

Article

Assessing the Fauna Diversity of Marudu Bay Mangrove Forest, Sabah, Malaysia, for Future Conservation

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Abstract: Mangrove is an evergreen, salt tolerant plant community, which grows in inter-tidal coastal zones of tropical and subtropical regions of the world. They are ecologically important for many fauna species and are rich in food resources and consist of many different vegetation structures. They serve as ideal foraging and nursery grounds for a wide array of species such as birds, mammals, reptiles, fishes and aquatic invertebrates. In spite of their crucial role, around 50% of mangrove habitats have been lost and degraded in the past two decades. The fauna diversity of mangrove habitat at Marudu Bay, Sabah, East Malaysia was examined using various methods: *i.e.* aquatic invertebrates by swap nets, fish by angling rods and cast nets, reptiles, birds, and mammals through direct sighting. The result showed that Marudu Bay mangrove habitats harbored a diversity of fauna species including 22 aquatic invertebrate species (encompassing 11 crustacean species, six mollusk species and four worm species), 36 fish species, 74 bird species, four reptile species, and four mammal species. The wide array of fauna species could be due to the availability of complex vegetation structures, sheltered beaches and tidal mudflats, which are rich in food resources and also offer safe foraging and breeding grounds for them. These heterogeneous habitats must be protected in a sustainable way in order to ensure the continued presence of aquatic and terrestrial fauna species for future generations.

Keywords: fauna; habitat; food; mangrove; Marudu Bay

1. Introduction

Mangrove is a salt tolerant plant that occurs within inter-tidal zones where a river enters into the sea, especially in the coastal belt [1,2]. They are a highly productive, tropical coastal ecosystem encompassing estuaries, creeks, lagoons, backwaters, mud-flats, salt-pans and islands which has both great aquatic and terrestrial biodiversity [3] and plays an integral role in coastal ecosystem functions at the interface between terrestrial, freshwater and marine systems [4]. Mangrove fauna are animal communities that inhabit or utilize mangrove habitats, such as coastal inter-tidal zones, estuaries and riverine areas where rivers drain into the sea, to fulfill their need for survival and reproduction [5,6]. The vegetation structure and composition of mangrove areas may vary depending upon soil texture and structure, rainfall pattern, and inflow of freshwater from rivers to the sea [7,2].

Mangrove forests are considered as a highly productive ecosystem, *i.e.*, they provide important ecological and economic services [8,9]. They play a crucial role in providing suitable habitats for fauna, safe breeding and chick rearing grounds, nurseries for a diversity of fishes and shellfishes, as well as ideal foraging grounds for animals such as fishes, birds and aquatic invertebrates and refuge from predators [10]. Mangrove habitats are consistently undervalued, degraded and are being lost at an alarming rate due to human intervention, *i.e.*, coastal development, deforestation, tin mining, urbanization, salt production, conversion into paddy fields and aquaculture ponds, over-harvesting of timber and fuel-wood, pollution, *i.e.*, dumping of domestic sewage and crude oil exploration [2,11–14].

It has been stated that around 50% of mangrove habitats has been lost and degraded in the past two decades due to human interventions [15,10]. The mangrove habitat loss and degradation have posed major threats to a wide array of fauna [16,17] bringing them among the ranks of endangered and extinct species [2,18–20].

Recently, considerable attention has been paid to mangrove fauna diversity and habitat due to their importance and functions [21]. There has been no detailed study undertaken to examine the fauna diversity in Marudu Bay mangrove forest, Sabah, Malaysia. Thus, there was an urgent need to examine the fauna diversity inhabiting mangrove habitats in order to understand the impact of disturbance for future conservation and management.

This current study was aimed at examining the fauna diversity (such as birds, mammals, reptiles, fishes and aquatic invertebrates) inhabiting or utilizing the downstream to upstream mangrove and river tributaries of Marudu Bay. The scientific baseline data obtained from the study would provide an in depth understanding of the current fauna diversity status for better future conservation and management initiatives.

