RESTORING THE LOST SHELLFISH REEFS OF PORT PHILLIP BAY

Final Evaluation Report | Stage 2 Extension
November 2017 to December 2018

Prepared for the Department of Environment, Land, Water and Planning

ALBERT PARK YACHTING & ANGLING CLUB INC. ESTABLISHED 1905

The Nature Conservancy Australia

VICTORIA State Government

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Cover: Loading vessel, Geelong Port © Simon Branigan

Mussel boat, Port Phillip Bay © Simon Branigan

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1.0 EXECUTIVE SUMMARY

Since 2014, The Nature Conservancy Australia, with foundation partners, the Victorian Government and the Albert Park Yachting and Angling Club, have been working towards a long-term vision of restoring Port Phillip Bay's lost shellfish reefs to enhance the Bay's biodiversity, fisheries and water quality. This unique partnership delivered through the Port Phillip Bay Shellfish Reef Restoration Project has taken a phased-approach to restoration which has included:

- Feasibility Study – An initial feasibility and site assessment study conducted by Fisheries Victoria (2013-2014);
- A restoration experiment to help determine optimal restoration methods (referred to as Stage 1, 2014-2016);
- A medium-scale (2 x reef patches) reef restoration deployment using limestone only as the reef base (referred to as Stage 2, 2016-2017);
- A medium-scale (4 x reef patches) reef restoration deployment using a new technique of shell cultch and limestone seeded with Australian flat oysters – *Ostrea angasi* and blue mussels – *Mytilus galloprovincialis* (referred to as Stage 2 Extension, i.e. this Project); and,
- Large-scale ecosystem restoration using the most cost-effective methods determined in Stage 2/Stage 2 Extension (planned for 2019-2021).

The Project objectives were to:

1. Restore a minimum of 1000 m^2 of shellfish reef (mussels and/or oysters) between two locations (Hobsons Bay and Wilsons Spit) using a combination of recycled shell cultch and limestone rubble as a base to seed oysters and mussels.
2. Deploy additional juvenile oysters onto the existing reefs previously established in Stage 2 (at Hobsons Bay and Wilsons Spit) to increase current oyster abundance to recommended densities (50 oysters/m^2).
3. Investigate new sites for future restoration with a focus on identifying existing degraded reefs and areas of high oyster or mussel density in Port Phillip Bay. Such sites may enable a future approach of *assisted rehabilitation* which can be a more cost-effective restoration option compared to undertaking *full restoration*.
4. Determine the most cost-effective method for restoring shellfish reefs (environmental benefits and economic measures).
5. Continue to engage the community and media in Port Phillip Bay Shellfish Reef Restoration activities.

Mussel seeding, Wilson Spit © Simon Branigan

Volunteer Day, Queenscliff © Simon Branigan

Orange Anemone, Margaret's Reef oyster reef © Jarrod Boord

The outcomes of this project have determined the most cost-effective method for restoring subtidal shellfish reefs in Port Phillip Bay whilst also extending reef-building activities and sustaining community engagement and media presence for 12 months. Key outcomes and findings include:

Reef construction, seeding and monitoring

- We constructed four new shellfish reefs with a total footprint of 2,549 m^2.
- These new and existing (Stage 2 reefs) reefs were seeded with a total of 1.689 million juvenile oysters and an estimated 446,000 mussels.
- The trial of a new oyster deployment method (surface-to-reef funnel) to seed the reefs from the surface was successful.
- The monitoring results indicate that the restored shellfish reefs are performing well, receiving an overall score of a 'A' (Scale from A to D restoration index), with high growth and survival of shellfish and encouraging signs of natural recruitment. There are increases in biodiversity at both sites, including many fish species (e.g. pinkie snapper).

Cost effectiveness

- The most cost-effective approach to building reef bases involves using a combination of limestone rubble and recycled shell.
- Fixed costs associated with project management, monitoring and evaluation indicate that building reefs at a larger scale over a shorter period of time is more efficient than building a small number of reefs over longer periods.

Reef exploration

- The exploration work confirmed that shellfish reefs are a collapsed ecosystem in Port Phillip Bay, however, areas suitable for assisted rehabilitation and full restoration were found as well as several broodstock locations.

Media and community engagement

Over the past 12 months, there were 96 media articles published in print, TV, radio and online sources, directly relating to either Port Phillip Bay or shellfish reefs.

Participation in the Restore the Bay Network continued to grow, with 2 information sessions, 21 days of volunteering, involving 117 volunteers, over 581 hours.

We used 170 m^3 of shells (46,750 kg) of recycled shell to construct reef bases and expanded the Shuck Don't Chuck Shell Recycling into Melbourne.

In partnership with the Victorian National Parks Association, we monitored the natural recruitment of oysters and mussels through the OysterWatch project, at 6 sites, deploying 144 settlement plates, engaging 6 community groups and 30 citizen science volunteers. Funding has been secured to scale-up the OysterWatch project for the next two years.

Shell cleaning, Queenscliff © Simon Branigan

Reef oyster, Margaret's Reef Stage 2 © Simon Branigan

Settlement plate assembly, Beaumaris © Ray Lewis

2.0 PROJECT BACKGROUND

Shellfish reefs once dominated up to 50% of Port Phillip Bay's (PPB) seafloor (Hamer et al. 2016), however historical overfishing, compounded by poor water quality and increased sedimentation have decimated these reefs.

Their loss removed a thriving ecosystem which provided many social and economic benefits to Melbournians. The restoration of shellfish reefs 'at scale' will provide new reef habitat for many marine species (including recreationally important fish species) and will enhance denitrification and natural water filtration in the Bay.

The Port Phillip Bay Shellfish Reef Restoration Project (PPB-SRRP) started in 2014 and is governed through a partnership among founding partners: The Nature Conservancy (TNC), Victorian Government and Albert Park Yachting and Angling Club (APYAC). The project is supported by several corporate partners, private foundations, NGOs, local government, recreational and commercial fishing sectors, universities, dive and fishing clubs, marine care and community groups.

The project has taken a staged approach to restoration (see Figure 1), including:

- Feasibility study – an initial feasibility and site assessment study conducted by the Victorian Fisheries Authority.
- Stage 1 pilot – a restoration experiment to help determine optimal restoration methods.
- Stage 2 – a medium-scale (2 x reef patches) reef deployment of oyster reefs.
- Stage 2 Extension – a medium scale (4 x reef patches) reef deployment of oyster and mussel reefs (as outlined in this *Final Evaluation Report*).
- Stage 3- proposed restoration of 20 ha of reef.
- Stage 4 – proposed restoration of total potential restorable area.

The long-term goal of the project is to restore PPB's lost shellfish reefs to enhance the Bay's biodiversity, fisheries and water quality.

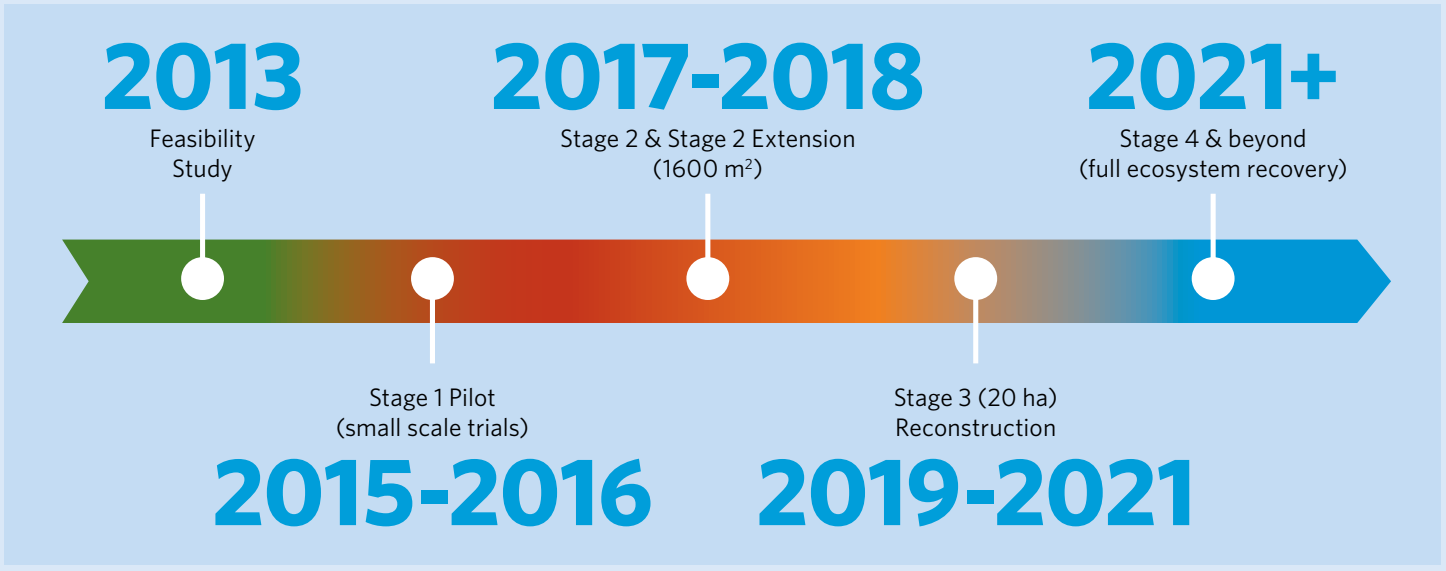


Figure 1: Staged approach for restoration for the PPB-SRRP

3.0 REEF DESIGN AND CONSTRUCTION

Reef construction activities occurred over two periods for Stage 2 Extension: in November 2017 where we constructed oyster reefs and in June 2018 where we constructed mussel reefs. For both construction periods, the reef base materials comprised a combination of limestone rubble and recycled shells. This reef design and construction method was different to Stage 2, where only limestone rock was deployed. The merits of this new construction approach are discussed in the Monitoring and Evaluation section.

3.1 Reef design

In Stage 2 Extension, we tested two complimentary reef designs that were comparable to Stage 2, to assess the optimal ratio of shell vs limestone that would balance reef stability versus cost of materials and deployment.

Stage 2 reefs were constructed wholly out of limestone rubble which maximizes reef heterogeneity and stability.

In Stage 2 Extension, we substituted various quantities of limestone for recycled shell (Figures 2A, 2B) which is cheaper to acquire but may be less stable (more prone to slumping, erosion and sedimentation) and less heterogeneous (i.e. more uniform profile) than reefs constructed entirely out of limestone. The preliminary results of these different trials are provided in the Monitoring and Evaluation Section of this report with longer-term assessments planned during Stage 3.

The reef construction methods for both construction periods associated with Stage 2 Extension involved the following approach:

- All reefs consisted of a composite design of limestone and recycled shells.
- In November 2017, limestone rubble was positioned near the edges of the reef to provide a physical boundary to keep the recycled shell-base stable within the center of the reef area (Figure 2B).
- In June 2018, limestone rubble was positioned as in Nov 2017 but also included limestone rubble within the shell matrix (Figure 2A).
- Limestone rubble was tipped from the surface from large steel bins, half a bin at a time, with the vessel positioned and held in place by using the onboard GPS positioning and thrusters.
- The limestone rubble had an average size of 400-500 mm with size variance of 100 mm to 1 m.
- Similar to the limestone rubble deployment, recycled shells were deployed from the surface from Bulka Bags.
- The marine contractor, Polaris Marine, used a multiple purpose vessel, an Aluminum Catamaran to construct all reef bases. The catamaran measures 34.4 m in length and gross registered tonnage of 300 tonnes.

Shellfish reef construction, Stage 2 Extension, Wilson Spit © Simon Branigan

Reef construction, Stage 2, Margaret's Reef © Simon Branigan

Cobbler Fish, Margaret's Reef © Jarrod Boord

Reef construction, Stage 2 © Anita Nedosyko

Oyster clutch attached to limestone © Ben Cleveland

The reef bases were constructed to coincide with the wild spawning cycles of remnant populations of oysters and mussels, to enhance the opportunity for natural recruitment. As highlighted in the Monitoring and Evaluation section, there is evidence of natural recruitment, which confirms the value of deploying reefs during the spawning season.

Another factor considered in the reef design was orientation. The reefs were constructed in a perpendicular orientation to the prevailing tidal currents, based on research carried out in field studies in the United States (Colden et al. 2016). According to the research (Colden et al. 2016):

Based on this research, recommendations from a local expert (Dr Greg Jenkins, pers.comm., 7 March 2017) and literature (Black 1993), the perpendicular orientation approach to reef orientation was selected.

Overall, 2,549 m^2 of shellfish reefs were constructed between the two permit area locations, exceeding the 1000 m^2 deliverable.

A summary of the key outcomes from reef construction activities that align with the project deliverables, milestones and objectives are outlined in Appendix 1, Table 8.

