



Full Paper

Terrestrial Mammals in the Del Carmen Mangrove Forest Reserve, Siargao Island, Philippines

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Field surveys for terrestrial mammals were conducted in the mangrove forests of Del Carmen, Siargao Island in 2019 and 2022. Standard techniques were employed across five sampling sites including netting, trapping and searches for non-volant mammals. A total of 16 species were recorded consisting of five fruit bats, five insectivorous bats, four rodents, colugo, and tarsier. Six of these are endemic species, two Philippine endemics and four Mindanao endemics. One of the highlights of both surveys is the discovery of a possible new rodent species (*Rattus* sp.) likely specialized for living in mangrove habitats. The findings of this study augment data on the mangrove-associated mammals and emphasize the importance of mangrove ecosystems as important wildlife zones.

Keywords; Mindanao, bats, diversity, occurrence, rodents

Article history

Received : 27 May 2024

Revised : 16 August 2024

Accepted: 04 November 2024

Introduction

Mangrove forests are habitats of a unique set of terrestrial vertebrates (Rajpar and Zakaria 2014). This forest type is characterized by intertidal plant formations lying along the tropical and subtropical coastlines (Hutchings and Saenger 1987) in which

the largest proportions occur in Asia (Valiela et al. 2001). The mangrove forest is one of the 12 forest formations in the Philippines (Fernando et al. 2008) which harbors 39 mangrove species out of the 73 found worldwide (Primavera 2004; ERDB 2012; Sandilyan and Kathiresan 2012). The Philippines has an estimated mangrove cover of 256,185 ha with the majority found in the southern part of the archipelago, i.e. Mindanao region (Long and Giri 2011).

Low et al. (1994) listed 213 vertebrate species in the ASEAN region that utilize mangroves for shelter, and as feeding and nursery grounds. Above water,



mangrove trees and its canopy cover also serve as habitats for a wide range of terrestrial species including insects, birds, amphibians, and reptiles (Nagelkerken et al. 2008). Assemblages of flora and fauna associated with mangroves are termed 'mangal' (Macnae 1968), among these are mammals which comprise globally of some 40-known mangrove-specialist species such as sloths and proboscis monkeys (Luther and Greenberg 2009). In the Philippines, terrestrial vertebrate studies in mangrove forests are less explored, particularly mammals. There remains a dearth of researches focused on mammal species and their distribution in this type of habitat. Majority of mammalian surveys have been conducted along elevational forest gradients in mountain ecosystems (e.g., Rickart et al. 1991; Balete et al. 2006; Heaney et al. 2006; Balete et al. 2010).

Siargao Island, a Protected Area in the northeastern coast of Mindanao houses one of the largest mangrove systems in the Philippines located in the municipality of Del Carmen. Despite covering some 8,700 ha, little has been known about the vertebrate fauna of these mangrove forests. Earliest accounts of birds, mammals, and herpetofauna of Siargao were first to be largely reported by duPont and Rabor (1973), Heaney and Rabor (1982), and Ross and Lazell (1990) respectively. In the past decade,

bat and herpetofauna were studied in Siargao caves (Nuñez and Galorio 2014; Nuñez and Galorio 2015). The 2019 study provides baseline information that would augment our understanding of mammals living in this habitat type. Monitoring of the same sites in 2022, especially after the island was devastated by Super Typhoon Rai (Odette) in December 2021, aids in understanding the role of the mangrove ecosystem during such calamities.

Methodology

Study area

Siargao Island, province of Surigao del Norte (N°9 30'–10°05', E 125°50'–126°15') was declared as a Protected Landscape and Seascape in 1996. It is also categorized as a Key Biodiversity Area (KBA) and Important Bird Area (IBA) that houses threatened and restricted range species such as the saltwater crocodile (*Crocodylus porosus*) and the Philippine cockatoo (*Cacatua haematuropygia*) (Mallari et al. 2001). Mammal sampling was conducted from August 20–28, 2019 and October 8–16, 2022.

Five barangays were surveyed; four in mainland Siargao and one island-barangay at the west coast of Del Carmen (see Figure 1). Latitude, longitude, and elevation (m) for the survey sites and stations were recorded using a hand-held GPS device.

