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ACTIVITIES, HABITAT USE AND DIET OF WILD DUSKY LANGURS, *Trachypithecus obscurus* IN DIFFERENT HABITAT TYPES IN PENANG, MALAYSIA

YAP JO LEEN, NADINE RUPPERT* AND NIK FADZLY NIK ROSELY

Primate Research and Conservation Lab, School of Biological Sciences, Universiti Sains Malaysia, Penang, Malaysia.

**Corresponding author: n.ruppert@usm.my*

Abstract: Most primates are threatened but studies that address their use of degraded habitats are scarce. Here, we report on activities, habitat use and diet of *Trachypithecus obscurus* in a human-impacted landscape in Penang Island. We studied the relationship of these primates with their habitat to facilitate conservation management plans. We used group scan sampling to assess activity budgets and recorded home range size, stratum use and food plant species and parts. The home range of the study group was 12.9 hectares, including secondary forest (61.2%), a nature park (23.9%) and beach (14.9%). Langurs mainly rested (43.5%) and fed (24.8%) and spent significantly more time resting and foraging in the secondary forest than elsewhere. They mainly fed on leaves (60.3%) and consumed 56 identified plant species from 32 families of wild and cultivated plants. Langurs behaved differently and ate different plant species in different habitat types and the group had to cross a busy motorway to reach the beach, thus, we also report on road crossing behaviour. These langurs have seemingly adapted well to disturbed habitat however, more comparative studies are needed to predict long-term effects of habitat degradation on the population of this species and to develop feasible conservation plans.

Keywords: Colobinae, road kills, feeding ecology, spectacled leaf monkey, road ecology.

Introduction

Dusky Langurs, also referred to as Dusky Leaf Monkeys or Spectacled Langurs (*Trachypithecus obscurus;* Colobinae; IUCN 2016) are arboreal primates that inhabit primary and secondary forests and are adapted to a leaf-eating diet (folivory). They additionally feed on flowers and fruits of a variety of plant species (McClure, 1964). Langurs have a fundamental relationship with the upper rainforest stratum as they exploit the most abundant food leaves and occur there at the highest biomasses (Chivers, 1989). However, destruction and fragmentation of forests for human land-use is negatively affecting primate habitats (Bennett & Saunders, 2010). Primates in Penang Island are abundant but understudied and due to the recent development of some forested areas around the island, the wildlife here faces threats through habitat loss, degradation and fragmentation by roads. Impacts of roads on wildlife is a global concern (Taylor & Goldingay, 2010), as wildlife has to survive in fragmented habitat patches leading to increased rates of agonistic behaviours, food competition, stress levels and exposure to various infections (Mbora & McPeek, 2009) and increased risk of road kills.

With 1,663 persons per square kilometre, Penang Island is one of the fastest growing and most densely populated places in the world (Penang Institute, 2017). The 1.77 million human population on the 1,032 km^2-state has an average annual population growth rate of 1.3% (Department of Statistics Malaysia, 2010) and the population of Penang Island is projected to rise exponentially over the next 15 years (Chee *et al*., 2017). Since the 1960s, the extent of Penang's urbanized areas increased leading to losses of natural habitats on the island (Chee *et al*., 2017; Elmahdy *et al.,* 2016), which can reduce local wildlife populations or lead to local extinctions (Hong & Chan, 2010). Thus, it is essential to understand how arboreal primates with a specialized leaf-eating diet can cope in anthropogenic environments in order to facilitate feasible conservation actions, if necessary.

It is not yet understood to what extend langurs that live in the forests of this island can cope with human development and resulting habitat degradation or fragmentation. Langurs on Penang Island are still found in primary lowland and hill forests and inhabit disturbed habitats, such as secondary forests, parks and human settlements. Habitat fragmentation may put pressures on their population, which is shown through the increased frequency of human-primate encounters in Penang Island during the recent years (Y. J. L., pers. obs.). Penang residents have been complaining about nuisance behaviour of (Md-Zain & Ch'ng, 2011; Karimullah *et al.,* 2014; Department of Wildlife and National Parks – per. comm.) or about langurs entering gardens and orchards and wildlife road kills are common on the island (Y. J. L., per. obs.). Forest fragmentation may further negatively impact gene flow and lead to decline of genetic diversity in fragmented populations, thus it is important to maintain canopy connectivity and natural arboreal routes (Gregory *et al*., 2017; Teixeira *et al.,* 2013).

In order to assess whether there is a need for targeted conservation management of this species on the island and to identify feasible management actions, we need to first answer the question: *"How do the langurs behave in anthropogenic environments?"* With this baseline study, we aimed at better comprehending the ecology of Penang Island by assessing activity budgets, habitat use and diet composition of a habituated group of wild *T. obscurus* in different habitat types. The study site comprised secondary forest, a public nature eco-tourism park and an open-canopy beach site divided from the forest and park by an asphalt road. As habitat types and their respective vegetation were substantially different from each other, we expected the activities, habitat use and diet of the langurs to vary between habitat types. Understanding ecological factors that influence behaviours is especially crucial in fragmented and human-impacted landscapes where seasonal food scarcity may also lead to road crossings between food patches or foraging in parks and orchards, which may result in road accidents and human-primate conflicts.

