# Final Evaluation Report

| Your Details | |
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| **Full Name** | Anoop Raj Singh |
| **Project Title** | Understanding the recovery of coastal vegetation and soil processes at the uplifted sites of Andaman Islands: A way forward for restoration |
| **Application ID** | 32387-1 |
| **Date of this Report** | 15.11.2022 |

**1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.**

| Objective | Not achieved | Partially achieved | Fully achieved | Comments |
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| To understand the vegetation composition in the terrestrial and mangrove vegetation colonizing at the uplifted sites. | | | ■ | Nine representative sites were selected randomly to capture the heterogeneity of 2004 tsunami impacts on the coastal vegetation of the North Andaman Islands (NA). The nine sites were categorised into three sub-sites based on uplift gradient i.e., a) ≥1m, b) ≤1m - ≥0.5m, c) ≤0.5m, and each uplift category constitutes three replicates which are distributed throughout the length of the study site. Additionally, three control mangrove sites were surveyed where the impact of the tectonic shift was not experienced.<br>A total of 90 belt transacts constitute 270 vegetation plots of each 100 $m^2$ across the four habitats - old & new growth mangrove forest, and old & new growth terrestrial forest was surveyed. Although, four sites did not have one habitat out of four (New Growth Terrestrial Forest (NGTF)), whereas one site did not have a remanent patch of old mangrove (OGMF).<br>The entire live plant specimen collected during the vegetation inventory were pressed under dry newspaper. To avoid fungal infection, the specimens were transferred to new dry sheets twice every week. Subsequently, an absolute alcohol was applied on the specimen. Further, all the treated specimens were identified referring herbarium library of Botanical Survey of India – Andaman centre (BSI-Andaman), and other published flora. We have identified all mangrove species found in the vegetation plot, whereas nearly 80% of plant samples found in the terrestrial forest could be identified. Further, all the samples were submitted to the herbarium repository of Wildlife Institute of India, Dehradun.<br>In addition, the centroid of all the vegetation |

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| | | | | plots was consistently utilised for testing onsite water parameters such as salinity using refractometer, and pH/temperature using Hanna digital meter. |
| Influence of propagule availability and soil interaction on vegetation colonization. | | | | We recorded the Euclidean distance between the corresponding old and new-growth habitats of mangrove and terrestrial forests for all nine sites.<br>A total of 91 soil core and 91 bulk cores (25 from OGMF, 27 from NGMF, 27 from OGTF, and 12 from NGTF) was collected at depth of 10cm from each vegetation belt (through self-designed and locally made stainless steel soil auger). The soil core samples were stored onsite in airtight zip-lock bags for further processing. We measured the soil-core fresh bulk weight before shade dry using milligram accuracy weighting balance. Thereafter, the soil core was shade dried until constant weight was obtained for two consecutive readings. After measuring the weight of dry soil samples, they were stored at room temperature for future laboratory analysis.<br>All 91 soil samples were analysed at the Analytical lab of the Wildlife Institute of India, mainly for basic yet essential parameters: electrical conductivity (EC) for soil salinity, soil pH, and soil organic carbon (OC) using a standard method. |
| Development of site-specific spatial maps along with their ecological details to depict the potential restoration sites for mangroves and terrestrial forests | | | | GPS location of all four-habitat categories was recorded using GARMIN GPSMAP-64csx. The boundaries between two different habitat categories were also noted for better training in supervised classification in the ArcGIS tool. Additionally, the extent of old and new-growth forests was marked to map the change in land use land cover of the study site.<br>The soil characteristics of the vegetation plot such as the percentage of dead corals, boulders, sand, and clay were recorded alongside phytological parameters of trees, saplings, and seedlings.<br>Sentinel-2 satellite imagery of 10-30m spatial resolution was downloaded from the freely available source Copernicus (https://scihub.copernicus.eu/dhus/#/home). Processing of these images to |

