REBUILDING AUSTRALIA'S LOST SHELLFISH REEFS

Reef Builder Monitoring and Evaluation Report

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Australian Government

The Nature Conservancy Australia

Contents

REEF BUILDER MONITORING AND EVALUATION REPORT

Award Information

Program Title: *Reef Builder*

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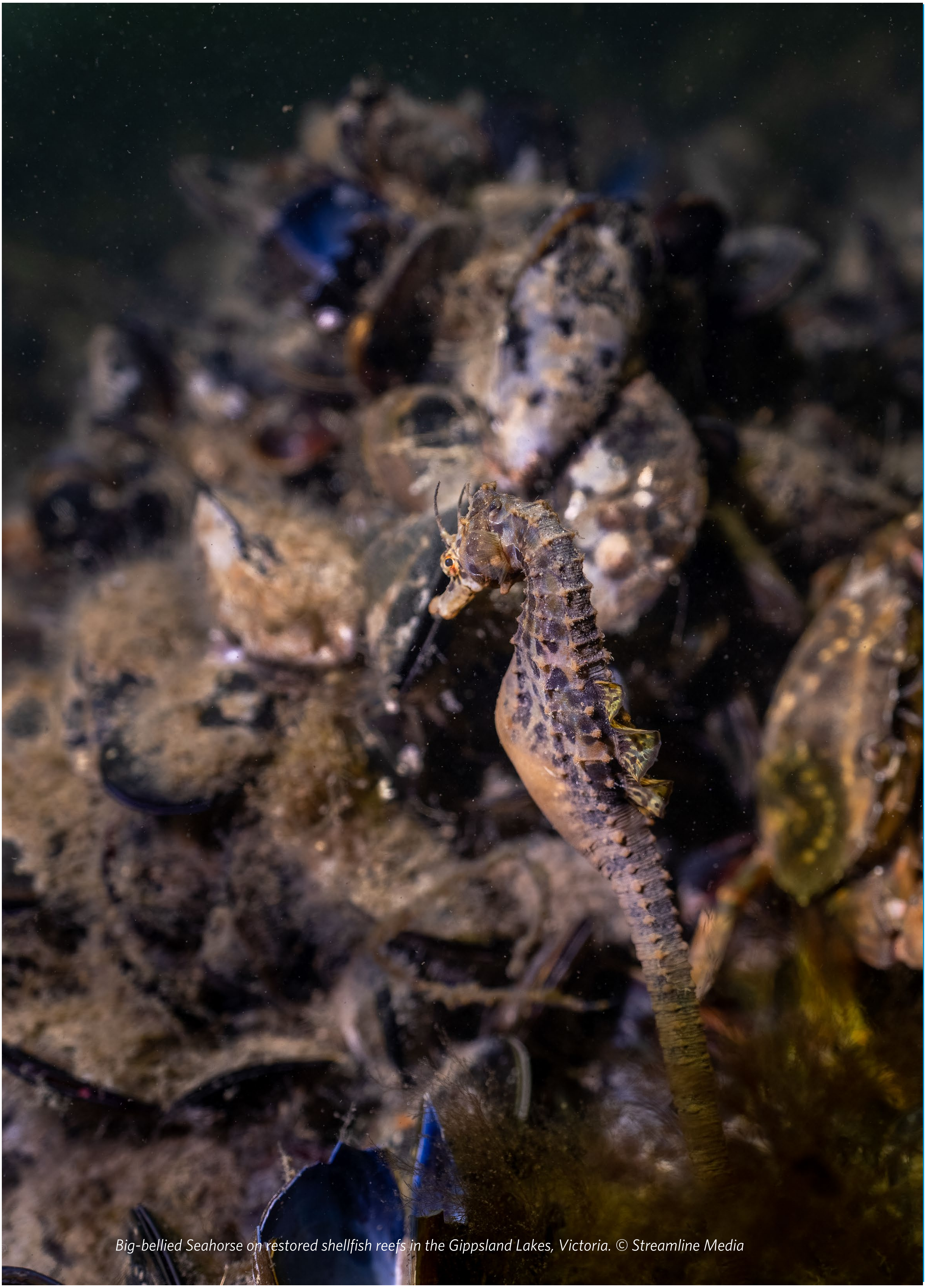
Photo credits:

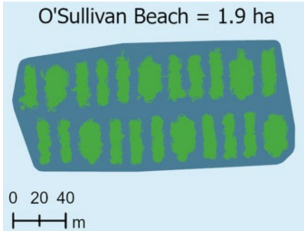
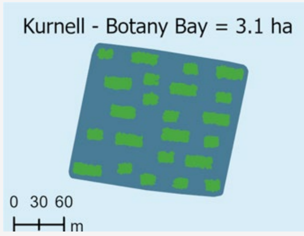
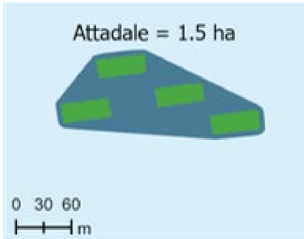
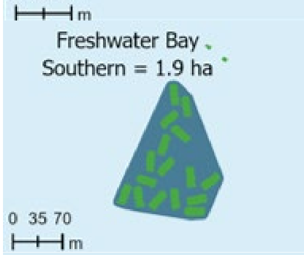
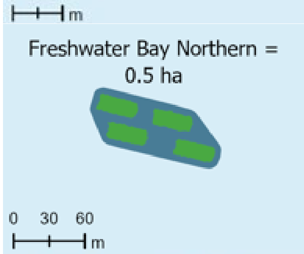
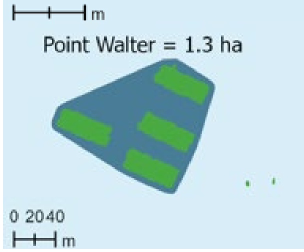
Front cover: *Australian Flat Oyster and Blue Mussel recruits on restored reef in Gippsland Lakes – VIC (2023) provided by Scott Breschkin – TNC Australia*

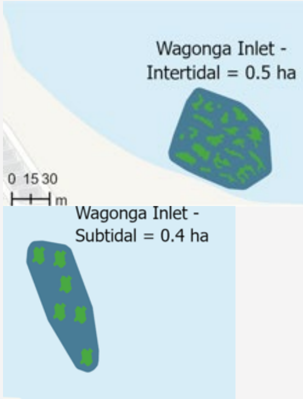
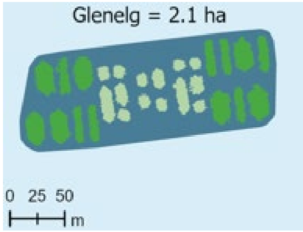
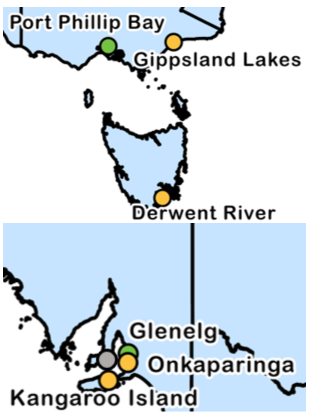
Back cover: *Bald octopus on restored Dromana reef in Port Phillip Bay – VIC (2023) provided by Elgin Associates*



Big-bellied Seahorse on restored shellfish reefs in the Gippsland Lakes, Victoria. © Streamline Media

Glossary of Terms

Term used	Explanation	Example	Visual
Reef patches	A shellfish habitat (i.e., an oyster reef or mussel bed) is defined as patches of living and nonliving oyster/mussel shell (or reef substrate with and without live oysters/mussels). **Reef patches** are the spatial area of restored shellfish reefs/beds.	The **Restoration location** 'O'Sullivan Beach' within the **Restoration project** 'Onkaparinga' has 22 individual **Reef patches** indicated in green.	
Restoration footprint	**Restoration footprint** is the total area of **Reef patches** and is calculated as the sum of area of all **Reef patches** at a **Restoration location**.	The **Restoration location**, 'Kurnell – Botany Bay' of the 'Botany Bay' **Restoration project** in NSW has the largest **Restoration footprint** 0.7 ha (7,428 m^2) which reflects the total area of 23 **Reef patches**. The **Restoration area** of this **Restoration location** is 3.1 ha (31,000 m^2). **Reef patches** are indicated in green, and the **Restoration area** is in dark blue.	
Restoration locations	**Restoration locations** are an aggregation of all sites where monitoring has been carried out. The term is inclusive of **Restoration area**.	'Attadale', 'Freshwater Bay Southern', 'Freshwater Bay Northern', and 'Point Walter' are the four **Restoration locations** of the **Restoration project** 'Swan-Canning Estuary'.	

Restored reefs	**Restored reefs** are counted towards the '60 Shellfish Reefs Target' for TNC by meeting the following criteria: i) **Reef patches** exceeding 250 m^2 (individual or mosaic) with at least one **Reef patch** exceeding 5 m^2 and a maximum distance between **Reef patches** of 30 m in mosaics, ii) **Restoration area** exceeding 0.5 ha, and iii) distance to nearest neighbouring **Restored reef** is equal to or greater than 2 km unless ecologically distinct (e.g. intertidal vs. subtidal reefs).	For the **Restoration project** 'Sapphire Coast', the **Restoration location** 'Wagonga Inlet - Intertidal' counts towards a **Restored reef** as the total area of **Reef patches** exceeds 250 m^2, at least one **Reef patch** exceeds 5 m^2, the maximum distance between **Reef patches** is less than 30 m and the **Restoration area** exceeds 0.5 ha. This is not the case for the 'Wagonga Inlet – Subtidal' which, although ecologically distinct, has a **Restoration area** of 0.4 ha.	 *(pictures have the same scale)*
Restoration area	**Restoration area** or restored ocean area is the area where ecological benefits (e.g., increase in fish biomass, improvement of water quality) are experienced from reef restoration. **Restoration areas** are obtained by calculating the minimum convex hull around all **Reef patches** (including a 5 m buffer around the patches) in a **Restoration location**, capturing the interstitial space between **Reef patches**.	The total **Restoration area** of the **Restoration location**, 'Glenelg' within the **Restoration project**, 'Glenelg' is 2.1 ha. It includes the sum of **Restoration footprints** (green and light green) as well as dark blue area indicating the convex hull around the **Reef patches.** In light green are **Reef patches** that were built prior to *Reef Builder* while **Reef patches** in green are the enhancements added during the *Reef Builder* Program (2021-2023).	
Monitoring sites	**Monitoring sites** are the lowest spatial level where monitoring is carried out at fixed sites repeatedly over time. Monitoring data is collected at a point in space through time at a **Monitoring site.** **Monitoring sites** also include data collected at positive and negative control sites or reference sites such as seagrass sites, soft-sediment sites, and shellfish reef reference sites. The type of **Monitoring site** is determined by the type of habitat e.g., 'shellfish reef' **Monitoring sites**, 'seagrass' **Monitoring sites**, or 'soft-sediment' **Monitoring sites.**	**Monitoring sites** are the places where divers carry out surveys e.g., deploy Baited Remote Underwater Video Stations (BRUVS) or lay transects to capture data following the Reef Life Survey methods. **Monitoring sites** have replicates (at least n=3) for each type of survey e.g., 'Margaret's Reef Site 1', 'Margaret's Reef Site 2', 'Margaret's Reef Site 3' for Reef Life Surveys etc.	
Restoration project	**Restoration projects** are an aggregation of **Restoration locations** for the purpose of geographic representation. **Restoration projects** can be one-to-one i.e., the **Restoration project** has only one **Restoration location** (e.g., 'Glenelg') or one-to-many where one **Restoration project** has multiple **Restoration locations** (e.g., 'Port Phillip Bay' or 'Swan-Canning Estuary').	'Port Phillip Bay' constitutes a **Restoration project** which contains multiple **Restoration locations** ('Dromana', 'Margaret's Reef', 'Wilson Spit'). 'Glenelg' is a **Restoration project** with only one **Restoration location** ('Glenelg') which has the same name as its **Restoration project.**	

Executive Summary

Reef Builder was a partnership between the Australian Government and The Nature Conservancy (TNC) with the ambitious goal of rebuilding lost shellfish reef ecosystems at 13 projects across southern Australia. With 21 shellfish reefs now restored to date, it has provided a significant boost towards TNC's broader goal of rebuilding 60 reefs across Australia by 2030 and recovering 30% of these lost habitats for the benefit of both people and nature.

Shellfish reefs, created when millions of oysters and mussels settle onto each other, are natural solutions to some of our greatest conservation challenges. They improve coastal water quality, boost fish stocks, provide homes for a diverse range of sea life, generate regional employment, and protect Australia's coastal communities and shorelines from coastal erosion.

Once expansive across Australia's estuaries and bays, most of these natural habitats have been decimated since the 1800s by years of commercial harvesting, sedimentation, pollution, introduced species and disease. Fewer than 8% of our natural shellfish reefs remain across southern Australia's coastline today, rendering them functionally extinct.

Reef Builder was an AU$20 million Program of work carried out between January 2021 and December 2023 to rebuild shellfish reefs at 13 projects across Western Australia, South Australia, Victoria, Tasmania, New South Wales, and Queensland to accelerate the recovery of our lost shellfish reef ecosystems. It builds on the demonstrated success of TNC and local delivery partners in restoring these vital habitats at multi-hectare scales across southern Australia since 2015.

The primary aims of *Reef Builder* were to (1) restore Australia's estuarine and coastal ecosystems through rebuilding a critically endangered marine ecosystem, improving local biodiversity and boosting fish populations, and (2) provide economic stimulus to shellfish aquaculture, marine engineering, construction, monitoring and ecotourism businesses in coastal and regional communities.

The Program was underpinned by four key targets and six goals, each aimed at specific, measurable, achievable, realistic, and time-bound (SMART) outcomes (**Table 1**).

The primary purpose of this report is to summarise key analyses of the ecological, social, and economic data collected during the *Reef Builder* Program to determine the level of success in achieving the Program targets and goals. It further outlines the monitoring and evaluation approach used to help inform future large-scale shellfish reef restoration efforts in Australia and worldwide.

The synthesis presented in **Table 1** demonstrates that *Reef Builder* has met or exceeded almost all of the Program targets spanning reef construction, biodiversity benefits, job creation and community engagement.

These outcomes verify the clear benefits that restoring Australia's lost shellfish reefs at meaningful scales can bring for people and nature.

***Table 1**. Summary of Reef Builder Program Targets and Key Outcomes.*

Program Targets (2021-2023)	Key Outcomes
1. **Build new reefs** – Construct shellfish reefs at 13 project locations, following established best practice project management, restoration, and siting protocols. *Goal 1 - Demonstrate construction of resilient reef structures*	Completed. Shellfish reefs were rebuilt through 13 projects, totalling an area of ocean deriving benefits from restoration of 40.5 ha. When combined with shellfish reefs rebuilt prior to *Reef Builder*, the total area restored is 61.9 ha.

2. **Improve local biodiversity** – Establish oyster and mussel populations and enhance associated ecological communities compared to benchmark ecological targets at each of the 13 projects. *Goal 2 - Rebuild a local shellfish population* *Goal 3 - Demonstrate the creation of habitat that benefits fish* *Goal 4 - Demonstrate that construction of the reef enhances marine biodiversity*	Completed. 30 million native shellfish (oysters and mussels) were seeded onto the reef bases across the 13 projects. 1,275 hours SCUBA diving undertaken to construct, seed and monitor development of the reefs. Fish biomass (for pelagic species) was typically greater at restored reefs than in nearby non-restored (reference) habitats. Species richness (spanning fish and invertebrates) was typically higher following reef restoration, and at restored reefs compared to nearby non-restored (reference) habitats.
3. **Boost local employment** – Create up to 170 jobs through employing 120 local contractors from maritime construction, earthmoving, aquaculture, engineering and natural resource management businesses across resource procurement, reef construction and reef monitoring activities. *Goal 5 – Demonstrate the benefit of shellfish reefs to local economies*	Completed. 425 direct jobs created. 51 local contractors were engaged.
4. **Strengthen community engagement** – Harness community interest, support and participation by communicating project progress and success through media opportunities, an online project dashboard, interactive graphics and a project video, as well as creating community volunteering opportunities. *Goal 6 – Engage the community in long-term stewardship of the shellfish reef*	Completed. 537 media events with a combined reach of 203 million viewers. 185 stakeholder and community events with 5,219 people attending. 2,903 hours of volunteering by 305 volunteers.

Graphical Summary of *Reef Builder*'s Achievements (2021-2023)

40.5
Hectares of reef restored

98
Tonnes of recycled shells used

30
Million shellfish seeded on reefs

1,275
Hours of diving for restoration

305
Volunteers involved

2,903
Hours volunteered

425
Jobs created by Reef Builder

51
Small to medium enterprises engaged

Introduction

Background

Marine and coastal ecosystems and the services they provide to support human health and wellbeing are rapidly declining due to habitat degradation, resource exploitation and climate change impacts (Reid et al., 2005; Myers et al., 2013; Cooley et al., 2022). Over the last decade, the importance of restoring these vital ecosystems has gained momentum following agreement by the United Nations General Assembly in 2015 on Sustainable Development Goal 14 to "conserve and sustainably use the oceans, seas and marine resources for sustainable development" and, more recently, adoption of the 2022 Kunming-Montreal Global Biodiversity Framework to "restore 30% of all degraded ecosystems by 2030" under the second of 23 global targets.

Like the more charismatic and colourful coral reefs, oyster reefs and mussel beds are ecosystem engineers that provide many services to people. They enhance water quality through vast filtration capacity and biogeochemical nutrient cycling, provide a habitat and/or food source for many fishes and invertebrates, and contribute to shoreline protection and stabilisation (Coen et al., 2007; Grabowski et al., 2012). These ecosystem services are valued around USD (2012) $5,000 - 99,000 per hectare of reef per year, without accounting for the value derived from harvesting oysters and mussels for human consumption (Grabowski et al., 2012).

Until the 20th century, the estuaries and bays across southern Australia were home to huge expanses of shellfish reefs, together stretching much further than the Great Barrier Reef. After years of wild commercial harvest, sedimentation and water pollution, introduced species and disease, Australia's historic shellfish reefs have virtually disappeared, with only 8% remaining today (Gillies et al., 2018). Worldwide, shellfish reefs are among the most degraded of all coastal habitats, with ~85% of oyster reefs lost globally since the 1800s due to overharvesting and disease (Lotze et al., 2006; Beck et al. 2009; Beck et al., 2011). In some locations, less than 1% of the original shellfish habitats remain, rendering them functionally extinct (Beck et al., 2011).

Shellfish reefs are created naturally when millions of oysters and/or mussels settle onto each other, forming hard reef structures or dense beds, either in intertidal or subtidal areas. The science and methodology of restoring these reefs towards a natural state has advanced significantly over the last decade, and has now become a global practice undertaken at increasing scales throughout the Asia-Pacific, United States and Europe (Fitzsimons et al., 2020). Backed by our global track record in shellfish reef restoration, The Nature Conservancy (TNC) has been progressively growing the scale and geographic breadth of shellfish reef restoration across southern Australia since 2015 in partnership with scientists, government, industry, Indigenous groups and the wider community. Over this timeframe, we have demonstrated that shellfish reefs can be restored at ecosytem scales and their social, economic and ecological benefits returned to coastal communities.

Supported by the Australian Government, the *Reef Builder* Program was established in 2021 to accelerate the recovery of Australia's shellfish reef ecosystems and bring them back from the brink of extinction. Led by TNC working together with local delivery partners and stakeholders, the overarching objective of this Program was to restore native shellfish reefs at 13 project locations across southern Australia from Perth to Noosa. Specifically, *Reef Builder* aimed to:

1. Restore Australia's estuarine and coastal ecosystems through rebuilding a critically endangered marine ecosystem, improving local biodiversity and boosting fish populations, and;
2. Provide economic stimulus to shellfish aquaculture, marine engineering, construction, monitoring and ecotourism businesses in coastal and regional communities.

Here, we present data on these combined efforts derived through the collaboration of more than 200 key stakeholders, including information collected from 2021-2023 for all projects, as well as that collected from 2015–2020 for pre-existing reef restoration projects led by TNC and partners (**Figure 1**).

Importantly, we demonstrate how shellfish reef restoration has not only recovered valuable structured habitat and led to signficant uplifts in biodiversity, but has also provided economic stimulus for shellfish aquaculture, marine engineering, construction and earthmoving businesses in coastal communities and boosted community engagement in habitat restoration.

Program Targets

The *Reef Builder* Program (2021-2023) was underpinned by four key targets.

1. **Build new reefs** – Construct shellfish reefs at 13 project locations, following established best practice project management, restoration, and siting protocols.
2. **Improve local biodiversity** – Establish oyster and mussel populations and enhance associated ecological communities compared to benchmark ecological targets at each of the 13 projects.

3. **Boost local employment** – Create up to 170 jobs through employing 120 local contractors from maritime construction, earthmoving, aquaculture, engineering and natural resource management businesses across resource procurement, reef construction and reef monitoring activities.
4. **Strengthen community engagement** – Harness community interest, support, and participation by communicating project progress and success through media opportunities, an online project dashboard, interactive graphics and a project video, as well as creating community volunteering opportunities.

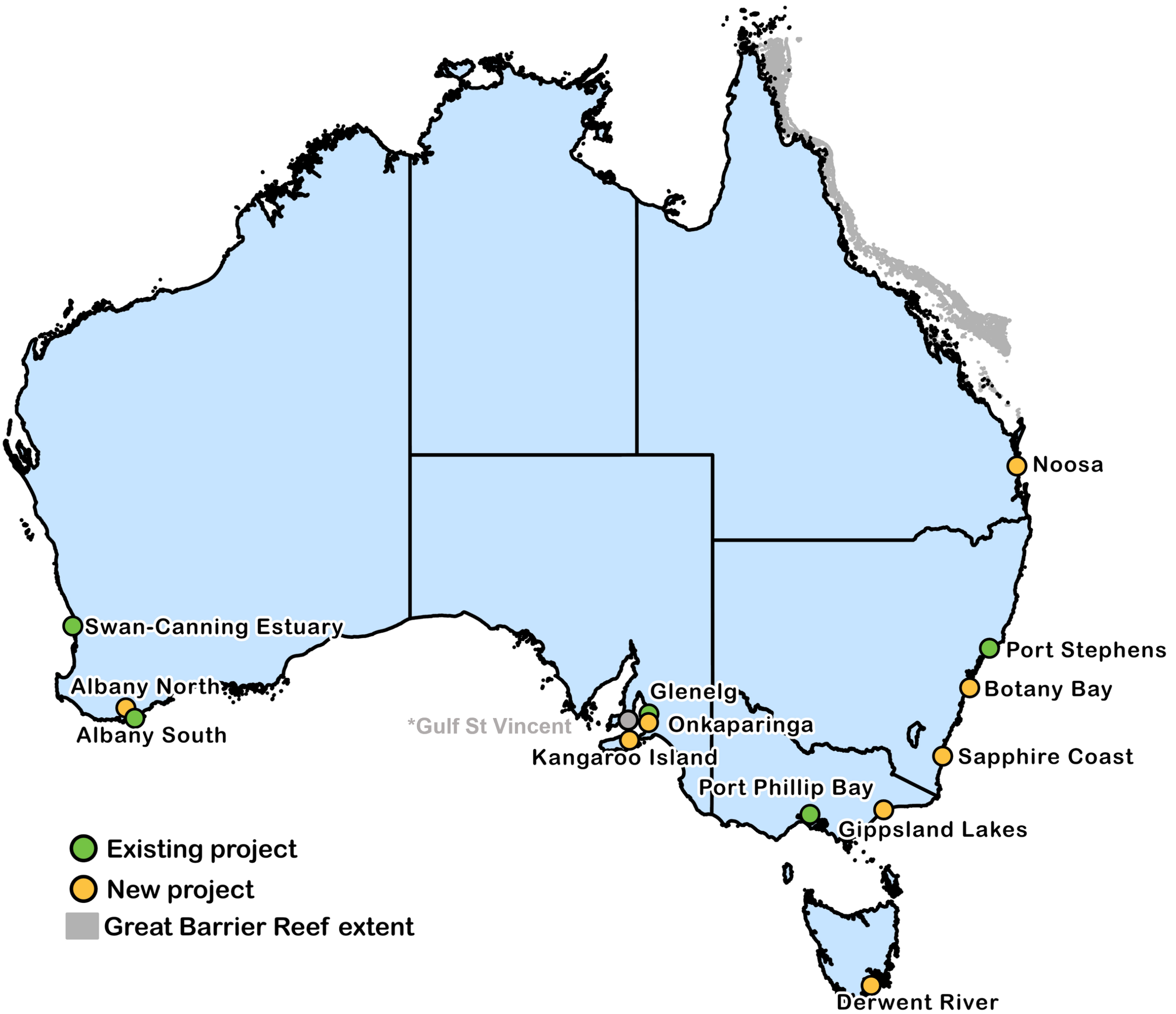


*Figure 1. The 13 project locations at which shellfish reefs were restored during the Reef Builder Program (2021-2023). 'Existing' projects are those at which TNC and partners had initiated reef restoration prior to 2021 and were expanded during Reef Builder, while 'New' projects are those at which shellfish reefs were started during Reef Builder. *Note that the Gulf St Vincent is an additional project at which shellfish reefs were restored by TNC and partners prior to 2021 but was not expanded during the Reef Builder Program. Hence, it has not been counted towards the 13 Reef Builder projects.*

Purpose of this Report

The primary purpose of this Monitoring and Evaluation Report is to summarise key analyses of all environmental and socio-economic data collected during the *Reef Builder* Program (2021-2023).

Specifically, we outline how all indicators recorded compare to the planned output or benchmark, and consequently the level of success in achieving the Program goals and objectives. We further outline the methods used and the monitoring and evaluation approach to help inform future large-scale restoration efforts in Australia and worldwide. The results from *Reef Builder* will also be used to develop publications aimed at sharing the key findings with the international scientific community.

Methods

Project Description

Shellfish reef restoration was undertaken through 13 *Reef Builder* projects between January 2021 and December 2023, which included expansion of reefs at five of those projects that were restored by TNC and partners between 2015 and 2020 (**Figure 1**). The restoration projects spanned (1) Western Australia – Albany North, Albany South, and the Swan-Canning Estuary; (2) South Australia – Glenelg, Onkaparinga, and Kangaroo Island; (3) Victoria – Port Phillip Bay and Gippsland Lakes; (4) Tasmania – Derwent River; (5) New South Wales - Port Stephens, Botany Bay, and Sapphire Coast; and (6) Queensland – Noosa. The restoration projects and specific locations, restoration approach, number of reefs restored, key stakeholders, target shellfish species and total reef area restored are summarised in **Table 2**.

Table 2. Reef Builder restoration projects and their accompanying locations. 'New' indicates shellfish reef restoration projects which started during the Reef Builder Program (2021-2023), while 'Existing' refers to TNC-led and partner projects initiated between 2015 and 2020 and expanded during the Reef Builder Program. Restored reefs are counted as restoration locations that contribute towards TNC's '60 Shellfish Reefs Target' if they meet the following criteria: (i) comprise reef patches exceeding 250 m² (individual or mosaic) with at least one reef patch exceeding 5 m² and a maximum distance between reef patches of 30 m in mosaics; (ii) their restoration area exceeds 0.5 ha, and (iii) the distance to the nearest neighbouring reef is equal to or greater than 2 km, unless ecologically-distinct (e.g. intertidal vs subtidal reefs).

State	Restoration Projects	Restored Reefs	Restoration Locations	New/ Existing	Target Species	Restoration Period	Project Restoration Area (ha)
WA	**1. Swan-Canning Estuary** The Swan-Canning Estuary lies in the heart of Perth. It covers an area of ~40 km² and comprises two rivers (Swan and Canning) that flow into a wide central receiving basin with an adjoining entrance channel which is permanently open to the Indian Ocean at Fremantle. This project expanded upon the 0.7 hectares of pilot mussel reefs restored by TNC in 2020. **Restoration approach**: Blue Mussel reefs were restored using locally sourced rock for the reef substrate and seeded with wild capture mussel stock from a local aquaculture farm. The stock were initially settled on longlines, grown out to adult size, then deployed onto the reef bases. **Key stakeholders**: Department of Biodiversity, Conservation and Attractions (DBCA), Whadjuk Traditional Owners and Derbarl Yerrigan knowledge holders, Department of Premier and Cabinet, Department of Primary Industry and Regional Development (DPIRD), Department of Planning, Lands and Heritage (DPLH), Department of Transport (DOT), Harvest Road Oceans, South East Regional Centre for Urban Landcare, Murdoch University, University of Western Australia, Minderoo Foundation, LotteryWest, Recfishwest, Australian Sailing, OzFish Unlimited, Local Government Associations, and local community members.	1. Attadale 2. Freshwater Bay 3. Point Walter	1. Attadale 2. Freshwater Bay Southern 3. Freshwater Bay Northern 4. Point Walter	Existing	Blue Mussel	2020-2023	New: 5.2 Existing: 0.7 **Total: 5.9**
SA	**2. Albany North and** **3. Albany South** The Albany North and South *Reef Builder* projects are situated in Oyster Harbour, a permanently open estuary	4. Oyster Harbour Northern	5. Green Island 6. Waterski site	Existing	Australi an Flat Oyster	2018-2023	New: 2.3 Existing: 0.4 **Total: 2.7**

	that covers an area of ~15 km² and is located on the south coast of Western Australia. This project expanded on the restoration 0.4 ha of oyster reefs by TNC in 2018-2020. **Restoration approach**: Australian Flat Oyster reefs were restored using locally sourced rock for the reef substrate and seeded with juvenile oysters. These juveniles, derived from local broodstock, were initially reared and settled onto cultch (recycled shell) in the hatchery, then grown out for ~6-months on a local aquaculture farm before deployment. **Key stakeholders**: South West Aboriginal Land and Sea Council, DPIRD, Department of Water, Environment and Regulation (DWER), DOT, DPLH, Albany Shellfish Hatchery, Harvest Road Oceans, City of Albany, Southern Ports Albany, Southern Aboriginal Corporation, Albany Heritage Reference Group Aboriginal Corporation, University of Western Australia, South Coast Natural Resource Management, recreational and commercial fishers, Albany Senior High School, the local Menang Elders and community members.	5. Oyster Harbour Southern	7. Oyster Harbour Northern 8. Oyster Harbour Southern				
SA	**4. Glenelg** Glenelg is a beach-side suburb along the Adelaide metropolitan coast, located on the shore of Holdfast Bay in Gulf St Vincent. This project built on the TNC-South Australian Government partnership to restore Australian Flat Oyster reefs along Adelaide's metropolitan coastline from 2019-2020. **Restoration approach**: Australian Flat Oyster reefs were restored using locally sourced rock for the reef substrate and seeded with hatchery-reared juvenile oysters that were derived from local broodstock and settled on cultch. **Key stakeholders**: Kaurna Traditional Owners, City of Holdfast, Department of Environment and Water (DEW), Department of Infrastructure and Transport (DIT), Primary Industries and Resources South Australia (PIRSA), Adelaide Club, Friends of Gulf St Vincent, South Australian Research and Development Institute (SARDI), University of Adelaide, Flinders University, local oyster growers, Green Adelaide, Recfish South Australia, and local community groups, schools, recreational divers and fishers.	6. Glenelg	9. Glenelg	Existing	Australian Flat Oyster	2019-2023	New: 1.2 Existing: 0.9 **Total: 2.1**
SA	**5. Onkaparinga** Onkaparinga is a coastal area located to the south of the Adelaide metropolitan area within the Gulf St Vincent. **Restoration approach**: Australian Flat Oyster reefs were restored using locally sourced rock for the reef substrate and seeded with hatchery-reared juvenile	7. O'Sullivan Beach	10. O'Sullivan Beach	New	Australian Flat Oyster	2021-2023	**Total: 1.9**

	oysters that were derived from local broodstock and settled on cultch. **Key stakeholders**: Kaurna Traditional Owners, City of Onkaparinga, DEW, DIT, PIRSA and the South Australian Government, SARDI, Flinders University, University of Adelaide, Adelaide Club, Friends of Gulf St Vincent, Green Adelaide, Recfish South Australia, local oyster growers, local community, schools, recreational divers and fishers.						
SA	**6. Kangaroo Island** Kangaroo Island is Australia's third-largest island, situated to the south-west of the Gulf of St Vincent. **Restoration approach**: Australian Flat Oyster reefs were restored using locally sourced rock for the reef substrate. Oyster larvae were reared from local Kangaroo Island broodstock in an Adelaide-based hatchery (SARDI), then transported to Kangaroo Island. In addition, 500,000 larvae were transported to Kangaroo Island and 'remotely set' on cultch on the wharf at the restoration site. The juvenile oysters were grown out for a minimum of 4 months at the hatchery and a subset of remote-set individuals on a local oyster farm then seeded onto the reef base. **Key stakeholders**: Kaurna, Ngarindjerri and Narungga Traditional Owners, Kangaroo Island Council, DEW, DIT, Environmental Protection Authority (EPA), PIRSA, Kangaroo Island Landscape Board, Kangaroo Island Tourism Alliance, American River Boat Shed, American River Progress Association, Kingscote Progress Association, Kangaroo Island Shellfish, OzFish Unlimited, University of Adelaide, Recfish South Australia, Flinders University, local oyster farmers, food and wine tourism operators, local community and schools.	8. Nepean Bay - Eastern Cove	11. Nepean Bay - Eastern Cove	New	Australian Flat Oyster	2021-2023	**Total: 1.9**
VIC	**7. Port Phillip Bay** Port Phillip Bay is a major embayment covering an area of nearly 2,000 km^2 and largely surrounded by urban areas, including the city of Melbourne. This project expanded on an existing 1.8 ha of shellfish reefs restored by TNC from 2017-2020. **Restoration approach**: Mixed Australian Flat Oysters and Blue Mussel reefs were restored using locally sourced rock for the reef substrate. The reefs were first seeded with hatchery-reared juvenile oysters derived from local broodstock and settled on cultch. They were then seeded with Blue Mussels which were naturally recruited onto longlines and grown out by a local farmer for at least six months. **Key stakeholders**: Kulin Nation Traditional Owners, Albert Park	9. Dromana 10. Margaret's Reef 11. Wilson Spit	12. Dromana 13. Margaret's Reef 14. Wilson Spit	Existing	Australian Flat Oyster, Blue Mussel	2017-2023	New: 4.7 Existing: 6.1 **Total: 10.8**

