Flora and vegetation of Pulau Babi Tengah, Johor, Peninsular Malaysia

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Abstract: Pulau Babi Tengah is a small granitic island, ca. 106 ha, lying off the south-east coast of Peninsular Malaysia. Except for plantation of coconut trees in the early 1900s and deforestation by refugees during the Vietnamese civil war, 1975–1981, the island has not been affected by human development and very few species have been introduced. Recently, a tourist resort has opened in the south and has initiated activities for the conservation of biodiversity. As part of that commitment, an exhaustive inventory of all terrestrial vascular plants has been done. The flora contains 312 taxa with 252 genera and 101 families. Several rare species, known only from this group of islands in Peninsular Malaysia, are recorded, as well as four Peninsular Malaysian endemic species. The most striking characteristic of Pulau Babi Tengah is the rarity of the exotic element, which is restricted to the anthropic areas.

Key words: Coastal, conservation, invasive species, island

INTRODUCTION

Ecosystems are generally difficult to delimitate physically and therefore they are difficult to conceptualize and understand in detail (Oldeman 1990). For this reason, islands have often been considered and used as models for understanding evolution processes (Leigh et al. 2007; Whittaker et al. 2008). Isolated islands constitute important centers of endemism (Kier et al. 2009) and they can provide stable refuges for species which originated from mainland areas (Cronk 1997). Unfortunately, tropical islands have most often been heavily impacted by human development and their biodiversity is threatened (Denslow 2003). Nevertheless, some islands lying off the south-east coast of Peninsular Malaysia, mainly Pulau Tioman, combine many remarkable features, i.e. being within a high biodiversity area, with perhumid climate, and still relatively unaffected by human development.

In this paper, we provide the first exhaustive inventory of the terrestrial vascular plant species occurring on one of the smaller islets of the Pulau Tioman group, i.e. Pulau Babi Tengah. This island has been mostly preserved from human influence and is now partly privately-owned and developed as an eco-responsible tourist resort, Batu Batu, which requested the current study. We discuss the most striking biodiversity features of the island in order to help the resort establish conservation priorities and sustainable development.

MATERIALS AND METHODS

Study area

Pulau Babi Tengah, 02°46′08″ N, 103°57′39″ E, is one of the many granitic islands lying off the southeast coast of Peninsular Malaysia. It has a round shape (ca. 1.3 km across, 106 ha) with hilly topography (reaching about 90–100 m of elevation) and is closely flanked by two islets: Pulau Babi Besar (on the southeast) which has a permanent local population, and Pulau Babi Hujung (on the northwest) which is uninhabited (Figure 1).

The largest and most intensively collected island in this region is Pulau Tioman (13,360 ha, highest peak at 1,038 m elevation), which is made of ca. 74 million years old granite (Lee et al. 1977). These islands belong to the “Peninsular Malaysian lowland rainforests” ecoregion (Olson et al. 2001; Olson and Dinerstein 2002; WWF 2011), which includes the lowland moist forests of Peninsular Malaysia and the extreme southern part of Thailand. This ecoregion presents floristic affinities mostly towards south-east, with Borneo and Sumatra, forming the “ever-wet Sundaland floristic group” (Van Welzen et al. 2011).

Nevertheless, the subdivision of the Malesian region into biogeographical sub-regions has been extensively discussed in the literature and the results depend not only on knowledge improvement but also on the taxonomic groups considered (e.g., mosses, ferns, other plants, birds,
Van Steenis 1935; Senterre 2012), soil drainage (swamps and marshes), proximity with the ocean (mangroves and coastal fringes) and the types of substrates (azonal edaphic variants on limestone, quartzite rocks, and on podzolized sands).

The seed plant flora of Peninsular Malaysia is estimated to include about 7,834 species (5,718 dicotyledons, 2,087 monocotyledons and 29 gymnosperms) with 1564 genera and 220 families (Kiew et al. 2010a), of which 12.9% are endemic (Van Welzen et al. 2011). The ferns and lycophytes of Peninsular Malaysia represent about 650 species for 137 genera and 40 families (Parris et al. 2010).

