus* (*Parias*) *sumatranus*) coiled in ambush position around 70 cm off the ground — our final target species for the trip! Ryan called out for me and Tom to come and see what he had found. The Sumatran pit viper is a highly venomous species of snake capable of causing fatalities in humans, and so we carefully set about photographing it. This beautiful snake, still going through its ontogenetic colour change between juvenile and adult colouration, made for a great end to our stay at Lupa Masa.

Our final few days of the trip were spent away from Mount Kinabalu in the village of Sukau, along the banks of the Kinabatangan River. Here, we took life a little easier than the previous week of long nights and gruelling treks in the pouring rain or sticky heat. During the day, we made trips along the river by boat to see the amazing array of mammals this region of Sabah has to offer including proboscis monkey and Orang-utan. Like most visitors to the Kinabatangan River, we kept our fingers firmly-crossed for the sight of pygmy elephants, but despite seeing many signs of their presence along the banks of the river in the form of footprints and damaged vegetation, we were not lucky enough to see the elephants themselves. On our final night at Sukau, we jumped into the hire car and drove slowly along the roads bordering oil palm plantations just outside of town to see what animals

Fig. 18 (left). Our third and final target species of the trip, the Sumatran pit viper (*Trimeresurus* (*Parias*) *sumatranus*). **Fig.** 19 (above). Close-up of head of the Sumatran pit viper (*Trimeresurus* (*Parias*) *sumatranus*). Photos: Tom Charlton.

Fig. 20. A young Asian water monitor (*Varanus salvator*) basking along the banks of the Kinabatangan River. Photo: Tom Charlton.

were crossing. Around 30 minutes into our drive we found a Malayan racer rat snake (*Coelognathus flavolineatus*) shooting across the road at high-speed. A common snake in and around agricultural land, this species takes advantage of the many rodents living within the plantations. After a few more hours, we had little else to show for our efforts except for getting a quick glimpse of a Sunda stink badger (*Mydaus javanensis*) moving into vegetation.

These final few nights along the Kinabatangan River concluded our time in Borneo, and the following day we made the long drive back to Kota Kinabalu, where we would stay for one night before dropping off our hire car and boarding a plane to make the homeward journey. Overall, this particular trip was a great success, exceeding our expectations on productivity with us managing to find and photograph all three of our target species, along with a whole range of other animals. I'm already looking forward to my next visit!

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The Extraordinary Snake Fauna of Mount Kinabalu

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Somewhere near Kinabalu Park Headquarters sometimes is heard a shrill cry, "Ular!!" ("Snake!!") —

Most Park visitors in the vicinity can hear it (except for the snake, which is deaf) but snakes still sense the vibrations of scampering feet, either of terrified — or perhaps interested — humans. A great many of the snake species encountered along the roads and trails of Kinabalu Park are indeed worth our attention since several are unlikely to ever be seen elsewhere in Borneo. Some of the most beautiful species are venomous, and must be viewed with that in mind, but their natural beauty can be extraordinary.

Mount Kinabalu, at 4095 metres the highest mountain in Southeast Asia, was formed from an enormous crystalised subterranean pocket of magma that eventually emerged through the much older sandstone skirt of the Crocker Formation to create the spectacular serrated crest of the mountain that is now visible. Geologically it is mostly metamorphic, granitic rock that incorporates sections of "ultrabasic" (ultramafic) material from the ancient Sunda seabed. The massive core of the mountain looms over sandstone remnants that have been broken and eroded away by glacial ice and millions of years of torrential rains.

The peak's tortured geological history gave birth to a diverse array of warm, moist habitats, sliced and diced even further into individual microhabitats within at least three distinct altitudinal sections, or zones. These areas until recently were covered by undisturbed stands of tropical hill dipterocarp, oak, or submontane forests with their own distinct biotic communities across a myriad network of streams, large and small. This physical and biological diversity in turn enhanced the species richness and abundance of snakes, from the lower elevations such as Poring Hot Springs (550 metres) to the submontane portions of the mountain reaching from 1500–2500 metres above sea level (asl).

One of the mountain's early international visitors, the explorer and professional biologist J.A. Griswold, Jr. provided one of the first assessments of the snake fauna of Kinabalu and reported that, "… snakes were … very numerous in this locality, there being some twenty different species...". More than half a century later, further surveys by Rudolf Malkmus et al. (2002) expanded the species list to 67, also noting that the number of snake species that were encountered within the boundaries of Kinabalu Park declined rapidly with altitude. While fewer in number, several of the most interesting species are found at the higher elevations. With additional records from Stuebing et. al (2014) and records from the Kinabalu

Fig. 1. Schmidt's Reed Snake (*Calamaria schmidti*), one of Kinabalu Park's most commonly seen snakes. Photo: Ron Eldie. **Fig. 2** (inset). J.A. Griswold. Image courtesy of Indraneil Das.

Fig. 3. Malcolm's Pit Viper (*Parias malcolmi*) is seen along the trails leading from the Park Headquarters. VENOMOUS. Photo: Ron Eldie.

Fig. 4. Sabah Pit Viper (*Trimeresurus sabahi*) is a semi-arboreal snake of the mountains, including Mount Kinabalu. VENOMOUS. Photo: Ron Eldie.

Park's own museum's specimen collection we can now increase the known species from Kinabalu Park to 80 (Appendix 1). This number represents more than 40% of the species known from the island of Borneo (including Kalimantan) and thus clearly indicates that the Mount Kinabalu is a "hotspot" for snake diversity. This is especially true for the endemic snakes of the genus *Calamaria*, for which the mountain is home to at least half of the known species in Borneo. The Sabah Parks staff have monitored reptile diversity on the mountain and maintained a synoptic collection of snake specimens since 1980, for reference purposes. Many of the specmens have inadvertently originated from road kill from the vicinity of the Park Headquarters.

Conspicuously missing from the Park are many exclusively lowland snakes as well as entire families of riverine and coastal groups such as the Acrochordidae, the Homalopsidae and, of course, the marine elapids ("cobras"), the sea snakes of the Laticaudinae and the Hydrophiinae.

At least six species have been identified as endemic, i.e., found exclusively on Mount Kinabalu. Species with the mountain (and its immediate surroundings) as their type locality include the Mountain Dwarf Pipe Snake (*Anomochilus monticola*), the Side-striped Reed Snake (*Calamaria lateralis*), the Greater Reed Snake (*Calamaria modesta*), Schmidt's Reed Snake (*Calamaria schmidti*), the Kinabalu Water Snake (*Hydrablabes praefrontalis*), and Malcolm's Pit Viper (*Parias malcolmi*). More than 20 species are endemic to Borneo. Until about the mid-20th century, many other snake species were assumed to to be Kinabalu endemics, but this number has been steadily eroded as a result of relatively recent discoveries on other mountain peaks in Borneo. Many Kinabalu "endemics" can be found in habitats at submontane elevations along the mountainous "spine" of Borneo of the Crocker Range such as along the Sunsuron ridge, Mount Trusmadi, Mount Lumaku, Mount Mulu, Mount Murud and probably several sites as yet unexplored by herpetologists. Nevertheless, some species routinely encountered at Poring Hot Spring or in the forests above Kinabalu Park Headquarters in fact have distinctive coloration and patterns compared with their "conspecifics" elsewhere in Borneo, and may turn out to be endemic. The most frequently encountered species in the Park (along the commonly travelled Mountain Garden, Liwagu, Kipungit, Langanan and Poring Hot Springs trails) are the small and unobtrusive Schmidt's Reed Snake (*Calamaria schmidti*), the Chequer-bellied Keelback (*Amphiesma saravacense*) and another natricine, the strikingly coloured — and mildly venomous — Fire-lipped *Keelback* (*Rhabdophis murudensis*). One of the conspicuous — but also venomous – favorites is the emerald green and black patterned Malcolm's Pit Viper (*Parias malcolmi*), a new favorite of scientists as well as "herp tour" photograhers. In Poring, the spectacularly patterned — and highly venomous — Kinabalu Krait (*Bungarus flaviceps*) is also much sought after by photographers.

