Partnering with mangrove forest communities, grassroots NGOs, researchers and local governments to conserve and restore mangrove forests and related coastal ecosystems, while promoting community-based, sustainable management of coastal resources.

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Tropical Mangroves; Biologically Most Diverse 'The Global 200' Ecosystem: Megachiroptera as Key Ecological and Conservation Tool

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Brief Introduction to Mangrove Forest

Mangrove forests are comprised of unique plant species that form the critical interface between terrestrial, estuarine, and near-shore marine ecosystems in tropical and subtropical regions. The term mangrove is generally used to describe the assemblage of trees and shrubs that grow in saline coastal habitats, normally found in the tropics and sub-tropics. Mangrove plants are not land builders but once established, play a key role in stabilization of newly accreted sediment. Mangrove tree species have developed a wide range of features, including specialized *stomatal*, leaf, seed, and root structures, as adaptations for living in a saline environment with high incidence of inundation. Most mangrove species are *viviparous*; seeds germinate while still attached to the tree. Buoyant seeds develop into mature *propagules*, which then drop and disperse by water. Of note is the diversity in root structures of the mangrove tree species, designed to facilitate anchorage, nutrient uptake, and gaseous exchange. Some species, such as *Heritiera fomes*, *Sonneratia apetala*, and *Avicennia officinalis*, have *pneumataphores*; upward projecting root branches that enable the gaseous exchange required for respiratory metabolism. Other species, such as *Rhizophora mucronata*, have "stilt" or "knee" roots for gaseous exchange, while additional features such as the "tap" roots (buttresses) of *Heritiera fomes* and the horizontal spread of roots in general, add to overall stability. Some plants also excrete excess salt through leaves.

The Significance of Mangroves

The importance of mangroves for humans and a variety of coastal organisms has been well documented. They protect inland human communities from damage caused by coastal erosion and storms, provide critical habitat for a variety of terrestrial, estuarine and marine species, and serve as both a *source and sink* for nutrients and sediments for other inshore marine habitats including *seagrass* beds and coral reefs. Mangrove species that form dense and often *monospecific* stands are considered "*foundation species*" that control population and ecosystem dynamics, including fluxes of energy and nutrients, hydrology, food webs, and biodiversity. Mangroves have been widely reviewed as supporting numerous ecosystem services including flood protection, nutrient and organic matter processing, sediment control, and fisheries. Mangrove forests are the economic foundations of many tropical coastal regions providing at least US$1.6 billion per year in "*ecosystem services*" worldwide. It is estimated that almost 80% of global fish catches are directly or indirectly dependent on mangroves. Mangroves sequester up to 25.5 million tonnes of carbon per year and provide more than 10% of essential organic carbon to the global oceans. Although the economic value of mangroves can be difficult to quantify, the relatively small number of mangrove species worldwide collectively provide a wealth of services and goods while occupying only 0.12% of the world's total land area. Mangrove ecosystems are biologically most productive ecosystem on earth. They are the keystone habitats by the sea and ecologically most diverse across the tropical belt. Briefly speaking mangroves provides essential six ecological services: (1) land maturation, (2) protection of human habitation from cyclones, (3) oxygen production, (4) waste recycling, (5) food supply, and (6) carbon cycling.

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Current State of the Mangrove Ecosystems