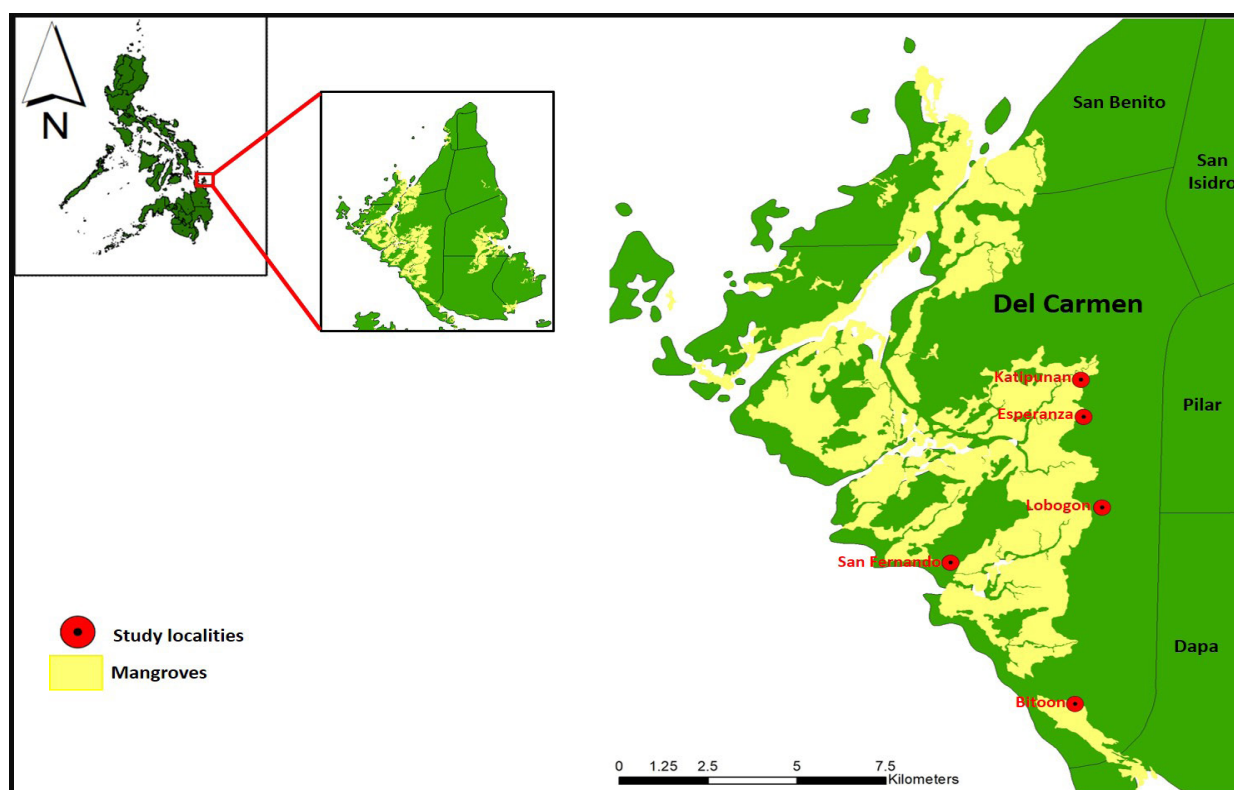


Figure 1. Map showing the 2019 and 2022 sampling site locations in the mangrove forests of Del Carmen, Siargao Island, Philippines.

Description of sampling sites

Site 1 – Barangay Katipunan, KAT (N 09.876331°, E 126.009°) is a mangrove forest adjacent to an agroforest (Figure 2A/3A). There were portions of the mangroves where tide levels do not reach stands on limestone, thereby allowing trapping and netting. Dominant mangroves observed belong to the genera *Rhizophora* and *Bruguiera*.

Site 2 – Barangay Esperanza, ESP (N 09.865889°, E 126.0097°) *Nypa fruticans* was dominant by the edges of limestone ground where the trap line was established (Figure 2B/3B). Human habitations are located approximately 100 meters from the mangroves. The area was easily accessible for setting-up sampling equipment.

Site 3 - Barangay Lobogon, LOB (N 09.84057°, E 126.0144°) This consists of mangrove patches including dense stands of *Nypa fruticans* and *Bruguiera gymnorhiza* near the shore (Figure 2C/3C). This sampling station was reached via pumpboat or canoe in about 10-15 minutes.

Site 4 - Barangay Bitoon, BIT (N 09.78554°, E 126.0075°) This is technically an agroforest dominated by coconut trees (*Cocos nucifera*), facing the mangroves (Figure 2D/3D). Mangroves are situated 8 meters from the shore and are affected by tide, thereby sampling equipment were set within the nearby agroforest area. Grass made up dominant ground cover and canopy cover was 40%. This sampling site was reached by hiking 1 km from the nearest residential area.

Site 5 - Barangay San Fernando, SF (N 09.82514°, E 125.976°) It is an island-barangay on the west coast of Del Carmen. Grasses composed the dominant ground cover with scattered *Musa* sp., bamboo, and coconut trees (*Cocos nucifera*) (Figure 2E/3E).

Field sampling methods

Field surveys of mammals and collection of specimens were conducted following the terms, conditions, and restrictions stipulated in the Wildlife Gratuitous Permit No. R13-2019-59 and R13-2019-27 issued by the Department of Environment and Natural Resources, Regional Office XIII (DENR-R13) for the 2019 sampling and Wildlife Gratuitous Permit No. R13-2022-20 for the 2022 sampling. A suite of sampling methods, whenever applicable, was employed including trapping, netting and active searches during both sampling periods. Accessibility was a challenge but we tried to sample within or as close as we can get to the mangrove areas.

Volant mammals - Mist nets of either 12 m or 6 m length, with height of 2.5 m (4-shelf, 36 mm mesh size) were established along potential flight paths, feeding grounds, and across open spaces. In each sampling site, 6-10 mist nets were used for 2-4 consecutive nights. Mist nets were installed singly or in series of 2-3 depending on the optimal habitat setting. Bottom edges of the nets were at least 0.3 m above ground. Mist nets were tended from 1800 h and checked after an hour to retrieve entangled bats. Thereafter, nets were left open and checked again in the early morning. For insectivorous bats, 1-2 museum harp-traps were set along narrow spaces or openings in Katipunan and Bitoon sites. Netting effort was measured in net-nights (defined as one mist-net set for an entire night) per site. Sky-nets were established in selected barangays of Esperanza and San Fernando. Netting was not possible in the Lobogon site. The total of number of net-nights and harp trap-nights during the two sampling periods are shown in Table 2.

Non-volant mammals – Small non-volant mammals were captured using a combination of snap traps (Victor brand, 7" x 3.5" x 0.5") and fabricated live traps. Traps were baited with thin slices of roasted coconut meat coated with peanut butter and set in the late afternoon on the ground, near roots or holes or along fallen logs. Some traps were tied onto tree branches or prop roots of mangroves to capture arboreal rodents. Traps were checked twice daily, one in the early morning (0700 h) and in the afternoon (1700 h) to retrieve captures and rebait as necessary. Purposive searches were also conducted at night. In addition, two camera traps were secured onto tree branches along possible runways of arboreal small mammals in Katipunan and San Fernando. Opportunistic searches were also conducted at night. There was a total of 458 trap-nights for the duration of the sampling. Local names of mammals were obtained from knowledgeable local people. The total of number of trap-nights during the two sampling periods is shown in Table 2.

