HOST-ECTOPARASITE RELATIONSHIPS ON BATS IN GOMANTONG FOREST RESERVE, SABAH, MALAYSIA

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DECLARATION

The materials in this thesis are original except for quotations, excerpts, summaries, and references, which have been duly acknowledged.

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ABSTRACT

The study of host-ectoparasites relationships in bats was conducted in Gomantong Forest Reserve, Sabah on December 2007 and December 2008 focusing on the patterns of ectoparasites distribution in bat hosts. This study examined if morphological characteristics of the host bats influence the levels of parasitism. The bats were captured using mist-nets and were examined for ectoparasite by screening the wing membranes and body. Sex, weight, forearm length, and reproductive stage were recorded for each bat. There were 288 individual bats in the sample that belong to eleven species i.e. *Myotis muricola, Hipposideros cervinus, Balionycteris maculata, Rhinolophus arcuatus, Hipposideros diadema, Kerivoula papillosa, Cynopterus brachyotis, Rhinolophus creaghi, Rhinolophus philipinensis, Hipposideros dyacorum,* and *Cynopterus* horsfieldi. The bats hosted 404 individuals of ectoparasites from six families i.e. Streblidae, Nycteribiidae, Spinturnicidae, Laelapidae, Psoroptidae, and Ixodidae. Seven individuals (1.7%) of ectoparasites were unidentified, which were even to five mites, a larva and an insect. Three groups of ectoparasites were detected, which were bat flies, mites, and ticks. No lice and fleas had been recorded from this study. Bat flies attributed for the highest infestation as against mites and ticks. The overall prevalence was 50.69 %. The highest infestation rate was seen in *Rhinolophus arcuatus* i.e. 92.86 % while the most preferable host for many kinds of ectoparasites families was *Myotis muricola.* There were significant differences in the infestation rates due to bats species, bats sex, bats reproductive stages, body size of bats, and also with emerging-arrival time. The levels of parasitism in bats were not related to parasite species on host, locality, distance from riparian area, canopy cover, or weather conditions. Ectoparasites from the family Nycteribiidae infected most of the host species, whereas the most dominant ectoparasites in terms of individual numbers were ectoparasites from the family Streblidae.

ABSTRAK

HUBUNGAN PERUMAH-EKTOPARASIT PADA KELAWAR DI HUTAN SIMPAN GOMANTONG, SABAH, MALAYSIA

Kajian mengenai hubungan perumah-ektoparasit pada kelawar telah dijalankan di Hutan Simpan Gomantong, Sabah pada Disember 2007 dan Disember 2008 dengan memberi tumpuan kepada corak taburan ektoparasit pada kelawar yang menjadi perumah. Kajian ini secara amnya bertujuan untuk menentukan samada faktor morfologi perumah dan faktor ekologi perumah mempengaruhi kadar parasitisme. Kelawar yang ditangkap akan diperiksa pada seluruh badannya termasuk membran sayapnya bagi mendapatkan ektoparasit. Jantina kelawar, timbangan berat dan ukuran lengannya, serta peringkat pembiakan dicatat bagi setiap kelawar yang ditangkap. Sebanyak 288 ekor kelawar daripada sebelas spesies telah ditangkap iaitu Myotis muricola, Hipposideros cervinus, Balionycteris maculata, Rhinolophus arcuatus, Hipposideros diaderma, Kerivoula papillosa, Cynopterus brachyotis, Rhinolophus creaghi, Rhinolophus philipinensis, Hipposideros dyacorum, dan Cynopterus horsfieldi. Secara keseluruhan didapati mempunyai sebanyak 404 ektoparasit telah dikumpulkan daripada semua kelawar dan ektoparasit ini tergolong di dalam enam famili iaitu Streblidae, Nycteribiidae, Spinturnicidae, Laelapidae, Psoroptidae, dan Ixodidae. Tujuh ektoparasit (1.7%) tidak dapat dikenalpasti iaitu lima tungau, satu larva, dan satu serangga. Tiga kumpulan ektoparasit yang dapat dikesan ialah lalat kelawar, tungau, dan sengkenit. Tiada kutu dan pinjal yang direkodkan dalam kajian ini. Lalat kelawar menyebabkan jangkitan lebih tinggi berbanding tungau dan sengkenit. Prevalens keseluruhan adalah 50.69%. Jangkitan tertinggi dapat dilihat pada Rhinolophus arcuatus iaitu 92.86 %, sementara perumah yang lebih cenderung dijangkiti oleh pelbagai famili ektoparasit ialah Myotis muricola. Terdapat perbezaan yang signifikan di antara jangkitan ektoparasit dengan spesies kelawar, jantina kelawar, peringkat pembiakan kelawar, saiz badan kelawar, dan juga masa keluar dan masuk gua. Perhubungan di antara spesies parasit pada perumah, lokasi tangkapan, jarak dari kawasan berair, litupan kanopi, dan cuaca tidak memberikan kesan yang signifikan kepada kadar jangkitan. Ektoparasit dari famili Nycteribiidae didapati menjangkiti hampir semua spesies perumah, manakala ektoparasit yang paling dominan dengan mencatatkan jumlah bilangan individu paling tinggi adalah ektoparasit dari Famili Streblidae.