	Yachting and Angling Club, Department of Energy, Environment and Climate Action (DEECA), Parks Victoria, Victorian Fisheries Authority (VFA), Deakin University, University of Melbourne, Victorian Shellfish Hatchery (VSH), Melbourne Water, OzFish Unlimited, Southern Ocean Environmental Link, VRFish, recreational fishers, divers, marine-care groups, hospitality sector.						
VIC	**8. Gippsland Lakes** The Gippsland Lakes are one of Australia's largest coastal lagoons and wetlands, covering more than 400 km^2. The area is also listed as a wetland of international importance under the Ramsar Convention in recognition of the outstanding coastal wetland values. This restoration project was led by TNC with support from the East Gippsland Catchment Management Authority (EGCMA). **Restoration approach**: Mixed Australian Flat Oyster and Blue Mussel reefs were restored using locally sourced rock for the reef substrate. The reefs were seeded with hatchery-reared juvenile oysters derived from local broodstock and settled on cultch. Additional oysters and mussels were also seeded onto the reefs, sourced from a local 'Shellfish Gardening' initiative. **Key Stakeholders**: Gunaikurnai Land and Waters Aboriginal Corporation, EGCMA, DEECA, VFA, Parks Victoria, VSH, Destination Gippsland, Gippsland Lakes Angling Game and Sports Fishing Club, Friends of Nyerimilang, Gippsland Ports, Metung Primary School, Nungurner Primary School, local businesses and community.	12. Nyerimilang	15. Nyerimilang	New	Australian Flat Oyster, Blue mussel	2021-2023	**Total: 2.5**
TAS	**9. Derwent River** The Derwent River Estuary covers an area of ~198 km^2 and bisects the city of Hobart before opening into the D'Entrecasteaux Channel. This new project was led by Natural Resource Management South in partnership with TNC. **Restoration approach**: Australian Flat Oyster reefs were restored using locally sourced rock for the reef substrate and seeded with hatchery-reared juvenile oysters that were derived from local broodstock and settled on cultch. **Key stakeholders**: Tasmanian Aboriginal Centre, Derwent Estuary Program, EPA, Department of Natural Resources and Environment Tasmania, CSIRO, Bruny Island Oyster Growers Association, Kingsborough Council, Marine Safety Tasmania, Marine Solutions, University of Tasmania, Oysters Tasmania, TasPorts, Tasmanian Association for Recreational Fishing, OzFish Unlimited, Tasmanian Parks and Wildlife Service, Marine Solutions, local schools and community.	13. Taroona 14. Woodbridge	16. Taroona 17. Woodbridge	New	Australian Flat Oyster	2021-2023	**Total: 1.4**

NSW	**10. Sapphire Coast** The Sapphire Coast is a coastal region of southeastern New South Wales. The project is located in Wagonga Inlet, Narooma, a drowned river valley estuary that is permanently open to the ocean and covers ~7 km^2. This new project was co-funded and co-delivered by TNC, Eurobodalla Shire Council and NSW DPI Fisheries. It is a 'living shorelines' project that combined restoration of subtidal oyster reefs, intertidal oyster reefs and riparian vegetation to protect the shoreline from coastal erosion and build natural ecosystem resilience. **Restoration approach**: Subtidal Australian Flat Oyster reefs and intertidal Sydney Rock Oyster reefs were restored using locally sourced rock as the reef bases. The Flat Oysters were first reared to the larvae stage from local broodstock at a hatchery near Port Stephens, transported to Wagonga Inlet and remotely set on cultch. The juvenile oysters were then seeded onto the subtidal reef bases. There is an abundant remnant population of Sydney Rock Oysters in Wagonga Inlet that are naturally recruiting onto the intertidal reef bases. For the shoreline works, an existing degraded seawall was removed, the slope of the bank reshaped, then planted out with endemic plant species. There have also been major improvements to public access to the shoreline area, such as a boardwalk, look-out and educational signage. **Key Stakeholders**: Joonga Land and Water Aboriginal Corporation Rangers, Wagonga Local Aboriginal Land Council, BIG4 Narooma East's Holiday Park, Nature Coast Marine, NSW National Parks and Wildlife Services (NPWS), NSW Department of Planning and Environment Crown Lands, NSW Marine Parks, NSW Marine Estate Management Authority, Eurobodalla Shire Council, NSW Department of Primary Industries (DPI) Fisheries, Transport for NSW, local oyster growers, OzFish Unlimited, local fishing businesses and community groups.	15. Wagonga Inlet – Intertidal	18. Wagonga Inlet – Subtidal 19. Wagonga Inlet – Intertidal	New	Australian Flat Oyster, Sydney Rock Oyster	2021-2023	**Total: 0.9**
NSW	**11. Botany Bay** Botany Bay is situated in the Greater Sydney region and is an oceanic embayment with an area of ~38.8 km^2 that receives freshwater discharge from the Georges and Cooks rivers. **Restoration approach**: Australian Flat Oyster reefs were restored using locally sourced rock for the reef substrate and seeded with hatchery-reared juvenile oysters that were derived from local broodstock settled on cultch. **Key stakeholders**: La Perouse Local Aboriginal Land Council, Gamay Rangers, NSW DPI Fisheries, NPWS, Greater Sydney Local Land Services, Sutherland Shire Council, Transport for NSW, Crown Lands, Port of Botany, Sydney Coastal Councils Group,	16. Kurnell - Botany Bay	20. Kurnell - Botany Bay	New	Australian Flat Oyster	2021-2023	**Total: 3.1**

	Georges River Environmental Alliance, Georges River Keeper, Birdlife Australia, NSW Wader Study Group, Oatley Flora and Fauna, Australian National Sportfishing Association, South Sydney Amateur Fishing Association, St George & Sutherland Shire Anglers Club, Sydney Coastal Councils Group, Macquarie University, Sydney Institute of Marine Sciences, University of New South Wales, OzFish Unlimited and local community groups.						
NSW	**12. Port Stephens** Port Stephens estuary is located on the Hunter coast and is ~134 km^2 in size. It is a drowned valley system fed by multiple tributaries (including Myall River, Karuah River and Tilligerry Creek) and is permanently open to the ocean via a large deep entrance. This existing project was led by NSW DPI Fisheries in partnership with TNC and built on the 1 ha oyster reefs restored in 2020. **Restoration approach**: For the Karuah location, intertidal Sydney Rock Oyster reefs were restored within the footprint of abandoned oyster leases by deploying locally sourced rock into reef patches. The Myall reefs were restored on open intertidal sand flats that had no history of oyster farming. The Port Stephens area has an abundant population of Sydney Rock Oysters which are naturally recruiting onto the reef bases. **Key stakeholders**: Woromi Local Aboriginal Land Council, Crown Lands, Port Stephens Council, Myall River Action Club, local oyster growers, local fishers and the general community.	17. Karuah (Garuwaguba Ninang) 18. Myall (Bindayimaguba Ninang)	21. Karuah (Garuwaguba Ninang) 22. Myall (Bindayimaguba Ninang)	Existing	Sydney Rock Oyster	2020-2023	New: 3.1 Existing: 3.3 **Total: 6.4**
QLD	**13. Noosa** The Noosa River flows south from the Cooloola section of the Great Sandy National Park into Laguna Bay, with the estuarine portion of the waterway covering ~18 km^2. The reefs restored in this project are collectively known as the 'Huon Mundy Reefs', named by the Kabi Kabi Traditional Owners after a great spiritual leader and the original name of the Noosa River. **Restoration approach**: Sydney Rock Oyster reefs were restored in the intertidal zone using locally sourced rock, which was deployed into an array reef patches over multiple sites. Recycled shell was also augmented between the rock crevices. The reef bases were seeded with hatchery-reared juvenile Sydney Rock Oysters reared from local broodstock and settled on cultch, augmenting natural recruitment from existing oyster populations. Additional seeding was also provided by a local community 'oyster gardening' initiative led by the Noosa Integrated Catchment Association (NICA). **Key stakeholders**: Noosa Shire Council, The Thomas Foundation, Noosa Parks	19. Noosa Sound	23. Tewantin 24. Goat Island 25. Noosa Sound, West 26. Noosa Sound, East	New	Sydney Rock Oyster	2021-2023	**Total: 0.9**

	Association, Kabi Kabi Traditional Custodians, Noosa Integrated Catchment Association, Noosa Environmental Education Hub, Noosa Community Biosphere Association, Resource Recovery Australia, Department of Fisheries, Maritime Safety Queensland, Ecological Service Professionals, Mooloolaba Fish Market, Tourism Noosa, SEQ universities plus a raft of local Noosa businesses, other community groups and committed volunteers.						
	Total	19	26				40.5

Prior to the commencement of *Reef Builder*, TNC and partners completed shellfish reef restoration at two additional restoration locations, namely **Windara** in the Gulf St Vincent, South Australia (2018-2020, 20.5 ha of Australian Flat Oyster restored area), and **9ft Bank** in Port Phillip Bay, Victoria (0.9 ha of Australian Flat Oyster restored area). While these locations were not expanded on or monitored during *Reef Builder*, their contributions bring the **total number of reefs that can be counted towards TNC's 60 Shellfish Reefs Target restored to date to 21, and the total area of restored ocean to 61.9 ha**.

Overview of the Monitoring, Evaluation, and Reporting (MER) Framework

The Monitoring, Evaluation, and Reporting (MER) framework for *Reef Builder* quantified the construction, ecological, economic and social outcomes of the Program. The framework followed the established principles of the International Society for Ecological Restoration (McDonald et al., 2016; Gann et al., 2019), the Open Standards for the Practice of Conservation (Conservation Measures Partnership, 2013) and best practice methods for shellfish reef restoration (Baggett et al., 2014; Fitzsimons et al., 2020). This included establishing a hierarchal framework that encompasses high level Program targets which are underpinned by measurable goals and objectives, and assesses 'success' against predefined reference ecosystems or models (**Figure 2**).

By defining a common set of indicators and methodologies to measure them, this MER framework provides a fundamental basis for enabling comparisons across all shellfish reef restoration projects nationally, both during and preceding *Reef Builder*.

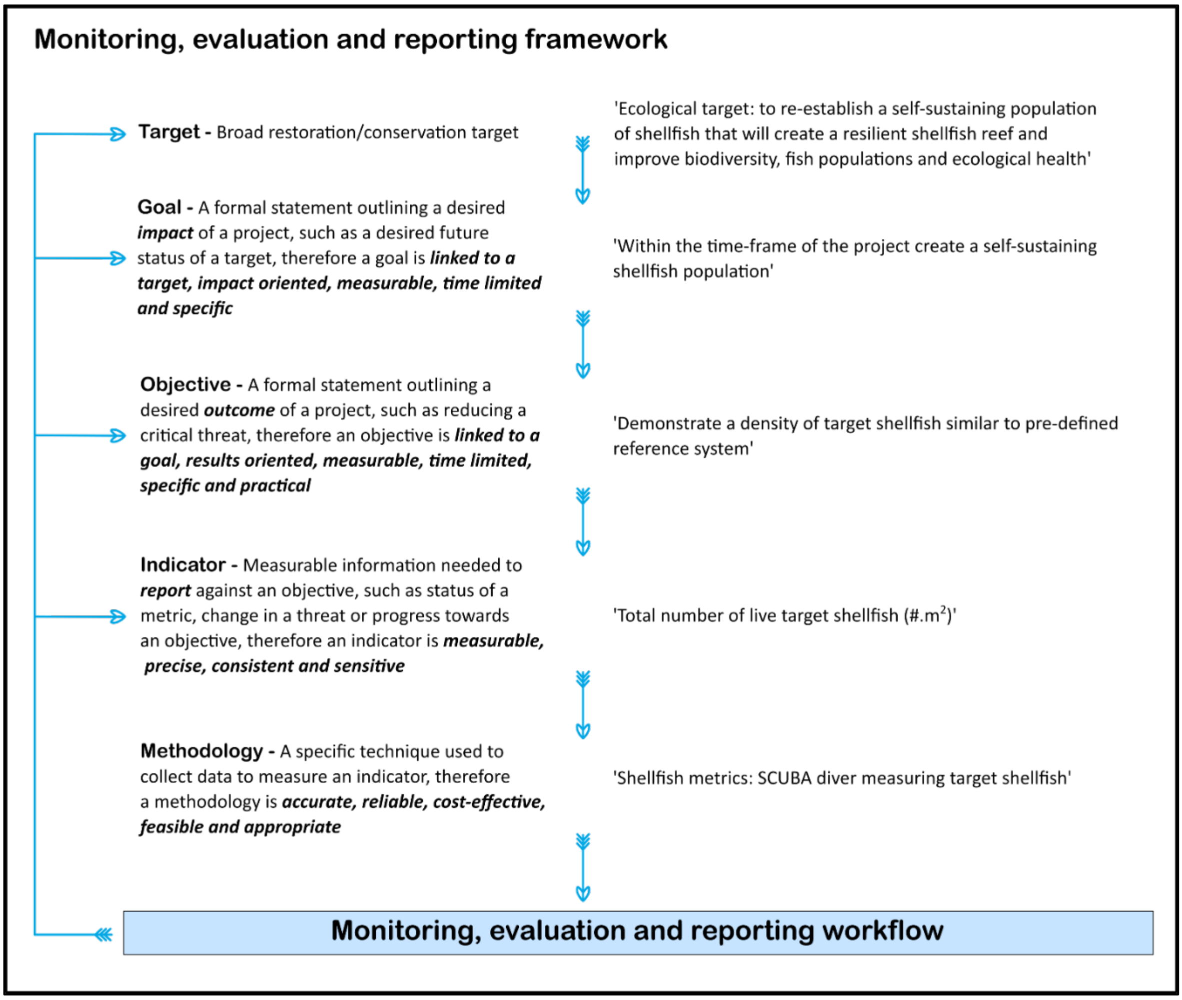


Figure 2. Reef Builder Monitoring, Evaluation, and Reporting (MER) framework used to develop reportable metrics to measure Program success. Definitions of monitoring and evaluation terminology are shown on the left and an example of each is given on the right.

Targets, Goals, and Objectives

Construction target

Vital to the restoration of shellfish reef habitats is the construction of a reef base that forms the 'skeleton' which shellfish inhabit and build upon to create a living reef for other invertebrates, fish and plants. This reef-base provides a fundamental 'helping hand' in the initial phases of the restoration process, elevating newly seeded shellfish from otherwise soft substrate which is often silty, degraded and/or unstable, and providing refuges from predation amongst the rock crevices. The base is constructed primarily from locally-sourced rock, giving the (seeded) shellfish and, for some locations such as those in Port Phillip Bay, can include recycled shell. Construction of the reef-base followed established best practice project management, restoration, design and siting protocols, and is always tailored to the specific conditions at each restoration location.

The construction goals (Goal 1) and objectives (Objective 1) measure whether the Program has delivered on MER Target 1 (see **Appendix 1**).

Ecological target and reference ecosystems

The goals and objectives underlying the Program's ecological target have been developed in accordance with best practice restoration monitoring guidelines (Baggett et al., 2014; McDonald et al., 2016; Gann et al., 2019; Fitzsimons et al., 2020). Reference models have been developed to guide appropriate benchmarks for the restoration of native shellfish reefs (**Figure 3**). Given that true reference ecosystems (i.e. an example natural ecosystem under environmental conditions comparable to those of the restoration location) were largely absent due to the widespread loss of shellfish reefs in Australia, reference models were developed from the scientific literature and expert opinion (e.g. Gillies et al., 2017; McAfee et al., 2020, Roberts et al., 2023). Monitoring used a Before–After Control–Impact (BACI) design that provided strong evidence for causal links between activity and response, and also measured change against the reference condition (Cottingham et al., 2005; Higgins & Zimmerling, 2013; Board et al., 2017).

The ecological goals (Goals 2-4) and objectives (Objectives 2-4) measure whether the Program has delivered on MER Target 2 (see **Appendix 1**). Reporting of ecological indicators included both reporting of trends or the ecological trajectory, as well as Program inputs and outputs (e.g. number of live shellfish deployed and shellfish densities achieved).

Figure 3. Example of expected ecological transition due to reef building from a) existing sand/muddy extinct reef habitats to b) newly laid reefs and c) new shellfish reef ecological communities.

A conceptual graphical timeline of the development of native shellfish reefs is outlined in **Figure 4**.

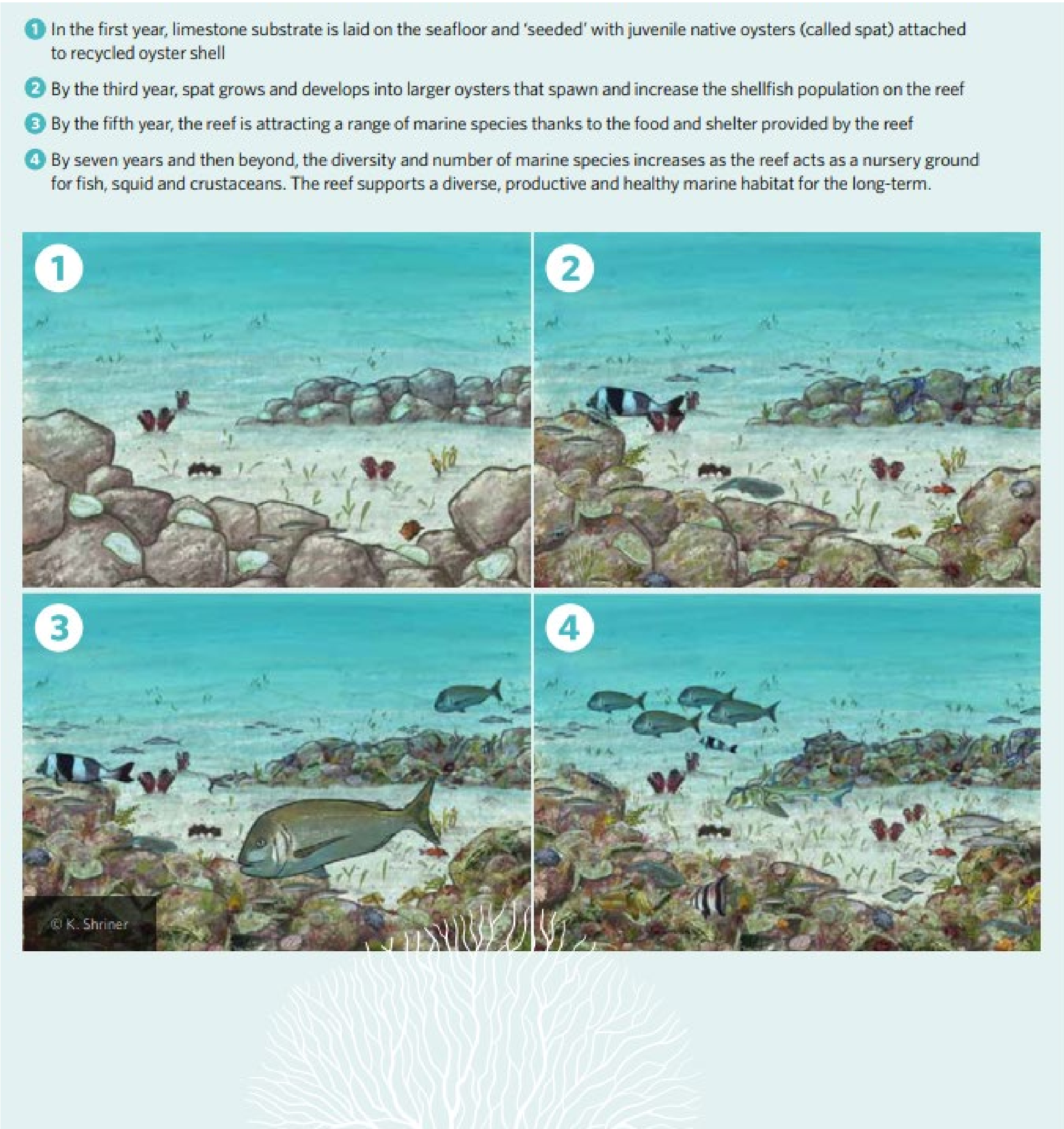


Figure 4. Stages of reef development during shellfish reef restoration © The Nature Conservancy.

Social and economic targets

Restoration is profoundly a human undertaking, and human influence, both positive and negative, dictates the future of restored ecosystems. The social facets of restoration (e.g. community engagement, stewardship and capacity building) are fundamental in building environmental optimism and social-licence, and shifting community focus away from ecosystem decline towards conservation, restoration and recovery. Additionally, the economic aspects of restoration are central to assessing its feasibility and long-term sustainability. Therefore, the ability to measure the social and economic aspects of restoration are essential to assessing its success.

The economic goals (Goal 5) and objectives (Objective 5) measure whether the Program has delivered on MER Target 3, while the social goals (Goal 6) and objectives (Objective 6-8) measure whether the Program has delivered on MER Target 4 (see **Appendix 1**).

Indicators and Methods

The quantitative indicators and methods used to measure the extent to which each Program objective was met are listed in **Appendix 1**.

The methods for monitoring the ecological indicators are adapted from the Oyster Habitat Restoration Monitoring and Assessment Handbook (Baggett et al., 2014), with detailed descriptions provided in **Appendix 2**.

Methods for monitoring social and economic indicators were developed from measuring contractor, community and stakeholder involvement with Program activities. This involved the collection of data on metrics such as the number of labour hours, volunteer hours, workshop/forum attendees, and media mentions. Details for these methods are also given in **Appendix 2**.

Evaluation

Ecological performance indicators

The experimental design for monitoring ecological indicators was based on a Before–After Control–Impact (BACI) design (Underwood, 1994), adapted to shellfish reef restoration.

To evaluate the ecological impact and assess the performance of the restored reef in meeting its targets, it was necessary to perform both pre- and post-construction monitoring and contrast those measurements against control sites located in adjacent habitats, i.e. soft-sediments and, where feasible, seagrass. The soft-sediment control habitats enabled comparison to a 'negative reference' (i.e. as if the restoration action never occurred, also referred to as 'counterfactual'), while seagrass control habitats enabled comparison with another 'positive reference' (i.e. another structured biogenic habitat). The soft-sediment and seagrass control sites were located ≥ 500 m from the restoration sites, but still resided within an area of comparable environmental conditions (**Figure 5**).

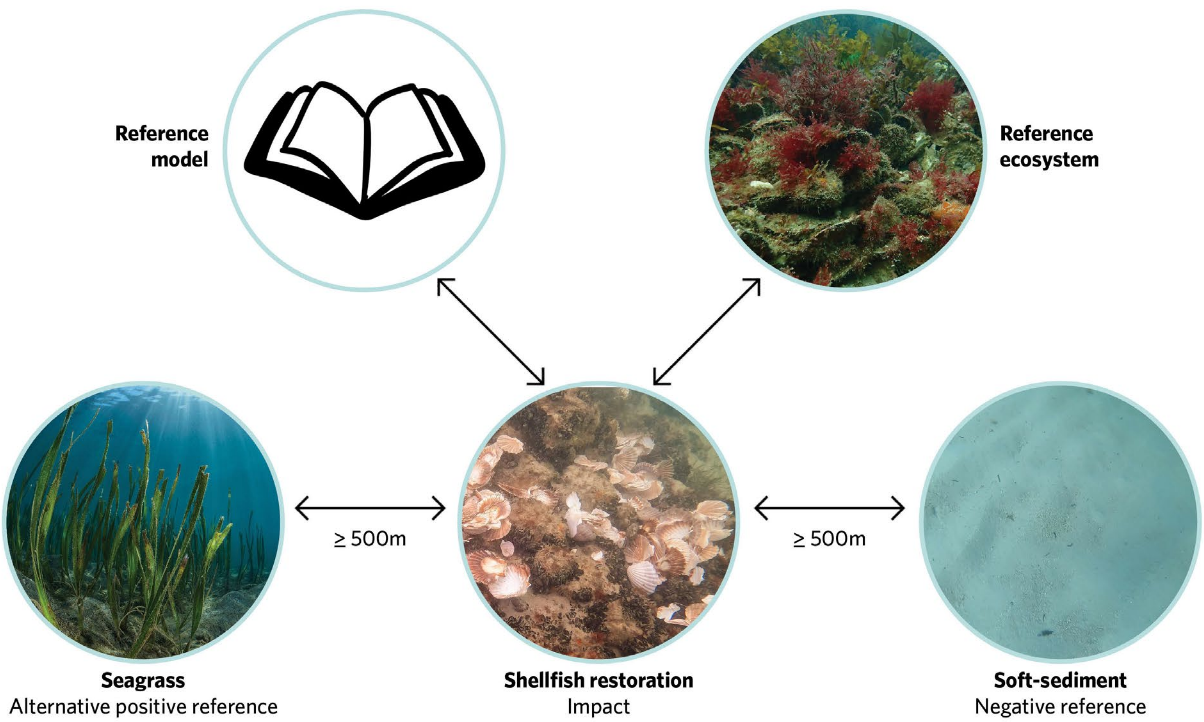


Figure 5. *Conceptual diagram of the ecological monitoring design, including the shellfish reef restoration sites ('impact'), seagrass sites (alternate 'positive reference') and soft-sediment sites ('negative reference'), as per the bottom panel. If an existing, comparable shellfish reef ecosystem was present, this acted as a preferential reference to a reference model derived from scientific literature and/or expert opinion (top panel).*

Social and economic performance indicators

Socio-economic indicators were evaluated by analysing data collected by the Project Coordinators and pre- and post-construction testimonials from key stakeholders and the community. Evaluation of these performance indicators was done by standard analysis workflows, ensuring clear and consistent evaluation products. Each indicator was assessed against a planned benchmark (output and timeframe).

Evaluation of performance indicators

The data for each performance indicator at each restoration location was compiled and initially summarised by calculating summary statistics (mean with standard deviation or standard error) across either location or project for construction, economic and social data. For ecological performance indicators, summary statistics were obtained by location and reef age categories (six monthly intervals post construction) to account for complex/multi-phase reef builds. Here, data was either summarised by location to get total values (e.g. total observed species richness at a location) or averaged across monitoring sites to compare at the transect level (e.g. for Reef Life Survey data) between restored reef sites, controls and reference sites for each age category. This data was visualised by plotting its values in comparison to the relevant benchmark, including time series plots for those sites with successive monitoring events to track progress as reefs mature.

Reporting

The *Reef Builder* reporting deliverables to the Australian Government were based on an agreed activity schedule and six-monthly reporting requirements over the life of the Program. This report constitutes the final Monitoring and Evaluation Report, as per those requirements.

Software

Data was evaluated using the R language (v.4.3.1; R Core Team, 2024) – an environment for statistical computing alongside RStudio, which allows scripts of code to be created and ensures standard analysis workflows, evaluation products and reproducibility.

Results

Target 1: Build new reefs

Overall, **shellfish reef ecosystems were restored at 26 locations covering 40.5 ha of ocean area spanning across six Australian states within the *Reef Builder* Program (2021-2023)** (**Table 2; Figure 6**). Most of the projects had multiple restoration locations and, in some locations such as Glenelg (South Australia) and Margaret's Reef (Port Phillip Bay, Victoria), reefs have been built in multiple phases both before and augmented during *Reef Builder* (**Figure 6**). In total, **19 restored reefs can be counted towards TNC's '60 Shellfish Reefs Target'** as they meet the following criteria: (i) comprise reef patches exceeding 250 m^2 (individual or mosaic) with at least one reef patch exceeding 5 m^2 and a maximum distance between reef patches of 30 m in mosaics; (ii) their restoration area exceeds 0.5 ha, and (iii) the distance to the nearest neighbouring reef is equal to or greater than 2 km, unless ecologically-distinct (e.g. intertidal vs subtidal reefs).

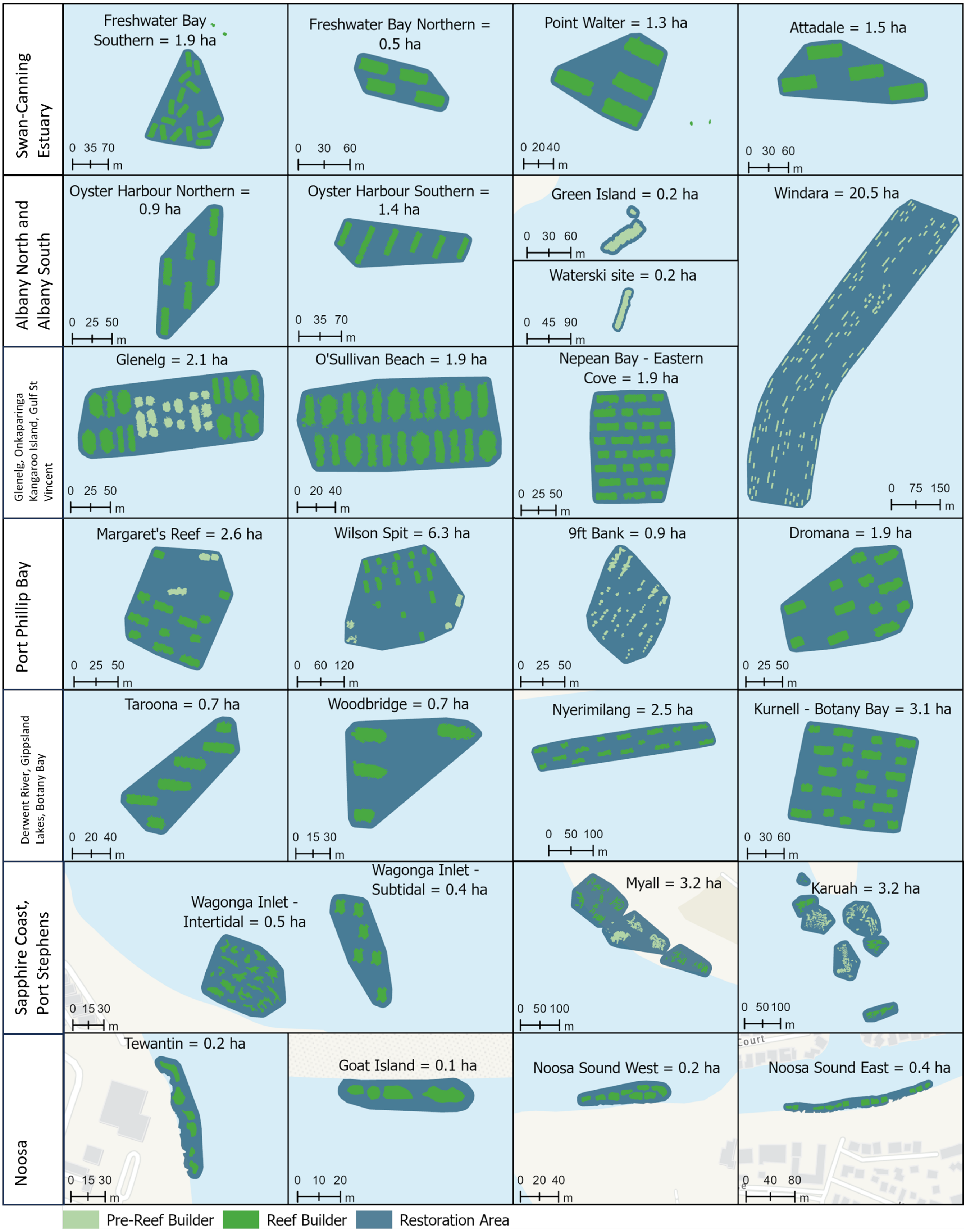


Figure 6. *Map of reef patches and restoration area per location. For each location, the name and restoration area (ha) are annotated. Reef patches are distinguished for their built during Reef Builder (green) or pre-Reef Builder (light green). Note the varying scale for each of the panels. Panels are grouped by project from West to East across Australia, including Swan-Canning Estuary (row 1), Albany (row 2), South Australia projects including Glenelg, Onkaparinga, Kangaroo Island, Windara (row 3), Port Phillip Bay (row 4), Derwent River, Gippsland Lakes, and Botany Bay (row 5), Sapphire Coast and Port Stephens (row 6) and Noosa (row 7). Note that 9ft Bank (Port Phillip Bay) and Windara (Gulf St Vincent) are existing pre-Reef Builder restoration locations, where no on-ground works or monitoring occurred during the Reef Builder Program and therefore have not been included in the results or discussion in this Monitoring and Evaluation Report.*

Goal 1 - Demonstrate construction of resilient reef structures.

