Flagship Species

4

4.1 What Are Flagship Species and Why They Are Important

'Flagship species' is a term coined to identify charismatic species associated with environmental causes (Primack 2004). Flagship species are chosen for their threatened or endangered conservation status. These organisms can be readily associated with their habitats; they are 'ambassadors' raising public awareness directly to the plight of the species, and indirectly toward the threats to their habitats (e.g. Burton 2003; UN-ESCAP 2007). Flagship species often possess morphological and behavioural features that invoke public sympathies. For this reason, flagship species are invaluable in promoting ecosystem management strategies, as the general public is better able to empathise with specific organisms, than with entire ecosystems or ideological and scientific concepts. Varied characterisations of flagship species have been applied to (i) elicit specific responses, such as anthropomorphising behavioural traits of animals; (ii) play on biases and preconceived notions, such as 'swans are committed partners' or 'tigers are majestic and wild'; (iii) appeal to a sense of usefulness, such as conserving wild relatives of cultivated crops for genetic vigor; and (iv) instill a sense of wonder for being ancient lineages or having unusual shapes and behaviours, such as coelacanths, horseshoe crabs, cycads, pangolins and pandas (Given and Harris 1994).

Ideal flagship species are distinctive organisms, easily accessible, and identifiable. The latter in particular, allows for easy popularisation and can facilitate discussions of environmental issues by making them the focal topics. Other than promoting conservation and ecosystem management initiatives, flagship species can also be used as emblems for ecotourism and to obtain public and political support (Polgar and Sasekumar 2010; Sect. 3.2.3). Flagship species even appear to attract researchers, and bias research efforts in protected areas (Marshall et al. 2016).

There are few large animals suitable as flagship species that live as adult residents within intertidal coastal and inland forested wetlands of Sundaland. The Bornean orangutan *Pongo pygmaeus* and the tiger *Panthera tigris*, for example, are

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vagile animals with large home ranges, and do not exclusively use these habitats. Similarly, hundreds of migratory wading bird species use mangrove forests and adjacent mudflats as resting and feeding grounds only during wintering months (Buelow and Sheaves 2015). Many commercially important prawns (Penaeidae) and fishes (e.g., Carangidae, Haemulidae, Lutjanidae, Polynemidae, Serranidae) use intertidal areas for a fraction of their life history (Primavera 1998; Chong 2007).

Smaller animals living in Sundaland wetland habitats are traditionally disregarded as flagship species. However, these animals have a considerable potential, especially when they are highly visible, closely associated to the wetlands, and of conservation value. Small charismatic mammals like otters make excellent flagship species for wetlands, as their home ranges are predominantly situated within mangrove forests, and include adjacent mudflats, coastal areas and lower reaches of rivers (Foster-Turley 1992). Mudskippers are charismatic fishes also typically found in mangrove forests and on mudflats. Their ability to remain out of water for extended periods of time, and fascinating life history make them excellent flagship species. Many invertebrate organisms, such as mangrove crabs and insects are ubiquitous and potential candidates as flagship species, because they are highly visible, attractive, and of conservation interest. While plants are less commonly considered as flagships species, there are several large and majestic or unusual plant species growing in the Sundaland wetlands (e.g., mangroves, dipterocarps, orchids, and pitcher plants) that can be considered.

4.2 Potential Flagship Species for the Wetlands of Sundaland

4.2.1 Vascular Plants

A full list of vascular plant species listed in the IUCN Red List (IUCN 2014) and found in the Sundaland forested wetlands is provided in Appendix I. Other information included are: habitat type (freshwater swamp forests, peat swamp forests and mangrove forests), IUCN status (near threatened, vulnerable, endangered, critically endangered), and some common names.

4.2.1.1 Freshwater and Peat Swamp Forest Plants

Mature peat swamp and freshwater swamp forests host a considerable variety of plants (Box 4.1; Figs. 4.1 and 4.2). In many wetland areas within Sundaland however, many of these plants are uncommon or locally extinct, primarily due to land conversion and unsustainable logging. The flora in freshwater and peat swamp forests overlaps significantly with those of adjacent lowland rainforests. In these habitat types, the majestic and iconic *Shorea* trees (Dipterocarpaceae; Fig. 4.2c, d), commonly known as ‘meranti’, make excellent flagship species. Many hardwood tree species of this genus are endemic to Sundaland. Celebrated for their high-quality timber (Fig. 2.3d), *Shorea* trees exemplify the rapid loss of large trees to unsustainable logging in this region. (Appendix I). In peat swamp forests, freshwater swamp forests, and lowland rainforests of Sundaland, the hardwood species

Fig. 4.1 Epiphytic mangrove orchids. *Cymbidium finlaysonianum*, on senescent *Sonneratia* sp. in the Brunei Bay; Pulau Bedukang, Brunei Darussalam; (**a**) entire plant; (**b**) detail of the flower; in Borneo it is believed that keeping this plant in the house can ward off evil spirits, and that its chewed roots can heal injured elephants (Pfal 2014; Box 4.1)

Gonystylus bancanus is also popular for its timber (WCMC 1998b). Commonly known as 'ramin', this species is listed as vulnerable in the IUCN Red List (Chua 2008; Appendix I). It is a slow-growing hardwood, and its valuable timber is made into toys, furniture and home furnishings. Its resin releases a sought-after fragrance and is coveted as incense, while pounded fruits are used to poison fishes, and roots are concocted into medicine by native people. International imports, including countries such as USA, Europe, Japan, Australia and Taiwan, have created a high demand that consequently led to unsustainable and illegal logging of this species (Chua 2008).

A high diversity of orchids occurs in pristine tropical wetland habitats (Box 4.1), making them valuable biomonitors and flagship species (Turner et al. 1994). Deforestation and illegal exploitation of orchids are the primary causes for their decline in the wild (Phelps and Webb 2015). The flowers of these charismatic plants have been sought for centuries, and today drive several billions of US dollars per year in the international trade (USDA/NASS 2015). Many species are native to Sundaland wetlands (see Appendix I), such as the epiphytic *Phalaenopsis violacea*, whose status is vulnerable in the wild, but is widely cultivated for its fragrance (Pfal 2014). In Borneo, the mangrove epiphytic *Cymbidium finlaysonianum* is a highly regarded species (Pfal 2014; Fig. 4.1). Other potential candidates as flagship species include *Bulbophyllum auratum* and *Taeniophyllum obtusum*, both of which are epiphytes in mangrove forests.

Box 4.1 Orchids in Wetlands

The family Orchidaceae (Angiospermae), or orchids, is the largest family of flowering plants, comprising 24,000 species (Dressler 2005). Their name is derived from 'orchis', the Greek word for 'testicles', referring to the paired tubers present in some species. Two-thirds of orchid species live as epiphytes on trees, a life form that is also predominant in orchids occurring within wetland habitats. Epiphytic orchids have modified aerial roots that help them anchor to trees and absorb moisture from the environment. Other than photosynthesis, the roots and stems can absorb nutrients from incidental sources, such as accumulated detritus. The flowers of many orchid species have features that drive complex interactions with insect pollinators (Nilsson 1992). In several orchid species, flowers appear and smell similar to specific female insects; while attempting to mate with these 'females', male insects pollinate the orchid plants (Cozzolino and Widmer 2005). Seeds of orchid plants are typically very small and are usually wind-dispersed. Due to their size, these seeds do not possess energy reserves. In order to germinate successfully, seeds must associate with mycorrhizal fungi that provide carbon and other nutrients to the embryo. Many orchids occurring in wetlands are endangered. Deforestation and land conversion remove trees that act as suitable hosts for epiphytic orchids. These orchids are also illegally harvested for trade. Once common in the peat swamp forests of Sundaland, species such as *Adenoncos sumatrana* are now rare, and even extirpated in highly urbanised countries such as Singapore (Chong et al. 2009).

Pitcher plants (*Nepenthes* species; Fig. 4.2a) are herbaceous low shrubs or climbers common in Sundaland wetlands. Modified leaves in the shape of a receptacle, give them their common name. These plants are also known as 'monkey pot' plants, as monkeys have been observed to drink collected rainwater from the pitchers. Many species of pitcher plants live in nutrient-poor areas, and supplement their intake by digesting small animals that fall into the pitchers. Specialised cells produce digestive secretions, while other cells at the base of the pitcher absorb the digested nutrients from the trapped prey. The Fanged pitcher plant *Nepenthes bicalcarata*, listed as vulnerable in the IUCN Red List (Schnell et al. 2000; Fig. 4.2a; Appendix I) derives its name from two distinctive giant nectaries located on the underside of the lid, which resemble the fangs of a viper. This species is endemic to Borneo and occurs in peat swamp forests. Their shallow root systems allow them to avoid the toxic concentrations of tannins and alkaloids in the peat soil. *Nepenthes bicalcarata* forms a close association with a species of carpenter ants, *Camponotus schmitzi* (Formicidae). These ants live both inside the hollow apical part of the tendril connecting the pitcher to a modified leaf stalk, and below the pitcher's rim. They feed on the nectar produced by the 'fangs', and on digested prey matter that they remove from the digestive fluid of the pitcher (Bohn et al. 2012).