Despite their enormous biodiversity significance, mangroves are most vulnerable to anthropogenic persecution due to varying degree of misconception surrounding its values to human and other animals in tropical *ecoregions*. With almost half (44%) of the world's population living within 150 km of a coastline, heavily populated coastal zones have spurred the widespread clearing of mangroves for coastal development, aquaculture, or resource use. At least 40% of the animal species that are restricted to mangrove habitat and have previously been assessed under *IUCN Categories and Criteria* are at elevated risk of extinction due to extensive habitat loss. Globally, mangroves cover approximately 22 million hectares in tropical and subtropical coasts. Mangroves can be found in over 118 countries and territories in the tropical and subtropical regions of the world. The largest percentage of mangroves is found between 5° N and 5° S latitudes. Approximately 75% of world's mangroves are found in just 15 countries. Asia has the largest amount (42%) of the world's mangroves, followed by Africa (21%), North/Central America (15%), Oceania (12%) and South America (11%). It is estimated that 26% of mangrove forests worldwide are degraded due to over-exploitation for *fuelwood* and timber production. Similarly, clearing of mangroves for shrimp culture contributes ~38% of global mangrove loss, with other aquaculture accounting for another 14%. In India alone, over 40% of mangrove area on the western coast has been converted to agriculture and urban development. However the overlapping of marine and terrestrial resources in mangroves creates tenure ambiguities that complicate management and may induce conflict between competing interests. Globally, between 20% and 35% of mangrove area has been lost since approximately 1980, and mangrove areas are disappearing at the rate of approximately 1% per year with other estimates as high as 2–8% per year. These rates may be as high as or higher than rates of losses of upland tropical wet forests and current exploitation rates are expected to continue unless mangrove forests are protected as a valuable resource. Given their accelerating rate of loss, mangrove forests may at least functionally disappear in as little as 100 years. The loss of individual mangrove species is also of great concern, especially as even pristine mangrove areas are species-poor compared with other tropical plant ecosystems. However, there is very little known about the effects of either widespread or localized mangrove area loss on individual mangrove species or populations. Additionally, the identification and implementation of conservation priorities for mangroves has largely been conducted in the absence of comprehensive species-specific information, as species-specific data have not been collated or synthesized. Species information including the presence of threatened species is important for refining conservation priorities, such as the designation of critical habitat, no-take zones, or marine protected areas, or to inform policies that regulate resource extraction or coastal development. Below we have provided graphic overview of native distributions of mangrove richness and the proportion of mangrove species that are in the *IUCN Threatened Species Category (Critically Endangered, Endangered, and Vulnerable)*.

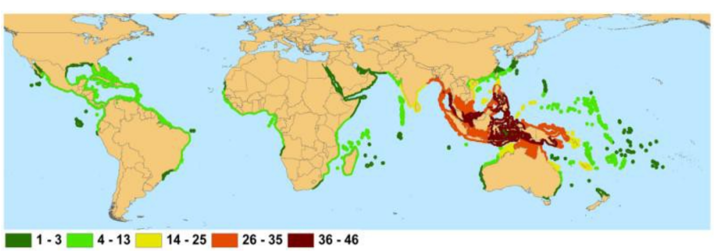

Fig 1: Mangrove species richness: Native distributions of mangrove species. Image Credit: Beth Polidoro

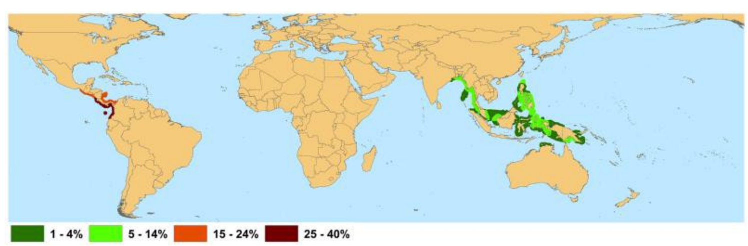

Fig 2: Proportion of threatened (Critically Endangered, Endangered, and Vulnerable) mangrove species. Image Credit: Beth Polidoro

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The Cost of Mangrove Species Loss

The loss of individual mangroves species and associated ecosystem services has direct economic consequences for human livelihoods, especially in regions with low mangrove species diversity and low ecosystem resilience to species loss. In the Gulf of California, for example, where there are only 4 mangrove species present (*Avicennia germinans*, *Rhizophora samoensis*, *Laguncularia racemosa*, *Conocarpus erectus*), it is estimated that one linear kilometer of the species *R. samoensis*, listed as *Near Threatened*, provides up to 1 ha of essential marine habitat and provides a median annual value of US$37,000 in the fish and blue crab fisheries. Nutrients and carbon from mangrove forests provide essential support to other near shore marine ecosystems such as coral reefs and *seagrass* areas, and enrich coastal food webs and fishery production. *Avicennia* species are dominant in inland or basin mangrove forests in many parts of the world. However, 3 of 8 (38%) species in this genus are in *Threatened or Near Threatened* categories. Loss of these species and the mangrove forests they dominate will have far reaching consequences for water quality and other near shore ecosystems in coastal communities around the globe. For example, water purification services provided by these mangrove species in the Muthurajawela Marsh, Sri Lanka are valued at more than $US 1.8 million per year. Riverine or freshwater-preferring species, such as the endangered *Heritiera fomes* and *Heritiera globosa*, buffer coastal rivers and freshwater communities from sedimentation, erosion and excess nutrients. *Heritiera globosa* is a very rare species confined to western Borneo, while *Heritiera fomes* is more widespread in south Asia, but has experienced significant declines in many parts of its range. Localized or regional loss of these coastal or fringe mangrove species reduces protection for coastal areas from storms, erosion, tidal waves, and floods with the level of protection also dependent on the quality of remaining habitat. Two of 4 (50%) fringe mangrove species present in southeastern Asia (*Sonneratia griffithii*, *Aegiceras floridum*) are listed in *Threatened or Near Threatened* categories. In other areas, such as Brazil, the Central Pacific Islands, or West Africa, fringe mangrove forests are often comprised of only one or two species. Even though these species are globally listed as *Least Concern*, local and regional loss of mangroves in these areas will have devastating impacts for coastal communities. The loss of species may indeed be of greatest economic concern in rural, high-poverty areas where subsistence communities rely on mangrove areas for fishing and for direct harvesting of mangroves for fuel, construction or other economic products. Finally it is important to note that the amount of mangrove area in some countries is increasing due to reforestation and restoration efforts. Although regeneration of degraded mangrove areas is thought to be a viable option in some areas, successful regeneration is generally only achieved by the planting of monocultures' of fast-growing species, such as *Rhizophora or Avicenna* species. Many rare and slow growing species are not replaced and many species cannot be easily replanted with success. In sum, mangrove areas may be able to be rehabilitated in some regions, but species and ecosystems cannot be effectively restored.