Adequacy of sampling

Species accumulation curves for all sampling sites were plotted as cumulative number of species captured to reflect sampling effort. Netting/trapping success was expressed as number of total captures divided by total number of nets/traps set. Frequency of occurrence was directly estimated using total captures in each site. Species diversity in each sampling site except Lobogon was determined using Shannon index (H') computed

in Paleontological Statistics software version 3.25 (Hammer et al. 2001).

Species checklist

A species checklist was made including common name, local name, residency status, and conservation status. Conservation status was based on the IUCN Red List of Threatened Species (IUCN 2022) and on the DENR Administrative Order (DAO) 2019-09 of the Philippine Wildlife Act.

Specimen processing

Standard external measurements (i.e., body weight, total length, forearm length, tail length, ear length, and

hindfoot length) sex, age category, and reproductive condition were recorded for the representative voucher specimens. Prior to release, representative individuals of species were photographed. All captured mammals were identified using taxonomic references by Ingle and Heaney (1992) and Heaney et al. (2010). Nomenclature and common names followed Heaney et al. (2010) Synopsis of Philippine Mammals. Voucher specimens taken during the 2019 sampling were catalogued and were stored at the zoological collection of the National Museum of the Philippines (NMP) while those collected during the 2022 sampling were deposited at the University of the Philippines Los Baños – Museum of Natural History (UPLB-MNH).



Figure 2. Characteristic appearance of sampling sites in Del Carmen in 2019:
A) Katipunan, B) Esperanza, C) Lobogon, D) Bitoon, and E) San Fernando.

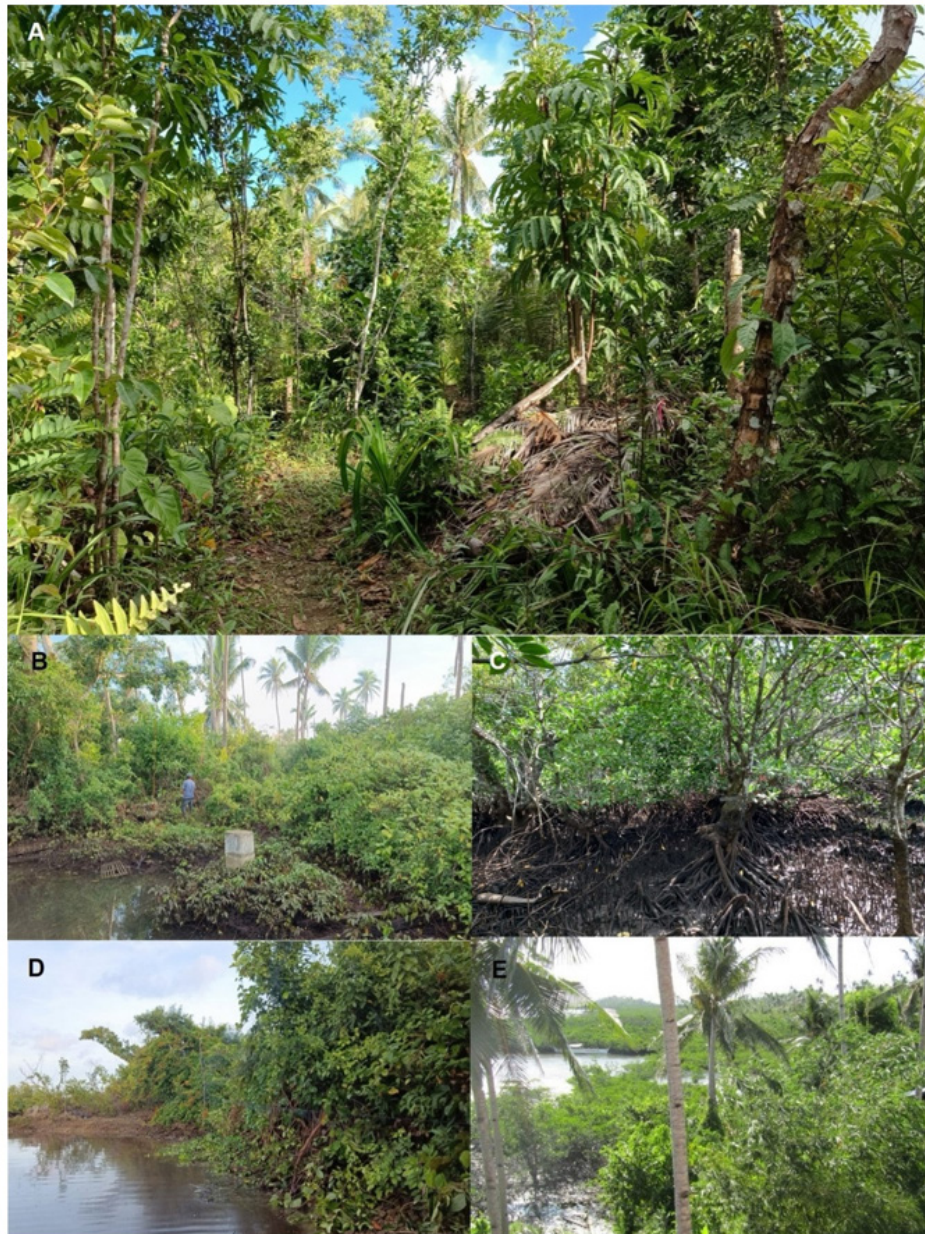


Figure 3. Characteristic appearance of sampling sites in Del Carmen in 2022:
A) Katipunan, B) Esperanza, C) Lobogon, D) Bitoon, and E) San Fernando.

