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Brief Documentation of Terrestrial Ecosystem in Kubah, Bako, and Santubong National Park, Sarawak

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ABSTRACT

The state of Sarawak is blessed with vast wilderness and thriving wildlife (Abu Bakar et al., 2016). The state has a flourishing biodiversity, ecology, and environment, packed with amazing national parks, which are world-renowned. The parks are home to lush tropical rainforests and peculiar wildlife, all of which can be found in natural parks such as Kubah, Bako, and Santubong National Park. This documentation was briefly notes biodiversity, ecology, and environment-related information in the exceptionally rich ecosystems of flora and fauna of these national parks.The documentation was aimed at observing and documenting the ecosystem in Kubah, Bako and Santubong National Parks to assess future needs for ecosystem and education for a sustainable future. The documentation is also targeted at creating awareness on ecosystem and education, inspiring sustainable development goals, studying the selected flora and fauna of the area, and boosting the academic, research, and development value. Multiple perspectives for biodiversity, ecology, and environment of the parks such as scientific, historical, geography, values, cultural, and sustainability (Tan et al., 2009) are significant in the forming of a valuable framework for sustainable development. The outcome of the observation comprised a basic discovery of the mangrove ecosystem, pitcher plant, plant-animal interaction, and invertebrates in the parks. These have enabled the short and basic research documentation from the park's ecosystem as well as presentation where valuable findings were shared.

Keywords: biodiversity, ecology, environment, national park, sustainable development goal

INTRODUCTION

The state of Sarawak is blessed with vast wilderness and thriving wildlife. The state has a flourishing biodiversity, ecology, and environment, packed with amazing national parks which are world-renowned. There are 42 national parks all over Sarawak. The parks are home to lush tropical rainforests and peculiar wildlife, all of which can be found in these natural parks such as Kubah, Bako, Santubong National Park. This article briefly documents the biodiversity, ecology, and environment-related information in the exceptionally rich ecosystems of flora and fauna in these national parks.

This study is aimed at observing and documenting the terrestrial ecosystem in the Kubah, Bako and Santubong National Parks to assess the future needs of the ecosystem, to educate and create awareness of the ecosystem for a sustainable future. Multiple perspectives for biodiversity, ecology, and environment of the parks such as scientific, historical, geography, values, cultural, and sustainability (Tan et al., 2009) are significant in the forming of a framework for sustainable development.

The observation and documentation activity was conducted in the Kubah, Bako, and Santubong National Parks, with permission obtained from the Sarawak Forestry Corporation.

The objectives of the observation and documentation activity, which were achieved, comprised the basic discovery of the mangrove ecosystem, pitcher plants, plant-animal interaction, and invertebrates.

DOCUMENTATION METHODS

Pre-documentation Preparation

The documentation activity was conducted by the students from Life Sciences Unit, Centre for Pre-University Studies, Universiti Malaysia Sarawak. A day trip visit was arranged to the assigned location to conduct trekking, observation, documentation and recording pertaining to the topics given.

Prior to the fieldwork, the students attended a series of lectures encompassing the learning units of biodiversity, ecology, and environment. In particular, the students learned about ecological diversity, taxonomy and classification of the plant kingdom system as well as threats to and conservation of biodiversity. Training was also conducted on ecological principles, ecosystems, quantitative ecology, ecology and environment in Sarawak, and the conservation status of the environment in Malaysia.

In addition, a briefing was conducted just prior to the visit in order for the students to engage with a proper plan of study, including time, selection of location, type of ecosystem, and distance or area of documentation. At that stage, the students had performed a literature review and pre-analysis of the Kubah, Bako, and Santubong National Park's ecosystems in order to establish a framework of selected studies.

Study Site

The study area is located in Kubah National Park (1° 36' 45.9"N, 110° 11' 49.2"E) (Figure 1). The park is located around 25 km from the Kuching city centre, and is a partially undisturbed natural forest situated on a small sandstone plateau which includes Gunung Selang, Sendok and Serapi. The parks also consist of five main vegetation types of forest namely lowland mixed dipterocarp, kerangas, alluvial, submontane and high mixed dipterocarp forest (Wahab, 2012).

Bako National Park is located at 1° 42' 59.99" N, 110° 27' 59.99" E (Figure 1). The park comprises approximately 2,742 hectares of a rugged sandstone peninsula in the south western region of Sarawak, at the tip of the Muara Tebas Peninsula, about 30 kilometres northeast of the Kuching city centre, with an altitude ranging from sea level to 244 m (Yee & Chin, 1984). Denudation over long periods of time has created this plateau into a unique landscape which offers excellent opportunities for field studies in geology and biology (Wilson, 2002).