Fig 3: Fruits of Avicennia mangrove species are often dispersed and germinated by fruit bats. Image Credit:Tan Hooi

Fig 4: Adult flying fox (Pteropus vampyrus) from Megachiroptera guild, in roosting mode. Image Credit: Terry Whittaker

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Megachiroptera as Potential Mangrove Pollinator

Megachiroptera is one of the two suborders of mammalian order *Chiroptera* that is bats. Of the rich diversity of vertebrate fauna, bats are unique in being the only group of mammals that, like birds, have sustained flight. One of the 26 mammalian orders, the *Chiroptera* includes 1117 species of bats in rather two unequal suborders - the *Megachiroptera* (consisting 186 species of Old World fruit bats or flying fox in one family) and the *Microchiroptera* (consisting 931 species in 17 families). *Megachiroptera,* also colloquially known as *Megabats* of the order *Chiroptera,* comprises fruit bats also known as flying foxes (Figure 4 & 5). The *Megabat*, contrary to its name, is not always large: the smallest species is 6cm long and thus smaller than some *microchiroptera or microbats*. The largest reach 40cm in length and attain a wingspan of 1.7m, weighing in at up to 1.6kg. Most fruit bats have large eyes allowing them to orient themselves visually in twilight and inside caves and forests. Their sense of smell is excellent. In contrast to the *microbats*, the fruit bats do not use echolocation apart from one or two species. *Megachiroptera* are *frugivorous or nectarivorous* i.e., they eat fruits or lick nectar from flowers. Often the fruits are crushed and only the juices consumed. The teeth are adapted to bite through hard fruit skins like mangrove fruits. Large fruit bats must land to eat fruit, while the smaller species are able to hover with flapping wings in front of a flower or fruit. *Frugivorous* bats aid the distribution of plants (and therefore, forests) by carrying the fruits with them and spitting the seeds or disseminating them elsewhere. *Nectarivores* actually pollinate visited plants. They bear long tongues that are inserted deep into the flower; pollen passed to the bat is then transported to the next blossom visited, thereby pollinating it. This relationship between plants and bats is a form of *mutualism* known as *chiropterophily*.

Fig 5: Golden-capped fruit bat also known as flying fox in its roosting mode before she visits nearby mangrove forest to collect fruits hence help pollinating mangrove species. Image Credit: Daniel Heuclin

***Megachiroptera* as Mangrove Pollinator**

Megachiroptera comprising flying foxes or fruit bats are animals of extraordinary ecological and economic importance throughout forests of the Old World tropics. Nearly 200 species play an essential role as mangrove pollinators and seed dispersers, yet they are frequently misunderstood, intensely persecuted and exceptionally vulnerable to extinction. Their role in the propagation of numerous important mangrove plants remains virtually non-investigated. However, our review of already available literature demonstrates that at least half of the total mangrove plant species (there are roughly 54 species of true mangrove trees and plants) rely on varying degrees on large populations of flying foxes for propagation. These plants, in addition to their many ecological contribution produce some 448 economically valuable products. The fact that flying foxes are increasingly threaten and that few baseline data exist on population trends is cause for concern. Many

