

THE HERPETOFAUNA AND MAMMALS OF SEMAKAU LANDFILL: A PROJECT SEMAKAU CHECKLIST

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INTRODUCTION

Semakau Landfill is a 3.5 km² man-made island located approximately 8 km southwest of the main island of Singapore. It was formed by enclosing the sea between Pulau [=Island] Semakau and Pulau Sakeng by a 7-km rock bund. The island is herein referred in this paper as ‘Semakau’. Since 1999, it functions as the nation’s only landfill site. After its construction, Pulau Sakeng houses the jetty area, visitor centre, and marine transfer station for handling incinerated waste from Singapore, while most part of Pulau Semakau remains intact. Although most of Semakau was once cleared for human habitation and had some parts of the mangrove and shore habitats destroyed during the construction of the landfill sites, the remaining habitats still hold considerable diversity of mangrove and marine organisms (Ng, 2011).

Semakau offers a variety of habitats for herpetofauna and mammals (Fig. 1). The terrestrial ones comprise of secondary forest (Fig. 1b) and new environment created by landfill cells and other built up areas. Secondary succession of filled cells has led to formation of grassland, marshes, and a scattering of shrubs and trees (Fig. 1a). These areas are undoubtedly highly disturbed. In addition, a wide variety of coastal and marine habitats are present on the island—sandy and rocky shore (Fig. 1d), seagrass meadow (Fig. 1c), intertidal coral reef (Fig. 1f), and mangroves (Fig. 1c), including the replanted areas. The locations of the range of terrestrial and intertidal habitats on the original Pulau Semakau can be found in Fig. 2.

Project Semakau is a community involvement and conservation project led by the Raffles Museum of Biodiversity Research (RMBR), National University of Singapore (NUS), and sponsored by the Hongkong and Shanghai Banking Corporation Limited (HSBC). The project aims to realise and enhance the island’s value as a nature education and conservation site. One of the main objectives is to collect data on Semakau’s biodiversity via comprehensive surveys.

The marine, mangrove and avian fauna on the island has been relatively well documented by the Raffles Museum of Biodiversity Research (RMBR) (Project Semakau, 2008; Tan & Yeo, 2010; Wang & Yeo, 2011); Nature Society (Singapore) (unpublished); Zeehan et al. (unpublished), WildSingapore (2005); and Ng (2009). However, the non-avian vertebrates, especially terrestrial herpetofauna and mammals on the island, have not been documented in depth. This annotated checklist was compiled with the aim of establishing baseline information for the diversity of herpetofauna and mammals of the island.

MATERIAL AND METHODS

The present checklist was compiled from review of available literature, authenticated sighting reports, as well as field surveys conducted by the author and the Project Semakau team from Nov.2009 to May 2011.

Seven day and five night surveys of the secondary forest, mangroves, and landfill area were conducted. In addition, mist netting and small mammal trapping for bats and small mammals (e.g., rodents) were carried out from 19–20 Mar.2010 for both methods, with additional dates for small mammal trapping on 28 May and 12 Jun.2010. Wire cage traps baited with banana, tuna, and bread were placed in trap lines in the secondary forest, landfill cells, and rock bund. Small mammal trapping effort amounted to 20 trap nights. For the core Project Semakau intertidal surveys, intertidal habitats surrounding the island extending up to 500 m from the highest tide mark were surveyed by line transects.

Nomenclature and classification of taxa follows Baker & Lim (2008), while the status of the recorded species in Singapore is based on Lim & Lim (1992), Baker & Lim (2008), and Davison et al. (2008). All species illustrated in this paper were photographed on the Semakau Landfill.



Fig. 1. Examples of habitats on Semakau: a, grassland and open country succession on filled landfill cell; b, coastal and secondary forest; c, mangroves; d, sandy shore; e, seagrass meadow; and f, intertidal coral reef. (Photographs by: Wang Luan Keng).

ANNOTATED CHECKLIST

1. Amphibians (Class Amphibia)

Order Anura

Family **Bufonidae**

Duttaphrynus melanostictus (Schneider), Asian Toad (Fig. 3a)

Widespread and common throughout the island, this human commensal was recorded in the secondary forest and also in landfill cells and built up areas, including the visitor centre and jetty area. Also recorded by Ng (2009).

