NATURE IN SINGAPORE 2013 **6**: 1–6
Date of Publication: 19 February 2013

RECENT RECORDS OF THE DUNG BEETLE *CATHARSIUS MOLOSSUS* (COLEOPTERA: SCARABAEIDAE) IN SINGAPORE

Xin Rui Ong[1*], **Siew Chin Chua**[2] and **Matthew D. Potts**[2]
[1]*Department of Biological Sciences, National University of Singapore*
14 Science Drive 4, Singapore 117543, Republic of Singapore
[2]*Department of Environmental Science, Policy & Management*
University of California, Berkeley, California, USA
(*[*]Corresponding author: ong.xinrui@nus.edu.sg*)

ABSTRACT. — Of the dung beetles collected in Singapore, *Catharsius molossus* (Linnaeus) is the largest and only large nocturnal tunnelling species, last recorded there in the late 1970s. To determine if the species is still extant in Singapore, we conducted dung beetle surveys at six study sites. Both cattle- and pig-dung baited pitfall traps were used to determine the species' dung preferences. In total, 52 individuals were captured, with 49 individuals from cattle-dung baited traps. Most of them were captured within the contiguous northern patch of forests in the Central Catchment Nature Reserve. *Catharsius molossus* appears to be a specialist of herbivores' dung. Established populations of both the Sambar deer (*Rusa unicolor*) and Eurasian wild pig (*Sus scrofa*) are likely sources of dung for this species.

KEY WORDS. — dung beetle, *Catharsius molossus*, secondary forest, Central Catchment Nature Reserve, Singapore

INTRODUCTION

Insects perform a variety of functions, some of which are critical for the health of tropical forest ecosystems (Didham et al., 1998). Dung beetles (Coleoptera: Scarabaeidae) are important decomposers that use faeces as a source of food and nesting material. They also provide the ecological services of secondary seed dispersal and dung removal (Davis et al., 2001). Finally, they display rapid and graded responses to many kinds of natural and anthropogenic disturbance and hence are often used to investigate the effects of disturbances on forest diversity, structure, and health (Davis et al., 2001; Nichols et al., 2007).

Dung beetles are often classified into three different functional groups, with regards to how they manipulate dung (Hanski & Cambefort, 1991). Rollers (telocoprids) construct balls from dung. They then roll the balls away and bury them for nesting purposes. Tunnellers (paracoprids) create tunnels directly under the dung and gather dung to use in their underground nests. Dwellers (endocorprids) live inside the dung source to nest and feed (Hanski & Cambefort, 1991). Among these functional groups, large nocturnal tunnellers are the most important group in maintaining the ecosystem functions of dung removal. Yokohoma et al. (1991) demonstrated that dung removal helps to increase nitrogen mineralisation. Large nocturnal tunnellers are also important secondary seed disperser (Slade et al., 2007), generally burying more and larger seeds to greater depths than smaller dung beetles (Andersen & Feer, 2005). Seeds buried at greater depths have been shown to suffer from lower seed predation risk, allowing them to germinate, and hence are advantageous for plant regeneration (Chambers & MacMabon, 1994; Shepherd & Chapman, 1998; Andersen & Feer, 2005).

Based on the historical collection of dung beetles in the Zoological Reference Collection (ZRC), Raffles Museum of Biodiversity Research, National University of Singapore, only two *Catharsius molossus* specimens have ever been captured in Singapore (Table 1). In addition, they are the only species of large (≥10 mm in length) nocturnal tunnellers as well as the largest dung beetle species ever collected in Singapore. Within the forests of the region, *Catharsius molossus* are commonly found in old-growth continuous forests, with large mammal communities such as elephants, rhinoceros, and clouded leopards (Marsh & Greer, 1992). A recent dung beetle survey by Lee et al. (2009a) in Bukit Timah Nature Reserve (BTNR) did not record *Catharsius molossus* and concluded that this species was most likely extinct in Singapore's forest fragments.

Table 1. *Catharsius molossus* specimens previously collected in Singapore.

