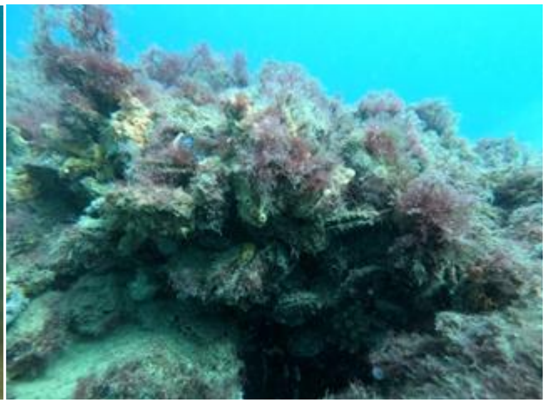
VFA Rock Recreational Fishing Reef Monitoring Report 2026



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VFA Rock Recreational Fishing Reef Monitoring Report 2026

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The VFA is committed to the Victorian Child Safe Standards and is focused on creating a safe environment that fosters the protection of all children to keep them safe from harm.

Contents

Summary

The Victorian Fisheries Authority (VFA) Rock Recreational Fishing Reefs were established within the Geelong Arm of Port Phillip to enhance recreational fishing opportunities while restoring shellfish reef habitat. Monitoring undertaken between 2022 and 2024 assessed fish communities, benthic invertebrates and native oyster establishment at Wilson's, Moolap and Merv's reefs.

Baited Remote Underwater Video Surveys recorded 39 fish species or families, including 18 recreationally targeted species. Reef sites consistently supported greater fish abundance and species richness than adjacent control sites, with species such as snapper (*Chrysophrys auratus*) and yellowtail scad (*Trachurus novaezelandiae*) occurring in higher numbers on reef habitats.

Underwater visual surveys at Wilson's Reef recorded a diverse assemblage of fish and invertebrates, demonstrating that the reefs provide valuable habitat and refuge for a range of marine species. Shellfish monitoring confirmed the successful establishment and growth of native oysters (*Ostrea angasi*), with evidence of natural recruitment observed across the reef structures.

Overall, the monitoring results indicate that the VFA Rock Recreational Fishing Reefs have successfully enhanced habitat complexity, increased fish abundance and diversity, and supported the establishment of self-sustaining oyster populations. The reefs are providing both recreational fishing benefits and broader ecological outcomes through the restoration of reef habitat and ecosystem functions within Port Phillip.

Introduction

Purpose-built Rock Recreational Fishing Reefs were established by the VFA in Port Phillip, Victoria, as part of a State Labor Government election commitment to improve recreational fishing opportunities. These shellfish reef complexes were designed to benefit both boat-based and land-based anglers by creating additional habitat that attracts and supports fish populations. The project also aimed to establish productive shellfish reefs that improve water quality, enhance benthic habitat, and increase ecosystem productivity.

Individual or small colonies of shellfish have long been known as ecosystem 'engineers' (Jones et al. 1994; Lenihan and Peterson 1998; McLeod et al. 2020) as they provide food and habitat for a variety of marine flora and fauna (Snelgrove 1999; Grabowski et al. 2012; McLeod et al. 2012; Christianen et al. 2017). When entire reefs are colonised by shellfish, they can modify an ecosystem by supporting complex food webs and broader trophic structures (Van Der Zee et al. 2012; McLeod et al. 2013; Christianen et al. 2017; Gillies et al. 2018; McLeod et al. 2020). Shellfish reefs provide both habitat and food resources for a diverse range of organisms, from benthic to pelagic species by offering complex physical structures that support colonisation and aggregation (Van Der Zee et al. 2012; McLeod et al. 2013; Christianen et al. 2017; Gillies et al. 2018; McLeod et al. 2020). Additionally, shellfish are highly efficient filter feeders, with fully grown oysters being able to filter as much as 300 L per day (Rice 2001; Rice 2008). By filtering suspended particles and phytoplankton from the water column, oysters can improve water clarity and contribute to nutrient cycling in adjacent waters (Rice 2001; Rice 2008; McLeod et al. 2013; Reidenbach et al. 2013).

Port Phillip was once home to extensive shellfish reefs mainly consisting of the native oyster (*Ostrea angasi*); however, with the introduction of dredging in the late 1800's to 1900's many of these shellfish reefs were harvested for food and lime production (Hamer et al. 2013). Today, only a small fraction of the original natural reefs remains. As such, the VFA and other organisations including The Nature Conservancy have initiated restoration efforts to help replenish Port Phillip's reefs.

The VFA established three reef complexes within the Geelong Arm of Corio Bay (Figure 1), constructed using 2,000 tonnes of locally sourced basalt to form a base layer, topped with 100 tonnes of limestone (Figure 2). Basalt was repurposed from the development of the Cherry Creek Youth Justice Centre. Each reef complex comprises 5–6 individual patch reefs, constructed to a height of approximately 1.5 m above the seabed. Basalt reef substrates were deployed in October 2020, followed by seeding with oysters in December 2020 at an approximate density of 7.5 oysters per square metre of reef, and blue mussels (*Mytilus galloprovincialis*) in January 2021 at approximately 3.3 tonnes per fishing reef location.

Post-installation monitoring is a critical component of this program, providing the data necessary to evaluate reef performance, ecological responses, and progress toward project objectives. This study aims to assess the ecological performance of the reef complexes by quantifying their effects on fish abundance and diversity relative to non-reef areas, characterising associated benthic communities (including invertebrates), and monitoring the growth seeded oysters.

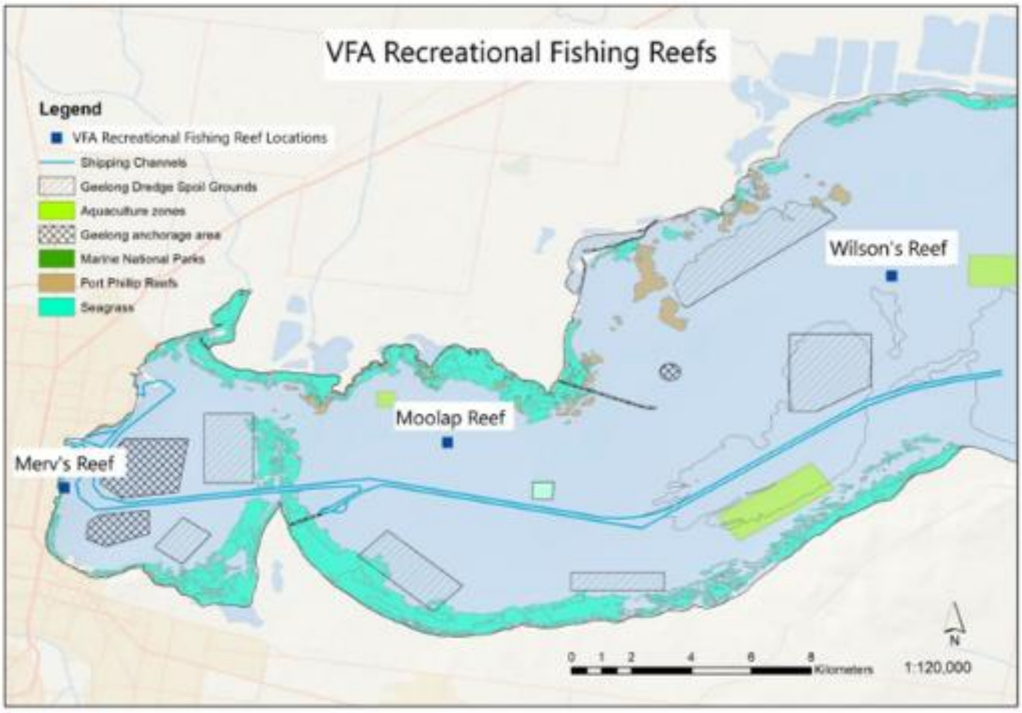


Figure 1. Diagrammatic map showing the locations of the Victorian Fisheries Authority’s Rock Recreational Fishing Reefs within the Geelong Arm of Port Phillip.