Our research is the first long-term study on the ecology of a wild, habituated group of *T. obscurus*. The results from this study are essential to understand the ecological flexibility of this species in order to design applicable conservation scenarios (Estrada & Coates-Estrada, 1996). As wildlife conservation can become a significant contributor to the socio-economic development of Penang (Kaffashi *et al*., 2015), data-driven communication with the public and government stakeholders is vital to create awareness and influence local decision makers (Chivers, 2013).

Materials and Methods

Study Site and Period

The study site was located at Teluk Bahang, Penang Island, Malaysia, surrounding and including inland secondary forest (habitat type 1), Tropical Spice Garden (TSG; habitat type 2) which is an eco-tourism park with native and cultivated plants, and the beach (habitat type 3; Figure 1). We (Y.J.L. and assistant) collected data from March 2016 to September 2017 for a total of 157 days, an average of eight days per month for seven hours per day, from 0630 to 1330 hours.

Study Group and Data Collection

At the study site, *T. obscurus* is sharing the habitat with two other sympatric non-human primate species, the Sunda Slow Loris (*Nycticebus coucang*) and Long-tailed Macaques (*Macaca fascicularis*). Further, there are three groups of langurs with partially overlapping home ranges near our habituated study group, "Group Lai". During the study period, Group Lai consisted of 14 individuals (one adult male, one adolescent male, eight adult females and four juveniles and subadults). The adolescent male is the offspring to the adult male.

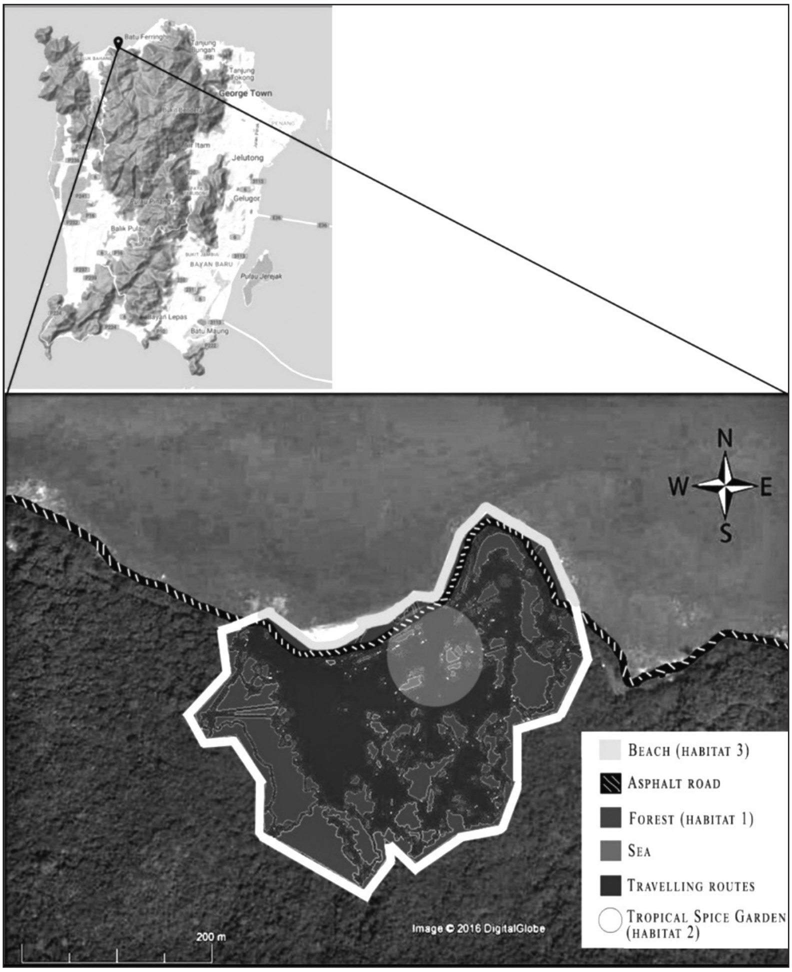

Figure 1: Above: Penang Island, Malaysia and the location of the study site (black balloon; 5°27’44.66”N 100°13’41.66”E; image adapted from Google Earth)
Below: Home range (white outline, 12.9 hectares) of a group of wild, habituated *Trachypithecus obscurus* at Teluk Bahang, Penang Island (March 2016 to September 2017)

For observational data collection, we used binoculars whenever the langurs were higher up in the trees and more difficult to spot. We always maintained a safe observation distance of at least 3 metres from the langurs although we could approach them closer without provoking a flight reaction. We used group scan data sampling (Altmann, 1974; Gilby *et al*., 2011) by applying a standardised ethogram (Table 1) that we designed for this species. The habituation process of the group started in November 2015, but we excluded the data of that period due to possible human errors and far observation distance.

