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# Building resilience in a climate crisis: best practices for mangrove restoration along the Coral Coast, Fiji

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## Abstract

A critical review of existing mangrove restoration practices was conducted to establish mangrove restoration best practices. The primary focus of this study was on four villages along Fiji's Coral Coast on Viti Levu, namely Yadua, Korotogo, Votua, and Tagaqe. These sites have the highest concentration of mangrove restoration projects in Fiji. This study utilised a ~3 yr mangrove seedling survival index to indicate mangrove restoration success. The study conducted 128 household surveys and seven interviews. The interviews were conducted with stakeholders involved in implementing mangrove conservation and restoration projects: village households, non-governmental organisations (NGOs), organisations in the private sector, and the Department of Environment. Onsite observations of the substrate type, exposure to waves, slope of the restoration site, and input of fresh water to the restoration sites were also assessed to identify biophysical factors that either helped or hindered the establishment of mangrove seedlings at the four sites. Yadua and Korotogo villages achieved an ~80% seedling survival rate, while Tagaqe and Votua had more modest success at ~20% survival. The study identifies four factors: consistent influx of freshwater, reduced exposure to high wave energy, presence of artificial breakwaters, and input of nutrient enhancers, all corresponded with increased mangrove seedling survival.

**Keywords**: Mangroves, Mangrove restoration, Site selection, Site preparation, Maintenance and monitoring.

## Introduction

Mangroves protect island coastlines throughout the Pacific and are simultaneously one of the most threatened coastal ecosystems (Sobey, 2018). Studies suggest that almost 50% of the world's mangrove forests have been lost due to various human activities such as tourism, commercial and infrastructure development, deforestation for aquaculture

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or agriculture, utilisation for fuel wood, charcoal, building materials, medicine and dyes (Valiela et al., 2001: 807). Mangroves are especially targeted for conversion because they inhabit flat land that is highly valued for both development and agriculture. The current average annual mangrove depletion rate worldwide is estimated to be 0.7% (Huxham, et al., 2015: 173). Asia has the world's largest area of mangrove forest, and an annual mangrove depletion rate of approximately 1.52 % (Valiela et al., 2009: 111). Fiji supports approximately 42,000 hectares of mangrove forests (Watling, 1985; Watling, 1986; Spalding, et al., 2010; Watling, 2013; Hamilton and Casey, 2016), of which approximately 4.5m$^3$ is harvested annually for timber, fuel wood and medicinal products in Fiji (Greenhalgh, et al. 2018: 26). Lal (1990) stated that about 2300 hectares of mangroves were converted to land reclamation for sugarcane farming, and according to Sobey (2018), Fiji's mangrove forests were depleted at an average rate of 5% per year from 1991 to 2007.

Mangroves are salt-tolerant plants found in the intertidal zones in the tropical and subtropical regions (Duke, 1992: 85). The term mangrove is used to refer to both individual plants, as well as the ecosystem that they support. "Mangal" is used to refer to a mangrove ecosystem (Macnae, 1968: 223). Because the term "mangal" is not well known, and even though it is ambiguous, for ease of communication "mangrove" will be used to refer to both the ecosystem as well as species in this report.

Mangroves have vast ecological benefits, and many socio-economic benefits. Mangroves provide a buffer zone that helps to protect the coast during extreme events such as tidal waves or storm surges (Sulaiman and Mohidin, 2018). The prop root system helps to increase accretion and reduce coastal erosion (Alongi, 2016: 3). With projected sea level rise, mangroves provide hope for adaptation by protecting coastal villages from coastal inundation and reducing coastal erosion. While mangrove depletion releases the carbon sequestered in the soil and trees back into the atmosphere to aggravate global warming (Ramsar Secretariat, 2001), enlarging forests will increase the ecosystem's capacity to store atmospheric carbon. Furthermore, the marine organisms extracted from this ecosystem are used for both subsistence and commercial purposes.

Human intervention is required to restore an ecosystem that has been depleted to the extent that it cannot replenish itself (Lewis, 1990: 101). The term "restoration" is used in this study because the natural mangrove stands at the study sites have been degraded due to various human activities to the extent that they will not recover to their natural state without human intervention. Only through conscious efforts will the forests regenerate and continue to provide ecosystem services (ES) that the coastal communities can benefit from.

Restoring the mangrove ecosystem to its pristine status is neither necessary nor possible; however, the recovery of key ecosystem services and functions can be successfully achieved (Choudhuri and Choudhury, 1994: 247). Mangroves are usually restored for a specified purpose, such as to protect the coastline or to increase the abundance of marine resources (Gilman et al, 2007: 113).

This study critically evaluated the mangrove restoration practices in the villages of Yadua, Korotogo, Tagaqe, and Votua, located on Fiji's Coral Coast, on the main island of Viti Levu, and established the best practices for a higher mangrove seedling survival rate. A framework derived from the studies of Ellison and Fiu (2010) and Lewis III and Brown (2014) was used to identify the factors that encourage or hinder the mangrove seedling survival rate (Figure 1).

Mangrove restoration involves natural regeneration, planting of propagules or seedlings in new areas, or the infusion of degraded mangroves with propagules or seedlings, is crucial for the re-establishment and survival of these ecosystems. Stressors are those factors whose presence results in the decline or removal of mangroves, such as pollution, pests/diseases, deforestation, and sea level rise. Ellison and Fiu (2010) particularly emphasise that after the identification of stress, it is vital to remove the stress to support mangrove re-establishment. Lewis III & Brown (2014) identify four stages of mangroves restoration: 1) site selection and choice of mangrove species, 2) site preparation, 3) planting mangrove propagules/seedlings and 4) maintenance and monitoring to support propagules or seedlings establishment and survival (Figure 1).

