

BIODIVERSITY ASSESSMENT AND UPDATED CHECKLIST OF FAUNAL DIVERSITY IN BAKO NATIONAL PARK, SARAWAK, MALAYSIAN BORNEO

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Abstract: A rapid assessment was conducted in Bako National Park (BNP), Kuching, Sarawak, Malaysian Borneo based on previous studies, published and unpublished reports. The habitat types in BNP can be classified into Kerangas forest, cliff vegetation, beach vegetation, mangrove forest, riverine (alluvial) forest and mixed dipterocarp forest. Up to date, a total of 224 species comprising 54 families and 18 orders of selected taxonomic groups (butterflies, amphibians, birds and mammals) in BNP were recorded throughout the study period in 2005 to presently. The highest number of species recorded was from class Insecta with relative abundance of 42.86% while class Aves showed the highest recorded number of families with relative abundance of 48.15%. The availability of good food resources, high forest structural and vegetation diversity were the major factors that could influence the density, relative abundance and diversity of faunal diversity in BNP. Periodical biodiversity monitoring of BNP is necessary in the face of potential poaching, local extinction and loss of buffer area to protect the integrity of the park. There are several gaps in our knowledge on the biodiversity of BNP that must be addressed in the near future.

Keywords: Rapid assessment, faunal diversity, relative abundance, abundance, Bako National Park.

Introduction

Bako National Park (BNP) established in 1957, is the first national park to be established in Sarawak (Hazebroek & Abang Kashim, 2000). It is located 37 kilometers from Kuching city. With an area of 2,742 hectares (ha), it is the smallest national park in Sarawak. Beyond the smallest area, BNP contains six types of vegetation, viz., Kerangas forest, cliff vegetation, beach vegetation, mangrove forest, riverine (alluvial) forest and mixed dipterocarp forest. It lies on the Muara Tebas Peninsula (1° 41'N 110° 17'E) surrounded by South China Sea on three sides with coastline providing secluded beaches and rock formations. BNP is well known among local and foreign eco-tourists because of the rich flora and fauna including the endemic and charismatic species *Nasalis larvatus* and many other protected

species, thus providing complete safeguard for the conservation of animals and plants.

Most studies in BNP were done by focusing on selected taxon per sampling period instead of covering many other faunal taxa. Mammals were the most studied taxa in BNP since three decades ago (Start, 1972; Francis *et al.*, 1984; Churchill & Zborowski, 1987). Other studies focused on the ecology and behaviors of endangered flying lemur and Proboscis monkey (Dzulhalmi & Abdullah, 2009; Kombi & Abdullah, 2013), biogeography and genetics of bats and primates (Hall *et al.*, 2004; Rovie-Ryan *et al.*, 2008; Noor-Aisyah *et al.*, 2014) and potentially zoonotic disease (Apun *et al.*, 2010; Thayaparan *et al.*, 2013; Madinah *et al.*, 2014). Meanwhile, there are shortages of knowledge on bird diversity and herpetofauna composition (Mohd Kashfullah Zaini & Abdul

Khalid, pers. comm.) and there was no study recorded for taxon Insecta in BNP.

This study aimed to provide rapid biodiversity assessment of selected fauna in BNP by focusing on four types of taxa, namely, insecta, herpetofauna, aves and mammals. The data collected in this study will be utilized to facilitate the BNP management and monitor of faunal diversity. Besides, this study would be useful in conservation action of endangered fauna and endemic species to fill the knowledge gaps for future fauna studies.

Material and Methods

Sampling was conducted at BNP on the 28 August 2005 until 4 September 2005. Since, then, additional data were also collected and compiled from published and unpublished reports on BNP and unstructured interviews or personal communications with *in situ* park officers (Siali Aban, Kashfullah Zaini, Abdul

Khalid & Abg Mutalib) who were involved in the administration and management of BNP.

There were two field methods used in this rain forest study area where animal trapping and line transects following the methods described by Hall *et al.* (2004), Kumaran *et al.* (2006), Anwarali Khan *et al.* (2007, 2008a, 2008b), Ketol *et al.* (2009), Mohd-Ridwan and Abdullah (2010) and Tingga *et al.* (2012). Animal trapping was carried out at four selected area namely as 1) Tanjung Sapi, 2) Ulu Assam Trail, 3) Lintang Trail and 4) Telok Delima. Meanwhile, line transect was carried along two trails which are Lintang to Teluk Delima and Lintang to Teluk Paku. Between 28 August 2005 to 30 August 2005, sampling was conducted at three selected sites after the preliminary survey which was in Tanjung Sapi, Lintang Trail and Ulu Assam Trail. For the rest days, sampling period was changed to Teluk Delima and Teluk Assam Trails only (Figure 1).