Fig 6: Megachiroptera; in this case a male flying fox (Pteropus vampyrus) roosting nearby mangrove stand. Image Credit: Fletcher & Baylis

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appear to be in severe decline, and several species are already extinct. Old World *phytophagous* bats (Megachiroptera: Pteropodidae) number 186 species of which 79% are Asian and 21% African. Early bats were perhaps initially attracted to mangrove flowers and fruit by the insects found around them, later finding the plants themselves nutritious. Species of *Megachiroptera* today feed upon floral resources, fruit and leaves from a total of at least 188 plant genera in 64 families. They may effect both pollination and seed-dispersal, and both *bat-flower and bat-fruit syndromes* are commonly recognized. Individual species are generally catholic in their feeding, favored food varying with locality and season. Depending upon roosting habits and season, *megabats* may travel considerable distances each night to feed and may undertake seasonal migrations. Their feeding in essentially valuable mangrove species is now seriously threatened by habitat destruction for shrimp aquaculture farming in many South and South East Asian countries. The single *Megachiropteran* family, the *Pteropodidae*, ranges from Africa, the eastern Mediterranean, Madagascar and the Indian Ocean islands in the west, across mainland southern Asia, throughout the islands of the western Pacific from the Ryukyu Archipelago and Ogasawara-shato in the north, to coastal eastern Australia, New Caledonia and the Loyalty Islands in the south, and east to Fiji, Tonga, Samoa and the Cook Islands. There are over 42 genera containing of over 186 species in *Megachiroptera*. The largest and best known genus, *Pteropus*, with 57 species, is primarily an island taxon, with 55 species (96.5%) having some or all of their distribution on islands that are mainly mangrove dominated coastal islands; for example Sunda islands of Indo-Malayan ecoregion. In this genus, levels of *endemism* are extremely high, with 35 species (61.4%) confined to single islands or small island groups. Only nine species are found in continental areas (five in Asia and four in Australia), and only two (*P. lylei and P. poliocephalus*) are restricted to continents. Below are two images, one shows the *Megachiroptera* distribution and other one shows mangrove distribution. Combined two images together, one can appreciate how closely the *Megachiroptera* distribution is fall into mangrove habitats across the globe.

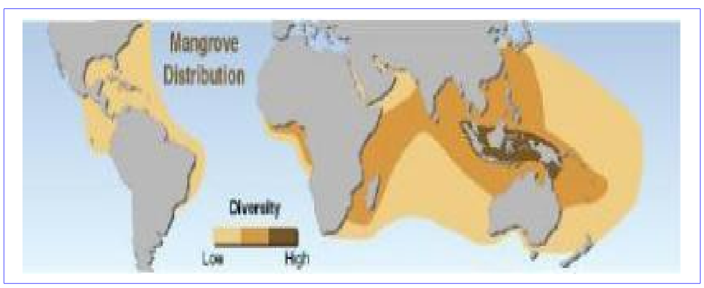

Fig 7: Global mangrove distribution from low to high species diversity. Modified from Tan Kim Hooi

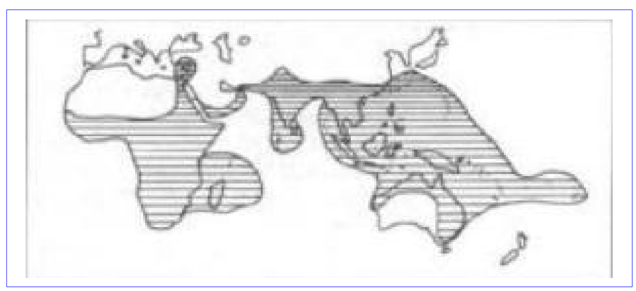

Fig 8: Global Megachiroptera (Fruit Bats) distribution that overlaps with mangrove distribution in the figure 3. Modified from IUCN Report on Bats

There are roughly 76 mangrove species so far documented and named. The true mangrove species however are no more than 54-58 species across the tropical belt. From taxonomical standpoint, these mangrove species are unevenly distributed in approximately 20 families and 20 genera. Notably, the family *Avicenniaceae* & *Rhizophoraceae* comprise nearly half of the total mangrove species with combined total of 25 species in these two groups alone (figure 12). The most richest diversity of mangroves is in Indo-West-Pacific biogeograpic realm (figure 9 & 10) where species diversity is as high as 40-46. More so Indo-Malayan islands hold the richest mangrove diversity where *endemism* of islandic *Megachiroptera* is also relatively high and a key contributor of the mangrove pollination.