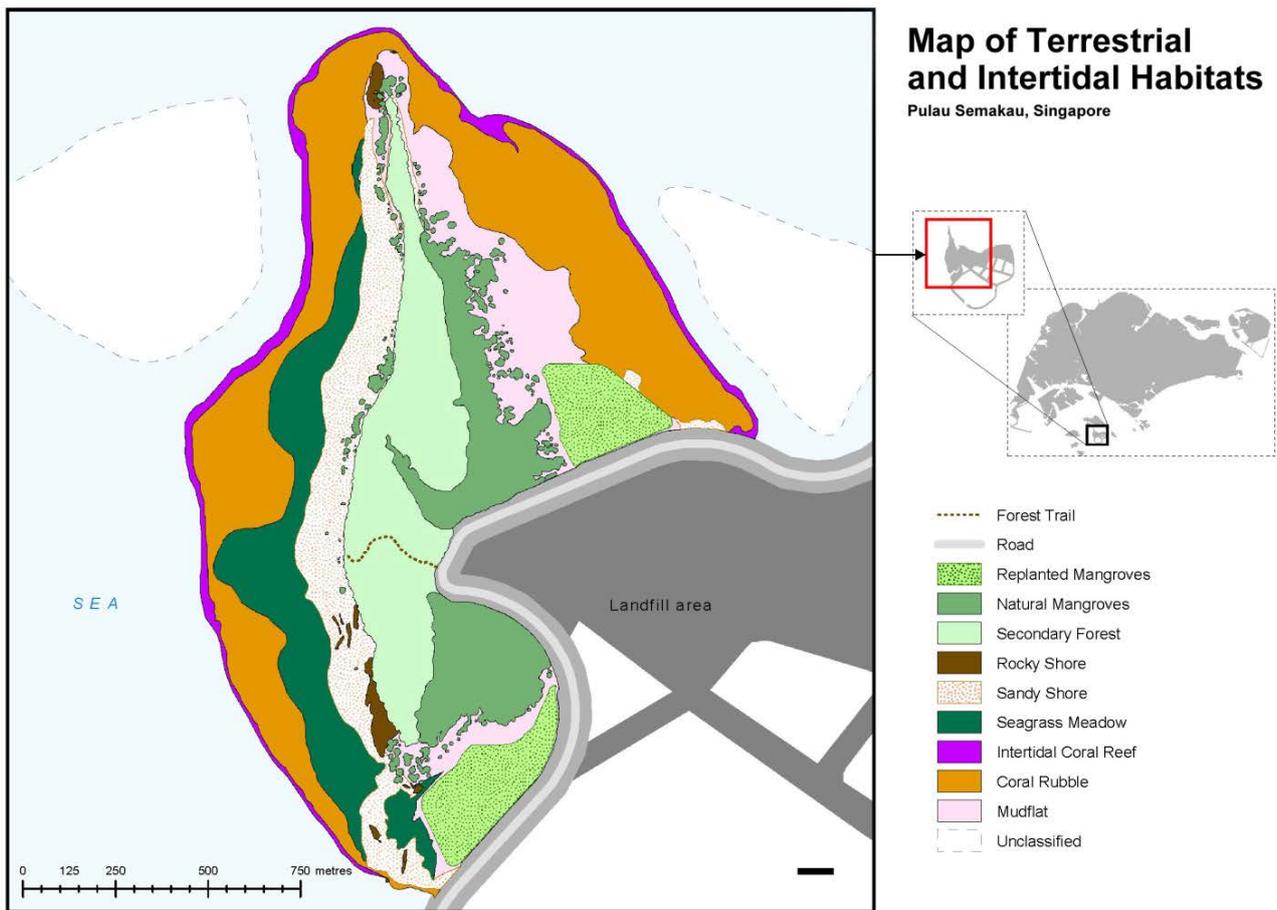


Fig. 2. Map of the terrestrial and intertidal habitats on Semakau. Insert on the right shows its location relative to the main island. The red box highlights the original Pulau Semakau before the construction of the Semakau Landfill. (Map by: Yang Yikang, for RMBR).