Meanwhile, Santubong National Park is located on the Damai Peninsula (1°45′46″N 110°19′20″E) (Figure 1), which is 35 km north of the Kuching city centre. This park is covered with rainforest up to a height of 810 m. It also includes 231 hectares' lowland of dipterocarp forest and kerangas (heath) forest with sandy soil (Mohd Azlan et al., 2019) . The park also has a few geographical features such as sandstone layer dip with a gentle slope of 10 to 200 m from the summit to the Park Headquarters (Mohd Azlan et al., 2019).

The Kubah, Bako, and Santubong parks have invited pertinent people to promote the sustainable development, conservation and well-being of the natural environment (Teo et al., 2013). Various research in these parks had been carried out by the Sarawak Forestry, and educational and research institutions, to support conservation and sustainable development while highlighting the eco-education of Sarawak (Hanan, 2014; Lateef et al., 2015; Mohd Azlan et al., 2019; Poulsen & Leong-Škorničková, 2017; Zahidin et al., 2016).

Field Observation

For all parks, the students conducted observation and documentation activities by hiking in the forest along a predetermined trek. Sampling method was set out to be random and all forest ecosystem at close distance (approximately 5 m) was observed and documented. Detailed documentation and recording was done at every 100m interval of the trail treks. Documentation of observation was made via physical notes, photographs and videos. Preliminary identification was made during the visit, but the detailed analysis was performed once students returned to the campus.

In the Kubah National Park, the students conducted the observation and documentation activities by trekking from the Park Headquarters at 0m up to the Waterfall Trail, which is a distance of 1,600 m (150-450 m altitude). The trek, which took about 2 hours, passed through kerangas and mixed dipterocarp forest until it reached the riverine

forest at the Rayu river valley. The trail had some steep and slippery sections, and showed a consistent descent into the river valley (Boyce & Yeng, 2008). *Nepenthes* plant species and plant-animal interaction were identified along the trek.

At the Bako National Park, observation and documentation activities were conducted by trek from the Park Headquarters, Teluk Assam to Teluk Pandan Kecil, a journey of 1.5 km taking 2 hours. The trekking passes through a sandy beach surrounded by sandstone formation, climbing through the forest until it reached an open plateau covered with shrubs. The trail demonstrated the cliff vegetation, dips in and out of the tall kerangas forest, and damping at certain areas (Wilson, 2002). Mangrove ecosystem along the trek was recorded.

In Santubong National Park, the trek began from the Park Headquarters at 0m up to the Santubong Jungle Trekking Trail, which is a distance of 2,000m taking about 2 hours. The trekking passed through jungle streams, dip pools, and waterfalls. As the trek got higher in altitude, the gradient became steeper, and the vegetation types gradually changed (Mohd Azlan et al., 2019). Invertebrate species were identified along the trekking journey.

Ecosystem Identification

Records of pitcher plant, mangrove ecosystem, plant-animal interaction, and invertebrates in the respective parks which were initially recorded were further categorized according to the scientific name. A brief analysis of the collected data was done based on reference metadata, scientific and academic books, articles, journals and official-related website to finalize the obtained results.

Figure 1: Map of Kubah, Bako, and Santubong National Parks, Sarawak. (Source: www.etawau.com)

SIGNIFICANT DISCOVERIES FROM THE FIELD TRIP

The documentation of Nepenthes in Kubah National Park

The Kubah National Park was established in 1989 and opened to the public in 1995. The park has an outstanding variety of flora and fauna species and has one of the wildest selection of palms and orchids in Borneo (Pearce, 1992; Poulsen & Leong-Škorničková, 2017). It is situated 22 km north west of Kuching city centre and covers an area of 2,230 hectare which consists of heavy forest slopes and ridges of the Serapi range (Figure 1) (Boyce & Yeng, 2008). The park comprises virgin natural forest with five main vegetation types which are alluvial forest, lowland mixed dipterocarp forest, kerangas (heath) forest, submontane forest, and secondary forest (Teo et al., 2013). The park is habitat to a diversity of wildlife; it has exceptionally rich plant life including ferns, palms, orchids, and pitcher plant. There are six well-marked trails which are the Waterfall, Rayu, Main, Selang, Summit, and Belian trails.

Pitcher plant is under family of *Nepenthaceae*, kingdom of plantae and a genus of *Nepenthes*. The morphology of the plant comprises a leaf-like lid, a digestive zone, a collar-like peristome (the lip) which is an entrance to trap the prey as it is slippery and often quite colourful. The purpose of these properties is to attract, capture, retain and digest small animals (Wahab, 2012). The prey is unable to escape due to the downward-pointing hairs inside the pitcher.