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SYMBOL LIST

%	-	percentage
N	-	total sampel
SPSS	-	Statistic Package for Social Science
t	-	t-test
χ^2	-	Chi square
P	-	significant value
df	-	degree of freedom
~	-	nearly or almost
/	-	divide
x	-	multiply
#	-	total
=	-	equal

APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Introduction

Parasitism is a type of symbiotic relationship between organisms of different species where one organism, the parasite, benefits at the expense of the host by taking nutrients from its host without killing the host but usually debilitating it. Parasitism is differentiated from parasitoidism, a relationship in which the host is always killed by the parasite (e.g. parasitic wasp larvae emerging from caterpillar).

In general, parasites are much smaller than their host, showing a high degree of specialization for their mode of life, and reproduce more quickly and in greater numbers than their hosts. The harm and benefit in parasitic interactions concern the biological fitness of the organisms involved. Parasites reduce host fitness in many ways, ranging from general or specialized pathology, impairment of secondary sex characteristics, to the modification of host behavior. Parasites increase their fitness by exploiting hosts for food, habitat and dispersal (Janovy and Roberts, 2005).

Parasites are classified based on their interactions with their hosts and on their life cycles. Those that live on its surface are called *ectoparasite* (e.g. some mites) and those that live inside the host are called *endoparasites* (e.g. hookworms). Endoparasites can exist in one of two forms: intercellular (inhabiting spaces in the host's body) or intracellular (inhabiting cells in the host's body). Intracellular parasites, such as bacteria or viruses, tend to rely on a third organism which is generally known as the carrier or vectoparasiter. The vectoparasite does the job of transmitting them to the host. An example of this interaction is the transmission of malaria, caused by a protozoan of the genus *Plasmodium*, to humans by the bite of an Anopheline mosquito.

An epiparasite is one that feeds on another parasite. This relationship is also sometimes referred to as hyperparasitism which may be exemplified by a protozoan (the hyperparasite) living in the digestive tract of a flea living on a dog.

Parasitism can be physical, like the parasitic worms found in the internal organs of animals, or social, like the brood or nest parasitism practiced by many species of cuckoo and cowbird. These birds do not build nests of their own but rather deposit their eggs in nests of other species and abandon them there. The host behaves as a "babysitter" as they raise the young as their own. If the host removes the cuckoo's eggs, some cuckoos will return and attack the nest to compel host birds to remain subject to this parasitism. The cowbird's parasitism does not necessarily harm its host's brood; however, the cuckoo may remove one or more host eggs to avoid detection, and furthermore the young cuckoo may heave the host's eggs and nestlings from the nest (Croston and Hauber, 2012).

Parasites inhabit living organisms and therefore face problems that free-living organisms do not. Hosts, the only habitats in which parasites can survive, actively try to avoid, repel, and destroy parasites (e.g. bats practice host grooming in order to expel parasites from its body). Parasites employ numerous strategies for getting from one host to another host for survival.