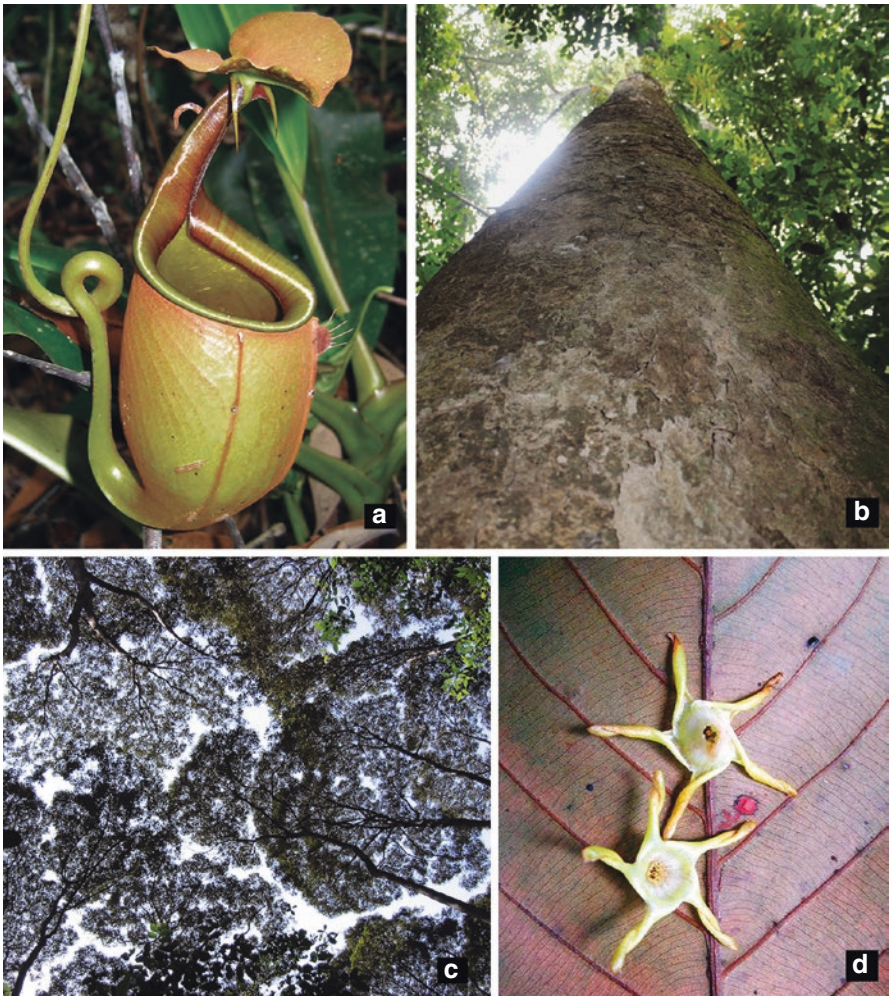

Fig. 4.2 Charismatic plants of Sundaland inland forested wetlands; (**a**) the Fanged pitcher-plant *Nepenthes bicalcarata* (vulnerable; Schnell et al. 2000); Labu Forest Reserve, Temburong, Brunei Darussalam (courtesy of Joachim Moog); (**b**) *Shorea macrophylla* (vulnerable; Ashton 1998m); Kepong, Selangor, Peninsular Malaysia (courtesy of Ahmad Fuad Morad); (**c**) canopy of *Shorea albida* (endangered: Ashton 1998g) in a peat swamp forest; Labu Forest Reserve, Temburong, Brunei Darussalam (courtesy of Joachim Moog); (**d**) leaf and flower buds of *Shorea palembanica* (critically endangered: Ashton 1998o); MacRitchie Reservoir Park, Singapore (courtesy of Ming Sheng Khoo)

4.2.1.2 Mangrove Forest Plants

Mangroves plants, of which there are approximately 80 species, are trees and shrubs that uniquely tolerate saline and inundated environmental conditions, enabling them to colonise tropical and subtropical shorelines worldwide (Tomlinson 1994; Duke and Schmitt 2015; Box 4.2, Figs. 1.2 and 4.3). Mangrove plants maintain

environmental conditions and create habitats crucial to mangrove forest ecosystems. These forests can extend for tens of kilometres inland, forming variably gradual transitions to other types of lowland forests, depending on the topography and hydrology of the intertidal zone. The majority of mangrove plant species (~25 species) are classified to two genera: *Avicennia* and *Rhizophora*. These plant species dominate mangrove forests throughout the world, including those within Sundaland (Tomlinson 1994; Hogarth 2007). Several species of plants, referred to

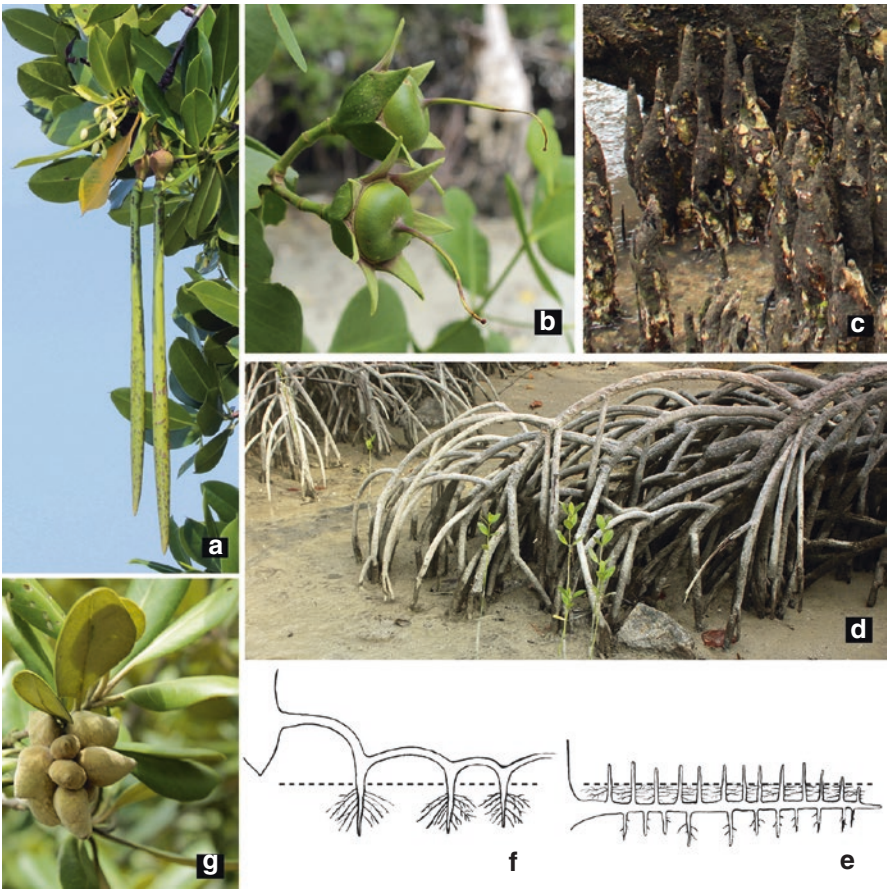

Fig. 4.3 Unique adaptations of mangrove plants; (**a**) propagules of the viviparous *Rhizophora stylosa*; Pulau (= Island) Besar, Malacca, Peninsular Malaysia (courtesy of Laura Ribero); (**b**) fruit of *Sonneratia alba*; Pulau Bedukang, Brunei Bay, Brunei Darussalam; (**c**) cigar-shaped aerial pneumatophores of *S. alba*; Tanjung Tuan, Negeri Sembilan, Peninsular Malaysia (courtesy of Laura Ribero); (**d**) stilt roots of *Rhizophora stylosa*; Pulau Besar, Malacca, Peninsular Malaysia (courtesy of Laura Ribero); (**e**) diagram of cable root, aerial pneumatophores, anchoring and absorbing roots of *Avicennia* or *Sonneratia* sp., redrawn from Tomlinson (1994); (**f**) diagram of aerial stilt root, anchoring and absorbing roots of *Rhizophora* sp.: pneumatophores are the vertical portions of the stilt root, immediately above ground level (*stippled line*: substrate level), redrawn from Tomlinson (1994); (**g**) fruits of *Avicennia rumphiana* (vulnerable; Duke et al. 2010a); Pulau Merambong, Johor, Peninsular Malaysia (courtesy of Laura Ribero)

as 'mangrove associates', are commonly associated with mangrove plants. Some mangrove associates are less tolerant of saline conditions, and occur only occasionally within the tidal wetlands, typically inhabiting adjacent freshwater ecosystems, such as peat and freshwater swamps; other species are tidal obligate and live in other intertidal habitats, such as saltmarshes.

Eleven mangrove plant species are considered threatened (Polidoro et al. 2010; IUCN 2014; Appendix I). Coastal areas in the IWP region are of particular concern, with approximately 14% of the mangrove species under threat of extinction.

Within Sundaland, two mangrove plant species are listed as critically endangered in the IUCN Red List. The first is *Bruguiera hainesii*, a species that occurs in the upper reaches of the tidal forest, or 'back mangroves' (Sheue et al. 2005), with a known global population of approximately 200 trees (Duke et al. 2010b; Appendix I). The second is *Sonneratia griffithii*, a pioneer species capable of rapidly colonising newly formed tidal mudflats. The overall population decline of the latter species is at least 80% since the 1950s (Duke et al. 2010d). *Camptostemon philippinense*, considered endangered, is found in the lower intertidal zone on the banks of tidal creeks, and has an estimated population of fewer than 200 mature individuals in Indonesia (Duke et al. 2010c). The endangered species *Heritiera fomes* (Kathiresan et al. 2010) and *Heritiera globosa* (Sukardjo 2010) are both distributed in the high intertidal zone (Appendix I). *Avicennia rumphiana* (Fig. 4.3g), often found in the high intertidal zone and able to tolerate hypersaline conditions (Tomlinson 1994; Appendix I), is listed as vulnerable (Duke et al. 2010a).

