Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

Preliminary research on insect diversity at Kulen Promtep Wildlife Sanctuary, Cambodia

PHAUK Sophany*, RIM Socheata, KEATH Sophorn, KEUM Theary,
DOEURK Bros & HOT Cheysen
Department of Biology, Royal University of Phnom Penh, Russian Federation Boulevard, Toul Kork, Phnom Penh, Cambodia
*Corresponding Author: PHAUK Sophany (phauk.sophany@rupp.edu.kh)

Cambodian insect fauna is virtually unstudied, especially compared to the extensive research completed on vertebrate biodiversity and conservation management. Kulen Promtep Wildlife Sanctuary (KPWS) in Preah Vihear province is one of the best examples of biodiverse habitats in Cambodia, including endangered and rare species such as *Thaumatibis gigantea* (the giant ibis). The study aims to: (1) conduct a preliminary insect survey at KPWS; (2) document species composition and the distribution of insect biodiversity across various habitat types; and (3) identify the insect species sampled and classify them in a database of insect fauna present at KPWS with references to new Cambodian species. An insect survey in KPWS was conducted between the 12th and 21st of October 2017 across six survey sites, where 775 insect specimens were collected comprising 12 orders, 53 families, and 147 morphospecies. The three dominant orders sampled were *Coleoptera* (beetles), *Hemiptera* (true bugs) and *Lepidoptera* (butterflies and moths). An analysis of the species diversity showed that the insect community at KPWS is abundant and evenly distributed within a Shannon's diversity index and Shannon's equitability value of H = 4.20694 and E_H = 0.85, respectively. The study also found the richness of insect species at KPWS is supported by the availability of different habitat types endemic to the region, including deciduous dipterocarp and dry evergreen forests.

Keywords: Kulen Phromtep Wildlife Sanctuary, entomology, insect survey, species diversity, habitat.

To cite this article: Phauk, C., Rim, S., Keath, S., Keum, T., Doeurk, B. & Hot, C. (2019) Preliminary research on insect diversity at Kulen Promtep

Wildlife Sanctuary, Cambodia. *Cambodia Journal of Basic and Applied Research (CJBAR), 1(1)*, 16–48.

Introduction

Cambodian insect fauna is virtually unstudied, especially compared to the extensive research conducted on vertebrate biodiversity. This oversight poses a problem as insects comprise a much higher proportion of total of global biomass than vertebrates, constitute irreplaceable components of ecosystem processes, and are vital for ecosystem health and function. In Cambodia, biodiversity has been seriously affected by many drivers, including deforestation, illegal logging, and climate change. Significant habitat loss in the country for many taxa has caused some species populations to decline, while others have become endangered or extinct. However, the impacts on insect diversity in Cambodia are largely unknown, as little research specific to insects has been conducted.

Globally, forests cover almost 30 % the land area on Earth and support 80 % of total terrestrial biomass by providing habitat for enormous number of plant and animal species (Morales-Hidalgo et al., 2015). In 2000, the FAO estimated that there was 1803 million ha of tropical forests, with 49% of these forests in tropical America, 34% in tropical Africa and 16% in tropical Asia; however, at this time, between 25 and 50% of the world's tropical forest had already been converted to other land-uses (Lewis, 2005). In Cambodia, the Royal Decree on the Protection of Natural Areas in Cambodia (1993) defined 23 Protected Areas across four categories, including natural parks, wildlife preserves, protected scenic view areas, and multipurpose areas (ICEM, 2003 & Souter et al., 2016). When the revised Protected Areas Law (2008) was

promulgated, a further four categories were also defined including Ramsar sites, biosphere reserves, natural heritage sites, and marine parks. The number of Protected Areas increased in Cambodia increased to 31 at this time (MoE, 2009).

Species diversity of Cambodian insects has received little attention in academic literature. However, several threats to insect biodiversity in the country clearly demonstrate a need for this knowledge. Kulen Promtep Wildlife Sanctuary (KPWS) is Cambodia's largest wildlife preserve, comprising 402,500 hectares of protected ecosystems (ICEM, 2003 & Frontier, 2012). The sanctuary is now part of the Prey Preah Roka National Park, which is the largest evergreen and semi-evergreen forest in the Northern Plains of Cambodia. This area was set aside in 1964 by King Norodom Sihanouk to protect critically endangered and possibly extinct national animals. It is of exceptional importance for biodiversity conservation as the largest remaining extensive, intact block of a unique ecosystem that once dominated most of the Indochina region. It is situated across Siem Reap, Preah Vihear and Oddor Meanchey provinces, bordering Thailand and Laos (ICEM, 2003). Currently, it is the largest protected area in Indochina (Frontier, 2012). KPWS comprises vital habitat for rare bird species such as *Thaumatibis gigantean (*the giant ibis) and other critically endangered, possibly extinct species such as *Bos sauveli* (the Kouprey) (Edwards, 2012), which is dependent on the preservation of habitat in the sanctuary including lowland forests and swamp.

Currently, there are no recent records available of catalogued insect species lists for KPWS. Thus, a preliminary study is required to support a verity distribution of species diversity for insects in the protected area. In Cambodia,

very few entomological or insect biodiversity surveys have been documented especially compared with volume of research conducted on species of vertebrates and plants. The few examples include, the Cambodian Journal Natural History, which has documented some insect orders, such as *Odonata* (dragon and damselflies) and *Lepidoptera* (butterflies and moths) (Roland et al., 2010); and the Cambodia Entomology Initiatives (CEI), which has documented other insect species including a study recording 82 species of bees in Cambodia (Ascher et al., 2016). More recently, a cooperative citizen science project, using Facebook and the Fulgoromorpha Lists On the Web (FLOW) website recorded 17 species of lantern fly, 12 of which had not previously been recorded Cambodia (Constant et al., 2016). However, these results are not comprehensive, nor are they representative of the insect diversity present at KPWS or in Cambodia. Insects are the most diverse group taxa with nearly one million species described globally and many more that are yet to be documented (Michael et al., 2010).

Thus, research on insect diversity is of high importance in Cambodia. A preliminary insect survey at the KPWS will enable enhanced knowledge, which will enable insect species specific to Cambodia to be identified. The specific aims of this study are to (1) conduct a preliminary insect survey at KPWS; (2) document the species composition and distribution of insect biodiversity in various habitat types; and (3) identify the insect species collected in the survey and classify them in a database of insect fauna present at KPWS with references to new Cambodian species.

