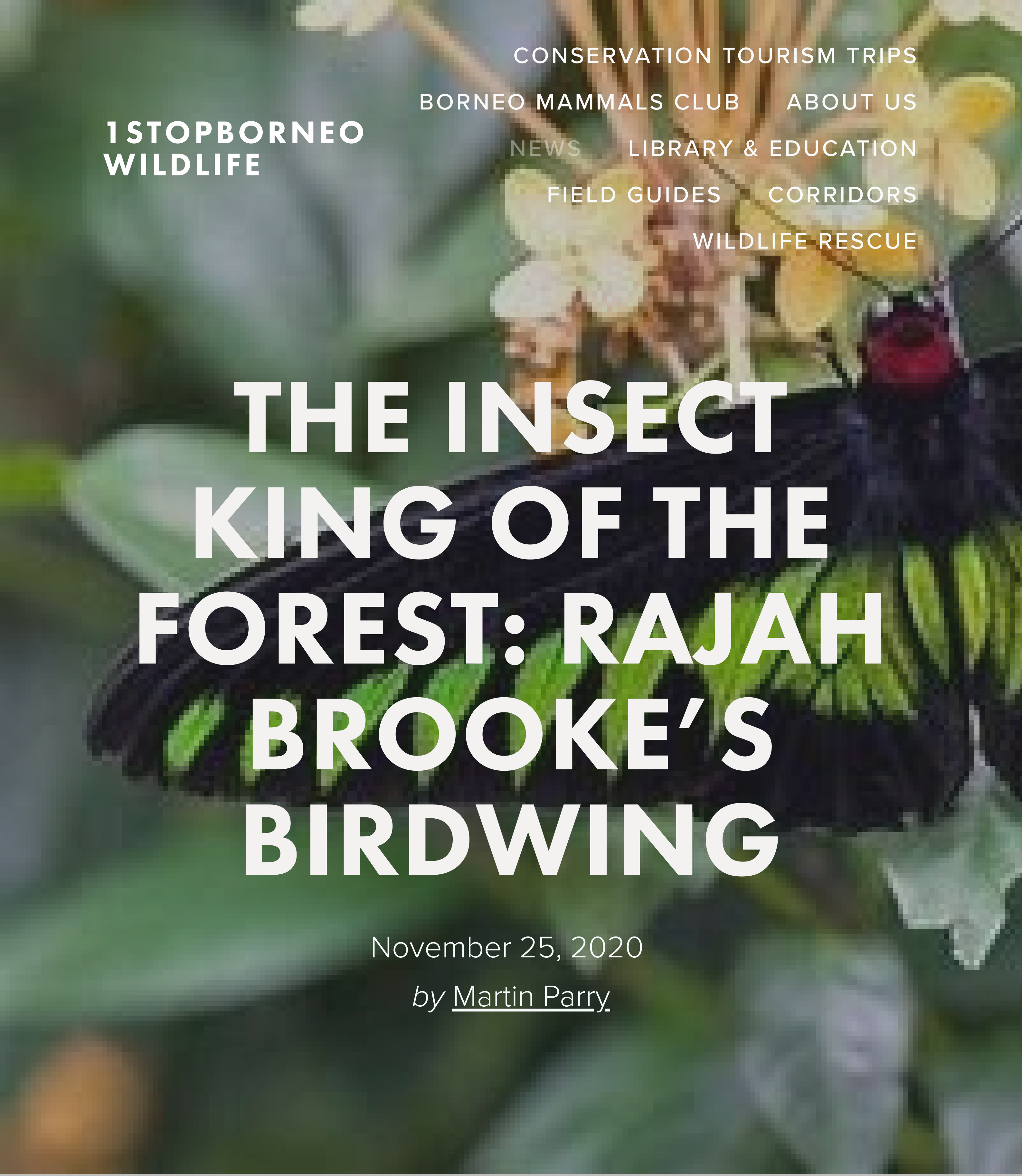

THE INSECT KING OF THE FOREST: RAJAH BROOKE'S BIRDWING

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Introduction

Rajah Brooke's Birdwing (RBB) is Malaysia's national butterfly, being found in rainforests of Peninsular Malaysia as well as in Sabah and Sarawak. In his book *The Malay Archipelago*, Alfred Russel Wallace describes how he named the butterfly after James Brooke, the first 'White Rajah', after enjoying his hospitality in Sarawak; this was in 1855 but of course it would have already been very familiar to many local people before that date because it is such a large and attractive insect. It is no surprise that Wallace describes feelings of intense emotion when he first encountered species of birdwing butterflies: they are all large and, for a European like him, display colours far more brilliant and exotic than his native butterflies.

The classification of the birdwings remains a little unclear, with the total number of species being estimated at between 20 and 30 and they are distributed across the tropical regions of the Indian subcontinent, S.E. Asia and Australasia. They are split into 3 genera: *Trogonoptera, Troides* and *Ornithoptera*, with Rajah Brooke's birdwing now confirmed as *Trogonoptera brookiana* (*T. brookiana*) despite being originally named by Wallace as *Ornithoptera brookiana* (literally, 'the birdwing of Rajah Brooke' translated to Latin).

