Indra Yustian

Ecology and Conservation Status of *Tarsius bancanus saltator* on Belitung Island, Indonesia

Göttingen 2007

Ecology and Conservation Status of *Tarsius bancanus saltator* on Belitung Island, Indonesia

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Goettingen, May 2007 Indra Yustian

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Chapter 1: Introduction

1.1 Background

Indonesia is one of the most biodiversity-rich and ecologically complex nations in the world. Although covering only 1.3% of the globe, the Indonesian archipelago accounts for nearly 10% of the world's remaining tropical forest (BAPPENAS 1993), ranked second after Brazil for its forest area and the amount of biodiversity.

Despite increasing concern over the loss of tropical forest, significant local and international efforts to find solutions to the problem, and despite the country's extensive system of protected areas and production forests (forests available for logging), and the abundance of detailed land-use plans, the rate of deforestation in Indonesia continues to increase (Jepson *et al.* 2001 & Whitten *et al*. 2001 cited in Kinnaird *et al.* 2003). Kinnaird *et al.* (2003) also mentioned that Indonesia provides one mostly relevant example of the devastating effects of enormous deforestation. According to World Bank (2001, cited in USAID/Indonesia 2004), 20 million ha of Indonesia's forests have been lost at an average annual deforestation rate of 1.5 million ha between 1985 and 1997. Since 1997, the rate of forest lost is 2.4 million ha per year or more. Of about five million ha of forests were degraded by fires in 1997-1998 alone.

Sumatra, the westernmost of the main islands and the second-largest island in Indonesia, has less than 40% of its natural forest remaining and is losing forest rapidly at the rate of almost 2.5% a year (Supriatna *et al.* 2002). According to Kinnaird *et al.* (2003), the dramatic loss of Sumatra's forest cover is attributed to a variety of factors, including logging (legal and illegal), development of estate crops (primarily oil palm and pulpwood plantations), conversion to agriculture (by opportunistic settlers and those arriving through Indonesia's official transmigration program) and forest fires. They also stated that the conversion of Sumatra's lowland forests will finally result in putting the fauna, especially large mammals, in serious jeopardy. The consequences also occur in Sumatra's nearby islands, such as Bangka and Belitung Island.

Belitung is an island southeast of Sumatra and Bangka Island. The total land of the Belitung Island is approximately 480,060 ha (*ca.* 4,800 km²) and human population was 215,859 in the year 2002 (BPS 2002). The main resources are tin mining, kaolin, quartz sands and granite rock.

During the Dutch occupation, the tin mining industry was established and is still continuing until now. The plantations are mainly oil palm and pepper, also coconut, coffee and natural rubber but relatively less expansive than both first two mentioned. The highest land is Gunung Tajam, only 500m above sea level (Whitten *et al*. 2000). The land surface was originally tropical forest, but since the development of the palm oil industry in 1992 more than 40% of the land surface has been converted to oil palm plantations. There are some small lakes but most of them were constructed because of tin mining (http://www.indahnesia.com/indonesia.php?page=SSEBEL).

Tin mining and large scaled oil palm plantations directly or indirectly affect the natural habitats on Belitung Island. There is a permanent threat to the flora and fauna on the island, while actually there is no terrestrial conservation area on Belitung Island (Supriatna *et al.* 2002). The continuing deterioration of forest on Belitung Island means that there is a higher probability of the species becoming threatened.

The tarsier family (Tarsiidae, Order Primates) is a distinctive taxon confined to the Sunda Islands, the Philippines, and Sulawesi. Currently, eight species (Merker & Groves 2006) of the genus *Tarsius* are recognized; with the possibility of another new species from Sulawesi and its surrounding islands. One of the eight species is *Tarsius bancanus* Horsfield 1821 (Western tarsier[*]), which is distributed in Borneo, southern Sumatra, Bangka, **Belitung**, Karimata and the South Natuna Islands.

Among the four subspecies of Western tarsiers that have been described, *Tarsius bancanus saltator* Elliot 1910 is restricted to the island of Belitung. Brandon-Jones *et al.* (2004) stated that Hill (1955) recognized *Tarsius bancanus saltator* as a poorly defined subspecies, perhaps synonymous with *T. b. bancanus*, but Groves (2001) recognized that *T. b. saltator* has fur that tends to be less woolly and its dorsal tone more iron grey than other subspecies.

Tarsiers receive little conservation attention within their geographic range. This lack of attention is probably due to the fact that tarsiers are uncommon, elusive, rarely seen (because of their nocturnal habit) and compete for conservation attention with well-known flagship species, especially in Sumatra, e.g. orang utans (*Pongo pygmaeus*), Sumatran rhinoceros (*Dicerorhinus sumatrensis*) and tigers (*Panthera tigris*).

[*] Throughout this dissertation the common name "Western tarsier" was used for any tarsier from Borneo, Sumatra, Bangka, Belitung and Natuna; the name "Eastern tarsier" for any tarsier from Sulawesi and its surrounding islands and "Philippine tarsier" for any tarsiers from the southern Philippine Islands.

1.2 Objectives of the study

The subspecies *Tarsius bancanus saltator* is endemic to the island of Belitung. Geologically, Belitung Island is separated from Sumatra since thousands of years ago (Whitten *et al*. 2000, Voris 2000). Belitung, like Bangka as the nearest neighbouring island but not mainland Sumatra, are known as the islands of tin. The rare “Kerangas” ecosystem (heath forest), which does not occur on Sumatra mainland island, can be found on Belitung. This island is mentioned as one of the endemism centres of the Sumatran region (Natus 2005), however, there is no conservation area on the island (Supriatna *et al.* 2002). Moreover, tarsiers in Belitung (*Tarsius bancanus saltator*) were recognized as a distinct sub-species from *Tarsius bancanus bancanus* which occupies Bangka and some places of southern Sumatra (Groves 2001, Brandon-Jones *et al.* 2004).

This study is about the ecology of the *Tarsius bancanus saltator* on Belitung Island, Indonesia. The home range sizes, population densities, insect abundance, substrates for movements and habitat selection of the tarsiers were studied by telemetry. The study was aimed to identify the critical resources for the tarsiers' survival and adaptation on Belitung Island. Thus, the research should contribute to the conservation action of the species.

The specific aims of this study are: (1) to provide home range estimates, (2) to provide an estimate of the population size and densities of *Tarsius bancanus saltator* on Belitung Island; (3) to discuss the implications of this information in terms of the conservation status of the Belitung Island tarsier and (4) to create and increase awareness of the local people for the conservation of this unique creature.

Crompton & Andau (1986, 1987) reported a very large home range and low population density of the Western tarsier compared to the Sulawesi tarsiers (e.g.: Gursky 1998b, Merker 2003). It was also reported that tarsiers utilized primary and secondary forest. Merker & Muehlenberg (2000), and Merker *et al.* (2004, 2005) reported that tarsiers responded to human interference by adapting their ranging patterns to different levels of disturbance. Since there are different types of habitat on Belitung Island, it was hypothesized that the Belitung tarsiers would also adapt their patterns of range use to different types of habitats. Tarsiers will use any suitable habitat as long as that habitat provides enough food resources and appropriate substrates for locomotion.

Because patches of forests are surrounded by oil palm plantations, the question arise whether tarsiers use only the forest patch or need the adjacent habitat as well to meet all requirements for the life history? Do they leave the forest patch into the plantation? Or do they modify their behavioural ecology? To answer these questions, it is necessary to study their home range size, the pattern of range use, the nightly travel distances and the population densities of tarsier.

Therefore, one of the main questions of this dissertation was: do tarsiers need more than one habitat type to satisfy their home range? Or is one habitat type big enough to support the required home range? Is the density of tarsiers really low and do they have wide home range or are tarsiers just hard to see according to their nocturnal habits?

A second objective of the dissertation was the setting of the following question: what are the differences between *Tarsius bancanus saltator* and *T. b. borneanus* (studied by Niemitz 1979, Crompton & Andau 1986, 1987), *T. dianae* (Merker 2003) and the Spectral tarsier (Gursky e.g. 1998b, 2000a, 2002a, c, 2003b, 2005a, and 2006) concerning their home ranges, population density and social system? Different location, different populations and sample sizes would be expected as factors to explain the differences among those studies. In addition, it was also expected that there are different behavioural ecology among the species.

A third issue of the dissertation focused on the conservation: how is the conservation status of tarsier on Belitung Island? Since the high rates of deforestation and habitat changed still occur, even in protected areas in Indonesia, it was predicted that it would threaten the population density of Belitung tarsiers. Based on the home range size and population densities, the population size should be able to predict. Combined with the estimation of remaining suitable habitat for tarsier, their conservation status could be assessed and should not remain data deficient.

Chapter 2: General Review on Tarsier

2.1 Biology of Tarsier

2.1.1 Systematics and Distribution of the Genus *Tarsius*

At present there is only one extant genus of Tarsiiformes, *Tarsius*. The relationship of tarsiers to other primates, both living and fossil, has been the focus of numerous controversies. Yoder (2003), Wright *et al.* (2003a) and Gursky (2006) have been resumed those controversies over the tarsier classification within the order of Primates. Morphological evidence, including soft-tissue characteristics, suggests that tarsiers are closely related to small nocturnal prosimian primates (lemurs, lorises and bush babies), called *strepsirhine primates*. Another suite of anatomical and reproductive characters yet suggests that tarsiers may be more closely related to monkeys, apes and humans, called *haplorrhine primates*. Yoder (2003) stated that the situations of extreme phylogenetic uncertainty, such as seems to be the case with tarsier affinities, often relate to problems of short internal branches confounded by long external branches. She mentioned that it can happen that speciation and cladogenesis occur very rapidly and are then followed by a long period of independent evolution for the resulting lineages.

The taxonomy of the tarsier is also momentarily still in debate. How many extant species are there? The answers range from three to eight (Hill 1955, Niemitz 1984d, Musser & Dagosto 1987, Groves 2001, Wright *et al.* 2003a, Brandon-Jones *et al.* 2004, Merker & Groves 2006). Morphological evidence splits extant tarsiers into two distinct phenetic groups: a Philippine-Western group from the Philippines and the Greater Sunda Islands respectively, and an Eastern group from Sulawesi (Brandon-Jones *et al.* 2004). Moreover, there are also differences in chromosom numbers between some tarsier species. The Bornean and the Philippine tarsier are having a karyotype of 80 chromosomes (Dutrillaux & Rumpler 1988), Dian's tarsier have 46 chromosomes (Niemitz *et al.* 1991), while the karyotypes of the other species are still unknown.

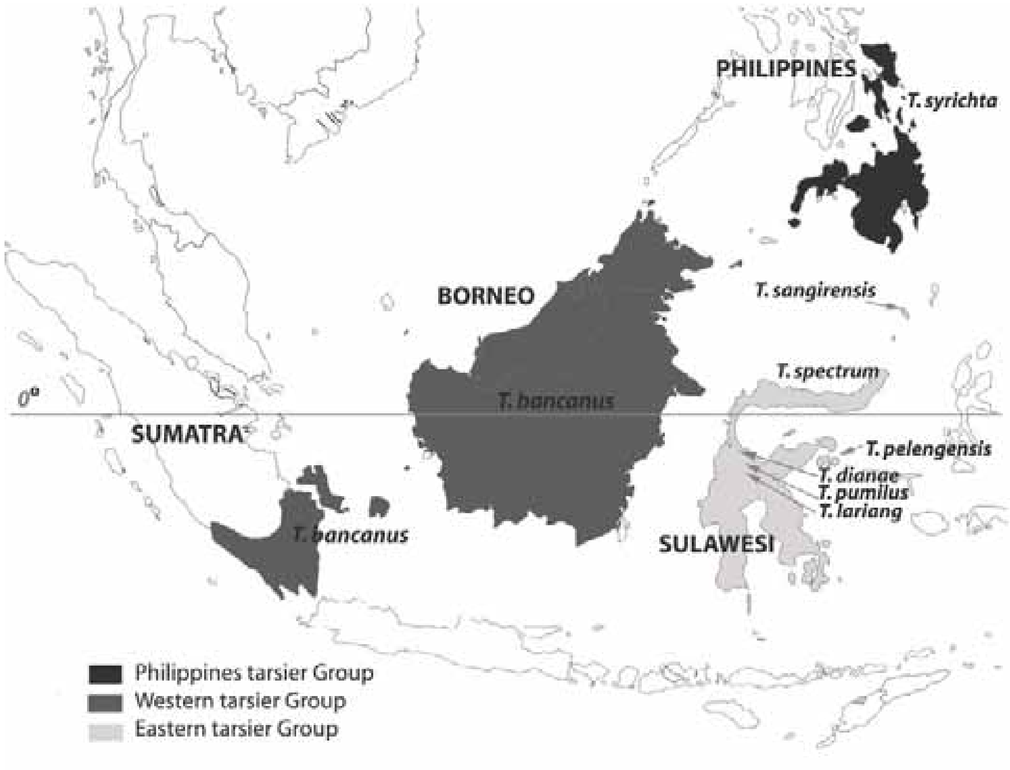

Figure 2.1. Geographic distribution of eight currently recognized tarsier species. Source: Niemitz (1984d), Supriatna & Wahyono (2000), Groves (2001), Brandon-Jones *et al.* (2004), Merker & Groves (2006).

Discoveries of new populations as well as morphological, genetic and vocal-acoustic investigations, and the processing of historical data lead to the fact that in the next years, with a large probability, new tarsiers will be described. Today, tarsiers have a unique distribution only on a few islands within 4 countries in Southeast Asia (Figure 2.1).

The eight species of tarsiers currently described are (Merker & Groves 2006, distributions according to Brandon-Jones *et al*. 2004):

1. Dian's tarsier *Tarsius dianae* Niemitz, Nietsch, Warter and Rumpler 1991; distribution in Indonesia (northern areas of Central Sulawesi, from the Lore Lindu National Park to Luwuk). Merker & Groves (2006) stated that the correct name for this species may be *Tarsius dentatus* Miller & Hollister, 1921 as described by Brandon-Jones *et al.* (2004) based on morphological characters and acoustic form found by Shekelle *et al.* (1997).

2. Peleng tarsier *Tarsius pelengensis* Sody 1949; distribution in Indonesia (Peleng Island and possibly other islands of the Banggai Island chain, Central Sulawesi)
3. Pygmy tarsier or Mountain tarsier *Tarsius pumilus* Miller and Hollister 1921, distibution in Indonesia (Latimodjong Mountains, 2,200 m, South Sulawesi; Mt. Rorekatimbu, 2,200 m; Rano Rano, 1,800 m, Central Sulawesi)
4. Sangihe tarsier *Tarsius sangirensis* Meyer 1897, distribution in Indonesia (Greater Sangihe Island, North Sulawesi)
5. Makassar tarsier *Tarsius tarsier* Erxleben 1777; distribution in Indonesia (the South West peninsula, north to the Tempe depression, South Sulawesi; Gorontalo to Tanjung Panjang, North Sulawesi; Gorontalo to Manado, North Sulawesi; Palu Valley, West Central Sulawesi; Near Sejoli, border of North and Central Sulawesi; Selayar, South Sulawesi; Buton Islands and SE. peninsula, South Sulawesi; Tinombo, south to Ampibabo, Central Sulawesi; Togian Islands, Central Sulawesi. The name *Tarsius spectrum* might be a junior synonym of *T. tarsier*.
6. Lariang tarsier *Tarsius lariang* Merker & Groves 2006; distribution on western Central Sulawesi (Gimpu, Lampelero, Tomua and Marena).
7. Philippine tarsier *Tarsius syrichta* Linnaeus, 1758, distribution in the South Philippines islands (Samar, Mindanao, Bohol, Leyte, Basilan, Dinagat, Siargao).

8.1. Western tarsier *Tarsius bancanus bancanus* Horsfield, 1821; distribution in Indonesia (Bangka, lowland southeast Sumatra from the Sunda Strait approximately to the Musi River; implausibly reported in Java)

8.2. Bornean tarsier *Tarsius bancanus borneanus* Elliot, 1910; distribution in Brunei, Indonesia (Kalimantan), Malaysia (Sabah, Sarawak)

8.3. Natuna tarsier *Tarsius bancanus natunensis* Chasen, 1940; distribution in Indonesia (Serasan, Subi, South Natuna Islands)

8.4. Belitung tarsier *Tarsius bancanus saltator* Elliot, 1910; distribution restricted to Belitung Island, Indonesia.

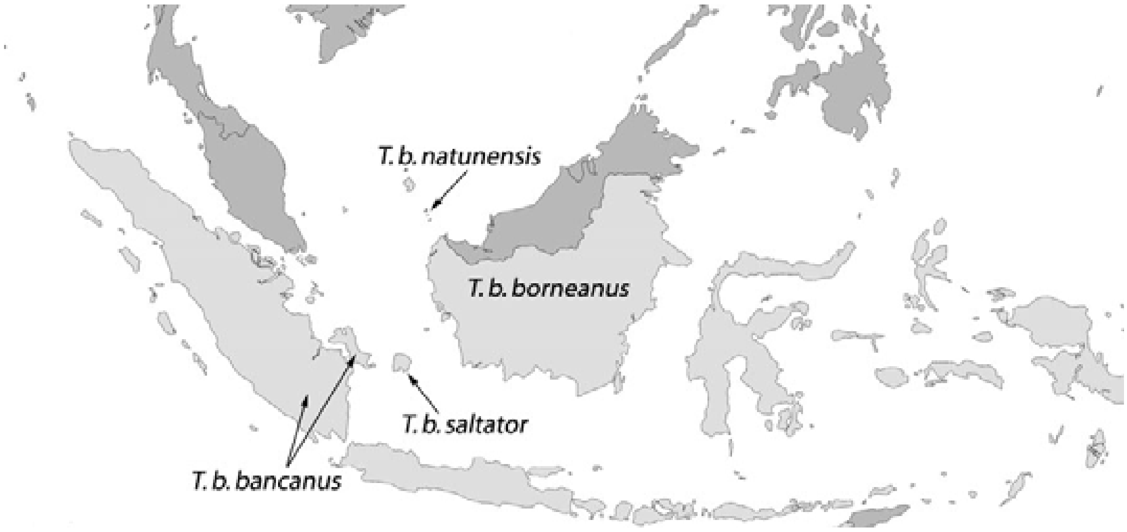

Figure 2.2. Geographic distribution of four subspecies of *Tarsius bancanus*

2.1.2 General Morphology of the Genus *Tarsius*

All tarsiers are small, nocturnal, vertical clinging and leaping, faunivorous animals and as such, they are anatomically and ecologically distinctive with regard to other primates. Schwartz (2003) resumed that the most clear-cut similarities between *Tarsius* and anthropoids include primary supply of the middle meningeal artery via the maxillary artery, lack of a tapetum, lack of a moist and hairless rhinarium and the inability to synthesize vitamin C.