Benefits of understanding local insect biodiversity

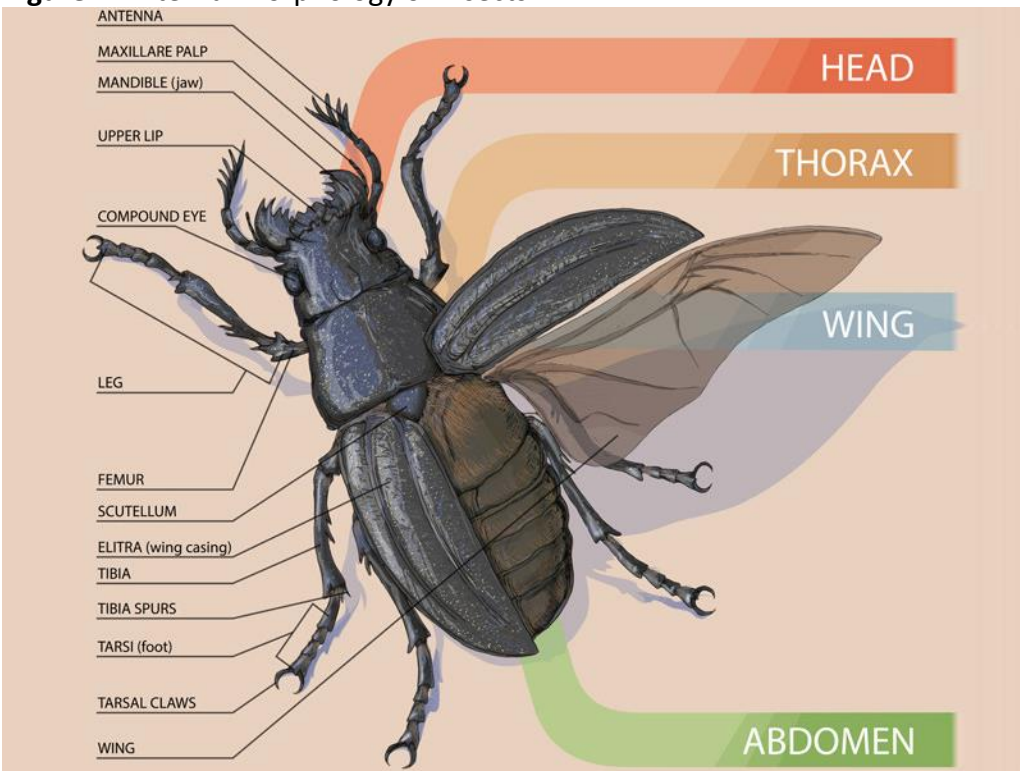
Insects are most diverse group of organisms on earth (Thomas, 2005). They are the most dominant terrestrial group and occur in all global ecosystems. Insects have been present on the planet for more than 350 million years and almost one million species have been described. Many species are yet to be identified or documented (Martin, 2012). Insect biodiversity provides vital ecosystem services such as pollination, providing raw materials for commercial products and medicines, and supporting scientific research (Borror et al., 1981). Insects have adapted to life in almost every type of habitat and have developed a broad range of unique functions (Borror et al., 1981; Triplehorn & Johnson, 2005). Understanding insect biodiversity is of high importance. For example, some insect taxa can feasibly be used as an indicator of habitat loss to related to the dynamics of climate change (Holt & Miller, 2010). Additionally, the capacity to accurately identify and characterize the behavior of insects, such as the *Membracidae* (treehopper) family, which feed on moisture contained within important crops, such as rice, is another benefit. This type of knowledge has the potential to mitigate the loss billions of dollars of agricultural production annually, through the development of strategies to prevent physical crop damage and the transmission of plant pathogens (Conti, 1985; Marmarosch and Harris, 1979). Knowledge of insect biodiversity may also be used to identify model organisms to be used in studies to better understand ecological processes or evolutionary behavior. This is important for efforts to conserve endangered species at risk due to degraded habitats (Biedermann et al., 2005; Dietrich, 2009).

Despite these benefits, insect surveys conducted by entomologists are rare in Cambodia, especially compared to vertebrate studies. There is an urgent need to improve the level of knowledge of local taxa for insect fauna in the region. KPWS is a significant site for research of insect biodiversity and thus important for the Cambodian National Strategy for Science and Technology (UNESCO, 2010). The study of insect biodiversity in frontier areas, such as KPWS, also has other benefits. For example, insect biodiversity indicators can assist with the monitoring of illegal activities, such as logging, or slash and burn agriculture. It can also act as a preliminary step for studying other animal species. For example, the Northern Plains of Cambodia are home to many internationally significant bird species, including the critically endangered *Asarcornis scutulata* (white-winged duck), which is in decline due to habitat loss (WCS, 2017). Knowledge of the dynamics of insect populations and their habitats may also help to plan conservation programs for other species such as *Urocissa erythroryncha* (the red-billed blue magpie), *Melogale personata* (large-toothed ferret badger), *Hylobates pileatus* (pileated gibbon), *Macaca fascicularis* (long-tailed macaque), and other endangered species (personal communication, Ben Davis, 2015).

Insects are group of invertebrates with six legs and either one or two pairs of wings (Snodgrass, 2015; Cranshaw & Redak, 2013 & Triplehorn & Johnson, 2005). Their body is divided into three parts, a head, thorax and abdomen (Figure 1). The head of an insect is a feeding and sensory center; bearing an antennae, eyes and a mouth. The eyes of an insect are either simple (ocelli) or compound and made up of a large number of individual lenses. The mouth of an insect comprises a labrum or upper lip; a pair of main

jaws, or mandibles; a pair of secondary jaws, or maxillae; and a labium, or lower lip (Borror et al., 1981). These mouthparts are often specific to various types of insect groups and are linked to a habitat and diet. Mouthparts are one major way of distinguishing between different insect orders. For example, all *Coleoptera* (beetles) have chewing mouthparts, whereas *Hemiptera* (true bugs) have a piercing, sucking tube.