Conservation of the Kinabalu snake fauna

Undoubtedly the development that has most dramatically expanded our knowledge of snakes and energised the trend towards their conservation has been the invention and perfection of digital cameras which has in turn engendered an enormous increase in the numbers and expertise of snake enthusiasts and dedicated amateurs, and eventually the number of field guides available. Prior to the mid-1990s, film was still the principal means of obtaining snake images. Thus, herpetologists were confronted with the dilemma of adding the inconvenience and expense of photography to their list of field research requirements. Good cameras and their flash units were separate, bulky and expensive, while films appropriate to the task could be costly, easily ruined by humidity and the number of frames limited by the number of species found and the time it took to capture quality photographs. The expense of publishing books with large numbers of colour plates could also be dauntingly expensive. Digital photography has changed all that, and has also vastly expanded the availability of high-quality images as ordinary ecotourists could now take advantage of the huge improvement in both point-and-shoot as well as electronic SLR cameras. This has been a revolution, and hugely positive in promoting conservation of reptile biodiversity in general, and of snakes in particular.

Quite obviously the development of plantation agriculture has sent perhaps millions of snakes to their deaths, as Borneo's lowland forests have been felled and burnt, and crushed as bulldozers cleared millions of hectares. Land clearing of "degraded" forests can and does proceed at a frightening pace, at one site which we have witnessed, at least 1000 hectares per month, and this may be a low estimate for some sites. The only remedy for this is to integrate conservation principles into plantation operations, not merely classify land as "High Conservation Value" after surveys of 10,000–20,000 hectare sites within a few days to a few weeks. Wildlife Department that "partners" with academic or professional herpetologists to provide more intensive inventories of the fauna of these "degraded areas" so that at the very least, scientifically valid, permanent data may be obtained and potentially endangered snake species can be spared. Long-term work by permanent, embedded Conservation staff of silvicultural and oil palm plantation companies in Sarawak and East Kalimantan has proven that such efforts not only provide adequate information for certification purposes, but actually at much lower cost (1–2% of net income) than the certification process itself.

Fortunately, in Totally Protected Areas such as Kinabalu Park, the snake fauna is not so vulnerable to serious intrusions from land clearing or other kinds of consumptive economic exploitation, although there continues to be patchy deforestation in some areas of the Park's boundaries. Mount Kinabalu and its surroundings have on the whole remained under active protection by the State of Sabah since the area was awarded status as a National (now State) Park, in 1964.

The Park's less than attractive forestry or agricultural resources (because of steep, high elevation terrain), and its distance from densely populated areas has assisted in the preservation of many uniqely diverse and species-rich forests. Of course, one might assume that the snakes would be one of the least threatened of any of the mountain's unique faunal communities.

However, on 7 June 2015, the Kinabalu earthquake — apart from thirteen tragic deaths of tourists and Kinabalu Park Staff — seems also have been one of the most unexpected threats to the mountain's snake fauna. As the great mountain shook, it is clear from post-earthquake photographs that huge landslides involving many of the forest floor habitats along steep gradients have occurred. These are the very habitats, mossy banks and leaf litter in which much of the snake fauna might have resided — and may have also perished. Nevertheless, over time perhaps to be measured in decades, this unique environment will slowly recover and hopefully will once again be occupied by their original inhabitants.

An additional threat over a longer time span is perhaps more serious: climate change may have an impact, especially on snake species of mossy, forested areas at higher elevations, since it has been reported that annual temperature has already gone up approximately 0.7ºC. Sadly, snake species, especially those of forested habitats of tropical highlands, have poor mobility and can be "trapped" in unsuitable habitats as the climate shifts. From another angle, unfortunately they also are among the last creatures to receive consideration in conservation management plans, a reality that derives partially from a dearth of knowledge of their natural history, and perhaps from non-inclusion among "flagship" or "Keystone" species of endangered habitats or communities under consideration.

But there is good reason for optimism. Conservation consciousness has always had a high profile in Sabah, and even creatures formerly as disdained as snakes have now acquired a positive new profile, as a significant part of Malaysia's extraordinary natural heritage. So, during your next visit to Kinabalu, if you happen to encounter a snake, make sure that you approach it with caution and respect; then, before you shout, please take a photograph.

Appendix 1. A checklist of snakes from Kinabalu Park.

1.	*Ahaetulla prasina*	Oriental Whip Snake
2.	*Amphiesma flavifrons*	White-nosed Keelback
3.	*Amphiesma sarawacense*	Chequer-bellied Keelback
4.	*Anomochilus monticola**	Mountain Dwarf Pipe Snake
5.	*Aplopeltura boa*	Blunt-headed Snail-eating Snake
6.	*Asthenodipsas laevis*	Smooth Snail-eating Snake
7.	*Asthenodipsas malaccanus*	Dark-necked Snail-eating Snake
8.	*Boiga cynodon*	Dog-toothed Cat Snake
9.	*Boiga dendrophila*	Yellow-ringed Cat Snake

10.	*Boiga drapiezii*	Pale-spotted Cat Snake
11.	*Boiga jaspidea*	Jasper Cat Snake
12.	*Boiga nigriceps*	Dark-headed Cat Snake
13.	*Bungarus fasciatus*	Banded Krait
14.	*Bungarus flaviceps*	Yellow-headed or Kinabalu Krait
15.	*Calamaria bicolor*	Bicoloured Reed Snake
16.	*Calamaria grabowskyi*	Grabowski's Reed Snake
17.	*Calamaria griswoldi*	Yellow-lined Reed Snake
18.	*Calamaria lateralis**	Side-striped Reed Snake
19.	*Calamaria leucogaster*	Ring-tailed Reed Snake
20.	*Calamaria lumbricoidea*	Variable Reed Snake
21.	*Calamaria modesta**	Greater Reed Snake
22.	*Calamaria schlegeli*	Pink-headed Reed Snake
23.	*Calamaria schmidti**	Schmidt's Reed Snake
24.	*Calamaria suluensis*	Lesser or Yellow-bellied Reed Snake
25.	*Calamaria virgulata*	Striped Reed Snake
26.	*Calliophis bivirgata*	Blue Coral Snake
27.	*Calliophis intestinalis*	Banded Coral Snake
28.	*Chrysopelea paradisi*	Paradise Tree Snake
29.	*Chrysopelea pelias*	Twin-barred Tree Snake
30.	*Coelognathus flavolineatus*	Sunda Racer or Rat Snake
31.	*Cylindrophis ruffus*	Common Pipe Snake
32.	*Dendrelaphis caudolineatus*	Striped Bronzeback
33.	*Dendrelaphis kopsteini*	Kopstein's Bronzeback
34.	*Dendrelaphis pictus*	Painted Bronzeback
35.	*Garthius chaseni*	Kinabalu Brown Pit-viper
36.	*Gongylosoma baliodeirum*	Spotted Ground Snake
37.	*Gongylosoma longicaudum*	Five-striped Ground Snake
38.	*Gonyosoma margaritatum*	Royal Tree Snake
39.	*Gonyosoma oxycephalum*	Grey-tailed Racer
40.	*Hydrablabes praefrontalis**	Kinabalu Water Snake
41.	*Lepturophis albofuscus*	Slender-tailed Wolf Snake
42.	*Liopeltis tricolor*	Masked Ground Snake
43.	*Lycodon subcinctus*	Banded Wolf Snake
44.	*Macropisthodon rhodomelas*	Blue-necked Water Snake
45.	*Naja sumatrana*	Sunda Spitting Cobra
46.	*Oligodon octolineatus*	Striped Kukri Snake
47.	*Oligodon purpurascens*	Brown Kukri Snake
48.	*Oligodon vertebralis*	Dark-spined Kukri Snake
49.	*Oligodon everetti*	Jeweled Kukri Snake
50.	*Ophiophagus hannah*	King Cobra
51.	*Opisthotropis typica*	Dwarf Water Snake
52.	*Oreocalamus hanitschi*	Mountain Reed Snake
53.	*Orthriopus taeniurus*	Cave Racer
54.	*Pareas nuchalis*	Barred Snail-eating Snake