Nepenthes may grow in a few environments such as high humidity, dense and shaded forest, clear-cut forest, roadside, and disturbed field. However, most of the *Nepenthes* species were found to inhabit areas at the altitude of 1,200 m or 3,937 feet above sea level (Adam et al., 1992). This explains why the plant is mostly found in Borneo montane forest. *Nepenthes* are significant in Kubah National Park because they act as ecological filters by altering the properties of their fluid microenvironment, hosting selected communities in nature, and acting as environmental pollution markers because they grow in soil that has little nitrogen (Chan et al., 2016; Greenwood et al., 2011). Therefore, *Nepenthes* need to be conserved because the plant is important for its ecological function. Conserving *Nepenthes* meaning conserving the ecology associated with the said plant and the surrounding communities (Gaume et al., 2016; Setiawan, 2017).

Nepenthes ampullaria is a small, low growing pitcher plant with sizes varying from an average of 2 to 5 cm (Figures 2.a and 2.b, and Table 1). It is a swamp dwelling species that grows alongside the Summit Trail and prefers hot and humid environment. It has a little pot shaped pitcher with narrow, backward turned lids and colours varying according to altitude. The species was observed at the altitude of 400 to 500 feet, usually displaying a pure green colour. The species is mostly found partially filled with rainwater enriched with digestive enzymes secreted by glands on a waxy internal wall. At altitudes ranging from 600 to 900 feet, this species usually displays a green colour with irregular patterns of red patches. *Nepenthes ampullaria* at higher altitude are morphologically different compared to that at lower altitude. It was found typically on higher reaches of climbing stem, narrowly funnel-shaped, often not upright, and contains no liquid or prey. This species also displays a prominent hairy wing. It is heat tolerant and survives well at hilly terrain (Adam & Hamid, 2007; Handayani et al., 2005; Wahab, 2012). Generally, *Nepenthes ampullaria* is quite good at catching large insects, such as stink bugs, wasps, and ants to gain nutrients. The majority can be found at the hill area as it prefers the shade of relatively dense, damp, and woody vegetation.

Nepenthes hirsuta is a green pitcher plant with occasional red blotches either on its surface or internally (Figure 2.c and Table 1). It has little hairs on its side including a lid above its peristome. What differentiates *Nepenthes hirsuta* from other species are usually its slightly rounded lower part and an acute apex. *Nepenthes hirsuta* is a terrestrial plant and was found along the trail of Gunung Serapi at the elevation of 2,100 feet. The biggest size found during the trip was more than 15 cm. It can also be found in montane forests, which refers to any montane ecosystems found in mountains and kerangas forests in Borneo (Adam et al., 1992; Moran et al., 2013).

Nepenthes mirabilis is a light green pitcher plant with irregular pattern of red patches in its internal surface (Figure 2.d and Table 1). It can be easily distinguished by its thin and lean elongated structure. Generally, it has a slight bulge circling the upper part of the structure between the peristome and the cup. The species also displays a significant thin wing (Adam & Hamid, 2007; Adam et al., 1992; Bunawan et al., 2017). The species was observed at an altitude of 2,500 feet with a length of 15 cm hanging off small, branched plants in open forest and a wet environment.

Figure 2: Pitcher plant documented at Kubah National Park. a: *Nepenthes ampullaria* (Green-red speckled) b: *Nepenthes ampullaria* (Bau Green) c: *Nepenthes hirsuta* d: *Nepenthes mirabilis*

Table 1: Description of *Nepenthes ampullaria* (Green-red speckled), *Nepenthes ampullaria* (Bau Green), *Nepenthes hirsuta*, and *Nepenthes mirabilis*.

Scientific name	*Nepenthes ampullaria* (Green-red speckled)	*Nepenthes ampullaria* (Bau Green)	*Nepenthes hirsuta*	*Nepenthes mirabilis*
Colour	Green with red spots	Green	Green	Green
Characteristics	▪ Lower and upper stems: cylindrical ▪ Stem diameters: 4 to 7 mm thick ▪ Leaves: shortly petiolate ▪ Lamina: spathulate ▪ Apex: round ▪ Mouths: horizontal and ovate, flat, and vertical in the inner part ▪ Lids: narrowly cuneate		▪ Leaves: coriaceous, not-strongly petiolate ▪ Canaliculate: spathulate or obovate ▪ Apex: acute or roundish ▪ Stem: covered with long brown hairs ▪ Hairs: not bristle ▪ Longitudinal: veins not prominent	▪ Leaves blade: acute to rounded ▪ Pitcher wings: simple, bearing multicellular fringe elements ▪ Leaves texture: chartaceous ▪ Stem: simple or rarely decurrent for 1/3 the length of the internode ▪ Gland density: 1,600 to 2,500 per cm^3 ▪ Position (upper pitcher): mid-way to lower half ▪ Position (lower pitcher): lower third to quarter
Size	▪ Stem: can climb up to 15 m (light brown) ▪ Leaves: up to 25 cm long and 6 cm width (light green) ▪ Urceolate: small, rarely exceeding 10 cm in height and 7 cm width		▪ Diameter: 7 cm or more ▪ Leaves: less than or equal 20 cm	▪ Stem: up to 3.5 cm thick ▪ Height: up to 150 cm ▪ Leaves: 30 cm long and 10 cm width ▪ Scrambling stem: up to 40 cm long and 15 cm width
Habitat	Damp level to 2,100 m altitude, shady forest from sea.		Grow at elevation at of 200 to 1,100 m. Mostly on sandstone substrate	Most abundant in disturbed, swampy sites, or grassland. Mostly found at low altitudes (200 m) and rarely at 1,400 m.