Figure 1. External morphology of insects



Source: Animal World: Discovery the world of animals[1]

The thorax, or middle segment of the body, is made up of three segments: the prothorax, mesothorax and metathorax. Each segment bears a

[1] http://www.animalsworlds.com/insect-anatomy.html

pair of legs. In flying insects, the second and third segments also bear a pair of wings. The wings of an insect have an upper and a lower membrane. The area between each membrane is strengthened by a framework of chitinous tubes or veins. The abdomen, or end segment of the body of an insect is its metabolic and reproductive centre, where food is digested and excreted and where reproductive organs are located. Most insects breathe through fine air tubes called tracheae that are opened at the abdomen by a pair of breathing pores, or spiracles. Reproductive systems often have specific structures, which vary across different species (Borror et al., 1981 and Cranshaw & Redak, 2013).

Insect orders such as *Coleoptera* (beetles), *Diptera* (flies), and *Lepidoptera* (moths) go through morphologically different stages in their life cycle. Immature insects (larvae) hatch from eggs, usually in the form of a caterpillar, grub, or maggot and pass through a major physical change, called metamorphosis, before reaching an adult stage. Each stage of maturing is called an instar. An insect that is about to metamorphose usually goes through a resting stage called a pupa. When the change is complete, an adult insect emerges. However, other insect species such as *Blattodea* (cockroaches), *Hemiptera* (true bugs), and *Orthoptera* (crickets and grasshoppers) go through a nymphal stage (instar), where they appear as tiny versions of an adult. The main difference being that the adult has fully functional wings, however, this is not always true.

Study area and methodology

The collection of insect specimens was conducted at several survey sites within and bordering KPWS in Preah Vihear. These activities were conducted

in two major locations across three districts, including (1) Choam Ksant; (2) Kuleaen; and (3) Sangkum Thmei. These areas included degraded forest, semi-evergreen forest, and tropical rainforest. The activities described were conducted over ten days in October 2017. The coordinates of each of the six survey sites are shown in Table 1 and their location has been identified on a map (Figure 3).

Research at the two of the study areas (Choam Ksant and Kulean) was conducted between the 12th of 16th of October, 2017. Both of these locations are within KPWS (Figure 2). Five specific survey sites were selected for completing the survey, representing a range of habitat types:

- CA0094 is close to Takeung station and the National Road. It is surrounded by deciduous dipterocarp forest and samples at this site were collected from areas near households including grassland habitats with sparsely populated trees, as well as rice fields, near a stream.
- CA0095 is close to Tmart Peuy village and surrounds an area of deciduous dipterocarp forest. At the site there are houses owned by villagers approximately 3 km from the main road. Other habitats present include grassland, agricultural land and wetlands.
- CA0096 is also near Tmart Peuy village. It is surrounded by deciduous dipterocarp forest and here includes wetland and patchy grassland habitats.
- CA0097 is close to Takeung Station and surrounded by deciduous dipterocarp forest. Samples from here were collected near households, in rice fields, near a stream, as well as from grassland along a small road.

- CA0098 is close to Trorpeang Preng village and is also surrounded by deciduous dipterocarp forest. Samples from this site were taken from grassland habitats with small shrubs, as well as areas deep in the forest, more than 10 km from the main road.

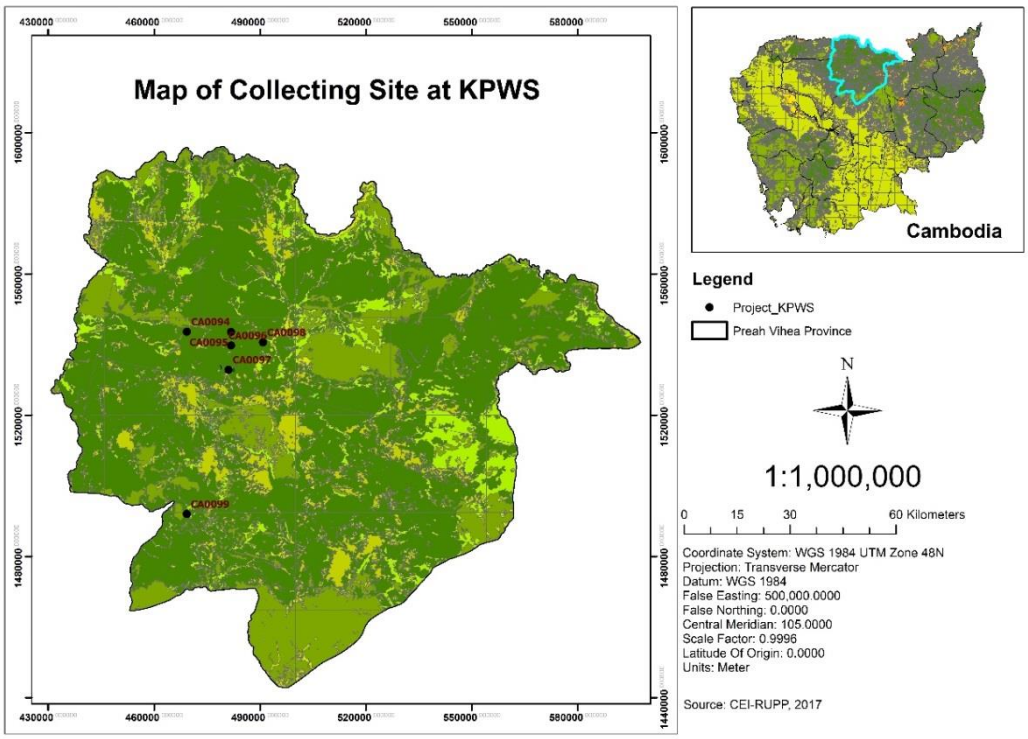
Table 1. Coordinates of survey sites at *KPWS* and *Phnom Tnout Community Forest*

Code sites	**Latitude**	**Longitude**
CA0094	N13°53.490’	E104°49.915’
CA0095	N13°57.782’	E104°49.915’
CA0096	N13°55.695’	E104°51.279’
CA0097	N13°51.963’	E104°49.506’
CA0098	N13°56.163’	E104°54.922’
CA0099	N13°29.798’	E104°42.953’

An additional insect survey was conducted at a third study area comprising just one survey site. It was managed by a ecotourism operator called ‘Be Treed adventures’ in the Phnom Tnout community forest, which is currently under consideration as a protected forest. The survey occurred between the 16th and 21st of October. The community forest is 6,400 hectares and located approximately 58 km outside of the KPWS. However, the area contains many endangered and threatened species including the *Bos javanicus* (benteng) and *Hylobates pileatus* (pileated gibbon). The survey site is described as follows:

- CA0099: is an evergreen forest, near a water fail and temple in a mountainous area. The weather at this site was more humid than the other sites surveyed.