S/No.	Catalogue No.	Location	Date	Length (mm)	Sex	Collector
1	ZRC.COL.01	Bukit Timah forest	12 Dec.1965	25	Female	ADR
2	ZRC.COL.02	Bukit Timah forest	No date	25	Female	D. H. Murphy

The apparent local extinction of *Catharsius molossus* in Singapore is probably due to two reasons: habitat exploitation loss and hunting activities. The cultivation of cash crops, especially gambier (*Uncaria gambir*), in the 19th century and rapid urbanisation in the late 20th century required the clearing of lowland dipterocarp forests on the main Singapore Island. The bulk of the remaining forests are now found in fragments scattered around the island's water catchment areas. Today, primary forests are now restricted to the 163-ha BTNR and scattered patches of about within the Central Catchment Nature Reserve (CCNR) totalling about 118 ha (Yee et al., 2011). Fifty- to 80-year old secondary forests occupy the majority of the catchment area and younger secondary forests (less than 40 years old) are scattered around the mainland and on several offshore islands (Corlett, 1992). Thus, the lack of old-growth continuous forests, where *Catharsius molossus* was historically found in (Lee et al., 2009b), may have likely played a role in its possible extirpation.

Second, the persistent hunting of forest-dwelling mammals also likely played a major role. Forest mammalian communities are fundamental for the maintenance of dung beetle communities, owing to the dependence of dung beetles on mammalian dung (Nichols et al., 2009). All indigenous large forest mammals are now locally extinct owing to hunting activities in 19th-century Singapore (Corlett, 1992). The mammals that remain are small and medium-sized, such as the long-tailed macaque (*Macaca fasicicularis*) and Eurasian wild pig (*Sus scrofa*; Sha et al., 2009; Yong et al., 2010). Larger-bodied dung beetles, like *Catharsius molossus*, have previously been shown to have strict or near strict obligate associations with the now locally extinct mammal species as they actively forage for large faecal depositions (Peck & Howden, 1984; Nichols et al., 2009). Hence, the removal of large forest mammals through hunting activities may have also caused the possible local extinction of *Catharsius molossus*.

However, recently published sightings of the Sambar deer (*Rusa unicolor*) in northern Central Catchment Nature Reserve (CCNR) provide indications that *Catharsius molossus* beetles may still persist in Singapore's forests. The Sambar deer is the largest known herbivorous mammal on Singapore island. This population does not appear to be originally native, but probably descended from some individuals that have escaped from the nearby Singapore Zoo (Chua & Lim, 2011a). Its occurrence shows that the remaining secondary forests may be able to support populations of large mammals. In addition to the Sambar deer, the Eurasian wild pig population is becoming increasingly abundant on Singapore Island, occurring mostly in areas north of the Pan-Island Expressway. It was recently estimated that the forests in the CCNR could support up to 552 pigs (Yong et al., 2010).

Therefore, we hypothesized that *Catharsius molossus* beetles may still persist in Singapore's remaining forests. Hence, we conducted this study in areas of primary and secondary forest fragments not previously surveyed by Lee et al. (2009a, 2009b), to determine if *Catharsius molossus* were still present in the regenerating forests of Singapore. In addition, if *Catharsius molossus* were still present, we were interested to see if they were using herbivorous or omnivorous dung to survive. This would allow us to determine this species' dung preferences, which had not been previously reported.

MATERIAL AND METHODS

Study sites. — This study was conducted within the CCNR and BTNR. A total of six study sites, comprising three secondary and three primary plots, were surveyed from 29 Jul.2011 to 9 Sep.2011 (Fig. 1).