2. Materials and Methods

2.1. Study Site

Marudu Bay mangrove forest is located between latitude 6°15" to 6°45" N and a longitude of 116° to 117° E, 113 km from Kota Kinabalu Sabah, Malaysia (Figure 1). The forest is still in pristine condition, *i.e.*, >90% intact, spread over several creeks and lagoons and covers an area of 9550 ha. This mangrove forest is managed, in accordance with the principles of conservation and sustainable use, by the Sabah Forest Department, Malaysia. The mangrove forest consists of 16 tree species of 12 genera and nine families, such as *Rhizophora apiculata*, *R. mucronata*, *Bruguiera parviflora*, *B. gymnorrhiza* and *Ceriops*

decandra. Marudu Bay mangrove forest is rich in fauna diversity, *i.e.*, aquatic invertebrates, fishes, birds, reptiles and mammals. This mangrove forest provides a wide range of ecosystem services such as timber, fuel-wood, fisheries, eco-tourism and nursery habitat for different animals. Marudu Bay mangrove forest is an important source of livelihood for local communities.

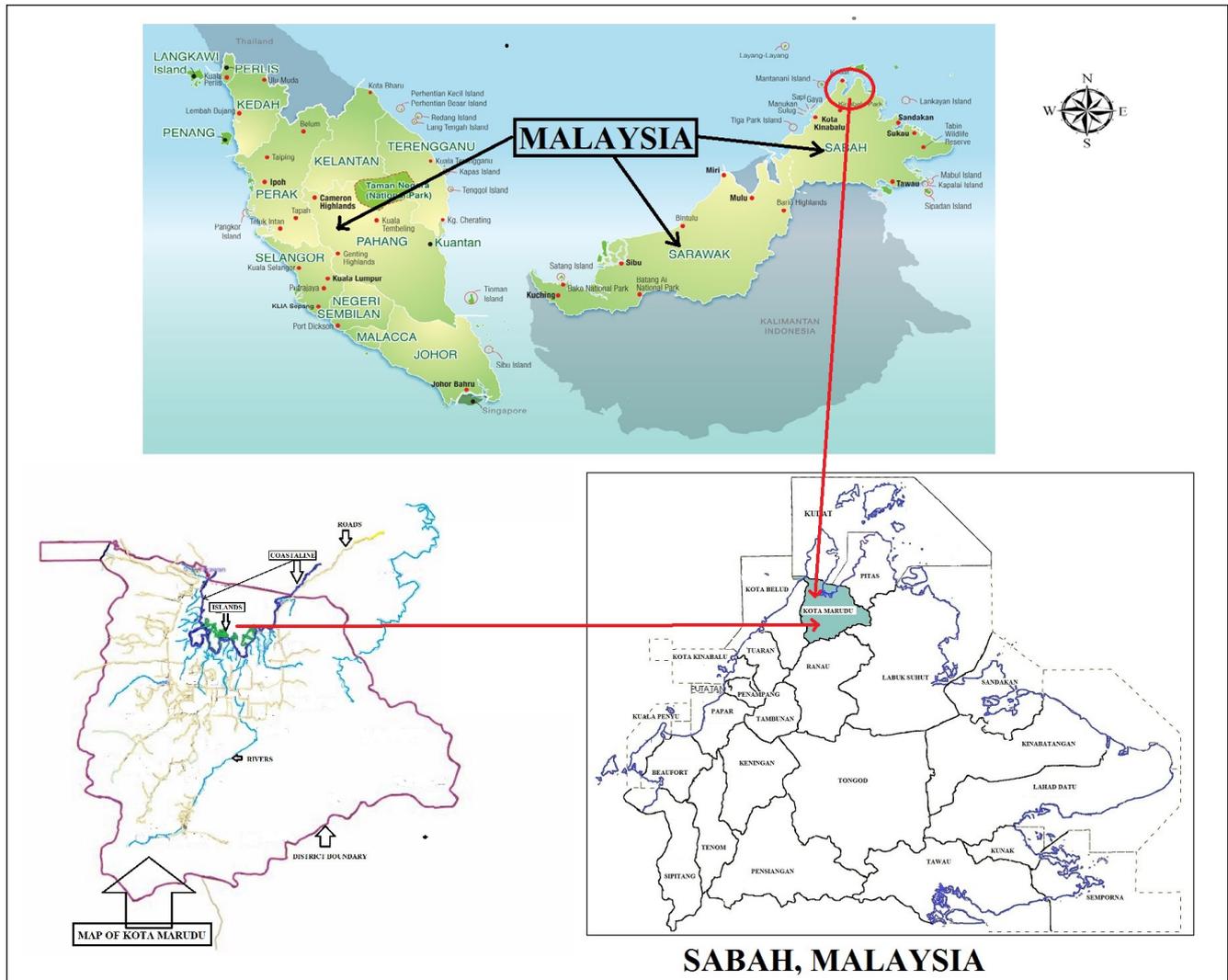


Figure 1. Location of the Marudu Bay Mangrove forest Sabah, Malaysia.

2.2. Fauna Surveys

The presence of birds, mammals, and reptiles was determined by boat using direct observation using 10×50 binoculars from 23 March to 3 April 2009, 21–27 May 2009 and 2–8 February 2010. A total of 60 point stations along the three rivers and mudflats was established randomly to cover different habitat types, *i.e.* from downstream to upstream Marudu Bay mangrove forest. The location of each point station was at intervals of 250 m apart. The main reason for locating point stations 250 m apart was to avoid double counting the same species at more than one station. This was based on the recommendation by [22] who stated this approach was suitable: (i) for dense habitats, such as forest and shrubs; (ii) to survey cryptic, shy, and skulking species; (iii) for the populations that are of higher density and are more species rich; (iv) for situations where access is restricted; and (v) particularly for bird-habitat studies.