Islands off the south-east coast of Peninsular Malaysia are characterised by the presence of species which are rare or absent from the mainland (Corner 1985; Turner et al. 1993; Turner 1995). Several floristic accounts of Pulau Tioman record a substantial list of rare plants, with at least 388 taxa of trees, 653 taxa of shrubs, eight hyper-endemic species and others that have a disjunct distribution skipping mainland Peninsular Malaysia and instead having Thai-Burmese or Bornean affinities (Henderson 1930; Lee et al. 1977; Latiff et al. 1999; Phang et al. 2008; Chew et al. 2013). Botanical explorations have been done mostly on the larger islands, e.g., Pulau Tioman, Pulau Aur (Henderson 1930; Turner et al. 1993; Turner 1995). Several floristic accounts of Pulau Tioman record a substantial list of rare plants, with at least 388 taxa of trees, 653 taxa of shrubs, eight hyper-endemic species and others that have a disjunct distribution skipping mainland Peninsular Malaysia and instead having Thai-Burmese or Bornean affinities (Henderson 1930; Lee et al. 1977; Latiff et al. 1999; Phang et al. 2008; Chew et al. 2013). Botanical explorations have been done mostly on the larger islands, e.g., Pulau Tioman, Pulau Aur (Henderson 1930; Turner et al. 1993; Turner 1995). Several floristic accounts of Pulau Tioman record a substantial list of rare plants, with at least 388 taxa of trees, 653 taxa of shrubs, eight hyper-endemic species and others that have a disjunct distribution skipping mainland Peninsular Malaysia and instead having Thai-Burmese or Bornean affinities (Henderson 1930; Lee et al. 1977; Latiff et al. 1999; Phang et al. 2008; Chew et al. 2013).
Pulau Pemanggil (Latiff 1982; Turner et al. 1998), Pulau Tinggi (Turner and Yong 1997) and Pulau Sibu (Turner et al. 1993; Turner et al. 1998). The remaining islands are described partly by Henderson (1930) and especially Corner (1985), who concentrated on the islets closer to the mainland, including Pulau Babi Tengah. Corner (1985) recorded 40 species, based on three day-trips done in the years 1932 and 1936, and he described the vegetation indicating that most of the north and east sides were still covered by natural forests, while the west and south sides of the island had been widely planted with coconuts. More recently, a study was done by an internship student from the Netherlands who recorded 70 species (Coolen 2012). The latter provides useful information about the occupation of the island by ca. 10,000 Vietnamese refugees during the years 1975 to 1981. During that period, most of the secondary forests which regenerated from previous coconut plantations from the early 20th century were again deforested to provide wood for construction. A photo taken in the year 1987 shows that the north and east sides of the islands remained mostly untouched (JSEDC 1990).

Figure 2. Map of Pulau Babi Tengah showing the exploration tracks and collecting sites (Projection system: WGS 1984 UTM zone 40S, coordinates in meters).
Data collection

This checklist is based on a compilation of the existing records for Pulau Babi Tengah (Corner 1985; Coolen 2012) and newly collected data. Field work has been carried out from 5–30 September 2013. Plant collections were conducted from explorations out of existing paths and trails, in such a way as to cover all vegetation types on all sides of the island (Figure 2). The necessary authorizations have been provided by the Johor National Parks Corporation and the Forestry Department.

All species were collected when seen for the first time or whenever there was a doubt on their identity. Specimens were prepared using a locally built dryer, and duplicates (up to three when it was possible) have been deposited at the herbaria KEP (Forest Research Institute of Malaysia) and KUL (Herbarium of Institute of Biological Sciences, Faculty of Science, University of Malaya). The third duplicate remained on Pulau Babi Tengah, under the responsibility of Batu Batu Resort, within its Environmental Unit. Mr Azmie Ahmad is the main local staff associated with the collecting is the person in charge of that reference collection.

