forests

MDPI

Review

A Systematic Review of the Physicochemical and Microbial Diversity of Well-Preserved, Restored, and Disturbed Mangrove Forests: What Is Known and What Is the Way Forward?

Jiayong Lai [1], Wee Cheah [1,*], Kishneth Palaniveloo [1,*], Rempei Suwa [2] and Sahadev Sharma [1]

[1] Institute of Ocean and Earth Sciences (IOES), Universiti Malaya, Kuala Lumpur 50603, Malaysia
[2] Japan International Research Center for Agricultural Sciences, Tsukuba 305-8686, Ibaraki, Japan
* Correspondence: wee.cheah@um.edu.my (W.C.); kishneth@um.edu.my (K.P.); Tel.: +60-379674640 (W.C. & K.P.)

Abstract: Mangrove forests are salt-tolerant intertidal vegetation in tropical and subtropical areas. Mangrove ecosystems provide commercial products, valuable fisheries, and aquaculture resources, protect and stabilize coastlines, and are important carbon sinks. However, they are threatened globally by human activities such as deforestation, pollution, and development causing fragmentation between the well-preserved, restored, and disturbed mangrove forests. Despite this, mangroves can adapt and strive well and are notable well associated with microbial diversity. Here, we investigate the diversity of microbes in different environmental settings using preferred reporting items for systematic and meta-analyses (PRISMA) analysis for publications from Scopus and the Web of Science databases. We report publications since 1987, and observed an exponential increase in publications beginning in the year 2000, which may be associated with the development of molecular and sequencing technologies. Differences in bacterial diversity was observed across the well-preserved, restored, and disturbed mangrove environments. Disturbed mangrove forests had a higher diversity (70 unique taxon orders reported) compared to well-preserved (33 unique taxon orders reported) and restored forests (38 unique taxon orders reported). Based on our analysis, we found that the microbial community plays an important role in the survival and adaptability of mangroves under varying environmental conditions. Thus, there is a need and a lot of potential for research in the area of mangrove microbiology with reference to ecology, biogeochemistry, and geomorphology.

Keywords: mangrove; sediment microbiome; bacterial diversity; systematic analysis

Citation: Lai, J.; Cheah, W.; Palaniveloo, K.; Suwa, R.; Sharma, S. A Systematic Review of the Physicochemical and Microbial Diversity of Well-preserved, Restored, and Disturbed Mangrove Forests: What is Known and What Is the Way Forward? *Forests* **2022**, *13*, 2160. https://doi.org/10.3390/f13122160

Academic Editors: Faridah Hanum Ibrahim, Abdul Latiff Mohamad and Waseem Razzaq Khan

Received: 18 November 2022
Accepted: 14 December 2022
Published: 16 December 2022

1. Introduction

Mangrove forests are salt-tolerant intertidal vegetation along coastal margins and brackish water of coastal estuaries, bordering the land and the sea in tropical and subtropical areas [1,2]. Adapted to harsh coastal conditions, they serve as a barrier for coastal protection and stabilization, play important roles in carbon fixation, and facilitate the reduction of terrestrial nutrient loading from upstream inputs [3]. Mangrove forests occupy approximately eight million ha of coasts worldwide [4] and the highest proportion is found in Asia with about 42% of the global coverage [5]. Mangroves are very dynamic and highly productive ecosystems [6].

Mangrove ecosystems provide valuable services to coastal communities and industries. As an important resource for human sustainability and livelihood, mangroves are exploited for food, timber, fuel, and medicine [7]. Mangrove forests act as carbon sinks that absorb CO_2 and sequester carbon as above-ground and below-ground biomass [8].