REHABILITATION OF MANGROVES IN SABAH

THE SFD-ISME COLLABORATION 2019-2024

Sabah Forestry Department
International Society For Mangrove Ecosystems
Tokio Marine & Nichido Fire Insurance Co., Ltd

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The SFD–ISME Collaboration (2019–2024)

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Front Cover Photo:	Project site at Pulau ISME, Beaufort
Inside Cover Photo:	View of the Sepilok Laut Mangroves, Sandakan
Back Cover Photo:	Project site at Teluk ISME-Marudu, Kota Marudu
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Proboscis monkey
(*Nasalis larvatus*)

The future of mangroves depends on concrete actions and adequate resources, not just expressions of concern. These vital ecosystems provide essential services, such as coastal protection, biodiversity support, and carbon sequestration. Yet, significant threats from deforestation, pollution, and climate change remain. Effective conservation requires enforcement, financial investment, scientific research, strong policies, and active community engagement. Mangrove forest restoration efforts, sustainable livelihoods, and capacity building are crucial for long-term success. By combining these strategies, we can ensure the preservation of mangroves and their vital role in environmental health and climate change mitigation.

Aerial view of Sulaman Lake FR.

SFD-ISME (PHASE 3)

SFD-ISME COLLABORATION PROJECT
(2019 – 2024)

ABOUT THE AUTHORS

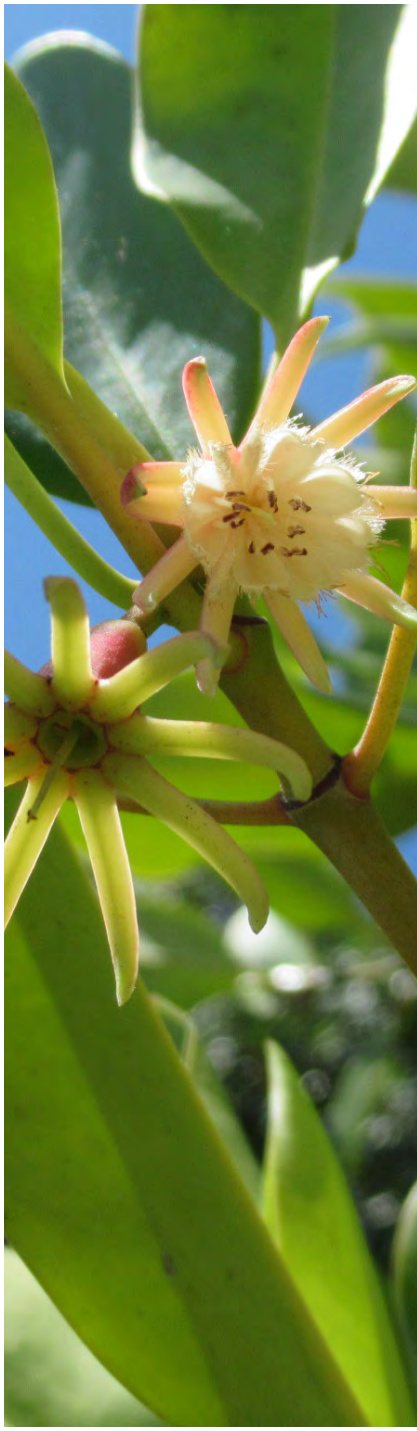
The contributors of this book are a diverse group of experts, researchers, and practitioners from various fields related to mangrove ecology, conservation, and restoration. The team includes scientists from the Sabah Forestry Department (SFD), local researchers from universities and environmental organizations, as well as international experts specializing in coastal ecosystems, climate change, and sustainable management practices. Together, they have contributed their knowledge and expertise to provide a comprehensive and scientifically sound perspective on the state of mangrove ecosystems in Sabah, as well as the restoration and conservation efforts underway through the SFD-ISME Collaboration Project.

The collaboration among the contributors reflects a shared commitment to understanding the challenges facing mangrove ecosystems and finding effective solutions to ensure their sustainability for future generations. Their collective experience spans across a range of disciplines, including marine biology, ecology, environmental science, and community engagement, making this book a valuable resource for anyone involved in mangrove conservation or restoration efforts.

FOREWORD

PROF. DR. SANIT AKSORNKOAE
President
International Society for Mangrove Ecosystems

Mangroves are among the most valuable and ecologically significant ecosystems in the world, and Sabah's coastal regions are home to some of the richest, and most pristine and diverse mangrove forests in Southeast Asia. These ecosystems not only provide crucial services such as shoreline protection and biodiversity support, but they also play a critical role in mitigating climate change by sequestering carbon and stabilizing coastal soils.



In light of the growing challenges facing mangrove ecosystems worldwide, including habitat degradation, pollution, and impacts of climate change, the SFD-ISME Collaboration Project has emerged as a beacon of hope for the restoration and sustainable management of mangroves in Sabah. This project is a testament to the dedication of the Sabah Forestry Department (SFD), International Society for Mangrove Ecosystems (ISME) and their partners in safeguarding these vital ecosystems for the benefit of both local communities and the environment. I would like to extend my sincere thanks and gratitude to Tokio Marine & Nichido Fire Insurance Co. Ltd. in Tokyo and Kuala Lumpur for funding the SFD-ISME Collaboration Project and for participating in the project activities. I also express my sincere thanks to Prof. Dr. Toyohiko Miyagi and team for conducting mangrove research activities in Sabah.

This book provides an invaluable resource for anyone seeking to understand the complexities of mangrove ecosystems in Sabah, the importance of their restoration, and the innovative approaches being implemented to ensure their long-term sustainability. It is my hope that this work will inspire further efforts to protect and restore mangroves not only in Sabah but also in other regions facing similar challenges.

MESSAGE

DATUK FREDERICK KUGAN
Chief Conservator of Forests
Sabah Forestry Department

On behalf of the Sabah Forestry Department (SFD) and all the partners involved in the SFD-ISME Collaboration Project, I am proud to present this book on the restoration and conservation of mangrove ecosystems in Sabah. As we work to restore and protect these vital coastal habitats, it is essential that we document and share our findings, challenges, and successes to support future mangrove conservation efforts. Mangrove forests in Sabah play key roles in safeguarding our coastlines, supporting marine biodiversity, and enhancing local livelihoods.

With the pressures of urbanization, coastal development, and climate change, the need for effective restoration and sustainable management has never been more urgent.

This book highlights the ongoing work of the SFD-ISME Collaboration Project, offering practical solutions and insights from a range of case studies and scientific research. It also underscores the importance of collaboration among government agencies, local communities, researchers, and international partners to ensure the continued health of mangrove ecosystems.

I extend my sincere gratitude to Tokio Marine & Nichido Fire Insurance Co. Ltd. (Tokyo and Kuala Lumpur), Prof. Toyohiko Miyagi and all those who have contributed to this important work. We hope that this book will serve as both a valuable resource and a call to action for everyone invested in the future of mangroves.

ACKNOWLEDGEMENTS

This book would not have been possible without the tireless contributions of many individuals and organizations. We would like to express our sincere gratitude to:

SABAH FORESTRY DEPARTMENT

The Sabah Forestry Department (SFD) for their leadership and commitment to mangrove conservation and restoration in Sabah.

ISME PROJECT TEAM

The ISME Project Team for their dedication to the implementation of sustainable mangrove management practices and restoration activities across Sabah.

LOCAL & INTERNATIONAL EXPERTS

Local and International Experts who provided invaluable technical support, guidance, and research insights into the mangrove restoration efforts.

COMMUNITY STAKEHOLDERS

Community Stakeholders in the restoration sites of Pulau ISME, Weston, Beaufort, Teluk ISME-Marudu, Kota Marudu, Pulau Loboh, and Sungai ISME, Sandakan for their active participation and support in restoration and monitoring efforts.

COLLABORATING ORGANIZATIONS & INSTITUTIONS

Collaborating Organizations and Institutions, including universities, research institutes, and environmental NGOs, for their support in research, monitoring, and data collection.

MANGROVE TASK FORCE (MTF)

Members of the Mangrove Task Force (MTF) of SFD-ISME Collaboration Project, namely Dr. Joseph Tangah (Leader), Marrynah Matami, Dauni Seligi, Jamiss Aribin, Fabian Koret, and Charlesvyne Xavier Francis for their dedication in the field to ensure the successful implementation of mangrove restorations throughout Sabah.

SPECIAL THANKS

Authors, editors and contributors who have dedicated their time and expertise to writing and compiling the research, case studies, and findings presented in this book.

OUR GRATITUDE

We also express our gratitude to the financial supporters and donors who have made the SFD-ISME Collaboration Project and its initiatives possible.

MALAY NAMES

Api	Fire
Bakau	Mangrove
Bukit	Hill
Berhad	Limited
Insurans	Insurance
Jambatan	Bridge
Kampung	Village
Kota	Town
Kuala	Estuary
Laut	Sea
Merah	Red
Pantai	Beach
Pisau	Knife
Pulau	Island
Putih	White
Semenanjung	Peninsular
Sungai	River
Tanjung	Promontory
Tapak Semaian	Nursery
Teluk	Bay

ABBREVIATIONS

asl	above sea level
Bhd.	Berhad
CCF	Chief Conservator of Forests
CO_2	Carbon dioxide
DFO	District Forestry Officer
Dr.	PhD or Doctor of Philosophy
FR	Forest Reserve
FRC	Forest Research Centre
FRIM	Forest Research Institute Malaysia
GIS	Geographical Information System
ha	hectare
HoB	Heart of Borneo
ISME	International Society for Mangrove Ecosystems
ITTO	International Tropical Timber Organization
Kg.	Kampung
Ltd.	Limited
LBPMS	Labuk Bay Proboscis Monkey Sanctuary
LTER	Long-Term Ecological Research
MoU	Memorandum of Understanding
MTF	Mangrove Task Force of SFD-ISME Collaboration Project
NGO	Non-Governmental Organization
PES	Payment of ecosystem services
Prof.	Professor
PSC	Project Steering Committee
RDC	Rainforest Discovery Centre
REDD	Reducing Emissions from Deforestation and Forest Degradation
SDGs	Sustainable Development Goals
SFD	Sabah Forestry Department
SMAP	Sabah Mangrove Action Plan (2024 – 2033)
TMN	Tokio Marine & Nichido Fire Insurance Co., Ltd.
TMIM	Tokio Marine Insurance Malaysia Bhd.
UMS	Universiti Malaysia Sabah
VJR	Virgin Jungle Reserve

GLOSSARY

Biofouling: The accumulation of aquatic organisms, such as barnacles, algae, and mussels on submerged surfaces, including planted propagules and the stems of mangrove seedlings.

Carbon Sequestration: The process by which carbon dioxide (CO_2) is absorbed and stored by plants, trees, and other organisms, playing an important role in mitigating climate change.

Intertidal Zone: The area between the high and low tide levels, which is periodically exposed or submerged by tidal action, and is home to a variety of coastal plant and animal species, including mangroves.

Mangrove Propagule: A seedling or young plant that is ready to grow and establish itself, often a part of a mangrove tree that is adapted to disperse in coastal waters.

Restoration: The process of returning a damaged or degraded ecosystem to its natural state, including the replanting of native species and the restoration of ecological functions.

***Rhizophora*:** A genus of mangrove trees known for their distinctive prop or stilt roots, commonly found in tropical coastal areas.

Salt Tolerance: The ability of a plant species to survive and grow in environments with high salinity levels, such as those found in mangrove ecosystems.

Sedimentation: The process by which particles of mud, sand, and other materials are deposited. If excessive, the sediments may stifle or choke plant and animal life in aquatic environments.