Figure 2. Basalt rocks being deposited to form ‘Merv's Reef’, St Helens, Geelong.

Methods

Three objectives were used to achieve the overarching aim of the research were:

- To quantify the influence of reef structures on fish abundance and species diversity relative to adjacent non-reef habitats.
- To investigate and characterise associated benthic communities including invertebrates.
- To quantify the abundance and size characteristics of native oysters (*Ostrea angasi*) and blue mussels (*Mytilus galloprovincialis*) established on the reef structures.

To address these objectives, a structured survey design was implemented, incorporating standardised sampling methods across reef and adjacent control sites to enable robust spatial and temporal comparisons.

Survey Design

A comparative monitoring approach was used to assess artificial reef sites against nearby control sites. Here, multiple complementary survey methods were employed to capture different components of the reef ecosystem, including:

- Baited Remote Underwater Video Surveys (BRUVS)
- Underwater Visual Census (UVC) transects
- Shell (oyster) Counts

Three reefs were surveyed in this study; Wilson's Reef, Moolap Reef, and Merv's Reef (Figure 1). Survey methods employed for each reef were tailored to site-specific visibility and environmental conditions to improve data quality and ensure valid comparisons within each reef system over time (Table 1).

We used Baited Remote Underwater Video (BRUV) systems to classify and quantify fish species of interest by mounting a camera on a pole approximately 1.5 m long with a bait cage attached at the distal end to attract fish into the camera's field of view (Mills et al., 2017). Historically, habitat monitoring commonly relied on underwater visual census (UVC) methods prior to the widespread adoption of high-resolution camera systems. UVC surveys provide valuable information on habitat condition and can detect a broader range of species, including pelagic taxa, and species not attracted to bait, making them a complementary approach when used alongside BRUVS. During UVC surveys, divers swim along a transect and record the species, abundance, and size of observed fish. While BRUVS can reduce dive time and associated operational costs, their effectiveness may be limited.

BRUV surveys were conducted on all reefs and adjacent control sites. BRUV surveys were conducted quarterly from June 2022 through to May 2024 to assess the species diversity and relative abundance of fish species.

Preliminary exploration dives indicated that conducting robust UVC and shell count surveys at Merv's Reef and Moolap Reef would be challenging due to poor visibility and soft, silty substrates, which may introduce sampling bias. As a result, UVC and Shell Counts surveys were only undertaken at Wilson's Reef, where conditions were suitable for accurate data collection.

Underwater Visual Census (UVC) surveys were conducted to assess fish, invertebrate, and mollusc assemblages using standardised methods developed by Reef Life Survey (https://reeflifesurvey.com/). Shell count surveys involved counting and measuring the number of oysters within 2 m × 2 m quadrats randomly placed across three areas of the reef.

Marine scientists also dived the reefs several times in addition to the described surveys. Fish and invertebrates that were observed during these dives were recorded qualitatively and included in the discussion section of this report.

Table 1. GPS coordinates of each of reef and control site surveyed including survey method and survey periodicity.

Sample location	Latitude	Longitude	BRUV Survey	UVC Survey	Shell Count Survey
Wilson's Reef	38 03.442 S	144 36.564 E	✓	✓	✓
Wilson's Control	38 03.554 S	144 37.284 E	✓	✓	
Moolap Reef	38 06.363 S	144 28.589 E	✓		
Moolap Control	38 05.822 S	144 28.180 E	✓		
Merv's Reef	38 07.252 S	144 21.656 E	✓		
Merv's Control	38 07.224 S	144 21.763 E	✓		
Conducted			Quarterly 2022 - 2024	Spring 2022	Spring 2022

Baited Remote Underwater Video Survey (BRUVS)

Baited Remote Underwater Video Survey (BRUV) methods were used to collect data on the relative abundance, species composition, and size of fish attracted to bait, with a primary focus on recreationally targeted and reef-associated species. The objective of this component was to compare fish abundance and diversity between reef and control sites. The system consisted of a GoPro Hero 9 mounted within an aluminium frame, with a bait pole and cage positioned 1.2 m from the camera (Figure 3). A standardized bait mixture comprising 330 g berley pellets, 330 g crushed pilchards, 160 ml water, 160 ml tuna oil, half a squid hood, and two bait fish (e.g. slimy mackerel) was used, with baitfish attached externally to the cage to encourage closer approach and improve species identification (Mills et al., 2017). At each reef location, two BRUVS were deployed at reef sites and two at control sites, with surveys conducted quarterly over two years, resulting in a total of 108 deployments. Each deployment had a soak time of 45 minutes, providing a consistent and effective framework for monitoring and comparing fish populations across reef environments over time.

BRUV Control Sites

Control sites were chosen based on their proximity and similarity to artificial reefs. These sites were chosen to best mimic pre-reef conditions. Control sites had to be carefully selected to ensure no confounding factors could influence their validity, such as depth, current, light penetration, sediment profile and turbidity. In most cases this was achieved by sampling outside the reef halo (the zone within which the reef effects the surrounding ecology). This was determined to be approximately 1 km in any direction of the reefs. Merv's Reef control sites proved more difficult to define due to its proximity to rock walls, boating channels, and piers. Consequently, control sites were selected only a few hundred meters from reef site.

Figure 3. A Baited Remote Underwater Video prepared for deployment.

Video Processing

All BRUV footage was processed through JVC player ™. The first five minutes of each recording was disregarded to allow for settlement of sediment and to acclimate fish to the camera's presence. Data was collected using the MaxN method, in which total species counts were recorded by the maximum number of a single species in the frame at any one time (Denney et al. 2017); thus, reducing recounting individuals moving in and out of frame. All data was recorded in Microsoft Excel ™.

Data analysis

Raw data was filtered into two datasets; one that included all species that were observed on the BRUV cameras, the other filtered to include only 'target species' i.e. species directly targeted by recreational anglers as a source of food and/or bait, sport or recreational enjoyment. Target species are defined by fish that are listed within the VFA Victorian Recreational Fishing Guide with size and bag limits. A PERMANOVA was used to determine whether a significant difference occurred between community composition groups (reefs and controls sites); whereas a nMDS analysis was used to provide visualisation between group and performed using Primer™. Resemblance matrixes were created using the Bray-Curtis similarity, each with 999 permutations. For PERMANOVA analysis, survey site and treatment were factors, with treatment nested within site. nMDS plots were created for the dataset 'all species' only, as the nMDS for 'target species showed no inherent value, likely due to the sample size being reduced significantly (i.e. some drops observed no target species, therefore the entire sample was redundant).

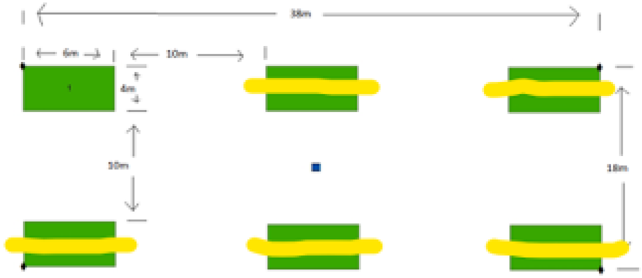
Underwater Visual Census (UVC) transects

Underwater Visual Census transects surveys at Wilson's Reef (Figure 4) were conducted approximately one year after reef installation. Here, a transect line was placed centrally over the longest dimension of individual reef patch. Ten-meter belt transects were specifically positioned centrally due to bare sediment between patch reefs. These surveys focused exclusively on Wilson's Reef, as consistently poor visibility at Moolap and Merv's Reef made Underwater Visual Census transect unfeasible at these locations.