Trapping technique. — The survey of dung beetles was carried out using dung-baited pitfall traps (Fig. 2). A total of 18 traps, nine using cattle dung and nine using pig dung, were placed in a 50 × 50 m grid. A square grid was used instead of a linear transect as the forests are highly fragmented in Singapore and a linear transect would have likely cut through different forest types, whereas a square grid ensured that the survey was conducted within the same forest type. Each trap consisted of a plastic cup (diameter = 8.5 cm and height = 14.5 cm) buried flushed into the ground. A 15 × 15 cm corrugated plastic board served as a rain cover and was supported 10 cm above the surface of the cup by stiff iron wires. The cattle (banteng, *Bos javanicus*) and pig (Malayan bearded pig, *Sus barbatus*) dung were collected from the Singapore Night Safari. Approximately 100 g of dung was wrapped in a 2 × 2 mm white mesh, secured with rubber bands and suspended 5 cm from the surface of the trap with nylon thread. Each pitfall trap contained saturated salt solution, filled to a depth of 4 cm, which killed and preserved trapped dung beetles. Traps were left in the field for 48 hours before collection. Beetles were collected and stored in 75% ethanol for lab processing and identification. The intact specimens (46 out of 52) were then preserved and deposited in the Zoological Reference Collection of the Raffles Museum of Biodiversity Research, National University of Singapore (catalogue numbers ZRC.COL.03–48).

RESULTS

A total of 52 individuals of *Catharsius molossus* was captured, with 49 and three individuals in cattle- and pig-dung baited pitfall traps, respectively (Fig. 3). These beetles ranged from 24–31 mm in body length and the sex ratio of

