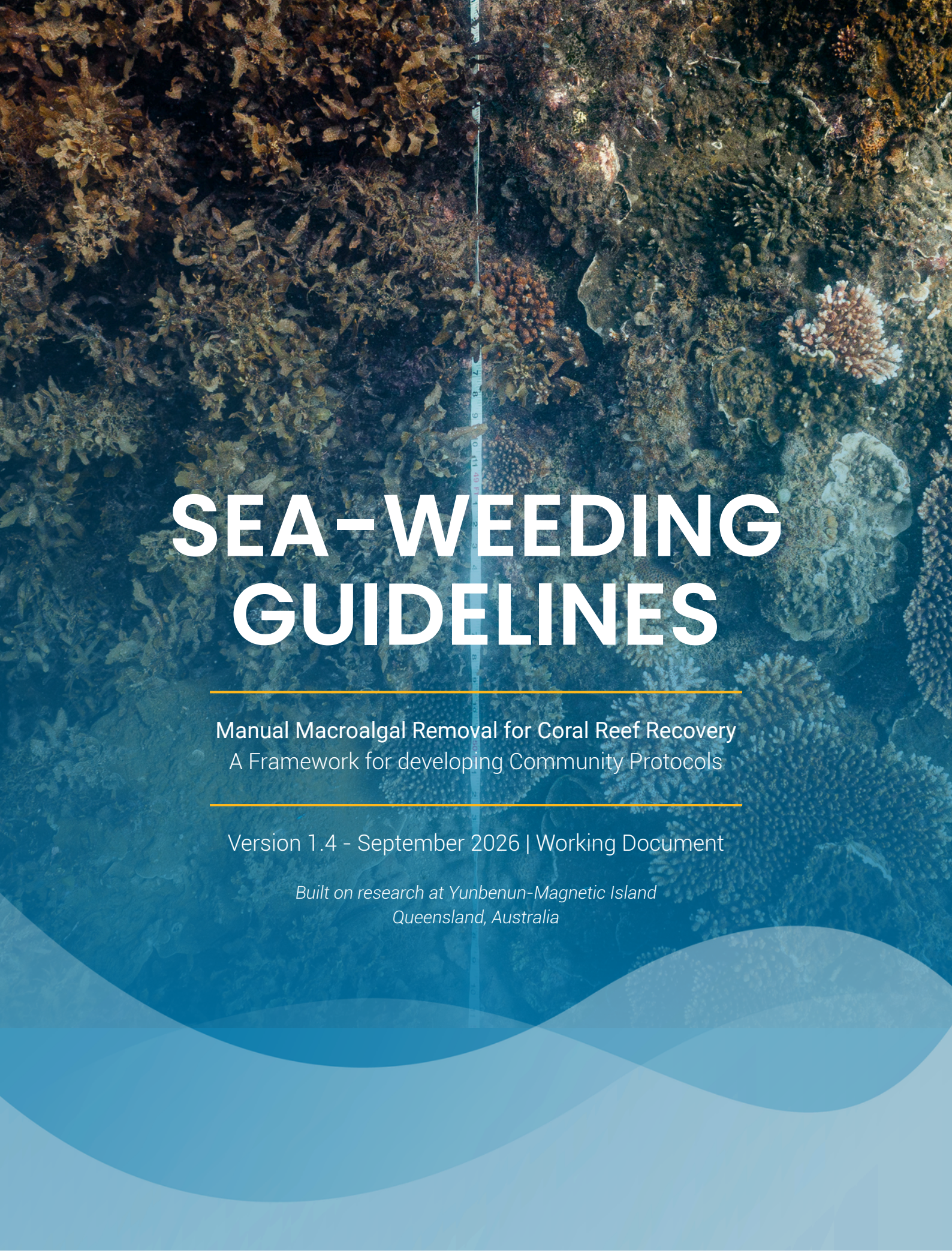


SEA-WEEDING GUIDELINES

Manual Macroalgal Removal for Coral Reef Recovery

A Framework for developing Community Protocols

Version 1.4 - September 2026 | Working Document

Built on research at Yunbenun-Magnetic Island
Queensland, Australia

Mitsubishi Corporation

JAMES COOK UNIVERSITY AUSTRALIA

earthwatch AUSTRALIA

Sea-weeding Guidelines

Manual Macroalgal Removal for Coral Reef Recovery: A Framework for developing Community Protocols

Lead author

Lucía Caldas Durán, Earthwatch Australia

Scientific reviewers

Hillary Smith, James Cook University, Australia
David Bourne, James Cook University; Australian Institute of Marine Science (AIMS), Australia

Publication details

Published by Earthwatch Australia
Version 1.4 - September 2026
Working document open for consultation - Available online at
https://earthwatch.org.au/research/wetlands-reefs

Developed by Earthwatch Australia in collaboration with James Cook University, with support from Mitsubishi Corporation.

Disclaimer

These guidelines provide general information to support the development of locally appropriate sea-weeding protocols. They are not a substitute for site-specific ecological assessment, cultural authority and consent, regulatory approval, professional safety advice or organisational risk-management procedures. Users are responsible for determining the governance arrangements, permits, qualifications, risk controls and monitoring methods applicable to their context.

Photography and figures

Photographs and figures remain the property of their respective creators.
Credits are provided on each image. AI-assisted illustrations are identified in their captions.
Cover photograph: © Jose Freyre

Acknowledgement of Country

These guidelines draw primarily on research undertaken on Wulgurukaba Sea Country at Yunbenun (Magnetic Island). We acknowledge the Wulgurukaba People as the Traditional Custodians of Yunbenun and its surrounding Sea Country, and recognise their continuing cultural authority, knowledge and responsibility for caring for Country. We sincerely thank Wulgurukaba Traditional Owners for their continued support, guidance and engagement in the program's development.

We also acknowledge the Indigenous Peoples, Traditional Custodians and customary owners of the lands and waters where sea-weeding programs may be considered or undertaken. We recognise their continuing rights, knowledge, governance and cultural responsibilities, and pay our respects to Elders past and present.

Suggested citation

Caldas Durán, L (2026). Sea-weeding Guidelines: Manual Macroalgal Removal for Coral Reef Recovery — A Framework for Developing Community Protocols. Earthwatch Australia.

For questions, comments or feedback, contact:
Lucía Caldas Durán
Program Manager - Wetlands, Coastal and Marine Environments
Earthwatch Australia
lcaldas@earthwatch.org.au

Table of Contents

Introduction

How to use this guide

1. Understanding the intervention

2. Understanding the evidence

3. Sea-weeding within a Staged Restoration Framework

4. Community readiness and realistic expectations

5. Governance, cultural authority and permits

6. Site selection

7. Environmental and ecological considerations

8. Operations framework and safety

9. Operational methods

10. Monitoring and adaptive management

11. Capacity building and long-term sustainability

12. Developing your site-specific protocol

13. Case study: Yunbenun

14. References and further reading

Acknowledgements

Introduction

Coral reefs worldwide face mounting pressures from warming oceans, cyclones, flooding, and local stressors. In disturbed inshore and fringing reef systems, one of the most persistent barriers to coral recovery is the overgrowth of macroalgae - large seaweeds - that compete with corals for space and light through multiple pathways, such as reducing available substrate for larval settlement, limiting their ability to perform photosynthesis through shading, decreasing fecundity, and increasing juvenile mortality. While macroalgae are a natural and important part of reef ecosystems providing food, habitat, and contributing to primary production, problems arise when they become abundant enough to suppress coral recovery processes.

Reefs can experience seaweed overgrowth when several pressures combine:

- **Nutrient-rich runoff** from land fuels algal growth
- Fish that would normally graze algae are reduced through **fishing**
- Coral mortality from **bleaching or storms** removes the competition that would otherwise keep algae in check

Once seaweeds take hold, they can be self-sustaining, making it harder for coral to recover even after the original disturbance has passed. Nearshore reefs are particularly prone to this, sitting at the receiving end of runoff and sediment, while also facing increasing heat stress and physical disturbance from storms and floods. These reefs are also often the most accessible and heavily used by local communities for tourism, fishing, and recreation, making their decline both an ecological and social concern.

In these situations, reefs can become locked in a degraded state, where feedback loops favour algal persistence and limit the ability of corals to re-establish, reducing structural complexity, biodiversity, and the ecosystem services reefs provide.

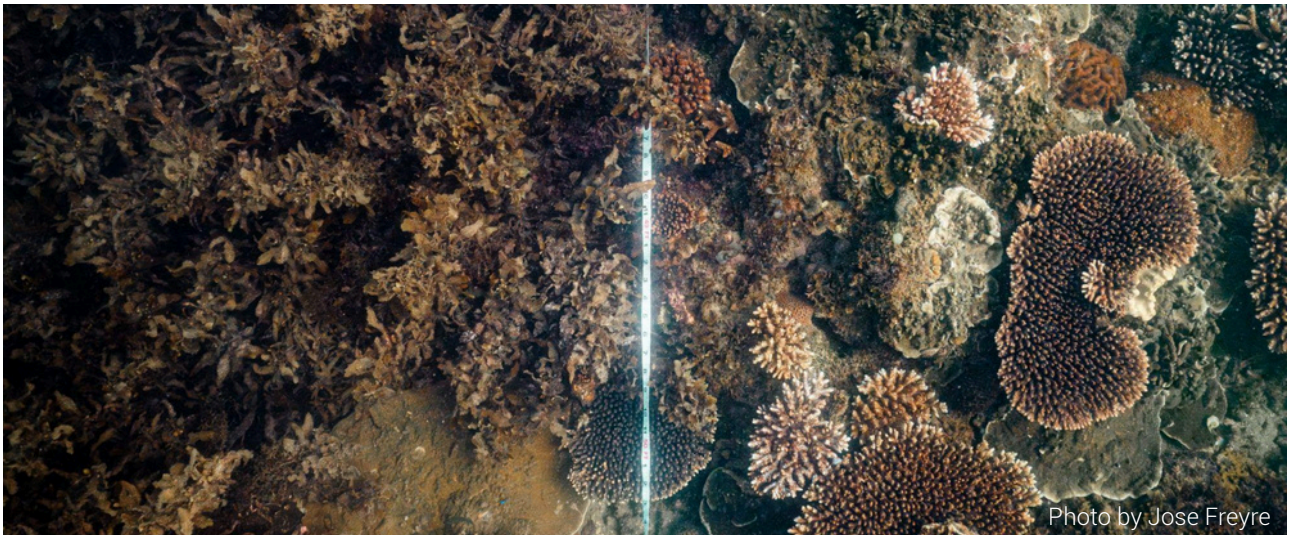


Image 1. Comparison between the outside (left) and inside (right) of a plot after consistent macroalgal removal

If your local reef has experienced a change from a coral-dominated system to a macroalgae-dominated system, sea-weeding might be a useful tool to help it recover. By manually removing macroalgae, you create clear patches of reef surface, where coral larvae can settle, and juvenile corals can grow without being smothered or shaded out. **The goal of sea-weeding is not to remove all seaweed from a reef, but to create periodic windows of opportunity for coral recovery in places where algal dominance is the primary barrier**. A well-designed program targets specific areas and timepoints where this bottleneck is clear, not the reef as a whole. Think of it as giving the reef a breathing space: not fixing the problem overnight, but removing one of the key elements standing in the way of recovery.

Sea-weeding refers to the manual removal of macroalgae from coral reef substrates, with the goal of returning the algae-dominated system to a coral-dominated system by creating space for coral recruitment and recovery. It is a **low-tech, high-impact, community-accessible** intervention that can create recovery windows for corals.

Experimental removal of macroalgae has shown promising results, such as improving coral growth and recruitment, and in some cases shifting reef communities toward conditions more favourable for recovery. However, results have not been uniform due to most studies to date being short-term, small in scale, or focused on a single removal event, leaving important questions about longer-term outcomes on degraded reefs unanswered.

This is the gap that the research project at Yunbenun-Magnetic Island was designed to fill. On this nearshore fringing reef system on the central Great Barrier Reef, repeated disturbances (including cyclones and bleaching events) enabled macroalgal growth to a point that suppressed natural coral recovery. Research currently spanning eight years has demonstrated that sustained, targeted removal of macroalgae can meaningfully increase coral cover and recruit survival in this highly disturbed nearshore reef environment. This research has documented clear ecological responses under specific conditions, and also identified important limitations, complexities, and unknowns that should shape any community program. It represents the most sustained field investigation of sea-weeding to date, and provides the primary evidence base for these guidelines.

🤿 **Picture this**

A small team of divers and snorkellers fins slowly across a patch of reef, pulling seaweed from the seafloor with their gloved hands — carefully, deliberately, making sure not to disturb the coral underneath.

That's sea-weeding. It's essentially underwater gardening: clearing the weeds to give corals room to grow.

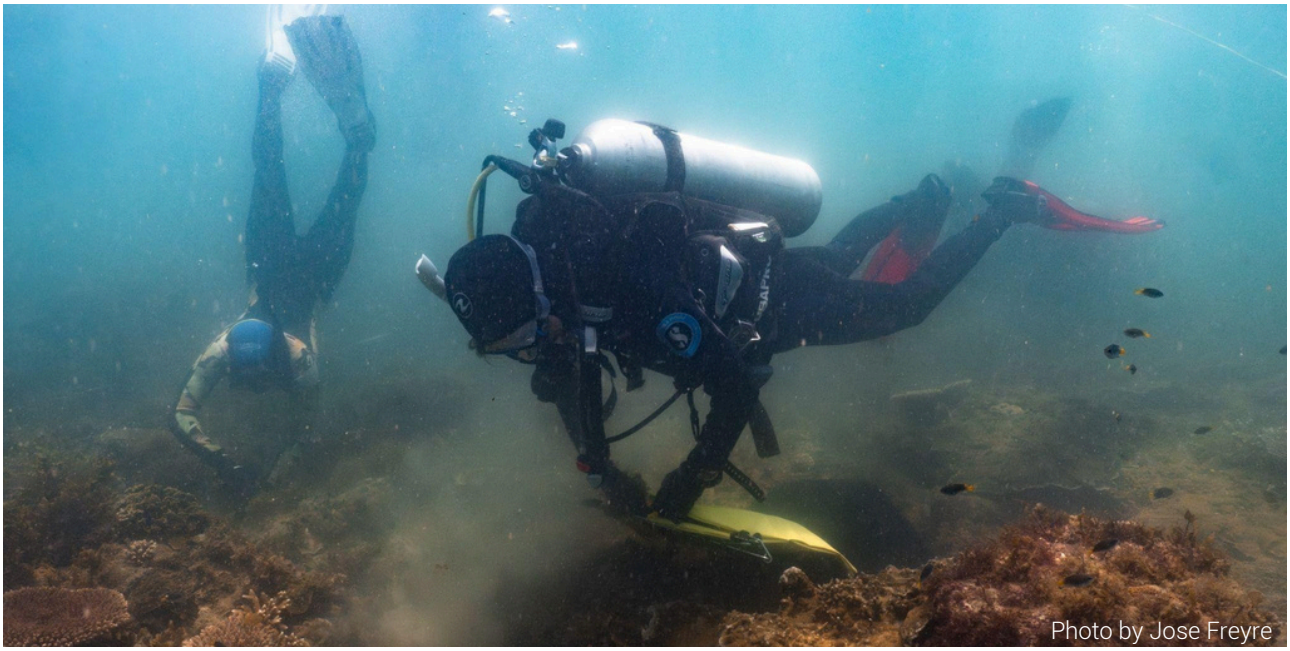


Image 2. Diver and snorkeller collecting macroalgae from a research plot

This document exists to help communities think through what it would take to design and run their own sea-weeding program. **It is a framework for developing local protocols, not a prescription**. Every reef is different. Every community is different. The right approach for your context will emerge from working through the considerations in this guide and adapting them to what you know about your reef, your governance systems, your team, and your goals.