> *'Perpendicular reefs produced conditions that were more conducive to reef persistence and improved oyster performance, including high flow velocities and enhanced resuspension of sediments from the reef, compared to parallel or circular reefs.'*

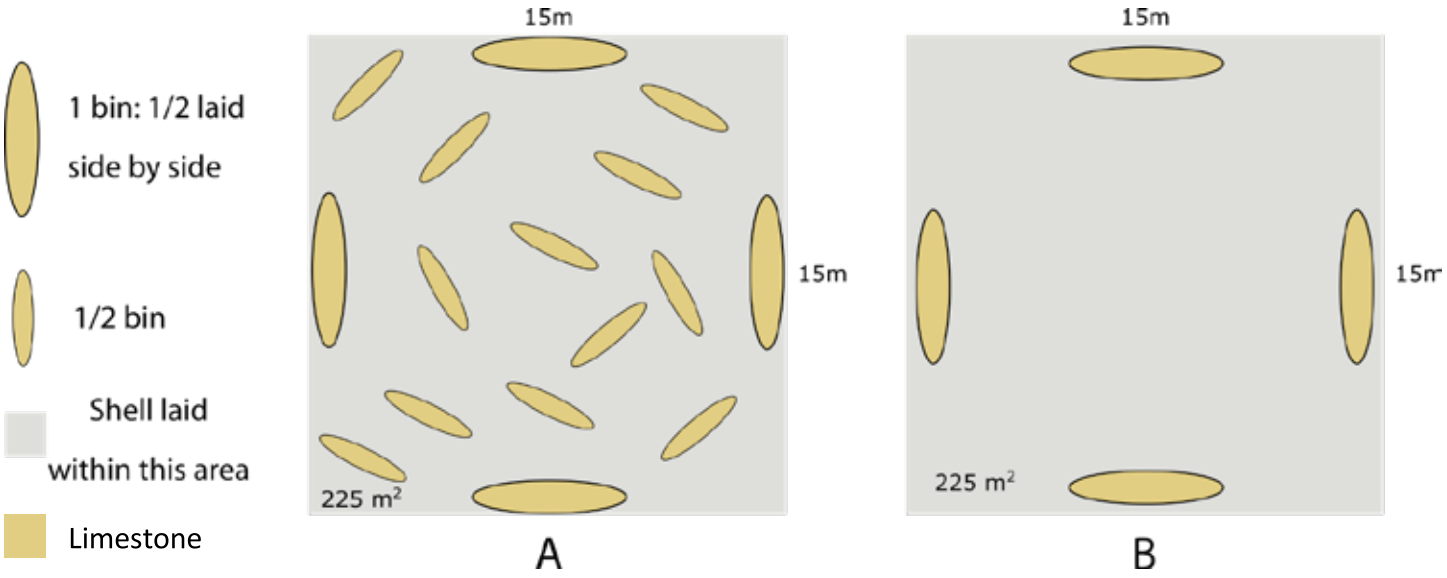


Figure 2: Shellfish reef designs for Stage 2 Extension reefs:
A) design of the reef to deployed June 2018; B) design of reef deployed Nov 2017

3.2 Reef seeding

Due to historical degradation, PPB is both substrate and recruitment limited, therefore oysters and mussels need to be added to the reef bases to support the growth and survival of the bivalve populations. During Stage 2 Extension, a new bivalve deployment method was trialled, using a prototype surface-to-reef funnel system (see left image below). In Stage 2, oysters were deployed from the surface from Bulka Bags using a davit arm.

This method was less effective compared to the reel funnel system as oysters end up in clumps on and off the reef bases, requiring divers to further hand spread the oysters. The merits of each deployment approach are discussed further in the Monitoring and Evaluation section.

Overall, the outcomes of the reef seeding activities are outlined in Table 1 below.

Table 1: Summary of reef seeding activities

Reef construction stage	Seeding period	Reef name	Oyster or mussel amount
Stage 2	December, 2017	Margaret's Reef 1	97,430 oysters
Stage 2	December, 2017	Wilsons Reef 1	149,850 oysters
Stage 2 Extension	December, 2017	Margaret's Reef 2	761,835 oysters
Stage 2 Extension	December, 2017	Wilson Reef 2	692,402 oysters
Stage 2 Extension	August, 2018	Margaret's Reef 2	151,000 mussels
Stage 2 Extension	August, 2018	Wilson Reef 3	150,000 mussels
Stage 2 Extension	August, 2018	Wilson Reef 4	146,000 mussels

Margaret's Reef 2 was seeded with both oysters and mussels as there was low survival of oysters detected in March 2018 post-deployment monitoring. In comparison, there was high survival of oysters on Wilson Reef 2 and ongoing high survival of oysters on Margaret's Reef 1. The reasons for this difference in oyster survival is discussed in Monitoring and Evaluation section.

A summary of the key outcomes from reef seeding activities that align with the project deliverables, milestones and objectives are outlined in Appendix 1, Table 9.

Mussel seeding, Stage 2 Extension, Margaret's Reef © Johno Rudge

Oyster cultch seeding, Stage 2, Wilson Spit © Ben Cleveland

4.0 PORT PHILLIP BAY EXPLORATION

The investigation of new sites in PPB involved a Bay-wide targeted search for degraded shellfish reefs and areas of high densities of oysters and mussels. This explorative work was guided by constraint mapping, compiled in collaboration with Victorian Fisheries Authority (VFA), Deakin University, recreational and commercial fishers and Bay users (Figure 3).

The constraint mapping prioritised areas for exploration based on historical evidence, fisher and Bay user interviews and interactions, catch records and environmental factors.

The in-water exploration was conducted over a four-month period and involved the following approaches:

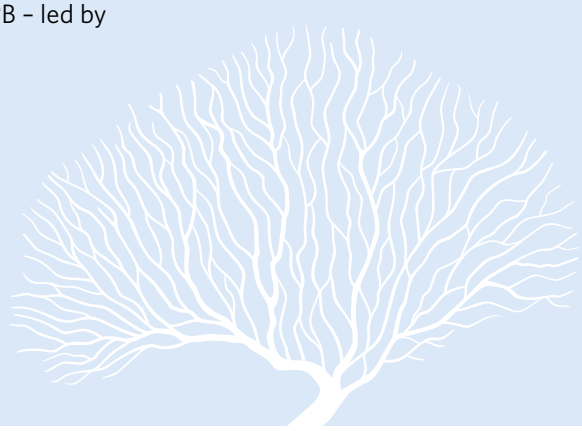
- Refinement of constraint mapping to prioritise areas and specific sites for exploration (full description provided below) – led by VFA and TNC.
- Camera drops at priority areas, with surface monitor providing a live view – led by TNC.
- Recording of GoPro footage for high priority areas – led by TNC.
- Diving on selected sites to ground truth visual evidence and verify reef footprint and or abundance of bivalves – led by TNC.
- Multibeam surveys of existing 25-hectare restoration permit areas (Wilson Spit, Hobsons Bay, Carrum Bight) all of which are old, largely dead shellfish reefs (see Figure 4). The surveys also covered all reefs restored since the projects inception to assess current reef footprint and structural integrity overtime – led by Deakin University.
- Towed video of Tedesco Reef to gather data about mussel cover (see Figure 4). Six tonnes of mussels were deployed in and around Tedesco Reef 2016 to trial the habitat enhancement of artificial reefs using shellfish – led by Deakin University.
- Multibeam surveys and towed video of 9ft Bank, the only known, degraded shellfish reef in PPB – led by Deakin University.

For the purposes of this report and based on national standards for ecological restoration, assisted rehabilitation (also known as assisted regeneration), is the recovery of degraded sites through minimal intervention (McDonald et. al 2016). In the context of shellfish reefs in PPB, this means, for example, a site that is substrate limited, but with a high abundance oysters and or mussels. These sites may require a 'lighter touch' to encourage natural recruitment by strategically deploying fresh settlement substrate such as recycled shell for larvae to settle on and grow.

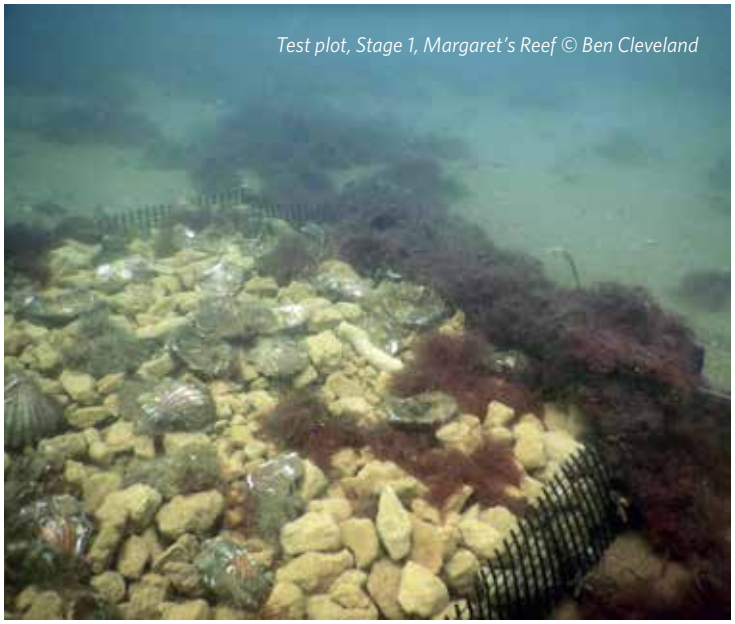
Furthermore, full restoration is where a full reconstruction of the ecosystem is required to facilitate community recovery. These are sites that are both substrate and recruitment limited, so require both the deployment of reef substrates and seeding with hatchery reared shellfish. Our surveys identified sites where both assisted regeneration and full reconstruction could occur.

During exploration, the opportunity was taken to collect additional information beyond the original proposal, which will be of benefit to long-term restoration efforts. This included:

- Potential broodstock locations – locations that had an abundance of oysters and or mussels but not suitable for restoration. These records will assist in the future collection of wild broodstock for hatchery purposes.
- Locations with potential for full restoration – there were several sites, whilst not suitable for assisted rehabilitation, may be ideal for reconstruction.



Old oyster reef, Wilson Spit © Paul Hamer



Test plot, Stage 1, Margaret's Reef © Ben Cleveland

4.1 Constraint Mapping

4.1.1 Methods

The constraint maps of target areas for exploration were compiled through multiple lines of evidence, including:

- A feasibility assessment led by VFA and funded by a grant from the Victorian Recreational Fishing Grants Program (Hamer et al. 2013). The outcome of this scoping report included an assessment of the environmental and ecological attributes required for restoration success and the selection of sites in areas where shellfish reefs once existed. The locations of these historical reefs were identified based several factors, including feedback at a workshop attended by long-time experienced recreational and commercial fishers, scientists and fisheries managers and a review of the scientific literature.
- The scientific literature review conducted as part of the feasibility assessment, highlighted two key published reports, which were further utilised to refine the constraint maps. The first report revealed results from a Bay-wide study focussed on sampling for newly-settled snapper that included data about bivalve presence (Hamer et al. 1988). The second report described a comprehensive epibenthic community structure survey in PPB (Cohen et al. 2000).
- The findings from this feasibility assessment were further refined through a Master's research project that used participatory GIS (PGIS) to map historic oyster reefs in PPB (Crawford 2015). This research involved one on one interviews with commercial and recreational fishers and divers about historical and present-day locations of shellfish reefs. The information compiled was then mapped on Google Earth and analysed in the GIS software Quantam GIS. The next step involved overlaying these spatial files with mussel catch records between 1978 and 1997 with striking similarities emerging (Crawford 2015). As a result, 'hotspot' maps of historical and potential remnant and degraded shellfish reefs were compiled, forming the basis of the current constraint maps.
- The hotspot maps compiled as part of the Master's research project, were used in a study about the historical loss shellfish reefs in coastal Victoria and concluded with the key finding that up to 50% of PPB seafloor was once dominated by these reefs (Ford & Hamer 2016). This study formed another line of evidence.
- New spatial and habitat layers were then incorporated into the constraint maps. This included areas where restoration activities are not permitted (e.g. shipping channels, aquaculture zone buffers, navigation markers etc) and known Victorian habitat layers (Butler 2017). A depth range of 5 to 15 meters was also added to further narrow the search area – a range where historical shellfish reefs are known to largely occurred.
- During in-water exploration activities, searches did occur outside of these depths and constraint boundary areas, as a result of consultation with VFA about prior knowledge of the survey areas and other sites that warranted investigation.
- In addition, a preliminary strategic planning meeting with Parks Victoria and DELWP planners was held to discuss the new site assessment approach and future scale-up plans.

4.1.2 Results

We identified 14,753 ha throughout PPB that were potentially suitable for restoration. These sites were located predominately in the northern, eastern and western sections of the Bay. A subset of these sites where then selected for further inspection through visual multibeam and towed video surveys.