Results

Study area

During the surveys, a total of 16 terrestrial mammal species was recorded to occur in the Del Carmen mangrove forest reserve and its environs. During each sampling period, 14 species each were encountered. Two species recorded in 2019 were not recorded in 2022. Meanwhile, two species recorded in 2022 were new site records (Table 1). The mammal species consisted of five fruit bats, five insectivorous bats, three rats, one squirrel, one flying lemur or colugo, and one tarsier. One species recorded is the invasive *Rattus tanezumi*, while the remaining (15) are native species including two widespread Philippine endemics (*Rattus everetti*

and *Hipposideros pygmaeus*) and four Mindanao endemics (*Hipposideros coronatus*, *Carlito syrichta*, *Sundasciurus philippinensis*, and *Cynocephalus volans*). One species was undetermined and assigned as *Rattus* sp. This study provides new occurrence records of four bats (*Eonycteris spelaea*, *H. pygmaeus*, *H. coronatus*, and *Megaderma spasma*) and two rodents (*R. everetti* and *S. philippinensis*) in mangrove environs of Del Carmen. The highest number of species and diversity (H') were recorded in Katipunan, with a total of 12 species recorded and an H' value of 1.736 (2019) and 1.799 (2022). Figures 4 and 5 show photographs of some mammal species that were documented in the sampling sites.

Table 1. Mammal species list and their conservation status. IUCN status: LC, Least Concern and NT, Near Threatened. DAO 2019-09: OTS, Other Threatened Species; OWS, Other Wildlife Species, and NL, Not Listed.

No.	Species	Common Name	Local name	Residency status	Conservation status		Sampling periods	
					IUCN	DAO 2019-09	2019	2022
Order Chiroptera								
Family Hipposideridae								
1	<i>Hipposideros pygmaeus</i>	Philippine pygmy roundleaf bat	<i>Kagi</i>	Philippine endemic	LC	OWS	✓	x
2	<i>Hipposideros coronatus</i>	Large Mindanao roundleaf bat	<i>Kagi</i>	Mindanao endemic	LC	OWS	x	✓
3	<i>Hipposideros diadema</i>	Diadem leaf-nosed bat	<i>Kagi</i>	Native	LC	OWS	x	✓
Family Megadermatidae								
4	<i>Megaderma spasma</i>	Lesser false vampire	<i>Kagi</i>	Native	LC	OWS	✓	✓
Family Pteropodidae								
5	<i>Cynopterus brachyotis</i>	Common short-nosed fruit bat	<i>Kagi</i>	Native	LC	OWS	✓	✓
6	<i>Eonycteris spelaea</i>	Common nectar bat	<i>Kagi</i>	Native	LC	OWS	✓	✓
7	<i>Macroglossus minimus</i>	Lesser long-tongued fruit bat	<i>Kagi</i>	Native	LC	OWS	✓	✓
8	<i>Rousettus amplexicaudatus</i>	Common rousette	<i>Kagi</i>	Native	LC	OWS	✓	✓
9	<i>Pteropus hypomelanus</i>	Common island flying fox	<i>Kabog</i>	Native	LC	OWS	✓	✓
Family Rhinolophidae								
10	<i>Rhinolophus arcuatus</i>	Arcuate horseshoe bat	<i>Kagi</i>	Native	LC	OWS	✓	✓
Order Dermoptera								
Family Cynocephalidae								
11	<i>Cynocephalus volans</i>	Philippine Colugo	<i>Kagu</i>	Mindanao endemic	LC	OWS	✓	✓
Order Primates								
Family Tarsiidae								
12	<i>Carlito syrichta</i>	Philippine tarsier	<i>Amag</i>	Mindanao endemic	NT	OTS	✓	✓
Order Rodentia								
Family Muridae								
13	<i>Rattus everetti</i>	Philippine forest rat	<i>Ambaw</i>	Philippine endemic	LC	OWS	✓	✓
14	<i>Rattus</i> sp.	-	-	-	-	-	✓	✓
15	<i>Rattus tanezumi</i>	Oriental house rat	<i>Ambaw</i>	Introduced, invasive	LC	NL	✓	✓
Family Sciuridae								
16	<i>Sundasciurus philippinensis</i>	Philippine tree squirrel	<i>Bu-ot</i>	Mindanao endemic	LC	OWS	✓	x

At least 26 species of mammals have so far been recorded in Siargao Island consisting of 15 bats and 11 non-volant mammals (Heaney and Rabor 1982; Heaney et al. 1998; Heaney et al. 2010; Nuñez and Galorio 2015; Amarga and Fernandez 2020; Fernandez and Amarga 2020). This represents ~27% of the ~98 terrestrial mammals of the Mindanao Pleistocene Aggregate Island Complex or PAIC (Heaney et al., 2010, Rickart et al. 2024). The 16 species we recorded in the Del Carmen mangrove and its environs, on the other hand, represent ~62% of the overall known mammal species richness in Siargao Island.

The most abundant bat species recorded were *C. brachyotis* (n=117) and *R. amplexicaudatus* (n=91), making up 63% of the total bat captures (n=330). These two species, along with *M. minimus* were recorded in all the netting sites. *C. brachyotis* is known to be abundant in lowland habitat types (i.e., secondary forests, agricultural areas) and are tolerant of habitat disturbances (Heaney et al. 2010). On the other hand, *R. amplexicaudatus* is widespread in agricultural areas and roosts in caves (Heaney et al. 1998). Several distributional records have also indicated *C. brachyotis* and *M. minimus* as occurring in mangrove habitats in Leyte and Palawan (Picardal et al. 2011; Dangan-Galon et al. 2015). *E. spelaea* and *P. hypomelanus* were both recorded in Esperanza and San Fernando. Setting of sky-nets in these two sites resulted in the capture of *P. hypomelanus*.