Ornithoptera remains the largest genus, containing several species observed by Wallace during his travels in Indonesia, including Wallace's Golden birdwing that he named *O. croesus* (Croesus was an Ancient Greek king who is thought to have been the first monarch to issue gold coins as a currency). The genus also includes the world's largest butterfly species, Queen Alexandra's birdwing, which is rare and confined to parts of Eastern Papua New Guinea; as with other birdwings, the female is the larger sex with a staggering wingspan of 25-28cm (the male is 16-20cm); in contrast the wingspan of Eurasian Tree Sparrow is just 20cm.

Rajah Brooke's birdwing (RBB)

The male RBB shown in *Figure 1* illustrates a consistent feature of birdwings: its large wings are angular; what such a photograph cannot show, however, is their characteristic fluttering, bird-like flight.

Figure 1: Adult male Rajah Brooke's Birdwing; at rest the forewings obscure the upper portion of the hind wings.

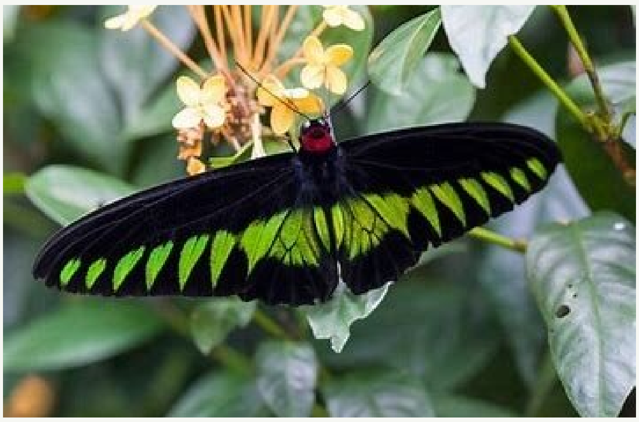


Figure 1: Adult male Rajah Brooke's Birdwing; at rest the forewings obscure the upper portion of the hind wings

https://www.weather2travel.com/images_blog/rajah-brookes-birdwing.jpg

The male has a wingspan of 16-18cm and *Figure 1* shows how each upper forewing displays 7 tooth-shaped ‘electric green’ markings on a velvet black background; the upper hind wing has a similarly coloured patch of green. The head is a bright red and matched by red markings on an otherwise black body. The larger female illustrated in *Figure 2* (her wingspan is 17-19cm) has browner wings, giving a less dramatic overall effect; she has white flashes at the tips of her forewing and at the base of the hind wing, which also has an area of glossy blue near the abdomen.