The documentation of plant-animal interaction at different elevation levels at Kubah National Park

The vegetation at Kubah National Park consists of mixed dipterocarp forest with some patches of scrub forest (Figure 1). The park is also home to a wide selection of palms and orchids (Pearce, 1992; Poulsen & Leong-Škorničková, 2017). Covering an area of 2,230 hectares, the park essentially consists of a sandstone plateau which includes three mountains, Gunung Serapi, Gunung Selang and Gunung Sendok. At elevations of 150 to 450 m the plateau is broken by bands of hardened limestone (Boyce & Yeng, 2008). The existence of layers of hard and soft rock at the lower elevations has resulted in a series of waterfalls and bathing pools located in beautiful jungle settings. The highest point of the park is Gunung Serapi. The well built trekking road leading to the peak of Gunung Serapi offered a good opportunity to observe any elevational changes in flora and fauna.

Species diversity along elevation gradient is of great interest as species occurrence varies with elevational band. In this regard, the plant and animal interaction at different elevations had received more attention as they were easier to observe. Species diversity on the mountains usually decrease with increasing elevation as the size of the area reduces with altitude (Corlett & Primack, 2005; Gray et al., 2017). There are three types of animal-plant interaction which are commensal, antagonistic, and mutualism.

This trip was conducted to observe and document plant and animal interactions in Kubah National Park at different elevations in order to note their differences therefrom. This interest is increasingly important due to current threat to biodiversity, ecology, and environment. In Kubah National Park, possible and potential threats can be attributed to human activities such as extinction, fragmentation, degradation of habitat, spread of invasive species, unsustainable use of natural resources, overexploitation, and climate change (IUCN, 2017; Othman & Wan Daud, 2012). Elevation diversity information will also help to specify the conservation need of a species by its elevational preferences, so that better conservation practices will be achieved in future.

The park covers a broad attitudinal range, which is from less than 20 to 777 m above sea level. However, except for low-lying areas (more than 33 m) in the west and southwest, most of the park is hilly. The south and southeast of the park comprise a hilly dissected area rising to 777 m in the southeast and 716 m in the south but not including the summit of Gunung Serapi to the southeast, or Gunung Bawang and Gunung Matang to the east. The topography of the area largely corresponds to its geology with the sedimentary terrain being heavily separated and the areas of old alluvium-forming lowlands (Poulsen & Leong-Škorničková, 2017; Teo et al., 2013). The tree canopy of a lowland forest has three layers. The upper layer towers at between 30 to 40 m, with occasional giants of 60 m, while the second layer is between 23 to 30 m. The lower level was made up of trees of several species. Specific combinations of light intensity, temperature, wind, and exposures to precipitation further determine where the tree species occur within generally accommodating forest canopies (Teo et al., 2013). This trip was conducted to observe plant-animal interaction at three different elevations which are more than 100 m (Park Headquarters), 400 m (more than 1,000 feet) and more than 700 m (more than 5,000 feet) (Table 2 and Figure 3). The lowland forest of the park is complex, dense and species-rich. The term “tropical lowland forest” is used to describe a forest where there is little or no seasonal water shortage and where the climate is continuously warm and humid (humidity can reach 100% at night) (Brahim, 2005).

Table 2: Description of plant-animal interaction in different elevation levels at Kubah National Park.