Due to these unique characteristics of parasites, it is rather compelling to study the host-parasite relationships in a highly mobile society of mammals, the bats. Bats are highly beneficial wild mammals. They are not flying rodents, but belong to a unique order of mammals called the Chiroptera (chiro= hand, ptera= wing). Bats are more closely related to primates (monkeys and humans) than they are to rodents (Kern, 2009). Bats are found throughout the world in tropical and temperate habitats. They are missing only from Polar Regions and from some isolated islands. Although bats are relatively common in temperate regions, they reach their greatest diversity in tropical forests.

Bats are often divided into two major groups, usually given the rank of suborders; Megachiroptera and Microchiroptera. There are several relevant ecological differences between them. Megachiroptera includes one family (Pteropodidae) and about 166 species. All feed primarily on plant material; fruit, nectar or pollen. The remaining 16 families (around 759 species) belong to Microchiroptera. The majority of species are insectivorous, and insectivory is widely distributed through all microchiropteran families.

However, many microchiropterans have become specialized to eat other kinds of diets. Some bats are carnivorous (feeding on rodents, other bats, reptiles, birds, amphibians, and even fish), many consume fruit, some are specialized for extracting nectar from flowers, and one subfamily (three species in the subfamily Desmodontinae) feeds on nothing but the blood of other vertebrates. Megachiropterans and microchiropterans differ in many other ways. Megachiropterans are found only in the Old World tropics, while microchiropterans are much more broadly distributed. Microchiropterans use highly sophisticated echolocation for orientation; megachiropterans orient primarily using their eyes, although members of one genus, *Rousettus*, are capable of a simple form of echolocation that is not related to echolocation in microchiropterans. Megachiropteran species control their body temperature within a tight range of temperatures and none hibernates; many microchiropterans have labile body temperatures, and some hibernate (Wund and Myers, 2005).

Because of their high metabolic needs and diverse diets, bats can impact the communities in which they live in a variety of important ways. They are important pollinators and seed dispersers, particularly in tropical communities. Also, carnivorous and insectivorous bats may significantly limit their prey populations. Bats may be keystone species in many communities, particularly in the tropics where they are most abundant and diverse.

Bats are associated with many kinds of internal and external parasites. Many flatworms (Cestoda and Trematoda) and roundworms (Nematoda) spend at least part of their life cycle within the tissues of bat hosts. Bats commonly harbor external, arthropod parasites. Ticks, mites and insects are known to live and feed on bats. Species that parasitize bats exhibit a range of host-specificity: some are found on one or a few bats, others occur on a wider variety of bat species, and still others can parasitize bats as well as other taxonomic groups.

1.2 Study Justification

Although bat parasites have been studied extensively during the last few decades, information concerning host-parasite relationships is scarce. So far, most studies on bat parasites dealt with either their taxonomy or their lifecycles. Also, the causal mechanisms underlying host specificity in bat parasites remains poorly understood (Lučan, 2006).

1.3 Objectives

The aims of this study are:

a. to determine whether parasite prevalence and intensity were different between host species
b. to investigate whether parasite prevalence were different between host gender.
c. to determine whether parasite prevalence were different between host reproductive stages.
d. to find out the relationship between the infection of ectoparasiteparasite and host body condition (weight and forearm) measurement.
e. to know whether the host ecological factors (locality, weather, distance from riparian area, canopy cover, emerging and arrival time) have any effect on infection of ectoparasiteparasite

1.4 Hypotheses

In order to achieve our objectives, there are some hypotheses in our prediction:

a. There is no significant difference between the infection of ectoparasite and the host species.
b. There is no significant difference between the infection of ectoparasite and the host gender.
c. There is no significant difference between the infection of ectoparasite and the host reproductive stages.

d. There is no significant difference between the infection of ectoparasite and the host body condition (weight and forearm).
e. There is no significant difference between the infection of ectoparasite and the host ecological factors.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Parasites have evolved in almost every phylum but are particularly prevalent in protozoa, platyhelminths, nematodes, and certain arthropods. Parasites are sometimes described as degenerate because they have lost some of the elaborations of their free-living relatives, but they are more accurately seen as specialized, being highly adapted to their particular way of life. They are very widespread and likely to be important in any ecosystem (Moore, 2001).