55.	*Parias malcolmi**	Smith's Mountain Pit-viper
56.	*Parias sumatranus*	Sumatran Pit-viper
57.	*Popeia sabahi*	Sabah Pit-viper
58.	*Psammodynastes pictus*	Painted Mock Viper
59.	*Psammodynastes pulverulentus*	Dusky Mock Viper
60.	*Pseudorabdion albonuchalis*	Ring-necked Litter Snake
61.	*Pseudorabdion collaris*	Mocquard's Litter Snake
62.	*Pseudoxenodon baramensis*	Baram Water Snake
63.	*Ptyas carinatus*	Keeled Rat Sanke
64.	*Ptyas fusca*	White-bellied Rat Snake
65.	*Python breitensteini*	Borneo Blood Python
66.	*Python reticulatus*	Reticulated Python
67.	*Ramphotyphlops braminus*	Common Blind Snake
68.	*Rhabdophis chrysargos*	Speckle-bellied Keelback
69.	*Rhabdophis conspicillatus*	Red-bellied Keelback
70.	*Rhabdophis murudensis*	Fire-lipped Keelback
71.	*Sibynophis melanocephalus*	White-lipped Dark-headed Snake
72.	*Stegonotus borneensis*	Bornean Black Snake
73.	*Stoliczkaia borneensis*	Stoliczkia's Rough-backed Snake
74.	*Trimeresurus borneensis*	Bornean Leaf-nosed Pit-viper
75.	*Tropidolaemus subannulatus*	Keeled Pit-viper
76.	*Typhlops* cf. *muelleri*	Bicoloured Blind Snake
77.	*Xenelaphis ellipsifer*	Ornate Brown Snake
78.	*Xenochrophis maculatus*	Large-eyed Water Snake
79.	*Xenochrophis trianguligerus*	Triangle Keelback
80.	*Xenopeltis unicolor*	Iridescent Earth Snake

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Wild Durians of Sabah

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INTRODUCTION

The durian fruits are so-named after the Malay word 'duri', referring to the thorns or spines on the fruit. One species has become a major commercial product which is widely cultivated in villages and suburban gardens in the tropics, as well as in commercial orchards, planted with selected varieties and cultivars. This is *Durio zibethinus* Murray. '*Zibethinus*' is from the Latin, referring to the fruits smelling like civet-cats.

These strong-smelling fruits are much loved by Asians for the sweet, creamy, nutritious aril around the seed and its strong fruity odour. However, the odour is objected to by many foreigners and as a result the fruit is banned from transportation in commercial vehicles, such as coaches, trains and aircraft. Most hotels also ban it from being brought into the hotel premises. Despite this, the fruit has become known as the "King of Fruits" with another tropical fruit, the Mangosteen, being called the "Queen of Fruits".

OCCURRENCE & BOTANICAL ASPECTS

The durian species fall into the small genus *Durio*, with 34 species, (according to the Kew Plant List), found in lowland and hill, wet, tropical rainforest, in the Sundaic region of tropical Asia and Sri Lanka. This is covered by the botanical region known as Malesia, that includes Myanmar, Indo-China, Thailand, the Malay Peninsula, Sumatra, Sulawesi, Borneo and the Philippines, and apparently three species in Sri Lanka.

Borneo, with 19–20 species, is the centre of diversity and distribution for the genus, followed by Peninsular Malaysia with 14 species and Sumatra with 7 species. There is one species in Myanmar which is endemic. In Borneo, Sabah has 15 species, with the same number in Sarawak. Brunei has 10 species, including the endemic *Durio bruneiensis*, with 2–3 other different species in Kalimantan, not found in Malaysian Borneo, such as *Durio beccarianus* and *D. bukitrayaensis*.

The genus *Durio* was previously placed in the family Bombacaceae. However, recent molecular studies based on DNA sequencing puts it in the family Malvaceae, in the broader order of the Malvales. This order, with 10 families containing c. 6000 species in 338 genera, has three families in tropical Asia and Borneo — Dipterocarpaceae (with 680 species in 17 genera), Thymeleaceae (with 8915 species in 50 genera) and the Malvaceae (with 4300 species in 250 genera), that is often referred to as the Hibiscus family.

The family Malvaceae is further divided into 10 groups or clades, that are equivalent to sub-families. These include the Bombax group, Sterculia group, Hibiscus group and the Durian group. The Durian group is part of the sub-family Helicteroideae, which has two tribes — the *Helicteres* group with 6 genera and 60 species, mostly shrubs, and the Durian group (tropical Asian trees), with 50 species in 4 genera: *Coelostegia*, *Kostermansia*, *Neesia* and *Durio*. All these four genera have fruits covered in spines or conical to pyramidal-shaped protrusions.

Durio species are understorey or lower canopy to main canopy trees of the wet tropical rainforest, mainly in lowland forests but with several species in the hill forests to 1200 m. The trees range from 10–60 m tall, depending on whether they are lower canopy or main canopy trees, with trunks or boles 5–30 m in height, often with low to tall buttresses. The canopy in some species can be very broad. The leaves are arranged alternately in the same plane. The leaves often have stipules at the base of the petiole or leaf stalk, but these often fall off. The petioles are 1–3 cm long, and have a swollen distal portion or 'knee joint' called a pulvinus.

The leaf blade (lamina) is lanceolate to ovate, or elliptic to oblong, or oblanceolate in shape. The upper surface is usually glabrous, dark green, with the lower surface, petioles and veins covered in silvery to white or golden brown fringed scales, covering stellate hairs, a distinct character of durian leaves.

Inflorescences and flowers are found on twigs between the leaves, or ramiflorous along the branches and in some cases cauliflorous, in clusters on bosses on the trunk or bole or at the base of the tree. The flowers can be borne as single flowers or in a cluster or cyme of 3–5 flowers, or in branched cymes with even more flowers. A cyme is a sympodial inflorescence, where the central flower opens first, followed by axillary buds below this, often with branches below. The flowers may be scented in many species. The flower stalks often have small to

large bracts, sometimes persistent. The epicalyx encloses the flower bud, splitting open into two or three lobes at flowering. The calyx is mostly toothed, sometimes splitting apart fully, in up to 5 saccate, stiff sepals. The 4–6, (rarely to 10 or more), petals are free, white to cream to yellow, pink, pale orange or red. In many species the petals can be dried or eaten raw as a vegetable. The stamens are free and numerous, sometimes in bundles (phalanges) of five. In several species the filaments of the stamens are fused in the basal part to form a tube with nectaries at the base, the upper portion having free filaments, which have single or several anthers that have either pores or split longitudinally to expose the pollen. The ovary is ovoid or ribbed, with a single style, with 3, to commonly 5, locules with 2 to several ovules per locule (valve).

The fruit is a fibrous to woody capsule with 3, 4, or commonly five, valves (carpels), glabrous inside, with pyramidal to conical to needle-like, short to long spines on the outside, sometimes covered in hairs or scales. The ellipsoid seeds, 2–4 cm long, have a brown or black testa, and are either fully or partially covered by the aril. The aril can be thick and creamy to thin and leathery and is edible to humans in several species. The seeds of some species are also edible if boiled or roasted.

POLLINATION AND DISPERSAL

Durian flowers that have clusters of free stamens and white petals are often strongly scented at night, often with a honey-like odour, as in the case of *Durio zibethinus* and *D. graveolens,* the commonly cultivated species, that exude copious drops of nectar. The nectar attracts bats which lick it up, and in the process, cover their foreheads in pollen, that will pollinate the flowers on another tree. In most cases durians are self-incompatible and will only set fruit if the pollen has come from a different tree.