Excluding the pre-*Reef Builder* locations, 9ft Bank and Windara, which were not augmented during 2021-2023, a total of **294 reef patches** were built across the 13 projects and 26 locations at which shellfish reefs were either newly built during *Reef Builder* (271 reef patches, 2021-2023) or expanded upon during *Reef Builder* (23 reef patches, 2015-2020). The **total restoration footprint,** i.e. the area covered by shellfish reefs/beds, **was 87,761 m^2 (8.78 ha)**. Per location, the number of reef patches varied from a singular reef (e.g. Waterski site and Green Island locations in Albany) to larger mosaics of more than 20 reef patches in South Australian locations (Glenelg, Nepean Bay and O'Sullivan's Beach) and Botany Bay in New South Wales, with an average of approximately 11 reef patches per location. Likewise, reef patches varied considerably in size. On average, reef patches were 384.4 m^2 (± 301.5 m^2 SD), with the largest patches built in Swan-Canning Estuary at Attadale and Point Walter where average areas covered by patches exceeded 1,000 m^2 (**Figure 7**). These locations also had the tallest reefs, with a maximum heights of approximately 1.9 m reflecting their complex and undulating profile, followed by those at Nepean Bay, Kangaroo Island (1.88 m). Across all locations, mean and maximum reef heights were on average 0.36 m (± 0.19 m SD) and 1.05 m (± 0.49 m SD), respectively.

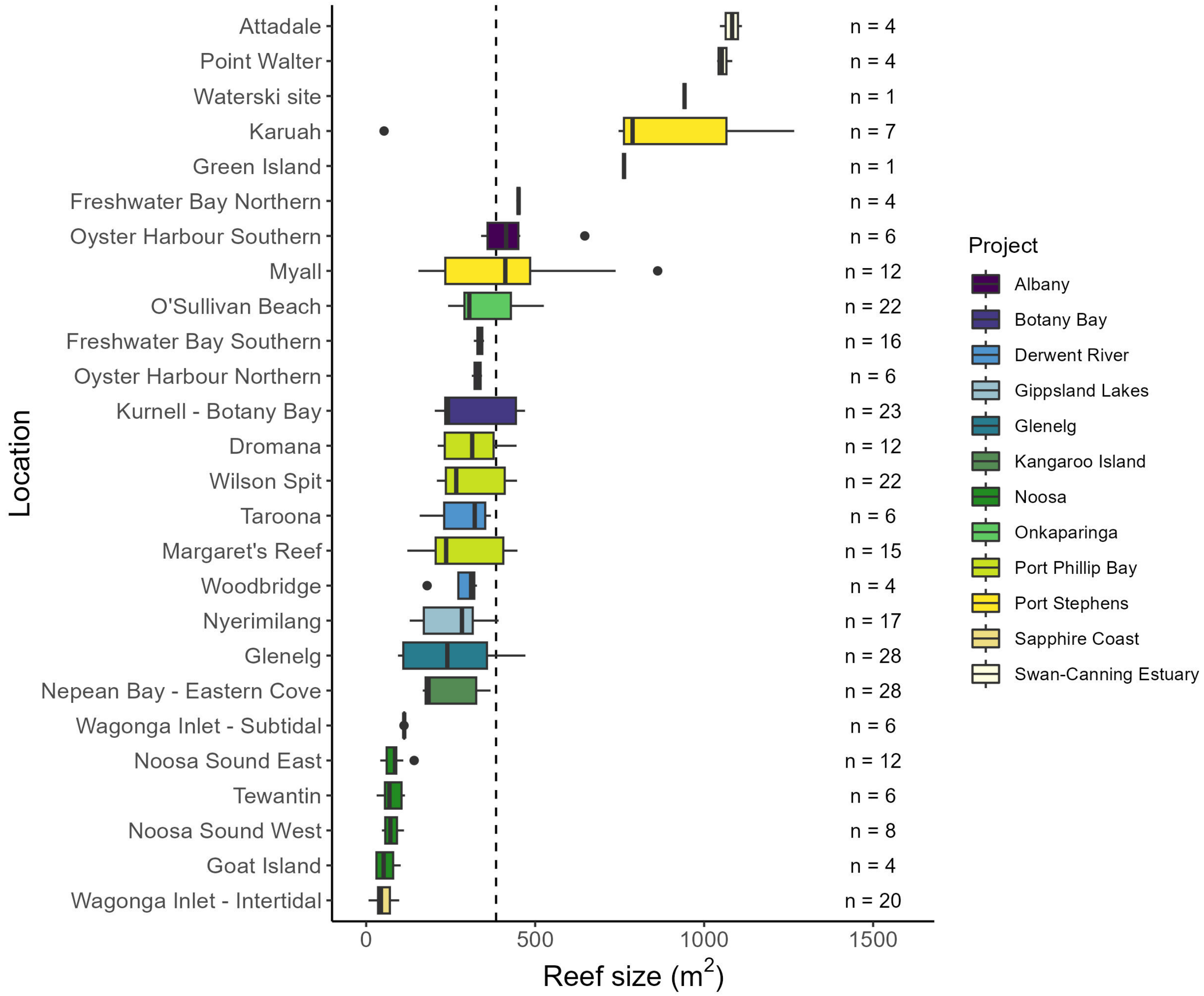


Figure 7. Size of reef patches (m^2) per location and project. For each location, the number (n) of reef patches is provided on the right-hand side. The dashed line reflects the average patch size across all reefs.

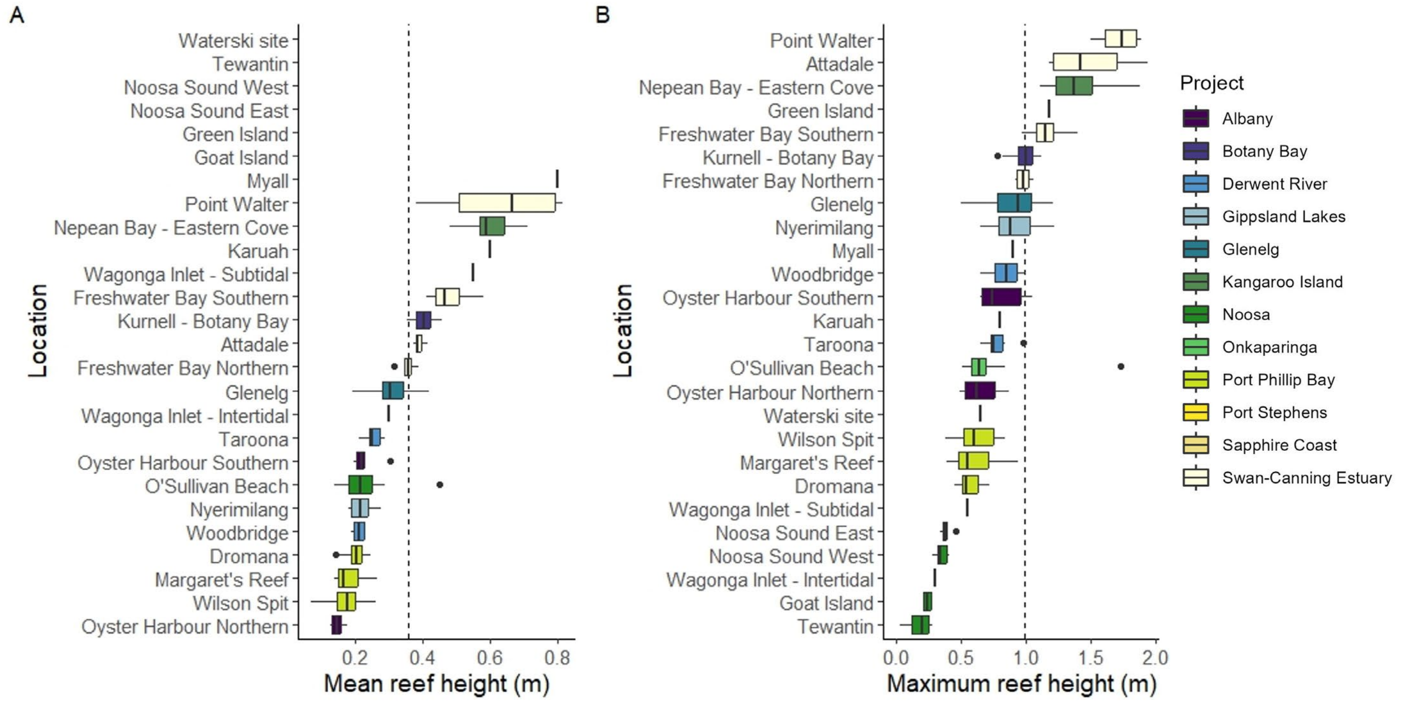


Figure 8. *Mean (A) and maximum (B) reef height (m) across locations and projects. The dashed line reflects the average height across all built reefs. Plots are ordered by height (largest value first), thereby varying the order of locations across panels.*

For construction of the reefs, **a total of 46,601 tonnes of rock and 97.6 tonnes of recycled shells were used**, with the latter primarily used for seeding of oyster reefs, but was also integrated into the reef base at Wilson Spit in Port Phillip Bay (**Figure 9**). The largest amount of rock was used for the reef construction at Kangaroo Island (Nepean Bay – Eastern Cove), followed by those at O'Sullivan Beach (SA), Botany Bay (NSW) and three locations in the Swan-Canning Estuary (WA).

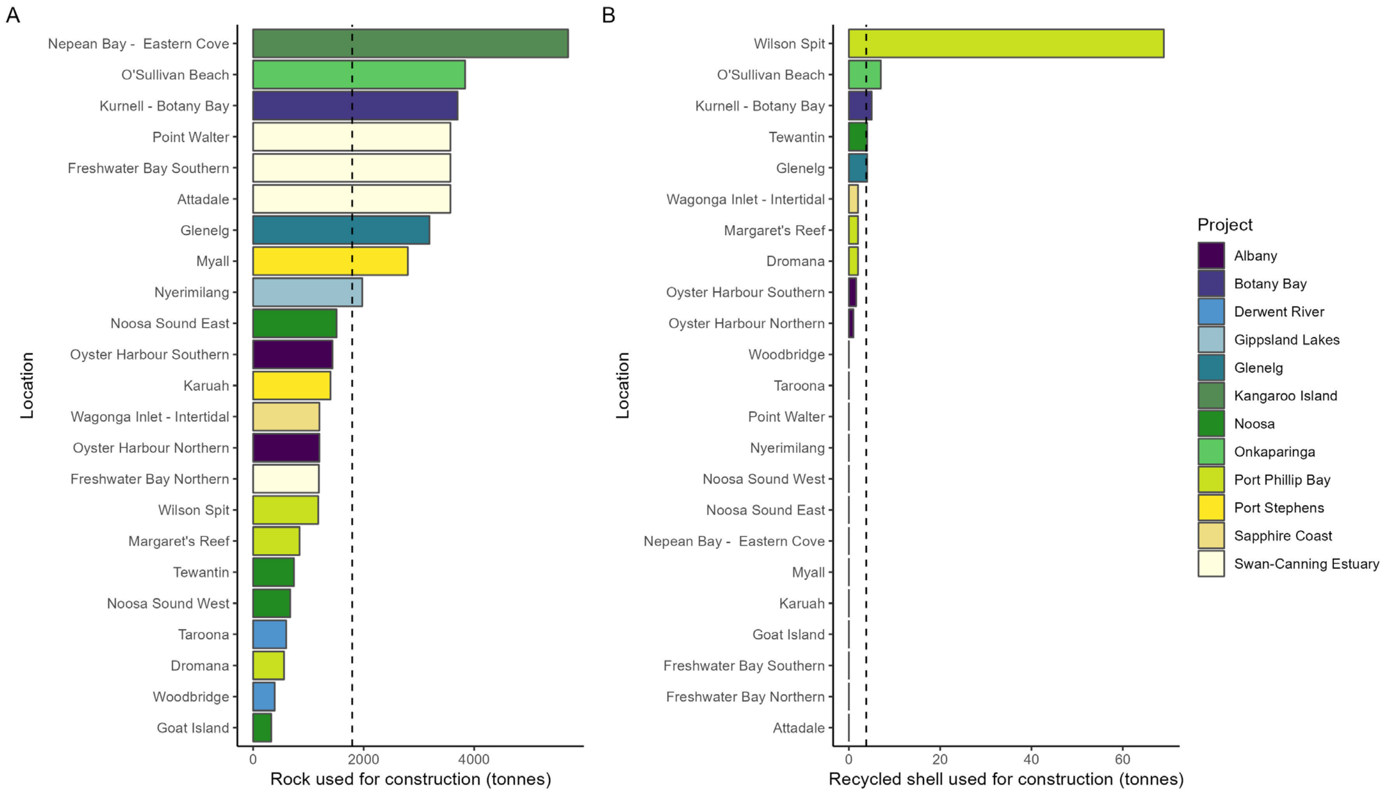


Figure 9. *Materials used for reef construction including total tonnage of rock (A) and recycled shell (B) by location and project. The dashed line reflects the average tonnage across all built reefs. Locations are ordered by value (largest value first) and the order of locations differs across panels.*

The construction of reefs patches across Australia's temperate coastline has resulted in **61.9 ha in total (Table 2) and 40.5 ha (excluding the pre-*Reef Builder* locations 9ft Bank and Windara which were not augmented or monitored during *Reef Builder*) of restored ocean area where ecological benefits are experienced from reef restoration** (**Figure 6**). Restoration area ranged between 0.09 ha (Noosa – Goat Island) to 6.26 ha (Wilson Spit) and averaged 1.53 ha (± 1.41 ha SD) per location. The area covered by reef patches within the restoration area (or percentage cover) ranged between 11 and 47%, with an average cover of 25.9% (± 9.4 % SD) (**Figure 10**). The target percentage cover of 15 to 25% was met in 13 of the 26 locations. One location had a cover of less than 15%, namely reefs built in multiple phases at Wilson Spit (Port Phillip Bay). Other locations such as O'Sullivan Beach and Nepean Bay in South Australia and Freshwater Bay Northern in the Swan-Canning Estuary in Western Australia notably exceeded the target cover of 25%, while locations with single reef units (i.e. Waterski site and Green Island locations in Albany, both of which were built prior to *Reef Builder*) had the highest percentage cover at 42 and 47%. While the latter reefs had no interstitial spaces, the 5 m restoration area buffer around the reef patch reduced bottom cover from 100% (**Figure 6 and 10**).

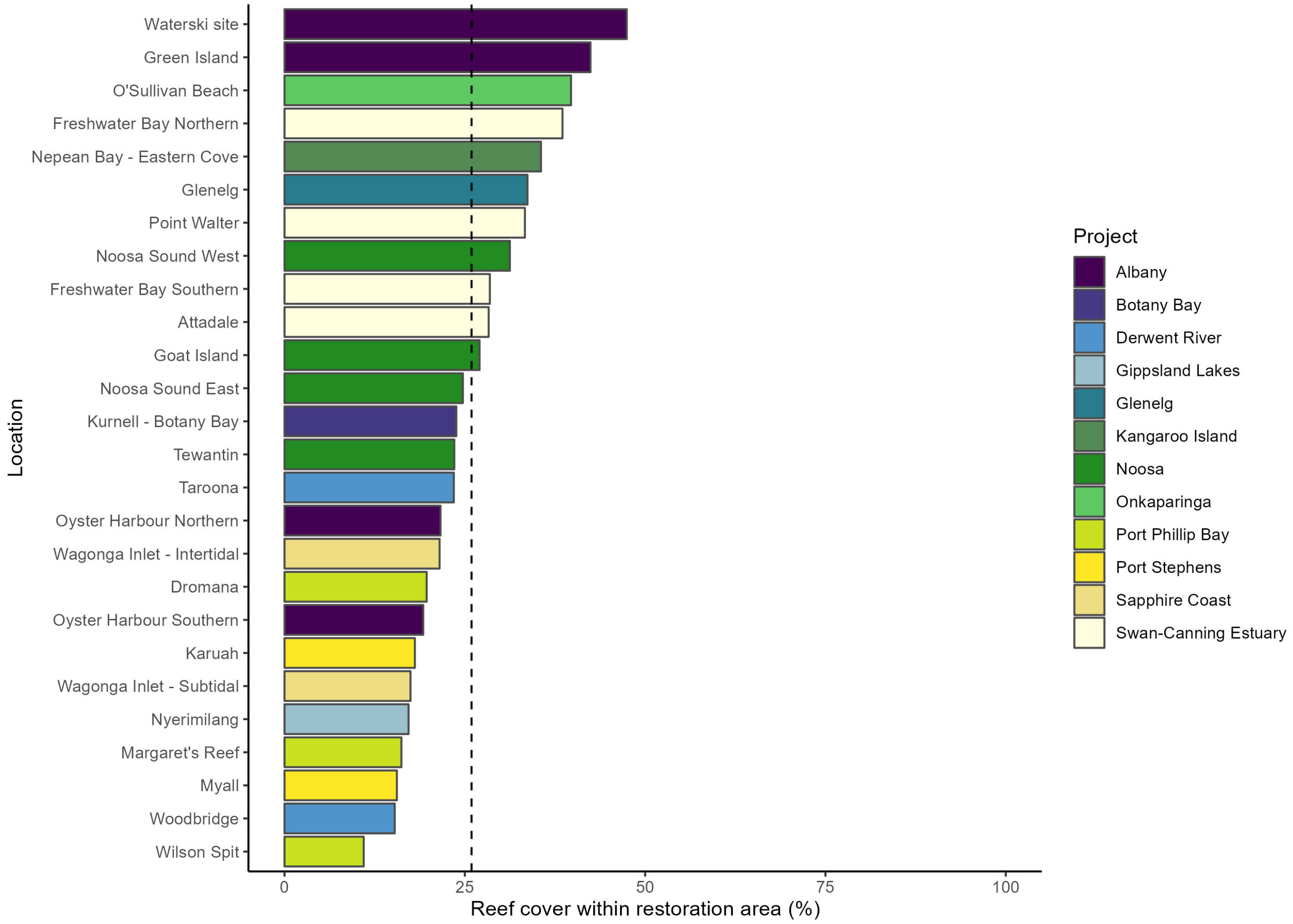


Figure 10. *Reef cover within the restoration area (%) across locations and projects. The dashed line reflects the average percentage cover across all locations. Locations are ordered by percentage cover (largest value first).*

Target 2: Improve local biodiversity

Goal 2 - Rebuild a local shellfish population.

Reef Builder targeted the key reef-forming shellfish species *Ostrea angasi* (Australian Flat Oyster), *Saccostrea glomerata* (Sydney Rock Oyster) and *Mytilus galloprovincialis* (native Blue Mussel). During the *Reef Builder* and pre-*Reef Builder* phases, **restoration locations were seeded with a total of 30,286,640** (juvenile or adult) shellfish including Australian Flat Oyster (*O. angasi*) and/or Blue Mussel (*M. galloprovincialis*) for subtidal reefs, and Sydney Rock Oyster (*S. glomerata*) for intertidal reefs (**Figure 11A**). Seeding with juvenile shellfish was carried out at 21 of the 26 *Reef Builder* restoration locations. For the subtidal locations Green Island and Waterski site in Albany South, seeding was carried out prior to *Reef Builder*, hence the data is not shown in **Figure 11**. Re-seeding is scheduled to be repeated for those two locations in 2024. The other three restoration locations (Karuah and Myall in Port Stephens and Wagonga Inlet – Intertidal in Sapphire Coast) showed natural recruitment, therefore were not seeded during *Reef Builder*. Total seeding included **more than 20 million Australian Flat Oyster juveniles** (20,937,640) in Victoria (Port Phillip Bay and Gippsland Lakes), Tasmania (Derwent River), South Australia (Glenelg, Kangaroo Island and Onkaparinga), New South Wales (Botany Bay and Wagonga Inlet) and Western Australia (Albany) (**Figure 11B**). Some reefs in Port Phillip Bay, namely Wilson Spit, Margaret's Reef and Dromana were seeded multiple times during different construction phases and were co-seeded with more than 750,000 Blue Mussels at once across the three locations. Reefs in the Swan-Canning Estuary were seeded solely with adult Blue Mussels, totalling 7 million individuals. Finally, intertidal reefs in Noosa were seeded with 590,000 Sydney Rock Oysters. On average, shellfish were seeded onto the reefs at densities of 395 ind. m^{-2}, with highest seeding density of around 800 ind. m^{-2} of Australian Flat Oysters at Nyerimilang (Gippsland Lakes) (**Figure 11B**). At the Botany Bay location, only 9 of the 23 reef patches were seeded due to lower than anticipated amounts of seeded cultch being available from the hatchery. To compensate, the centre reef patches were targeted to establish a dense, healthy core population that would provide high potential to support natural recruitment of oysters to neighbouring reef patches. Despite limitations in cultch availability, shellfish were still seeded at a reasonable density of 108 ind.m^{-2} when calculated over the total restoration footprint at that location. The lowest seeding density was recorded for the Oyster Harbour locations at less than 20 ind.m^{-2}. This also reflected lower than anticipated amounts of seeded cultch, which was due to unexpected mortalities in the post grow-out phase on a local aquaculture lease. As part of the restoration process, there are contingencies for reseeding at all project locations if required. For example, in Botany Bay, reseeding will occur in mid-2024, and planning is also underway to reseed the Oyster Harbour locations. Finally, not all reef locations were seeded given abundant natural recruitment, including the intertidal reefs at Wagonga Inlet - Intertidal (Sapphire Coast) and Port Stephens locations in New South Wales.

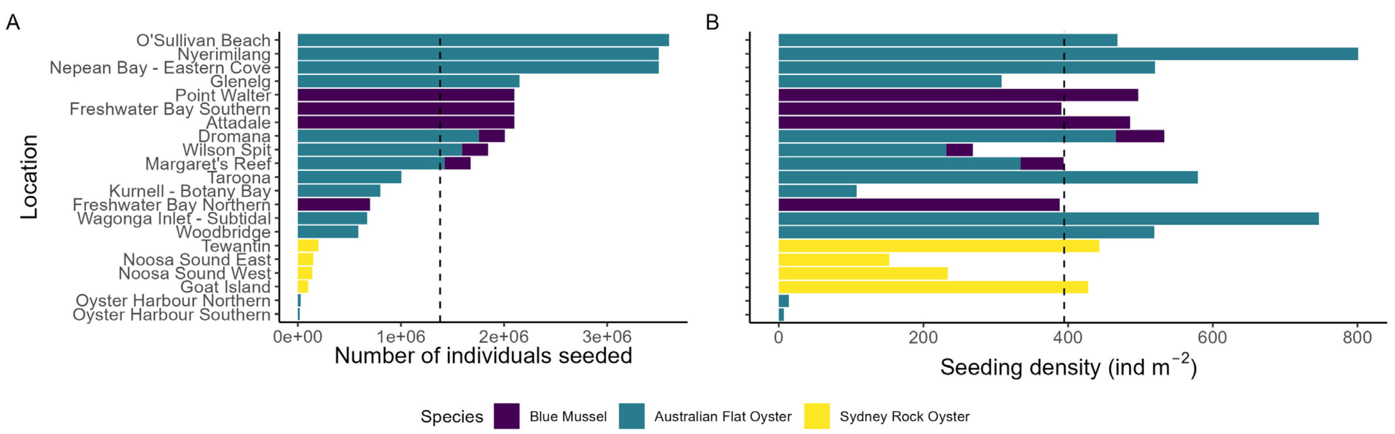


***Figure 11**. Shellfish seeded at 21 reef restoration locations including (A) Number of individuals seeded and (B) Seeding density for Blue Mussels (M. galloprovincialis), Australian Flat Oyster (O. angasi) and Sydney Rock Oyster (S. glomerata). Note that data is not included for the restoration locations Green Island, Waterski site (Albany South) as they were seeded pre-Reef Builder. The locations Karuah, Myall (Port Stephens) and Wagonga Inlet – Intertidal (Sapphire Coast) were not included in seeding due to high natural recovery.*

The average density of live target shellfish was monitored before and after reef restoration (i.e. reef construction and seeding) at the restoration ('impact') sites and nearby reference and control sites (e.g. seagrass, soft-sediment and/or remnant shellfish reefs or beds, where locally relevant) (**Figure 12**). The shellfish densities have been presented by reef age (in 6-month increments) to standardise reefs that were built in multiple stages. At the end of the *Reef Builder* Program, reef age varied from newly built reefs at less than 6 months old (Botany Bay, Oyster Harbour Northern/Southern) to older reefs up to 70 months old (Wilson Spit and Margaret's Reef). Note, however, that not all reefs were sampled in every age category. In total, **188 ecological monitoring events** were undertaken across all locations, with over **2.5 million individuals** counted. For restored reef locations, shellfish density was tracked for the target species that were seeded, with no shellfish present at the baseline monitoring event for all locations and shellfish present at all locations at the latest sampling event (**Figure 12**). The highest densities of Australian Flat Oyster were found at Glenelg, with densities of 2,436 ind. m^{-2} after 19-24 months (**Figure 12A**). For Blue Mussel, Margaret's Reef contained the highest and very large densities of 9,614 ind. m^{-2} after 7-12 months (**Figure 12B**), while for Sydney Rock Oyster, the highest densities were recorded at Karuah after 1-6 months (1,597 ind. m^{-2}) (**Figure 12C**). Densities dropped after these peaks in both of the latter cases, and particularly for Blue Mussel. Notably, Myall had consistently high densities of Sydney Rock Oysters at around 1,000 ind. m^{-2} at all ages. Nyerimilang (Gippsland Lakes) had high densities of Blue Mussel at after 7-12 months (3,850 ind. m^{-2}), which developed entirely from natural recruitment as the reefs were only seeded with Australian Flat Oyster but not Blue Mussel (**Figure 12B**).

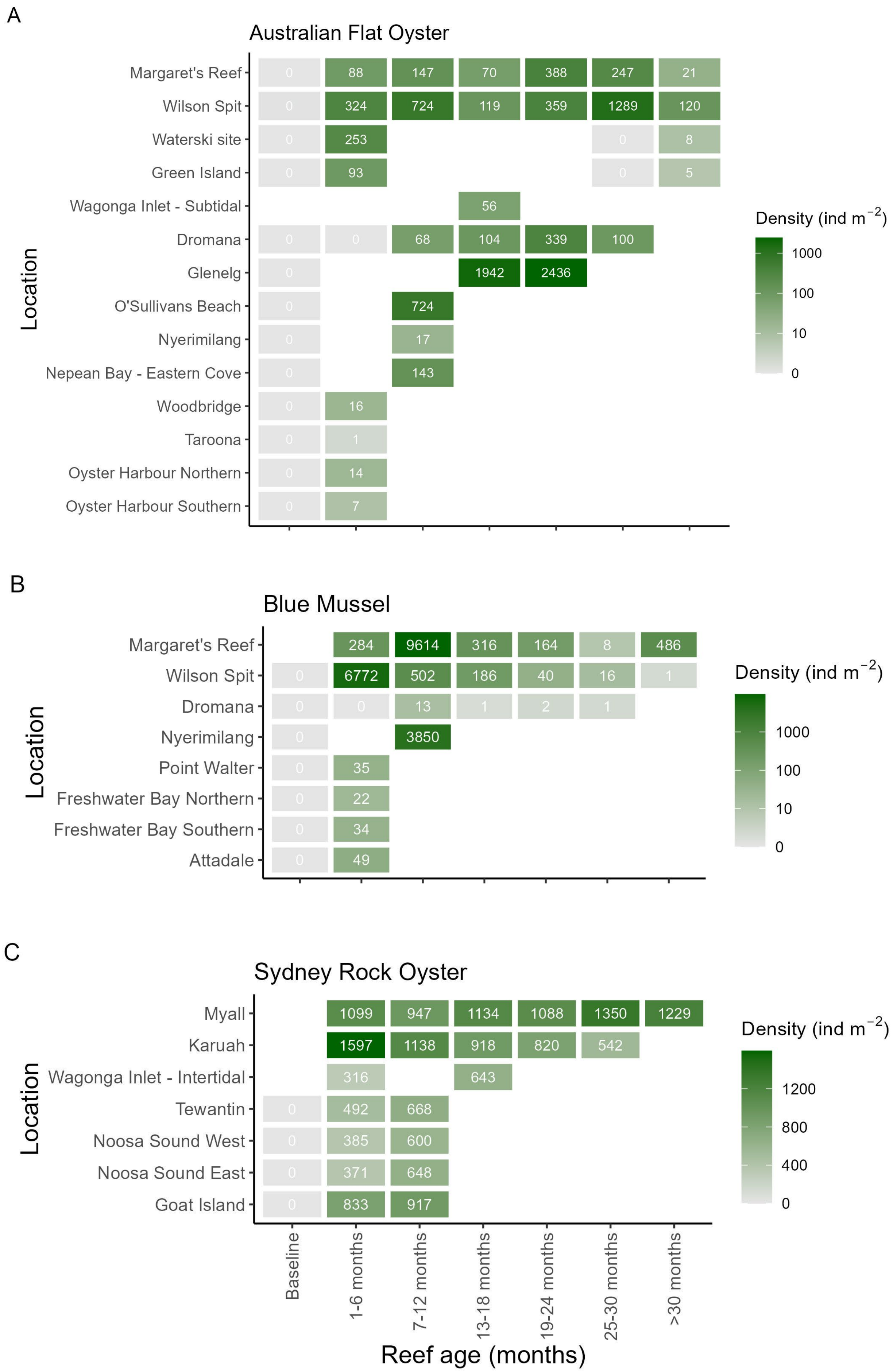


Figure 12. Mean shellfish density across reef age (months since construction completed) for restored reef locations seeded with (A) Australian Flat Oyster (O. angasi), (B) native Blue Mussel (M. galloprovincialis), or (C) Sydney Rock Oyster (S. glomerata). The colour gradient depicting density varies between panels and is set between zero and the highest density recorded for each species.

Shellfish densities at restored reef locations were compared against benchmarks for restoration success (**Appendix 1**) and compared to available reference and control sites (**Figure 13-15**). For Australian Flat Oyster, the benchmark of 50 adult ind. m^{-2} was reached at all South Australian, Sapphire Coast and Port Phillip Bay locations, although in some cases the densities dropped below the benchmark at later sampling points and fluctuated with reef age (**Figure 13**). Benchmarks have not yet been met at several more recently-constructed locations such as Albany (South and North) and Derwent River. In all instances, target shellfish densities were low at reference seagrass and soft-sediment sites. For Blue Mussels, the benchmark of 1000 ind. m^{-2} was reached for Nyerimilang, Margaret's Reef and Wilson Spit (after seeding in the case of the latter two locations) (**Figure 14**). Newer reef locations built in the Swan-Canning Estuary did not meet the benchmark in the first 1-6 months. Benchmarks for Sydney Rock Oysters (200 ind. m^{-2}) were reached at all intertidal sites in Noosa, Port Stephens and the Sapphire Coast (**Figure 15**). Karuah and Myall had among the highest densities for this shellfish species, with Karuah showing a slow decline in densities as the reefs aged, whereas densities at Myall remained consistent. Compared to remnant reefs, such as those in Noosa, the restored reef locations were performing well in their first year.