Figure 2: Adult female Rajah Brooke’s Birdwing The female is less colourful than the male; at rest, the butterfly’s forewings are partially covering the hind wings but leaving their blue patches exposed.

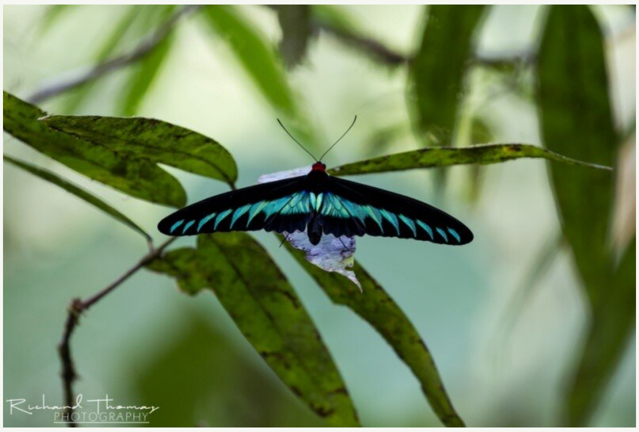
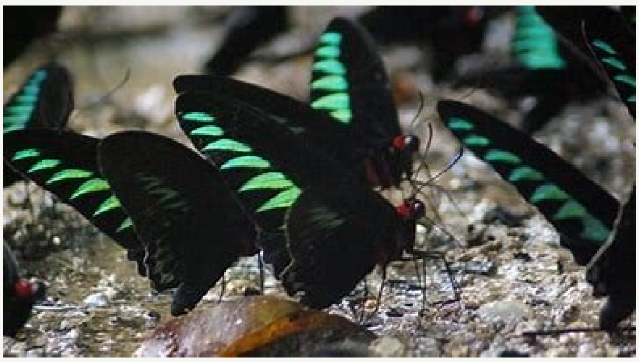


Figure 2: Adult female Rajah Brooke’s Birdwing The female is less colourful than the male; at rest, the butterfly’s forewings are partially covering the hind wings but leaving their blue patches exposed.

Image included courtesy of Richard Thomas.

This butterfly clearly shows sexual dimorphism. It is not surprising that the brightly coloured male is seen more often and, although thought of as a ‘jungle’ species, in regions where the RBB occurs he is not uncommon along the banks of forest streams, often at quite low elevations. When Wallace first discovered RBB, he complained that he was only able to capture males and only later was he able to acquire specimens of the dowdier female. Initially, this would have been a concern for him since he was first and foremost a collector, supporting his travels in the region by the sale of exotic birds, butterflies and beetles back in Europe. People building their own private collections would pay more money for a pair rather than individual butterflies. It is shocking today to realise that men such as Wallace caught large numbers of animals, preserved them and shipped them back to UK for their agents to sell. In his ‘*The Malay Archipelago*’, for example, he recorded that in one area in the Moluccas, he was able to obtain >100 pairs of *O. croesus*. He certainly wasn’t a conservationist!



The female of RBB not only differs in appearance but also in behaviour, being more rarely seen at very low altitudes. She spends most time in the canopy, often up to 10 metres from the ground; Yong (1989) describes her being on the wing later than the male, especially in the early evening, and only descending to the forest floor in the early morning. The males, in contrast, may be seen during the day settling together in moist areas at river banks where they 'puddle' to obtain minerals from the damp soil. This behaviour of 'puddling' (*Figure 3*) is common amongst many species of butterfly and offers a good opportunity to observe them since they may congregate in quite large numbers and settle for long enough for good sightings.

Figure 3: Male Rajah Brookes puddling on mud; when feeding in this way, adult males are likely to be visible to predators.