Species identification

Species names have been identified in a first attempt using existing local checklists published in the region: Henderson 1930; Latiff 1982; Corner 1985; Turner et al. 1993; Turner and Yong 1997; Turner et al. 1998; Jaman and Latiff 1999; Latiff et al. 1999. This allowed us to identify 200 taxa to species level (see specimen labels). Secondly, after the field expedition, first author visited the Herbarium, Forest Research Institute Malaysia (KEP) from 9 October to 4 November 2013. All preliminary identifications were verified or corrected using the KEP reference specimens and literature. The preliminary identifications were verified or corrected using the KEP reference specimens and literature. The main references used are the Flora of the Malay Peninsula (Ridley 1922–1925), the Tree Flora of Malaya (Whitmore 1972, 1973; Ng 1978; 1989), the Flora Malesiana (many volumes, initiated by Van Steenis 1950), the Flora of Peninsular Malaysia (Kiew et al. 2010b; Parris et al. 2010, 2013; Kiew et al. 2011, 2012), and Wayside trees of Malaya (Corner 1988). A detailed index to these references, and additional ones, is provided by Turner (1995), which also compiles basic information on species distribution.

For ferns, we used the following additional references: Holttum 1954; Piggott 1988. For monocots, we also used Seidenfaden and Wood (1992: orchids), Gilliland (1971: grasses), and Henderson (1954). When necessary, for preliminary identification of some genera and families, we used the practical identification guide of Van Balgooy (1997, 1998, 2001). For exotic species identity and origin status, we complemented our search with Chong et al. (2009) and Milow et al. (2010). Endemic species are defined as being restricted to Peninsular Malaya (Turner 1995); “indigenous” species are defined as non endemic natives; “cultivated” species are not self-sustained populations (cultivated sensu stricto) or self-sustained but non spreading populations (“naturalized” sensu Richardson et al. 2000); “naturalized” species are self-sustained and spreading populations; “invasive” species are the naturalized species which are considered as threats to biodiversity in other regions (e.g., De Poorter and Browne 2009).

RESULTS

The flora

In total, 308 specimens have been collected and deposited at KEP (274 specimens; first duplicate) and at KUL (195 specimens; second duplicate), in Kuala Lumpur. The third duplicate remained on Pulau Babi Tengah, with Batu Batu Resort (256 specimens). In addition, 54 observation records have been made for species which we judged inappropriate to collect (e.g., well-known or sterile cultivated species). Historical specimens collected in the 1930s by E.J.H. Corner are located at the Herbarium of Singapore Botanic Gardens (SING).

The flora of Pulau Babi Tengah includes 312 taxa (Table 1), of which ca. 16 will require further collecting to confirm or complete identification. Unidentified taxa are named using numbered morphospecies (e.g., Salacia sp.1) in order to explicitly account for the number of taxa. The 312 taxa belong to 252 genera and 101 families (APG III 2009; Christenhusz et al. 2011). They include 208 dicotyledons, 70 monocotyledons, four gymnosperms and 30 ferns. Considering biological types, the native flora of Pulau Babi Tengah is represented by 216 taxa corresponding to 77 trees, 54 terrestrial herbs, 39 shrubs (including climbing shrubs, e.g., Caesalpinia

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Table 1. Number of taxa recorded on Pulau Babi Tengah for the different biological types and for the different status of origin of the taxa (see definitions in materials and methods).

<table>
<thead>
<tr>
<th>Biological types</th>
<th>Endemic</th>
<th>indigenous</th>
<th>Cultivated</th>
<th>Naturalized</th>
<th>invasive</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>T (trees)</td>
<td>77</td>
<td>24</td>
<td>4</td>
<td></td>
<td></td>
<td>105</td>
</tr>
<tr>
<td>S (shrubs)</td>
<td>1</td>
<td>38</td>
<td>18</td>
<td>2</td>
<td></td>
<td>59</td>
</tr>
<tr>
<td>L (woody lianas)</td>
<td>2</td>
<td>13</td>
<td>2</td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>C (climbing / creeping herbs)</td>
<td>21</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>H (terrestrial herbs)</td>
<td>1</td>
<td>53</td>
<td>14</td>
<td>25</td>
<td>2</td>
<td>95</td>
</tr>
<tr>
<td>E (epiphytes)</td>
<td>10</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4</strong></td>
<td><strong>212</strong></td>
<td><strong>60</strong></td>
<td><strong>32</strong></td>
<td><strong>4</strong></td>
<td><strong>312</strong></td>
</tr>
</tbody>
</table>
pulau babi tengah), 21 climbing/creeping herbs, two woody lianas, and 10 epiphytes. The exotic flora is represented by 96 species corresponding to 28 trees, 41 terrestrial herbs, 20 shrubs, four climbing/creeping herbs, two woody lianas, and one epiphyte. Fifty-seven exotic species are found only cultivated (22 trees, 13 terrestrial herbs, 18 shrubs, one climbing herb, two woody lianas, and one epiphyte). Therefore, the most important naturalized exotic element comes from the herbaceous flora and has invaded mostly the areas of human development (Table 1). The natural and semi-natural forests from the inland and east coast are mostly unaffected by invasive species, both in terms of diversity of the invasive element and in terms of its dominance. *Clidemia hirta* can be observed mostly in the wetter valleys and foothills, but is only represented by localized clumps of few individuals. This situation is contrasting to what is described on most other tropical islands (Denslow et al. 2009). The nearby Pulau Babi Besar, which we visited on a one-day trip, appears obviously more affected, with more exotic species observed on the forested slopes. *Clidemia hirta* is abundant along trails and it is likely that its presence on Pulau Babi Tengah is the result of a recent colonisation event from P. Babi Besar, probably dispersed by birds.