Detection of insectivorous bats was low owing to the capture methods of this study. These bats possess sophisticated echolocation abilities and are able to evade nets compared to fruit bats (Neuweiler 1989; Schnitzler and Kalko 2001). Among these species, *H. pygmaeus* and *R. arcuatus* were captured using harp-traps in the survey conducted in 2019, while *M. spasma* was captured in mist net in the 2022 survey along with *R. arcuatus*. In addition, two species not captured in the 2019 survey were captured during the 2022 survey, *H. coronatus* and *H. diadema*.

Rodents were present in all five sites. *R. everetti* is a Philippine endemic rat which is broadly distributed throughout the Philippines and also among the elevational gradients in mountain ecosystems (Heaney et al. 2010). It has a broad diet and has a tolerance for habitat disturbances because it has been recorded even in shrubby and agricultural areas near forests. It was present in Katipunan and Lobogon sites during the 2019 and 2022 surveys. *S. philippinensis* is a Mindanao endemic and was only captured in the Katipunan site during the 2019

sampling. The species is active during the daytime, foraging both on the ground and in trees. The suspected new species, *Rattus* sp., is currently only known from Lobogon where it was recorded during both surveys. *R. tanezumi*, a human commensal and invasive species, was present in all sites except for Lobogon. As an invasive species, it may not affect other native mammals but may have devastating effects particularly on birds on which it preys upon. Interestingly, where it is absent, the endemic *R. everetti* and *Rattus* sp. were recorded. *R. everetti* and *R. tanezumi* occurred sympatrically in Katipunan.

An adult female *C. volans* and its young were caught by locals on a coconut tree in Katipunan during the 2019 survey. The species was also observed in Esperanza on a mabolo tree (*Diospyros discolor*) during both surveys. The Kagwang or Kagu is an arboreal folivore. It is a crepuscular species (Wischusen and Richmond 1998) which prefers young leaves of a variety of tree species and is regarded as a generalist forager. It also prefers larger trees in terms of diameter and height.

Individuals of *C. syrichta* were observed singly, grasping mangrove branches during separate occasions in Katipunan and Bitoon during both survey periods. In addition, an adult male Tarsier was captured by a cat inside the compound of the Siargao Islands Wildlife Conservation Foundation Inc. (SIWCFI) in Barangay Katipunan, during the 2019 sampling. One of the local guides was able to retrieve the body which sustained bites around the neck and face. This is an example of how stray, feral and even free-roaming pet cats cause mortality to wildlife.

Table 2. Occurrence, distribution, and diversity of mammals in the mangrove forests of Del Carmen, Siargao Island. Netting and trapping success are written inside parentheses.

Scientific name	Method	KAT		ESP		LOB		BIT		SF		Total	
Volant		2019	2022	2019	2022	2019	2022	2019	2022	2019	2022	2019	2022
Family Hipposideridae													
1 <i>Hipposideros pygmaeus</i>	harp trap	1 (0.13)	0	0	0	-	-	0	0	0	0	1	0
2 <i>Hipposideros coronatus</i>	mist net	0	2 (0.07)	0	0	-	-	0	0	0	0	0	2
3 <i>Hipposideros diadema</i>	mist net	0	1 (0.04)	0	1 (0.08)	-	-	0	0	0	0	0	2
Family Megadermatidae													
4 <i>Megaderma spasma</i>	mist net	0	0	0	1 (0.08)	-	-	5 (0.36)	3 (0.3)	0	0	5	4
Family Pteropodidae													
5 <i>Cynopterus brachyotis</i>	mist net	24 (0.8)	9 (0.33)	13 (1.08)	5 (0.42)	-	-	31 (2.21)	2 (0.2)	33 (2.06)	0	101	16
6 <i>Eonycteris spelaea</i>	mist net	0	0	14 (1.17)	0	-	-	0	0	17 (1.06)	1 (1.23)	31	1
7 <i>Macroglossus minimus</i>	mist net	23 (0.77)	9 (0.33)	7 (0.58)	0	-	-	5 (0.36)	2 (0.2)	2 (0.13)	0	37	11
8 <i>Rousettus amplexicaudatus</i>	mist net	9 (0.3)	7 (0.26)	18 (1.5)	6 (0.5)	-	-	0	4 (0.4)	37 (2.31)	10 (0.63)	64	27
9 <i>Pteropus hypomelanus</i>	mist net	0	0	3 (0.25)	5 (0.42)	-	-	0	6 (0.6)	5 (0.31)	2 (0.13)	8	13
Family Rhinolophidae													
10 <i>Rhinolophus arcuatus</i>	harp trap mist net	4 (0.13)	1 (0.04)	0	0	-	-	2 (0.14)	0	0	0	6	1
Total bat captures		61	29	55	18	-	-	43	17	94	13	253	77
Total net-nights		30	27	12	12	-	-	14	10	16	16	72	65
Bats per net-night		2	1.07	4.6	1.5	-	-	3.07	1.7	5.88	0.81	-	-
Total harp-trap nights		8	0	0	0	-	-	2	0	0	0	10	0

Continuation of Table 2.

