



Status of Mangrove Forest Coverage and Species Composition in Northern Langkawi Island, Malaysia

Mohamad Saupi Ismail^{1*}, Khairul Naim Abd Aziz², Sharir Aizat Kamaruddin², Siti Syafiqah Hashim², Md. Nizam Ismail¹, Chee Kong Yap³ and Jamil Tajam²

¹Fisheries Research Institute, Department of Fisheries Malaysia, Batu Maung, 11960 Pulau Pinang, Malaysia

²Faculty of Applied Sciences, Universiti Teknologi MARA, Arau, 02600 Perlis, Malaysia

³Department of Biology, Faculty of Science, Universiti Putra Malaysia, Serdang, 43400 Selangor, Malaysia



Abstract

Mangrove ecosystems provide indispensable ecological and socio-economic services, yet their effective conservation requires rigorous spatial assessments. Conventional survey methodologies often prove inadequate for mapping extensive mangrove tracts, resulting in critical data gaps. This study evaluated the spatial extent and taxonomic composition of mangrove forests across four reserves in northern Langkawi Island, encompassing Kilim, Teluk Datai, Tanjung Rhu, and Kubang Badak, utilizing high-resolution remote sensing imagery and Geographic Information System (GIS) techniques. Mangroves encompassed 1,669.52 ha, representing 14.5% of the total forest area within the northern zone. Coverage varied significantly across reserves, dominated by Tanjung Rhu (731.13 ha; 6.35%), followed by Kilim (500.10 ha; 4.34%), Kubang Badak (433.94 ha; 3.77%), and Teluk Datai (4.35 ha; 0.04%). Floral composition was predominantly composed of the family Rhizophoraceae, with *Rhizophora apiculata* identified as the ubiquitous dominant species across all sampling sites. These baseline findings establish critical spatial data to inform future monitoring, sustainable land-use management, and conservation strategies for Langkawi's coastal wetlands.

Keywords: Mangrove Cover; Remote Sensing; GIS; Rhizophoraceae; Strait of Malacca

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*Correspondence:

Mohamad Saupi Ismail, Fisheries Research Institute, Department of Fisheries Malaysia, Batu Maung, 11960 Pulau Pinang, Malaysia, E-mail: saupi@dof.gov.my

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Introduction

Mangrove forests occur between 30°N and 30°S latitudes, inhabiting intertidal and brackish-water environments shaped by the interaction of seawater and freshwater. Mangrove trees have unique adaptations that let them survive in extreme marine environments with high salinity and temperature, dynamic water movement, and anoxic sediments [1]. Beyond their high biological productivity, mangroves deliver crucial physical ecosystem services, acting as natural biological barriers that attenuate wave energy, prevent shoreline erosion, and cushion coastal zones from storm surges [2].

These coastal wetlands provide essential nursery grounds and habitat niches for diverse fauna, including 20 species of Felidae, 60 species of Primates [3], and over 200 avifaunal species [4], alongside varied assemblages of reptiles, amphibians, teleosts, lepidopterans, and coleopterans. Furthermore, they shelter threatened and ecologically sensitive species, such as the saltwater crocodile (*Crocodylus porosus*), proboscis monkey (*Nasalis larvatus*), Indo-Pacific humpback dolphin (*Sousa chinensis*) [5], and commercially important serranids [6].

High primary productivity, favorable water quality, nutrient subsidies from detrital degradation, and structural complexity provided by prop roots and pneumatophores sustain faunal richness in mangrove habitats. These root networks offer crucial refuge from predation while creating vital foraging and spawning microhabitats [4].

Despite their ecological significance, global mangrove cover faces intense degradation driven by climatic shifts and land-use changes. In Southeast Asia, people have clear-felled extensive mangrove ecosystems and converted them for aquaculture, industrial expansion, and coastal infrastructure [7]. The loss of mangrove habitat compromises coastal ecosystem integrity, undermining coastal protection, carbon sequestration, and dependent biodiversity.