The survey was conducted by boat along selected streams as it was the easiest way to observe the birds in the mangrove forests early in the morning (between 6:30 a.m. and 7:00 a.m. depending on weather) and to be completed before 12:00 p.m. The methodology followed was developed by [23,24].

The fish fauna were caught through angling rods and cast nets while aquatic invertebrate were collected through swap nets.

3. Results

3.1. Aquatic Invertebrate Fauna

Marudu Bay mangrove habitats were rich in aquatic invertebrate fauna (*i.e.*, 22 species), which comprised crustaceans (crabs, prawns and shrimps), mollusks (snails, clams, periwinkle, murex and oysters) and worms (lug worms, tube worms, eunicid worms and polychaete worms; Table 1).

Table 1. List of aquatic invertebrate species detected in Marudu Bay mangrove habitat.

Family Name	Common Name	Scientific Name
Crustacean Species		
Alpheidae	Mangrove Snapping Prawns	<i>Alpheus</i> sp.
Grapsidae	Mangrove Root Crab	<i>Goniopsis cruentata</i>
Limulidae	Horseshoe Mangrove Crab	<i>Tachypleus gigas</i>
Ocypodidae	Orange-clawed Fiddler Crab	<i>Uca coarctata</i>
	Orange Fiddler Crab	<i>Uca vocans</i>
	Rosy Fiddler Crab	<i>Uca rosea</i>
Penaeidae	Greasy-back Shrimp	<i>Metapenaeus ensis</i>
	Banana Prawn	<i>Penaeus merguensis</i>
Portunidae	Giant Mud Crab	<i>Scylla serrata</i>
Sesarmidae	Mangrove Tree Crab	<i>Aratus pisonii</i>
Squillidae	Silver Mantis Shrimp	<i>Harpisquilla harpax</i>
Mollusks Species		
Cerithiidae	Cerith Snail	<i>Cerithium</i> sp.
Cyrenidae	Mud Clam	<i>Polymesoda erosa</i>
Ellobiidae	Mangrove Helmet Snail	<i>Cassidula</i> sp.
Lithorinidae	Mangrove Periwinkle	<i>Littorina angulifera</i>
Muricidae	Mangrove Murex	<i>Chicoreus capuncinus</i>
Onchidiidae	Grey-footed Mangrove Onch Slug	<i>Platyvindex</i> sp.
Ostreidae	Mangrove Tree Oyster	<i>Crassostrea</i> sp.
Worm Species		
Arenicolidae	Lugworms	<i>Arenicola cristata</i>
Chaetopteridae	Parchment Tube Worm	<i>Chaetopterus</i> sp.
Eunicidae	Eunicid Worm	<i>Lysidice</i> sp.
Onuphidae	Polychaete worms	<i>Diopatra</i> sp.