UVC Fish Survey

Divers worked in pairs swimming along one 10 m transect line surveying an area 5 m high x 5 m wide on either side of the transect (Figure 5). Each diver surveyed 2.5 m either side of the transect. Divers recorded the size and number of individual fish species observed within this area.

Figure 4. Scientific diver conducting an Underwater Visual Census transect at Wilson's Reef.



10-m transect line

Figure 5. A diagrammatic depiction of Wilson's Reef (Green modules). Five out of six reefs were surveyed using a 10m belt transect (Yellow).

UVC Invertebrate Survey

Large macro-invertebrates and cryptic fishes were counted along the same transect line set for fish surveys (Figure 5). Invertebrate surveys were conducted following UVC fish transect surveys with macro invertebrates identified 1 m of either side of a transect. Only invertebrates greater than 2.5 cm in maximum length or diameter were recorded. Permanently attached invertebrates were not counted (e.g. sponges).

UVC Fish and Invertebrate Surveys - Control Sites

Underwater surveys at Wilson's Reef were also conducted at two control sites, located approximately 1 km west and 1 km east of the reef site. Fish transects and invertebrate surveys at these sites followed the same method as the reef surveys, using a 50 m continuous transect line instead of five shorter 10 m transects.

Shell Counts

Underwater detection of oyster shells relies on good visibility. As both Moolap and Merv's Reefs didn't meet this requirement, Shell Counts surveys were only conducted at Wilson's Reef.

Two divers conducted the shell count simultaneously. One diver set out a random 2 m^2 quadrat on the reef. The quadrat was then divided in half and each diver counted and measured the length and width (Figure 6) of each oyster detected. A total of three quadrats were surveyed on a different patch of reef. A minimum of 20 oysters were measured in each quadrat, and the total number of oysters counted.

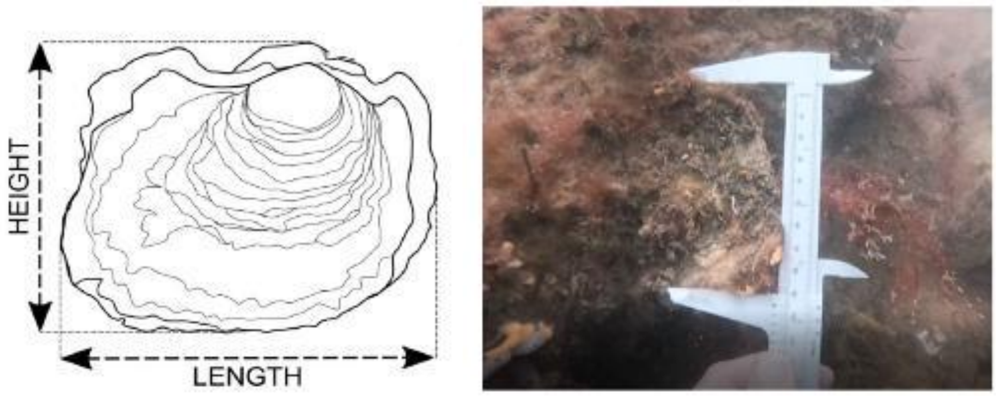


Figure 6. Morphometric characteristics of a native oyster (*Ostrea angasi*) used to measure lengths (left) and measuring an oyster in situ (right).

Timing

Underwater Visual Census surveys and shell counts were conducted in Spring 2022 at Wilson's Reef. BRUVS were conducted quarterly at each reef location over a two-year period: Merv's, Moolap and Wilson's Reef (Table 1).

Results

Baited Remote Underwater Video Survey

Summary of fish species observed

A total of 108 individual BRUVs deployments encompassing all four seasons was conducted from June 2022 through to May 2024. Sixteen deployments were deemed unsuccessful due to excessive algal blooms, which rendered the footage unusable. These occurred at Moolap and Merv's Reef during summer of 2023. A further three deployments were not used in analyses due to camera failure, which affected all three reefs during Autumn of 2023. The total number of deployments used in analyses was 89. Thirty-nine different fish species and/or families were observed over the two-year study, 18 of which were considered 'target species'. Yellowtail scad (*Trachurus novaezelandiae*) (Figure 7) were most abundant (n=1314), with schools of over 260 individuals observed at a single reef. The second most abundant species were snapper (*Chrysophrys auratus*, n= 471, Figure 8); silver trevally (Figure 9) and sand flathead (*Platycephalus bassensis*, n=189, **Error! Reference source not found.**). Yellowtail scad and snapper were almost exclusively found at reef sites. Three times as many flat head were found at the control sites compared to the reef sites (Appendix 1). Wilson's Reef presented the greatest diversity and abundance of species. However, this result may be influenced by reduced visibility at Moolap and Merv's reef which may have influenced detection.

Figure 7. An image captured from a BRUV showing yellowtail scads (*Trachurus novaezelandiae*); the most abundant fish species observed at Wilson's Reef.

Figure 8. An image captured from a BRUV showing a school of juvenile snapper (*Chrysophrys auratus*) at Wilson's Reef.

Figure 9. An image captured from a BRUV showing a school of silver trevally (*Pseudocaranx dentex*) at Wilson's Reef.

Figure 10. An image captured from a BRUV showing a sand flathead (*Platycephalus bassensis*) at Wilson's Reef

Analysis of all species

Results from a pairwise PERMANOVA between reef sites showed no significant difference between any of the reefs (Wilson’s v Moolap, *p* = 0.676) (Wilson’s v Merv’s, *p* = 0.327) (Moolap v Merv’s, *p* = 0.35). A PERMANOVA pairwise-treatment analysis of individual reef sites for all reefs showed a significant difference between reef and control sites at Wilson’s Reef (*p* = 0.001, t = 2.703), Moolap Reef (*p* = 0.001, t = 2.0592) and Merv’s Reef (*p* = 0.057, t = 1.3063). nMDS plots representing the effect of site (Figure 11) and the effect of treatment (Reef vs Control, Figure 12) show clear groupings at an acceptable 2D stress level of 0.2 (i.e. not a strong fit but within bounds of acceptable range). The effect of treatment (Reef or Control site) has clear separation (Figure 12), with only a few outliers seen in samples 38, 86 and 11, belonging to Moolap and Merv’s reef respectively. The effect of site showed less separation; however, groupings are still distinct.

Figure 11. nMDS showing the effect of location.

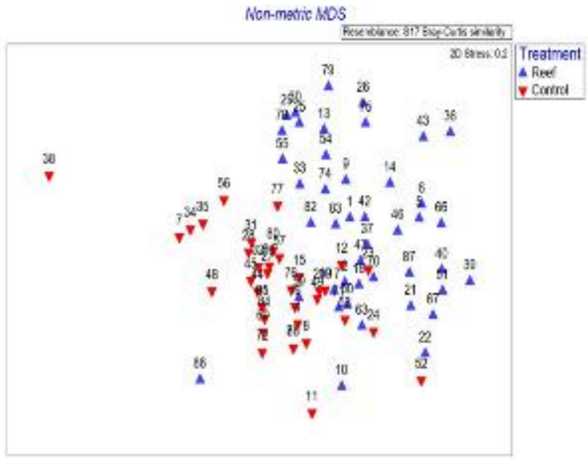


Figure 12. nMDS showing the effect of the reef and controls sites.

