Fauna Diversity in Tropical Rainforest: Threats from Land-Use Change

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Abstract

Tropical rainforests are the cradle of life (perfect conditions for life) on Earth, i.e., rich in plant species composition (>250 plant species/hectare) and fauna diversity (>50% of animal species in the world). Rainforests occur near the Earth’s equator and cover 6% of the Earth’s surface across the tropical regions and are characterized by wet climate, i.e., heavy rainfall (125—660 cm), relative humidity (77—88%) and temperature (20—34°C). They are dominated by a wide range of broad-leaved trees that form dense canopy and the most complex ecosystem. Currently, the tropical rainforest ecosystem is changing faster than ever in human history due to anthropogenic activities, such as habitat loss and degradation due to deforestation for timber and conversion into agricultural fields (oil palm plantation), mining, fire, climate change, etc. The habitat loss and degradation had adversely influenced the distribution and richness of the fauna species. The current information on the fauna diversity of tropical rainforest is not sufficient and in the future, more research is required to document the various community parameters of the fauna species in order to conserve and protect them. For better future, conservation, and management, we must identify the major drivers of changes and how these factors alter the tropical rainforest.

Keywords: fauna, diversity, rainforest, landscape, vegetation

1. Introduction

Tropical rainforest usually occurs 10° north and south of the equator, where climate conditions are unique such as humid, warm, and wet. The monthly mean temperature is 18°C and the annual rainfall is not less than 168 cm. Tropical rainforest occurs in four main regions; Central
and South America, Central and West Africa, Indo-Malaya and Australia [1]. They are store-
houses of a range of food resources for a wide variety of fauna species as well as for human
beings, raw material for buildings, and medicines [2, 3] and affect the climate [4, 5].

1.1. Ecological importance of tropical rainforest

Tropical rainforests are the most diverse in the vegetation structure and composition (Figure 1)
that supported a diversity of fauna species such as birds, reptiles, mammals, amphibians, and
invertebrates, which directly or indirectly depend on them for their survival and existence.
They are rich in habitat diversity and provide a variety of resources for the avian species, such
as food, habitat, and shelter [6]. Tropical rainforest is vital ecosystem, i.e., it provide crucial
ecosystem services such as raw materials, reservoirs of biodiversity, soil protection, sources of
timber, medicinal plants, carbon sequestration, and watershed protection [7–9].

1.2. Threats to tropical rainforest

Tropical rainforest covers less than 10% of the land area of the Earth, representing the largest
biological diversity reservoir, i.e., >50% of known plant species grow in tropical rainforest.
Despite being rich in fauna diversity, every year, huge areas of tropical rainforests are being
lost and degraded due to human interference [10–15]. It has been stated that 25–50% of the
world’s tropical rainforest has been lost and degraded due to the land-use change such as

![Figure 1. Aesthetic view of tropical rainforest.](image-url)
deforestation for palm oil plantations, agriculture expansion, cattle ranches, mining, and
development of housing societies [16–19], while the rest of the rainforest areas is under a major shift in the dynamic structure and productivity.

It has been reported that Southeast Asia had the highest rate of land-use change (such as deforestation of tropical rainforest for conversion into oil palm plantation, commercial logging for timber and development of human settlement) as compared to other regions [12, 20–22]. Deforestation and fragmentation due to agriculture expansion, human settlement, logging, and fire had altered the plant species composition, richness, and diversity [23–26]. Deforestation and fragmentation, over-exploitation, invasive species, and climate change are the major factors due to which the biodiversity of tropical forest had declined at an alarming rate. For example, some of the fauna species became extinct, while others became threatened and vulnerable due to habitat loss, fragmentation, and degradation.

Changes in the vegetation structure and composition due to deforestation and fragmentation may alter the habitat suitability and food productivity. Habitat suitability, i.e., vegetation structure, species composition, species richness, canopy layers, and food productivity are key drivers, which predominantly influence fauna community parameters such as species composition, relative abundance, species richness, species diversity, and the density of tropical rainforest. Furthermore, it has been stated that the deforestation in humid tropic may be in the range of 4.9–5.7 million ha/year. Likewise, each year, 2.3 million ha of humid forests had been degraded due to logging and fire activities. Similarly, around 2.2 million ha/year tropical moist deciduous and 0.7 million ha/year tropical dry forest has been deforested due to anthropogenic activities [27].

Deforestation may cause habitat loss and fragmentation that adversely affect the population and the community parameters such as species composition, relative abundance, species richness, species diversity, and density of different wildlife species [28–30]. However, the effect of habitat loss and fragmentation on the wildlife species may vary depending on remaining vegetation and the surrounded landscape [31, 32].

Land-use change such as deforestation, i.e., depletion of tree crown cover due to conversion of forested areas in agricultural fields, human settlements, excessive logging, and road constructions are major factors of habitat loss and degradation [10, 33, 34]. The habitat loss and degradation are responsible for biodiversity loss [35], low production of food, and habitat fragmentation [27, 36, 37] that ultimately affects different fauna species. Due to deforestation, large areas become isolated, i.e., temporal refuge, which serves as corridors for different wildlife species, especially bird species [38–40].

1.3. Floral composition

Tropical rainforests are the most rich tree species forest on the Earth and encompasses of broad-leaved trees with large buttress, and covered with climbers, epiphytes, and hemi-epiphytes. They have multi-layered canopy, i.e., upper, middle, and dense understory vegetation composition and are rich in diversity of flora and fauna, especially birds, mammals, reptiles, amphibians, and invertebrates [41–44]. Tropical rainforest is blessed with an enormous variety
of flora species. The vegetation species composition of rainforests encompasses of four distinct layers of trees, namely; emergent, upper canopy, understory, and forest floor.

1.3.1. Emergent vegetation layer
Emergent or sunlit layer is dominated by broad-leaved, hardwood and evergreen. The trees may attain the height from 30.48 to 76.2 m and a trunk size up to 4.48 m around. The winds and sunlight are major environmental factors, which play a significant role (such as pollination and seed dispersal) in the tropical rainforest management ecosystem. The emergent layer is rich in the fauna species, such as birds (hummingbirds, macaw, harpy eagle, etc.), mammals (i.e., monkeys, bats, etc.), snakes, and insects such as butterflies, moths, etc. The birds and insects play a crucial role in the pollination of tropical rainforest plant species. The microclimate of this layer often fluctuates from time to time depending upon temperature and wind speed.

1.3.2. Canopy layer
The canopy is the main layer of tropical rainforest ecosystems, which is thick and dense like an umbrella. This layer is composed of a variety of vegetation structures and tree species composition such as philodendron, *strychnos toxifera*, rattan palms, etc. The trees may grow up to 18.29—27.42 m above the forest floor. Epiphytes such as orchids, mosses, ferns, and lichens are a common feature of this layer, which grow on tree trunks and branches. The canopy layer is rich in food diversity and an ideal habitat for a wide range of fauna species such as birds, mammals, reptiles, amphibians, and diversity of insect species. The members of fauna species are often observed flying, jumping, gliding, and hoping for canopy gaps.

1.3.3. Understory layer
The understory layer encompasses usually small trees, shrubs, ferns, and native bananas, which may attain 3.66 m height. Mosses, fungi, and algae often grow on the trees. This layer is rich in insects, such as bees, stick insects, ants, beetles, and butterflies, which serve as sources of food for a wide array of birds and reptiles. The fauna species encompass bats, monkeys, snakes, lizards, jaguars, frogs, and invertebrates.

1.3.4. Forest floor
This is the bottom layer of tropical rainforest. This layer is dark due to dense ground vegetation and only 2% of sunlight reaches the floor. Due to less availability of sunlight, only few plant species can grow. This layer is rich in organic matter such as fallen leaves, seeds, fruits, and branches. Furthermore, this layer is rich in fungi and mosses. The fauna species of the forest floor include elephants, tigers, pumas, leopards, jaguars, ocelots, mongoose, tapirs, cassowaries, okapis, armadillos, pigs, and gorillas.

1.4. Environmental services provided by fauna in tropical rainforest
Faunas are the important component of the tropical rainforest ecosystem and provide a wide array of environmental services such as; they keep tropical rainforest systems in balance
through pollinating a variety of plant species, dispersing seeds, controlling pest population and reducing the damage caused by different pest species, scavenging carcasses, and recycling nutrients back into the soil.

2. Fauna composition

Fauna species are not only confined to specific habitats but also utilize various habitats in search of food, shelter, and reproduction. Tropical rainforest is rich in fauna species such as birds, reptiles, mammals, amphibians, and invertebrates.

2.1. Bird species composition of tropical rainforest

Birds are highly motile animals, i.e., they may fly to different areas in search of food, shelter, and for breeding purposes. They are ecologically diverse and had occupied a wide array of habitats. Bird species depend on the vegetation structure and composition (such as trees, shrubs, and herbs) and food resources for their survival and reproduction [45, 46]. They are the functional group of tropical rainforest ecosystems as seed dispersers, pollinators, top predators, pest control, and scavengers [47–50].

Birds are conspicuous and an important component of tropical rainforest ecosystems, often exhibit distinction associated with vegetation structure and composition (Figures 2–4; Table 1). They are sensitive to habitat alteration and landscape modification [51–54]. This might be because the vegetation structure and composition may influence habitat selection and foraging efficiency of all birds. For example, large trees and ground dense herbaceous vegetation layers often harbor a higher avian abundance and diversity. This might be because old growth stands provide suitable nesting and breeding sites, plenty of food resources, and also provide

![Asian paradise flycatcher — Terpsiphone paradisi.](image)

**Figure 2.** Asian paradise flycatcher — *Terpsiphone paradisi.*
protection from predators and harsh weather [55, 56]. Likewise, ground vegetation also offers ideal habitat and safe breeding sites and shelter for different fauna species residing in dense ground cover vegetation, such as birds, mammals, reptiles, and amphibians. It has been illustrated that height and density of the tree [57], dense understory vegetation [58, 59], and logs and snags [60] are key elements, which affect avian distribution, richness, and diversity in tropical rainforest.