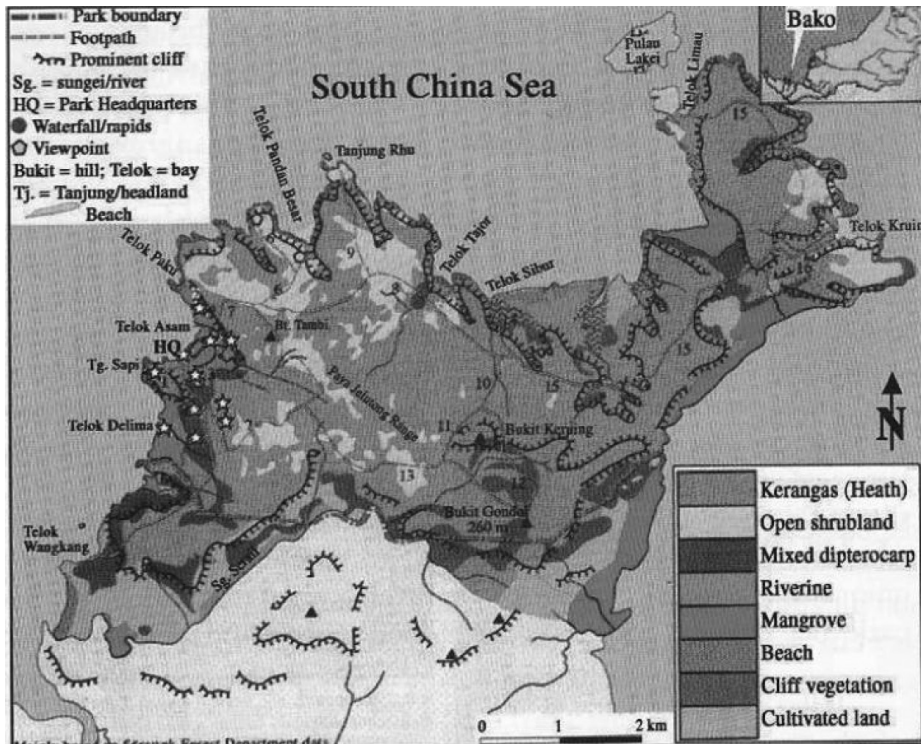


Figure 1: Map showing the trails and type of vegetation at BNP in this study. (Source: Hazebroek and Abang Kashim, 2000)

Each of study site differs based on the forest types and the ecological habitats. The study area can be categorized into two types, namely as disturbed habitat in the beach forest. Others forest areas such as Kerangas forest, cliff vegetation, mixed dipterocarp forest, mangrove forest and riverine forest are categorized as undisturbed areas.

Kerangas forest (KF) – This particular vegetation occupies much plateau area of BNP with forest has its own canopy about 30m high. Dipterocarps are prominent among the larger trees with *Cratoxylon glaucum*, *Callophyllum langigerum* and *Ploiarium alternifolium* are the most dominant tree species. However, the diversity of this forest is very simple and its species compositions are lower than mixed dipterocarp forest in tropical zone by Paijmas (1975). Brown and reddish colors are common amongst the leaves of the canopy which give the filtered sunlight in this forest a reddish-brown hue. The soil is shallow, being leached and particularly poor nutrients accumulation made the leaves biomass in this vegetation was very low compared to other type of forest (Katagiri *et al.*, 1991). They found that, high acidity in soil contents made the nutrient elements were simply leached out and decreased the nutrient absorption from the exterior to the inferior layer.

Cliff vegetation – Sandstone cliff once formed from sediments deposited as a delta with ancient coastline (Onn & Fay, 1989). The porous rock present at Teluk Assam nowadays was the result by natural ecosystem occurrence which the vertical cliff resisted to erosion. There are many small shrubs and herbs with thick leathery leaves that resist drought and salt-spray from the sea. The root systems penetrate cracks and fissures in the rock. They hold the plant firmly in place and gather scarce nutrients. In a few places along the coastal cliff grows the sea almond (*Terminalia catappa*). Small ferns grow round the bases of the trees and shrubs add in dense tuff of grass.

Beach forest (BF) – Herbs and creepers are found above the high tide level on the

beach. Behind this is a narrow belt of trees and shrubs that form the main part of the beach forest. Together these plants protect the land from being washed away by the sea. The beach pandan, *Pandanus odoratissimus* a screw pine with a tree-like habit is common in beach forest. The most conspicuous trees are the tall casuarinas or “rhu-laut” (*Casuarinas equisetifolia*) which grows often in purrs stands.

Mangrove forest (MF) – There are three major types of mangrove forest in Bako where each associated with different coastal habitats. Pedada (*Sonneratia alba*) is the most common tree among sheltered parts of the coast with saline sands and clays such as in Teluk Assam and Teluk Delima. It has a leathery leaves and lines of erect, spike-like breathing roots radiating from the base of the tree. They are pollinated fruit bats which drink the nectar. Sunbirds have also seen drinking the nectar at dawn and dusk. The fruit consists of a green berry seated on a white-purplish star-like calyx. Bakau kurap (*Rhizophora mucronata*) forms almost pure sands near the river mouth as at Lakei River where the clay is less sandy. These trees have long, curved stilt roots that form seemingly impenetrable networks. Api-api (*Avicenna officinalis*) also occurs at this area. On a good night, hundreds of these small insects (fire-flies) may display on one tree, emitting a wonderful vivacious night. “Nipah palms” (*Nypah fruticans*) form dense stands on land that is flooded during high tide for instance at Telok Sibur. The feather-like leaves are huge, reaching a length of 10m and stand erect on an underground stem that creeps through the mud.

Riverine forest (RF) – The most fertile soils occur in the valleys of larger rivers such as the Assam River with sandy clay alluvium. *Coelostegia borneensis* is a stately tree with prominent buttresses. The Malay name is “durian isa” that comes from the woody fruits which resembles durians and are resistant to rot. The presence of many fruit tree makes this forest as a rich wildlife habitat.