Insects such as honey-bees are seen in the early morning also gathering nectar that is left over, but are probably not pollinators. *Apis dorsata*, the Giant Honey-bee, collects nectar on half- to full-moon nights, and could be accidental pollinators. Durian species with a similar flower structure, but with pink or red flowers, are probably visited by nectar-feeding birds in the daytime such as sunbirds, for species such as *Durio kutejensis, D. dulcis* and *D. griffithii*.

Other species of durians have flowers where the basal parts of the filaments of the stamens, holding the anthers with the pollen, fuse to form tall tubes in which the nectar is contained. These include several species with white flowers and some species with pink or red flowers. Examples are *Durio testudinarius* (syn. *D. macrophyllus* sensu Kosterm.), *D. oblongus* and *D. singaporensis*, all with white flowers that are visited by hawk moths, either night or daytime species, that have a long proboscis to suck out the nectar. Spiderhunter birds that have long bills,

enabling them to drink nectar from tubular flowers, may also be pollinators of the red or pink-flowered durian species such as *Durio johorensis* and *D. pinangensis* in Peninsular Malaysia.

Seed dispersal of durians also falls into two main categories. In the first category, those species such as *Durio zibethinus, D. oxleyanus* and *D. dulcis*, for example, in which the ripe fruits fall to the ground, emitting a strong odour to attract animals, and where the fruit valves open on the ground. Though mammals such as wild boar may crunch both seeds and arils and so do not disperse the seeds, others such as sun bears swallow the aril with the seeds which are dispersed later in the faeces. I met sun bears at wild durian trees tearing open the fruits and also watched monkeys, orang-utans, civets and mousedeer eating the fallen fruits. Some of these mammals may devour the seeds but many seeds probably also pass through as they are mainly interested in the sweet and nutritious aril.

Mousedeer, being very shy, were observed to rush to the fallen fruits and consume as many seeds and arils as they could in one go, by filling their mouth pouches, and then retreating to a safer place to digest the arils, either spitting out the seeds or swallowing them to be passed in their faeces.

In the second main category, durians have fruits where the valves open on the tree, such as *Durio griffithii, D. crassipes,* and *D. lanceolatus*, with relatively small fruits and seeds partly or wholly covered in an edible aril, which are consumed by hornbills, squirrels and civets, but probably also by monkeys, gibbons and orang-utans. The latter would be even more attracted to the larger-fruited species that open on the branches such as *Durio grandiflorus,* with blue-green fruits opening to reveal seeds with a red or orange aril and *D. graveolens* that has even larger fruits with red or yellow arils, which are less sweet and more oily, and *D. kutejensis*, also with a red and yellow aril. It appears that hornbills, after swallowing the seed and aril, may regurgitate the seed later, dropping it far from the mother tree

DURIAN HABITATS

Many durian species in Sabah with edible fruits are found in lowland mixed dipterocarp forest on alluvial and clay soils up to 300 m altitude. In particular, these include *Durio zibethinus, D. oblongus, D. dulcis, D. excelsus, D. graveolens, D. kutejensis and D. testudinarius. Durio carinatus* is commonly found in swampy lowland forest and peat swamp forest. On the more sandy hills and ridges from 500 m to 1000 m are found *D. griffithii, D. crassipes*, and commonly *D. lanceolatus* and *D. oxleyanus*. *D. kinabaluensis*, however, is only found above 700 m on Mount Kinabalu, and in the Crocker Range, on sandstone soils in mixed hill forest.

FRUITING SEASON

The fruiting seasons vary for Borneo. Sabah, unlike southern parts of Borneo, has a dry season of about one month in March, followed by flowering in late April and May, the fruits ripening between July and September. However, in years when the dry season fails, it follows the rest of Borneo, where hot sunny spells in late August and September are followed by flowering in late September and October with a fruiting season starting in December through to February. Some durian species, such as *Durio griffithii*, flower and fruit throughout the year.

LOCAL NAMES FOR THE SPECIES

There are many different ethnic groups in Borneo, including 30 or more in Sabah, and with all these different dialects, many durian species have different names in different areas, so under the species notes, I refer only to the common Malay name, if there is one.

The main cultivated species, *Durio zibethinus*, is mostly referred to as '*durian biasa*', '*durian puteh*' and '*durian kampong*', or simply as '*durian*'. Most of the wild edible species are often referred to as '*durian hutan*', 'hutan' meaning forest. *Durio testudinarius*, with fruits at the base of the trunk, is called the 'tortoise durian' or '*durian kura-kura*', as it is believed that forest tortoises, which feed mainly on fallen fruits can reach these fruit when they open. Edible species with red or yellow arils are called '*durian merah*' or '*durian kuning*'.

Many of the wild durians with fruits that open on the branches are called '*durian burung*', '*durian monyet*' or '*durian tupai*', as they are commonly eaten by birds, squirrels and monkeys. The rare or non-edible species often do not have Malay names.

GENERAL USES

In the past, many of the tribes lived in villages along rivers, or near forested areas and were avid gatherers of forest produce for all their needs, from building houses and making furniture to gathering edible fruits and seeds in Borneo, and other jungle products. Nearly 500 species of plants are recorded as having edible fruits or seeds and durians were among the most popular. The nutritional value of the aril makes durian one of the most nutritious fruits there is, as it is rich in carbohydrates, protein, fat, calcium, Vitamin A and Vitamin C.

Several *Durio* species are timber trees, referred to as durian timber, which has several commercial uses. Species popular for their fruits however are rarely felled, but the huge trees of *Durio lanceolatus*, with boles up to 20 m, were.

However, durian timber cannot be exposed to rain for very long, and is therefore mainly used indoors, for door and window frames, furniture, tool handles, floors, plywood and veneer. Old branches are used as firewood.

Durian timber was more commercially utilized in the past, and was compared to '*seraya*' timber, (Dipterocarpaceae), especially trees with large boles such as *Durio lanceolatus* and *D. oxleyanus*, as the fruits were not highly regarded and rarely cultivated. Hence these species are now quite rare and must be sadly missed by the wildlife!

The native edible species of Sabah are seldom cultivated, in many cases because they cannot compare to the '*durian puteh*' (*Durio zibethinus*). Hence local farmers would rather utilize the space on their farms for '*durian puteh*', which they know they can sell for a good price.

The other species, should, in fact, be rated in a separate category, with their own distinct flavours and textures of the arils. For instance, '*durian kura-kura*' (*Durio testudinarius*) is rarely cultivated in Sabah, but is in Brunei and Sarawak, because the fruits are very different, having a juicy or watery aril that, to Europeans taste like caramel cream, with no resemblance to the flavour and odour of the durian. Similarly, *D. graveolens,* with red or yellow flesh, varies from a cheesy to oily textured aril, that is more like Avocado, and is often made into a relish with no durian odour. The fruits of *D. dulcis*, unfortunately, have an incredibly strong odour which gives many people a headache, but to Europeans, the aril is akin to eating peppermint creams, and is liked by certain tribes.

Many of the edible species have flowers in which the petals fall off after one day or night. These petals, but not the hard calyx lobes or sepals, are often gathered and eaten as a vegetable, either raw or cooked. The petals can be eaten fresh or dried and may also be stored for one to three months. They are often cooked as a vegetable in curries and even in omelettes or mixed with other vegetables.

For several species, the unripe fruits are also cooked as a vegetable, including *Durio crassipes, D. dulcis, D. graveolens, D. kutejensis, D. oblongus, D. oxleyanus,* and *D. zibethinus*.

The arils of most durian species are edible but for some with small fruits, such as *Durio griffithii* and *D. lanceolatus*, there is very little aril, and though the aril is eaten it is rather tasteless. In other species, where the aril is slightly leathery such as in *D. grandiflorus*, it is made into a relish called '*tempoyak*'.