Box 4.2 With Their Roots in the Sea

Mangrove plants are characterised by their adaptations to physiologically challenging conditions, such as periodic immersion in seawater, fluctuating salinity, anoxic substrate and high temperatures (Hogarth 2007). Due to the fine silt sediments and bacterial activity in the substrate, these plants grow in anoxic waterlogged soils, with a prevalence of toxic compounds such as sea salt and sulphides. For this reason, the roots of mangrove plants do not penetrate deep into the soil, and taproots are absent in tidal wetlands. In order to remain stable, these plants have long, lateral cable roots that run 20–30 cm below the substrate and radiate from the main stem (e.g., species of *Avicennia* and *Sonneratia*; Fig. 4.3e), or looping adventitious roots that originate from the stem above ground (stilt roots; e.g., species of *Rhizophora*; Fig. 4.3f). Anchoring roots grow from these cable or stilt roots, and are mostly below ground; absorbing roots penetrate the superficial layer of the substrate, and grow from the anchoring roots. Specialised aerial roots, or 'pneumatophores' store air when exposed during low tide, which the roots then utilize for respiration when submerged (Fig. 4.3e, f; Tomlinson 1994).

Mangrove plants cope in a saline environment by: (1) salt exclusion at the roots; (2) salt secretion at specialised salt glands in the leaves; and (3) tolerating accumulated salts in the leaves and bark (Tomlinson 1994; Hogarth 2007).

All mangrove plants are dispersed by water, either as seeds or as seedlings. Seedlings can float for variable distances depending on factors such as specific attributes of the species, propagule characters, buoyancy, temperature tolerance, longevity at sea, and exposure to herbivorous fauna. Many species of *Bruguiera*, *Ceriops*, and *Rhizophora*, are viviparous; their seeds germinate and develop while still on the parent tree (Fig. 4.3a). Consequently, these plants undergo long development periods, some extending to 2.5 years (Duke et al. 1984). When they finally fall, disperse, and arrive at a suitable location with specific environmental conditions, they take root and become established.

While many mangrove plant species are potential candidates as flagship species, the most iconic symbol of mangroves is the stilt roots of the species of *Rhizophora* (Figs. 1.2b and 4.3d, f), already common as logos of mangrove-related NGOs and societies.

4.2.2 Invertebrates

A full list of invertebrate animal species listed in the IUCN Red List (IUCN 2014) and found in the Sundaland forested wetlands is provided in Appendix II. Other information include their habitat type (freshwater swamp forests, peat swamp forests and mangrove forests), IUCN status (near threatened, vulnerable, endangered, critically endangered), and some common names.

4.2.2.1 Dragonflies and Damselflies

Dragonflies (Insecta: Odonata: Anisoptera) and damselflies (Insecta: Odonata: Anisoptera; Fig. 4.4) are flying insects whose larvae are aquatic; adult and juvenile of both dragonflies and damselflies are closely associated with lotic and lentic freshwater aquatic habitats. Adult dragonflies can reach relatively large sizes, with wingspans of more than 10 cm; they are powerful fliers and prey on smaller insects. Damselflies are close relatives of dragonflies, but are smaller in size, and weaker fliers. Odonata, the order in which dragonflies and damselflies belong, is the first insect group whose IUCN conservation status was reviewed (Clausnitzer et al. 2009) in recognition of the increasing threats to their habitats. The main anthropogenic threats to odonates are wetland deforestation, siltation of the water bodies within the habitats, wetland reclamation and drainage, and pollution (Clausnitzer et al. 2009). Odonate species in lotic habitats are especially sensitive to environmental stress; those in lentic habitats are better adapted to dynamic and ephemeral conditions, and generally have better dispersal capabilities.

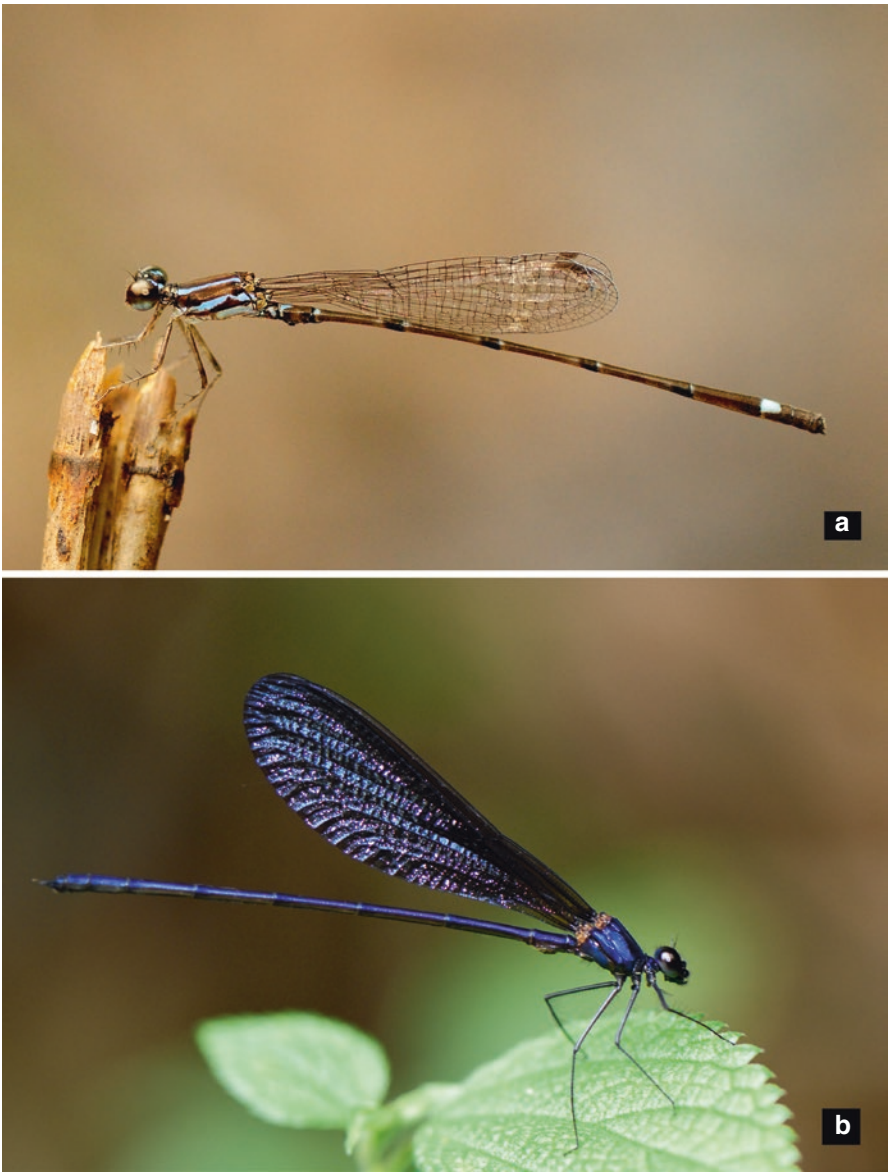

Fig. 4.4 Threatened damselflies of Sundaland wetlands; (**a**) *Mortonagrion arthuri* (near threatened; Dow 2013), occurring in brackish water streams; Simpang Forest, Singapore (courtesy of Cai Yixiong); (**b**) *Vestalis luctuosa* (near threatened; Dow 2009) along an irrigation dike; Bali, Indonesia (courtesy of Yi-Kai Tea)

Odonate insects, while popular in art and folklore of several cultures worldwide, have not always been considered positively. For example, in parts of North America, they were often referred to as 'devil's needles' and thought to be venomous (Mitchell and Lasswell 2005). Odonates however, are revered in many Asian and Native American cultures (Mitchell and Lasswell 2005). They are considered a culinary delicacy in Indonesia, and they are also widely used in traditional Chinese medicine (Corbet 1999). In the USA, the hobby of observing and identifying odonate species is becoming popular, a pursuit informally known as 'oding'. The public awareness of odonate species, coupled with their attractive colours, place dragonflies and damselflies in good steed as potential flagship species of Sundaland forested wetlands.

The species present in Sundaland that are of conservation interest are: *Aciagrion fasciculare*, *Ictinogomphus acutus*, *Mortonagrion arthuri* (Fig. 4.4a), *Oligoaeschna platyura*, and *Vestalis luctuosa* (Fig. 4.4b). Except *Mortonagrion arthuri* that also occurs in the upper reaches of mangrove forests, all these species only occur in freshwater swamp habitats (IUCN 2014; Appendix II).

4.2.2.2 Fiddler Crabs

Brachyuran or 'true' crabs (Decapoda: Brachyura) are abundant in mangrove forests and tidal areas. Fiddler crabs of the genus *Uca* (family Ocypodidae) are especially iconic, and comprise approximately 100 species (Crane 1975; Rosenberg 2001; Box 4.3, Fig. 4.5). While no fiddler crab species is listed in the IUCN Red List (IUCN 2014), their highest diversity occurs in the endangered coastal intertidal wetlands of Sundaland. Species such as *Uca annulipes* (Fig. 4.5b) and *Uca vocans* form dense aggregations on exposed intertidal areas; *Uca triangularis* and *Uca rosea* occur in high intertidal mangrove forests; and *Uca dussumieri* is found on tidal mudflats and mudbanks (Fig. 4.5a). Male fiddler crabs are especially striking in colour and behaviour; one of their claws is significantly enlarged, and is used for territorial displays and attracting mates, while the other claw is small, and is used for feeding (Pratt and McLain 2006). In females, both claws are small. These feeding claws aid in picking on their dietary staple, the biofilm that covers the substrate (Hogarth 2007). During low tide, when the biofilm is exposed, these crabs spend a considerable time feeding. During high tide, they shelter within burrows that they excavate and maintain, re-emerging to feed during the next low tide (Hartnoll 1987). While these crabs shelter in burrows during high tide, a pocket of air is maintained within the burrow for respiration (Kristensen and Kostka 2005).

