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Seagrass Restoration Guidelines for Kiribati

SPREP
Secretariat of the Pacific Regional Environment Programme

For: Secretariat of the Pacific Regional Environment Programme (SPREP)

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New Zealand – Pacific Partnership on Ocean Acidification:

Seagrass Restoration Guidelines for Kiribati

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1. BACKGROUND

The New Zealand - Pacific Partnership on Ocean Acidification (NZPPOA) Project is a collaborative effort between the Secretariat of the Pacific Regional Environment Programme (SPREP), the University of the South Pacific, and the Pacific Community to build resilience to ocean acidification (OA) in Pacific island communities and ecosystems with financial support from the New Zealand Ministry of Foreign Affairs and Trade and the government of the Principality of Monaco. Kiribati is one of three pilot sites under the NZPPOA project.

The NZPPOA Project has three main focal areas; [1] research and monitoring, [2] capacity building and awareness raising, and [3] practical adaptations. Seagrass restoration is one of the practical adaptation actions selected for implementation at Nanikai village (in South Tarawa), the NZPPOA project's pilot site in Kiribati.

The present report presents guidelines for seagrass restoration in Kiribati. Although the focus of this report is on Kiribati, much of its contents can also be applied elsewhere in the Pacific region. These guidelines are based on a combination of a thorough literature review of seagrass restoration efforts worldwide and hands-on practical experience in the establishment of a pilot trial and a large-scale seagrass restoration program at Nanikai (Kiribati) where many of the photographs used to illustrate these guidelines were taken.

The objectives of these guidelines is to offer practical guidance and technical support to any future seagrass restoration efforts and initiatives in Kiribati and the wider South Pacific region.

These guidelines have been written for local government staff (e.g. from the Ministry of Fisheries or Environment), scientists and NGO's in the region, with the intention that they work in close collaboration with local communities to implement seagrass restoration when and where that would considered appropriate.

Figure 1. Striped Puffer (*Arothron manilensis*) in seagrass bed at Nanikai.

2. SEAGRASSES IN KIRIBATI

Distribution and species

Information around the marine flora in Kiribati is limited. No seagrass maps were presented in the recent marine atlas of Kiribati (Gassner, et al. 2019) as there are currently no publicly available data that adequately capture the distribution of seagrass in Kiribati.

However, seagrass and seagrass habitat have been documented in Tarawa Atoll (Paulay, 2000; Delisle et al. 2016; Brodie and N'Yeurt 2018; ADB 2018), Butaritari (Delisle et al. (2016), Abaiang, Abemama, Kuria and Kiritimati (Awira et al., 2004), as recently reviewed by Brodie et al. (2020).

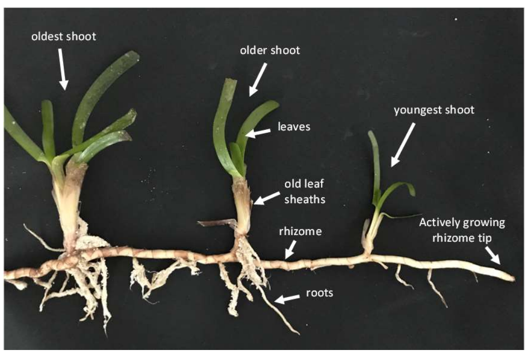


Figure 2. The seagrass *Thalassia hemprichii.*

The only seagrass species recorded from Tarawa to date is *Thalassia hemprichii* (Figure 2), which occurs in scattered patches on the intertidal sandflats and in a dense zone along the shallow subtidal sandy transition towards the deeper parts of Tarawa lagoon.

ADB (2018) recorded "extensive" seagrass in South Tarawa lagoon and this matches to Paulay (2000) who documented "extensive" largely unbroken seagrass habitat along the lagoon margin of the intertidal flats, approximately 18 km long, between Banraeaba and east of Bikenibeu in the south east of Tarawa lagoon (prior to 1995) and in the far north of the lagoon at Buariki (Figure 3). Paulay (2000) also reported discontinuous bands of seagrass from Bikenibau to Buota and small patches of seagrass off Abatao Islet and between Tabangaroi and Tabonimata islets.