3.2. Fish Fauna

Angling rods and cast nets caught a total of 36 fish species belonging to 22 families from mangrove and river tributaries of the Marudu Bay habitats. The findings highlighted that *Leiognathidae*, *Lutjanidae*

and *Sciaenidae* were three most abundant fish families based on the number of captured species (*i.e.*, each three fish species) in the study area. In contrast, 12 fish families were recorded as the rarest in the study area, *i.e.*, only one fish species was captured for each family (Table 2).

Table 2. List of fish species captured in Marudu Bay mangrove and river tributaries.

Family Name	Common Name	Scientific Name
Ambassidae	Buru Glass Perchlet	<i>Ambassis buruensis</i>
	Naked-head Glassy Perchlet	<i>Ambassis gymnocephalus</i>
Apogonidae	Hookfin Cardinalfish	<i>Apogon griffini</i>
Belonidae	Spottail Needle Fish	<i>Strongylura strongylura</i>
Carangidae	Hardtail Scad	<i>Megalaspis cordyla</i>
	Talang Queenfish	<i>Scomberoides commersonianus</i>
Chirocentridae	Whitefin Wolf herring	<i>Chirocentrus nudus</i>
Drepaneidae	Concertina Fish	<i>Drepane longimana</i>
Eleotridae	Flatheaded Sleeper	<i>Ophiocara porocephala</i>
	Tenpounder	<i>Elops machnata</i>
Engraulidae	Anchovy Fish	<i>Anchovia spp.</i>
Gerreidae	Whipfin Silver-biddy	<i>Gerres filamentosus</i>
	Silver Biddy	<i>Gerres erythrourus</i>
Gobiidae	Mangrove Goby	<i>Acentrogobius caninus</i>
	Tank Goby	<i>Glossogobius giuris</i>
Haemulidae	Saddle Grunt	<i>Pomadasys maculatus</i>
	Javelin Grunt	<i>Pomadasys kaakan</i>
Hemiramphidae	Halfbeak or Garfish	<i>Hemiramphus spp.</i>
Leiognathidae	Whipfin Ponyfish	<i>Equulites leuciscus</i>
	Spotnape Ponyfish	<i>Nuchequula nuchalis</i>
	Shortnose Ponyfish	<i>Leiognathus brevirostris</i>
Lutjanidae	Black Snapper	<i>Apsilus dentatus</i>
	One Spot Snapper	<i>Lutjanus monostigma</i>
	Mangrove Red Snapper	<i>Lutjanus argentimaculatus</i>
Megalopidae	Indo-Pacific Tarpon	<i>Megalops cyprinoides</i>
Mugilidae	Greenback Mullet	<i>Liza subviridis</i>
	Square-tail Mullet	<i>Liza vaigiensis</i>
Plotosidae	White-lipped Eel Catfish	<i>Paraplotosus albilabris</i>
Scatophagidae	Spotted Scat	<i>Scatophagus argus</i>
Sciaenidae	Goatee Croaker	<i>Dendrophysa russelii</i>
	Orange Spotted Grouper	<i>Epinephelus coioides</i>
	Cloudy Grouper Fish	<i>Epinephelus erythrurus</i>
Siganidae	Streaked Spinefoot Fish	<i>Siganus javus</i>
	Goldlined Spinefoot	<i>Siganus guttatus</i>
Terapontidae	Jarbug Terapon	<i>Terapon jarbug</i>
Trichiuridae	Large-head Hairtail	<i>Trichiurus lepturus</i>

Very few reptile species were detected during the study. The reptile fauna comprised of crocodiles, monitor lizards and skinks (Table 3).