The life of a metazoan parasite demands special adaptations; an ectoparasiteparasite must be able to attach to the host's outer surface, an endoparasite must penetrate the host, find and perhaps attach itself to a particular tissue and resist the host's defenses. A gut parasite must resist the host's digestive enzymes, a blood parasite must adapt its surface antigens to resist the host's immune system.

Host specificity gauges the degree to which a parasite occurs in association with a single host species. The measure is indicative of properties of the host and parasite, as well as their ecological and co-evolutionary relationships. Host specificity is influenced by the behavior and ecology of both parasite and host. Where parasites are active, vagile and coupled with hosts whose behavior and ecology brings the parasite into contact with many potential hosts, the likelihood of host switching is increased, usually leading to lowered specificity (Dick and Patterson, 2007).

According to Madinah *et al.,* (2014), the literature regarding the diversity of ectoparasite and their interaction with their hosts remains largely inadequate in Malaysian tropical rainforest. Survey done by Madinah *et al.*, (2013) which produced the first list of ectoparasite in urban park, Sarawak, found some species of ectoparasite are known to have potential health risk. A survey of acarine ectoparasite of bats (Chiroptera) in Malaysia done by Ahamad *et al.* (2013) also focused on identified acarines of known public health importance from bats. In Malaysia, there is still need more researchs to be done to confirm the actual risk by determine the relationships of ectoparasite with those potential vectoparasiters.

Ectoparasites reduce the reproductive success and survival of hosts and thereby exert selection pressure on host life-history traits. Although the negative effect of ectoparasiteparasitism on fitness was studied in variety of animals, very little data have been available in the case of bats. Different underlying causal mechanisms may exist that influence parasite load and, especially, body condition, with respect to the particular sex and age category of bats. A body condition index was calculated as a ratio of weight to forearm length (Lučan, 2006).

Host specificity is the tendency of parasites to occur on one or few host species versus a broader range of hosts. There are, of course, advantages to the parasite in being host specific but at times non-host specificity may be adaptive. Non-host specificity allows parasites the advantage of being able to expand their population beyond the taxonomic confines and geographic ranges of one or few hosts. Another advantage is that they can find a host more easily.

The disadvantage is that they must remain rather generalized (i.e. they cannot become closely tied to the life history of a host). Host specific parasites, on the other hand, can evolve specifically to exploit the phenology and life history of its host. As long as the host maintains its abundance, the parasite will thrive since it has evolved in parallel with the host. Another advantage is that the increasing of host specificity should tend to decrease competition. Disadvantages of host specificity are that the parasite cannot expand its population beyond the confines of its host and also that if the host declines or become extinct, so will the parasite (Kunz, 1990).

The Gomantong Forest Reserve has many species of bats that most likely harbor many kinds of ectoparasite. The bats congregate and facilitate the ectoparasite infection amongst the most preferable hosts. From there, we can see the factors that influence the distribution patterns of the ectoparasite within the community of hosts.

2.2 Bat Fly (Order: Diptera)

Among all ectoparasite on bat, the bat flies (Diptera: Hippoboscoidea) are highly specialized ectoparasite and only associate with bats (Mammalia: Chiroptera). They live in the fur and on the wing membranes where they feed on host blood. Bat flies are divided into two cosmopolitan families; Streblidae and Nycteribiidae. Nycteribiids are more specious in the Eastern Hemisphere, whereas the Streblids are richer in the Western. Generally, both families are most diverse in the tropics, less diverse in subtropics, and rather impoverished in temperate regions. However, this latitudinal richness gradient is more pronounced in the Western Hemisphere (Dick and Patterson, 2006).

2.2.1 Family Nycteribiidae

Nycteribids are completely wingless and are called bat spider flies because of their superficial resemblance to spiders (Janovy and Roberts, 2005). Although species vary greatly in size (around 1.5-5.0 mm), their overall aspect is rather similar across the species. Their flight muscles are atrophied, which in turn reduces the overall bulk of the thorax. Their legs and small head all protrude from the dorsal thoracic surface, and the insects are somewhat dorsoventrally flattened. All species possess a head that is folded back against the thorax when at rest. Most of nycteribiids have been observed only on furred regions of their hosts. Like fleas, nycteribiids possess several ctenidae or combs. The ctenidia are thought to facilitate host attachment, preventing the animal from being brushed backwards from the fur. Nycteribiids generally move equally well in any direction, and their movement may be very fast when agitated. Such frenetic mobility may allow them to evade host grooming, inferred to be the greatest cause of mortality in adult bat flies. When feeding, nycteribiids thrust their bodies downward into the fur. Their mouthparts contact the host’s skin and the tip of their abdomen is generally visible at this time (Dick and Patterson, 2006).