For each scan, we randomly picked three adult females and three juveniles and/ or subadults and the two largest males and recorded their respective behaviours at first sight (i.e. activity, stratum, consumed plant species and parts) within a maximum scan duration of five minutes for all eight individuals. If we could not spot all individuals within five minutes the scan was finished but data was taken into the analysis. The next scan started after a pause of

Table 1: Ethogram for group scan and ad-libitum sampling.

Behaviour	Definition
Resting	Daytime resting without movement, including eyes opened or closed postures, e.g. sitting, lying, standing, etc.
Locomotion	Directed movement without any other associated behaviour, e.g. walking, climbing, descending, running, etc.
Feeding	Ingestion of food by chewing and swallowing; browsing.
Foraging	Directed search for food and/or handling of food items without ingestion, e.g. plucking of leaves or flowers, inspection of food items by smelling, etc.
Social Grooming	Combing the fur of another individual or being groomed by another individual.
Social-Playing	Affiliative social interaction, e.g. wrestling, chasing, mock biting, usually between juveniles and/or subadults.
Aggression	Aggressive physical contact: bite, push, pull, hit etc. between group members.

ten minutes. We collected 135 minutes of scans (equivalent to 4,082 individual scan data points).

Activity Budgets

For the langurs' activity budgets in the different habitat types, we calculated the frequencies of observed behaviours during the scans assessing their means (M), standard deviations (SD) and standard error of the mean (SEM).

Habitat Use

We used a Garmin 64s GPS device to record the daily travel routes of the group while we followed them and calculated their overall home range area (minimum convex polygon, MCP) using the programmes *Garmin Base Camp* and *Google Earth* (Burgman & Fox, 2003). Additionally, we used *ad-libitum* sampling (Altman, 1974) to record the daily road crossing behaviour of the individuals. We also noted the position of each scanned individuals in the stratum for ground (0 m); stratum 1 (above ground - 10 m); stratum 2 (10 m – 20 m); stratum 3 (20 m – canopy); and stratum 4 (above canopy).

Diet

During each scan, we noted the food plant of a feeding individual and for the calculation of the feeding budget, we used scan frequencies. Additionally, during the scan breaks, we recorded *ad libitum* data on food plant consumption that we compiled into a comprehensive food plant list (Table 2). We identified food plant species with the help from botanists from Universiti Sains Malaysia (USM) and Tropical Spice Garden (TSG).

Road crossings

We recorded the time, number of individuals crossing the road and crossing methods (i.e. cable wire walking, tree leaping and road running) by *ad-libitum* sampling.

Analysis

We compared activity budgets, diet and forest stratum use (i.e. mean frequencies of recorded behaviours and locations during the scans) of the group between the three different habitat types: secondary forest, TSG and beach by using one-way ANOVA and Tukey's post hoc test (significance level set at $p \leq 0.05$) with GraphPad Software (GraphPad, 2017). Data sets were tested for normality using Kolmogorov-Smirnoff test ($p \geq 0.05$).

Results

Activity Budgets

Overall, the langurs spent almost half of their time resting (43.5%, ± 3.8%), a quarter of their time feeding (24.8%, ± 4.8%) and locomoting

(24.4%, ± 2.0%); and very small proportions of their time on social grooming (3.8%, ± 1.5%), social playing (2.6%, ± 1.5%) and foraging (0.9%, ± 0.3%). They spent significantly more time resting [One-way ANOVA, F (2,54) =3.6, p≤0.05] and foraging [One-way ANOVA, F (2,54) =4.4, p≤0.05; N=4,082] in the secondary forest compared to the other sites (Figure 2). They rested significantly more often in the secondary forest (M=46%, SD=7%) than at the beach (31.4%, ± 23.8%, Tukey HSD test, p≤0.05) and foraged significantly more often in the secondary forest (1.1%, ± 0.7%) than at beach (0.3%, ± 0.6%, Tukey HSD test, p≤0.05).

Habitat Use

During the study period, the group covered a total home range of 12.9 hectares (multiple convex polygon) with three habitat types (i.e. inland secondary forest, TSG and the beach). Overall, the *T. obscurus* spent significant more time in the forest (61.2% ± 16.6%; N=3,317,), compared to in TSG (23.9%, ±15%; N=3,317) or the coast (14.9% ± 9.5%; N=3,317, F (2,54) = 58.4, p≤0.001). The coast is divided from the forest and TSG by an asphalt road with heavy traffic that the group had to cross to reach the beach.

In total, we recorded 2,114 individual road crossings during the study period. Dusky Langurs used tree leaping as their main method to cross the road [F (2,54)=57, p≤ 0.001, N=2.114] and the mean frequency of tree leaping (63.2%, ± 0.2%) was significantly higher than cable wire crossing (34.2%, ± 0.2%) or road running (2.6%, ± 0.1%; Tukey HSD test, p≤0.01).

During the study period, we recorded five fatal incidents related to the road crossings. Three subadult males and one adult female fell on the asphalt road from either the power line or trees that they used for leaping to the other side of the road. Also, one Sunda Slow Loris (*Nycticebus coucang*) was electrocuted when it attempted to cross this road via the power line (Figure 3).