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| | | | | incorporate the above field data to produce site-specific restoration maps for mangroves and the terrestrial forest is currently underway. As the project team lacked the professional experience to process satellite images with multivariate data, this objective requires more time than initially anticipated. We plan to achieve it by the end of December 2022.<br>The project team however identified a few locations based on field expertise and the intensive data collection for the restoration planning implemented by the forest department. We have identified three mangrove sites (Austin Bridge-Mayabunder, Aerial Bay-Diglipur, and Radhanagar Mouth-Hathilevel), and one terrestrial site (Barmachad-Kishorinagar) for the plantation drive. The sites were recommended considering the availability of seed sources from the nearby remanent mangrove patch, and the suitable soil substratum that would enable high success ratios for the plantation drive. |
| Knowledge dissemination with local stakeholders to provide a scientific basis for the restoration of sites affected by upliftment | | | | To achieve this objective, we followed a two-tier consultation approach with local stakeholders. We had several one-to-one consultation/stakeholder meetings with top forest officials who are in the driving seat of decision making which includes four DFO-officer (Divisional Forest Officer), four ACF-officer (Assistant Conservator of Forest), and eight RO (Range officers). These one-to-one meetings with forest officials were to highlight the reasons leading to the failure of plantation efforts. The discussion also involved dos and don'ts for the upcoming plantation efforts in the recommended sites.<br>The second approach was adopted to educate the field staff of the forest department who are directly involved in a plantation drive through a 1-day sensitisation workshop. The workshop included two sessions, one was a classroom-based discussion about mangrove definition, zonation pattern, the influence of tidal water, ecosystem services, and introduction to all the mangrove species found locally with their unique identification features. |

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| | | | | Other sessions were hands-on training in the field about mangrove identification, seed collection, which species to plant where, etc.<br>A total of 53 field staff (17 female and 36 male) were sensitised about the mangroves and the restoration techniques during the two sensitisation workshops. The workshop deliberately targeted a mix of new/young recruit officers who would be involved in the plantation drive in future, and aged officers who were previously involved in some plantation drive to share their field experiences and insights with other participants. |

**2. Describe the three most important outcomes of your project.**

**a).** The present study has documented the baseline information on the tree, sapling, and seedling species colonising at tectonically uplifted-cum-newly formed vegetation colonising sites. A total of 127 vegetation plots were marked with GPS coordinates for future longitudinal as well as long-term studies which include 36 NGTF and 91 NGMF. We documented 39 tree species in the NGTF habitat where *Phoenix paludosa* (true mangrove) was most dominant species, followed by *Ficus microcarpa* (terrestrial species). Further, we recorded eight mangrove species in NGMF habitat, however, the overall mangrove diversity of NA is 30. *Rhizophora mucronata,* and *Avicennia marina* were nearly equally dominant mangrove species found in the uplifted dead coral reef bed, whereas *Bruguiera gymnorrhiza* was noticed as the least dominant mangrove species. The vegetation documentation of such newly created habitats provides a unique opportunity to understand the mangrove succession and natural recovery post disturbances concerning altered sea levels.

North Andaman Island has few remanent mangrove patches of varying shapes and sizes. We surveyed 86 old-growth mangrove plots, located in the close vicinity of the NGMF habitat and recorded 15 mangrove species with *Rhizophora apiculate,* and *Rhizophora mucronata* being the most dominant tree species. The influence of remnant mother trees which plays a crucial role in facilitating the colonisation process at disturbed habitats was evident, as at NGMF habitat *Rhizophora* and *Ceriops species* are among the dominant pioneer species. In addition, our primary field data clubbing with personal observation suggests that there are many rare mangrove species (*Pemphis acidula, Sonneratia ovata,* and *Avicennia alba*) colonising the uplifted site despite lesser mature individuals on the island. This indicates that alongside seed availability, several other environmental parameters are also important for mangrove recovery and need to be considered in future studies. These parameters include soil and water salinity, rate of propagule establishment, tidal frequency, soil profile, and local hydrology.

**b).** A baseline information was also documented on soil samples collected from each belt transect through laboratory analysis. However, before analysis, we measured the fresh weight and dry weight of the bulk soil core. The average fresh weight encountered in NGMF habitat was 128.8 g, which was higher than the average fresh weight of OGMF - 111.2 g. Contrastingly, an opposite trend was noticed in the terrestrial forest where the average fresh weight of NGTF 119 g was lesser than OGTF 123.37 g. Similarly, the average dry weight of NGMF was 81.7 g, which was significantly higher than OGMF's dry weight 56.64 g, whereas the dry weight of NGTF 81.4 g was narrowly lesser than the dry weight of OGTF 93.3 g. The soil pH, and soil salinity (milli-Siemens) of NGMF were 6.52 mS and 8.32 mS respectively, which was higher compared with OGMF 5.40 mS and 8.26 mS. Similarly, the soil pH and soil salinity of NGTF was 6.22 mS and 3.1 mS respectively, which was lower, compared to its counterpart OGTF 6.1 mS and 0.5 mS.