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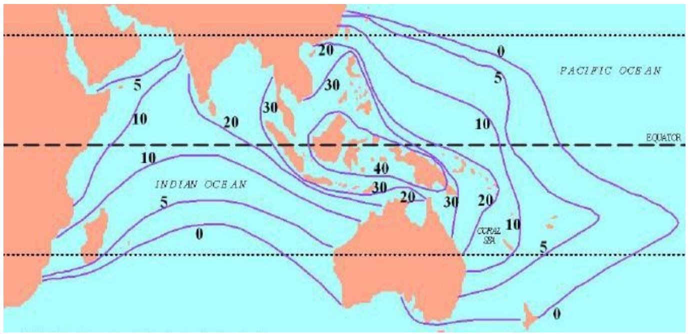

Fig 9: Mangrove diversity and richness is as high as 40 species in Indo-West-Pacific Biogeographic Realm. The curved lines represent species number boundary. Image Credit: Tan Kim Hooi

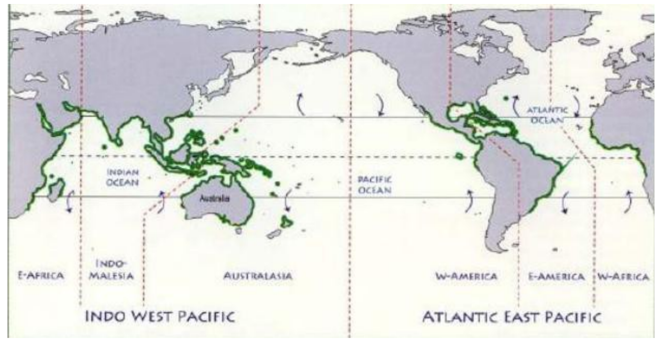

Fig 10: Global mangrove distribution curved in Green lines, Image Credit: Tan Kim Hooi

Despite lack of ecological research linking the significant correlation of mangrove pollination by species of fruit bats (flying foxes) of the *Megachiroptera* guild, it is evident that mangrove and fruit bats developed an interesting symbiotic relationship that may have far reaching conservation implications for saving mangroves and the flying foxes. Below is a polynomial function curve that shows the associated relationship between the number of mangrove species and 'fruit bat-pollinating' species in each genus. It reflects that both functions are oscillating in similar pattern in southeast Asia. The graph exemplify the fact that there is a strong correlation between various mangrove species and fruit bats of *Megachiroptera* guild that pollinates them.

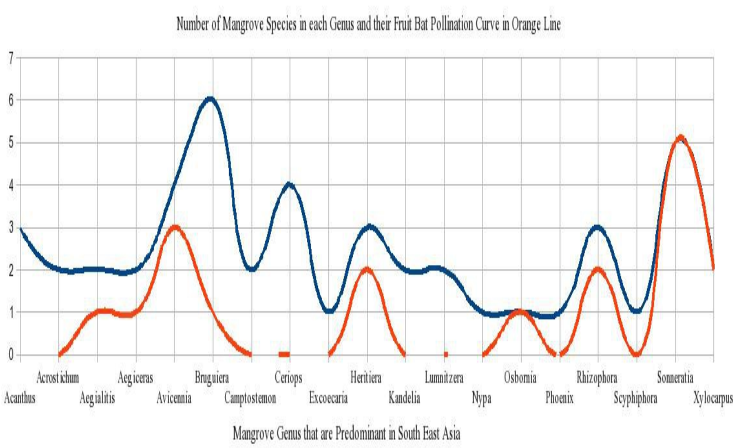

Fig 11: Synchronized polynomial functions reflect that large number of mangrove species are pollinated by fruit bats from Megachiroptera guild.