Mixed dipterocarp forest (MDF) – This type of forest is found on the deepest and more fertile soils (sandy loams) found on the hills and also on the lower scrap slopes bounding the plateau. Here, drainage is good but moist conditions prevail. There are few ground herbs in this forest and tree seedlings and saplings from most of the ground vegetation. Among the many big dipterocarp trees present, *Anisoptera grossivenia* is remarkable for its bright yellow, fallen leaves which are very conspicuous on the forest floor. Amongst the larger trees are also the members of oak family (Fagaceae). Mixed dipterocarp forest and riverine forest occupy relative modest areas in BNP.

Brief descriptions of methodologies that were used in this study:

Cage trap – In this study, standard 100 cage traps (45cm x 15.5cm x 15.5cm) were used to capture non-volant small mammals such as rodents and scardia. Basically, cage traps were used on the ground and branch of trees and were marked by flagging tape. Three different baits which were bananas, pineapples and sweet potatoes were used. The traps were set at five different habitats which 50 cage traps for each habitat (beach forest, mixed dipterocarp forest, cliff vegetation, kerangas forest and riverine forest). The cage traps were checked or re-baited twice daily at 7.00am and 4.00pm.

Harp trap – Three sets of four-bank harp traps were used to capture volant mammals particularly bats in different habitats. The four-bank harp traps with approximately two meter high and 1.8m wide. All the harp traps were set up along the trail which is identified as the flyway to the bats. At the side and over the harp traps were the natural barriers to increase its effective in captured bats. Checking was done starting from 6.30pm until 10.00pm before re-checked at 6.30am in the next morning. The harp traps were removed from the trails during daytime to give way to tourists who might use the trail.

Mist net – A total of 20 mist nets (2.5m x 12m, mesh size 36mm) were used approximately 0.5 - 2m above ground at the identified areas (Helman & Churchill, 1986; Kunz & Kurta, 1988). The mist nets were used to capture species of volant mammals and aves. Each net were checked daily at two types of time framework of different taxonomic groups; 1) checked between 6.00am until 6.00pm, between 30 minutes to two hours interval (for aves), and 2) checked in the morning at 7.00am and from 7.30pm until 10.00pm (for mammals).

Quadrat – For quadrat sampling precision, eight quadrats sized 5m x 5m was used and located randomly at selected areas along the Lintang Trail (William, 1996). A 20m nylon rope was used to demarcate the quadrat area and ecological characteristics such as intensity of light, moisture, forest litter and vegetation were observed and recorded daily in the morning from 8.00am to 10.00am. The anuran found in quadrat were captured using bare hand and kept in marked plastic bag for identification purposed.

Line transect – Forest and stream transect were done on anuran at Lintang Trail and along the river sides started at 7.00pm to 9.00pm every night. The anuran normally can be found on the forest floor, rock or tree branches based on sighting and anuran vocalization.

Baited trap – This is a passive type trap to capture butterflies by placing the bait with strong fragrance in isolation from the trail with moderate intensity of light (Mohd Jalani Mortada, pers. comm.). Bait was changed once in a few days to ensure the bait was not too rotten for every 20 traps. The distance between each trap was 10m to 20m and rechecked twice per day.

Aerial net – An active method traps that required man power and skill to catch butterfly in the vegetation surrounding. Butterflies were caught by net once they rest on certain spot with quick clapping net over them while on the ground (Upton, 1991).

Identification – Morphological measurement and sex identification of captured species were recorded using calipers, rulers and Pasola weighing scales. Individuals caught were identified based on Payne *et al.* (1998) (mammals), MacKinnon and Phillips (1994) (aves), Inger and Stuebing (1997) (anuran) and Hills and Abang (2010) or comparing to the museum voucher for species of butterfly. A maximum of five individuals for each species were selected for killed and preserved in 95% of alcohol solution. All preservation samples were kept in Museum of Zoology UNIMAS as voucher specimen for future studies following Abdullah *et al.* (2010). Meanwhile, captured butterfly were placed in the triangle envelopes alive and kept in triangle case. Later, all individuals were spread, pinned, dried and labeled inside special wooden boxes (Upton, 1991; Hills & Abang, 2010). Individuals from mammals and aves were only tagged with UNIMAS metal barcode before released with other species into their own habitats.

Results

A total of 224 species comprising insecta, herpetofauna, aves and mammals were recorded (Appendix 1) from unpublished dataset 2005 and additional data from Anwarali Khan *et al.* (2007). Class insecta was the highest species recorded with 42.86% of relative abundance species meanwhile class amphibian was the lowest species recorded (8.93%) (Table 1). The most abundance in family was class aves (48.15%) and the least abundance was class insect (9.26%).

About 3% from 224 species of faunal diversity in BNP are facing extinction threats (endangered (EN) and vulnerable (VU)) so far, 6% are near threaten (NT) and 48% are least concern (LC) due to lesser extinction risk. A total of 1% of species are deficient in data (DD) for assessment meanwhile 42% of species in BNP are not been evaluated (NE) for Red Listed International United for Conservation of Nature (IUCN) (2014) (Figure 2).