Habitat alteration due to land change use may alter the avian community parameters such as relative abundance, species richness, species diversity, and density [65]. This might be that bird community structure strongly associated with canopy openness and understory vegetation...
| Family          | Scientific name | Common name            | Habitat                                         | Authors |
|-----------------|-----------------|------------------------|-------------------------------------------------|---------|
| Acanthizidae    | Gerygone chrysogaster | Yellow-bellied Gerygone | Lowland tropical rainforest (Papua New Guinea)   | [61]    |
|                 | Gerygone magnirostris | Large-billed Gerygone  | Tropical Rainforest (Australia)                  | [62]    |
|                 | Gerygone sulphurea | Golden-bellied Gerygone | Tropical Rainforest (Malaysia)                   | [63]    |
|                 | Acipiter virgatus | Besra                   | Tropical Rainforest (India)                      | [64]    |
| Accipitridae    | Haliastur indus  | Brahminy Kite           | Lowland tropical rainforest (Papua New Guinea)   | [61]    |
|                 | Harpyopsis novaeguineae | Papuan Harpy Eagle     | Lowland tropical rainforest (Papua New Guinea)   | [61]    |
|                 | Henicopernis longicauda | Long-billed Buzzard    | Lowland tropical rainforest (Papua New Guinea)   | [61]    |
|                 | Accipiter virgatus | Besra                   | Lowland tropical rainforest (Papua New Guinea)   | [61]    |
|                 | Spilornis cheela  | Crested Serpent Eagle  | Lowland tropical rainforest (Papua New Guinea)   | [61]    |
| Alcedinidae     | Aegithina viridissima | Green Heron            | Green forrest                                    | [6]     |
|                 | Alcedo atra     | Blue-banded Kingfisher | Blue-banded Kingfisher                           | [6]     |
|                 | Alcedo cyanenwelt | Blue-eared Kingfisher  | Blue-eared Kingfisher                            | [6]     |
|                 | Alcedo affinis  | Rufous-backed Kingfisher| Rufous-backed Kingfisher                         | [6]     |
|                 | Alcedo arass    | Common Kingfisher       | Common Kingfisher                                | [6]     |
|                 | Alcedo pusio    | Azure Kingfisher        | Azure Kingfisher                                 | [61]    |
|                 | Alcedo azara    | Blue-banded Kingfisher  | Blue-banded Kingfisher                           | [6]     |
|                 | Alcedo ursinus  | Hook-billed Kingfisher  | Hook-billed Kingfisher                           | [61]    |
|                 | Alcedo everest  | Little Kingfisher       | Little Kingfisher                                | [61]    |
|                 | Alcedo rufus    | Variable Dwarf Kingfisher| Variable Dwarf Kingfisher                        | [61]    |
|                 | Alcedo phoenicurus | Common Paradise Kingfisher | Common Paradise Kingfisher                     | [61]    |
|                 | Alcedo pusio    | Azure Kingfisher        | Azure Kingfisher                                 | [6]     |
|                 | Ceyx rufidorsa  | Rufous-backed Kingfisher| Rufous-backed Kingfisher                         | [6]     |
|                 | Ceyx erithaca   | Oriental Dwarf Kingfisher| Oriental Dwarf Kingfisher                        | [61]    |
|                 | Ceyx lepidus    | White-capped Swiftlet   | White-capped Swiftlet                            | [61]    |
|                 | Peltops blainvillii | Lowland Peltops       | Lowland Peltops                                  | [61]    |