Table 3. List of reptile species detected at Marudu Bay mangrove river tributaries.

Family Name	Common Name	Scientific Name
Crocodylidae	Crocodile	<i>Crocodylus palustris</i>
Varanidae	Mangrove Monitor Lizard	<i>Varanus indicus</i>
	Malaysian Water Monitor Lizard	<i>Varanus salvator</i>
Scincidae	Mangrove Skink	<i>Emoia atrocostata</i>

3.3. Bird Fauna

Bird fauna of downstream to upstream mangrove and river tributaries included 74 species representing 33 families. The results showed that Ardeidae (nine bird species), Scolopacidae (six species), Cuculidae and Picidae (each five species) were the four most dominant families in Marudu Bay mangrove habitats. On the contrary, 17 families, *i.e.*, Anhingidae, Apodidae, Artamidae, Campephagidae, Chloropseidae, Ciconiidae, Coraciidae, Dicaeidae, Hemiprocnidae, Hirundinidae, Muscicapidae, Pachycephalidae, Psittacidae, Rhipiduridae, Sittidae, Timaliidae, and Sternidae were the rarest in the study area (*i.e.*, only one species detected for each family). Out of all bird species, six species were endangered, one rare and one nearly threatened (Table 4).

Table 4. List of bird species detected in Marudu Bay Mangrove habitat.

Family Name	Common Name	Scientific Name
Accipitridae	Brahminy Kite	<i>Haliastur indus</i>
	White-bellied Fish-Eagle	<i>Haliaeetus leucogaster</i>
	Osprey	<i>Pandion haliaetus</i>
Alcedinidae	Stork-billed Kingfisher	<i>Pelargopsis capensis</i>
	Common Kingfisher	<i>Alcedo atthis</i>
	Collared Kingfisher	<i>Halcyon chloris</i>
	White-throated Kingfisher	<i>Halcyon smymensis</i>
Anhingidae	Oriental Darter (E)	<i>Anhinga melanogaster</i>
Apodidae	White-bellied Swiftlet	<i>Collocalia esculenta</i>
Ardeidae	Little Egret	<i>Egretta garzetta</i>
	Little Heron	<i>Butorides striatus</i>
	Great Egret	<i>Casmerodius albus</i>
	Intermediate Egret	<i>Egretta intermedia</i>
	Chinese Egret (E)	<i>Egretta eulophotes</i>
	Cattle Egret	<i>Bubulcus ibis</i>
	Schrenck's Bittern	<i>Ixobrychus eurhythmus</i>
	Yellow Bittern	<i>Ixobrychus sinensis</i>
	Rufous Night-Heron	<i>Nycticorax caledonicus</i>
Artamidae	White-breasted Wood-Swallow	<i>Artamus leucorhynchus</i>
Campephagidae	Pied Thriller	<i>Lalage nigra</i>
Charadriidae	Pacific Golden-Plover	<i>Pluvialis fulva</i>
	Little Ringed Plover	<i>Charadrius dubius</i>
	Common Ringed Plover	<i>Charadrius hiaticula</i>
Chloropseidae	Common Iora	<i>Aegithina tiphia</i>
Ciconiidae	Lesser Adjutant (E)	<i>Leptoptilos javanicus</i>

Table 4. Cont.