Analysis of target species

Results from the PERMANOVA pairwise-treatment analysis of individual reef sites for all reefs, showed a significant difference between reef and control sites at Wilson’s reef and Moolap Reef (*p* = 0.001, t = 3.6339 and *p* = 0.001, t = 3.012 respectively). Merv’s Reef showed no significant difference between reef and control sites (*p* = 0.352, t =0.352). Results from the pairwise PERMANOVA between reef sites showed no significant difference between any of the reefs (Wilson’s v Moolap, *p* = 0.688) (Wilson’s v Merv’s, *p* = 0.337) (Moolap v Merv’s, *p* = 0.524). Average species richness was higher at reef treated sites when compared to control sites, with all three reefs showing a higher level of diversity in species (Figure 13). Average species abundance was higher at reef treated sites when compared to control sites, with all three reefs showing a higher level of abundance in species (Figure 14). combined species richness shows the effect of reef treatment having a positive relationship with the number of species at reef treated sites compared with control sites (Figure 15). Combined species abundance shows the effect of reef treatment having a positive effect on overall abundance compared to control sites (Figure 16). This appears to be driven by the high level of abundance seen at Wilson’s Reef. All year classes of snapper (0+, 1+, 2+ & 3+) show greater abundance at reef treated sites compared to control sites (Figure 17).

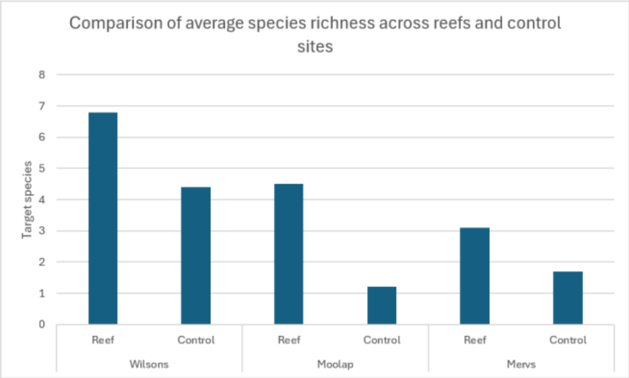


Figure 13. Graph comparing average fish biodiversity across each reef and control sites.

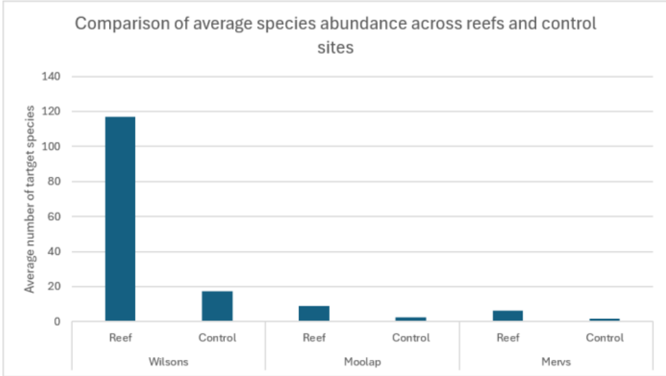


Figure 14. Graph comparing average species abundance across each reef and control sites.

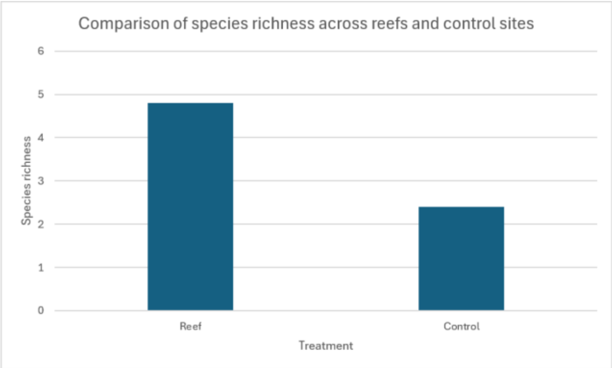


Figure 15. Comparison of average species richness between combined reef and control sites.

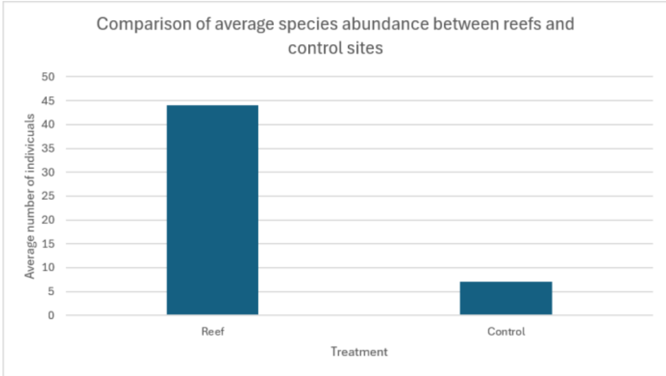


Figure 16. Comparison of average species abundance between the combined reef and control sites.

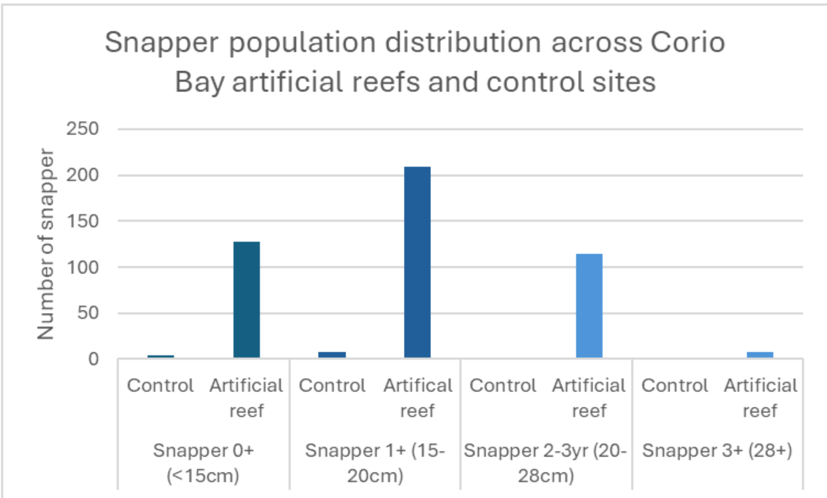


Figure 17. Comparison of snapper abundance on the rock reefs compared to the control sites.

Underwater Visual Census– Fish

Underwater Visual Census surveys for fish were conducted on the 9th of August 2022 on Wilson's Reef and its two control sites. Water temperature was approximately 12°C, and visibility was 10 m at the reef and 6 – 8 m at the control sites.

Several fish species were observed during 50 m underwater visual census transects conducted at Wilson's Reef and control sites 1 and 2 (Table 2). Small Hula fish (*Trachinops caudimaculatus*), Rock Ling (*Genypterus tigerinus*) and Leather jackets (*Acanthaluteres* sp.) were the predominant species observed within the reef transects. A smaller number of fish were sighted during the control transects including two of flathead. Eight rock ling were observed habituating larger holes within the limestone rocks.

Table 2. Comparative observations of fish species along a 50 m transect line at Wilson's Reef and Control Sites one and two.