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|-------------------|----------------------|----------------------|-----------------------------------------------------------|----------|
| Bucerotidae       | *Rhyticeros plicatus* | Papuan Hornbill      | Lowland tropical rainforest (Papua New Guinea)            | [61]     |
| Bucerotidae       | *Ocyceros griseus*   | Malabar Grey Hornbill| Tropical Rainforest (India)                               | [64]     |
| Cacatuidae        | *Cacatua galerita*   | Sulphur-crested Cockatoo | Lowland tropical rainforest (Papua New Guinea), Tropical Rainforest (Australia) | [61, 62] |
| Campephagidae     | *Hemipus hirundinaceus* | Black-winged Flycatcher Shrike | Hill dipterocarp tropical rainforest (Malaysia) | [65]     |
|                   | *Boyer's cuckoo-shrike* | Boyer's Cuckoo-shrike | Lowland tropical rainforest (Papua New Guinea)            | [61]     |
|                   | *Campechera sloetii* | Golden Cuckoo-shrike | Lowland tropical rainforest (Papua New Guinea)            | [61]     |
|                   | *Coracina melas*     | New Guinea Cuckoo-shrike | Lowland tropical rainforest (Papua New Guinea)            | [61]     |
|                   | *Coracina novaehollandiae* | Black-faced Cuckoo-shrike | Lowland tropical rainforest (Papua New Guinea)            | [61]     |
|                   | *Coracina papuensis* | White-bellied Cuckoo-Shrike | Lowland tropical rainforest (Papua New Guinea)            | [61]     |
|                   | *Lalage leucomela*   | Varied Triller       | Lowland tropical rainforest (Papua New Guinea), Tropical Rainforest (Australia) | [61, 62] |
|                   | *Hemipus picatus*    | Bar-winged Flycatcher-shrike | Tropical Rainforest (India)                              | [64]     |
|                   | *Pericrocotus flammeus* | Scarlet Minivet      | Tropical Rainforest (India)                               | [64]     |
|                   | *Caprimulgus macrurus* | Large-tailed Nightjar | Lowland tropical rainforest (Papua New Guinea)            | [61]     |
| Casuariidae       | *Casuarius unappendiculatus* | Northern Cassowary   | Lowland tropical rainforest (Papua New Guinea)            | [61]     |
| Chloropseidae     | *Chloropsis cochin chinensis* | Blue-winged Leafbird | Hill dipterocarp tropical rainforest (Malaysia) | [6]      |
|                   | *Chloropsis cyanogon* | Lesser Green Leafbird | Hill dipterocarp tropical rainforest (Malaysia)          | [6]      |
|                   | *Chloropsis aurifrons* | Gold-fronted Leafbird | Tropical Rainforest (India)                               | [64]     |
| Cisticolidae      | *Prinia rufescens*   | Rufescent Prinia      | Hill dipterocarp tropical rainforest (Malaysia)          | [65]     |
|                   | *Orthotomus atrogularis* | Dark-necked Tailorbird | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
|                   | *Orthotomus sericeus* | Rufous-tailed Tailorbird | Tropical Rainforest (Malaysia)                           | [63]     |
|                   | *Orthotomus sutorius* | Common Tailorbird     | Tropical Rainforest (Malaysia)                            | [63]     |
| Colluricinclidae  | *Colluricinclia megarhyncha* | Little Shrike-thrush | Lowland tropical rainforest (Papua New Guinea)           | [61]     |
|                   | *Colluricinclia boweri* | Bower's Shrike-thrush | Tropical Rainforest (Australia)                          | [62]     |
| Family       | Scientific name | Common name            | Habitat                                           | Authors |
|--------------|-----------------|------------------------|---------------------------------------------------|---------|
| Columbidae   | *Ducula pinon*  | Pinon Imperial Pigeon  | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Ducula rufigaster* | Purple Tailed Imperial Pigeon | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Ducula zoae*   | Zoe Imperial Pigeon    | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Macropygia amboinensis* | Brown Cuckoo-dove   | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Ptilinopus coronulatus* | Coronated Fruit Dove  | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Ptilinopus iozonus* | Orange-bellied Fruit Dove | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Ptilinopus perlatus* | Pink-spotted Fruit Dove | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Ptilinopus pulchellus* | Beautiful Fruit Dove  | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Ptilinopus superbus* | Superb Fruit-dove     | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Reinwardtina reinwardtii* | Great Cuckoo-dove   | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Ptilinopus magnificus* | Wompoo Fruit Dove     | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Chalcophaps indica* | Emerald Dove           | Tropical Rainforest (Australia), Isolated Tropical Rainforest (Malaysia) | [6, 62] |
|              | *Ducula badia*   | Mountain Imperial Pigeon | Tropical Rainforest (India)                      | [64]    |
|              | *Geopelia striata* | Zebra Dove             | Tropical Rainforest (Malaysia)                   | [63]    |
|              | *Goura chinensis* | Spotted Dove           | Tropical Rainforest (Malaysia)                   | [63]    |
| Coraciidae   | *Eurystomus orientalis* | Common Dollarbird    | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
| Corvidae     | *Platylophus galericulatus* | Crested Jay           | Hill dipterocarp tropical rainforest (Malaysia)  | [64]    |
|              | *Corvus tristis* | Bare-eyed Crow        | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Dendrocitta leucogaster* | White-bellied Treepie | Tropical Rainforest (India)                      | [64]    |
| Cuculidae    | *Cacomantis merulinus* | Plaintive Cuckoo      | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
|              | *Cacomantis variolus* | Brush Cuckoo          | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Centropus bernsteini* | Lesser Black Coucal   | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
|              | *Centropus melboki* | Greater Black Coucal  | Lowland tropical rainforest (Papua New Guinea)    | [61]    |
| Family       | Scientific name                  | Common name               | Habitat                                                               | Authors |
|--------------|----------------------------------|---------------------------|-----------------------------------------------------------------------|---------|
|              | Centropus phasianinus            | Pheasant Coucal           | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Chrysococcyx lucidus             | Shining Bronze Cuckoo     | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Eudynamys scolopaceus            | Common Koel               | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Probosciger aterrimus            | Palm Cockatoo             | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Scythrops novaehollandiae        | Channel-billed Cuckoo     | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Chrysococcyx minutillus          | Little Bronze-Cuckoo      | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Cacomantis sonneratii            | Banded Bay Cuckoo         | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Cuculus micropterus              | Indian Cuckoo             | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Surniculus lugubris              | Drongo Cuckoo             | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Dendrocolaptidae                 | Campylorhamphus pusillus  | Brown-billed Scythebill                                              | [65]    |
|              |                                  | Xiphorhynchus guttatus    | Buff-throated Woodcreeper                                            | [65]    |
|              | Dicaeidae                        | Prionochilus percussus    | Crimson-breasted Flowerpecker                                         | [6]     |
|              |                                  | Dicaeum tringustigma      | Orange-bellied Flowerpecker                                           | [6, 63] |
|              | Dicaeapis gelvinkianum           | Red-capped Flowerpecker   | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Dicaeum hirundinaceum            | Mistletoebird             | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Dicaeum concolor                 | Nilgiri Flowerpecker      | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Prionochilus maculatus           | Yellow-breasted Flowerpecker| Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|              | Dicruridae                       | Cheatorhynchus papuensis  | Pygmy Drongo                                                          | [61]    |
|              |                                  | Dicrurus bracteatus       | Spangled Drongo                                                       | [61]    |
|              |                                  | Dicrurus aeneus           | Bronzed Drongo                                                        | [61]    |
|              |                                  | Dicrurus paradiseus       | Greater Racket-tailed Drongo                                          | [61]    |
|              |                                  | Dicrurus annectans        | Crow-billed Drongo                                                   | [63]    |
|              |                                  | Dicrurus remifer          | Lesser Racket-tailed Drongo                                           | [63]    |
| Family          | Scientific name            | Common name             | Habitat                                      | Authors |
|-----------------|---------------------------|-------------------------|----------------------------------------------|---------|
| Estrildidae     | *Lonchura leucogastra*    | White-bellied Munia     | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                 | *Lonchura kelaarti*       | Black-throated Munia    | Tropical Rainforest (India)                  | [64]    |
| Eurylaimidae    | *Calyptomena viridis*     | Green Broadbill         | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                 | *Cymbirhynchus macrorhynchos* | Black-and-red Broadbill | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                 | *Eurylaimus javanicus*    | Banded Broadbill        | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                 | *Corydon sumatranus*     | Dusky Broadbill         | Tropical Rainforest (Malaysia)               | [63]    |
| Falconidae      | *Microhierax fringillarius* | Black-thighed Falconet | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                 | *Herpetotheres cachinnans* | Laughing Falcon         | Tropical forest (Costa Rica)                 | [65]    |
| Formicariidae   | *Thamnophilus bridgesi*  | Black-hooded Antshrike  | Tropical forest (Costa Rica)                 | [65]    |
| Furnariidae     | *Automolus ochrolaemus*   | Buff-throated Foliage-gleaner | Tropical forest (Costa Rica)                 | [65]    |
| Halcyonidae     | *Lacedo pulchella*        | Banded Kingfisher       | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                 | *Todiramphus sanctus*     | Sacred Kingfisher       | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Dacelo gaudichaud*       | Rufous-bellied Kookaburra | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Syma torotoro*           | Yellow-billed Kingfisher | Lowland tropical rainforest (Papua New Guinea) | [61]    |
| Hirundinidae    | *Hirundo tahitica*        | Pacific Swallow         | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Hirundo rustica*         | Barn Swallow            | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
| Icteridae       | *Cacicus uropygialis*     | Scarlet-rumped Cacique  | Tropical forest (Costa Rica)                 | [65]    |
|                 | *Psarocolius wagleri*     | Chestnut-headed Oropendola | Tropical forest (Costa Rica)                 | [65]    |
| Irenidae        | *Irena puella*            | Asian Fairy-bluebird    | Tropical Rainforest (India),                 | [6, 64] |
|                 |                           |                         | Hill dipterocarp tropical rainforest (Malaysia) |         |
| Laniidae        | *Lanius cristatus*        | Brown Shrike            | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                 | *Lanius tigrinus*         | Tiger Shrike            | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
| Leiotherichidae | *Garrulax jerdoni*        | Kerala Laughingthrush   | Tropical Rainforest (India)                  | [64]    |
|                 | *Garrulax delesserti*     | Wynaad Laughingthrush   | Tropical Rainforest (India)                  | [64]    |
| Maluridae       | *Malurus amabilis*        | Lovely Fairy-wren       | Tropical Rainforest (Australia)              | [62]    |
| Family          | Scientific name   | Common name             | Habitat                                      | Authors |
|-----------------|-------------------|-------------------------|----------------------------------------------|---------|
| Megalaimidae    | *Megalaima rubricapilla* | Crimson-fronted Barbet | Tropical Rainforest (India)                  | [64]    |
|                 | *Talegalla jobiensis* | Brown-collared Brush Turkey | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Megalopius reinwardt* | Orange-footed Scrubfowl | Tropical Rainforest (Australia)               | [62]    |
| Melanocharitidae | *Melanocharis nigra*   | Black Berryecker         | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Oedistoma biolophus* | Plumed Longbill          | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Toxorhamphus novaeguineae* | Yellow-bellied Longbill | Lowland tropical rainforest (Papua New Guinea) | [61]    |
| Meliphagidae    | *Meliphaga analoga*   | Mimic Honeyeater         | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Meliphaga montana*   | White-marked Forest Honeyeater | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Philemon meyeri*     | Meyer’s Friarbird        | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Xanthotis flaviventer* | Tawny-breasted Honeyeater | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Philemon buceroides* | Helmed Friarbird         | Lowland tropical rainforest (Papua New Guinea), Tropical Rainforest (Australia) | [61, 62] |
|                 | *Meliphaga notata*    | Yellow-spotted Honeyeater | Tropical Rainforest (Australia)               | [62]    |
|                 | *Myzomela obscura*    | Dusky Honeyeater         | Tropical Rainforest (Australia)               | [62]    |
|                 | *Xanthotis macleayana* | Madeley’s Honeyeater     | Tropical Rainforest (Australia)               | [62]    |
|                 | *Meliphaga gracilis*  | Graceful Honeyeater      | Tropical Rainforest (Australia), Isolated Tropical Rainforest (Malaysia) | [62, 63] |
| Meropidae       | *Merops viridis*      | Blue-throated Bee-eater  | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                 | *Merops ornatus*      | Rainbow Bee-eater        | Tropical Rainforest (Australia), Lowland tropical rainforest (Papua New Guinea) | [61, 62] |
| Monarchidae     | *Hypothymis azurea*   | Black-naped Monarch      | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia), | [6, 63] |
|                 | *Terpsiphone paradisi* | Asian Paradise Flycatcher | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 62] |
|                 | *Arses telescopthalmus* | Frilled Monarch          | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Machaerirhynchus flaviventer* | Yellow-breasted Boatbill | Lowland tropical rainforest (Papua New Guinea) | [61]    |
|                 | *Monacha chrysomela*  | Golden Monarch           | Lowland tropical rainforest (Papua New Guinea) | [61]    |
| Family          | Scientific name | Common name               | Habitat                                                      | Authors |
|-----------------|-----------------|---------------------------|--------------------------------------------------------------|---------|
| Monarchidae     | Monarcha guttula| Spot-winged Monarch       | Lowland tropical rainforest (Papua New Guinea)               | [61]    |
| Monarchidae     | Monarcha manadensis| Hooded Monarch            | Lowland tropical rainforest (Papua New Guinea)               | [61]    |
| Monarchidae     | Monarcha rubiensis| Rufous Monarch            | Lowland tropical rainforest (Papua New Guinea)               | [61]    |
| Monarchidae     | Myiagra alecto  | Shining Flycatcher         | Lowland tropical rainforest (Papua New Guinea)               | [61]    |
| Monarchidae     | Arsès kaupi     | Pied Monarch              | Tropical Rainforest (Australia)                              | [62]    |
| Monarchidae     | Monarcha leucotis| White-eared Monarch       | Tropical Rainforest (Australia)                              | [62]    |
| Monarchidae     | Monarcha trivirgatus| Spectacled Monarch       | Tropical Rainforest (Australia)                              | [62]    |
| Muscicapidae    | Ficedula nigrofusa| Black-and-Orange Flycatcher| Tropical Rainforest (India)                                 | [64]    |
| Muscicapidae    | Muscicapa sibirica| Dark-sided Flycatcher     | Tropical Rainforest (Malaysia)                               | [63]    |
| Philentoma      | Philentoma pyropterus| Chestnut-winged Flycatcher| Tropical Rainforest (Malaysia)                               | [63]    |
| Enicurus        | Enicurus ruficapillus| Chestnut-naped Forktail  | Hill dipterocarp tropical rainforest (Malaysia)              | [6]     |
| Eumyias         | Eumyias thalæsinus| Verditer Flycatcher       | Hill dipterocarp tropical rainforest (Malaysia)              | [6]     |
| Ficedula        | Ficedula munginaki| Mugimaki Flycatcher       | Hill dipterocarp tropical rainforest (Malaysia)              | [6]     |
| Ficedula        | Ficedula zanthopygia| Yellow-rumped Flycatcher | Hill dipterocarp tropical rainforest (Malaysia)              | [6]     |
| Muscicapa       | Muscicapa davurica| Asian Brown Flycatcher    | Hill dipterocarp tropical rainforest (Malaysia)              | [6]     |
| Muscicapa       | Muscicapa hodosonii| Pygmy Blue Flycatcher     | Hill dipterocarp tropical rainforest (Malaysia)              | [6]     |
| Philentoma      | Philentoma pyroptera| Rufous-winged Philentoma  | Hill dipterocarp tropical rainforest (Malaysia)              | [6]     |
| Rhinonyiasus    | Rhinonyiasus umbratilis| Grey-chested Jungle Flycatcher| Hill dipterocarp tropical rainforest (Malaysia)              | [6]     |
| Copsychus       | Copsychus malabaricus| White-rumped Shama        | Hill dipterocarp tropical rainforest (Malaysia), Isolated   | [6, 63] |
| Microeca        | Microeca flavovirescens| Olive-yellow Flycatcher  | Lowland tropical rainforest (Papua New Guinea)               | [61]    |
| Brachypteryx     | Brachypteryx major| White-bellied Robbin     | Tropical Rainforest (India)                                  | [64]    |
| Cyornis         | Cyornis pallipes| White-bellied Blue Flycatcher| Tropical Rainforest (India)                                  | [64]    |
| Eumyias         | Eumyias albinuchatus| Nilgiri Flycatcher        | Tropical Rainforest (India)                                  | [64]    |
| Myophonus       | Myophonus horsfieldii| Malabar Whistling Thrush | Tropical Rainforest (India)                                  | [64]    |
| Family       | Scientific name       | Common name             | Habitat                                    | Authors  |
|--------------|-----------------------|-------------------------|--------------------------------------------|----------|
| Culicicapa   | ceylonensis           | Grey-headed Canary Flycatcher | Tropical Rainforest (India),                | [63, 64] |
|              |                       |                         | Isolated Tropical Rainforest (Malaysia)    |          |
| Ficedula     | elisae                | Green-backed Flycatcher  | Tropical Rainforest (Malaysia)             | [63]     |
| Muscicapa    | dauurica              | Asian Brown Flycatcher   | Tropical Rainforest (Malaysia)             | [63]     |
| Nectarinidae |                       |                         |                                             |          |
| Nectarinia   | minima                | Crimson-backed Sunbird  | Tropical Rainforest (India)                | [64]     |
| Arachnothera | magna                 | Streaked Spiderhunter   | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
| Arachnothera | modesta               | Grey-breasted Spiderhunter | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
| Anthreptes   | simplex               | Plain Sunbird           | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
| Arachnothera | flavigaster           | Spectacled Spiderhunter | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
| Arachnothera | longirostra           | Little Spiderhunter     | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
| Cinnyris     | jugularis             | Olive-backed Sunbird    | Lowland tropical rainforest (Papua New Guinea) | [61]     |
| Nectarinia   | jugularis             | Yellow-bellied Sunbird  | Tropical Rainforest (Australia)             | [62]     |
| Nectarinia   | lotenia               | Loten’s Sunbird         | Tropical Rainforest (India)                | [64]     |
| Hypogramma   | hypogrammicum         | Purple-naped Sunbird    | Tropical Rainforest (Malaysia)             | [63]     |
| Oriolidae    |                       |                         |                                             |          |
| Oriolus      | xanthomelas           | Dark-throated Oriole    | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
| Oriolus      | szalayi               | Brown Oriole            | Lowland tropical rainforest (Papua New Guinea) | [61]     |
| Pitohui      | kirhocephalus         | Variable Pitohui        | Lowland tropical rainforest (Papua New Guinea) | [61]     |
| Oriolus      | flavicinctus          | Yellow Oriole           | Tropical Rainforest (Australia)             | [62]     |
| Oriolus      | chinensis             | Black-naped Oriole      | Tropical Rainforest (Malaysia)             | [63]     |
| Pachycephalidae | hyperythra         | Rusty-breasted Whistler | Lowland tropical rainforest (Papua New Guinea) | [61]     |
| Pachycephala | simplex               | Grey Whistler           | Lowland tropical rainforest (Papua New Guinea) | [61]     |
| Pitohui      | ferrugineus           | Rusty Pitohui           | Lowland tropical rainforest (Papua New Guinea) | [61]     |
| Family         | Scientific name       | Common name                     | Habitat                                         | Authors |
|---------------|-----------------------|---------------------------------|------------------------------------------------|---------|
| Paradisaeidae | *Cicinnurus regius*   | King Bird of Paradise           | Lowland tropical rainforest (Papua New Guinea)  | [61]    |
|               | *Paradisaea minor*    | Lesser BOP                      | Lowland tropical rainforest (Papua New Guinea)  | [61]    |
| Pardalotidae  | *Crateroscelis murina*| Rusty Mouse Warbler             | Lowland tropical rainforest (Papua New Guinea)  | [61]    |
| Paridae       | *Parus xanthogenys*   | Himalayan Black-lored Tit       | Tropical Rainforest (India)                     | [64]    |
| Parulidae     | *Dendroica virens*    | Black-throated Green Warbler    | Tropical forest (Costa Rica)                    | [65]    |
|               | *Oporornis formosus*  | Kentucky Warbler                | Tropical forest (Costa Rica)                    | [65]    |
|               | *Setophaga ruticilla* | American Redstart               | Tropical forest (Costa Rica)                    | [65]    |
|               | *Vermivora chrysoptera* | Golden-winged Warbler          | Tropical forest (Costa Rica)                    | [65]    |
|               | *Wilsonia pusilla*    | Wilson's Warbler                | Tropical forest (Costa Rica)                    | [65]    |
| Pellorneidae  | *Alcippe poioicephala*| Brown-cheeked Fulvetta          | Tropical Rainforest (India)                     | [64]    |
|               | *Alcippe brunnea*     | Brown Fulvetta                  | Tropical Rainforest (Malaysia)                  | [63]    |
| Petroicidae   | *Poecilodryas hypoleuca* | Black-sided Robin            | Lowland tropical rainforest (Papua New Guinea)  | [61]    |
|               | *Microeca flavigaster*| Lemon-bellied Flycatcher        | Tropical Rainforest (Australia)                 | [62]    |
|               | *Tregellasia capito*  | Pale-yellow Robin               | Tropical Rainforest (Australia)                 | [62]    |
| Phasianidae   | *Galoperdix spaticea* | Red Spurfowl                    | Tropical Rainforest (India)                     | [64]    |
|               | *Gallus sonneratii*   | Grey Junglefowl                 | Tropical Rainforest (India)                     | [64]    |
|               | *Gallus gallus*       | Red Junglefowl                  | Tropical Rainforest (Malaysia)                  | [63]    |
| Phylloscopidae| *Phylloscopus borealis* | Arctic Warbler                 | Tropical Rainforest (Malaysia)                  | [63]    |
| Picidae       | *Sasia abnormis*      | Rufous Piculet                  | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|               | *Blythipicus rubiginosus* | Maroon Woodpecker          | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
|               | *Meiglyptes tukki*    | Buff-necked Woodpecker          | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
|               | *Picus mentalis*      | Checker-throated Woodpecker     | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
|               | *Picus miniaceus*     | Banded Woodpecker               | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
| Family      | Scientific name         | Common name                  | Habitat                                                                 | Authors |
|------------|-------------------------|------------------------------|------------------------------------------------------------------------|---------|
| Pipridae   | Corapipo leucorrhoa     | White-bibbed Manakin        | Tropical forest (Costa Rica)                                          | [65]    |
|            | Manacus auranticus      | Orange-collard Manakin      | Tropical forest (Costa Rica)                                          | [65]    |
| Pittidae   | Pitta guajana           | Banded Pitta                | Hill dipterocarp tropical rainforest (Malaysia)                       | [6]     |
|            | Pitta erythrogaster     | Red-bellied Pitta           | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|            | Pitta sordida           | Hooded Pitta                | Tropical Rainforest (Malaysia)                                        | [63]    |
| Podargidae | Batrachostomus stellatus| Gould’s Frogmouth           | Hill dipterocarp tropical rainforest (Malaysia)                       | [6]     |
| Psittaculida| Loriculus  | Black Capped Lori          | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|            | vernalis                | Vernal Hanging Parrot       | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|            | Eclectus roratus        | Eclectus Parrot             | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|            | Geoffroyus geoffroyi    | Red-cheeked Parrot          | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|            | Geoffroyus simplex      | Blue-collared Parrot        | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
|            | Micropsitta pusio       | Buff-faced Pygmy Parrot     | Lowland tropical rainforest (Papua New Guinea)                        | [61]    |
| Family          | Scientific name          | Common name               | Habitat                                                                 | Authors |
|-----------------|--------------------------|---------------------------|-------------------------------------------------------------------------|---------|
|                | *Pseudeos fuscata*       | Dusky Lory               | Lowland tropical rainforest (Papua New Guinea)                          | [61]    |
|                | *Psittaculirostris edwardsii* | Edward’s Fig Parrot     | Lowland tropical rainforest (Papua New Guinea)                          | [61]    |
|                | *Cyclopsitta diophthalma* | Double-eyed Fig-parrot   | Tropical Rainforest (Australia)                                         | [62]    |
|                | *Trichoglossus haematodus* | Rainbow Lorikeet         | Tropical Rainforest (Australia), Lowland tropical rainforest (Papua New Guinea) | [61, 62] |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psophodidae*            |                           |                                                                         |         |
|                | *Psophodes olivaceus*    | Eastern Whipbird         | Lowland tropical rainforest (Papua New Guinea)                          | [62]    |
|                | *Psittacula edwardsii*   | Blue-winged Parakeet     | Tropical Rainforest (India)                                             | [64]    |
|                | *Psittacula cyanecephala* | Plum-headed Parakeet     | Tropical Rainforest (India)                                             | [64]    |
| Family          | Scientific name        | Common name            | Habitat                                                      | Authors |
|-----------------|------------------------|------------------------|--------------------------------------------------------------|---------|
| Tricholestes criniger | Hairy-backed Bulbul | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
| Hypsipetes leucocephalus | Black Bulbul | Tropical Rainforest (India) | [64] |
| Iole indica     | Yellow-browed Bulbul   | Tropical Rainforest (India) | [64] |
| Pycnonotus jocosus | Red-whiskered Bulbul  | Tropical Rainforest (India) | [64] |
| Pycnonotus melanicterus | Black-capped Bulbul | Tropical Rainforest (India) | [64] |
| Pycnonotus pricephalides | Grey-headed Bulbul | Tropical Rainforest (India) | [64] |
| Alophoixus finschii | Finsch's Bulbul   | Tropical Rainforest (India) | [64] |
| Pycnonotus atriceps | Black-headed Bulbul  | Tropical Rainforest (India) | [63] |
| Pycnonotus goiavier | Yellow-vented Bulbul | Tropical Rainforest (India) | [63] |
| Ramphastidae    | Caloramphus fuliginosus | Brown Barbet          | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
| Pteroglossus frantzii | Fiery-billed Aracari | Tropical forest (Costa Rica) | [65] |
| Rhipiduridae    | Rhipidura rufifrons   | Northern Fantail       | Lowland tropical rainforest (Papua New Guinea) | [61]    |
| Rhipidura threnothorax | Sooty Thicket Fantail | Lowland tropical rainforest (Papua New Guinea) | [61]    |
| Rhipidura fuliginosa | Grey Fantail      | Tropical Rainforest (Australia) | [62]    |
| Rhipidura rufifrons | Rufous Fantail   | Tropical Rainforest (Australia) | [62]    |
| Rhipidura javanica | Pied Fantail      | Tropical Rainforest (Malaysia) | [63]    |
| Rhipidura perlata | Spotted Fantail    | Hill dipterocarp tropical rainforest (Malaysia) | [65]    |
| Rhipidura leucomelas | White-bellied Thicket-Fantail | Lowland tropical rainforest (Papua New Guinea) | [61]    |
| Sittidae        | Sitta frontalis      | Velvet-fronted Nuthatch | Tropical Rainforest (India) | [64]    |
| Strigidae       | Otus rufescens       | Reddish Scope Owl     | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
| Sturnidae       | Apalos cantoroides   | Singing Starling       | Lowland tropical rainforest (Papua New Guinea) | [61]    |
| Mino dumontii   | Yellow Faced Myna    | Lowland tropical rainforest (Papua New Guinea) | [61]    |
| Family            | Scientific name  | Common name             | Habitat                                    | Authors |
|-------------------|------------------|-------------------------|--------------------------------------------|---------|
| Thraupidae        | Malacocincla sepiaria | Horsfield’s Babbler | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                   | Malacopteron affine | Sooty-capped Babbler  | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                   | Pellorneum capistratum | Black-capped Babbler | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                   | Tephrodornithidae | Chestnut-rumped Babbler | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                   | Malacoptron magnirostre | Moustached Babbler | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |
|                   | Malacoptron magnum | Rufous-crowned Babbler | Hill dipterocarp tropical rainforest (Malaysia) | [6]     |