This structured approach will help guide readers through the contents of the book, making it accessible, informative, and engaging for all those interested in mangrove restoration and conservation efforts in Sabah.

CHAPTER 1
INTRODUCTION

1.1. Mangroves of Sabah

Mangrove ecosystems in Sabah, Malaysia, are among the most diverse and ecologically significant coastal habitats in Southeast Asia. Located along the coastal regions and river estuaries, mangroves provide critical ecosystem services, including shoreline protection, carbon sequestration, and support for rich biodiversity. Sabah's mangrove forests are home to a wide range of flora and fauna, including species of mangrove trees, invertebrates, birds, and marine life. These forests are not only vital for coastal communities but also serve as important breeding grounds for fish and other marine organisms, thus contributing to the local fisheries industry.

The mangrove ecosystems in Sabah are predominantly found in sheltered bays, river deltas, and tidal estuaries, where the brackish water and fluctuating tides create unique environmental conditions. The diversity of mangrove species in the region includes representatives from the *Rhizophora*, *Avicennia*, *Sonneratia*, and *Bruguiera* genera, each playing a distinct role in maintaining the ecological balance of the coastal zone. These forests are also vital in mitigating the effects of climate change, serving as carbon sinks and protecting the coastline from erosion and storm surges.

However, the mangrove ecosystems of Sabah face increasing pressures from human activities, including deforestation, land reclamation, and pollution. These threats have highlighted the need for restoration and sustainable management of these important coastal resources to preserve their ecological integrity and ensure their continued contribution to the well-being of both local communities and the environment.

1.2. The SFD–ISME Collaboration Project

The SFD-ISME (Sabah Forestry Department – International Society for Mangrove Ecosystems) project is a collaborative initiative focused on restoring and conserving mangrove ecosystems in Sabah. The project is led by the Sabah Forestry Department (SFD) in partnership with local stakeholders, scientific institutions, and international experts from International

Society for Mangrove Ecosystems (ISME), with the aim of strengthening mangrove conservation efforts, improving restoration practices, and enhancing community engagement in the protection of these vital ecosystems.

The SFD–ISME project focuses on several key areas:

1. **Mangrove Restoration:** Restoring degraded mangrove areas through the planting of native mangrove species and implementing strategies to ensure seedling survival and ecosystem recovery.

2. **Biodiversity Monitoring:** Conducting regular assessments of the health and biodiversity of mangrove ecosystems to track the progress of restoration efforts and ensure the sustainability of these habitats.

3. **Community Involvement:** Engaging local communities in conservation activities, such as mangrove planting and monitoring, and providing education on the importance of mangroves for coastal protection, fisheries, and climate change mitigation.

4. **Research and Data Collection:** Collaborating with local and international researchers to enhance scientific understanding of mangrove ecosystems, focusing on the impacts of climate change, sea level rise, and human activities.

By integrating scientific research with community participation, the SFD-ISME project aims to promote sustainable mangrove management practices and contribute to the broader goals of ecosystem conservation and climate change adaptation in Sabah.

1.3. About This Book

This book provides an in-depth exploration of the mangrove ecosystems in Sabah, with a specific focus on the ongoing restoration efforts under the SFD-ISME project. It presents the findings of research activities, case studies, and observations made during the project, offering valuable insights into the challenges and successes of mangrove conservation in the region. Through this book, we aim to share knowledge on mangrove restoration techniques, the ecological values of mangroves, and the role of community involvement in successful ecosystem rehabilitation.

The book includes:

- Case Studies: Detailed reports on specific mangrove restoration sites in Sabah, highlighting both the successes and challenges faced during the restoration process.
- Research Findings: Results from scientific studies conducted by local and international experts, focusing on the dynamics of mangrove ecosystems and their responses to environmental stressors such as sea level rise and biofouling.
- Management Strategies: Practical recommendations for improving the management and sustainability of mangrove forests, including innovative approaches to overcoming challenges, such as invasive species, coastal development, and pollution.
- Future Directions: A look ahead to the future of mangrove conservation in Sabah, with an emphasis on the need for continued research, monitoring, and community-based management approaches to safeguard these valuable ecosystems.

By compiling the collective knowledge and experiences from the SFD-ISME project, this book aims to serve as a comprehensive resource for researchers, practitioners, policymakers, and community stakeholders involved in mangrove conservation and restoration. Ultimately, it seeks to promote a greater understanding of the importance of mangroves and encourage ongoing efforts to protect and restore these critical ecosystems for the benefit of both people and the environment.

CHAPTER 2
CASE STUDIES

2.0. Case Studies in Key Locations

These case studies examine the mangrove ecosystems in four significant locations in Sabah: Pulau ISME-Weston, Beaufort, Teluk ISME-Marudu, Kota Marudu, Pulau Loboh, Sandakan, and Sungai ISME, Sandakan. Each of these sites has been part of ongoing mangrove restoration and conservation efforts, offering valuable insights into the health, growth, and resilience of mangrove forests in response to both natural and anthropogenic pressures.

2.1. Pulau ISME–Weston, Beaufort

Location Overview: Pulau ISME is situated in the Weston area of Beaufort, on the west coast of Sabah. This coastal zone is characterized by mudflats, mangrove forests, and estuarine habitats. The site plays a crucial role in the protection of coastal areas from erosion and provides important habitats for marine life. Below are the drone photos of Pulau ISME since 2019.

Pulau ISME in 2019.

Pulau ISME in 2021.

Pulau ISME in 2022.

Pulau ISME in 2023.

Mangrove Ecosystem Characteristics:

The mangrove species present in Pulau ISME include:

Sonneratia caseolaris, Rhizophora apiculata, Kandelia candel, and *Avicennia alba*

The site experiences seasonal tidal fluctuations and is exposed to periodic changes in salinity due to freshwater influx from rivers.

Restoration and Monitoring:

- Mangrove restoration at Pulau ISME started in 2016 with the planting of propagules of *Rhizophora apiculata* and seedlings of *Sonneratia caseolaris*. In 2020, propagules of *Kandelia candel* were used for planting which are known adapted to the local environmental conditions.

- Initial monitoring data indicates successful seedling establishment, with propagules showing healthy growth and the emergence of leaves.

- However, in February 2017, a few thousand hairy caterpillars were found attacking some young and mature *Sonneratia caseolaris* trees at the mudflats of Sungai Weston and Pulau ISME, Weston Forest Reserve (Class I), Beaufort. The location of Pulau ISME (~75 ha) is a new mudflat area designated for mangrove rehabilitation programme under the SFD-ISME collaboration project in Sabah. Some of the plants were completely defoliated by the voracious caterpillars within a short time. The mature caterpillar pupated and was encapsulated in a whitish silky cocoon and attached to the hostplant. Some of the cocoons were brought back to the Forest Research Centre, Sandakan, and they were observed in captivity. The emerged moth was identified as *Streblote helpsi* Holloway (Lepidoptera: Lasiocampidae). A few weeks after the attack, observation by end of March 2017, the defoliated plants flushed on new leaves. Hence, control measure was not necessary. Nevertheless, this is a new record for moth of *Streblote helpsi* defoliating mangrove species, *Sonneratia caseolaris*.

Key Challenges:

• Sedimentation: The continuous deposition of sediments from particles, such as mud, sand, and other materials and continuously forming islands of sedimentary mudflats. In the case of Pulau ISME, it is a result from accumulation of mud and sand particles from the upland and accumulation of sand particles at almost every river mouth in Beaufort district.

• Erosion: While mangroves provide natural coastal protection, increased human activity and infrastructure development in the area have contributed to coastal erosion and habitat degradation.

Successes and Recommendations:

• Continued monitoring of mangrove health and its growth.

• Continued assessment of mudflats restoration and explore the best management strategies for successful rehabilitation efforts following the Sabah Mangrove Action Plan (SMAP) 2024–2033 strategies.

2.2. Teluk ISME–Marudu, Kota Marudu

Location Overview: At Teluk ISME-Marudu located in the Kota Marudu district, a significant mangrove ecosystem plays a vital role in coastal protection, carbon sequestration, and biodiversity support. The area includes both restored and natural mangrove forests along sheltered coastal bays and mudflats.

Drone photo of Teluk ISME-Marudu taken in 2024.

Planting of *Rhizophora apiculata* seedlings started in 2023.

Mangrove Ecosystem Characteristics:

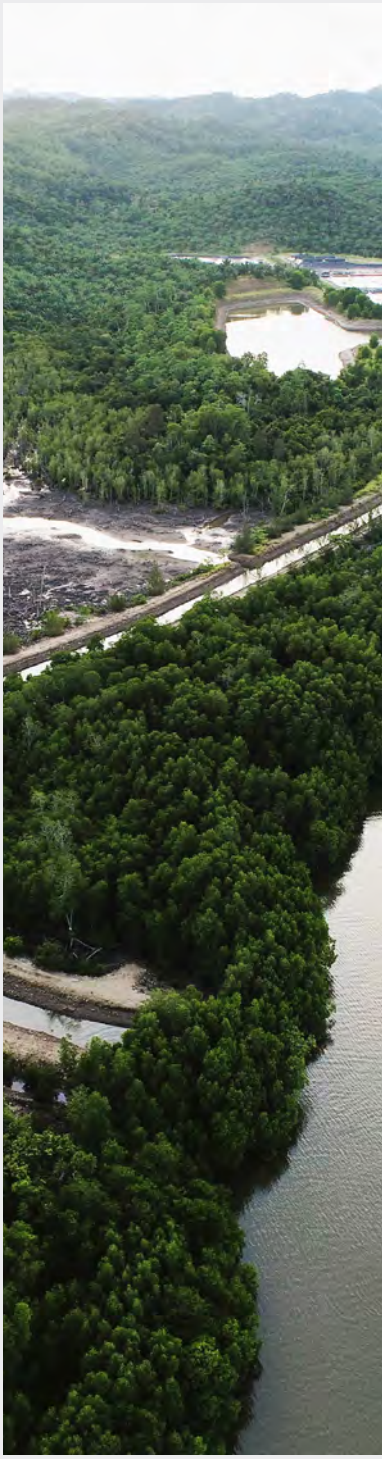
- The mangrove species planted in Teluk ISME include *Rhizophora apiculata*, *Rhizophora mucronata*, *Rhizophora stylosa*, and *Sonneratia alba*.
- The site is influenced by a combination of tidal movements, seasonal rains, and freshwater runoff from nearby rivers, resulting in varying salinity levels.

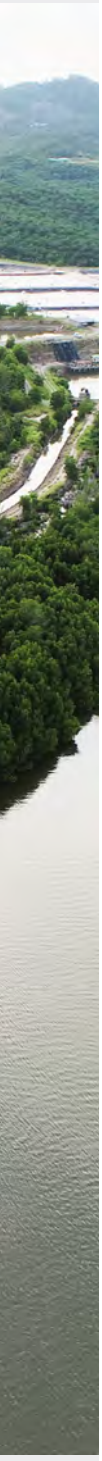
Restoration and Monitoring:

- Mangrove planting efforts at Teluk ISME-Marudu were initiated in January 2023. The project aimed to rehabilitate mudflats areas that were developed due to continued accumulation of sediments which indirectly formed the mangrove mudflats at Teluk ISME-Marudu. The influx of runoff consists of particles caused by the unsustainable land-use practices and coastal development inland continued.
- Early-stage monitoring indicated that seedlings were growing well initially, with healthy leaf development and root establishment.
- However, after five months, barnacle infestation became a major concern. Severe barnacle attachment on the stems of seedlings was observed, leading to physical damage and increased mortality among younger plants, particularly those under 12 months.