Family Name	Common Name	Scientific Name
Columbidae	Pink-necked Green Pigeon	<i>Treron vernans</i>
	Little Green-Pigeon	<i>Treron olax</i>
	Jambu Fruit-Dove	<i>Ptilinopus jambu</i>
Coraciidae	Dollar Bird	<i>Eurystomus orientalis</i>
Cuculidae	Black-bellied Malkoha (E)	<i>Phaenicophaeus diardi</i>
	Chestnut-bellied Malkoha (E)	<i>Phaenicophaeus sumatranus</i>
	Greater Coucal	<i>Centropus sinensis</i>
	Malayan Bronze Cuckoo	<i>Chrysococcyx minutillus</i>
	Lesser Coucal	<i>Centropus bengalensis</i>
Dicaeidae	Scarlet-backed Flowerpecker	<i>Dicaeum curentatum</i>
Estrilidae	Dusky Munia	<i>Lonchura fuscans</i>
	Black-headed Munia	<i>Lonchura articapilla</i>
Hemiprocnidae	Whiskered Treeswift	<i>Hemiprocne comata</i>
Hirundinidae	Pacific Swallow	<i>Hirundo tahitica</i>
Laniidae	Bar-winged Flycatcher-Shrike	<i>Hemipus picatus</i>
	Black-winged Flycatcher-Shrike	<i>Hemipus hirundinaceus</i>
Meropidae	Blue-tailed Bee-eater	<i>Merops philippinus</i>
	Blue-throated Bee-eater	<i>Merops viridus</i>
Muscicapidae	Mangrove Blue-Flycatcher	<i>Cyornis rufigastra</i>
Nectariniidae	Olive-backed Sunbird	<i>Nectarinia jugularis</i>
	Plain Sunbird	<i>Anthreptes simplex</i>
	Brown-throated Sunbird	<i>Anthreptes malacensis</i>
	Purple-throated Sunbird	<i>Nectarinia sperata</i>
Pachycephalidae	Mangrove Whistler	<i>Pachycephala grisola</i>
Phalacrocoracidae	Great Cormorant (R/A)	<i>Phalacrocorax carbo</i>
	Little Cormorant	<i>Phalacrocorax niger</i>
Picidae	Common Flameback	<i>Dinopium javanense</i>
	Brown-capped Woodpecker	<i>Picoides moluccensis</i>
	Speckled Piculet	<i>Picumnus innominatus</i>
	White-bellied Woodpecker	<i>Dryocopus javensis</i>
	Maroon Woodpecker	<i>Blythipicus rubiginosus</i>
Psittacidae	Blue-crowned Hanging Parrot	<i>Loriculus galgulus</i>
Rhipiduridae	Pied Fantail	<i>Rhipidura javanica</i>
Scolopacidae	Common Redshank	<i>Tringa totanus</i>
	Nordmann's Greenshank (E)	<i>Tringa guttifer</i>
	Grey-tailed Tattler (NT)	<i>Tringa brevipes</i>
	Common Sandpiper	<i>Tringa hypoleucos</i>
	Terek Sandpiper	<i>Xenus cinereus</i>
	Whimbrel	<i>Numenius phaeopus</i>
Sittidae	Velvet-fronted Nuthatch	<i>Sitta frontalis</i>
Sturnidae	Philippine Glossy Starling	<i>Aplonis panayensis</i>
	Hill Myna	<i>Gracula religiosa</i>

Table 4. Cont.

Family Name	Common Name	Scientific Name
Sylviidae	Ashy Tailorbird	<i>Orthotomus ruficeps</i>
	Common Tailorbird	<i>Orthotomus sutorius</i>
	Rufous-tailed Tailorbird	<i>Orthotomus sericeus</i>
Timaliidae	Striped Tit-Babbler	<i>Macronus gularis</i>
Turdidae	Magpie Robin	<i>Copsychus saularis</i>
	White-rumped Shama	<i>Copsychus malabaricus</i>
Sternidae	Whiskered Tern	<i>Chilodnius hybrida</i>

NT = Nearly Threatened; R/A = Rare/Accidental; E = Endangered.

3.4. Mammal Fauna

Only three mammal species belonging to three families were detected during the study period, which include monkeys, pigs and squirrels (Table 5).