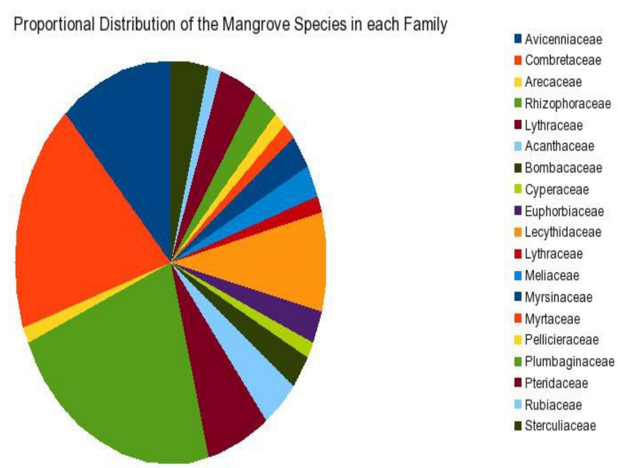

Fig 12: Proportional distribution of the mangroves in each family representing nearly half of the species are from Avicenniaceae & Rhizophoraceae guild.

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Mangrove habitat loss has been cited by a number of authors as a major factor contributing to declines in fruit bat populations. Although information on habitat requirements is limited for some species, it is evident that there is considerable ecological variation within the family in terms of their feeding habit, spatial and temporal distribution within the proximity of the flowering plants, roosting behavior and so forth. Deforestation, widespread in almost all tropical mangroves of the world, has had several identifiable consequences for fruit bat populations. Many species, particularly those inhabiting mangrove swamps (e.g. *Pteropus vampyrus* in Malaysia and Indonesia) and lowland forest, have lost critical roosting areas. Mangrove swamps are being destroyed by the shrimp aquaculture, oil/gas transnational corporate (TNC) tycoons, woodchipping industry, firewood, and coastal development. For example in the genus *Sonneratia*, all the 8 species of mangrove are pollinated by fruit bats. *Sonneratia* species (Figure 3 & 14) are economically valuable mangrove tree hence subject to anthropogenic disturbance and human persecution. The low number of *Sonneratia* in mangrove stands mean the low population size or local extinction of fruits bats in south and southeast Asia. Many of the plants that benefit from pollination or seed dispersal by bats are economically important to man. At least 100 products useful to man derive from over 70 mangrove and its associated species that rely to some degree on bats for pollination or seed dispersal. These products include timber, fruits, fiber and tannins that contribute significantly to world markets as well as less well known products, such as medicines and food items important in local economies. The increasingly popular *Heritiera littoralis* and *Heritiera globasa* depends on bats for pollination, so as *Avicennia* species: economically popular in southeast Asia. Monetary value of these species that are pollinated by fruit bats may exceed over $US 2 million annually in Indonesia. Annual sales of timber products from the mangrove genus *Heritiera* may also exceed $US 1 million in Peninsular Malaysia alone. Over 5 mangrove tree species, dependent on bats for pollination, are major timber species in Malaysia; one of the largest timber exporters in the world.

Fig 13: Large flying fox (Pteropus vampyrus) an essential mangrove pollinator and seed disperser busy collecting fruits from nearby forest. Image Credit: Ch'ien Lee

Conclusion

Tropical mangroves are the lungs of the planet. Its socio-economic, amenity, spiritual, and recreational values to human is slowly receiving steep recognition in tropical south and southeast Asia. Despite large scale shrimp aquaculture and its long term devastating impact on mangrove biota and the overall ecosystems, considerable research has been carried out to reforest the degraded land with mangrove species with mixed result. For effective and successful pollination of mangroves, science based ecological research focusing *Megachiroptera* and its conservation cannot be over emphasized. This paper is a preliminary research review in this direction. It demonstrates that mangroves and fruits bats are entwined both in terms of its ecological

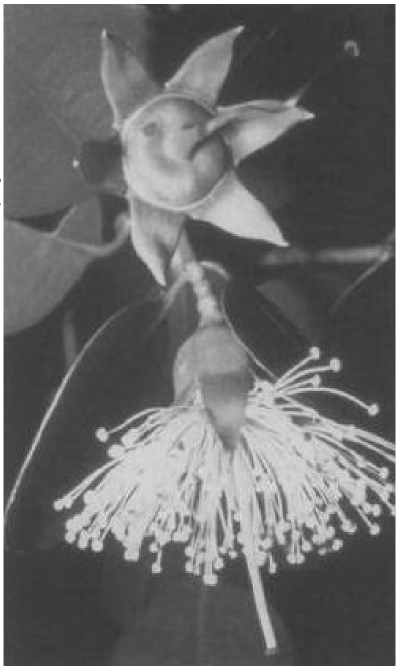

Fig 14: The flowers of Sonneratia alba, an important mangrove timber tree, are especially 'designed" to attract bats for pollination. Image Credit: W. E. Rainey.