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| Family         | Scientific name            | Common name                  | Habitat                                                                 | Authors  |
|----------------|----------------------------|------------------------------|-------------------------------------------------------------------------|----------|
|                | *Stachyris nigricollis*    | Black-throated Babbler       | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63] |
|                | *Garritornis isidorei*     | Isidore’s Rufous Babbler     | Lowland tropical rainforest (Papua New Guinea)                         | [61]     |
|                | *Ptilorrhoa caerulescens*  | Blue Jewel-babbler           | Lowland tropical rainforest (Papua New Guinea)                         | [61]     |
|                | *Megalaima viridis*        | White-cheeked Barbet         | Tropical Rainforest (India)                                            | [64]     |
|                | *Pellorneum ruficeps*      | Puff-throated Babbler        | Tropical Rainforest (India)                                            | [64]     |
|                | *Pomatorhinus horsfieldii* | Indian Scimitar Babbler      | Tropical Rainforest (India)                                            | [64]     |
|                | *Rhopocichla atriceps*     | Dark-fronted Babbler         | Tropical Rainforest (India)                                            | [64]     |
|                | *Turdoides subrufus*       | Rufous Babbler               | Tropical Rainforest (India)                                            | [64]     |
|                | *Pellorneum capistratum*   | Black-capped Babbler         | Tropical Rainforest (Malaysia)                                         | [63]     |
|                | *Napothera epikoikota*     | Eyebrowed Wren-babbler       | Tropical Rainforest (Malaysia)                                         | [63]     |
|                | *Stachyris erythroptera*   | Chestnut-winged Babbler      | Tropical Rainforest (Malaysia)                                         | [63]     |
|                | *Yuhina zantholeuca*       | White-bellied Yuhina         | Tropical Rainforest (Malaysia)                                         | [63]     |
|                | *Pachyramphus aglaiae*     | Rose-throated Becard         | Tropical forest (Costa Rica)                                           | [65]     |
|                | *Campylopterus hemileucurus* | Violet Sabrewing            | Tropical forest (Costa Rica)                                           | [65]     |
|                | *Phaethornis guy*          | Green Hermit                 | Tropical forest (Costa Rica)                                           | [65]     |
|                | *Phaethornis longuemarca*  | Little Hermit                | Tropical forest (Costa Rica)                                           | [65]     |
|                | *Tityra rufalbus*          | Rufous-and-white Wren        | Tropical forest (Costa Rica)                                           | [65]     |
|                | *Harpactes diardi*         | Diard’s Trogon               | Hill dipterocarp tropical rainforest (Malaysia)                       | [6]      |
|                | *Harpactes ornithocephus*  | Cinnamon-rumped Trogon       | Hill dipterocarp tropical rainforest (Malaysia)                       | [6]      |
|                | *Trogon bairdi*            | Baird’s Trogon               | Tropical forest (Costa Rica)                                           | [65]     |
|                | *Harpactes fasciatus*      | Malabar Trogon               | Tropical Rainforest (India)                                            | [64]     |
|                | *Capsylius saularis*       | Oriental Magpie Robin        |                                                                         | [6, 63]  |
| Family          | Scientific name       | Common name          | Habitat                                                | Authors   |
|-----------------|-----------------------|----------------------|--------------------------------------------------------|-----------|
|                 | *Luscinia cyane*      | Siberian Blue Robin  | Hill dipterocarp tropical rainforest (Malaysia), Isolated Tropical Rainforest (Malaysia) | [6, 63]   |
| Turdus merula   |                       | Common Blackbird     | Tropical Rainforest (India)                            | [64]      |
| Zoothera citrina|                       | Orange-headed Thrush | Tropical Rainforest (India)                            | [64]      |
| Vireonidae      | *Hylophilus decurtatus*| Lesser Greenlet      | Tropical forest (Costa Rica)                           | [65]      |
|                 | *Vireo flavifrons*    | Yellow-throated Vireo| Tropical forest (Costa Rica)                           | [65]      |
|                 | *Vireolanius pulchellus*| Green Shrike-vireo  | Tropical forest (Costa Rica)                           | [65]      |
| Zosteropidae    | *Zosterops lateralis* | Silvereye            | Tropical Rainforest (Australia)                        | [62]      |
|                 | *Zosterops palpebrosus* | Oriental White-eye  | Tropical Rainforest (India), Isolated Tropical Rainforest (Malaysia) | [63, 64] |