Family **Dicroglossidae**

Fejervarya cancrivora (Gravenhorst), crab-eating frog (Fig. 3b)

This species was recorded in the secondary forest. Although known for its ability to tolerate brackish water, this species was not recorded in the mangrove areas during the survey period. Adults can be differentiated from the next species by their larger size (> 6 cm), more extensive webbing on the feet, and a rattling call (Lim & Lim, 1992). Also recorded by Ng (2009).

Fejervarya limnocharis (Gravenhorst), field frog

The field frog is usually found in open disturbed environments and around human habitation. On Semakau, it is widespread and common along the secondary forest edge and in landfill areas. Its raspy calls can often be heard from the landfill cells after rain. Also recorded in Ng (2009).

Family **Rhacophoridae**

Polypedates leucomystax (Gravenhorst), four-lined tree frog (Fig. 3c)

The four-lined tree frog is often associated with human habitation. It has been seen in shallow pools of water or on vegetation in secondary forest habitats, and was the only amphibian species observed during all sessions of the night surveys. This species was also recorded by Ng (2009) and Zeehan et al. (unpublished).

Family **Microhylidae**

Kaloula pulchra Gray, banded bull frog (Fig. 3d)

This human commensal is widespread on the island in secondary forest, landfill cells, and also around the visitor centre. It was first recorded on 19 Mar.2010 in the landfill area. An individual was encountered about 2.5 m up a tree in secondary forest habitat, and at least one was observed by the author to be feeding on ants attracted to the bait used for small mammal traps. Its loud bellowing calls were heard from the landfill cells after a heavy rain. This introduced species (Yeo & Chia, 2010) is a new record for Semakau.



Fig. 3. Amphibians seen on Semakau: a, Asian toad (*Duttaphrynus melanostictus*); b, crab-eating frog (*Fejervarya cancrivora*); c, four-lined tree frog (*Polypedates leucomystax*); and d, banded bull frog (*Kaloula pulchra*). (Photographs by: Marcus Chua).

2. Reptiles (Class Reptilia)

Order Testudines

Family Cheloniidae

Chelonia mydas (Linnaeus), green turtle (Fig. 4)

Confirmed records of at least two individuals of this marine turtle were recorded along the northern coast in 2009. At least four separate turtle sightings at the same location during Project Semakau walks and surveys in 2009 were also likely to be of the same species (Manta's Experience, 2009; Tide Chaser, 2009b, 2009c). In late 2000s, one individual was rescued after being trapped in drift net, while in Aug.2011, a turtle that was seen swimming in an unused cell is likely to be of this species as well (S. Lim, pers. comm.). Green turtles are listed as internationally endangered and nationally critically endangered (Seminoff, 2004; Davison et al., 2008).



Fig. 4. The locally critically endangered green turtle *Chelonia mydas* spotted off the northern coast of Semakau. (Photograph by: Marcus Chua).

Eretmochelys imbricata (Linnaeus), hawksbill turtle

There was no record of this marine turtle during the survey period. However, one was recorded in the waters off the island in 2007 (Urban Forest, 2007). This species is listed as internationally and nationally critically endangered (Davison et al., 2008; Mortimer & Donnelly, 2008).

Family **Geoemydidae**

Cuora amboinensis Daudin, Malayan box terrapin (Fig. 5a)

The Malayan box terrapin was recorded twice, in 2009 and 2011, in the secondary forest. The natural origin of this species is doubtful, as terrapins are generally long-lived and often become abandoned pets or are released by the public for gaining spiritual merit (Ng & Lim, 2010).

Order **Squamata**

Family **Agamidae**

Calotes versicolor (Daudin), changeable lizard (Fig. 5b)

Widespread and common on terrestrial habitats throughout the island, except in mangroves. The changeable lizard is an introduced species (Yeo & Chia, 2010), and has been recorded in secondary forests, landfill sites, on the rock bund, and other built up areas. Also recorded by Ng (2009).