**The vegetation**

Eleven habitat types are distinguished on Pulau Babi Tengah. These habitat types belong to two distinct categories in Saw’s classification (2010), i.e., the “beach vegetation” and the “mangrove forests”. Lowland dipterocarp forests (Saw 2010) are absent due to the small size of the island. We regroup our eleven habitat types into five major groups:

**GROUP 1:** The mangroves (“mangrove forests” of Saw 2010)—Two mangrove forests (abbreviated “MF”) are found on the north coast of the island: one is dominated by *Pemphis acidula* and one dominated by *Rhizophora mucronata*. Two other species, i.e., *Sonneratia griffithii* and *Bruguiera gymnorrhiza* are both represented by one single tree.

**GROUP 2:** The marshes—Coastal marshes/swamps (CS) once occurred on the north coast and has been completely transformed into a dense grassland as a result of the Vietnamese occupation. The dominant species are *Imperata cylindrica*, *Ischaemum muticum*, and *Mikania cordata*.

**GROUP 3:** The coastal zone (“beach vegetation” of Saw 2010, *pro parte*)—The coastal zone occupies a belt from the coast line up to less than 10–30 m inland. It corresponds to what Corner (1985) called the “*Terminalia*-zone” and can be further subdivided into three categories, based on the vegetation physiognomy and types of substrate.

3.a. The coastal sandy beaches (Co) are characterized by a narrow shrubby fringe, generally 1–5 m wide, dominated by shrubs, creepers and terrestrial herbs: *Colubrina asiatica*, *Cyperus radians*, *Ipomoea pes-caprae*, *Lepturus repens*, *Paspalum vaginatum*, *Remirea maritima*, *Scaevola sericea*, *Vigna marina*. Some species previously recorded have not been seen again and could be extinct on the island, i.e. *Schizachyrium brevifolium*, *Spinifex littoreus*.

3.b. The coastal rocky shores (CR) occur mostly on the northeastern side, also on a very narrow belt, and are characterized by rupicolous species, like orchids and dry zone terrestrial species, e.g., *Schizaeaceae*.

3.c. The coastal forests (CF) occur directly after the habitats 3.a or 3.b and extend also on a relatively narrow belt, up to 30 m inland. On other islands or coastal regions where a coastal plateau occurs, the coastal forests can extend inland up to a few hundred meters. It is characterized by *Atalantia monophylla*, *Barringtonia asiatica*, *Hernandia nymphaeifolia*, *Planchonella obovata*, *Terminalia catappa*, and many other species (43 recorded, see Table 2).