Table 1: Relative abundance (%) of selected faunal recorded in this study

	Relative abundance (%)			
	Insecta	Herpetofauna	Aves	Mammals
Order	5.56	16.67	50.00	27.78
Family	9.26	18.52	48.15	24.07
Species	42.86	8.93	27.23	20.98

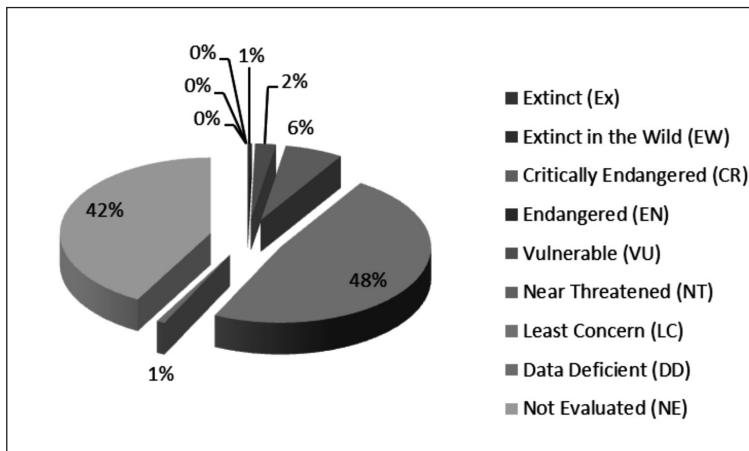


Figure 2: Summary of the selected faunal status in BNP according to IUCN (2014) category in this study

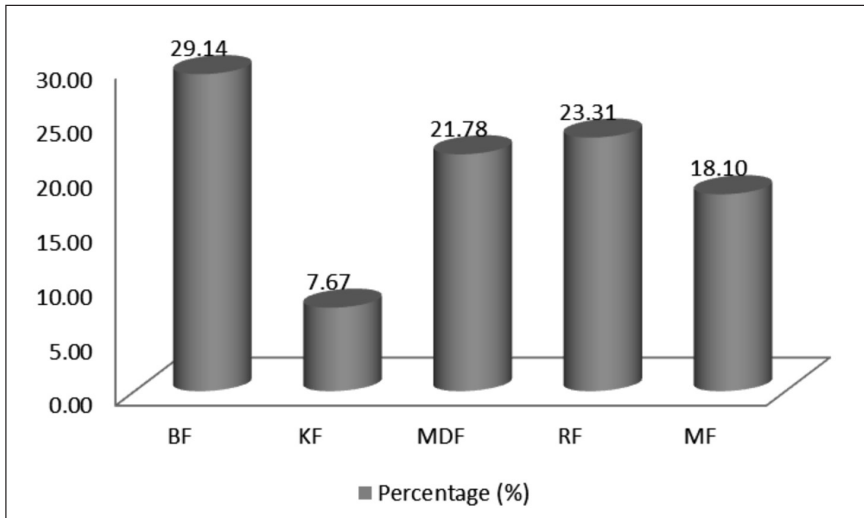


Figure 3: Habitat occupancy of the selected faunal species in BNP in this study.

Figure 3 showed that the summary of habitat occupancy by selected faunal species where the highest occupancy was in BF (29.14%) and followed by RF (23.31%), MDF (21.78%), MF (18.10%) and KF (7.67%).

Discussion

Through this study, species diversity is relatively high of 224 species of fauna were recorded in BNP. It constitutes one endangered species (*Nasalis larvatus*) and five vulnerable species (*Heusemy grandis*, *Sus barbatus*, *Nycteris javanica*, *Tarsius bancanus* and *Maxomys whiteheadi*). Out of this total number, five species were endemic to Borneo Island which is *N. larvatus* and *T. bancanus* for mammals, *Cyornis superba* for aves, *Microhyla petrigena* and *Leptolax dringi* for anuran.

Beach forest recorded the most abundance species whereas Kerangas forest recorded the least number of species in Bako National Park. Most species recorded in the beach forest were mainly from order aves. This might be due to the availability of food resources that attract them there. Kerangas forest can be found on sandstone plateau, cuesta formations and dip slopes especially in Sarawak, Sabah and Brunei (Whitmore, 1984). Kerangas forest has low faunal diversity (Mackinnon et al., 1996).

This study has shown that Kerangas forest have low number of animal diversity due to the low abundance of fruit trees and resources in the habitat.

Conclusion

In conclusion, the availability of food resources might be the major influenced of faunal diversity in BNP since various types of ecosystem lead to the variety of vegetation. The data in this study can be used by BNP management for long conservation action and nature guides to use and inform the eco-tourists on the high diversity of fauna in the area. This is the first checklist to include four taxonomic groups for BNP and we hope that all other protected area in Sarawak would compile and publish similar checklist of biodiversity.

The result of our surveys and literature review since 2005 are not conclusive and there are several gaps in our knowledge on the biodiversity of BNP that must be addressed in the near future. Although the arthropods are the highest in diversity in Malaysia, our survey had listed only the butterflies, leaving a very wide knowledge gap on many other taxonomic groups of insects and other terrestrial invertebrates. Fish, aquatic invertebrates and vertebrates, reptiles, large mammals, shrew

and migratory birds should be surveyed in the future. Survey methods should include such as light traps and malaise traps for insects, pitfall and drift fence for shrews; tracks, feces and feeding signs for mammals; ultrasonic detector for chiropterans, call count for birds and camera trapping for forest floor animals. Vertical stratifications of animals should employ methods like canopy crane, canopy walkway, scaffoldings and unmanned aerial vehicles. Periodical monitoring should be done to cover different seasonal variations (e.g. wet vs. dry; fruiting vs. non-fruiting) within BNP. Depleting of the BNP mangrove forest due to die-back (Mohamad-Kombi & Abdullah, 2014) should be investigated because the habitat is very important for the rare and endangered species of *N. larvatus*. The population ecology, diet and carrying capacity of all endangered species found in BNP should also be monitored by the wildlife management authorities.