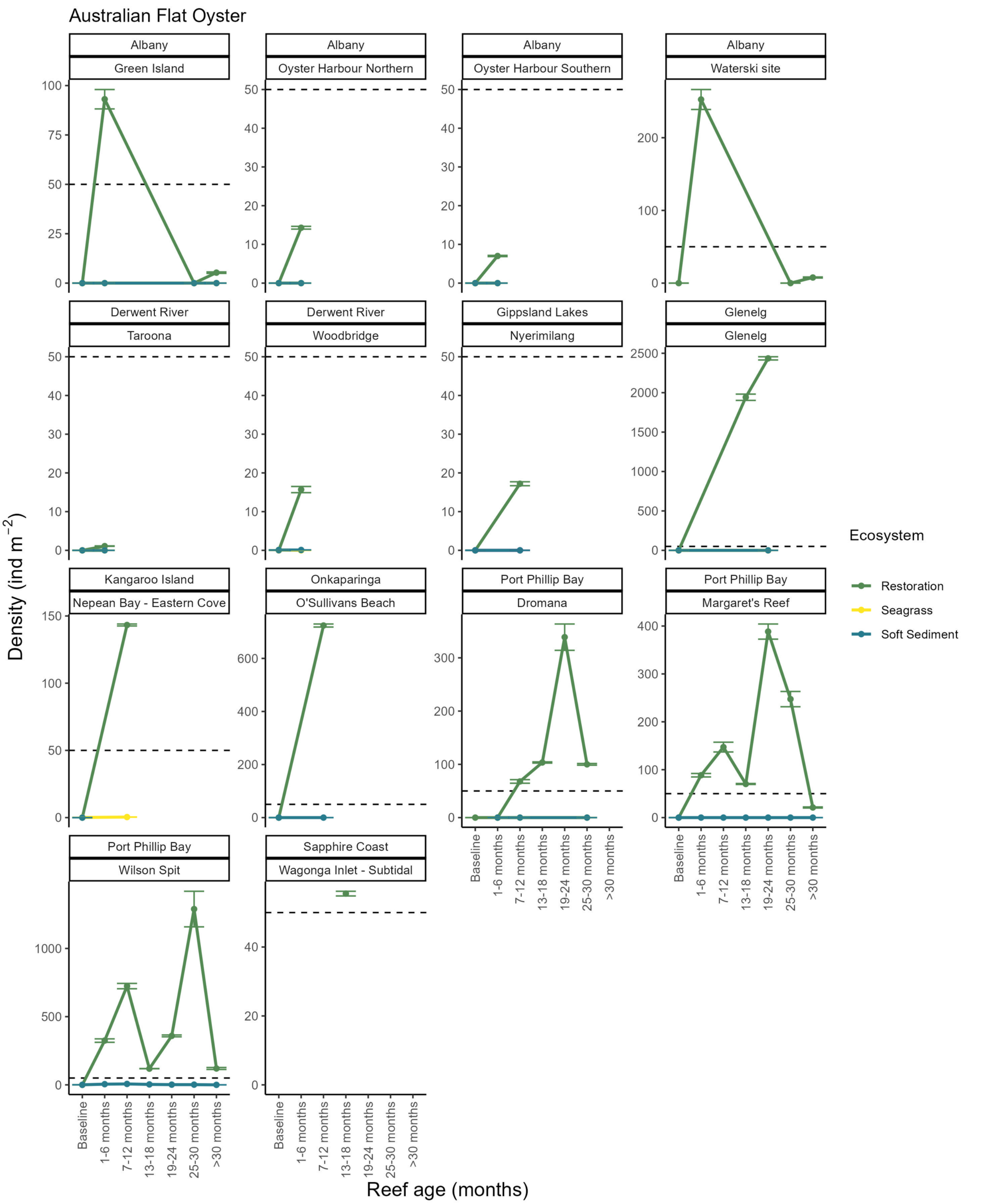

Australian Flat Oyster
Albany
Green Island
Albany
Oyster Harbour Northern
Albany
Oyster Harbour Southern
Albany
Waterski site
Derwent River
Taroona
Derwent River
Woodbridge
Gippsland Lakes
Nyerimilang
Glenelg
Glenelg
Kangaroo Island
Nepean Bay - Eastern Cove
Onkaparinga
O'Sullivans Beach
Port Phillip Bay
Dromana
Port Phillip Bay
Margaret's Reef
Port Phillip Bay
Wilson Spit
Sapphire Coast
Wagonga Inlet - Subtidal
Density (ind m^{-2})
Reef age (months)
Baseline
1-6 months
7-12 months
13-18 months
19-24 months
25-30 months
>30 months
Ecosystem
Restoration
Seagrass
Soft Sediment

Figure 13. Shellfish density at reef age for locations seeded with Australian Flat Oyster (O. angasi). For each location, shellfish density is given for restored reefs (green), reference seagrass (yellow) and soft-sediment (blue) ecosystems. No data for remnant shellfish bed or reefs was available for Australian Flat Oysters. The dashed line reflects the benchmark for Australian Flat Oyster restoration at 50 ind. m^{-2}. Note that the upper range of density values on the y-axis differs between locations.

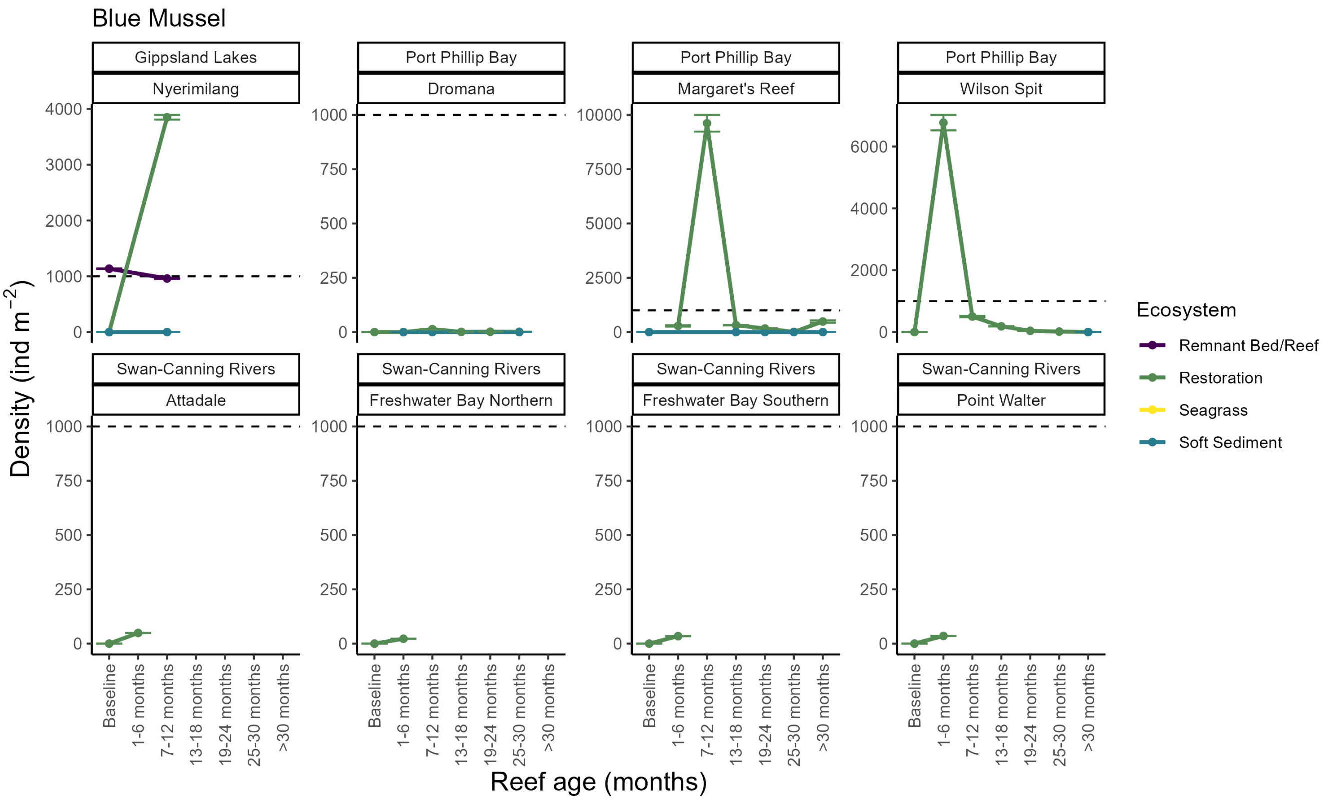


Figure 14. Shellfish density at reef age for locations seeded with Blue Mussel (M. galloprovincialis). For each location, shellfish density is given for restored reefs (green), remnant shellfish bed or reefs (purple), reference seagrass (yellow) and soft-sediment (blue) ecosystems. The dashed line reflects the benchmark for Blue Mussel restoration at 1000 ind. m^{-2}. Note that the upper range of density values on the y-axis differs between locations.

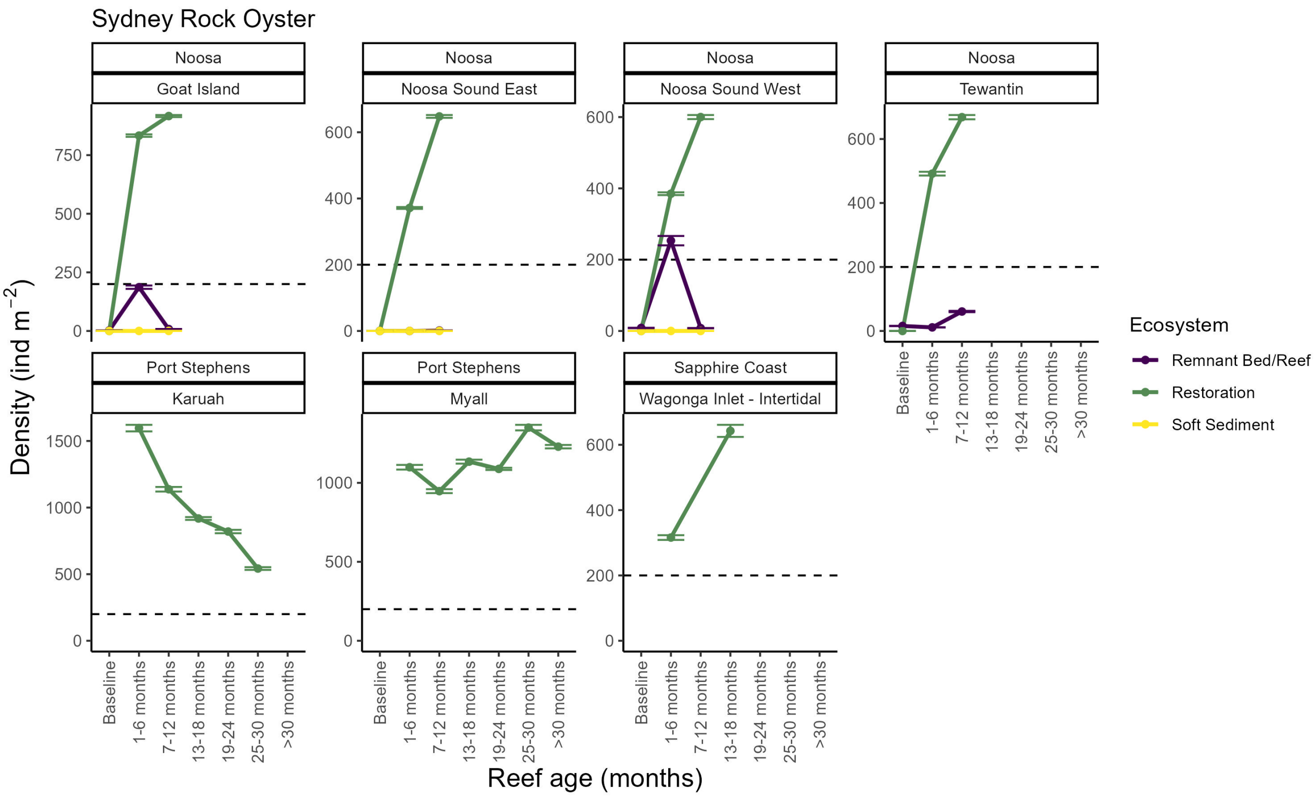


Figure 15. Shellfish density at reef age for locations seeded with Sydney Rock Oyster (S. glomerata). For each location, shellfish density is given for restored reefs (green), remnant shellfish bed or reefs (purple), reference seagrass (yellow) and soft-sediment (blue) ecosystems. The dashed line reflects the benchmark for Sydney Rock Oyster restoration at 200 ind. m^{-2}. Note that the upper range of density values on the y-axis differs between locations.

Goal 3 - Demonstrate the creation of habitat that benefits fish.

Each location was monitored to measure the benefits to fish (and in particular, biomass) of restored reef locations compared to nearby control and reference habitats. Reef Life Survey (RLS) methodology was used to count pelagic and cryptic fish for subtidal reefs (**Appendix 2**), but could not be utilised for intertidal reef monitoring due to methodological issues associated with low visibility and disturbance to faunal communities from divers or snorkellers opperating in shallow water. Baited remote underwater video stations (BRUVs) were used to sample fish counts at the intertidal reef sites (see Goal 4), but that method could not be used to estimate fish biomass.

In total, **529 monitoring events** were undertaken at subtidal locations between 2019 and 2023. Fish biomass at restored reef locations varied substantially within and between reefs as reefs aged. Highest total observed biomass across all restored reefs at a location were found in Port Phillip Bay at Margaret's Reef and Dromana after 13-18 and 25-30 months, respectively, and after 1-6 months at the Waterski site and Green Island locations in Albany, each with biomass exceeding 300 kg (300,000 g) (**Figure 16**). Lower total fish biomass was found at Glenelg which never exceeded 1 kg (1000 g). Patterns in fish biomass over reef age varied substantially among locations, with some showing consistent increases to high fish biomass at the most recent sampling event (e.g. Dromana), to peak biomass in the first 1-6 months after construction (e.g. Waterski site and Green Island), or fluctuating biomass over time (e.g. Margaret's Reef and Wilson Spit). Many of the younger reef locations with only one or two RLS time points (baseline and 1-6 or 7-12 months) generally showed increases in biomass (e.g. all Swan-Canning Estuary locations in Western Australia, all South Australian locations and Botany Bay in New South Wales) although some showed decreases (e.g. Woodbridge, Tasmania and Oyster Harbour Northern, Albany) (**Figure 16**). Especially for the latter, more sampling over time is required to show the general trend in fish biomass, as strong fluctuations are common and observed in shellfish reefs generally. Increases in fish biomass were found at 74% of the locations between baseline and the latest sampling event, and at 84% of the locations between baseline and any sampling event. Note that the location comparison for total fish biomass across a restored reef locations is not corrected for effort (n. transects), which is captured in **Figures 17 and 18** below where biomass patterns are given per transects.

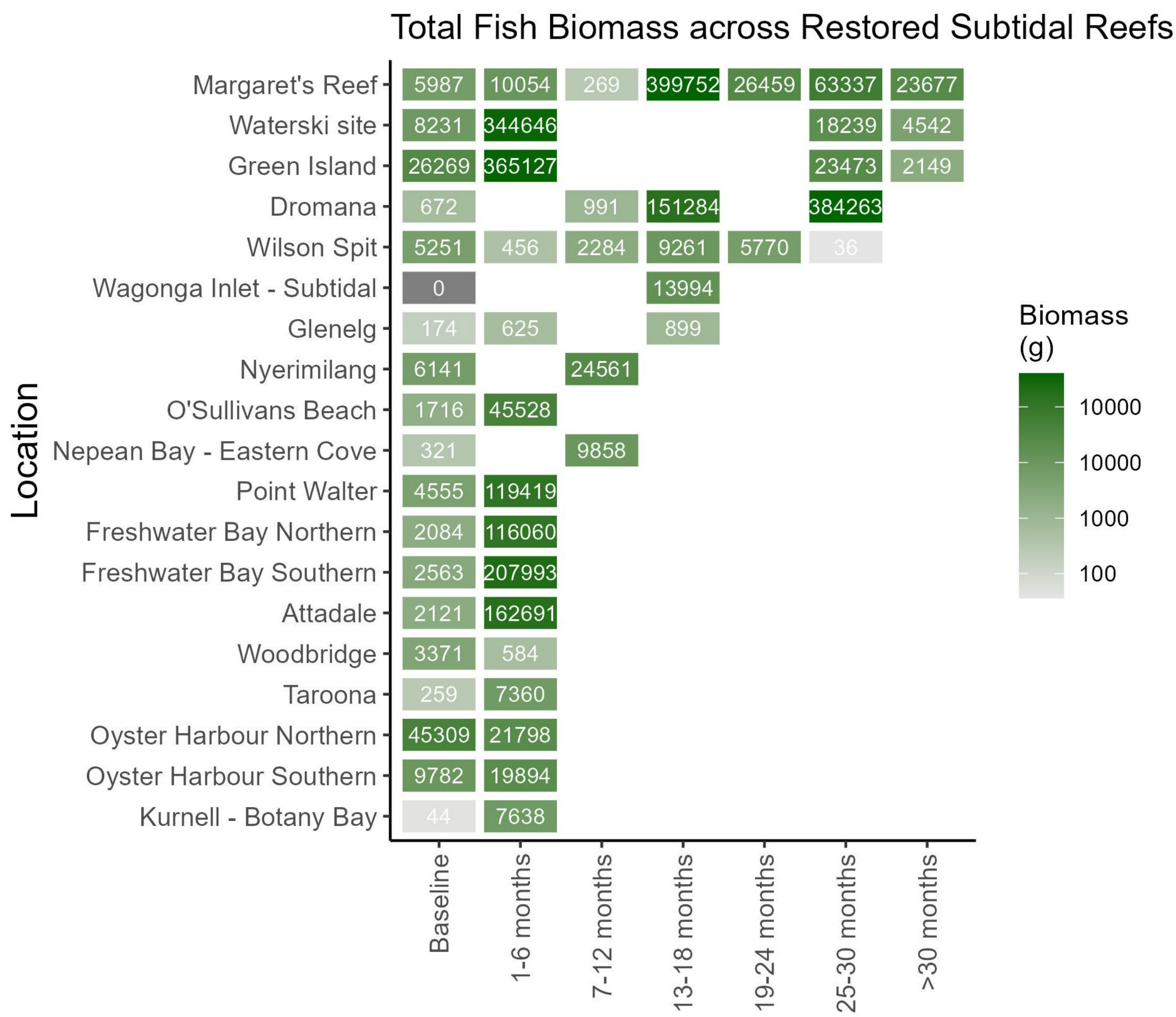


Figure 16. Total fish biomass across reef age (months) for all restored reefs in subtidal locations, combining data from all Reef Life Survey methods including demersal fish, cryptic fish, and ad-hoc observations (Method 0, see Appendix 2). Locations are ordered by oldest reefs first.

Fish biomass at restored reef locations was compared to the soft-sediment control and seagrass/reef reference sites (where available) for each location. For pelagic and reef-associated fish, biomass was generally higher at restored sites compared to nearby soft-sediment and, where present, seagrass (**Figure 17**). Reefs in Port Phillip Bay showed strong increases in fish biomass on restored reefs for Dromana and Margaret's Reef compared to soft-sediment controls. Some reefs, however, did not exhibit notably higher fish biomass compared to control and/or seagrass reference sites, such as the Derwent River, Wilson Spit and Glenelg. Reefs in Nyerimilang (Gippsland Lakes) were the only ones with a remnant shellfish bed/reef measured as a reference site. Both the restored and remant reefs showed strong increases in fish biomass between successive sampling points and were markedly higher than the soft-sediment controls, although biomass was higher at the remnant site (**Figure 17**).

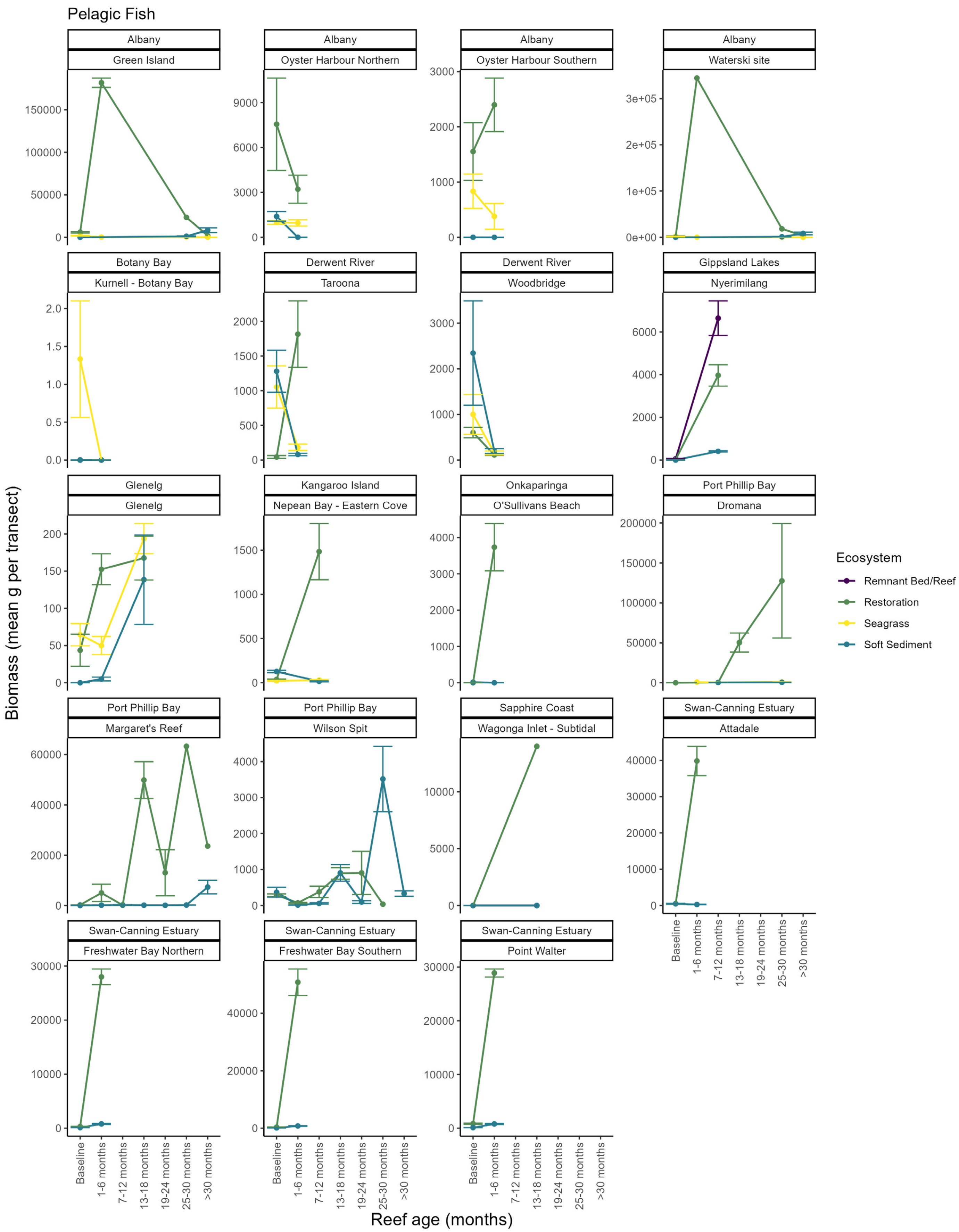


Figure 17. *Biomass of pelagic and reef-associated fish across reef age (months) for all subtidal reef locations. For each location, biomass per transect is given for restored reefs (green), reference remnant shellfish beds/reefs (purple), reference seagrass (yellow) and soft-sediment (blue) controls. Note that the upper range of biomass values on the y-axis differs between locations.*

Patterns in biomass for cryptic fish species showed less consistent patterns (**Figure 18**). In some locations (e.g. Oyster Harbour Southern, Dromana, Nepean Bay and those in the Swan-Canning Estuary), an increase in cryptic fish biomass on the restored reefs was observed compared to baseline and control/reference ecosystems. However, most other locations showed either no noticeable difference between the restored and control or reference sites, or exhibited a decrease in biomass over time (**Figure 18**). It is worth noting that a similar pattern was observed for the Nyerimilang remnant reef in Gippsland Lakes.

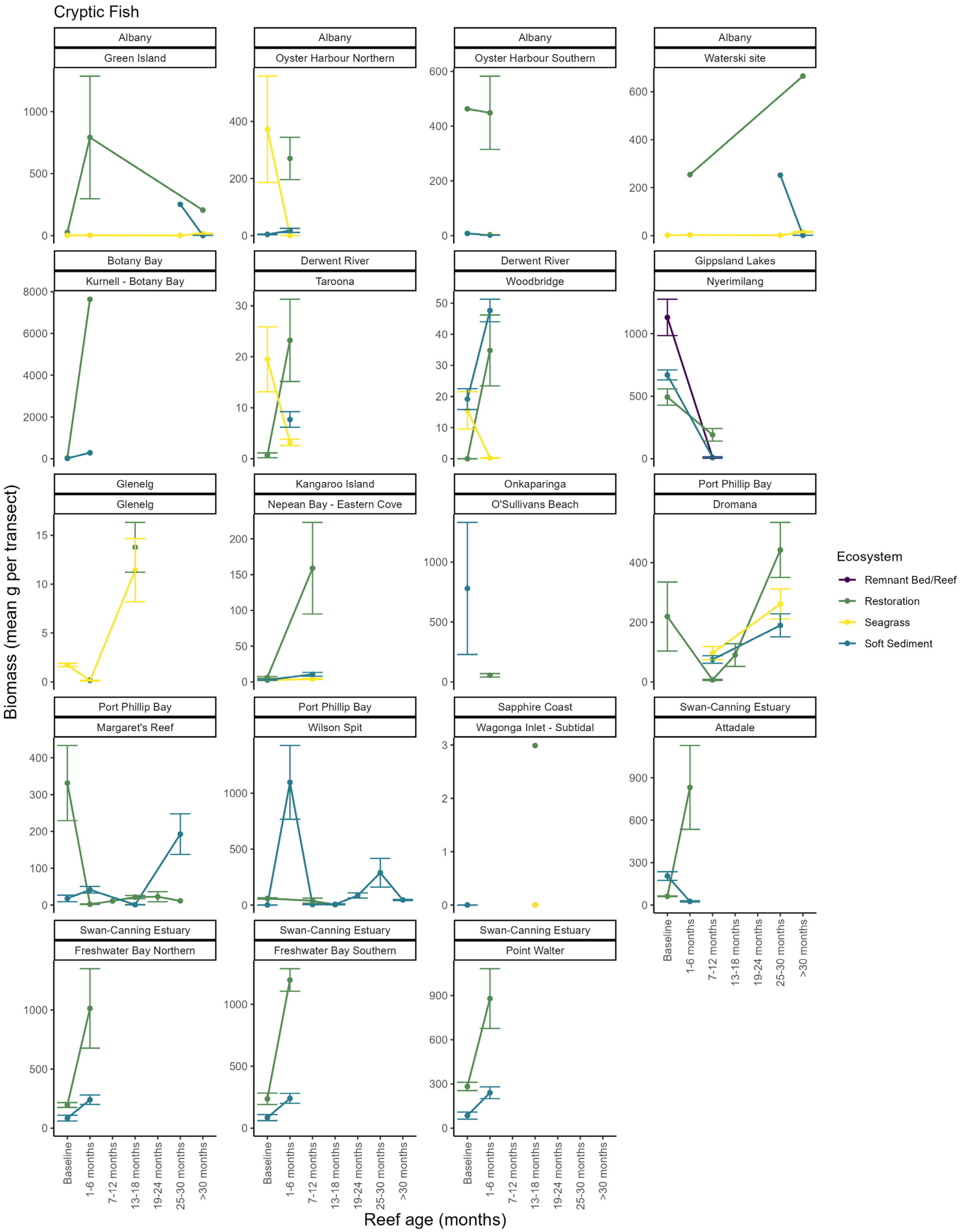


Figure 18. Biomass of cryptic fish across reef age (months) for all subtidal reef locations. For each location, biomass per transect is given for restored reefs (green), remnant shellfish beds/reefs (purple), reference seagrass (yellow) and soft-sediment (blue) ecosystems. Note that the upper range of biomass values on the y-axis differs between locations.

For each location, the count of the top three most abundant fish species at the restored reefs were determined across all monitoring events as shown in **Table 3**. Broad geographic trends in the dominant species were evident among projects. For example, in Western Australia, Western Gobbleguts (*Ostorhinchus rueppellii*) was the most abundant species at all Albany and most Swan-Canning Estuary locations. In all Swan-Canning Estuary locations the top three species were consistent, also including Eight-lined Trumpeter (*Pelates octolineatus*) and triped Sandgoby (*Acentrogobius pflaumii*). In all South Australian projects (Glenelg, Nepean Bay and O'Sullivans Beach), Silverbelly (*Parequula melbournensis*) was found in the top three of most abundant fish species. In other locations, most abundant fish species were more varied. Other species of interest include Snapper (*Chrysophrys auratus*) which was found frequently at Dromana and Margaret's Reef (Port Phillip Bay), the Common stingaree (*Trygonoptera testacea*) found in Kurnell – Botany Bay, and Big-bellied seahorse (*Hippocampus abdominalis*) in Gippsland Lakes.

Location Name	Big-bellied seahorse (*Hippocampus abdominalis*)	Cheekspot Scorpionfish (*Scorpaenodes littoralis*)	Common bullseye (*Pempheris multiradiata*)	Common stingaree (*Trygonoptera testacea*)	Degens leatherjacket (*Thamnaconus degeni*)	Eastern fortescue (*Centropogon australis*)	Eastern striped trumpeter (*Pelates sexlineatus*)	Eight-lined Trumpeter (*Pelates octolineatus*)	Goby (*Nesogobius spp.*)
Green Island									
Oyster Harbour Northern									
Oyster Harbour Southern									
Waterski site									
Kurnell - Botany Bay		1		3		2			
Taroona			3						
Woodbridge									2
Nyerimilang	1					2			
Glenelg					2				
Nepean Bay - Eastern Cove									
O'Sullivans Beach									
Dromana									
Margaret's Reef									
Wilson Spit									
Wagonga Inlet - Subtidal							3		
Attadale								2	
Freshwater Bay Northern								2	
Freshwater Bay Southern								2	
Point Walter								1	

Location Name	Hardyhead (*Leptatherina presbyteroides*)	Hulafish (*Trachinops caudimaculatus*)	Jackass morwong (*Nemadactylus macropterus*)	Little rock whiting (*Neoodax balteatus*)	Little siphonfish (*Siphamia cephalotes*)	Luderick (*Girella tricuspidata*)	Rock blackfish (*Girella elevata*)	Sand flathead (*Platycephalus bassensis*)	Silver trevally (*Pseudocaranx georgianus*)
Green Island									
Oyster Harbour Northern									3
Oyster Harbour Southern				2					
Waterski site									3
Kurnell - Botany Bay									
Taroona	2		1						
Woodbridge		1						3	
Nyerimilang									3
Glenelg									
Nepean Bay - Eastern Cove									1
O'Sullivans Beach									
Dromana									
Margaret's Reef		3							
Wilson Spit		2		1	3				
Wagonga Inlet - Subtidal						1	2		
Attadale									
Freshwater Bay Northern									
Freshwater Bay Southern									
Point Walter									

Location Name	Silverbelly (*Parequula melbournensis*)	Snapper (*Chrysophrys auratus*)	Southern goatfish (*Upeneichthys vlamingii*)	Striped Sandgoby (*Acentrogobius pflaumii*)	Tommy rough (*Arripis georgianus*)	Wavy grubfish (*Parapercis haackei*)	Western Gobblegut (*Ostorhinchus rueppellii*)	Yellow-tail scad (*Trachurus novaezelandiae*)
Green Island						3	1	2
Oyster Harbour Northern							1	2
Oyster Harbour Southern						3	1	
Waterski site						2	1	
Kurnell - Botany Bay								
Taroona								
Woodbridge								
Nyerimilang								
Glenelg	1		3					
Nepean Bay - Eastern Cove	3		2					
O'Sullivans Beach	2				1			3
Dromana	3	1						2
Margaret's Reef		2			1			
Wilson Spit								
Wagonga Inlet - Subtidal								
Attadale				3			1	
Freshwater Bay Northern				3			1	
Freshwater Bay Southern				3			1	
Point Walter				3			2	

Albany | Botany Bay | Derwent River | Gippsland Lakes | Glenelg | Kangaroo Island | Onkaparinga | Port Phillip Bay | Sapphire Coast | Swan-Canning Estuary

Table 3. Top three most abundant fish species (based on total counts) at each restoration location across all monitoring events, colour-coded by project.