Family **Gekkonidae**

Hemidactylus frenatus Duméril & Bibron, spiny-tailed house gecko (Fig. 5c)

This human commensal is commonly seen in man-made areas such as the rock bund, landfill cells, and buildings on Semakau. It was also recorded in the secondary forest edge and on coastal vegetation. Also recorded by Ng (2009).

Gekko monarchus (Schlegel), spotted house gecko

Recorded by Ng (2009). This species was not seen during surveys on the island.

Family **Scincidae**

Lygosoma bowringii (Günther), garden supple skink

Recorded by Ng (2009). This species was not seen during surveys on the island.

Family **Varanidae**

Varanus salvator (Laurenti), Malayan water monitor (Fig. 5d)

The Malayan water monitor has been recorded in mangroves, coastal areas, seagrass meadow, and secondary forest. This species is tolerant to seawater and has been seen swimming in coastal waters around the island. Also recorded by Ng (2009) and Zeehan et al. (unpublished).

Broghammerus reticulatus (Schneider), reticulated python

This species, the island's largest terrestrial predator, was not seen during surveys on the island but was recorded by Ng (2009). The reticulated python is an excellent swimmer which can easily colonise islands.

Family **Acrochordidae**

Acrochordus granulatus (Schneider), banded file snake (Fig. 6d)

Relatively uncommon in coastal habitats, this marine snake was encountered on 13 occasions in coastal habitats, including seagrass meadows, coral rubble, and even close to the reef edge during Project Semakau surveys and walks. Also recorded by Ng (2009).

Family **Colubridae**

Boiga dendrophila (Boie), gold-ringed cat snake

There are no prior records of this species on the island. However, an individual was seen in the secondary forest in 2008 by a volunteer (Heigermoser, pers. comm.). WildSingapore (2011c) recorded the species on Semakau in Sep.2011. This species is listed as "widespread but rare" by Baker & Lim (2008), and vulnerable to nationally extinction in the Singapore Red Data Book (Davison et al., 2008).



Fig. 5. Reptiles of Semakau: a, Malayan box terrapin (*Cuora amboinensis*); b, changeable lizard (*Calotes versicolor*); c, spiny-tailed house gecko (*Hemidactylus frenatus*); and d, Malayan water monitor (*Varanus salvator*). (Photographs by: Marcus Chua).

Family Pythonidae

Lycodon capucinus Boie, common wolf snake (Fig. 6a)

This non-venomous species was seen on one occasion amongst leaf litter in secondary forest. As it is a human commensal, it is likely to be present in landfill cells and built up areas. Also recorded by Ng (2009).

Family Homalopsidae

Cerberus rynchops (Schneider), dog-faced water snake (Fig. 6c)

This aquatic snake is most frequently encountered in mangroves and coastal areas. There were 15 records of this species during Project Semakau surveys and walks. This mildly-venomous but usually placid snake feeds on fish and is harmless to humans. Also recorded by Ng (2009).

Family Elapidae

Laticauda colubrina (Schneider), yellow-lipped sea krait

This marine snake was recorded once in 2010 after a Project Semakau survey. Also recorded in Ng (2009), and notably in some nature blogs (WildSingapore, 2005; SGbeachbum, 2009). A locally uncommon species, it has only been recorded from the Southern Islands and surrounding reefs (Lim & Lim, 1992; Baker & Lim, 2008). This species is listed as nationally endangered due to loss and modification of coastal habitat by development (Davison et al., 2008).

Family Viperidae

Cryptelytrops purpureomaculatus (Gray), shore pit-viper (Fig. 6b)

This species of mangrove and coastal snake was encountered twice in 2009—once, on the rock bund facing a section of replanted mangroves, and the second by volunteers on the main road. Not recorded previously and probably rare on the island. The shore pit-viper is restricted to a few areas in Singapore and is nationally endangered (Baker & Lim, 2008; Davison et al., 2008).