Among tarsiers, however, there exists previously underemphasized variability. The differences may include body weight, intramembral indices, finger pads, absolute orbit size, absolute tooth size, limb proportions, the proportion of tail that is covered by hair, locomotor's behaviour, habitat selection, nesting/sleeping sites, communication, and social and ranging behaviour (Niemitz 1984, Jablonsky & Crompton 1994, Gursky 1999, Sussman 1999, Anemone & Nachman 2003).

The body of a tarsier is only around 12-13 cm long, but its tail is twice that length. Adult tarsiers weigh generally 100-140 gram, with differences among various species. Males may be slightly heavier than females (Fogden 1974, Niemitz 1984d, Crompton & Andau 1987, Neri-Arboleda *et al.* 2002, Merker 2003, 2006, Gursky 2006).

Tarsiers have huge eyes with the retina containing a fovea, but the eyes lack a light-reflecting *tapetum lucidum* and unlike most nocturnal animals whose eyes reflect light vividly, tarsiers' eyes only glow a dull orange/red when light is shone on them. The eyes' position is mobile in the orbital, as compensation of the head for over nearly 180° swivelling (Hill 1955, Niemitz 1984, Sussman 1999).

The colour of the dense fur of the Tarsier varies between gold-brown, dark-brown and grey, depending upon species and age of the animals (Hill 1955, Niemitz 1984). The hind-limb of the tarsier is characterized by an extremely extended tarsal (*tarsus*). The fingers and toes of the tarsier are extremely long and provided with terminal pads for better substrate adhesion. As vertically clingers and leapers, tarsiers are thus excellently adapted to the arboreal and jumping way of life. At the second and third toe there are grooming claws – a primitive characteristic within Primates – the other toes and fingers are protected by flattened and distally pointed nails.

2.1.3 General Behaviour of the Genus *Tarsius*

Insects represent the main food of the tarsier. Grasshoppers, crickets, cicadas, butterflies and moths are its favourite prey. In addition, ants, termites, beetles, cockroaches and even small birds and also lizards are eaten. Tarsier is the only primate, which has a diet exclusively consisting of animals. (Hill 1955, Fogden 1974, Niemitz 1979, 1984c, Crompton & Andau 1986, 1987, Jablonski & Crompton 1994, Crompton *et al.* 1998, Gursky 2002a, Merker 2003, Merker *et al.* 2004, 2005).

Little is known about the natural enemies of the tarsiers. Gursky (2002b) observed one successful predation of a tarsier by a snake (*Python reticulatus*). Shekelle (cited in Sussman 1999) observed similarly catch attempts by snakes and a successful predation by a Monitor lizard (goanna). In the presence of snakes, goannas, civets and raptors (and/or of mock-ups of these animals) tarsiers give warning calls (Gursky

2002a, b, c, 2005b). Further threats to the tarsier possibly come from large owls, wild cats and dogs (Niemitz 1979, 1984c, MacKinnon & MacKinnon 1980). In fact, tarsiers are generally considered to be predators of snakes as evidenced by Niemitz's classic photo of a tarsier consuming a neurotoxic snake (Niemitz 1979, 1984).

The social structures differ between the three groups of tarsier. Sussman (1999) suggested that the social group of *Tarsius bancanus* was solitary but social, in terms of some individuals may sleep together in nesting groups but forage separately. Fogden (1974) found that *Tarsius bancanus* was solitary, and he discussed a social organization of *T. bancanus* which has a similarity to *Galago demidovii* or *Microcebus murinus*. Niemitz (1979, 1984b) believed *Tarsius bancanus* to typically live in pairs. However, he stated that: "It is questionable whether Bornean tarsiers are strictly monogamous. Members of both sexes, however, live synterritorially for a long period, developing strong pair bonds". Wright *et al.* (1986a) could confirm this by their investigations of the courtship and copulations of this species in captivity. However, Crompton & Andau (1987) did not find this pattern in their radio-tracked animals. They found that individuals foraged and slept alone. They believe that the social structure of the Bornean tarsier "seems to be closer to the generalized 'noyau' pattern of many lorisines and galagines than to any form of monogamy or pair bonding", though distinguished from these by the extreme degree of solitariness and the lack of contact at sleeping sites.

The Philippine *Tarsius syrichta* is reported to show a polygamous, without-firm-group structure (Dagosto & Gebo 1997, Neri Arboleda *et al*. 2002). Wright *et al.* (1985, cited in Sussman 1999) noted that the amount of contact between *T. bancanus* individuals is minimal compared to that for *T. syrichta*. Individuals of the latter species play, allogroom, urine mark, genital sniff and call frequently throughout the night, while the Western tarsiers interact infrequently and rest alone for long periods.

More recent studies on the Sulawesi tarsiers indicate that those species are able to live in groups containing more than one adult of the same sex, for example, one adult male with one to three adult females and their offspring (e.g. MacKinnon & MacKinnon 1980, Gursky 1995, 1998b, 2000a, 2005a, Merker 2003, Merker *et al.* 2004, 2005).

The group members of Sulawesi tarsiers hunt solitarily, however, they spend the daily hours usually together in the same sleeping tree. The sleeping tree or sleeping site are usually strangler figs (*Ficus* spp.) or could be in bamboos, bushes or other sites which can protect them from rains and predators (MacKinnon & MacKinnon 1980, Gursky 1998b, Merker & Muehlenberg 2000, Yustian 2002, Merker 2003). During sunrise, and/or sometimes also at sunset, the adult and sub-adult tarsier of a family group of the Sulawesi tarsier specify a so-called "calling-duet", which functions as both territorial and social. The calling-duets differ between the different tarsier species on Sulawesi. Male and female of one species is likewise well distinguishable based on their call (MacKinnon & MacKinnon 1980, Niemitz 1984a, b, Niemitz *et al.* 1991, Shekelle *et al.* 1997, Nietsch & Kopp 1998, Nietsch 1999, Merker & Groves 2006). However, Fogden (1974) noted that Bornean tarsiers in Sarawak are relatively silent, and the Belitung tarsiers observed in this study also performed no duet calls or vocal signals.

Tarsiers mark their territory as well by urine and secretions from an epigastric and a circumoralic gland as well as by rubbing the genital region against the substrate (Niemitz 1979, 1984b, MacKinnon & MacKinnon 1980, Nietsch 1993 cited in Merker 2003). Niemitz (1984b) assigned a clear territorial meaning to this behaviour.

Usually, females give birth to only one offspring per year. The gestation lasts six months (Izard *et al*. 1985). The newborn tarsier is exceptionally large, attaining 25-33% of the mother's weight at birth, 20-30 g (Izard *et al.* 1985, Wright *et al.* 1987, Roberts 1994, Gursky 1999, 2006, Merker 2003). Infant tarsier will be parked by their mothers, while the mother goes on foraging (MacKinnon & MacKinnon 1980, Gursky 2000b, 2002c, 2006, Roberts 1994). The infant and its mother sleep in the same sleeping site, even the infant sleeps in the "lactation" position (Figure 4.3 in Chapter 4). Except in Sulawesi tarsier, male and female tarsiers were sleep in different sleeping sites (Fogden 1974, Niemitz 1984, Crompton & Andau 1986, 1987).

Tarsiers live in the under-storey of different forest types, both in primary forests and also in anthropogenic used forest areas. The population densities can reach of up to 1,000 animals/km^2 (MacKinnon & MacKinnon 1980) or as low as 14–20 individuals/km^2 (Crompton & Andau 1987). The home range sizes of the tarsier vary between 0.5 hectares (Tremble *et al.* 1993) and 11.3 hectares (Crompton & Andau 1986, 1987). The population densities and home range sizes will be discussed in Chapter 4. In captivity, the Philippine tarsier (*T. syrichta*) can live until 14 years (Ulmer 1960, Fitch-Snyder 2003). For animals living in the wild there is a reference that they can reach an age of 10-15 years (Shekelle pers. comm.).

2.2 Literature review on Tarsier Ecology and Behaviour

Some field studies on the Western tarsier's, *Tarsius bancanus*, ecology and behaviour have been conducted in Borneo (e.g. Fogden 1974 and Niemitz 1979, 1984 in Sarawak and Crompton & Andau 1986, 1987 in Sabah). There are very limited publications on the ecology of *Tarsius bancanus* in Sumatra or other islands where this species is known to occur and no study at all has been conducted on the Belitung tarsier (*Tarsius bancanus* ssp. *saltator*). The IUCN red data book (Eudey *et al.* 2000) has still listed the endemic Belitung Island tarsier under the category data deficient (DD). However, all tarsier species has been listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna (CITES 2003).

Merker (2003) stated that until the 1980s, tarsiers were hardly subject of scientific views. Besides Hill (1955) with his comprehensive volume on Tarsioidea, only Fogden (1974) and Niemitz (1979, 1984) for tarsiers on Borneo and MacKinnon & MacKinnon (1980) for tarsiers on Sulawesi had studied and contributed to wild tarsier's research at that time. Niemitz summarized the knowledge of this species on his own field research and reports of other authors in the "Biology of Tarsiers" (1984).

Meanwhile, Musser & Dagosto (1987) confirmed the identity of a mountain pigmy tarsier species, *Tarsius pumilus*, based on morphometrical investigations of museum specimens and gave a good overview of the morphological and anatomical characteristics to that species. A new species, *Tarsius lariang,* from western Central Sulawesi was also described by Merker & Groves (2006) on the basis of morphological, anatomical, and acoustic analyses.

Crompton & Andau (1986, 1987) provided valuable information on habitat utilization by the first radio telemetry of Bornean tarsier; compiled also information on locomotion, ranging, activity rhythms and social structure of the Bornean tarsier. By telemetry study, the home range sizes and nightly travel distances could be determined and related to habitat preferences and social structure. A pilot study of Dagosto & Gebo (1997) over the Philippines tarsier found its continuation in the work of Neri-Arboleda *et al.* (2002), determined home ranges, spatial movements and patterns of habitat use during a radio-tracking study. Other valuable telemetry studies on the tarsiers were those by Tremble *et al.* (1993), Gursky (e.g.: 1995, 1998a, b, c, 2000a, b, c, 2002a, c), Merker (2003, 2006) and Merker *et al.* (2004, 2005).

Since the middle of 1980s, much research on the tarsier was conducted in addition to telemetry studies. The reproduction and developmental biology of the tarsier in captivity was described by, e.g., Izard *et al.* (1985), Wright *et al*. (1986a, b) and Roberts (1994). Many aspects of the biology of tarsiers in captivity were also provided by Wright *et al.* (1987), as well as on locomotion and functional anatomy (Niemitz 1985, Gebo 1987), feeding behavior and tooth wear (Jablonski & Crompton 1994, Crompton *et al*. 1998). An analysis of the tarsier genes based on mitochondrial sequences was done by Schmitz *et al*. (2001, 2002)

However, the main emphasis of research on the tarsier in the last two decades has still focused on Sulawesi. MacKinnon & MacKinnon (1980) estimated population densities in different habitats and studied, like Niemitz (1984), substrate use and vocalization. Tremble *et al*. (1993) conducted telemetry studies of four individuals of the new tarsier species, which were described by Niemitz *et al*. (1991) as *Tarsius dianae*, informed about home range sizes and quantified substrate use. Nietsch & Niemitz (1991, 1992) examined morphometry, development and behaviour of tarsiers in North Sulawesi. Nietsch & Kopp (1998) and Nietsch (1999) analyzed the connection between sound expressions of different populations and the speciation of the Eastern tarsier. Nietsch (2003) also outlined the vocal behaviour of the Spectral tarsier. Shekelle *et al*. (1997) and Shekelle (2003) integrated acoustic, genetic and biogeographical aspects, in order to reconstruct the radiation of the genus *Tarsius,* especially Eastern tarsier. Gursky (e.g.: 1995, 1998a, b, c, 1999, 2000a, b, c, 2002a, b, c, 2005a, 2006) investigated the social structures and behaviour of the Spectral Tarsier (the correct name for this species might be *Tarsius tarsier* as mentioned by Brandon-Jones *et al*. 2001, Merker & Groves 2006 and Gursky 2006) in north Sulawesi with special consideration of the infant care, gregariousness, determined population densities, home range use, nightly travel distances and analyzed the influence of seasonality on the animals. Gursky (1998a, 1999) also documented the population sizes of the Tarsier in north Sulawesi and differentiated for the first time population densities from *Tarsius dianae* (or possibly synonymous *T. dentatus* as mentioned by Brandon-Jones *et al.* 2004 and Merker & Groves 2006) with respect to primary and secondary habitat in central Sulawesi in order to assess the conservation status of the two species. Furthermore, Gursky shares the results of her long-term field study in the book “The Spectral Tarsier” (2006).

Wright *et al.* (2003a) and other authors summarized a tarsier volume after Niemitz (1984) and make a significant contribution to the literature on tarsier biology. The book collected articles by tarsier experts, bringing together a representative sample of recent advances in tarsier studies. Some of them are based on new theoretical approaches, others represented new fossil finds. The contributors draw on a range of scientific disciplines - from the origins, phylogeny, anatomy, genetics, behavioural ecology, taxonomy, bioacoustics and conservation - to provide a detailed examination of not only the past and present, but also to give recommendations for the future conservation of these intriguing primates.

Merker *et al*. (2004, 2005) found that Dian’s tarsiers in Central Sulawesi to be quite adaptable to traditional human land-use; the animals responded to human interference by adapting their ranging patterns to different levels of disturbance. Merker & Muehlenberg (2000) and Merker *et al.* (2004, 2005) also found that population densities of Dian’s tarsier have declined during the last years in all the habitat types they have observed. Last but not least, Merker (2006) reported the habitat-specific ranging patterns of Dian’s tarsier as revealed by radio tracking.

Chapter 3: Materials and Methods

3.1 The Species *Tarsius bancanus* and Subspecies *T. b. saltator*

The species *Tarsius bancanus* (Western tarsier) was firstly described by Horsfield 1821 (Hill 1955). The species distribution covers Borneo, southern Sumatra, Bangka, Belitung, Karimata and South Natuna Islands. Four subspecies of Western tarsiers have been described (Hill 1955, Niemitz 1984, Musser & Dagosto 1987, Groves 2001 with the exception of *T. b. natunensis* and Brandon-Jones *et al.* 2004), these include (see Figure 2.2 for its geographic distribution):

- *Tarsius bancanus bancanus* Horsfield 1821 (type specimen lost, type locality is Jebus on the northwest tip of the island of Bangka, also found in southern Sumatra);
- *T. b. borneanus* Elliot 1910 (type locality Borneo);
- *T. b. natunensis* Chasen 1940 (type locality South Natuna Island of Serasan) and
- *T. b. saltator* Elliot 1910 (type locality Belitung or Beliton).

The last subspecies is restricted to the island of Belitung, has hairs which tend to be less woolly than other subspecies and dorsal tone more iron gray (Hill 1955, Groves 2001). Although Brandon-Jones *et al.* (2004) noted that Hill (1955) recognized *Tarsius bancanus saltator* as a poorly defined subspecies, perhaps synonymous with *T. b. bancanus*, they mentioned that Groves (2001) recognized it, except the museum specimen dissimilarity seemed insignificant to Niemitz (1984) and an inadequate basis for judgement according to Musser and Dagosto (1987).

All field studies on the Western tarsier *T. bancanus* have been conducted in Borneo (Fogden 1974, Niemitz 1979, 1984, Crompton & Andau 1986, 1987). There are no publications on the ecology of *T. bancanus* in Sumatra, and no study at all had been conducted on the Belitung Island tarsier (*T. b. saltator*).

Figure 3.1. Adult male of *Tarsius bancanus saltator*.

3.2 Study Area

3.2.1 Belitung Island

This study was conducted on Belitung Island, 107°35' - 108°18' Latitude and 2°30' - 3°15' Longitude (Figure 3.2). Belitung is an island southeast of Sumatra and Bangka. The study was concentrated in the north-eastern part of the island where tarsiers are reported to exist (Bappekab Belitung 2003, http://www.nature-conservation.or.id/primates/tarsius_bancanus.html). The total land cover is approximately 4,800 square kilometer. The length of diameter from east to west is approximately 79 km and from north to south is approximately 77 km. The climate is tropical, temperature around 27 - 31 C degree during the day and 23 -25 C degree during the night. There are only 2 seasons a year, a rainy season from October to April and hot season during April to October (BPS 2002, http://www.belitungisland.com).