Figure 2. Survey sites at *KPWS* and *Phnom Tnout Community Forest.*



Source: Cambodian Entomology Initiatives, 2018

KPWS comprises mainly deciduous dipterocarp forest. The insect survey was conducted in these areas, as well as focusing on other habitats such as open grasslands, rice fields, and rainforests, as well as aquatic environments such as streams, ponds and wetlands, as outlined in Figure 3. The collection of specimens was conducted between 9am and 5pm each day, and during the evening between 7pm and midnight. Samples were collected at random along forest paths. Insect specimens were collecting via several

methods as outlined below (Figure 3). Photographs were taken using a high resolution camera (Canon EOS7D), with either a macro lens (Canon EF 100mm f/2.8) or macro lens (MPE 65 mm f/2.8) with a flashlight (Macro Ring Lite MR-14EX). Insect specimens less than 2cm in size, such as those from the *Hemiptera* (true bug) and *Diptera* (fly) orders were collected and preserved in test tubes with a 70% ethanol solution. Larger insect specimens of between 2cm and 20cmm were preserved in a killing box containing ethyl acetate ($C_4H_8O_2$). All specimens were transferred to the CEI laboratory of the Department of Biology at the Royal University of Phnom Penh. They were stored at a temperature below 0^oC awaiting future identification.

Figure 3. Habitat types at *KPWS* and *Phnom Tnout Community Forest* (October 2017)

Specimen collections method varied for different insects and different habitats For example, insect such as *Lepidoptera* (butterflies and moths) and *Odonate* (dragonflies) were primarily collected using sweep nets. However various types of traps, including light traps, malaise traps, and pitfall traps, were used for other species at *KPWS.* At *Phnom Tnout Community Forest* pitfall traps were used in addition to other types. The selection of equipment in each habitat was based the time of day and the type of insects observed. At

night, samples were only collected using light traps or sweep nets. Pit traps were used at Phnom *Tnout Community Forest* as there was sufficient time available to use them effectively.

Hand collection (sweep nets) A standard, coarse net was used around foliage to directly capture free-living insects; specific to certain taxa in calm, dry weather. The nets had a handle with a length of 1 m, enabling samples to be collected in heavy vegetation. Sweep nets were used to collect a wide range of insects; however, other traps were also used as sweep nets tend to be selective of insects that are easy to dislodge from their habitat. The collection of specimens by this method was standardized in grassland and rice fields by using a consistent length of the sweep. It was the primary method used to collect specimens from grassland and the foliage of trees. In dense forests, a short-handled net was used. When collecting *Lepidoptera* (moths and butterflies) specimens in treetops, it would have been possible to collect samples by hand, however, sweep nets were used as they tend to be less damaging to the specimen. A sweep net with a veil was used to collecting aquatic insect specimens from ponds and streams (Figure 4).

Malaise Traps Large, mesh interception traps were used to capture a large number of flying insects over longer periods of time. However, as these traps are indiscriminate, they were not used in areas, where it was perceived that rare or threatened species may have been present. The method was particularly effective for orders of *Diptera* (flies) and *Hymenoptera* (wasps, bees, and ants). Malaise traps were found to be more effective in open areas and installed in high locations.

Light Traps A broad variety of light trap designs are available. They were used in this survey to collect specimens with a tendency to be attracted to light, particularly UV light.

Figure 4. Collection methods used for the insect survey at *KPWS* and Phnom *Tnout Community Forest*. From left to right: (a) sweep nets (b) light traps (c) malaise-traps and (d) pit traps.

They were used both to retain live insects for classification before they are later released; and with a collection sheet, where the insects were killed. When collecting specimens using light traps, the weather conditions were taken into account, as well as size of the sample area, as these traps tend to attract species from a broad range. Light traps using lamps were primarily used at night to capture insect species such as *Orthoptera* (grasshopper) and *Hemiptera* (leafhoppers) near roads and other open areas.

Pitfall Traps Pitfall traps were used to collect surface-moving insect specimens, which were captured by falling into containers sunken into the

surface of the ground surface and then held awaiting later classification and/or preservation. They were constructed using a plastic box containing soup, salt, and water and held in the ground by the surrounding soil. The traps were used in open areas at *Phnom Tnout Community Forest* that were cleared of leaves and roots within a 50 cm of the trap. After a number of days, select specimens were collected and preserved in a 70% ethanol solution in a test tube.

Species Identification Specimens were mounted and categorized into orders and families of insect groups as shown in the Figure 5. They were classified using manuals, textbooks, and publications with specific reference to the order of insect specimens collected. Smaller specimens of less than 2 cm were examined using stereomicroscopes to assist with identification. High-resolution cameras with macro lenses were also used during fieldwork. The morphological characteristics of each specimen were used to identify the species based on specific characteristics, followed by morphospecies (Ascher et al., 2016; Borror et al., 1981; Ek-Amnuay, 2008 & Ek-Amnuay, 2012).

Statistical Analysis

Shannon's diversity index was used to characterize the species diversity of insects at KPWS. Diversity indices provide more detailed information about community composition than just the number of species present by taking into account the relative abundance of each species. Shannon's diversity index (H) at once provides a simple summary of the richness and evenness of a biological community. It increases as an indicator of abundance, as both variables increase. Typical values generally lie between 1.5 and 3.5 and are rarely above 4. Shannon's equitability value (E_H) is used to

indicate the evenness of species in a community, where a value of 1 represents a community that is very evenly distributed, where no one species dominates.