Elevation	Organism and Interaction Characteristics		Type of Interaction
	Plant	**Animal**	
100 m	Scientific name: *Cheilocostus speciosus* Kingdom: Plantae Family: Costaceae	Scientific name: *Lasius niger* Kingdom: Animalia Family: Formicidae	Mutualism (Figure 3.a)
	The plant gives the food and nutrition to the ant.	The ant helps to disperse the plant seed. Ants take the seed back to their home where they eat and discard the seed into a very fertile area. This helps the seed to grow and develop into new plant.	
100 m	Scientific name: *Calophyllum ianigerum* Kingdom: Plantae Family: Clusiaceae	Scientific name: *Nephilia pilipes* Kingdom: Animalia Family: Araneidae	Commensalism (Figure 3.b)
	Tree as a host.	The spider builds the web between the trees.	
100 m	Scientific name: *Podocarpus polystachyus* Kingdom: Plantae Family: Podocarpaceae	Scientific name: *Brookesia micra* Kingdom: Animalia Family:Chamaeleonidae	Commensalism (Figure 3.c)
	Act as host and shelter for the lizard.	Live in the tree trunk. They also deposit eggs in a small burrow in the tree.	
100 m	Scientific name: *Ficus elastica* Kingdom: Plantae Family: Moraceae	Name: Frog's egg	Commensalism (Figure 3.d)
	Has wooden stem.	Frog lay eggs on this tree to make sure that the eggs are safe from predators. When the eggs hatch, the tadpoles drop into water below.	
400 m	Scientific name: *Arundina graminifolia* Kingdom: Plantae Family: Orchidaceae	Scientific name: *Junonia hedonia* Kingdom: Animalia Family: Nymphalinea	Commensalism (Figure 3.e)
	Foliage: Its alternate leaves are grass-like. Found occurring naturally in lowland secondary forests, right up to higher altitudes in the montane forests. Its natural habitats include open areas, grassland, mountains, and rock places by stream.	Wingspan of adult butterfly: 55 to 60 mm. It can be found in the nature reserves as well as in urban and suburban areas. The butterfly act as a pollinator.	

400 m	Scientific name: *Nepenthes ampullaria* Kingdom: Plantae Family: Nepenthaceae	Scientific name: *Dinomyrmex gigas* Kingdom: Animalia Family: Formicidae	Prey and Predators (Figure 3.f)
	Has enzyme to digest insects. Need nitrogen from insects to grow.	Contain nutrition such as nitrogen. The ants may supply source of nitrogen for plant to grow from various resources such as dried leaves and branches, decomposed and decayed biomes.	
400 m	Scientific name: *Litchi chinensis* Kingdom: Plantae Family: Sapindaceae	Scientific name: *Pyrops candelaria* Kingdom: Animalia Family: Fulgoridae	Parasitism (Figure 3.g)
	The plant acts as a host where lantern bug feeds on its saps.	The bug feeds on plant. Its long, slender proboscis is used to pierce tree bark to reach the phloem.	
700 m	Scientific name: *Dioscorea sp.* Kingdom: Plantae Family: Dioscoreaceae	Scientific name: *Orchamus gracilis* Kingdom: Animalia Family: Pamphagidae	Commensalism and Parasitism (Figure 3.h)
	Have oval shape of leaves. Have rough surface of leaves so that it easier for insect to stay.	Eat insects like ants on the plant. As herbivores, *Orchamus* will feed on shoots or leaves that is available. This will cause substantial damage to the leaves. They also contribute as fertilizer to the plants when they die.	

Figure 3: Plant-animal interaction documented at Kubah National Park. a: *Cheilocostus speciosus* and *Lasius niger* b: *Calophyllum ianigerum* and *Nephilia pilipes* c: *Podocarpus polystachyus* and *Brookesia micra* d: *Ficus elastica* and Frog's egg e: *Arundina graminifolia* and *Junonia hedonia* f: *Nepenthes ampullaria* and *Dinomyrmex gigas* g: *Litchi chinensis* and *Pyrops candelaria* h: *Dioscorea sp.* and *Orchamus gracilis*.

The documentation of mangrove ecosystem in Bako National Park

Bako National Park is the smallest (covering 27 km^2) and oldest national park in Sarawak, since 1957. The park is 37 km north of the city of Kuching (Figure 1) (Mohamad Bukhori et al., 2018). The parks offer the perfect introduction to Sarawak's biodiversity, ecology, and environment. The parks contain a wide range of vegetation, swamp forest, scrub-like padang vegetation, mangrove forest, dipterocarp forest, delicate cliff vegetation and more (Yee & Chin, 1984). In fact, it is possible to observe almost every type of vegetation found in Borneo in Bako National Park.