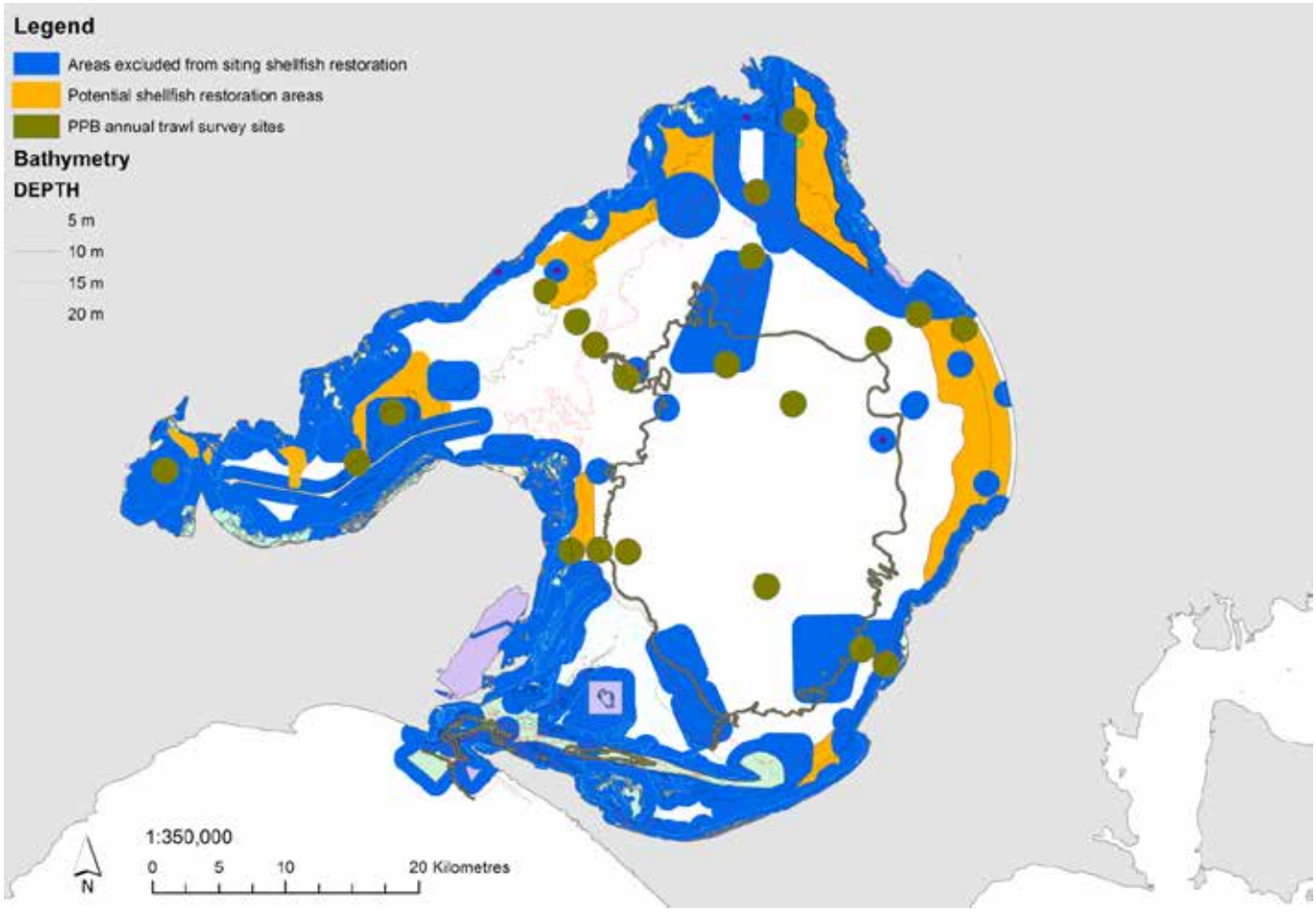


Figure 3: Constraint mapping illustrating areas where remnant and or degraded shellfish reefs may exist and areas that may be suitable for restoration

Figure 4: PPB Shellfish Reef restoration permit areas, 9ft Bank and Tedesco Reef

4.2 Reef Exploration

4.2.1 Visual surveys

The following field-based parameters were used in addition to the constraints mapping to further define areas suitable for survey:

- Sediment or seafloor profile – e.g. Hobsons Bay has a largely sandy bottom.
- Biota presence – e.g. Dromana has areas of sparse seagrass coverage, ascidians and filamentous algae, with scattered bivalve shells and evidence of oysters.
- Depth – the constraint mapping was in areas of 5 m to 15 m, however during in-field exploration, sites to lowest depth of 1 m were also surveyed, if there was the potential for either degraded reefs or abundance of oysters or mussels to be present.
- Access – access to boat ramps and other infrastructure necessary to undertake restoration activities.

The observational assessment approach, using camera drops, GoPro footage and ground truth dives, characterised the sites into the following categories:

- Limited potential for restoration.
- Potential for full restoration (or reconstruction).
- Potential for assisted rehabilitation.
- Potential broodstock location.
- Further investigation required.

4.2.2 Visual survey results

We surveyed 13 areas and 75 sites within these areas, throughout PPB, over 7 days. Within these areas only two sites were found to be potentially suitable for assisted rehabilitation (see Figures 5 and 6) due to the presence of degraded shellfish reefs. There were 7 sites recorded as potential broodstock locations, due to the abundance of oysters and mussels (see Figures 5, 6 and 9). In addition, 14 sites were identified as potentially suitable for full restoration (see Figures 5, 6, 9, 10, 11 and 12). The visual surveys conducted by TNC further confirms that shellfish reefs are a collapsed ecosystem in PPB.

As discussed in the Recommendations section, further survey work (e.g. ground truth dives, multibeam surveys, towed video) will be necessary before confirming areas are suitable for either full restoration or assisted rehabilitation.

Carrum exploration © Brent Womersley

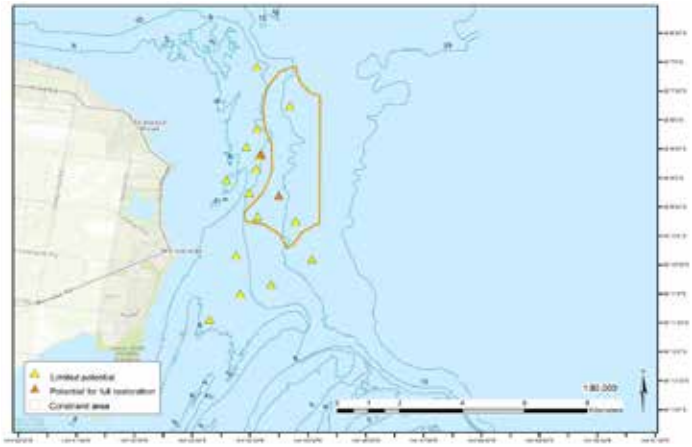


Figure 5: St Leonards exploration area

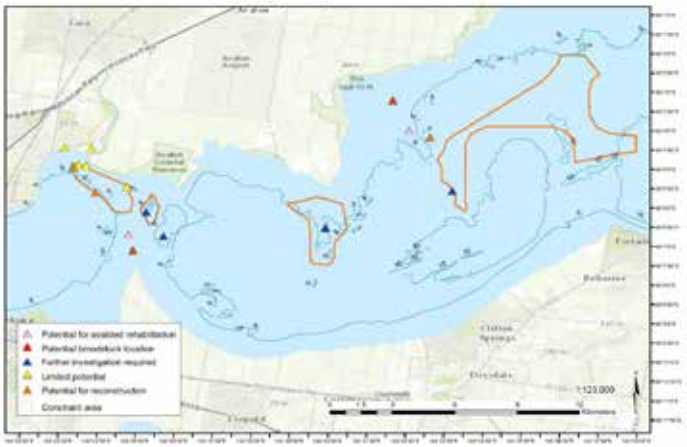


Figure 6: Geelong Arm exploration area

Figure 7: 9Ft Bank exploration area

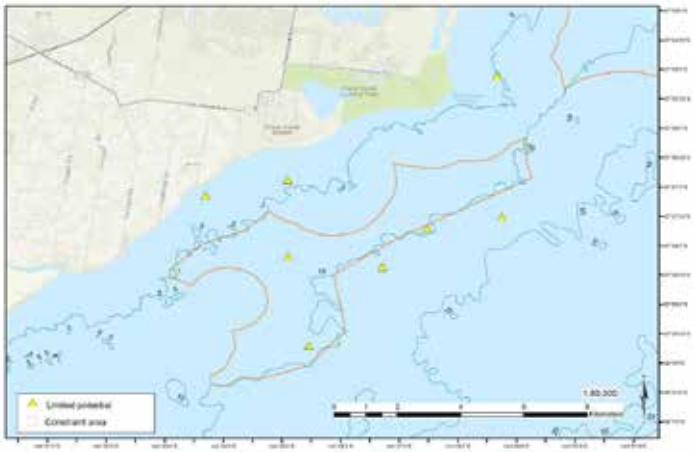


Figure 8: Point Cook exploration area

Loading barge with limestone, Stage 2, North Geelong © Simon Branigan

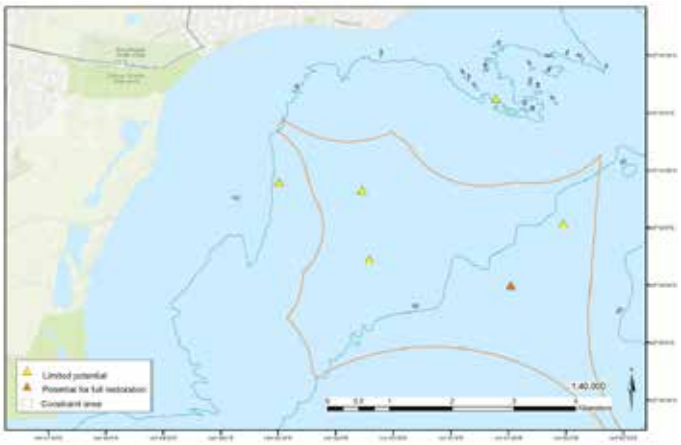


Figure 9: Altona exploration area

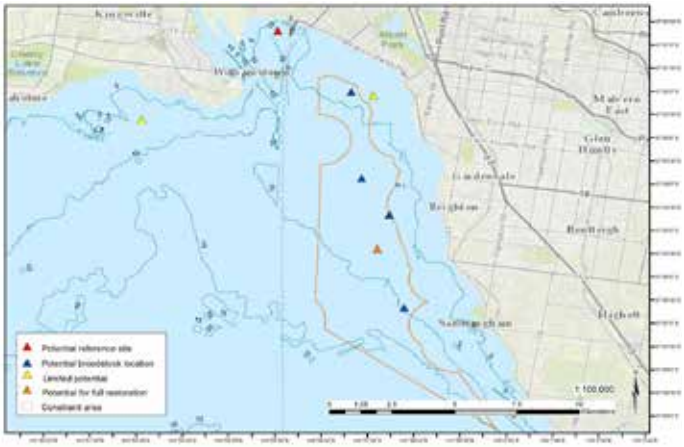


Figure 10: Hobsons Bay exploration area

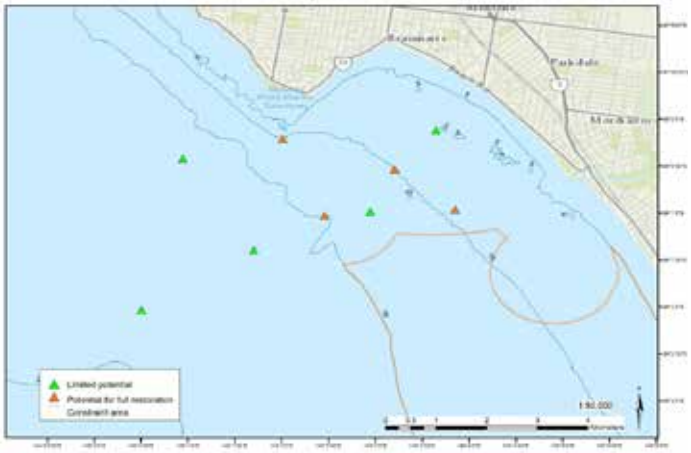


Figure 11: Carrum exploration area

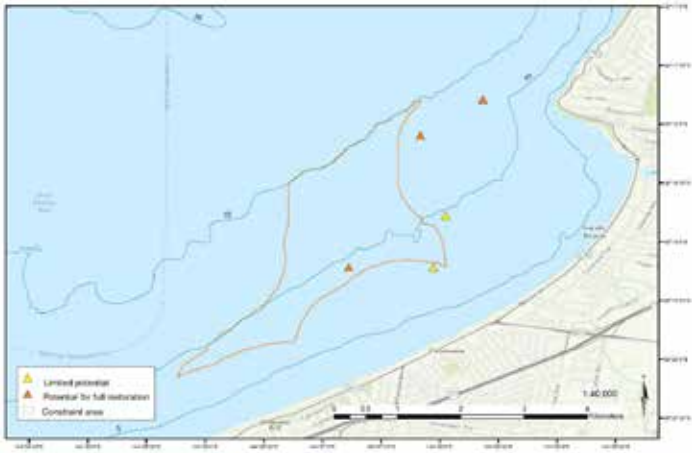


Figure 12: Dromana exploration area

Settlement plate assembly, Beaumaris © Ray Lewis

A summary of the key outcomes from TNC exploration activities that align with the project deliverables, milestones and objectives are outlined in Appendix 1, Table 10.