Scientific name	Method	KAT		ESP		LOB		BIT		SF		Total	
Non-volant mammals		2019	2022	2019	2022	2019	2022	2019	2022	2019	2022	2019	2022
Family Cynocephalidae													
11 <i>Cynocephalus volans</i> ^a	observed	2	0	1	1 ^a	0	0	0	0	0	0	3	1
Family Tarsiidae													
12 <i>Carlito syrichta</i> ^a	observed	1	1 ^a	0	0	0	0	1 (0.01)	1 ^a	0	0	2	2
Family Muridae													
13 <i>Rattus everetti</i>	live trap ¹ snap trap ²	3 (0.02)	2 ² (0.02)	0	0	1 (0.01)	22 (0.02)	0	0	0	0	4	4
14 <i>Rattus</i> sp.	live trap snap trap	0	0	0	0	4 (0.04)	4 ² (0.04)	0	0	0	0	4	4
15 <i>Rattus tanezumi</i>	live trap snap trap camera trap ³	5 (0.03)	4 ² (0.03)	1 (0.01)	5 ² (0.07)	0	0	3 (0.04)	2 (0.03)	5 ^b (0.06)	7 ² (0.09)	14	18
Family Sciuridae													
16 <i>Sundasciurus philippinensis</i>	snap trap	1 (0.01)	0	0	0	0	0	0	0	0	0	1	0
Total rodent captures		9	6	1	5	5	6	3	2	5	7	23	26
Total trap-nights		150	120	80	75	100	100	76	80	72	80	458	455
Rodents per trap night		0.04	0.05	0.01	0.07	0.05	0.06	0.03	0.03	0.06	0.09	-	-
Total camera trap-nights		8	-	0	-	0	-	0	-	4	-	12	-
Species richness (S)		10	8	7	7	2	2	6	6	6	4	-	-
Shannon Index (H)		1.74	1.80	1.6	1.62	-	-	1.14	1.70	1.42	1.09	-	-

^aObservations only^bOne (1) individual captured by camera trap*Highest number are written in **boldface (2019 & 2022)**

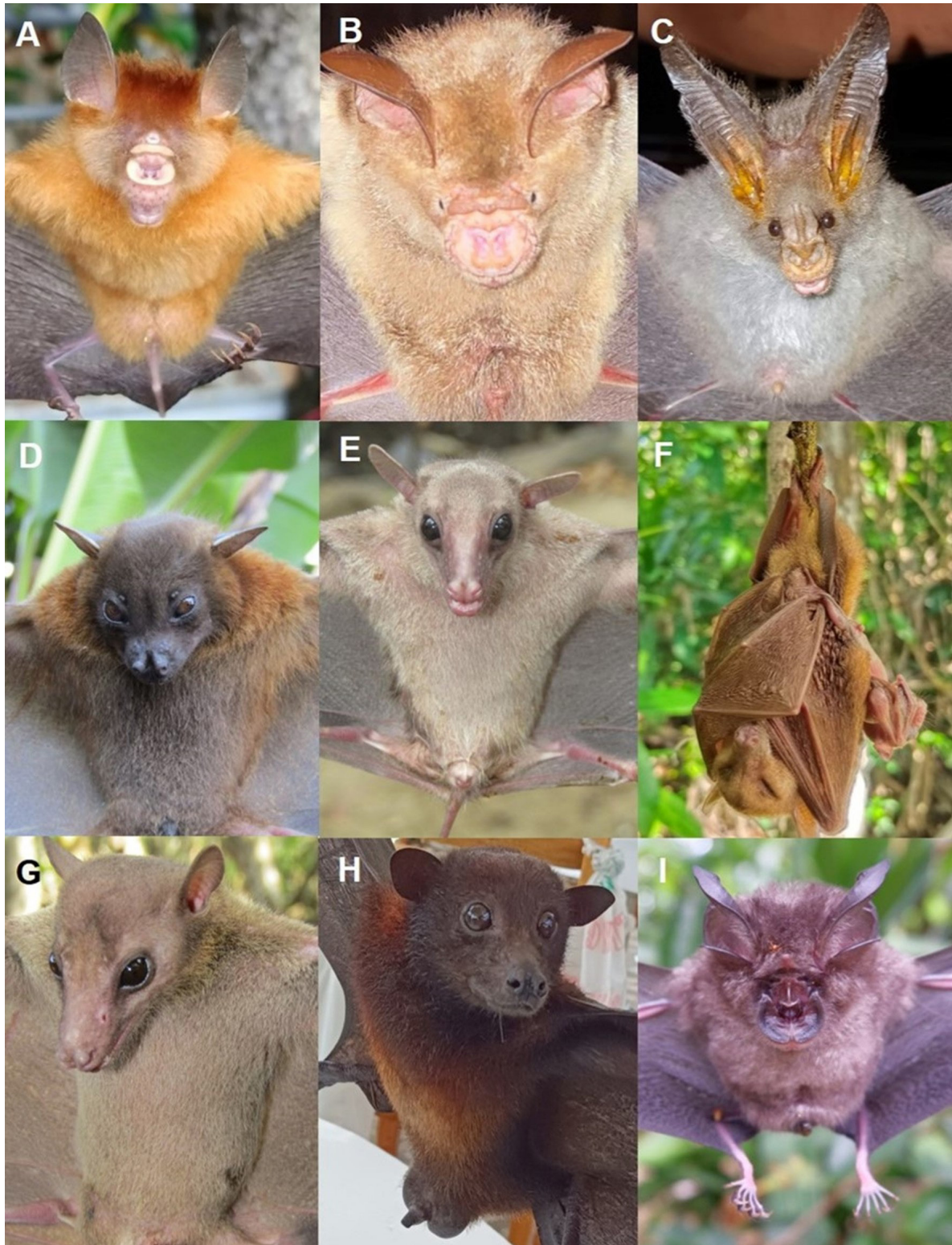


Figure 4. Photographs in life of A) *Hipposideros coronatus* (Hipposideridae), B) *Hipposideros diadema* (Hipposideridae), C) *Megaderma spasma* (Megadermatidae), D) *Cynopterus brachyotis* (Pteropodidae), E) *Eonycteris spelaea* (Pteropodidae), F) *Macroglossus minimus* (Pteropodidae), G) *Rousettus amplexicaudatus* (Pteropodidae), H) *Pteropus hypomelanus* (Pteropodidae), and I) *Rhinolophus arcuatus* (Rhinolophidae).