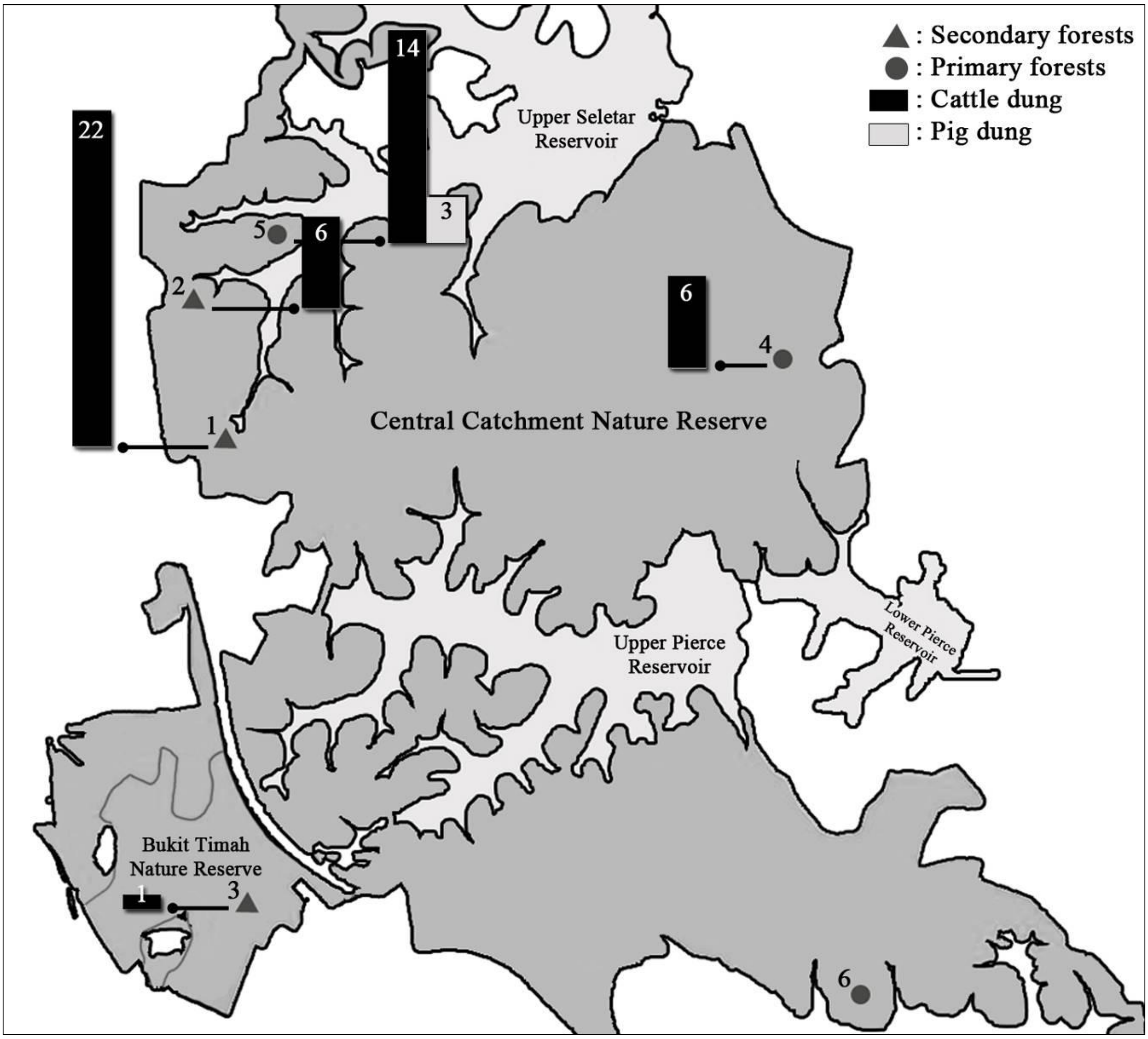

Fig. 1. Map of the six surveyed forest plots and the number of *Catharsius molossus* captured in the cattle- and pig-dung baited pitfall traps.

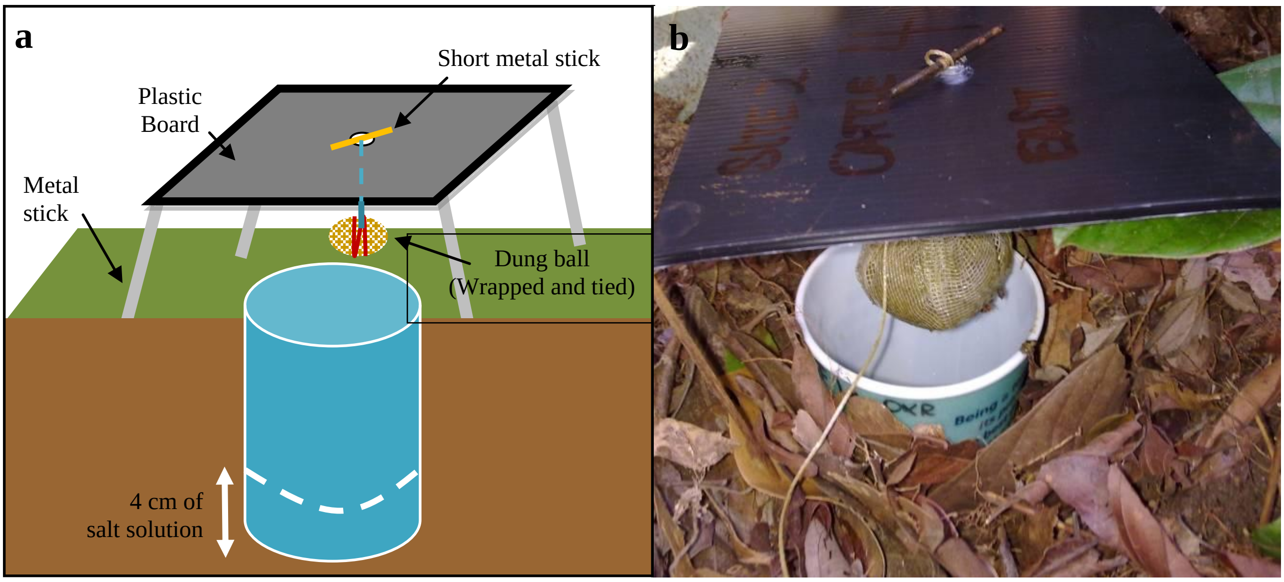

Fig. 2. Dung-baited pitfall trap: a, a diagram of the set-up; b, the actual set-up used.