**GROUP 4:** The littoral zone (“beach vegetation” of Saw 2010, *pro parte*)—The littoral zone is characterized by the reduction or absence of the typical coastal elements,

<table>
<thead>
<tr>
<th>Habitat-Types</th>
<th>Endemic</th>
<th>Indig.</th>
<th>Cultivated</th>
<th>Naturalized</th>
<th>Invasive</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma (mangrove forests)</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Co (coastal sandy beaches)</td>
<td>1</td>
<td>27</td>
<td>1</td>
<td></td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>CR (coastal rocky shores)</td>
<td>15</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>CF (coastal forests)</td>
<td>1</td>
<td>40</td>
<td>2</td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>CS (Coastal marshes / swamps)</td>
<td>1</td>
<td>27</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>Subtotal (coastal)</td>
<td>2</td>
<td>86</td>
<td>3</td>
<td></td>
<td></td>
<td>91</td>
</tr>
<tr>
<td>DF (dry littoral forests)</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>MF (mesic littoral forests)</td>
<td>3</td>
<td>67</td>
<td></td>
<td></td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>VF (valley littoral forests)</td>
<td>1</td>
<td>27</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>Subtotal (littoral)</td>
<td>3</td>
<td>101</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>107</td>
</tr>
<tr>
<td>2F (secondary forests)</td>
<td>3</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>An (anthropic areas)</td>
<td>25</td>
<td></td>
<td>29</td>
<td>3</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>Pi (pioneer vegetation)</td>
<td>21</td>
<td></td>
<td></td>
<td>2</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Subtotal (secondary)</td>
<td>42</td>
<td>59</td>
<td>29</td>
<td>3</td>
<td>133</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>212</td>
<td>60</td>
<td>32</td>
<td>4</td>
<td>312</td>
</tr>
</tbody>
</table>
e.g., *Barringtonia asiatica*, by the higher species diversity (107 species) compared to the coastal forests, and by the dominance of some species such as *Syzygium grande*. This zone corresponds to what was named the “*Eugenia grandis*-zone” by Corner (1985). It can extend several km inland, depending on topography and climate. On islands with a steep topography, this zone can be restricted to a few hundred meters, or absent due to human impact. We further subdivide this zone into three categories based on the drought effect due to sea sprays during the north-east monsoon (windward vs. leeward slopes) and based on soil drainage due to landform patterns (valleys vs. slopes and ridges).

4.a. The mesic littoral forests (MF) are the most widespread habitat type. They still cover most of the ridges and slopes of the center of the island. The most characteristic species here are *Barringtonia macrostachya*, *Gironniera subaequalis*, *Gnetum gnemon*, *Maranthes corymbosa*, *Palaquium obovatum*, and *Syzygium grande*.

4.b. The valley littoral forests (VF) are more localized and found on stretches 3–10 m wide along the valleys and ravines (concave landforms). They share many species with the mesic forests and are characterized by the diversity and abundance of lianas and palms, e.g., *Arenga brevipes*, *Bauhinia semibifida*, *Caryota mitis*, *Flagellaria indica*, *Oncosperma tigillarium*. Some herbs and ferns are also found frequently, e.g., *Homalomena sagittifolia*, *Mapania palustris*, *Pronephrium asperum*, *Taenitis blechnoides*.

4.c. The dry littoral forests (DF) are found on the eastern slopes, exposed to the north-eastern monsoon. These forests share many elements of the mesic forests and are characterized by the dominance of *Podocarpus polystachyus* and species such as *Dillenia pulchella*, *Pandanus odoratissimus*, *Rhodamnia cinerea*, *Syzygium zeylanicum*.

GROUP 5: The secondary and anthropic vegetation types—Here, we distinguish three entities based on the disturbance factor and development stage.

5.a. The pioneer vegetation (Pi) includes the deforested stands which are regenerating naturally after punctual human impact or natural tree fall gaps. Relatively few exotic species are observed. The most common native species include *Cissus hastata*, *Dicranopteris linearis*, *Gynochthodes sublanceolata*, *Hedyotis capitellata*, *Macaranga javanica*, *Melastoma malabathricum*, *Pteridium caudatum*, and *Tetracera scandens*.

5.b. The secondary forests (2F) correspond to pioneer stands which have recovered their forest cover. They are found mostly on the margins of the areas deforested during the Vietnamese civil war, i.e., on the southwestern slopes. They are characterized by a dense regrowth of *Syzygium grandis* about 10–15 m tall.

5.c. The anthropic areas (An) include all the areas continuously affected by human influence, like the cultivated lands, gardens, waste lands, and developed coastal areas. Most of the naturalized and invasive exotic species are found there. Possibly native species include *Acalypha indica*, *Blechnum finlaysonianum*, *Cyclosorus dentatus*, *Dactylocentrum aegyptium*, *Eleusine indica*, and *Physalis minima*.