Table 1. List of bird species that occur in tropical rainforest.
cover. Forest logging [66–68], habitat degradation and fragmentation [69], slash-and-burn agriculture [61], and fires are major factors, which had adversely affected the population of the avian species in different forest ecosystems [51]. These factors altered the vegetation structure and composition, which affects the avian richness and diversity by affecting the food resources, increased nest predation and brood parasitism. The diversity and richness of food resources are closely associated with the vegetation structure and composition, such as foliage, flowers, fruits, and barks. Furthermore, large-scale logging for valuable timber harvesting,

Figure 5. Bornean pygmy elephant—*Elephas maximus borneensis*.

Figure 6. Sambar deer—*Rusa unicolor*. 
| Family         | Scientific name          | Common name                  | Habitat                        | Authors |
|---------------|--------------------------|------------------------------|--------------------------------|---------|
| Emballonuridae| Saccopteryx bilineata    | Greater Sac-winged Bat       | Tropical Rainforest (Mexico)   | [73]    |
|               | Diclidurus virgo         | White Bat                    | Tropical Rainforest (Mexico)   | [73]    |
| Mormoopidae   | Pteronotus davyi         | Davy's Naked-backed Bat      | Tropical Rainforest (Mexico)   | [73]    |
|               | Mormoops megalophylla    | Ghost-faced Bat              | Tropical Rainforest (Mexico)   | [73]    |
|               | Pteronotus parnellii     | Parnell's Mustached Bat       | Tropical Rainforest (Mexico)   | [73]    |
| Muridae       | Rattus annandalei        | Annandale's Rat              | Primary Rainforest (Malaysia)  | [74]    |
|               | Niviventer fulvescens    | Chestnut White-bellied Rat    | Primary Rainforest (Malaysia)  | [74]    |
|               | Niviventer cremoriventer | Dark-tailed Tree Rat          | Primary Rainforest (Malaysia)  | [74]    |
|               | Leopoldamys edwardsi     | Edwards's Long-tailed Giant Rat | Primary Rainforest (Indonesia) | [75]    |
|               | Lenothrix canus          | Gray Tree Rat                | Primary Rainforest (Malaysia)  | [74]    |
|               | Leopoldamys sabanus      | Long-tailed Giant Rat         | Primary Rainforest (Malaysia), | [74, 75]|
|               |                          |                              | Tropical Rainforest (Indonesia)|         |
|               | Niviventer rapi          | Long-tailed Mountain Rat      | Tropical Rainforest (Indonesia)| [75]    |
|               | Rattus titanicus         | Malayan Field Rat            | Primary Rainforest (Malaysia)  | [74]    |
|               | Sundamys muelleri        | Muller's Giant Sunda Rat      | Primary Rainforest (Malaysia), | [74, 75]|
|               |                          |                              | Tropical Rainforest (Indonesia)|         |
|               | Maxomys rajah            | Rajah Spiny Rat              | Primary Rainforest (Malaysia), | [74, 75]|
|               |                          |                              | Tropical Rainforest (Indonesia)|         |
|               | Maxomys surifer          | Red Spiny Rat                | Primary Rainforest (Malaysia)  | [74]    |
|               | Maxomys whiteheadi       | Whitehead’s Spiny Rat         | Primary Rainforest (Malaysia), | [74, 75]|
|               |                          |                              | Tropical Rainforest (Indonesia)|         |
| Natalidae     | Natalus stramineus       | Mexican Funnel-eared Bat      | Tropical Rainforest (Mexico)   | [73]    |
| Phyllostomidae| Desmodus rotundus        | Common Vampire Bat            | Tropical Rainforest (Mexico)   | [73]    |
|               | Choeroniscus godmani     | Godman’s Long-tailed Bat      | Tropical Rainforest (Mexico)   | [73]    |
|               | Mimon bennettii          | Golden Bat                   | Tropical Rainforest (Mexico)   | [73]    |
| Family | Scientific name | Common name | Habitat | Authors |
|--------|----------------|-------------|---------|---------|
|        | *Artibeus lituratus* | Great Fruit-eating Bats | Tropical Rainforest (Mexico) | [73] |
|        | *Chiroderma villosum* | Hairy Big-eyed Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Platyrrhinus helleri* | Heller’s Broad-nosed Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Sturnira ludovici* | Highland Yellow-shouldered Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Artibeus jamaicensis* | Jamaican Fruit-eating Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Vampyressa pusilla* | Little Yellow-eared Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Leptonycteris sanborni* | Long-nosed Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Lampronycteris brachyotis* | Orange-throated Big-eared Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Phyllostomus discolor* | Pale Spear-nosed Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Glossophaga soricina* | Pallas’s Long-tongued Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Artibeus phaeotis* | Pygmy Fruit-eating Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Carollia brevicauda* | Silky Short-tailed Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Vampyrodes major* | Stripe-faced Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Uroderma bilobatum* | Tent-making Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Artibeus watsoni* | Thomas’s Fruit-eating Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Artibeus toltecus* | Toltec Fruit-eating Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Hystriconycteris underwoodi* | Underwood’s Long-tongued Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Euchisthenes hartii* | Velvety Fruit-eating Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Centurio senex* | Wrinkle-faced Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Sturnira lilium* | Yellow-shouldered Bat | Tropical Rainforest (Mexico) | [73] |
|        | *Sundasciurus lowii* | Low’s Squirrel | Primary Rainforest (Malaysia) | [74] |
|        | *Callosciurus notatus* | Plantain Squirrel | Primary Rainforest (Malaysia) | [74] |
|        | *Callosciurus prevostii* | Prevost’s Squirrel | Primary Rainforest (Malaysia) | [74] |

Sciuridae
| Family          | Scientific name | Common name               | Habitat                                      | Authors |
|-----------------|-----------------|---------------------------|----------------------------------------------|---------|
| Sundasciurus tenuis |                 | Slender Squirrel          | Tropical Rainforest (Indonesia)              | [75]    |
| Lariscus insignis |                 | Three-striped Ground Squirrel | Tropical Rainforest (Indonesia)              | [75]    |
| Thyropteridae    | Thyroptera tricolor | Spix's Disk-winged Bat     | Tropical Rainforest (Mexico)                 | [73]    |
| Tupaiidae        | Tupaia glis     | Common Treeshrew           | Primary Rainforest (Malaysia), Tropical Rainforest (Indonesia) | [74, 75] |
|                 | Tupaia tana     | Large Treeshrew            | Tropical Rainforest (Indonesia)              | [75]    |
| Vespertilionidae | Antrozous sp.   | Pallid Bat                 | Tropical Rainforest (Mexico)                 | [73]    |

Table 2. List of mammal species that occur in tropical rainforest.
damage to forest, and replacement of native vegetation by exotic species [70] are the main problems, which affect the fauna species. Loss of forested areas is responsible for the loss of biodiversity.

### Table 3. List of reptile species that occur in tropical rainforest.

| Family       | Scientific name | Common name                     | Habitat                  | Authors |
|--------------|-----------------|---------------------------------|--------------------------|---------|
| Agamidae     | Gonyocephalus semperi | White-Spotted Angle head | Tropical Rainforest (Philippine) | [94]     |
| Colubridae   | Boiga dendrophilia | Mangrove Blunt-Headed Snake | Tropical Rainforest (Philippine) | [94]     |
|              | Psammodynastes pulverulentus | Dark- Spotted Mock Viper | Tropical Rainforest (Philippine) | [94]     |
|              | Oxyrhadinum leporinum | Banded Philippine Burrowing Snake | Tropical Rainforest (Philippine) | [94]     |
|              | Oligodon maculatus | Barred ShortHeaded Snake | Tropical Rainforest (Philippine) | [94]     |
|              | Calamaria gervaisii | Gervais’ Worm Snake | Tropical Rainforest (Philippine) | [94]     |
|              | Lycodon dumerili | Dumeril’s Wolf Snake | Tropical Rainforest (Philippine) | [94]     |
|              | Tropidolaemus sp. | Wagler’s Pit Viper | Tropical Rainforest (Philippine) | [94]     |
|              | Phyton reticulatus | Reticulated Phyton | Tropical Rainforest (Philippine) | [94]     |
| Gekkoniidae  | Gekko mindorensis | Mindoro Narrow-Disked Gecko | Tropical Rainforest (Philippine) | [94]     |
| Scincidae    | Sphenomorphus variegatus | Black-Spotted Sphenomorphus | Tropical Rainforest (Philippine) | [94]     |
|              | Sphenomorphus bayeri | Beyer’s Sphenomorphus | Tropical Rainforest (Philippine) | [94]     |
|              | Lipinia pulchella | Yellow-Striped Slender Tree Skink | Tropical Rainforest (Philippine) | [94]     |
|              | Eutropis multicarinata borealis | Northern Two-Striped Mabuya | Tropical Rainforest (Philippine) | [94]     |
|              | Eutropis englei | Six-Striped Mabouya | Tropical Rainforest (Philippine) | [94]     |

### 2.2. Mammal species composition of tropical rainforest

Tropical rainforest had harbored rich mammal diversity and density due to richness of plant communities and higher productivity (Figures 5 and 6; Table 2). Mammals are a versatile group of animals and a major component of the tropical rainforest ecosystem, i.e., they serve a wide range of ecosystem functions; such as pollination, seed dispersal, pest control, herb control, food source for other animals and nutrient cycling. In addition to ecological
functions, the mammals also provide a wide array of benefits to human beings, such as food, recreation, and source of income, i.e., various byproducts such as bush meat, skin, oil, musk, fur, etc. [71, 72].