Transect	Reef	Fish species						
		Flathead *Platycephaus sp.*	Rock Ling *Genypterus sp.*	Leatherjacket *Meuschenia sp.*	Globefish *Diodon sp.*	Hula Fish *Trachinops sp.*	weed whiting *Haletta sp.*	Blenny *Parablennius sp.*
1	Wilsons		8	2	1	25	2	
2	Wilsons Control 1	2						
3	Wilsons Control 2			1	1			1

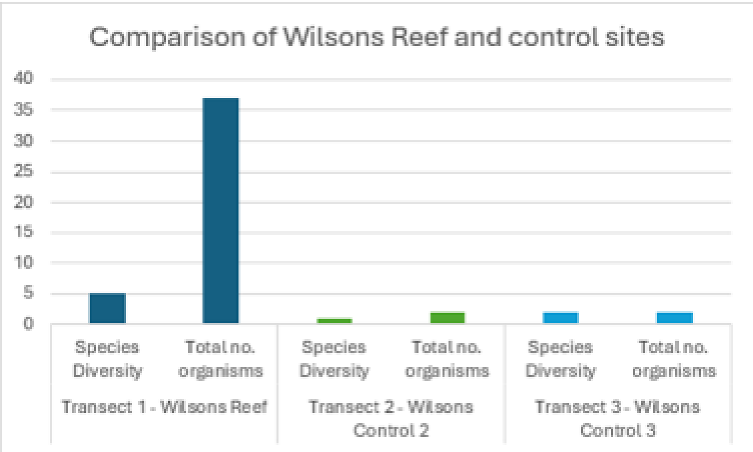


Figure 18. Comparison of species diversity and abundance between the survey transect at Wilson's Reef and the control sites.

Several reef-associated species and ecological indicators were observed during underwater surveys, including rock ling inhabiting reef crevices, boarfish and snapper utilising the reef structure, and southern calamari egg masses attached to the reef, while blue-spotted flathead were observed at the adjacent control site (Figures 19-23).

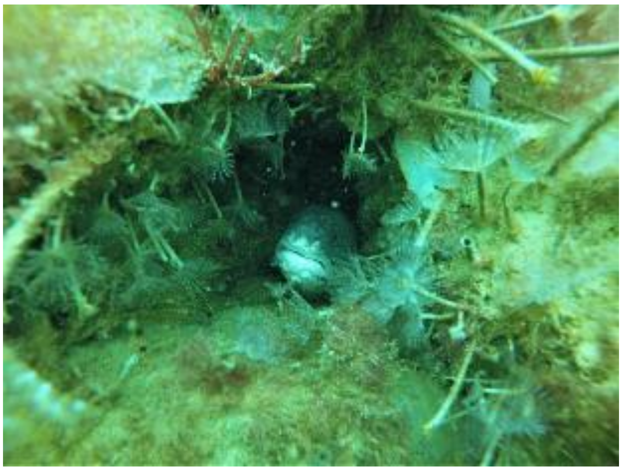


Figure 19. Rock ling (*Genypterus tigerinus*) were observed in many of the basalt rock cervices at Wilson's Reef.

Figure 20. Southern, blue-spotted flathead (*Platycephalus speculator*) observed at Wilson's Reef control site.

Figure 21. Boarfish (*Pentaceropsis recurvirostris*) observed at Wilson's Reef, two months after the rock was installed.

Figure 22. A large snapper (hiding bottom right of the image) observed at Wilson's Reef.

Figure 23. Squid eggs most likely coming from southern calamari (*Sepioteuthis australis*) were sighted on the reef, six months after installation.

Underwater Visual Census - Invertebrates

Various species of sea stars, including Tosia (*Tosia* sp.) and Asterias (*Asterias amurensis*) were observed (Table 3). A diverse range of invertebrates including urchins, sea cucumbers, and fan worms were observed and recorded. Other marine life such as squid eggs and crabs has been sighted whilst not conducting monitoring dives, indicating a broader range of marine life (Figure 24).

Table 3. A comparison of invertebrate species observed at Wilson's Reef during underwater visual swim transects

		Invertebrate species							
Transect	Reef	Tosia *Tosia sp.*	11 arm sea star *Coscinasterias sp.*	Asterias sea star *Asterias sp.*	Urchin *Holopneustes sp.*	Sea cucumber *Australostichopus sp.*	European fanw *Sabella sp.*	Squid eggs	Crab *Microhalimus sp.*
1	Wilsons	3	9	3	1		10%	1	1
2	Wilsons Control 1		1						
3	Wilsons Control 2		2			1			

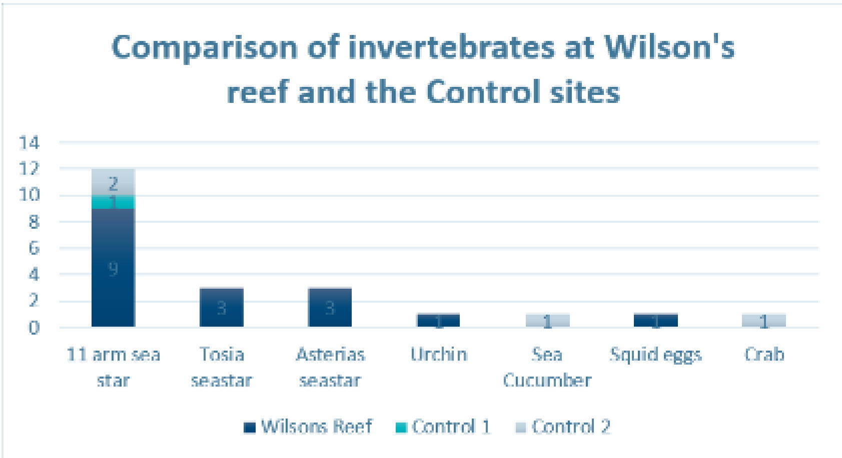


Figure 24. Graph comparing number of invertebrates at Wilson's Reef and the control sites.

Shellfish Abundance and Growth

Very few live mussels were observed on the reef structures during post-deployment surveys, and in some area's mussels were absent. As mussel survival and establishment appeared limited, subsequent shellfish monitoring focused primarily on native oysters (*Ostrea angasi*), which were more readily detected across the reef structures and provided a clearer indication of shellfish establishment and reef development.

Wilson's Reef Shellfish Monitoring 8 November 2022

Divers placed a 2 m x 2 m quadrat onto the patch reef, then proceeded to count and measure each native oyster observed. Quadrat one had 37 oysters, quadrat two had 31 oysters and quadrat three had greatest amount with a total of 58 oysters. The smallest oyster measured had a height of 28 mm and length of 30 mm and the largest oyster measured was 99mm high with a length of 74 mm. The mean height of the oysters was 51.5mm and the mean length was 53.0mm (Table 4). A minimum of 20 oysters were measured in each quadrat.

Table 4. Mean oyster height (mm) and length (mm), and their standard deviations (SD), for a minimum of 20 randomly selected oysters measured within each 2 m × 2 m quadrat at Wilson's Reef.

	Quadrat 1		Quadrat 2		Quadrat 3	
Oyster	**Height**	**Length**	**Height**	**Length**	**Height**	**Length**
Average	52.2	53.9	50.2	51.7	56.1	57.2
SD	11.1	13.11	10.6	11.4	17.7	15.3

Oyster measurements demonstrated a positive relationship between shell height and length across the surveyed quadrats, while photographic comparisons indicated substantial reef development and colonisation by oysters and other invertebrates over time (Figures 25-27).