Figure 5. Photographs of A) *Carlito syrichta* (Tarsiidae), B) *Cynocephalus volans* (Cynocephalidae), C) *Rattus everetti* (Muridae), D) *Rattus* sp. (Muridae), and E) *Rattus tanezum*i (Muridae).

Adequacy of sampling

Figures 6A and B show the sampling efforts for both netting and trapping. During the 2019 and 2022 sampling periods, the Species Accumulation Curve for netting levels off at 60 and 40 net-nights, respectively. For the small non-volant mammals, the Species Accumulation Curve levels off at 350 trap-nights in 2019 and 300 trap-nights in 2022. These suggest that sampling efforts were sufficient and that additional netting and trapping efforts may not yield additional species.

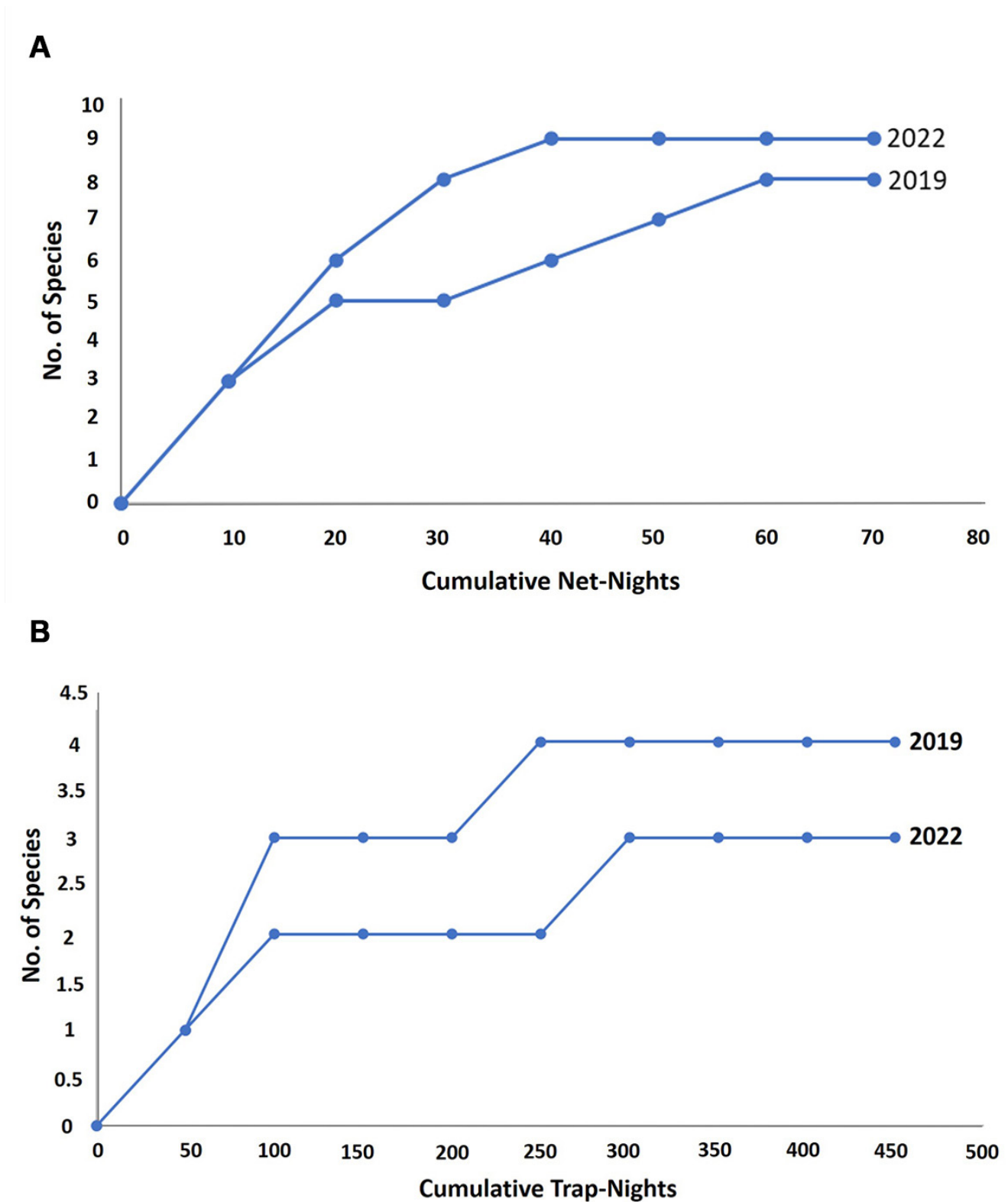


Figure 6. Species Accumulation Curve for Volant Mammals and Species Accumulation Curve for Non-volant Mammals

Discussion

Mammals constitute a unique proportion of fauna in mangrove habitats but are relatively less studied (Cuenca et al. 2015). Based on our experience, this is due to the difficulty of applying standardized sampling techniques used in terrestrial habitats. Rog et al. (2020) offers sampling techniques for this challenging ecosystem which involve the use of camera traps, bat detectors, hair tubes and traps which might prove useful in future mammal studies. The Katipunan site offered a suitable and safe sampling area for us to conduct netting and setting of snap traps, cage traps, harp traps and camera traps. In this site a suitable portion of the mangrove was not inundated. Moreover, there was little human interference due to the absence of human settlements. Thus, the high species richness in Katipunan which comprised 12 species or 75% of the total species recorded may be a consequence of sampling bias. In the other sites, sampling methods were limited due to accessibility and safety issues. Take for example our Lobogon site where only trapping was possible. It had the lowest species richness but is the habitat of the endemic *R. everetti* and the undetermined *Rattus* species. This site provides mammal data for isolated mangrove stands and may provide answers on how rodents utilize the mangrove ecosystems. It is important to continue the monitoring of the five sites, especially Katipunan and Lobogon. We believe the current data is still an underestimation and conducting additional sampling within the core of the mangrove reserve may yield additional species.