Unfortunately, these rich mammal communities are facing severe threats from human activities such as over exploitation (intensive hunting), land-use change (habitat loss and degradation), and climate change [76–78]. These populations of different mammal species had declined abruptly due to change in land use, i.e., habitat fragmentation and degradation due to logging, and deforestation and habitat loss due to agriculture expansion and excessive hunting [79–83]. It has been reported that around one-fifth of mammal species in the wild are at risk of extinction due to human activities such as deforestation for agriculture expansion, logging for timber, and excessive hunting [84]. It has been stated that changes in vegetation cover may affect the richness of food resources and habitat preferences of the mammalian species [85, 86]. This could be due to fact that home range preferences of the mammal species and their population are strongly associated with the vegetation structure and composition [87].

The primates residing in a rainforest are habitat specific, some occupy large continuous forested areas such as Diademed Sifakas—*Propithecus diadema*—while others prefer fragmented forested areas such as Black Howler Monkey—*Alouatta pigra*—for their survival and reproduction [25, 88–90]. Monkeys are diet specific, they consume a variety of food resources such as fruits, seeds, flowers, leaves, arthropods, etc. [91, 92], and their diet is strongly influenced by the plant species composition and richness of the particular dwelling habitat [93].

### 2.3. Reptile species composition of tropical rainforest

Reptiles are carnivorous in nature and play a significant role in controlling various pests present in the forest, such as beetles, arthropods, caterpillars, termites, bugs, rats, mice, etc.,
| Family       | Scientific Name            | Common Name                  | Habitat                                           | Authors |
|--------------|----------------------------|------------------------------|---------------------------------------------------|---------|
| Bufonidae    | *Ingerophrynus divergens*  | Malayan Dwarf Toad           | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Ansonia muelleri*         | Mueller’s Toad               | Tropical Rainforest (Philippine)                  | [94]    |
| Dicroglossida| *Limnonectes finchi*       | Finch’s Wart Frog            | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Limnonectes ingeri*       | Inger’s Wart frog            | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Limnonectes leporinus*    | Giant River Frog             | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Limnonectes malesianus*   | Malaysian Frog               | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Occidozyga baluensis*     | Balu Oriental Frog           | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Occidozyga laevis*        | Puddle Frog                  | Lowland Tropical Rainforest (Malaysia)            | [106]   |
| Microhylidae | *Chaperina fusca*          | Brown Thorny Frog            | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Kalophrynus pleurostigma*| Black-spotted Sticky Frog    | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Kaloula baleata*          | Smooth-fingered Narrow-mouthed Frog | Lowland Tropical Rainforest (Malaysia)   | [106]   |
|              | *Metaphrynella sundana*    | Borneo Tree-hole Frog        | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Microhyla borneensis*     | Matang Narrow-mouthed Frog   | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Kalophrynus pleurostigma*| Black-spotted Narrow-mouthed Frog | Tropical Rainforest (Philippine)                  | [94]    |
| Ranidae      | *Hylarana erythraea*       | Common Green Frog            | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Hylarana glandulosa*      | Rough-sided Frog             | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Hylarana nicobariensis*   | Cricket Frog                 | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Hylarana raniceps*        | White-lipped Frog            | Lowland Tropical Rainforest (Malaysia)            | [106]   |
|              | *Staurois natator*         | Rock Frog                    | Tropical Rainforest (Philippine)                  | [94]    |
|              | *Rana grandocula*          | Big-eyed Frog                | Tropical Rainforest (Philippine)                  | [94]    |
|              | *Limnonectes magnus*       | Mindanao Fanged Frog         | Tropical Rainforest (Philippine)                  | [94]    |
|              | *Platymantis corrugata*    | Rough-backed Forest Frog     | Tropical Rainforest (Philippine)                  | [94]    |
| Family          | Scientific Name       | Common Name               | Habitat                                              | Authors |
|-----------------|-----------------------|---------------------------|------------------------------------------------------|---------|
| Rhacophoridae   | Megophrys stejnegeri  | Mindanao Horned Frog      | Tropical Rainforest (Philippine)                     | [94]    |
|                 | Nyctixalus pictus     | Cinnamon Frog             | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Polypedates colletti  | Black-spotted Tree Frog   | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Polypedates leucomystax | Common Tree Frog         | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Polypedates macrotis  | Dark-eared Tree Frog      | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Polypedates otikophus | Borneo Eared Frog         | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Rhacophorus appendiculatus | Frilled Tree Frog      | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Rhacophorus dulitensis | Jade Tree Frog           | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Rhacophorus harrissoni | Brown Tree Frog          | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Rhacophorus pardalis  | Harlequin Tree Frog       | Lowland Tropical Rainforest (Malaysia)               | [106]   |
|                 | Polypedates leucomystax | Four-lined Tree Frog   | Tropical Rainforest (Philippine)                     | [94]    |
|                 | Philautus acutirostris | Pointed-Snouted Tree Frog| Tropical Rainforest (Philippine)                     | [94]    |

Table 4. List of amphibian species that occur in tropical rainforest.
which may cause severe loss, such as defoliation, seed, and wood damage. Even though they are crucially important for tropical forest ecosystems (Table 3), they are facing critical threats from human induced factors such as land-use change (i.e., deforestation, fragmentation and degradation) that have altered the natural habitat of the reptile species that directly or indirectly depend upon tropical rainforests for their survival and reproduction.

Reptiles are highly sensitive species compared to other fauna species, i.e., they become more vulnerable due to land use change, i.e., habitat alteration [95]. This might be because they have a small home range, which is adversely affected by habitat loss and degradation [96, 97]. For example, deforestation may cause severe habitat loss, fragmentation, and degradation which adversely affect the population, community parameters of reptiles inhabiting in a tropical rainforest ecosystem [98–100].

Anthropogenic activities had altered the reptilian intact habitat through land-use change, their habitats becomes degraded and lost thus ultimately becoming unsuitable for them. This is because forested reptile prefers dense and moist habitat, which provides them shelter and rich food resources for their survival, protection, and reproduction. Deforestation may disturb their breeding sites, reduce home range, and increase visibility for predators. Likewise, fragmentation reduced their home range, while degradation reduced their food resources and breeding behavior. Furthermore, land-use changes such as deforestation, fragmentation, and degradation may alter microclimatic conditions of particular dwelling habitats such as temperature, relative humidity, rainfall, and sunlight that ultimately modify the vegetation structure and composition.

2.4. Amphibian species composition of tropical rainforest

Amphibians are cold-blooded vertebrates and are carnivorous in nature. They play a key role to control the various pests, thus balancing the nature [101]. Amphibians are a significant component of the tropical rainforest ecosystem (Figure 7; Table 4) and play an important role in pest control. Habitat loss due highest deforestation is responsible for one-third population decline of the amphibians [10, 102–104]. One-fifth amphibians of Southeast Asia are reported as threatened species [105]. This is because they have small home ranges, i.e., specific aquatic habitat, higher vulnerability to habitat change, and visibility to predators. In addition, over-harvesting from natural habitat for food supply (human consumption), medicine (traditional use), and pet trade also had exerted great pressure on the population of amphibians [104].

2.5. Invertebrate species composition of tropical rainforest

In tropical rainforests, logging creates gaps and alters the habitat structure and microclimatic conditions, e.g., temperature, relative humidity, and light [107, 108], which influence on the invertebrate diversity and distribution. After logging, new habitat with a different microclimate may develop which tend to be unsuitable for a wide array of invertebrates [109, 110]. This indicates that land-use changes influence invertebrate diversity, richness, and distribution. It has been stated that disturbing the habitat affects invertebrate colonization and distribution [111, 112]. Basset [113] reported that the canopy of tropical rain forest is rich in Coleoptera,
Hymenoptera, Lepidoptera, and Araneae taxa. However, their home range and foraging habitats may vary from species to species depending upon the types of vegetation, forest types, and bio-geographical regions.

3. Conclusion and future perspective

Even though, faunas are a crucial component of tropical rainforest ecosystems, detailed information on different aspects of fauna community parameters such as species composition, distribution, diversity, richness and population trend, impact of anthropogenic activities, associated with microclimate and habitat variables is still lacking. The current review highlighted that tropical rainforest is an ideal productive habitat for a wide array of fauna species, i.e., birds, mammals, reptiles, amphibians, and invertebrates. These fauna are a major component of the food web of the rainforest ecosystem and functions. Furthermore, it was revealed that the diversity of rainforest fauna is facing many threats that directly or indirectly affected the population; community parameters of various fauna species inhabited the tropical rainforest. There is an urgent need to study various fauna species of tropical rainforest in order to reduce the impact of human activities and for future conservation and management. We hope that the findings of this chapter will provide the ways and means to conserve the fauna in and around the tropical rainforest.

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References

[1] Hill JL, Hill RA. Why are tropical rain forests so species rich? Classifying, reviewing and evaluating theories. Progress in Physical Geography, 2001; 25(3): 326–354.
2 Lawrence A, Phillips OL, Ismodes AR, Lopez M, Rose S, Wood D, Farfan AJ. Local values for harvested forest plants in Madre de Dios, Peru: towards a more contextualized interpretation of quantitative ethnobotanical data. Biodiversity Conservation, 2005; 14: 45–79.

3 Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC. 2005.

4 Betts RA. Global vegetation and climate: self beneficial effects, climate forcing and climate feedbacks. Journal de Physique IV, 2004; 121: 37–60.

5 Delire C, Foley JA, Thompson S. Long-term variability in a coupled atmosphere-biosphere model. Journal of Climate, 2004; 17: 3947–3959.

6 Rajpar MN, Zakaria M. Assessing the effects of logging activities on avian richness and diversity in different aged post-harvested hill dipterocarp tropical rainforest of Malaysia. American Journal of Applied Sciences, 2014; 11(9): 1519–1529.

7 Foody GM, Cutler MEJ. Tree biodiversity in protected and logged Bornean tropical rain forests and its measurement by satellite remote sensing. Journal of Biogeography, 2003; 30: 1053–1066.

8 Dent DH, Wright SJ. The future of tropical species in secondary forests: a quantitative review. Biological Conservation, 2009; 142: 2833–2843.

9 Berry NJ, Phillip SL, Lewis SL, Hill JK, Edwards DP, Tawatao NB, Ahmed N, Magintan D, Ken CV, Maryati M, Ong RC, Hamer KC. The high value of logged tropical forests: lessons from northern Borneo. Biodiversity Conservation, 2010; 19: 985–997.

10 Achard F, Eva HD, Stibig H-J, Mayaux P, Gallego J, Richards T, Malingreau P. Determination of deforestation rates of the world’s humid tropical forests. Science, 2002; 297: 999–1002.