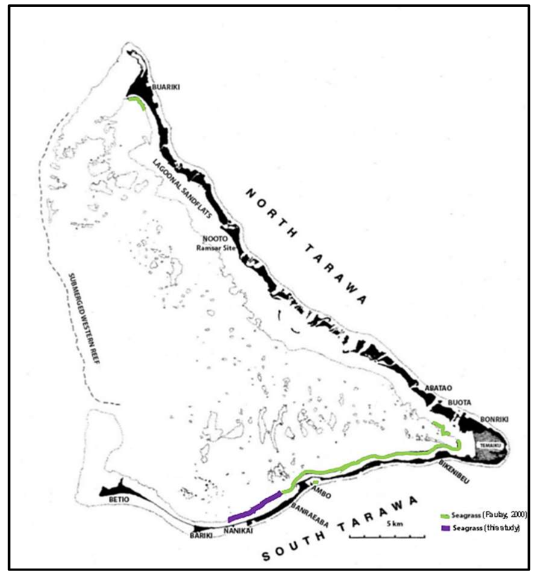


Figure 3. Seagrass distribution map of Tarawa Lagoon (based on Paulay, 2000 (in green), supplemented with observations in 2020 (purple).

According to Paulay (2000) the average widths of South Tarawa seagrass beds in 1984 were 100-150 m, reaching a maximum of 250 m. Via the use of historical photographs, Paulay determined that the geographic spread of seagrass beds did not appear to have changed much between 1943 and 1984 in South Tarawa (adapted from Brodie et al., 2020). Recent observations (2020, this study) show that the seagrass beds extend further west till the western end of the village of Nanikai.

Ecosystem values and benefits for people

The seagrass beds in Kiribati (and the wider South Pacific region), host a relatively high biodiversity of associated plant and animal species. Due to their high primary production and complex habitat structure, many fish and shellfish species, including those targeted by local communities and commercial fisheries, are attracted to seagrass habitats for foraging and shelter, especially during their juvenile life stages.

Due to the complex architecture of the leaf canopy in combination with the dense network of roots and rhizomes, seagrass beds stabilize bottom sediments and serve as effective hydrodynamic barriers reducing wave energy and current velocity, thereby reducing turbidity and coastal erosion. Further, seagrass beds trap large amounts of nutrients and organic matter in the bottom sediment (Figure 4).

Figure 4. Seagrass beds trap fine particles and strip nutrients from the water column.

Through microbial decomposition, seagrass biomass enters the marine food web as detritus and thus supports productivity through recycling of nutrients and carbon.

More recently, seagrass meadows have been acknowledged for their considerable carbon storage potential ('blue carbon') and buffering capacity of the pH of the ocean, thus playing a key role in mitigating the effects of climate change (incl. ocean acidification).

Drivers of decline

Over half of the national population of Kiribati live on Tarawa, with exceptional population growth in South Tarawa (now home to >56,000 people). The rapid increase in human population has substantially increased the pressure on the environment, resulting in impacts such as water pollution, eutrophication, over-fishing, and increased coastal erosion as a result of infrastructure development and overcrowding (Brodie et al., 2020).

Causeway construction between many of the islets of Tarawa (Figure 5) has changed lagoon hydrology and blocked seasonal migration pathways of some economically important fish species (Brodie et al., 2020). The causeway construction process itself is likely to have caused significant sediment disturbances and turbidity plumes, which can cause significant impacts on seagrasses (Maragos, 1993; Chunting and Howorth, 2003; Erftemeijer and Lewis, 2006).

Figure 5. Aerial view of South Tarawa, showing a string of islets connected by causeways.

Discharge of untreated sewage at the edge of the intertidal reef flat from broken sewage pipes in South Tarawa have caused significant water quality impacts for several years, contributing significantly to the degradation of the coral reefs and wider marine environment along South Tarawa (Fellenius and Hess, 2015).

Rationale for restoration

While the highest priority should always be given to avoid degradation and loss of seagrasses, this is not always possible and seagrass restoration through active intervention may be necessary. The ultimate goal of seagrass restoration would be to not only revegetate damaged or degraded areas but also to restore the lost ecosystem services these areas used to provide. For the purpose of this guideline, it is assumed that natural recovery processes will take care of that over longer time scales, once the vegetation cover has been restored.

For South Tarawa, there are a number of arguments that would justify seagrass restoration. Following the completion of the causeway between Bairiki and Betio around 1994, and repairs and extension of the sewage discharge pipes in South Tarawa in 2016, water quality in South Tarawa has improved.