Image included courtesy of blogspot.com

Biological significance of differences in appearance and behaviour of adult sexes

The male RBB has a confident and obvious flight and this, together with his bright colours, may give the impression that he is almost flaunting himself. The less colourful female is more difficult to see as not only is she less colourful but also she flies less frequently in areas where she might be spotted. These differences are shared by many species but they are more obvious in such large and colourful butterflies. Perhaps the study of such a large butterfly can help us to understand why there are such consistent differences between the sexes of many butterflies?

If the male RBB didn't seem to fly in such a way that seems to deliberately to advertise himself, it would be tempting to think that the green and black colour of his upper wings might be a camouflage strategy when flying in a rainforest habitat, where there is often a dark and green backdrop. But this confident flight doesn't match a camouflage strategy. In addition, these colours don't offer camouflage when puddling in open areas such as by the side of rivers. Although highly visible to potential predators such as birds, the RBB birdwing doesn't seem to be at a disadvantage. It seems likely that his obvious colours and confident flight have an important role in attracting females for mating; they may also help individual males establish a territory to patrol when searching for females. In other words, behaviour and appearance may have the same function as the assertive behaviour, feather colour and song of many male birds. Since the need to successfully mate and produce offspring is paramount, characters that ensure such success are hugely advantageous.

However, the birdwings illustrate another defensive behaviour seen in some larger butterfly species: their bright colours, large wings and obvious flight act as warning signals. This is *aposematism*, in which potential predators are warned that these butterflies are unpleasant to taste. By signalling 'I am unpleasant to eat', a butterfly's strategy is based on the ability of a predator to learn, after one unpleasant meal, not to attack other members of the species. The bigger and more visually striking, the quicker the lesson is learnt and so the fewer butterflies lost. The larger and more brightly coloured butterflies will be more likely to survive long enough to successfully mate; this ‘selection of the fittest’ illustrates driving force behind evolution of species.

Life cycle

The toxicity of the adult RBB is acquired from the larva as it undergoes metamorphosis in the pupa (chrysalis). The chemicals responsible are sequestered (stored) by the larva as it feeds on the leaves of a woody liana, *Aristolochia foveolata* shown in *Figure 4*; this species is one of over 500 in the genus *Aristolochia* but is the only one on which the larvae of RBB have been found in the wild. Its distribution in SE Asia seems to coincide with that of RBB. Goh (1994) describes how a RBB larva will remain on its host plant for 31 days, moulting 4 times as it increases in size, before pupating on the plant’s stem; throughout this period, *A. foveolata* metabolites will accumulate within the larva’s body without affecting its ability to feed or the later metamorphosis into the adult butterfly.

At least 14 other species of the Papilionidae have been described as having *Aristolochia species* as their larval food plant, including other birdwings such as the Cairns Birdwing of Australia. These plants have been used extensively in ancient medicines, notably Chinese, Greek, Roman and Egyptian, and have been prescribed for a range of conditions, such as arthritis in Chinese herbal medicine. The plants produce active metabolites which can be seen as being both beneficial and harmful to animals since some have been associated with renal disease and even some cancers after ingestion by humans and all products of the genus are banned from use in Europe. In contrast, some are still available for use elsewhere in the world as medicines, for example in China.

Figure 4: Aristolochia foveolata

It is clear that this plant can be toxic to both humans and other vertebrates; the ability of RBB to accumulate metabolites *of A. foveolata* after eating the leaves of the plant has proved advantageous to help protect them from being eaten by bird predators. This strategy may have evolved from a much ‘broader evolutionary battle’ between herbivorous insects and the plants on which they feed: plants produce toxic chemical defences; insects then develop the means to inactivate these toxins. An insect species that can inactivate or sequester a plant toxin so that it avoids harm, will gain an advantage over insect species that cannot, since these will tend to avoid the plant, leaving the 'inactivating' insect larvae with no competition for their food source. Ultimately, the insect may become totally dependent on the single plant species as its food source; it is described as *monophagous*, since the larvae seem to be unable to feed on any other plant. RBB appears to have evolved to become monophagous, feeding only on *A. foveolata*, with little or no competition from other insects for its larval food source. As with other butterflies, adult RBB only feed on nectar, which they take from a range of flowering plants.