11 Curran LM, Trigg SN, McDonald AK, Astiani D, Hardiono YM, Siregar P, Caniago I, Kasischke E. Lowland forest loss in protected areas of Indonesian Borneo. Science, 2004; 303: 1000–1003.

12 Fitzherbert EB, Struiebig MJ, Morel A, Danielsen F, Bruhl CA, Donald PF, Phalan B. How will oil palm expansion affect biodiversity? Trends in Ecology & Evolution, 2008; 23: 538–545.

13 Clark CJ, Poulsen JR, Malonga R, Elkan PW. Logging concessions can extend the conservation estate for central African tropical forests. Conservation Biology, 2009; 23: 1281–1293.

14 Morris RJ. Anthropogenic impacts on tropical forest biodiversity: a network structure and ecosystem functioning perspective. Philosophical Transactions of the Royal Society of London B, 2010; 365: 3709–3718.

15 Fisher B, Edwards DP, Larsen TH, Ansell FA, Hsu WW, Roberts CS, Wilcove DS. Cost-effective conservation: calculating biodiversity and logging tradeoffs in Southeast Asia. Conservation Letters, 2011; 84: 443–450.
[16] Houghton RA. Why are estimates of the terrestrial carbon balance so different? Global Change Biology, 2003; 9: 500–509.

[17] Lewis SL, Malhi Y, Phillips OL. Finger printing the impacts of global change on tropical forests. Philosophical Transactions of the Royal Society of London B, 2004; 359: 437–462.

[18] Castelletta M, Thiollay JM, Sodhi NS. The effects of extreme forest fragmentation on the bird community of Singapore Island. Biological Conservation, 2005; 121: 135–155.

[19] Lewis LS. Tropical forests and the changing earth system. Philosophical Transactions of the Royal Society of London B, 2006; 361: 195–210.

[20] Wright SJ, Muller-Landau HC. The future of tropical forest species. Biotropica, 2006; 38: 287–301.

[21] Sodhi NS, Koh LP, Clements R, Wanger TC, Hill JK, Hamer KC, Clough Y, Tscharntke T, Posa MRC, Lee TM. Conserving Southeast Asian forest biodiversity in human-modified landscapes. Biological Conservation, 2010; 143: 2375–2384.

[22] Miettinen J, Shi C, Liew SC. Deforestation rates in insular Southeast Asia between 2000 and 2010. Global Change Biology, 2011; 17: 2261–2270.

[23] Barlow J, Peres CA. Effects of single and recurrent wildfires on fruit production and large vertebrate abundance in a central Amazonian forest. Biodiversity and Conservation, 2006; 15: 985–1012.

[24] Cristobal-Azkarate J, Arroyo-Rodriguez V. Diet and activity pattern of howler monkeys (Alouatta palliata) in Los Tuxtlas, Mexico: effects of habitat fragmentation and implications for conservation. American Journal of Primatology, 2007; 69: 1013–1029.

[25] Irwin MT. Feeding ecology of Propithecus diadema in forest fragments and continuous forest. International Journal of Primatology, 2008; 29: 95–115.

[26] Gonzalez-Zamora A, Arroyo-Rodriguez V, Chaves OM, Sanchez-Lopez S, Stoner KE, Riba-Hernandez P. Diet of spider monkeys (Ateles geoffroyi) in Mesoamerica: current knowledge and future directions. American Journal of Primatology, 2009; 71: 8–20.

[27] Mayaux P, Holmgren P, Acharf S, Eva H, Stibig H-J, Branthomme A. Tropical forests cover change in the 1990s and options for future monitoring. Philosophical Transactions of the Royal Society of London B, 2005; 360: 373–384.

[28] Chagnon FJE, Bras RL, Wang J. Climatic shift in patterns of shallow clouds over the Amazon. Geophysical Research Letters, 2004; 31.

[29] Soh MC, Sodhi NS, Lim SL. High sensitivity of montane bird communities to habitat disturbance in Peninsular Malaysia. Biological Conservation, 2006; 129: 149–166.

[30] Trainor CR. Changes in bird species composition on a remote and well-forested island, Wallacea, South-East Asia. Biological Conservation, 2007; 140: 373–385.

[31] Sodhi NS, Lee TM, Warkentin IG. Effects of disturbance or loss of tropical rainforest on birds. The Auk, 2008; 125: 511–519.
[32] Laurance WF, Camargo JLC, Luizão RCC, Laurance SG, Pimm SL, Bruna EM, Stouffer PC, Williamson GB, Benitez-Malvido J, Vasconcelos HL, Van Houtan KS, Zartman CE, Boyle SA, Didham RK, Andrade A, Lovejoy TE. The fate of Amazonian forest fragments: a 32-year investigation. Biological Conservation, 2011; 144: 56–67.

[33] Geist HJ, Lambin EF. Proximate causes and underlying driving forces of tropical deforestation. BioScience, 2002; 52: 143–150.

[34] Maas B, Putra DD, Waltertz M, Clough Y, Tscharnkte T, Schulze CH. Six years of habitat modification in a tropical rainforest margin of Indonesia do not affect bird diversity but endemic forest species. Biological Conservation, 2009; 142: 2665–2671.

[35] Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH. Global biodiversity scenarios for the year 2100. Science, 2000; 287: 1770–1774.

[36] Bagchi R, Philipson CD, Slade EM, Hector A, Phillips S, Villanueva JF, Lewis OT, Lyal CHC, Nilus R, Madran A, Scholes JD, Press MC. Impacts of logging on density-dependent predation of dipterocarp seeds in a South East Asian rainforest. Philosophical Transactions of the Royal Society of London B, 2011; 366: 3246–3255.

[37] Chaves ÓM, Stoner KE, Arroyo-Rodríguez V. Differences in diet between spider monkey groups living in forest fragments and continuous forest in Mexico. Biotropica, 2012; 44: 105–113.

[38] Fischer J, Lindenmayer DB, Manning AD. Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes. Frontiers in Ecology and the Environment, 2006; 4: 80–86.

[39] Arriaga-Weiss SL, Calmé S, Kampichler C. Bird communities in rainforest fragments: guild responses to habitat variables in Tabasco, Mexico. Biodiversity & Conservation. 2008; 17: 173–190.

[40] Höbinger T, Schindler S, Seaman BS, Wrbka T, Weissenhofer A. Impact of oil palm plantations on the structure of the agroforestry mosaic of La Gamba, southern Costa Rica: potential implications for biodiversity. Agroforestry Systems. 2012; 85: 367–381.

[41] Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca G, Kent J. Biodiversity hotspots for conservation priorities. Nature, 2000; 403: 853–858.

[42] Carmona, M, Armesto JJ, Aravena JC, Perez C. Coarse woody debris biomass in successional and primary temperate forests in Chiloe Island, Chile. Forest Ecology and Management, 2002; 164: 265–275.

[43] Aravena JC, Carmona M, Perez CC, Armesto JJ. Changes in tree species richness, stand structure and soil properties in a successional chronosequence of forest fragments in northern Chiloe Island, Chile. Revista Chilena de Historia Natural, 2002; 75: 339–360.

[44] Laurance WF, Oliveira AA, Laurance SG, Condit R, Nascimento HEM, Sanchez-Thorin AC, Lovejoy TE, Andrade A, D’Angelo S, Ribeiro JE, Dick CW. Pervasive alteration of tree communities in undisturbed Amazonian forests. Nature, 2004; 428: 171–175.
[45] Poulsen BO. Avian richness and abundance in temperate Danish forests: tree variables important to birds and their conservation. Biodiversity and Conservation, 2002; 11: 1551–1566.

[46] Nadkarni NM, Schaefer D, Matelson TJ, Solano R. Biomass and nutrient pools of canopy and terrestrial components in a primary and a secondary montane cloud forest, Costa Rica. Forest Ecology and Management, 2004; 198: 223–236.

[47] Sekercioglu CH. Increasing awareness of avian ecological function. Trends in Ecology & Evolution, 2006; 21: 464–471.

[48] Lozada T, De Koning GHJ, Marche R, Klein AM, Tscharntke T. Tree recovery and seed dispersal by birds: comparing forest, agroforestry and abandoned agroforestry in coastal Ecuador. Perspectives in Plant Ecology Evolution and Systematics, 2007; 8: 131–140.

[49] Kellermann JL, Johnson MD, Stercho AM, Hackett SC. Ecological and economic services provided by birds on Jamaican Blue Mountain coffee farms. Conservation Biology, 2008; 22: 1177–1185.

[50] Whelan CJ, Wenny DG, Marquis RJ. Ecosystem services provided by birds. Annals of the New York Academy of Sciences, 2008; 1134: 25–60.

[51] Sekercioglu CH, Ehrlich PR, Daily GC, Aygen D, Goehring D, Sandi RF. Disappearance of insectivorous birds from tropical forest fragments. Proceedings of the National Academy of Sciences of the United States of America, 2002; 99: 263–267.

[52] Raman TRS. Effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats, India. Biodiversity and Conservation, 2006; 15: 1577–1607.

[53] Gomes LGL, Oostra V, Nijman V, Cleef AM, Kappelle M. Tolerance of frugivorous birds to habitat disturbance in a tropical cloud forest. Biological Conservation, 2008; 141: 860–871.

[54] Tscharntke T, Sekercioglu CH, Dietsch TV, Sodhi NS, Hoehn P, Tylianakis JM. Landscape constraints on functional diversity of birds and insects in tropical agro-ecosystems. Ecology, 2009; 89: 944–951.

[55] Reid S, Diaz IA, Armesto JJ, Willson MF. Importance of native bamboo for understory birds in Chilean temperate forests. The Auk, 2008; 121: 515–525.

[56] Diaz IA, Armesto JJ, Reid S, Sieving KE, Willson MF. Linking forest structure and composition: avian diversity in successional forests of Chiloe Island, Chile. Biological Conservation, 2005; 123: 91–101.

[57] Munoz AA, Chacon P, Perez F, Barnet ES, Armesto JJ. Diversity and host tree preferences of vascular epiphytes and vines in a temperate rainforest in southern Chile. Austral Ecology, 2004; 51: 381–391.

[58] Sieving KE, Willson MF, De Santo TL. Defining corridors for endemic birds in fragmented south-temperate rainforest. Conservation Biology, 2000; 14: 1120–1132.
[59] Cornelius C, Cofre H, Marquet PA. Effects of habitat fragmentation on bird species in a relict temperate forest in semiarid Chile. Conservation Biology, 2000; 14: 534–543.

[60] DeSanto TL, Willson MF, Sieving KE, Armesto JJ. Nesting biology of Tapaculos (Rhinocryptidae) in fragmented south-temperate rainforests of Chile. The Condor, 2002; 104: 482–495.

[61] Tvardiková K. Bird abundances in primary and secondary growths in Papua New Guinea: a preliminary assessment. Tropical Conservation Science, 2010; 3(4): 373–388.

[62] Johnson DDP, Mighell JS. Dry-season bird diversity in tropical rainforest and surrounding habitats in North-east Australia. Emu, 1999; 99: 108–120.