In Borneo, when there is a glut of fruits, local tribes often preserve the aril with salt for future use in cooking, often for condiments or relish ('*empikau*') and this has been recorded for *Durio crassipes, D. oblongus, D. oxleyanus* and *D. zibethinus*. Also when there is a surplus of fruits, or where it is popular, the arils

of several species are made into a paste and dried and eaten as a condiment, and will keep for up to three months, and this is recorded for *Durio dulcis, D. kutejensis, D. grandiflorus* and *D. zibethinus.*

The arils of some species are often cooked as a vegetable, or with glutinous rice and coconut milk and even fermented to make the relish called '*tempoyak*'.

However, in general, the arils of the popular wild species are eaten fresh and for most species the seeds can also be eaten after boiling or roasting, though for some species, the seeds are reputed to be rather tasteless.

The popular *Durio zibethinus* is now traded on a large scale and often the aril, or aril and seeds, are frozen or freeze dried for export, and are very popular in China.

The aril of the durian is often utilised to flavour cakes, biscuits, cookies, jam, ice-cream, smoothies, milkshakes and as a filling in chocolates, and even for flakes or crisps, and the aril is often freeze-dried and packeted. These products have become popular in stores in Sabah for sale to visiting tourists.

Durians have minor uses in medicine, mainly the roots used as a liquid decoction for fevers. The fruits are considered to be 'heaty', however, and should not be eaten with alcoholic drinks.

Drinking warm water, mixed with a little salt, that has been poured into the empty husk is supposed to reduce the 'heatiness' and the after-effects of eating too much! The water can also be used for washing your fingers to remove the durian smell.

CULTIVATION

Durio zibethinus is the only species planted on a large scale, with many selected varieties having been grown for decades. Many of these varieties were cloned by bud-grafting onto a disease-resistant rootstock seedling, from the selected tree. This was then given a name or clonal number, with well over 150 clones selected to date, such as "*Musang King*", *Tembaga*, *Mas Johor,* etc.

A really successful clone can produce a lot of revenue for commercial nurseries, but it has to be remembered that certain clones are self-incompatible and have to be planted out in a mixed orchard with other clones to ensure pollination and fruit set.

Bud-grafted trees come into bearing one or two years earlier than trees grown from the seedlings of selected trees, which can still be variable depending on pollination sources.

Fig. 1. *Durio* Tenom Beauty (*Durio zibethinus* × *D. graveolens*) fruits. Photo: A. Lamb.

Fig. 2 (above). *Durio* Tenom Beauty (*Durio zibethinus* × *D. graveolens*). Photo: A. Lamb.
Fig. 3 (below). Author Datuk Anthony Lamb (left) and Mr Frederick Chu (right) who planted Durian Tenom Beauty in Tenom. Photo: A. Phillipps.

More recently efforts have been made to improve the fruit quality of other durian species with edible fruits, and in some cases hybrids with *Durio zibethinus* have been successful. In Sabah, a natural hybrid of *D. zibethinus* and *D. graveolens* was found in the wild by a local Murut tribe, and bud-grafted material from that tree has produced a popular clone called Tenom Beauty, with the pink to red aril of *D. graveolens*, and the creamy texture and flavour of *D. zibethinus*.

CONSERVATION

Sabah was largely developed after soil surveys and other data such as slope gradient were gathered, allowing the main areas for agricultural development or Forest Management Units to be identified. Sabah has the three highest mountains in Borneo and steep hilly terrain and mountain ranges, where conservation of the forest for water catchment and conservation of flora and fauna is deemed important. The Mount Kinabalu area with around 6000 species of vascular plants, is considered to have the richest plant diversity per unit area in the world. In the past, logging of the forest was a major source of income for Sabah, and many durians and other fruit trees were felled, and many areas of rich lowland forest were developed for agriculture. However, despite the huge loss of diversity, Sabah's forest policies and the controlled sustainable management of the Forest Management Units mean that over 50% of Sabah is still under the Forest Estate, of which 30% is to be totally protected in the next few years (26% at present). National and State Parks and Totally Protected Forest Reserves are, therefore, now protecting most of the species currently known. However, for wildlife, the replanting and enrichment of the logged forest with fruit tree species is a much to be desired target for their conservation and sustainable maintenance. Various programmes for this are currently being undertaken. An expansion of the *ex-situ* collections of native wild fruits, however, is needed to produce the seeds and planting material for these programmes, with only relatively small germplasm collections established at the Agricultural Research Stations in Tenom, and in Ulu Dusun in Sandakan.

THE DURIANS OF SABAH

Of the estimated 20 species of *Durio* in Borneo, the state of Sabah (10% of Borneo) has been found to have 15 species, the same as the state of Sarawak, wirth 2–3 species that differ. The Borneo species so far not recorded for Sabah include *Durio bruneiensis* Kosterm.; *D. beccarianus* Kosterm. & Soegang;, *D. butkitrayaensis* Kosterm.; *D. lissocarpus* Mast.; *D. macrophyllus* (King) Ridl. (which has been confused with *D. testudinarius* Becc.) and *D. purpureus* Kosterm. & Soegang.

Table 1. *Durio* species in Sabah.

Country abbreviations used: For Borneo — B (Brunei); Sa (Sabah); Sk (Sarawak); Kal (Kalimantan). Thai (Thailand); P.Mal (Peninsular Malaysia); Sum (Sumatra).

No.	Botanical name	Author	Distribution	Uses
1.	*D. affinis*	Beccari	P.Mal; Borneo (B, Sa, Sk, Kal.)	Timber
2.	*D. carinatus*	Mast.	Sum, P.Mal, Borneo (B, Sa, Sar.)	Timber
3.	*D. crassipes*	Kost. & Soeg.	End. Borneo (Sa, Sk)	Flowers, seeds, aril edible. Timber
4.	*D. dulcis*	Becc.	End. Borneo (B, Sa, Sk)	Aril edible, unripe fruit cooked. Timber
5.	*D. excelsus*	(Korth.) Bakh.	End. Borneo (B, Sa, Sk, Kal.)	None
6.	*D. grandiflorus*	(Mast.) Kost. & Soeg.	End. Borneo (B, Sa, Sk, Kal.)	Aril edible
7.	*D. graveolens*	Becc.	P.Mal; Borneo (B, Sa, Sk, Kal.)	Flower and aril edible; unripe fruit cooked. Timber
8.	*D. griffithii*	(Mast.) Bakh.	Sum, P.Mal, Borneo (B, Sa, Sk, Kal.)	None
9.	*D. kinabaluensis*	(Bakh. ex. Wyatt-Smith) Kost. & Soeg.	End. Borneo (Sa)	Flowers and aril edible
10.	*D. kutejensis*	(Hassk.) Becc.	End. Borneo (B, Sa, Sk, Kal.)	Flowers, unripe fruit, aril edible. Timber
11.	*D. lanceolatus*	Mast.	End. Borneo (B, Sa, Sk, Kal.)	Timber
12.	*D. oblongus*	Mast.	End. Borneo (Sa, Sk)	Timber. Flowers and unripe fruit edible.
13.	*D. oxleyanus*	Griff.	Sum, P.Mal, Borneo (B, Sa, Sk, Kal.)	Flowers, unripe fruit, aril edible. Timber
14.	*D. testudinarius*	Becc.	End. Borneo (B, Sa, Sk, Kal.)	Flowers and aril edible
15.	*D. zibethinus*	Murray	Burma, Thai, P.Mal, Sum, Borneo	Flowers, unripe fruit, seeds, aril edible. Timber

As can be seen from Table 1, 9 species are endemic to Borneo of which one, *Durio kinabaluensis*, is endemic to Sabah only, out of a total of 14 species endemic to Borneo.