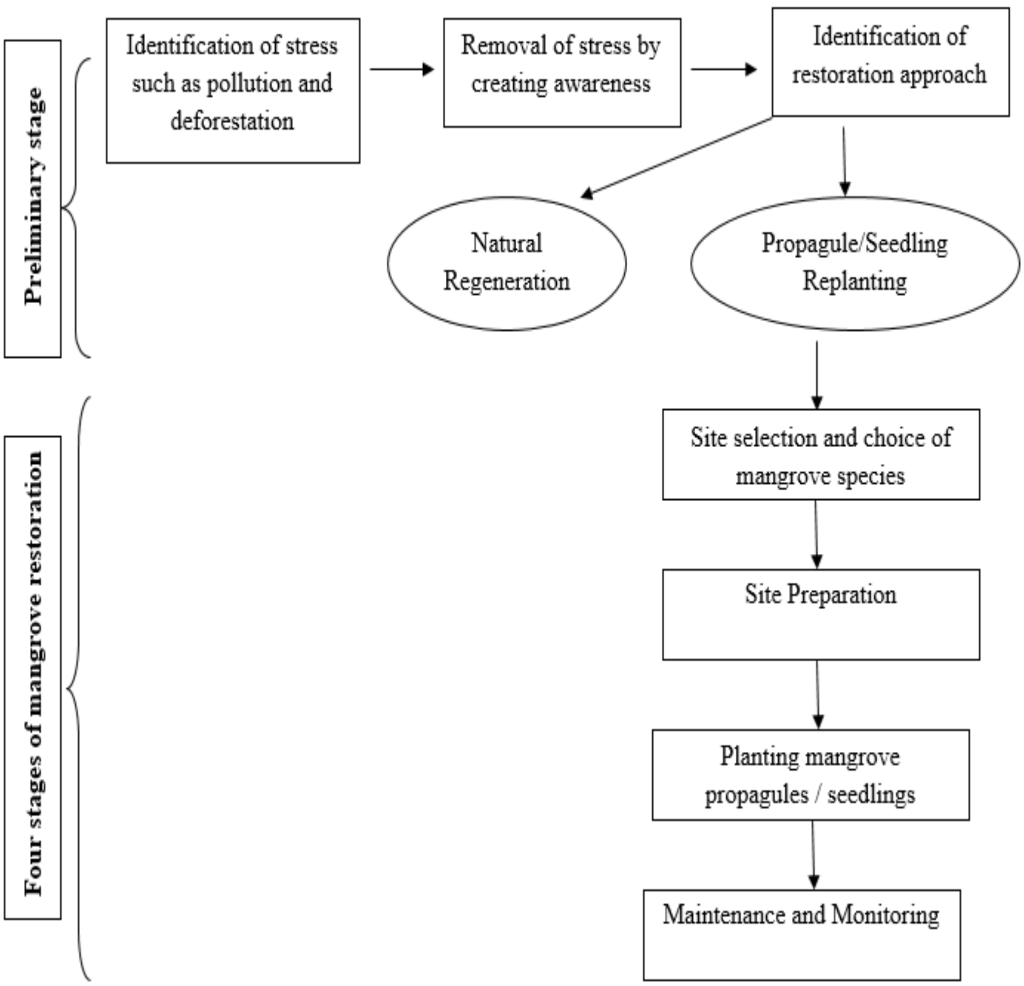


**Figure 1**: A conceptual framework for mangrove restoration

## Method

*Study Area*

This study was conducted in four villages and the adjacent mangrove restoration sites along Fiji's Coral Coast, situated on the southwestern coast of the main island of Viti Levu. The sites are Yadua (longitude 18°10' 02.52" S and latitude 177°28' 04.04" E in Cuvu district, Korotogo (longitude 18°10' 08.26" South and latitude 177°32' 18.06" East) in Conua district, Tagaqe (longitude 18°11' 47.88" South and latitude 177°39' 33.76" East), and Votua (longitude 18°12' 41.85" South and latitude 177°42' 45.96" East) in Korolevu-i-wai district (Figure 2).

Yadua village had two phases of mangrove restoration, with planting in 2001 followed by a 2011 replanting resulting in a total of 0.4 ha replanted. In 2016, Yadua had 0.4 ha of restored mangroves. Korotogo village restored a total of 0.8 ha of mangroves in three phases starting in 2000. In 2016, Korotogo had 0.8 ha of restored mangroves. Both Yadua and Korotogo have natural mangrove ecosystems located nearby but separate from the restored mangrove ecosystems. The satellite imagery analysis estimated natural mangrove stands to be 0.6 ha in Yadua and 20.7 ha in Korotogo with a total mangrove coverage of 1 ha in Yadua and 21.5 ha in Korotogo (Table 1). Meanwhile, Tagaqe and Votua, replanted .01 ha of mangroves in 2007 and 2011 respectively. The satellite imagery analysis showed that Tagaqe had approximately 105 $m^2$, whereas Votua had approximately 110 $m^2$ of replanted mangroves. Neither Tagaqe nor Votua had any natural mangrove stands. With an estimated 20% seedling survival rate for both Tagaqe and Votua sites, 2016 total mangrove coverage was estimated to be approximately 0.01 ha, 3-4 orders of magnitude lower than Yadua and Korotogo (Dakai Tevita, Personal communication from the Principal Research Officer of OISCA, December 2015). The sites were selected based on the availability of mangrove data. The Japanese Organisation for Industrial, Spiritual and Cultural Advancement (OISCA) was responsible for planting and monitoring mangrove growth at all four sites.

**Table 1**: Natural and restored mangrove areas at for the four villages: Yadua, Korotogo, Tagaqe and Votua along Fiji's Coral Coast

| Village | Area of Restored Mangroves | Area of Natural Mangroves | Total Area of Mangroves |
|---|---|---|---|
| Yadua | 0.4 ha | 0.6 ha | 1 ha |
| Korotogo | 0.8 ha | 20.7 ha | 21.5 ha |
| Tagaqe* | 0.01 ha | None | 0.01 ha |
| Votua* | 0.01 ha | None | 0.01 ha |

* With a difference of only 5 $m^2$ in estimated mangrove coverage, restored mangrove coverage was assumed to be 0.01 ha in both Tagaqe and Votua villages for all ecosystem services calculations.