The park is also home to the proboscis monkey, bearded pig, over 100 species of birds and many more. The trip was conducted beginning at the Park Headquarters, Teluk Assam, for a distance of 1.5 km from the end of the beach through the Telok Pandan Kecil, comprising about 90 minutes of trekking. There are a few types of mangrove trees observed at this area, and there are three dominant types namely, the *Avicennia* species, *Sonneratia* species, and *Rhizophora* species which can be identified by the array of aerial roots descending from the tree into the substrate (Zahidin et al., 2016). The interactions between the mangrove trees and the animals around them are various. The fiddler crabs make holes and whenever the tide is in, they will close their holes. The mudskipper are amphibians, giving them an advantage because they do not have to run away or hide when the tide is in. The mangrove ecosystem is significant in Bako National Park because it is an important feature of tropical coasts and play a crucial role in influencing the ecological health of the inshore and offshore coastal-related ecosystem. The mangrove trees provide a protective barrier to the land and can reduce coastal damage from natural disasters such as heavy storms and tidal waves (Wilson, 2006) (Figure 4 and Table 3). These living things reside with and rely on each other. The ecosystem is diversified with an encircling variety of life forms which have specific roles to play in their surroundings to maintain the balance of the environment (Hanan, 2014). Therefore, the ecosystem needs to be conserved as it is under threat through a variety of destructive human practices. Many aquatic and marine species, including some important to commercial and subsistence reptiles, birds, mammals, insects, plant, algae, and fungi are dependent on mangroves or other river mouth habitats for at least part of their life cycle (Wilson, 2006).

The Red Mangrove, *Rhizophora mucronata* was identified by looking at the type of roots it has which is a prop root (Figure 4.a and Table 3). The prop roots are used for the stability of the tree by providing a broader base and support in the soft and unstable mud. They also help in aeration as they are exposed for at least most of the day between tides. The roots also act as a temporary shelter for some fishes to lay and take care of their eggs (Teo et al., 2013). This tree has small, shiny, and brightly-coloured leaves that make it easier to be identified.

The Black Mangrove, *Avicennia officinalis* has pneumatophores or also known as pencil roots (Figure 4.b and Table 3). This root grows vertically up from the underground root systems. The pencil roots have numerous lenticels that enable gas exchange directly above the surface. The pencil roots provide the additional needed oxygen which cannot be taken from the soil for survival (Low et al., 1994). Furthermore, this tree was identified based on its small and dull green-coloured leaves which are obviously different from that of the *Rhizophora mucronata*. This tree seems to show greater population representation at the observation area as it can grow on a quite dry mud as well as on wet muddy soil.

The Sea Hibiscus, *Hibiscus tiliaceus* are classified under associated mangrove tree while the *Rhizophora mucronata* and *Avicennia officinalis* are under true mangrove. This tree grows in colonies and can grow well on well drained, organic soils, but tolerate salty and sandy ones (Figure 4.c and Table 3). From the observation, the tree cannot grow in the forest nor too close to the high tide area. This tree has tap roots and heart shaped leaves that makes it different from the other mangroves. It is small and shrubby tree with many branches. Since this tree prefers a well-drained area, many fiddler crabs can be found around these tree colonies (Zahidin et al., 2016).

The Fiddler Crab is one of the most common biotic aquatic ecosystems organisms for mangrove trees (Figure 4.d and Table 3). The crab is intertidal and lives in the mangrove forest with suitable soil conditions where it can build burrows for living. The burrow is extremely important as a refuge during high tide, a place of escape from predators and a site for mating and incubation (Zahidin et al., 2016). Fiddler crabs were found in huge numbers living in small, adjacent territories.

The Mudskipper is an amphibian that lives in the burrow and a biotic component for the mangrove ecosystem. From observation, the mudskipper favours a wet and muddy soil which make it easier to be found near the red and black mangroves (Figure 4.e and Table 3), due to the type of root which it can use for survival during high tide. The mudskipper has different ways of breathing depending on where it is . The mudskipper is said to favour muddy areas because it needs to keep its skin wet (Zahidin et al., 2016).

The Proboscis Monkey is endemic to the jungles of Borneo. It can be found at coastal mangroves as it never strays far from it due to its habitat (Figure 4.f and Table 3). They are a highly arboreal species and will venture onto land only occasionally to search for food. They live in groups and are prolific swimmers that frequently leap from tree limbs and hit the water, which makes the mangrove forest a suitable habitat for them. The presence of mangrove trees helps these monkeys to survive as their diet are leaves, seeds and unripe fruits but they will occasionally consume insects as well. The monkey also relies on mangrove trees as a home because various groups of this monkey will move near water at night to sleep (Kombi & Abdullah, 2016).