Figure 4: Aristolochia foveolata

Image included courtesy of: www.earth.com/earthpedia/plant/pl/aristolochia-foveolata/

However, being monophagous brings with it a challenge: the female must lay her eggs on just one species of plant and so must be able to detect the larval host plant in the rainforest; she probably uses chemoreception for this, being able to detect the profile of chemicals produced by *A. foveolata*. Once mated, her sole purpose becomes the detection of this larval host plant on which she can lay her eggs (oviposition). We can begin to understand why she is less brightly coloured and behaves in a more secretive fashion: she needs to avoid predators whilst she searches and oviposits. Monophagy carries with it a high risk: if the larval food plant is destroyed, for example due to forest destruction or a change in climate, the RBB female, if she is truly monophagous, cannot lay eggs on an alternative host; the life cycle is broken and the butterfly will die out since a new generation cannot develop. The alternative is to fly over greater distances to search for *A. foveolata* in another area of the forest, exposing her to possible predation but also using precious time and energy.

The importance of aposematism

Aposematism is found in a range of tropical butterfly species. For example, RBB is just one of 135 species in 12 genera displaying aposematism and grouped into the butterfly tribe, Troidini, within the Papilionidae family. Adults of all these species are unpleasant to taste; most are predominantly black in colour with red or yellow colours on the thorax and pink or red areas on the hind wings. The Rajah Brooke's Birdwing is the best known in Malaysia but the genus *Ornithoptera* contains even more dazzling species, for example The Common Birdwing (*T. helena*) and The Golden Birdwing (*Troides amphyrysus*) that are both found in Borneo.

The behaviour and morphology of both male and female RBB have evolved, therefore, to enable successful completion of their life cycle in a highly competitive environment. The aposematism displayed by the male enables it to fly freely during mate selection with reduced risk of predation, assuming that the predators learn to avoid the unpalatable males.

This learning will involve the loss of some males as they are 'tasted' by birds before they learn, but these losses are offset by the subsequent protection of other males. The female, whilst still distasteful, is less conspicuous, enabling her to detect *A. foveolata* and lay her eggs, monophagy relies on her, not the male, as she alone must ensure the larvae hatch on their specific food plant. These are sophisticated strategies and illustrate the powerful evolutionary pressures that continually apply to plants and animals in the rainforest.

The continuing evolution of *Trogonoptera brookiana*

The pressure of natural selection means that species do not remain unchanged but are continually evolve to ensure their long term survival. In his description of the life cycle of RBB, Goh (1994) listed 11 subspecies (races) of RBB, distinguishable by morphology and geographical distribution. For example, he described *T. brookiana albescens* as occurring in Peninsular Malaysia, in the states of Pehang, Perak and Selangor, whereas *T. brookiana trojana* was found on the island of Palawan in the Philippines; in fact this latter subspecies is now classified as *Trogonoptera trojana* so that the genus now contains two species. Whilst all other subspecies are still in the genus, *T. brookiana*, they have, over time, spread into different areas of their range and, as populations have become more isolated, so through experiencing subtle changes in selective pressure, for example different predators, their morphologies and behaviours have changed sufficiently to produce distinguishable subspecies; in the future, this process may, ultimately, result in new species, unable to interbreed. Today's RBB offers evidence of the continuing power of natural selection, famously described by both Wallace, in present day Indonesia, Papua New Guinea and Eastern Malaysia, and by Darwin, for example in the Galapagos islands of Ecuador, whereby species continually adapt, ensuring the 'survival of the fittest'.

Reading the descriptions of the travels of Darwin and Wallace somehow conjures up an innocent time for scientists, when European 'men of science' travelled to distant lands and made new discoveries about the natural world. Their books and papers made them famous and eventually these two collaborated to describe how natural selection was responsible for the evolution of new species.