Figure 5. Specimens mounted into boxes categorizing specific groups

Findings and Results

Insect specimens collected from KPWS show a high level of abundance and species richness, however, the level of diversity was found to vary across each of the survey sites. A total of 775 individual specimens were collected, mounted, categorized into groups, and then labelled with details of where and when the specimen was collected (Figure 5). Mounted specimens were then kept in drawers at the CEI laboratory at the Department of Biology at the Royal University of Phnom Penh. A preliminary classification shows that 12

different orders of insects were identified during the survey. At KPWS, the species richness of 12 orders were found to be more abundant than others (Figure 6) including *Coleoptera* (beetles) (28%), *Hemiptera* (21%) (true bugs) and *Lepidoptera* (butterflies and moths) (15%)

Table 3. Insect orders present at each of the survey sites at *KPWS* and *Phnom Tnout Community Forest*

Sites / **Order**	**CA0094**	**CA0095**	**CA0096**	**CA0097**	**CA0098**	**CA0099**
Coleoptera	✓	✓	✓	✓	✓	✓
Dermaptera	✓				✓	✓
Diptera	✓	✓				✓
Hemiptera	✓	✓	✓	✓	✓	✓
Hymenoptera	✓	✓	✓	✓	✓	✓
Heteroptera			✓	✓	✓	✓
Lepidoptera	✓	✓			✓	
Mentodea	✓	✓	✓	✓	✓	✓
Odonata						✓
Orthoptera	✓	✓	✓	✓	✓	✓
Plasmatodea	✓	✓	✓	✓	✓	✓
Plecoptera	✓					✓

Table 4. A list of some morphospecies collected during the insect survey at *KPWS* and *Phnom Tnout Community Forest*.

Orders	**Families**	**Species**

Orders	**Families**	**Species**
Hymenoptera	Apidae	*Apis sp*
Hymenoptera	Crabronidae	*Crabronidae sp*
Hymenoptera	Formicidae	*Formicidae sp*
Hymenoptera	Vespaidae	*Vespaidae vespa*
Hymenoptera	Pompilidae	*Pompilidae sp*
Orthoptera	Acrididae	*Acrididae sp*
Orthoptera	Gryllotalpidae	*Gryllotalpidae sp*
Orthoptera	Tettigoniidae	*Tettigoniidae sp*
Heteroptera	Gravidae	*Aradidae sp*
Heteroptera	Unknown	*Aphrophorida sp*
Heteroptera	Alydidae	*Alydidae sp*
Heteroptera	Pentatomidaae	*Pentatomidae sp*
Heteroptera	Berytidae	*Berytidae sp*
Hemiptera	Belostomatidae	*Belostoma sp*
Hemiptera	Coreidae	*Coreidae sp*
Hemiptera	Unknown	*Ledrinae sp*
Hemiptera	Tessaratomidae	*Tessaratomidae sp*
Hemiptera	Cicadellidae	*Cicadellidae sp*
Hemiptera	Cixiidae	*Cixiidae sp*
Hemiptera	Cicadidae	*Cicadidae sp*
Hemiptera	Reduviidae	*Reduvidae sp*
Hemiptera	Unknown	*Membracoidae sp*

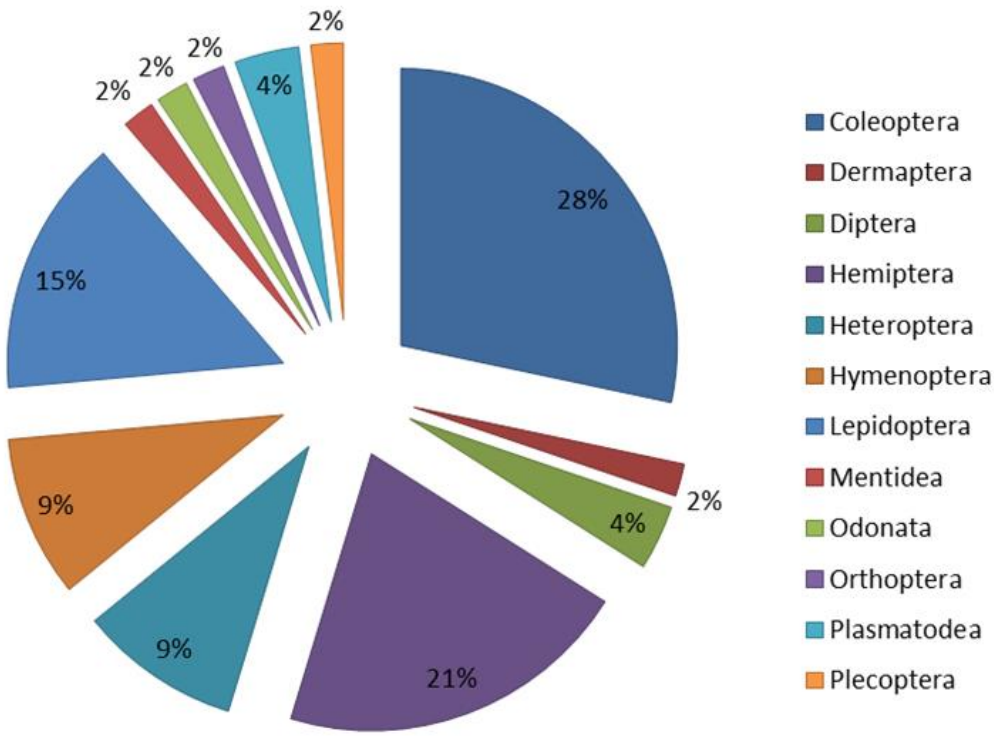
Orders	**Families**	**Species**
Hemiptera	Lophopidae	*Lophopidae sp*
Hemiptera	Heterogastridae	*Heterogastridae sp*
Coleoptera	Cerambycidae	*Cerambycidae sp*
Coleoptera	Cicindelidae	*Cicindelidae sp*
Coleoptera	Curculionidae	*Curculionidae sp*
Coleoptera	Scirtidae	*Scirtidae sp*
Coleoptera	Unknown	*Unknown Coleoptera*
Coleoptera	Doliehopodidae	*Doliehopodidae sp*
Coleoptera	Disteniidae	*Disteniidae sp*
Coleoptera	Elateridae	*Elateridae sp*
Coleoptera	Hydrophilidae	*Hydrophilidae sp*
Coleoptera	Lygacidae	*Lygacidae sp*
Coleoptera	Scarabaeidae	*Melolonthinae sp*
Coleoptera	Meloidae	*Meloidae sp*
Coleoptera	Passalidae	*Passalidae sp*
Coleoptera	Scarabaeidae	*Helicopris bucephalus*
Coleoptera	Scarabaeidae	*Helicopris sp*
Diptera	Asilidae	*Asilidae sp*
Diptera	Unknown	*Unknown Diptera*
Dermaptera	Forficulidae	*Forficulidae sp*