**c).** The recovery processes on the island are currently challenged by many natural and anthropogenic threats, which delay the ecosystem recovery process. The current study has documented the herbivory pressure by invasive chital/spotted deer (*Axis axis*), and domestic cattle being the dominant threat to the natural ecosystem recovery process. These results will provide a scientific basis for the management of the invasive chital population in the islands.

The commonly used method of plantation/restoration does not consider scientific basics, and hence often lead to failure in plantation, and loss of money. Therefore, the sensitisation workshop for more than 50 field staff of the Andaman Forest department, and one-to-one discussion with 16 high-ranked officials will surely help the department to better plan, strategies, executive, and manage the future afforestation/restoration drive.

**3. Explain any unforeseen difficulties that arose during the project and how these were tackled.**

We started the project under COVID-19 uncertainties, which delayed the project by approximately 6 months. The proposed study site – the Andaman and Nicobar Islands - is an isolated island ecosystem and possesses limited resources in terms of medical facilities. Hence, the concerned Andaman authority restricts project team members (mainland residents) for free movement on the island. Eventually hampering the project team's inter-island movement and primary data collection.

The vegetation sampling was carried out during the dry season (January to April 2022) as Andaman Island witnesses high rainfall (more than 3800 mm) every year from May to December. During the dry season, most of the plant individuals were either in the deciduous or non-flowering phase of phenology. Subsequently, onsite identification of most of the terrestrial plant species was highly doubtful. To reduce the ambiguity in the data, we collected live specimens of all the plant species and processed them for identification. Plant specimens without reproductive parts (i.e., flower, fruit, seed, etc.) required consultation with experts for the proper identification of the species. There are very few experts who possess sufficient knowledge of the plant diversity of North Andaman. Setting up consultation meetings with the experts took more time than expected.

The budget for the boat hire was later realised to be under-budgeted. However, through the active participation and engagement of the local community and the forest department, the project team managed to undertake multiple site visits with less expenditure.

**4. Describe the involvement of local communities and how they have benefitted from the project.**

The involvement of Andaman local residents will be a key basis for the rapid recovery of degraded mangrove habitat and conservation of remnant mangrove patches. The positive relationship built by the team member with forest managers through consultative meetings or regular one-on-one dialogue has sensitised the local stakeholders in the scientific restoration of mangroves.

Further, the forest department annually conducts awareness programmes to reduce human-crocodile conflict. In addition to the human-crocodile conflict, this year the forest department field staff along with the project team have also spread awareness about mangroves, and the importance of mangroves in restoring the ecosystem services that are lost after the 2004 tsunami.

For the successful execution of field data collection, we involved/hired 17 boatmen, 31 mazdoors (forest department contractual labours), eight field assistants, and two motor drivers who are local from Andaman Island and understand the larger goal of the current Rufford mangrove project. Also, a few of the individuals are the point of contact for their village, through whom we maximised the project objectives by spreading awareness among the community about the importance of mangroves.

**5. Are there any plans to continue this work?**

Yes, we wish to continue this work and carry forward the awareness building regarding mangroves among the local residents of North Andaman Island. It has been roughly 18 years since the deadliest earthquake of 9.3 $M_w$ intensity occurred that directly inflicted a change in Andaman and Nicobar hydrology. The tectonic shift further altered the frequency and inundation pattern of tidal water in the mangrove forest. As a result, several mangrove trees die off and the earthquake has indirectly changed the lives of many marginal communities that are primarily dependent on mangrove resources for livelihood and income. Hence, the plan of this study could be to analyse the change in ecosystem services in North Andaman Island, and how it is varying from high uplift (≥1m) area to a low uplift area (≤0.5m) or vice-versa. Also, to understand what adoptive measure local community endorses to cope with such sudden changes.

The other way forward in line with the current project could be to resurvey the established vegetation plots in NGTF and NGMF to understand the rate of colonisation process and model the timeframe required to achieve the status quo of new habitat corresponding to mature forest. Also, the long-term monitoring of mangroves at uplift sites will not only add to the ecological science, but it will help

forest managers in taking precise and efficient decisions to restore the mangrove and associated ecosystem services at the earliest.