NOTES ON THE DURIAN SPECIES OF SABAH

1. ***Durio affinis*** Becc.
'*durian daun tajam*' (sharp-pointed leaves)

Tree to over 30 m, with short buttresses. 2–3 white flowers in a cyme, the bases of the stamens forming a tube, along the branches. The yellowish fruits are round to ellipsoid, 9 × 8 cm, with short conical spines, 5–7 mm, that drop to the ground when ripe. The fruit is not edible and in Sabah, this species is not common and is little known, found along the West Coast in mixed hill dipterocarp forest to 150 m.

2. ***Durio carinatus*** Mast.
'*durian burung*' (bird) or '*durian paya*' (swamp).

Tree to 35 m, with no buttresses. The flowers are arranged in clusters of branching cymes with many cream flowers, along the old branches. The fruit is yellow, 7–10 cm long × 6–9 cm, opening on the tree, with pyramidal spines 9–11 mm long. The fruit opens with five valves, with a thin red aril fully or partially covering the dark brown to black, 3–4 cm long seeds. Fruit not edible. This species is rare in Sabah and is found in lowland dipterocarp forest, mostly in swampy areas, where knee roots have been observed, and in peat swamp forest.

3. ***Durio crassipes*** Kosterm & Soeg.
'*durian burung*'(bird); '*Durian tembaga*' (Iban)

Tree to 60 m. Buttresses not recorded. The small leaves have copper-coloured scales on the underside. The flowers are between the leaves, with reddish petals, with the stamens in 5 bundles. The fruits, with five valves, are sub-globose, 7–10

Fig. 4. *Durio crassipes.* Photo: A. Lamb.

Fig. 5 (above). Fruits of *Durio crassipes*. **Fig. 6** (below). Flowers of *Durio crassipes*.
Photos: A. Lamb

× 7 cm, covered in red pyramidal spines, to 5 mm. The brown seeds are covered in a sweet edible yellow aril. The flower petals are eaten raw or cooked, as a vegetable and are also dried. The unripe fruit is cooked as a vegetable, and the sweet edible aril is much prized by the Ibans and Kelabits in the Central Range in Sarawak. In Sabah, where it was originally discovered, it is very rare, found only in the Crocker Range, Sipitang and Paling Paling hills and is little known. It is found in mixed hill dipterocarp forest above 600 m.

4. ***Durio dulcis*** Beccari.
'*durian merah*', '*durian tahis*' (smelly)

A large tree to over 50 m, with tall buttresses. The flowers are arranged in clusters of branched cymes, with 4–5 flowers, along the older branches and have pink to red petals, with the stamens in five clusters. The fruits, with five valves, fall unopened to the ground when ripe. They are ovoid to globose, 10–20 × 15–20 cm with dark red conical spines, 1–1.5 cm long, the spines sometimes with yellow tips. The fallen fruits are difficult to open. The roundish brown seeds are covered in a white to cream edible aril, sweet, with a bitter aftertaste. They are considered delicious by local tribes, but the general public find the strong odour of the fruits often offensive, leading to headaches. Probably the strongest odour of any durian species. In Sabah it is found on sandstone, in mixed hill dipterocarp forest to 500 m. Beccari, who discovered it in Sarawak in 1865, wrote in his book *Wanderings in the Great Forests of Borneo* (1904) *"... attracted by the sweet and delicious scent exhaled by some of the fallen fruits, I discovered one of the most exquisite wild durians of Borneo"*.

Fig. 7. *Durio dulcis*. Photo: A. Lamb.

Fig. 8 & 9 (above & below). *Durio dulcis.* Photos: A. Lamb.

5. ***Durio excelsus*** (Korth.) Bakh.
'*durian daun*' (refers to the large leaves)

An understorey tree to 25 m with buttresses. The solitary white flowers with many free stamens are found in the leaf axils and along the branches. The obovoid fruit, with five valves, is 11 × 7cm with yellow to orange conical spines, 1–1.2 cm long. The 2 cm long brown seeds are covered in a dark red, thin, tasteless aril. It is rare in Sabah, but common in Sarawak and Kalimantan on sandy soils in mixed hill dipterocarp forest to 150 m.

6. ***Durio grandiflorus*** (Mast.) Kosterm. & Soeg.
'*durian hantu*' (ghost), '*durian hutan*' (forest)

A tree 30–40 m, usually a lower canopy tree with low buttresses. The white flowers are arranged in cymes of 2–3 flowers in the axils of the leaves and along the branches. In full flower the tree is very ornamental. The stamens are arranged in 5 bundles and the flowers are scented. The fruits, with five valves, are ellipsoid, 13–20 × 10–15 cm and are a grey to bluish-green in Sabah (may be orange-yellow in other parts of Borneo), with conical spines 10–15 mm long. The fruits split open on the tree, the valves opening out fully to reveal the black seeds covered in a thin red, edible, leathery aril (may have a yellow aril in other parts of Borneo), that is often prepared as a relish, eaten with rice by local tribes in Borneo, who sometimes cultivate it in villages. It is found in mixed lowland to hill dipterocarp forest and secondary forest. The fruits are favoured by hornbills and squirrels.

Fig. 10. *Durio grandiflorus.* Photo: A. Lamb.

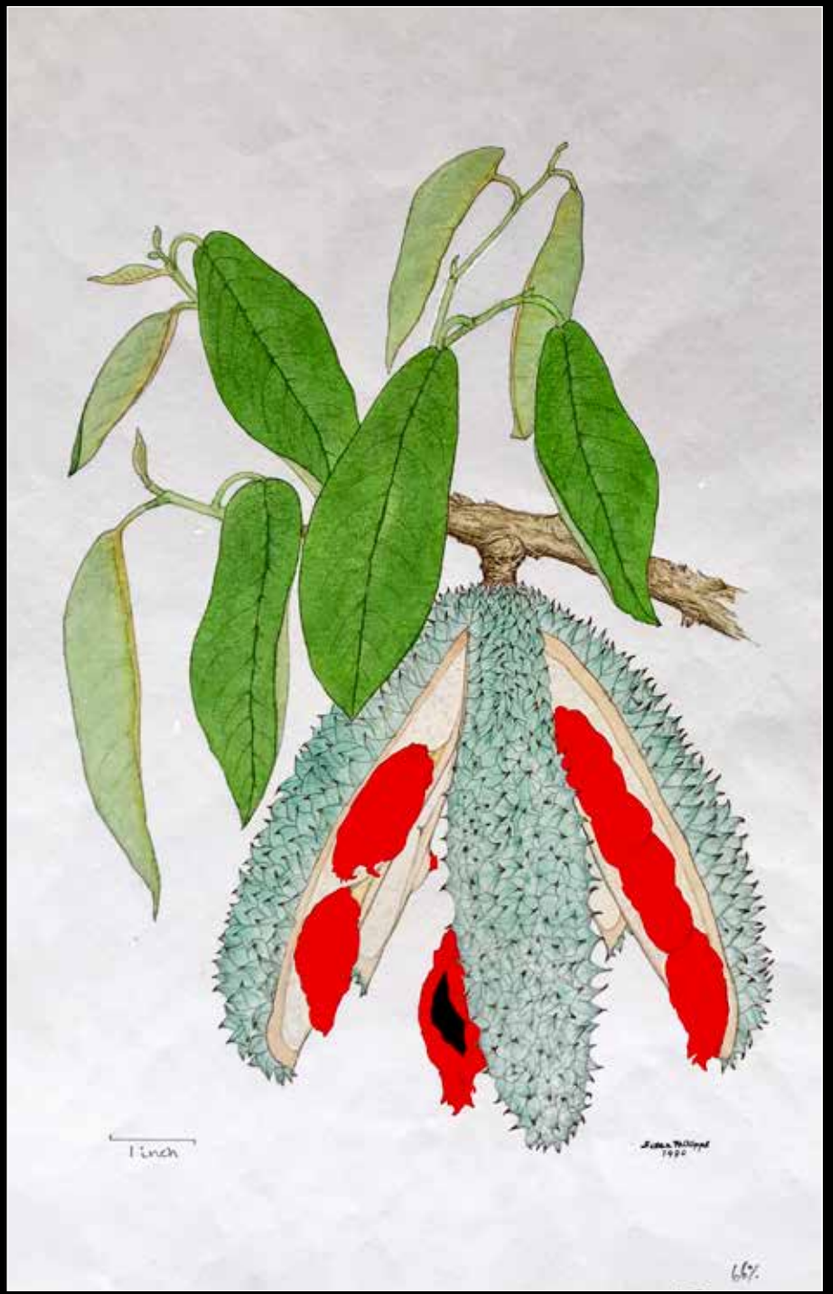

Fig. 11. A watercolour painting of the fruit of *Durio grandiflorus* by Susan Phillipps. Photo: C.L. Chan.