Orders	**Families**	**Species**
Mentidea	Hymenopus	*Hymenopus sp*
Odonata	Odonata	*Odonata sp*
Phasmatodea	Phasmatodea	*Phasmatodea sp*
Phasmatodea	Toxoderidae	*Toxoderidae sp*
Plecoptera	Unknown	*Unknown Plecoptera*
Lepidoptera	Papilionidae	*Papilio memnon*
Lepidoptera	Pieridea	*Pieridea sp*
Lepidoptera	Nymphalidae	*Nymphalidae sp*
Lepidoptera	Nymphalidae	*Cethosia sp*
Lepidoptera	Nymphalidae	*Christmas sp*
Lepidoptera	Nymphalidae	*Ariadne sp*
Lepidoptera	Heterocera	*Heterocera sp*
Lepidoptera	Lycaenidae	*Lycaenidae sp*

The insect survey found 12 orders of insects at KPWS including *Coleoptera* (beetles)*, Diptera* (flies)*, Dermaptera* (earwigs)*, Hemiptera* (true bugs)*, Heteroptera* (true bugs)*, Hymenoptera* (wasps, bees, and ants)*, Lepidoptera* (butterflies and moths)*, Mentidea* (mantis)*, Odonata* (dragonflies and damselflies)*, Orthoptera* grasshoppers and crickets)*, Phasmatodea* (stick insects)*,* and *Plecoptera* (stoneflies), representing 53 families presented in Table 4. A total of 147 morphospecies were identified, with 7 of these still unidentified. These results are comparable to other morphological studies in

Cambodia conducted by the CEI in other locations such as Kirirom and Phnom Kulen National Parks, and Keo Seima Wildlife Sanctuary.

Figure 6. Species abundance based on the number of families identified in each order.



In total, there were 53 insect families identified across the orders including *Coleoptera* (15 families), *Hemiptera* (11 families), *Lepidoptera* (8 families), Hymenoptera and *Heteroptera* (5 families of each), *Diptera* and *Phasmatodea* (2 families of each), as well as *Mentidea, Odonata, Orthoptera*, and *Dermaptera* (1 family or each). A total of 147 morphospecies were identified from the 755 specimens collected at KPWS. Eleven of these morphospecies were identified as new species not previously identified in Cambodia. These specimens included *Curculionidae* (true weevils) (2 species), *Pentatomidae* (stink bug) (1 species), *Elateridae* click beetle (1 species),

Membracidae (treehopper) (1 species), *Ruduvidae* (assassin bug) (2 species), *Toxoderidae* (mantis) (1 species), *Meloidae* (blister beetle) (1 species), and *Heterocera* (moth) (2 species). The insect survey at Kulen Promtep found many morphospecies present across different habitat in significant abundance, as indicated by the species diversity of other wildlife species in the area. Kulen Promtep has much potential for future beyond the preliminary insect survey.

Discussion

Based on Shannon's diversity index (H) insect diversity in PKWS is highly abundant (H = 4.20694) and displays good evenness of species distribution (E_H = 0.85). These results are consistent across each of the major survey sites used for the study, with the sites within *KPWS* (CA0094-CA0098) showing similar results (H = 3.89733; E_H = 0.85) and to those at the second major survey site at *Phnom Tnout Community Forest* (CA0099). It is therefore assumed that the insect community in KPWS is diverse and abundant for all the specimens collected. However, the mixed habitat of dipterocarp and dry semi-evergreen forest in KPWS showed that some insect species were more dominant than others including Coleoptera (28%), Hemiptera (21%) and Lepidoptera (15%) orders. This reflects the results of a study on scarab beetles in a similar forest types in Northeastern Thailand (Sukapanpotharam, 1979), which shows that the results of this preliminary insect survey cannot be used to assume consistent species diversity over time. While the habitat of KPWS was shown to support abundant insect diversity and richness in May 2017, it is not feasible for one insect survey and diversity assessment to suggest that these ecosystems provide habitat to support insect diversity over different

seasons or as changes to land use patterns occur associated with land use changes or the impacts of climate change. For example, a major threat to the habitat of insects at KPWS could be introduced by illegal logging activities (WCS Cambodia, 2017). There are also a range of other threats that could affect insect biodiversity. For example, if a large number of people settled in the forest and started to hunting food. These type of changes to species diversity, abundance, or evenness of insect population distribution would not be detected in a single preliminary survey (Hartmann et al., 2013).

Conclusion

KPWS and the surrounding forests of Phnom Tnout Community Forest comprise of diverse landscape including dipterocarp and dry semi-evergreen forest, as well other rainforested areas that support an abundant diversity of insect species. In total, the insect survey identified 147 morphospecies, including 7 species that have not yet been identified in Cambodia previously. However, these results were achieved over a relatively short preliminary survey. The inventory was also conducted in the dry season, where temperature reached between 36^{o}C and 40^{o}C, which is a not ideal method for obtaining a representative insect sample. The methodology used to conduct the survey, including specimen collection during the day and night, should be replicated at other times of the year to obtain more insight into the dynamics of insect communities in KPWS. Notwithstanding this, the specimens collected and their classification as a preliminary study of insect diversity at KPWS adds significant value to the body of knowledge of insect diversity in a protected forest ecosystem in Cambodia. However, the recorded taxa are unlikely to represent the total number of species present in KPWS. The six sampling sites

used to conduct the insect survey were chosen with budget limitations and time constraints in mind. This restricted the scope of the study to random locations chosen on the basis of ease of access. Future insect surveys and species inventories in the region should consider a broader range of habitat types and include the participation of local and indigenous knowledge, as well as from international experts. This type of collaboration is likely to improve the outcomes of the survey and result in a more useful assessment of species richness and abundance.

Acknowledgments

We would like to thank for the Royal University of Phnom Penh for their financial support of this research through access to a University Research Grant (G2021117), especially the staff from the Research Office, who helped to facilitate this including Dr Sok Serey. Furthermore, we would like to acknowledge the research team of the Cambodian Entomology Initiative, Ms Keum Theary, Ms Keath Sophorn, Ms Rim Socheata, Mr Hout Cheysen, Mr Douerk Bros and other CEI members for assistance with field sampling equipment and the preparation and storage of insect specimens. We are grateful for the assistance of the Ministry of Environment and local rangers at KWSP in accessing the field survey sites during the fieldwork.