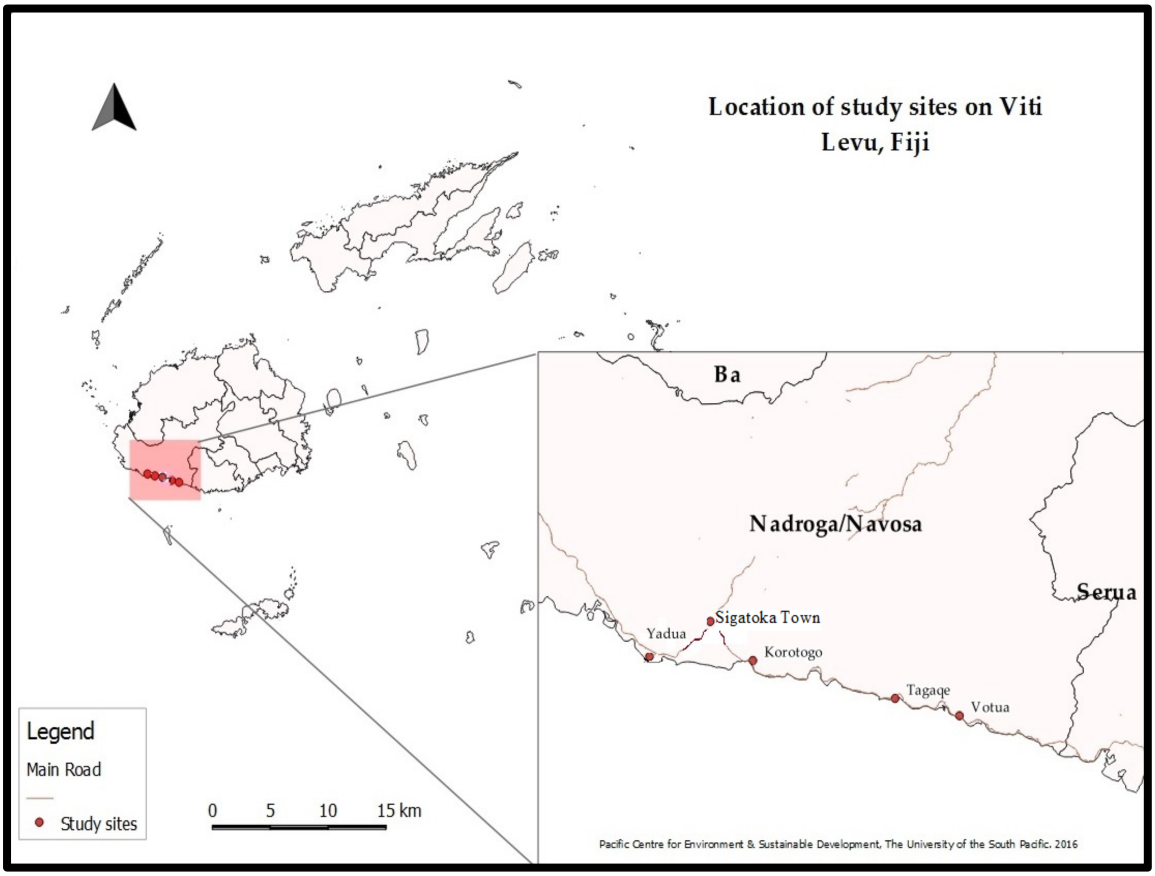


**Figure 2**: Map showing the location of the four study sites, Yadua, Korotogo, Tagaqe and Votua along the Coral Coast of Fiji, on Fiji's main island, Viti Levu (Courtesy of Siu Jione)

*Data collection methods*

On-site field observations were carried out at the four mangrove restoration sites. Habitat maps digitised by the Fiji Department of Forestry using 2001 Landsat Enhanced Mapper Plus (EMT+) satellite imagery were used to calculate the area of restored mangroves at the study sites. Observation of substrate type, exposure to waves, the slope of the restoration site, and freshwater supply to the sites were recorded. This assessment was carried out to identify the physical factors that have either helped or hindered the establishment of mangrove seedlings at the four sites. The height of the mangroves that have matured (15 years and above) was measured randomly using a stick that was later measured using a measuring tape.

The socioeconomic data was obtained through key informant interviews and household surveys in the four villages. The interviewees were categorised into three groups: 1) non-governmental organisations (NGOs) involved in mangrove conservation and replanting projects (including OISCA, WWF, Projects Abroad, IUCN); 2) the Department of Environment; and 3) hoteliers (Outrigger on the Lagoon and the Fijian Sangri-La Resort) that have made a visible investment in mangrove ecosystem health. Each group was interviewed regarding their perceived importance of mangrove restoration, and their current involvement in mangrove restoration projects in Fiji. An hour-long face-to-face interview was conducted with OISCA. All remaining interviewees preferred to answer a written questionnaire due to time constraints. The same questionnaire format was used for the face-to-face interview as for the written questionnaire. The questions were tailored to each of the three groups. The household survey was conducted using a random selection of households within each village. Fifty percent of the households in each of the four villages were interviewed for a total of 128 household interviews from December 2015 to January 2016.

*Data analysis*

Data collected from key informant interviews with NGOs and hoteliers were analysed to compare mangrove restoration techniques and to understand perceptions and roles in mangrove restoration projects. Data from the Department of Environment was organised thematically, covering legislation, environmental impact assessments, climate change mitigation, ecosystem services valuation, and adaptation plans. Household survey and key informant interview responses were analysed using Microsoft Excel. A framework (Figure 1) was developed to evaluate mangrove restoration practices at the four study sites.

*Biophysical factors suitability analysis*

The biophysical factors analysis was based on the environmental and freshwater feeding agent data which significantly contributes to mangrove physiological development. The analysis comprised six parameters of biophysical factors (Table 2) based on based on the study of Iman (2014), Lewis III and Brown (2014) and Sahidin et al. (2020).