4.2.3 Multibeam surveys

The Deakin University led surveys in PPB consisted of two components - multibeam sonar and towed video data collection. The purpose of the surveys were to:

1. Quantify the total reef footprint and reef profile of all existing reefs (Stage 2 and Stage 2 Extension at each site (Margaret's Reef and Wilson Spit); and,
2. Determine the bottom structure and profile at future potential restoration sites (Carrum Bight, 9ft Bank, Tedesco reef) to support baseline assessments and planning.

A summary of the Deakin University's survey work is outlined below in Table 2. Full results of the multibeam and towed video surveys will be supplied in the Final Port Phillip Bay Shellfish Reef Fieldwork Report, due January 31st.

Table 2: Summary of Deakin University's survey work

Location	Multibeam Complete	Linear Distance for Multibeam (km)	Towed Video Complete	Linear Distance of Towed Video Transects	Number of Downward Stills	GoPro Footage Complete
Carrum Bight	Yes	15.9	NA	NA	NA	NA
Wilsons Spit	Yes	31.4	NA	NA	NA	NA
Margaret Reef	Yes	17.2	NA	NA	NA	NA
9ft Bank	Yes	43.5	Yes	1.7km	1124	Yes
Tedesco Reef	Yes	1 (approx.)	Yes	1.3km	677	Yes

Preliminary results of the multibeam surveys for Stage 2 and Stage 2 Extension reefs is outlined below.

4.2.4 Reef surveys at existing sites

All shellfish reefs constructed in Stage 2 and Stage 2 Extension were surveyed with square meter areas per planer area, surface area and volume and calculated as shown in Table 3.

Table 3: Summary of survey results from constructed shellfish reefs

Location	Planar Area calculated (m^2)	Surface Area calculated (m^2)	Volume calculated (m^3)
Wilsons spit Reef 1	642.3	729.5	504.4
Wilsons spit Reef 2	334.4	355.6	113.4
Wilsons spit Reef 3	687.1	718.0	124.9
Wilsons spit Reef 4	949.8	995.4	281.6
Margaret's Reef 1	448.2	532.6	181.8
Margaret's Reef 2	445.1	480.8	215.3
Total	**3506.9**	**3811.9**	**1421.4**

Margaret's Reef

Two reefs have been constructed in the Margaret's Reef restoration area, one during Stage 2 of the project (Margaret's 1) and one as part of the Stage 2 Extension works (Margaret's Reef 2). The bathymetry map's displaying the survey overview of the constructed reefs is shown in Figure 13 and for Margaret's Reef 2 in Figure 14.

The results from the broader survey of the Margaret's Reef restoration area be will used as baseline data to guide future scale up plans and for monitoring purposes. The surveys of the constructed reefs will be used to track reef footprint and height overtime, with additional surveys anticipated to occur on an annual basis.

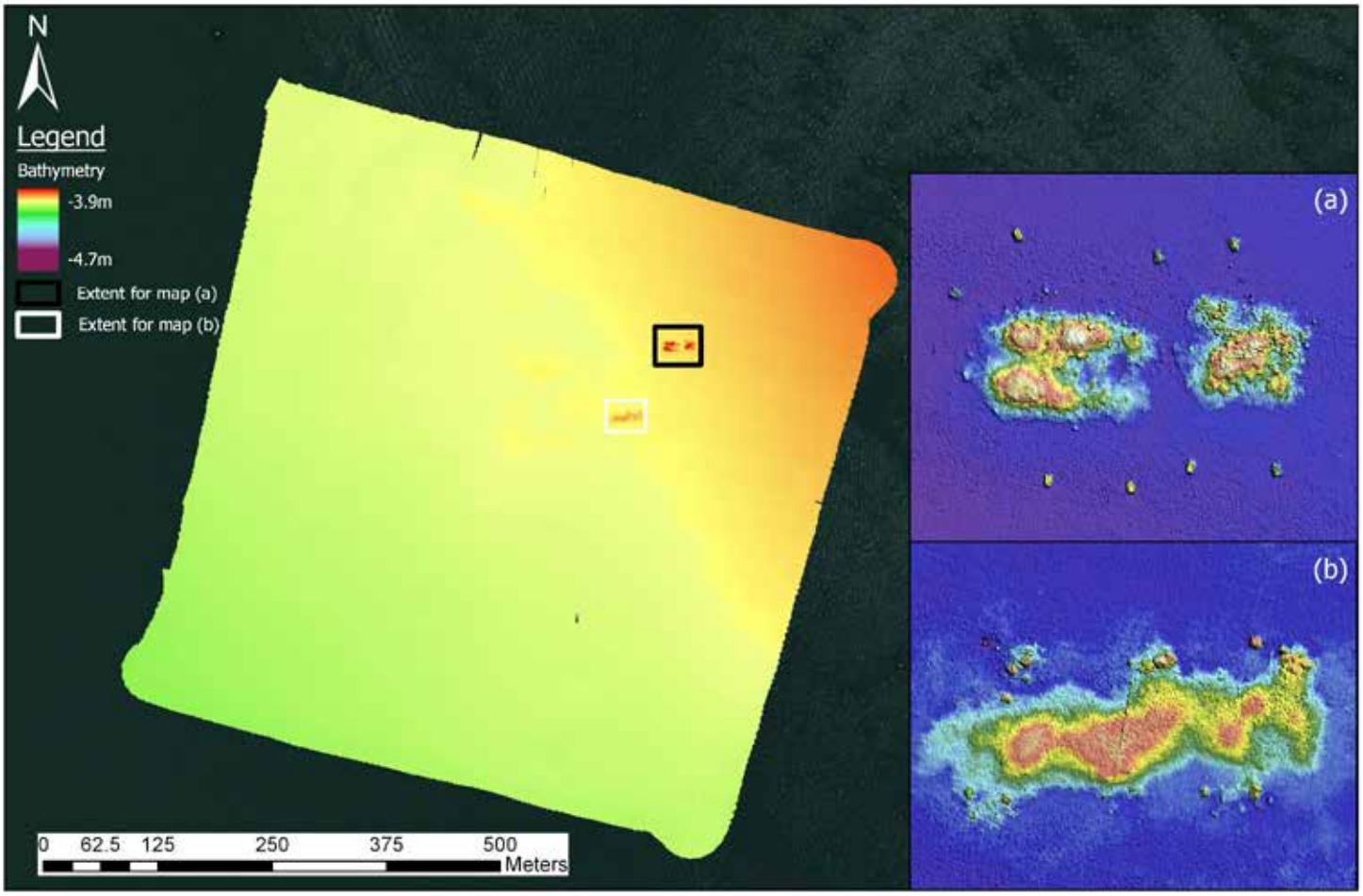


Figure 13: Bathymetry overview of Margaret's Reef, gridded at 25cm. (a) Margaret's Reef 1. (b) Margaret's Reef 2

Mussel boat, Margaret's Reef © Simon Branigan

Margaret's Reef recycled shell reef with pinkie snapper © Jarrod Boord

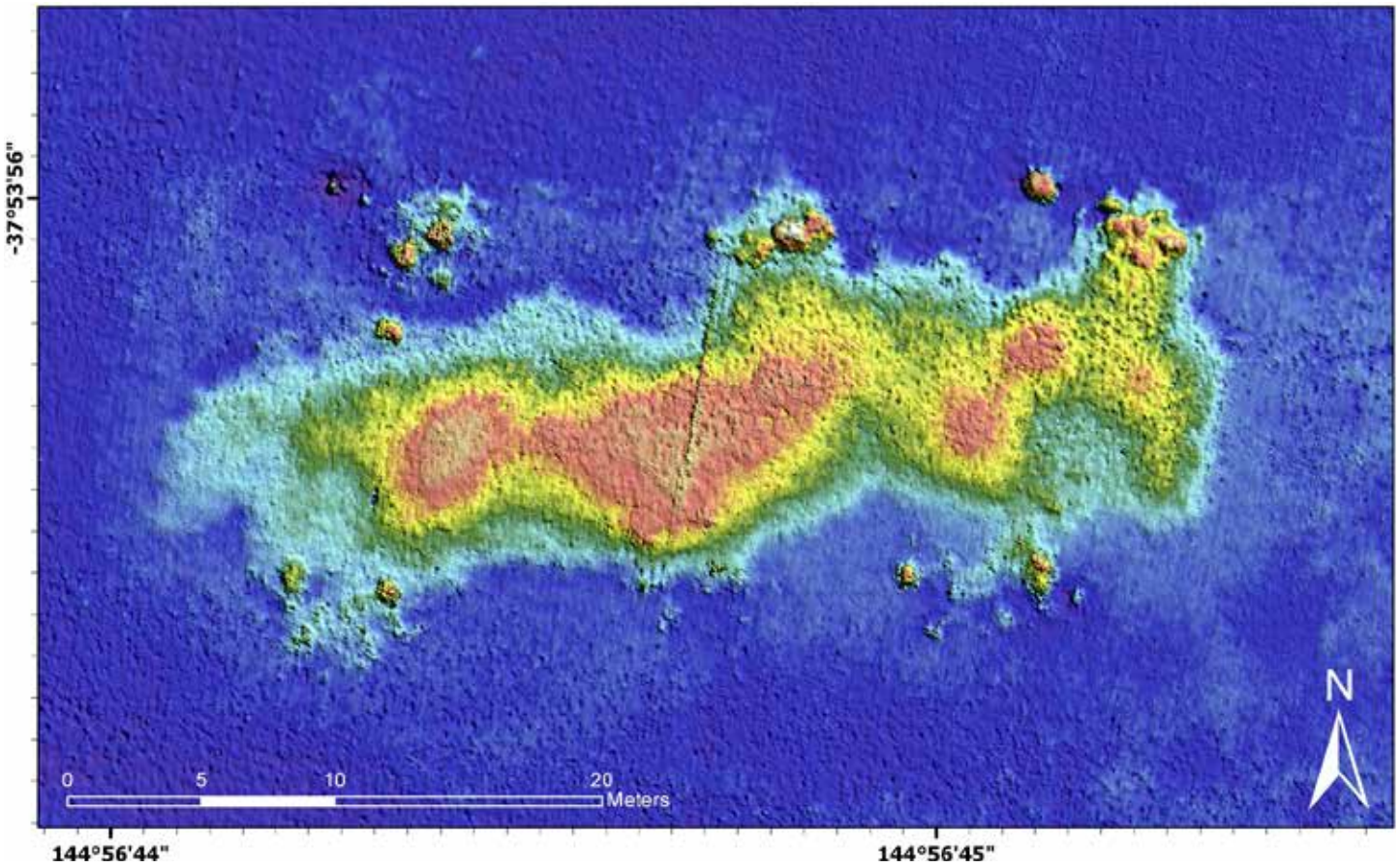


Figure 14: Close up of Margaret's Reef 2 constructed as part of Stage 2 Extension

Oyster clutch, Wilson Spit © Simon Branigan

Wilson Spit

Four reefs have been constructed at Wilson Spit, one during Stage 2 (Wilson Reef 1) and three as part of the Stage 2 Extension restoration works (Wilson Reef 2, 3 and 4). The bathymetry maps displaying the survey overview of all Wilson Spit reefs and per individual reef are shown in Figures 15 and 16 respectively.

Similar to Margaret's Reef, the Wilson Spit Reef restoration area surveys be will used as baseline data for future reef construction activities and to track reef footprint and height overtime, with additional surveys anticipated to occur on an annual basis.