Fig. 4.5 Sundaland fiddler crabs; (**a**) male of *Uca dussumieri*; Sungai Ular, Pulau (= Island) Kukup, Johor, Peninsular Malaysia (courtesy of Graeme Chow); (**b**) male of *Uca annulipes*; Pulau Ubin, Singapore (courtesy of Marcus Ng)

Box 4.3 Small, Colourful, and Active Crabs

Fiddler crabs hatch as pelagic larvae that undergo several stages in the water column, before entering intertidal areas to metamorphose into amphibious adults. The eyes of adult fiddler crabs are positioned at the tip of elongated eye-stalks, a specific adaptation to spatial vision in a flat environment (Zeil et al. 1986). Males partake in complex visual signalling systems during aggressive

and reproductive interactions, in which their more colourful and larger cheliped is moved up and down, thus resembling a fiddler, and providing a suitable common name (e.g., How et al. 2008). Several species are able to communicate acoustically, tapping the substrate to transmit vibrations (Aicher and Tautz 1990). Fiddler crabs can occur at high densities in intertidal areas (Hogarth 2007), and their burrowing activity can have profound effects on soil hydrology (Ridd 1996), geochemistry (Botto et al. 2005; Kristensen and Alongi 2006), and, consequently, forest productivity (Smith et al. 1991; Kristensen et al. 2008). For these reasons, fiddler crabs make good bioindicators of coastal habitats (e.g., Macintosh et al. 2002; Ashton et al. 2003) and have been the subject of eco-toxicological studies (e.g., Ismail et al. 1991).

Hogarth (2007) described fiddler crabs as "the most colourful mangrove invertebrates". Their behaviour has been the subject of many scientific studies and their occurrence in high densities make them excellent wildlife-watching subjects.

4.2.2.3 Freshwater and Semi-terrestrial Crabs

Unlike species from the genus *Uca*, crabs living in freshwater and peat swamp forests of Sundaland do not typically exhibit conspicuous colours or behaviours (Fig. 4.6). However, freshwater crabs have unique adaptations to terrestrial or ephemeral aquatic habitats in tropical wet forests. They can breathe by trapping a bubble of air in their gill chambers, and many species are extremely active while out of water (Ng 2004). Females do not need to return to the sea to release eggs. Unlike other crabs that undergo planktonic larval stages, the eggs of freshwater crabs hatch into miniature versions of adults. Females often care for their young, brooding the juvenile crabs until they are ready to disperse.

These crabs are good candidates as flagship species, to promote both conservation of freshwater systems and scientific investigations. New species of freshwater and semi-terrestrial crabs are still being discovered regularly, exemplifying how little is known of their diversity, distribution, and autecology. Two species of the genus *Irmengardia*, *I. didacta* and *I. nemestrinus* (Fig. 4.6a; Appendix II), exemplify the current state of scientific knowledge. Both species are listed as endangered in the IUCN Red List (Esser and Cumberlidge 2008a, c). *Irmengardia didacta* occurs in shallow, acidic streams in the southern Malay Peninsula, on mud deposits covered with leaf litter (Ng and Tan 1991). *Irmengardia nemestrinus* was found in Batam Island, Indonesia, in a stream draining from a freshwater swamp forest overgrown with sedges of the genus *Eleocharis* (Ng 1992). Like the majority of wetland organisms, not much else is known of both species of *Irmengardia*, other than short ecological notes accompanying the species description. We do know, however, that many species of freshwater crabs are syntopic. In the same freshwater swamp forest where *Irmengardia nemestrinus* was discovered, another endangered species, *Parathelphusa batamensis* (Esser and Cumberlidge 2008d) was also found in burrows along the water line of streams crossing a disturbed swamp forest fringed by

Fig. 4.6 Freshwater crabs of Sundaland wetlands; (**a**) *Irmengardia johnsoni* (vulnerable; Esser and Cumberlidge 2008b); Chestnut Forest, Singapore; (**b**) *Parathelphusa maculata*; Nee Soon Swamp Forest, Singapore (both photos courtesy of Nick Baker)

Pandanus sp. (Ng 1992). The anthropogenic impacts to freshwater systems within Sundaland are rampant (Ng 2004), and are likely to be the main contributing factor for the loss of many crab populations. In Singapore, where peat swamp forests have almost but disappeared, the critically endangered *Parathelphusa reticulata* is poorly known (Esser and Cumberlidge 2008e). This species is found in shallow and still, or slow flowing, acidic waters. Entrances to their burrows open a few centimeters above the water level, and they have been found to be more active at night (Ng 1990). Their restricted distributional ranges, endangered habitats, and unique biology make these animals symbols of the rapid disappearance of freshwater wetland forests.

4.2.3 Vertebrates: Sharks and Rays

Sharks and rays are not readily visible in wetlands; sharks are usually fast and elusive, while rays are bottom dwellers. Yet, these cartilaginous fishes are often featured in aquaria worldwide, and easily capture public attention. Sharks and rays in estuaries and rivers of Sundaland have high conservation value, and are suitable candidates as flagship species.

Indiscriminate fishing practices have caused a global decline in shark and ray populations over the past several decades. While shark meat is consumed widely, sharks are targeted for their fins, which when dried, fetch high prices. Public opinion is increasingly turning against the shark-fin fishing industry, due to aggressive campaigns and education programs that highlight its toll on wild shark populations (Clarke et al. 2007). The Broadfin shark *Lamiopsis temminckii* uses estuarine mangrove areas and rivers, is listed as endangered, and is affected by anthropogenic habitat destruction and pollution (White et al. 2009). Capture fisheries by gillnets and longlines also affect populations of the Sharptooth lemon shark, *Negaprion acutidens*, listed as vulnerable globally. However, this species is listed as endangered in Southeast Asia, where its sharp declines can be attributed to the added effects of fishing, and the destruction of its mangrove and coral reef habitats. Once abundant in Indonesia, *Negaprion acutidens* is no longer encountered in markets and is considered extirpated in Thailand (Pillans 2003).

Capture fisheries also negatively impact sawfishes (Pristidae), thus named for the presence of a toothed rostrum. The rostrum is hypothesised to have multiple functions, and functions as an electroreception sensory organ, and a tool to dig out or impale prey (Wueringer et al. 2012). This saw-like rostrum causes sawfishes to be vulnerable to incidental gill and trawl net captures, and to suffer from high post-release mortality (Tobin et al. 2010; Dulvy et al. 2008; Simpfendorfer 2000). Two sawfish species are listed as critically endangered: *Pristis pristis*, and *Pristis zijsron* (Kyne et al. 2013, and Simpfendorfer 2013, respectively; Appendix III; Fig. 4.7a). Juveniles of *Pristis microdon* (= *P. pristis*) are also captured for the aquarium trade (Ng and Tan 1997), while their rostra are collected and sold as curios (Morgan et al. 2016). These two species are presently listed in Appendix I

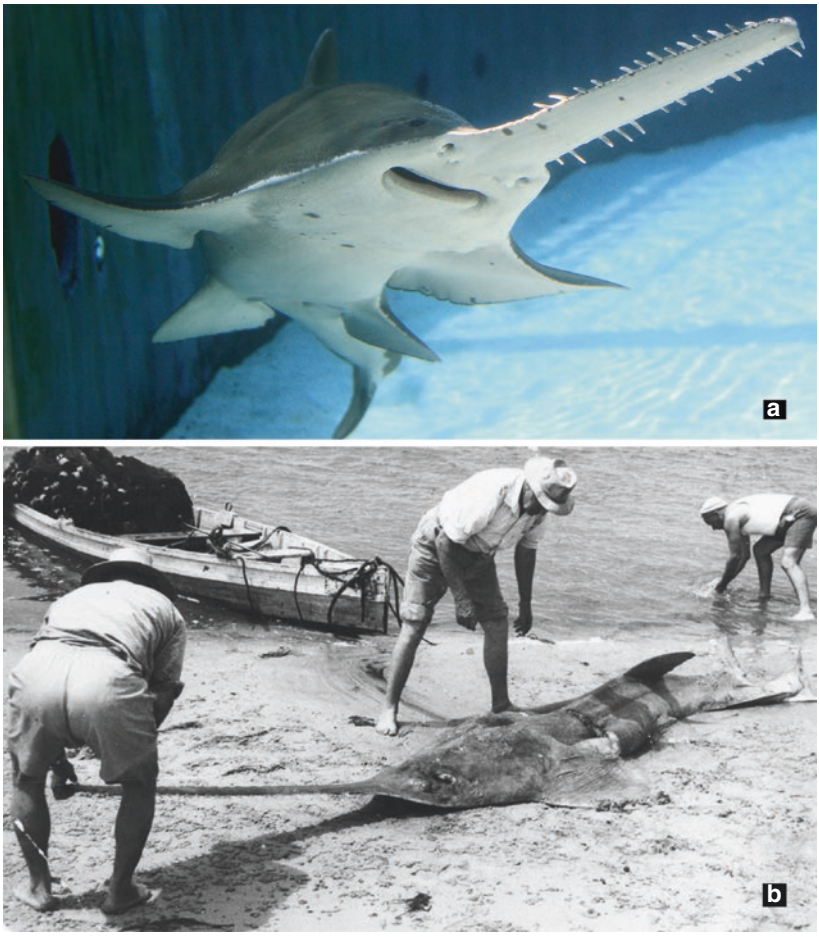

Fig. 4.7 Critically endangered sawfishes of Sundaland wetlands. Sawfishes include critically endangered species closely associated to coastal wetlands; (**a**) *Pristis microdon* (= *P. pristis*) (critically endangered; Kyne et al. 2013); Aquarium of the Pacific, California USA (courtesy of Christopher Wilson); (**b**) *Pristis* sp., caught off Picnic Point, Maroochydore, Queensland Australia in the 1940s (courtesy of the State Library of Queensland)

of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2015), an international agreement regulating international trade of wild organisms.