Key Challenges:

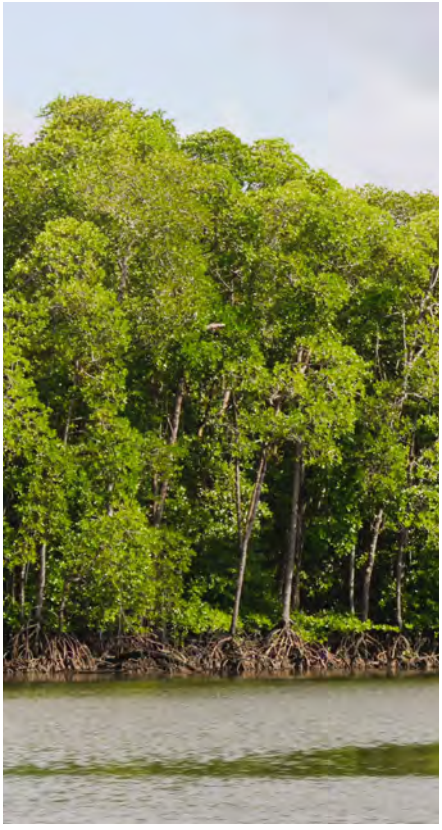
- Barnacle Infestation: Barnacles (*Amphibalanus* sp. and *Europhia withersi*) have caused significant damage to seedlings, affecting their growth and survival.
- Water Quality: Local water quality fluctuates due to agricultural runoff, which can affect mangrove health, especially in areas closer to agricultural lands.





Successes and Recommendations:

- The use of barnacle-resistant materials or treatments for seedlings could help reduce biofouling intensity.
- Continue community engagement and educate local stakeholders on the importance of mangrove conservation and the threats posed by human activities, particularly in relation to water quality and sedimentation.



2.3. Pulau Loboh, Sandakan

Location Overview: Pulau Loboh is an island formed by the accumulation of mangrove mudflats. Located off the coast of Sandakan opposite Sg. Gum-Gum & Sg. Loboh FR in the east coast of Sabah. The island's mangrove forests are part of a larger coastal ecosystem that supports both marine biodiversity and local fisheries.

Jetty at Sg. Loboh – Ecological & Biodiversity Monitoring Station.

Mudflats of Pulau Loboh with natural regeneration of *Avicennia alba*.

Restoration site at Pulau Loboh during low tide.

Restoration site at Pulau Loboh during high tide at 2.0 m asl.

- Dominant mangrove species include *Avicennia alba*, *Ceriops tagal*, *Rhizophora apiculata*, *Rhizophora mucronata and Sonneratia alba*.
- The site experiences daily tidal changes and is influenced by freshwater discharge from nearby streams and rivers.

Restoration and Monitoring:

- The restoration effort in Pulau Loboh focuses on rehabilitating mudflats areas where mangrove ecosystems have been newly formed due to influx of runoff from the upland bringing together particles consists of mud and sand that formed the mudflats island.
- Monitoring has shown that the planted propagules are establishing well, and the area is also showing early signs of natural regeneration of pioneer species such as *Avicennia alba*.
- The restoration sites are being closely monitored for changes in biodiversity, particularly for primates, crocodiles, fish and other invertebrate populations that rely on the mangrove habitats.

Key Challenges:

- Coastal Development: Proximity to local settlements and development has led to habitat fragmentation and an increase in pollution.

Successes and Recommendations:

- Continuing efforts to manage coastal development and land use around Pulau Loboh will be essential for maintaining the success of restoration activities.
- Incorporating diverse species into restoration projects to ensure ecosystem stability and biodiversity resilience.

2.4. Sungai ISME, Sandakan

Location Overview: Sungai ISME is a 2-ha restoration site formerly encroached by oil palm plantation located near the town of Sandakan. The area serves as an important buffer zone between the coastal and inland habitats, providing essential ecological services, such as water filtration and coastal protection.

Sg. ISME established in 2011 whereby mangrove restoration started in 2012.

Visitors at Sg. ISME in 2017, five years after planting.

Sg. ISME mangrove vegetation in 2024 (white frame) after 12 years of successful restoration activities.

Mangrove Ecosystem Characteristics:

- The mangrove species present include *Rhizophora mucronata*, *Rhizophora apiculata*, *Bruguiera gymnorhiza*, *Ceriops tagal*, *Xylocarpus granatum*, *Avicennia alba*, and *Sonneratia alba*.
- Sungai ISME is influenced by both tidal fluctuations and the influx of freshwater from surrounding rivers.

Restoration and Monitoring:

- Sungai ISME is part of a long-term restoration project that has focused on improving water quality, restoring degraded mangrove areas, and monitoring biodiversity.
- Restoration activities have involved planting of mangrove propagules and monitoring the survival and growth rates of mangrove seedlings.
- The site has shown positive results, with early-stage plantings growing well, although there are concerns about the impacts of seasonal flooding and freshwater runoff.

Key Challenges:

- **Flooding and Sedimentation:** Periodic flooding and high sedimentation levels in the river system can hinder seedling establishment and natural regeneration.
- **Water Pollution:** Industrial runoff and waste from nearby settlements may continue to pose a challenge to the health of the mangrove ecosystem.
- **Species Competition:** In some areas, faster-growing non-native species may outcompete native mangrove species, threatening biodiversity.

Successes and Recommendations:

- Enhancing local environmental monitoring and promoting pollution control measures can help improve the long-term sustainability of mangrove ecosystems in Sungai ISME.
- Active involvement of local communities in monitoring and protecting the area is critical for the success of the restoration efforts.

2.5. Conclusion and Cross-Site Observations

- The case studies of mangrove restoration and monitoring in Pulau ISME-Weston, Beaufort; Teluk ISME-Marudu, Kota Marudu; Pulau Loboh, Sandakan; and Sungai ISME, Sandakan; provide valuable insights into the dynamics of mangrove ecosystems in Sabah. While restoration efforts are yielding positive results in terms of seedling establishment and biodiversity recovery, challenges such as biofouling, water quality deterioration, and coastal development pressures need to be addressed for long-term success.

Key recommendations for improving mangrove restoration efforts across these sites include:

- Strengthening biofouling management to protect young seedlings.
- Enhanced monitoring of water quality and pollution sources to support mangrove health.
- Community engagement to raise awareness about mangrove conservation and sustainable land use practices.

These efforts will ensure that mangrove ecosystems in Sabah continue to thrive and provide critical ecological services to coastal communities and may provide baseline data for payment of ecosystem services (PES).

CHAPTER 3
RESEARCH ACTIVITIES

3.1. Plant Diversity and Ecology

Mangrove ecosystems are a unique and highly productive component of the coastal environments, characterized by their ability to thrive in saline, intertidal areas where the land meets the sea. These ecosystems are found in tropical and subtropical regions around the world, with Southeast Asia—particularly Sabah, Malaysia—hosting some of the most biologically diverse and ecologically important mangrove forests. The complex interaction between the mangrove trees, their associated flora and fauna, and the tidal, saline, and muddy environments in which they grow, creates a rich and dynamic habitat that supports diverse plant and animal species.

3.2. Mangrove Plant Diversity

Mangroves are plant communities specifically adapted to live in coastal environments with high salinity, fluctuating tidal patterns, and waterlogged, oxygen-poor soils. These plants have developed specialized physiological and morphological adaptations that allow them to thrive in harsh, saline, and dynamic conditions. In Sabah, the diversity of mangrove species is remarkable, with over 30 species of trees, shrubs, and herbaceous plants identified across the region's coastal zones. An assessment of mangrove plants diversity was conducted focusing on mangrove trees, along with their scientific names, families and local names, occurring in Sabah (Table 1.). These species belonging to key genera, have their own ecological role and habitat preferences. For example, species of *Avicennia alba* and *Sonneratia alba* are found in the seaward zone, *Rhizophora apiculata* and *Bruguiera parviflora* in the middle or main mangrove zone.

Table 1. List of mangrove plants found in Sabah.

No	Scientific Name	Family	Local Name
1	*Aegiceras corniculatum*	Primulaceae	Kacang Kacang
2	*Aegiceras floridum*	Primulaceae	Teruntun
3	*Acanthus ebracteatus*	Acanthaceae	Jeruju Hitam
4	*Acanthus ilicifolius*	Acanthaceae	Jeruju Putih
5	*Acrostichum aureum*	Pteridaceae	Piai Raya
6	*Acrostichum speciosum*	Pteridaceae	Piai Lasa
7	*Avicennia alba*	Verbenaceae	Api-Api Hitam
8	*Avicennia marina*	Verbenaceae	Api-Api Putih
9	*Avicennia officinalis*	Verbenaceae	Api-Api Jangkang
10	*Brownlowia argentata*	Malvaceae	Durian Laut
11	*Bruguiera cylindrica*	Rhizophoraceae	Beus, Berus Putih
12	*Bruguiera hainesii*	Rhizophoraceae	Berus Mata Buaya
13	*Bruguiera gymnorhiza*	Rhizophoraceae	Putut
14	*Bruguiera parviflora*	Rhizophoraceae	Lenggadai
15	*Bruguiera sexangula*	Rhizophoraceae	Mata Buaya
16	*Ceriops tagal*	Rhizophoraceae	Tengar
17	*Ceriops zippeliana*	Rhizophoraceae	Tirog
18	*Camptostemon philippinense*	Malvaceae	Gapas Gapas
19	*Excoecaria agallocha*	Euphorbiaceae	Buta Buta
20	*Kandelia candel*	Rhizophoraceae	Linggayong
21	*Lumnitzera littorea*	Combretaceae	Geriting Merah

No	Scientific Name	Family	Local Name
22	*Lumnitzera racemosa*	Combretaceae	Geriting Putih
23	*Nypa fruticans*	Arecaceae	Nipah
24	*Osbornia octodonta*	Myrtaceae	Myrtle Mangrove
25	*Rhizophora apiculata*	Rhizophoraceae	Bangkita, Bakau Minyak
26	*Rhizophora mucronata*	Rhizophoraceae	Bakau Kurap
27	*Rhizophora stylosa*	Rhizophoraceae	Bakau Pasir
28	*Sonneratia alba*	Lythraceae	Pedada
29	*Sonneratia caseolaris*	Lythraceae	Perepat
30	*Sonneratia ovata*	Lythraceae	Pedada Jambu
31	*Sonneratia x hainanensis*	Lythraceae	Pedada Pondan
32	*Scyphiphora hydrophyllacea*	Rubiaceae	Landing Landing
33	*Xylocarpus granatum*	Meliaceae	Nyireh Bunga
34	*Xylocarpus moluccensis*	Meliaceae	Nyireh Batu

Lumnitzera littorea

Key to Mangrove Tree Species in Sabah

Rhizophora spp. (Bakau Kurap, Bakau Pasir, Bangkita)

Species such as *Rhizophora stylosa*, *Rhizophora apiculata*, and *Rhizophora mucronata* dominate most of Sabah's mangrove forests, particularly in areas subject to strong tidal movements. These species are easily recognizable by their characteristic prop roots that emerge from the stem to anchor the plant in soft, muddy sediments. Flowers of *Rhizophora stylosa* have a long style, *Rhizophora apiculata* are in pairs, and *Rhizophora mucronata* are yellowish in colour. The roots of Rhizophora species are highly effective at stabilizing the substrate and reducing coastal erosion. These trees also provide habitat for a variety of marine organisms, including crustaceans, mollusks, and juvenile fish. The genus Rhizophora is particularly adapted to areas with high salinity and can survive in conditions where other plants would struggle to survive. Their network of prop roots helps in the establishment of water-borne propagules.