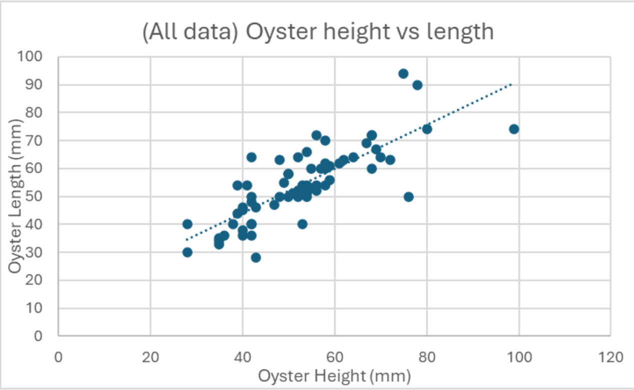


Figure 25 The relationship between height and length oysters measured on Wilson's Reef.

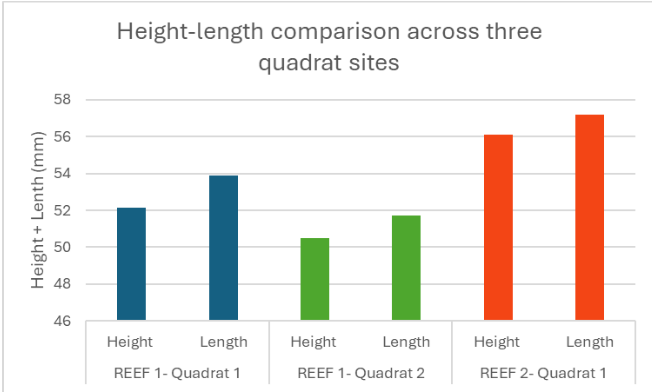


Figure 26. Height and length comparison of oysters observed across three quadrats.

Figure 27. Image comparison of the same rocky reef patch on Wilson's Reef. The image on the left was taken in 2020 soon after installation. The right image was taken in 2025 looking like a natural reef covered in oysters and other invertebrates.

Discussion

The VFA Rock Recreational Fishing Reefs have successfully enhanced habitat complexity and supported greater fish abundance, diversity, and oyster establishment compared with adjacent control areas. These findings indicate that the reefs are providing both recreational fishing benefits and broader ecological outcomes within the Geelong Arm of Port Phillip.

Wilson's and Moolap reef sites revealed a greater prevalence of identified key recreational species, in particular snapper (*Chrysophrys auratus*) that have a preference towards reef structure as habitat compared to non-structure (Ross et al. 2007, Mills et al. 2017). High attraction of juvenile snapper to new reef structures is consistent with their naturally observed patterns of habitat use and may relate to a combination of increased availability and diversity of food, predation and refuges provided by the reef structures (Hamer et al 2011, Francis 1995; Thrush et al. 2002). Underwater visual surveys indicated higher fish biodiversity at reef sites compared to control sites. Typically, prey fish will utilise the presence of a structure to avoid predators (Rountree, 1989).

At Wilson's Reef, BRUVS recorded yellowtail scad and snapper as the most abundant fish species. Southern hula fish exhibited the highest abundance during the underwater visual swims, likely due to the reef's complex structure, which offers suitable microhabitats for predator avoidance and facilitates sustained population growth in this vulnerable species (Hunt et al. 2011). Using a variety of rock sizes and types increases reef complexity, thus providing a range of habitable spaces. Design aspects of an artificial reef are crucial for the development of reef communities (Hutchinson, N., 2009; Sherman, R. L. et al. 2002) with Cameron et. al. (2014) finding a positive correlation between the intricacy of an artificial reef to diversity and strength of reef fish populations. The opposite was noted for flathead as they were observed more frequently at control sites which consisted of their preferred habitat of silt and sand.

BRUV results were positive despite the impact of significant algal blooms restricting surveys. Schools of fish such as yellowtail scad (*Trachurus novaezelandiae*) and snapper were observed. Yellowtail scad were the most abundant fish species sited on the reefs. This supports a study conducted by Stewert and Ferel (2001) that yellowtail scad are associated with rocky reefs, particularly if the reefs are isolated with no other structure nearby. A further investigation into sizes of snapper at the reef sites found that majority were juvenile/younger fish which suggests that natural recruitment at the reef site has occurred. Adult snapper tend to spread out over reefs offshore, with adults entering Victoria's Bays to spawn in October/November (Hamer et al 2007).

Divers observed fish and invertebrates in greater diversity and abundance around larger basalt boulders compared to smaller limestone rubble. These boulders provided increased cracks and crevices between rocks which provides optimal fish habitat and protection. Oysters (*Ostrea angasi*) and other filter feeders were observed on exposed upper boulder areas that were open to increased water flow and away from sedimentation. Increasingly complex 3D structures provide more heterogeneous habitat space, and thus a diverse array of refuge types, foraging opportunities, and resources which are associated to high species diversity and abundances (Helder et al 2022).

During additional dives conducted outside the formal monitoring program, scientists observed snapper, boarfish (*Pentaceropsis recurvirostris*), rock ling (*Genypterus tigerinus*), common pufferfish (*Tetractenos hamiltoni*), old wife (*Enoplosus armatus*) and moonlighter (*Tilodon sexfasciatus*) utilising the reef structures for shelter and foraging. These observations are consistent with known habitat preferences, with boarfish and old wife commonly associated with rocky reefs and ledges, and rock ling frequently occupying crevices and cavities within reef habitats (Bray 2020-2026).

Divers observed slow growing invertebrates, such as colonial ascidians and sponges colonising available rock habitat. While southern calamari were not observed, 'mops' of eggs, recently deposited by breeding individuals, were detected. Although such results are preliminary, reef structures are supporting several interrelated ecosystems. Underwater invertebrate species are vital for health of reefs and fish populations, performing functions like creating habitat, acting as a food source, filtering water, and cleaning other species. They recycle nutrients, control algae, and provide essential shelter and food for a vast number of fish, making them crucial for a thriving marine ecosystem (NSW DPI 2024) (Glenn and Enochs 2010).

Oysters were larger than expected and were counted and measured within random 2m x 2m quadrats in situ. The width of most oysters was 40mm – 70mm (around 18 months old). This growth rate is typical, comparative to other studies finding that adults reach reproductive maturity from about 2 years and growth rates vary from 8-40mm per year (Mitchell et al. 2000, Gillies et al 2019). Counts where conservative as oysters were very cryptic, either covered in invertebrates or algae or under rock ledges.

Some of the original seeded oysters from the Victorian Shellfish Hatchery encountered are now outgrowing the scallop shells that they originally settled on. However, most oysters were attached to the basalt and limestone, so it is likely that these oysters spawned, settled, and established in the wild. *Ostrea angasi* are hermaphrodites, maturing first as a male, then becoming females. Males release sperm into the water whilst females brood and fertilize the eggs in their gills before releasing small larvae back into the water column. Discovering these established oysters was satisfying as they are now brood stock that will hopefully assist to restore the oyster populations and improve water quality within Port Phillip.

This survey supports the existing theory that by providing structure in an open ocean area, a population of reef species can be established. This theory is further supported by confirming reef design is critical to the type of species that will aggregate (Vivier et al. 2021). Species of fish will utilise different areas of a habitat to fulfill a niche that best supports their survival, such as old wives and boarfish residing under rocky ledges (Bray 2020 – 2025) and oysters being most prevalent on exposed edges of rock. The Wilson’s Reef patchy rock design directly supported species such as rock ling which were the second most observed species during the underwater visual count swims, as a very solitary species they notoriously inhabit rocky cave areas among reef structures.

A total of eight tonnes of mussels were seeded onto the three rock reefs. Post-deployment dive assessments indicated low survival rates, with few live mussels observed during the surveys (pers. obs. Womersley 2023). The translocated mussels originated from a nearby aquaculture facility where they had been cultured off a rope midwater. Consequently, their relocation to the benthic environment and direct exposure to the substrate impeding their ability to filter likely contributed to increased mortality. Although survival was limited, the seeding of the mussels may have provided ecological benefits through the addition of an organic food source and shell substrate, thereby contributing to the development and structural complexity of the reef footprint. Although tolerant, hypoxia is harmful to mussels, as they are sessile and rely on oxygen-rich water to survive (Yoo et al. 2024).