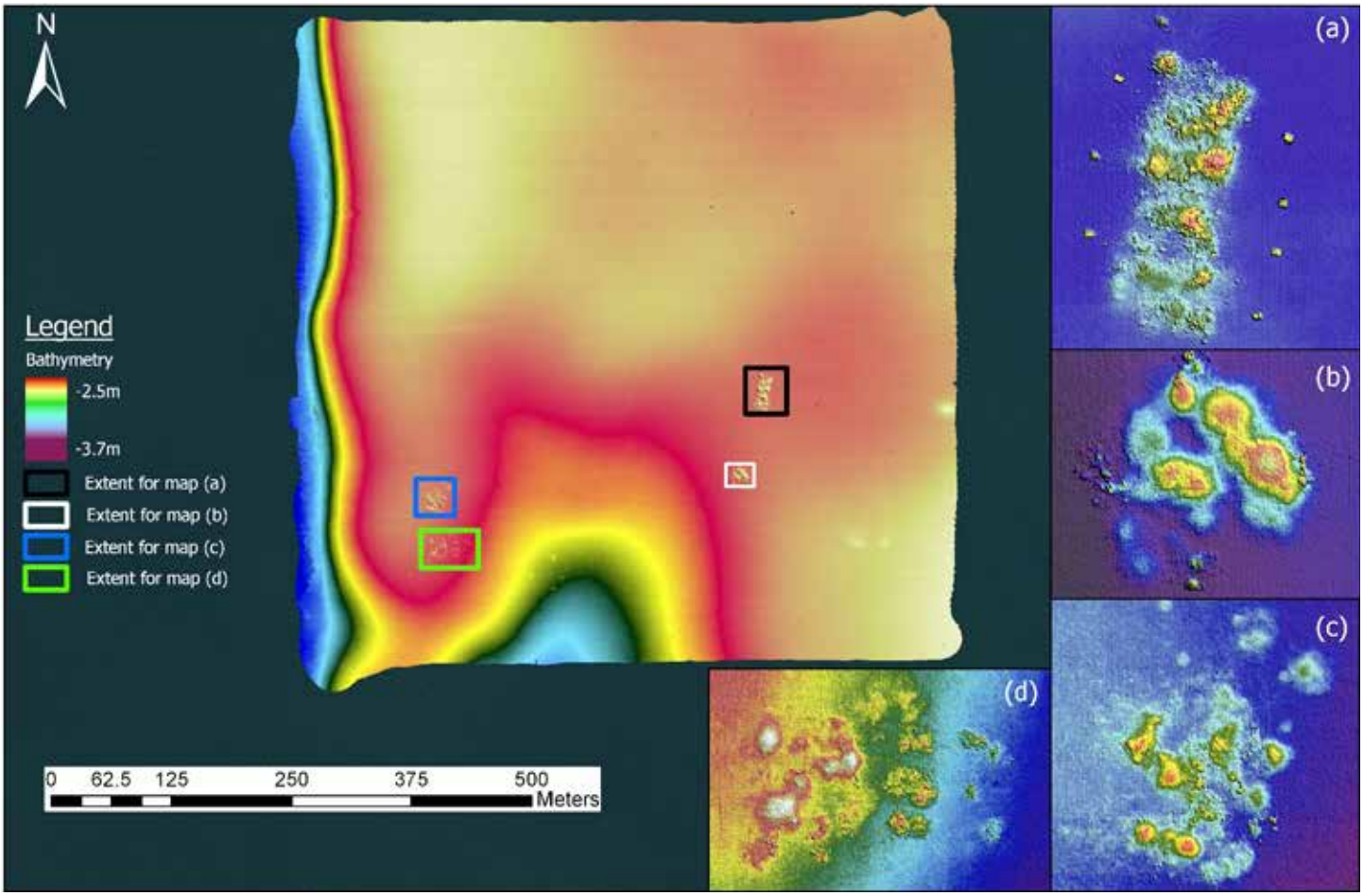


Figure 15: Overview of Wilson Spit site, with inserts depicting restoration reefs constructed, including: (a) Wilson Reef 1 (b) Wilson Reef 2 (c) Wilson Reef 3 (d) Wilson Reef 4

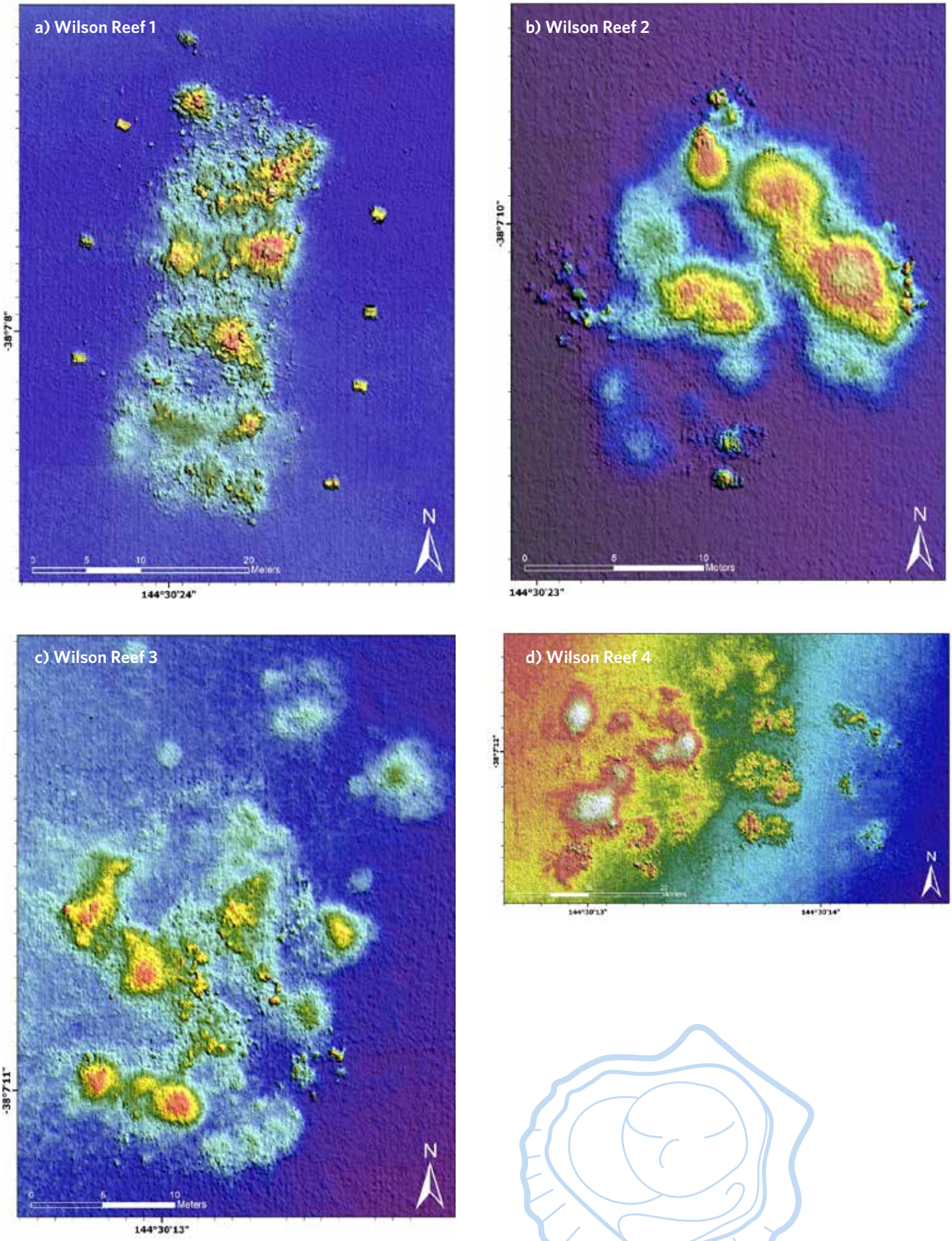


Figure 16: Wilson Spit constructed reefs

5.0 MONITORING AND EVALUATION

The monitoring, evaluation and reporting (MER) approach for the PPB-SRRP includes activities to assess if the restoration works can be considered 'successful' based on several predefined environmental performance targets (Figure 22) in addition to tracking social and economic benefits.

The development of the MER process follows the steps outlined by TNC's Conservation Action Planning (TNC 2007) and is based on the best management practices for monitoring shellfish restoration projects (Baggett et al. 2014). The 'lessons learnt' will be embedded into future scale-up management planning for Stage 3 and beyond (i.e. adaptive management).

This section provides an overview of monitoring and evaluation results. A detailed assessment can be found in the *Port Phillip Bay Shellfish Reef Summary* Report Card and *Technical Report Supporting the 2018 Restoring the Lost Shellfish Reefs of Port Phillip Bay: Final Evaluation Report*.

5.1 Restoration targets

Monitoring and evaluation is based on a number of environmental, social and economic indicators, group into five categories (Figure 17). These indicators provide a measure of how the reef is performing biologically and physically compared to reference ecosystems and benchmark targets. It also provides a measure of how the project is tracking against predefined social and economic targets. Further information on how the Restoration Targets were developed can be found in the Technical Report.

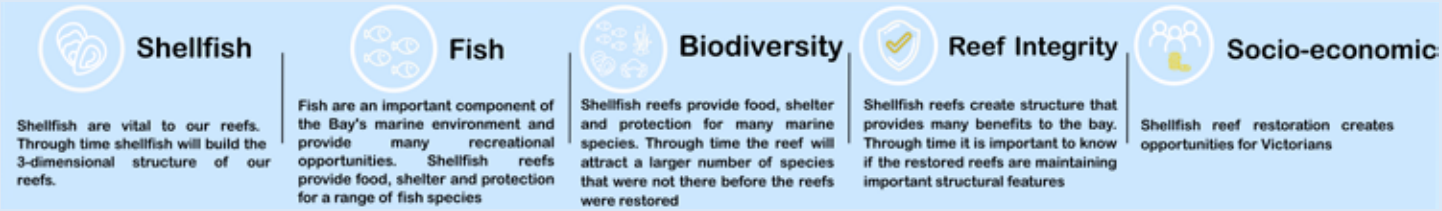


Figure 17: Restoration targets for the PPB-SRRP monitoring and evaluation approach

Mussel reef, Stage 2 Extension, Wilson Spit © Jarrod Boord

Oyster reef, Stage 2, Margaret's Reef © Jarrod Boord

Red Swimmer Crab, mussel reef, Stage 2 Extension, Wilson Spit © Jarrod Boord

5.2 Reef performance

The restored shellfish reefs are performing well, receiving an overall score of a 'A' (Scale from A to D restoration index). The monitoring results include high growth and survival of shellfish and encouraging signs of natural recruitment. There are increases in biodiversity at both sites, including many fish species (e.g. pinkie snapper). A summary of monitoring results for all constructed reefs is shown below (Table 4) with indicators and benchmarks adapted from Gillies et al. (2017).

Table 4: Summary of scores and trends for each indicator and reef

Restoration target	Indicator	Benchmark	Margaret's - Reef1: oyster	Margaret's - Reef2: mussel	Wilsons - Reef1: oyster	Wilsons - Reef2: oyster	Wilsons – Reef3 mussel	Wilsons – Reef4 mussel
	Retention of live seeded shellfish	To retain 5% of total seeded shellfish	A+ →	ND	A+ →	A+ →	ND	ND
	Survival of shellfish (%.m^2)	Survival ≥30% per m^2	A+ →	A+	A+ →	A+ ↗	A+	A+
	Recruitment of shellfish (%.m^2)	Recruitment > mortality or population growth	D →	ND	D →	C →	ND	ND
	Number of live shellfish (m^2)	≥50 per m^2 for *O. angassi* or ≥1000 for *M. edulis*	A+ →	A+	A+ →	A+ →	A+	A+
	Biomass of fish	Compared to control	A+ →	B →	D →	D →	D →	D →
	Biomass of recreationally important fish	Compared to control	A+ →	B →	A+ →	C →	D →	D →
	Species richness	Compared to control	A+ →	A+ →	C →	B →	B →	B →
	Number of community volunteers	>100 community volunteers contributing to the project				A+ ↗		
	Number of community volunteer hours	>500 community volunteer hours donated to the project				A+ ↗		

A summary of the key outcomes from monitoring and evaluation activities that align with the project deliverables, milestones and objectives are outlined in Appendix 1, Table 11.

5.3 Evaluation of Restoration Methods

A comparison of restoration methods between Stage 2 and Stage 2 Extension and the effectiveness of these approaches are discussed below.

Reef construction

A summary of reef construction methods is outlined in Table 5 below. The construction costs varied between stages with the June 2018 deployment method producing the largest reef footprint, at the lowest per square meter cost. However, as discussed in the Reef Design section below, the design of the reef, including reef base material used, may need to be tailored so that it is suitable for site specific dynamics (e.g. wave energy and currents).

Scale is the overriding factor to consider for future reef construction methods, as mobilization and demobilization costs are significant fixed costs, so deploying more reefs over a single time period is more cost effective than deploying reefs over multiple time periods.

There are benefits in using either the barge or multipurpose vessel method, however if a suitably sized barge is available and mobilization costs are not cost prohibitive, we recommend the use of a barge as the most effective approach for large scale deployments of reef bases. However, the multipurpose vessel can still play a role in the construction of mussel reefs, as there is often an opportunistic supply of mussels from the aquaculture industry, that doesn't necessarily fit within reef base construction schedules. From time to time, the aquaculture industry offers waste mussels to the project, mussels that are not suitable for market and would otherwise be stripped from longlines. Like oysters, mussels also need to be elevated off the seafloor in order to survive and grow, so require a reef base. A local, multipurpose vessel, could be contracted and mobilized more quickly than a barge for either mussel deployment or smaller adhoc deployments of reef bases.

Reef design and bivalve survival

As outlined in the *Technical Report Supporting the 2018 Restoring the Lost Shellfish Reefs of Port Phillip Bay: Final Evaluation Report*, there was a difference in response following seeding of oysters on Margaret's Reef 2 compared to all other reefs. The reduced survival of oysters, particularly in comparison to survival rates observed at Wilson Spit, suggests that the interplay between site environmental dynamics, reef design and age of oysters following seeding could be important at driving restoration success, at least for shellfish indicators, at this site.