A curtain of aerial roots sprouting from branches provides extra anchorage for *R. apiculata*.

Avicennia marina (Api-Api Putih)

This species is highly tolerant of salinity and is often seen in areas with lower tidal energy, such as sheltered bays and estuaries. *Avicennia marina* is found in both the seaward and landward intertidal zones on sheltered shores, where it forms dense stands of vegetation acting as pioneer species. Avicennia species have evolved pneumatophores (aerial roots) that stick up from the soil to facilitate gas exchange in oxygen-deprived soils. The presence of these roots helps the plant cope with the anaerobic conditions typical of mangrove sediments. The trees can grow up to 8 m tall. Fruits of *Avicennia marina* are fleshy, light grayish in colour, and covered with fine hairs, and petals of flowers are yellow to orange in colour. Leaves are elliptical with rounded tip.

Fruits (left) and flowers (right) of *Avicennia marina.*

Luxuriant growth of *A. marina* in coastal areas of Semporna FR.

Sonneratia spp. (Mangrove Apple)

Sonneratia spp. are common species in Sabah's mangrove forests. There are three species and one hybrid in Sabah i.e. *Sonneratia alba*, *Sonneratia ovata*, *Sonneratia caseolaris*, and *Sonneratia* x *hainanensis*. They thrive in areas of landward intertidal zones. Trees are known for their distinctive large, round fruit that are dispersed by the tides. The thick, leathery leaves of *Sonneratia* spp. help reduce water loss, making it more resilient to dessication and salinity stress. The species are particularly important for sediment trapping and shoreline stabilization.

A planted *Sonneratia caseolaris* at Pulau ISME in Beaufort, has started flowering and fruiting.

Fruits of *Sonneratia alba* at Sg. ISME, Sandakan.

Bruguiera spp. (Black Mangrove)

Species such as *Bruguiera gymnorhiza*, *Bruguiera cylindrica*, *Bruguiera sexangula*, and *Bruguiera parviflora* are typically found in areas with moderate to low salinity. They are distinguished by their large, prominent knee roots that grow above the sediment surface. *Bruguiera* spp. can survive in slightly less saline conditions compared to Rhizophora, and they often dominate the middle intertidal zone, where they help to stabilize coastal soils and prevent erosion. Their roots are also home to a variety of marine invertebrates, which contribute to the overall biodiversity of the mangrove ecosystem.

The dense stand of *Bruguiera parvilora* in Labuk Bay, Sandakan.

Flowers of *Bruguiera cylindrica* consist of three white flowers, turning brownish with age.

Lumnitzera spp. (Geriting Putih and Geriting Merah)

Known as the Mushroom Mangrove, there are two species, i.e. *Lumnitzera racemosa* (Geriting Putih) with white flowers is less common but is an important species in the restoration of degraded mangrove habitats, and the more common species is *Lumnitzera littorea* (Geriting Merah). These species grow on saline mudflats and have been shown to be resilient to environmental stress, including variations in salinity. They play a role in coastal regeneration by stabilizing the substrate and providing shelter for variety of marine organisms.

L. racemosa can grow up to 8 m tall, found on sandy and consolidated substrates.

Lumnitzera racemosa with white flowers.

Lumnitzera littorea with red flowers.

Ceriops tagal (Tengar)

Ceriops tagal is a distinctive mangrove species known for its yellowish stems and can grow up to 6 m tall. It often grows in the seaward intertidal zone and is highly effective in trapping sediments, thereby building up the mangrove forest floor. May coexist with *Ceriops zippeliana* but usually more abundant. *Ceriops tagal* plays a key role in mitigating the impacts of erosion and protecting the shoreline. The main threat for *Ceriops tagal* in Sabah is the illegal activities of extracting mangrove tree's bark which eventually kill the trees. Illegal smuggling of Tengar bark in Sabah still needs continuous enforcement by SFD although such activity is seasonal.

Illegal activities of extracting Tengar bark in Trusan Sugut.

Bundles of illegally smuggled mangrove bark in the forest awaiting transportation.

A mature tree of *Ceriops tagal* with copious production of propagules.

Tree of *Ceriops zippeliana* with upward protruding propagules.

Rhizophora stylosa (Bakau Pasir)

The species can grow up to 10 m tall. They grow on a variety of tidal habitat on mud, sands, coarse grits and rocky areas. The leaves, normally with pointed leaf tip, are leathery with regularly spotted on under surface.

First fruiting of planted *Rhizophora stylosa* at Semporna FR.

***Rhizophora stylosa* at the height of ~3.5 m, are fruiting in Semporna.**

Xylocarpus granatum (Nyireh Bunga)

Trees of *Xylocarpus granatum* can grow up to 15 m tall. They occur at the back mangrove zone or low salinity mangrove areas and along banks or tidal creeks. The *Xylocarpus granatum* in Sepilok Laut grows fairly gregariously. The distinctive features are the undulating snake-like or cable roots, with cannon-ball fruits.

The cannon-ball fruits of *Xylocarpus granatum.*

Flowers of *Xylocarpus granatum.*

3.2. Ecology of Mangrove Forests

Mangroves are integral to the functioning of coastal ecosystems and contribute to the food web at multiple levels. Their dense root systems provide habitat and shelter for a wide range of marine and terrestrial organisms, including fish, mollusks and crustaceans. Mangroves also play a crucial role in nutrient cycling, as fallen leaves and organic matter decompose and release nutrients that support both terrestrial and marine food chains. These nutrients support plankton growth, which forms the base of the food chain for larger marine organisms. Additionally, mangroves help maintain water quality by filtering out excess nutrients and trapping sediment. This process contributes to the health of nearby coral reefs and seagrass beds, as well as the overall health of coastal waters.

Mangrove ecosystems are dynamic, constantly shifting between terrestrial and marine environments as a result of tidal changes. The interplay between these two realms creates a unique set of ecological conditions that shape the structure and functioning of the mangrove forest. Tidal fluctuation, salinity levels, and sediment composition are all critical factors that influence the distribution and growth of mangrove species.

Zones of Mangrove Forests

Mangrove forests in Sabah are typically divided into distinct ecological zones based on factors such as tidal elevation, salinity, and substrate type. These zones reflect the adaptability of different mangrove species to varying environmental conditions:

1. Upper (Landward) Intertidal Zone

This zone experiences the highest tidal variation and is typically home to mangrove species such as *Avicennia marina* and *Sonneratia alba*. These species are better suited to coastal areas with and longer exposure to air during low tide.

2. Middle (Main) Intertidal Zone

Mangrove species, such as *Rhizophora apiculata*, *Bruguiera* spp. and *Ceriops* spp. dominate this zone, which is more exposed to brackish water with the influence of tides less frequently. These species are adapted to moderate salinity and are more tolerant of anaerobic soil conditions.

3. Lower (Seaward) Intertidal Zone

The seaward zone is frequently submerged and experiences higher salinity levels. It is dominated by species such as *Rhizophora stylosa* and *Rhizophora mucronata,* which have specialized root structures to anchor them in soft, unstable sediments. *Avicennia alba* and *Sonneratia alba* with cable roots also thrive in seaward zone.

4. Nipah *(Nypa fruticans)* and mixed Nipah Zone

This zone occurs most predominantly along upstream banks of rivers where there is greater freshwater influence. *Nypa fruticans*, the mangrove palm, and several riverine mangrove species, grow gregariously, interspersed with mud lobster mound. The mangrove flora consists of trees, shrubs, woody climbers (e.g. *Derris trifoliata*), palms, ferns, and herbs.

Adaptations to the Mangrove Environment

Mangrove plants have evolved a range of specialized adaptations that allow them to survive in their unique coastal habitat. These adaptations are critical for enabling mangroves to cope with salinity, tidal fluctuations, anoxic (low oxygen) soils, and shifting sedimentation levels. Some of these key adaptations include:

Salt Tolerance

Mangrove species have developed various mechanisms to tolerate the high salinity of coastal waters. Some species excrete excess salt through glands in their leaves, while others limit salt uptake through specialized roots. Some mangrove trees, such as those in the *Avicennia* genus, are capable of excluding salt at the root level, while others like Rhizophora store salt in their older leaves, which eventually drop off.

Prop Roots and Pneumatophores

One of the most iconic features of mangrove plants is their prop roots (e.g. *Rhizophora*) and pneumatophores (e.g. *Avicennia*). These root structures help mangroves stabilize the soft, shifting sediments of the intertidal zone. The prop roots grow down from the tree's trunk, anchoring the plant into the muddy soil, while pneumatophores rise above the soil surface, allowing the plant to obtain oxygen in waterlogged, low-oxygen soils.

Vivipary (Predispersal Germination of Seedlings)

Many mangrove species exhibit vivipary, where the seeds germinate while still attached to the parent tree, producing a propagule or young seedling. This adaptation allows the young plant to be more resilient when it is eventually dispersed by tides, as it is already capable of starting its growth immediately after it settles on the mudflats.

Sediment Trapping

Mangrove plants are effective in trapping sediments by their dense root systems. Their roots slow down water flow, causing sediments to settle and accumulate around the plant. Over time, this sedimentation process contributes to the building of coastal land, elevating the habitat above high tide levels. This sediment-trapping ability is vital for coastal regeneration and shoreline protection.

Temperature and Light Tolerance

Mangrove trees are also highly adapted to the harsh environmental conditions of the tropics. They are capable of thriving in areas with intense sunlight, high temperatures, and significant tidal fluctuations. Their thick, waxy leaves reduce water loss through transpiration, while their root systems provide stability in the face of frequent tidal changes.


Lumnitzera racemosa

3.4. Biofouling Activities of Barnacles

Biofouling activities in marine environment are due to organisms, such as barnacles, algae, oysters, and clams. These organisms easily get attached to any surface or wall. In the case of barnacle's activities in planting location at Teluk ISME-Marudu, barnacles have been identified as the potential cause of seedling mortality, due to attachment of these fouling organisms to mangrove seedlings (for seedlings with age below 12 months in the field), especially attached on the stems of seedlings.

Photo showing hundreds of barnacles attached to the planted propagules of *Rhizophora apiculata* which caused considerable damage, by the weight of the barnacles.

Close-up photo of barnacles attached to mangrove seedling at Teluk ISME, Kota Marudu.

Barnacles are living marine organisms. They are crustaceans, related to crabs, shrimps and lobsters. They live in the intertidal area where it is easy for them to feed because they are filter feeders.

Barnacles use their sensory appendages called cirri to grab food in the seawater. Unlike other crustaceans, barnacles are sessile organisms, which means they can only stay in one place (sedentary). Barnacles begin their lives as larvae, floating in the seawater until they find a suitable substrate to attach. Once a suitable attachment is found, barnacles secrete an extremely adhesive glue that cements onto the outer stems of young mangrove seedlings. Like other crustaceans, barnacles also outgrow their shells through the moulting processes and they do not feed on mangroves seedlings, rather they attach themselves to enable them to filter feed on planktons brought in by the wave actions.

The SFD-ISME project carried out a short-term study on the effect of barnacles on mangrove seedlings planted at Teluk ISME. Mangrove planting at Teluk ISME started in February 2023 with propagules of *Rhizophora stylosa*, *Rhizophora mucronata* and *Rhizophora apiculata* as planting materials. Initially, the planted mangrove propagules exhibited healthy growth as expected, based on the emergence of young leaves. However, after five months of planting, attachment of barnacles to the young seedlings occurred at an alarming rate. Infestation of barnacles was so severe that caused permanent damage and seedling mortality as observed by the MTF team of SFD-ISME Collaborative Project. Sometimes, the hard calcareous shells of the barnacles cause the mangrove seedlings to bend. Mortality may also be caused by suffocation due to blockage of lenticels. When the infested seedlings are under stress, they become vulnerable to strong wave actions. In the case of Teluk ISME, two species of barnacles were identified, i.e., *Amphibalanus* sp. and *Europhia withersi*.