Goal 4 - Demonstrate that construction of the reef enhances marine biodiversity

On the subtidal restored reefs, species richness (considering pelagic and demersal/cryptic fish, invertebrates and marine mammals as sampled across all Reef Life Survey [RLS] methodologies) was consistently higher following reef restoration compared to the baseline condition (**Figure 19**). In 79% of reef building locations, species richness was higher at the latest sampling event compared to the baseline, and in 89% of locations (all except Wilson Spit and Oyster Harbour Southern for total richness) between baseline and any sampling event. On average, 13.3 species were recorded at the baseline, compared to 14.5 species when reefs were 1-6 months old. Species richness generally increased as reefs matured, with a peak in species richness occuring at 13-18 months (27.33 species on average across the six monitoring sites with Reef Life Surveys performed in this age bracket). Given that many of the reefs built during *Reef Builder* have had only one sampling event after restoration, continued monitoring of these locations will be necessary to understand their influence on local biodiversity over the longer term. Note that the location comparison for total species richness across a restored reef location is not corrected for effort (n. transects), which is captured in **Figures 20 and 21** below where richness patterns are given per transect.

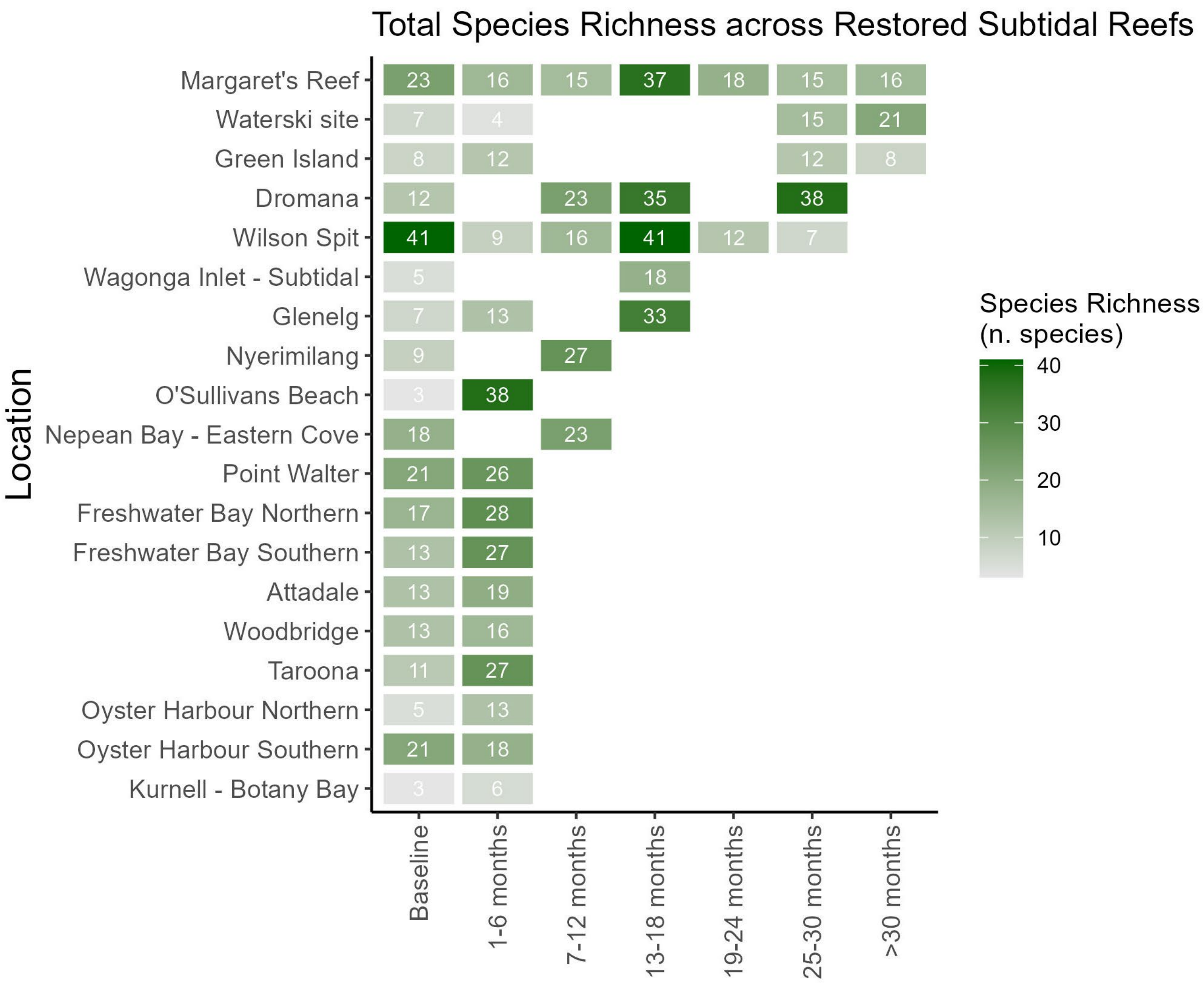


*Figure 19. Species richness across reef age (months) for all restored reefs in subtidal locations, combining data from all Reef Life Survey methods including pelagic and demersal fish, cryptic fish and ad-hoc observations of other marine life (see **Appendix 2**). Locations are ordered by oldest reefs first (top to bottom).*

Species richness trends between restored reefs, soft-sediment controls and reference sites (seagrass or remnant beds/reefs) showed mixed responses as reefs age. Here, richness is compared per transect. Notably, Port Phillip Bay reef locations (Dromana, Margaret's Reef, and Wilson Spit) showed increased richness of pelagic fish and invertebrates at restored sites compared to soft-sediment controls for some of the older reefs (**Figure 20**). Margaret's Reef also showed higher richness of cryptic fish and invertebrates at all age categories in comparison to the soft-sediment control, as did the reefs at Dromana (**Figure 21**). Likewise, all Swan-Canning Estuary reef locations showed increases in richness compared to soft-sediment controls for pelagic species (**Figure 20**), although this trend was less pronounced for cryptic species (**Figure 21**). In other locations such as those within the Albany projects, the restored reefs typically had notably higher species richness compared to the soft-sediment control (especially for pelagic species), although were not always richer in species compared to the seagrass reference site.

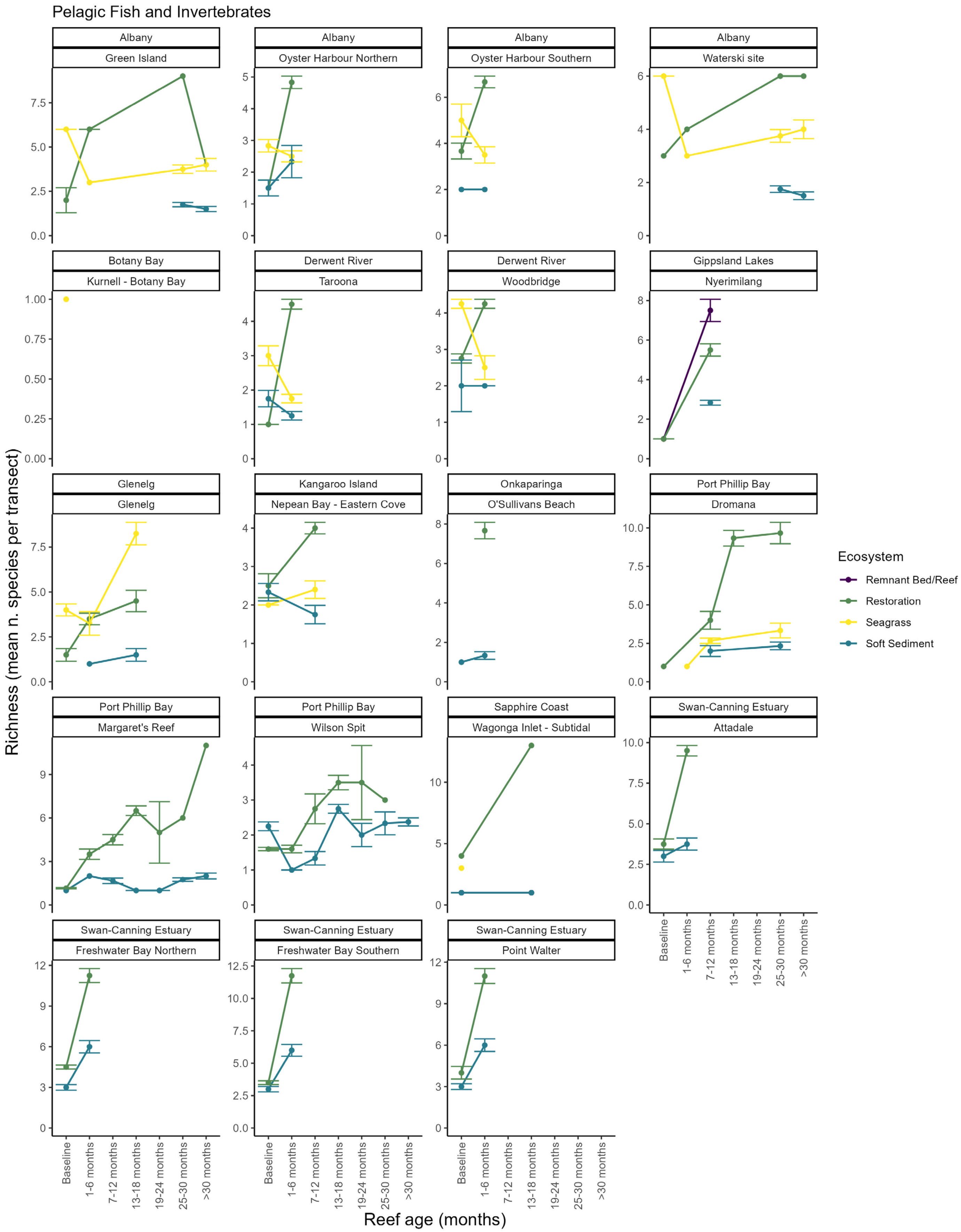


Figure 20. Species richness of cryptic fish and invertebrates across reef age (months) for all subtidal reef locations. For each location, species richness is given for restored reefs (green), remnant shellfish beds/reefs (purple), reference seagrass (yellow) and soft-sediment (blue) ecosystems. Note that the upper range of richness values on the y-axis differs between locations.

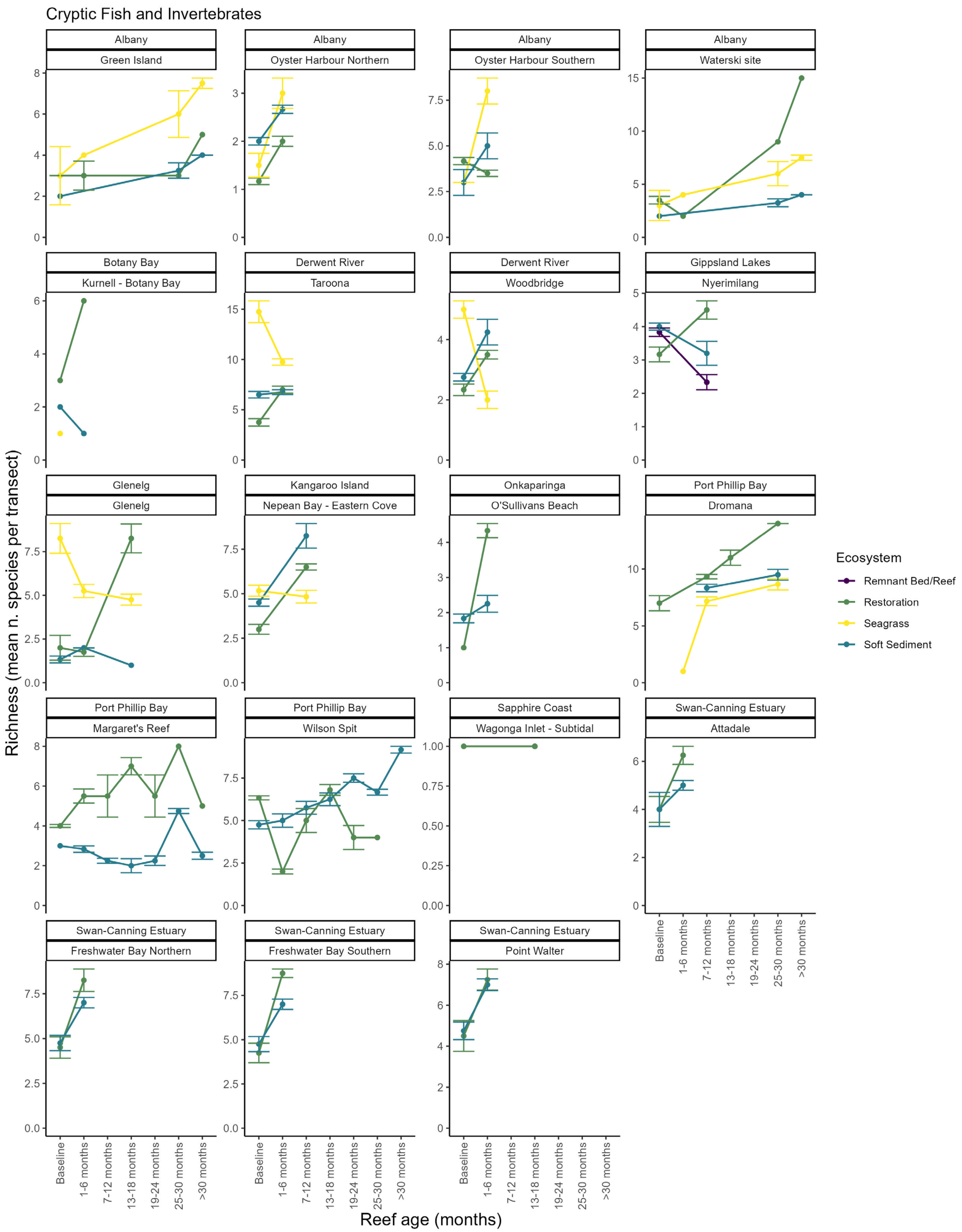


Figure 21. Species richness of cryptic fish and invertebrates across reef age (months) for all subtidal reef locations. For each location, species richness is given for restored reefs (green), remnant shellfish beds/reefs (purple), reference seagrass (yellow) and soft-sediment (blue) ecosystems. Note that the upper range of richness values on the y-axis differs between locations.

For intertidal reefs and comparable control and reference sites, Baited Remote Underwater Video Stations (BRUVs) were used to estimate relative species richness (**Figure 22**). Relative richness of species was compared against control and reference habitat and often showed similar mixed patterns in dynamics over time. The largest improvement in richness on restored sites compared to controls and reference locations was found for Noosa Sound East comparing baseline to 0-6 months post reef construction. Noosa Sound West reefs and controls showed a similar increase in species richness to a comparable level as the reference sites with no distinction between controls and restored reefs. For Goat Island (GI) and Tewantin, no baseline data was available due to poor visibility and technical malfunctions, and averages for the Noosa Sounds monitoring sites were used as an Estuary baseline. For New South Wales projects, including Port Stephens (Myall and Karuah) and Sapphire Coast (Wagonga – Intertidal), mixed results were observed. For Karuah, no differences were observed in species richness compared to controls and restored reefs, but note the large variability (standard errors) for the control sites at baseline. In Myall, species richness on restored reefs fell in between reference and control sites, showing similar trends over time. Finally, for Wagonga – Intertidal restored reefs, controls and references had similar species richness after 0-6 months post construction, with a decrease in richness at reference sites (**Figure 22**).

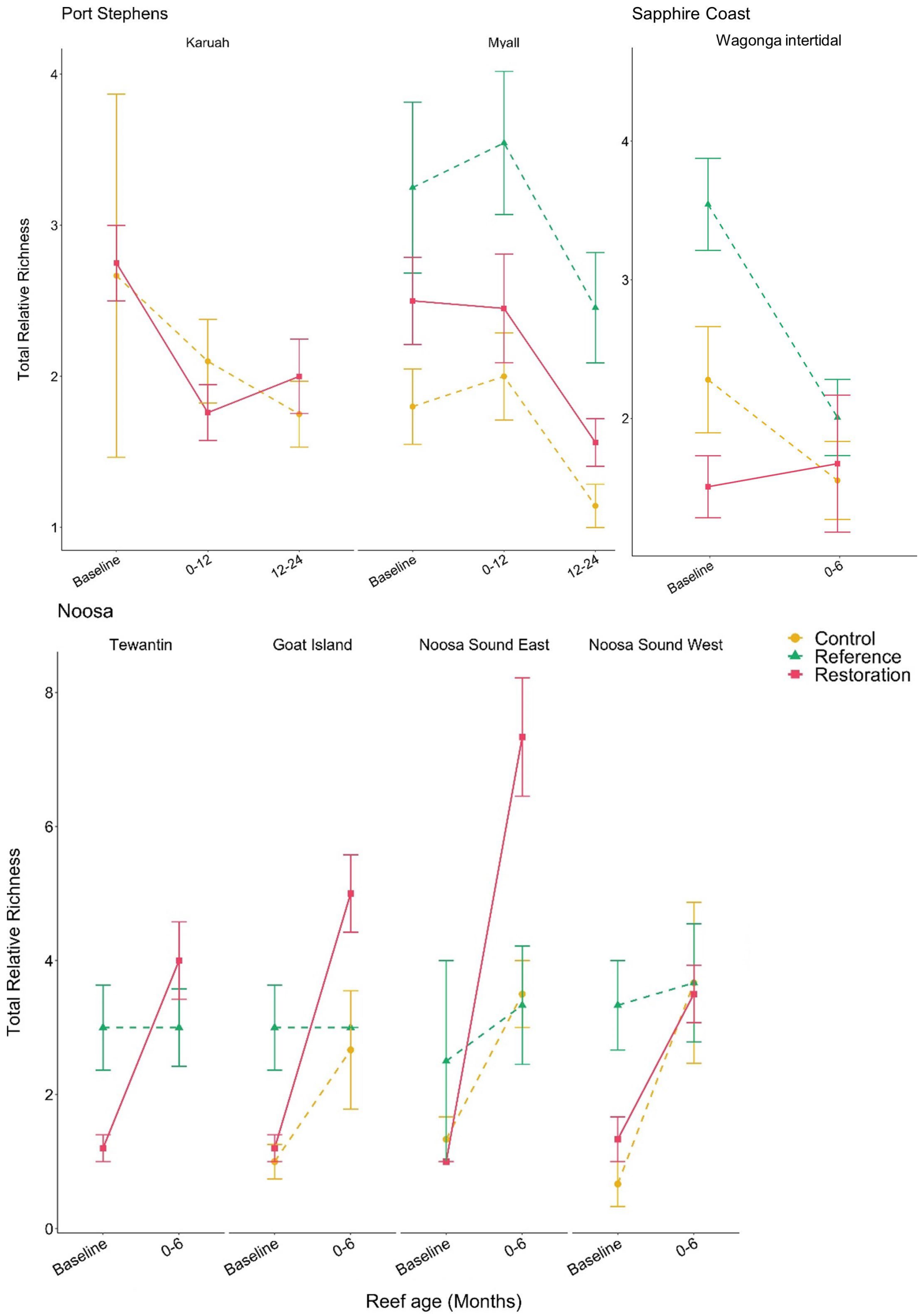


Figure 22. Relative species abundance as observed at the intertidal reef locations in New South Wales (top row) and Queensland (bottom row). Abbreviations: SRO = Sydney Rock Oyster, GI = Goat Island, NS-E = Noosa Sound East, NS-W = Noosa Sound West.

Target 3: Boost local employment

Goal 5 - Demonstrate the benefit of shellfish reefs to local economies

Employment data under the *Reef Builder* Program was tracked across the delivery of the 13 reef construction projects, as well as a broader project ('*Reef Builder* General') which provided oversight and coordination for delivering the Program. As a whole, the *Reef Builder* Program **directly contracted 51 organisations, and mainly (96%) small-medium enterprises** (**Figure 23**). The most organisations were contracted for the Port Phillip Bay, Noosa, and Derwent River Projects (10), with an average of six organisations per reef building project. In total, these contracts created **employment opportunities for 425 people working 100,367 hours, at the equivalent of 64 (FTE) paid full-time jobs.**

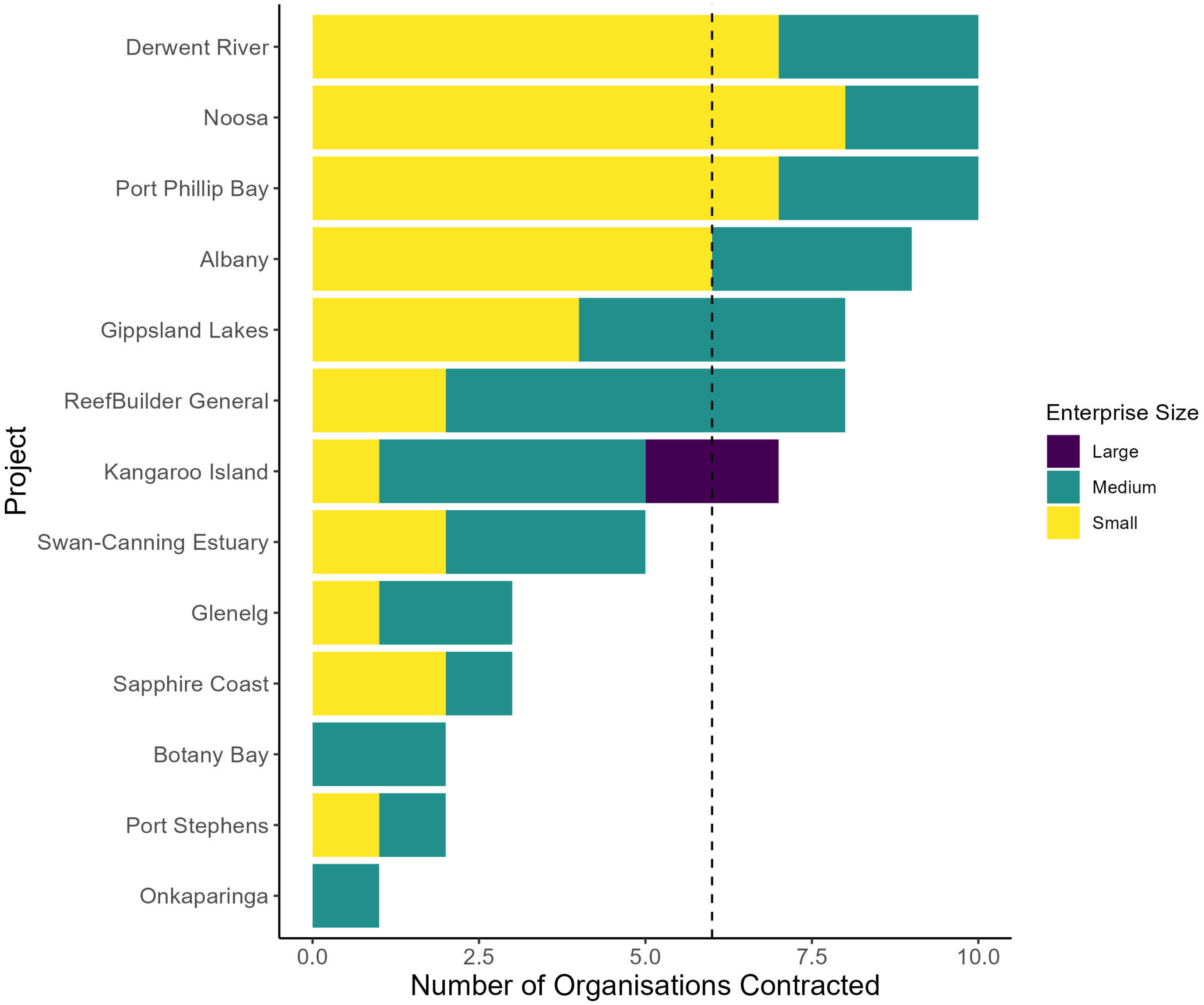


Figure 23. Number of organisations contracts for each reef building project, with the proportion of large, medium, and small enterprises also illustrated. The dashed line reflects the average number of organisations contracted across all projects.

Most people were employed through *Reef Builder* General (86), followed by Port Phillip Bay Project (65), and Derwent River which engaged 53 people, respectively (**Figure 24A**). **On average, projects employed 33 people, creating 4.9 full-time equivalent (FTE) jobs per project.** The *Reef Builder* General project had a proportionally higher ratio of FTE to people reflecting the consistency of employment required to oversee and deliver the Program, although in general, the number of employment opportunities (FTE) per project did not always reflect the pattern of number of people employed (**Figure 24**). For example, the Swan-Canning Estuary project employed fewer people that worked proportionally more hours resulting in a higher FTE, whereas the Derwent River project created relatively fewer FTE to the number of people employed. Most jobs went to people in full-time employment (64.2%), followed by casuals (30.1%) and part-time staff (5.6%) (**Figure 24**).

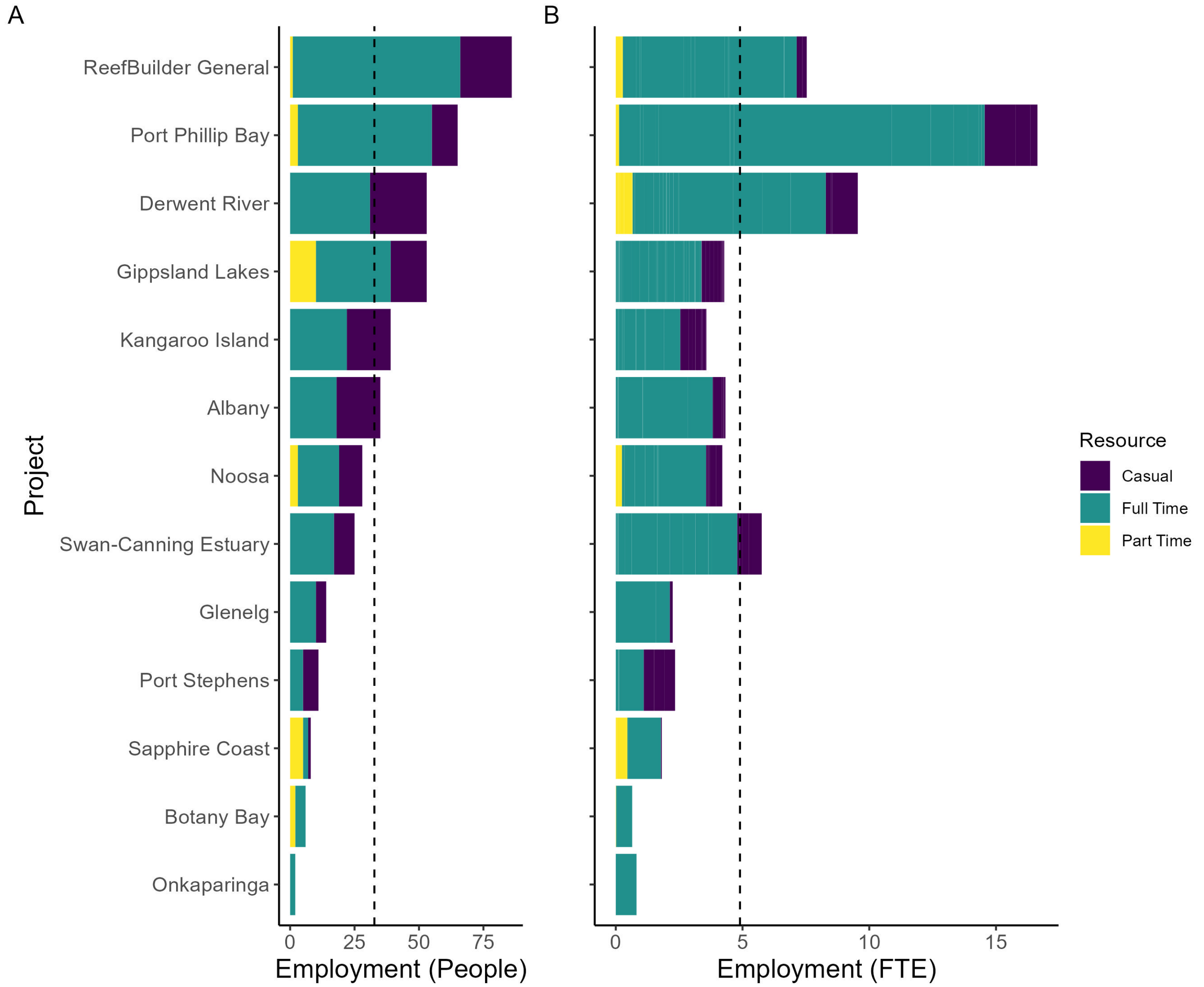


Figure 24. The number of employment opportunities as part of the Reef Builder Program. Measured as the number of people (A) and FTE (B) employed per project. The dashed line reflects the average employment opportunity (people and FTE, respectively) across all projects.

Across all projects, most people employed worked for small (64.7%) and medium (31.4%) enterprises, of which 68% and 42%, respectively, worked locally (**Figure 25A**). Only 1.4% of people employed directly through the *Reef Builder* Program worked for large enterprises, and predominantly worked intrastate (83%). Regarding employment across the project lifecycle, most people were employed during the reef restoration phase (232 people), followed by monitoring and evaluation (112 people), and planning and permitting (39 people) (**Figure 25B**). Across the other three project lifecycle stages, 9-19 people per stage were employed, totalling less than 10% of all employment. During both the reef restoration and planning and permitting stages, most people employed worked locally (63 and 59% respectively) or intrastate (26 and 23% respectively), whereas during the monitoring and evaluation stage, relatively more people were employed from interstate (43%).

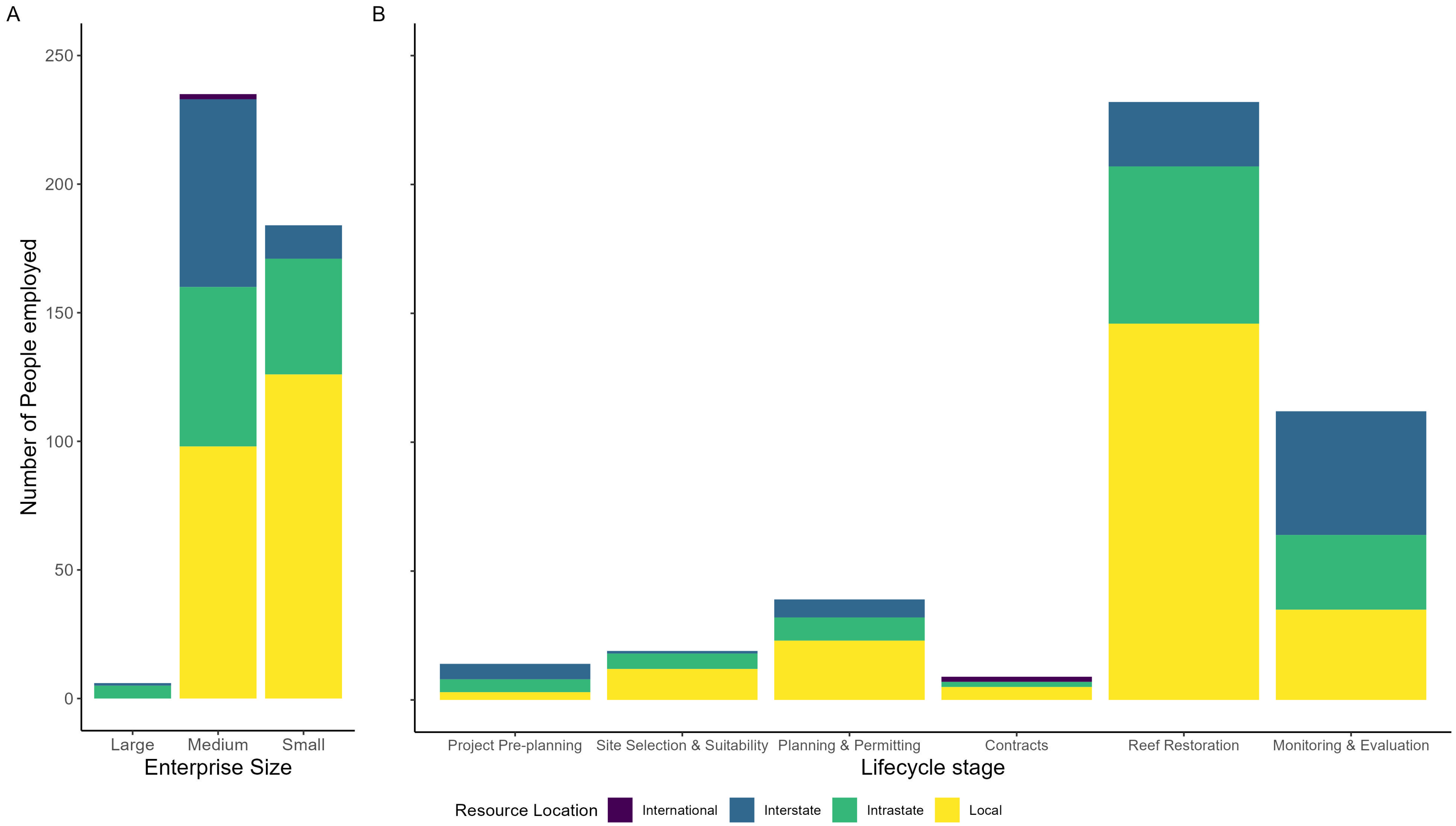


Figure 25. The number of people employed across various enterprise sizes (A) and across the project lifecycle (B), and their relative location to the work.