**Table 2:** A suitability matrix for biophysical factors for mangrove restoration

| | **Parameter** | **Category** | **Criteria** | **Suitability class** |
|---|---|---|---|---|
| 1 | Proximity to Natural Mangrove Stand | < 1km | Very Suitable | S1 |
| | | 1 – 5 km | Suitable | S2 |
| | | 6 – 10 km | Conditionally Suitable | S3 |
| | | > 10 km; No natural mangrove stand | Unsuitable | S4 |
| 2 | Elevation of Rehabilitation Site | 0 - 0.05 m | Very Suitable | S1 |
| | | 0.06 – 0.55 m | Suitable | S2 |
| | | 0.56 – 0.78 m | Conditionally Suitable | S3 |
| | | < 0 m; > 0.78 m | Unsuitable | S4 |
| 3 | Wave Energy | Sheltered | Very Suitable | S1 |
| | | Moderately Sheltered | Suitable | S2 |
| | | Exposed | Conditionally Suitable | S3 |
| | | Very Exposed | Unsuitable | S4 |

| | Parameter | Category | Criteria | Suitability class |
|---|---|---|---|---|
| 4 | Slope of the Restoration Site | Gentle Slope | Very Suitable | S1 |
| | | Moderate Slope | Suitable | S2 |
| | | Steep Slope | Conditionally Suitable | S3 |
| | | Very Steep Slope | Unsuitable | S4 |
| 5 | Freshwater Feeding Agent | Creek or River | Very Suitable | S1 |
| | | Surface Runoff | Suitable | S2 |
| | | Limited freshwater source | Conditionally Suitable | S3 |
| | | Saline Water | Unsuitable | S4 |
| 6 | Substrate | Silt, Clay | Very Suitable | S1 |
| | | Silt, Fine sand | Suitable | S2 |
| | | Medium – Coarse sand | Conditionally Suitable | S3 |
| | | Gravel, coral rubble | Unsuitable | S4 |

## Results and discussion

*Preliminary Assessment Stage*

Human intervention was required at all four sites because the mangroves in Yadua and Korotogo were extensively depleted (> 50%) and the mangroves in Tagaqe and Votua were completely depleted (100%). Mangrove depletion extent in Yadua and Korotogo was not available from OISCA. However, interviews with the village elders concluded that the depletion for both sites was more than 50%. All four steps of the preliminary stage were carried out in the four villages (Table 3).

*Stage 1 - Site selection and choice of mangrove species*

Successful mangrove restoration entails careful consideration of site selection based on the six biophysical factors (Table 2) for mangrove growth, proximity to natural mangrove stands, elevation, wave energy, slope, freshwater supply, and substrate type (Gilman et al., 2007; Lewis III & Brown, 2014). The index of mangrove seedling survival rate was used to critically evaluate the mangrove restoration practices at the four sites. The Principal Research Officer at OISCA confirmed that these factors were considered to select the suitable site for restoration. A site-specific breakdown of these factors for *Rhizophora stylosa* (Tiri tabua), which is the sole species replanted in the four study sites is provided in Table 4. Regrettably, information on species that previously inhabited the coastlines at the four sites before degradation was unavailable.

**Table 3**: Processes considered during a preliminary assessment before mangrove restoration at the four sites. Data was provided by the Principal Research Officer of OISCA in 2015

| **Processes** | **Yadua** | **Korotogo** | **Tagaqe** | **Votua** |
|---|---|---|---|---|
| Percentage of mangrove area being depleted before restoration | Approximately >50% (no exact data available) | Approximately >50% (no exact data available) | 100% | 100% |
| Identification of stress | Deforestation of mangroves for fuel wood and building materials | Deforestation of mangroves for road construction | Natural mangrove stands completely deforested for fuel wood and building materials | Natural mangrove stands completely deforested for fuel wood and building materials |
| Removal of stress | -Mangrove awareness program provided by OISCA.<br>-Village protocol prohibiting mangrove cutting implemented. | -Awareness programs on importance of mangroves by OISCA.<br>-Village protocol prohibiting villagers to deforest replanted mangroves. | -Awareness programs on importance of mangroves by OISCA, Fiji National University<br>-Village protocol prohibiting villagers to deforest replanted mangroves. | -Awareness programs on importance of mangroves by OISCA, USP.<br>-Village protocol prohibiting villagers to deforest replanted mangroves. |
| Identification of restoration approach | Extensively depleted, hence, required seedling replanting | Extensively depleted, hence, required seedling replanting | Completely depleted, hence, required seedling replanting | Completely depleted, hence, required seedling replanting |

Yadua and Korotogo had superior mangrove seedling survival, attributed to the ideal biophysical conditions (Table 4). Both Yadua and Korotogo achieved 80% mangrove seedling survival. The seedlings at Yadua have grown approximately five meters in height since planting in 2001. Korotogo, had four phases of restoration in 2000, 2002, 2013, and 2015. The mangroves replanted in 2002 have reached their mature stage (15-20 years of age). *Rhizophora stylosa* can reach heights of 30 meters at maturity (Ellison et al., 2010). However, at Korotogo, most trees have reached 5-10 m in height, including the 15-year-old seedlings. This is threefold lower than the expected height at maturity.

**Table 4**: Biophysical factors taken into consideration for selecting mangrove restoration sites along the Coral Coast on Fiji's main island, Viti Levu based on the study of Lewis III and Brown (2014)

| Biophysical Factors | Expected features for successful restoration | Study Sites (Villages) | | | |
|---|---|---|---|---|---|
| | | Yadua | Korotogo | Tagaqe | Votua |
| Proximity to Natural mangrove stand | Close proximity to natural mangrove stand enables propagule dispersal and is cost-effective. | Natural mangroves stand along the Yalasuna Creek, east of the restoration site. | Natural mangroves stand behind the village along Korotogo Creek. | No natural mangrove stand. | No natural mangrove stand. |
| Suitability | | S1 | S1 | S4 | S4 |
| Elevation of rehabilitation site | *Rhizophora stylosa* grows in the tidal zone where it is submerged every day by high tide. | The intertidal zone is flooded at high tide and exposed at low tide. | The intertidal zone is flooded at high tide and exposed at low tide. | The intertidal zone is flooded at high tide and exposed at low tide. | The intertidal zone is flooded at high tide and exposed at low tide. |
| Suitability | | S2 | S2 | S2 | S2 |
| Wave energy | Needs to be in sheltered areas on the shoreline with low wave energy. | Sheltered low wave energy along the beach. | Sheltered low wave energy bay. | Exposed beach to high waves as very close to fringing reef. | Exposed to high waves as very close to fringing reefs. |
| Suitability | | S1 | S1 | S3 | S3 |
| Slope of the restoration site | Should have a gentle slope. | Gentle slope | Gentle slope | Gentle slope | Gentle slope |
| Suitability | | S1 | S1 | S1 | S1 |
| Freshwater feeding agent | Mangroves need freshwater and thrive in brackish areas near creeks or rivers. | Yalasuna Creek on the east of the restoration site. | Korotogo Creek on the east of the restoration site. | Tagaqe Creek on the far east of the restoration site. The mangroves are reliant on surface runoff. | Has no creeks but mangroves are reliant on surface runoff. |
| Suitability | | S1 | S1 | S3 | S3 |