How to use this guide

These guidelines present considerations, not rules. They are designed for communities, managers, and researchers who are evaluating whether sea-weeding might be appropriate for their reef system, or who are in the early stages of designing a program. The document:

- Summarises what the published evidence does and does not demonstrate about sea-weeding outcomes
- Positions sea-weeding within a broader staged framework of reef restoration
- Provides practical, operational, and governance considerations to inform program design
- Draws on the Yunbenun case study as the primary empirical reference, with explicit acknowledgement that this context will not match every reef system. **Examples drawn from Yunbenun are illustrative only; your site will differ**

Each section contains questions, factors, and examples to help you develop your own site-specific protocol. Your community will make the decisions that are right for your reef, your people, and your governance context. Work through sections in order the first time, then revisit individual sections as your program evolves.

🌊 **About Yunbenun-Magnetic Island**

Most of the quantitative evidence cited in these guidelines comes from research at Yunbenun, a fringing reef system near Townsville, Queensland, in the nearshore central Great Barrier Reef. This context is characterised by turbid water, flood plume exposure, periodic thermal bleaching, and seasonal *Sargassum* dominance - conditions that are likely quite different from clear-water or offshore reef systems.

The transferability of findings to other reef types, macroalgal communities, or climatic settings has not been formally tested. Communities working in different contexts should treat the Yunbenun evidence as indicative, not directly applicable.



Image 3. Canopy-forming macroalgae in a nearshore reef at Yunbenun

Research trials run between 2018 and 2025 in nearshore reefs at Yunbenun demonstrated that repeated manual removal of macroalgae led to consistently higher coral cover and juvenile coral recruitment, compared to unmanaged control plots. This site serves as a reference example throughout these guidelines. **Your site may share some of the features and differ in others**.

1. Understanding the intervention

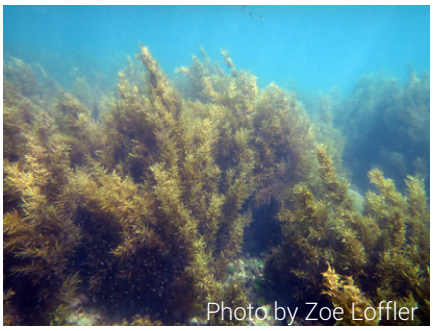
1.1 What is macroalgae (seaweed)?

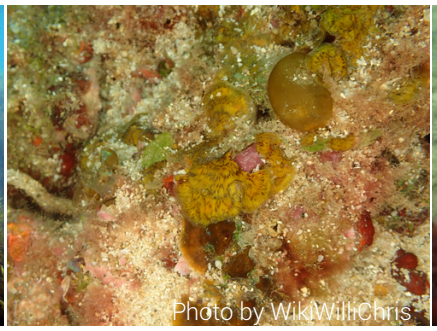
Macroalgae (commonly called seaweed) are large, photosynthetic organisms that grow on hard surfaces on the seafloor.

Despite looking plant-like, **they are not plants**: they are algae, a fundamentally different group of organisms. On healthy reefs, macroalgae play important roles in primary production, providing food and habitat for marine life, and in consolidating reef structure. The problem arises when they become dominant, covering large areas of reef substrate and outcompeting corals.

The **main types of macroalgae** you are likely to encounter when sea-weeding include:

- **Canopy-forming algae** (left), which can grow tall fronds that shade large areas of reef below
- **Mat-forming algae** (centre), which spread as low, dense crusts or foliose mats across the substrate
- **Turf algae** (right), which are short, dense, mixed-species mats that can quickly colonise bare substrate







Images 4, 5 & 6. Canopy-forming algae, mat-forming algae, turf algae

Different species have different growth forms, holdfast structures, and competitive effects on corals. Developing familiarity with the dominant species at your site (what they look like, how they grow, and how they respond to removal) is an important part of preparing a sea-weeding program.

1.2 Seaweed vs. seagrass - important distinctions

Seaweed and seagrass can sometimes be confused. While they might look similar, they are fundamentally different, and this distinction is critical for safe sea-weeding.

- **Seaweed is algae**. It does not have true roots, stems, or flowers, and is typically attached to hard surfaces like rock or coral
- **Seagrasses are flowering plants**. They have roots, veins, and can produce flowers and seeds, and they grow in soft sediments forming meadows

This distinction matters because **seagrass ecosystems are protected habitats in many regions** and must not be removed. Accidental removal can cause long-term ecological damage and may breach environmental regulations.

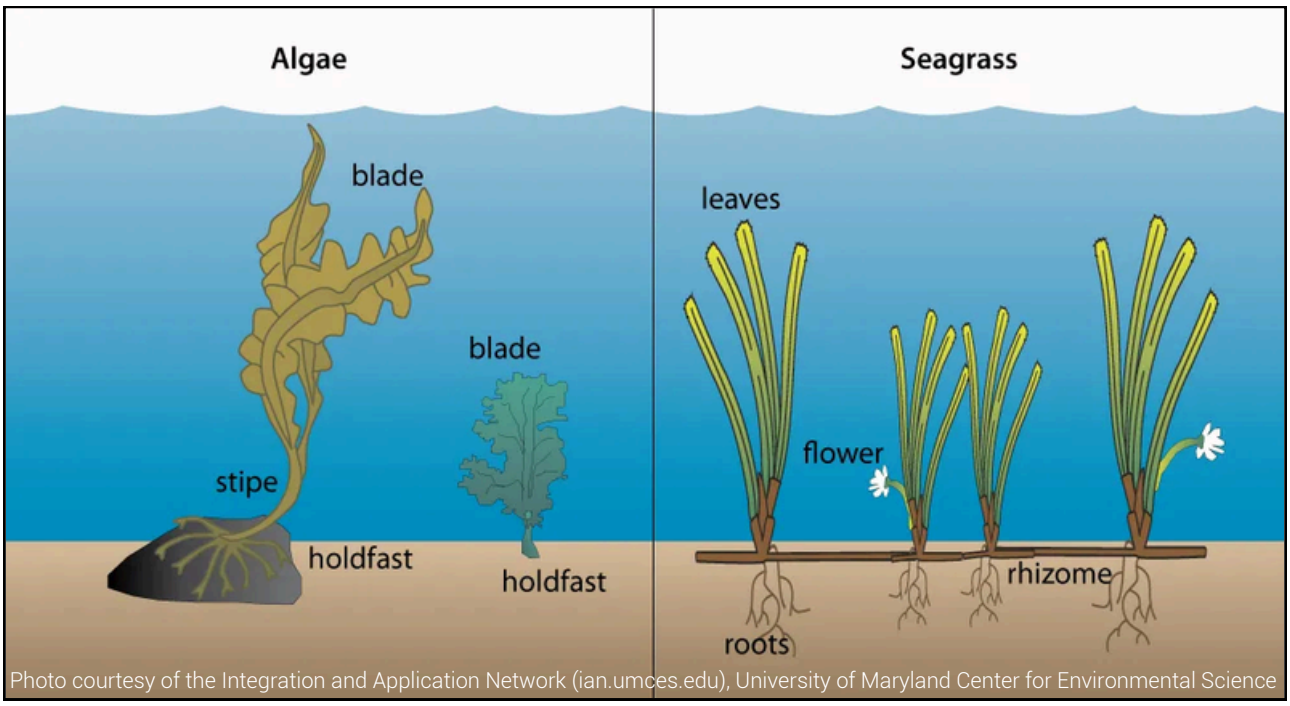
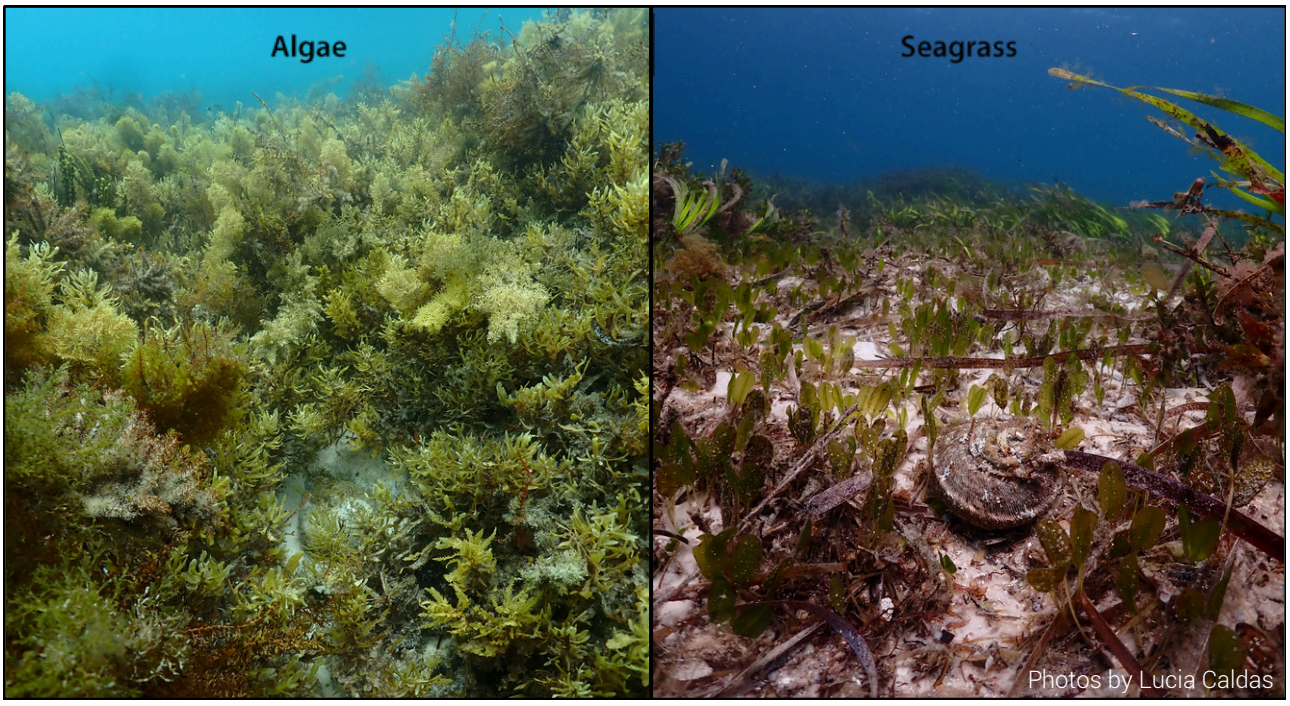


Image 7. Seaweed vs seagrass diagram



Images 8 & 9. Seaweed vs seagrass images

⚠ **Seagrass is protected in many places — do not remove it**

Seagrass meadows are protected marine habitats in many places and must not be disturbed during sea-weeding activities.

If you are working near seagrass, make sure your whole team can confidently tell the difference before entering the water. When in doubt, do not pull it out.

1.3 How does sea-weeding work ecologically?

Sea-weeding targets the competitive bottleneck. By physically removing macroalgal canopy, teams create patches of cleared substrate, making space that coral larvae settling from the water column can access. The mechanism works through several pathways:

- **Substrate availability:** coral larvae need hard, clear substrate to settle on. Dense algal cover physically blocks access
- **Light availability:** canopy-forming algae like *Sargassum* shade the reef below, making conditions unsuitable for coral recruits that need light to survive
- **Allelopathy:** some macroalgae release chemicals that are directly toxic to coral recruits and reduce settlement rates, even where physical space is available
- **Physical abrasion:** algal fronds sweeping across the reef in surge can dislodge or damage small coral recruits

Manual removal temporarily reduces these pressures, potentially allowing coral larvae to settle and juveniles to survive. Whether this translates into measurable reef recovery depends on many other factors, which is why monitoring is central to any sea-weeding program.

Seaweed is not necessarily the enemy

Macroalgae are a natural and important part of healthy marine ecosystems. On coral reefs, native seaweeds provide food and habitat and contribute to reef productivity. Their presence alone does not mean that something is wrong or that removal is appropriate.

In coral reef systems, sea-weeding is most relevant where macroalgae have become dominant, coral recovery has stalled, and excessive algal cover is limiting coral recruitment or survival. **The goal is not to remove all seaweed**, but to create targeted windows of opportunity for coral recovery.

In other environments, the management objective may be different. Introduced seaweeds can spread into native marine habitats and compete for space with native algae and other organisms. Mills (2025) documents a community-led underwater weeding program in Port Phillip Bay/Nerm, Victoria, Australia, where divers and snorkellers remove the introduced kelp *Undaria pinnatifida*. The program aims to limit its spread and provide native marine communities, including Golden Kelp, *Ecklonia radiata*, with greater opportunity to establish and persist.

Whether seaweed removal is appropriate therefore depends on the species involved, their ecological role and the management objectives for the site.



Image 10. Coral and seaweed coexisting on a reef at Yunbenun

2. Understanding the evidence

2.1 What the research has demonstrated

Research at Yunbenun (Smith et al. 2021, 2023, 2025) provides the most detailed published evidence for community-led sea-weeding. Key demonstrated outcomes include:

Ecological response (Smith et al. 2023)

- Across a three-year study involving eight removal events at 25 m² plots, **coral cover in weeded plots increased approximately six-fold** - rising from around 5.65% at baseline to approximately 35% by the end of the study. Control plots showed only modest change (approximately 7.5% to 10.4% over the same period)
- Each removal event approximately **halved macroalgal cover**, with an average reduction of around 52.5% per event, though complete removal was not achieved (holdfasts were retained and regrowth occurred between events)
- The ecological benefits of sea-weeding did not become apparent until **after approximately three years of sustained effort**. Sporadic or single removal events are therefore unlikely to produce detectable outcomes
- Outcomes varied between reef sites within the same study system, influenced by local conditions, background disturbance, and macroalgal community composition

Effort and cost (Smith et al. 2023)

- Two people cleared approximately 25 m² of reef substrate in around 30 minutes per removal event, which indicates feasibility of scaling up through citizen science initiatives
- Extrapolating costs per hectare and including cost of labour estimates,this yields an indicative cost of approximately $67,250 per hectare per event, excluding volunteer labour. These figures are **context-specific and should not be assumed to apply elsewhere**

Natural recruitment and comparison with seeding (Smith et al. 2025)

- In plots that received sustained sea-weeding, natural juvenile coral density reached approximately 3.02 juveniles per m² — exceeding the density of recruits surviving on seeding devices (~1.57 per device)
- Sea-weeding enhanced first-year survival of corals on seeding devices when both approaches were used together, but this benefit was not sustained to the second year

2.2 What has not been demonstrated

- The evidence comes primarily from nearshore turbid-reef contexts with seasonal *Sargassum* dominance. Outcomes on clear-water reefs, offshore reefs, or reefs dominated by different macroalgal genera have not been tested comparably
- Post-removal macroalgal community changes are ecologically complex. At Yunbenun, removal of *Sargassum* canopy was associated with increased cover of other species of macroalgae. This shift should be monitored to get data on the ecological implications of weeding
- Long-term outcomes of this intervention are not yet fully documented

Important considerations

- Sea-weeding does not address underlying causes of coral decline
- One-off sea-weeding events are unlikely to produce measurable ecological outcomes
- Sea-weeding is not necessarily appropriate for all reef types or all macroalgal species
- Results will vary between sites and seasons, even with identical effort

2.3 What sea-weeding cannot do

Sea-weeding **does not address the underlying conditions** that allowed algae to become dominant in the first place. If nutrient-rich runoff continues, if herbivorous fish remain depleted, or if the reef faces repeated thermal stress or severe storm impacts, the pressures driving macroalgal growth will persist regardless of how well the weeding is done. Removing algae without reducing these pressures may buy time and create recovery windows, but it doesn't solve the problem. For sea-weeding to contribute to lasting recovery, efforts to reduce the drivers of algal dominance need to be considered alongside the weeding program, not instead of it. Understanding the broader reef health context (fish communities, water quality, disturbance history) matters for predicting whether sea-weeding is likely to succeed at a given site.