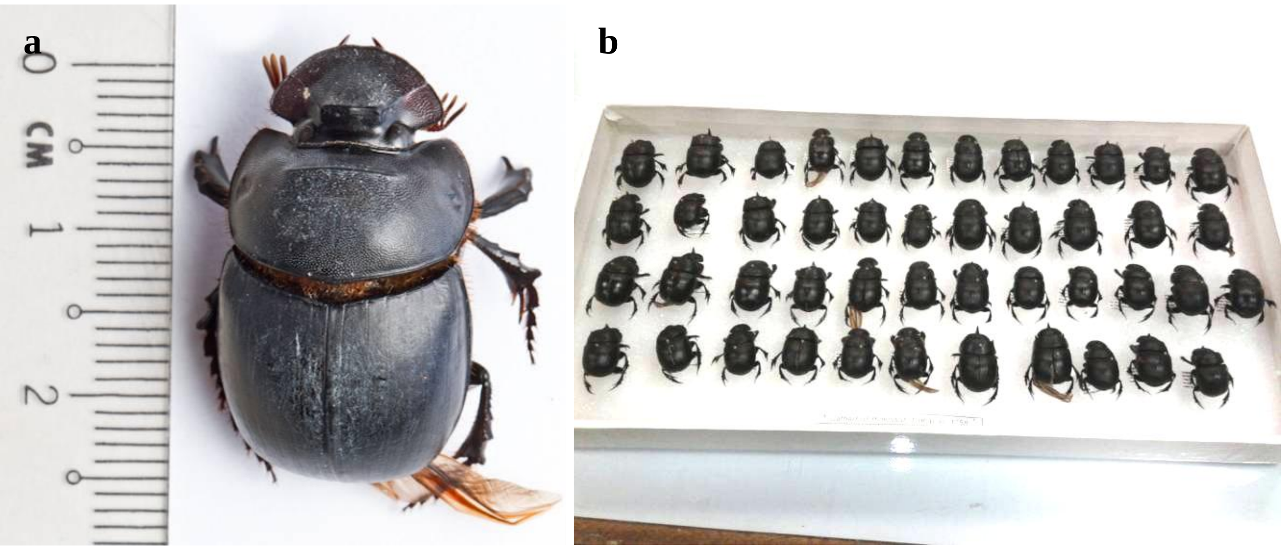

Fig. 3. *Catharsius molossus* specimens collected: a, close-up of an individual; b, the preserved specimens (ZRC.COL.03–48).

individuals captured is approximately 1:1. Beetles were captured in both primary (23 individuals in two out of three sites) and secondary forests (29 individual in three out of three sites). Site 2 (secondary forest site) had the highest number of *Catharsius molossus* captures (22 individuals), while Site 6 (primary forest site) had the fewest captures (0 individuals; see Fig. 1).

DISCUSSION

In support of our hypothesis, *Catharsius molossus* was captured in five of the six study sites, demonstrating that this species still exists in Singapore's fragmented forests. The majority of these beetles were captured within the contiguous northern patch of forests in the CCNR, in particular, within the secondary forests on the northwestern side, near the Gangsa cycling track (Fig. 1). *Catharsius molossus* appears to prefer cattle dung, with only three out of the 52 individuals captured using pig-dung baited traps. This suggests that *Catharsius molossus* is a specialist that feeds on herbivores' dung, and further, that there are enough herbivorous mammals in the northern CCNR to support it.

The sources of herbivorous dung are limited since few remaining species of herbivorous forest mammals exist on Singapore Island. Those that persist include the greater mousedeer (*Tragulus napu*), the lesser mousedeer (*Tragulus kanchil*), and the Sambar deer (Chua & Lim, 2011b). Deer are known to produce dung in pellet or clump form (Winand, 2012). Dung in clump form loses its moisture at a slower rate (Sowig & Wassmer, 1994), thus making it more suitable for large dung beetles. Large beetles dissipate heat slowly (Bartholomew & Heinrich, 1978). Thus, they prefer dung with high moisture content as it allows them to avoid desiccation (Chown, 2001) and it leads to higher rates of brood-ball production (Edwards, 1991). However, such clump-formed dung has never been encountered in Singapore's remaining forests. Instead, pellet-like dung is more common. Even though pellet-like dung tends to lose moisture more rapidly, studies have shown that rainfall rehydrates dung (Edwards, 1991; Sowig & Wassmer, 1994). This is extremely likely to occur in Singapore, which experiences about 2.36 m of rain a year (National Environmental Agency, 2007).