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Appendix
 Appendix 1: Updated taxonomic checklist of faunal diversity, habitat types and conservation status of species at BNP.

Order	Family/ Subfamily	#	Species	Anwarali Khan et al 2005				Anwarali Khan et al 2007	Conservation status	
				BF	KF	MDF	RF		MF	WLPO (1998)
INSECTA										
Lepidoptera	Hesperiidae Coeliadinae	1	<i>Hasora taminatus</i>			x				NE
	Hesperiinae	2	<i>Ampittia dioscorides</i>	x						NE
		3	<i>Pelopidas lubricant</i>				x			NE
		4	<i>Potanthus omaha</i>	x						NE
		5	<i>Taractrocera ziclea</i>	x						NE
	Pyrginae	6	<i>Tagiades parra</i>				x			NE
	Lycaenidae Miletinae	7	<i>Miletus biggsii</i>	x			x			NE
	Polyommantinae	8	<i>Athene embolism</i>					x		NE
		9	<i>Arhopala ace</i>				x			NE
		10	<i>Arhopala achelous</i>	x			x			NE
		11	<i>Arhopala alaconia</i>							NE
		12	<i>Arhopala atosia</i>				x			NE
		13	<i>Arhopala baluensis</i>	x						NE
		14	<i>Arhopala dajogaka</i>	x						NE
		15	<i>Arhopala delta</i>	x			x			NE
		16	<i>Arhopala democritus</i>	x			x			NE
		17	<i>Arhopala epimuta</i>	x			x			NE
		18	<i>Arhopala hypomuta</i>					x		NE
		19	<i>Arhopala lurida</i>	x						NE
		20	<i>Arhopala major</i>	x						NE

Order	Family/ Subfamily	#	Species	Anwarali Khan <i>et al</i> 2005						Anwarali Khan <i>et al</i> 2007		Conservation status	
				Type of forest						RF	MF	WLPO (1998)	IUCN (2014)
				BF	KF	MDF	RF	MF	MF				
		21	<i>Arhopala moolaiana</i>			X						NE	
		22	<i>Arhopala pseudocentaurus</i>	X		X	X	X	X			NE	
		23	<i>Arhopala semperi</i>	X					X			NE	
		24	<i>Arhopala similis</i>			X						NE	
		25	<i>Arhopala vihara</i>									NE	
		26	<i>Charitra freja</i>			X						NE	
		27	<i>Chilades pandava</i>	X		X			X			NE	
		28	<i>Dacalana lowii</i>	X								NE	
		29	<i>Drupadia ravindra</i>			X						NE	
		30	<i>Drupadia theda</i>	X								NE	
		31	<i>Jamides arattus</i>	X								NE	
		32	<i>Jamides zebra</i>	X					X			NE	
		33	<i>Miletus drucei</i>			X						NE	
		34	<i>Nacaduba pactolus</i>						X			NE	
		35	<i>Prosotas dubiosa</i>	X								NE	
		36	<i>Zizina otis</i>	X					X			NE	
		37	<i>Hypochorysops coelisarsus</i>									NE	
	Theclinae												
	Nymphalidae												
	Danainae												
		38	<i>Anoxia melanippus</i>	X								NE	
		39	<i>Ideopsis juvena</i>	X		X			X			NE	
		40	<i>Ideopsis vulgaris</i>	X								NE	
		41	<i>Neptis omeroda</i>						X			NE	
		42	<i>Parantica agleoides</i>	X		X			X			NE	
		43	<i>Athyma clerical</i>			X			X			NE	
		44	<i>Athyma kamwa</i>									NE	
		45	<i>Athyma nefte</i>			X						NE	
		46	<i>Cirrochroa emalea</i>	X		X			X			NE	
		47	<i>Cirrochroa malaya</i>			X			X			NE	
		48	<i>Cupha erymanthis</i>			X			X			NE	