Fig. 6. Snakes of Semakau: a, common wolf snake (*Lycodon capuchinus*); b, shore pit viper (*Cryptelytrops purpureomaculatus*); c, dog-faced water snake (*Cerberus rynchops*); and d, banded file snake (*Acrochordus granulatus*). [Photographs by: Marcus Chua (a, b); Hazel Chew (c); and Soo Wai Kit (d)].

Order Crocodylia

Family Crocodylidae

Crocodylus porosus (Schneider), estuarine crocodile

This species was not sighted during the survey period. However, a large estuarine crocodile was seen in the mangroves between the mid to late 1990s during the construction of the landfill (L. Tan, pers. comm.). There are no records since. It is not certain if the species is still present on Semakau as of 2011. The estuarine crocodile is listed as nationally critically endangered (Davison et al., 2008).

3. Mammals (Class Mammalia)

Order Chiroptera

Family Pteropodidae

Cynopterus brachyotis (Müller), lesser dog-faced fruit bat (Fig. 7a)

Widespread and common across the island in secondary forests, landfill cells, and around fruit trees near the visitor centre. Recorded during night surveys and in mist nets. Previously unrecorded in literature on Semakau.

Order Soricomorpha

Family Soricidae

Suncus murinus (Linnaeus), Asian house shrew

One was seen on 20 Mar.2010 on the western rock bund at dawn. This species is a human commensal which is usually seen around buildings (Baker & Lim, 2008). The Asian house shrew is a new record for the island.

Order **Rodentia**

Family **Muridae**

Rattus tiomanicus (Miller), Malaysian wood rat (Fig. 7b)

Recorded during surveys and small mammal trapping, this species seems to be restricted to the secondary forest and adjacent areas. Two individuals were caught in small mammal traps during the survey period, of which one was trapped on the western rock bund. Two Malaysian wood rats were also photographed in the secondary forest during the study period.

This species was previously not recorded from the island in published literature. However, a review of rat specimens trapped by Paperna et al. (2004) from the island preserved in the Zoological Reference Collection of the Raffles Museum of Biodiversity Research showed that at least some of the specimens originally identified as *Rattus rattus* were actually *Rattus tiomanicus*.

Rattus tanezumi Temminck, Oriental house rat (Fig. 7c)

Four individuals were trapped during the survey period in the landfill cells and secondary forest. This adaptable human commensal is also likely to be present in other man-made areas including the visitor centre. Previously recorded as *Rattus rattus* (Paperna et al., 2004; Paperna, 2006).

Order **Carnivora**

Family **Felidae**

Felis catus Linnaeus, domestic cat (Fig. 7d)

Domestic cats were mostly seen around the visitor centre and buildings, and were recorded on all night surveys. They have also been observed in the replanted mangroves, on rock bunds, along the roads on the island, and even at the southern-most tip of Semakau (Wang L. K. & R. Yeo, pers. comm.). These cats could have descended from village pets abandoned on the island when the villagers of Pulau Semakau and Pulau Sakeng were relocated.



Fig. 7. Mammals of Semakau: a, lesser dog-faced fruit bat (*Cynopteris brachyotis*); b, Malaysian wood rat (*Rattus tiomanicus*); c, Oriental house rat (*Rattus tanezumi*); and d, domestic cat (*Felis catus*). [Photographs by: Marcus Chua (a, b, c) and Pang Wei Han (d)].

Family **Mustelidae***Lutrogale perspicillata* (Geoffroy), smooth-coated otter

A lone smooth-coated otter was seen by a volunteer along the northern mangroves in 2011 (H. Wong, pers. comm.). As early as 2007, various NEA staff have reported regular sightings of an otter basking in the sun on the rock bund near the mangroves (Wang L. K., pers. comm.). As of 2011, sightings of this species, which are usually found in groups in the wild (Sivasothi & Burhanuddin, 1994), have only been of a single animal (S. Lim, pers. comm.; WildSingapore, 2011a, 2011b). Records of the species in the Singapore Straits are rare. The nationally critically endangered smooth-coated otter is threatened by habitat loss, human disturbance, and possible persecution (Davison et al., 2008). Globally, this species is listed as vulnerable by IUCN (Hussain et al., 2008).