Of the three deer species that persist, both species of the local mousedeer are probably too small to provide sufficient dung resources for *Catharsius molossus*. However, Sambar deer dung may be a plausible dung resource. Sambar deer are large mammals (Chua & Lim, 2011b) and hence produce large-pellet dung depositions that are likely sufficient for *Catharsius molossus* beetles. The actual population of Sambar deer in the CCNR has yet to be determined. However, there have been many sightings in the northwestern forests of the reserve, such as along Mandai Road, Mandai Lake Road, and Mandai Track 15 over the past few years (Cai, 2010; M. A. H. Chua, pers. comm.).

In addition to deer, the Eurasian wild pig, Malayan colugo (*Galeopterus variegatus*), long-tailed macaque, and the banded leaf monkey (*Presbytis femoralis*) may also provide dung resources for *Catharsius molossus*. Eurasian wild pigs have also been sighted in the northern forests of the CCNR (M. A. H. Chua, pers. comm.). A possible reason why the pig dung used in our dung-baited pitfall traps was not favoured by *Catharsius molossus* beetles was likely owed to the fact that the dung was obtained from pigs fed with a well-balanced omnivorous diet in captivity. In the wild, 90% of the diet of the Eurasian wild pig consists of fruits, seeds, roots, and tubers (Oliver & Leus, 2008). Thus, the dung produced by these mammals in the wild could be likened to that of a herbivorous mammal, likely making it suitable for *Catharsius molossus*.

Malayan colugos are also a fairly common mammal in the BTNR and CCNR. Little information is known about its diet, but we do know that it consists of leaves and flowers (Lang, 2006; Chua & Lim, 2011c). Hence, the Malayan colugo may produce herbivorous dung suitable for *Catharsius molossus*. However, as the colugo is not larger than the mousedeer, the dung it produces may also be insufficient.

Besides pigs and colugos, the very conspicuous long-tailed macaque is the most common primate in Singapore forests, with the majority of its population being found in both the BTNR and CCNR (Sha et al., 2009). Although the long-tailed macaque is predominantly frugivorous, it can exploit other food sources during periods when fruit is scarce (Yeager, 1996). Such food sources include insects, crabs, young and mature leaves, and stems (Lang, 2006; Chua & Lim, 2011d). Thus, the long-tailed macaque would produce herbivorous dung whenever it consumes a predominantly plant-based diet. Such dung may be suitable for *Catharsius molossus*.

Finally, the banded leaf monkey is another primate found in the CCNR that feeds on leaves and fruits (Chua & Lim, 2011e). Unfortunately, it is locally confined to the CCNR and is a critically endangered animal in Singapore (Chua & Lim, 2011e), with population estimates of about 40 individuals (Ang et al., 2012). Despite its small population size, this primate may still contribute herbivorous dung resource for *Catharsius molossus*.

To be certain of the variety of dung resources that *Catharsius molossus* can utilise, future research should incorporate more dung types in dung-baited pitfall traps, such as that of the Sambar deer and the Malayan colugo.

CONCLUSIONS

From our surveys, *Catharsius molossus* appears to be a herbivorous dung specialist and is relatively abundant in the northern CCNR. This correlates well with local known distribution of the Sambar deer and the Eurasian wild pig. Our study demonstrates that Singapore's contiguous secondary forests with patches of primary forests are able to support mature forest dung beetle species. Overall, the confirmed occurrence of *Catharsius molossus* in Singapore is a welcomed trend as these beetles provide important ecosystem functions such as secondary seed dispersal (Slade et al., 2007) and plant regeneration (Andersen & Feer, 2005).

ACKNOWLEDGEMENTS

We thank the National Parks Board for providing research permits to the Central Catchment and Bukit Timah nature reserves (Research permit no. NP/RP11-050a); Lua Hui Kheng of the Raffles Museum of Biodiversity Research for allowing access to the insect collection; Wang Luan Keng for providing sufficient material and equipment for this project; Marcus A. H. Chua for his eyewitness accounts on mammalian sightings; and Janice S. H. Lee for sharing her knowledge on dung beetles.