and symbiotic niche factors. Our work also found that not many work has been carried out to understand the intricate relationship between mangroves and *Megachiroptera* hence we suggest that it is imperative to carry out basic ecological survey in mangrove ecosystem to understand the relationship of pollinating species i.e. fruit bats of mangrove that may enable resource professionals and protected area managers to devise effective conservation management plan grounded to solid science of conservation biology that takes pollinating *Megachiroptera* into account. With some exceptions, mangrove areas and species of concern e.g. fruit bats are generally not adequately represented within protected areas. In addition to legislative actions, initiatives are needed on the part of governments, NGOs, and private individuals to acquire and protect privately-owned parcels of coastal land, especially those that contain viable populations of threatened mangrove species. National legislation and management plans are in place in some countries, but enforcement and further planning are required to protect individual species that may be locally uncommon or threatened, as well as to protect the entire mangrove areas and important ecosystem functions. *IUCN Red List* assessments for species can be regularly updated, depending on the availability of better or new data, and any subsequent changes in a species *Red List Category* can be an important indicator of the success or failure of conservation actions. At least two mangrove species are at high risk of extinction and may disappear within the next decade if protective measures are not enforced. Although not formally assessed by *IUCN Red List Categories and Criteria*, hybrid mangrove species that are also pollinated by fruit bats face the same threats and provide ecosystem services equivalent to true mangrove species. Their conservation should not be overlooked, especially as they are important for *speciation* and can be significant drivers of diversification over time. We maintain that the loss of individual species will not only contribute to the rapid loss of biodiversity especially species from *Megachriopteran* guild, but will also negatively impact human livelihoods and ecosystem function, especially in areas with low species diversity and/or high area loss.

References

Barbier EB, Koch EW, Silliman BR, Hacker SD, Wolanski E, et al. (2008) Coastal ecosystem based management with non-linear ecological functions and values. Science 319: 321–323.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, et al. (1997) The value of the world's ecosystem services and natural capital. Nature 387: 253–260.

Das S, Vincent JR (2009) Mangroves protected villages and reduce death toll during Indian super cyclone. Proc Nat Acad Sci 106: 7357–7360

Dahdouh-Guebas F, Jayatissa LP, Di Nitto D, Bosire JO, Lo Seen D, et al. (2005) How effective were mangroves as a defence against the recent tsunami? Curr Biol 15: 443–447.

Duke NC, Meynecke JO, Dittmann S, Ellison AM, Anger K, et al. (2007) A world without mangroves. Science 317: 41.

Ellison AM, Bank MS, Clinton BD, Colburn EA, Elliott K, et al. (2005) Loss of foundation species: consequences for the structure and dynamics of forested ecosystems. Front Ecol Environ 3: 479–486.

Ellison AM (2008) Managing mangroves with benthic biodiversity in mind: moving beyond roving banditry. J Sea Res 59: 2–15.

Ewel KC, Twilley RR, Ong JE (1998) Different kinds of mangrove forests provide different goods and services. Global Ecol Biogeog Let 7: 83–94.

Field CB, Osborn JG, Hoffman LL, Polsenberg JF, Ackerly DD, et al. (1998) Mangrove biodiversity and ecosystem function. Global Ecol Biogeog Let 7: 3–14.

Fosberg FR (1971) Mangroves vs. tidal waves. Biol Conserv 4: 38–39.

Kathiresan K, Bingham BL (2001) Biology of mangroves and mangrove ecosystems. Advances Mar Biol 40: 81–251.

Luther D, Greenburg R (2009) Mangroves: a global perspective on the evolution and conservation of their terrestrial vertebrates. Bioscience 59: 602–612.

Millenium Ecosystem Assessment (2005) Ecosystems and human well-being: Synthesis. Washington DC: Island Press. 137 p.

Mumby PJ, Edwards AJ, Arias-Gonzalez JE, Lindeman KC, Blackwell PG, et al. (2004) Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427: 533–536.

Ong JE (1993) Mangroves – a carbon source and sink. Chemosphere 27: 1097–1107.

Robertson AI, Duke NC (1987) Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. Mar Biol 96: 193–205.

Walters BB, Rönnbäck P, Kovacs JM, Crona B, Hussain SA, et al. (2008) Ethnobiology, socio-economics and management of mangrove forests: a review. Aquatic Bot 89: 220–236.

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