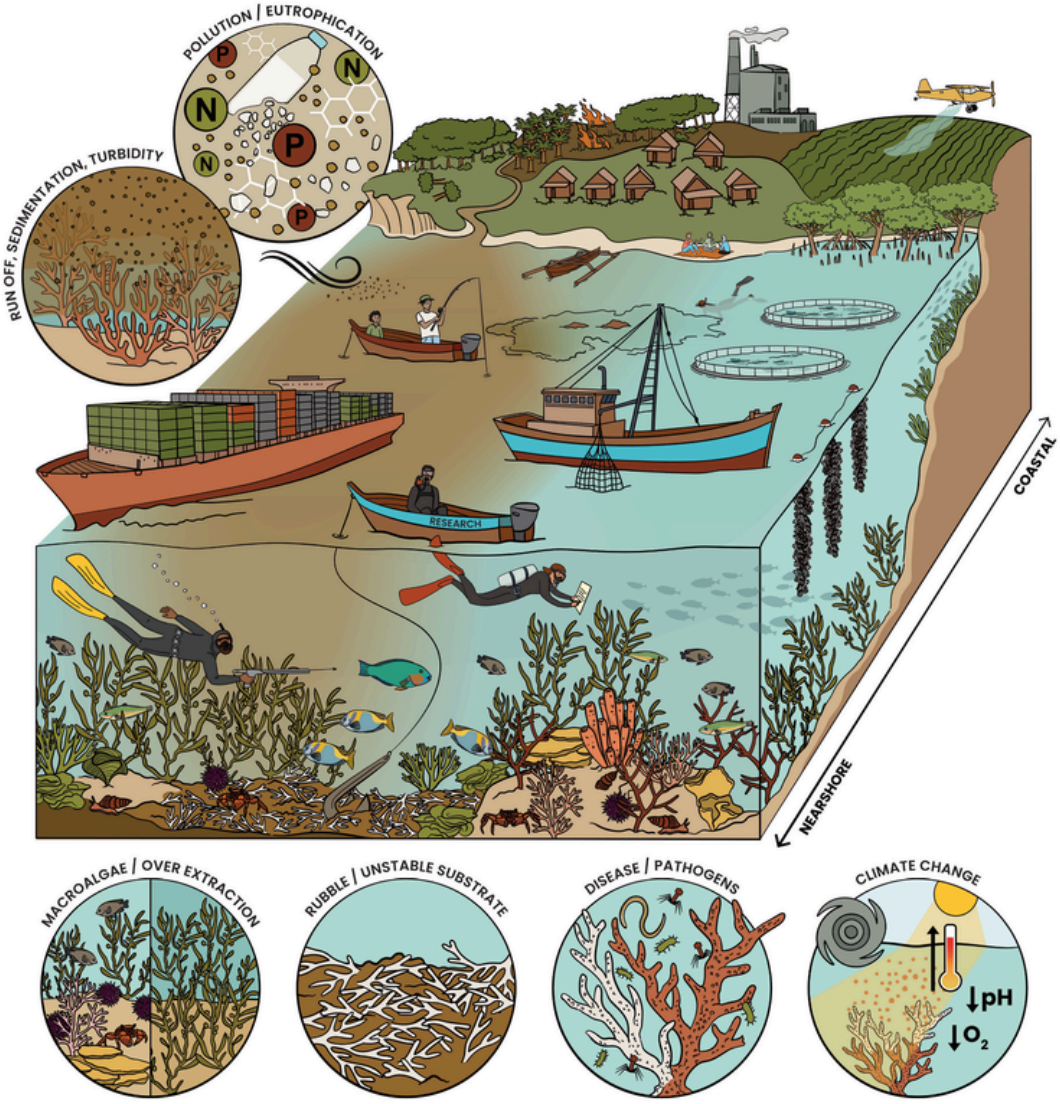


Image 11. Attributes of, and pressures impacting turbid nearshore coral reefs (Page et al. 2026)

Importantly, sea-weeding does not eradicate the algae. Holdfasts are sometimes left in place because removing them completely is complicated and it can damage the reef surface. Regrowth from holdfasts between events is expected. This means sea-weeding is a repeated management practice, not a one-time fix: it creates periodic windows of opportunity for coral larvae to settle and establish, bought by sustained effort over multiple seasons.

Finally, sea-weeding only helps if there is coral to recover. Cleared substrate needs to receive coral larvae, either from adult corals still present on or near the site, or from connected reefs. Where adult populations have been catastrophically reduced and larval supply is very limited, sea-weeding alone may not be sufficient and may need to be combined with active coral delivery as a second stage. A staged approach framework is outlined in section 3.

3. Sea-weeding within a Staged Restoration Framework

Sea-weeding is most usefully understood as one component of a staged approach to reef recovery, not as a standalone restoration technique. This framing has practical implications for how programs are scoped, sequenced, and evaluated.

3.1 A three-stage approach

Page et al. (2026) describe a staged framework for restoring turbid nearshore coral reefs that positions different interventions in sequence depending on the ecological state of the site and the outcomes of earlier stages:

Stage	Intervention	When indicated
Stage 1 Habitat modification	Manual macroalgal removal (sea-weeding), physical habitat preparation, removing impediments to recruitment	Where macroalgae are suppressing natural coral recovery in the presence of adequate larval supply
Stage 2 Coral delivery	Active coral seeding (larval or fragment-based), seeding devices, outplanting of nursery-grown corals	Where Stage 1 alone is insufficient because larval supply is limited or adult populations have been catastrophically reduced
Stage 3 Maintenance and monitoring	Ongoing monitoring, follow-up removal events, herbivore enhancement, adaptive management	Throughout — and especially if Stage 1 or 2 responses are insufficient or short-lived

Table 1. Stages, interventions and considerations for sea-weeding programs (Page et al. 2026)

3.2 Implications for sea-weeding programs

Sea-weeding is a first-stage habitat modification intervention. It is most clearly indicated where macroalgal dominance is the primary bottleneck to recovery, and where larval supply and remaining adult coral populations suggest natural recruitment is possible if substrate becomes available. This approach may be sufficient on its own in systems where larval supply is adequate. At Yunbenun, sustained removal over multiple seasons supported sufficient natural coral recruitment that additional interventions, such as active coral seeding, were not considered necessary.

Active coral delivery (Stage 2) is most justified where adult populations have been catastrophically reduced and/or larval supply is severely limited. The frequency of repeat removal required in Stage 3 may be reduced if sufficient herbivore populations can be established or restored.

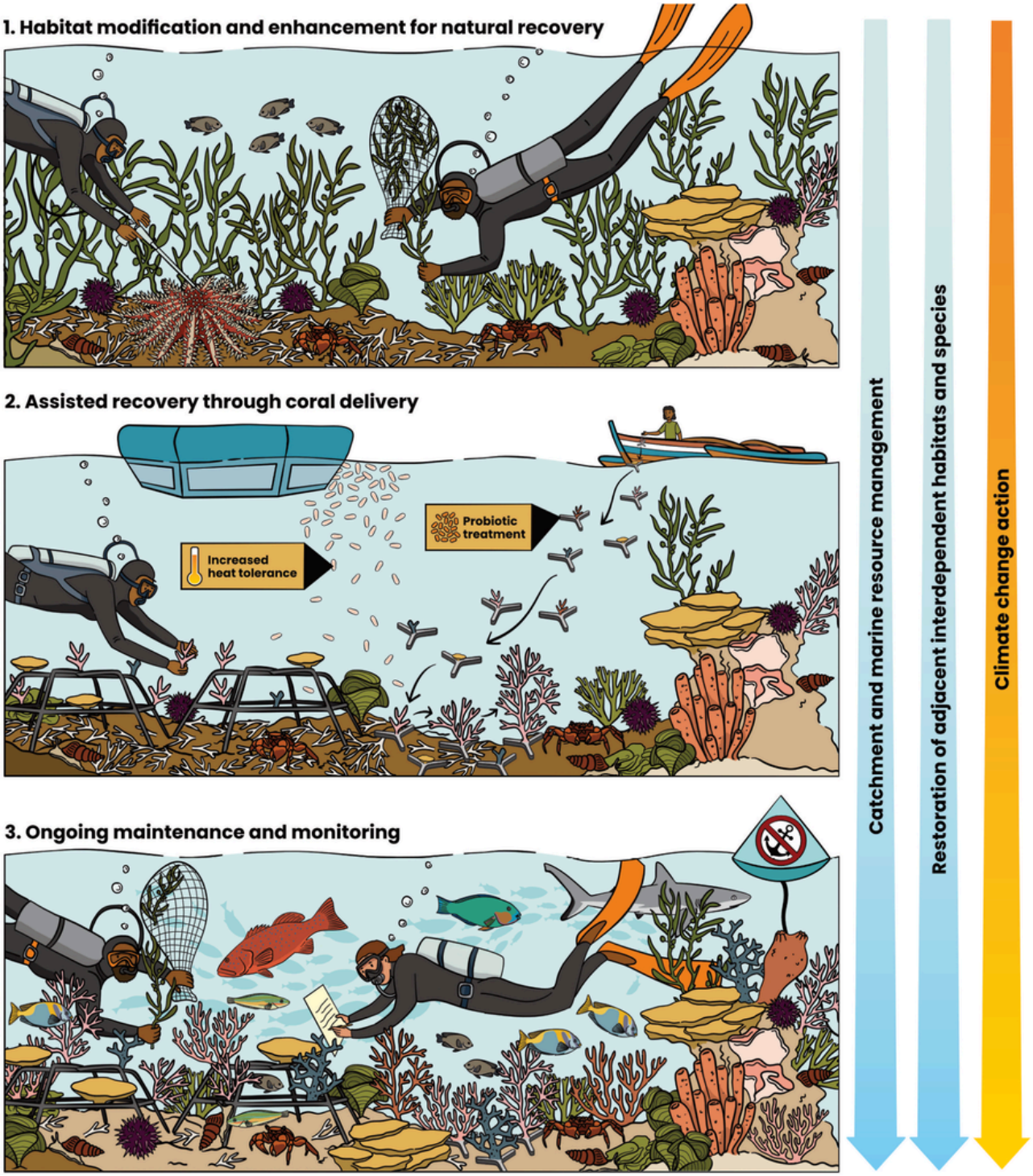


Image 12. **Proposed staged and layered approach to restoration of turbid nearshore coral reefs, and concomitant actions (right arrows) required to maximise the success of restoration. Stage 1 – Habitat modification and enhancement for natural recovery; Stage 2 – Assisted recovery through coral delivery; Stage 3 – Ongoing maintenance and monitoring. Concurrently, catchment and marine resource management, restoration of adjacent interdependent habitats, and species and climate change action are required to maximise restoration success (Page et al. 2026)**

⚠ **Important caveat on applicability**

The evidence described in these guidelines was generated at a specific type of reef (nearshore, turbid, GBR fringing reef with seasonal *Sargassum* dominance). **It should not be assumed that sea-weeding will produce the same outcomes at other reef types without further investigation**. Before committing to developing a sea-weeding program, communities and managers should assess whether the ecological conditions at their site are similar enough to the Yunbenun context that comparable responses might be expected, and be prepared for the possibility that they're not.

3.3 Questions to consider before you begin

Sea-weeding is most relevant where macroalgal dominance is limiting coral recovery. Before investing in a sea-weeding program, communities should consider whether removal addresses the underlying ecological problem and whether there is capacity to sustain and evaluate the intervention.

- What is the history of the site? Do you know what caused the current state, and have those drivers been (or are they being) addressed or reduced?
- Is macroalgal dominance the primary bottleneck to coral recovery, or are there other limiting factors?
- Are there still living adult corals and evidence of sufficient natural coral recruitment to support recovery?
- Are local herbivorous fish populations present to help maintain cleared substrate?
- Is there capacity to commit to sustained, multi-season effort?
- Is there access to the scientific or ecological monitoring support needed to evaluate outcomes?



Image 13. Coral bommie around the study area

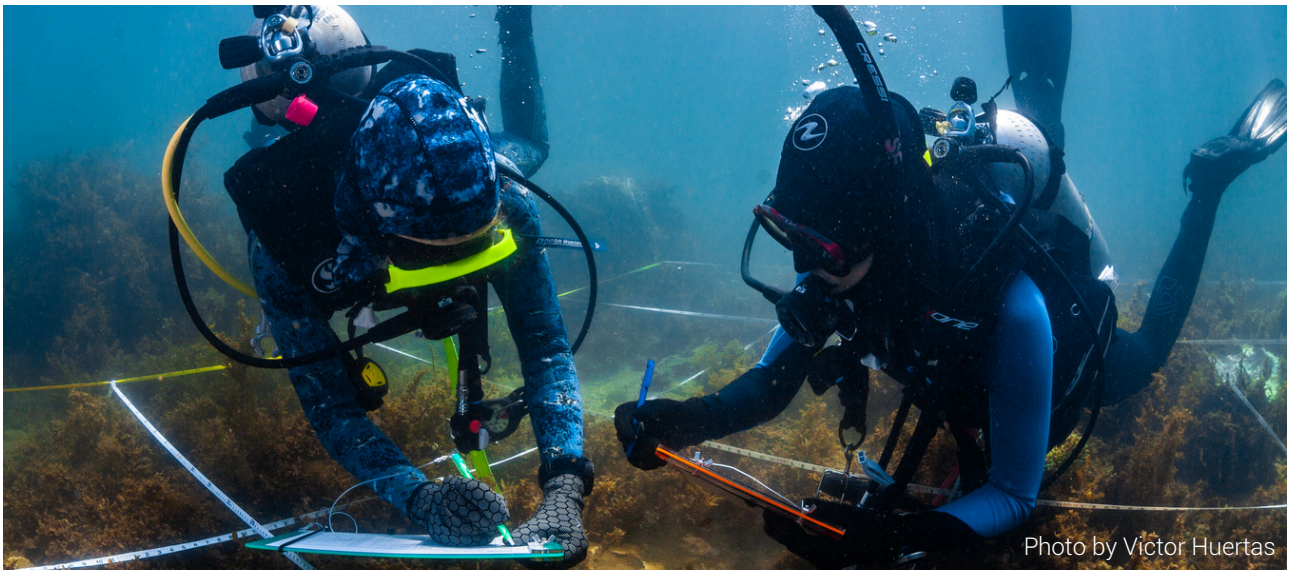


Image 14. Researchers surveying a plot in the study area

4. Community readiness and realistic expectations

4.1 Thinking about capacity

The outcomes of any sea-weeding program are directly related to the effort applied, the consistency of that effort, and the team's capacity to sustain it over time. Before developing your protocol, it is worth honestly assessing what your community can realistically commit to.

Aspects to consider include:

- How many trained people are available for in-water work?
- How many days per season can realistically be committed?
- Is there capacity for multi-year engagement? It may require at least two to three years before meaningful trends are detectable
- Can monitoring support be secured — either through partnerships with researchers or trained community members?
- What is the team's current level of water skills, and what training pathways exist?

It is also worth understanding how **effort is expected to change over time**. In a successful program, the amount of algae available to remove should gradually decrease as corals begin to recover and reclaim substrate. This means that if the program is working, **the effort required — and the volume of material harvested — should naturally decline over the years**. Planning should reflect this trajectory: the heaviest lifting comes early, and a well-functioning program works toward making itself less necessary over time.

This has a practical implication for how harvested algae is used. It can be tempting to develop secondary uses for the biomass removed — compost, fertiliser, building materials, or other products — and while small-scale local use may be appropriate, programs should avoid creating arrangements that depend on a sustained high volume of harvest.

Unlike free-floating pelagic *Sargassum*, which washes ashore reliably and can support industries in some regions, the algae removed through reef sea-weeding programs is expected to diminish as the intervention succeeds. Building infrastructure or commitments around a permanent supply could work against the program's own goals.