[63] Zakaria M, Rajpar MN, Moridi HW, Rosli Z. Comparison of understorey bird species in relation to edge-interior gradient in an isolated tropical rainforest of Malaysia. Environment, Sustainability and Development, 2014; 16(2): 375–392.

[64] Shankar Raman TR, Joshi NV, Sukumar R. Tropical rainforest bird community structure in relation to altitude, tree species composition and null models in the Western Ghats, India. Journal of the Bombay Natural History Society, 2005; 102(2): 145–157.

[65] Hughes JB, Daily GC, Ehrlich PR. Conservation of tropical forest birds in countryside habitats. Ecology Letters, 2002; 5: 121–129.

[66] Lim HC, Sodhi NS. Responses of avian guilds to urbanization in a tropical city. Landscape Urban Planning, 2004; 66: 199–215.

[67] Fraterrigo JM, Wiens JA. Bird communities of the Colorado Rocky Mountains along a gradient of exurban development. Landscape Urban Planning, 2005; 71: 263–275.

[68] Campbell SP, Witham JW, Hunter Jr ML. Long-term effects of group selection timber harvesting on abundance of forest birds. Conservation Biology, 2007; 21: 1218–1229.

[69] White JG, Antos MJ, Fitzsimons JA, Palmer GC. Non-uniform bird assemblages in urban environments: the influence of streetscape vegetation. Landscape Urban Planning, 2004; 71:123–135.

[70] Atlegrim O, Sjoberg K. Selective felling as a potential tool for maintaining biodiversity in managed forests. Biodiversity and Conservation, 2004; 13: 1123–1133.

[71] Archabald K, Naughton-Treves L. Tourism revenue- sharing around national parks in Western Uganda: early efforts to identify and reward local communities. Environmental Conservation, 2001; 28: 135–149.

[72] Fa J, Currie D, Meeuwig J. Bushmeat and food security in the Congo Basin: linkages between wildlife and people’s future. Environmental Conservation, 2003; 30: 71–78.

[73] Estrada A, Coates-Estrada R, Meritt Jr. D. Bat species richness and abundance in tropical rainforest fragments and in agricultural habitats at Los Tuxtlas, Mexico. Ecography, 1993; 16: 309–318.
[74] Ruppert NB, Mansori A, Anuar SMS. Diversity and biomass of terrestrial small mammals at a Malaysian primary rainforest (Segari Melintang forest reserve, Peninsular Malaysia). Journal of Tropical Life Sciences, 2015; 5(1): 3–34.

[75] Boubli JP, Grelle CEV, van Schaik CP. Small mammal species diversity and composition in two ecologically distinct rain forest sites in Northern Sumatra, Indonesia. Ecotropica, 2004; 10: 149–154.

[76] Brodie JF, Gibbs H. Bushmeat hunting as climate threat. Science, 2009; 326: 364–365.

[77] Jansen P, Muller-Landau HC, Wright S. Bushmeat hunting and climate: an indirect link. Science, 2010; 327, 30.

[78] Visconti P, Pressey RL, Giorgini D, Maiorano L, Bakkenes M, Boitani L, Alkemade A, Falcucci A, Chiozza F, Rondinini C. Future hotspots of terrestrial mammal loss. Philosophical Transactions of the Royal Society of London B, 2011; 366: 2693–2702.

[79] Cardillo M, Mace GM, Jones KE, Bielby J, Bininda-Emonds ORP, Sechrest W, Orme CDL, Purvis A. Multiple causes of high extinction risk in large mammal species. Science, 2005; 309: 1239–1241.

[80] Laurance WF, Croes BM, Tchignoumba L, Lahm SA, Alonso A, Lee ME, Campbell P, Ondzeano C. Impacts of roads and hunting on Central African rain forest mammals. Conservation Biology, 2006; 20: 1251–1261.

[81] Western D, Russell S, Cuthill I. The status of wildlife in protected areas compared to non-protected areas of Kenya. PLoS One, 2009; 4: e6140.

[82] Craigie ID, Baillie JEM, Balmford A, Carbone C, Collen B, Green RE, Hutton JM. Large mammal population declines in Africa’s protected areas. Biological Conservation, 2010; 143: 2221–2228.

[83] Nijman, V. An overview of international wildlife trade from Southeast Asia. Biodiversity Conservation, 2010; 19: 1101–1114.

[84] Hoffmann M, Belant JL, Chanson JS, Cox NA, Lamoreux J, Rodrigues ASL, Schipper J, Stuart SN. The changing fates of the world’s mammals. Philosophical Transactions of the Royal Society of London B, 2011; 366: 2598–2610.

[85] Ferraz G, Russell GJ, Stouffer PC, Bierregaard RO, Pimm SL, Lovejoy TE. Rates of species loss from Amazonian forest fragments. Proceedings of the National Academy of Sciences of the United States of America, 2003; 100: 14069–14073.

[86] Kinnaird M, Sanderson E, O’Brien TG, Wibisono H, Woolmer G. Deforestation trends in a tropical landscape and implications for endangered large mammals. Conservation Biology, 2010; 17: 245–257.

[87] Henle K, Davies KE, Kleyer M, Margules C, Settele J. Predictors of species sensitivity to fragmentation. Biodiversity Conservation, 2004; 13: 207–251.
[88] Felton AM, Felton A, Wood J, Lindenmayer DB. Diet and feeding ecology of *Ateles chamek* in a Bolivian semihumid forest: the importance of *Ficus* as a staple food resource. International Journal of Primatology, 2008; 29: 379–403.

[89] Silva SSB, Ferrari SF. Behavior patterns of southern bearded sakis (*Chiropotes satanas*) in the fragmented landscape of eastern Brazilian Amazonia. American Journal of Primatology, 2009; 71: 1–7.

[90] Boyle SA, Smith AT. Behavioral modifications in northern bearded saki monkeys (*Chiropotes satanas chiropotes*) in forest fragments of central Amazonia. Primates, 2010; 51: 43–51.

[91] Palacios E, Rodriguez A. Ranging pattern and use of space in a group of red howler monkeys (*Alouatta seniculus*) in a southeastern Colombian rainforest. American Journal of Primatology, 2001; 55: 233–251.

[92] Veiga LM, Ferrari SF. Predation of arthropods by southern bearded sakis (*Chiropotes satanas*) in eastern Brazilian Amazonia. American Journal of Primatology, 2006; 68: 209–215.

[93] Boyle SA, Zartman CE, Spironello WR, Smith AT. Implications of habitat fragmentation on the diet of bearded saki monkeys in central Amazonian forest. Journal of Mammalogy, 2012; 93(4): 959–976.

[94] Rolex RE, Leano EP, Ates-Camin FB. Herpetofaunal endemism and diversity in tropical forests of MT. Hamiguitan in the Philippines. Herpetological Conservation and Biology, 2010; 6(1): 107–113.

[95] Brown GW. The influence of habitat disturbance on reptiles in a box-ironbark eucalypt forest of south-eastern Australia. Biodiversity and Conservation, 2001; 10: 161–176.

[96] Irschick DJ, Carlisle E, Elstrott J, Ramos M, Buckley C, Vanhooydonck B, Meyers J, Herrel A. A comparison of habitat use, morphology, clinging performance and escape behaviour among two divergent Green Anole Lizard (*Anolis carolinensis*) populations. Botanical Journal of the Linnean Society, 2005; 85: 223–234.

[97] Kanowski JJ, Reis TM, Catterall, CP, Piper SD. Factors affecting the use of reforested sites by reptiles in cleared rainforest landscapes in tropical and subtropical Australia. Restoration Ecology, 2006; 14: 67–76.

[98] Fahrig L. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology and Systematics, 2003; 34(1): 487–515.

[99] Rocha CFD, Bergallo HG, Van Sluys M, Alves M, Jamel C. The remnants of restinga habitats in the Brazilian Atlantic Forest of Rio de Janeiro State, Brazil: habitat loss and risk of disappearance. Brazilian Journal of Biology, 2007; 67 (2): 263–273.

[100] Rocha CFD, Vrcibradic D, Kiefer MC, Menezes VA, Fontes AF, Hatano FH, Galdino CAB, Bergallo HG, Van Sluys M. Species composition, richness and nestedness of lizard
assemblages from Restinga habitats along the Brazilian coast. Brazilian Journal of Biology, 2014; 74(2): 349–354.

[101] Rajpar MN, Zakaria M. Mangrove Fauna of Asia. In: Mangrove Ecosystems of Asia, Status, Challenges and Management Strategies Hanum, F., Mohamad, A.L., Hakeem, K. R., Ozturk, M. (Eds.). Springer Science + Business Media New York, USA. 2014; 500 p. ISBN: 978-1-4614-8581-0.

[102] Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues ASL, Fischman DL, Waller RW. Status and trends of amphibian declines and extinctions worldwide. Science, 2004; 306: 1783–1786.

[103] Rowley J, Brown R, Bain R, Kusrini M, Inger R, Stuart B, Wogan G, Thy N, Chanard T, Trung CT, Diesmos A, Iskandar DT, Lau M, Ming LT. Opinion piece; impending conservation crisis for Southeast Asian amphibians. Biology Letters, 2010; 6: 336–338.

[104] Bickford D, Iskandar DT, Barlian A. A lungless frog discovered in Borneo. Current Biology, 2008; 18: 374–375.

[105] International Union for Conservation Nature. IUCN Red List of Threatened Species, Version 2009.1. Web accessed on 1st May, 2009 at URL: www.iucnredlist.org.

[106] Gillespie GR, Ahmad E, Elahan B, Evans A, Ancrenaz M, Goossens B, Scroggie MP. Conservation of amphibians in Borneo: relative value of secondary tropical forest and non-forest habitats. Biological Conservation, 2012; 152: 136–144.

[107] Schnitzer SA, Carson WP. Treefall gaps and maintenance of species diversity in a tropical forest. Ecology, 2001; 82: 913–919.

[108] Laurance WF, Peres CA. Emerging threats to Tropical Forests. University of Chicago Press, Chicago, USA. 2005; 520 p. ISBN: 9780226470221.

[109] Ewers RM, Didham RK. Confounding factors in the detection of species responses to habitat fragmentation. Biological Reviews, 2006; 81: 117–142.

[110] Santos AB, Benitez-Malvido J. Insect herbivory and leaf disease in natural and human disturbed habitats: lesson from early-successional Heliconia herbs. Biotropica, 2012; 44: 53–62.

[111] Laurance WF, Goosem M, Laurance SG. Impacts of roads and linear clearings on tropical forests. Trends in Ecology & Evolution, 2009; 24: 659–669.

[112] Sendoya SF, Silva PSD, Farji-Brener AG. Does inundation risk affect leaf-cutting ant distribution? A study along a topographic gradient of a Costa Rican tropical wet forest. Journal of Tropical Ecology, 2013; 30(1): 82–90.

[113] Basset Y. Invertebrates in the canopy of tropical rain forests How much do we really know? Plant Ecology, 2001; 153: 87–107.