The future

Today, discovery of *new* species is much rarer but, instead, there is growing concern about the threat of extinction of *existing* species because of the impact on the natural world of human activities. The link below to the website of the Natural History Museum in London describes how many scientists now believe that we are living in a new geological epoch, the

Anthropocene, characterised by the significant and lasting impact of the human race on the Earth and its flora and fauna. https://www.nhm.ac.uk/discover/what-is-the-anthropocene.html

Although there is currently no agreement on when this epoch began, various suggestions include the detonation of the first atomic bombs in 1945 or the 'Industrial Revolution' in the 19th century; both of these are very recent events in the history of the Earth. It is clear that global warming, destruction of rainforests and rising levels of plastics in the oceans are important characteristics of the Anthropocene today. Unlike the time of Wallace and Darwin, many scientists are now openly referring to a 'time of mass extinction' caused by the impact of humans on the natural world. Whilst evidence of previous mass extinctions is seen in fossil records millions of years old, these were not caused by human activity; there is now an increasing realisation that the disappearance of species is not only being caused by humans but is also happening over dramatically short periods of time.

Recognising this, can offer opportunities to take action to slow or even prevent extinctions. In Borneo, monitoring the impact of human activity on rainforests and their biodiversity should provide information to guide interventions. Tropical regions of the world, for example our rainforests, are where natural selection, driving evolution, is regarded as being amongst the most intense on the planet. But these are also regions where human activity continues to have a dramatic impact, for example through forest clearance for agriculture, housing and road building. Monitoring the changes to the flora and fauna of the rainforest often involves observations on 'indicator species', species which are regarded as being 'ecological indicators'. If the populations of these animals or plants are in decline, then it is likely that more widespread declines in less visible species are also occurring. Some butterflies of the rainforest may be good indicators: their presence and abundance can indicate of the condition of their rainforest environment.

Finlay (2020) reviews how the monitoring of some butterfly populations in Europe is demonstrating the impact of climate change on these indicator species adapted to temperate climates. For example, as European temperatures rise, some butterfly species are expanding northwards into cooler regions: intense selective pressure is resulting in rapid population change. Often, it is the impact of climate on host plants as well as butterflies themselves that is most significant, so that the insect life cycle becomes 'out of step' with the larval host plant, in other words when the larvae hatch, the plant isn't available to feed on. A relationship that had evolved over hundreds of thousands of generations has broken down in a much shorter period; these butterflies are almost certainly indicating what is happening simultaneously to large numbers of less visible species.

In Malaysian rainforests, it is reasonable to argue that RBB is a key indicator species: a stable population, a decline in abundance or even a rise in its numbers should provide important information on the general state of the rainforest. Such observations may indicate trends amongst a whole range of invertebrates, which in turn feed on plants as well as serving as food for many predators, including birds, amphibians and mammals.

So how well is the ‘poster boy’ of Malaysia’s butterflies responding to the enormous and rapid selective pressures that we have discussed? Today, its distribution is described as the Thai-Malay Peninsula, Borneo, including Brunei, Natuna, Sumatra and islands west of Sumatra but do we know if its abundance in these areas is decreasing or increasing? Which sub-species are thriving and which are in decline? Do we know if *A. foveolata*, its larval food plant, is thriving or under threat? Perhaps it is time to find answers to these questions.

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- Figure 1: Male Rajah Brookes Birdwing:

  https://www.weather2travel.com/images_blog/rajah-brookes-birdwing.jpg accessed 23.11.20
- Figure 2: Female Rajah Brookes Birdwing: courtesy of Richard Thomas
- Figure 3: *Trogonoptera brookiana* puddling: courtesy of *blogspot.com* accessed 23.11.2020
- Figure 4: *Aristolochia foveolata: courtesy of www.earth.com/earthpedia/plant/pl/aristolochia-foveolata/ accessed 23.11.20*

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