| Biophysical Factors | Expected features for successful restoration | Study Sites (Villages) | | | |
|---|---|---|---|---|---|
| | | Yadua | Korotogo | Tagaqe | Votua |
| Substrate | Grows in various substrates, including coral rubble, sand, mud, and even rocks. | A mixture of sand and silt along with detritus leaf litter underneath mangrove plants. | A mixture of sand and silt. | Coarse sand, coral rubble. | Coarse sand. |
| Suitability | | S2 | S2 | S3 | S3 |

Tagaqe and Votua, only had a 20% mangrove seedling survival rate due to the inconsistent input of freshwater, exposure to high wave energy at the restoration site, and lack of natural mangrove stands (Table 4). Despite limited funds to construct wave barriers and the urgent need for mangroves to mitigate coastal erosion, OISCA continued with mangrove restoration efforts at Tagaqe and Votua (Tevita Dakai, personal communication, January 8, 2016). To compensate for the lack of natural mangrove stands, OISCA utilised seedlings from their nursery at Korotogo. However, the pre-existing issue of inconsistent freshwater input was not addressed, which could potentially hinder mangrove growth (Table 4).

*Rhizophora stylosa*'s high salt-tolerance (it can grow in waters with > 25 ppt salinity) enables it to thrive in areas with dry climate such as the Coral Coast (Kainuma et al., 2015). The daily inundation of the intertidal zones at high tides helps in the successful establishment of the newly planted *Rhizophora stylosa* seedlings (Elster 2000; Bosire et al. 2008; IUCN 2009; Lewis 2009; Kathiresan 2011; Kainuma et al., 2015).

Mangrove restoration at all sites targeted coastal erosion control, and *Rhizophora stylosa* was a primary choice due to its exceptional root system that stabilises sediments (Duke, 2006; Ratnayake et al., 2012). The prop roots in a matured plant of *Rhizophora stylosa* can be 5 meters long and 10 meters in radius in favourable growing conditions and produce approximately three kilograms of biomass per square meter (Ruiz-Jaen & Aide 2005; Duke, 2006). *Rhizophora stylosa* grows approximately 60 centimeters per year, and flowers within a year (Peter and Sivasothi, 1999). The Principal Research Officer at OISCA endorsed these reasons for replanting *Rhizophora stylosa* along the Coral Coast.

A study on mangrove restoration projects in Sri Lanka revealed that only three sites had a seedling survival rate exceeding 50% (Kodikara et al., 2017: 715). For comparison, this study focuses on four sites with similar weather patterns to Sigatoka: Pambala and Kalpitiya (arid zone) with survival rates of 78% and 68%, respectively, and Panakala and Halawa (wet zone) with survival rates of 10% (Ranasinghe, 2012: 79). *Rhizophora mucronata*, the mangrove species used in Sri Lanka, is morphologically and genetically similar to Rhizophora stylosa and is also suitable for dry climates (Wee et al., 2015: 207).

The four mangrove restoration projects in Sri Lanka adhered to biophysical guidelines (Lewis III and Brown, 2014) but differed in their success rates. Pambala and Kalpitiya, with high survival rates comparable to Yadua and Korotogo, had suitable biophysical conditions and followed restoration guidelines (Kodikara et al., 2017: 716). In contrast, Panakala and Halawa, like Tagaqe and Votua, disregarded guidelines and lacked natural mangrove stands (Ranagsinghe, 2012; Kodikara et al., 2017: 716). Despite their sheltered location, Panakala and Halawa's poor survival rates underscore the importance of suitable biophysical factors and species selection for successful mangrove restoration. Following similar guidelines outlined by Lewis III and Brown (2014), mangrove restoration projects in Thailand and Kenya achieved comparable seedling survival rates (Wee et al., 2015: 208).

Stage 1 site selection and mangrove species choice are important for successful mangrove restoration. Selecting an unsuitable site, as was the case with Tagaqe and Votua, despite using appropriate mangrove species, will hinder mangrove establishment. Kodikara et al. (2017) study in Sri Lanka similarly attributed restoration failures to inappropriate site selection and the absence of suitable biophysical factors. Other NGOs involved in mangrove restoration, including Projects Abroad Fiji Shark Conservation, WWF, and IUCN, also emphasise the importance of biophysical assessments prior to restoration efforts.

*Stage 2 - Site preparation and seedling preparation*

Site preparation for mangrove restoration involves community engagement and clearing debris to facilitate seedling establishment. OISCA informed communities about the project's significance and collaborated with them to remove debris such as palm fronds, logs, plastics, and clothes from the restoration sites.

In contrast, Lewis III and Brown (2014) outlined six key activities for site preparation:

- putting up a signboard to create community awareness;
- clearing the site of rubbish as well as other plants;
- leveling intertidal flats, especially mounds created by mud lobsters;
- Substrate enhancement or compost application to promote seedling growth;
- fencing the restoration site to keep grazing animals away; and
- establishing artificial breakwaters to reduce the wave energy.