Margaret's Reef is considered a higher wave energy site than Wilson Spit, with greater water motion. The construction method of the reef also creates greater heterogeneity of the reef surface, with reefs constructed by limestone alone having a greater number of cracks and crevices to capture loose cultch with the oyster hatchlings on, whilst recycled shell reefs represent a smoother, less rugose surface.

The oysters used during Stage 2 were grown out on long lines and were larger and more irregular in shape at the time these were placed on the reef, which likely supported greater capture and retention of oysters compared to Stage 2 Extension deployment where younger oysters were deployed on shell cultch (which saw lower retention rates). Our interpretation of why the oysters failed to take hold on Margaret's Reef 2 is likely a result of oyster weight, shape and reef rugosity at time of deployment. The younger newly seeded oysters (lighter and less irregular in shape) did not settle and lock into the reef structure on the recycled shell reef (Margaret's Reef 2) as well as when they were deployed on the limestone reef (Margaret's Reef 1). The Margaret's Reef site has higher wave energy compared to Wilsons Spit and this may have resulted in the oysters being swept off the reef at Margaret's Reef but not at Wilsons Spit. This effect was not seen for mussels (which can use their byssal threads to rapidly attach to the reef base) with high survival and stabilization following seeding at both sites.

Constructing reef bases using both limestone rubble and recycled shell will continue to be the recommended approach to reef restoration, however at Margaret's Reef we recommend a reef composite with more limestone rubble and less recycled shell to facilitate better retention and survival of oysters. In addition, for Margaret's Reef it may be advantageous to grow out juvenile oysters longer in the hatchery or on long-lines to reduce oyster mortality at time of deployment.

Reef seeding

The reef seeding methods in Stage 2 and Stage 2 Extension are summarized and compared in Tables 5 and 6 below. Seeding the reef bases with the funnel prototype developed as part of Stage 2 Extension, is the most effective approach, both in terms of even spread and quantities that can be deployed in a relatively short period of time.

TNC is working with the marine contractor to further refine the prototype, to improve ergonomics of the design (e.g. reduce the need for heavy lifting) and size of the funnel, to minimize system blockages which can occur from time to time.

Table 5: Comparison of reef base construction methods between Stage 2 and Stage 2 Extension

Project Stage	M^2 reef constructed	Reef base construction cost per m^2 (ex GST)	Reef base materials	Loading method
Stage 2 – March, 2017	1,253	$62	Using all limestone rubble.	Truck and trailer delivery of limestone to loading site (St Helens) then loaded onto barge with long reach excavator.
Stage 2 Extension – November, 2017	837	$85	Using limestone rubble only in the outer edges, with recycled shell in middle.	Limestone loaded in skip bins and recycled shells into bulka bags. Truck and trailer delivery to Port of Geelong and loaded with A frame crane.
Stage 2 Extension – June 2018	1,713	$52	Using limestone rubble edges and interspersed within recycled shell.	Same as November 2017 method.

Oysters growing on recycled shells, Stage 2 reef, Wilson Spit © Simon Branigan

	Deployment method	Benefits	Challenges
	Barge, tug and long reach excavator.	• A more uniform consolidated reef structure. • The accuracy of deployment could be further enhanced by using a GPS positioning system. • This method would also be suitable for using recycled shells deployment.	• Access to suitable loading site. City of Greater Geelong provided a site at no cost subject to implementing all site management specifications. • The lack of available suitably sized barges in Victoria, with the possibility of needing to mobilise a barge from interstate for Stage 3.
	Multiple Purpose Vessel with A frame crane and dynamic positioning.	• Reef structure deployment not as uniform (influenced by currents and tides) and varied from conceptual design supplied. • Availability of suitable vessels in Victoria.	• Timing of deployment determined by the availability of a berth at Port of Geelong that can be subject to change at short notice. However, loading could also occur at a site outside of the Port, similar to the approach in Stage 2.
	Same as November 2017 method.	• Same as the benefits for the November 2017 deployment, however the extra reef footprint produced may have been as result of a different operator in the June deployment to the November 2017. However, the result was consolidated reef coverage over the reef footprint.	• Same as November 2017 challenges.

Table 6: Comparison of seeding methods between Stage 2 and Stage 2 Extension

Project Stage	Number of bivalves deployed	Deployment method	Notes
Stage 2	215,000	Oysters loaded in bulka bags and deployed using davit arm.	This method was largely inaccurate, with oysters landing in clumps on and off the reef base. Divers were required to follow-up and spread the oysters by hand.
Stage 2 Extension	1,700,000	Oysters loaded in bulka bags and deployed via funnel prototype. Same system for mussels but mussels loaded in fish crates.	This method produces an even spread of bivalves on the reef base but does require calm weather condition for deployment.

6.0 MEDIA & COMMUNITY ENGAGEMENT

6.1 Media

Since November 2017, there has been 96 media articles published in print, TV, radio and online sources, directly relating to either Port Phillip Bay or shellfish reefs. This is a substantial amount of media coverage which has directly contributed towards increasing awareness and support for the project and TNC's partnership with the Victorian Government. These articles included coverage on:

- Reef construction and seeding (26), for example -
  - Ch7
  - Herald Sun
- Shell Recycling (25), for example:
  - Australian Geographic
  - Sustainability Matters
- Shellfish Reef Restoration (45), specifically the publication of the PLOS One Journal article about the status of Australian shellfish ecosystems, which includes reference to Victoria and the PPB-SRRP (Gillies et al. 2018). For example:
  - The Guardian
  - News Corps
  - The Conversation

The PPB-SRRP was also a finalist in the 2018 Victorian Coastal Awards in the biodiversity category, which didn't feature in any media stories but contributed to building further awareness about the project in the marine and coastal community, State and local Governments.

A summary of the key outcomes from monitoring and evaluation activities that align with the project deliverables, milestones and objectives are outlined in Appendix 1, Table 12.


Innovation allows city to flex mussels

Rebecca CASSON

Geelong Advertiser, August 2016


Australian GEOGRAPHIC


PERSONAL TOUCH

NOTHING TO SEE HERE

DITCH THE DECEIT

Ex-minister lobbies for franchisees

Shuck & awe

'Arrest me', 97 year old accused hoon tells police

Watchdog accuses Apple of misle

The Age, April 2017

6.2 Community Engagement

Community engagement activities and the positive support from partners continued to underpin the success of the project in 2017 and 2018. The foundation partnership between TNC, the Victorian Government and Albert Park Yachting and Angling Club, is complimented by a diverse and growing range of new partnerships and support from the following organisations, with the majority formed during Stage 2 Extension:

- The Thomas Foundation, Portland House Foundation, HSBC Australia, Brambles Limited, CHEP Australia, J & M Wright Foundation, SUEZ Australia & New Zealand, Victorian Ports Corporation, Dow Chemical Australia, Victorian Shellfish Hatchery and commercial shellfish growers, City of Greater Geelong, University of Melbourne, Deakin University, Australian Shellfish Reef Restoration Network, VRFish, Seafood Industry Victoria, Victorian National Parks Association, OzFish Unlimited, Geelong Disabled Peoples Industries, South Melbourne Markets, Little Creatures Geelong, Mantzaris Seafoods, Portarlington Mussel Festival and many local dive and fishing clubs and marine care groups.

One of the key mechanisms for community members and partners to contribute to the project is through the Restore the Bay Network.

6.2.1 Restore the Bay Network & Volunteering

The Restore the Bay Network is the volunteer support arm to the project with participants from marine care, dive and recreational fishing groups, government, industry and TNC corporate partners. Restore the Bay is administered by TNC and has been set-up as an informal network with the following goals:

- To share PPB-SRRP updates through six-monthly information sessions and e-news letters.
- To provide practical opportunities for community volunteers to contribute to restoration activities.
- To provide opportunities for network participants to collaborate on marine habitat restoration activities.

Two Restore the Bay information sessions were held in Geelong, with the first in April 6th, 2018, involving 20 attendees from government, academia, NGO, dive businesses, yacht clubs and recreational fisher clubs. A second information session was held in September 7th in Geelong, with 10 attendees, from a similar mix of groups to the first. These sessions provided a valuable platform to share updates about the project and receive feedback from policy makers (e.g. Parks Victoria and DELWP), fishers and divers (e.g. exploration sites) and community groups (e.g. recruitment of volunteers).

Other groups were also provided with the platform to present about habitat restoration related activities in PPB, including, for example, University of Melbourne (e.g. Ramblers Road Living Shoreline Project on the Bellarine Peninsula), Deakin University (e.g. sea urchin culling), Victorian National Parks Association (e.g. OysterWatch) and OzFish Unlimited (e.g. Baited Remote Underwater Video Monitoring).

In the future, information sessions will be organised in other locations around PPB, to promote the project to different audiences and open the opportunity for new attendees.

In addition to the information sessions, through the Restore the Bay Network, volunteers contributed to the restoration outcomes listed earlier in this report through:

- Cultch preparation for the oyster hatchery runs, which involved cleaning and bagging up shells.
- Assisting in six-monthly monitoring activities, by measuring subsamples of oysters and mussels from the restored reefs.
- Citizen science activities initiated by TNC and now led by NGO partners, including OysterWatch and Baited Remote Underwater Video Monitoring (BRUV).

The outcomes of these volunteer days are outlined in Table 7.

Volunteers cleaning shells, Queenscliff
© Simon Branigan

Volunteers measuring oysters
© Simon Branigan

Table 7: Volunteer day outcomes

Volunteers	Activity	Timeframe	Days	Number of Volunteers	Hours Worked
Dive clubs, marine care groups, Tafe students TNC staff, shell recycling and corporate partners	Hatchery preparation and monitoring	November 2017 and March, 2018	5	35	175
Marine care, dive and recreational fisher groups	Settlement plate construction, deployment and monitoring	November 2017 to March 2018	6	30	150
Recreational fishers	Deploying BRUVs	March 2018 to October 2018	3	12	60
Dive clubs, marine care groups, Tafe students, NGO, community groups, Government, academia and corporate partners	Monitoring and hatchery preparation	September 2018	7	40	196
Totals			**21**	**117**	**581**

6.2.2 *Shuck Don't Chuck*

The *Shuck Don't Chuck* Shell Recycling Project is an extension of the shellfish reef restoration works in PPB and involves recycling shells from hospitality venues and seafood wholesalers. The shells are quarantined and cured for up to six months at a site on the Bellarine Peninsula. After curing, the shells are used either as reef substrate or in the Victorian Shellfish Hatchery to settle baby oysters onto, before being placed on the reef.

Shuck Don't Chuck continued throughout the year in the Greater Geelong Region and expansion has started into Melbourne. South Melbourne Markets is the first venue outside of Geelong to come onboard in April 2018. To further expand into Melbourne, an additional shell curing site is required closer to the city. TNC is currently working with project partner, Dow Chemicals, to set-up an additional site at their Altona property.

Additional funding has been secured to scale up in Melbourne and it is anticipated more restaurants and seafood wholesalers will start contributing shells in early 2019 in both the city and Geelong.

Other outcomes for *Shuck Don't Chuck* included:

- In 2018, 170 m^3 of shells (46,750 kg) were recycled that would have otherwise been destined for landfill.
- Two promotional events to both promote shell recycling and build awareness about the broader PPB-SRRP:
  - A 'Craft Beer, Oyster & Mussel' event, organised in collaboration with partners Little Creatures in June 2018, with over 100 Geelong locals and Melbourne supporters attending.
  - A collaboration with Barking Spider Visual Theatre, Seafood Industry Victoria and South Melbourne Markets on a 'Oyster Art Installation' at Southbank in Melbourne. The installation featured the parallel historical stories of oyster reef degradation in Port Phillip Bay and New York with up to 100 members of the public attending.

Recycled shell curing site, St Leonards © Simon Branigan

6.2.3 OysterWatch

OysterWatch (formerly known as Settlement Plate Watch) is a citizen science initiative led by the Victorian National Parks Association's Reef Watch Program, which was established as pilot project through a grant provided by TNC. This citizen science initiative involves marine-care and recreational fishing groups deploying settlement plates in locations throughout PPB to monitor natural recruitment of Australian flat oysters and blue mussels. This community led initiative has assisted in:

- identifying recruitment hotspots in the PPB.
- guiding decisions about future shellfish reef restoration locations.
- providing further practical ways for citizen science volunteers to contribute to the project.

TNC continued financial and logistical support for OysterWatch with 30 volunteers engaged in the project over the past year, contributing valuable data about recruitment hotspots in PPB. This data will be uploaded onto the Atlas of Living Australia database and used to inform future planning for shellfish reef restoration in PPB.

The pilot phase of OysterWatch is now complete and TNC has secured $173,000 from the Port Phillip Bay Fund to scale-up the project over the next two years. In addition, the University of Melbourne are now project partners, leading eDNA testing and larval dispersal modelling as part of the new funding and scale-up.

Oyster Bar, Little Creatures Event © Ben Cleveland

OysterWatch, Margaret's Reef © Jarrod Boord

7.0 RECOMMENDATIONS

Recommendations are framed in the context of assisting with planning for Stage 3 of the project – i.e. scaling up to the restoration of 20 hectares of shellfish reefs.