Fig. 12 (left). *Durio grandiflorus* in flower. **Fig. 13** (right). A young fruit of *Durio grandiflorus*. Photos: A. Lamb.

7. ***Durio graveolens*** Beccari.
'*durian burung*', '*durian merah*', '*durian kuning*' (Malay),
'*durian dalit*' (Sabah).

A tall tree to 50 m, forming part of the main forest canopy, with a trunk or bole to 25 m, with buttresses. The large leaves have distinctive coppery-brown scales and hairs on the underside. The inflorescences can form dense masses along the branches with clusters of 3–4 cymes with 2–6 flowers per cyme. The large, open white flowers have stamens arranged in five clusters. The yellow to orange or green fruit are globose to ovoid, 7–19 × 10–16 cm, with the five valves splitting open on the tree when ripe, to reveal a yellow or red edible aril covering the seed. The fruit is covered in long conical spines, 1.5–3 cm long, covered in scales. The large brown seeds are 3–6 cm long. The edible aril, in the red form, tastes like avocado with a similar oily texture. However, trees with yellow to orange arils, sometimes mixed with red, have a more cheesy texture, with a more pungent odour. This species prefers lowland mixed dipterocarp forest on clay soils and sometimes is found in more swampy forest. However, it is also found on sandy soils, along rivers and along ridges up to 300 m. This is a commonly cultivated and popular species in Sabah.

Fig. 14 & 15 (above & below). *Durio graveolens*. Photos: A. Lamb.

Fig. 16 & 17 (above & below). *Durio graveolens.* Photos: A. Lamb.

Fig. 18 & 19 (above & below). *Durio graveolens.* Photos: A. Lamb.

8. ***Durio griffithii*** (Mast.) Bakh. (syn. *D. acutifolius* (Mast. Kosterm.)).
'*durian monyet*', '*durian tupai*'.

An understorey tree to 30 m, with fluted buttresses, the undersurface of the leaves mostly covered in dense stellate hairs and not so many scales. However, a variety found in Sabah that was previously described as *D. acutifolius* does have the undersurface covered in scales. It was sunk into a variety, as the flowers and fruits are the same as *D. griffithii*. The tree appears to flower and fruit throughout most of the year. The small flowers are white to cream or with pink stamens and petals and are solitary or in cymes of 2–3 flowers, with 10 or more narrow cream petals and nearly 100 stamens in two whorls that are white to cream, sometimes turning pink. The red fruits are small, 4–6 × 1.5–2 cm wide, with small conical red spines 2–3 mm long. The fruits split open with 2–3 valves, and become reflexed. The black seed, 2 cm long, is partly covered at the base with a thin orange to red tasteless aril. The seeds normally drop to the ground, whereas the reflexed valves remain on the tree. The seeds with arils are reputed to be collected and the aril consumed by squirrels and monkeys. The variety *griffithii* is distributed in Sumatra, Peninsular Malaysia and Borneo, whereas var. *acutifolius* is endemic to Sabah, Sarawak and Kalimantan. The species has no use with local tribes, neither for fruits nor timber.

It is found on a wide range of soils in lowland to hill mixed dipterocarp forest to 900 m, and occasionally in heath forest.

Fig. 20. Flowers of *Durio griffithii.* Photo: A. Lamb.

Fig. 21. *Durio griffithii* showing the brilliantly-coloured fruits with three valves. Photo: A. Lamb.

9. ***Durio kinabaluensis*** (Bakh. ex Wyatt-Smith) Kosterm. & Soeg.
'*durian tapuloh*' (Dusun)

A tree to 40 m tall with a bole of 10–15 m, with buttresses. The inflorescences are arranged in clusters, ramiflorous along the branches in branched cymes of 5–6 large pink-petalled flowers with 5 whorls of pink stamens. The fruits, with 5 valves, are globose to ovoid, yellow to yellowish brown, 9–10 × 8–10 cm, with conical spines 1–1.5 mm long, covered in scales. Fruits fall unopened to the ground when ripe. The c. 3 cm long, brown ellipsoidal seeds are covered in an edible, thinnish, creamy, sweet aril, treasured by the Dusun people. The species is found in hill forest from 700–c. 1200 m near Mount Kinabalu and in the Crocker Range and is endemic to Sabah. It grows on ridges and slopes in mixed hill dipterocarp forest and is often part of the main canopy. It is rarely utilised for timber as the trees are conserved for their fruits, and it is also planted around villages in these hill areas.

Fig. 22. Pink flowers of *Durio kinabaluensis.* Photo: A. Lamb.

Fig. 23. Young fruits on the tree of *Durio kinabaluensis.* Photo: A. Lamb.

Fig. 24 & 25 (above & below). *Durio kinabaluensis*. Photos: A. Lamb.

Fig. 26 & 27 (above & below). *Durio kinabaluensis*. Photos: A. Lamb.

10. ***Durio kutejensis*** (Hassk.) Beccari.
'*durian kuning*' (Brunei), '*durian luas*' (Sabah),
'*durian lai*' (Sabah, Kalimantan)

A medium-sized understorey tree 20–25 m with a short bole and small or no buttresses, and a low branching habit. The inflorescences are in clusters, 2–3 flowers in a cyme, along young and older branches. The flowers have very showy, large red petals, with over 20 reddish stamens. The greenish yellow to yellow fruits are globose to ovoid or oblong, 8–22 × 8–14 cm. The fruits are distinctly 5-lobed, with pyramidal spines 1–1.3 cm long. When ripe, the fruits drop to the ground before the five valves split open. The ellipsoid brown seeds, c. 3–4 cm long, are covered in a thick, creamy, yellow to orange or pink aril, with usually no or slight fragrance. The aril is dried into a fruit paste, or eaten raw and the unripe fruits are sometimes cooked as a vegetable. The tree is sometimes cultivated, but its small size means it is of no use for timber. It is an understorey tree in lowland mixed dipterocarp forest, in alluvial valleys and on the lower slopes of surrounding hills to 300 m in the south-eastern part of Sabah, where the fruits are quite popular.

Fig. 28. *Durio kutejensis* fuiting on the branches. Photo: A. Lamb.

Fig. 29. *Durio kutejensis.* Photo: A. Lamb. **Fig. 30.** *Durio kutejensis.* Photo: Anthea Phillipps.

Fig. 31. *Durio kutejensis* showing the distinct lobes. Photo: A. Lamb.

Fig. 32 (above). *Durio kutejensis.* Photo: A. Lamb. **Fig. 33** (below). Dark pink flower of *Durio kutejensis.* Photo: Sylvester Gimil.

11. ***Durio lanceolatus*** Mast.
'*durian beludu*' (Malay), '*durian burung*'

A main canopy tree to 50 m, with a clear bole up to 25 m, with large buttresses. The lower surfaces of the leaves are covered in a dense layer of coppery scales. The inflorescences are in clusters, ramiflorous along the older branches, with 3–4 fragrant flowers per cyme. The flowers have yellow petals. The small to medium-sized, ellipsoid fruits, 5–10 cm in diameter, have orange to orange-brown pyramidal spines to 6 mm long. The fruit, which has five valves, splits open on the branch, revealing the 3 cm long, brown seeds covered in a tasteless cream to yellow aril. It is consumed by hornbills and squirrels. The fruits are not consumed by people, but the tree is a commercial timber species. It occurs in lowland to hill mixed dipterocarp forest mainly on sandy soils and is common in Kalimantan and Sarawak.