**6. How do you plan to share the results of your work with others?**

We have a multilevel scheme to share our results with the wider community including scientific and non-scientific background:

1. We have published an interesting observation made during the project reconnaissance survey in the form of a short note on turtle stranding due to land uplift on the western coast of North Andaman Island. https://doi.org/10.11609/jott.7603.13.12.19860-19863

   We have communicated two research articles during September-October 2022. One article is about mangrove species diversity and composition colonising on 2004 tsunami-created small island system with emphasis on its long-term monitoring (Title: Mangrove colonization on the uplifted reef bed in the west coast of North Andaman Island, India, *Current Science*). The second article is about confirming the presence of one rare yet doubtful mangrove species with its geo-coordinates and photographic evidence from the intertidal of Andaman and Nicobar Island (Title: Distribution of a rare mangrove species *Avicennia alba* Blume in Andaman and Nicobar Island, *Tropical Ecology*).

2. To outreach to our non-scientific readers, we have drafted a cover story on mangrove response to change in tidal water inundation due to the 2004 earthquake in the form of a popular article (to be submitted in November 2022).

3. Among four objectives of this project, two (objectives 1 and 2) of them will be partially used to fulfil the team leader's PhD objective, which will be eventually included in the thesis work and submitted to libraries of the Wildlife Institute of India, Dehradun, and Gurukula Kangri (Deemed to be) University, Haridwar India for future reference.

4. We have prepared the layout of two full length manuscripts to be communicated at the end of this year. The article will showcase a checklist of species diversity and species composition in the new growth terrestrial and mangrove forest. The article will also enumerate the total area available for colonisation with the plausible recommendation and management plan for afforestation.

5. A foldable pictorial mangrove guide for the field staff of the Andaman Forest department will be prepared to showcase mangrove key identification features, IUCN status, with their vernacular names, which will be a significant outcome of this project.

**7. Looking ahead, what do you feel are the important next steps?**

The study has the potential for drafting a management plan for the uplifted sites. Such a plan can have direct policy implications and could be used by the local forest department for the long-term management and protection of these uplifted seabed that are now colonised by mangroves and terrestrial plants. Also, completing the restoration map that are under preparation will be crucial step to help the forest department in planning their management efforts.

The one-time vegetation sampling through the current project has provided a snapshot/baseline of what is the vegetation community that is now colonising the new habitats. However, repetitive sampling in the same sites will be crucial to understand how different species are making use of this habitat for colonisation. Such an exercise would provide much needed insight into the long-term management and restoration of sites where vegetation colonisation is slow. Moreover, the repetitive sampling will also enable to build of a prediction model to estimate the time required for the complete natural recovery of the uplift-affected sites.

**8. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?**

- The RF logo was used in the poster and banner printed for the consultative workshop with the forest department.
- The RF logo is acknowledged in the published article under the funding category, and it is also documented in all the submitted peer-reviewed article and popular article.
- The RF logo will also be used in a foldable pictorial mangrove guide to be distributed among the field staff of the Andaman Forest department.
- The RF was acknowledged as one of the primary sources of funding in the PhD synopsis defence of one team member (Mr. Anoop), and the logo will be used in his PhD thesis.

**9. Provide a full list of all the members of your team and their role in the project.**

**Mr. Anoop Raj Singh:** Project conceptualization, project writing, methodology designing, developing vegetation datasheet, site selection, field data collection, data entry, plant identification, data sorting and analysis, manuscript and report writing.

**Dr. Nehru Prabakaran:** Project conceptualization, project writing, editing and approving methodology design, editing and approving vegetation datasheet, site selection, availing forest department permission letter, field data collection, plant identification, data analysis, manuscript, and report writing.

**Mr. Thirumurugan V.:** Developing vegetation datasheet, field data collection, plant identification, data analysis, manuscript, and report writing.

**10. Any other comments?**

All the team members are highly grateful to the RF committee member for approving and funding this project. We also extend our gratitude to RF members for being extremely patient, prompt, and cooperative to all our requests. We are also grateful for granting timely extensions to the project due to which we could achieve most of our proposed objectives.

New growth mangrove forest (NGMF)- a) muddy surface, b) relatively hard surface with grasses

Mature mangrove trees dying off due to retreating of tidal water led by land uplift (NGTF)

Remnant Old growth mangrove forest (OGMF) with disturbed understorey

NGMF – Uplift dead micro atoll, forming small island like structure with boulders

Old growth terrestrial forest (OGTF) with high commercial valued tree (*Pterocarpus dalbergioides)*

Measure onsite water parameter a) Salinity measurement using Refractometer, b) pH and Temperature measurement using digital meter

Mangrove sensitization workshop with Forest department field staff of Mayabunder division, Andaman Islands a) classroom session, b) field session

Mangrove sensitization workshop with Forest department field staff of Rangat Division Andaman Island a) classroom session, b) field session