Also, given the apparent expansion of seagrass areas further west to as far as Nanikai over the past 2 - 3 decades (i.e. in comparison to the map in Paulay (2000), which described the situation in 1996), and anecdotal historic accounts by Nanikai village elders that seagrass historically extended further west to Bairiki (pers. discussions, October 2019), there seems to be potential for seagrass expansion to areas (of similar depth and substrate) further west.

Figure 6. Patch expansion through lateral rhizome elongation of a circular seagrass patch at Nanikai.

Given the fact that *Thalassia hemprichii* primarily expands its meadows vegetatively through rhizome elongation (Figure 6) (with only low levels of sexual propagation through seeds), and that this is a slow process (advancing with approximately 0.5 to 1 m per year), there is scope for seagrass restoration / planting to try and speed up that process.

Other potential sites in Kiribati (and elsewhere in the South Pacific) would be areas of physical damage (e.g. from boat groundings, destructive fishing gear or anchor- or propeller scars), storm damage or areas affected by dredging or sand mining. Pre-requisite for any of such attempts is to ensure that the cause of the damage has been stopped before any restoration effort is made.

3. SEAGRASS RESTORATION: GENERAL CONSIDERATIONS

General considerations

Seagrass restoration can be considered when seagrass loss, damage or degradation in an area has advanced to such an extent that it can no longer be expected to recover on its own (or this may take a very long time). Under such conditions, the normal process of natural recovery is inhibited in some way.

Before moving straight into planting of seagrasses as the primary tool in restoration, it is critically important to always first assess the reasons for the loss of seagrasses in the area. After first addressing those underlying root causes, one can aim to work along with natural recovery processes of the ecosystem.

In some cases, seagrass relocation is conducted as a form of compensatory mitigation by salvaging seagrass from sites earmarked for construction (e.g. for port expansion) and moving this seagrass to other areas that appear suitable for growth, in an attempt to substitute (commonly referred to as an 'offset') for unavoidable loss due to the 'footprint' of the development. This may be an obligatory requirement as part of environmental regulations and permit approvals under a principle of 'no-net-loss'. However, it is emphasized here that seagrass restoration should never be considered the first alternative when planning for the mitigation of coastal development projects or to justify mitigation as a compensation measure for economic activities.

Common sense considerations

If seagrass is not growing somewhere, there are two possibilities: [1] it has never grown there because the conditions at the site are unsuitable, or [2] it used to grow there in the past but it disappeared due to an adverse (human or natural) impact. In both cases, the environmental conditions are apparently not suitable for seagrass at present. As such, it would not make much sense to plant seagrass at such sites and expect any of these transplants to survive. Instead, the underlying cause(s) of the seagrass loss needs to be addressed first by improving the environmental conditions.

Once conditions have significantly improved or returned back to what they were before the disturbance, seagrass generally comes back by itself, gradually recovering its former cover and ecological functioning with time (Vaudrey et al., 2010).

The only potential bottleneck to such natural recovery could be recruitment limitation (a lack of supply of seeds or fragments), either due to barriers to connectivity with adjacent (unaffected) meadows or due to the absence of any significant populations remaining nearby, from which the site could be re-populated.

In such cases, it would make sense to bring seagrass seeds or plant material from elsewhere to restore some vegetative cover. When such revegetated patches are large enough, they will eventually be capable of sustaining themselves, expand and gradually recolonize the site.

Common reasons for failure

Common reasons for failure of seagrass restoration attempts include:

- Inappropriate site selection
- Uprooting of transplants due to strong flows, high wave energy or swell
- Sediment instability causing erosion or smothering and burial of seedlings
- Poor water quality (turbidity, eutrophication, low light)
- Algal blooms and/or excessive epiphyte growth
- Inadequate anchorage of transplants (washed away)
- Poor planning (no reversal of threats, lack of consideration for site selection)
- Too shallow (desiccation) or too deep (insufficient light)
- Excessive bioturbation (e.g. by polychaetes or stingrays) uprooting transplants
- (Over)grazing of transplants (e.g. by sea urchins or amphipods)
- Too small-scale (poor resilience, insufficient self-facilitation)
- Lack of donor material
- Damage from human activities, storms, floods or spills
- Large-scale application of unproven technology (insufficient testing)
- Unrealistic expectations (re: costs, scale, duration, chances of success)