Order	Family/ Subfamily	#	Species	Anwarali Khan et al 2005						Anwarali Khan et al 2007	Conservation status IUCN (2014)
				Type of forest							
				BF	KF	MDF	RF	MF	MF		
		49	<i>Euthalia godarti</i>						X		NE
		50	<i>Euthalia monina</i>				X		X		NE
		51	<i>Hypolimnas bolina</i>	X							NE
		52	<i>Junonia atlites</i>	X		X					NE
		53	<i>Junonia hedonia</i>	X							NE
		54	<i>Junonia orithya</i>	X							NE
		55	<i>Lasippa monata</i>	X							NE
		56	<i>Lasippa tiga</i>	X		X		X			NE
		57	<i>Lebadea martha</i>				X				NE
		58	<i>Lexias pardalis</i>	X		X		X			NE
		59	<i>Pantoporia dindinga</i>	X							NE
		60	<i>Pantoporia paraka</i>	X		X					NE
		61	<i>Pantoporia sandaka</i>						X		NE
		62	<i>Parthenos sylvia</i>	X			X		X		NE
		63	<i>Tanaecia aruna</i>				X		X		NE
		64	<i>Tanaecia clathrata</i>			X			X		LC
		65	<i>Tanaecia munda</i>	X			X				LC
		66	<i>Tanaecia pelea</i>				X		X		LC
		67	<i>Coelites epiminthia</i>							X	NE
		68	<i>Elymnias hypermnestra</i>							X	NE
		69	<i>Elymnias nexaea</i>	X							NE
		70	<i>Elymnias penaga</i>	X		X					NE
		71	<i>Faunis stomphax</i>					X			NE
		72	<i>Mycalopsis anapita</i>	X							NE
		73	<i>Mycalopsis fusca</i>								NE
		74	<i>Mycalopsis jamaradhana</i>	X							NE
		75	<i>Mycalopsis mineus</i>	X							NE
		76	<i>Thaumantis klugius</i>	X				X			NE
		77	<i>Thaumantis noureddin</i>	X		X					LC
		78	<i>Ypthima pandocus</i>	X		X		X			NE
		79	<i>Zeuxidia amethyustus</i>			X		X			NE

Order	Family/ Subfamily	#	Species	Anwarali Khan <i>et al</i> 2005						Anwarali Khan <i>et al</i> 2007		Conservation status	
				Type of forest						MF	WLPO (1998)	IUCN (2014)	
				BF	KF	MDF	RF	MF	MF				
		80	<i>Zexidia doubledayi</i>			X			X			NE	
	Papilionidae	81	<i>Graphium agamemnon</i>						X			NE	
	Papilioninae	82	<i>Graphium antiphates</i>	X								NE	
		83	<i>Graphium empedovana</i>	X								NE	
		84	<i>Losaria neptunus</i>						X			NE	
		85	<i>Pachliopta antiphus</i>	X								NE	
		86	<i>Papilio demolion</i>					X				NE	
		87	<i>Papilio iswara</i>									NE	
		88	<i>Troides amphrysus</i>	X								NE	
		89	<i>Troides helena</i>	X								NE	
	Pieridae	90	<i>Catopsilia pyranthe</i>	X								NE	
	Pierinae	91	<i>Eurema andersoni</i>			X			X			LC	
		92	<i>Eurema blanda</i>			X						NE	
		93	<i>Eurema niceville</i>	X								NE	
		94	<i>Eurema sari</i>	X								NE	
		95	<i>Gandaca harina</i>			X			X			NE	
		96	<i>Leptosia nina</i>			X						NE	
HERPETOFAUNA													
Anura	Bufonidae	1	<i>Bufo quadrivorcatus</i>			X			X			LC	
	Dicroglossidae	2	<i>Limnonectes kuhlii</i>		X				X			LC	
		3	<i>Limnonectes laticeps</i>		X				X			LC	
		4	<i>Limnonectes paramacrodon</i>							X		LC	
		5	<i>Occidozyga laevis</i>	X		X			X			LC	
	Megophryidae	6	<i>Leptolalax dringi</i>				X					NT	

Order	Family/ Subfamily	#	Species	Anwarali Khan et al 2005						Anwarali Khan et al 2007	Conservation status	
				Type of forest							IUCN (2014)	WLPO (1998)
				BF	KF	MDF	RF	MF				
	Microhylidae	7	<i>Kalophrynus pleurostigma</i>		x						LC	
		8	<i>Microhyla perrigena</i>		x						NT	
	Ranidae	9	<i>Hylarana chalconota</i>			x		x			LC	
		10	<i>Hylarana glandulosa</i>					x			LC	
		11	<i>Hylarana baramica</i>					x			LC	
		12	<i>Hylarana signata</i>		x						LC	
	Rhacophoridae	13	<i>Polypedates leucomystax</i>	x							LC	
		14	<i>Polypedates colleti</i>			x		x			LC	
		15	<i>Polypedates macrotis</i>			x					LC	
Squamata	Agamidae	16	<i>Phoxophrys nigrilabris</i>			x					NE	
	Geckkonidae	17	<i>Cyrtodactylus consobrinus</i>								NE	
	Scincidae	18	<i>Tropidophorus brookei</i>								NE	
Testudines	Geoemydidae	19	<i>Cyclemys dentata</i>					x			NT	
		20	<i>Heosemys grandis</i>								VU	
AVES	Accipitridae	1	<i>Haliastur indus</i>						x		LC	
		2	<i>Spilornis cheela</i>						x		LC	
Caprimulgiformers	Apodidae	3	<i>Apus pacificus</i>					x			LC	
		4	<i>Collocalia esculenta</i>						x		LC	
		5	<i>Collocalia maxima</i>			x			x		LC	
		6	<i>Cypsiurus balastensis</i>	x				x	x		LC	
		7	<i>Rhaphidura leucopygialis</i>						x		LC	
	Hemiprocidae	8	<i>Hemiprocne longipennis</i>	x							LC	