Table 5. List of mammal species detected at Marudu Bay mangrove river tributaries.

Family Name	Common Name	Scientific Name
Cerocopithecidae	Long-tailed Macaque	<i>Macaca fascicularis</i>
	Dusky-leaf Monkey	<i>Trachypithecus obscurus</i>
Suidae	Wild Pigs	<i>Sus scrofa</i>
Sciuridae	Plantain Squirrel	<i>Callosciurus notatus</i>

4. Discussion

The recording of a higher diversity of avian, fish, reptile, mammal and aquatic invertebrate species illustrated that Marudu Bay mangrove and river tributary habitats had attracted a wide array of fauna species. It has been stated that mangrove habitats may harbor a wide range of animals such as birds, mammals, reptiles, fishes, and aquatic invertebrates [25–28]. The presence of a higher diversity of fauna could be due to the habitat's pristine condition (*i.e.*, no disturbance), complex vegetation structure and composition [29,30], the availability and richness of food resources such as fish, polychaetes, mollusks, crabs, and crustaceans [31–33] and low predation risk [25]. The vegetation structure and composition, occurrence of mudflat and richness of food resources are the major driving factors that influence the distribution and diversity of animals directly or indirectly. Vegetation heterogeneity abundance of food resources and habitat diversity may increase avian richness and diversity [34,35]; *i.e.* they provide suitable foraging and chick rearing grounds, and protection from harsh weather and predators [2].

The recording of a higher number of fish species illustrated that Marudu Bay mangrove areas serve as a nursery ground for various juvenile fish communities [36–40]. It may be that these areas are rich in invertebrate assemblages such as crustaceans (crabs, prawns and shrimps), mollusks (snails, clams, periwinkle, murex and oysters) and worms (lugworms, tube worms, eunicid worms and polychaete worms). In addition, the extensive root systems of mangroves create habitat heterogeneity and complexity, offering suitable foraging sites for juvenile fishes and protecting them from predators by reducing their visibility [32,33]. Habitat heterogeneity and complexity is a major factor that influences fauna diversity and distribution [6,41–43].

The sampling of a higher number of aquatic invertebrate species—*i.e.*, 22 species including crustacean, mollusk, periwinkle, murex and worm species—indicated that the Marudu Bay mangrove and river tributary habitats are rich in organic food material that created suitable habitats for them. The presence of the high diversity of invertebrates could also be due to the availability of sheltered beaches and tidal mudflats, which are rich in organic matter. It has been stated that aquatic invertebrates such as periwinkle inhabit the bottom of mudflats (periwinkle—*Tympanotonus fuscatus*, oysters—*Crassostrea* sp., mangrove crab—*Goniopsis* sp., mud crab—*Panopeus* sp., land crab—*Cardiosoma* sp.) [44]. Mangrove aquatic invertebrates are a major dietary component of birds, fishes and even other invertebrates.

The recording of sufficient numbers of threatened, nearly threatened and rare bird species such as Oriental Darter, Chinese Egret, Lesser Adjutant, Black-bellied Malkoha, Nordmann's Greenshank, and Grey-tailed Tattler shows that Marudu Bay mangrove forest is potentially vital habitat for a wide array of avian species. These avian species utilize these areas as an important wintering ground, *i.e.*, they fulfill their daily requirements such as habitat, water and food and also protection from predators and harsh weather. These endangered avian species has become threatened from habitat loss and destruction due to conversion of mangrove areas into oil palm plantation and coastal development. The habitat loss and degradation has seriously affected on their population. For their continuous survival and existence, they need special attention for protection and conservation.

5. Conclusion

Based the results of this study, it is concluded that Marudu Bay mangrove forest, Sabah, Malaysia, must be protected in a sustainable way in order to protect its diverse aquatic and terrestrial fauna species for future generations.

Author Contributions

Mohamed Zakaria Reviewed and edited the manuscript.

Muhammad Nawaz Rajpar Developed the experimental design, Collected and analyzed the data and wrote the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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