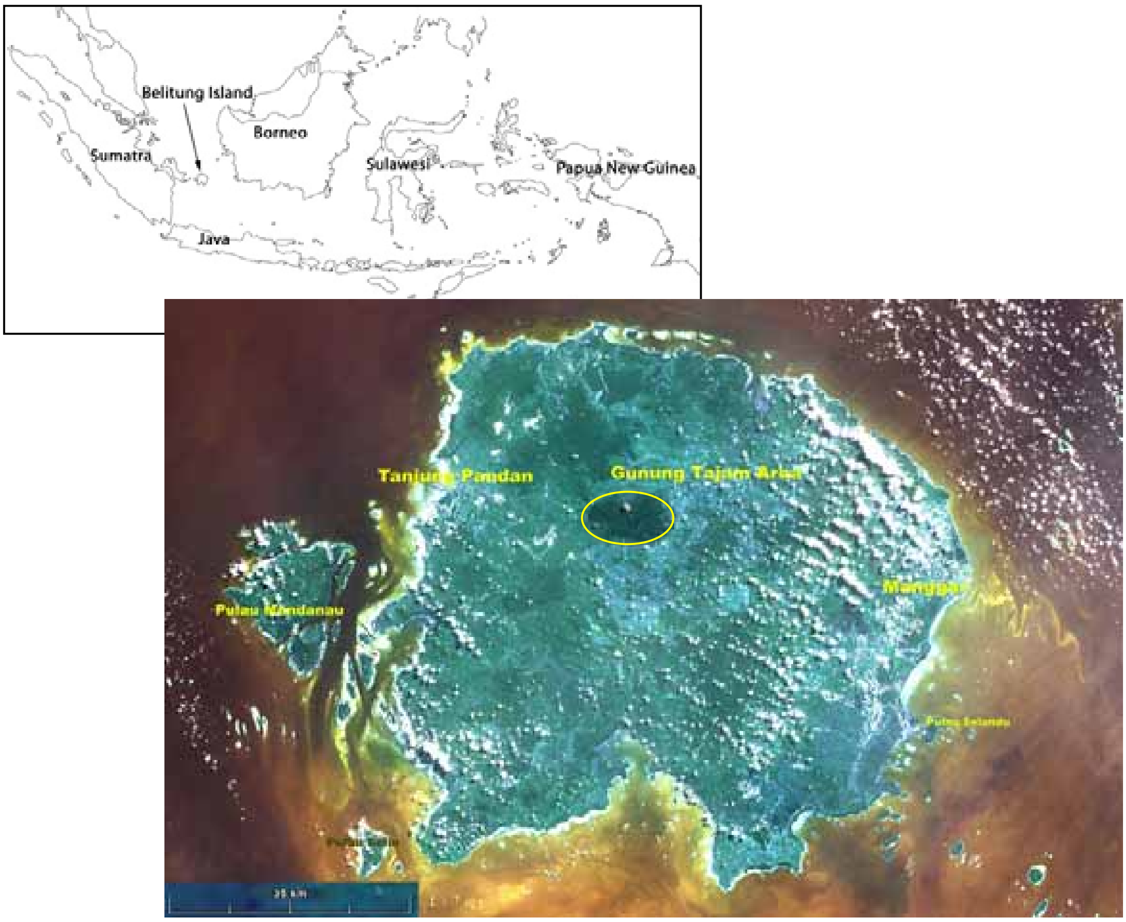

Figure 3.2. Map of Belitung Island and the location of field study (source of Landsat image: http://glcfapp.umiacs.umd.edu8080esdiindex.jsp).

The highest area is Gunung Tajam Mountain, located 25 km from Tanjungpandan (the district capitol), only 500m above sea level, still containing of a wide area of forest. Tanjung Pandan is located on northwest of the Island (Figure 3.2). The main resources are tin mining, kaolin, quartz sands and granite rock. During the Dutch occupation, the tin mining industry was established and continued by the Government of Indonesia (http://www.indahnesia.com/indonesia.php?page=SSEBEL). At the beginning of the 1990s, the main tin exploration managed by the Government of Indonesia was officially closed, but the tin exploration was still continued by the local communities using *in-conventional* mining method.

The land surface in Belitung was originally tropical lowland forest, but currently, much of the land surface is changing into oil palm plantations. The tropical lowland forest in Belitung consist some plant species from Family i.e.: Dipterocarpacea, Fabacea, Sapindacea, Lauracea and Euphorbiacea (Bappekab Belitung 2003). Harcourt (1999) and Bappekab Belitung (2003) also reported that there are only three primates occupying Belitung, i.e.: the long-tailed macaque (*Macaca fascicularis*), the silvery leaf-monkey (*Trachypithecus cristatus*) and the tarsier (*Tarsius bancanus*).

Although there are some Protection Forests (*Bahasa*: *Hutan Lindung)* on the island, which mainly designated to preserve watershed and ecosystem functions and despite the island being one of the endemism centre of the Sumatran region (Natus 2005), there is no conservation area on Belitung Island (Supriatna *et al.* 2002).

3.2.2. Gunung Tajam Protection Forest and its Environment

Gunung Tajam Mountain, located 25 km from Tanjungpandan (the district capital), is the highest land on the island. Although it is only 500m above sea level, the local people call it a "mountain" (*Bahasa: Gunung*). The Gunung Tajam Area, with a total area approximately 45 km^2, still consists of a wide area of forest. Bappekab Belitung (2003) reported 26 plant species from 17 Family found in Gunung Tajam. Some plant species for example: *Hopea bilitonensis*, *Calophyllum* sp, *Aquilarria malaccensis, Palaquium rostratum, Ilex cymosa* and *Oncosperma horridum.* All three species of primates on Belitung Island can be found in the Gunung Tajam Area. A list of plant species is given in the appendix.

The status of the Gunung Tajam is Protection Forest. Even though, Gunung Tajam is also an ecotourism area and many people come especially at weekends. For subsistence purposes, such as wood-fire or wood-house structure, the villagers and local people often harvest the trees from the Gunung Tajam Area. At some locations, which border the protected forest area, there are some small-scale (0.2-0.5 ha) pepper plantations belonging to the villagers.

Based on the report from Bappekab Belitung (2003), in the Gunung Tajam Area more than 50% of 93 birds species of Belitung Island are found. Some of the interesting species are for example: *Pycnonotus atriceps, Anthracoceros malayanus* and *Copsycus malabaricus*.

3.2.3 The Study sites

The field work was done in three periods, from early March to the end of August 2004, early March to the end of July 2005 and from mid February to the end of May 2006. Four habitat types could be classified at Gunung Tajam; i.e.:

(1) secondary forests with small-scale pepper plantations and selective harvesting for wood fire, afterwards will be referred as **study site H1**,
(2) secondary forest with small scale logging and surrounded completely by large oil palm plantations or **study site H2**,
(3) old secondary forest in the very steep-hilly area and
(4) oil palm plantations.

For the purpose of this work, it was decided to focus only on habitats at the study sites H1 and H2. Considering of safety and practical reasons, but also size of the patch of the old secondary forest in the very steep-hilly area which is relatively small (less than 20 ha), this type of habitat was not studied. Since it seems not suitable for tarsiers and not a single sign of urine mark were found, the oil palm plantations were not studied as well.

Study site H1 is located on the border of Gunung Tajam Potected Forest with the total area approximately 96 ha (Figure 3.3). There are some small-scale (0.2-0.5 ha) pepper plantations and also small-scale selective harvesting for wood fire or wood-house structure. Study site H2 is located on the outside of Gunung Tajam Protection Forest. It is a retained forest, with total area approximately 80 ha, of the big oil palm plantation company. This secondary forest is surrounded completely by oil palm plantations and pepper plantations, thus logging for wood fire and building are more frequent.

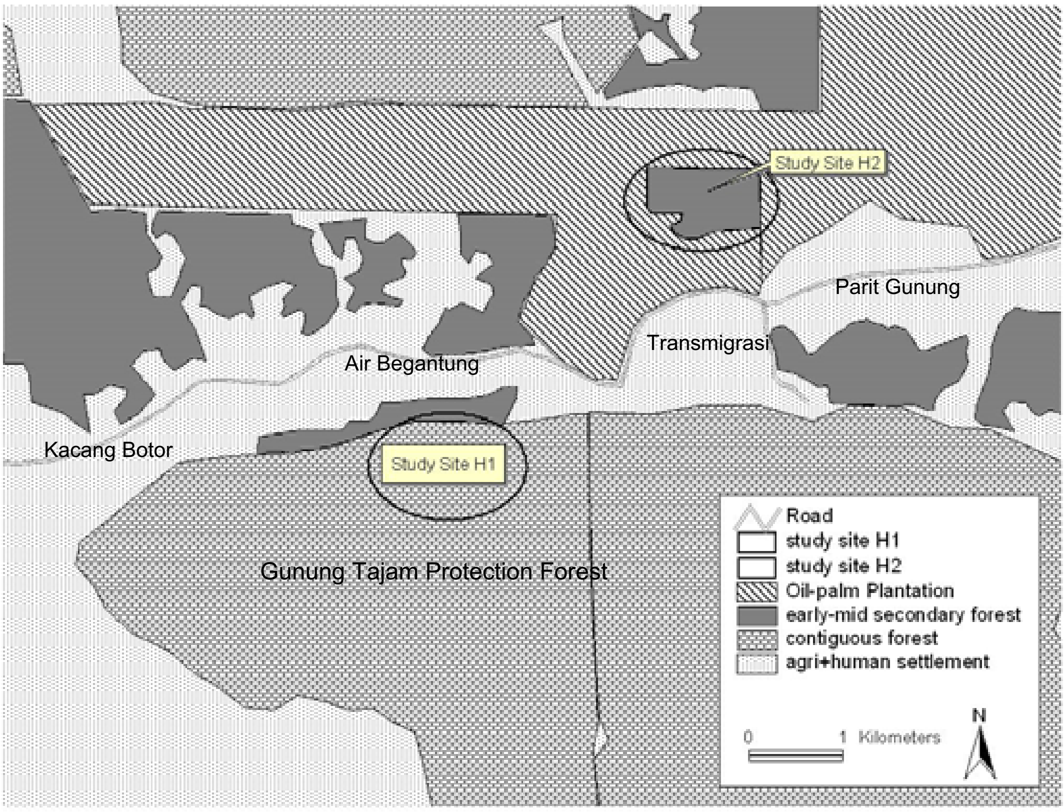

Fig. 3.3. Locations of the two different study sites on Belitung Island.

3.3 Data Collection

3.3.1 Localization and Capture of the animals

Selection of Study Sites

Gunung Tajam Protection Forest area had been chosen as a study site because it still consists of about 4,500 ha of contiguous forest, and reported as the only one from 6 locations tarsiers are found (Bappekab Belitung 2003). In this area, there are four types of habitat that could be classified as mentioned in Chapter 3.2.3.

Localization of Tarsiers

Localization of tarsiers had been done by recording urine marks as well as consultation of local people and scanning suitable habitats. It was not possible to identify tarsiers sleeping sites in a first survey. Because the Belitung tarsiers do not perform a duet vocalization in the morning (morning duets) like tarsiers in Sulawesi, the localization seems possible only by their urine marks on tree trunks. Indeed, tarsiers are more difficult to study than most other nocturnal mammals because they do not possess a *tapetum lucidum*, the reflective layer behind the eye that helps observers locate most nocturnal mammals in the dark (Fogden 1974, Niemitz, 1984, Sussman 1999).

Capture and radio collar attachment

Tarsiers were captured using mist-nets. Three to five polyester mist-nets (length: 9-12 m; height: 2.10-2.70 m; mesh-size: 16 mm) were set up for each trapping occasion, from ground level up to 2.5 m above the ground in areas where tarsiers have been located. Nets were either opened 1-2 hours before dusk and close after dawn or closed before midnight and reopened at dawn. The nets were checked every 1 to 2 hours and any trapped birds, bats or insects were released.

The mist-nets were transferred to other locations when no animals were caught for 3 to 7 consecutive nights. Individuals that evaded the nets were also captured by hand. Each captured individual was placed in a bag and weighed with a spring scale. Animals were examined through visual assessment and palpation to determine gender, reproductive condition (pregnant, non-pregnant) and any injuries that might have been occurred during capture.

The radio-collar was fastened around the animal's waist. A hand-held radio receiver (STABO XR100-Radioscanner) was tuned to a frequency band of 150-151 MHz or to the appropriate frequency. The radio receiver was attached by a coaxial cable to a folding hand-held portable H-antenna. The maximum effective reception distance at the site was about 100-150 m depending on weather and vegetation density.

3.3.2 Biometrical Measurements

The following morphological measurements were taken using a calliper and tape measure: (1) tail length, (2) tuft length, (3) body length, (4) head+body length, (4) hindlimb length, (5) hindfoot length, (6) arm length, (7) forearm length, (8) hand length, (9) thumb diameter and (10) ear length.

Adult individuals weighing more than 100 g and the sub-adult male were equipped with radio transmitters (model PD-2C, Holohil Systems Ltd., Ontario) of different set frequencies within a 150 MHz band with an average life span of 6 months. The morphological measurements and attachment procedure took approximately 20 minutes and did not require the use of any immobilizing drug.

3.3.3 Radio telemetry

Radio-collared animals were tracked using continuous monitoring. A single sampling shift is equivalent to 12 h: dusk (18:00) to dawn (06:00); 6 h: dusk (18:00) to midnight (24:00) or 6 h: midnight (24:00) to dawn (06:00). Continuous tracking involves following the movements of an animal through an entire sampling shift and taking bearings at 15-minute intervals. Animal positions were estimated by triangulation of the signals from different fixed-reference points and record of the compass direction. Locations of fixes were obtained by simultaneous triangulation (Kenward 1987, White & Garrot 1990) and animal positions estimated from marked and measured reference points. Data derived from continuous tracking were used for the home-range analysis. Nightly travel distance was calculated using points from the 15-minute interval tracking. The home range size of each animal was estimated using the Minimum Convex Polygon method (Kenward 1987, White & Garrot 1990). The radio tracking gave 60-95 locations for each tarsier and each tarsier was radio-tracked over the course of *ca.* 1 week.

At the first phase of fieldwork, from March to August 2004, only five animals could be catched in study site H1, 3 males and 2 females. All of the tarsiers were measured and then radio tracked. In the second phase of fieldwork in the year 2005, a total of 14 captures were made (9 new captured animal and 5 recaptured). Three of the newly captured animals, which were captured in the same study site H1 as in the first phase, were radio tracked. In the 3rd phase of the fieldwork in the year 2006, a total of 15 animals were captured (including recaptured animals) in study site H1 and H2. Altogether, 22 (twenty two) different individuals of Belitung tarsier *Tarsius bancanus saltator* were captured within 42 captures (including recaptures). A total of 660 hours of radio-tracking was spent collecting field data. The collecting of field data was not set up to predict or to observe the effect of seasonality, therefore, it was not possible to discern a seasonal effect on home-range sizes and nightly travel distances

3.3.4 Habitat Parameters

Habitat parameters were recorded in order to know the ecological factors which affected the home range sizes, nightly travel distances and population densities of *Tarsius bancanus saltator* in both observed study sites.

3.3.4.1 Tree species

To characterize the habitat within the study area quantitatively, a vegetation survey had been conducted using the Point-Centre-Quarter (PCQ) method in 16 randomly chosen points within each habitat type. Trees that were higher than 1 m and more than 10 cm diameter at breast height (dbh) were counted and their Importance Value Index calculated. Importance Value Index indicates the frequency, dominance, and density of the plant species in a certain area (Brower *et al.* 1990).

3.3.4.2 Abundance of Substrates for Locomotion

<u>Density of locomotion supports</u>: Based on the results of the habitat-use analysis by Crompton & Andau (1986, 1987) and Merker (1999, 2003), the branch/trunk/sapling trees with a diameter between 1-4 cm were measured, in vertical and horizontal orientation, to analyse the substrate for locomotion abundance. The sampling method used PCQ, with the same 16 random points in each habitat.

3.3.4.3 Insect abundance.

Relative insect abundance*:* Two sampling methods were employed to estimate the abundance of insects, at eight sample points and three replicate counts for different evenings over 19.00-21.00, followed the method which was developed by Merker 2003, and Merker *et.al.* 2005.

Light traps: were used for counting flying-insects. One petroleum lamp was hung on the trees at a height of 1.5 m. Five minutes after the set up of the lamp, all flying-insects with body size $\geq$ 1 cm attracted to the light along 5 minutes were counted. By differentiating the animals by species, size and locations it was possible to avoid repeat counts of a single specimen. Identified insects by this method mainly were moths, winged termites and mantids.

Insects Sound: At the same random points, singing insects in an area around radius 10-15 meters were counted over 5 minutes. Repeated counts were avoided by noting specific vocalization patterns and the locations of individuals. Identified insects by this method were mainly grasshoppers, crickets and cicadas.

3.4 Data Analysis

To test significance of difference, first of all, all data was examined with the Kolmogorov-Smirnov test for normal distribution. In the case of a deviation from the normal distribution ($p<0.05$) or with very small random inspection sizes, non-parametric tests were used for the investigation of differences (Mann-Whitney-U-test). Normal-distributed or approximately normal-distributed data by means of parametric procedures were evaluated (t-test). If otherwise not specified, all examinations of statistic significance were two-tailed. If not separately characterized, average values and standard deviations are always indicated during the representation of normally distributed data in diagrams and tables.

The following computer programs were used during the collection, evaluation and representation of the data (manufacturers in parentheses): Adobe Photoshop 7.0 (Adobe system), ArcView GIS 3.2 (ESRI, Redlands), SPSS for windows (SPSS Inc.), Excel 2002 (Microsoft) and Word 2002 (Microsoft).

The population size of the *Tarsius bancanus saltator* over the island of Belitung was estimated based on information on habitat availability from satellite images. The satellite image (Orthorectified Landsat Enhanced Thematic Mapper (ETM+) Compressed Mosaics, from the year 2000) was downloaded from https://zulu.ssc.nasa.gov/mrsid/. The satellite image was used to estimate the suitable habitats for tarsier, i.e. remaining forested area on the island. After entering the image into the ArcView GIS 3.2 program (ESRI, Redlands), three different available habitats were classified and calculated, i.e.: contiguous forest (which is similar with the study site H1), secondary forest with bushes (which is similar to H2) and oil palm plantations.

Chapter 4: Results

4.1 Population Parameters

In total, ten adult males, ten adult females, one juvenile male and one juvenile female were radio-tracked. Table 4.1 shows the number of animal captured and radio-tracked within 3 phases of fieldwork conducted in the two study sites.

Table 4.1. The number of captured, recaptured and radio tracked tarsiers in two different study sites on Belitung Island.

Study site	**H1**			**H2**			**Total**
Year of field work	2004	2005	2006	2004	2005	2006	
Number of animals Captured	5	3	3	-	6	5	22
Number of animals Recaptured	5	5	4	-	-	6	20
Number of animals Radio-tracked	5	3	3	-	-	11	22

4.1.1 Home Range Size

In study site H1, the average home-range area was 10.25 $\pm$ 1.08 ha for adult males and 2.32 $\pm$ 0.48 ha for adult females. In study site H2, the average home-range was 4.29 $\pm$ 0.09 ha for adult males and 3.04 $\pm$ 0.16 ha for adult females. The home range sizes for each radio-tracked tarsier in both study sites are presented in Table 4.2.