Order **Cetacea**Family **Delphinidae***Sousa chinensis* (Osbeck), Indo-Pacific hump-backed dolphin (Fig. 8)

These dolphins have been sighted in the waters off Semakau on a few instances during Project Semakau walks and surveys (Tide Chaser, 2009a). The Marine Mammal Laboratory (MML), Tropical Marine Science Institute of the National University of Singapore, has eight confirmed records of the species between 1997 and 2011, with most sightings in the northern and western waters off Semakau (MML, unpublished data). Seven of the records were made from 2008 to 2011, and up to six dolphins were recorded in a pod. The Indo-Pacific hump-backed dolphin is nationally endangered and classified as near threatened by IUCN (Davison et al., 2008; Reeves et al., 2008).



Fig. 8. Pod of Indo-Pacific hump-backed dolphins seen off the northern coast of Semakau. (Photograph by: Ron Yeo).

DISCUSSION

At least five species of amphibians, 16 species of reptiles, and seven species of mammals are presently recorded from the Semakau Landfill. The diversity of herpetofauna and mammals is expected for an island of its size, although the list is expected to grow with more intensive surveys, particularly with aquatic snakes and bats.

What is more significant, however, is the presence of seven nationally threatened species: five species of reptiles (including two nationally critically endangered and globally threatened marine turtles) and two species mammals (including the globally vulnerable and nationally critically endangered smooth-coated otter). The relatively rich reef environment, seagrass meadows, and mangroves of Semakau may thus be an important area for the conservation of these marine and semi-aquatic animals in the Singapore Straits. This also shows that with judicious planning to minimise impact during construction and operation of the landfill island (Ng, 2011), habitat conservation can still go hand-in-hand with development. None of the species recorded are confined to the landfill areas.

Most of the terrestrial mammals and herpetofauna of Semakau are unlikely to be native to the island. These include three species of mammals, four species of amphibians, and at least four species of reptiles. Non-native species could have been introduced by two possible means. Before the construction of the landfill island, Pulau Sakeng and Pulau Semakau housed villages with a total population of about 600 (Ng, 2009). These settlers might have deliberately introduced species which are not native to the island, such as the domestic cat and the Malayan box terrapin. Human commensals such as the Oriental house rat, Asian house shrew, Asian toad, four-lined tree frog, and spiny-tailed house gecko, probably arrived on the island as 'stowaways' on boats. During construction and operation of the landfill, other

human commensal species or their eggs, such as the changeable lizard, the banded bull frog, the field frog, and the common wolf snake, might have arrived together with construction material and soil that were used to cover each landfill cell after they have been filled (Ng, 2009, 2011).

Although no confirmed sightings have been recorded, the habitats of Semakau may also support a few other species of mammals or herpetofauna. The extensive seagrass meadows around Semakau may be the grazing grounds of the dugong (*Dugong dugon*). As dugongs feed mostly on seagrass, 'bulldozed' strips seen in seagrass meadows around Semakau may have been feeding trails left behind by these marine mammals (God's Wonderful Creation, 2011). The mangroves may also support aquatic snakes such as the crab-eating water snake (*Fordonia leucobalia*) and the yellow-lipped water snake (*Gerarda prevostiana*). The various man-made habitats on Semakau may also host species that are found close to human habitation such as the flat-tailed gecko (*Hemidactylus platyurus*), four-clawed gecko (*Gehyra mutilata*), and the brahminy blind snake (*Ramphotyphlops braminus*).

CONCLUSIONS

Semakau's mammal and herpetofauna diversity includes at least five species of amphibians, 16 species of reptiles, and seven species of mammals. The presence of extensive and relatively well-preserved marine ecosystems and records of seven nationally threatened species may make Semakau an important site for the conservation of these species in the Singapore Straits.

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CORRIGENDUM

9 Dec.2011

Page 281, under the heading 'Order Squamata': Insert subheading 'Family **Pythonidae**' before '*Broghammerus reticulatus* (Schneider), reticulated python'. *Broghammerus reticulatus* (Schneider) is not under Family Varanidae.

Page 282, line 1: Delete 'Family **Pythonidae**'.