Rays (Dasyatidae) are common in mangrove areas and rivers of Sundaland, where four species are of conservation value. Three species are listed as vulnerable (IUCN 2014; Appendix III): *Himantura lobistoma* (= *Urogymnus lobistomus*), *Himantura pastinacoides* (= *Maculabatis pastinacoides*) and *Himantura uarnak* (Manjaji et al. 2009a, b; Manjaji and White 2009, respectively). Two others,

Pastinachus solocirostris, and *Himantura polylepis* (= *Urogymnus polylepis*) are listed as endangered (Fahmi et al. 2009; Vidthayanon et al. 2013, respectively). Similar to sharks and sawfishes, capture fisheries and habitat degradation also heavily impact rays. Population numbers of *Himantura polylepis* in Cambodia, Indonesia, Malaysia, and Thailand are especially dire, with reports of up to 88% decline in one year (Vidthayanon et al. 2013). A full list of cartiligenous fishes listed in the IUCN Red List (IUCN 2014) and found in the Sundaland wetlands can be found in Appendix III.

4.2.4 Vertebrates: Ray-Finned Fishes

Ray-finned fishes (Actinopterygii) are abundant within the Sundaland wetlands, but like cartilaginous fishes, they are challenging to observe in the field. Habitat destruction and degradation, capture fisheries, and harvesting for the aquarium trade are some of the major causes for the unsustainable decline of ray-finned fishes. Yet, the sheer diversity and familiarity to the general public make ray-finned fishes appealing mascots. A full list of ray-finned fishes listed in the IUCN Red List that occur in Sundaland wetlands can be found in Appendix IV (IUCN 2014).

4.2.4.1 Estuarine Fishes

Ray-finned fishes of coastal and intertidal wetlands are either resident or tidal-dependent visitors; the latter utilise these areas during high tide. Three resident ray-finned fish species in the Sundaland coastal wetlands are of conservation interest (Appendix IV). Formal and thorough assessments will probably increase this number in the future, as there are many resident yet poorly known ray-finned fishes in mangrove forests. One resident inhabitant of small streams and tide pools of mangrove forests, the Dwarf pygmy goby, *Pandaka pygmaea*, is listed as critically endangered in the IUCN Red List (WCMC 1996); its common and scientific names allude to its size, as this species is one of the smallest extant vertebrates. The two other species, the Tiger tail seahorse, *Hippocampus comes* and the Spotted seahorse, *Hippocampus kuda*, are listed as vulnerable (Aylesworth 2014; Lim 2015). They are found in nearshore seagrass lagoons, reefs, and mangrove forests. Seahorses are particularly charismatic, and are commonly used as flagship species. Seahorse populations are rapidly declining globally, with estimates of up to 60% (Vincent et al. 2011). These fishes are captured alive for the aquarium trade, fished and dried for traditional Chinese medicine, and also dried and sold as tourist curios (Vincent 1995). Some of the most charismatic ray-finned fishes within coastal forests are the mudskippers (Box 4.4; Fig. 4.8). These amphibious fishes are able to survive out of water for extended periods of time (Murdy 1989). They are ubiquitous in mangrove forests and coastal habitats, and can be easily observed at low tide foraging on the exposed seabed, defending territories, or attracting mates. For these reasons, they are excellent nominees as flagship species for coastal forested wetlands.

Fig. 4.8 Sundaland mudskippers; (**a**) *Periophthalmodon septemradiatus*; specimen imported from Vietnam, photographed in aquarium; (**b**) *Periophthalmus chrysospilos*; Pulau (=Island) Kukup, Johor, Peninsular Malaysia

Box 4.4 Fishes Out of Water

'Mudskippers' is a common name for 40–50 fish species from the gobioid subfamily Oxudercinae, but is also used to refer to species in only four of the ten oxudercine genera. These four genera – *Boleophthalmus*, *Periophthalmodon*, *Periophthalmus* (Fig. 4.8), *Scartelaos*, and *Zappa* – live out of water for part of their daily cyle (Murdy 1989; Polgar et al. 2010). Like fiddler crabs (Box 4.3), mudskippers hatch as pelagic larvae before undergoing metamorphosis to an amphibious adult in the intertidal zone (Ishimatsu et al. 2007). Mudskippers are distributed in coastal wetland habitats throughout IWP and western Africa (Murdy 1989; Jaafar and Larson 2008). Sundaland hosts a

high diversity of mudskippers at 13 species (Polgar 2012), of which one species, *Periophthalmus spilotus*, is endemic (Murdy and Takita 1999).

During low tide, several species of mudskippers can be observed on exposed mudflats and mudbanks, where they form conspicuous and dense aggregations. Herbivores such as species of *Boleophthalmus* actively defend their territories, graze on microphytoplankton on the substrate surface, and exhibit dynamic courtship displays during this time. Carnivores, such as *Periophthalmodon schlosseri* are less active, but are capable of powerful energy bursts to capture prey items such as crabs and smaller fishes. Mudskippers have also been reported to communicate acoustically while out of water (Polgar et al. 2011).

Mudskippers are wild-caught and consumed in countries such as Peninsular Malaysia and Sierra Leone (G.P. pers. obs., Turay et al. 2006) or cultivated for food in Thailand, Taiwan, and China (G.P. pers. obs., Zhang et al. 1989). These fishes are also live-captured to meet the demand of the aquarium trade. Mudskippers have been gaining popularity as pets due to their amphibious habits, large 'expressive' eyes, and striking fin colours; *Periophthalmodon septemradiatus* (Fig. 4.8a) and *Periophthalmus barbarus* are commonly traded. However, all traded mudskipper species are wild caught; the impact of harvesting for global aquarium demand is unknown. Mudskippers have also been used as biomonitors to monitor coastal pollution in mangrove forests (Kruitwagen et al. 2006).

Like the imperilled habitats they are closely associated with, mudskipper populations are likely threatened. Yet, only two non-Sundaland species of mudskippers are listed in the IUCN Red List (IUCN 2014), probably reflecting the dearth of information on these habitats and their inhabitants. In particular, species that live in back mangrove and riverine areas, such as *Periophthalmodon septemradiatus* (Fig. 4.8a) and *Periophthalmus malaccensis* (Polgar 2016) are probably most affected by land conversion and agriculture (Polgar 2008). With the high and rapid rates of coastal conversion and reclamation, local extirpations are probable. This scenario is not foreign; *Boleophthalmus pectinirostris* is almost extirpated from the Ariake Sea in Japan (Takegaki 2008). *Periophthalmus malaccensis*, described based on a collection from Singapore, and named after the Straits of Malacca (Eggert 1935), had not been reported in Singapore (Larson et al. 2008; 2016), Malaysia or Thailand (Jaafar and Larson 2008) since its description.

4.2.4.2 Freshwater Fishes

Sundaland inland forested wetlands host unique communities of stenotopic, and often endemic, freshwater fish species (Figs. 4.9 and 4.10). Freshwater fish populations in inland forested wetlands face some of the same threats as those by the coast. Capture fisheries, as well as habitat degradation (draining of wetlands, damming of rivers, pollution) and conversion, have resulted in significant declines to the Sundaland freshwater ichthyofauna. Freshwater wetland areas also face higher

levels of harvesting of live fishes for the aquarium trade. Many freshwater fishes make excellent conservation mascots as they already have a wide public appeal and are easily recognised by the general public.

Sphaerichthys vaillanti is an example of a potential flagship species endemic to the Kapuas River basin in the Kalimantan Barat province of Indonesian Borneo (Kottelat and Widjanarti 2005). This species is currently listed as vulnerable in the IUCN Red List (Jenkins et al. 2009; Appendix IV). Mercury pollution from illegal gold mining activities in the Kapuas River (Adijaya and Yamashita 2004) is the major threat. In addition, remaining wild populations are also impacted by deforestation, land conversion to agriculture, and harvesting for the aquarium trade.

This scenario is true for many inland wetland forest fishes (Kottelat and Whitten 1996; Ng and Tan 1997), such as the Asian arowana *Scleropages formosus* (Box 4.5; Fig. 4.9a), and several species of fighting fishes of the genus *Betta* (Box 4.6; Fig. 4.10a; Appendix IV).