Throughout the restoration of reefs, a variety of roles were required for successful implementation. Under the *Reef Builder* Program, people were employed from 14 industry divisions, seven occupation divisions, and 23 unique occupations/roles. Across industries and occupations, most people were employed in (i) Professional, scientific and technical services (214 people), and predominantly as professionals (153 people) or technicians and trade workers (41 people); (ii) in Construction (104 people) as machinery operators and drivers (58 people) or labourers (22 people), and; (iii) in Agriculture, Forestry and Fishing (43 people), including technicians and trade workers (19 people) or professionals (9 people) (**Figure 26**). Another notable combination of Industry and Occupation is through Transport, postal and warehousing, working as machinery operators and drivers (22 people). In all other industries, between 1 and 12 people were employed at less than 10 people each (**Figure 26**).

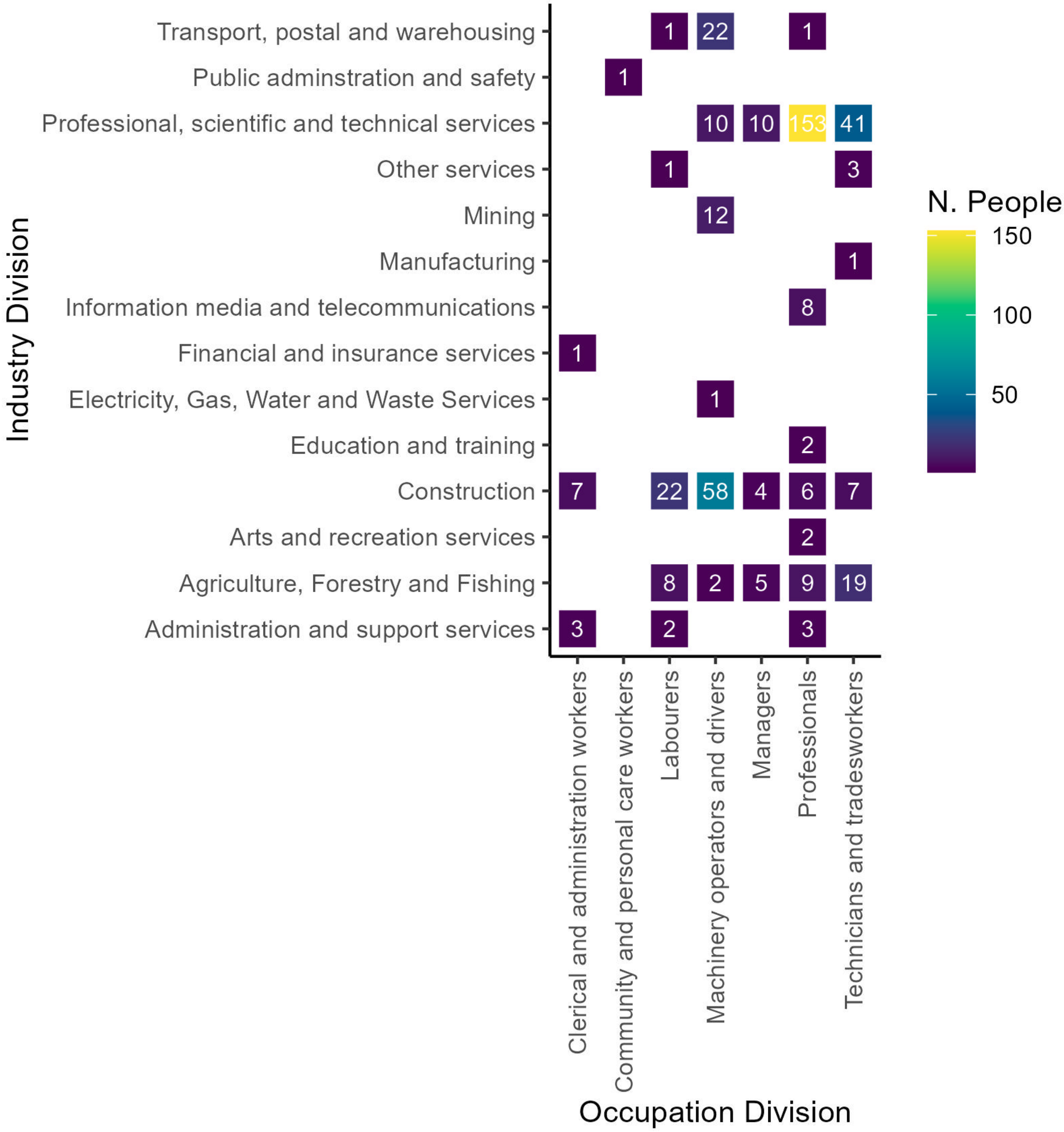


Figure 26. *Heatmap of the number of people employed across combinations of Industry and Occupation division categories.*

Target 4: Strengthen community engagement

Goal 6 - Engage the community in long-term stewardship of the shellfish reef

During the *Reef Builder* Program, **185 stakeholder and community** events were held across Australia with a total of **5,219 people attending** these events. For each of the 13 projects and including *Reef Builder* General, the number of events ranged from 4 to 29, averaging 14 people per project with an average attendance of 28.2 people per event. Most stakeholder and community engagement events were held under the *Reef Builder* General project, followed by the Kangaroo Island, Botany Bay, and Swan-Canning Estuary projects, with over 20 events each (**Figure 27A**). Regarding the number of attendees, however, the Noosa Project had the most attendees overall (1,165 people), followed by the *Reef Builder* General and Sapphire Coast projects (**Figure 27B**). While the Kangaroo Island, Port Phillip Bay, Derwent River, and Botany Bay projects had lower attendance in terms of the number of people, they did reach many different organisations and community groups (**Figure 27B & C**). Most events were held during the reef restoration (55), monitoring and evaluation (40), and planning and permitting (38) project lifecycle stages, which was also reflected in the number of attendees per stage (**Figure 28**).

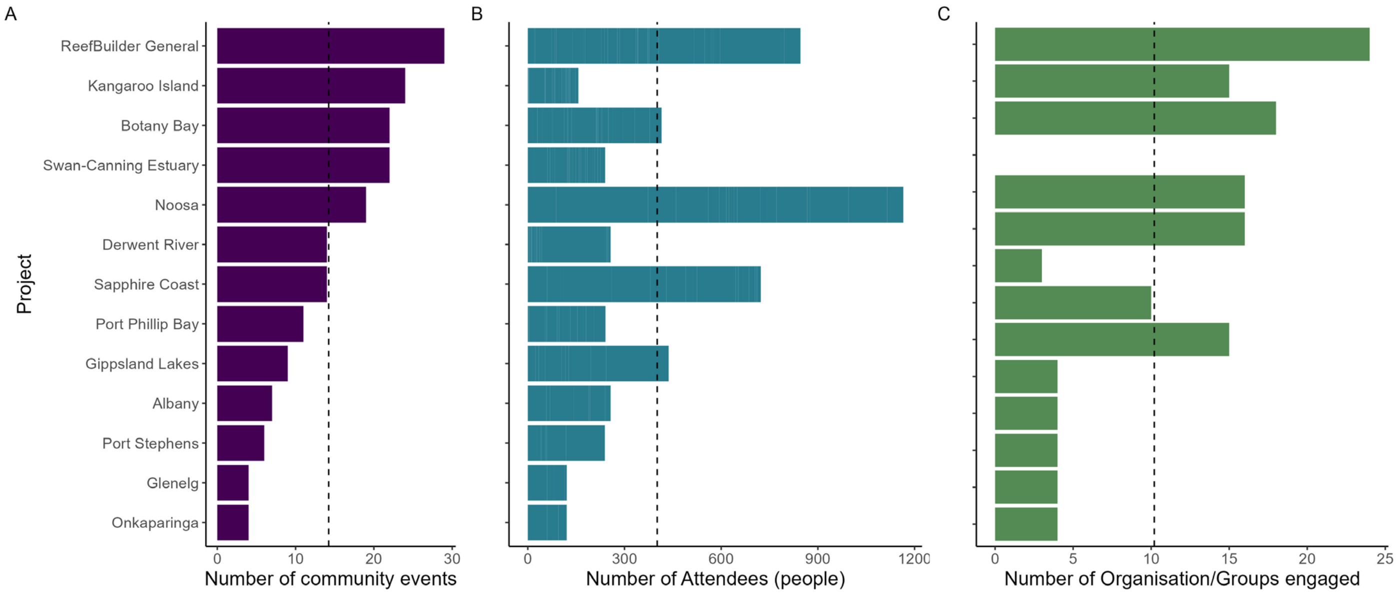


Figure 27. Stakeholder and community engagement metrics by project, including number of engagement events (A), number of attendees (B), and number of organisations/groups engaged (C). The dashed lines in each plot reflect the average value across all projects.

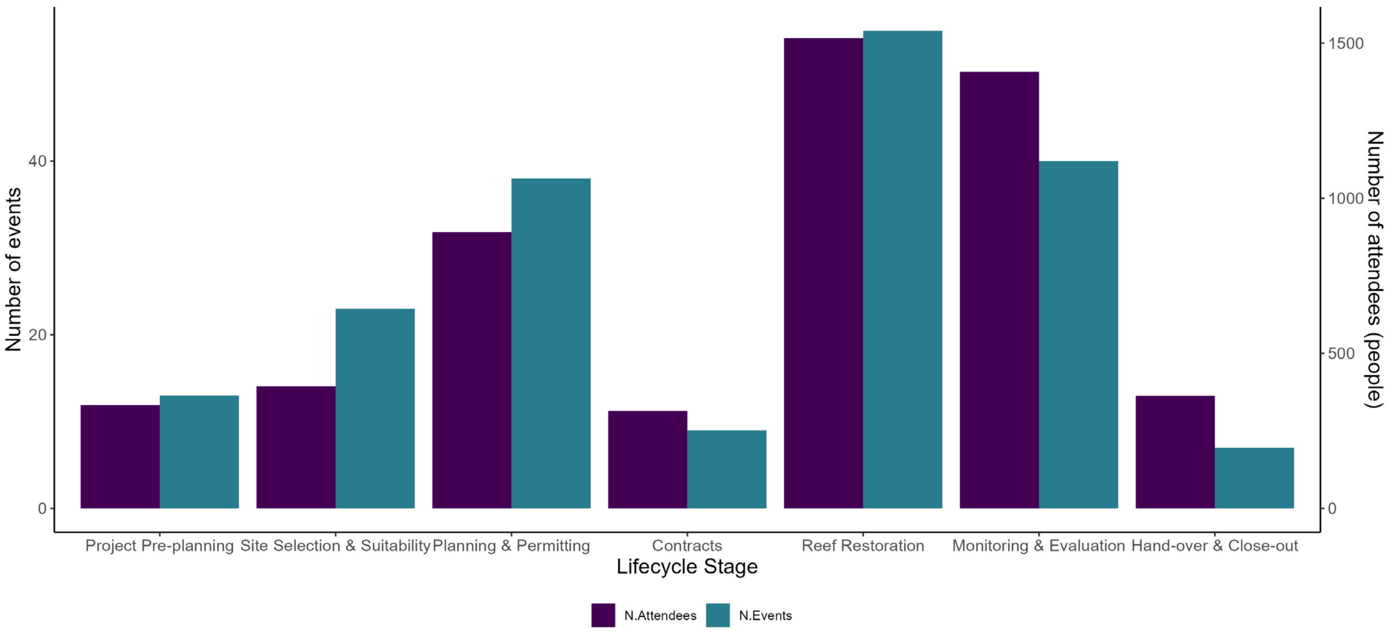


Figure 28. Stakeholder and community engagement across various lifecycle stages of a reef restoration project, including the number of events held (blue; primary axis) and number of people attending the events (purple; secondary axis).

At each of the lifecycle stages, various types of events were held to connect with stakeholder and community groups (**Figure 29**). The largest number of attendees were reached through presenting project findings at conferences (nearly 1,400 individuals), of which 16 events were attended, particularly during the monitoring and evaluation project stages (655 people). Community forums and education events also had substantial outreach throughout the project lifecycle, each of which were attended by over 1,200 community members. During the planning and permitting phase, most stakeholder engagement happened via Technical Advisory Groups, Government meetings, and Community Forums, reaching 891 people across 47 different organisations or community groups. Technical Advisory Groups in general reached most different organisations or community groups (59) across 25 events, although fewer people in total (169) (**Figure 29**).

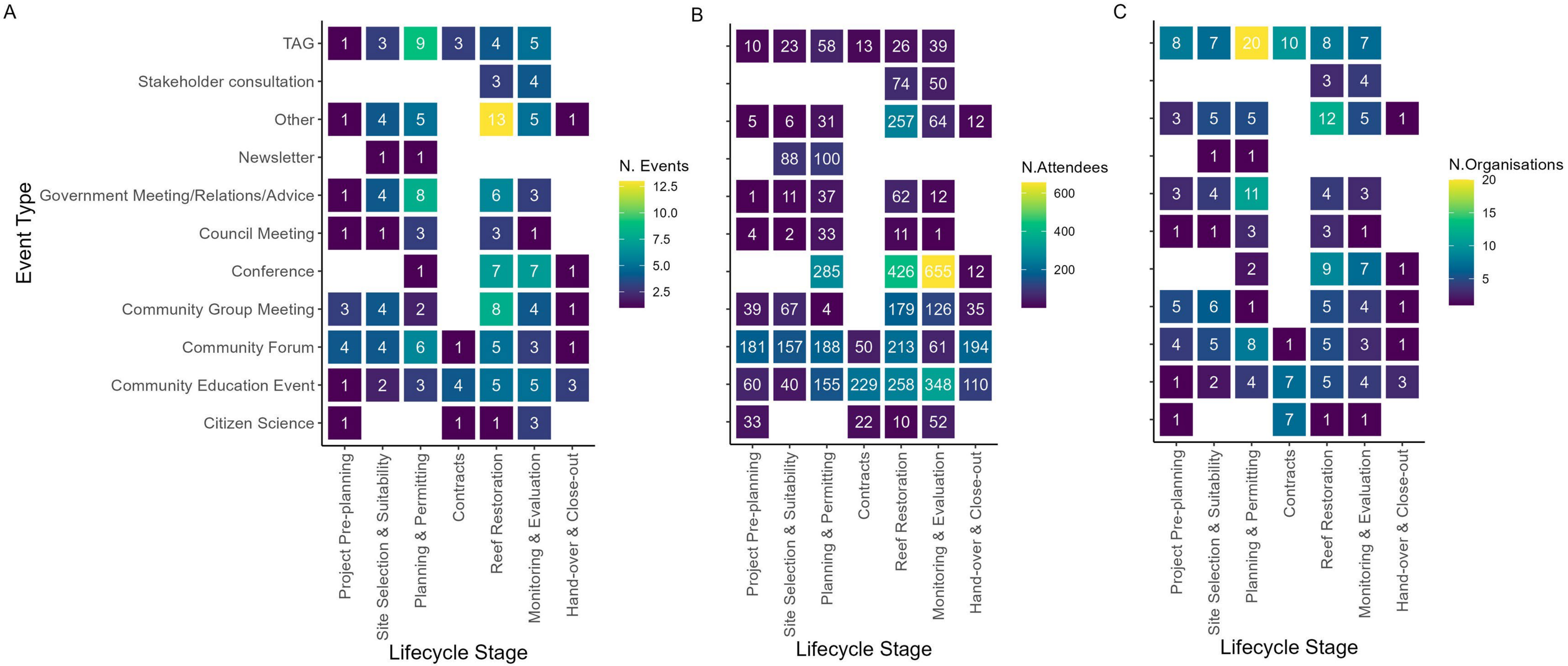


Figure 29. Heatmap of community engagement event types across different project lifecycle stages, including the number of events held *(A)*, the number of people attending *(B)*, and the number of organisations or community groups present *(C)*.

The *Reef Builder* Program has created a range of opportunities for community members to participate in the restoration process, engaging **305 people who volunteered a total of 2,903 hours** across all projects. Volunteers engaged in 10 of the 13 projects, with an average of 30.5 people and 290 hours per project, with each volunteer spending an average of 9.5 hours volunteering (**Figure 30**). The greatest volunteering effort was recorded for the Noosa Project, with a total of 16 volunteer engagement events and more than 100 volunteers providing 1,819 hours of their time (over half the total hours volunteered). These volunteers supported an 'Oyster Gardening' program and a sediment study of the Noosa River. It should be noted that the Noosa project had a dedicated staff member to facilitate local community engagement. In general, volunteer engagement was highest during the reef restoration lifecycle stage, followed by monitoring and evaluation (**Figure 31**).

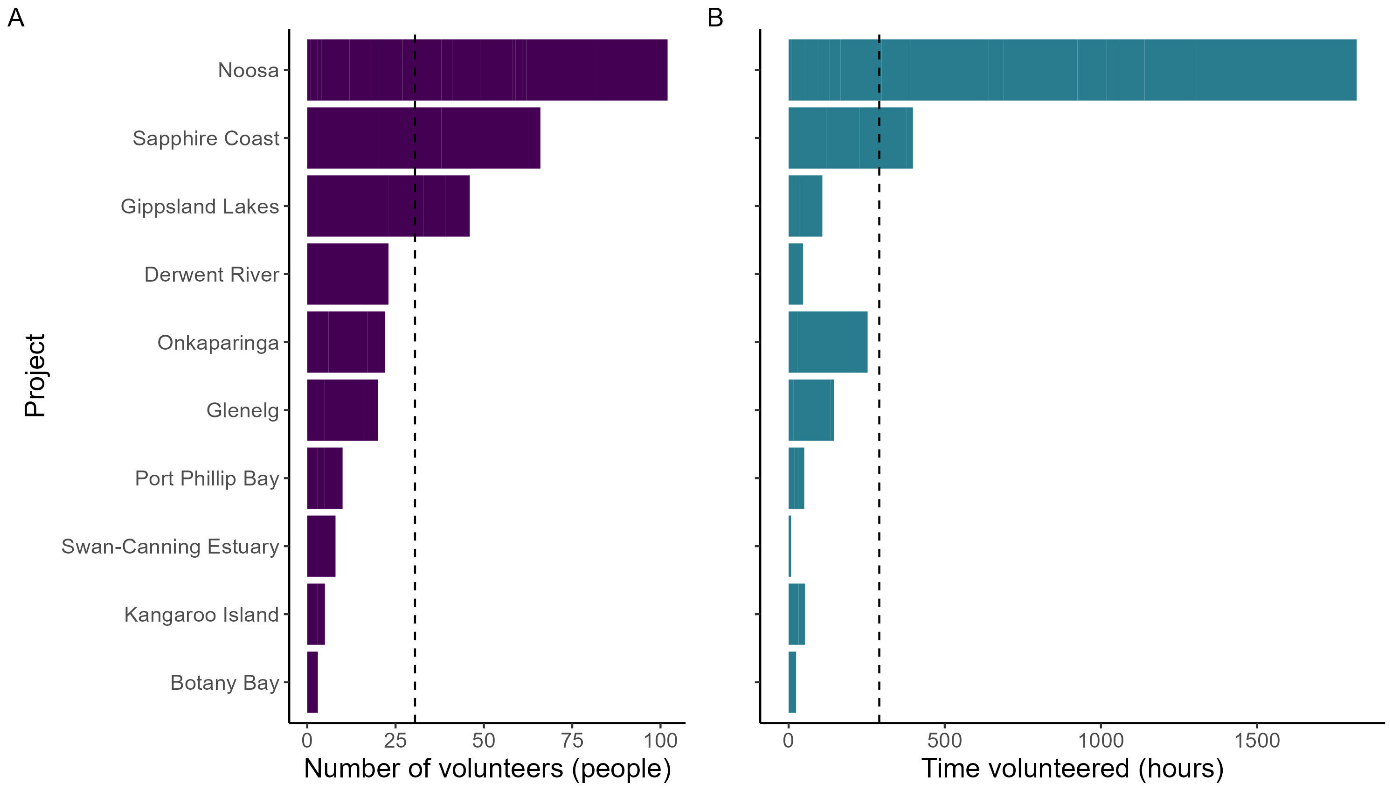


*Figure 30. Volunteer engagement during the Reef Builder Program by project, including number of people who volunteered **(A)** and the time volunteered **(B)**. The dashed lines reflect the average volunteer engagement across all projects.*

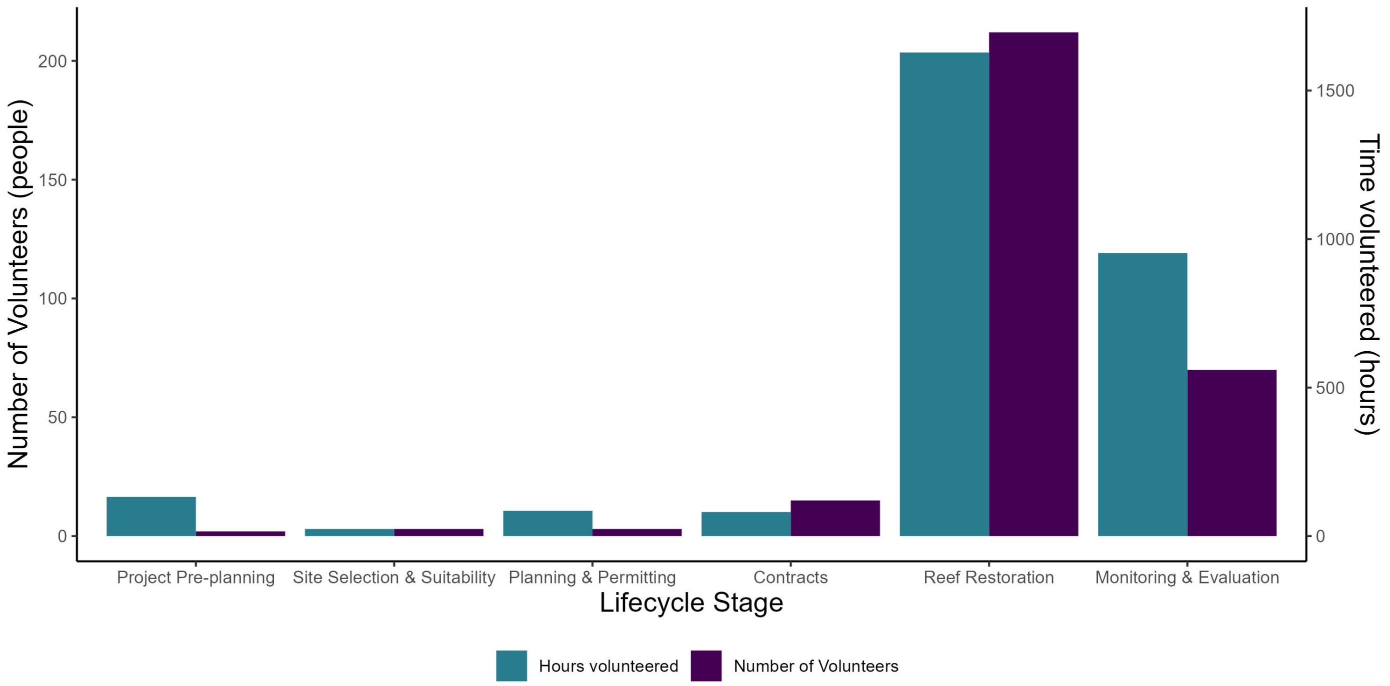


Figure 31. Volunteer engagement across project lifecycle stages, including the number of volunteers (purple, primary axis) and the time volunteered (blue, secondary axis).

Most volunteers engaged with shell preparation (114 people) and oyster gardening (66 people) during the reef restoration lifecycle stage. Likewise, most volunteer hours were spent on shell preparation, water quality monitoring, and oyster gardening across reef restoration and monitoring and evaluation stages (**Figure 32**). Shell Recycling in the project pre-planning stage was also notable for its high ratio of hours spent (132) to number of volunteers (2).

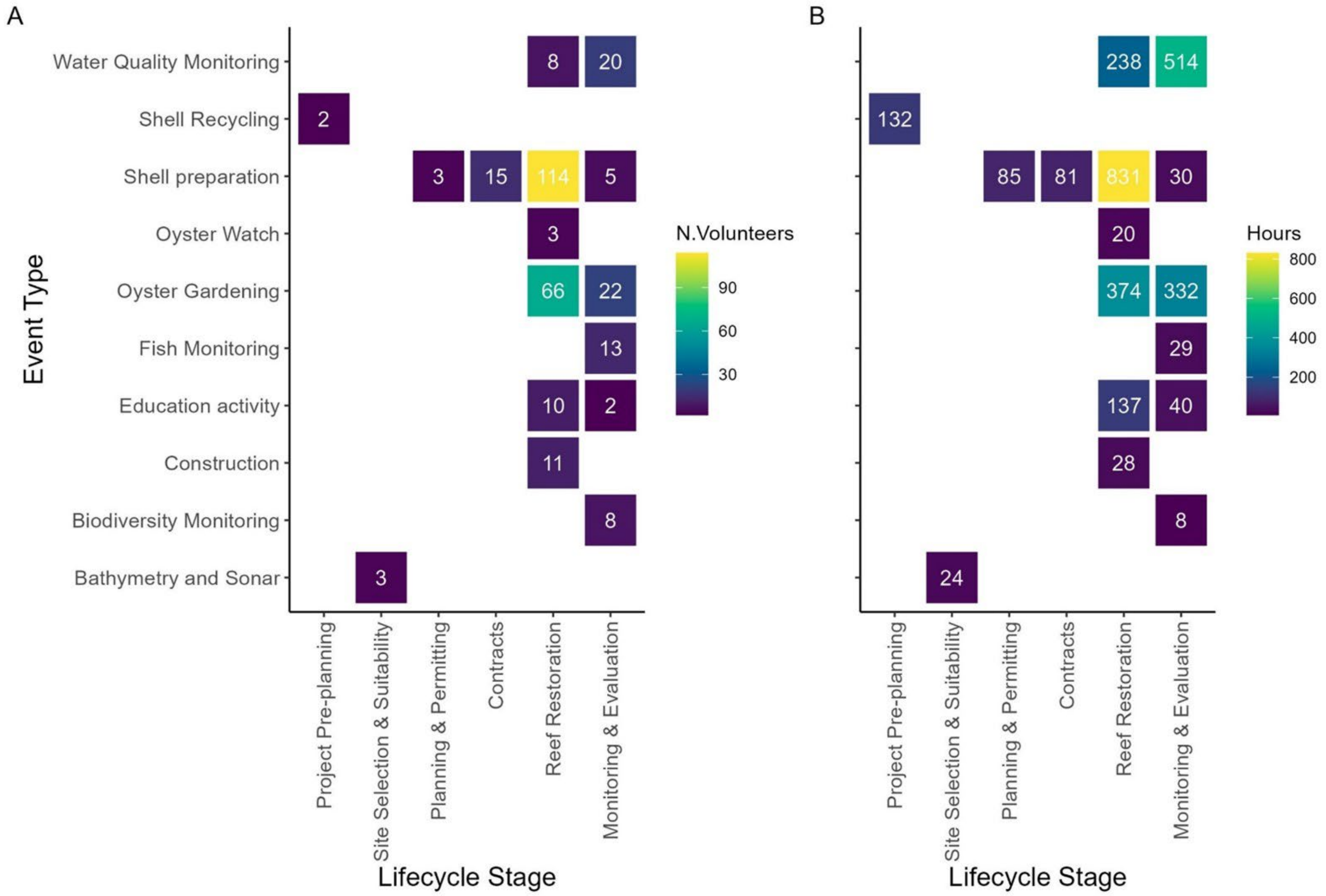


Figure 32. *Heatmap of Volunteer Engagement across lifecycle stages and event types, including number of volunteers (A) and time volunteered (B).*

Lastly, it should be noted that the COVID-19 lockdowns during 2020-2022 impacted the ability to engage volunteers in the *Reef Builder Program*. These lockdowns were particularly severe for the projects in Victoria (Port Phillip Bay and Gippsland Lakes) where rolling lockdowns occurred between February to October 2021.

Demonstrate media engagement

Media data during the *Reef Builder* Program was tracked across the full delivery lifecycle for all 13 reef restoration projects, as well as for the overarching *Reef Builder* General project. Media data was tracked for five main media types, namely print, radio, television, social media, and webinars. Media engagement occurred over **a total of 537 media events** and with a combined potential **audience reached of 203 million views** across all media types. The *Reef Builder* General and Port Phillip Bay projects, respectively, had both the greatest number of media events and potential audience reached across all projects (**Figure 33**). On average, 41 media events with a potential audience of 1.5 million views occurred for each project. In some instances, a greater number of media events did not necessarily equate to a greater potential audience reached. For example, Derwent River had a greater number of media events than Sapphire Coast, but the latter reached a greater potential audience (**Figure 33**). Similarly, Kangaroo Island had relatively few media events, but reached a similar potential audience compared to Gippsland Lakes and Derwent River, both with greater numbers of media events.

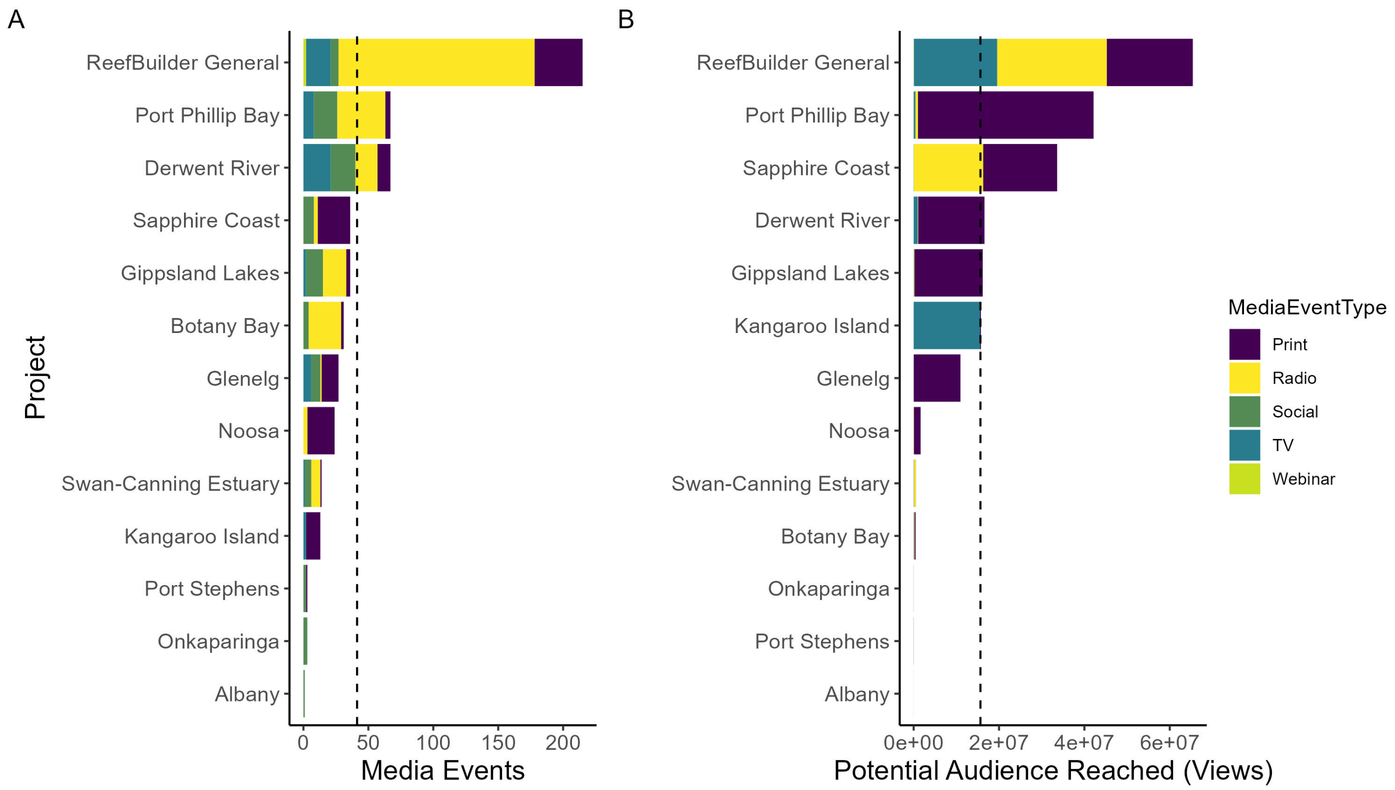


Figure 33. Number of media events (A) and potential audience reached (B) by each Reef Builder project. The colour reflects the type of media event, while the dashed lines show the respective average values across all projects.