4. RESTORATION METHODS

Recommended method for Kiribati

The method recommended and tested to be the most suitable method for the restoration of *Thalassia hemprichii* in Kiribati is the 'sods method', using a spade or shovel. It is recommended to follow the following general guidelines when implementing this method:

- Excavate square 25x25 cm blocks or 'sods' of seagrass (including roots and soil) from an existing (healthy and relatively dense) donor meadow using a spade or shovel

- The use of a small 25x25 cm quadrat (which can be made from PVC pipes or wood) can be helpful when excavating the sods, making sure they are of correct shape and size

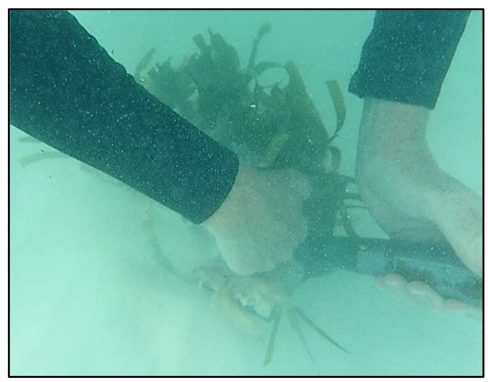
- It is recommended to space out the excavations, keeping them apart at a minimum distance of approximately 3 m (or more), to minimize the impact of the harvesting of seagrass material (i.e. to less than 10% of the donor meadow)

- Backfill the gaps created by the excavation of the sods with sand from the surrounding area to enable the damaged areas of the donor meadow to recover

- Small gaps or scars of this size (25x25 cm) also occur naturally (e.g. from storm waves, turtle grazing or bioturbation) and generally ‘self-repair’ through lateral expansion by clonal re-growth from the surrounding seagrass in 6 months to a year

- Transport the sods in large tubs (that can float) or stacked onto a floating object such as a surf board or kayak from donor site to restoration site

- At the restoration site, dig holes (with the spade/shovel) that are big and deep enough to accommodate a 25x25 cm sod, and then place the sod (it is best to deposit the excavated sand as close to the hole as possible, for later use in sediment infilling)



- Fill in and firmly press and compact sediment along the edges of the sod after it has been placed in the hole

- An optimum spacing of the 25x25 cm sod plantings would be 3 to 5 m (assuming lateral expansion of surviving patches to be in the order of 25 to 50 cm (Marba and Duarte, 1998; Sintes et al., 2006), in either direction, which would translate in the sods expanding and growing together within 3 to 5 years.

Overview of other methods

A plethora of methods for seagrass restoration have been developed and tested over the past few decades. Seagrass restoration is a relatively young discipline with new methods, innovative ideas and approaches being developed all the time.

Development and implementation of appropriate methods requires experience and familiarity with species' growth habits and life histories. Numerous methods have been shown to establish seagrass successfully, but familiarity with handling and planting methods are essential.

Planting methods in deeper waters will require the use of SCUBA equipment, a boat and trained SCUBA divers. Shallow waters may allow for restoration works to be carried out by snorkelling. Intertidal areas are often easily accessible on foot during low tide (provided they are not extremely muddy) and offer the least logistical challenges to planting activities.

Planting projects typically involve either sediment-free seagrass units, seagrass sods with sediment & intact root systems, or seeds/fruits.

Sediment-free methods

For most sediment-free methods, plants are dug up using a shovel (or other device), the sediment is shaken off from the roots and rhizomes and the plants are placed in tanks, floating pens or similar, for holding until made into 'planting units'. It is important to ensure the presence of growing rhizome tips in individual planting units as these provide a source of new shoots and horizontal growth, a means of colonizing of new areas. Planting units are planted either directly into the bed (as sprigs) or anchored using a device such as a peg or a staple, attached to metal frames or woven into biodegradable mats. While labour-intensive, these methods reduce the burden of carrying heavy associated sediment and have been successful for some species (usually at small scales).