Overall, the langurs spent significantly more time in lower to medium forest strata between 1 m to 20 m [F (4,90) =105.06, p≤0.00, N=4,082]. They spent half of their time at lower forest strata between 1 m to 10 m (50.2%) and slightly less at 10 m to 20 m (39.5%). They

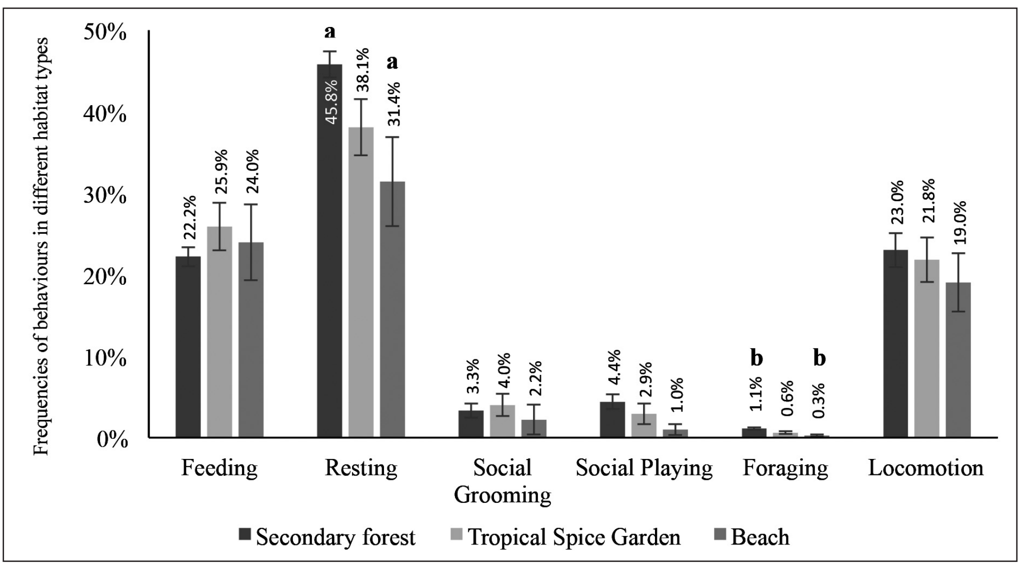

Figure 2: Activity budget of a wild group of *Trachypithecus obscurus* in three habitat types in Penang Island from March 2016 to September 2017 (N=4,082). Columns with identical letters indicate significant difference (Tukey HSD test, p≤0.05)

Figure 3: Road accidents of arboreal primates caused by vehicles and electrocution (when crossing the road via power line) at the study site. From left: An electrocuted Sunda Slow Loris (circled); Dusky Langur roadkill; Y.J.L and assistant handling another Dusky Langur roadkill by taking body measurements before handing the body over to the Wildife Department

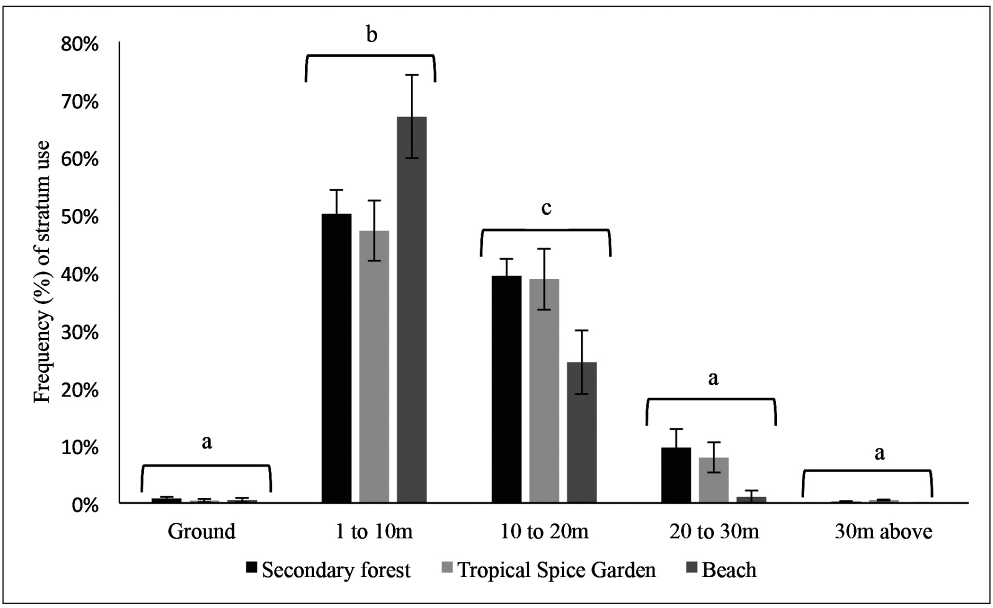

Figure 4: Stratum use of a wild group of *Trachypithecus obscurus* in three habitat types in Penang Island; March 2016 to September 2017 (N=4,082). Different letters indicate significant differences between the stratum groups (Tukey HSD test, $p \leq 0.05$)

spent almost one tenth of their time in higher strata (20 m to 30 m; 9.3%) while they almost never used the ground (0.8%) or higher strata above 30 m (0.3%). In the forest, the group used the ground for certain activities, such as feeding on lower shrubs or soil, drinking stream water and for social playing. We collected data on the individuals feeding and playing on the forest floor (0 m -1 m) since March 2017, which made up 44.5% of the total social playing time and 34.7% of the feeding time. This seems worth mentioning as this species is reported to be primarily arboreal.