Chemical Treatment (ethanol and Clorox bleach)	**Natural Remedy (lemongrass + water)**
Method: Spray onto the live barnacles' operculum during low tide. Avoid droplets of solution to the ground.	Method: Spray onto operculum of barnacles during low tide.
Result after 3 weeks: Barnacles reduced dramatically and seedlings survived. Chemical treatment seems to be effective but precaution is still needed.	Results after 3 weeks: Seedlings died due to barnacles' infestation. Lemongrass and water are not really effective.

3.5. Long-Term Ecological Research

In July 2024, ISME brought experts from Japan to carry out research activities focused on the restored mangroves areas and in the long-term ecological research (LTER) of mangroves in Sabah. The following summary of studies by the experts from Japan indicates that mangroves forest in Sabah has been developing since the recent sea level fluctuations within the mangrove ecosystems of different environmental conditions. Short-term research activities conducted in Sabah were carried out at the LTER Sepilok, Sandakan (pristine mangrove forests), Pulau ISME, Beaufort (reforestation of island mangrove) and Sg. Tokio Marine, Lahad Datu (restoration of degraded mangroves area), in collaboration with Sabah Forestry Department.

Prof. Shigeyuki Baba (third, right) and Prof. Toyohiko Miyagi (sixth, right) posing for a group photo after completion of soil sampling at Pulau ISME.

3.6. Key Findings and Observations

The research team observed that mangrove forests in Sabah are showing signs of adaptation to recent fluctuations in sea levels. These fluctuations are a natural part of the coastal ecosystem dynamics, and mangroves have evolved to thrive in the intertidal zone, where the balance of saltwater and freshwater is constantly changing. However, increased sea level rise linked to climate change is putting additional pressure on these ecosystems, potentially influencing the distribution and growth patterns of certain mangrove species.

Mangrove Development and Ecological Trends

The team's observations across different restoration sites suggest that mangroves in Sabah are gradually developing and becoming more resilient. In areas, such as Sepilok, Sandakan, and Pulau ISME, mangrove seedlings planted in recent years are showing promising growth, especially in sheltered tidal zones. The ongoing restoration efforts in Beaufort and Lahad Datu have also resulted in the successful establishment of mangrove forests, with early signs of biodiversity recovery.

Species-Specific Responses to Environmental Changes

Certain mangrove species have demonstrated varying degrees of adaptability to the changing sea levels. Species such as *Rhizophora stylosa*, *Rhizophora mucronata*, and *Rhizophora apiculata* are more resilient to sea level rise and saltwater intrusion, whereas other species may be more sensitive to these changes. The study found that the success of mangrove restoration efforts heavily depends on selecting the right species for the specific environmental conditions at each restoration site.

Long-Term Ecological Monitoring

The data collected from the LTER plots in Sabah is invaluable for understanding long-term trends in mangrove forest dynamics. Monitoring has shown that mangroves in these areas are responding to both natural and anthropogenic stresses, such as fluctuating sea levels and coastal development. The research emphasizes the importance of long-term ecological monitoring to predict how mangrove ecosystems will evolve under future environmental changes, particularly as sea levels continue to rise due to climate change.

Restoration Site Success and Challenges

The Sg. Tokio Marine restoration site in Lahad Datu and other areas, such as Pulau ISME, have seen significant success in restoring mangrove cover, with some sites showing rapid colonization by mangrove species. However, challenges remain, particularly with the issue of biofouling (e.g., barnacle attachment) on young seedlings, which has been observed at some restoration sites. These biofouling organisms are negatively impacting seedling survival, especially in the first 12 months after planting, as seen in earlier studies at Teluk ISME-Marudu.

Collaborative Efforts and Future Directions

The study highlights the importance of collaboration between local and international experts in enhancing the understanding of mangrove ecology and improving restoration strategies. The Japanese experts emphasized the need for continued research to better understand the impact of climate change on mangrove resilience and to develop adaptive management strategies that can mitigate the negative effects of sea level rise and other environmental stressors.

The research conducted by the Japanese experts has provided valuable insights into the ongoing development and resilience of mangrove forests in Sabah. While the mangroves are adapting to sea level fluctuations, it is clear that continued efforts in restoration, monitoring, and species selection are crucial for the long-term success of these ecosystems. The findings also underscore the importance of comprehensive ecological studies, such as those conducted in the LTER plots, to guide future conservation and restoration practices in Sabah. Moving forward, the collaboration between local and international researchers will be key to ensuring the sustainability of mangrove ecosystems in Sabah and their ability to withstand future environmental challenges.

Mangrove soil sampling to analyze soil carbon content in Sepilok Laut (left) and Lahad Datu (right).

3.7. Some Insights on Mangrove Rehabilitation

This SFD-ISME rehabilitation project which was started since 2012, has revealed insights into the future of mangrove forests in Sabah for the coming decades as follows;

1. Pulau ISME, Weston FR (Ext. Class I) ~ 75 ha

These activities performed under this collaboration is considered the afforestation of mangroves, whereby accumulation of runoff sediment merged and becoming firm to form mangrove mudflats and suitable for growth on two particular riverine mangrove species, i.e. *Kandelia candel* and *Sonneratia caseolaris*. Continuous mudflats accumulation caused by sedimentation at the estuary Weston River has successfully formed ~ 300 hectares of mangrove mudflats. Afforestation at the estuary started at the end of 2016. Based on initial field observation, the soil at Pulau ISME is now reasonably firmed and enabled the colonization of mangrove vegetation has attracted not only marine life but other wildlife, such as proboscis monkeys (*Nasalis larvatus*),

long-tail macaques (*Macaca fascicularis*), crocodiles (*Crocodylus porosus*), variety of birds and thousands of insects.

Photo of Pulau ISME showing young and healthy planted mangroves trees of *Avicennia alba* and *Sonneratia caseolaris*, spreading their pneumatophores roots.

2. Sepilok Mangrove VJR (Class VI) ~ 1,235 ha

The first recorded soil samples from the Sepilok mangrove have been collected as part of the Collaborative Project between Sabah Forestry Department (SFD) and International Society for Mangrove Ecosystems (ISME). These soil samples offer valuable insights into the long-established and highly unique mangrove ecosystems of Sabah. The formation of the mangrove soils in Sepilok can be traced back thousands of years, as observed through the structure and texture of the soil, which reaches a depth of 1.3 meters.

What's remarkable is that even at this considerable depth, the soil remains enriched with living and fresh roots of mangrove plants, seamlessly integrated with the surrounding clay soils. This pristine and untouched environment is a testament to the resilience and productivity of mangrove ecosystems. Beyond their ecological beauty, these mangroves serve as one of the most effective carbon sinks, playing a crucial role in sequestering carbon and other nutrients, helping to mitigate climate change while supporting diverse marine and terrestrial life.

Photos showing mangrove soil samples from different locations in the LTER Sepilok Laut.

3. Sg Tokio Marine, Kuala Tingkayu FR, Lahad Datu (~ 56 ha)

The rehabilitation site is an abandoned shrimp farm located within Class V Forest Reserve. This reforestation efforts of suitable mangrove species started in 2014-2015. The soil conditions are typical of mangrove ecosystems. The history of these abandoned shrimp ponds is that, mangroves were clear cut in 1988 for shrimp farming. The evidence from soil samples also suggests that the dead mangroves bark and wood are within the soil layers. This perhaps has resulted in the removal of carbon and other nutrients from mangroves trees and soil. During the period of 2014-2015, massive reforestation was carried out under this collaboration and planted thousands of suitable mangrove plants. It took approximately 10 years of reforestation efforts for the mangrove ecosystem to be functional again and available for our lifetime and able to serve humanity and others, not only as a carbon sink, but also as habitat for many more living organisms.

Aerial photo of reforestation site (left) and soil sampling successfully completed at Sg Tokio Marine, Lahad Datu, with Prof. Toyohiko Miyagi and his wife (right) expressing their satisfaction for a job well done.

Preliminary findings by the Japanese experts based on the allometric equation estimation for the volume of prop roots and diameter at the top of prop root (cm) of *Rhizophora apiculata* mangrove trees in Sabah, showed higher biomass content for Sabah probably due to bigger trees and denser prop roots, compared to other *Rhizophora* forests in Japan, Vietnam and Mauritius.

Other findings of research activities within LTER Sepilok Laut were published in Sepilok Bulletin (2024) 33:1-13. The following are highlights of the research. After the first assessment in 2017, the LTER Sepilok Laut was revisited in 2021, and estimated the mortality, recruitment, species turnover rates and changes in diversity indices and above-ground biomass. The study indicated that mortality rates were slightly higher than recruitment rates, mainly attributed to natural death of small stems. Low relative growth rate was recorded for inland communities primarily dominated by mangrove associates. Further analysis on cluster for species assemblages of the enumerated mangrove plants remained unchanged, partly due to the absence of disturbances. It is suggested that the gap of censuses to be increased in order to detect any temporal diversity gradient, especially in species poor plots. Despite these limitations, the study provided important baseline data in monitoring the dynamics of mangrove forests in Sabah.

3.8. Publications and Reports

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Suis, M.A.F., Matami, M., Nakabayashi.M., Hasanah, A., Ismail, F., Kanak, F.A., & Tangah, J. (2024). Isolated population of proboscis monkeys and their status in Sulaman Lake Forest Reserve, Sabah, Malaysia. *Tropical Life Sciences Research* (in press).

CHAPTER 4
PLANTING TARGETS

4.1. SFD–ISME Project on Mangrove Rehabilitation

The MoU of Phase Three (2019–2024) of SFD-ISME Collaboration Project on Rehabilitation of Mangroves in Sabah was signed on 23 August 2019 at the Auditorium, SFD Headquarters in Sandakan, in conjunction with the Eighteenth PSC Meeting. The annual targets depended on the amount of funds agreed upon by Tokio Marine & Nichido Fire Insurance Co., Ltd., the main funding agency based in Tokyo, Japan. Annual targets were 35 ha for Phase Three. By the end of 2024, the project area totaled more than 175 ha of mangroves within eight planting sites with approximately 174,185 planting materials used.

Planting in 2020

Planting progress for 2020 during the COVID-19 pandemic was rather unusual. Restricted movement was in place for most of the time during the calendar year. Four districts included in the restoration project in 2020 with a total of 41 ha and 39,990 planting materials.

