

ENVIRONMENTAL DNA (eDNA) METABARCODING'S POTENTIAL AND DIFFICULTIES FOR MANGROVE RESTORATION IN SOUTHEAST ASIA

Aditi Dinda¹, Sandip Ghosh², Srijan Haldar^{1*}

¹Department of Biotechnology, School of Life Sciences, Swami Vivekananda University, Barrackpore, Kolkata-700121, West Bengal, India

²The Climate Thinker, Kolkata, India

*Corresponding author: srijanh@svu.ac.in

ABSTRACT

Mangrove forests in Southeast Asia are crucial for coastal protection, carbon sequestration, and biodiversity. However, rapid deforestation and habitat degradation necessitate efficient restoration strategies. Environmental DNA (eDNA) metabarcoding offers a non-invasive and cost-effective method for assessing biodiversity and monitoring ecosystem recovery. By analyzing genetic material from water and sediment samples, eDNA provides insights into species composition, including cryptic and rare organisms, which traditional surveys might overlook. This technology enables real-time tracking of restoration progress and ecosystem health. Despite its potential, eDNA metabarcoding faces challenges such as environmental degradation of DNA, taxonomic reference gaps, and data interpretation complexities. Factors like salinity, temperature, and microbial activity influence DNA persistence, potentially biasing results. Additionally, Southeast Asia's diverse yet under-documented biodiversity limits the accuracy of genetic reference databases. Standardization of sampling protocols and bioinformatics pipelines is essential to ensure reliability across studies. Integrating eDNA with conventional monitoring can enhance mangrove restoration efforts by providing comprehensive biodiversity assessments. Addressing methodological challenges will be key to leveraging eDNA metabarcoding as a powerful tool for conservation and ecological restoration in

Southeast Asia's threatened mangrove ecosystems.

Keywords: *Conservation, eDNA, Metabarcoding, Mangrove Restoration, Southeast Asia*

Introduction:

The technique of environmental DNA (eDNA) metabarcoding is used to discover and track biodiversity by analysing genetic material found in environmental samples (such as soil, water, or air). The possibilities and difficulties of employing environmental DNA (eDNA) metabarcoding to track and improve mangrove restoration initiatives in Southeast Asia are covered in the research (Naputo, C. F. P, 2024). It draws attention to the advantages of eDNA as a non-invasive, reasonably priced way to monitor species presence, measure biodiversity, and analyse ecosystem health in mangrove habitats --- areas that are sometimes challenging to sample using conventional techniques. (Wee, A. K, 2023) The potential of eDNA in mangrove restoration lies in its capacity to identify a variety of species, including cryptic and uncommon organisms, and its use in tracking the effectiveness of restoration initiatives. eDNA can shed light on how well restoration methods work and how quickly biodiversity is returning. But the study also addresses a number of issues, such as the requirement for standardized procedures for data collecting, DNA extraction, and sample collection.

Application of Environmental DNA in mangrove restoration:

The study investigates several uses of environmental DNA (eDNA) metabarcoding in the conservation and restoration of mangroves (Naputo, C. F. P, 2024). By making it possible to conduct quick, economical, and consistent assessments of biodiversity across several sites, eDNA can improve tracking functional recovery (Wee, A. K, 2023). It makes it possible to track changes across the entire community, find rare or cryptic species, and gain a better knowledge of ecosystem connections and species mobility. By tracking key species, their habitat boundaries, and movement ecology, eDNA also supports the design of restoration sites and helps prioritize conservation areas (Naputo, C. F. P, 2024). Furthermore,

eDNA offers early warnings for dangers like invasive species, dangerous plants, and algae that could impair mangrove ecosystem function and biodiversity. Through species-specific qPCR assays, it provides an affordable, repeatable way to identify the existence and abundance of vulnerable taxa, including enigmatic species like dugongs and proboscis monkeys (Foster, N. R, 2020). In order to support adaptation efforts, eDNA also monitors how climate change is affecting mangrove communities. Additionally, by facilitating local engagement in data gathering with little training, eDNA promotes community-based restoration by guaranteeing greater participation and more thorough monitoring. By encouraging early hazard detection and enhancing ecological results, this cooperative strategy, supported by molecular ecologists, promotes a more efficient and sustainable mangrove restoration process.

Challenges:

There are various obstacles to overcome when using environmental DNA (eDNA) metabarcoding for mangrove conservation and restoration. Risks of contamination during sample collection and eDNA degradation in tropical regions, which impacts amplification success, are examples of technical hurdles (Xing, Q,2024). A number of variables, such as pH and suspended particles, affect eDNA filtration techniques, and PCR inhibitors in murky waters make analysis more difficult (Basyuni, M,2021). Furthermore, the design of particular primers is crucial for effective amplification, particularly in biodiverse mangrove habitats. Methods still need to be standardized because variations in water types and sampling strategies impact taxon detection and make it more difficult to compare research. Data on biodiversity in Southeast Asian (SEA) mangroves is uneven due to the lack of a standard approach(Foster, N. R, 2020. Delineating sampling limits is made more challenging by the dynamic nature of mangrove fauna, which varies depending on factors including salinity and tidal conditions. Furthermore, nothing is known about how eDNA is released and removed in these intricate settings. One of the data disadvantages is the lack of an extensive regional reference database, which

makes it more difficult to accurately identify species. Current databases lack worldwide applicability and are frequently region-specific. Furthermore, further research is needed to develop trustworthy connections when measuring species biomass or abundance using eDNA(Helfer, V., 2018). Lastly, because molecular analyses are expensive and frequently only available in high-income nations, there are still issues with finance, infrastructure, and capacity-building. Widespread eDNA implementation in SEA is hampered by a lack of resources and experience, underscoring the need for improved infrastructure development and training.

Future Prospective and discussion

The possibility of eDNA metabarcoding as a biomonitoring technique for mangrove restoration in Southeast Asia (SEA) is covered in this paper. In order to fill in data gaps, increase capacity, and create an extensive reference database, it emphasizes the necessity of international cooperation. Initiatives that have been successful at the national level, such the Atlas of Living Australia, are mentioned as examples of regional collaboration. International collaborations, such as the Japan-Philippines-Indonesia initiative, show how beneficial teamwork is for improving eDNA research. In order to inform biomonitoring methods, the study emphasizes the significance of standardizing methodology, developing a cooperative platform for data exchange, and carrying out baseline investigations(Cahyani, N. K. D.2024). The study comes to the conclusion that eDNA metabarcoding can help data-driven coastal management and conservation initiatives, particularly in SEA, where cooperation is necessary to achieve restoration objectives and shared coastal resources. While eDNA metabarcoding has great potential to improve mangrove biomonitoring and restoration efforts, its successful implementation will necessitate overcoming a number of obstacles, according to the paper's conclusion on the prospects and challenges of environmental DNA (eDNA) metabarcoding in mangrove restoration in Southeast Asia. Promoting regional and global cooperation to overcome data constraints, increase capacity, and create an extensive reference database are important components. Furthering the application of eDNA

in mangrove ecosystems also requires baseline investigations, the development of cooperative platforms for data sharing, and the standardization of procedures. The study comes to the conclusion that, with consistent international cooperation and funding, eDNA metabarcoding can be incorporated into mangrove restoration projects to support data-driven coastal management, enhance conservation results, and advance the ecological and socioeconomic objectives of the area, such as coastal defense and food security(Helfer, V., 2018).

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