Diet

With 63.0% of all food items, leaves were the main diet component of the langurs [F (3.37) =111.0, $p \leq 0.001$) followed by fruits (19.9%) and flowers (13.5%). They also fed on seedpods, tree bark, invertebrates and soil (3.6%). The langurs fed similar amounts of plant parts in the three habitat types, except for flowers (mostly of *Adinandra dumosa*), which they consumed significantly more often in TSG [F (2,54) =19.2, p≤0.001] (Figure 5).

The langurs fed on 56 plant species from 32 families of which 32 identified plant species were found in the secondary forest, 25 species in TSG and 13 species at the beach. There are still approximately 20 species of plants that have yet to be identified (11 species of unknown wild seedlings, *Ficus* sp., bamboos and lianas/ vines) (Table 2).

Discussion

The activity budgets may not represent the full-day activities of these langurs as we as we could follw the group only during the first part of the day due to logistical constraints in the field. Still, the results from this study provide

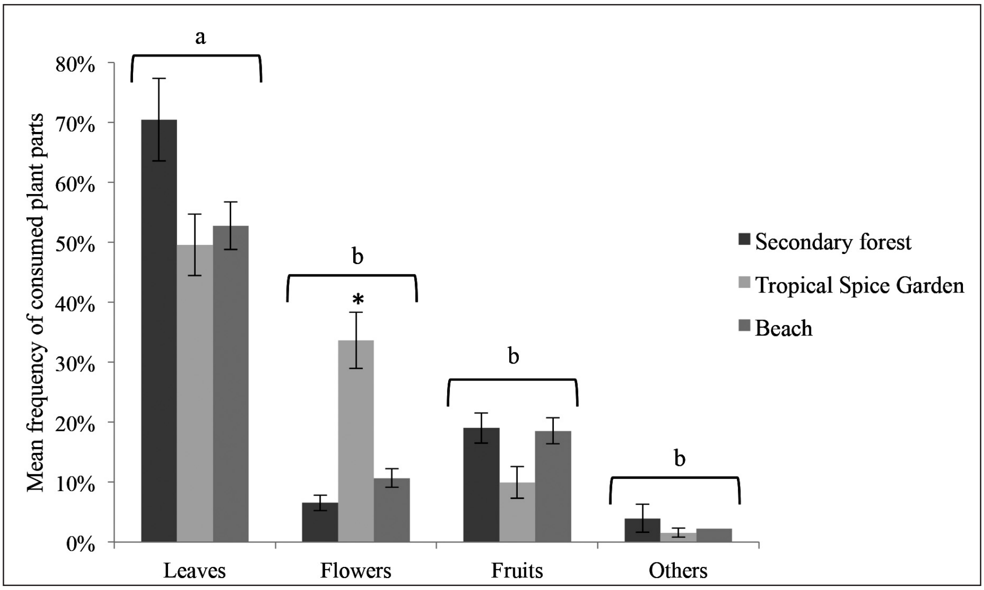

Figure 5: Diet composition of a wild, habituated group of *Trachypithecus obscurus* in three habitat types in Penang Island from March 2016 to September 2017 (N=4,082). 'Others' means seedpods, tree bark, invertebrates and soil. Different letters indicate significant differences between consumed food part groups (One-way ANOVA, p≤0.001). Asterisk indicates significant difference of consumed parts in different habitat types (Tukey HSD test, p≤0.001)

Table 2: Food plant species and plant parts consumed by a wild group of *Trachypithecus obscurus* in Penang Island from March 2016 to September 2017

No.	Species	Family	Local Name	Consumed Parts
1	*Acacia auriculiformis* [a,c]	Fabaceae	Earleaf Acacia	leaves, fruits
2	*Adinandra dumosa* [a]	Pentaphylacaceae	Tiup-tiup	leaves, fruits, flowers
3	*Albizia saman* [c]	Fabaceae	Rain Tree	leaves, fruits, flowers
4	*Alstonia* sp. [c]	Apocynaceae	Milkwood pine	leaves
5	*Antidesma bunius* [c]	Phyllanthaceae	Wild Cherry	leaves, fruits
6	*Aquilara* sp. [b]	Thymelaeaceae	Agarwood	leaves
7	*Archidendron jiringa* [a,b]	Fabaceae	Jering	leaves, fruits, flowers
8	*Artocarpus elasticus* [a,b]	Moraceae	Terap nasi	leaves, fruits, flowers