District	Forest Reserve (FR)	Area (ha)	Species (total planting materials)
Beaufort	Weston FR (ext.) (Class I) * Pulau ISME 2	17 ha	*Avicennia alba* (2,300) seedlings *Avicennia marina* (50) seedlings *Bruguiera parviflora* (100) seedlings *Ceriops tagal* (450) seedlings *Rhizophora apiculata* (12,800) propagules *Sonneratia caseolaris* (50) seedlings **Total = 15,750**
Semporna	Semporna FR (Class V)	9 ha	*Avicennia alba* (300) seedlings *Ceriops tagal* (2,000) propagules *Rhizophora apiculata* (7,000) propagules *Rhizophora mucronata* (3,000) propagules **Total = 12,300**

District	Forest Reserve (FR)	Area (ha)	Species (total planting materials)
Kota Kinabalu	Sulaman Lake FR (Class V)	10 ha	*Bruguiera cylindrica* (200) propagules *Calophyllum inophyllum* (120) seedlings *Ceriops tagal* (3,000) propagules *Ceriops zippeliana* (500) propagules *Excoecaria agallocha* (200) seedlings *Excoecaria indica* (15) seedlings *Lumnitzera racemosa* (45) seedlings *Rhizophora apiculata* (6,500) propagules *Sonneratia caseolaris* (10) seedlings *Terminalia catappa* (250) seedlings **Total = 10,840**
Kota Belud	Abai FR (Class V)	5 ha	*Calophyllum inophyllum* (50) seedlings *Excoecaria agallocha* (200) seedlings *Excoecaria indica* (150) seedlings *Rhizophora apiculata* (200) propagules *Terminalia catappa* (500) seedlings **Total = 1,100**
	Grand total:	**41 ha**	**39,990 (propagules and seedlings)**

Planting in 2021

In 2021, a total of 49,898 planting materials were planted in four locations, as follows;

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Beaufort	Weston FR (ext.) (Class I) * Pulau ISME 2	6 ha	*Avicennia* sp (85) seedlings *Bruguiera cylindrica* (10) seedlings *Bruguiera parviflora* (100) seedlings *Bruguiera sexangula* (60) seedlings *Ceriops tagal* (1,600) seedlings *Ceriops zippeliana* (130) propagules *Kandelia candel* (1,577) propagules *Rhizophora apiculata* (3,235) propagules *Rhizophora mucronata* (240) propagules *Xylocarpus granatum* (30) seedlings **Total = 7,067**
Semporna	Semporna FR (Class V) * Kg Gading	6 ha	*Avicennia* sp (340) seedlings *Bruguiera sexangula* (185) seedlings *Ceriops tagal* (1,650) propagules *Ceriops zippeliana* (110) seedlings *Nypa fruticans* (500) mature seeds *Rhizophora apiculata* (3,703) propagules *Rhizophora mucronata* (200) propagules *Rhizophora stylosa* (562) propagules *Xylocarpus granatum* (50) seedlings **Total = 7,300**

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Sandakan	Labuk Bay Proboscis Monkey (LBPMS), Miles 19, Jln Semawang * Private owned land	14.5 ha	*Bruguiera cylindrica* (45) seedlings *Bruguiera parviflora* (7,639) seedlings/ propagules *Bruguiera sexangula* (100) seedlings *Calophyllum inophyllum* (150) seedlings *Ceriops tagal* (5,159) propagules/ seedlings *Ceriops zippeliana* (200) seedlings *Excoecaria agallocha* (100) seedlings *Ficus benjamina* (4) seedlings *Ficus callosa* (3) seedlings *Ficus sundaica* (2) seedlings *Kandelia candel* (1,200) propagules *Lumnitzera littorea* (120) seedlings *Osbornia octodonta* (80) seedlings *Rhizophora apiculata* (11,620) propagules *Rhizophora mucronata* (630) propagules *Rhizophora stylosa* (248) propagules *Sonneratia caseolaris* (10) seedlings *Terminalia catappa* (100) seedlings *Terminalia copelandii* (20) seedlings *Xylocarpus granatum* (67) seedlings **Total = 27,497**

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Kota Belud	Abai FR (Class V)	8.5 ha	*Nypa fruticans* (6,801) mature seeds *Avicennia alba* (20) seedlings *Terminalia copelandii* (55) seedlings *Calophyllum inophyllum* (70) seedlings *Excoecaria agallocha* (20) seedlings *Excoecaria indica* (40) seedlings *Ficus benjamina* (52) cuttings *Kandelia candel* (976) propagules **Total = 8,034**
	Grand Total:	**35**	**49,898 (propagules, seedlings and cuttings)**

The year 2021 was still being affected by the global pandemic. In Sabah, activities pertaining to the environment were allowed but with limited movement, especially in public areas. Strict standard operating procedure (SOP) for COVID-19 was adhered to during planting in the field.

The Mangrove Task Force (MTF) members had also carried out the planting of Rhizophora stylosa using mature propagules and seedlings in Kg. Gading and Labuk Bay Proboscis Monkey Sanctuary (LBPMS) in 2021. Line planting and cluster planting techniques were applied in LBPMS and Kg. Gading, respectively. Field observation by end of 2023 showed healthy growth of the cluster planting of the planted *Rhizophora stylosa* in Kg. Gading, Semporna. Line planting of propagules flourished. The planting sites in Kg. Gading, Semporna are facing the open sea of South China Sea whereas, in LBPMS planting sites are an abandoned oil palm plantation facing the Sulu Sea. Mature propagules of *Rhizophora stylosa* were collected from mangrove areas in Semporna.

Cluster planting of *R. stylosa* using seedlings with a 25 m distance between clusters in Kg. Gading, Semporna.

Cluster planting (50 propagules) of *R. stylosa* using propagules and ten seedlings, side by side also flourished.

Cluster planting of *R. stylosa* propagules behind bamboo stakes as barricade.

After three years of cluster planting of *Rhizophora stylosa* using mature propagules showed promising growth. Previous attempt using line planting of propagules was not successful in Kg. Gading, Semporna. The use of bamboos stakes as barricades at the seaward side for each cluster was to break and reduce the wave action during ebb and high tides. Attack by barnacles was not significant in Kg. Gading, Semporna.

In 2021, twenty seedlings of *Terminalia copelandii* (Talisai Paya) were planted in Labuk Bay Proboscis Monkey Sanctuary (LBPMS) for the first time, under this SFD-ISME collaboration project, an effort to enrich the pool of biodiversity of planted species.

Photos of planted *Terminalia copelandii* taken in 2024. The species was planted in 2021 on hardened bund top at LBPMS.

Planting in 2022

The year 2022 was the third year of the Collaborative Project (2019–2024). In 2022, another 32 ha of degraded mangrove sites had been planted with ~ 32,602 seedlings/ propagules located in six locations throughout Sabah. Approximately 26,117 of the planting materials used were mangrove propagules collected from various places in Sabah. Direct planting method performed well for the healthy and mature propagules.

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Beaufort	Weston FR (ext.) Class I * Pulau ISME (# 2)	8 ha	*Kandelia candel* (3,987) propagules *Rhizophora apiculata* (75) seedlings *Sonneratia caseolaris* (6,238) seedlings *Xylocarpus granatum* (20) seedlings **Total = 10,320**
Semporna	Semporna FR Class V * Tingol-Tingol	8 ha	*Ceriops tagal* (1,000) seedlings *Ceriops zippeliana* (700) propagules *Rhizophora apiculata* (2,000) seedlings & propagules *Rhizophora mucronata* (500) seedlings *Rhizophora stylosa* (3,500) propagules *Bruguiera parviflora* (1,000) *Aglaia cucullata* (10) seedlings **Total = 8,710**

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Kota Kinabalu	Sulaman Lake FR Class V	3.5 ha	*Aglaia cucullata* (111) seedlings *Avicennia alba* (100) seedlings *Bruguiera cylindrica* (300) seedlings & propagules *Rhizophora apiculata* (1,000) propagules *Ceriops tagal* (1,229) propagules **Total = 2,740**
Sandakan	LBPMS, Miles 19 * Private owned land (~ 280 ha)	3 ha	*Ceriops tagal (500)* seedlings *Rhizophora apiculata* (1,500) seedlings & propagules *Rhizophora mucronata* (250) propagules *Sonneratia caseolaris* (50) seedlings *Avicennia alba* (420) seedlings *Avicennia marina* (100) seedlings *Bruguiera sexangula* (100) seedlings *Bruguiera cylindrica* (100) seedlings **Total = 3,020**
Kota Belud	Abai FR (Class V * Hardened bund top and submerged surface	1.5 ha	*Rhizophora apiculata* (1,000) seedlings & propagules *Xylocarpus granatum* (100) seedlings *Kandelia candel* (40) propagules **Total = 1,140**

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Beluran	Kuala Bonggaya & Kuala Labuk FR (Class V) *Sg Mattangar II	8 ha	*Rhizophora apiculata* (3,070) seedlings & propagules *Rhizophora mucronata* (10) propagules *Rhizophora stylosa* (20) propagules *Ceriops tagal* (2,200) propagules *Excoecaria agallocha* (10) seedlings *Terminalia catappa* (10) seedlings *Calophyllum inophyllum* (10) seedlings **Total = 6,672**
	Grand Total:	**32 ha**	**32,602 (seedlings and propagules)**

The Labuk Bay Proboscis Monkey Sanctuary (LBPMS) has a total of ~ 280 ha mangrove area.

Planting in 2023

2023 was the fourth year of the SFD-ISME Collaboration Project, and another 33 ha of mangrove areas were planted with suitable species. A total of 21,738 planting materials were planted during the year.

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Beaufort	Weston FR (ext.) (Class I) * Pulau ISME (# 2)	5 ha	*Kandelia candel* (3,987) propagules *Rhizophora apiculata* (75) seedlings *Sonneratia caseolaris* (476) seedlings *Xylocarpus granatum* (20) seedlings **Total = 4,558**

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Semporna	Semporna FR (Class V) * Tingol-Tingol	5 ha	*Ceriops tagal* (50) seedlings *Rhizophora apiculata* (230) seedlings & propagules *Rhizophora mucronata* (60) seedlings *Rhizophora stylosa* (200) propagules **Total = 540**
Kota Kinabalu	Sulaman Lake FR (Class V)	5 ha	*Aglaia cucullata* (15) seedlings *Avicennia alba* (3) seedlings *Bruguiera cylindrica* (40) seedlings & propagules *Calophyllum inophyllum* (50) seedlings *Ceriops tagal* (200) seedlings & propagules *Ceriops zippeliana* (10) propagules *Excoecaria agallocha* (5) seedlings *Lumnitzera littorea* (2) seedlings *Rhizophora apiculata* (100) propagules *Taliparitii tiliaceum* (16) seedlings *Terminalia catappa* (70) seedlings **Total = 511**
Beluran	Sg. Sugut, Sg. Paitan & P. Jambongan FR (Class V) * Tanjung ISME	5 ha	*Avicennia officinalis* (10) seedlings *Bruguiera cylindrica* (30) seedlings *Ceriops tagal* (227) seedlings *Rhizophora apiculata* (220) seedlings & propagules *Rhizophora mucronata* (40) propagules *Xylocarpus moluccensis* (10) seedlings **Total = 537**

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Kota Marudu	Marudu Bay FR (Class I) * Teluk ISME-Marudu A	10 ha	*Rhizophora apiculata* (4,545) seedlings & propagules *Rhizophora mucronata* (1,595) propagules *Rhizophora stylosa* (1,453) propagules *Ceriops tagal* (1,989) seedlings & propagules *Sonneratia caseolaris* (50) seedlings *Avicennia alba* (349) seedlings *Avicennia marina* (12) seedlings *Bruguiera sexangula* (45) seedlings *Bruguiera cylindrica* (80) seedlings *Xylocarpus granatum* (119) seedlings *Kandelia candel* (25) propagules **Total = 10,262**
Lahad Datu	Kuala Tingkayu FR (Class V)	3 ha	*Rhizophora apiculata* (3,100) seedlings & propagules *Rhizophora mucronata* (10) propagules *Rhizophora stylosa* (20) propagules *Ceriops tagal* (2,200) propagules **Total = 5,330**
	Grand Total:	**33 ha**	**21,738 (propagules and seedlings)**

Planting in 2024

For the year 2024, two new planting sites with muddy mudflats were selected with a total of ~ 29,957 propagules/seedlings planted. One location is in Sandakan and another is in Kota Marudu district. Planting site in Sandakan (~ 25 ha) is known as

Pulau Loboh and Kota Marudu (~10 ha), is named as Teluk ISME-Marudu B. These two project sites were the last under Phase Three (2019-2024).