Fig. 4.9 Threatened freshwater fishes of Sundaland forested wetlands; (**a**) the Asian arowana *Scleropages formosus* (variety Red tailed golden; Pouyaud et al. 2003; Bian et al. 2016) (endangered; Kottelat 2013) in a private tank (courtesy of Jamalludin Ab Rahman); (**b**) the Armoured stickleback *Indostomus crocodilus* (vulnerable; Vidthayanon 2013b) in a private tank (courtesy of Lim Teow Yeong)

Box 4.5 The Demise of the Dragon

The Asian arowana, *Scleropages formosus* (Fig. 4.9a), naturally occurs in a variety of freshwater habitats, from whitewater rivers to lakes adjacent to peat swamp forests, and is distributed from the Malay Peninsula eastward to the island of New Guinea (Pouyaud et al. 2003). This fish is a formidable predator, with a large body and striking scales, earning it the name 'Dragon Fish' within the aquarium trade. For these same reasons, Chinese beliefs attribute the capacity to bring luck and wealth to this fish, leading to the harvesting of wild populations for the aquarium trade since the late 1970s. Wild fishes are also harvested for food, and further impacted by rampant habitat losses. *Scleropages formosus* is listed as endangered in the IUCN Red List (Kottelat 2013). It is also listed in CITES Appendix I, therefore specimens can only be legally traded if bred in captivity for at least two generations. Due to these regulations and the very high prices they fetch, these fishes are individually microchipped. Each fish can be sold for hundreds, to tens of thousands, of US dollars; and sales >300,000 US dollars have been reported (Arowana.co.uk 2016). Four colour morphs of *S. formosus* (Green, Red tailed golden, Super red and Silver Asian arowanas) are present in different regions within its distribution, and the species status is being debated (Kottelat and Widjanarti 2005; Bian et al. 2016).

Inland wetlands of Sundaland host a high diversity of fishes that have evolved by becoming smaller. Termed 'miniaturisation', the process is hypothesised to be an adaptation to nutrient-poor and ephemeral waters, such as the slow-flowing streams crossing peat swamp forests (Kottelat et al. 2006). Miniature species include *Paedocypris micromegethes*, *Paedocypris carbunculus, Sundadanio axelrodi* (Fig. 4.10c), *Boraras maculatus*, and *Boraras urophthalmoides* (near threatened; Vidthayanon 2013a; Fig. 4.10a). A celebrated species identified as one of the smallest extant vertebrates, *Paedocypris progenetica*, measures less than 1 cm long when sexually mature (Kottelat et al. 2006). These miniature species have high public appeal as evolutionary curiosities and would make excellent flagship species. The conservation statuses of many miniature species are unknown, as the threats to their populations have not been studied. Because many species are endemic and are not widely distributed, ecosystem conversion and habitat loss are real and imminent threats.

Fig. 4.10 Specialist fishes of Sundaland peat swamp streams; (**a**) *Betta brownorum* (courtesy of Vemund Vennetsrøm); (**b**) *Boraras urophthalmoides* (near threatened; Vidthayanon 2013a) (courtesy of Peter McGuire); (**c**) *Sundadanio axelrodi* (courtesy of Peter McGuire). All photos were taken in private aquaria

Box 4.6 The Fighters' Trade

There are about 70 species of fighting fishes (*Betta* species), all of which are endemic to South East Asia (Tan and Ng 2005). Three species, *Betta miniopinna*, *Betta persephone*, and *Betta spilotogena* (the latter is one of the few species occurring in freshwater swamps), are currently listed as critically endangered, while seven others are listed as vulnerable in the IUCN Red List (Kottelat 1996c, d, e; Appendix IV).

These fishes are capable of breathing atmospheric air with an accessory 'labyrinth organ', located above their gills. The ability to utilise atmospheric air allows fighting fishes to live in aquatic environments with fluctuating oxygen levels, such as ephemeral wetland waterways and rice paddy fields. Males perform a variety of parental care behaviours; some species protect fertilised eggs within their mouths, while others deposit them in bubble nests (Rüber et al. 2004). The common name of these fishes is derived from natural male-male agonistic interactions. The Siamese fighting fish *Betta splendens* has

been reared for centuries in Thailand, to participate in fish-fighting tournaments. Fighting fishes were probably imported to Europe and the USA in the late eighteenth century (Ostrow 1989). They are now commonly found in pet shops and aquariums globally. The demand of the aquarium trade for exotic and rare fighting fish species has caused some concern over extirpations, such as in the case of the "Brunei beauty" *Betta macrostoma*, endemic to northern Borneo (vulnerable; Kottelat 1996b; Appendix IV).

4.2.5 Vertebrates: Amphibians

Frogs and toads form dominant amphibian communities in the inland wetlands of Sundaland, colonising freshwater and peat swamp habitats (Fig. 4.11). Several species inhabit canopies of trees within swamp areas, such as *Kurixalus appendiculatus* (Fig. 4.11b) and *Polypedates colletti*. *Fejervarya cancrivora* is one of the few frog species known to inhabit mangrove forests and supralittoral habitats. Sundaland is home to ~240 species of frogs and toads, 200 of which are endemic to this region (Bickford et al. 2010); larval amphibians are intolerant of saline water, thus limiting their distribution to archipelagos and island groups, such as Sundaland. Frogs and toads make relatable and easily recognised flagship species, due to the striking transformations during metamorphosis, widely taught in schools.

Amphibians are particularly vulnerable to climate change and anthropogenic impacts, due to their high sensitivity to temperature, humidity, pathogens and pollutants (Sodhi et al. 2008; Wake and Vredenburg 2008). Populations of some frog species occurring in several inland forested wetlands have also dramatically decreased due to overharvesting for food, with Indonesia being one of the largest global consumers (8,000–35,000 t per year) and exporters (4,000–5,000 t per year) of frogs' legs (Warkentin et al. 2009).

A peat swamp forest specialist, *Ingerophrynus kumquat* was only described in 2001 from Sabak Bernam in Peninsular Malaysia. This frog species is not known from any other site within or outside of Peninsular Malaysia. Since its discovery, assessments indicate that the species is endangered (Das et al. 2004). Unfortunately, the peat swamp forest in which it is found does not have any protection status. Another example of an amphibian species with a small population is *Fejervarya nicobariensis*, listed as endangered in the IUCN Red List (Vijayakumar 2008). This species is endemic to the Nicobar Islands, and can be found in the littoral zone. A full list of amphibians listed in the IUCN Red List (IUCN 2014) and occurring in the Sundaland forested wetlands can be found in Appendix V.

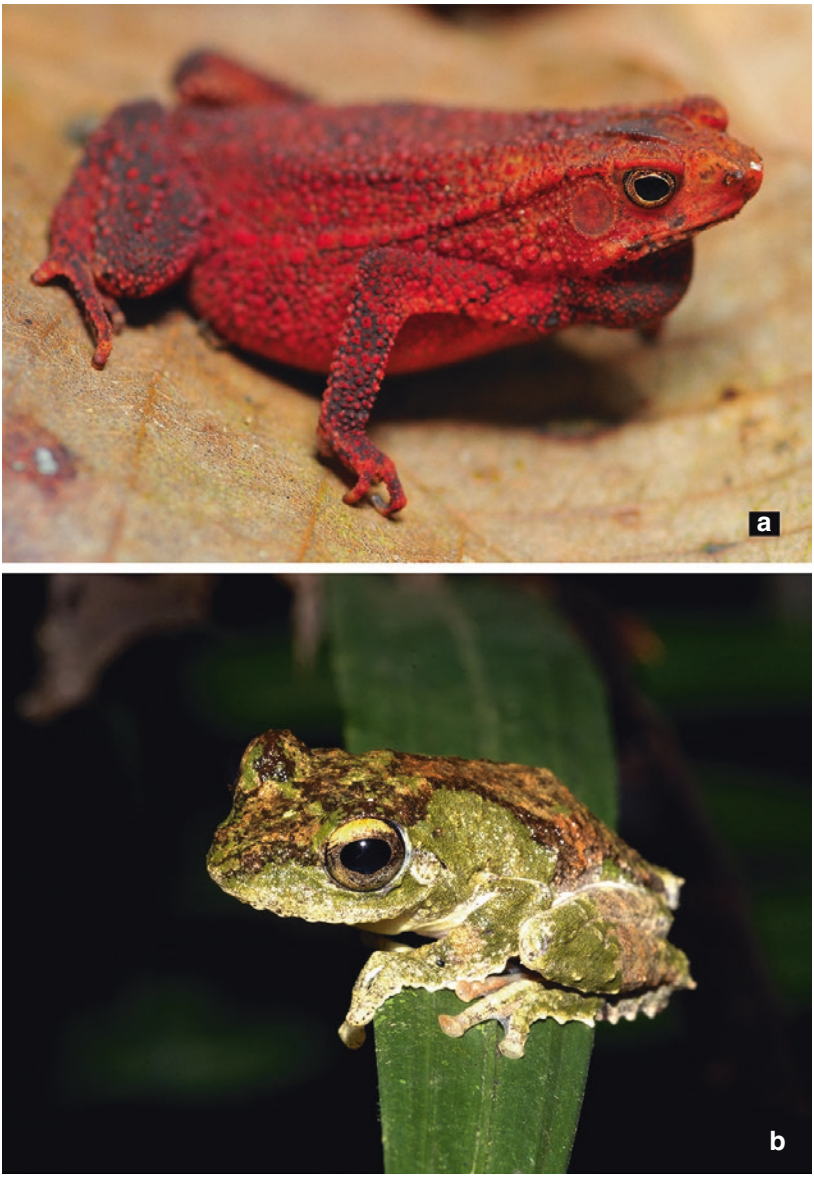

Fig. 4.11 Frogs and toads of Sundaland wetlands; (**a**) *Ingerophrynus quadriporcatus*; Nee Soon Swamp Forest, Singapore (courtesy of Kane Koh); (**b**) *Kurixalus appendiculatus*; Taman Negara, Peninsular Malaysia (courtesy of Nick Baker)

4.2.6 Vertebrates: Reptiles

The Sundaland region hosts 450 species of reptiles (snakes, lizards, turtles and crocodiles), 250 of which are endemic to the region (Bickford et al. 2010). While reptiles are ubiquitous and have colonised a wide range of forested wetlands (Lim and Lim 1992), snakes are generally not considered as flagship species, because of the fear they invoke in many humans (Öhman and Mineka 2003). Turtles (Box 4.7; Fig. 4.12) and crocodiles (Fig. 4.13) are arguably among the most charismatic of reptiles, and both are common flagship species. A full list of reptiles listed in the IUCN Red List (IUCN 2014) and found in Sundaland forested wetlands can be found in Appendix VI.