Order	Family/ Subfamily	# Species	Anwarali Khan <i>et al</i> 2005					Anwarali Khan <i>et al</i> 2007	Conservation status	
			Type of forest						IUCN (2014)	WLPO (1998)
			BF	KF	MDF	RF	MF			
Charadriiformers	Charadriidae	9	<i>Charadrius dubius</i>	x				x	PA	LC
	Scolopacidae	10	<i>Actitis hypoleucos</i>	x				x	PA	LC
		11	<i>Tringa totanus</i>	x				x	PA	LC
		12	<i>Xenus cinereus</i>	x					PA	LC
Columbiformers	Columbidae	13	<i>Ducula aenea</i>	x					TPA	LC
		14	<i>Treron fulvicollis</i>	x			x			NT
		15	<i>Treron vernans</i>				x			LC
Coraciiformers	Alcedinidae	16	<i>Ceyx rufidorsa</i>	x	x			x	PA	LC
		17	<i>Halcyon chloris</i>					x	PA	LC
Cuculiformers	Cuculidae	18	<i>Eudynamis scolopacea</i>					x		LC
Passeriformers	Aegithinidae	19	<i>Aegithina tiphia</i>	x	x			x		LC
	Campephagidae	20	<i>Hemipus hirundinaceus</i>	x						LC
		21	<i>Lalage nigra</i>	x				x		LC
	Corvidae	22	<i>Corvus macrorhynchos</i>	x						LC
	Dicaeidae	23	<i>Dicaeum cruentatum</i>	x				x		LC
		24	<i>Dicaeum trigonostigma</i>		x					LC
	Dicruridae	25	<i>Dicrurus anaethetus</i>			x				LC
		26	<i>Dicrurus paradiseus</i>	x				x		LC
	Eurylaimidae	27	<i>Cymbirhynchus macrorhynchos</i>	x						LC
	Irenidae	28	<i>Irena puella</i>	x				x		LC
	Muscicapidae	29	<i>Copsychus saularis</i>	x				x		LC

Order	Family/ Subfamily	#	Species	Anwarali Khan et al 2005						Anwarali Khan et al 2007	Conservation status	
				Type of forest							IUCN (2014)	WLPO (1998)
				BF	KF	MDF	RF	MF				
		30	<i>Copsychus malabaricus</i>		X	X					LC	
		31	<i>Cyornis banyumas</i>	X							LC	
		32	<i>Cyornis superba</i>	X								
	Nectariniidae	33	<i>Aethopyga siparaja</i>						X		LC	
		34	<i>Anthreptes malacensis</i>						X		LC	
		35	<i>Anthreptes simplex</i>						X		LC	
		36	<i>Arachnothera longirostra</i>	X		X					LC	
		37	<i>Nectarinia jugularis</i>						X		LC	
	Pycnonotidae	38	<i>Alophoixus ochraceus</i>				X				LC	
		39	<i>Alophoixus phaeocephalus</i>					X			LC	
		40	<i>Pycnonotus brunneus</i>	X			X				LC	
		41	<i>Pycnonotus eutilotus</i>				X				NT	
		42	<i>Pycnonotus erythrophthalmos</i>	X		X	X		X		LC	
		43	<i>Pycnonotus plumosus</i>	X					X		LC	
		44	<i>Tricholestes criniger</i>	X							LC	
	Rhipiduridae	45	<i>Rhipidura javanica</i>	X			X		X		LC	
	Sittidae	46	<i>Sitta frontalis</i>			X					LC	
	Sturnidae	47	<i>Gracula religiosa</i>			X	X		X		LC	PA
	Sylviidae	48	<i>Abrosopus superciliaris</i>	X					X		LC	
		49	<i>Orthotomus atrogularis</i>			X			X		LC	
		50	<i>Orthotomus ruficeps</i>	X					X		LC	
		51	<i>Orthotomus sericeus</i>	X		X	X		X		LC	
	Timaliidae	52	<i>Macronous gularis</i>	X							LC	
		53	<i>Malacopteron affine</i>	X							NT	
		54	<i>Malacopteron magnum</i>	X		X					NT	

Order	Family/ Subfamily	#	Species	Anwarali Khan <i>et al</i> 2005						Anwarali Khan <i>et al</i> 2007	Conservation status	
				Type of forest							IUCN (2014)	WLPO (1998)
				BF	KF	MDF	RF	MF				
		55	<i>Stachyris erythroptera</i>	x							LC	
		56	<i>Stachyris maculata</i>					x			NT	
		57	<i>Stachyris poliocephala</i>			x					LC	
		58	<i>Trichastoma rostratum</i>		x	x					NT	
Piciformers	Megalaimidae	58	<i>Caloramphus fuliginosus</i>	x							LC	
	Picidae	59	<i>Picoides moluccensis</i>					x		PA	LC	
Strigiformers	Strigidae	60	<i>Otus bakkamoena</i>	x						PA	LC	
MAMMALS												
Dermoptera	Cynocephalidae	1	<i>Cynocephalus variegatus</i>				x			PA	LC	
Chiroptera	Pteropodidae	2	<i>Balionycteris maculata</i>						x	PA	LC	
		3	<i>Cynopterus brachyotis</i>	x	x		x	x		PA	LC	
		4	<i>Eonycteris spelaea</i>		x		x			PA	LC	
		5	<i>Macroglossus minimus</i>		x			x		PA	LC	
		6	<i>Penthetor lucasi</i>		x	x				PA	LC	
		7	<i>Pteropus vampyrus</i>						x	PA	NT	
	Emballonuridae	8	<i>Emballonura alecto</i>				x			PA	LC	
		9	<i>Emballonura monticola</i>				x			PA	LC	
		10	<i>Saccolaimus saccolaimus</i>						x	PA	LC	
		11	<i>Taphozous melanopogon</i>						x	PA	LC	
	Nycteridae	12	<i>Nycteris javanica</i>					x		PA	VU	
		13	<i>Nycteris tragata</i>						x	PA	NT	
	Megadermatidae	14	<i>Megaderma spasma</i>						x	PA	LC	
	Rhinolophidae	15	<i>Rhinolophus borneensis</i>						x	PA	LC	