Corresponding Biography

PHAUK Sophany has worked as lecturer and researcher at the Department of Biology in the Faculty of Science at the Royal University of Phnom Penh since 2012. He studied the use of acoustics by bat species in Cambodia to assist with their identification for his MSc. His work is now focused on Cambodian insect diversity and its link to ecological processes to

better understand scenarios such as climate change and agricultural pest control. He is also the manager and curator of the entomological collection at Cambodian Entomology Initiatives at the Department of Biology at the Royal University of Phnom Penh.

References

Ascher, J.S., Heang P., Kheam S., Ly K., Lorn S., Chui S.X., de Greef, S., Chartier,, G. & Phauk S. (2016). A report on the bees (Hymenoptera: Apoidea: Anthophila) of Cambodia. Cambodian Journal of Natural History, 2016, 23–39

Borror, D. J., Delong, D. M., & Triplehorn, C. A. (1981). An introduction to the study of insects (5th ed.). New York: CBS College Publishing.

Biedermann, R., R. Achtziger, H. Nickel, & A.J.A. Stewart. (2005). Conservation of grassland leafhoppers: a brief review. J. Insect Cons. 9: 229-243.

Conti, M. (1985). Transmission of plant viruses by leafhoppers and planthoppers. pp. 289- 307. In Nault, L. R. and J. G. Rodriguez (eds.), The Leafhoppers and Planthoppers. Wiley and Sons, New York

Constant, J., Phauk, S. & Bourgoin, T. (2016). Updating lanternflies biodiversity knowledge in Cambodia (Hemiptera: Fulgoromorpha: Fulgoridae) by optimizing field work surveys with citizen science involvement through Facebook networking and data access in FLOW website. Belgian Journal of Entomology 37, 1-16.

Cranshaw, W. & Redak, R. (2013) Bugs Rule! An Introduction to the World of Insects. Princeton University Press. ISBN 978-0-691-12495-7

Dietrich, C. H. (2009). Chapter 7. Terrestrial insects: a hidden biodiversity crisis? Pp. 111- 129. In Taylor, C. A., J. B. Taft and C. E. Warwick (eds)

Canaries in the Catbird Seat: The Past, Present and Future of Biological Resources in a Changing Environment. Illinois Natural History Survey, Champaign.

Edwards, S. (2012) Small carnivore records from the Oddar Meanchay sector of Kulen–Promtep Wildlife Sanctuary, northern Cambodia. Small Carnivore Conservation, 46, 22–25.

Ek-Amnuay, P. (2012). Butterflies of Thailand. 2nd Revised edition.- Bangkok: Baan Lae Suan Amarin Printing and Publishing. 944 pp. ISBN: 978-616-207-988-7

Ek-Amnuay, P. (2008). Beetles of Thailand. 2nd Edition Siam Insect-Zoo & Museum, Mae Rim, Chiang Mai, Thailand. ISBN: 974-289-045-5.

Farr, E. P. (2012). Cambodia comfirm the first record sun bears in Kulen Promtep Wildlife Sanctuary, Frontier Cambodia.

Frontier, (2012). Frontier Cambodia Forest Programme Phase 123. CBF123 Science Report MT/BDB. https://frontiergap.com/publications/files/2012_10_15_10_17_21 _832.pdf

Hartmann, T., Ihlow, F., Edwards, S., Sovath, S., Handschuh, M. & Böhme, W. (2013) A Preliminary Annotated Checklist of th Amphibians and Reptiles of the Kulen Promtep Wilflife Sanctuary in Northern Cambodia. Asian Herpetological Research. 2013, 4(1): 36-55.

Holt, E. A. & Miller, S. W. (2010) Bioindicators: Using Organisms to Measure Environmental Impacts. Nature Education Knowledge 3(10):8

ICEM. (2003). Cambodia National Report on Protected Areas and Development. Review of Protected Areas and Development in the Lower Mekong River Region, Indooroopilly, Queensland, Australia. 148 pp

Lewis, S.L. (2005) Tropical forests and the changing earth system. Philosophical Transactions of the Royal Society B. 2006:361, 195-210.

Marmarosch, K., and K. F. Harris, (1979) Leafhopper vectors and plant disease agents. Academic Press, New York.

Martin, W. (2012). An illustrated directory of the Insects of the world. Southwater, an imprint of Anness Publishing Ltd.

MICHAEL J. MELODIE A. McGEOCH. (2010). *Insect Conservation, A handbook of Approaches and Methods.* Oxford biology.

Ministry of Environment, (2009) Cambodia Environment Outlook. Ministry of Environment, Kingdom of Cambodia. Pp: 106. ISBN: 978-974-300-197-0

Morales-Hidalgo, D., Oswalt, S.N. & Somanathan E., (2015) Status and trends in global primary forest, protected areas, and areas designated for conservation of biodiversity from the Global Forest Resources Assessment 2015. Forest Ecology and Management. 352 (2015). 65-77.

Roland, H.-J, Roland, U. & Pollard, E. (2010). Incidental records of dragonflies and damselflies (Order Odonata) in Cambodia. Cambodian Journal of Natural History, 2010, 97 - 102.

SIRIVEJJABHANDU, A., & WHYTE, S. J. (2010). Poverty Alleviation through Community-based Ecotourism in the Trans-Boundary Protected Areas: The Emerald Triangle Perspective.

Snodgrass, R.E., (2015) Insects – Their Ways and Means of Living. Dover Edition by Smithsonian Institution Series, Inc., in 1930. ISBN-13: 978-0-486-21801-4

SOUTER, N. J., SIMPSON, V., MOULD, A., EAMES, J. C., GRAY, T. N., & SINCLAIR, R. (2016). Will the recent changes in protected area management and the

creation of five new protected areas improve biodiversity conservation in Cambodia? Cambodian Journal Natural History, 2016, 1st ser., 1-5.

Sukapanpotharam V. (1979). Scarab Beetle Communities in Deciduous Dipterocarp and Dry Evergreen Forests in Northeastern Thailand. Nat. Hist. Bull. Siam Soc. 28: 55-100.