9	*Asplenium nidus* [a,b]	Aspleniaceae	Bird Nest Fern	leaves
10	*Asystasia gangetica* [b,c]	Acanthaceae	Chinese violet	leaves, flowers
11	*Averrhoa bilimbi* [b]	Oxalidaceae	Belimbing	leaves
12	*Buchanania arorescens* [a]	Anacardiaceae	Otak Udang	leaves
13	*Caryota mitis* [a,b]	Arecaceae	Fish-tailed palm	leaves, fruits
14	*Cinnamomum verum* [b]	Lauraceae	Ceylon Cinnamon	leaves
15	*Clitoria ternatea* [b]	Fabaceae	Blue Pea Flower	leaves, flowers
16	*Cronton caudatus* [a]	Euphorbiaceae	Hamba Raja	leaves
17	*Crypteronia peniculata* [a]	Crypteroniaceae	Blume	leaves, flowers
18	*Davidia involucrata* [b]	Nyssaceae	Handkerchief Tree	leaves, flowers
19	*Dillenia suffruticosa* [a,c]	Dilleniaceae	Simpoh Air	leaves, fruits
20	*Duranta erecta* [b]	Verbenaceae	Skyflower	flowers
21	*Eurycoma longifolia* [b]	Simaroubaceae	Tongkat Ali	leaves
22	*Fagraea fragrans* [a,b]	Gentianaceae	Tembusu	leaves
23	*Ficus caulocarpa* [a]	Moraceae	Stem-Fruited Fig	leaves, fruits
24	*Ficus fistulosa* [b]	Moraceae	Yellow Stem Fig	leaves, fruits
25	*Ficus hispida* [a,c]	Moraceae	Hairy fig	leaves
26	*Ficus superba* [c]	Moraceae	Sea Fig	leaves, fruits
27	*Greena corymbosa* [a]	Rubiaceae	Tinjau belukar	leaves, flowers
28	*Gustavia superba* [b]	Lecythidaceae	Gustavia	flowers
29	*Hevea brasiliensis* [b]	Euphorbiaceae	Rubber Tree	leaves
30	*Ixora congesta* [a,b,c]	Rubiaceae	Malaysian Ixora	leaves, fruits, flowers
31	*Macaranga gigantea* [a,b]	Euphorbiaceae	Mahang Gajah	leaves, fruits, flowers
32	*Melastoma malabathricum* [a,b]	Melastomataceae	Senduduk	leaves, fruits
33	*Microcos tomentosa* [a,c]	Malvaceae	Cenderai	leaves, flowers
34	*Millettia pinnata* [a,b,c]	Fabaceae	Sea Milettia	leaves, fruits, flowers
35	*Morinda citrifolia* [b]	Rubiaceae	Indian Mulberry	leaves
36	*Morinda umbellata* [b]	Rubiaceae	Morinda	leaves, fruits
37	*Myristica fragrans* [b]	Myristicaceae	Nutmeg	leaves, flowers
38	*Nepenthes albomarginata* [a]	Nepenthaceae	Monkey cup	leaves, modified leaves
39	*Nepenthes gracilis* [a]	Nepenthaceae	Monkey cup	leaves, modified leaves
40	*Peltophorum pterocarpum* [a,c]	Fabaceae	Yellow Flame	leaves, fruits, flowers
41	*Phyllanthus acidus* [b]	Phyllanthaceae	Cermai	leaves
42	*Phyllostachys* sp. [a,b]	Poaceae	Asian bamboo	leaves
43	*Prismatomeris tetrandra* [a]	Rubiaceae	Haji Samat	leaves, flowers
44	*Psyhotria sarmentosa* [a]	Rubiaceae	Akar Daldaru	leaves, fruits
45	*Sandoricum koetjape* [a]	Meliaceae	Santol	leaves, fruits
46	*Schima wallichii* [a,b]	Theaceae	Needlewood	leaves
47	*Syzygium antisepticum* [a,b]	Myrtaceae	Shore Eugenia	leaves
48	*Syzygium grande* [a,b]	Myrtaceae	Jambu Air Laut	leaves, fruits, flowers

49	*Syzygium lineatum* [a]	Myrtaceae	Common Kelat	leaves
50	*Syzygium zeylanicum* [a,b]	Myrtaceae	Kelat Nasi	leaves
51	*Tabebuia* sp [b]	Bignoniaceae	Tabebuia	leaves, flowers
52	*Terminalia catappa* [a,b,c]	Combretaceae	Sea Almond	leaves, fruits, flowers
53	*Tetracera indica* [a,c]	Dilleniaceae	Fireweed	leaves, fruits, flowers
54	*Thunbergia laurifolia* [b]	Acanthaceae	Blue Trumpet Vine	leaves, flowers
55	*Vitex pinnata* [a,b]	Verbenaceae	Leban	leaves, flowers
56	*Wedelia* sp. [b]	Asteraceae	Creeping oxeyes	leaves, flowers