Example from the field

At Yunbenun, sustained effort over eight years by trained teams working at defined plots has produced detectable differences in coral cover and recruit numbers compared to unweeded control plots. **Over that period, approximately 3,000 kg of macroalgae has been removed in total — but critically, the amount removed each year has declined steadily as coral has recovered and reclaimed substrate**. This is what a successful program is expected to look like: not a constant or growing harvest, but a gradual reduction in the work required.

Results varied between years and were influenced by background disturbances including bleaching events, cyclones, and flood plumes. Outcomes were most consistent where teams maintained high-frequency visits and systematic monitoring.

4.2 Setting realistic expectations

Communities should consider what success looks like in their context. Some programs may aim primarily for ecological outcomes; others may prioritise community engagement, skill-building, cultural connection to the reef, or generating evidence to support management decisions. These are all legitimate goals, and your protocol should reflect which matter most to you. It is also important to set realistic expectations around the time, effort, and ecological response involved.

A few considerations:

- **Detectable ecological change takes time**. In the Yunbenun study, meaningful differences between weeded and control plots were not apparent for approximately three years. Programs should consider planning for multi-year commitment
- **Physical effort can be substantial**. At Yunbenun, removal is carried out by divers, with snorkellers providing surface support by transporting full catch bags to the vessel and supplying divers with empty bags. Two trained divers can usually clear a 25 m² plot in around 30 minutes. Clearing a meaningful area of reef over multiple seasons requires sustained effort
- **Regrowth between weeding events is expected**. Sea-weeding reduces macroalgal cover by approximately half per event, not permanently. Holdfasts can remain and regrowth occurs
- **Outcomes are not guaranteed**. The ecological response varies between sites, seasons, and years. Bleaching events, flood plumes, and other disturbances can disrupt or mask the effects of sea-weeding

4.3 Reference effort table

The reference effort below is based on the diver- and snorkeller-based approach used at Yunbenun and is **provided as a guide only**. Actual effort will vary with site conditions, depth, team experience, macroalgal biomass, and the removal method used.

Effort of intervention	Team size	Approximate area manageable Dependent on depth, number and duration of dives, and amount of algae present
2-3 dives per day From 30 min to 60 min per dive, dependent on depth of site, SCUBA tank size available **50m² cleared per hour** At 6m maximum depth, a pair of divers could clear 2 plots (50m²) per hour	**Small (2-4 divers)**	50m² to 300m² per day
	Medium (5-10 divers)	150m² to 750m² per day
	Large (10+ divers)	250m² + per day

Table 2. Reference effort table

These figures are indicative only. Your team may find they can cover more or less area depending on algal density, depth, current, number and duration of dives, and team experience.

4.4 Readiness checklist

The table below is a quick checklist to assess your team's readiness to undertake sea-weeding in a site. Communities should complete this based on their own assessment of capacity and site conditions. These are not absolutely necessary or a deal-breaker, just worth considering carefully.

Dimension	Key considerations
Ecological basis	Is there evidence that macroalgae is suppressing recovery at your site, and that adequate larval supply exists?
Dive/snorkel capacity	Does your team have the diving and/or snorkelling skills, certifications and safety cover to operate safely?
Long-term commitment	Is there community will and capacity to sustain effort across multiple seasons?
Monitoring capacity	Can baseline and ongoing monitoring be established?
Governance and authority	Have the required approvals from Indigenous groups and relevant regulatory authorities been obtained?
Financial resources	Have the ongoing costs of the intervention - including equipment, safety, monitoring and processing or disposal - been scoped?
Knowledge partnerships	Are ecological expertise and scientific partnerships accessible to support the program design and delivery?

Table 3. Readiness checklist

Example from the field

Research from Yunbenun is clear that consistent, repeated removal across multiple seasons was required to produce detectable ecological change in the area.

Programs that cannot sustain this level of commitment should carefully consider whether sea-weeding is currently the right investment of community time and resources, as sporadic events are unlikely to produce significant lasting impacts.

The next point addresses the scenario where long-term commitment is not in the plan.

4.5 One-off events or absence of monitoring

Monitoring is strongly recommended for any sea-weeding program, but it could happen that your group does **not have the capacity to return to a site for systematic data collection**. The evidence from Yunbenun is clear that a single removal event is unlikely to produce detectable ecological change on its own. One event can reduce macroalgal cover at the time, but without follow-up, regrowth is expected and any benefit to coral recruitment may be short-lived. However, a one-off event is not necessarily without value - it contributes to the evidence base if documented, and may be a meaningful first step toward a longer-term program - but it should not be presented on the premise that it will measurably restore the reef.

If your group can do the weeding but not the monitoring, or if you are planning a single event rather than a sustained program, the following questions are worth working through honestly before committing.

Is sea-weeding already part of your planned operation, or does it require extra resources?

If your group is already visiting the site for another purpose and weeding can be folded into that activity with the team and equipment already present, the cost-benefit equation is quite different from building a separate weeding operation from scratch. If weeding requires extra funding, extra people, or a dedicated trip that isn't already planned, weigh that investment carefully against the likelihood of measurable outcomes from a one-off effort.

How much do you know about the life cycle of your target seaweed?

Some seaweeds may respond differently to removal than others, and the timing of your intervention relative to the algal life cycle is likely to affect the outcomes. With *Sargassum* at Yunbenun, at least two years of consistent weeding were needed before positive results became apparent - and it took systematic monitoring to confirm it. Research the biology of your dominant species and seek scientific advice from local researchers where possible before committing.

Could another local group take on the monitoring role?

Is there a dive school, research institution, university, tourism operator, government office or conservation group that regularly visits or could visit the site? A partnership where one group weeds and another monitors can make both efforts more valuable. Even informal photo documentation by a visiting group at regular intervals is better than no record at all.

What is your minimum viable record-keeping?

The following cost very little extra time and maximise what can be learned from a one-off or low-capacity effort:

- Weigh and record the total biomass removed (wet weight of bags on land before disposal)
- Take photographs from fixed reference points before and after the removal
- Record the macroalgal species targeted and any other species observed in the removal area
- Note the date, conditions, team size, time in water, and obvious changes in coral or algal cover

These records make your effort legible to funders, partners, and future programs - and may help a future team decide whether to return, or teams at other sites facing similar species overgrowth.

Could undetected negative outcomes go unaddressed?

Without monitoring, you won’t be able to detect if things move in an unexpected direction. For example, removing one algal species can lead to a different species increasing in its place. Without anyone watching, adverse community shifts could persist without triggering a change in approach. This risk is worth acknowledging and discussing with your team before you begin.

5. Governance, cultural authority and permits

Sea-weeding activities take place in marine areas that may hold cultural significance, customary ownership or custodianship, and formal or customary governance arrangements. In Australia, these areas are referred to as Sea Country, cared for by Aboriginal and Torres Strait Islander peoples through enduring cultural rights, responsibilities, knowledge and connections. In other countries, equivalent relationships may be held by Indigenous Peoples, customary owners, local communities or other recognised rights-holders.

Before proceeding, programs must identify and engage the appropriate rights-holders and understand the cultural protocols, customary governance arrangements and legal requirements that apply locally. No program should proceed without a clear and locally appropriate governance foundation. This is fundamental to the legitimacy, integrity and longevity of community-led restoration, not simply a procedural requirement.

5.1 Indigenous rights and cultural authority

Where a sea-weeding program is proposed within the traditional lands, waters or territories of Indigenous Peoples, its planning and delivery must recognise their rights, authority, knowledge and continuing custodianship. Engagement should begin before sites, methods, partnerships or intended outcomes are decided and continue throughout the life of the program. This approach reflects the United Nations Declaration on the Rights of Indigenous Peoples, particularly the rights to self-determination; participation in decision-making; maintenance, control and protection of cultural knowledge; and consultation in good faith to obtain Free, Prior and Informed Consent before projects affecting Indigenous lands, waters, territories or resources proceed.

Key principles include:

- **Identify the appropriate cultural authority:** determine which Indigenous Peoples, customary owners or other recognised rights-holders hold authority for the relevant marine area and how they wish to be represented. Do not rely solely on general maps, individual contacts or informal community support. Engage the appropriate Indigenous governance bodies, community organisations, Elders, knowledge holders or other authorised representatives, as advised locally. In Australia, these may include Traditional Owner organisations, prescribed bodies corporate and Indigenous ranger groups
- **Free, Prior and Informed Consent (FPIC):** seek consent before sites, methods, partnerships or public commitments are finalised. Information should be provided in an accessible and culturally appropriate form, with adequate time and resources for internal decision-making. Participation must be voluntary, and the group must be able to decline, place conditions on, or request changes to the proposed activity. Consent should be treated as an ongoing process rather than a one-off approval
- **Indigenous leadership and co-design:** involve the relevant Indigenous Peoples in determining whether the program should proceed and, if so, its objectives, methods, governance, monitoring and measures of success. Where desired by the group, programs should support Indigenous leadership or co-governance rather than limiting involvement to consultation or endorsement after decisions have been made. In Australia, the AIATSIS Code of Ethics provides further guidance on Indigenous self-determination, leadership, impact and value, sustainability and accountability

- **Cultural protocols and restricted knowledge:** work with the appropriate cultural authorities to identify relevant protocols. These may relate to access, culturally significant or restricted places, seasonal activities, gender-specific responsibilities, collection or removal of organisms, photography, mapping, sharing site locations, or who may hold and communicate particular knowledge. Some information may be unsuitable for publication or wider circulation
- **Indigenous knowledge and cultural and intellectual property:** recognise that cultural knowledge, practices, ecological knowledge, stories, languages, images and other cultural expressions remain connected to the Indigenous Peoples who hold them. Agree in advance how this material may be recorded, attributed, stored, interpreted, reproduced and shared. Permission for one use should not be assumed to permit future or unrelated uses. In Australia, these rights and interests are commonly described as **Indigenous Cultural and Intellectual Property (ICIP)**; other countries and communities may use other terms, such as traditional knowledge or traditional cultural expressions
- **Indigenous data sovereignty and governance:** Indigenous Peoples should have meaningful authority over data concerning their people, knowledge, cultural values, territories and resources. Data arrangements should cover what is collected; who owns, holds and can access it; where it is stored; how culturally sensitive information is protected; how findings are interpreted; and whether information may be published, mapped, reused or shared with third parties. Indigenous data sovereignty recognises the right of Indigenous Peoples to govern the collection, ownership and application of data relating to their communities, lands, waters and resources
- **Mutually agreed terms:** document agreed roles, responsibilities and decision-making processes in a form supported by the relevant Indigenous group. Agreements should address resourcing and payment, use of cultural knowledge, data governance, attribution, communications, monitoring, publication, conflict-resolution processes, review points, and what will happen if consent or circumstances change
- **Access and benefit-sharing:** agree how benefits arising from the program will be shared fairly. Benefits may include paid employment, contracts for Indigenous organisations or businesses, training, equipment, research opportunities, shared authorship, access to monitoring results and support for Indigenous-led priorities. Where biological resources or associated traditional knowledge are collected or used for research or commercial purposes, national laws and international frameworks (such as the Convention on Biological Diversity and the Nagoya Protocol) may establish additional access and benefit-sharing requirements

Indigenous consent and government authorisations serve different purposes: a regulatory permit does not replace meaningful engagement or consent, and Indigenous consent does not remove the need to obtain applicable permits and approvals. Existing Indigenous and customary governance arrangements must be identified and respected. In Australia, these may include Sea Country plans, Indigenous Protected Area plans, and Traditional Use of Marine Resources Agreements (TUMRAs). Similar governance arrangements may exist elsewhere, so it is important to identify what applies in your local context.

Example from the field

At Yunbenun, research partnerships were developed in consultation with the local Traditional Owners, the Wulgurukaba people, and local ranger groups. Active participation in sea-weeding activities is still being developed, with practical considerations including access to in-water training, available time, and appropriate resourcing.

Building pathways towards greater Traditional Owner and ranger involvement, with the longer-term goal of locally led delivery, remains an important objective, guided by local priorities and governance structures.

5.2 Legal permits and approvals

Depending on your jurisdiction, sea-weeding activities may require:

- Marine Park permits or research/management permits
- Environmental impact assessment or notification requirements
- Approval from relevant government agencies (state, territory, or national marine authorities)
- Workplace health and safety compliance for in-water work (Risk assessments, Emergency response plans)
- Insurance and liability coverage for participants

Your protocol should document what approvals have been obtained, by whom, and their validity period. This should include expiry dates, renewal requirements, and any applicable conditions or reporting obligations. Requirements will vary significantly between jurisdictions, so it is important to identify what applies to your specific context well before activities begin.

5.3 Governance structures to consider

Governance arrangements should be proportionate to the program's scale and build on existing structures wherever possible. **Not every program will require separate committees or advisory groups**, but authority, responsibilities and decision-making processes must be clear. Consider:

Community governance

- Existing governance frameworks, such as Traditional Use of Marine Resources Agreements (TUMRAs) or local equivalents
- Indigenous ranger programs, plans and community-led management priorities
- Native Title, customary rights and other recognised rights and interests
- A community steering committee or advisory group with meaningful decision-making authority
- Appropriate representation of relevant rights-holders, knowledge holders and communities
- Agreed decision-making, dispute-resolution and consent processes
- Clear data governance and cultural knowledge protocols
- Defined processes for raising concerns, reviewing decisions or withdrawing consent
- Appropriate payment or resourcing for participation

Partnership structures

- Scientific and technical advisory support (formal or informal)
- Partnership agreements with research institutions
- Clearly defined roles, responsibilities and decision-making authority across all partners
- Engagement with local delivery partners such as NGOs, community groups, ranger teams and education providers
- Funding management and accountability arrangements
- Procedures for managing conflicts of interest, risks and disputes
- A long-term stewardship and succession plan beyond the initial funding period
- Regular review and adaptation of governance arrangements

Government and regulatory coordination

- Early engagement with relevant local, regional and national government agencies
- Coordination with Marine Park authorities, protected-area managers and other relevant bodies
- Alignment with applicable management plans, zoning arrangements and restoration priorities
- Clear responsibility for obtaining and maintaining permits and approvals
- Compliance, monitoring and reporting responsibilities
- Coordination across jurisdictions where multiple authorities or overlapping requirements apply

6. Site selection

6.1 Importance of site selection

Sea-weeding is a context-dependent intervention. It is most likely to support coral recovery on reefs that still have ecological potential (i.e. where natural recovery is being suppressed by macroalgal competition, but the underlying conditions for recovery remain). Applying effort at unsuitable sites is unlikely to produce meaningful outcomes and may divert resources from where they could make a difference.

6.2 Site suitability: a decision framework

The following questions provide a structured starting point for assessing a potential sea-weeding site. They are not strict pass/fail criteria. Where the answer is uncertain, undertake further assessment, seek local and technical knowledge, or conduct a small, monitored pilot before proceeding.

1. **Is macroalgal competition likely to be suppressing coral recruitment, survival or recovery at the site?**

Yes Proceed to question 2	**No / uncertain** Sea-weeding may not be the priority intervention. Investigate other factors limiting coral recovery

2. **Does the site retain ecological potential for coral recovery?**
   Consider remaining living corals, juvenile corals or recruits, nearby reproductive coral populations, and evidence of past or ongoing recruitment.

Yes Proceed to question 3	**No / uncertain** Site may be too degraded for sea-weeding alone — consider whether other restoration actions are needed before or alongside sea-weeding

3. **Is there sufficient stable suitable substrate for coral settlement & growth?**
   Consider consolidated reef surface, loose rubble, sand, sediment accumulation and whether suitable surfaces could be exposed through sea-weeding.