Thomas J. A (2005). Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. Philosophical Transactions of the Royal Society B: Biological Sciences

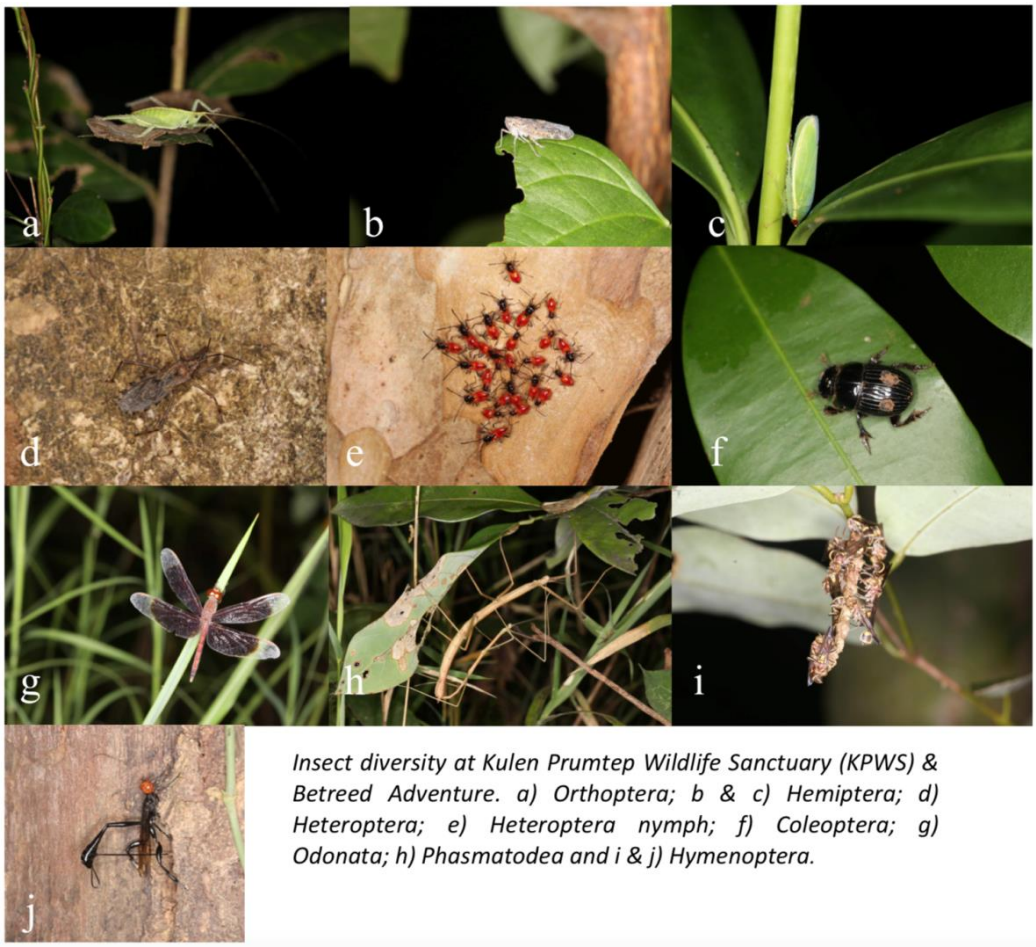
Triplehorn, C.A., & Johnson, N.F., (2005) Borror and DeLong's Introduction to the Study of Insects (7th Edition). Peter Marshall. ISPN 0-03-096835-6

UNESCO (2010). Cambodia – Unesco Country Programming Document 2009-2010. KH/2009/RP/25. Phnom Penh.

WCS Cambodia. (2017). WCS Cambodia 2017 Activity Report. Wildlife Conservation Society (WCS) Cambodian Program.

Animals Worlds: Discover the world of animals. www.animalsworlds.com/insect-anatomy.html (Accessed: 30 April, 2018)

Appendix



Insect diversity at Kulen Prumtep Wildlife Sanctuary (KPWS) & Betreed Adventure. a) Orthoptera; b & c) Hemiptera; d) Heteroptera; e) Heteroptera nymph; f) Coleoptera; g) Odonata; h) Phasmatodea and i & j) Hymenoptera.

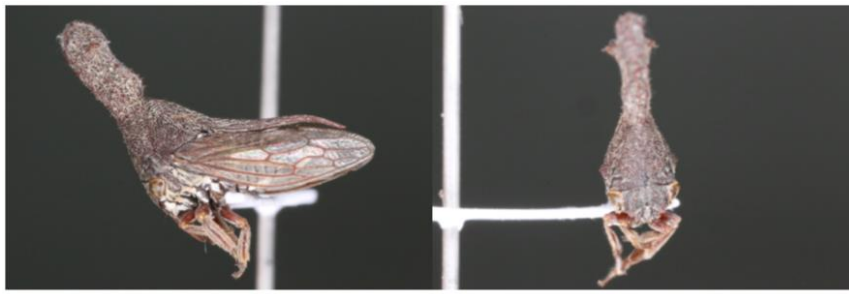
Morphospecies of some insect species collected

Coreinae sp1.

Coreinae sp2.

Reduviidae sp1.

Cicadellidae sp1.



Membracidae sp1.

Membracidae sp2.

Dynastinae sp.

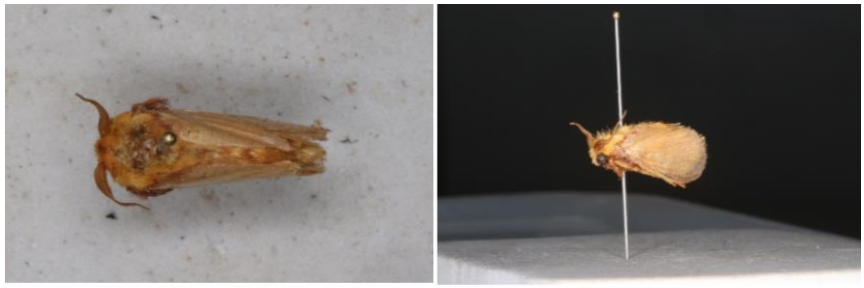
Odonata sp.

Curculionidae sp1.

Curculionidae sp2.

Elateridae sp1.

Meloidae sp1.



Heterocera sp1.

Heterocera sp2.

Vespoidae sp1.

Bothrogonia sp.