Constructing a reef with the correct substrate such as limestone allows oysters to attach to the structure, which assists in maintaining oyster populations, encouraging growth and sustains populations (Walles et al 2016). Shellfish surveys were limited as poor visibility inhibited the diver’s ability to sight small oysters and those with cryptic growth were unable to be correctly identified. Many oysters had self-seeded on other oyster shells and within rock crevices which may have resulted in an underestimated total shellfish count and measurement. Impressive growth of self-seeded oysters was observed on the exposed edges of the larger basalt boulders in open water areas with high water flow.

Shellfish reefs were once abundant in Port Phillip prior to commercial dredge fishing and introduced pests. Shellfish reefs have been in decline in Port Phillip since European settlement (Ford and Hamer 2016). In 1836 Port Phillip had extensive reefs and beds of *Ostrea angasi* and blue mussel (*Mytilus galloprovincialis*) which may have covered up to 50% of the seafloor (Ford and Hamer 2016). In current times, there is a lack of reef habitat in Port Phillip as the substrate mainly consists of soft sand and silt, other than few isolated reefs and those found around Port Phillip Heads (Blake et al 2012). This project has shown that increased fish habitat benefits underwater biodiversity and recreational angling by supporting fish populations. Creation of the reefs has increased structural habitat and food sources for fish, whilst increased numbers of oysters will improve water quality through filtration and provide brood stock to support future shellfish populations.

Overall, the monitoring results demonstrate that the VFA Rock Recreational Fishing Reefs are functioning as intended by increasing habitat complexity, supporting higher fish abundance and diversity, and facilitating the establishment of native oysters. Although mussel establishment was limited, the seeded mussels may have contributed shell material and organic matter that supported early reef development. Continued monitoring will be important to determine whether these ecological responses are sustained over time and whether oyster recruitment contributes to the development of self-sustaining shellfish reef habitat within Port Phillip.

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References

Blake, S., Ball, D., Coots, A. (2012) Marine video survey of Victoria. Fisheries Victoria Technical Report No. 155, 95 pages. Department of Primary Industries, Queenscliff, Victoria, Australia. DOI: 10.13140/RG.2.2.18730.21446

Bray, D.J. (2020) *Pentaceropsis recurvirostris* in Fishes of Australia, accessed 02 Jan 2026, https://fishesofaustralia.net.au/home/species/629

Bray, D.J. (2025) *Chrysophrys auratus* in Fishes of Australia, accessed 02 Jan 2026, https://fishesofaustralia.net.au/home/species/678

Bray, D.J. (2025) *Enoplosus armatus* in Fishes of Australia, accessed 02 Jan 2026, https://fishesofaustralia.net.au/home/species/445

Bray, D.J. (2025) *Tilodon sexfasciatus* in Fishes of Australia, accessed 02 Jan 2026, https://fishesofaustralia.net.au/home/species/527

Bray, D.J. (2026) *Genypterus tigerinus* in Fishes of Australia, accessed 02 Jan 2026, https://fishesofaustralia.net.au/home/species/4581

Cameron, M.J., Lucieer, V., Barrett, N.S., Johnson, C.R., & Edgar, G.J. (2014) Understanding community-habitat associations of temperate reef fishes using fine-resolution bathymetric measures of physical structure. Marine Ecology Progress Series 506, 213-229. DOI: 10.3354/meps10788

Christianen, M.J.A., van der Heide, T., Holthuijsen, S.J., van der Reijden, K.J., Borst, A.C.W. & Olff, H. (2017) Biodiversity and food web indicators of community recovery in intertidal shellfish reefs. Biological Conservation 213, 317-324. DOI: 10.1016/j.biocon.2016.09.028

Denney, C., Fields, R., Gleason, M. & Starr, R. (2017) Development of New Methods for Quantifying Fish Density Using Underwater Stereo-video Tools. Journal of Visualized Experiments 129, e56635. https://doi.org/10.3791/56635

Ford, J.R. & Hamer, P. (2016) The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement. Proceedings of the Royal Society of Victoria 128, 87-105. DOI: 10.1071/RS16008

Gillies, C.L., Crawford, C. & Hancock, B. (2018) Restoring Angasi oyster reefs – what is the endpoint ecosystem we are aiming for and how do we get there? DOI: 10.1111/emr.12278

Gillies, C.L., McLeod, I.M., Alleway, H.K., Cook, P., Crawford, C., Creighton, C., Diggles, B., Ford, J., Hamer, P., Heller-Wagner, G., Lebrault, E., Le Port, A., Russell, K., Sheaves, M. & Warnock, B. (2018) Australian shellfish ecosystems: Past distribution, status and future direction. PLoS ONE 13, 1-23. DOI: 10.1371/journal.pone.0190914

Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., Keeler, A.G., Opaluch, J.J., Peterson, C.H., Piehler, M.F., Powers, S.P. & Smyth, A.R. (2012) Economic Valuation of Ecosystem Services Provided by Oyster Reefs. BioScience 62, 900-909. DOI: 10.1525/bio.2012.62.10.10

Hamer, P. & Jenkins, G.P. (2007) Migratory dynamics and recruitment of snapper, Pagrus auratus, in Victorian waters. Final report to Fisheries Research and Development Corporation Project No. 199/134. Primary Industries Research Victoria, Queenscliff.

Hamer, P., Mills, K., Grixti, D. & Rogala, R. (2011) Trial of recreational fishing reefs in Port Phillip Bay. Fisheries Victoria Research Report Series No. 36.

Hamer, P., Pearce, B. & Winstanley, R. (2013) Towards reconstruction of the lost shellfish reefs in Port Phillip Bay. Recreational Fishing Grants Program Research Report. Project SG/117, Department of Environment and Primary Industries.

Helder, N., Burns, J. & Green, S.O. (2022) Intra-habitat structural complexity drives the distribution of fish trait groups on coral reefs. Ecological Indicators. DOI: 10.1016/j.ecolind.2022.109266

Hunt, T.L., Ford, J.R. & Swearer, S.E. (2011) Ecological determinants of recruitment to populations of a temperate reef fish, *Trachinops caudimaculatus* (Plesiopidae). Marine and Freshwater Research 62, 502-509. DOI: 10.1071/MF10262

Hutchinson, N., Pecl, G.T., Doubleday, Z., Ward, T., Clarke, S., Day, J., Dixon, C., Frusher, S., Gibbs, P., Hobday, A., Jennings, S., Jones, K., Li, X., Spooner, D. & Stocklosa, R. (2009) Risk Assessment of Impacts of Climate Change for Key Marine Species in Southeastern Australia. Fisheries Research and Development Corporation.