Most media events resulted from Radio (262), followed by Print (128), Social (86), TV (59) and Webinar (2). Traditional media (Print, Radio, and TV) reached a greater potential audience than non-traditional media (Social and Webinar) (**Figure 34**).

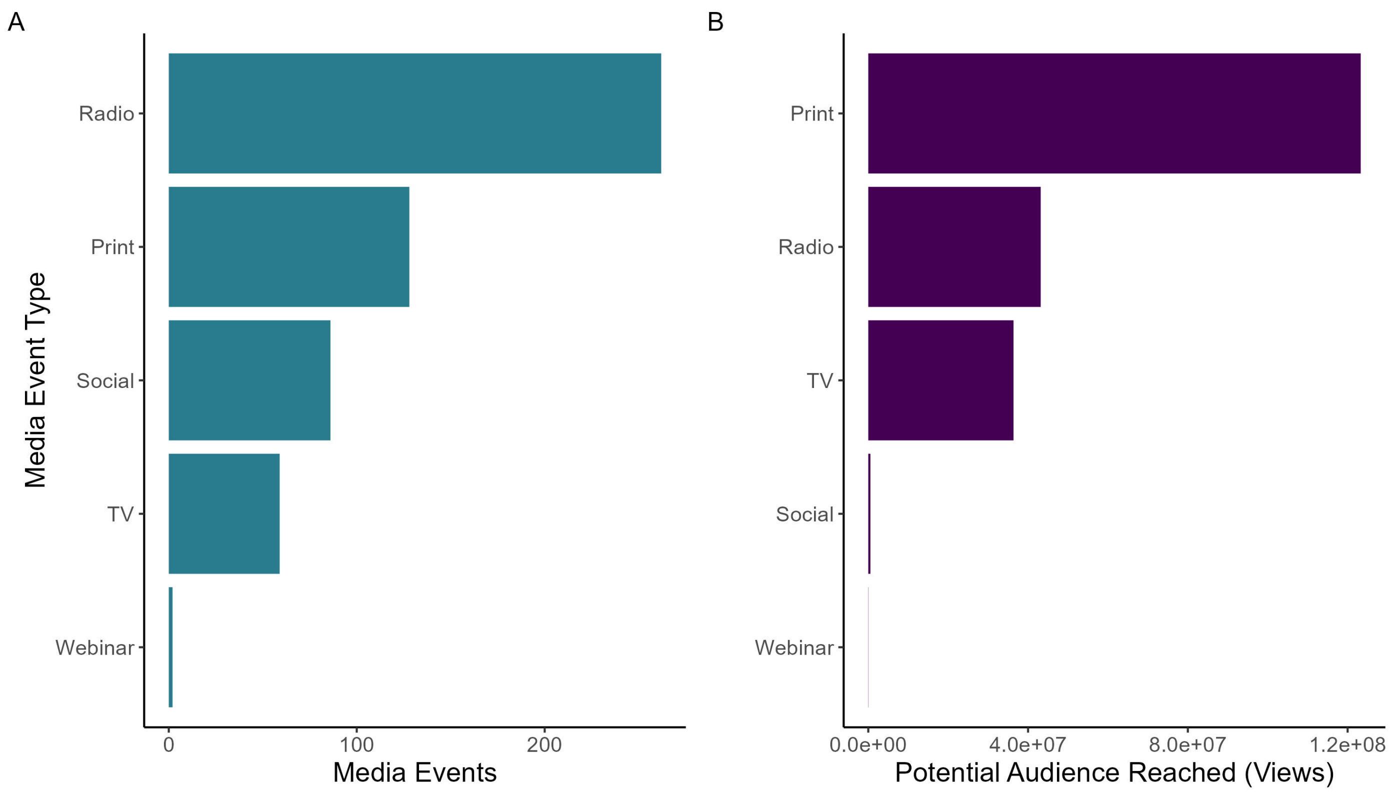


Figure 34. Media events (A) and potential audience reached (B) by project lifecycle stage summarised across all Reef Builder projects.

Media engagement was highest for both number of media events and potential audience reached during reef restoration and monitoring & evaluation project lifecycle stages (**Figure 35**).

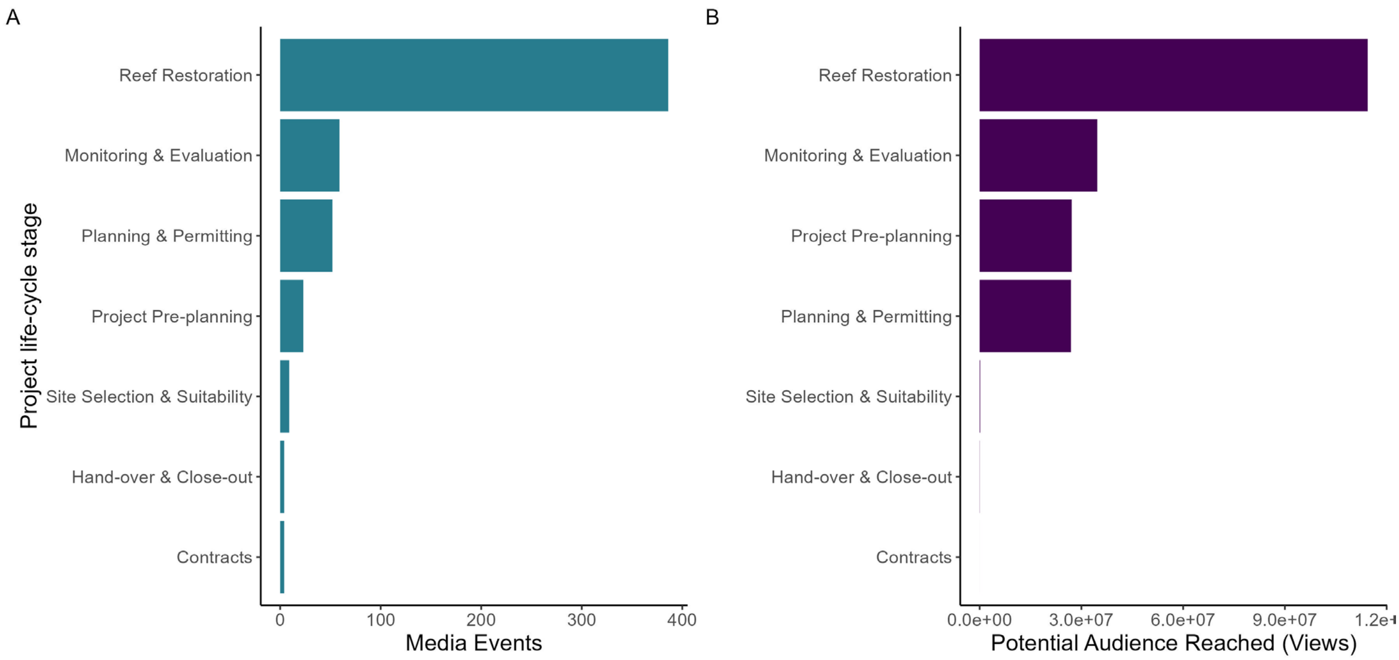


Figure 35. Media events (A) and potential audience reached (B) by project lifecycle stage summarised across all Reef Builder projects.

Radio had the highest number of media events during reef restoration (**Figure 36A**). Print followed by Radio had the highest potential audience reached during reef restoration followed by Print during monitoring and evaluation lifecycle stage (**Figure 36B**).

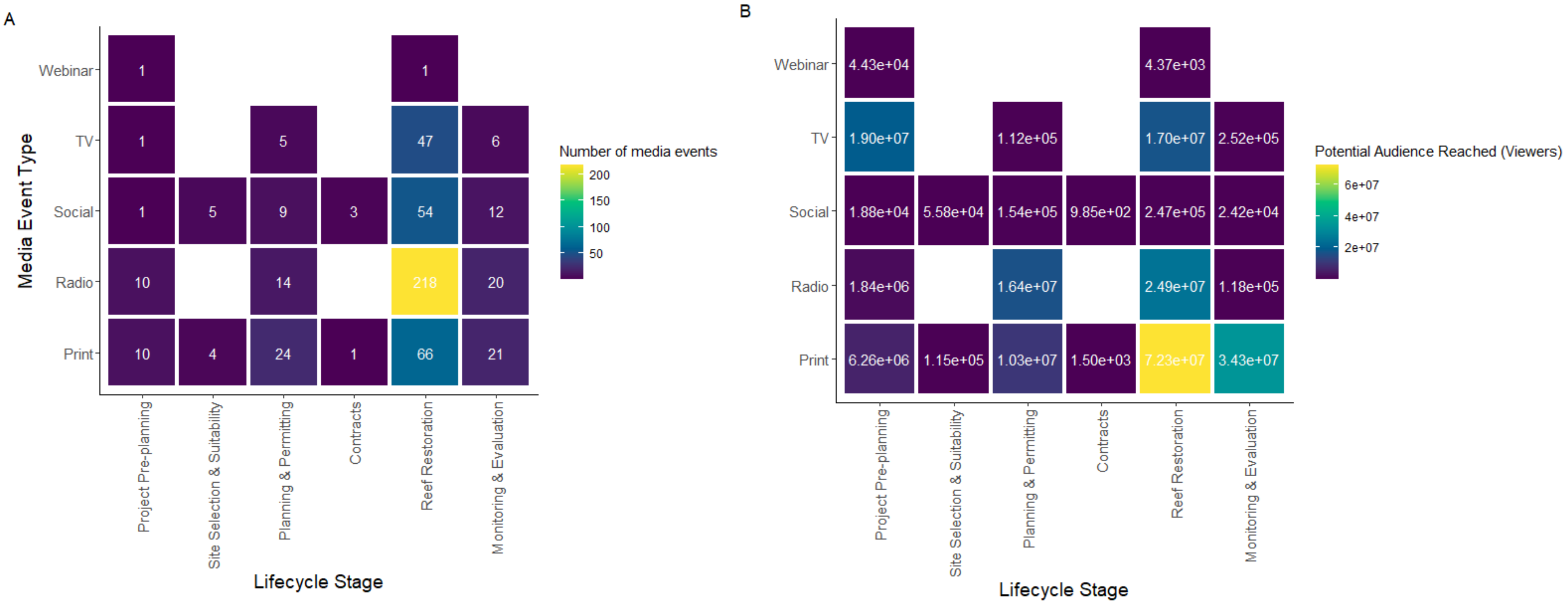


Figure 36. *Heatmap of media event types across different lifecycle stages, including the number of media events held (A), and the potential audience reached (B). The colour spectrum reflects the magnitude for each metric.*

Synthesis

The *Reef Builder* Program (2021-2023) has met or exceeded almost all planned targets and goals spanning reef construction, biodiversity benefits, job creation and community engagement, as summarised in **Table 4.** The only exception was the number of local contractors engaged (i.e., 51 vs a target of 120), but this was counteracted by the far greater number of direct jobs created (425) than anticipated (170).

Further synthesis of each of these Program Targets is provided below.

Table 4. *Summary of Reef Builder Program Targets and Key Outcomes.*

Program Targets (2021-2023)	Key Outcomes
1. **Build new reefs** – Construct shellfish reefs at 13 project locations, following established best practice project management, restoration, and siting protocols. *Goal 1 - Demonstrate construction of resilient reef structures*	Completed. Shellfish reefs were rebuilt through 13 projects, totalling an area of ocean deriving benefits from restoration of 40.5 ha. When combined with shellfish reefs rebuilt prior to *Reef Builder*, the total area restored is 61.9 ha.
2. **Improve local biodiversity** – Establish oyster and mussel populations and enhance associated ecological communities compared to benchmark ecological targets at each of the 13 projects. *Goal 2 - Rebuild a local shellfish population* *Goal 3 - Demonstrate the creation of habitat that benefits fish* *Goal 4 - Demonstrate that construction of the reef enhances marine biodiversity*	Completed. 30 million native shellfish (oysters and mussels) were seeded onto the reef bases across the 13 projects. 1,275 hours SCUBA diving undertaken to construct, seed and monitor development of the reefs. Fish biomass (for pelagic species) was typically greater at restored reefs than in nearby non-restored (reference) habitats. Species richness (spanning fish and invertebrates) was typically higher following reef restoration, and at restored reefs compared to nearby non-restored (reference) habitats.
3. **Boost local employment** – Create up to 170 jobs through employing 120 local contractors from maritime construction, earthmoving, aquaculture, engineering and natural resource management businesses across resource procurement, reef construction and reef monitoring activities. *Goal 5 – Demonstrate the benefit of shellfish reefs to local economies*	Completed. 425 direct jobs created. 51 ocal contractors were engaged.
4. **Strengthen community engagement** – Harness community interest, support and participation by communicating project progress and success through media opportunities, an online project dashboard, interactive graphics and a project video, as well as creating community volunteering opportunities. *Goal 6 – Engage the community in long-term stewardship of the shellfish reef*	Completed. 537 media events with a combined reach of 203 million viewers. 185 stakeholder and community events with 5,219 people attending. 2,903 hours of volunteering by 305 volunteers.

Target 1. Build new reefs

- Reef construction was successfully completed at each of the 13 projects, encompassing 26 restoration locations producing 19 reefs that provide restoration benefits to 40.5 ha of seafloor spanning the Swan-Canning Estuary in WA to Noosa in QLD (**Figure 37**).
- *Reef Builder* has significantly advanced progress towards the national target of restoring 30% of lost shellfish reef habitats by 2030 (TNC's '60 Shellfish Reefs Target'), bringing the collective total since 2015 to 21 reefs with a restored area of nearly 62 ha.
- The total area of constructed reef units within the broader restoration envelope met or exceeded the target standards established by the Society for Ecological Restoration (15-25%) in all but one of the restoration locations.
- All reefs have been built in accordance with stringent environmental, engineering and user-conflict specifications relevant to local geographies. However, reef design (e.g., height, shape, spatial arrangement of reef units) varied considerably among locations, in part reflecting tailoring to local conditions to maximise success and minimise any negative impacts, and in part reflecting growth of restoration practitioner and construction industry experience in large-scale reef restoration across Australia (see 'Lessons Learnt' section in the accompanying *Reef Builder Final Summary Report*) (The Nature Conservancy, 2024).

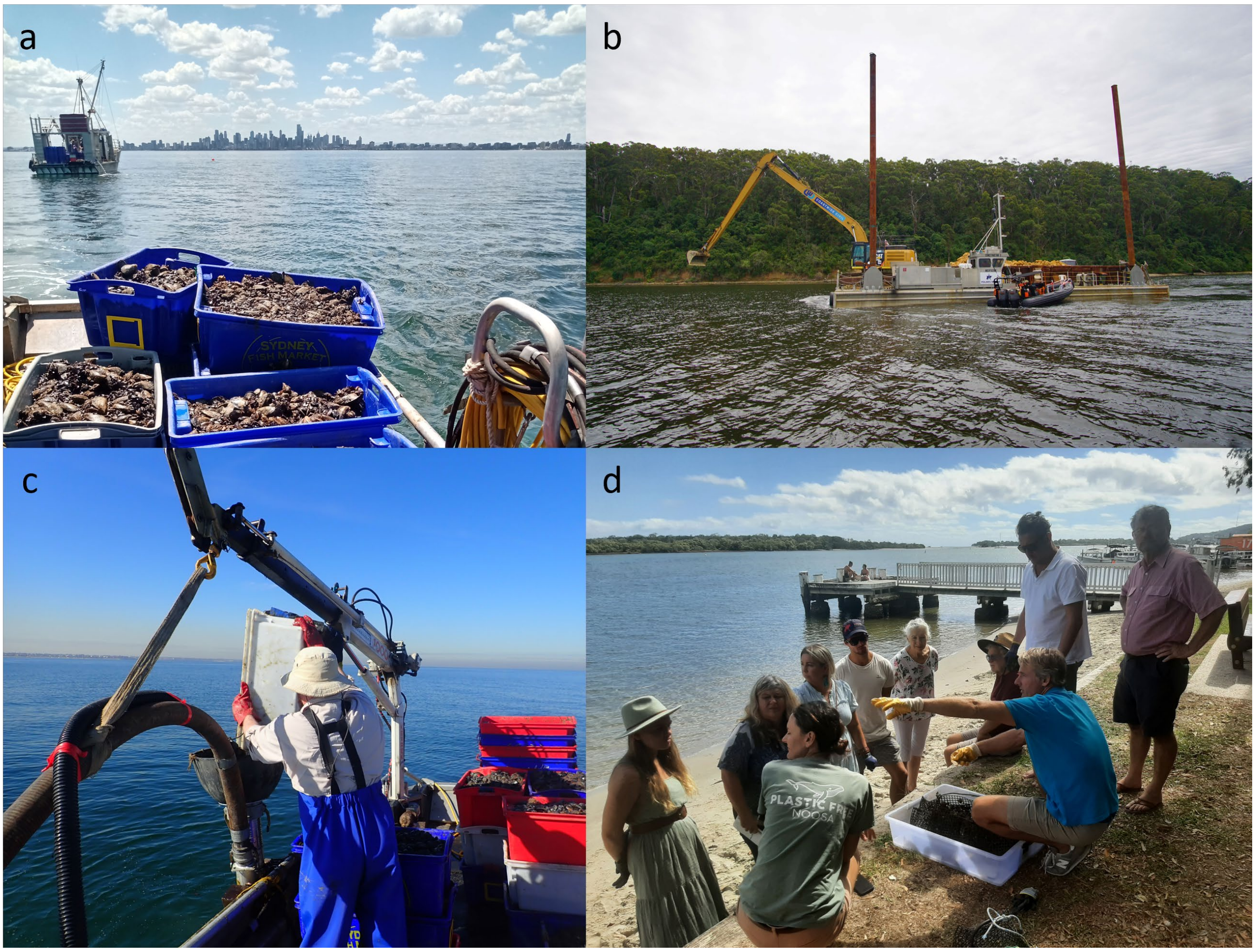


Figure 37. Reef construction in action with a) mussel seeding of reefs in Port Phillip Bay, VIC (2022), b) restoration barge with limestone rubble in Gippsland Lakes, VIC (2022), c) 'bivalve blaster' for spreading seeded cultch into the reef basis in Port Phillip Bay, VIC (2021), d) expert groups consulting with engineers and restoration project teams on reef designs in Noosa, QLD (2023). Credits a) Andrew Dunlop - TNC, b) Scott Breschkin - TNC, c) Kina Diving and d) Megan Connell – TNC.

Target 2. Improve local biodiversity

- Ecological monitoring of the restored locations and nearby reference (un-restored) habitats both before and after reef construction (i.e., 'Before–After Control–Impact') provides a robust framework for measuring their ecological benefit, not only for the target shellfish species of interest, but also for wider biodiversity (**Figure 38**). Repeated monitoring post-construction further enables the ecological development of the reef to be tracked over time, as demonstrated for the existing and more mature restoration locations at which some restoration had been initiated prior to *Reef Builder*.

- Reef bases built during *Reef Builder* were seeded with an average of nearly 400 individuals per m^2 of the target shellfish species soon after construction to initiate the restoration process. Some bases did not require seeding, given high natural recruitment from local remnant shellfish stocks.
- Target shellfish densities (as per reference models for each species; see **Appendix 1**) have been met or exceeded for all restoration locations in South Australia, Port Phillip Bay and Gippsland Lakes (VIC), Sapphire Coast and Port Stephens (NSW), and Noosa (QLD). This reflected a mix of reef age, number of seeding events, and/or very high natural recruitment.
- Some of the younger reefs built during *Reef Builder* and monitored only once to date (i.e., within the first six months post-construction), have not yet met the benchmark shellfish densities, including Albany South & North and Swan-Canning Estuary (WA) and Derwent River (TAS). This reflects some unanticipated loss of seeding stock (either prior to or just after seeding), as well as reef age (insufficient time for sizeable natural recruitment). As with any restoration project, multiple re-seeding events may be required, and contingencies for reseeding are in place.
- The re-built reefs, even within the first six months of construction in several cases, typically demonstrated substantial uplifts in pelagic fish biomass at the restoration location compared to pre-restored (baseline) conditions and nearby reference habitats (i.e., soft-sediment controls and other structured habitats such as seagrass). This was particularly evident for young reefs in Albany South & North and Swan-Canning Estuary (WA) and for some of the more mature reefs in Port Phillip Bay at particular reef ages. Dominant fish species at those restoration locations included Snapper, Little rock whiting and Yellow-tail scad.
- Regarding biodiversity (species richness) benefits for broader invertebrate and fish life, the restored locations also showed notable improvements compared to baseline conditions in most cases for pelagic fish and invertebrates, but trends were less clear for cryptic fish and invertebrates.
- The full Reef Life Survey and/or Baited Remote Underwater Video Stations data captured on the restored reef locations and adjacent un-restored habitats provide rich data sets to support fuller analyses of biotic community composition in the future.
- Ongoing monitoring of the reefs, ideally on an annual basis until they reach maturity (5-7 years from construction), is essential for building understanding of their ecological trajectories, benefits to the local environment and community, and need for further restoration support. As identified in the 'Lessons Learnt' section in the *accompanying Reef Builder Final Summary Report*, it is vital that the monitoring methods remain standardised to allow for comparisons across restoration locations and over time, but the core indicators recorded can be simplified to suit resourcing and need (The Nature Conservancy, 2024).

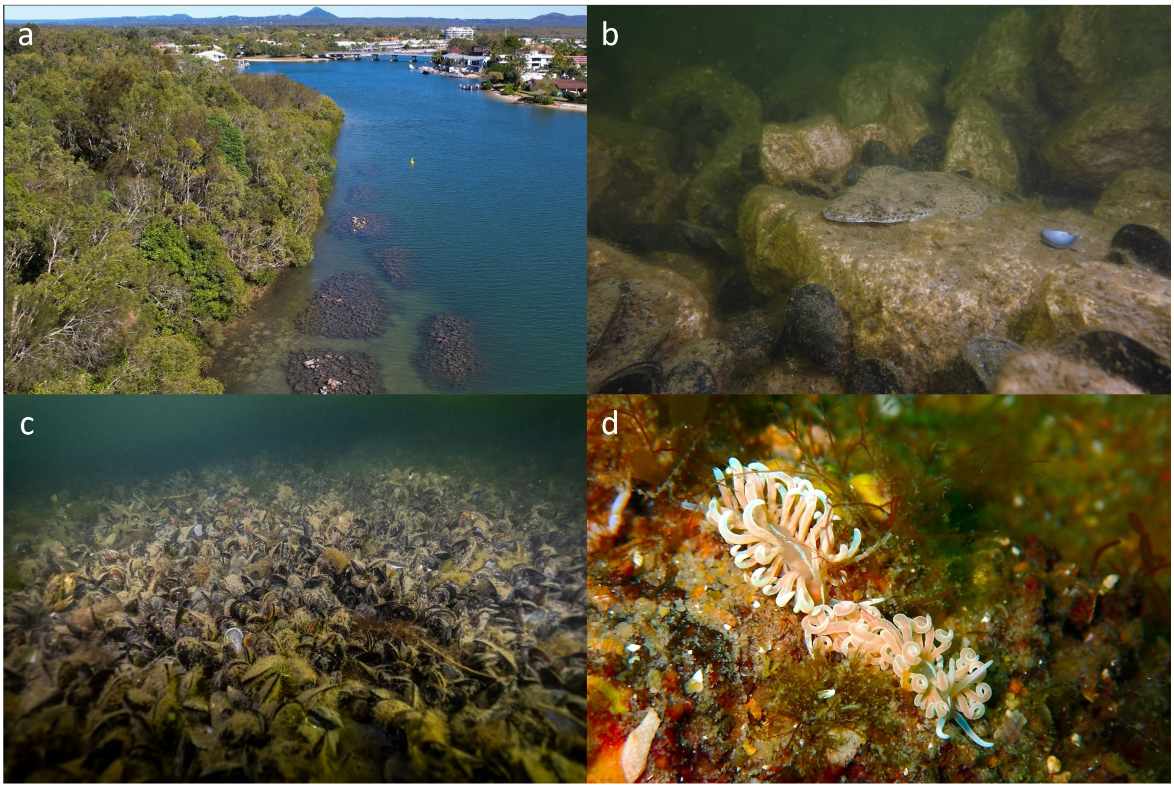


Figure 38. *Biodiversity improvements through shellfish reefs with a) restored reefs in Noosa, QLD (2023), b) a flathead on seeded mussel reef in Swan-Canning Estuary, WA (2022), c) a restored mussel reef in Gippsland Lakes, VIC (2022), and d) two nudibranchs in restored reefs of Port Phillip Bay, VIC (2023). Credits a) NSW Drone S. Cairns PANGA, b) Scott Breschkin - TNC, c) Streamline media and d) Elgin Associates.*

Target 3. Boost local employment

- In practice, *Reef Builder* generated 2.5 times the number of jobs than originally anticipated (i.e., 425 vs 170), demonstrating its clear effectiveness in creating employment opportunities. On average, nearly 5 full-time equivalent jobs were created per project.
- Most jobs were generated during the reef restoration phase (54%, where most people were employed locally) and monitoring and evaluation phase (26%, where again the majority of people employed were local to the project geography, but 43% of people were employed from interstate).
- Almost all (96%) of the 51 organisations employed during *Reef Builder* were small-medium enterprises, reinforcing the Program's commitment to supporting this sector. Less organisations were engaged than anticipated (42% of the original target), which mainly reflected limitations in the number of (i) construction companies with appropriate marine restoration experience and capabilities; (ii) shellfish hatchery/aquaculture facilities; (iii) marine monitoring consultants with appropriate Reef Life Survey and scientific diving qualifications but also capacity. These limitations were further compounded by at least half of the projects being delivered during COVID-19 lockdowns and travel restrictions.

Target 4. Strengthen community engagement

- *Reef Builder* directly strengthened community engagement in shellfish reef restoration through a wide spectrum of event types including (i) community forums (e.g. public presentations, education workshops); (ii) on-ground citizen science activities (e.g. oyster gardening, shell cleaning and recycling, water quality monitoring and fish monitoring); (iii) consultation with Technical Advisory Groups, key stakeholder groups and regulators; and (iv) scientific and restoration practitioner conferences (**Figure 39**).
- These events (185) were attended by more than 5,200 people, and particularly during the planning and permitting, reef restoration and monitoring phases of project lifecycles. Community members (305) participating in on-ground restoration activities volunteered more than 2,900 hours of their time, demonstrating strong interest and commitment to active restoration work. This type of engagement is vital for building local capacity and long-term stewardship of shellfish reef restoration projects.
- In addition to face-to-face engagement, an extensive media campaign spanning print, radio, television, social media, and webinars across all stages of the *Reef Builder* Program had a combined potential audience reach of more than 200 million views.

Figure 39. Strengthening community engagement through Reef Builder with a) primary school education day with shellfish reef crafting in Gippsland Lakes, VIC (2023), b) Friends of Nyerimilang group volunteering in Gippsland Lakes, VIC (2023), c) smoking ceremony at restored reef in Swan-Canning Estuary, WA (2022), and d) volunteers cleaning recycled shellfish in Gippsland Lakes, VIC (2022). Credits a) Elgin Associates, b) Elgin Associates, c) Fiona Valesini - TNC and d) Scott Breschkin - TNC.

In just three years, *Reef Builder* has clearly demonstrated the benefits that restoring Australia's lost shellfish reefs at impactful scales can bring for people and nature.

Appendices

Appendix 1 – Monitoring, Evaluation and Reporting Framework

Table 5. *Summary of the monitoring and evaluation approaches adopted for assessing the success of the Program targets and their underpinning goals and objectives.*

Goal	Objective	Indicator	Metric	Method	Planned Output or benchmark	Frequency/Timing	Restoration	Soft-	Seagrass	Responsibility
TARGET 1: Build new reefs – Construct shellfish reefs at 13 project locations, following established best practice project management, restoration, and siting protocols.										
GOAL 1. Demonstrate construction of resilient reef structures	OBJECTIVE 1. Construct the reef to meet design and project outputs	i 1. Area of constructed reef footprint	m^2 or ha	Multi-beam bathymetry and GIS	Defined per project	One survey, early post construction	X	-	-	TNC/Delivery partner
		i 2. Total project restoration area	m^2 or ha	Multi-beam bathymetry and GIS	Defined per project	One survey, early post construction	X	-	-	TNC/Delivery partner
		i 3. Percent reef coverage in project area	%	Multi-beam bathymetry and GIS	15-25%	One survey, early post construction	X	-	-	TNC/Delivery partner
		i 4. Total reef-base deployed	tonnes	Order and delivery dockets	Defined per project	Tracked by project manager throughout construction	X	-	-	TNC/Delivery partner
TARGET 2: Improve local biodiversity – Establish oyster and mussel populations and enhance associated ecological communities compared to benchmark ecological targets at each of the 13 projects.										
GOAL 2. Rebuild a local shellfish population	OBJECTIVE 2. Demonstrate a density of target shellfish similar to a pre-defined reference system	i 5. Total shellfish deployed	Total number of individuals deployed	Data from aquaculture manager	Defined in No. of shellfish	Once following reef seeding	X	-	-	TNC/Delivery partner
		i 6. Total number of live target shellfish	(count/m^2)	Diver surveys: shellfish metrics	50 per m^2 (adult *O. angasi*), 200 per m^2 (adult *S. glomerata*), 1000 per m^2 (*M. galloprovincialis)*	Before and after reef seeding	X	X	X	Delivery partners

GOAL 3. Demonstrate the creation of habitat that benefits fish	**OBJECTIVE 3.** Demonstrate more fish post reef construction	i 7. Fish abundance	Total biomass of fish (g/m^2, kg/ha), or MaxN for BRUVS	Diver Surveys – Reef Life Survey and stereo Baited Remote Underwater Video stations (BRUVS)	Biomass > baseline	Before reef construction and after reef seeding	X	X	X	Delivery partners
GOAL 4. Demonstrate that construction of the reef enhances marine biodiversity	**OBJECTIVE 4.** Demonstrate an increase in biodiversity	i 8. Species richness of mobile epifauna	Total number of species	Visual census surveys (Reef Life Survey for subtidal; quadrat surveys for intertidal)	Richness > baseline	Before reef construction and after reef seeding	X	X	X	Delivery partners
TARGET 3: Boost local employment – Create up to 170 jobs through employing 120 local contractors from maritime construction, earthmoving, aquaculture, engineering and natural resource management businesses across resource procurement, reef construction and reef monitoring activities										
GOAL 5. Demonstrate the benefit of shellfish reefs to local economies	**OBJECTIVE 5.** Demonstrate delivery of jobs	i 9. No. local contractors engaged	No. of local contractors/ businesses engaged	Data collected by Project Mgr	No. of unique organisations engaged with; no. of employees engaged	Ongoing throughout each project	X	-	-	TNC/Delivery partner
		i 10. No. of full-time jobs	FTE across project activities	Data collected by Project Mgr	FTE of employees	Ongoing throughout each project	X	-	-	TNC/Delivery partner
TARGET 4: Strengthen community engagement – Harness community interest, support and participation by communicating project progress and success through media opportunities, an online project dashboard, interactive graphics and a project video, as well as creating community volunteering opportunities.										
GOAL 6. Engage the community in long-term stewardship of the shellfish reef	**OBJECTIVE 6.** Demonstrate engagement by the local community	i 11. Number of community events	No. of community events for the project (e.g., public information meetings, volunteer events)	Data collected by Project Mgr	No. of events	Ongoing throughout each project	X	-	-	TNC/Delivery partner
		i 12. Attendees at public	No. of attendees at public/consultative forums	Data collected by Project Mgr	No. of attendees	Ongoing throughout each project	X	-	-	TNC/Delivery partner

		consultation meetings								
		i 13. Community and partner organisations engaged	No. of community and partner groups engaged	Data collected by Project Mgr	No. of organisations/groups engaged	Ongoing throughout each project	X	-	-	TNC/Delivery partner
	OBJECTIVE 7. Demonstrate media engagement	i 14. Media engagement	No. of times the project is mentioned in the media (excluding TNC's social media)	Media Monitoring. Data collected by Project Mgr	Media Monitoring e.g., Meltwater	Ongoing throughout each project	X	-	-	TNC/Delivery partner
	OBJECTIVE 8. Demonstrate involvement opportunities for community members to participate in marine restoration	i 15. Total No. of volunteers	No. of community volunteers contributing to citizen science or restoration activities	Data collected by Project Mgr	No. of volunteers	Ongoing throughout each project	X	-	-	TNC/Delivery partner
		i 16. Volunteer hours donated	No. of volunteer hours donated over project	Data collected by Project Mgr	Time volunteered in hours	Ongoing throughout each project	X	-	-	TNC/Delivery partner

Appendix 2 – Monitoring Methodologies

The following section describes methodologies used to track progress towards the construction (reef contruction), biodiversity (shellfish metrics, Reef Life Surveys, Baited Remote Underwater Video Stations), local employment and community engagement (socio-economic) goals.