Seagrass-with-sediment methods

Within this method there are different extremes, depending on the volume of seagrass to be planted. The *sod technique* (using a shovel or spade) has already been described above. Other variations include the *plug method*, which uses coring devices (of metal or PVC) to extract the plants with the sediment and rhizomes intact, or the *tray method*, which uses metal trays to dig and collect larger (50x50cm) sods. Mechanical methods, such as using a modified *backhoe* to excavate 1x1m sods have also been used in a few projects.

Seed-based methods

Seed-based restoration techniques have been used successfully in large-scale restoration of several seagrass species that mass-produce large quantities of seeds and/or form dense seed banks.

A disadvantage of seed-based approaches is their dependence on the availability of seeds, which may be low or poorly understood. This is an issue in Kiribati and indeed most of the South Pacific region, where the timing, intensity and frequency of flowering and seed production of its seagrass species are still largely unknown.

Further details on these and other techniques (including descriptions of various case studies) are described in the recently published 'Guidelines for Seagrass Ecosystem Restoration in the Western Indian Ocean' by UNEP/WIOMSA (Erftemeijer, 2020).

OTHER PRACTICAL ASPECTS

Site selection

Selection criteria for restoration sites:

- habitat suitability (environmental conditions conducive to seagrass growth, including temperature, salinity, light, flow velocity, wave exposure, tidal conditions, substrate)
- level of human disturbance (from activities or developments that affect seagrass health and survival)
- previous experience (at similar sites)
- advice from local area experts (or elders that know the area well)
- practical considerations (accessibility, distance, logistical, institutional and legal considerations)
- proximity to existing seagrass beds
- evidence of historical seagrass presence at the site
- recent incidental sightings of seagrass colonisation in or near the area
- depth: seagrass restoration sites should have similar depths to nearby healthy meadows and not be subject to chronic storm damage

Figure 8. Sufficient spacing between subsequent sods (here ~5m apart) when harvesting seagrass material for restoration will minimise damage to donor beds and ensure successful recovery.

Considerations for donor sites:

Aspects to be considered when verifying if a certain site is appropriate for taking plant material for seagrass restoration include:

- Extensive enough (for the harvesting of sufficient plant material or seeds
- In good health condition (to offer high quality material/viable seeds)
- Located within the same biogeographical area
- Nearby (to minimize transportation costs and logistical constraints)

Spacing

The choice of appropriate spacing of planting units will depend on the method and species. Practical experience with seagrass restoration elsewhere suggests spacing between 0.5 m (for individual seagrass shoots) to anywhere from 2 to 5 m for larger units such as sods (depending on size and species). Obviously, the closer planting units are together, the more rapidly they will close up the gap over time (or attain a desired % cover or patchiness similar to what was there before). However, the benefit of increased rate of coalescence is soon offset by the substantially higher costs due to the larger number of planting units involved to cover the same surface area.

For example, a 100m x 100m (1 ha) planting area planted at 5.0, 2.0 or 1.0 m spacing would require 400, 2,500 or 10,000 planting units respectively. Taking into consideration that *Thalassia hemprichii* patches expand laterally with ~0.5 to 1m per year, 25x25cm sods spaced at 5m apart would be expected to grow together and coalesce within 3 to 5 years from planting. Depending on the size of the site to be restored (target), availability of material and number of people, and the desired success rate (within *'x'* years), a spacing for 25x25cm *Thalassia hemprichii* sods of 3 to 5m is recommended for Tarawa.

Community participation

Community-based projects are projects that take place in community settings with the involvement of local communities from design to implementation. Such projects recognize local knowledge and other contributions made by community partners (or other local stakeholders) to project success.

Effective community participation can greatly contribute to achieving local ownership and long-term sustainability of the outcome of a seagrass restoration project beyond the initial intervention. This will be particularly so when the community is (made) aware of the values of the restored seagrass ecosystem as fish habitat and coastal protection asset and thus its contribution to securing a better livelihood and future.

It can also play a factor when weighing skill and experience against costs for the implementation of restoration objectives. It is critical to carefully manage realistic expectations of the outcome of the restoration efforts and maintain transparent communication throughout the restoration project.

Seasonality and tide

When planning for the restoration, seasonal changes in weather (e.g. avoid periods of heavy rainfall or disturbance by storm waves) and site conditions (e.g. water quality) that may affect growth and survival of the planting units (or seedlings) and thus restoration success need to be considered.