Jones, C.G., Lawton, J.H. & Shachak, M. (1994) Organisms as Ecosystem Engineers. Oikos 69, 373-386. https://doi.org/10.2307/3545850

Lenihan, H.S. & Peterson, C.H. (1998) How Habitat Degradation Through Fishery Disturbance Enhances Impacts of Hypoxia on Oyster Reefs. Ecological Applications 8, 128-140. https://doi.org/10.1890/1051-0761(1998)008[0128:HHDTFD]2.0.CO;2

McLeod, I.M., Parsons, D.M., Morrison, M.A. & Le Port, A. (2012) Factors affecting the recovery of soft-sediment mussel reefs in the Firth of Thames, New Zealand. Marine and Freshwater Research 63, 78-83. DOI: 10.1071/MF11083

McLeod, I.M., Parsons, D.M., Morrison, M.A., Van Dijken, S.G. & Taylor, R.B. (2013) Mussel reefs on soft sediments: a severely reduced but important habitat for macroinvertebrates and fishes in New Zealand. New Zealand Journal of Marine and Freshwater Research 48, 48-59. DOI: 10.1080/00288330.2013.834831

McLeod, I.M., Boström-Einarsson, L., Creighton, C., D'Anastasi, B., Diggles, B., Dwyer, P.G., Firby, L., Le Port, A., Luongo, A., Martínez-Baena, F., McOrrie, S., Heller-Wagner, G. & Gillies, C.L. (2020) Habitat value of Sydney rock oyster (*Saccostrea glomerata*) reefs on soft sediments. Marine and Freshwater Research 71, 771-781. DOI: 10.1071/MF18197

Mills, K., Hamer, P. & Quinn, G. (2017) Artificial reefs create distinct fish assemblages. Marine Ecology Progress Series 585, 155-173.

Mitchell, I.M., Crawford, C.M. & Rushton, M. (2000) Flat oyster (*Ostrea angasi*) growth and survival rates at Georges Bay, Tasmania (Australia). Aquaculture 191, 95-109. DOI: 10.1016/S0044-8486(00)00441-5

Reidenbach, M.A., Berg, P., Hume, A., Hansen, J.C.R. & Whitman, E.R. (2013) Hydrodynamics of intertidal oyster reefs: The influence of boundary layer flow processes on sediment and oxygen exchange. Limnology and Oceanography: Fluids and Environments 3, 225-239. DOI: 10.1215/21573689-2395266

Rice, M.A. (2001) Environmental Impacts of Shellfish Aquaculture: Filter Feeding to Control Eutrophication 1, 77-86.

Rice, M.A. (2008) Environmental Effects of Shellfish Aquaculture in the Northeast. Northeast Regional Aquaculture Centre 105, 1-6.

Ross, P.M., Thrush, S.F., Montgomery, J.C., Walker, J.W. & Parsons, D.M. (2007) Habitat complexity and predation risk determine juvenile snapper (*Pagrus auratus*) and goat fish (*Upeneichthys lineatus*) behaviour and distribution. Marine and Freshwater Research 58, 1144-1151. DOI: 10.1071/MF07017

Rountree, R.A. (1989) Association of fishes with fish aggregation devices: effects of structure size on fish abundance. Bulletin of Marine Science 44(2), 960-972.

Sherman, R.L., Gilliam, D.S. & Spieler, R.E. (2002) Artificial reef design: void space, complexity, and attractants. ICES Journal of Marine Science 59(Suppl.), S196-S200.

Snelgrove, P.V.R. (1999) Getting to the Bottom of Marine Biodiversity: Sedimentary Habitats. BioScience 49, 129-138. https://doi.org/10.2307/1313538

Van Der Zee, E.M., van der Heide, T., Donadi, S., Eklöf, J.S., Eriksson, B.K., Olff, H., van der Veer, H.W. & Piersma, T. (2012) Spatially Extended Habitat Modification by Intertidal Reef-Building Bivalves has Implications for Consumer-Resource Interactions. Ecosystems 15, 664-673. DOI: 10.1007/s10021-012-9538-y

Vivier, M., Dauvin, J., Navon, M., Rusig, A., Mussio, I., Orvain, F., Boutouil, M. & Claquin, P. (2021) Marine artificial reefs, a meta-analysis of their design, objectives and effectiveness. Global Ecology and Conservation 27. DOI: 10.1016/j.gecco.2021.e01538

Walles, B., Troost, K., van den Ende, D., Nieuwhof, S., Smaal, A.C. & Ysebaert, T. (2016) From artificial structures to self-sustaining oyster reefs. Journal of Sea Research 108, 1-9. DOI: 10.1016/j.seares.2015.11.007

Yoo, C., Wilms, T., Stoehr, S., Latuta, L., Timmermann, K., Moltesen, M. & Svendsen, J. (2024) Mussel reefs promote taxonomic biodiversity and host a unique assemblage of mobile marine fauna in a coastal area of poor ecological status. Journal of Sea Research 202. https://doi.org/10.1016/j.seares.2024.102544

Appendix 1.

Table 5. Total number of marine species observed by the BRUV analysis across all sites and all seasons.

Marine species	Wilson's Reef	Wilsons Control	Marine species	Moolap Reef	Moolap Control	Marine species	Merv's Reef	Merv's Control
Yellowtail scad	1309	5	Snapper	36	0	Southern Hulafish	49	0
Snapper	407	8	Wrasse (all species)	21	3	Leatherjacket	33	3
Blue warehou	119	0	little weed whiting	20	5	little weed whiting	21	5
KGW	100	1	Flathead	19	29	Snapper	16	4
Goatfish	38	1	Baitfish	19	131	Wrasse (all species)	13	8
Southern Hulafish	36	0	Blue warehou	11	0	Silverbelly	7	0
Flathead	26	109	Silver trevally	3	0	Goby	5	6
Silver trevally	18	92	KGW	3	0	KGW	4	0
Leatherjacket	15	2	Gummy Shark	3	0	Stingray, All species	4	0
little weed whiting	12	0	Rock cod	2	0	Flathead	2	4
Crab	10	4	Leatherjacket	2	1	Blenny	2	0
Stingray, All species	8	17	Goby	2	11	Blue warehou	2	0
Moonlighter	8	0	Goatfish	2	0	Goatfish	1	1
Gobbleguts	7	0	Unknown	1	0	Toadfish	1	0
Wrasse (all species)	6	1	Stingray, All species	1	0	Mantis shrimp	1	1
Rock cod	4	0	Port Jackson Shark	1	0	Asterias a.	1	0
Goby	4	36	Moonlighter	1	0	Yellowtail scad	0	0
Blue trevally	3	8	Yellowtail scad	0	0	Blue trevally	0	0
Baitfish	3	260	Toadfish	0	0	Silver trevally	0	0
Toadfish	3	4	tiny school fish <1cm	0	0	Australian salmon	0	1
Blenny	3	0	Southern Hulafish	0	0	Gobbleguts	0	0
Largetooth Beardie	3	0	Southern cardinal fis	0	0	Southern cardinal fis	0	0
Southern cardinal fish	2	0	Silverbelly	0	0	Baitfish	0	0
Australian Herring	1	54	Shrimp	0	0	Gummy Shark	0	0
Shrimp	1	0	Octopus	0	0	Port Jackson Shark	0	0
Unknown	1	2	Mantis shrimp	0	3	Rock cod	0	0
Australian salmon	0	0	Largetooth Beardie	0	0	Moonlighter	0	0
Silverbelly	0	0	Gobbleguts	0	0	Australian Herring	0	0
Gummy Shark	0	2	Crab	0	0	tiny school fish <1cm	0	0
Port Jackson Shark	0	2	Blue trevally	0	0	Largetooth Beardie	0	0
Arrow squid	0	1	Blenny	0	0	Arrow squid	0	0
Mantis shrimp	0	0	Australian salmon	0	0	Shrimp	0	0
Octopus	0	1	Australian Herring	0	0	Octopus	0	0
Northern pacific sea st	0		Asterias a.	0	0	11 Arm sea star	0	0
11 Arm sea star	0	2	Arrow squid	0	0	Crab	0	0
tiny school fish <1cm	1650	20	11 Arm sea star	0	1	Unknown	0	1

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