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GLOBAL CHANGE RESEARCH

FINAL REPORT

Investigating the impacts
of human activities and
climate change on
mangrove systems in East
and Southeast Asia



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浙江大学 海洋学院
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1. Summary

Mangrove forests support the global ecosystem and serve as blue carbon reservoirs. However, they are facing threats from climate change phenomena, such as sea level rise, and human activities, such as deforestation, erosion, pollution, reservoir construction, and coastal development. Few studies have examined the trends regarding carbon, nutrients, and pollutants in mangrove systems due to climate change and human activities over a timescale of 100–150 years. Thus, in this study, sediment cores were collected from the coastal fringes of mangrove forests across East and Southeast Asia to evaluate total organic carbon, total nitrogen, sediment phosphorus species, and microplastics. Our results showed that the differences in spatial and vertical distribution of sedimentary organic matter, carbon stock, phosphorus species, and microplastic were attributable to various factors such as tree age, geomorphic settings, sediment characteristics such as particle size, organic matter, and nutrient contents, and physical influence such as tidal effect and the intensity of human activities. The results of this study will provide important information for policymakers to use in maintaining the sustainability of these fragile ecosystems.

1.1. Study areas

Sediment cores were collected from Kuala Gula, Malaysia (on March 21, 2021); Sohghkla and Pattani provinces, Thailand (March 30, 2021, and April 5, 2021); the Ximen Island and Guangxi mangrove forests, China (May 28–29, 2021, and June 30, 2021); Kampot Province, Cambodia (January 14–16, 2022); Mangrove Park at Sungai Pinyuh, Pontianak, West Kalimantan, Indonesia (July 2022); and Kuala Selangor mangrove, Malaysia (July 26, 2022; Appendix 1).

1.2. Sampling of sediment cores

Sediment cores of approximately 1 m in length were collected from each location using a gravity columnar sampler lined with a 60-mm-diameter polyvinyl chloride core tube (sampling photos in Appendix 2). The sediments were sliced at 2-cm depth intervals and transported back to the laboratory under cool storage. In the laboratory, each of the 2-cm sediment slices were freeze dried, ground with a mortar and pestle until homogenous, and determined for ^{210}Pb activity, particle size, bulk elemental composition, stable carbon isotope, lignin, microplastics, and P species.

1.3. Analytical methods

In brief, the ^{210}Pb dating was carried out using a high-purity germanium low-gamma spectrometer GWL series with a high-purity germanium coaxial-well photon detector system. Sedimentation rates were calculated based on ^{210}Pb activity. For particle size determination, sediment samples were subjected to H_2O_2 digestion and $(\text{NaPO}_3)_6$ dispersion, followed by the determination of particle size using a particle size analyzer. For bulk elemental analysis, 1 M HCl will be added to the dried sediments to remove inorganic carbon, dried, homogenized, weighed into tin foil, and analyzed for total OC (TOC) and total nitrogen (TN) using an elemental analyzer. The $\delta^{13}\text{C}$ compositions of the sediments were

determined using an isotope ratio mass spectrometer and reported in permille (‰) form relative to the Vienna Pee Dee Belemnite standard. Microplastics were extracted using the density-based floating separation technique (Chinfak et al., 2021; Wang et al., 2020). Dry sediment samples will be subjected to lignin analysis using the cupric oxide oxidation method described by Hedges and Ertel (1982). Various sedimentary P forms were extracted using the sequential P extraction procedures described by Ruttenberg (1992).

1.4. Data obtained

Locations	Data						
	TOC, TN, TOC/TN	$\delta^{13}C$	^{210}Pb	Particle size	Lignin	P species	Microplastic
Ximen Island & Guangxi, China	√	√	√	√	√	√	√
Songkhla & Pattani, Thailand	√	√	NR	√	√	√	√
Kuala Gula, Malaysia	√	√	NE	√	√	√	√
Kuala Selangor, Malaysia	√	√	√	√	√	√	NE
Sungai Pinyuh, Indonesia	√	√	√	√	√	√	NE

NR = not relevant as the cores are rather short

NE = not enough samples for microplastic analysis

1.5. Summary of Results and Implications

The sediments in older mangrove forest have higher capacity to preserve organic carbon and phosphorus compared to sediments in younger mangrove, salt marsh and bare mudflat, most probably due to the more developed root systems and trapping of finer particles in older mangrove system resulting in increased trapping and absorption of organic matter and nutrients. Our results showed that age, geomorphic setting, particle size, tidal effect and human activities affect the sources, abundance and distribution of sedimentary organic matter, carbon, phosphorus, and microplastic in the mangrove forests in this study.

2. Objectives

The objectives of this study were (i) to determine the effects of human activities and climate change on the abilities of mangrove forests to serve as carbon and nutrient sinks, and (ii) to determine the potential of these mangrove forests facing deterioration over the past century.

3. Outputs, Outcomes and Impacts

Outputs	Outcomes	Impacts
Published papers	Increased knowledge on mangrove dynamics in East and Southeast Asia	Reduced mangrove degradation
Completed meeting and conference	Increased awareness and collaboration	Mangrove conservation

4. Key facts/figures

- Held one internal/online meeting among collaborators (Appendix 4);
- Held one international conference event (Appendix 5);
- Published five peer-reviewed papers in scientific journals (Appendix 6);
- Two papers were submitted to peer-reviewed journals for consideration of publication.

5. Publications

Hu J, Loh PS*, Pradit S, Le TPQ, Oeurng C, Mohamed CAR, Lee CW, Lu X, Anshari GZ, Kandasamy S, Wang J, Li Z, Qin H, Ji L, Guo J. (2022). Assessing the effect of age and geomorphic setting on organic carbon accumulation in high-latitude human-planted mangroves. *Forests* 13 (1), 105. doi:[10.3390/f13010105](https://doi.org/10.3390/f13010105).