There was a significant difference in home-range sizes among adult males and females (Mann-Whitney U-test, $P<0.001$, $n=20$). There were also a significant difference in home-range sizes among adult males and females in study site H1 (Independent Samples t-test, $P<0.001$, $n = 11$) and in study site H2 (Independent Samples t-test, $P<0.001$, $n=9$).

Comparing between habitats, the home-range size of adult males in study site H1 (10.25 $\pm$ 1.08 ha, $n = 5$) were significantly higher than the home-range size of adult males in study site H2 (4.29 $\pm$ 0.09 ha, $n = 5$). On the other hand, adult females home-range sizes in H1 (2.32 $\pm$ 0.48 ha, $n = 6$) were significantly smaller (Mann-Whitney U-test, $P = 0.019$, $n = 10$) than those of females in H2 (3.04 ha $\pm$ 0.16, $n=4$).

Table 4.2. The home range sizes of all captured and radio tracked tarsiers in the two different study sites on Belitung Island.

Study site H1		Study site H2	
Animal	**Home-range-size (ha)**	**Animal**	**Home-range-size (ha)**
M1H1	10,04	M1H2	4,41
M2H1	10,26	M2H2	4,35
M3H1	11,98	M3H2	4,25
M4H1	9,91	M4 H2	4,27
M5H1	9,03	M5 H2	4,18
F1H1	1,59	Mjuv1H2	0,99
F2H1	1,99	F1H2	3,25
F3H1	2,20	F2H2	2,88
F4H1	2,89	F3H2	2,98
F5H1	2,67	F4H2	3,06
F6H1	2,57	Fjuv2H2	0,88
Average ± s.d.	**Male: 10.25 ± 1.08** **Female: 2.32 ± 0.48**	**Average ± s.d.**	**Male: 4.29 ± 0.09** **Female: 3.04 ± 0.16**

* s.d = standard deviation. The juveniles were excluded in the calculation of average ± standard deviation

The pictures below show the home-range of Belitung tarsiers in study site H1 and H2, reconstructed using Minimum Convex Polygon (MCP) method.

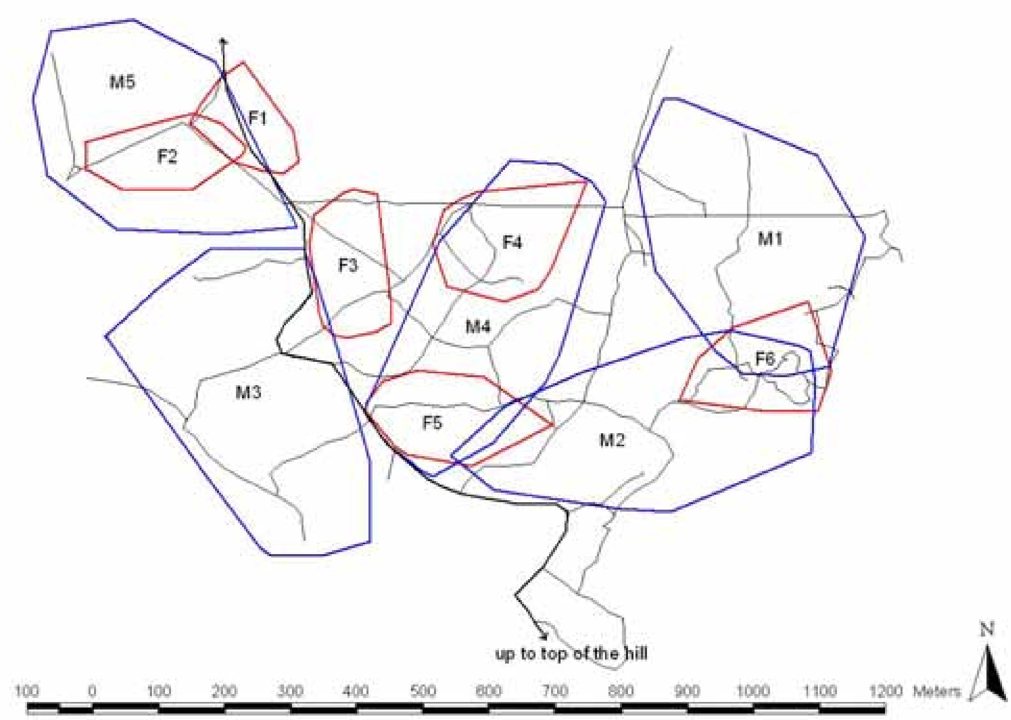

Fig. 4.1. The home range sizes of Belitung tarsiers in secondary forest with small-scale pepper plantations and selective harvesting (study site H1) on Belitung Island.

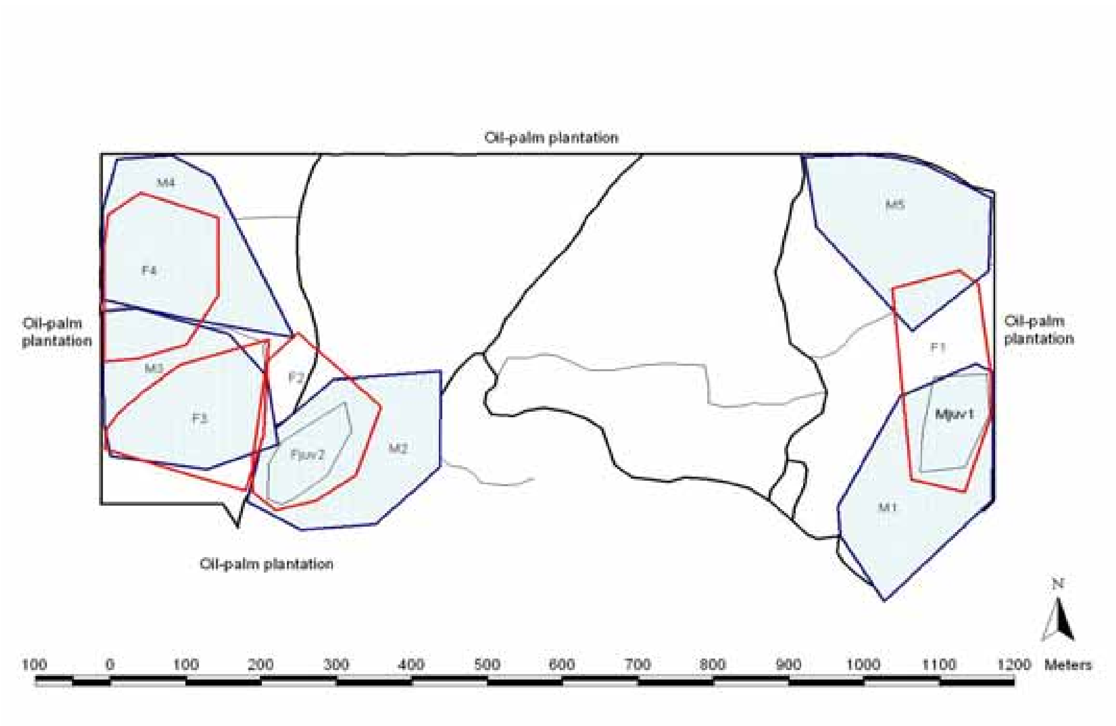

Fig. 4.2. The home range sizes of Belitung tarsiers in secondary forest with logging and surrounded by oil palm plantations (study site H2) on Belitung Island.

The pictures above show that the home-range of one adult female could be visited by more than one adult male. It also shows that the adult male's range overlaps the range of more than one adult female. Belitung tarsiers were observed to forage and sleep solitarily except for females carrying their infants (Figure 4.3).

Fig. 4.3. An adult female with its offspring at their sleeping site.

Considering the possibility that juvenile/sub-adult tarsiers do not have a stable home range and that they might still be dispersing, such data not included in the overall analysis of home-ranges. Figure 4.4 and 4.5 shows the incremental plot of home-range area of all radio-tracked tarsiers in study site H1 and H2, respectively. The stability of home ranges are sufficient after 70-90 of fixes for males and 60-75 fixes for females in study site H1, and 65-80 fixes for males and females in H2 were taken.

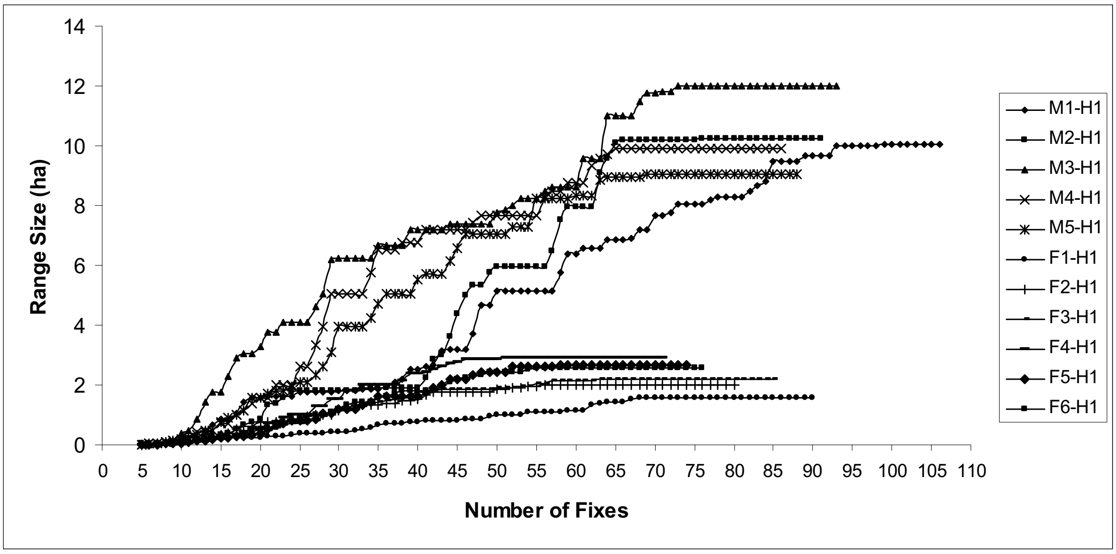

Figure 4.4. The relationships between range sizes and number of fixes taken of individual radio-tracked tarsiers in study site H1. Range size was calculated using the MCP method.

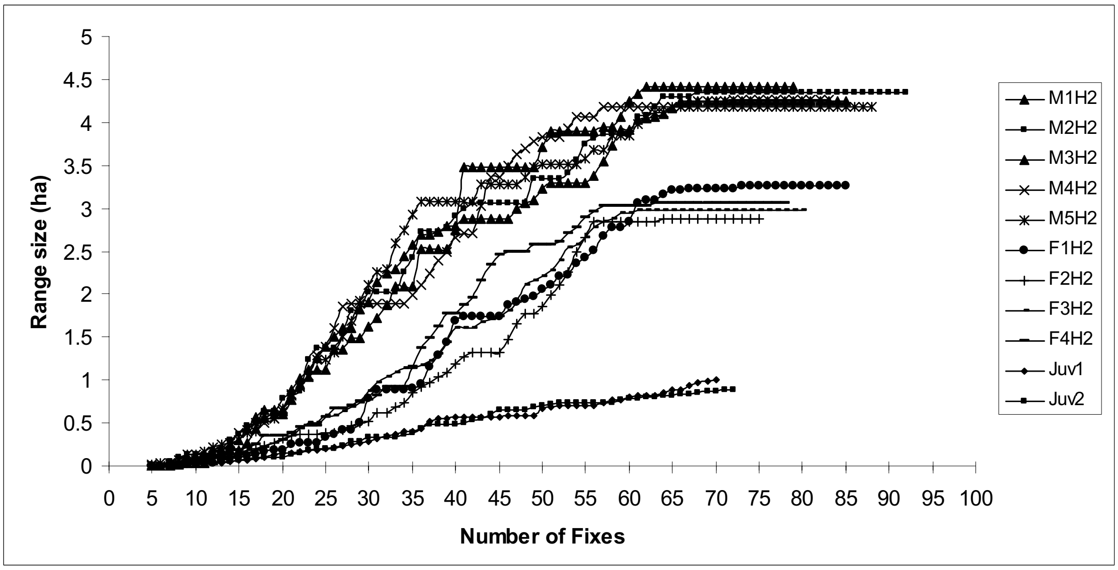

Figure 4.5. The relationships between range sizes and number of fixes taken of individual radio-tracked tarsiers in study site H2. Range size was calculated using the MCP method.

4.1.2 Nightly Travel Distance

Results of continuous monitoring were obtained from individual tarsiers for a total of 44 full night shifts (dusk to dawn; 18:00 pm to 6:00 am). The mean distance travelled in study site H1 during a single night was 1,128 ± 62 m by adult males (five adult males were followed for a total of 12 nights) and 839 ± 39 m for six adult females (followed over 14 nights). In study site H2, the mean nightly distance travelled by five adult males (followed for a total of 12 nights) was 994 ± 59 m and 697 ± 88 for four adult females (followed over 10 nights).

The average nightly travel distance in adult males was significantly higher than in adult females (Independent Samples t-test, $P<0.001$, $n=20$). There were also significant differences in nightly travel distances among adult males and females in study site H1 (Independent Samples t-test, $P<0.001$, $n = 11$) as well as in study site H2 (Independent Samples t-test, $P<0.001$, $n=9$). Comparing between habitats, the nightly travel distance of adult males in study site H1 (1128 ± 62 m, n = 5) was significantly higher than that of males in H2 (994 ± 59 m, n = 5). Meanwhile, adult females in study site H1 (839 ± 39 m, n = 6) travelled significantly further (Mann-Whitney U-test, $P<0.05$, $n = 10$) than females did in H2 (697 ± 88 m, n =4). Table 4.3 shows the nightly travel distances of each individual of radio-tracked *Tarsius bancanus saltator* in both study sites on Belitung Island.

Table 4.3. Nightly travel distances of all captured and radio tracked tarsiers in both study sites on Belitung Island.

Study site H1		**Study site H2**	
Animal	**Nightly travel distance (m)**	**Animal**	**Nightly travel distance (m)**
M1H1	1132	M1H2	1063
M2H1	1185	M2H2	964
M3H1	1191	M3H2	1014
M4H1	1089	M4 H2	1018
M5H1	1046	M5 H2	909
F1H1	802	Mjuv1H2	n.a.
F2H1	805	F1H2	777
F3H1	855	F2H2	654
F4H1	824	F3H2	595
F5H1	906	F4H2	763
F6H1	845	Fjuv2H2	n.a.
Average ± s.d.	**Male: 1,128 ± 62** **Female: 839 ± 39**	**Average ± s.d.**	**Male: 994± 59** **Female: 697 ± 88**

* s.d = standard deviation. The juveniles were excluded in the calculation of average ± standard deviation

Casual observations during the day revealed that individuals were almost totally inactive. Aside from sleeping and resting, the latter characterized by the animal scanning its surroundings without movement from its sleeping site. However, tarsier will leave their sleeping site if there are any disturbances or if they felt threatened.

4.1.3 Population Densities and Population Size

Based on the results of the estimated home range sizes from this work and references from other authors (e.g. Niemitz 1984, Crompton & Andau 1986, 1987, Merker 2003) some assumptions have to be made before calculating the population density:

1. The sex ratio of male to female is 1:1.
2. The male's ranges are more or less exclusive, no overlap between male's ranges.
3. 80% of the total suitable habitat is used by males
4. 50% of the offspring can survive until adulthood.

Considering those assumptions and the results on Table 4.2, we can calculate the "absolute" population density of tarsiers in study site **H1**. In an area of around 1 km^2 (100 ha), we estimated the population density as **19-20** animals/km^2 (based on the average of 10.25 ha for one adult male in study site H1). In study site **H2**, we estimated the population density up to **46-47** animals/km^2 (4.29 ha for one adult male).

Considering that there are no primary forests in Belitung Island, the results show that *Tarsius bancanus saltator* are quite numerous in forest with small-scale logging and surrounded by oil palm plantation. Indeed, the average number of captured animals per capture efforts (using 12 meter nets) also shows that study site H2 seemed to be more dense than study site H1 (Table 4.4).

Table 4.4. Average number of captured animals per capture efforts (12 m nets-hour)

Location	Capture efforts (12 m net*hour)	Captured animals (individual)	Average (Net*hour/ind.)
Study site H1	1201	11	109.18
Study site H2	868	17	51.06

It was also attempted to estimate the population size of the *Tarsius bancanus saltator* over the island of Belitung based on satellite images. Three different available habitats for tarsiers were classified based on the landsat image, i.e.: contiguous forest (which is actually similar with the study site H1), secondary forest with bushes (which is similar to study site H2) and oil palm plantations. Table 4.5 shows the estimated suitable habitat and population size of tarsier over the Belitung Island. Figure 4.6 shows estimated suitable habitats and its distribution over the island.

Table 4.5. Estimated suitable habitats and population size of tarsiers on Belitung Island.