Crocodiles are some of the apex predators in tropical wetlands, and a source of fascination for the general public; crocodiles attract crowds of tourists be it in zoos, or nature reserves. Like other wetland species, crocodile populations are also affected by habitat destruction and overharvesting for meat and skin. Once widely distributed throughout Southeast Asia, and common in Sundaland, populations of the Siamese crocodile, *Crocodylus siamensis* (Fig. 4.13a), have plummeted with only small remnant populations surviving in the wild, and is listed as critically endangered in the IUCN Red List (Bezuijen et al. 2012). The Siamese crocodile inhabits rivers, lakes, and freshwater swamp forests. Little else is known of their ecology. Recent efforts to repopulate suitable wild habitats with farmed crocodiles were touted as a solution to the falling population sizes. However, special attention must be paid to these reintroduced individuals, as *Crocodylus siamensis* hybridises with the Saltwater crocodile *Crocodylus porosus* in captivity (Britton 2011).

The False gharial *Tomistoma schlegelii* (Fig. 4.13b) is listed by IUCN as vulnerable (Bezuijen et al. 2014) and is included in CITES Appendix I (UNEP-WCMC 2015). This species is found in the Malay Peninsula and throughout Indonesia (Stuebing et al. 2006). Although found in freshwater swamp forests and flood plains, *Tomistoma schlegelii* is considered a peat swamp specialist (Bezuijen et al. 1998). It is one of the largest animals occurring in the oligotrophic Southeast Asian peat swamp forests (up to 4–5 m in total length), and naturally occurs at low densities. False gharial populations are becoming increasingly isolated and fragmented since the 1940s, primarily due to habitat destruction (Stuebing et al. 2006; Rödder et al. 2010). Populations will remain low if unaided, as parental care of hatchlings is absent in this species, and hatchling mortality is high (Britton 2011).

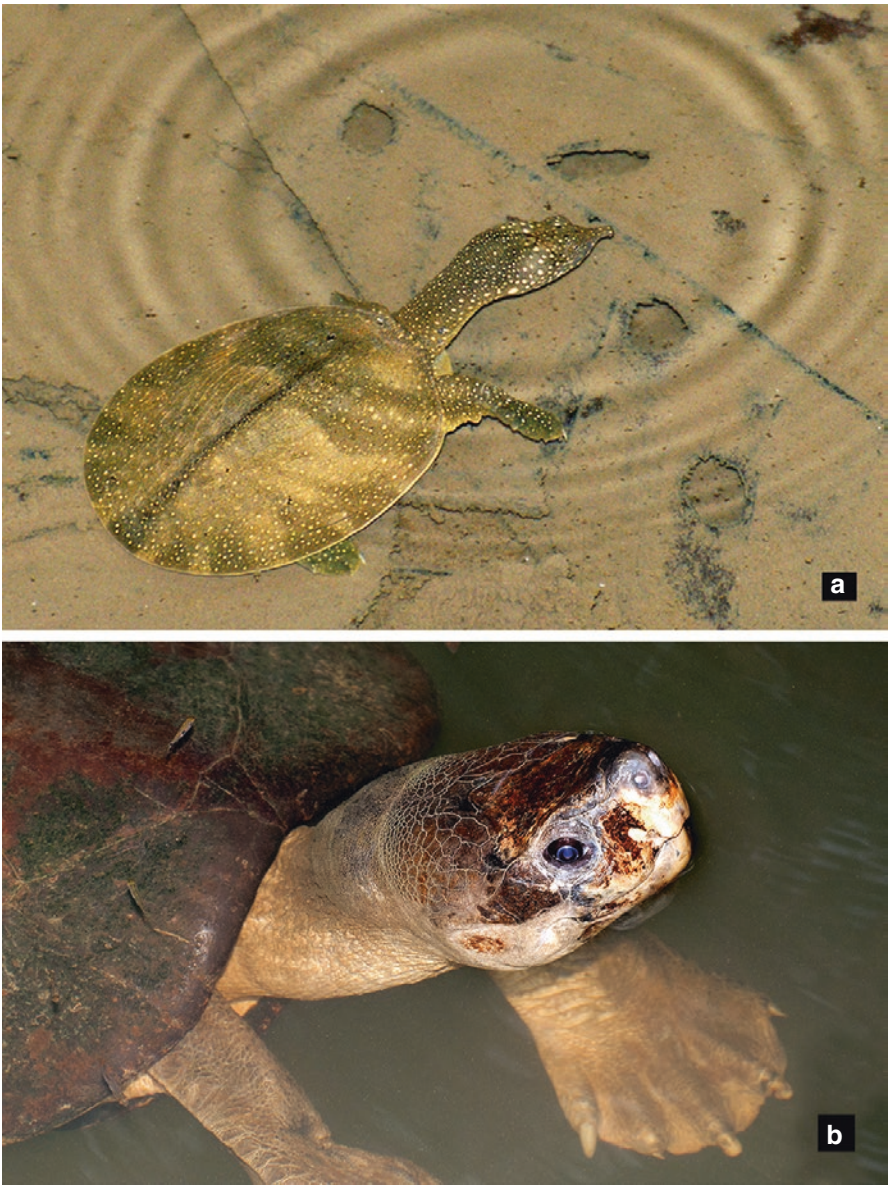

Fig. 4.12 Threatened freshwater turtles of Sundaland wetlands; (**a**) the Asiatic softshell turtle *Amyda cartilaginea* (vulnerable; ATTWG 2000a), in a forest stream in Singapore; (**b**) the Malayan giant turtle *Orlitia borneensis* (endangered; ATTWG 2000e), in a forest stream in Singapore (both photos courtesy of Nick Baker)

Box 4.7 Turtles of Sundaland

The Hawksbill sea turtle, *Eretmochelys imbricata*, listed as critically endangered in the IUCN Red List (Mortimer and Donnelly 2008; Appendix VI), is familiar to members of the public as it is a common mascot and flagship species. Similar to all other species of sea turtles, the sharp decline in global *Eretmochelys imbricata* populations has been brought about by unregulated harvesting for consumption, shells, and turtle eggs. Additionally, destruction of nesting beaches, incidental catch by trawlers, and plastic pollution have added to this downward population trend (Campbell 2003). Marine educational materials often use turtles as flagship species. For example, an educational advertisement by the Mediterranean Association to Save the Sea Turtles received global attention when they depicted jellyfishes and upside-down floating plastic bags with the caption "You see the difference. A turtle does not." The awareness created by the campaign aided green groups to advocate for balloons not to be released during large public and private functions in Singapore (Z.J., pers. obs.). Nets with turtle-exclusion devices have also been fitted into trawlers in fishing areas with dense turtle populations. These nets have escape holes which allow turtles, but not fishes, to swim out of. The ban of turtle meat and egg consumption has also been enforced in some countries within Sundaland. *Eretmochelys imbricata* is also listed in CITES Appendix I, and transboundary trade of this species is prohibited.

Freshwater turtles are less commonly used as flagship species. They are a popular symbol of health and longevity in Southeast Asia, especially among the Chinese community and those of Buddhist faith. Freshwater turtles are popular pets, but those native to Sundaland are uncommon in the pet trade. The Red-eared sliders, *Trachemys scripta*, commonly sold in petshops are from the United States of America. In Sundaland, freshwater turtles typically occur in rivers and lakes, but some species are also found in freshwater and intertidal swamps (Appendix VI). Two critically endangered species listed in the IUCN Red List, the River terrapin, *Batagur baska* and the Painted terrapin, *Batagur borneoensis* (ATTWG 2000b, c) are also listed in CITES Appendix I, and their trade is prohibited. Many species of freshwater turtles are harvested for turtle soup, a common Chinese dish in Sundaland. These turtles are also captured, dried, and used in traditional Chinese medicine. Habitat degradation and conversion, together with the influx of invasive species, such as *Trachemys scripta*, have caused sharp declines to native freshwater turtle populations (Ramsay et al. 2007). Resultantly, many of the freshwater turtles in Sundaland such as *Heosemys annandalii*, *Orlitia borneensis* (Fig. 4.12b), and *Pelochelys cantorii* are listed as endangered (ATTWG 2000d, e, f). The trade in these endangered turtles, as well as those listed as vulnerable such as *Siebenrockiella crassicollis*, is restricted, as they are listed in CITES Appendix II (ATTWG 2000g; UNEP-WCMC 2015).

Fig. 4.13 Endangered crocodiles of Sundaland; (**a**) the Siamese crocodile, *Crocodylus siamensis* (critically endangered; Bezuijen et al. 2012); Khao Yai National Park, Thailand (courtesy of Sam Rowley); (**b**) the False gharial, *Tomistoma schlegelii* (vulnerable; Bezuijen et al. 1998, 2014); Singapore Zoological Gardens, Singapore (courtesy of Shirley Ng)

4.2.7 Vertebrates: Birds

Birds are among the most vagile animals and are often associated with several habitat types. The abundant food resources of wetland habitats are crucial for specific ontogenetic stages of several migratory and non-migratory birds (BirdLife International 2014a; Fig. 4.14). Birds commonly appear as mascots and flagship species due to their striking coloured feathers and vocalisations.