Pradit S*, Noppradit P*, Loh PS, Nitiratsuwan T, Le TPQ, Oeurng C, Mohamed CAR, Lee CW, Lu X, Anshari GZ, Kandasamy S, Wang J. (2022). The occurrence of microplastics in sediment cores from two mangrove areas in southern Thailand. *Journal of Marine Science and Engineering* 10, 418. doi:[10.3390/jmse10030418](https://doi.org/10.3390/jmse10030418).

You S, Loh PS*, Li Z, Qin H, Pradit S, Le TPQ, Oeurng C, Mohamed CAR, Lee CW, Lu X, Anshari GZ, Kandasamy S, Wang J, Ji L, Guo J. (2022). Geochemical behavior of sedimentary phosphorus species in the northernmost artificial mangroves in Ximen Island, China. *Forests* 13, 610. doi:[10.3390/f13040610](https://doi.org/10.3390/f13040610).

Mohamed CAR, Shahrudin AN, Pradit S*, Loh PS, Nitiratsuwan T, Kobkeatthawin T, Noppradit P, Le TPQ, Oeurng C, Sok T, Lee CW, Bong CW, Lu X, Anshari GZ, Kandasamy S, Wang J. (2023). Depth profiles of microplastic in sediment cores in the mangrove area of Kuala Gula Mangrove, Malaysia. *Journal of Marine Science and Engineering* 11, 1223. doi:

Hu J, Pradit S*, Loh PS*, Chen Z, Guo C, Le TPQ, Oeurng C, Sok T, Mohamed CAR, Lee CW, Bong CW, Lu X, Anshari GZ, Kandasamy S, Wang J. (2024). Storage and dynamics of soil organic carbon in allochthonous dominated and nitrogen-limited natural and planted mangrove

forests in southern Thailand. Marine Pollution Bulletin 116064.
doi:[10.1016/j.marpolbul.2024.116064](https://doi.org/10.1016/j.marpolbul.2024.116064).

Guo C, Loh PS*, Hu J, Chen Z, Pradit S, Le TPQ, Oeurng C, Sok T, Mohamed CAR, Lee CW, Bong CW, Lu X, Anshari GZ, Kandasamy S, Wang J. Factors influencing mangrove carbon storage and its response to environmental stress. (Submitted to Frontiers in Marine Science on 31 March 2024)

Pradit S*, Loh PS*, Jitkaew P, Nitiratsuwan T, Le TPQ, Oeurng C, Sok T, Mohamed CAR, Lee CW, Bong CW, Lu X, Anshari GZ, Kandasamy S, Wang J. Occurrence of microplastic in sediment cores of planted mangroves in XimenIsland and natural mangroves in Guangxi, China. (Submitted to Regional Studies in Marine Science on 1 April 2024)

6. Media reports, videos and other digital content

“2023 Mangrove Conference” websites:

“<https://www.apn-gcr.org/event/2023-mangrove-conference-call-for-participation/>” and

“<http://oc.zju.edu.cn/2023/0905/c30428a2797670/page.htm>”.

7. Pull quotes

“The project and conference event have been successfully carried out, well done” - Professor Deqing MEI, Ocean College, Zhejiang University.

“This project has provided us a good opportunity to collaborate with scientists from other universities to conduct research to determine the dynamics of one of the most important blue carbon ecosystems in the world, mangrove forests” - Dr Pei Sun Loh, Ocean College, Zhejiang University.

“After listening to the researches from experts around the world at the Mangrove Conference, I feel that the task of protecting mangroves is both important and challenging. Mangrove forests face threats not only from natural factors such as sea-level rise and extreme weather, but also from man-made influences like deforestation. Moreover, some countries introduce foreign species of mangrove plants for conservation purposes. While this might bring some short-term benefits, if inadequately managed, these foreign species could potentially become invasive, negatively affecting the local ecology in the long run. I believe that through the dedicated efforts of researchers worldwide, we would be able to fully understand the growth and developmental trends of mangrove forests and the effects of external influences on them. This would in turn enable us to take targeted measures and adopt strategies to protect these coastal guards, thereby creating ecologically stable coastal environments.” - Chuanyi Guo, Ocean College, Zhejiang University.

“The convening of this conference not only facilitates the preservation and sustainable development of global mangroves but also significantly contributes to fostering a community with a shared future for the ocean and achieving the global "double carbon" objective. Experts and scholars expressed their commitment to enhancing collaboration and jointly contributing their wisdom and efforts towards safeguarding our planet's homeland and advancing human civilization. The conference was jointly organized by the School of Oceanography of Zhejiang University, renowned universities, and research institutions in Southeast Asian countries, with support from the Asia-Pacific Global Change Research Network Fund. Wu Feng, Deputy Secretary of the Party Committee and Secretary of the Commission for Discipline Inspection of the College of Oceanography of Zhejiang University, congratulated the conference and highlighted the college's research and noteworthy progress in exploring mangrove ecological functions and species diversity. He expressed his hope that participating experts and scholars would enhance learning and exchanges, foster academic innovation, further strengthen international cooperation, and realize the aspirational vision of "Blue Bay" governance through the platform established by this conference.”- Zengxuan Chen, Ocean College, Zhejiang University.

8. Acknowledgments

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9. Appendices

APPENDIX 1	MAPS
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APPENDIX 4	ONLINE GROUP MEETING
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APPENDIX 6	PAPERS PUBLISHED