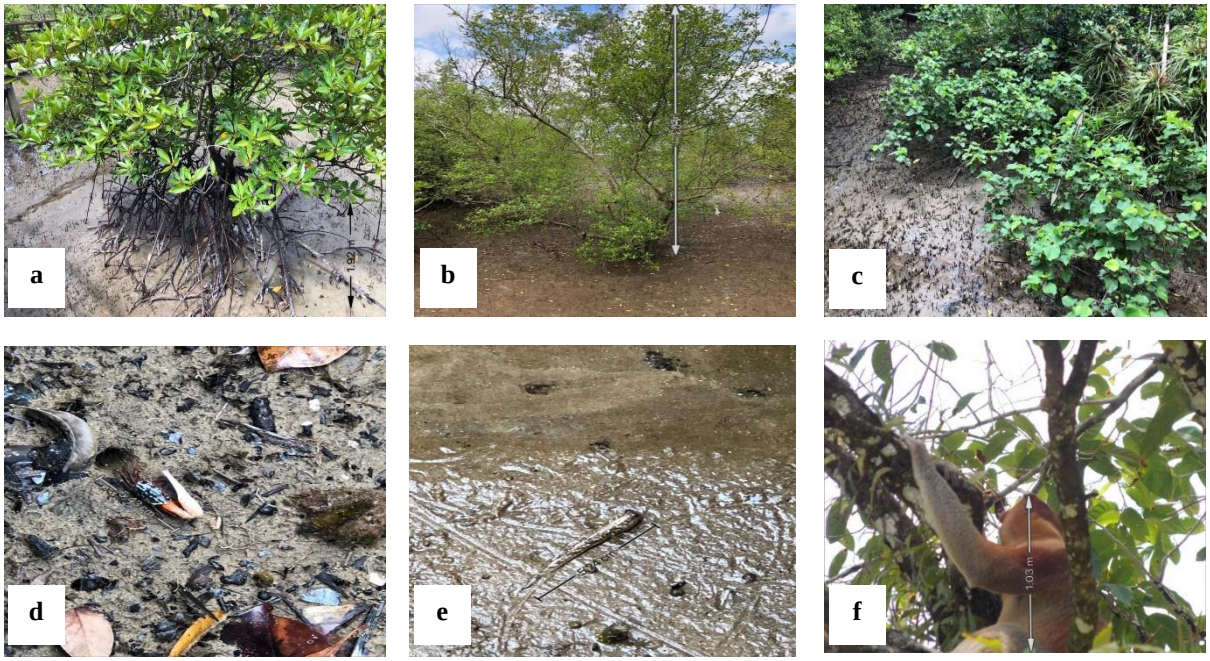

Figure 4: Ecosystem documented at Bako National Park. a: *Rhizophora mucronata* b: *Avicennia officinalis* c: *Hibiscus tiliaceus* d: *Uca annulipes* e: *Periophthalmodon schlosseri* f: *Nasalis larvatus*.

Table 3: Classification of *Rhizophora mucronata, Avicennia officinalis, Hibiscus tiliaceus, Uca annulipes, Periophthalmodon schlosseri,* and *Nasalis larvatus*.

Scientific name	*Rhizophora mucronata*	*Avicennia officinalis*	*Hibiscus tiliaceus*	*Uca annulipes*	*Periophthalmodon schlosseri*	*Nasalis larvatus*
Kingdom	Plantae	Plantae	Plantae	Animalia	Animalia	Animalia
Phylum	-	-	-	Arthropoda	Chordata	Chordata
Class	Magnoliopsida	Magnoliopsida	Magnoliopsida	Malacostraca	Actinopterygii	Mammalia
Order	Malpighiales	Lamiales	Malvales	Decapoda	Perciformes	Primates
Family	Rhizophoraceae	Acanthaceae	Malvaceae	Ocypodidae	Gobiidae	Cercopithecidae
Genus	Rhizophora	Avicennia	Hibiscus	Uca	Periophthalmodon	Nasalis
Species	*R. mucronata*	*A. officinalis*	*H. tiliaceus*	*U. annulipes*	*P. schlosseri*	*N. larvatus*
Common name	Red mangrove	Black mangrove	Sea Hibiscus	-	Belacak Lumpur	Proboscis monkey

The documentation of invertebrates in Santubong National Park

The observation was conducted primarily to document various species of invertebrates in the park, including the habitat and niches which were possibly and potentially effected by environmental impact such as pollution, development, climate change, and tourism. Invertebrates are significant in Santubong National Park because they are crucial components of food webs and fulfill many ecosystem services, such as pollination, biological control agent, decomposition, and nutrient release (soil, water, and nutrient regulator) (Demies et al., 2008). Therefore, invertebrates need to be conserved because they have a right to existence, provide aesthetical impacts, are legally mandated, and provide valuable ecosystem services (Zahidin et al., 2016).