The heightened vulnerability of mangrove-associated taxa underscores the urgent need for precise quantitative spatial monitoring to guide coastal resource planning and conservation

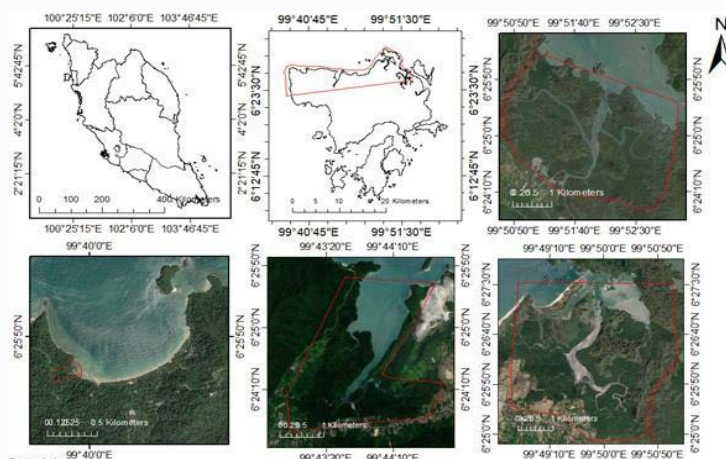


Figure 1: Location of Langkawi Island in Malaysia (top left); the northern zone of Langkawi Island (top centre); the Kilim mangrove forest (top right); Teluk Datai (bottom left); the Kubang Badak mangrove forest (bottom centre); and the Tanjung Rhu mangrove forest (bottom right).

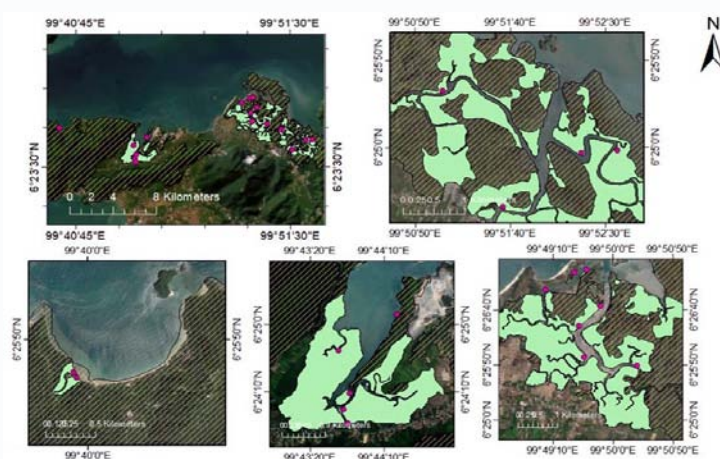


Figure 2: Randomly selected locations in the northern zone of Langkawi.

management. This study evaluates the spatial coverage of mangrove forests across northern Langkawi Island and characterizes species distribution and floristic composition using high-resolution SPOT-5 satellite imagery coupled with GIS spatial analysis and structured field surveys.

Methodology

Study areas

The study area encompasses four major mangrove forest reserves located in northern Langkawi Island, Kedah, Malaysia: Tanjung Rhu, Kubang Badak, Kilim, and Teluk Datai (Figure 1). While Langkawi is a premier ecotourism destination, intensive coastal development and anthropogenic activities have induced notable environmental pressures, particularly affecting sensitive marine ecosystems [8].

Spatial analysis of mangrove extent was conducted using high-resolution SPOT-5 satellite imagery (5 m spatial resolution). Image processing, classification, and thematic mapping were performed using ArcGIS (v10.8; Esri Inc.).