Order	Family/ Subfamily	#	Species	Anwarali Khan et al 2005						Anwarali Khan et al 2007	Conservation status	
				Type of forest							IUCN (2014)	WLPO (1998)
				BF	KF	MDF	RF	MF				
		16	<i>Rhinolophus luctus</i>	x						PA	LC	
		17	<i>Rhinolophus philippinensis</i>						x	PA	LC	
		18	<i>Rhinolophus trifoliatus</i>	x		x				PA	LC	
	Hipposideridae	19	<i>Hipposideros ater</i>			x				PA	LC	
		20	<i>Hipposideros bicolor</i>			x				PA	LC	
		21	<i>Hipposideros cervinus</i>			x		x		PA	LC	
		22	<i>Hipposideros cineraceus</i>	x		x				PA	LC	
		23	<i>Hipposideros coxi</i>			x			x	PA	DD	
		24	<i>Hipposideros diadema</i>				x			PA	LC	
		25	<i>Hipposideros dyacorum</i>				x		x	PA	LC	
		26	<i>Hipposideros galeritus</i>		x		x		x	PA	LC	
		27	<i>Hipposideros larvatus</i>			x		x		PA	LC	
	Vespertilionidae	28	<i>Kerivoula hardwickii</i>						x	PA	LC	
		29	<i>Kerivoula pellucida</i>						x	PA	NT	
		30	<i>Miniopterus australis</i>						x	PA	LC	
		31	<i>Murina sutilla</i>						x	PA	LC	
		32	<i>Myotis ater</i>						x	PA	LC	
		33	<i>Myotis hasseltii</i>						x	PA	LC	
		34	<i>Myotis horsfieldii</i>						x	PA	LC	
		35	<i>Myotis muricola</i>						x	PA	LC	
		36	<i>Pipistrellus temnis</i>						x	PA	LC	
		37	<i>Pipistrellus vordermanni</i>						x	PA	DD	
Primates	Cercopithecoidea	38	<i>Macaca fascicularis</i>			x				TPA	LC	
		39	<i>Nasalis larvatus</i>		x					TPA	EN	
		40	<i>Presbytis cristata</i>			x				TPA	NT	
	Tarsiidae	41	<i>Tarsius bancanus</i>							TPA	VU	
Artiodactyla	Suidae	42	<i>Sus barbatus</i>								VU	

Order	Family/ Subfamily	#	Species	Anwarali Khan <i>et al</i> 2005					Anwarali Khan <i>et al</i> 2007	Conservation status	
				Type of forest						WLP0 (1998)	IUCN (2014)
				BF	KF	MDF	RF	MF			
Rodentia	Muridae	43	<i>Maxomys whiteheadi</i>				x			VU	
		44	<i>Sundamys muelleri</i>	x			x			LC	
	Sciuridae	45	<i>Callosciurus notatus</i>	x	x	x	x	x		LC	
		46	<i>Sundasciurus hippurus</i>				x			NT	
		47	<i>Sundasciurus lowii</i>			x				LC	
Total number of orders											
Total number of families											
Total number of species											

WLPO = Wild Life Protection Ordinance (1998); IUCN = International United for Conservation of Nature
 National status: TPA = Totally Protected Animal, PA = Protected Animal
 International Status = EN = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern, DD = Data Deficient, NE = Not Evaluated
 BF = Beach forest; KF = Kerangas forest; MDF = Mix dipterocarp forest; RF = Riverine forest; MF = Mangrove forest

Appendix 2. ⁴List of consortium of Bako researchers

I. Butterfly

Muhamad Merza Sulaiman
Hanim Syuhada Mahyudin
Senty Leykom
Jamilah Ismail
Nor Jannah Yunus
Shirly Lo
Tang Fei Chui
Catherine Lee Sie Hwan

II. Herpetofauna

Azlezan Pahramli
Eileen Lit
Pui Yong Min
Rizoh Bosorang
Sharrazlin Anas
Siti Mariam Jamaluddin
Siti Shuhada Mustaffa
Yolande Direp

III. Aves

Kannan Karupaya
Mohd Fizl Sidq Ramji
Vanessa Eric
Cassie Kaloni
Arina Shahirah Ahmad Fauzi
Nur Suhana Razali
Nurul Ain Hasbullah
Noorazizi Bahridan

Mohd Farhan Ihsan Ab. Aziz
Nor Salmizar Azmi
Vijaya Menon
Jane Chai Hui Lee

IV. Mammals

Akidah Baharuddin
Mohd Azlan Yakub
Hairi Hedeir
Siti Hasmah Taha
Mohd Ridwan Abdul Rahman@ Tahir
Siti Fairuz Othman
Wong Siew Fui
Izwan Asraf Md Zin
Mona Octavia Sulai Albans
Chah Cheng Peng
Siti Zubaidah Ismail
Roberta Chaya Tawie Tingga