Habitat type	Contiguous forests	Secondary forest with bushes	Oil-palm plantations	Total land
Estimated Size (km^2)	290.83	510.10	531.73	4,483.15
Estimated population density (individuals/km^2)	19 - 20	46 - 47	0	
Estimated Population Size of tarsier (individuals)	5671,2	23,770.7	0	29,442

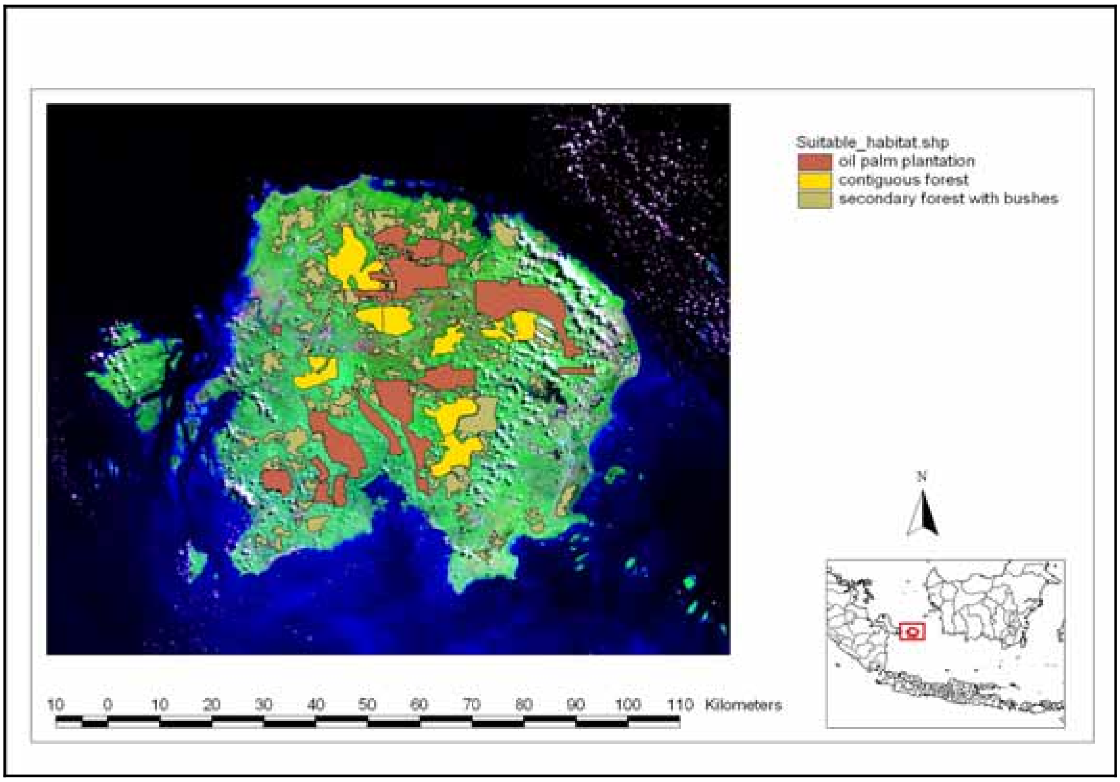

Figure 4.6. Estimation of available habitats for tarsiers on Belitung Island.

4.1.4 Body Measurements: Body Weight and Head+Body Length

The body weight and head+body length of all radio-tracked tarsiers in study site H1 and H2 is presented in Table 4.6. All of the means of body weight and head+body length between males and females show significant differences (Independent Samples t-test, $P<0.001$). Only in study site H2, head+body length of males and females were similar (Independent Samples t-test, $P = 0.391$).

Comparing between habitats, the average body weight of adult males in study site H1 (123.0 ± 6.7 g, n = 5) was not significantly higher (Independent Samples t-test, $P = 0.736$) than of males in H2 (121.4 ± 7.7 g, n = 5), but the average head+body length of males in H1 (12.5 ± 0.5 cm, n = 5) was longer (Independent Samples t-test, $P<0.05$) than that of males in H2 (11.4 ± 0.2 cm, n = 5). The body weight of adult females in study site H1 (108.5 ± 7.7 g, n = 6) was not significantly different (Mann-Whitney U-test, $P = 0.188$, n = 10) from that of females in H2 (101.2 ± 4.8 g, n =4), as well as the average of females head+body length in H1 (11.4 ± 0.3 cm, n = 6) was also not significantly different (Independent Samples t-test, $P = 0.233$) from that of female head+body length in H2 (11.6 ± 0.3 cm, n = 4).

Table 4.6. Body Weights and Head + Body Length of all captured and radio tracked tarsiers in two different study sites on Belitung Island.

Study site H1			Study site H2		
Animal	**Body weight (g)**	**Head+Body Length (cm)**	**Animal**	**Body weight (g)**	**Head+Body Length (cm)**
M1H1	120	12.4	M1H2	130	11.5
M2H1	130	12.5	M2H2	120	11.3
M3H1	120	12.2	M3H2	110	11.5
M4H1	130	13.3	M4 H2	127	11.7
M5H1	115	11.9	M5 H2	120	11.2
F1H1	100	11.5	Mjuv1H2	60	86
F2H1	115	11.4	F1H2	100	11.6
F3H1	116	11.6	F2H2	105	11.9
F4H1	100	10.9	F3H2	95	11.5
F5H1	105	11.3	F4H2	105	11.3
F6H1	115	11.5	Fjuv2H2	75	99
Average ± s.d.	**M: 123.0 ± 6.7 F: 108.5 ± 7.7**	**M: 12.5 ± 0.5 F: 11.4 ± 0.3**	**Average ± s.d.**	**M: 121.4 ± 7.7 F: 101.2 ± 4.8**	**M: 11.4 ± 0.2 F: 11.6 ± 0.3**

* s.d = standard deviation. The juveniles were excluded in the calculation of average ± standard deviation, M= male, F= Female

4.2 Habitat Parameters

4.2.1 Abundance of Substrates for Locomotion

The substrate features were measured in order to analyse the abundance of substrate for movements. Only branches, trunks and sapling trees with a diameter of 1 to 4 cm and in height of 1 to 5 m above the ground, in vertical (0^o-30^o) and horizontal (70^o-100^o) orientation was taken (MacKinnon & MacKinnon 1980, Crompton & Andau 1986, Tremble *et al.* 1993, Merker 2003).

Figure 4.7 shows the relevant supply of vegetation structures used for locomotion in study site H1 and H2. Study site H1 and H2 provide substrates for locomotion in almost equal conditions. There is no significant difference in the mean substrate density between study site H1 and H2 (Mann-Whitney U-test, P = 0.814).

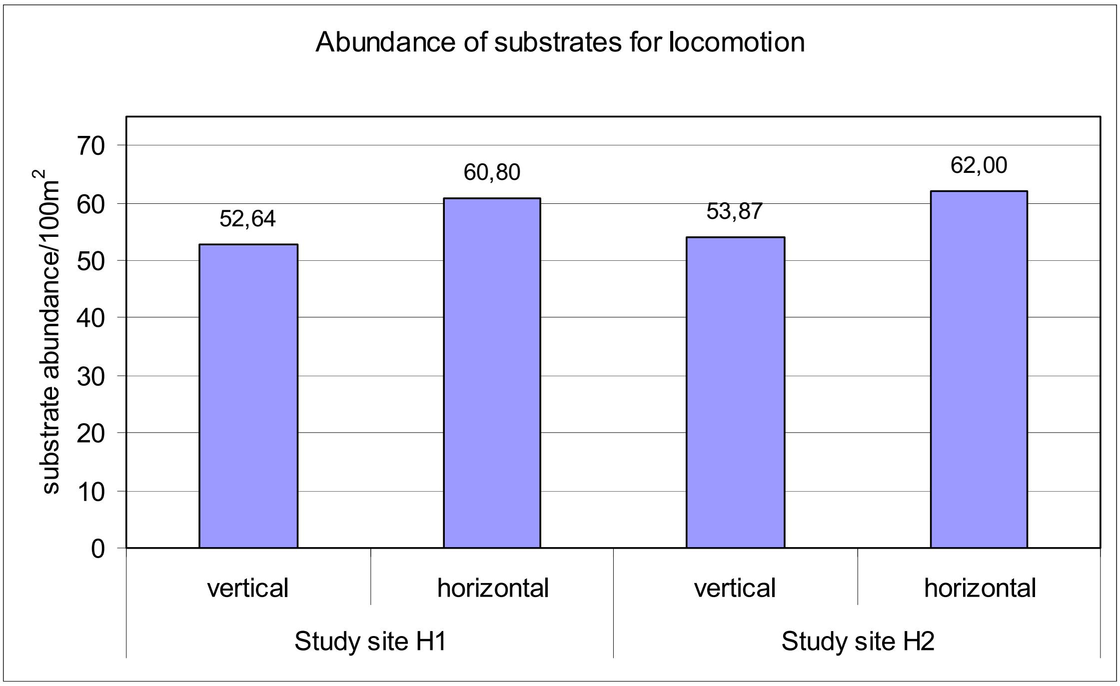

Fig. 4.7. The relative density of substrates for locomotion per 100 m^2 in vertical and horizontal orientation in both study sites on Belitung Island, Indonesia.

4.2.2 Food Supply: Abundance of selected insects

The relative abundance of insects in two different study sites H1 and H2 on Belitung Island is presented in Figure 4.8. The abundance of insect in study site H2, both "acoustically signalling" (9.7 $\pm$ 1.4 individuals/points/5 min) and "flying" insects or insects that are attracted to light (3.0 $\pm$ 1.5 individuals/points/5 min) was almost higher (at the 5% level, Mann Whitney U-test, P = 0.063) than that in study site H1 (8.3 $\pm$ 1.3 individuals/points/5 min and 2.1 $\pm$ 1.3 individuals/points/5 min for acoustically signalling and flying insects, respectively)

Identified flying insects (or insects that are attracted by light) were mainly moths (Lepidoptera), winged termites (Isoptera) and mantids (Mantodea). Identified acoustically signalling (vocalizing) insects were mainly grasshoppers and crickets (Orthoptera) but also cicadas (Homoptera). Unfortunately, there is no available data from this study to distinguish the different abundance of each kind of insects between study site H1 and H2. However, based on the observation, the kind of insects in both study sites were not different. All identified insects could be observed in almost all sampling points.

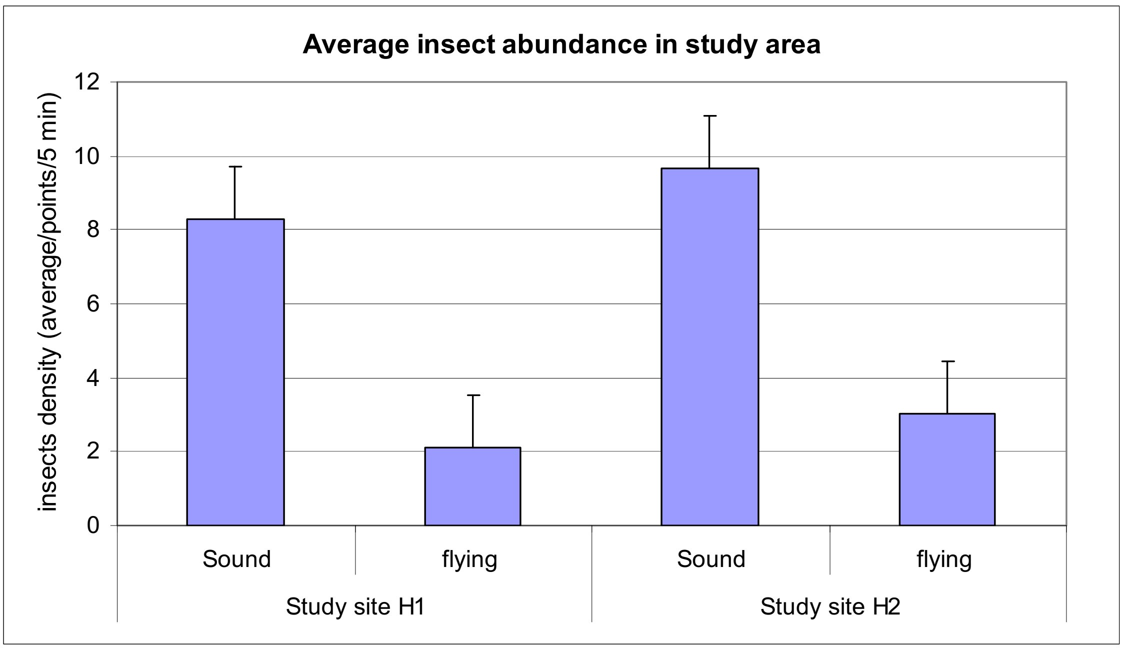

Fig. 4.8. The relative insect abundance (individuals/point/5 minutes) in both study sites on Belitung Island, Indonesia.

Chapter 5: Discussion

Based on the observation of juvenile/sub-adult tarsiers and considering the average gestation length of *Tarsius bancanus* (178 days in captivity, Izard *et al.* 1985, Roberts 1994) and also the estimates of the mean gestation period (193 days in the Spectral tarsier, Gursky 2006), the juveniles were predicted to be born between November and January. Unfortunately, the whole fieldwork was done between March and August.

Wright *et al.* (2003b) stated that *T. bacanus* clearly breeds seasonally. Gursky (2006) also found that infants of the Spectral tarsiers were born between April-May and between November-December. However, the predicted Belitung Island tarsier breeding season between November and January is similar to the breeding season of *T. syrichta* which was also estimated to fall in the same months (Neri-Arboleda *et al.* 2002). Unfortunately, this study was not set up to predict or to observe the effect of seasonality and/or the breeding season of the Belitung tarsier. Therefore, it was not possible to discern a seasonal effect on home-range sizes and nightly travel distances.

5.1. Home Range Size

Home-range is a concept that can be traced back to a publication in 1943 by W. H. Burt, who constructed maps delineating the spatial extent or outside boundary of an animal's movement during the course of its everyday activities. A popular definition of home range is "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt 1943 cited in Harestad & Bunnell 1979, Anderson 1982, White and Garrott 1990).

Gursky (2003b, 2006) explained that in nearly all primate species, groups range over a relatively fixed area and members of a group can be always found in that area over time. She mentioned that the majority of these ranges, commonly called home ranges, represent an undefended living space. Gursky also mentioned that for territorial primates, the boundaries of the territory are essentially the same as for their home range, and the territories do not overlap. A territory refers to any geographical area where an animal of a particular species consistently defends against conspecifics and of other species. Tarsiers are often referred to have a high degree of territorial behaviour (e.g.: MacKinnon & MacKinnon 1980; Niemitz 1979, 1984; Crompton & Andau 1987; Gursky 2003b, 2006, Merker 2003, 2006).

Unfortunately, for *Tarsius bancanus saltator* in this study, no spatial difference between the home range of an animal and its territory could be observed. Tarsiers on Belitung Island are very silent. Any vocalizations of Belitung's tarsier were heard on no occasion while collecting data. They do not perform any vocalization. There are two possibilities for this silence: (1) they do have vocalizations but can not be heard by the human ear, or (2) they just do not perform any sound to avoid competitors or predators, especially when they realize the presence of humans.

Vocalization and scent-marking by urinating are recognized as important components of tarsier behaviour (Niemitz, 1979, 1984; Wright *et al*., 1986, 1987). Although this work did not directly observe scent-marking behaviour, trees that had been urine marked were discernible by smell within the home ranges of the study animals and this implies territorial behaviour. On no occasion in this study vocalization was observed to be the main mode of contact between conspecifics.

Indeed, Belitung Island tarsiers mark their area (or their territory) by urine and secretions by rubbing the genital region against the substrate (tree trunks/branches). The conspecific intruders in the same sex are expelled possibly by aggression from the area in the form of fights, as many of the tarsiers observed (both males and females) have wounds on their ears or their tails.

5.1.1. Comparison of Home-ranges between Habitats

Male ranges in both study sites are significantly bigger than female ranges. Females seem to maintain ranges simply for a stable food supply, while males seem to maintain their territories to maximize access to females (Crompton & Andau 1986). The fact that male ranges in study site H1 are much bigger than male ranges in H2 and female ranges in H1 are smaller than that of females in H2 needs to be discussed.

Regarding home range sizes, study site H1 would be considered better-quality for tarsiers, while females in H1 have smaller range than those in H2. According to Crompton & Andau (1986), the habitat use by the females shows more directly to resource availability but by males are more to territoriality. Merker (2003, 2006) and Merker *et al*. (2004, 2005) also used ranges of females as one factor to determine the quality of habitat for the Dian's tarsier.

The function of territoriality as the defence of mates suggests that, female reproductive success is limited by access to resources and is expected to compete among one another primarily for it, whereas male reproductive success is limited by access to fertile mates and will compete mainly for mating (Bateman 1948 & Trivers 1972 both cited in Gursky 2003b). Gursky (2003c, 2006) also found that the pattern of territorial behaviour in the Spectral tarsier fits better to the model of mate defence than does the model of resource defence, where males are travelling outside their own territory to mate with females, and females will always try to exclude female intruders. Unfortunately, there are no attempts in this study have been made to observed the function of territorial behaviour of the Belitung tarsiers.

Study site H1 is more contiguous forest and provides more space than study site H2. At the first glance, it was predicted that females range in H2 would be smaller than that of females in H1 because of limited space in patch of forest H2 and more insects and more substrate for locomotion in H2. Merker (2003, 2006) and Merker *et al.* (2004, 2005) found that small home ranges are correlated with a high density of substrate for locomotion and a high abundance of insects. Contrary to Merkers findings, in this study, the abundance of substrates for locomotion and the abundance of insects as tarsier's favourite prey, was found to be higher in study site H2, even though not significant than those in H1. In fact, female ranges in study site H1 were smaller than those in H2.

In addition, study site H2 is a forest patch which is surrounded almost completely by oil palm plantations and therefore, with very little immigration or emigration. Female ranges are bigger in study site H2 than that in H1 probably due to low resource availability or renewal rate of resources (Ford 1983). Females in H2 have a bigger range to find food. Even though, the females in H2 did not travel in one night further than females in H1 (see Chapter 4.1.2 and more explanation in Chapter 5.2.1). This might be indicating the quality of habitat H1 is better than H2. However, social factors also might have influenced the home range sizes, and more studies are needed.

Male ranges in study site H2 are smaller than male ranges in H1 and could be explained as follows. As mentioned previously, there is the possibility that Belitung's tarsiers are so silent in order to avoid predators or competitors, to avoid fighting. Considering avoiding fighting, they might adjust their ranges. Smaller ranges usually correspond to smaller body size, but the body weight of males in both study sites is equal (see Chapter 4.1.4). Another explanation that could be proposed is, in study site H2, males have smaller body size (in terms of body height) to avoid aggression from other males because of high stress level which come out because of high population density in that patch. It might be also possible, that male ranges in H2 reflect their territory, whereas male ranges in H1 are seen as a "home range" which is much bigger and undefended. Once more, social factors might have a role in the differences of home range size. Regarding the differences of male ranges in both study sites, the social system in study site H1 might also be different with the social system in study site H2.