Yes Proceed to question 4	**No / uncertain** Unstable rubble, mobile sediment or heavily sedimented sites may require other management or restoration actions first

4. **Are the main drivers of macroalgal dominance understood and sufficiently manageable?** Consider nutrient inputs, sedimentation, loss of herbivores, physical disturbance and other chronic pressures.	
Yes Proceed to question 5	**No / uncertain** Address the underlying pressures before or alongside sea-weeding
5. **Can the dominant macroalgae be removed effectively without causing unacceptable ecological or cultural impacts?** Consider the species and growth form of the algae, its method of attachment, expected regrowth, sensitive organisms, culturally significant species and important habitat.	
Yes Proceed to question 6	**No / uncertain** Develop a specific method to address the potential impacts, seek further advice or consider an alternative site/intervention
6. **Can work at the site be undertaken safely and effectively by the delivery team?** Consider depth, currents, tides, waves, visibility, weather exposure, entry and exit points, required equipment and team capability.	
Yes Proceed to question 7	**No / uncertain** Build the necessary skills and capacity, modify the approach or consider other more manageable sites
7. **Can the site be accessed consistently enough to support repeated sea-weeding and monitoring?** Consider seasonal access, weather, travel time, cost, permissions and the expected rate of macroalgal regrowth.	
Yes The site may be a strong candidate for weeding. Confirm governance requirements (refer to section 5).	**No / uncertain** The site may not be suitable for an ongoing program. Consider whether a realistic approach to follow-up treatment and monitoring can be established (refer to section 4.5)

Table 4. Site suitability decision framework

This framework should be applied alongside local ecological and cultural knowledge rather than as a stand-alone technical assessment. Final site selection should be guided by the relevant Indigenous rights-holders and communities, project partners, local managers and site-specific ecological evidence. **Where suitability remains uncertain, baseline surveys and a small pilot intervention can help test assumptions before substantial resources are committed.**

6.3 Ecological survey before committing

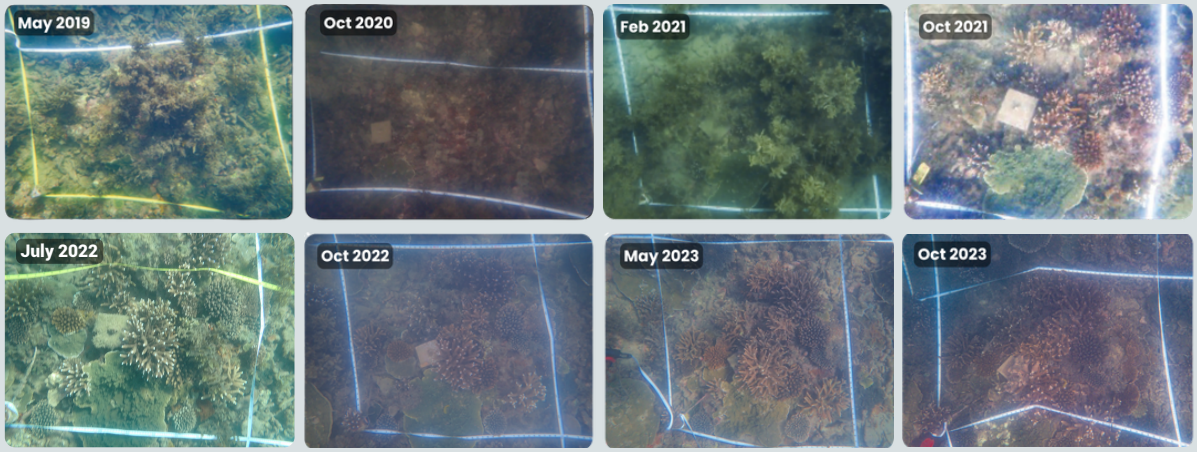
Before finalising a site, a baseline ecological survey is strongly recommended. This baseline serves as the foundation for monitoring outcomes and for adaptive management as the program develops. Establishing permanent photo-points or plot-based imagery at baseline is strongly recommended, as repeat photos provide a simple and powerful way to visualise change over time.

Ideally, this would capture:

- Percent cover of macroalgae, coral, and other benthic organisms
- Presence and density of coral recruits
- Substrate availability (hard substrate vs rubble vs soft sediment)
- Dominant macroalgal species and growth form
- Herbivorous fish abundance and composition

Example from the field: Baseline photos and timelapse comparison

At Yunbenun, permanent monitoring plots are photographed at consistent intervals before and after macroalgal removal. These photo time-series provide a clear visual record of change, showing reductions in macroalgal cover and increases in coral recruits over time. Below is a timelapse example from one of the weeded plots in Yunbenun.



This sequence shows the same monitoring plot over time, illustrating how macroalgal cover can be reduced and coral recruits begin to establish following repeated removal. While outcomes vary between sites and seasons, time-series imagery like this provides a clear, visual record of ecological change that supports both monitoring and adaptive management.



Image 15. Researcher surveying a plot in the study area

6.4 Plot design considerations

How you define the working area matters for both operations and monitoring. Things to think about:

- **Plot size and number:** how large an area do you want to target, and how much can your team effectively weed in one field visit/operational day?
- **Plot boundaries:** how will you mark or identify boundaries underwater?
- **Control plots:** designating areas of similar ecology where no weeding occurs is important for evaluating outcomes
- **Depth range:** consider tidal range for operations. Shallow plots may be inaccessible at low tide, or pose a risk to divers and the reef if there isn't much water
- **Spacing:** plots far apart increase travel time; plots too close may influence each other
- **Anchoring/mooring:** consider the availability of anchoring/mooring areas, and the proximity to your desired plots

Example from the field: Plot design at Yunbenun (1)

Twenty-four 25m^2 (5m × 5m) experimental plots were established on fringing coral reefs of Arthur Bay and Florence Bay (12 plots per bay). Plots were established haphazardly at a depth of approximately 3m after conducting visual surveys to ensure topographical consistency and representation of the wider reef ecosystem.

Within each bay, six plots were randomly assigned as controls (referred to as 'control plots') while the remaining six treatment plots (referred to as 'removal plots') were periodically cleared of fleshy macroalgae.

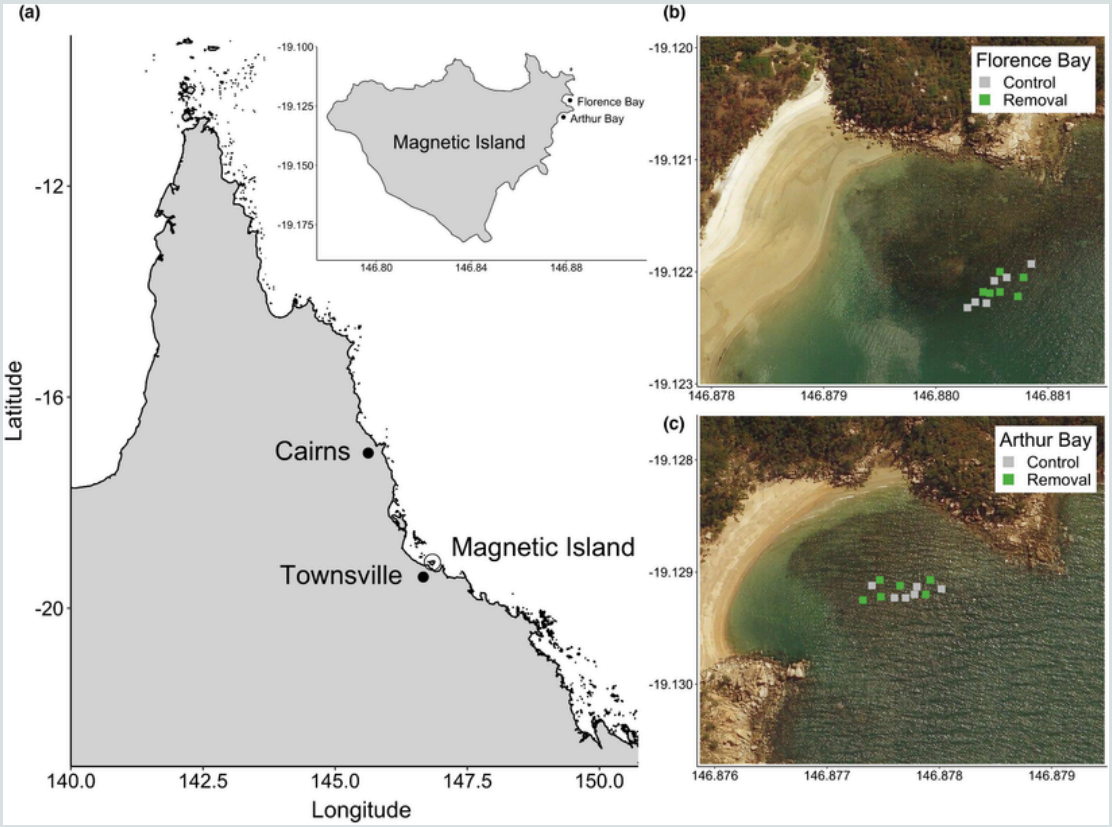


Image 16. Location of study sites in (a) Queensland, Australia; and maps of (b) Florence Bay and (c) Arthur Bay showing experimental plot arrangement. In each bay, six 25m^2 control plots (grey squares), and six 25m^2 removal plots (green squares) were periodically cleared of macroalgae. Note plot icons are not to scale. (Smith et al. 2023)

Example from the field: Plot design at Yunbenun (2)

Research plots at Yunbenun used fixed quadrats marked with metal rods and numbered tags. All plots were revisited 3 times a year, allowing comparisons over multiple years.

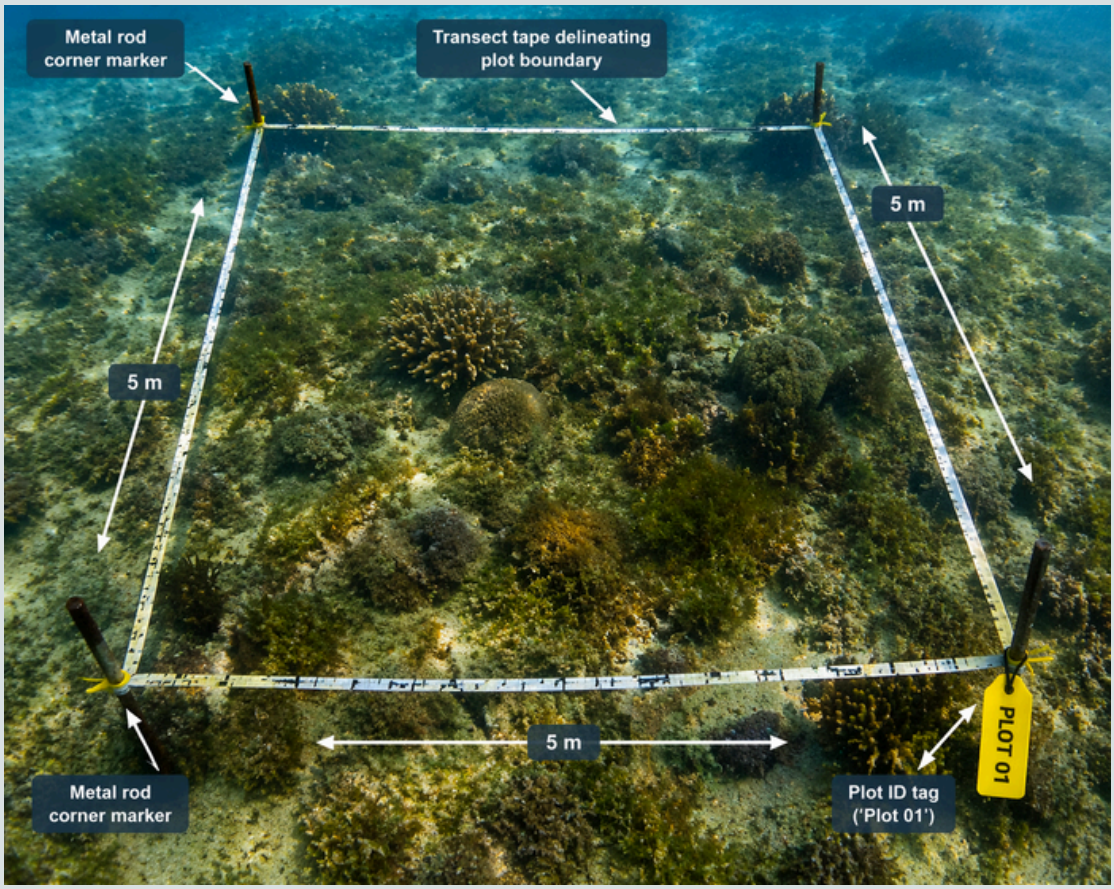


Image 17. Example of a research plot. Image generated with AI assistance

Plots are set up by measuring out a defined area (e.g. 5m × 5m) using transect tape, with each corner marked by permanent stakes such as metal rods. A numbered tag is attached to one marker so the plot can be easily recognised and revisited over time. Wherever possible, markers should be durable, securely placed, and positioned to minimise disturbance to the surrounding reef. Transect tape is deployed during each survey to delineate the plot boundaries and then removed at the end of the session, while corner markers and tags remain in place.

This setup enables repeat monitoring of the same area across seasons, supporting consistent data collection and reliable comparison of ecological change. Changes in coral cover can be documented using photographic surveys before and after each removal event.

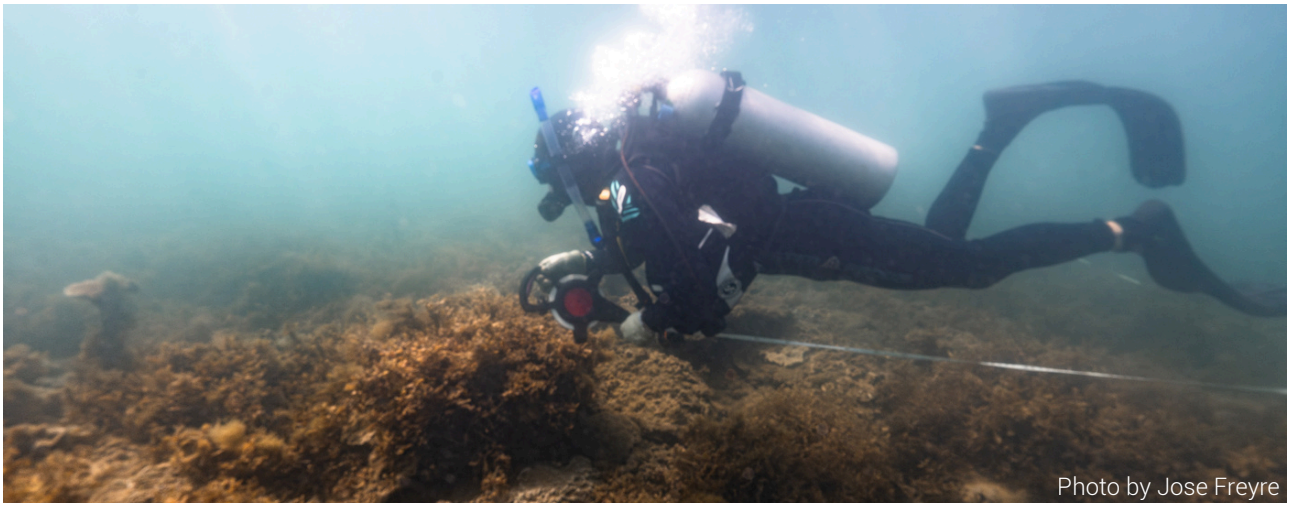


Image 18. Researcher laying out the transect to delineate one of the plots

Example from the field: Surveys

To enable systematic photo surveys, transect tapes are laid across the plot to form a grid of 1m² sections (5 × 5 = 25 cells). Each cell is photographed individually, producing 25 images per plot per time point. This method provides consistent spatial coverage and supports quantitative analysis of changes in benthic cover, recruitment, and algal dynamics over time.