2.2.2 Family Streblidae

The Streblidae also vary greatly in size, with total length generally 1.5-2.5mm, but ranging from 0.73 mm (e.g. *Mastoptera minuta*, the smallest bat fly) to 5.50mm (e.g. *Joblingia schmidti*). In contrast to the conservative body plan of nycteribiids, streblids possess radically different body plans from strongly laterally compressed to dorsoventrally flattened to uncompressed. The strong and rapid “swimming” movement of these insects makes them especially difficult to capture alive on the host. Other differences among streblid species include extremely elongated legs in some genera of trichobiines and a well-developed ctenidium in all species of streblines.

Observations of living flies reveal that the long-legged species run across the top of the host’s fur. These species are accordingly the most conspicuous parasites when bats are handled. The most important structures of bat flies for host attachment appear to be tarsal claws. When streblids are collected alive from the host, nearly always their final and strongest resistance to capture involves grasping hairs or wing membrane with flexed tarsal claws. Unlike the nycteribiids that are wingless, most streblids possess wings, but not all these possess functional, macropterous wings. Typically even the fully winged forms are rather weak flyers, but species vary in their proclivity to fly when disturbed (Dick and Patterson, 2006).

2.2.3 Life Cycle of Bat Fly

Generally all bat flies reproduce via viviparous puparity, in which eggs are fertilized internally and all larval stages develop within the female, nourished by intrauterine “milk” glands. Larvae moult twice inside the female, and gravid females deposit a single, terminal (3rd-instar) larva on the roosting substrate. Once deposited, the larva (referred to as a prepupa) immediately forms a puparium. Following a pupal stage that lasts 3-4 weeks, an adult fly emerges and must locate and colonize a host for a blood meal before mating (Dick and Patterson, 2006).

2.2.4 Pathogenesis of Bat Fly

Although bat fly bites are painful to humans, host bats exhibit no reaction to the nearly constant feeding of bat flies. As blood-feeding parasites, bat flies would appear excellent vectoparasiters of zoonoses. It is possible that parasitic bat flies not only transfer pathogens among host bats, but given that bat flies occasionally bite humans, it is theoretically possible that bat flies could transmit pathogens to humans. Parasitism may also effect the site fidelity of bats, as has been shown for other host species such as barn swallows. Bat flies deposit their prepupae inside the roost, and newly emerged flies depend on the presence of host bats. Moving to a different roost before the adult flies emerge may be an effective means for bats to lower both prevalence and intensity of ectoparasiteprasite infestation (Dick and Patterson, 2006).

2.3 Flea

The scientific name for fleas is *Siphonaptera*, which comes from the Greek words 'siphon', meaning pipe, and 'aptera', meaning wingless, relating to the sucking mouthparts and wingless condition of fleas. The approximately 2500 species of fleas are small insects, from about one up to several milimeters in length (Ford *et al*., 2004). Most are parasites of mammals, but approximately a hundred species regularly occur on birds.

They are rather heavily sclerotized, bilaterally flattened, and secondarily wingless. Evolutionary loss of wings is a condition commonly found in parasitics insects. Strong evidence suggests that fleas descended from a winged ancestor much-like present-day scorpion flies (Mecoptera). In fact, several features of the jumping mechanism, which is well-developed in most fleas, seem to be homologous with flight structures of flying insects. Females have a downward sloping abdomen, males have an upward pointed abdomen. They can be light yellow to almost black in colour and are generally shiny and with varying numbers of bristles.

The presence of backward pointing combs in some species helps the flea retain itself in the feathers or fur of its host, and prevents easy removal from the host's body by preening or grooming. The short antennae have three segments and