The highest number of species is observed in the anthropic area (An, 116 species), seconded by the mesic littoral forests (MS, 70 species, Table 2). But if we consider the native species only (endemic + indigenous), the mesic littoral forests are the richest (70 species vs. 25 for the anthropic areas), i.e., all species observed in the mesic littoral forests are natives. The invasive species are observed in natural habitats only in the coastal habitat types and in the valley forests (*Clidemia hirta*). This situation contrasts with other tropical islands which are generally strongly impacted by these invasive species (Baret et al. 2006).

The checklist

The exhaustive list of species recorded from Pulau Babi Tengah is presented in Table 3 along with the most relevant information on these species, i.e., biological types, preferred habitat-types on the island, rarity on the island, and origin status. Most species have been photographed in their natural habitat and the images will be presented on the Batu Batu resort website (http://www.batubatu.com.my) in the form of thematic galleries where other important information will be made available, e.g., vernacular names. About 2,000 images of plants have been taken and managed using ThumbsPlus (http://www.cerious.com) and Microsoft Access.

DISCUSSION

Rare species and endemic species

*Margaritaria indica* is one of the most interesting discoveries and it is a relatively common coastal tree on Pulau Babi Tengah. This species is widely distributed from India to Indo-China, and is scattered through Malesia. In its Peninsular Malaysian range, it is known only from a few islands in the Pulau Tioman group (Pulau Pemanggil, Pulau Sibu Tengah and two small islets to the north of P. Tioman (Turner et al. 1998). It is here recorded for the first time on Pulau Babi Tengah.

*Mangifera pentandra*: This tree is classified as vulnerable by IUCN (2013), and it is characteristic of coastal forests, which is a habitat remaining pristine only in poorly inhabited coasts. It has been recorded from Pulau Tinggi and was once a common village tree in Peninsular Malaysia and old orchards are found in Peninsular Thailand. It is suspected that the interest in the species is declining in favour of *M. indica*, although it is still useful in improving the genetic stock of the common mango (Turner 1995).
Sonneratia griffithii: Widely distributed species, from Bengal, Burma, Lower Siam, Mergui, Andamans. In Malaysia, it is recorded only from the West Malay Peninsula and is said to be very rare (most records being misidentifications of S. caseolaris (L.) Engl., which differs in the leaf shape, not obovate, and characteristics of the fruit).

Arachnis hookeriana: This species is known from Borneo, Riau archipelago and other islands south of Singapore. Turner (1995) records it in scrub near the seashore, commonest along the east coast. Within the Pulau Tioman group, it is recorded on Pulau Sibu (Turner et al. 1993).

Eulalia ridleyi: This is an endemic species to Peninsular Malaya, rare and locally found in coastal sand dunes on the east coast. It is recorded from Johor Jambu Larang (Feilding), Pahang, Sungei Meang and Lumpini rivers, Rahman, and Kota Bharu (Yapp). Other Malayan endemic species found on Pulau Baby Tengah are Calamus burkiliannus, Draecena maingayi and Rourea rugosa.

Nephrolepis acutifolia: Widely distributed species, locally rare and found often near the sea (in Malaysia). It is considered as near threatened by IUCN. Other relatively uncommon species include Actinostachys digitata, Ardisia ridleyi, Cerbera manghas, Litsea johorensis, and Schizaea dichotoma.

Two species might be new records for the flora of Peninsular Malaysia, but one of them needs to be confirmed based on fertile specimen (Arenga brevipes) and the second one (Pavetta multiflora), collected in fruits, should be confirmed by a specialist of the genus. Reference specimens have been compared and matched with our specimens. Several other species from the Pulau Tioman group have a Bornean distribution and are absent from the mainland (Latiff et al. 1999; Phang et al. 2008).