Only the first two activities were carried out by OISCA at the four sites due to financial constraints. OISCA increased seedling density at Tagaqe and Votua to compensate for the high wave energy. OISCA deviated from the standard seedling density of two per square meter by planting four seedlings per square meter at Tagaqe and Votua to mitigate the high wave energy at these sites. This coincides with Sykes' (2007) suggestion. Leveling and fencing were not required since the intertidal flats were naturally level and grazing animals were controlled. OISCA is funded by the Japan Sumitomo Company and has sufficient funds to maintain the nursery and assist with replanting activities, but site preparation is not included in the budget.

Despite implementing all six recommended site preparation activities, approximately 54% of mangrove restoration projects in Sri Lanka experienced seedling survival rates below 20% (Kodikara et al., 2017). Unsuitable site selection and poor monitoring and maintenance were identified as main causes for the unsuccessful mangrove establishment.

OISCA's mangrove restoration protocol involves preparing seedlings for planting in stage 2. Propagules are raised in nurseries and then transplanted to the restoration sites. OISCA maintains a nursery at Korotogo village, where propagules are collected from Saweni, Lautoka, between early December and late February. These propagules are planted in biodegradable polythene bags and placed in a shed for protection. While Sykes (2007) suggests that polythene bags can hinder root development, OISCA claims to carefully remove the bags before planting.

OISCA's mangrove nurseries acclimatise seedlings to salinity levels and light conditions using brackish water and appropriate light exposure (Sykes, 2007). Nursery maintenance is assisted by Korotogo volunteers, and seedlings are protected indoors during cyclones. After five months, seedlings with six leaves are considered ready for planting, deviating from the eight to nine-month timeline recommended by Sykes (2007) and Lewis III and Brown (2014). By contrast, Projects Abroad Fiji Shark Conservation adheres strictly to Lewis III and Brown's (2014) guidelines, including nursery preparation and nine-month seedling growth before transplanting. With a capacity of 18,000 seedlings, their nursery is the largest in the South Pacific. They use biodegradable polythene bags and upcycled plastic bottles for propagation and replant after four to twelve weeks. WWF Fiji and IUCN's mangrove rehabilitation projects also focus on *Rhizophora stylosa* replanting, maintaining independent nurseries with an eight to nine-month seedling preparation period. IUCN primarily utilises nursery-reared *Bruguiera genus* specimens for replanting in Papua New Guinea.

*Stage 3 - Planting mangrove seedlings*

OISCA replants seedlings when they reach 50 centimeters in height. Replanting involves community participation, especially youths, fostering ownership. OISCA also welcomes overseas volunteers, such as Tokyo University students who participated in mangrove replanting in 2014. OISCA hand-plants each seedling. The restoration team demonstrates the transplanting procedures to all participants prior to each replanting event. During planting, OISCA's restoration officers maintain ideal spacing between seedlings to prevent drainage issues during growth while avoiding excessively sparse planting that could lead to seedling mortality or washout.

OISCA plants mangrove seedlings in a one-meter grid, resulting in four seedlings per square meter (Figure 3). This linear planting method contrasts with Lewis III and Brown's (2014) recommendation of random planting at one to two-meter intervals to facilitate root establishment and canopy expansion. Observations at Korotogo suggest that the current linear planting hinders mangrove growth due to inadequate space (Kodikara et al., 2017: 712). Therefore, adopting Lewis III and Brown's (2014) protocol might be beneficial. During planting, biodegradable polythene bags are removed, and seedlings are placed in 20-centimeter-deep holes, covering the roots. Silt substrate is then added, and stones are placed around the transplants to prevent wave damage.