Although birds are among the most studied animal groups globally, there are still knowledge gaps for many bird species. The Silvery pigeon, *Columba argentina*, for example, listed as critically endangered in the IUCN Red List (BirdLife International 2015d), is often misidentified with the similar Pied imperial pigeon *Ducula bicolor*, with which it often associates. Considered to be one of the rarest bird species, with fewer than 50 individuals, *Columba argentina* is found only in forested coastal wetlands of the Malay Archipelago. Similarly, there are fewer than 1,000 mature individuals of the Masked finfoot, *Heliopais personatus*, in the wild. At present, this species is listed as endangered in the IUCN Red List (BirdLife International 2012b). A full list of the IUCN-listed (IUCN 2014) bird species found in Sundaland forested wetlands can be found in Appendix VII.

Two bird groups most typically associate with wetlands: waders (e.g., herons, storks) and shorebirds (e.g., ibises, plovers, sandpipers). These birds, such as two stork species, the Lesser adjutant, *Leptoptilos javanicus*, and the Milky stork, *Mycteria cinerea* (Fig. 4.14a), both listed as vulnerable (BirdLife International 2013b, c; Fig. 2.4), roost within mangrove forests and feed at adjacent mudflats and creek networks during ebb tide. Waders and shorebirds prey on invertebrates such as polychaetes, bivalves, and gastropods, and on small fishes (Swennen et al. 1982; Pepping et al. 1997). The tidal mudflats of Sundaland are wintering grounds for many species of migratory shorebirds seeking refuge from the northern winter. These birds begin migration from areas such as Alaska and Siberia, where they return to breed in the northern spring (MWWG 1987). For example, the Bar-tailed godwit, *Limosa lapponica*, native to Europe and North America, overwinters in several tropical and subtropical regions, including Sundaland. An individual of this species flew across the Pacific Ocean non-stop for 9 days. The distance it travelled, 11,500 km, holds the record for the longest flight by a migratory bird species (Gill et al. 2009). Forested wetlands and intertidal mudflats along migratory routes importantly serve as pitstops for waders, shorebirds, and many other species of migratory birds. The conservation of many wader and shorebird species depends on the strategic management of these staging sites.

Habitat conversion is a big threat to many species of birds, especially if nesting requirements are specific. For example, the critically endangered *Fregata andrewsi* (BirdLife International 2015e; CITES Appendix I; UNEP-WCMC 2015), is known to roost and nest only in the back-mangrove forests of Christmas Island, an area threatened by mining activities. The endangered White-winged duck, *Asarcornis scutulata* (= *Cairina scutulata*; BirdLife International 2013a; CITES Appendix I;

Fig. 4.14 Birds of Sundaland wetlands; (**a**) the Milky stork *Mycteria cinerea* (endangered; BirdLife International 2013c; Fig. 2.4); Sungei Buloh Wetland Reserve, Singapore; (**b**) the White-browed crake, *Porzana cinerea*; Pulau Burung (Byram), Penang, Peninsular Malaysia (both photos courtesy of Nick Baker)

UNEP-WCMC 2015), inhabits freshwater forests where nests are constructed in the cavities or hollows of large-enough trees. Other birds live in specific habitats such as the Storm's stork, *Ciconia stormi*, listed as endangered in the IUCN Red List (BirdLife International 2012a). This species is endemic to Sundaland and is found prevalently in peat swamp forests. Such birds suffer heavily the consequences of habitat destruction and fragmentation (Appendix VII; Posa 2011).

Other than scientific interests in birds, there exist many amateur clubs that centre activities on birds, unparalleled in scale when compared to other animal groups. These activities range from bird watching, to citizen science, to photography (Cordell and Herbert 2002). Given the momentum and popularity of birds and activities associated with them, birds are an excellent choice as flagship species.

4.2.8 Vertebrates: Mammals

Mammals are vagile, relatively large, and adaptable animals found in a wide range of habitats. They are popular as flagship species and are most often anthropomorphised. Otters (genera *Aonyx*, *Lutra*, *Lutrogale*, all listed in CITES Appendices I or II; UNEP-WCMC 2015; Fig. 4.15b) for example, are often used as flagship species for mangrove forests, as they spend the majority of their time in forested wetlands and adjacent habitats. A list of mammals in the IUCN Red List (IUCN 2014) occurring in the Sundaland forested wetlands is provided in Appendix VIII.

As with birds, there are still significant knowledge gaps in our understanding of the biology and ecology of many mammal species, despite their popularity as study subjects. The Otter civet, *Cynogale bennettii*, is a case in point. This species is endemic to Sundaland and it is both listed as endangered in the IUCN Red List (Ross et al. 2015), and in CITES Appendix II (UNEP-WCMC 2015). Otter civets are active predators of fishes and crabs in the freshwater, estuarine, and marine habitats where they live. Land reclamation, land conversion, aquaculture, and water pollution, are among the most serious causes of the decline of Otter civet populations in Sundaland (Ross et al. 2015). Two fishing cat species, *Prionailurus planiceps* and *Prionailurus viverrinus*, are closely associated with forested riverine habitats, especially along river banks, and are also extremely elusive. They are both listed as endangered in the IUCN Red List and included in CITES Appendices I and II, respectively (Wilting et al. 2015; Mukherjee et al. 2010; UNEP-WCMC 2015; Fig. 2.4). As with many other wild cat species, the activities of these fishing cats peak from sunset to dawn, making them difficult to observe.

Primates have large home ranges, and utilise different habitat types. Several species of primates are closely associated with forested wetlands (Box 4.8, Fig. 4.15a). Troops of the Crab-eating macaque, *Macaca fascicularis*, forage within mangrove forests and, as their common name implies, also feed on mangrove crabs in addition to the variety of plants and animals they consume. Both extant orangutan species utilise peat swamp forests. The Sumatran orangutan, *Pongo abelii*, listed as critically endangered in the IUCN Red List (Singleton et al. 2008), is endemic to the island of Sumatra. The Bornean orangutan, *Pongo pygmaeus*, listed as endangered in the IUCN Red List (Ancrenaz et al. 2008; Fig. 2.4), is endemic to the island of

Fig. 4.15 Mammals of Sundaland wetlands; (**a**) the Proboscis monkey, *Nasalis larvatus* (endangered; Meijaard et al. 2008); Pulau Berambang, Brunei Bay, Brunei Darussalam (courtesy of Shavez Cheema); (**b**) the Smooth-coated otter, *Lutrogale perspicillata* (vulnerable; de Silva et al. 2015); Bishan-Ang Mo Kio Park, Singapore (courtesy of Nick Soo)

Borneo. The impacts from burning of peat swamp forests and habitat conversion have negatively affected both orangutan populations; additionally, orangutans are also captured alive for the illegal pet trade, or hunted for their meat and the perceived medicinal or magical benefits of their body parts (Marshall et al. 2006).

Box 4.8 The Big Noses

The Proboscis monkey, *Nasalis larvatus* (Fig. 4.15a), is endemic to Borneo, it is listed as endangered in the IUCN Red List (Meijaard et al. 2008), and is in CITES Appendix I (UNEP-WCMC 2015). This is an arboreal species that predominantly lives in riverine and coastal forests (Meijaard and Nijman 2000). Proboscis monkeys weigh 10–20 Kg; unlike many other primates of their size, they feed predominantly on young leaves and unripened non-fleshy fruits (Yeager 1989). Their large gut is highly adapted to a diet consisting of plant matter, with multiple chambers where symbiotic bacteria digest cellulose (Chivers 1994). Their common name is derived from the large pendulous noses of the males. These enlarged noses aid in amplifying their calls during social interactions (Röper et al. 2014). Males are twice as big and heavy as females (Napier and Napier 1985). Typically, one male will form a natural grouping, known as 'harem', with several females and their offspring. Territorial areas overlap, resulting in temporary bands (Boonratana 2002). Proboscis monkeys are well adapted to their aquatic environment; they possess webbed feet (Napier 1985), are good swimmers, and often swim across rivers (Boonratana 2000). Unsurprisingly, crocodiles and False gharials are among their main predators (Yeager 1991; Matsuda et al. 2005). Anthropogenic impacts affecting Proboscis monkeys include habitat destruction and fragmentation, hunting, poaching and forest fires (Meijaard and Nijman 2000; Sha et al. 2008).

Some marine mammals are also associated with forested wetlands. The Indo-Pacific finless porpoise, *Neophocaena phocaenoides*, is listed as vulnerable in the IUCN Red List (Wang and Reeves 2012) and occurs in coastal areas, mangrove forests, and estuaries. The Irrawady dolphin, *Orcaella brevirostris*, is also listed as vulnerable in the IUCN Red List (Reeves et al. 2008) and can be found in mangrove forests and estuaries, as well as within rivers. Additionally, the Dugong, *Dugon dugon*, a representative of a group of aquatic mammals related to elephants (Sirenia), is also listed as vulnerable in the IUCN Red List (Marsh and Sobtzick 2015) and occurs in mangrove forests and adjacent seagrass beds. All three marine mammals are listed in CITES Appendix I (UNEP-WCMC 2015). Although porpoises and river dolphins are not closely related to the dugongs, they live in the same habitats and are affected by similar impacts. Anthropogenic impacts to these marine mammals include: habitat destruction, becoming incidental victims to trawling activities, entanglement in gillnets laid out in coastal and estuarine areas, and collision with boats and small watercrafts as they surface to breathe (Reeves et al. 2008; Wang and Reeves 2012). Marine mammals are perceived to be cognisant and intelligent animals. They are large, and most often encountered when they surface. They are also universally well-liked (Laidlaw 2013), thus fulfilling the most important criteria for a successful flagship species.