District	Forest Reserve (FR)	Area (ha)	Species (total plants planted)
Sandakan	Sg Gum Gum & Sg Loboh FR (Class V) * Pulau Loboh	25 ha	*Rhizophora apiculata* (16,908) propagules & seedlings *Rhizophora stylosa* (931) propagules & seedlings *Rhizophora mucronata* (3,171) propagules & seedlings *Avicennia alba* (187) seedlings *Xylocarpus molucennsis* (70) seedlings *Xylocarpus granatum* (20) seedlings *Bruguiera cylindrica* (77) seedlings *Ceriops tagal* (144) seedlings **Total = 21,508**
Kota Marudu	Marudu Bay FR (Class I) * Teluk ISME-Marudu B	10 ha	*Avicennia alba* (100) seedlings *Avicennia marina* (13) seedlings *Ceriops tagal* (1,019) seedlings *Ceriops zippeliana* (20) seedlings *Kandelia candel* (25) seedlings *Rhizophora apiculata* (4,465) seedlings *Rhizophora mucronata* (2,083) propagules & seedlings *Rhizophora stylosa* (50) seedlings *Xylocarpus moluccensis* (550) seedlings *Lumnitzera littorea* (24) seedlings *Bruguiera cylindrica* (100) seedlings **Total = 8,449**
	Grand total:	**35 ha**	**29,957 (propagules and seedlings)**

Transporting 2,000 seedlings of *Rhizophora apiculata*, for planting in Pulau Loboh, Sandakan in September 2024.

Rhizophora apiculata planted at Pulau Loboh, Sandakan.

Drone photo of planting location in Teluk ISME-Marudu, Kota Marudu.

Planting under SFD-TMIM Collaboration Project

It is also important to note that during the first year of SFD-TMIM collaboration project (2023-2024), the collaboration project managed to plant 6,580 seedlings of *Sonneratia caseolaris* at Weston FR with a total of 6.5 ha covered. The year 2024, have proved to be less source of planting material attributed by the mangrove plants not producing enough or abundance of fruits. For the record Kandelia candel is observed not in fruiting in 2024, and it is anticipated that 2025 will be a mass fruiting for most of the mangrove's species in Sabah.

4.2. Sources of Funds

Besides the main funding from Tokio Marine & Nichido Fire Insurance Co., Ltd. (TMN), based in Tokyo, the Sabah Forestry Department (SFD) also allocated additional funds for the project via a special fund or through the recurrent budget at Forest Research Centre, Sandakan. Another additional funding for mangrove restoration in Sabah is from Tokio Marine Insurance Malaysia Berhad (TMIM), based in Kuala Lumpur since 2023, in which a separate Memorandum of Understanding (MoU) between SFD and TMIM for five years (2023–2027). TMN's headquarters is based in Tokyo, Japan

whereas TMIM is under the Tokio Marine Insurance Group, and the headquarters of TMIM is based in Kuala Lumpur.

The three organizations, namely TMN, SFD and ISME have collaborated well since Phase I (2011–2014), Phase II (2014–2019), Phase III (2019–2024) and will be extended into Phase IV (2024–2028). For the extension of Phase IV (2024–2028), an MoU was signed on 19 September 2024. It is envisaged that the Phase IV (2024–2028) of this collaboration project will be focusing more on research and monitoring activities of the selected restoration sites in Sabah.

Recognizing the successful implementation of the SFD-ISME Collaboration Project, the TMIM Kuala Lumpur, have officially signed an MoU on 3 July 2023 between Sabah Forestry Department and TMIM. The signed MoU is for the duration of five years (2023–2027) and pledged to plant 11,111 mangrove seedlings every year, covering some 10 ha per year.

4.3. Cooperation and Friendship

The success of Phase One (2011–2014) and Phase Two (2014–2019) of the project was largely due to spirit of cooperation and friendship between SFD and ISME officials, which continued to strengthen into Phase Three (2019–2024). The relationship started in September 2007, when a delegation of SFD visited the mangroves of Okinawa, Ishigaki and Iriomote Islands in Japan. ISME hosted the visit and since then, mutual friendship has established between SFD and ISME officials.

In September 2013: The SFD officials together with official from ISME, (Prof. Shigeyuki Baba, Dr. Hung Tuck Chan and Ms. Nozomi Oshiro) visited the Manko Waterbird and Wetland Center in Okinawa, Japan.

In August 2019: Staff members of TMN, ISME and SFD planted mangroves at Pulau ISME.

In July 2023: The SFD officials organized a study tour to Sapporo and Sendai, Japan and was welcomed by senior officials from Tokio Marine Nichido & Fire Insurance Co. Ltd. in Tokyo.

In September 2023: The TMIM and SFD officials organized a mangrove planting activity at Pulau ISME, Beaufort to commemorate the launching of this collaboration project.

In November 2023: The TMIM and SFD officials organized another mangrove planting activity at Pulau ISME, Beaufort and planted ~ 450 seedlings of *Sonneratia caseolaris* and *Kandelia candel*.

4.4. The Way Forward

The Sabah Forestry Department (SFD), in collaboration with Tokio Marine & Nichido Fire Insurance Co., Ltd.—the main funding agency—has approved funding to cover Phase Four (2024-2029) of a significant mangrove restoration project. The goal of Phase Four is to restore 100 hectares of mangroves over a period of five years, with a target of planting 20 hectares per year. For the year 2024, the SFD identified two key locations for the restoration efforts:

Pulau Loboh

- Location: In the seaward mangrove area of Sg. Gum-Gum & Sg. Loboh FR, within the Sandakan Forestry District, Sabah.
- Area: Approximately 300 hectares of mangrove mudflat.
- Significance: Pulau Loboh is part of a larger mangrove ecosystem, crucial for supporting biodiversity and coastal protection.

Drone photo of Pulau Loboh in Sandakan Forestry District.

Photos of planting sites at Pulau Loboh, Sandakan taken in February 2024.

Teluk ISME-Marudu

- Location: In the seaward mangrove area of Marudu Bay FR, within the Kota Marudu Forestry District, Sabah.
- Area: Approximately 250 hectares of mangrove mudflat.
- Special Naming: This location has been named Teluk ISME-Marudu in honour of the International Society for Mangrove Ecosystems (ISME), recognizing the global importance of mangrove conservation.

Areial view of project site at Teluk ISME-Marudu in Kota Marudu Forestry District.

Photos of planting sites at Teluk ISME-Marudu taken in January 2024.

Photos of planting sites at Teluk ISME-Marudu taken in November 2024.

Project Details for Phase Four:

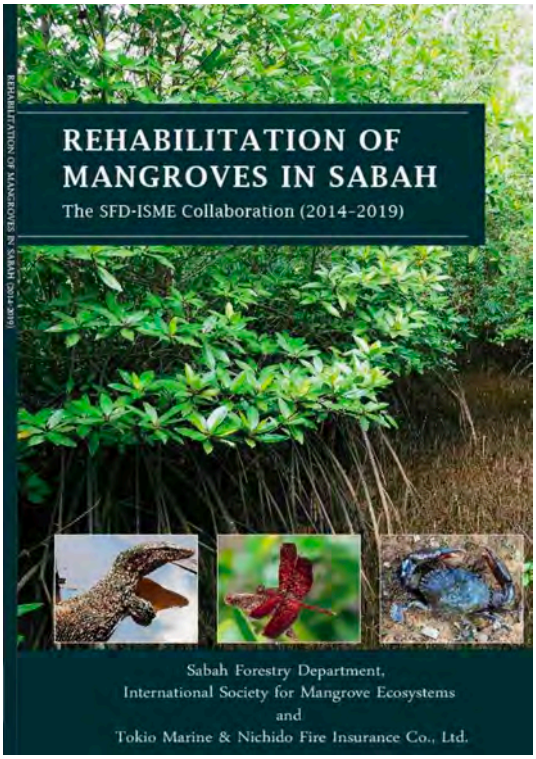
- Funding: Phase IV (2024–2028) of the project will be funded by Tokio Marine & Nichido Fire Insurance Co., Ltd.
- Planting Target: The goal is to plant 20 hectares per year, which will total 100 hectares over the five-year period.

These restoration projects aim to enhance the ecological value of these mangrove areas, which provide crucial services, such as coastal protection, biodiversity support, carbon sequestration, and livelihood opportunities for local communities.

CHAPTER 5
CALENDAR OF ACTIVITIES

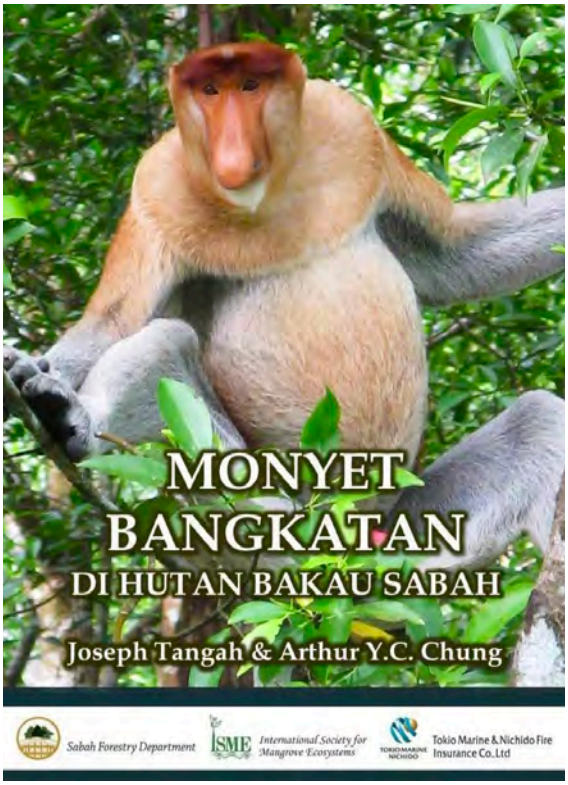
January 2020

At the end of Phase II (2014-2019), the second coffee table book was published in January 2020. Publication of the book was funded by the Tokio Marine & Nichido Fire Insurance Co., Ltd, with Dr. Joseph Tangah, Dr. Arthur Y.C. Chung, Prof. Shigeyuki Baba, Dr. Hung Tuck Chan and Ms. Mio Kezuka as the authors.



September 2021

In September 2021, another book was published under this collaborative project. Written in Malay, the book on proboscis monkeys in mangroves habitat of Sabah was funded by Tokio Marine & Nichido Fire Insurance Co., Ltd., Japan. The book was intended to create public awareness on the important of mangrove ecosystems which are also harbouring one of the most endangered primates in Sabah. In 2023, the book won the Best Book Category Award (Kategori Anugerah Buku Terbaik) for Sabah by the Chief Minister Department in collaboration with Dewan Bahasa dan Pustaka (DBP) Malaysia. Dr. Joseph Tangah and Dr. Arthur Chung received the recognition award from the deputy Chief minister III – Datuk Seri Panglima Dr. Joachim Gunsalam, on behalf of the Chief Minister of Sabah.



The book cover on proboscis monkeys in mangroves of Sabah (left) and a pair of arboreal female proboscis monkeys (right).

March 2022

In mid-2021, the Springer publisher based in Singapore sponsored the publication of a book on Mangroves: Biodiversity, Livelihoods and Conservation. The Sabah Forestry Department was invited to contribute a chapter on Mangroves of Malaysia, which was written by Dr. Joseph Tangah, Dr. Elizabeth C. Ashton, Dr. Hung Tuck Chan and Prof. Shigeyuki Baba.