The five fruit bats recorded are known to be mangrove-associated species. *M. minimus*, *E. spelaea* and *R. amplexicaudatus* are morphologically adapted to nectarivory. They have elongated snouts and characteristically long tongues used to lap nectar. *M. minimus*, is a known pollinator of some mangrove species along with *E. spelaea*. Specific mangroves that are said to be chiropterophilous are *Sonneratia* sp.. Nor Zalipah et al. (2016) found that *R. amplexicaudatus* and *C. brachyotis* in Malaysia visited *Sonneratia* species as well but noted that their effectiveness as pollinators pales in comparison to *E. spelaea*. *P. hypomelanus* is classified as frugivorous and its role as mangrove pollinators in the Philippines is understudied. What is more known is that this species roosts in mangrove areas. Other species of flying foxes have been observed to display increased roosting in mangroves especially under extreme hunting pressures.

All of the five species of insectivorous bats recorded

are known to roost in caves which are present throughout Siargao Island. *H. pygmaeus* and *R. arcuatus* were also previously recorded in cave habitats of Siargao Island (Nuñeza and Galorio 2015). The presence of these bats in Katipunan, Esperanza and Bitoon although very low in numbers indicate the use of the areas probably as feeding grounds since various insects are known to occur in mangrove areas. In addition, *M. spasma*, is also known to feed on small frogs, lizards, and birds (Balete 2010).

For the rodent species, the mangrove forest could be regarded as a sub-optimal habitat for rodents due to daily tidal inundation, and studies have shown that diet of rodents in mangroves may be composed of marine mollusks. The Philippine tarsier are known to occur within primary and secondary tropical rainforests, mangrove forests, amongst bush thickets, tall grasses, and bamboo. However, mangrove utilization of Philippine tarsier is still unknown. On the other hand, it is possible that the Kagwang may only be found in secondary or agroforest areas but will possibly not venture into the mangroves.

Mammals associated with mangroves usually utilize this area as an extension of their range, as a substitute habitat, or connecting habitat between terrestrial gradients to exploit resources for short visits or long periods (Hutchings and Saenger 1987; Fernandes 2000). The mangrove and adjacent agroforest areas may have become the substitute habitat for the Kagwang, Tarsier and Squirrel that were recorded in Katipunan, Esperanza and Bitoon sites. For *R. everetti*, the mangrove may have also become a substitute habitat but it is unclear for *Rattus* sp. which might be adapted to living exclusively in mangrove forests. Most of the insectivorous and cave-roosting bats may be visitors of these areas while *C. brachyotis* and *M. minimus* may possibly inhabit the adjacent agroforest areas. Thus, most of these mammals are facultative users that occupy both mangrove and adjacent terrestrial habitats. Utilization can be categorized by their resource use (Rog et al. 2017) such as for (1) feeding; (2) breeding; (3) dispersal route between primary habitats; (4) shelter from biotic (e.g., predators, competitors) and abiotic stressors (e.g., temperature extremes); (5) use as refugia from human disturbance; and (6) novel use of mangroves as a result of human disturbance. The 2022 survey results suggest that the mammal species were protected by the mangrove forest which served as their refuge during the onslaught of Super Typhoon Odette.

While it has been shown that mangrove forests are considerably important for terrestrial mammals than generally acknowledged, the mangroves and adjacent habitats also benefit through pollination, seed dispersal and insect control. However, the presence of *R. tanezumi* and free-roaming feral cats threaten other terrestrial fauna as they can compete with the resources and can act as predator, respectively. The mangrove forest reserve and its biodiversity must be protected and managed, especially now that it has been recognized as the Philippines' 10th Ramsar Site.

Conclusion

Our findings have significant implications for the conservation of mammals in mangrove areas and with the official recognition of the Del Carmen Mangrove Reserve (DCMR) in Siargao Island Protected Landscape and Seascape (SIPLAS) as the 10th Ramsar Site of the Philippines. The presence of diverse mammals in mangroves indicate that this habitat is an important wildlife zone. This further strengthens the need for conservation of mangrove ecosystems. Eradication or control of invasive alien species such as the house rat and feral cats should be done to protect not only native mammals but other wildlife species as well. Continuous biodiversity monitoring may yield additional mammal species records. Other methods to survey the mangrove should also be explored to detect presence of other species utilizing the area. Further studies should be conducted in the mangrove core areas as well as adjacent and/or related ecosystems (e.g. caves) near mangrove forests. Ecosystem services of mangrove-associated mammals is also an avenue worth exploring.

Ethics Statement

Field surveys and collection of specimens were conducted following the terms, conditions, and restrictions stipulated in the Wildlife Gratuitous Permit No. R13-2019-59 and R13-2019-27 issued by the Department of Environment and Natural Resources, Regional Office XIII (DENR-R13) for the 2019 sampling and Wildlife Gratuitous Permit No. R13-2022-20 for the 2022 sampling.

Declaration of conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors would like to thank Maria Josefa S. Veluz[†], Renz Alfred P. Fernando, Jerry A. Cantil, Joel Sarmiento, Ariel Gonzalez, Waljohn W. Mainit, and Joveniano P. Ravelo Jr. for their assistance during the field sampling. The authors would also like to thank the local government of Del Carmen, Siargao headed by Hon. Mayor Alfredo M. Coro II and MENRO Gina Barquilla for allowing and assisting in the conduct of the study. Our utmost gratitude to the Department of Environment and Natural Resources Region XIII (DENR DENR-R13) and the Siargao Island Protected Landscapes and Seascapes (SIPLAS) Protected Area Management Office for issuing the necessary permits to conduct the research.

Funding

This research was funded by the Department of Science and Technology (DOST) and monitored by the National Research Council of the Philippines (NRCP).

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