Species identification

Field verifications and floristic inventories were conducted across accessible, randomly selected sampling locations within the four reserves (Figure 2). At each sampling point, a 50 m transect

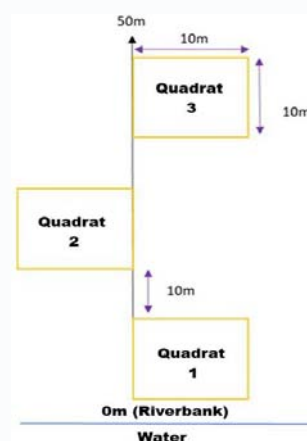


Figure 3: Fieldwork methodology for identifying mangrove tree species.

oriented perpendicular to the shoreline was established. Ground assessments were conducted within three 10 m × 10 m (100 m²) quadrats positioned at 10 m intervals along each transect (Figure 3). All mangrove species within the quadrats were identified based on diagnostic morphological features, including leaf, stem, root, floral, and propagule structures, with reference to standard botanical

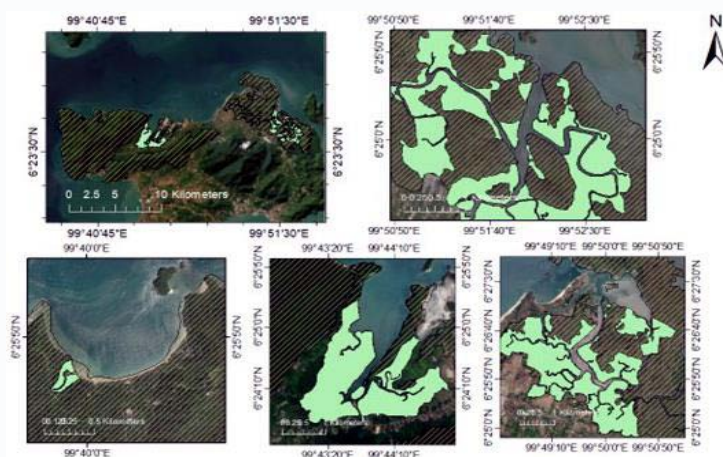


Figure 4: Mangrove forest coverage in northern Langkawi (top left), including Kilim (top right), Teluk Datai (bottom left), Kubang Badak (bottom centre), and Tanjung Rhu (bottom right).



Figure 5: Erosion areas (red circles) were observed in the Tanjung Rhu mangrove forest, with exposed mangrove roots indicating sediment loss and reduced substrate stability, thereby increasing the potential risk of tree collapse.

taxonomic keys.

Results and Discussion

Forest and mangrove forest area coverage

GIS-based satellite image classification indicated that mangrove vegetation covers a total of 1,669.52 ha, representing 14.5% of the total forested landscape (11,511.53 ha) in northern Langkawi (Figure 4).

Among individual reserves, Tanjung Rhu comprised the largest mangrove extent (731.13 ha; 6.35% of total forest cover), followed by Kilim (500.10 ha; 4.34%) and Kubang Badak (433.94 ha; 3.77%). Teluk Datai recorded the smallest area, accounting for only 4.35 ha (0.04%).

Prior to this investigation, comprehensive baseline spatial quantitative assessments for Tanjung Rhu, Kubang Badak, and Teluk Datai were lacking. These baseline data provide essential spatial benchmarks for monitoring ongoing land-use changes, assessing coastal vulnerability, and implementing target conservation policies.

The observed limitations in mangrove spatial extent may be further compounded by ongoing environmental stress, including projected regional sea-level rise of up to 0.5 m by 2100 [9, 10]. Accelerating sea-level rise can alter inundation regimes, cause mangrove dieback or forcing landward migration where topographically feasible.

Additionally, intense vessel traffic associated with nature-based tourism generates repetitive wake waves, accelerating bank erosion along tidal channels. Substrate undermining destabilizes root systems, leading to severe tree destabilization and collapse along riverbanks [11, 12] (Figure 5).

Furthermore, direct encroachment and proximity to tourism infrastructure (e.g., resort developments, jetties) present cumulative risks (Figure 6). In the absence of stringent waste management protocols and sustainable carrying capacity limits, anthropogenic pressure risks compromising the ecological function and long-term resilience of these ecosystems.