Reef construction

Typically, reefs were built by contracting marine construction companies to deploy a base of locally sourced rock using long reach excavators in line with reef design specifications. Load-out sites were established at each of the project locations. Those sites served as places to stockpile rock transported from local quarries before being loaded onto a barge. A tug then transported the barge and long reach excavator out to the restoration site, where the rock was carefully laid over the seafloor in accordance with specifications. For projects that used recycled shells e.g., Port Phillip Bay, the same process as per limestone was undertaken for the use of recycled shell to construct reef bases, which was transported from a local shell curing site.

Wherever possible, the timing of reef construction was planned to occur just before the natural spawning and settlement cycle the target shellfish to enhance the probability of natural recruitment onto the reef bases. However, this was not always possible due to contractor availability, timing of permits/approvals and weather conditions.

Reef designs varied between project locations and were tailored to local conditions. In most cases, the reefs comprised an array of reef patches deployed over the restoration area, with a target bottom coverage of 15-25%. All reefs were designed to minimise possible impacts on coastal processes and water users/uses, and to enhance ecological recovery. This involved expert advice from construction and coastal engineers, coastal modellers and local stakeholders/technical advisors spanning Traditional Owner Groups, universities, government, consultancy, fishing and marine care sectors and NGOs.

Following construction, the reef patches were seeded with the target shellfish, which were either reared in a local hatchery and/or grown on local aquaculture leases. For restoration locations involving oysters, juvenile oysters were settled onto clean recycled shell ('cultch') in a hatchery setting, with the oyster larvae reared from local broodstock sourced in line with each State's biosecurity and translocation protocols. The shell cultch was obtained from a variety of sources, including TNC's 'Shuck Don't Chuck' project in Victoria (Branigan et al., 2020), local oyster farmers and seafood wholesalers. The shells were cleaned using a mussel tumbler and pressure washer, then bagged up ready for placement into hatchery tanks for larvae settlement. Commercial divers were employed to hand-spread the seeded cultch onto the reef bases and initiate the restoration process.

For restoration locations involving mussels, shellfish were sourced from local aquaculture farmers. Wild mussel spat naturally recruited onto long-lines deployed on aquaculture leases and were grown out (to adult or sub-adult size) for approximately one year. Mussels were then stripped from the long lines, tumbled/cleaned if required by local biosecurity and translocation protocols, and seeded onto the reef bases from the water surface. This seeding process involved purpose-built surface-to-reef apparatus, that generally had a large tray (or 'hopper') mounted to the side of a vessel, with a subsurface chute (metal or flexible tubing) attached. Mussels were loaded into the hopper then directed onto the reefs via the chute, which in some locations was guided with the assistance of commercial divers.

Data on the reef construction and seeding materials used during each project was collected by the Project Managers and/or contractors to track and report on quantities deployed.

The **Total reef-base deployed** [tonnes] (see **Appendix 1**, i 4) was used as an indicator representing the total amount of reef-base (rock and recycled shell) used to construct reefs.

The **Total shellfish deployed** [No. of juvenile shellfish] (see **Appendix 1**, i 5) was used as an indicator representing the total number of shellfish seeded onto the reef.

Subtidal reef measurement of constructed area

For subtidal reefs, multi-beam echo sounder (MBES) bathymetric surveys were used to characterise the layout and dimensions of the built reef structures. These surveys were undertaken soon after completion of the reef construction and captured the entire restoration area. The MBES surveys were undertaken in depth ranges of 1-15 m, and typically had a Horizontal Accuracy of ~ +/-0.40m and a Vertical Accuracy of ~ +/- 0.06 m. To quantify the reef bathymetry, transects were undertaken in a grid pattern following established best-practice. The survey grid was provided in ASCII format to Chart Datum at both 5 m and 2.5 m grid spacing or determined using one of the following formulas:

Side-scan Sonar Lane width = Range – (Altitude + Overlap)

Where *Altitude* is the height of the tow fish above the seafloor (this would be a value equal to 10% of the range), and *Overlap* is the desired overlap between transect lanes (overlap of 10%).

Multi-beam Sonar Lane width = Total Range – Overlap

Where *Total range* was determined by the frequency used (generally three times the water depth as per manufacturer's specifications) and *Overlap* is the desired overlap between transect lanes (a suggested overlap is 10%).

Intertidal reef measurement of constructed area

For project locations at which intertidal reefs were built (i.e., Noosa, Sapphire Coast, and Port Stephens), measurements of reef layout, morphology, area and elevation were conducted using a combination of methods adapted from Windle et al. (2019) and Genchi et al. (2020). Methods below outline both low cost/less involved (Aerial Imagery, RTK-GPS) and higher cost/more involved (Unoccupied Aircraft System) approaches, which were selected depending on their applicability for each project.

Baseline restoration area elevation - topographical survey: RTK-GPS Method

Prior to restoration, five RTK GPS transects using a 1m survey interval were conducted across the intertidal area restoration area of the oyster reef and bare sediment control. Transects occurred at spring low tide and run along the intertidal longitudinal gradient of the site, from the highest intertidal to the low water mark. Within each habitat, the five transects were equidistantly separated along the habitat range. To ensure that transects are run consistently through the years, each transect was georeferenced.

Reef structure: RTK-GPS Method

A real-time kinematic (RTK) GPS was used to monitor the intertidal reef at a spring low tide. The RTK (GPS) used a base station correction to achieve a maximum 3 cm-level accuracy. To calculate reef area, continuous measurements of 1 m increments were undertaken while walking around the perimeter of each reef patch. To calculate the reef elevation profile, transects were established along the centreline of the long axis of each reef patch, and continuous measurements of 1 m increments undertaken.

Reef footprint: Digitisation Method

Outlines of restored reef patches in intertidal restoration locations were otherwise obtained through high-resolution (5-7 cm) aerial imagery (provided by Nearmap Australia Pty Ltd.). Reef patches were manually digitized tracing the outline of restored reefs at these locations in ArcGIS Pro (v3.2.2).

Baseline restoration area elevation - topographical survey: Unoccupied Aircraft Systems (UAS)

A multi rotor aircraft equipped with a camera and a survey grade RTK GPS capable of 2 cm horizontal error, 5 cm vertical error and a GSD of 2.5 cm was used on the oyster reef area and the bare sediment control area. To ensure a high degree of overlap, the flight path was designed as straight flight lines sampling a grid pattern within each habitat area. The flight average height and flight speed were adjusted to the characteristics of each monitoring site.

Ground control points (GCPs), typically black and white 'checker' targets with defined centre points, were used to help increase geolocation accuracy of UAS imagery, which also helped during the structure from motion photogrammetry process. Before each flight, the centre of 4 to 10 GCPs was surveyed using an RTK GPS. All UAS imagery was processed with a photogrammetry software to output RGB orthomosaics and digital surface models (DSMs) in the appropriate UTM Zone and projection. The DSMs were created using an inverse distance weighting method, allowing for surface smoothing at 1.12 to 2.21 cm/pixel. DSMs generated by the UAS surface model heights were converted to elevations in the Australian Height Datum (AHD) to create a digital elevation model.

Reef structure: Unoccupied Aircraft Systems (UAS)

A multi-rotor aircraft equipped with a camera and a survey grade RTK GPS capable of 2 cm horizontal error, 5 cm vertical error and a ground sample distance (GSD) of 2.5 cm, was used on the oyster reef area. Ground control points (GCPs), typically black and white 'checker' targets with defined centre points, were used to help increase geolocation accuracy of UAS imagery, which also helped during the structure-from-motion photogrammetry process. Before each flight, the centre of 4 to 10 GCPs was surveyed using a RTK GPS. All UAS imagery was processed with photogrammetry software to output RGB orthomosaics and digital surface models (DSMs) in the appropriate UTM Zone and projection. The DSMs were created using an inverse distance weighting method, allowing for surface smoothing at 1.12 to 2.21 cm/pixel. DSMs generated by the UAS surface model heights were converted to elevations in the Australian Height Datum (AHD) to create a digital elevation model.

The **Area of constructed reef footprint** [m^2] (see **Appendix 1**, i 1) was systematically obtained for all subtidal reefs through a slope analysis on the MBES bathymetry data. For intertidal reef locations at Port Stephens and Sapphire Coast locations, reefs were manually digitized using high-resolution (5.5-7.5 cm) aerial imagery (provided by Nearmap Australia Pty Ltd.). Footprints of intertidal reefs in Noosa were obtained through RTK-GPS.

The **Total project restoration area** [ha] (see **Appendix 1**, i 2) was used as an indicator representing the minimum total area encompassing all reef patches at each location, determined from project GIS outputs. Restoration area was determined using the minimum bounding geometry (convex hull) around polygons of reef patches plus a 5 m buffer, thereby capturing the interstitial space between reef patches and the area surrounding the reef array where ecological benefits are likely to occur.

The **Percent reef coverage in project area** [%] (see **Appendix 1**, i 3) was used as an indicator representing the percentage of the project restoration area covered by re-constructed reef.

*Percent reef coverage in project area = (Area of constructed reef footprint ÷ Total project restoration area) * 100*

Mean and maximum reef height [m] were obtained through either (i) direct comparison between pre- and post-construction MBES data or UAS-derived DEM data, taking the difference in bathymetry/DEM for areas identified as reef patches (see area of constructed reef footprint) and summarised using zonal statistics in ArcGIS Pro per reef location to obtain the mean and maximum height; (ii) In locations without pre-construction MBES data, areas identified as reef were compared against the surrounding water depth, and the difference between the depth at the reef area and its surroundings was used to calculate and summarise mean and maximum reef height; (iii) For reef locations with no data available, reef height was obtained from dive surveys or technical construction reports provided.

Ecological monitoring

Data on the target shellfish species and biodiversity of other epifauna was collected both before ('baseline') and after restoration in areas where shellfish reefs were restored and in nearby areas without restoration. Restored areas were compared to an area of soft-sediment serving as a control ('negative reference'), or a representation of what would occur if restoration was never undertaken. Ideally, restored areas would be compared to a 'positive reference', and in particular an area of natural shellfish reef that can act as a guide to the anticipated restoration trajectory and performance of a restored reef in a given system. Due to a lack of naturally occuring shellfish reefs at most restoration locations except for Gippsland Lakes, a modelled reference system was used (Gillies et al., 2017; McAfee et al., 2020; Roberts et al., 2023). For Gippsland Lakes locations, a reference shellfish ecosystem with multiple remnant patches served as a 'positive reference' to guide effectiveness of restoration. In most other locations, restored shellfish reefs were compared with nearby seagrass habitats to provide an alternative structured habitat or positive reference. For some locations such as those in the Swan-Canning Estuary, nearby seagrass beds were not present. Depending on availability, up to four habitats were monitored with a minimum of at least two (the shellfish restoration site vs the 'negative reference') at each location (**Figure 40**, below):

1. Shellfish restoration area
2. A soft-sediment – 'negative reference'
3. A natural shellfish reef – 'positive reference' (if available)
4. A seagrass reference or rocky reef reference – alternate 'positive reference'

Where possible, monitoring sites with similar hydrodynamic or water quality conditions were selected in order to reduce confounding influences. In addition, monitoring transects within habitats were sufficiently spaced apart to minimise spatial dependence (mutual influence) between them.

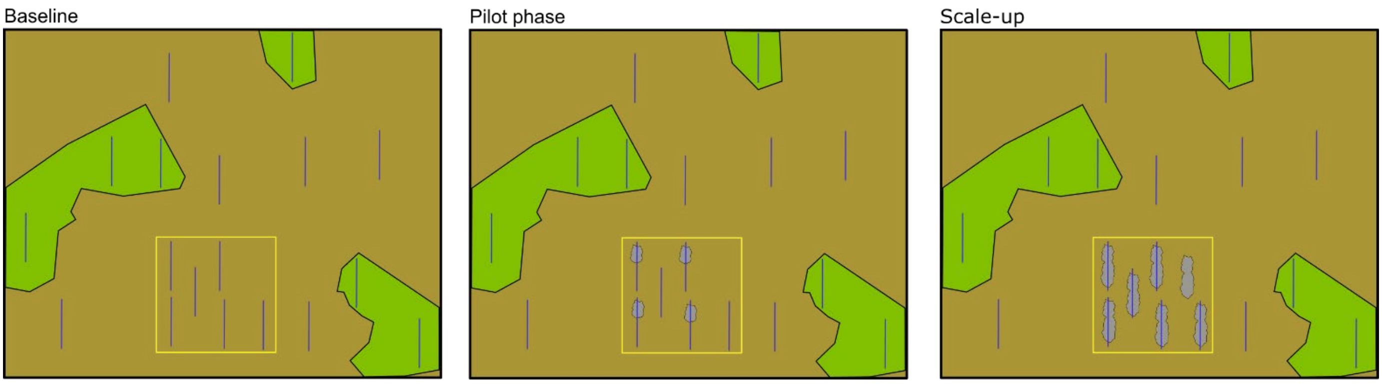


Figure 40. A schematic of a randomised, spatially balanced monitoring design for Reef Builder. At a given location, a project area (the minimum total area encompassing all monitoring and restoration sites for a project or restoration location) is defined encompassing three habitat types: (1) the reef restoration area – yellow polygon and grey reef structures; (2) soft-sediment – brown; and (3) seagrass – green (or other designated habitat). Within each habitat, each monitoring methodology is undertaken and replicated equally. Vertical lines = underwater visual census (6 per habitat).

Intertidal ecological monitoring methods

Target shellfish

At intertidal restoration locations, sampling occured at spring low tide. Within each habitat type (reef, control and reference), 50 x 50 cm quadrats positioned along three 10 m-long transects per habitat were used to undertake a count and size assessment of the target shellfish. Quadrat placement was randomised

Quadrats were placed using two independent random number sets from a random number generator (e.g., https://www.calculatorsoup.com/calculators/statistics/random-number-generator.php). Fifteen random quadrats within a defined reef patch area were placed within a grid, defined by the length and width of the reef patch.

Using the first random number set a perpendicular transect was placed at the distance along the length axis of the shoal (base transect) defined by the first of fifteen numbers e.g. 7 = 7 m. Along the perpendicular axis a single quadrat position was determined from all possible positions along the reef patch width axis (e.g. 1 – 10 m) i.e. the first number from the second random number set. This is repeated for all 15 numbers generated in both number sets such that as perpendicular transects are consecutivly laid along the base transect, quadrats effectively randomly sample across the entire possible reef patch area (**Figure 41**)

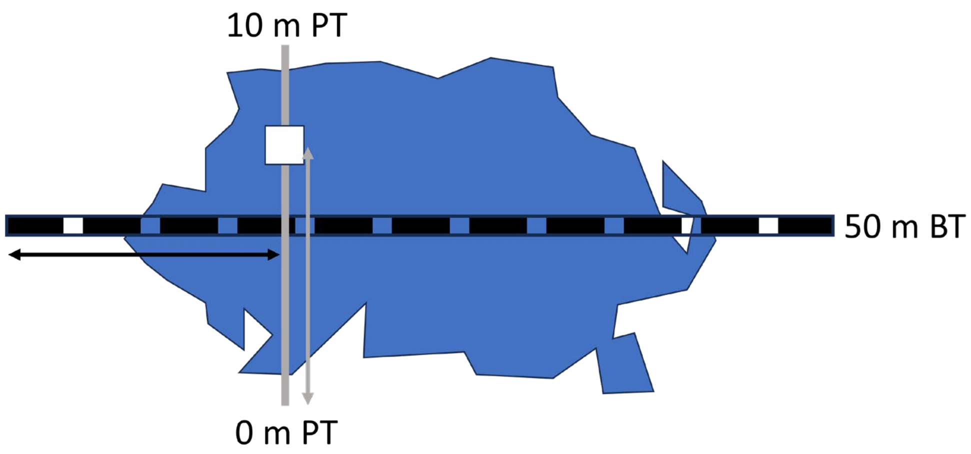


Figure 41. Stylised diagram of randomised quadrat placement approach. Black line shows 50 m base transect (BT) placement down centre of reef patch (blue). The black arrow showing the placement for the perpendicular transect as per first number from randomised number set in (15 numbers randomised between 1 and 50). Grey line shows the first of 15 perpendicular transects, with the grey arrow showing the placement of the quadrat (white square) according to the first number from the second randomised number set (15 numbers randomised between 1 and 10).

Ten replicate 50 x 50 cm quadrats were placed per transect, and a photograph taken of each quadrat. Additionally, shellfish size (i.e., distance from the hinge axis to the distal margin of the shell) was measured using callipers, with 10 individuals spanning the size range measured per quadrat. Shellfish density was determined by counting all live target shellfish (up to 10 cm deep into the reef) in each quadrat then expressing as a number per unit area (see below). If shellfish were particularly dense within a 50 x 50 cm quadrat, a subsample covering 25 x 25 cm was measured.

The following considerations were taken into account when deploying the monitoring transects within the different habitats:

a) For restored reefs: Base transects were aligned along the longest axis of reef patches; Multiple reef patches were combined to achieve a transect distance of 10 m where necessary.

b) For control and reference ecosystems: Base transects were aligned parallel to shore along a depth contour and placed in equivalent tidal heights to restored reef arrays.

i. Percentage cover of shellfish and sessile invertebrates and algae were assessed from quadrat photographs by scoring benthic composition under 10 random points using the annotation Software Squidle+ (https://squidle.org/).

ii. Shellfish density: Density of shellfish per quadrat (0.25 m^2) was calculated by multiplying the average density of shellfish from the smaller quadrats (25 x 25cm) by the percentage cover of the larger quadrat.

[Mean density] *Shellfish.m^2 = (shellfish per sampling unit) * multiplier*

For example: *Shellfish.m^2 = (shellfish per 0.25 m^2) * 4*

*[Mean density of shellfish in restoration area] Shellfish$_i$ = mean shellfish per m^2 * area of reef [m^2]*

The **Total number of live target shellfish** [No. of shellfish per m^2] (**Appendix 1**, i 6) was used as an indicator representing the number of live shellfish, including recruits, per m^2.

Mobile epifauna community

At each intertidal restoration site, the mobile epifauna community was sampled in each habitat type (reef, control and reference) using the same quadrats as for live target shellfish above.

Species richness of mobile epifauna [No. of different species per transect] (see **Appendix 1**, i 8) was used as an indicator representing the count of species at the monitoring site, and is a key measure of biodiversity.

Fish community

At each intertidal restoration site, the fish community was sampled in each habitat type (reef, control and reference) at slack high tides, typically during the morning.

Stereo-Baited remote underwater video stations (BRUVS)

At locations which were too shallow to carry out effective RLS (i.e. < 1.5 m water depth), baited remote underwater video stations (BRUVs) were used as an alternative method to measure the development of the nektonic community. Three SeaGIS stereo Mini-BRUV frames with a stainless steel 0.5 m arm and attached bait bag (containing 3 x pilchards crushed, *Sardinops sagax*) were independently deployed in each habitat and separated by at least 20 m. Videos were record for 30 minutes.

Video processing. Videos were processed through EventMeasure software (https://www.seagis.com.au/). Fish were identified to the lowest taxonomic level possible and the MaxN per species recorded (i.e., the maximum number of individuals of the same species present in a frame at a time across each video; Cappo et al., 2004). The total length of each species was also recorded alongside MaxN (i.e. tip of fish nose to tip of the longest caudal lobe).

Relative species abundance (see **Appendix 1**, i 7) .The maximum number of individuals per species was measured by BRUVS as relative species counts (MaxN) at monitoring sites.

Relative species richness [No. of species] (see **Appendix 1**, i 8) was used as an indicator representing the count of species at a monitoring site, and is a key measure of biodiversity.

Subtidal ecological monitoring methods

Target shellfish

Target shellfish were monitored by sampling 15 replicate quadrats (typically 0.25 m^2, i.e., 50 x 50 cm) or blocks (5 x 1 m) along each 50 m transect (4 – 6 per habitat) in both restoration (quadrats) and control/reference habitats (blocks). For the soft-sediment control and structured reference habitats, shellfish were surveyed in 1 m (wide) x 5 m (long) blocks along each side of the 50 m transect, given shellfish were typically absent or occurred in low densities in these habitats.

The following considerations were taken into account when deploying the monitoring transects at subtidal locations:

a) For restoration reefs: 15 randomly placed quadrats (0.25 m^2) per transect were deployed for target shellfish

b) For seagrass, soft-sediments or other reference ecosystem: the entire 50m transect was surveyed with one diver each side, breaking into 5 m (long) x 1m (wide) blocks or 10 blocks per side of transect.

Quadrat placement was randomised as per intertidal quadrat placement.

During sampling, divers measured *in-situ* or collected all identified target shellfish within the surveyed quadrat. If the shellfish were on rock or shell reefs, divers collected 10 cm into the reef substrate. All shellfish and sampled substrate were placed into mesh collection bags. The mesh collection bags were then attached to a shotline and lifted to the surface for measurement on the research vessel or on shore. For seagrass and soft-sediment surveys, shellfish were measured underwater or taken to the surface and measured depending on numbers of shellfish present. All shellfish were returned to their original habitat after measurements were undertaken.

Measuring shellfish. Shellfish were measured for height (the distance from the hinge axis to the distal margin of the shell) to the nearest millimetre using callipers.

The height of a maximum of 250 target shellfish per transect was measured, ensuring no size bias. Therefore:

a) For restored reefs: in each quadrat, if target shellfish were present, a maximum of 17 target shellfish were measured.

b) For control/reference habitats: in each block, if target shellfish were present, a maximum of 13 target shellfish were measured.

Including those measured for height, the number of live target shellfish per quadrat/block was counted.

The **Total number of live target shellfish** [No. of shellfish per m^2] (see **Appendix 1**, i 6.) was used as an indicator representing the number of live shellfish, including recruits, per m^2.

Fish and epifauna - Reef Life Survey Transects and Photo Quadrats

Visual census techniques provide an effective, non-destructive way to monitor species. Large amounts of data on a broad range of species can be collected within a short period, with little post-processing time required. The surveys include visual observations of mobile fish, cryptic fish, mobile epifauna, encrusting invertebrates, algae and benthic substrate.

Underwater visual census surveys were based on Reef Life Survey (RLS), a standardised sampling method utilised globally to monitor major marine taxonomic groups in rocky and coral reef ecological communities. The method was designed to allow volunteer and professional SCUBA divers trained in scientific techniques of underwater surveys to collect quantitative data and enter it into a global database. The database is open access and allows the study of spatial patterns in marine communities (Reef Life Survey, 2015; Edgar et al., 2020). Surveys are undertaken along 50 m transects as a standard.

In the Reef Builder Program, RLS was utilised to capture the development of benthic and nektonic communities at the restored reefs over time compared to control and reference ecosystems nearby. Therefore, a 50 m transect line was deployed at each monitoring site (restored reefs, reference and control monitoring sites) per sampling event by a scientifically-trained SCUBA diver. Over each transect, the three standard RLS methods were applied:

- Method 1: to measure fishes and larger mobile fauna,
- Method 2: to measure mobile invertebrates and cryptic fishes and
- Method 3: photoquadrats to capture the benthic sessile community.

Together, these methods cover the majority of large biota on reefs that can be surveyed visually, i.e., >2.5 cm in size (Stuart-Smith et al. 2017). Only the first two of these methods have been included in this report, but all methods are outlined further below for completeness.

Method 1. Fishes, reptiles, mammals and cephalopods were surveyed in duplicate 5 m-wide belts on either side of the transect line, with abundance recorded for all species observed during a single swim-through. All species sighted within the blocks were recorded, including unidentified individuals, which were usually photographed for later identification with the assistance of taxonomic keys and/or expert opinion. Size bins used were 2.5, 5, 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 50, 62.5, 75, 87.5, 100, 112, 125, 137.5, 150, 162.5, 175, 187.5, 200, 250, 300, 350 and 400 mm, with larger individuals estimated to the nearest 125 mm. Fish counts were later converted to biomass estimates using species-specific length-weight relationships provided in Fishbase (http://www.fishbase.org/search.php). The total area and volume sampled was 500 m^2 and 2500 m^3, respertively.

Method 2. Large mobile invertebrates (echinoderms, molluscs and crustaceans >2.5 cm) and cryptic fishes were counted in duplicate 1 m-wide belts on either side of the transect line, with divers brushing aside any vegetation and looking closely in crevices, under ledges or amongst other sessile biotic structure, e.g. sponges, corals, shellfish clumps. Total area and volume sampled was 100 m^2 and 200 m^3, respectively.

Method 3. Photoquadrats were collected as digital photoquadrats (~30 cm of substrate) taken at 2.5 m intervals along the transect line for algae, sessile invertebrates and benthic substrate (e.g., sand and seagrass). Photoquadrats were processed using the Australian Morphospecies Catlalogue (AMC) annotation schema with the tool SQUIDLE+ (A tool for managing, exploring & annotating images, video & large-scale mosaics; https://squidle.org/) with 10 points per photoquadrat and an additional full-frame annotation for genral benthic classification. Benthic functional groups were identified using the the AMC schema which is an extension of the Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) v1.4 Classification Scheme (https://catami.org/; CATAMI Technical Working Group, 2014). Taxa underlying points were identified to the lowest classification group. The CATAMI Classification Scheme provides an Australian-wide acknowledged, standardised terminology or vocabulary for annotating benthic substrates and biota in marine imagery (Althaus et al., 2015). Benthic functional groups were then grouped by major functional groups to allow a comparison across sites. Note that data collected with Method 3 is not included in this report.

Method 0. This method is not a defined part of RLS transect, but rather a way of recording species that were not included wihtin the time and space boundaries of method 1 and 2, and can be included at any stage of the dive. The main purpose and benefit for including method 0 is to allow a mechanism for recording the presence of these species (particularly important for rare species or those outside their usual distribution range), and to ensure unbiased results for method 1 and 2 by allowing divers to record such species separately.

The **Total biomass of fish** [g/transect] (see **Appendix 1**, i 7) was used as an indicator representing the total biomass of the fish assemblage over the area of survey.

Species richness of mobile epifauna [No. of different species per transect] (see **Appendix 1**, i 8) was used as an indicator representing the count of species within the survey area, and is a key measure of biodiversity.

Socio-economic monitoring

Social and economic considerations are central to assessing shellfish restoration feasibility and long-term sustainability. Metrics on the socio-economic impact of reef construction (e.g., job delivery and community engagement) were collected by Project Managers through project records and tracking workflows. Project Managers captured the total number of people and hours worked directly and indirectly (in-kind) on each project. Labour and full-time equivalent (FTE) roles were coded in accordance with ANZSCO (Australian and New Zealand Standard Classification of Occupations, 2013) and ANZSIC

(Australian and New Zealand Standard Industrial Classification, 2006) categories to ensure consistent data collection and reporting.

Economic Monitoring

Employment opportunities

Occupations

The labour and FTE were categorised based on the ANZSCO occupationi or role groupings (Table 6).

Table 6. Major occupation groups as per ANZSCO 2013.

No	Occupation Group
1	Managers
2	Professionals
3	Technicians and Trades Workers
4	Community and Personal Service Workers
5	Clerical and Administrative Workers
6	Sales Workers
7	Machinery Operators and Drivers
8	Labourers

Industry types

Organisations involved in the delivery of *Reef Builder* were categorised into industries based on the ANZSIC (2006) classification (Table 7).

Table 7. ANZSIC (2006) Industry Division codes and Titles.

Division code	Title
A	AGRICULTURE, FORESTRY AND FISHING
B	MINING
C	MANUFACTURING
D	ELECTRICITY, GAS, WATER AND WASTE SERVICES
E	CONSTRUCTION
F	WHOLESALE TRADE
G	RETAIL TRADE
H	ACCOMMODATION AND FOOD SERVICES

I	TRANSPORT, POSTAL AND WAREHOUSING
J	INFORMATION MEDIA AND TELECOMMUNICATIONS
K	FINANCIAL AND INSURANCE SERVICES
L	RENTAL, HIRING AND REAL ESTATE SERVICES
M	PROFESSIONAL, SCIENTIFIC AND TECHNICAL SERVICES
N	ADMINISTRATIVE AND SUPPORT SERVICES
O	PUBLIC ADMINISTRATION AND SAFETY
P	EDUCATION AND TRAINING
Q	HEALTH CARE AND SOCIAL ASSISTANCE
R	ARTS AND RECREATION SERVICES
S	OTHER SERVICES

Enterprise/organisation size

Additionally, each organisation contributing to *Reef Builder* was categorised as a micro, small, medium or large enterprise using both the Australian Tax Office (ATO) and Australian Bureau of Statistics (ABS) definitions, with ATO based on turnover and ABS based on how many people an enterprise employs.

ATO

- Large Business: turnover > $250 million
- Medium business: turnover >$10 million ≤ 250 million
- Small business: turnover >$2 million ≤ 10 million
- Micro-business: ≤ $2 million

ABS

- Micro-business: employs 0-4 persons
- Small business: employs 5-19 persons
- Medium business: employs 20-199 persons
- Large business: employs 200 or more persons

Jobs per project were tracked monthly via a standardised '*Reef Builder* works and employment log form' to track jobs alongside delivery of project activities. Once filled out by contractors, the logs were supplied back to TNC Project Managers upon job completion and reporting on the activity outcomes. The following restoration activities were tracked for each project:

Table 8. Restoration activities recorded for each project.

Activity

Project pre-planning
Site selection and suitability
Planning and permitting
Contracts
Reef restoration
Monitoring and evaluation

The locality of workers engaged in each restoration project was also tracked in accordance with the following definitions:

Table 9. Worker locality categories and definitions.

Locality of worker	Definition
Local	Travels daily to work site
Intrastate	Lives in the same Australian state as work site, but is not local, i.e., cannot travel daily to work site
Interstate	Lives in a different Australian state to work site
International	Lives in a different country to worksite

The **Number of local contractors engaged** (see **Appendix 1**, i 9) was used as an indicator summarising the number of local contractors/businesses employed.

The **Number of full-time jobs** (see **Appendix 1**, i 10) was used as an indicator summarising the FTE across project activities.

Social Monitoring

The social component of the *Reef Builder* Program was aimed at building local stewardship for shellfish reefs and their surrounding coastal environments. Stewardship can be reflected by opportunities for local communities to get involved in restoration activities through volunteering, and/or to grow their education about restoration approaches through attending public seminars/workshops, or through reading media articles.

Therefore, data on the number of community engagement programs, number of volunteers attending those programs and attendance at project workshops/events was collected regularly by project managers throughout the Program using standardised volunteer and event logs.

Media mentions were tracked by TNC's Communications Team using the online media tracking platform Meltwater and social media metrics tracked per platform e.g. Facebook and Instagram for each six monthly reporting period.

Number of community events (see **Appendix 1**, i 11) was used as an indicator summarising the total number of community engagement opportunities provided by each project. These opportunities were categorised as public information events, restoration activities (e.g., shell cleaning, shellfish deployment), citizen science, fundraising, stewardship groups (e.g., 'friends of' groups, coast-care groups) or technical advisory groups.

Attendees at public consultation meetings (see **Appendix 1**, i 12) was used as an indicator reflecting the total number of people attending project/Program events. This is a measure of active engagement by the local community and was tracked across each of the key project lifecycle stages shown in Table 8.

Community and partner organisations engaged (see **Appendix 1**, i 13) was used as an indicator of the level of engagement of local community and delivery partner groups in each restoration project, and therefore its influence on building local capacity in shellfish reef restoration.

Media engagement (see **Appendix 1**, i 14) was used as an indicator of how actively the wider community engages with each restoration project and the wider Program through media articles. This indicator tracks how often each restoration project, and the wider Reef Builder Program is mentioned in traditional and social media.

Total number of community volunteers (see **Appendix 1**, i 15) was used as an indicator reflecting the total number of community volunteers contributing to citizen science, restoration and/or other project activities.

Volunteer hours donated (see **Appendix 1**, i 16) was used as an indicator to track the number of hours committed by volunteers to citizen science, restoration, or other project activities.

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