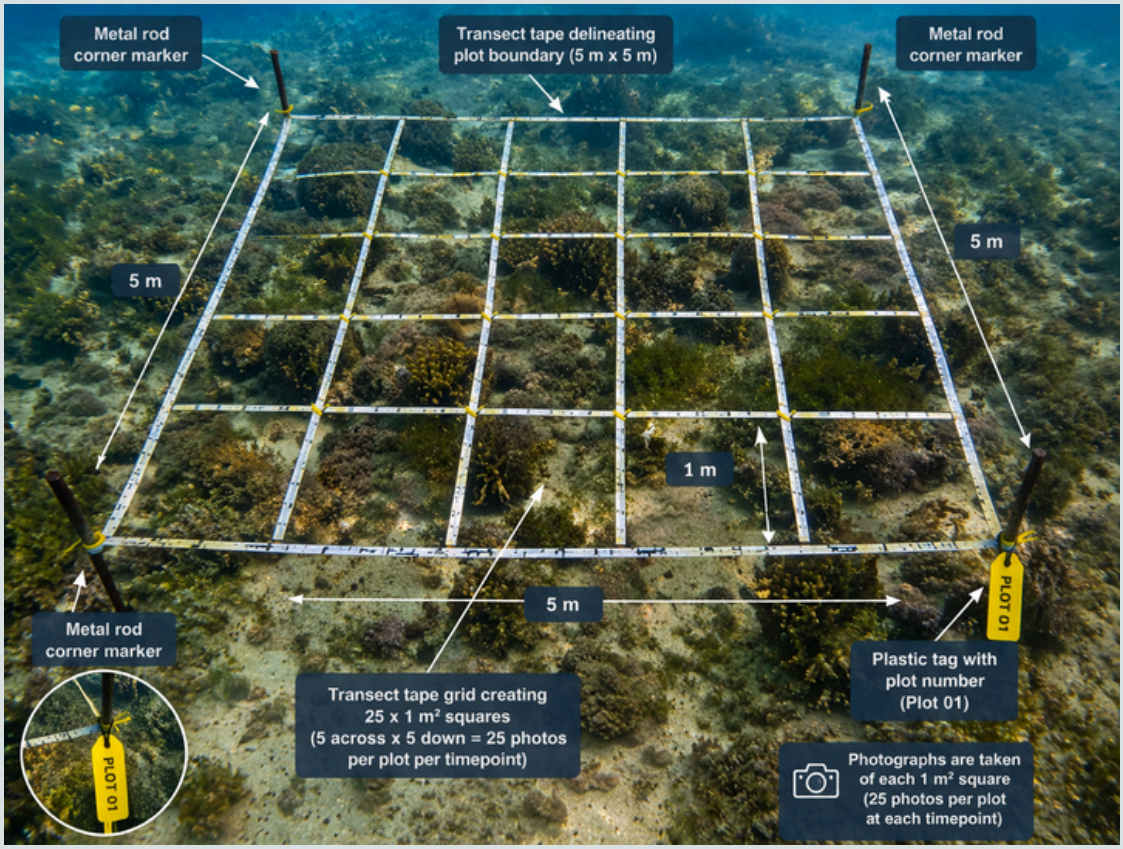


Image 19. Example of a research plot. Image generated with AI assistance



Image 20. Researcher surveying a plot in the study area

7. Environmental and ecological considerations

7.1 Removal event timing

The timing of carrying out removal activities (when) matters as much as the location (where). Consider the following factors when developing your timing protocol:

Algal growth cycles

Macroalgae grow more rapidly in certain seasons — typically warmer months with higher nutrients. Understanding the seasonal growth patterns of the dominant species at your site can help identify when removal effort has the greatest impact and when regrowth between visits is fastest.

Coral spawning and larval settlement

Reducing algal cover before the peak coral spawning season may help maximise settlement success by increasing available substrate. The timing of coral spawning varies by species and region — local ecological knowledge and published literature for your area can help identify this window.

Post-disturbance conditions

After bleaching events, cyclones, or flood plumes, reef conditions may be temporarily unsuitable for in-water activities due to reduced visibility, debris, altered currents, or stressed coral colonies. Teams should assess conditions carefully before commencing work after significant disturbance events.

Example from the field: Removal timing

At Yunbenun, removal timing has been aligned with the seasonal growth cycle of Sargassum, the dominant macroalgal species at the site. Removal efforts are typically conducted in winter (July), when biomass is low and accessible, and again in spring (October) at peak canopy development, when algal cover is most likely to suppress coral recruitment. This timing helps maximise available substrate ahead of coral spawning and larval settlement. Monitoring surveys are usually carried out in summer (January–April), following peak growth. February is often avoided due to rough conditions and cyclone risk.

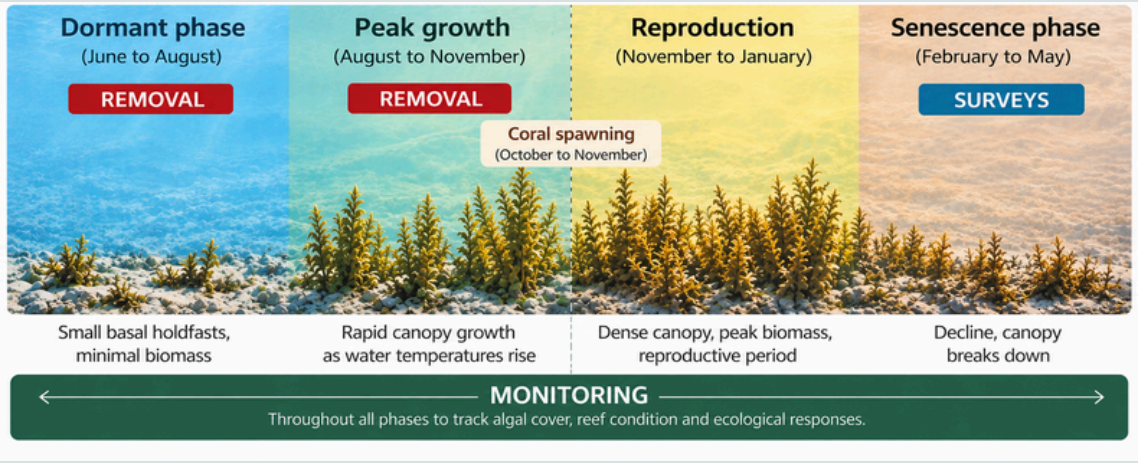


Image 21. Example of interventions based on *Sargassum* life cycle. Image generated with AI assistance

This seasonal approach reflects a balance between algal dynamics, coral recruitment processes, and operational constraints such as weather and site accessibility.

7.2 Physical conditions and operational windows

Conditions that affect both safety and effectiveness include:

- **Tides —** plan activities during favourable tidal phases for the site; slack water periods often provide better conditions. Tidal height should also be considered to ensure safe vessel access and avoid grounding or contact with reef structures
- **Waves and swell —** exposed sites may have narrow windows of suitable conditions
- **Wind —** wind strength and direction influence surface conditions, vessel safety, and site accessibility; strong or persistent winds can generate chop, reduce visibility, and limit safe operational windows
- **Currents —** strong currents affect diver safety, algal bag management, and removal efficiency
- **Visibility —** turbid conditions reduce effectiveness and increase safety risk
- **Depth —** shallow sites may restrict vessel access and increase the risk of grounding or coral damage, particularly at low tide. This may require divers/snorkellers to enter the water further from the site and swim to the plot

Your protocol should **define minimum acceptable conditions** for activities to proceed, and identify how these will be assessed prior to each event.

7.3 Herbivore considerations

Manual removal of macroalgae can create space for coral recovery, but herbivorous fish may play an important role in keeping cleared areas from becoming overgrown between removal events. Factors to consider:

- What is the local abundance and diversity of herbivorous fish?
- Are there fishing pressures that may be reducing herbivore populations?
- Would complementary fisheries management enhance the effectiveness of sea-weeding?

If algal regrowth is extremely rapid between visits, herbivore abundance may be insufficient to support sea-weeding as a standalone intervention. **Understanding the herbivore community** at your site **through fish surveys** is an important input to program design.

7.4 Macroalgal species considerations

Not all macroalgae are equal in their impact on coral recovery, their ease of removal, or their regrowth rates. Before developing your protocol, consider:

- Which species dominate your site? Are they canopy-forming species, turf algae, or crustose?
- Are any species known to be particularly toxic to corals or especially resistant to removal?
- **Are any species ecologically important or protected?**
- What is the likely source of regrowth? Retained holdfasts, fragmentation, or recruitment from nearby populations?



Image 22. Fish, coral and different species of macroalgae on the reef

8. Operations framework and safety

8.1 Defined roles and responsibilities

All in-water activities must operate within a clearly defined safety and supervision structure, with every participant briefed on their role before entering the water. The roles, qualifications and supervision required will vary according to local regulations, operating conditions, activity type, participant experience and organisational procedures. The table below outlines **key functions to consider** rather than prescribing universal minimum qualifications. Programs must determine and document the necessary competency, certification and licensing requirements for each operation.

Role	Key responsibilities	Competency considerations
Dive supervisor	Pre-dive risk assessment, buddy pairs, depth/time limits, emergency planning	Rescue Diver or equivalent; First aid
Vessel operator/ Skipper (if needed)	Dedicated vessel command, navigation, man-overboard and other emergency procedures	Relevant marine licence per local regulations
Surface Safety Lead	Constant visual oversight of all in-water participants (divers & snorkellers)	First aid
Monitoring / Data lead	Record biomass weights, counts, photoquadrats, transects	Trained in protocol
Removal team	Manual weeding, bag collection, algal transport to surface	Appropriate dive or snorkelling certification

Table 5. Role and responsibility reference guide

Importantly, **no individual should hold conflicting safety roles simultaneously**. Anyone responsible for vessel operation, surface supervision or in-water safety must remain focused on that role and should not participate in sea-weeding where doing so would compromise their safety responsibilities.



Image 23. Research vessel attached to a mooring line, snorkellers and divers swimming to the research plots

8.2 SCUBA operations

Where SCUBA diving is used, activities must comply with relevant national or state regulations and occupational diving standards. Factors to consider when developing your diving protocol include:

- Minimum certification levels required for removal team members
- Certification requirements for safety roles (SCUBA certifications, first aid, oxygen provider)
- Buddy system requirements and maximum group size in water simultaneously
- Maximum depth and bottom time limits for each dive
- Pre-dive risk assessment procedures
- Emergency response planning (nearest hospital with hyperbaric chamber, coast guard contact, emergency procedures)

All divers must understand the dive plan, their assigned role, operational limits and emergency procedures before entering the water. Conditions should be reassessed throughout the operation, with clear authority given to suspend or end diving when safety limits are approached or conditions change.

8.3 Snorkelling operations

Snorkelling may provide an accessible way for community members, youth groups and participants without dive certification to contribute in suitable shallow-water conditions. A sea-weeding activity may involve snorkellers supporting divers or may be conducted entirely as a snorkel-only operation. Snorkelling also carries inherent risk, and participation must be based on individual competency, site conditions and local requirements.

Snorkelling roles may include:

- Removing and collecting macroalgae in shallow areas
- Transporting collection bags and supporting equipment handling and in-water logistics
- Undertaking basic visual monitoring under guidance
- Relaying observations or communications between the in-water team and surface support

Snorkelling operations require their own supervision and safety structure, including buddy arrangements, participant competency checks, defined working boundaries, suitable flotation where required, and clear entry, exit and emergency procedures. Currents, waves, visibility, depth, marine traffic, weather and entanglement risks must be assessed before each activity.

For snorkel-only operations, a designated supervisor or surface safety lead must maintain oversight of all participants and remain free from conflicting tasks. Snorkellers supporting a dive operation should not be assigned formal oversight of divers. Additional safeguarding and supervision requirements may apply when working with children or young people.

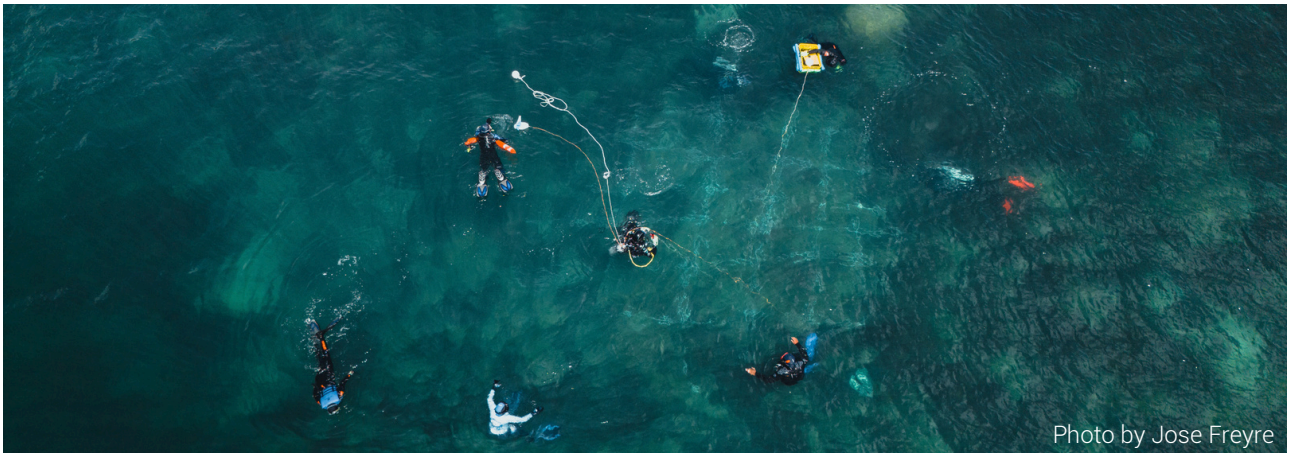


Image 24. Research plot laid out, snorkellers and divers gathered around

8.4 Vessel operations

Where vessel access or support is required, operations must comply with applicable maritime laws, licence conditions, operating limits and organisational procedures. The vessel must be suitable for the site, number of participants, equipment carried and type of in-water activity.

Factors to address include:

- Skipper qualifications required under local maritime regulations
- Vessel insurance and liability coverage
- Pre-departure risk assessment checklist
- Diver-down signalling and engine neutral procedures during in-water activities
- Emergency procedures and diver recall
- Anchoring/mooring requirements or limitations
- Embarkation and disembarkation safety

The skipper must remain in command of the vessel and should not enter the water while responsible for vessel operations. Engine use near participants must be strictly controlled, with procedures clearly communicated during the pre-departure and in-water safety briefings.



Image 25. Example of a pre-activity checklist. Image generated with AI assistance

9. Operational methods

9.1 Equipment

Sea-weeding is intentionally low-tech, but equipment needs will vary according to the site, removal method, monitoring design and whether activities involve snorkelling or SCUBA. The checklist below reflects equipment used in research and community programs, but not all items will be necessary or available in every context. It should be **adapted to local needs and resources**.

Removal and collection

- Mesh collection bags fine enough to retain algal fragments and able to be securely closed
- Suitable gloves for hand protection
- Containers or crates for consolidating and transporting collected algae
- Floats or lift systems for transporting equipment and algae, where appropriate
- Tools approved for the selected removal method, if hand removal alone is insufficient
- Scale and suitable container for weighing macroalgae
- Containers or bags for transporting algae to the approved disposal or use location

Site marking and monitoring

- Transect tapes, quadrats and plot markers
- Waterproof slates, pencils and data sheets
- Underwater camera with sufficient storage, charged batteries and spares
- Sample labels, waterproof tags or identification materials, where required
- GPS or another suitable system for recording site and plot locations

In-water operations, safety and surface support

- Appropriate personal snorkelling or SCUBA equipment for each participant and spares
- Diver floats, surface marker buoys, flags and other locally required signals
- First-aid kit and emergency oxygen appropriate to the operation
- Reliable communication equipment such as marine radio and mobile phones
- Drinking water and appropriate sun and weather protection
- Basic equipment repair kit and spare parts

All equipment should be inspected before use, secured during transport and positioned so it does not create entanglement, manual-handling or trip hazards.