Locally extinct species
Several species recorded by Corner (1985) on Pulau Baby Tengah have not been observed during our survey. Although we might have missed some of them (Allophyllus cobbe, Cordia subcordata, Schizachyrium brevifolium), the others are very noticeable coastal species and are possibly extinct: Heritiera littoralis (possibly removed for the Vietnamese refugees camp), Tournefortia argentea (very rare, also recorded from Pulau Langkawi and Pulau Tinggi), Erythrina variegata (also disappeared from the neighbouring islands; Turner 1993), Tristellatea australasiae, and Spinifex littoreus. Among these, Schizachyrium brevifolium was only recorded from Pulau Baby Tengah for the Malay Peninsula.

Potential threats
Some exotic species naturalized on Pulau Baby Tengah are often considered as invasive species in other regions and they need to be monitored to record their spread (or non-spread) into the distinct natural habitat types of the islands. These species are mostly Chromolaena odorata, Clidemia hirta, Epipremnum pinnatum, Lantana camara, Leucaena leucocephala, and Mikania cordata. Among these, only Clidemia hirta has been observed in natural forests (valley forests).

Potential uses
The flora of Pulau Baby Tengah contains about 30 native species which we consider as having good potential as ornamental species. Rather than importing more exotic species to the island for landscaping, it is advisable to consider the development of sustainable propagation of some of these species. This could also allow developing restoration projects for the degraded west side of the island. The most interesting species include climbers (Bauhinia semibifida and Hoya diversifolia), epiphytes (Dischidia major and the orchid species), light tolerant trees (Cycas edentata, Fagraea auriculata, Pemphis acidula, and Podocarpus polystachyus) and herbs (Dianella ensifolia), and shade tolerant shrubs (Clerodendrum myrmecophila, Dillonia pulchella, Draecena elliptica, D. maingayi, and Pandanus tetrodon) or herbs (Staurogyne setigera).

Conclusion
Very few islands in the Pulau Tioman group have been inventoried exhaustively, mostly because of the more complex diversity of the bigger islands such as Tioman. Our study provides the baseline data for further studies on the invasion process and on the patterns of biodiversity on small island ecosystems, as models for understanding evolution processes. The most remarkable characteristic of Pulau Baby Tengah is the rarity of the exotic element, almost absent from non-anthropic areas. Only one other island in the group has been inventoried to more than 90% (Pulau Sibu, ca. 450 ha, 154 m elevation, ca. 390 vascular plants (Turner et al. 1993) and constitutes a good site for more detailed comparative studies. Our inventory of the plant life of Pulau Baby Tengah also provides detailed information for Batu Batu Resort in order to develop responsible ecotourism on this island. Nevertheless, non-vascular plants remain to be studied (30–40 species to be expected, K.T. Yong, pers. comm.) as well as fungi, which constitute an important group of organisms in these small island ecosystems.
Azmie Ahmad and authorizations have been provided by the Johor National Parks Corporation and the Forestry Department. Identification of specimens has been done with the contribution of the Forest Research Institute of Malaysia (Abu Husin Harun, Avelinan Julius, Kamarudin Saleh, Kamarul Hisham Mustafa, Dr. Francis Ng and Yao Tze Leong). This study has been done in collaboration with the Herbarium, Forest Research Institute of Malaysia (KEP), and the data collected will be integrated within the floristic study. We are also thankful to Dr. Saw Leng Guan (KEP) for supporting this study and to Dr. Yong Kien Thai (University of Malaya) for receiving the second set of duplicate specimens at KUL Herbarium.

LITERATURE CITED


Authors' contribution statement: BS collected the data, worked on the identification of specimens and wrote the text; MYC and CKC reviewed and corrected the draft and provided the institutional support for the collaboration with the Forest Research Institute Malaysia.

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Table 3. Checklist of the terrestrial vascular plant species recorded from Pulau Babi Tengah. Previous records ("PR") are indicated for Pulau Babi Tengah: C, Corner (1985), Q, Quijin Coolen (2012, unpublished). All specimens cited ("Specimen n°") are collected by B. Senterre (2012, unpublished). Rarity is abbreviated as follows: R, rare; O, occasional; F, frequent; C, common; A, abundant. Origin status (Orig) is abbreviated as follows: end, endemic; ind, indigenous; cult, cultivated; nat, naturalized; inv, invasive (see definitions in materials and methods).

(A) Dicotyledons (Palaeodicots and Eudicots)

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(B) Monocotyledons

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### (C) Gymnosperms

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