Considering habitat utilization, the Belitung Island tarsier never use oil palm plantations which are well-managed (see Fig. 4.2). However, tarsiers were often observed to forage near or along the boundary of a forest patch, presumably to get a better view and a better chance to get food. But tarsier could be found in "unmanaged" oil palm plantations where the shrubs and sapling trees were abundant. One of the field assistants who works for the oil palm company, once found a tarsier in dense shrubs between oil palm trees when he was clearing the shrubs with his machete.

5.1.2. Comparison of Home-ranges with Other Studies

This study is hoped to provide new information on the behaviour and ecology of the Belitung Island tarsiers *Tarsius bancanus saltator* in the wild. The home-range sizes of the males *T. b. saltator* (in the two different study sites) were larger relative to *Tarsius spectrum* and *T. dianae* in Sulawesi but smaller or equal to that of *T. syrichta* in Bohol, South Philippines and *T. bancanus* in Borneo (Table 5.1). On the other hand, the home-range sizes of females *T. b. saltator* were larger relative to *Tarsius dianae* but equal or smaller to that of *T. spectrum*, *T. syrichta* and *T. bancanus borneanus*.

Table 5.1. Reported home-range sizes of different wild tarsier species in different habitat types from radiotelemetry studies.

Species	Mean Home-range (ha)	Habitat	Study location	Source
T. dianae	Males = 1.77 Females = 1.08 – 1.81	Various man-influenced habitats in Primary and secondary rainforest	Kamarora, Lore Lindu, Central Sulawesi	Merker (2003, 2006), Merker *et al* (2005)
T. spectrum	Males = 3.07 Females= 2.32	Lowland rainforest, sea level	Tangkoko, North Sulawesi	Gursky (1998b, 2006)
T. syrichta	Males = 6.45 Female = 2.45	Secondary lowland rainforest 100-200 m a.s.l	Corella, Bohol	Neri-Arboleda *et al.* (2002)
T. bancanus	Males = 8.75-11.25 Females = 4.5-9.5	Primary and secondary lowland rainforest	Sabah, Borneo	Crompton & Andau (1986, 1987)
T. b. saltator	Males = 4.29 – 10.25 Females = 2.32 – 3.04	Secondary lowland forest with human influence	Gunung Tajam, Belitung Island	Present study

Male home ranges of Belitung Island tarsier incorporated more than one female range (see Figures 4.1 and 4.2). However, individuals were always forage and sleep solitary, except the females and its offspring, as was observed with tarsiers in Leyte (Dagosto & Gebo, 1997), Bohol (Neri-Arboleda *et al.* 2002) and in Sabah, Borneo (Crompton & Andau, 1986, 1987).

The difference between the home range sizes of the tarsiers on Sulawesi and Borneo, thus the differences on Belitung Island, presumably lie in the different structure of the forests of those islands (Gursky 1998b, Merker 2003). Citing Whitten *et al.* 1987, Gursky (1998b, 2000a) mentioned that the fauna and flora in Borneo and Sulawesi are so distinct that an ecological line, Wallace's line, is often invoked to distinguish between the two ecological communities. The tropical lowland forest in Belitung (at least in both observed study sites), consists of some plant species from Theaceae, Lauraceae, Myrtaceae, Clusiaceae, Dipterocarpaceae and Euphorbiaceae (see table A1 in Appendix), whereas the Sulawesian forest has very few trees from this family and has figs *Ficus* spp. in a very high diversity and abundance (Whitmore 1984, Whitten *et al.* 1987, Gursky 2002c). Gursky (1998b, 2000a, 2002c) discussed that such distinct forest types clearly have implications for the spatial and temporal distribution of food and other resources within the forest and therefore, the range an animal must traverse to fulfil its daily needs.

Another reason for the difference could lie in the social systems. While the Spectral tarsier is described as both monogamous and polygynous (MacKinnon & MacKinnon 1980, Gursky 2006), *Tarsius bancanus* shows a variant of "noyau" social system in which the range of females are visited by several males (Fogden 1974, Crompton & Andau 1986, 1987), while Niemitz (1984) suggested a pair bond system. Nietsch (1993, cited in Merker 2003) stated that social factors are the main reasons for the different habitat use between tarsiers in Sulawesi and Borneo. Crompton & Andau (1987) also stated that social factors must be involved in determining range size in Bornean tarsier.

There are similarities between the observed pattern of range overlap of *Tarsius bancanus saltator* and those of *T. syrichta* and *T. bancanus*. Fogden (1974) determined large areas of overlap between sexes and smaller areas of overlap within each sex in *Tarsius bancanus*. Crompton & Andau's (1986, 1987) data on *T. bancanus* also indicated that the ranges of individual females were visited by multiple males. Neri-Arboleda *et al.* (2002) found that the home range of one male of the Philippine tarsier overlapped extensively with that of one female and to a lesser extent with a second female. In the Spectral tarsier, the home range of one male overlapped with one or more females whose ranges also overlap (Gursky 1995, 2000a).

It has been also suggested that facultative polygamy may best describe the social structure of *Tarsius bancanus* (Crompton & Andau 1986, 1987), *T. syrichta* (Neri-Arboleda *et al.* 2002), and *T. spectrum* (Gursky 1995, 2006). The social structure of *Tarsius bancanus saltator* seems to be non-monogamous with obvious overlap between home ranges of males and females. The male range overlapped with two females whose ranges slightly overlapped, even though minimally. Males and females foraged apart and did not share the same sleeping site. Therefore, opportunities for extra pair mating were available. These could be the evidence for the explanation of social structure of the Belitung tarsier.

Gursky (2006) also found that male care in the spectral tarsier was very limited, seemed to be restricted to defending the territorial boundaries, scanning for predators and giving alarm calls. Roberts (1994) found no male care in *T. bancanus* in captivity. The Belitung tarsier was also observed to have minimal male care. It was found that parental care was mainly provided by the mother as shown in Fig. 4.3.

5.2. Nightly Travel Distances

The exact distance an animal travels per unit time is difficult to determine (Altmann & Samuels 1992 cited in Gursky 2006). One measure that is frequently used in calculations of the distance individual travel per unit time is the daily path length. While tarsiers are nocturnal, it is referred to Nightly Travel Distance. The distance travelled was calculated as the straight-line distance between successive fifteen-minute locations throughout the night (from dusk to dawn) and summarized it as the total distance individuals travelled per night. This interval was chosen to be able to be compared with other studies (e.g.: Gursky 1998c, 2000c, Neri-Arboleda *et al.* 2002, Merker 2003, 2006, and Merker *et al.* 2005).

5.2.1. Comparison of Nightly Travel Distance between Habitats

The mean nightly travel distance for the Belitung tarsier in study site H1 and H2 was **1,128 ± 62 m and 994± 59** m for males respectively, while in females it was **839 ± 39 m and 697 ± 88 m**. The mean nightly travel distance of males in H1 was substantially greater than the mean nightly travel distance of males in H2. This is understandable because the ranges of males in H1 were also greater than that of males in H2. Interestingly, females in study site H1 have a longer travel distance and smaller home range size but females in study site H2 have a shorter travel distance and a larger home range size.

According to White & Garrot (1990), good habitat quality could mean more food and more substrate for locomotion. Therefore, animals do not need to forage far away to find food and do not need to spend much energy. Merker (2003) added that the more energy used the more unfavourable is the resource availability, the longer the way to find resources, the worse is the habitat. Regarding nightly travel distance of the females, the study site H2 might be considered better than H1. However, according to Boinski (1987) & Dunbar (1988), both cited in Gursky (2000c), some primates might increase their daily range to find adequate food resources when the resource is in low abundance, but other species might decrease the amount of time allocated to travel in order to diminish their daily energy needs.

Overall insect abundance and density of substrate for locomotion in both study sites was not significantly different (see Chapter 4.2.2). One explanation might be due to the capability of habitat to quickly replenish food resources. Possibly, study site H1 which is mentioned previously as contiguous forest, has the capability to replenish insects better than H2.

In addition, study site H1 has a higher renewal rate for insects than H2. Garber (1987) mentioned that among some primate species, there is evidence that the size, distribution and renewal rate of food patches have a direct influence on the size of foraging. In study site H1, females travelled further than females do in H2 but do not need to maintain ranges big enough for a stable food supply (Crompton & Andau 1986). Females in study site H1 find other insects again in the same place faster than females do in H2. Insects which are eaten by individual females in H1 are immediately replenished by other insects. On the other hand, females in H2 have to maintain bigger ranges in order to find insects while if they go back to the same place (in the same night), they would not find more insects. Insects eaten in H2 are not rapidly replenished by other insects.

There is also a possibility that moonlight affects the tarsier activities. Gursky (2003a, 2006) found that the spectral tarsier to be lunar philic. The Spectral tarsier increases their activity levels during moonlight. It is unfortunate that this work does not have available data about the effect of moonlight. However, since the ranges and nightly travel distances of males in H1 was greater than that of males in H2, the possibility of moonlight effects should not be considered but could not be disregarded. Again, besides those possible effects of ecological factors, social factors might answer why females in H2 have a shorter travel distance but larger home ranges than those in H1.

5.2.2. Comparisons of Nightly Travel Distance with other Studies

The mean distance travelled per night by *Tarsius bancanus saltator* on Belitung Island (1,061 meter for males and 768 meter for females in both study sites) were smaller than those of the Bornean tarsier (2,081.6 m for males and 1,448.1 m for females; Crompton & Andau, 1987) and *T. syrichta* (1,636 m for males; 1,119 m for females; Neri-Arboleda *et al*. 2002). The difference is possibly because of the different structure of forest between Belitung Island and Sepilok Forest Reserve (Sabah, Borneo) and Corella Forest Reserve (Bohol, Philippine). The Sepilok Forest Reserve is composed primarily of dipterocarps, with the most common large trees in their study area being *Shorea* spp., *Dipterocarpus* spp. and *Hopea* spp. whose canopy can reach 40 to 50 m (Crompton & Andau 1986, 1987).

In the Corella Forest Reserve, Neri-Arboleda *et al.* (2002) characterized their study area as lowland evergreen type of forest and forest over ultramafic soils with represented species such as *Aglaia* sp., *Arctocarpus blancoi*, *Trema orientalis*, *Mallotus philippinensis* and *Macaranga* spp. On the other hand, the study site in Gunung Tajam, Belitung Island was represented by species such as *Schima wallichii* (Theaceae), *Eugenia lepidocarpa* (Myrtaceae), *Ilex cymosa* (Aquifoliaceae) and *Calophyllum* spp. (Clusiaceae). Such distinct forest structures might provide different distribution of insects and other resources. The dipterocarps bear fruit in 7-year cycles (Whitmore 1984, Whitten *et al.* 2000). As the tarsiers seem to consume lots of insects that are attracted to the fruit, this may account for some differences (Gursky 2002c, 2006). It is unfortunate that comparison of food (insects) diversity and density within these three study sites (Sepilok, Tangkoko and Gunung Tajam) could not be presented here since there is no available data. Crompton & Andau (1986, 1987) believes that the Bornean tarsier eats large ground-dwelling insects (Arthropods) and suggests that secondary regrowth forest may be a suboptimal habitat for tarsiers. Contrary to their suggestion, in the case of the Belitung Island tarsier, the study site H1 (secondary forest with small scale of pepper plantation and selective harvesting for woodfire) and study site H2 (secondary forest with selective harvesting and surrounded by oil palm plantation) was found to provide insects in about equal density and tarsiers did not travel any further, and even the female ranges are smaller than those of tarsiers in Sepilok (Table 4.1). Hill's (1955) and Fogden's (1974) suggestion that primary forest is a marginal habitat for tarsiers is probably true for tarsiers on Belitung Island, since there is no more primary forest existing on the island.

Another explanation that could be taken into account to describe the difference between Belitung Island tarsiers and those of Bornean tarsiers, Philippine tarsiers and Sulawesi tarsiers is the communication or vocalization. As mentioned in the previous chapter, the Belitung Island tarsiers are so silent, do not perform duet call and their communication is presumably by urine-marking as well as genitalia glands. The silence of the Belitung Island tarsiers seems to be similar to the Bornean tarsiers in Semongok, Sarawak (Fogden 1974, Niemitz 1979, 1984b). In contrast, Crompton & Andau's (1986, 1987) heard numerous clear calls while following tarsiers in Sepilok and believe that vocal communication appears to be the major mode of social interaction among Bornean tarsiers, as Neri-Arboleda *et al.* (2002) also observed in the Philippine tarsiers.

The nightly distance travelled by the Belitung tarsier were relatively larger but still comparable to those of *Tarsius spectrum* (447.68 m for adult females and 790.62 m for adult males, Gursky, 1998c, 2006; but it was recalculated to be 1150-2200 m according to Merker 2003) and *T. dianae* (mean = 905 m for males in the primary forest and 945-1263 m for females in different habitats; Merker 2003, 2006). Given the significantly smaller home range of individuals observed by Gursky in her study, the smaller distance travelled of the Spectral tarsiers can be understood. The considerable differences of the females nightly travel distance between the Belitung tarsier and those of the female Dian's tarsiers studied by Merker (2003, 2006), are probably due to the renewal rate of food resources in forests patches and the major differences of forest structures as described for differences in home range size, also because of different social structures and social system among those species.

The movements of *Tarsius bancanus saltator* varied each night among males and females. Females tended to remain in one corner of their home range. Neri-Arboleda *et al.* (2002) also found the same pattern of female ranges, especially when the females were near parturition or foraging with their offspring. They also reported that pregnant and lactating females *T. syrichta* like the *T. spectrum*, have limited mobility and move significantly shorter distances than females in other reproductive phases. In contrast, as can be seen from Table 4.3, the female Belitung tarsier F1H2 and F2H2, both have an offspring each, travelled not less than other females in study site H2. One possible explanation could be that the offspring is not in the lactating phase anymore and considered as juveniles, with body weight of 60 g and 75 g respectively.

Males *Tarsius bancanus saltator* were found to go reach the boundary of their range frequently and patrol their territory, but sometimes they went across from one end to the other end. Males often used a different sleeping site not too far from that used the night before. Females followed a customary path for several nights and sometimes changed to a new travel path. Similar pattern of movements, especially in female Philippine tarsiers are reported by Neri-Arboleda *et al.* (2002). In contrast to the males, they found that male Philippine tarsiers often go across the circumference of their range and to travel from one end to the other end and often use a different sleeping site than used the previous night. However, again, females seemed to maintain a home-range only large enough to provide food for themselves and their offspring (Crompton & Andau 1986).

5.3. Population Density

5.3.1. Comparison of Population densities between Habitats

A fundamental requirement for many research studies and management operations involving animals is the accurate assessment of a species' density in its natural habitat (Parmenter *et al.* 2003). Studies on the population density of tarsiers as well as their distribution are critical if we are to develop any conservation schemes for the tarsiers (Gursky 2006). The population density is the number of individuals in a population per area or space unit (Begon *et al.* 1998).

Considering the assumptions made in Chapter 4.1.3, the "absolute" population density of tarsiers in study site **H1** was calculated and given the estimate of population density of **19-20** animals/km^2 (based on the average of home range size: 10.25 ha for one adult male). On the other hand, the population density was estimated up to **46-47** animals/km^2 in study site **H2** (holds for average home range size: 4.29 ha for adult male). Considering that there are no primary forests in Belitung Island, the estimation of population density of *Tarsius bancanus saltator* is quite numerous in secondary forest with logging and surrounded by oil palm plantation (study site H2). However, primate density does not always reflect habitat suitability (Muehlenberg 1993 cited in Merker *et al*. 2005). It does not mean that the study site H2 is a better-quality of habitat than the study site H1. The explanation for the different number of population density in the two study sites mainly because of different range sizes and distance travelled as could be seen in Chapter 5.1.1 and 5.1.2.

The satellite image was used to estimate the suitable habitats of the tarsier. The available habitats were classified into three different categories, i.e.: contiguous forest, secondary forest with bushes and oil palm plantations. The suitable habitats for tarsiers do not include oil palm plantations, since there was no occasion when the tarsier utilized oil palm plantations. Results of the estimation of the available habitat showed that the distributions of the first two suitable habitats are also clearly fragmented (Figure 4.6).

The estimated population size of *Tarsius bancanus saltator* on Belitung Island was 29,442 animals (see Table 4.5). However, because the satellite image was taken from the year 2000, there is a possibility that some area has already been converted from forested area to developed area and unfortunately, it was not possible to determine the amount of such an area. Therefore, the estimation of suitable habitat might be overestimates, making the estimation of population size of tarsiers also overestimation. Field surveys to prove the existence of tarsiers in other remaining suitable habitat, in addition to both observed study sites in this study, on Belitung Island are needed.

5.3.2. Comparison of Population densities with Other Studies

In comparison to the other studies, Table 5.2 shows several numbers of the population densities of different species/subspecies from different studies, all of them except Niemitz (1979) have used the telemetry study.

Table 5.2. Population densities of different species/subspecies of tarsiers.

Species / Subspecies	Population density	Source
Tarsius dianae	14 – 57 Groups/km^2 45 – 268 individuals/km^2	Merker (2003, 2006) and Merker *et al.* (2004, 2005)
Tarsius dianae	129 individuals/km^2	Gursky 1998a
Tarsius spectrum *Tarsius spectrum*	56 Groups/km^2 (156 individuals/km^2) 83 individuals/km^2	Gursky 1998a, b Gursky (2006)
Tarsius syrichta	57 adult individuals/km^2	Neri-Arboleda *et al.* (2002)
Tarsius bancanus borneanus	< 80 individuals/km^2	Niemitz (1979)
Tarsius bancanus borneanus	14 – 20 individuals/km^2	Crompton & Andau (1987)
Tarsius bancanus saltator	19 – 46 individuals/km^2	Present study

The values determined here for *T. b. saltator* show that this species is slightly more abundant than the tarsier on Borneo studied by Crompton & Andau (1987). The densities of those Belitung Island tarsiers and Bornean tarsiers were lower than the densities of tarsier found on Sulawesi and the Phillipines. A possible explanation, once again, might come from the different geographical situation of these islands or archipelagos (Merker 2003, Gursky 1998b, 2002c). The Wallace line, which runs through the Malay Archipelago, between Borneo and the Philippines on one side and Sulawesi on the other side, not only a boundary that separates the zoogeographical regions, but also different major forest types. The tarsier on both sides of the Wallace-line has survived appropriately with a different forest type and consequently different resource availability. Although, Gursky (1999, 2006) mentioned that the variation in population density is somewhat deceptive because density values change substantially with altitude and habitat type. For example, Gursky (1998b, 2006) explained that the population density of Diana's tarsier was significantly lower at higher altitudes than lower altitudes. The lack of predators could also be taken into account to give differences in population densities. Gursky (2006) never observed any individuals or faeces or footprints of the Sulawesi palm civet, *Macrogalidia musschenbrockii*, which thought to be the predator of tarsier.