When working on intertidal flats, timing of the fieldwork should consider the tidal conditions as this will determine accessibility and ease of working (for excavation, backfilling, transport and planting of the sods), and may pose safety restrictions for participating community members. Work in deeper subtidal areas may require the use of SCUBA equipment and is probably best left for trained Fisheries staff and restoration specialists.

Cost considerations

It is of critical importance that the limited financial means that are available for restoration of sensitive marine environmental assets (especially in the South Pacific region) are used as effectively and efficiently as possible on successful projects. In order to achieve an as high as possible return for investment (of both labour and costs), it is of paramount importance to keep the costs for each and every step of the restoration process as low as practically and technically feasible. This will allow for the greatest possible restoration outcome (in terms of hectares). However, a comprehensive feasibility study, thorough site selection (prior) and follow-up monitoring (after) to evaluate survival remain essential to maximise the chances of success for any restoration project.

Expectations

It is important to manage realistic expectations of the outcome of restoration efforts. To achieve this a clear communication strategy is critical. If there is a restoration pilot trial, then it needs to be viewed as it is, i.e. an experiment and learning process, to be scaled up and modified over time, with transparent sharing and learning of failures and unexpected developments along the way to determine what works and what doesn't.

The outcome of a pilot trial will define whether a full restoration program is worth pursuing. Expectations may be too high if people expect and conclude that a particular restoration approach will be successful without any prior learning experience and/or proven demonstration of success under similar circumstances (or from earlier pilot trials at the site).

A recent review of 1786 seagrass restoration trials conducted worldwide concluded that majority of the seagrass restoration trials have been very small and had an overall (low) survival rate of 37% (Van Katwijk et al., 2016).

Scale

While it is wise to conduct some small-scale pilot trials to test methodologies (especially for species and regions that have no previous restoration experience), all the latest research suggests that the best results are obtained with large-scale plantings (and preferably large-sized planting units, e.g. sods).

Depending on resources and logistics, restoration efforts at the scale of hectares are probably more likely to succeed and persist in the long term than smaller projects at the level of tens of square metres. Large-scale restoration efforts are also more likely to be ecologically meaningful, with measureable ecosystem effects over time.

5. MONITORING & EVALUATION

Implementing a systematic monitoring plan to document the progress, challenges, effect of remedial measures and ultimate degree of success of the restoration is an essential component of any seagrass restoration project.

Although monitoring can be labour-intensive and expensive, a systematic and statistically robust monitoring program using standard methodologies is indispensable not only for measuring success but also as a basis for 'mid-course' corrections (e.g. remedial planting, site modifications) and for deriving valuable lessons for improved planning of future seagrass restoration initiatives.

Monitoring of performance of plantings and restoration success should always be linked to agreed standards and pre-defined metrics. Success should be evaluated against clearly defined success criteria that are preferably quantitative and scientifically valid. Success criteria can be as simple as the extent of restored area (in hectares) or a desired percent seafloor coverage (% cover or shoot density) of the vegetation and its persistence over time.

Seagrass restoration monitoring programs are best run for a duration of at least three to five years, with quarterly or half-yearly monitoring in the first year (to allow for remedial action and modifications, if required) and then annual monitoring in the remaining years.

Monitoring specifications typically include most (or some) of the following indicators:

- **Survival:** The %-age of the number of transplanted plants/sprigs, sods or broadcasted seeds that survived.

- **Aerial coverage:** A random sample of the surface area (in m^2) covered per planting unit should be recorded until coalescence (when individual planting units have grown together and become indistinguishable). By counting the total number of surviving planting units, they may then be multiplied by the average area per planting unit to determine the total area covered at the restoration site.

- **Shoot density:** A random assessment should be done of the density of shoots (by counting). Alternatively, a visual estimate can be made of the %cover of the replanted patches, which can then be compared against known shoot densities of a reference series of samples taken within the same general area to estimate shoot density.

- **Photography/video:** Repeated photo-graphy of restoration plots (best from standardised positions) and video transects of restored areas can be an additional (attractive) way of providing useful semi-quantitative records of progress of the restoration project.

- **Ecosystem functions:** Where identified as valuable indicator of project success, quantitative measures of selected ecosystem functions (predefined at the onset of the project), such as associated biodiversity, water quality, sediment stability, nursery ground, fish densities, carbon storage etc.) can be incorporated in the monitoring program as appropriate.

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