Image 26. Example of equipment list. Image generated with AI assistance

9.2 Removal technique

The core sea-weeding technique is hand removal: macroalgae is pulled from the substrate manually, while minimising disturbance to the reef surface and surrounding organisms.

Key considerations:

- Wear gloves to protect hands and corals
- Remove algae by grasping the base of the thallus (the algal body) and pulling gently but firmly
- Avoid scraping the substrate, which can damage crustose coralline algae, coral recruits, and other biota
- Removal technique may need to vary by species. Some macroalgae have extensive holdfast systems that are difficult to remove completely; others fragment easily and must be collected carefully
- Where holdfasts are firmly attached, focus on removing the canopy rather than forcing removal that can risk damaging the surrounding area
- Place removed material directly into collection bags — try to avoid fragments drifting



Image 27. Removal sequence

9.3 Collection and disposal

How removed algal biomass is contained, measured and disposed of affects ecological integrity, biosecurity and the consistency of monitoring data.

- Place removed algae directly into secure collection bags and retain all material for transport to the surface or shore
- Check collected material for corals and other unintentionally captured organisms and, where safe and appropriate, return them carefully to the collection site
- Keep biomass from different plots, treatments or removal periods separate where required by the monitoring design
- Measure wet weight using a consistent method, including the same drainage time, weighing container, scale and units
- Tare the scale or subtract the weight of the empty container before recording biomass
- Record the number of bags, total wet weight, treated area, removal effort and disposal method for each event
- Prevent collected algae and fragments from re-entering the marine environment during transport, weighing and disposal
- Dispose of biomass on land in accordance with local waste, biosecurity and land-management requirements. Options may include approved composting, green-waste processing or another authorised disposal method



Image 28. Weighing and disposal of macroalgae

9.4 Working with community participants

Community-led programs may involve participants with varying experience levels. When designing your protocol, consider:

- Induction and briefing requirements for all new participants
- Differentiated roles that match tasks to skill levels (e.g. experienced divers on removal; newer members on surface support, data recording, or logistics)
- Structured pathways for participants to build skills over time — toward dive certifications, maritime accreditations, or leadership roles
- How to maintain participant engagement and motivation between seasons



Image 29. Snorkelling participants with seaweed bags in a crate with floats

10. Monitoring and adaptive management

10.1 The importance of monitoring

Monitoring serves multiple functions in a sea-weeding program:

- It informs on whether the intervention is working
- It generates the evidence needed to sustain funding and partnerships
- It enables adaptive management - adjusting what you do based on what you are learning

Where capacity allows, a Before–After–Control–Impact (BACI) monitoring design provides a strong basis for evaluation. It compares conditions:

- Before intervention begins and after each removal event / season
- Sites where weeding occurs and comparable control sites, where no weeding occurs

Where possible, multiple treatment and control plots or sites should be monitored using the same methods and timing. This helps distinguish the effects of sea-weeding from background changes associated with seasonality, weather, disturbance or broader environmental conditions. **Without suitable control areas, it is much harder to determine whether observed ecological changes resulted from sea-weeding or would have occurred anyway.** A full BACI design may not be practical for every community program. Where it is not feasible, repeated monitoring of permanent plots or photo-points before and after removal can still provide valuable information.

Programs do not need to measure everything. Monitoring priorities should reflect the objectives of the program and the team's available capacity. Some commonly used monitoring metrics include:

- **Benthic cover:** measure the percentage cover of coral, macroalgae and other major benthic groups using photoquadrats or point-intercept transects
- **Juvenile coral abundance and growth:** count and/or measure juvenile corals, such as colonies smaller than 5 cm, using belt transects or another consistent survey area
- **Herbivorous fish abundance:** conduct standardised underwater visual census transects where appropriately trained observers are available
- **Environmental conditions:** record relevant variables such as water temperature, depth, visibility, current, tides and weather conditions
- **Photographic documentation:** take images from permanent or repeatable photo-points using consistent locations, orientation and framing
- **Macroalgal biomass removed and removal effort:** weigh collected algae before disposal, using a consistent wet-weight method. Record the area treated, removal time, number of participants and frequency of intervention

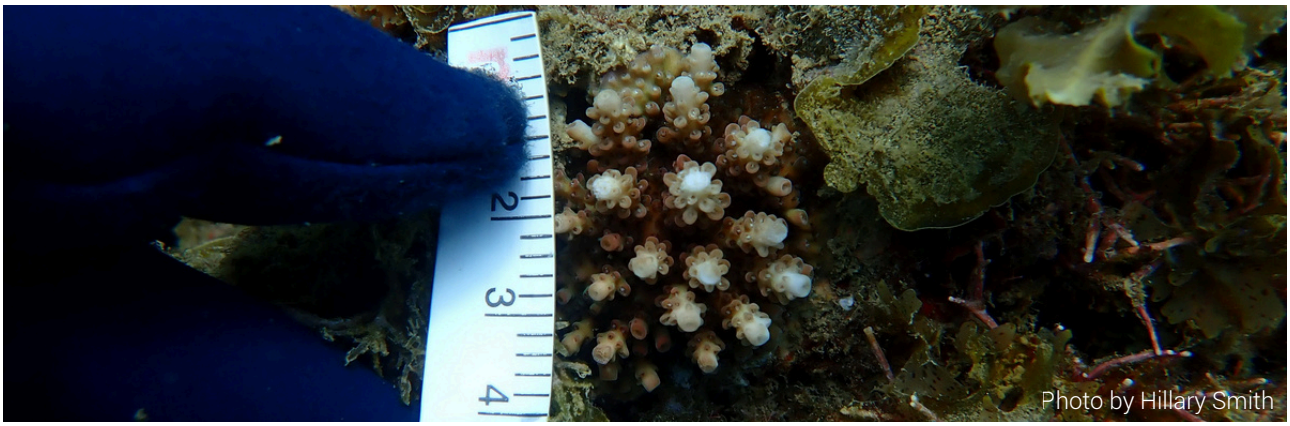


Image 30. Measuring coral juveniles as part of the monitoring program

10.2 Adaptive management

Monitoring findings should inform how the program develops over time. Where possible, agree on decision rules before work begins, including what will be reviewed, when it will be reviewed and who has authority to change, expand or pause the program. For example:

- If coral recruitment, survival or cover improves in weeded areas relative to controls over an appropriate monitoring period, consider maintaining or carefully expanding the treated area
- If macroalgae regrow rapidly, review removal frequency and technique, and investigate possible drivers such as incomplete holdfast removal, nutrient inputs, sedimentation or low herbivore abundance
- If little or no difference is detected between weeded and control areas, check whether the monitoring period, sampling effort and methods were sufficient, reassess the overall approach
- If removal causes unexpected damage to corals, recruits, substrate or other organisms, stop or modify the technique before continuing
- If safety risks, access arrangements or community priorities change, review the operating plan

Adaptive management includes knowing when to stop. Sea-weeding should be treated as a targeted intervention rather than a permanent activity. Programs should define an exit strategy covering when removal can cease, how long monitoring will continue, what would trigger renewed intervention, and how to respond if funding, personnel, governance or operational capacity can no longer support the program safely and effectively.

Any substantial change to the program should be checked against the governance arrangements outlined in section 5.

10.3 Data management and sovereignty

Before monitoring begins, develop an agreed data management plan consistent with the governance arrangements in section 5. This should address:

- Data storage, ownership and access, including who can analyse, publish, present or share data
- How Indigenous data sovereignty principles will be applied to ecological and cultural data
- How contributors and knowledge holders will be acknowledged
- Whether data may be reused for future or unrelated purposes and additional consent required
- How results will be returned to participating communities in useful and accessible formats
- The long-term archiving plan for images, field records, and datasets
- What will happen to the data if the program, partnership or host organisation ends

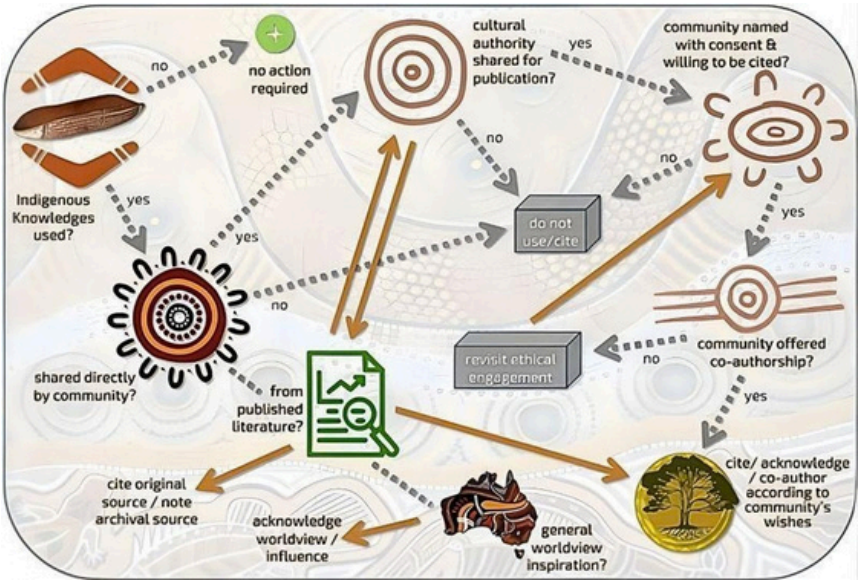


Image 31. An example decision tree demonstrating how researchers could work with Knowledge holders to determine the appropriate citation process that supports the aspirations of relevant First Nations group(s). Barry et al. 2026

11. Capacity building and long-term sustainability

11.1 Investing in people

The long-term success of any community-led program depends on building local capacity. This means developing the skills, knowledge, and confidence for communities to lead and adapt their own programs over time. Training pathways to consider:

- Reef ecology fundamentals: understanding what you are managing and why
- Macroalgal and coral identification: being able to recognise key species in your area of interest
- Monitoring protocols: quadrats, transects, algal removal, coral recruit counting, data recording
- SCUBA or freediving accreditation: formal training pathways toward recognised certifications
- Maritime accreditation: formal training pathways toward recognised certifications for vessel operations
- Leadership skills: dive supervision, safety leadership, scientific and monitoring leadership

11.2 Advisory and governance structures

Larger or longer-term programs may benefit from establishing more formal advisory structures. These can provide accountability, expertise, and cultural governance. Structures to consider include:

- **Scientific advisory group or committee:** provides ecological guidance, research partnerships, and peer review
- **Indigenous advisory or reference group:** ensures cultural governance and Traditional Owner self-determination
- **Community steering committee:** represents the broader community's interests and concerns

11.3 Funding and partnerships

Long-term sea-weeding requires reliable funding and strong partnerships. When planning your program, consider:

- What funding sources are available, such as government grants, philanthropy, research partnerships, conservation programs, responsible tourism or private-sector support?
- Does the budget cover the full cost of the program, including planning, community participation, training, equipment, insurance, monitoring and follow-up visits?
- Will community members, Indigenous rights-holders and local knowledge holders be appropriately paid or otherwise supported for their time and expertise?
- What in-kind support can partners provide, and how will this be recognised without relying too heavily on unpaid labour?
- What partnership agreements will define how authority and decision-making are shared?
- How will funding be managed and reported in a way that is transparent and suitable?
- How will conflicts of interest, commercial benefits, branding and public claims be managed?
- What will happen when the initial funding ends? Which activities can realistically continue?

Funding and partnership agreements should clearly set out each party's roles, responsibilities, decision-making authority and reporting requirements. They should also explain what will happen to project equipment, data and ongoing responsibilities if the funding or partnership ends.

12. Developing your site-specific protocol

12.1 From guidelines to protocol

This document provides a framework for developing a site-specific protocol. Your protocol sets out what the program will do, where and when activities will occur, who holds responsibility, and how decisions will be made. It should reflect the site, participants, governance arrangements, local requirements and agreed objectives.

A complete site-specific protocol should include:

- Program objectives and intended outcomes
- Site description, selection process and ecological baseline
- Target macroalgae and proposed removal method
- Governance arrangements, cultural protocols, permits and approvals
- Partner responsibilities and decision-making arrangements
- Team roles, required competencies and supervision
- Site-specific risk assessment, operational limits and emergency procedures
- Equipment, collection, measurement and disposal procedures
- Operational calendar, including the timing and frequency of activities
- Monitoring methods and data management arrangements
- Community engagement, communications and reporting
- Funding and resourcing arrangements
- Adaptive management triggers and exit strategy
- Process and schedule for reviewing and updating the protocol

12.2 Key questions to answer

- Where will the program operate, and how was the site selected?
- What is the program trying to achieve, and how will success be assessed?
- Which macroalgae will be removed, over what area and using what method?
- Who is involved, and what are their roles, competencies and responsibilities?
- What governance processes, cultural protocols, permits and approvals apply?
- When and how often will activities occur?
- What environmental or operational conditions will trigger a no-go decision?
- What are the main risks, operational limits and emergency procedures?
- What equipment is required, and how will it be inspected, maintained and replaced?
- How will removed algae be contained, measured, transported and disposed of?
- What will be monitored, using which methods and at what intervals?
- How will data be recorded, stored, accessed, shared and governed?
- What findings or changes will trigger a review of the approach, and who will decide?
- When should active removal pause or cease, and what would trigger it to resume?
- How will the program build and retain local skills, knowledge and leadership?
- How will the program be funded, and who is responsible for financial management and reporting?
- Who will review and update the protocol, and how often will this occur?

13. Case study: Yunbenun

This case study shows how the considerations covered in Sections 1–12 have been applied at the established sea-weeding sites at Yunbenun (Magnetic Island). It follows the same structure as the guidelines so readers can compare each consideration with its practical application.

13.1 Understanding the intervention

The Yunbenun sea-weeding program developed from research into coral recovery around the Palm Island Group following Cyclone Yasi. This work highlighted the limited recovery of some disturbed nearshore reefs and the need to investigate active interventions that could help overcome barriers to natural coral recovery.

The substrate and environmental conditions at the Palm Island study areas were not suitable for establishing the proposed intervention. Researchers therefore assessed other nearshore reefs and identified suitable macroalgae-dominated sites at Arthur Bay and Florence Bay on Yunbenun. The sea-weeding research program was established at these sites in 2018.

The intervention uses repeated manual removal of fleshy macroalgae to reduce competition with corals and create opportunities for natural recruitment and recovery. The primary target is canopy-forming *Sargassum*, although other fleshy macroalgae are also removed. The aim is not to remove all macroalgae from the reef, but to reduce excessive cover within defined treatment plots while minimising disturbance to corals, coral recruits, reef substrate and other organisms.

13.2 Evidence and program development

Long-term research at Yunbenun has shown that repeated macroalgal removal can increase coral recruitment and coral cover within treatment plots compared with control plots. Sea-weeding was considered appropriate at Arthur and Florence Bays because:

- Macroalgal competition was identified as an important barrier to coral recovery
- Living adult corals and juvenile corals remained present
- Natural coral recruitment continued to occur
- Stable reef substrate was available for settlement
- The sites could be accessed repeatedly for removal and monitoring
- Treatment and control plots could be established to evaluate ecological change

Research found approximately three times more coral recruits in removal plots than in controls during the initial recruitment study. Over the first three years, coral cover also increased substantially more in removal plots, while macroalgal cover remained lower than in untreated plots.

The program was initially delivered through research expeditions in which corporate partners and citizen scientists could register to participate. From 2025, the expedition model was discontinued as the program began transitioning towards community implementation. During this transition, field activities have been undertaken by James Cook University and Earthwatch Australia staff, together with JCU students participating as volunteers or through research projects connected to the program.

The transition to broader community delivery is ongoing, with community implementation expected to begin in late 2026 or early 2027. This will require continued development of local partnerships, governance arrangements, training pathways, resourcing and operational capacity.