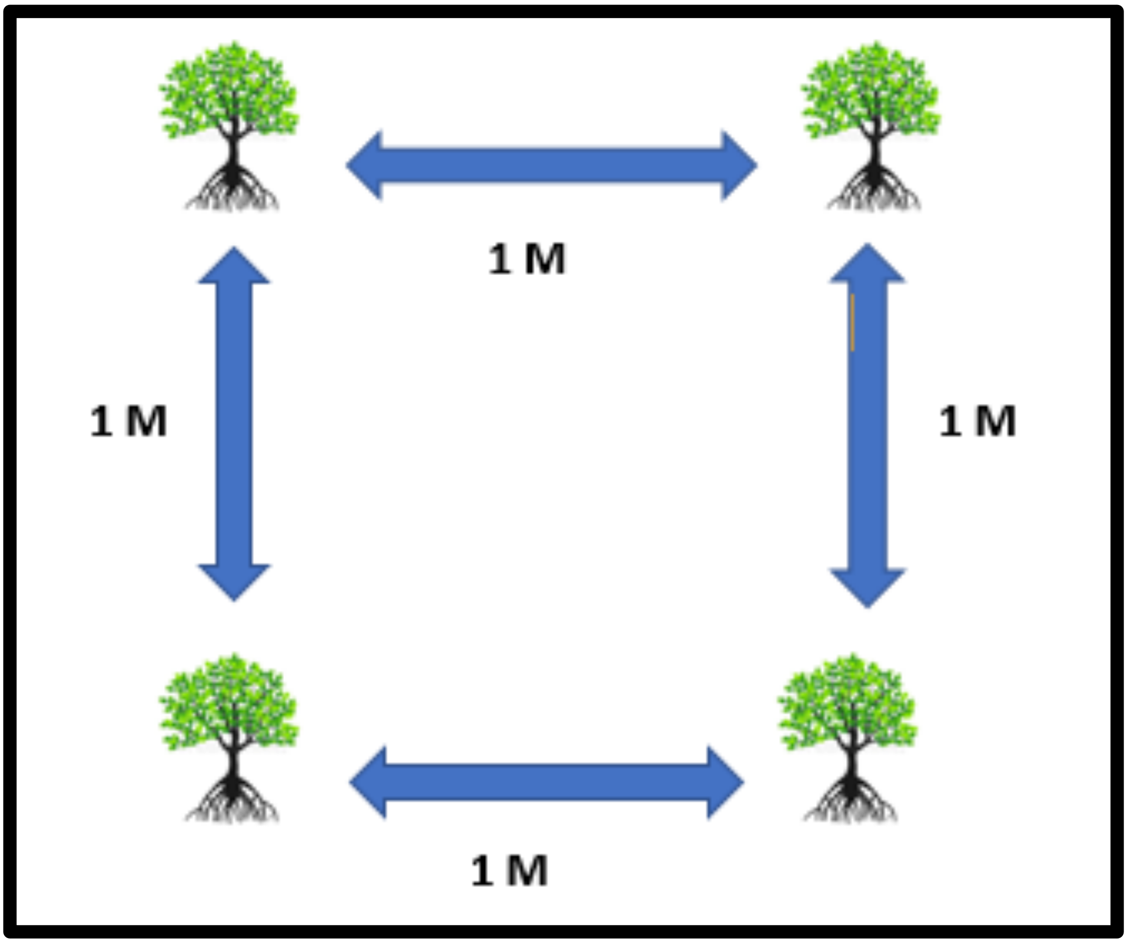


**Figure 3:** Mangrove seedlings planted in a grid at the four restoration sites of Yadua, Korotogo, Tagaqe and Votua by OISCA.

Community members from all four replanting sites actively participated in the restoration efforts, contributing labor and food for the restoration team. They expressed a sense of ownership over the mangroves and coastline, recognising their responsibility for restoration and maintenance. Additionally, they appreciated OISCA's work on the Coral Coast.

In Sri Lanka, mangroves were planted in strips with one-meter spacing (Figure 4) to prevent future hydrological issues and provide ample space for leaf and root growth in mature plants. The thriving five-year-old mangrove plants at Pambala and Kalpitiya (with survival rates of 78% and 68%, respectively) demonstrate the effectiveness of strip planting. Kodikara et al. (2017:712) emphasise the importance of community involvement in mangrove replanting, as it fosters a sense of ownership and environmental stewardship. Community awareness programs enhance understanding of the importance of mangroves.

Projects Abroad Fiji Shark Conservation, WWF, and IUCN also engage local communities in the replanting process. Due to resource constraints, these NGOs provide technical expertise while relying on communities to provide labor for replanting.

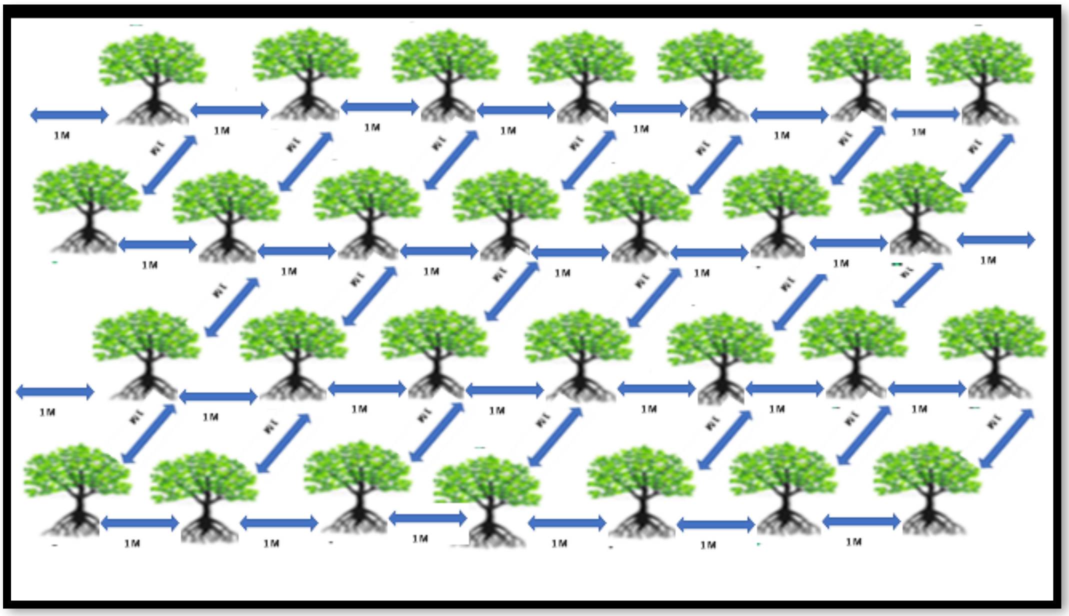

**Figure 4:** An example of planting mangroves in strips. The distance between the plants is one meter.

*Stage 4 - Maintenance and monitoring*

Post-planting maintenance is essential for mangrove seedling survival. Lewis and Brown (2014) recommend activities like debris removal, grazing animal control, replanting dead or washed-away seedlings, preventing human exploitation, and minor hydrological repairs. OISCA officers regularly monitor seedling growth, while community members remove debris daily. The Turaga ni Koro (village headman) oversees the project and coordinates community involvement.

Limited funding restricted seedling replacement at two sites. OISCA did not replant lost seedlings at Tagaqe and Votua due to prohibitive transportation costs. Replacement was carried out at Yadua and Korotogo, as they were closer to the nursery. Mature mangroves require less maintenance. Weekly cleanups are sustained at Korotogo and Votua. OISCA produces quarterly progress reports. Thinning may be necessary after five to seven years, as recommended by Lewis and Brown (2014). Community involvement is crucial for post-planting maintenance. In Sri Lanka, communities actively participated in maintenance and monitoring, achieving an approximately 80% survival rate at Pambala and Kalpitiya. Conversely, Panakala and Halawa neglected seedling replacement, resulting in a 20% survival rate. Projects Abroad Fiji Shark Conservation and WWF conduct regular monitoring and seedling replacement at their respective mangrove restoration sites.

*Strengths and weaknesses of the restoration projects undertaken by OISCA at the four villages along the Coral Coast*

Despite deviating from certain guidelines in Lewis and Brown's (2014) restoration manual, OISCA achieved an 80% mangrove seedling survival rate at Yadua and Korotogo. This success can be attributed to factors such as careful site selection with favorable biophysical conditions (Table 4) and the choice of *Rhizophora stylosa*, a suitable species for arid environments (Sykes, 2007). Community involvement and awareness programs fostered a sense of ownership among villagers, encouraging them to protect the restored mangroves. Regular debris removal was carried out by villagers under the direction of their Turaga ni Koro, even in OISCA's absence.