Recommended future approaches to restoration

The exploration work undertaken as part of Stage 2 Extension further confirmed that shellfish reefs are a collapsed ecosystem in PPB, however, further searches are warranted to investigate whether there are degraded reef habitats outside of the sites explored. The following recommendations are based on the results of the exploration activities described above and listed in the order of assisted rehabilitation, full restoration and further exploration:

Assisted rehabilitation

Geelong Arm was the standout candidate for assisted rehabilitation which is consistent with historical evidence of the presence of oyster reefs and the commercial dredge fishery catch records. These areas and sites included:

- An area north of Pt Henry, that appeared to be a possible degraded shellfish reef with live mussels, scattered shell substrate, in a depth of 5m. Urchins and drift algae were also observed. This site requires further investigation, ideally multibeam and towed video surveys to verify the extent of the reef, followed by Reef Life Surveys before any restoration work occurs.
- 9ft Bank – which was previously known as a potential degraded shellfish reef. The multibeam and towed video survey work has verified the extent of this reef. The next suggested steps, are to first conduct baseline biological monitoring to assess the current ecological community, followed by as an assisted rehabilitation trial within a smaller footprint of the area, to test if such an approach is conducive to reef recovery. In addition, the data gathered about 9ft Bank will assist in determining if this site qualifies as a degraded shellfish reef, as part of TNC's nomination of shellfish reefs as a threatened ecosystem under the Environmental Protection and Biodiversity Conservation Act.

Full restoration

The current full restoration approach of reconstruction remains the primary option for working towards the recovery of shellfish ecosystems in PPB.

The areas and sites that have potential based on TNC's exploratory work, include:

- St Leonards – two sites that appeared to be old shellfish reefs, with no visible live bivalves but abundance of shell substrate, depths of 8 to 10m and absence of other biota (e.g. seagrass).
- Geelong Arm – three sites that appeared to be old shellfish reefs, with no visible live bivalves but abundance of shell substrate, depths of 5 to 6m and in close proximity to populations of wild oysters and mussels.
- Altona – one site that appeared to have a limited population of oysters and some other biota (e.g. sponges and ascidians) and depth of 12m.
- Hobsons Bay – one site that appeared to be an old shellfish reef (similar to the existing site where restoration activities are occurring), with no visible live bivalves but abundance of shell substrate, depth of 9m and absence of other biota. This site was in close proximity to populations of wild oysters and mussels.
- Carrum – four sites that appeared to be old shellfish reefs, with no visible live bivalves but abundance of shell substrate, depth of 9 to 14m and limited other biota.
- Dromana – three sites that appeared to be old shellfish reefs, with no visible live bivalves but abundance of shell substrate, depth of 9 to 12m and limited other biota.

It is suggested that full restoration activities continue at the existing CMA permit restoration areas and expanded to Carrum Bight, in the next three years, however over this period, additional surveys could be conducted at the sites listed above to inform future restoration planning.

Further exploration

During exploration in Geelong Arm, there appeared to be a direct correlation between depth and the presence of oysters or mussels. The commercial dredge fishery that operated up until the early 1990's was largely excluded from areas above 5m depth, which was where the remnant bivalves were found. Further exploration is warranted in the shallower regions of Geelong Arm beyond the boundaries of the current constraint mapping. This may also be the case for other areas in PPB.

9ft Bank, Geelong Arm © Paul Hamer

Reef siting and design

For Stage 3, it is proposed that the reef siting at each location comprises of a series of reef patches, approximately 500 m^2 each spread across a 20-hectare area. This siting design would maximise the establishment of a reef-sand matrix, providing larger-scale habitat heterogeneity across the restoration sites. Wilson Spit and Margaret's Reef should continue to be the primary focus for restoration, with the inclusion of a new site at Carrum Bight where there is an existing permit to undertake restoration.

The final reef design of Stage 3 will be developed through the following process:

- Initial conceptual reef layout design – to be developed by TNC and based on the Stage 2 and Stage 2 Extension reef patches and TNC's experience with implementing similar sized projects in South Australia and internationally.
- Expert stakeholder workshop – to review the outcomes of Stage 2 and Stage 2 Extension and the initial Stage 3 design options. Experts will be invited to participate from a wide range of disciplines, including from fish ecology, shellfish ecology, benthic ecology and reef restoration as well as representatives from TNC, Victorian Government, Albert Park Yachting Club and the preferred marine contractor and coastal engineer. Key themes at this workshop will include – reef alignment, size and height, material availability, rock size/voids and oyster colonisation.
- Review of hydrodynamic modelling and engineering requirements to ensure the reefs are within risk assessment tolerances.
- Final design – to be led by TNC Project Manager in consultation with preferred marine engineering contractor and signed off in consultation with project partners.

Beyond the 20-hectare restoration target, the goal is to work towards restoring 10% of the restorable bottom in PPB, which based on current constraint mapping, is approximately 100 hectares. The exploration work in Stage 2 Extension has provided important base line information. The development of a Habitat Suitability Model (currently in development) will further assist with identifying and confirming suitable areas. This is common approach for large-scale shellfish reef restoration in North America (Theuerkauf et al. 2016), including in Charlotte Harbour, Florida and Chesapeake Bay, Washington DC.

The information used in the constraint mapping process and collated during the exploration work will be incorporated into the model to determine suitable restoration areas. This includes physical and environmental parameters, degraded shellfish reefs, other habitats (e.g. seagrass, rocky reefs etc), no go restoration areas (e.g. shipping channels, aquaculture zones etc), marine protected areas and cultural sensitive areas to avoid.

Beyond PPB, it is recommended that exploration work starts in other bays and estuaries in Victoria, that are known to have historically supported shellfish reef ecosystems. Locations such as Western Port, Corner Inlet and Gippsland Lakes. For expanding in-water restoration works outside of PPB, a similar staged process to PPB should be followed.

Oyster deployment, Stage 2, Port Phillip Bay © Brent Womersley

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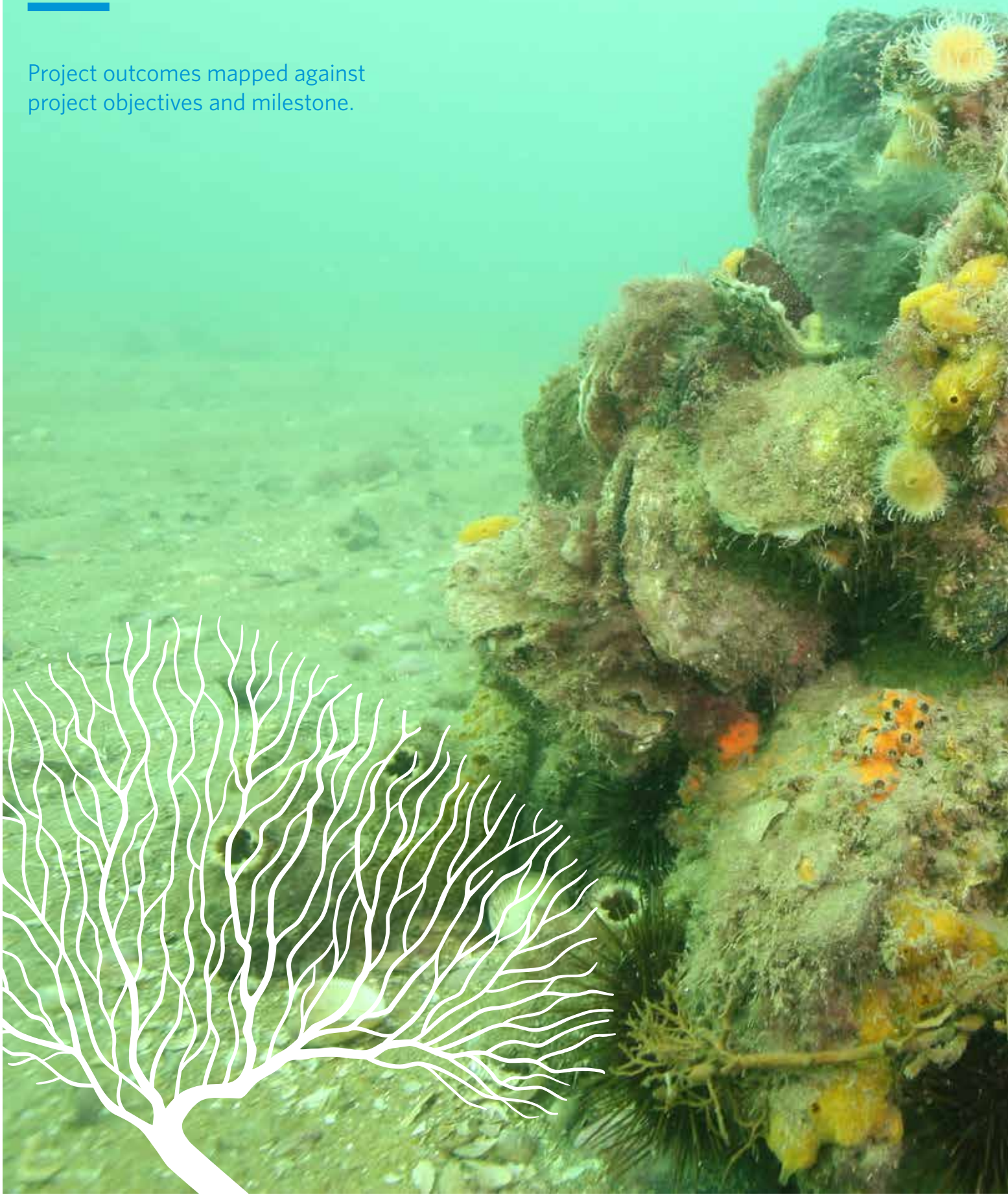
9.0 APPENDIX 1.0

Project outcomes mapped against project objectives and milestone.



Margaret's Rock, Margaret's Reef © Paul Hamer

Table 8: Summary of outcomes for all construction activities

Stage 2 Extension Deliverable: A minimum of 1000 m^2 of oyster and mussel reefs constructed between Hobsons Bay and Wilsons Spit

Milestones	Anticipated Completion Date	Date Completed
No. 4: Procurement of transport and reef construction subcontractor/s	By 30th November 2017	30th October 2017
No. 5: Completion of hatchery run by the Victorian Shellfish Hatchery	By 30th November 2017	21st December 2018
No. 7: Construction of new oyster base using shell cultch	By 31st December 2017	22nd November 2017
No. 13 Construction of new mussel base using shell cultch	By 31st May 2018	21st June 2018

	Activities	Notes
	• Initiated procurement process by inviting local marine construction contractors to submit tenders. • Three tenders received. • Tenders reviewed, and contractor selected.	Victorian and New South Wales based contractor, Polaris Marine were awarded the subcontract. Polaris Marine successfully constructed the Stage 2 reefs deployed in March 2017. Kina Diving, a commercial and scientific diving business, were also subcontracted to deploy the oyster spat onto all reefs.
	Established oyster spawning run at Victorian Shellfish Hatchery, including fulfilling the following tasks: • Transported 750 kg of recycled shell cultch from the quarantine and curing site (St Leonards) to Victorian Fisheries Authority premises in Queenscliff. • Washed the recycled shell cultch, to ensure it was adequately clean for the hatchery. • Worked with Restore the Bay volunteers, to prepare bag netting and fill with recycled shell cultch, ready for the larvae settling stage. • The hatchery lead the oyster rearing process by conditioning broodstock, preparing settlement tanks and settling oyster larvae on recycled shell cultch.	Hatchery run completed by 21st December to take advantage of the availability of additional oyster larvae on offer. This resulted in the bonus of more oysters being deployed onto the Stage 2 Extension reefs than originally planned.
	Deployed shell cultch and limestone rubble onto reef sites, including fulfilling the following tasks for Phase 1 (November 2017): • Loaded recycled shells at storage site into bulka bags – 144 m^3 (39,600 kg). • Transported recycled shell cultch from storage site to loading site at Corio Bay, Geelong Port. • Loaded limestone rubble at Bellarine Peninsula quarry into skip bins – 20 m^3 (30 tonnes). • Transported limestone rubble from Bellarine Peninsula quarry to loading site. • Mobilisation of multiple purpose vessel by Polaris Marine, loading of all reef base materials at Port of Geelong, travelled out to restoration sites, deployed recycled shell and limestone rubble as per design specifications. • TNC staff on the vessel to supervise the deployment including diving each restoration site post reef base deployment to ensure design specifications were met.	Polaris Marine effectively constructed reefs at both sites, in line with TNC's reef design. A Works Permit was required from Parks Victoria for both phases of reef construction. As per the Subcontract Agreement conditions, Polaris Marine supplied a '*Marine Works Deployment Report*' for both phases of deployment, which includes future recommendations. Some of these ideas are included Recommendations section below. This report is included in the final reporting documents.
	Deployed shell cultch and limestone rubble onto reef sites, with tasks completed as per Milestone No.7. The Phase 2 (June 2018) reef base material amounts include: • 80 m^3 (22,000 kg) of recycled shell. • 40 m^3 (60 tonnes) of limestone rubble.	The decision was made, in consultation with DELWP, to shift the mussel reef construction to June 2018. The reason for this timeframe adjustment was based on advice from the hatchery and mussel farmers that hotspot for natural recruitment of mussels is during June/July. Therefore, to maximise natural recruitment onto the new reefs, this window was deemed the best option.
	OUTCOME: Restored 2,549 m^2 of shellfish reefs, which exceeded the minimum 1000 m^2 target	