13.3 Sea-weeding within the Staged Restoration Framework

At Yunbenun, sea-weeding is currently used as a Stage 1 habitat-modification intervention. It improves conditions for natural coral recovery before more intensive interventions.

Monitoring has shown that natural recruitment at the established sites is sufficient to support recovery when macroalgal competition is reduced. Active coral delivery is therefore not currently warranted within the sea-weeding plots. This may be reconsidered if:

- Natural recruitment becomes insufficient
- Adult coral populations decline substantially
- A major disturbance fundamentally alters the ecological condition of the sites

13.4 Community readiness and realistic expectations

The program is currently supported by established scientific, cultural, community, operational and funding partnerships. Together, these provide access to:

- Scientific and ecological expertise
- Trained divers and snorkellers
- Vessel and field support
- Monitoring equipment and methods
- Cultural and local knowledge
- Program coordination and funding

The program aims to:

- Reduce macroalgal competition in the reef
- Increase opportunities for coral settlement, survival and growth
- Track long-term ecological change
- Build local knowledge, skills and participation
- Support increased Wulgurukaba and Yunbenun Ranger involvement over time
- Generate evidence to inform future sea-weeding programs

The Yunbenun experience has demonstrated that repeated effort over multiple seasons is required. Ecological responses have varied between sites, seasons and years, and have been influenced by bleaching, flooding, cyclones and other background disturbances.



Image 32. Damselfish swimming around branching corals affected by bleaching and covered by macroalgae

13.5 Governance, cultural authority and permits

The program has historically been delivered through collaboration between James Cook University and Earthwatch Australia, with financial support from Mitsubishi Corporation. Activities take place on Wulgurukaba Sea Country, with ongoing engagement with Wulgurukaba Traditional Owners.

Current roles include:

- **James Cook University:** scientific leadership, research design, permits, monitoring methods, data management and analysis
- **Earthwatch Australia:** program coordination, partner engagement, participant management, funding administration and reporting
- **Wulgurukaba Traditional Owners:** cultural authority, local and cultural knowledge, guidance on Sea Country priorities, and developing involvement in program planning and delivery
- **Mitsubishi Corporation:** financial support and engagement with program outcomes

Decisions are made through discussion among the relevant partners. Scientific information guides ecological and operational decisions, with acknowledgement of each partner's responsibilities and agreement from the relevant parties before substantial changes are made.

Wulgurukaba cultural authority, knowledge and priorities are recognised throughout planning and delivery. Engagement includes developing pathways for ranger training, resourcing and greater active involvement in activities.

As the program transitions towards community implementation, the local dive centre **Pleasure Divers** and a local not-for-profit organisation **CANOE Projects** are joining as local delivery partners. Their roles and responsibilities are currently being developed and will be agreed as part of the community adaptation process. James Cook University currently manages the research permits and approvals required for activities at the established sites. Permit status, conditions and reporting requirements are checked as part of field-season planning.

13.6 Site selection

Activities take place within established research plots at Arthur Bay and Florence Bay. Visual surveys were used to select areas at approximately 3m to 6m depth with comparable topography that were representative of the wider reef system. Twenty-four 25 m² plots were then established across the two bays, with six plots in each bay randomly assigned as controls and six assigned for macroalgal removal.

These sites are shallow, inshore fringing reefs characterised by:

- Seasonal dominance of fleshy macroalgae, particularly *Sargassum*
- Remaining adult coral colonies and juvenile corals
- Evidence of continuing natural recruitment
- Stable reef substrate suitable for coral settlement
- Exposure to flood plumes, elevated temperatures, cyclones and periodic bleaching
- Seasonal variation in weather, visibility and access

Plot boundaries are identified using permanent markers and temporary transect tapes. The same plots are revisited over time, allowing changes in removal and control areas to be compared.

13.7 Environmental and ecological considerations

The program generally undertakes three field periods each year. Monitoring is undertaken during all three field periods, while macroalgal removal occurs only during the two dry-season visits:

- **Wet-season monitoring — February to April or May:** ecological surveys
- **Dry-season removal — July:** macroalgae are removed during the cooler dry-season period
- **Pre-spawning removal — October:** macroalgae are removed before the expected coral spawning and settlement period to increase the availability of suitable substrate

The timing of individual activities may change in response to weather, tides, visibility, site access, bleaching, flooding, cyclones or participant availability.

At Yunbenun, there are no fleshy macroalgal species that are protected, so they are all subject to removal. Although *Sargassum* is the dominant species present, teams also remove other fleshy macroalgae while avoiding damage to corals, recruits, reef substrate or other organisms.

13.8 Operations framework and safety

Field activities operate under relevant James Cook University and Earthwatch Australia risk assessments and emergency response plans.

Roles are assigned before each activity and include:

- Dive and snorkel supervisor
- Vessel operator or skipper (usually the same person as surface watch)
- Monitoring and data lead
- Removal team

The qualifications and competencies required for each role are determined according to the activity, site conditions, organisational procedures and applicable regulations.

Before entering the water, participants are briefed on:

- Their assigned roles, buddy arrangements and planned monitoring or removal tasks
- Dive or snorkel limits
- Vessel and surface-support procedures, including emergency, evacuation and diver-recall
- Expected weather and environmental conditions
- Communication and participant-accounting procedures



Image 33. Divers being briefed on operations for the day

13.9 Operational methods

Equipment

Equipment is selected according to the planned activities. Commonly used items include:

- Mesh collection bags and gloves
- Containers or floating crates
- Transect tapes and quadrats
- Underwater cameras
- Waterproof slates and data sheets
- Personal SCUBA or snorkelling equipment
- Diver flags, floats and surface marker buoys
- First-aid equipment, emergency oxygen and communication equipment
- Handheld weighing scales (when removal happens)

Equipment is inspected before use, secured during transport and thoroughly cleaned after each trip.

Removal technique

Within treatment plots, removal teams:

- Confirm plot boundaries and target macroalgae
- Grasp macroalgae near the base of the thallus and pull slowly and firmly
- Avoid scraping the substrate or damaging corals, recruits and other organisms
- Leave firmly attached holdfasts where removal could damage the reef surface
- Place removed algae directly into securely closed mesh bags
- Minimise the release of fragments
- Avoid dragging bags or equipment across the reef

Collection, measurement and disposal

At the end of each removal activity:

- Collection bags are brought to the vessel
- Each bag is weighed using a handheld scale
- Wet weight, plot, site and date are recorded
- Participant numbers and removal time are recorded
- Collected biomass is currently taken to the primary school on Yunbenun for composting

Community participation

The program was originally delivered through Earthwatch expeditions involving participants from corporate partners, citizen scientists and JCU students. Participants worked alongside researchers and Earthwatch staff, contributing to macroalgal removal, monitoring, equipment preparation and data collection under supervision.

From 2025, the expedition model was discontinued as the program began transitioning towards community implementation. During this transition, field activities have been undertaken by JCU researchers and students and Earthwatch staff.

The next phase will establish a locally delivered community model, with involvement from Wulgurukaba Traditional Owners, Pleasure Divers, CANOE Projects and other community participants. This transition is underway, with community implementation expected to begin in 2027 and supported by appropriate governance, training, resourcing and safety arrangements.

13.10 Monitoring and adaptive management

Monitoring is led by James Cook University using consistent methods across removal and control plots. Monitoring includes:

- Photoquadrats and benthic surveys
- Coral recruit counts and growth measurements
- Herbivorous fish surveys
- Environmental DNA sampling
- Macroalgal biomass removed
- Removal effort, including area, participant numbers and time
- Environmental measurements and observations
- Repeat photographic documentation

Methods and timing remain consistent between years wherever possible. Any changes are recorded and considered during analysis.

James Cook University manages the monitoring data. Intellectual property generated through the program is shared between the relevant partners under the applicable partnership arrangements. Data arrangements cover access, analysis, publication, acknowledgement, future use and the protection of culturally sensitive information.

Monitoring results are reviewed collectively by the partners. The approach may be reconsidered if:

- Macroalgal regrowth changes substantially
- Coral recruitment, survival or cover changes
- Little difference is detected between removal and control plots
- Removal causes unexpected ecological impacts
- Bleaching, flooding, cyclones or other disturbances alter site condition
- Safety, access, governance, funding or partner capacity changes

Active removal may be reduced or cease if coral recovery is sustained and macroalgae remain at acceptable levels without continued intervention. Monitoring would continue at agreed intervals, with triggers for renewed removal if macroalgal dominance returns.



Image 34. Coral pinnacle on a Yunbenun reef

13.11 Capacity building and long-term sustainability

The program is moving towards community adoption by building the local skills and capacity needed for ongoing delivery. This includes:

- Reef ecology training
- Macroalgal removal and ecological monitoring
- Diving, snorkelling and vessel-operation pathways
- Scientific and data-management skills
- Safety and leadership development
- Opportunities for Wulgurukaba Traditional Owners, rangers and other community members to take greater roles in program delivery

Long-term sustainability at Yunbenun will depend on establishing a locally supported delivery model with appropriate governance, training, resourcing and scientific support.



Image 35. Participants loading the vessel

Beyond Yunbenun, these guidelines are intended to support other communities, Traditional Owners, managers and delivery partners to assess whether sea-weeding is appropriate for their reefs and, where suitable, develop locally adapted programs.

They capture lessons from Yunbenun while recognising that adoption elsewhere will require its own ecological assessment, governance arrangements, partnerships and monitoring approach.

14. References and further reading

The following references informed the development of these guidelines. Communities developing their own protocols are encouraged to consult the literature relevant to their context.

Sea-weeding research

- Page, C.A. et al. (2026). A staged and layered approach to restoring turbid nearshore coral reefs. Journal of Environmental Management.
- Mills, K. (2025). Underwater Weeding in Port Phillip Bay: Community-led Removal of the Introduced Algae Undaria pinnatifida. Victorian National Parks Association, Melbourne.
- Smith, H.A. et al. (2025). Sea-weeding enhances early coral survival. Journal of Marine Restoration.
- Smith, H.A. et al. (2023). Manual removal facilitates coral recovery. Journal of Applied Ecology.
- Smith, H.A. et al. (2021). Removal of macroalgae enhances coral recruitment. Restoration Ecology.
- Ceccarelli, D.M. et al. (2018). Rehabilitation of coral reefs through removal of macroalgae. Restoration Ecology.

Coral reef restoration frameworks

- Coral Restoration Consortium (2025). Guide to Coral Reef Restoration: Optimizing efficiency and scale for in situ nurseries and outplanting. CRC Field-based Propagation Working Group.
- Shaver, E.C. et al. (2022). Integrating resilience into coral reef restoration design and practice. Global Change Biology.
- Edwards, A.J. & Gomez, E.D. (2007). Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty. Coral Reef Targeted Research & Capacity Building for Management Programme.
- Reef Restoration & Adaptation Program (RRAP). A Practical Guide to Restoration and Rehabilitation of Rubble on Coral Reefs. Australian Government / GBRF.

Governance and Indigenous rights

- Barry, C., et al. (2026). Crediting and citing Indigenous Knowledges within research. BioScience
- Australian Government National Indigenous Australians Agency (2024). Framework for Governance of Indigenous Data
- Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) (2020a). AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research
- Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) (2020b). A Guide to Applying the AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research
- Carroll, S.R. et al. (2020). The CARE Principles for Indigenous Data Governance. Data Science Journal, 19(1)
- Australian Human Rights Commission (2014). Indigenous peoples' right to participate in decision-making
- United Nations General Assembly (2007). United Nations Declaration on the Rights of Indigenous Peoples
- Australian Government Department of Climate Change, Energy, the Environment and Water (n.d.). The Nagoya Protocol—Convention on Biological Diversity.
- Australian Government Office for the Arts (n.d.). Protecting First Nations traditional knowledge and traditional cultural expressions
- Great Barrier Reef Marine Park Authority (n.d.). Traditional Use of Marine Resources Agreements

Acknowledgements

These guidelines draw primarily on research conducted at Yunbenun (Magnetic Island), as well as the collective knowledge of Traditional Owners, communities, researchers and reef managers who have advanced coral reef restoration practice over many decades.

We acknowledge the Wulgurukaba People as the Traditional Custodians of Yunbenun and its surrounding Sea Country. We recognise their continuing cultural authority, knowledge and responsibility for caring for Country, and pay our respects to Elders past, present and emerging.

The research underpinning these guidelines was led by James Cook University in partnership with Earthwatch Australia and supported by the contributions of researchers, students, citizen scientists and participants from corporate partners. We thank everyone who has contributed their time, knowledge and effort to the long-term monitoring and removal program.

We acknowledge Mitsubishi Corporation for its long-term financial support of the program and the development of these guidelines. We also recognise the Wulgurukaba Traditional Owners and Rangers, Pleasure Divers and CANOE Projects for their involvement in shaping the program's transition towards community adoption and delivery.

Finally, we thank the communities, practitioners and partners who have reviewed these guidelines, provided invaluable feedback and shared their experience. Their input has helped ensure that this document reflects both the evidence from Yunbenun and the practical realities of adapting sea-weeding to other places.

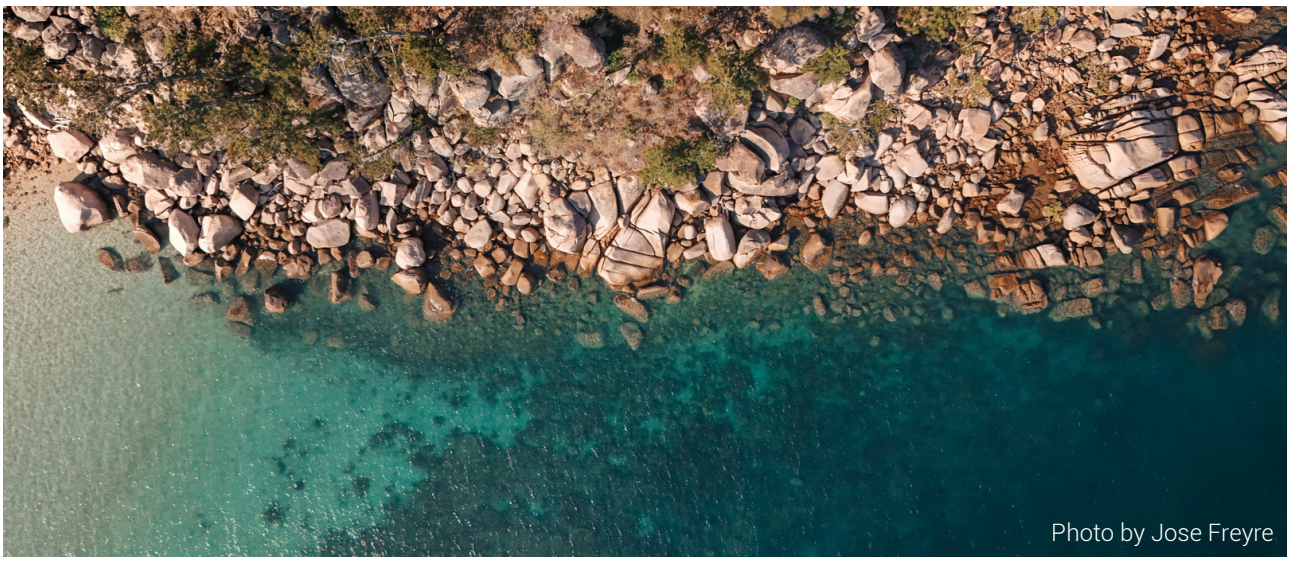


Photo by Jose Freyre

These guidelines are currently undergoing wider consultation. We welcome feedback from Traditional Owners, partners, communities, researchers, practitioners, managers and other interested groups. If you'd like to provide feedback, comments or suggestions, please contact Lucía Caldas Durán at lcaldas@earthwatch.org.au.

Contact

Lucía Caldas Durán
Program Manager
Wetlands, coastal and marine environments
lcaldas@earthwatch.org.au