While Yadua and Korotogo benefited from seedling replacement, Tagaqe and Votua did not, resulting in a 20% survival rate.

The lower survival rate at Tagaqe and Votua highlights shortcomings in OISCA's practices. Failure to address the biophysical factors listed in Table 4 and neglecting the four crucial activities outlined by Lewis III and Brown (2014) – leveling, substrate addition, fencing, and breakwater construction – contributed to the poor outcome. High wave energy at both sites exacerbated the situation, with many seedlings washed away. OISCA's lack of post-planting monitoring and seedling replacement, citing transportation costs, further hindered success. The after-care practices like thinning and pruning were not implemented.

*Roles of government in mangrove conservation and restoration*

NGOs play a leading role in mangrove restoration projects, adapting to and mitigating the impacts of climate change on coastal communities. Government involvement in monitoring after replanting is minimal, according to the Acting Director of Environment. NGOs rely on donor funding, with OISCA supported by Sumitomo Company, IUCN's MARSH project funded by USAID, WWF by GEF, and Projects Abroad Fiji Shark Conservation privately funded. Prior to project initiation, NGOs seek permission from the Ministry of Lands and the Ministry of iTaukei Affairs (Sykes, 2007).

Mangrove management in Fiji lacks a centralised body, with responsibilities fragmented across various government departments, including the Ministry of Lands, Department of Forestry, Department of Environment, and the Ministry of iTaukei Affairs. A range of legislation governs mangrove usage, including the Environment Management Act 2005, Fiji Forest Policy (2012), Foreshore Act 2005, and Biodiversity Strategy and Action Plan (BSAP) of 2020 (Sloan and Chand, 2015). However, these policies address broader environmental concerns beyond solely mangrove protection or conservation (Department of Environment, 2020).

The Environment Management Act (EMA) 2005 mandates an Environmental Impact Assessment (EIA) for any major development that could significantly impact the environment, including mangrove removal or destruction, coastal land reclamation, mining, dredging, logging, quarrying, gravel extraction, hotel or resort construction, commercial and industrial development, and residential subdivisions with more than ten lots (Sloan, 2018; Environmental Management Act, 2005). EIA requires a comprehensive assessment of environmental impacts before allowing development in these areas (Environmental Management Act, 2005). Based on the EIA, developers are informed whether the project is permitted and, if so, under what conditions to minimise environmental impacts (Environmental Management Act, 2005). Unauthorised development without EIA in these areas results in severe penalties, including imprisonment for up to 10 years or a fine of FJD750,000 (Environmental Management Act, 2005). EIA serves as a crucial tool to achieve the EMA's objective of ensuring development "to apply the principles of sustainable use and development of natural resources. It also ensures that the use and utilisation of natural and physical resources must recognise and have regard to the following matters of national importance:

a. the preservation of the coastal environment, margins of wetlands, lakes and rivers;
b. the protection of outstanding natural landscapes and natural features;
c. the protection of areas of significant Indigenous vegetation and significant habitat of Indigenous fauna;
d. the relationship of Indigenous Fijians with their ancestral lands, waters, sites, sacred areas and other treasures; and
e. the protection of human life and health" (Environmental Management Act, 2005: 6).

While the *Endangered and Protected Species Act* 2002 (Fiji, 2002) aims to protect endangered flora and fauna in international trade, its effectiveness in safeguarding mangroves is limited due to their widespread subsistence use rather than international trade. Mangrove deforestation for commercial land development falls under the protection of the EMA 2005.

The *Fiji Forest Policy* (2012) promotes sustainable forest management, including mangroves, to achieve social, environmental, and economic benefits for current and future generations. It also encourages sustainable terrestrial and marine forest management by resource owners. The *Foreshore Act* 2005, a subsection of the *Environment Management Act* (EMA) 2005, mandates an Environmental Impact Assessment (EIA) for any foreshore development. It prohibits activities detrimental to marine ecosystems, such as coral reefs, seagrass meadows, and mangroves, including mining, mineral extraction, and coastal agriculture. These activities can lead to chemical discharge, erosion, and even the loss of marine ecosystems.

The *Biodiversity Strategy and Action Plan* (BSAP) 2020 emphasises mangrove conservation and sustainable use for climate change mitigation. Its Principle 9 promotes ecosystem-based adaptation (EbA) to enhance resilience and reduce vulnerability through sustainable management, conservation, and restoration of ecosystems, including mangroves (Department of Environment, 2020). The revised Mangrove Management Plan 1986/1987 awaits implementation due to stakeholder consultations (Walting, 2013).

Three government committees oversee mangrove management:

- Mangrove Management Committee (MMC): Reviews mangrove usage and development under the Ministry of Lands.
- Integrated Coastal Management Committee (ICMC): Addresses broader coastal management aspects.
- National Wetland Steering Committee (NWSC): Manages and conserves wetlands, including mangrove areas.

An Environmental Impact Assessment (EIA) is mandatory for government-endorsed development projects requiring mangrove clearing. Illegal mangrove cutting for subsistence use is regulated under Fiji Forest Policy (Ellison et al., 2010). The government advocates for ecosystem-based adaptation approaches, including mangrove restoration, considering their cost-effectiveness over technological measures (Cuthbert et al., 2016: 12).

## Conclusion and recommendations

This study emphasises the significance of context-specific mangrove restoration strategies along the Coral Coast in Fiji. Mangrove seedling survival rate at Yadua and Korotogo have been successful (80%) because all four stages of restoration processes were followed. However, challenges in Tagaqe and Votua with a low mangrove seedling survival rate (20%) highlight the need for subtle and site-specific approaches taking into consideration biophysical parameters such as wave energy and freshwater input. At the national level, the fragmented responsibility for mangrove management calls for a centralised authority and synchronised legislation. The findings suggest future research should delve into refining biophysical factors influencing restoration, understanding community dynamics, conducting comparative analyses across regions, and exploring long-term ecological impacts. By addressing these aspects, future initiatives can contribute to more effective and resilient mangrove restoration as well as conservation efforts on local, regional, and national scales, crucial for coastal ecosystem sustainability in the face of climate change.

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