Table 9: Summary of all reef seeding activities

Stage 2 Extension Deliverable: Oysters deployed on the two existing reefs at Hobsons Bay and Wilsons Spit to meet a minimum density of 50 oysters/m^2

Milestones	Objective	Anticipated Completion Date	Date Completed
No. 6: Deployment of oysters onto the existing Stage 2 reefs	2	By 31st December 2017	23rd December 2017
No. 8: Deployment of oysters onto the existing Stage Extension 2 reefs	1	By 31st December 2017	23rd December 2017
No. 14: Deployment of mussels onto reefs	1	By 31st May 2018	28th August, 2018

	Activities	Amount of Shellfish Deployed	Notes
	Deployed oysters onto reef sites, including fulfilling the following tasks: • Transported seeded cultch from VSH to Clifton Springs Boat Ramp for Wilsons Spit and Warmies Boat Ramp for Margaret's Reef. • Kina Diving, with the assistance of TNC staff member, deployed oysters. • TNC diver supervised deployment to ensure oysters were evenly spread across existing Stage 2 reefs.	In total, 247,280 juvenile oysters (seeded onto scallop cultch) deployed onto Stage 2 reefs.	Juvenile oysters successfully deployed by Kina Diving, utilising a new surface to reef funnel prototype to achieve even spread.
	As above	1.455 million juvenile oysters (seeded onto scallop cultch).	As above
	Deployed mussels onto reef sites, including fulfilling the following tasks: • Purchased mussels from mussel farmer. • Mussels were from natural recruitment and grown out and maintained by farmer on long line for 3 months. • Mussel farmer collected mussels from lease and transported mussels to reef sites. • Kina Diving, with the assistance of TNC staff member, deployed the mussels. • TNC diver supervised deployment to ensure mussels were evenly spread across Stage 2 Extension reefs.	An estimated total of 446,000 juvenile mussels deployed, which included: Wilson Reef 3, on 22nd August 2018, 151,000 mussels; Wilson Reef 4, on 22nd August 2018, 150,000 mussels Margaret's Reef 2, on 28th August 2018, 146,000 mussels.	Mussel deployment was delayed due to the change in the reef base construction timeframe and to allow the juvenile mussels to grow out longer on the longline to assist in maximizing survival.

OUTCOME: Stage 2 reefs seeded with 247,280 juvenile oysters, with on average, 186 oysters/m^2.
Stage 2 Extension reefs seeded with 1.454 million juvenile oysters and an estimated 446,000 mussels.

Table 10: Summary of results from TNC's exploration activities in PPB

Stage 2 Extension Deliverable: An assessment of potential new sites in Port Phillip Bay suitable for assisted rehabilitation or full restoration

Milestones	Objective	Area	Figure	Anticipated Completion Date
No. 9: Initiation of new site assessment; and No 11: Completion of new site assessments	3	St Leonards	4	30th September, 2018
No. 9: Initiation of new site assessment; and No 11: Completion of new site assessments	3	Geelong Arm (four sites)	5	30th September, 2018
No. 9: Initiation of new site assessment; and No 11: Completion of new site assessments	3	9ft Bank	6	30th September, 2018
No. 9: Initiation of new site assessment; and No 11: Completion of new site assessments	3	Pt Cook	7	30th September, 2018
No. 9: Initiation of new site assessment; and No 11: Completion of new site assessments	3	Altona	8	30th September, 2018
No. 9: Initiation of new site assessment; and No 11: Completion of new site assessments	3	Hobsons Bay	9	30th September, 2018
No. 9: Initiation of new site assessment; and No 11: Completion of new site assessments	3	Carrum	10	30th September, 2018
No. 9: Initiation of new site assessment; and No 11: Completion of new site assessments	3	Dromana	11	30th September, 2018

	Date Completed	Method	Notes
	20th August, 2018	Video drops (17); and GoPro footage (2).	No remnant or degraded shellfish reef found but potential suitability for full restoration.
	1st November, 2018	Video drops (16); and GoPro footage (2).	**Potential degraded shellfish reef found that may be suitable for assisted rehabilitation and sourcing of broodstock**.
	1st November, 2018	Video drops (5); multibeam surveys; and towed video.	**Degraded shellfish reef suitable for assisted rehabilitation**.
	30th October, 2018	Video drops (8).	No remnant or degraded shellfish reef found so limited potential for assisted rehabilitation.
	30th October, 2018	Video drops (6).	No remnant or degraded shellfish reef found so limited potential for assisted rehabilitation but requires further investigation.
	31st October, 2018	Video drops (8); diving (2); and GoPro footage (2).	No remnant or degraded shellfish reef found so limited potential for assisted rehabilitation but potential broodstock locations and for full restoration.
	28th October, 2018	Video drops (10)	No remnant or degraded shellfish reef found so limited potential for assisted rehabilitation but may be suitable location for full restoration.
	28th October, 2018	Video drops (5)	No remnant or degraded shellfish reef found so limited potential for assisted rehabilitation but may be suitable location for full restoration.

OUTCOME: Surveyed 13 areas and 75 sites within these areas with 2 sites found to be potentially suitable for assisted rehabilitation. There were 7 sites recorded as broodstock locations and 14 sites were identified as potentially suitable for full restoration.

Table 11: Key outcomes for monitoring and evaluation

Stage 2 Extension Deliverable: A monitoring and evaluation report including assessment of the cost-effectiveness of different restoration methods

Milestones	Objective	Anticipated Completion Date	Date Completed
No. 3: Six-month monitoring and pre (oyster reef) monitoring	4	By 30th November 2017	6th October 2017
No. 11: Post (oyster reef) monitoring and pre (mussel reef) monitoring	4	By 20th January 2018	
No. 11: Post (oyster reef) monitoring and pre (mussel reef) monitoring	4	By 31st March 2018	29th March 2018
No. 16: Post (oyster and mussel reef) monitoring	4	By 30th June 2018	20th September 2018

	Activities	Notes
	Scheduled six-monthly monitoring of all Stage 2 reefs at Margaret's Reef and Wilson Spit and baseline monitoring of Stage 2 Extension reef sites over 5 days. Key tasks involved: • Chartering vessel. • Mobilising dive team and equipment. • Conducting all in-water dive monitoring activities over a two-week period. • Working with volunteers to complete shellfish metric monitoring. • Demobilisation. • Monitoring data uploading and analysis.	The allowance of a two-week window for monitoring to allow for adverse weather conditions.
		The decision was made, in consultation with DELWP, to shift the post deployment monitoring to March 2018 for the new oyster reefs – the reason for this is that the oysters deployed onto the reefs were too small to measure and will require at least 3 months of growth to be able to accurately track survival and growth overtime.
	Scheduled six-monthly mmonitoring of all Stage 2 and Stage 2 Extension reefs. Key tasks same as listed for Milestone No.3.	Oysters deployed on the new Stage 2 Extension are of sufficient size measure.
	Scheduled six-monthly mmonitoring of all Stage 2 and Stage 2 Extension reefs. Key tasks same as per Milestone No.3.	As discussed in the Reef Construction section, with the shifting of the mussel reef construction timeframe, this monitoring milestone was also adjusted.

OUTCOME: A summary of the Monitoring and Evaluation outcomes outlined in this report. In addition, two other reports have been supplied – *Port Phillip Bay Shellfish Reef Summary Report Card* and *Technical Report Supporting the 2018 Restoring the Lost Shellfish Reefs of Port Phillip Bay: Final Evaluation Report*.

Table 12: Summary of media outcomes

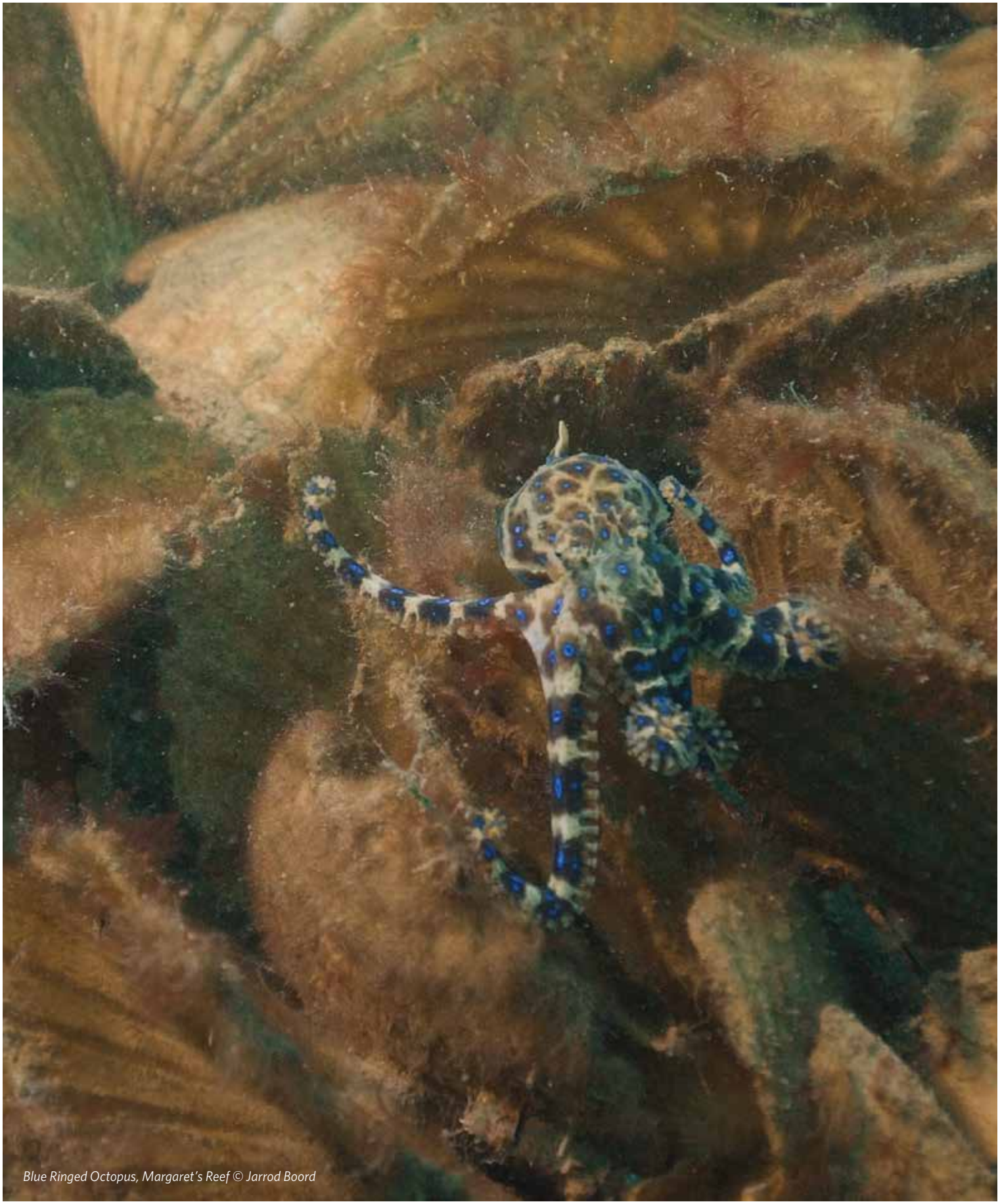
Stage 2 Extension Deliverable: A communication and engagement plan, with agreed protocols and activities; and minimum of two media releases and several stories to feature on TNC website and social media pages

Milestones	Objective	Anticipated Completion Date	Date Completed	Activities
No: 2 1st media announcement	5	23rd November 2017	10th November, 2018	The release of the 1st media statement to coincide with the Minister for Environment, Energy and Climate Change Lily D'Ambrosio's announcement of Port Phillip Bay funding initiatives.
-	5	No set date	1st April 2018 (first draft submitted), August 2018 (final TNC draft submitted)	TNC submittal of Communications and Engagement Plans.
No: 15 2nd media announcement	5	1st June, 2018	25th June, 2018	The release of the 2nd media statement, resulting in 3 print and 8 articles, 2 radio, including a special feature on Sunday Night Ch 7 News.

OUTCOME: Compilation of Communications and Engagement Plan; two media releases resulting in 96 media articles published in print, TV, radio and online sources.

Geelong Disabled Peoples Industries transporting shells © Simon Branigan

Stage 2 grow out of oysters, Bates Point © Ben Cleveland



Blue Ringed Octopus, Margaret's Reef © Jarrod Boord

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