LITERATURE CITED

Andersen, E. & F. Feer, 2005. The role of dung beetles as secondary seed dispersers and their effect on plant regeneration in tropical rainforests. In: Forget, P.-M., J. E. Lambert, P. E. Hulme & S. B. Vander Wall (eds.), *Seed Fate: Predation, Dispersal and Seedling Establishment*. CABI Publishing, United Kingdom. Pp. 331–349.

Ang, A., A. Srivasthan, B. M. Md.-Zain, M R. B. Ismail & R. Meier, 2012. Low genetic variability in the recovering urban banded leaf monkey population of Singapore. *Raffles Bulletin of Zoology*, **60**: 589–594.

Bartholomew, G. A. & B. Heinrich, 1978. Endothermy in African dung beetles during flight, ball making, and ball rolling. *Journal of Experimental Biology*, **73**: 65–83.

Cai, A., 2010. Rare deer knocked down by car on SLE. *The Straits Times*, 4 Mar.2010. http://www.straitstimes.com/Singapore/Story/STIStory_497641.html. (Accessed 25 May 2012).

Chambers, J. C. & J. A. MacMabon, 1994. A day in the life of a seed: Movements and fates of seeds an their implications for natural and managed systems. *Annual Review of Ecology and Systematics*, **25**: 263–292.

Chown, S. L., 2001. Physiological variation in insects: Hierarchical levels and implications. *Journal of Insect Physiology*, **47**: 649–660.

Chua, M. A. H. & K. K. P., Lim, 2011a. Deer. In: Ng, P. K. L., R. T. Corlett & H. T. W. Tan (eds), *Singapore Biodiversity: An Encyclopedia of Natural Environment and Sustainable Development.* Editions Didier Millet, Singapore. P. 290.

Chua, M. A. H. & K. K. P., Lim, 2011b. Mammals. In: Ng, P. K. L., R. T. Corlett & H. T. W. Tan (eds), *Singapore Biodiversity: An Encyclopedia of Natural Environment and Sustainable Development.* Editions Didier Millet, Singapore. P. 370.

Chua, M. A. H. & K. K. P., Lim, 2011c. Colugos. In: Ng, P. K. L., R. T. Corlett & H. T. W. Tan (eds), *Singapore Biodiversity: An Encyclopedia of Natural Environment and Sustainable Development.* Editions Didier Millet, Singapore. P. 270.

Chua, M. A. H. & K. K. P., Lim, 2011d. Macaques. In: Ng, P. K. L., R. T. Corlett & H. T. W. Tan (eds), *Singapore Biodiversity: An Encyclopedia of Natural Environment and Sustainable Development.* Editions Didier Millet, Singapore. P. 370.

Chua, M. A. H. & K. K. P., Lim, 2011e. Mammals.In: Ng, P. K. L., R. T. Corlett & H. T. W. Tan (eds), *Singapore Biodiversity: An Encyclopedia of Natural Environment and Sustainable Development.* Editions Didier Millet, Singapore. P. 370.

Corlett, R. T., 1992. The ecological transformation of Singapore , 1819–1990. *Journal of Biogeography*, **19**: 411–420.

Davis, A. J., J. D. Holloway, H. Huijbregts, J. Krikken, A. H. Kirk-Spriggs & S. L. Sutton, 2001. Dung beetles as indicators of change in the forests of northern Borneo. *Journal of Applied Ecology*, **38**: 592–616.

Didham, R. K., P. M. Hammond, J. H. Lawton, P. Eggleton & N. E. Stork, 1998. Beetle species responses to tropical forest fragmentation. *Ecological Monographs*, **68**: 295–323.

Edwards, P. B., 1991. Seasonal variation in the dung of African grazing mammals, and its consequences for coprophagous insects. *Functional Ecology*, **5**: 617–628.

Hanski, I. & Y. Cambefort, 1991. *Dung Beetle Ecology.* Princeton University Press, Princeton. 481 pp.

Lang, C. K. A., 2006. *Primate Factsheets: Long-tailed Macaque (Macaca fascicularis) Taxonomy, Morphology, & Ecology*. Primate Info Net. http://pin.primate.wisc.edu/factsheets/entry/long-tailed_macaque/taxon. (Accessed 7 Oct.2012).