Fig. 34. *Durio lanceolatus.* Photo: A. Lamb.

Fig. 35. A fruiting tree of *Durio lanceolatus*. Photo: A. Lamb.

Fig. 36 & 37. *Durio lanceolatus.* Photos: A. Lamb.

12. ***Durio oblongus*** Mast.
No Malay name; '*nyekak*' (Sarawak Iban)

An understorey tree to c. 30 m, with buttresses. It has large oblong leaves, from 14–40 × 7–10 cm, with the lower surface covered in coppery scales, and the upper surface with hairs. The inflorescences are in prolific clusters along the older branches and consist of cymes of 3–5 flowers with white petals and white stamens with many anthers, the basal part of the filaments fused into a tube. The obovoid to ellipsoid, yellow to orange fruits, 8–15 × 7–11 cm, with 5 valves, some forming distinct lobes, are covered in conical spines 1–2.5 cm long, covered in stellate (branching) hairs. The ellipsoid brown seeds, 3.5–4.5 cm long, are covered in a thin, red, edible but tasteless aril, which is slightly sweet. In Sarawak the Kelabit and Iban tribes collect the flowers which are dried or eaten raw as a vegetable and the young fruits are also cooked and eaten as a vegetable. The aril is also sometimes separated from the seed, salted, and used in cooking as a condiment. It is rare in Sabah, found in mixed hill dipterocarp forest up to 300 m. The fruit is not known in Sabah but its timber is used in construction.

13. ***Durio oxleyanus*** Griff.
'*durian sukang*' (Sabah)

A large tree of the main canopy to 50 m, with a bole to 25 m and large buttress roots. It has relatively large leaves, c. 10–20 × 3–8 cm, with a lower surface covered in distinct stellate hairs and no scales except on the midvein. The inflorescences form dense clusters of small flowers, ramiflorous along the branches, in shortly branched cymes of 5–15 flowers, with 4–5 white to cream petals, and four bundles of white stamens. The globose, green fruit, 8–18 cm

Fig. 38. *Durio oxleyanus.* Photo: A. Lamb.

Fig. 39 & 40 (above & below). *Durio oxleyanus*. Photos: A. Lamb.

diameter, has 4 valves, and has conical green spines, 1–3 cm long, often curved, pointed and covered in stellate hairs. The fruit drops to the ground and is hard to open. The dark brown seeds, 3–4 cm long, are covered in a thick, white to cream or pale yellow aril that is creamy and sweet with a pleasant fragrance. The fruit is popular and considered to be the second best durian to eat after '*durian puteh*' (*D. zibethinus*). The aril is also preserved with salt, to store for use in cooking as a condiment. The petals of the flowers are eaten fresh or dried and cooked as a vegetable. The unripe fruits are also cooked as a vegetable. The timber is a light hardwood, but the tree is rarely felled, as the fruits are popular and it is widely cultivated. It is found in lowland to mixed hill dipterocarp forest, in valleys, near rivers and on hill slopes to 850 m.

Fig. 41. *Durio oxleyanus.* Photo: A. Lamb.

Fig. 42. *Durio oxleyanus.* Photos: A. Lamb.

14. ***Durio testudinarius*** Beccari.
'*durian kura-kura*' (Malay), tortoise durian.

A medium tree to 40 m, which is low-growing and often remains as an understorey tree. In orchards it can get taller. Older trees can have a slightly fluted base to the bole, which is 3–5 m. Flowering is cauliflorous, the flowers produced in bosses on the bole, but mostly around the base of the tree near the ground (in reach of tortoises). Inflorescences are in cymes of 2–4 flowers, or solitary, but can be in clusters of cymes to form a mass of flowers. The flowers, with large white petals, have white stamens in which the basal part of the filaments is fused to form a tube containing nectar, and the free apical parts of the filaments, with several anthers, surround the style and stigma. It is most likely pollinated by hawk moths (night and/or day species), or spiderhunter birds in the daytime. The yellowish-brown fruits are born singly or in clusters on the bole or around the base of the tree. They are ovoid to globose, often with distinct lobes, 10–15 × 8–10 cm, splitting open on the tree, or sometimes falling to the ground, and have pyramidal spines 5–8 mm. The 3–4 cm long, ovoid, brown seeds are covered in a thin, watery to creamy, edible, sweet, aril, cream to white in colour, with an unusual aroma. There is no hint of 'durian' flavour, and some people liken the flavour to caramel custard.

Fig. 43. *Durio testudinarius.* Photo: A. Lamb.

Fig. 44. *Durio testudinarius.* Photo: A. Lamb.

Fig. 45 (above). The white flowers with stamens forming a tube in *Durio testudinarius*.
Fig. 46. *Durio testudinarius.* Photos: A. Lamb.

There are two varieties found in Sabah, var. *testudinarius* and var. *crassifolium* Salma, the latter having more leathery leaves with conspicuous lateral veins on both surfaces. The species is found in lowland primary mixed dipterocarp forest to 150 m. In Sabah it is not common, as most of the lowland forest has been cleared for oil-palm and it is rarely cultivated. It is more common in cultivation in Brunei.

15. ***Durio zibethinus*** Murray.
'*durian*', '*durian puteh*' (Malay, referring to the white aril), '*durian biasa*' (common durian), '*durian kampung*' (village durian)

A tall, main canopy tree to 50 m, with a straight bole to 20 m, with short buttresses. Flowering is ramiflorous, mostly on older branches, with branching cymes of 4–8 large flowers, that can form dense clusters. The flowers produce copious nectar and a strong, sweet, honey-like fragrance, which attracts bees and bats in particular. The large, green to yellowish-green to brownish fruits fall unopened to the ground when ripe, where they split open into 4–5 valves. The fruits are globose to ovoid, obovoid or oblong, sometimes lobed, 13–31 × 16–25 cm, with

Fig. 47. *Durio testudinarius*. Agriculture Park, Tenom. Photo: A. Lamb.

Fig. 48. *Durio zibethinus*. Photos: A. Lamb.

Fig. 49 (above). Flowers of *Durio zibethinus.* Photo: A. Lamb. **Fig. 50** (below). Feasting on *Durio zibethinus.* Photos: A. Phillipps.

Fig. 51. *Durio zibethinus.* Photo: A. Lamb.

broad pyramidal to conical spines, covered in scales. The 3–5 cm long, ovoid to ellipsoid, brown seeds are covered in a thick, creamy, sweet aril, white to cream to pale yellow or pale orange in colour, with a strong odour. The special delicious flavour, often with a bitter aftertaste, makes it very popular. Truly wild trees in Sabah (from which selected varieties have been planted in villages) usually have a greyish-white aril, also with a bitter aftertaste, but these cultivars are just as popular as the very creamy, sweet Thailand cultivars. In Borneo, wild trees mostly produce fruit in alternate years. Uses, apart from eating the fresh arils, include cooking the unripe fruit as a vegetable or in curries. The aril is also separated and dried as fruit paste. Commercially, the aril is used in many products, as already mentioned.

NOTES

This article is based on knowledge gathered over many years working for the Department of Agriculture in Sabah, where I was involved in collecting and establishing species of the wild fruit trees of Sabah in germplasm collections at the Research Stations in Ulu Dusun in Sandakan and in Tenom, as well as from many years working with botanists at the Forest Research Centre at Sepilok and at the herbarium of the Royal Botanic Gardens, Kew. Information has also been gathered from referring to published literature, as enumerated in the references, and in particular, to work by James La Frankie Jr. (Philippines) and Idris Salma (Malaysia).

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