Notes: Plants recorded at: a) secondary forest; b) Tropical Spice Garden; c) beach

valuable information about the ecology and behavior of this species. The primary activity of the langurs during the observation period was resting. Reportedly the genus *Trachypithecus* spends more time on resting than on any other activities: white-headed langurs (*Trachypithecus leucocephalus*) in China spend 50% of their time resting, 18% moving and 13% feeding (Li & Rogers, 2005); the Francois' langur (*Trachypithecus francoisi*) spends an average of 51.5% of the daytime resting, 23.1% feeding and 17.3% locomoting (Zhou *et al*., 2006) and Luo *et al*. (2007) showed that the Francois' langurs spent 63.8% on resting, 22.0% on foraging and 1.3% on traveling (locomoting). Resting for prolonged hours is necessary for digesting leaves and to keep energy expenditure low and is typical for folivorous primates (Chaves *et al*., 2011), due to the energy-costly fermentation processes of cellulose in their plant diet (Long *et al*., 2010). Other sympatric primate species at the study site that are not depending on leaves as their main diet component have different activity budgets. Diurnal frugivorous Long-tailed Macaques (*Macaca fascicularis*) spend the majority of their time locomoting (20.3%) and equally much time on feeding (18.8%) and resting (17.1%; Hambali *et al.,* 2012). Activity budgets in this species may vary with group size, as larger groups spend more energy on obtaining food and groom less due to tension in the group (van Schaik *et al*., 1983). The nocturnal gummivorous Sunda Slow Loris (*Nycticebus coucang*) spends an average of 20.5% feeding and 5.4% resting during its active time (Wiens, 2002).

Variations in activity budgets within the same species can arise from several external factors, such as level of disturbance, observation techniques or food plant availability across habitats and seasons. Primates can flexibly adjust their activity budgets to deal with changing environmental conditions (Li, 2008). The food availability may have varied in the different habitat types across our 19 months of data collection, which may have led to the differences of activity budgets in the different habitat types. Other factors, such as food abundance, predator pressure and human interferences may as well have influenced the respective activity budgets (Chhangani & Mohnot, 2006). We assume that competition with the Long-tailed Macaques and the presence of humans in TSG and at the beach, which both are popular tourism attractions in Penang, are important factors that influenced the traveling routes and habitat use of the group. However, during fruiting season of certain fruit trees, like jering (*Archidendron jiringa*) and ketapang (*Terminalia catappa*) we frequently observed both Dusky Langurs and Long-tailed Macaques feeding together in the same area, occasionally even on the same trees. Ruslin *et al*. (2019) found that the monthly feeding overlap between Dusky Langurs and Long-tailed Macaques was correlated to monthly fruit availability.

The secondary forest was the preferred environment for our study group and here they rested significantly more often than at the beach as the individuals may have felt safer in the forested areas (including TSG) due to a lack of vehicles or humans and the presence of high trees.

The group also foraged significantly more often in the secondary forest than at the beach area. Although TSG is a man-made attraction with a variety of cultivated plants, the former curator remained the native *Syzygium* and *Ficus* trees in the garden and the Dusky Langurs visited the garden during seasonal fruiting and flowering periods of these selected food plants. The beach area is separated from the forest and TSG by an asphalt road. The individuals frequently crossed the road, mainly for the food plants available at the beach (e.g. *Acacia auriculiformi, Millettia pinnata, Terminalia catappa).* Resting, social grooming and social playing was lowest at the beach. The disturbance at the beach area is high due to loud vehicle noise and human presence, nevertheless the group visited the area for feeding, indicating the presence of important food plant species.

The study group fed on 56 identified species of plants and leaves made up the majority of their diet while they selectively fed on other plant parts such as flowers, fruits, young shoots and seeds. *Trachypithecus* is reported to rely more on leaves than any other Asian colobine (Suarez, 2013) and consumes more young leaves than mature leaves (*T. auratus:* Kool, 1993; *T. francoisi:* Zhou *et al*., 2006; *T. pileatus*: Solanki *et al*., 2008a; *T. phayrei*: Suarez, 2013) as young leaves contain more proteins and water and less fiber and tannins (Takemoto, 2003). However, selected leaves consumed by Black-shanked Douc Langurs (*Pygathrix nigripes*) were higher in cellulose than non-food leaves and no evidence was found that tannin was the key determinant of food selection in *P. nigripes* (Duc *et al*., 2009). Besides feeding on green plant parts (leaves, flowers and unripe fruits), the study group also fed on the tree bark of rotten wood, clay soil and invertebrates. It is not uncommon for langurs to feed on invertebrates, living in plants, soil and tree bark to obtain minerals like sodium and protein (Rahman *et al*., 2015).