Lee, J. S., Y. K. Cheung, L. Qie & J. Hujibregts, 2009a. Possible extinctions of dung beetles (Coleoptera: Scarabaeidae) in Bukit Timah Nature Reserve, Singapore. *Raffles Bulletin of Zoology*, **57**: 537–542.

Lee, J. S., I. Q. W. Lee, S. L.-H. Lim, J. Huijbregts & N. S. Sodhi, 2009b. Changes in dung beetle communities along a gradient of tropical forest disturbance in South-East Asia. *Journal of Tropical Ecology*, **25**: 677–680.

Marsh, C. W. & A. G. Greer, 1992. Forest land-use in Sabah, Malaysia: An introduction to Danum Valley. *Philosophical Transactions: Biological Sciences*, **335**: 331–339.

National Environmental Agency, 2007. *Frequently Asked Questions*. Singapore Weather Portal. http://www.weather.gov.sg/wip/web/home/faq. (Accessed 5 Jul.2012).

Nichols, E., T. Larsen, S. Spector, A. Davise, F. Escobarc & M. Favilad, 2007. Global dung beetle response to tropical forest modification and fragmentation: A quantitative literature review and meta-analysis. *Biological Conservation*, **137**: 1–19.

Nichols, E., T. A. Gardner, C. A. Peres, S. Spector & The Scarabaeinae Research Network, 2009. Co-declining mammals and dung beetles: An impending ecological cascade. *Oikos*, **118**: 481–487.

Oliver, W. & K. Leus, 2008. Sus scrofa. IUCN, 2011. http://www.iucnredlist.org/apps/redlist/details/41775/0. (Accessed 27 May 2012).

Peck, S. B. & H. F. Howden, 1984. Response of a dung beetle guild to different sizes of dung bait in a Panamanian rainforest. *Biotropica*, **16**: 235–238.

Sha, J. C. M., M. D. Gumert, B. P. Y.-H. Lee, A. Fuentes, S. Rajathurai, S. Chan & L. Jones-Engel, 2009. Status of the long-tailed macaque *Macaca fascicularis* in Singapore and implications for management. *Biodiversity and Conservation*, **18**: 2909–2926.

Shepherd, V. E. & C. A. Chapman, 1998. Dung beetles as secondary seed dispersers: Impact on seed predation and germination. *Journal of Tropical Ecology*, **14**: 199–215.

Slade, E. M., D. J. Mann, J. F. Villanueva & O. T. Lewis, 2007. Experimental evidence for the effects of dung beetle functional group richness and composition on ecosystem function in a tropical forest. *Journal of Animal Ecology*, **76**: 1094–1104.

Sowig, P. & T. Wassmer, 1994. Resource partitioning in coprophagous beetles from sheep dung: Phenology and microhabitat preferences. *Zoologische Jahrbücher*, Abteilung für Systematik, Ökologie und Geographie der Tiere, **121**: 171–192.

Winand, C. J., 2012. *Deer Pelletology*. Bowsite.com. http://bowsite.com/bowsite/features/armchair_biologist/poop/index.htm. (Accessed 25 Jun.2012).

Yeager, C. P., 1996. Feeding ecology of the long-tailed macaque (*Macaca fascicularis*) in Kalimantan, Tengah, Indonesia. *International Journal of Primatology*, **17**: 51–62.

Yokohoma, K., H. Kai, T. Koga & S. Kawagushi, 1991. Effect of dung beetle *Onthophagus lenzii* H. on nitrogen transformation in cow dung and dung balls. *Soil Science and Plant Nutrition*, **37**: 341–345.

Yee, A. T. K., R. T. Corlett, S. C. Liew & H. T. W. Tan, 2011. The vegetation of Singapore–An updated map. The *Gardens' Bulletin, Singapore*, **63**: 205–212.

Yong, D. L., B. P. Y.-H. Lee, A. Ang & K. H. Tan, 2010. The status on Singapore island of the Eurasian wild pig *Sus scrofa* (Mammalia: Suidae). *Nature in Singapore*, **3**: 227–237.