Citation of the chapter is as follows:

Tangah, J., Ashton, E.C., Chan, H.T. & Baba, S. (2022). Mangroves of Malaysia. (In) Das, S.C., Pullaiah, T., & Ashton, E.C. (eds.), Mangroves: Biodiversity, Livelihoods and Conservation. Singapore: Springer.

July 2023

PSC meeting, chaired by Prof. Shigeyuki Baba, took place on 15 July 2023 in the Sapporo Kokusai Building in Sapporo, Hokkaido, Japan. This meeting was attended by a 10-member delegation from SFD, led by the Chief Conservator of Forests, Datuk Frederick Kugan. The delegation members are as follows:

- Datuk Frederick Kugan
- Mr. Fadzil Hj Yahya
- Mr. Musa Salleh
- Mr. Indra P. Sunjoto
- Dr. Joseph Tangah
- Mr. Paul Leo Lohuji
- Ms. Rosila Anthony
- Mr. Kinus Mais
- Mr. Osman Bangkong
- Ms. Viviannye Paul

The visit to Sapporo and the leadership of both Prof. Baba and Datuk Kugan involved important meeting with discussions, related to regional or international cooperation, scientific research and cultural exchanges, with a focus on SFD's objectives and initiatives. The visit to key sites in Hokkaido before or after the meeting, as mentioned previously, provided an excellent opportunity for the delegation to deepen their understanding of the local context and explore potential collaborations in various fields.

The 19th PSC Meeting held in Sapporo Kokusai Building, Hokkaido, Japan, hosted by Prof. Shigeyuki Baba, the Executive Director of ISME.

Additionally, the delegation's visits to notable sites in Hokkaido, including Hokkaido University, Furukawa Fruit Farm, Mount Moiwa Ropeway, and Odori Park, served as an enriching opportunity for further engagement with the local context. These visits would not only provide insights into regional agricultural, academic, and cultural strengths but could also lay the groundwork for future partnerships, research opportunities, or other collaborative efforts between the SFD delegation and entities in Hokkaido.

These visits allowed the SFD delegation to immerse themselves in the local culture, science, and natural beauty of Hokkaido, enriching their overall experience during the PSC meeting.

The famous Ginkgo Avenue at the main campus of Hokkaido University in Sapporo.

Visit to the Furukawa Fruit Farm in Yoichi Town, Sapporo.

February 2024

The 20th PSC Meeting was held on 23 February 2024 at the Conference Room, Kota Kinabalu Forestry District Office in Lok Kawi, Kota Kinabalu, Sabah. The meeting was chaired by Datuk Frederick Kugan, the Chief Conservator of Forests.

Prior to the meeting, the ISME official delegation visited Pulau ISME-Weston, where they participated in a significant environmental activity by planting approximately 200 seedlings of Sonneratia caseolaris, a species of mangrove, on the island's mudflats. This effort will enhance the local ecosystem and contribute to the restoration or preservation of mangrove habitats.

The 20th PSC Meeting held in Lok Kawi, Kota Kinabalu, Sabah, hosted by SFD.

During their time in Sabah, the ISME delegation also visited the LTER (Long-Term Ecological Research) sites in Sepilok Laut, Sandakan. These visits provided valuable insights into ongoing ecological research and conservation initiatives in the region, likely enhancing collaboration and understanding between the delegation and local conservation efforts.

Overall, the combination of the PSC meeting and the field visits reflected a strong commitment to both scientific collaboration and hands-on environmental stewardship, particularly in the context of mangrove conservation and long-term ecological research in Sabah.

Having a nice refreshment before the 20th PSC Meeting.

Visit to Pulau ISME, Beaufort by boat after the completion of PSC meeting.

Planting of *Sonneratia caseolaris* at Pulau ISME in Beaufort.

Visit to LTER plots in Sepilok Laut, Sandakan.

Ms. Mio Kezuka trying her best to estimate the diameters at breast height of several stems of *Rhizophora apiculata* at the LTER Sepilok Laut.

July 2024

In July 2024, a field visit was conducted by ISME officials and scientists from Japan to the mangrove rehabilitation project under the collaboration between SFD and ISME. The purpose of the visit was to assess and support ongoing efforts in mangrove conservation and rehabilitation in Sabah, Malaysia.

The distinguished team of Japanese scientists and officials included:

- Prof. Shigeyuki Baba
- Dr. Ko Hinokidani
- Prof. Toyohiko Miyagi
- Ms. Fumiko Miyagi
- Mr. Atsuya Yamamoto
- Ms. Nodoka Wada
- Prof. Hideaki Yanagisawa
- Dr. Mami Kainuma
- Mr. Motoichi Umekawa

These experts brought their wealth of knowledge and experience in mangrove ecosystems, environmental science, and rehabilitation techniques to the field visit, helping to guide and evaluate the progress of the rehabilitation project.

Their involvement underscores the international collaboration between SFD and ISME in advancing sustainable mangrove conservation practices.

Visit to project site in Sg Tokio Marine, Lahad Datu (rehabilitated since 2014).

Visit to project site in Sg ISME, Sandakan (rehabilitated since 2012).

Recording data on soil sample in Sg Tokio Marine, Lahad Datu.

Group photo in front a concrete signboard at Sg Tokio Marine, Lahad Datu.

August 2024

In August, another field visit to Sabah by ISME official led by Prof. Shigeyuki Baba and Ms. Nozomi Oshiro. They also brought students and teachers from Japan to visit Sabah. The students were Ms. Kiko Suematsu, Ms. Mei Uchino, Ms. Kaeda Ishikawa, Ms. Yuka Kobayashi, Ms. Momoka Miyagawa, Ms. Mona Tomita and Ms. Riho Katsuhara, whereas teachers are, Ms. Chie Otake, Ms. Akiko Miyata, Ms. Rumiko Hashimoto, Ms. Aki Kazono, Mr. Hiroshi Itayama, and Mr. Atsuhiko Nakamura.

Visiting Pulau ISME in Weston, Beaufort.


Prof. Shigeyuki Baba giving explanation on the importance of mangroves.

November 2024

In November 2024, a group consists of eleven (11) senior officials from Tokio Marine Insurance Malaysia Berhad (TMIM), Kuala Lumpur, led by their Chief Executive Officer (CEO), Mr. Ng Hang Ming visited Sandakan on 21-22 November 2024, and they successfully planted ~ 300 mangrove seedlings of *Rhizophora apiculata* at Pulau Loboh project site in Sandakan.

Senior officials from TMIM together with MTF members completed the planting of mangrove seedlings on 22 November 2024 during low tide.

The CEO of TMIM participated in the mangrove planting at Pulau Loboh, Sandakan.

CHAPTER 6
CONCLUSION

Pulau ISME

The future of mangroves cannot simply rest on expressions of love or goodwill—it requires concrete action supported by adequate resources to ensure that these vital ecosystems are preserved and restored. Mangroves, which provide essential ecological services like coastal protection, carbon sequestration, and biodiversity support, are under constant threat from deforestation, pollution, climate change, and urban development. To secure the future of mangroves, we must move beyond emotional appeals and address these challenges with well-planned, resource-driven efforts. They include the following:

1. Financial Investment

For mangrove conservation and rehabilitation to be effective, significant financial resources are required. Funding is essential not only for large-scale restoration projects but also for the continued monitoring, management, and scientific research that support these efforts. Financial investment ensures that local governments, NGOs, and research institutions can carry out necessary activities such as planting mangrove seedlings, restoring degraded coastal areas, and maintaining protective infrastructure. The establishment of dedicated funds for mangrove protection, along with partnerships with international donors, can significantly increase the scope and sustainability of these projects.

2. Research and Knowledge Sharing

Ongoing scientific research is critical for understanding mangrove ecosystems and their response to environmental changes. By continuously studying the health, growth patterns, and biodiversity of mangroves, researchers can develop effective restoration techniques and adapt strategies to local conditions. In addition to funding research, knowledge sharing between international experts and local communities helps spread best practices for mangrove management and conservation. Collaborative efforts, such as those between SFD and ISME, bring together diverse perspectives and expertise, enriching the global body of knowledge on mangrove ecosystems.

3. Policy and Legal Frameworks

Strong environmental policies are vital for the long-term protection of mangroves. Governments need to create and enforce regulations that prevent mangrove destruction and regulate activities such as logging, coastal development, and industrial pollution. In many cases, mangroves are not given the legal protection they deserve, leading to their continued loss. Legal frameworks that include zoning regulations, protected areas, and penalties for violations will help safeguard these ecosystems. Additionally, integrating mangrove conservation into national and international climate change policies, such as the United Nation's REDD+ (Reducing Emissions from Deforestation and Forest Degradation) program can further support these efforts.

4. Community Engagement

The involvement of local communities is a key factor in the success of mangrove conservation. People who live near mangrove forests often depend on them for their livelihoods through activities like fishing, farming, and tourism. By engaging these communities in conservation efforts, we can build a sense of ownership and stewardship that fosters sustainable practices. Education and awareness campaigns can help locals understand the importance of mangroves and the benefits of preserving them. Empowering communities with skills for sustainable resource management and creating alternative livelihoods that reduce pressure on mangroves (such as eco-tourism or sustainable aquaculture) can make conservation efforts more effective and inclusive.

5. Restoration Projects and Partnerships

Active mangrove restoration projects are vital to reversing the damage done to mangrove ecosystems. These projects typically involve planting native mangrove species, rehabilitating degraded areas, and monitoring the health of newly restored ecosystems. Restoration efforts often require partnerships between government agencies, non-governmental organizations (NGOs), local communities,

and international experts. The success of restoration depends on using native species, proper site selection, and consistent monitoring to ensure that the replanted mangroves survive and thrive. Moreover, sharing successful restoration case studies globally can help inform future efforts.

6. Monitoring and Evaluation

To understand the effectiveness of conservation and restoration efforts, it is crucial to have systems in place for monitoring mangrove health. This includes tracking changes in mangrove forest cover, biodiversity, and ecological functions. Monitoring allows for early identification of problems such as disease outbreaks, invasive species, or environmental degradation, which can then be addressed in a timely manner. Furthermore, monitoring data provides valuable feedback that can guide adaptive management—making sure that strategies remain flexible and responsive to changing conditions.

7. Technical Expertise and Capacity Building

Effective mangrove conservation requires specialized knowledge and technical expertise. By providing training and capacity-building opportunities for local staff, communities, and conservation practitioners, we can ensure that those on the ground have the necessary skills to implement and maintain successful conservation projects. This includes training in areas such as mangrove restoration techniques, biodiversity monitoring, and community-based management. In regions where technical expertise may be limited, international partnerships and knowledge-sharing initiatives become essential in developing local capacity.

8. Sustainable Livelihoods

Promoting sustainable livelihoods alongside conservation efforts can help reduce the pressure on mangroves. For instance, eco-tourism can provide financial incentives for local communities to protect mangroves, offering income opportunities while raising awareness about the importance of these ecosystems. Additionally,

sustainable fisheries and aquaculture practices that do not harm mangrove habitats can be encouraged, ensuring that communities can continue to rely on mangroves for their livelihoods without depleting or damaging the ecosystem. By integrating conservation with economic development, we can create a balance that benefits both people and the environment.

9. Conclusion

In conclusion, the future of mangroves lies not in declarations of support but in practical actions that are well-funded, scientifically sound, and supported by strong policies and engaged communities. With concrete efforts in research, restoration, monitoring, and sustainable livelihoods, and by fostering partnerships among governments, scientists, and local communities, we can ensure that mangrove ecosystems thrive for generations to come. As we take these actions, we not only protect biodiversity and coastal communities but also contribute to global efforts in combating climate change through the critical role mangroves play in carbon sequestration.

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