The seasonal proportion of food items in langurs' diet is determined by food plant availability and phenological stages and habitat type (Solanki *et al*., 2008b). Luo *et al*. (2007) indicated that a natural habitat provided adult Francois' Langurs (*Trachypithecus francoisi francoisi*) with different food resources during different seasons, which changed the foraging frequency of this species. Activity budgets also varied with the season for Gray Langurs (*Presbytis antellus;* Wolfheim, 1979). During the study period, we were not able to collect data of food plant biomass, availability and phenology, which is part of the ongoing research. Based on our long-term observation, langurs are particularly attracted to cultivated flowering plants in TSG (e.g. *Syzygium grande* and *Gustavia superba*) and coastal plants (e.g. *Syzygium antisepticum, Acacia auriculiformis*, *Milletia pinnata*, *Tetracera indica* and *Terminalia catappa*) that cannot be found in the forest. The langurs also spent seasonally more time at TSG (in March 2016 and October 2016) due to flowering and fruiting of various ornamental and cultivated plants (i.e. *Ficus* sp. and *Cinnamomum cassia* and *Myristica fragrans*) that they consumed. In June and July and toward the end of the year (in both observation years), the langurs spent more time at the beach to forage for the seasonal Earleaf Acacia (*Acacia auriculiformis),* Sea Milettia (*Millettia pinnata)* and Sea Almond *(Terminalia catappa).*

Most food plant species, however, were found in the secondary forest, possibly explaining the larger home range area in the forest. Groups of white-headed langurs (*Trachypithecus leucocephalus*) in Fusui, Precious Animal Reserve, Guangxi, China had large home range sizes varying from 28 to 48 ha, where group size and food plant species diversity increased significantly with habitat quality (Li & Rogers, 2005). *Trachypithecus vetulus* at urban areas, in contrast, had home ranges of 3.06 and 2.86 ha, respectively (Moore *et al*., 2010).

Some of the tallest trees in the secondary forest at the study site reach 30 m. The langurs spent most time between 1 to 20 m in all habitat types. In the secondary forest, the group spent more time feeding in lower strata on small shrubs, climbers and seedlings that grow close to the forest floor, such as *Syzygium*, wild Ixora (*Ixora congesta*) and Otak Udang (*Buchanania arorescens).* The secondary forest is also spatially more complex compared to TSG or the beach, with a variety of vines, climbers and epiphytic plants growing in the understory and canopy and the langurs spent more time foraging in the forest than in the other habitat types. The vegetation at the beach is lower compared to the forest and TSG and the langurs were resting in low trees by the beach during resting hours after feeding periods.

To move from the forest and TSG to the beach, the langurs travelled at least once daily on the connecting power lines above the road. The decline in natural arboreal pathways forces primates to utilize artificial structures or the ground to travel within their territory (Moore *et al*., 2010). For the juveniles and pregnant females in our group, the thin and unstable cable wires pose a challenge. Thus, they chose to run across the busy driveway, which caused several deaths and injuries during the 19 months observation period. Forest clearance is the most significant threat to the survival of primates and many other forest animals (Nijman, 2004) and primates are particularly vulnerable to habitat fragmentation (Arroyo-Rodríguez *et al*., 2013) and the increasing development threatens forested areas on Penang Island (Hong & Chan, 2010). Habitat loss or fragmentation causes wildlife to forage in human-impacted areas, which can lead to competition for resources and creates negative public perception about wildlife when it damages gardens or orchards (Karimullah *et al.,* 2014).)

The *Trachypithecus obscurus* is now categorised as Near Threatened (IUCN, 2016) due to habitat loss and the illegal and unsustainable trade in these primates which poses a severe threat to their population and conservation (Shepherd, 2010). Therefore, it is crucial to work together with local communities to create public awareness about the threats to local primates and to deliver feasible outputs for conservation and sustainable development (Meadows, 2011). With the knowledge of food plants and habitat use, we recommend the use of canopy bridges to reconnect habitat patches that contain preferred food plants in order to minimise dangerous road crossings and/or garden raiding. We also recommend the cultivation of important food plants (i.e. *Ficus* sp., *Vitex pinnata* and *Artocarpus elasticus*) in degraded landscapes where langurs are found to feed on cultivated plants (e.g. near orchards or gardens) to compensate for lost habitat. Hence, we are currently developing canopy bridges in designated areas with high langur populations and where roads are cutting through their home range to mitigate road kills. By better understanding the ecological needs of the *T. obscurus*, we also educate the public about how to address conflicts and to point out the importance of Penang's secondary forests, natural and cultivated plants and natural coastal habitats to sustain primate populations on this island.

Conclusion

Malaysia is rich in primate diversity that should receive increased scientific attention and enhanced conservation efforts as these species play an important role in forest regeneration. Here, we provided valuable baseline information regarding the ecology and behaviour of *T. obscurus* in degraded habitats in Penang and reported on their preferred food plants. Activities, habitat use and diet composition of *T. obscurus* differed in different habitat types that are impacted by human activities. Although the langurs seem to have adapted well, movement between these habitat patches is risky and conservation plans, such as canopy bridges or food plant cultivation in non-risk areas could be considered to mitigate negative effects of habitat fragmentation. In order to draw a more comprehensive conclusion, an extended study period with more groups using focal sampling to investigate behavioural changes during seasons is needed, especially to understand to effects of climate change and growing urbanization in Penang. Other future research avenues include the seed dispersal role of *T. obscurus*, the relationship with sympatric species that share the same ecological niche, and the life history and social behaviours of this species.

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