The park is located on the Damai Peninsula, which is 35 km north of Kuching city centre (Figure 1). This park is steeply covered with rainforest to 810 m. It also includes a 231 ha lowland of dipterocarp forest and kerangas

(heath) forest with sandy soil. The park also has a few geographical features such as sandstone layer dip with a gentle slope of 10 to 200 m from the summit to the Park Headquarters (Mohd Azlan et al., 2019). There are two official trails at the park, namely Mount Santubong Summit Trail and Santubong Jungle Trek Trail. It was decided to take the Jungle Trekking Trail for observation and documentation of invertebrates. The trekking passed through jungle streams, dip pools, and waterfalls and was approximately 2 km in distance (1 to 2 hours journey). As the trek gained altitude, the gradient became steeper, and the vegetation types gradually changed. The altitude affected the composition of invertebrates in terms of types and number according to ecological gradient (moisture and drought air, dense and open forest, and plant and animal interactions) (Bunawan et al., 2017; Gilbert et al., 2018).

The *Melanoplus ponderosus* is a grasshopper which is also known as ponderous spur-throat grasshopper (Figure 5.a and Table 4). The species may appear as a yellow, orange, or green insect with additional brown or red colour. The body may be spectacularly coloured in some cases, with bands, spots or blotches throughout its surfaces and the antennas are generally short (Mohd Azlan et al., 2019). It can be found in the fields and open meadows, travelling from place to place.

The *Dinomyrmex gigas* is a type of ant that was very noticeable and easy to observe because of its big size (Figure 5.b and Table 4). They live in colonies. It is black and reddish brown in colour, and has five segments which are the antennae, head, thorax, abdomen, and legs. The pair of antennae on its head senses its surroundings. The head (black) contains the compound eyes, antennae, and mandible. The ant has six pairs of legs attached to the thorax, which is the centre-body section (Demies et al., 2008). In its natural habitat, the ant lives in a nest that is built in a dead tree or in rotting logs and stumps because it prefers to infest wood that is moist and rotting. Wood that has been wet previously may be soft enough to allow the ants to hollow it out and produce a colony; hence simultaneously, the ants aid in the decomposition of dead, decaying trees. They gather food and water to feed the colony and gnaw out the wood to make more areas in which the colony lives. The ant is not poisonous and does not have stingers, but the bite of the ant can still hurt because of its large mouth parts (Mohd Azlan et al., 2019).

The *Pseudopolydesmus serratus* is a millipede and known as thousand-legger (Figure 5.c and Table 4). It was found on the forest floor. The millipede requires a lot of moisture, so they tend to live in damp areas such as under the rocks, in the leaf litter, rotting logs and occasionally in burrows. It has twelve body segments, two pairs of legs attached to each body segment, one pair of antennae and chewing mouth parts. The amount of water they lose will usually be reduced because they are surrounded by a moist environment. In physical adaption, their bodies, or exoskeletons are covered with a waxy coating that held moisture and reduces water loss when they are active on a dry surface (Mohd Azlan et al., 2019). Millipedes protect themselves by curling up into a spiral whenever they feel threatened. This protects their soft undersides.

The *Harmonia axyridis* is a type of beetle which is also known as Asian lady beetle and it could hardly be seen because of its small size (Figure 5.d and Table 4). It is a typical coccinellid beetle. The species was found on the wood bark of a tree. It is often found on deciduous trees, flowering plants, and other plant species found in open areas. It has eight body parts and ranges from 5.5 to 8.5 mm in size. The size is small, hemispherical in shape, and can be found with and without spots (Mohd Azlan et al., 2019). The colours may vary from red, orange to a dull cream.

Figure 5: Invertebrates documented at Santubong National Park. a: *Melanoplus ponderosus* b: *Dinomyrmex gigas* c: *Pseudopolydesmus serratus* d: *Harmonia axyridis*

Table 4: Classification of *Melanoplus ponderosus*, *Dinomyrmex gigas*, *Pseudopolydesmus serratus*, and *Harmonia axyridis*.

Scientific name	*Melanoplus ponderosus*	*Dinomyrmex gigas*	*Pseudopolydesmus serratus*	*Harmonia axyridis*
Kingdom	Animalia	Animalia	Animalia	Animalia
Phylum	Arthropoda	Arthropoda	Arthropoda	Arthropoda
Class	Insecta	Insecta	Diplopoda	Coleoptera
Order	Orthoptera	Hymenoptera	Polydesmidae	-
Family	Acrididae	Formicidae	Polydemmidae	Coccinellidae
Genus	Melanoplus	Dinomyrmex	Pseudopolydesmus	Harmonia
Species	*M. ponderosus*	*D. gigas*	*P. serratus*	*H. Axyridis*
Common name	Grasshopper	Ant	Millipede	Beetle

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