Mangrove tree species

Field inventories documented seven true mangrove species across the sampling sites. The floral assemblage was overwhelmingly dominated by the family Rhizophoraceae, with *Rhizophora apiculata* recorded across all reserves (Table 1). Notably, despite their classification as "Least Concern" (LC) on the IUCN Red List, global population assessments indicate declining trends for almost all recorded mangrove species [13].

Species such as *Acanthus ilicifolius* (Acanthaceae) display restricted local distributions within Malaysia, predominantly restricted to northern estuaries such as Tanjung Rhu [14] (Figure 7).

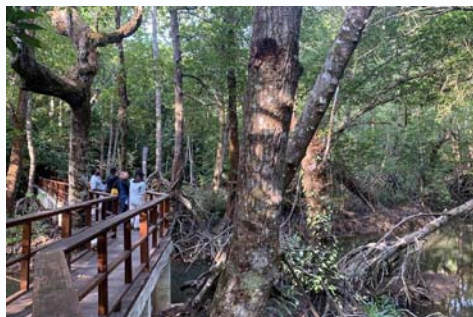


Figure 6: The presence of mangrove trees surrounding the hotel area in Teluk Datai.

Table 1: Summary of mangrove tree species recorded at the four study sites.

Location	Family	Species	IUCN Status
Tanjung Rhu	Acanthaceae	<i>Acanthus ilicifolius</i>	LC
	Rhizophoraceae	<i>Bruguiera cylindrica</i>	LC
		<i>Bruguiera gymnorhiza</i>	LC
	Lythraceae	<i>Sonneratia alba</i>	LC
	Rhizophoraceae	<i>Ceriops tagal</i>	LC
		<i>Rhizophora apiculata</i>	LC
Kilim	Rhizophoraceae	<i>Bruguiera gymnorhiza</i>	LC
		<i>Ceriops tagal</i>	LC
		<i>Rhizophora apiculata</i>	LC
Kubang Badak	Rhizophoraceae	<i>Bruguiera cylindrica</i>	LC
		<i>Bruguiera gymnorhiza</i>	LC
		<i>Bruguiera parviflora</i>	LC
		<i>Ceriops tagal</i>	LC
		<i>Rhizophora apiculata</i>	LC
Teluk Datai	Rhizophoraceae	<i>Rhizophora apiculata</i>	LC

LC = Least Concern



Figure 7: *Acanthus ilicifolius* species found in Tanjung Rhu.

Given the expanding ecotourism footprint in Langkawi, establishing ecosystem-based management frameworks is essential to balance conservation objectives with local economic activities [15]. Sustained protection of mangrove floristic diversity is vital for maintaining coastal ecosystem services, ecological connectivity, and climate adaptation capacity.

Conclusion

This study demonstrates that mangrove forests in northern Langkawi Island encompass 1,669.52 ha (14.5% of regional forest cover), dominated by Rhizophoraceae, particularly *Rhizophora apiculata*. Evidence of riverbank erosion, substrate loss, and anthropogenic pressure highlights the vulnerability of these coastal habitats to ongoing degradation.

To maintain ecosystem health and ensure long-term resilience, proactive conservation policies, including boat speed regulations along estuarine channels, mangrove restoration, and continuous GIS-based monitoring, must be integrated into regional spatial planning. Protecting these key coastal ecosystems is critical for preserving Langkawi's unique marine biodiversity and supporting sustainable coastal development.

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Author Contributions

Conceptualization, M.S.I., C.K.Y. and J.T.; Data curation, K.N.A.A. and S.A.K.; Formal analysis, K.N.A.A., S.A.K. and S.S.H.; Funding Acquisition, M.S.I. and M.N.I.; Investigation, K.N.A.A., S.A.K. and S.S.H.; Methodology, K.N.A.A. and S.A.K.; Writing-original draft, M.S.I., K.N.A.A., S.A.K. and S.S.H.; Writing-review and editing, M.S.I.

Ethics Statement

The authors affirm that this research complies with the relevant ethical guidelines for research and publication.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data that support the findings of this study are available upon reasonable request from the authors.

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Declaration of Competing Interests

The authors declare no conflict of interest.

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