Some behaviour characteristics and social systems (as described in previous subchapter) could give a further explanation for this difference of population densities. The different abundance is probably also due to a difference in the recording methods. Recent studies using radio-telemetry open up the possibility to know more exact variety about the habitat use of the animals. For example, the difference in population density mentioned by Niemitz (1979) was obviously due to his different method. Niemitz's work was not based on telemetry. Meanwhile, discrepancy to Crompton & Andau's (1987) estimated population density presumably are due to the assumptions that the Bornean tarsier individuals in Sepilok do not live in shared and family-groups ranges. Crompton & Andau also adopted a much lower of estimation. If we recalculate Crompton & Andau's finding on home range size of males (i.e.: 8.75 ha for male 1 and 11.25 ha for male 2) then we have an average 10 ha for the male range. Thus, if we apply the same assumptions as this study assumed, we have an estimate very close to the population density of the Belitung Island tarsier (recall that the average range of males in this study was 10.25 ha in study site H1).

Unfortunately there are no comparable data for the population densities of Belitung tarsiers within a different time period. However, since habitat change and fragmentation are still undergoing and become major threats for flora and fauna, even in protected areas, in Indonesia (e.g.: Supriatna *et al.* 2002, Kinnaird *et al.* 2003, USAID/Indonesia 2004), it is predictable that the Belitung tarsiers are also facing the same threats.

Merker (2003) and Merker *et al.* (2004, 2005) noted that the type of land-use changed within 3 years (1998 to 2001) and found that the population densities of Dian's tarsier generally declined. Within different disturbed habitats, they found that population densities of the Dian's tarsiers decreased with increasing human influence, with 268 individuals/km^2 in undisturbed forest and only 45 individuals/km^2 in heavily disturbed habitats. Gursky (2006) also found that the density of the Spectral tarsier had significantly decreased over time (1994 to 2004) from 156 individuals per square kilometer to as low as 83 individuals per square kilometer.

5.4. Body Measurements: Body Weight and Head+Body Length

Morphological data, in terms of body size, could describe indirectly the social system and thus, breeding system within primate (Clutton-Brock *et al.* 1977 cited in Mueller & Thalmann 2000). Sexual-selection theory predicts that differences in body mass between males and females are correlated, with strong male-male competition associated with highly polygynous mating systems (Darwin 1971 and Alexander *et al.* 1979, both cited in Wright *et al*. 2003b). Sexual-selection theory predicts that males will compete among themselves for access to female because in general, they can increase their reproductive success by maximizing the numbers of matings they achieve (Bateman 1948 and Trivers 1972, both cited in Gursky 2006). Gursky also mentioned that in monogamous species in which male-male competition for access to females is minimal, sexual dimorphism also will be minimal. The sexual dimorphism could be indicated by differences in body size between male and females (Kappeler 1990, 1991).

5.4.1. Comparison of Body Measurements between Habitats

As can be seen from Table 4.6 and subchapter 4.1.4, male Belitung tarsiers have a significantly larger body weight than the females in both observed study sites. Males also have a significantly larger head+body length than females, but only in H1. This could indicate that there is dimorphism in body weight between male and female Belitung tarsiers. Although, sexual size dimorphism did not show the same pattern in all morphological data, as in H2, the head+body length of males and females were similar.

Comparing between habitats, adult males in study site H1 was not significantly heavier but has a larger head+body length than those of males in H2. Meanwhile, body weight and head+body length of adult females in both study sites were not significantly different. One interesting fact found in this study was the similarity of head+body length of males and females in study site H2. There are some possible explanations for the differences of head+body length of males but equal body weight in both observed study sites and for the equality of head+body length of males and females in H2.

One possibility to explain the equality of head+body length between males and females in H2 is because of different sampling periods (sampling error). There are some limitations to this study, such as logistic difficulty to capturing and radio-tracking tarsiers in all study sites at the same time. All the tarsiers in study site H2 plus one male (M5H1) and two females (F5H1 and F6H1) in H1 were measured in the year 2006. If we look inside Table 4.6, it seems that the measurements in the year 2006 (especially in head+body length of males in H2) are smaller than those in H1 which notably measured in the fieldwork phase in year 2004 and 2005. However, since the measurements of body weight on the females seem to be “normal”, generally body measurements should not indicate the possibility of sampling error.

Another explanation is because of the influence of habitat factors. The size of the patch of H2 is about 75 ha and, as mentioned in previous subchapter, H2 is a patch of forest surrounded almost completely by oil palm plantations. There is only very little possibility of migration for the tarsiers. Because of the small patch size, thus higher population density (see Chapter 4.1.3), then the tarsiers in H2 have a smaller range and smaller body size (in terms of head+body length) than those in H1. However, the body weight of tarsiers in both study sites is the same and female ranges in H1 is still smaller than the male ranges in H2.

If it is assumed that the study site H2 is a “sink” habitat (Pulliam 1988), then we have to assume that many tarsiers in H2 are still sub-adult animal and not reproduce yet. But, again, the body weight of males is the same and female body measurements showing no difference between both habitats. In addition, all males in H2 were observed to have testes which were already descended proving that they were adult individuals, and there are two females which each have an offspring was observed in H2. The study site H2 is more considered as a “source” rather than a “sink” habitat.

Another explanation is habitat history. There is possibility that the food shortages in the childhood or adolescence of tarsiers happened in H2 in the recent past (last year or before) or in their ancestors. Therefore, because of small patch and limited migrations, there might be very limited gene flow in H2. This could lead to the possibility that there is inbreeding depression in H2 (Begon *et al.* 1998). It is noteworthy that more studies are still needed, especially to prove whether there is an inbreeding depression within population of the Belitung tarsier, especially in such habitat as study site H2 were tarsiers found to be more abundant than in H1.

5.4.2. Comparison of Body Weight with Other Studies

For the purpose of comparison, only body weights from adult wild-captured tarsier would be presented here. Table 5.3 shows the comparison of wild-caught body weights of different species and subspecies of tarsiers. The mean body weight of *Tarsius bancanus saltator* (122 g for males and 105 g for females) were relatively smaller than those of wild-caught Bornean tarsiers (Niemitz 1984d, Crompton & Andau 1987, Wright *et al.* 1987, 2003b). The mean body weight of the male *T. b. saltator* in this study is about equal with the male *T. b. borneanus* in Sarawak (Fogden 1974). The body weight difference within the subspecies of *T. bancanus* is probably due to the studies being conducted not only at different field sites, but with different groups and different sample sizes.

The difference between female body weights of the *T. bancanus* varies considerably because of the different reproductive status (pregnant, lactating or no reproductive) when the females were caught and measured. Wright *et al.* (2003b) mentioned that when captured in the wild, 50% of their samples of females *T. bancanus* were pregnant. Neri-Arboleda *et al*. (2002) also reported that during their study, female body weights were varied depending on reproductive status. However, Philippine tarsiers were reported to have larger body weights (Neri-Arboleda *et al.* 2002, Kappeler 1990, 1991). In comparison to other tarsiers from Sulawesi, the body weights of the Belitung tarsier were slightly larger than the Dian's tarsier (Merker 2003, 2006) but relatively smaller than the Spectral tarsier (Gursky 2006).

Regarding sexual dimorphism, the Spectral tarsiers and the Philippine tarsiers were confirmed to exhibit sexual size dimorphism (Gursky 2006, Wright *et al.* 2003b, Neri-Arboleda *et al.* 2002, Kappeler 1990, 1991). Data on *T. dianae* presented in Table 4.3 also indicate that there is dimorphism in body weight between male and females in this species. Previous reports suggested that there is no sexual dimorphism in the Bornean tarsiers (e.g.: Kappeler 1990, 1991, Wright *et al.* 1987, 2003b). Although, data on body weights as shown in Table 5.3 might indicate sexual dimorphism. However, sexual dimorphism might not be ascertained only from differences in body weight, but also from other morphological data such as body length, limb proportions, etc. It is unfortunate that there is no available data to present here to be able to compare between the subspecies of *Tarsius bancanus*, either because of truly no morphometric data available or because of the differences in the methods of morphological measurements.

Table 5.3. Wild-Caught Body Weights (g) of different species/subspecies of tarsiers.

Species/Subspecies	Mean Body Weight (g)		Source
	Male	Female	
Tarsius bancanus saltator	122.2 (n= 10)	104.9 (n=10)	Present study
Tarsius bancanus borneanus	127.5 (n=6)	128.2 (n=6)	Wright *et al* (1987, 2003b)
Tarsius bancanus borneanus	128.2 (n=5)	117.5 (n=2)	Crompton & Andau (1987)
Tarsius bancanus borneanus	127.8 (n=21)	116.9 (n=16)	Niemitz (1984d)
Tarsius bancanus borneanus	120.0 (n=9)	111.0 (n= 10)	Fogden (1974)
Tarsius syrichta	135.5 (n=4)	120.0 (n=6)	Neri-Arboleda *et al.*(2002)
*Tarsius dianae**	121.2 (n=6)	99.5 (n=6)	Merker (2003, 2006)
Tarsius spectrum	127.4 (n=24)	105.6 (n=25)	Gursky (2006)

* Data for *T. dianae* only from undisturbed habitat.

Wright *et al.* (2003b) and Gursky (2006) mentioned that increased body size is seen and expected in polygynous species, while monogamous species are expected to demonstrate reduced sexual dimorphism. Thus, intrasexual competition among polygynous male primates may lead to a single-male or multi-male breeding system. Wright *et al.* (2003b) found that *Tarsius bancanus* (from Borneo) demonstrated a less polygynous system based on sperm competition and body dimorphism, and they predicted that Bornean tarsiers may have a more monogamous social organization while they found no sexual dimorphism in their small population sample. Although, they also found that based on the relationship between testicle volume, body weight and season indicates that Bornean tarsiers clearly breed seasonally.

However, the presence of sexual dimorphism (body weights in both study sites but not head+body length in H2) and the pattern of ranges overlap between male and female as shown in Figures 4.1 and 4.2, might indicate that the Belitung Island tarsier exhibits the facultative polygynous and not the monogamous breeding system. Niemitz (1979, 1984) suggested that the Bornean tarsier in Sarawak form pair bonds, although Fogden (1974) and Crompton & Andau (1986, 1987) have suggested that this subspecies seems to be closer to the generalized noyau social system. As stated by Gursky (2006), it is possible that *Tarsius bancanus* exhibits both pair bonds (monogamous) and a noyau social system (polygynous).

5.5. Conservation Status of *Tarsius bancanus saltator*

5.5.1. Habitat of *Tarsius bancanus saltator*

The results of this study underline that the Belitung tarsier is not restricted to pristine forest. This subspecies were adaptable to secondary forest with selective harvesting and small scale pepper plantation, thus, even in a small patch of such forest which is surrounded by oil palm plantations.

Field studies on tarsier species have reported a wide variety of habitat types. Primary forest, secondary forest, shrub, mangrove, coastal areas and areas bordering plantations were inhabited by *Tarsius bancanus* (Niemitz, 1979, 1984). Tremble *et al.* (1993), Yustian (2002), Merker (2003, 2006) and Merker *et al.* (2004, 2005) observed

Tarsius dianae having a preference for a dense tangle of liana vines, bamboos, strangler figs (*Ficus* sp.) and a tree hole for sleeping sites, and these sites were located in early successional habitat near secondary forest with vegetation comprised mainly of bushes, ferns and small trees. Wild spectral tarsier was reportedly found in almost all habitat types, hence varied sleeping sites (Leksono *et al.* 1997, Gursky 1998b, 2006).

Leksono *et al*. (1997) reported that areas of dense human population and intensive agriculture were two habitat types that showed local extinctions of the Spectral tarsier population on Sulawesi. The Belitung tarsier had also been observed to use land cultivated for agro-forestry, i.e pepper plantation and "rubber forest-plantation" which has dense undergrowth vegetation or in an "unmanaged" oil palm plantations where the shrubs and sapling trees were abundant. But *Tarsius bancanus saltator* has not been observed to use "well-managed" oil palm or rubber plantations.

The results of this study show that the population densities of tarsiers are about 19-20 individuals per square km in H1 and 46-47 individuals per square km in H2. However, the absence of any designated protected area on Belitung Island would still make habitat destruction a major threat to their survival. Although *T. b. saltator* is mainly a rainforest dweller, several types of rainforest in different stages of succession are found on Belitung Island. The results that *T. b. saltator* were more abundant in secondary forest in early to mid succession stage indicates the importance of maintaining the cycle of undergrowth vegetation of tropical rainforest in areas tarsiers are known to inhabit to provide a sufficient habitat.

5.5.2. Conservation Assessment of Tarsius *bancanus saltator*

Determining conservation status of the Belitung Island tarsier is obviously essential and conserving these primates is evenly essential. Identifying the major threats to the tarsier and ways to minimize the threats are important. Habitat change, fragmentation and deforestation are still ongoing and in fact are major threats for flora and fauna, even in protected areas, in Indonesia (e.g.: Supriatna *et al.* 2002, Kinnaird *et al.* 2003, USAID/Indonesia 2004).

Between 1985 and 1997, 20 million ha of Indonesia's forests have been lost at an average annual deforestation rate of 1.5 million ha; since 1997, the rate of forest lost is 2.4 million ha per year or more; and 5 million ha of forests degraded by fires in 1997-98 alone (World Bank 2001 cited in USAID/Indonesia 2004). Sumatra, the second-largest island of Indonesia and the nearest mainland to Belitung Island, has less than 40% of its natural forest remaining and the deforestation rate of almost 2.5% a year (Supriatna *et al.* 2002). Kinnaird *et al.* (2003) found that between 1985 and 1999, deforestation in the Bukit Barisan Selatan National Park (one of few National Parks in Sumatra) averaged 2.0 % per year. In Lore Lindu National Park, Central Sulawesi, the type of land-use changed within 3 years (1998 to 2001) and found that the population densities of the Dian's tarsier generally declined (Merker & Muehlenberg 2000, Merker 2003, Merker *et al.* 2004, 2005). Within different level disturbed habitats, they found that population densities of the Dian's tarsiers decreased with the increasing human influence, with 268 individuals/km^2 in undisturbed forest and only 45 individuals/km^2 in heavily disturbed habitats. Meanwhile, in Tangkoko Dua Saudara Naturre Reserve, North Sulawesi, Gursky (2006) also found that the density of the Spectral tarsier had significantly decreased over time (1994 to 2004) from 156 individuals per square kilometer to as low as 83 individuals per square kilometer. She mentioned that ..."the spectral tarsier population at Tangkoko is on the road of extinction" (Gursky 2006:192).

It is predictable that the Belitung tarsiers are also facing the same major threats: habitat change, habitat loss and fragmentation. Much of the land surface is converted to oil palm plantation, pepper plantation and/or destroyed because of tin mining (*pers. observ.*). One page in internet even mentioned, that since the development of palm oil industry in 1992 more than 40% of the land surface is converted to oil palm plantations (http://www.indahnesia.com/indonesia.php?page=SSEBEL).

A species' conservation status can be determined based on a variety of different criteria (IUCN 2001). The criteria include: reduction in population size, geographic range in the form of extent of occurrence or area of occupancy, limited population size in terms of mature individuals, and/or quantitative analysis showing high probability of extinction (for example by using the Population Viability Analysis technique). By means of various levels of these criteria, a species can be classified as critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), and least concern (Lc) if there is adequate information to make an assessment of its risk of extinction based on its distribution and/or population status. A taxon is Data Deficient (DD) when there is inadequate information (IUCN 2001). The current conservation status of *Tarsius bancanus* ssp. *saltator* is "Data Deficient" (Eudey *et al.* 2000).

To determine the conservation status of the Belitung Island tarsier, firstly it was chosen to use the extent of occurrence's criteria. The total land of Belitung Island was estimated using satellite image. The estimated total main land of Belitung Island was **4,483.15 km^2**. This is the maximum area that tarsiers could potentially inhabit, over the whole land surface on the island, including human settlements and the entire unsuitable habitat for the tarsier. Based only on this number, the assessment from data deficient should be changed to Endangered (**EN B1**; extent of occurrence less than 5,000 km^2).

Subsequently, it was attempted to estimate the availability of habitat (or area of occupancy) for the tarsier on Belitung Island. Three categories were classified, i.e: contiguous forest, secondary forest with bushes and oil palm plantations. Excluding oil palm plantations as a suitable habitat for the tarsier, since the tarsier does not use this kind of habitat, estimated total suitable habitat for Belitung tarsiers is about **800 km^2** and the distribution of these suitable habitats is severely fragmented (Figure 4.6). The total population density of Belitung tarsier within this area is estimated to be 29,442 individuals (see Table 4.5). However, there is a different population density between both observed study sites. In addition, most of the area that categorized as "secondary forest with bushes" is very small in size (under 5 km^2) and relatively isolated. A brief survey only could confirm that tarsiers are known to exist in 4 locations of "contiguous forest" and 5 locations of "secondary forest with bushes". Base on those findings, the criteria that nearly match is Vulnerable under B2 criteria (**Vu B2a**, area of occupancy less than 2000 km^2, severely fragmented, known to exist at no more than 10 locations).

Unfortunately, a quantifiable rate of habitat destruction on Belitung Island over time can not be provided. Such an estimate of forests loss has also never been previously reported. However, because of the absence of protected areas on Belitung Island, the deforestation rate is suspected not to be below the average of 2.5% per year as mentioned for Sumatra (Supriatna *et al.* 2002) or 2% per year as occurred in Bukit Barisan Selatan National Park and estimated by Kinnaird *et al.* (2003). This rate of deforestation could be used to infer that there is a continuing decline in the area of occupancy, extent of suitable habitat, and consequently, is followed by a decline in number of locations/populations and population density including mature individuals.

Therefore, it should be proposed that the status of Belitung tarsier (*Tarsius bancanus saltator*) be changed from "data deficient" into vulnerable or following standard format of IUCN's citation, **Vu B1ab(ii,iii,iv,v)+2ab(ii,iii,iv,v)**.

Of course, in determining the conservation status of the Belitung tarsier, it would be better and would give a more accurate estimation if more criteria are used. Besides using criteria B (extent of occurrence or area of occupancy), using criteria A (quantified reduction in population) should be employed and would be beneficial for the assessment.

5.5.3. Conservation Implications

The following implications can be drawn for the conservation of *T. b. saltator*:

1. It is noteworthy that the status of Gunung Tajam should be promoted to Nature Reserve, not only to conserve Belitung tarsiers but other two primates which are known to exist, i.e: the long-tailed macaque (*Macaca fascicularis*) and the silvery leaf-monkey (*Trachypitecus cristatus*), and more than 50% of 93 birds species found on Belitung Island (Bappekab Belitung 2003) such as *Pycnonotus atriceps, Anthracoceros malayanus* and *Copsycus malabaricus*. The promoted status, of course would keep protecting the watershed and ecosystem functions. The reserve would keep up to 890 tarsier individuals in an area of about 45,633 km^2.
2. Based on the GIS database on the tarsier's density and distribution and map of the remaining available forest habitat in other areas on Belitung Island where tarsiers are known to exist that had been done in this study, it could possibly be set up a regional network of reserves, instead of just one reserve. The network reserve could give a better opportunity for gene flows and anticipate the possibility of inbreeding depression. Advance studies would be needed.
3. A longer field study covering both breeding and non-breeding seasons, inbreeding depression, examine variations of home-range size and configurations in different habitat types and carry out PVA (Population Viability Analysis) to provide a quantifiable measure of the threat of extinction need to be conducted and would be valuable for the future research of the Belitung tarsiers and its conservation action.

4. Tarsiers require a diet of live prey (e.g.: Niemitz 1984, Gursky 2003b, 2006) and are tremendously difficult to maintain in captivity because needs very extensive efforts to provide an adequate diet and of very high infant mortality rate (Fitch-Snyder 2003). Although there has been success in studying *T. bancanus* in captivity (e.g.: Roberts & Kohn 1993, Roberts 1994, Wright *et al.* 1986a, b), the record of captive births of tarsier remains low (Wright *et al*. 1987, Fitch-Snyder 2003). Fitch-Snyder also suggested that captive conservation efforts should concentrate on developing successful tarsier husbandry within the habitat countries and only after successful offspring are produced and we have a second generation should colonies of captive tarsiers outside of Asia be considered.
5. Conservation status of *Tarsius bancanus saltator* should be upgrade to vulnerable.

Chapter 6: Summary

The main aims of this study are to provide an estimate of home range sizes and the population densities of *Tarsius bancanus saltator* on Belitung Island and to discuss the implications of this information in terms of the conservation status of one of the subspecies of Western tarsier *T. bancanus*. The field study was conducted in Gunung Tajam, Air Begantung Village, Belitung Island, Indonesia. There are only two available different habitat types observed in this study. The first is a secondary forest with small scale (< 0.2 ha) pepper plantation and selective harvesting for wood-fire (study site H1) and the second is a secondary forest with small scale of logging and surrounded completely by large oil palm plantations (study site H2).

The following parameters were used to identify critical resources for the tarsiers' survival and adaptation in both different habitats on Belitung Island: home range size, nightly travel distances, population density, body weight and body size. 22 individuals were captured within 42 captures using mist-nets. All captured tarsiers (five adult males and 6 adult females in the first study site, 5 adult males, 4 adult females and 2 juveniles in the second study site) were radio-tracked to estimate their home range sizes and nightly distance travelled by telemetry survey.

Home range sizes of *Tarsius bancanus saltator* vary from 1.59 to 3.25 ha for females and 4.18 to 11.98 ha for males in both study sites. Female ranges are smaller than male ranges. Females in the secondary forest with small scale pepper plantation and selective harvesting used a significantly smaller area than females in forest patch with small scale logging and surrounded by oil palm plantation. In both observed study sites, male Belitung tarsier travelled (1,128 and 994 m in H1 and H2 respectively) significantly further than females did (839 and 697 m). Females in the forest patch with small scale logging and surrounded by oil palm plantation travelled less than females in the other habitat. Mean body weights of males are larger than females, indicating a sexual dimorphism. However, the head+body lengths of males in the second study site were not different to that of females in the same site.

Even though the substrate feature for locomotion and the abundance of insects were not different between both study sites, small home ranges might indicate the capability of habitat to quickly replenish resources. On the subject of home range sizes, nightly travel distances and body size, contiguous forest with small scale pepper plantation and selective harvesting can be considered as better quality sites for tarsiers. In addition, social factors might have an important role in determining home range sizes and nightly distances travelled by each individual.

The home-range sizes and nightly travel distances of *T. b. saltator* were different relative to *Tarsius spectrum* and *T. dianae* in Sulawesi, *T. syrichta* in Bohol, South Philippines and *T. bancanus* in Borneo. The difference between the home range range pattern of tarsiers on Sulawesi and Borneo, could also be applied to the differences with Belitung Island tarsier, presumably lie in the different structure of the forests of those islands. Different forest types clearly have implications for the spatial and temporal distribution of food and other resources within the forest and therefore, the range an animal must traverse to fulfil its daily needs. Another reason for the difference could lie in the social systems. While the Spectral and Dian's tarsier are described as both monogamous and polygynous, *Tarsius bancanus* shows a variant of "noyau" social system in which the range of females is visited by several males. It is possible that *Tarsius bancanus* exhibits both pair bonds (monogamous) and a noyau social system (polygynous). Social factors might be the main reasons for the different habitat use between tarsiers in Belitung, Sulawesi and Borneo.

The population density of tarsiers in the first study site was estimated at 19-20 animals/km^2 and the estimated population density in the second habitat type up to 46-47 animals/km^2. The total population size of tarsier on Belitung Island was estimated at 29,442 individuals. Comparing to other species, the population densities of Belitung tarsier were lower than those of tarsier on Sulawesi or the Philippines.

Considering the high rate of deforestation in protected areas in other regions of Indonesia and considering that there is no protected area on Belitung Island, the population of the tarsier on Belitung Island also faces major threats of habitat loss and fragmentation. Based on the area of occupancy, known population that exist only in 9 locations and projected population decline in the future, conservation status of the Belitung tarsier should be upgraded from data deficient to vulnerable.

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APPENDIX

Table A1. Cumulative list of tree species found on Belitung Island

Nr.	Latin name	Family	Local name
1	*Acmena acuminatissima*	Myrtaceae	Sisilan
2	*Adinandra dumosa*	Theaceae	Pelempang hitam
3	*Adenanthera tamarindifolia*	Fabaceae	Saga
4	*Aporosa aurita*	Euphorbiaceae	Pelangas
5	*Aporosa nervosa*	Euphorbiaceae	Pelangas
6	*Aquilaria malaccense*	Thymelaceae	Kepang
7	*Atuna excelsa*	Rosaceae	Pelepak
8	*Baccaurea deflexa*	Euphorbiaceae	Rupis
9	*Bouea oppositifolia*	Anacardiaceae	Urisan
10	*Buchanania arborescens*	Anacardiaceae	Pao
11	*Calophyllum* sp. 3	Clusiaceae	Betor belulang
12	*Calophyllum pulcherrimum*	Clusiaceae	Betor padi
13	*Calophyllum rigidum*	Clusiaceae	Betor rambai
14	*Calophyllum tetrapterum*	Clusiaceae	*No name*
15	*Campnosperma auriculatum*	Anacardiaceae	Terentang
16	*Castanopsis trisperma*	Fagaceae	Berangan duri
17	*Cleistanthus sumatranus*	Euphorbiaceae	*No name*
18	*Cratoxylum arborescens*	Hypericaceae	Gerunggang
19	*Cratoxylum formosum*	Hypericaceae	Mampat
20	*Cryptocaria lucida*	Lauraceae	*No name*
21	*Dacryodes costata*	Burseraceae	Samak
22	*Dillenia eximia*	Dilleniaceae	Simpur laki
23	*Dyxoxylum* sp	Meliaceae	Melantingan
24	*Elaeocarpus grandiflorus*	Elaeocarpaceae	*No name*
25	*Elaeocarpus valetonii*	Elaeocarpaceae	Rendudongan
26	*Engelhardia serrata*	Juglandaceae	Beberi
27	*Eugenia lepidocarpa*	Myrtaceae	Samak
28	*Eugenia leptantha*	Myrtaceae	*No name*
29	*Eugenia tetrandra*	Myrtaceae	Gelam tikus
30	*Eurya acuminata*	Theaceae	Kayu batu
31	*Eusideroxylon zwageri*	Lauraceae	Ulin
32	*Evodia aromatica*	Rutaceae	*No name*
33	*Ficus* sp.	Moraceae	*No name*
34	*Ficus fulva*	Moraceae	*No name*
35	*Ficus vasculosa*	Moraceae	*No name*
36	*Fissistigma manubriatum*	Annonaceae	Belangir
37	*Garcinia celebica*	Clusiaceae	Kiras
38	*Garcinia dioica*	Clusiaceae	Asam kandis
39	*Garcinia rostrata*	Clusiaceae	*No name*

Tabel A1 *(continued)*

Nr.	Latin name	Family	Local name
40	*Gardenia carinata*	Rubiaceae	Tembalau
41	*Haemocharis subintegerrima*	Theaceae	Pelempang
42	*Hopea bilitonensis*	Dipterocarpaceae	Pelepak
43	*Hopea sangal*	Dipterocarpaceae	Cengal
44	*Ilex cymosa*	Aquifoliaceae	Mensira
45	*Laplacea subintegerrima*	Theaceae	Pelempang putih
46	*Lithocarpus gracilis*	Fagaceae	Kabal
47	*Lithocarpus spicatus*	Fagaceae	Ketemak/Tembab
48	*Litsea elliptica*	Lauraceae	Medang
49	*Litsea firma*	Lauraceae	Medang
50	*Litsea* sp.1	Lauraceae	Medang miang
51	*Neolitsea latifolia*	Lauraceae	Meladingan
52	*Macaranga gigantea*	Euphorbiaceae	Keruleung
53	*Manihot carthaginensis*	Euphorbiacea	Singkang
54	*Memecylon edule*	Melastomataceae	Ubar
55	*Palaquium rostratum*	Sapotaceae	Nyatoh
56	*Pandanus furcatus*	Pandanaceae	Lais
57	*Planchonella firma*	Sapotaceae	Miang/Kayu buluh
58	*Podocarpus polystachyus*	Podocarpaceae	Penyao
59	*Polyalthia* sp.	Annonaceae	*No name*
60	*Prunus arborea*	Rosaceae	Muntisan
61	*Quercus argentata*	Fagaceae	Jurong
62	*Quercus subsericea*	Fagaceae	Mempinangan
63	*Rhodamnia cinerea*	Myrtaceae	Jemang
64	*Schima wallichii*	Theaceae	Seru
65	*Shorea multiflora*	Dipterocarpaceae	Berangan bayam
66	*Shorea ovalis*	Dipterocarpaceae	Meranti
67	*Syzygium adenophylla*	Myrtaceae	*No name*
68	*Syzygium bankense*	Myrtaceae	Sesundong
69	*Syzygium decipiens*	Myrtaceae	Arang-arang
70	*Syzygium palembanicum*	Myrtaceae	Pulas
71	*Syzygium umbilicatum*	Myrtaceae	Bange
72	*Syzygium* sp.	Myrtaceae	Jambu hutan
73	*Tristania obovate*	Myrtaceae	Pelawan kupur
74	*Tristania whiteana*	Myrtaceae	Pelawan kuring
75	*Vatica venulosa*	Dipterocarpacea	Resak
76	*Vitex pubescens*	Verbenaceae	Laban

Note: *No name* means that the local name is not known. A tree could have more than one local name because of different characteristic between young and old stage. Source: personal observation, Bappekab Belitung (2003) and Whitten *et al.* (2000)

Table A2. Lists of tree species in **study site H1** (secondary forest with small scale pepper plantation and selective harvesting).

Nr.	Scientific name	Density per km^2	Coverage in km^2	Frequency (%)	Importance Value Index
1	*Engelhardia serrata*	4229.94	32.46	0.0588	0.181
2	*Ilex cymosa*	6344.91	21.32	0.0588	0.192
3	*Eugenia lepidocarpa*	5287.43	22.83	0.0784	0.199
4	*Schima wallichii*	20092.23	394.75	0.2353	**1.257**
5	*Cratoxylum arborescens*	1057.49	0.34	0.0196	0.036
6	*Calophyllum pulcherrimum*	5287.43	6.13	0.0980	0.187
7	*Calophyllum rigidum*	2114.97	15.77	0.0392	0.099
8	*Rhodamnia cinerea*	1057.49	0.15	0.0196	0.036
9	*Manihot carthaginensis*	3172.46	25.42	0.0588	0.152
10	*Litsea* sp1.	1057.49	0.29	0.0196	0.036
11	*Hopea bilitonensis*	1057.49	0.52	0.0196	0.036
12	*Elaeocarpus valetonii*	3172.46	3.98	0.0588	0.113
13	*Laplacea subintegerrima*	2114.97	6.20	0.0392	0.082
14	*Vitex pubescens*	1057.49	0.47	0.0196	0.036
15	*Hopea sangal*	1057.49	0.70	0.0196	0.037
16	*Calophyllum sp3*	1057.49	0.64	0.0196	0.036
17	*Lithocarpus gracilis*	3172.46	10.13	0.0392	0.105
18	*Acmena acuminatissima*	1057.49	0.24	0.0196	0.036
19	*Quercus argentata*	1057.49	1.42	0.0196	0.038
20	*Vatica venulosa*	1057.49	0.60	0.0196	0.036
21	*Syzygium* sp.	1057.49	0.27	0.0196	0.036
22	*Garcinia celebica*	1057.49	0.25	0.0196	0.036

Table A3. Lists of tree species in **study site H2** (secondary forest with small scale logging and surrounded by oil palm plantation).

Nr.	Name	Density per km²	Coverage in km^2	Frequency (%)	Importance Value Index
1	*Eugenia lepidocarpa*	10433.61	49.04	0.22	**0.789**
2	*Ilex cymosa*	1956.30	2.84	0.03	0.100
3	*Aporosa nervosa*	1956.30	5.40	0.05	0.133
4	*Schima wallichii*	7825.21	71.57	0.19	**0.836**
5	*Cratoxylum arborescens*	652.10	0.21	0.02	0.034
6	*Dillenia eximia*	652.10	0.57	0.02	0.037
7	*Calophyllum pulcherrimum*	1956.30	4.24	0.05	0.126
8	*Lithocarpus gracilis*	1956.30	5.77	0.05	0.136
9	*Rhodamnia cinerea*	652.10	0.26	0.02	0.035
10	*Atuna excelsa*	652.10	0.43	0.02	0.036
11	*Manihot carthaginensis*	652.10	0.89	0.02	0.039
12	*Macaranga gigantea*	652.10	0.31	0.02	0.035
13	*Syzygium palembanicum*	1304.20	2.38	0.03	0.081
14	*Quercus subsericea*	652.10	0.20	0.02	0.034
15	*Laplacea subintegerrima*	1304.20	3.82	0.03	0.090
16	*Elaeocarpus valetonii*	652.10	0.25	0.02	0.035
17	*Vitex pubescens*	1956.30	1.99	0.03	0.094
18	*Quercus argentata*	1304.20	2.24	0.03	0.080
19	*Calophyllum rigidum*	652.10	0.29	0.02	0.035
20	*Vatica venulosa*	1304.20	1.01	0.03	0.072
21	*Calophyllum* sp.	652.10	0.26	0.02	0.035
22	*Syzygium* sp.	652.10	0.33	0.02	0.035
23	*Syzygium decipiens*	652.10	0.64	0.02	0.037
24	*Garcinia dioica*	652.10	0.89	0.02	0.039

Curriculum Vitae

Name:	Indra Yustian
Date / Place of Birth:	26 July 1973 in Jakarta
Nationality:	Indonesian
Family status:	married

Education

1979 – 1985:	Elementary School at SD N 05 Pagi, Jakarta (Indonesia)
1985 – 1988:	Junior High School at SMP N 58, Jakarta (Indonesia)
1988 – 1991:	Senior High School at SMA N 55, Jakarta (Indonesia)
08/1991 – 07/1996:	Undergraduate at Department of Biology, Faculty of Mathematics and Natual Sciences, University of Sriwijaya, Palembang (Indonesia), majoring in Plant Ecology.
08/1999 – 02/2001:	Graduate at Study Program of Biology, Magister Programme, Faculty of Mathematics and Natural Science, University of Indonesia, Jakarta (Indonesia), majoring in Conservation Biology. *Thesis title*: Kepadatan populasi relatif dan pohon tempat tidur *Tarsius dianae* Niemitz *et al.* 1991 pada beberapa habitat yang terpengaruh aktivitas manusia di Taman Nasional Lore Lindu, Sulawesi (in Bahasa Indonesia) *Translation*: Relative population densities and sleeping tree choise of *Tarsius dianae* in different human-influenced habitats in Lore Lindu National Park, Sulawesi.
09/2003 – 05/2007:	Postgraduate at the Department of Conservation Biology, Center for Nature Conservation, Georg-August University of Goettingen (Germany). *Dissertation Title*: Ecology and Conservation Status of *Tarsius bancanus saltator* on Belitung Island, Indonesia. Supported by Deutschen Akademischen Austauschdienst (DAAD).

Occupation:

1997 – current:	Lecturer at the Department of Biology, Faculty of Mathematics and Natural Sciences, University of Sriwijaya, Palembang, South Sumatra.