Western Port Bryozoan Reefs Project

Report 3: Macrofauna Biodiversity

Report to La Trobe University, AGL and Port Phillip and Westernport Catchment Management Authority

May 2020

Fathom Pacific Pty Ltd
ACN 158 508 279

ACN	585 082 79
ABN	801 585 082 79
GST	The company is registered for GST
Postal Address	1/56 Bond Street
	Mordialloc VIC 3195
	AUSTRALIA
Phone	+ 61 (0) 421 693 120
Email Contact	adrian.flynn@fathompacific.com
Website	http://www.fathompacific.com

Western Port Bryozoan Reefs Project

2020 Macrofauna Biodiversity Report

Report to La Trobe University, AGL and Port Phillip and Westernport Catchment Management Authority

Document Control Sheet

Author(s) David Donnelly, Adrian Flynn (Fathom Pacific) & Travis Dutka (La Trobe University)

Document ID 934_R3_Biodiversity_v1

Citation Fathom Pacific (2020). Western Port Bryozoan Reefs Project: 2020 Macrofauna Biodiversity Report Annual Report. Report to AGL and La Trobe University by Fathom Pacific Pty Ltd.

Versions

Doc. No.	Sections	Date	Amendments	Approved	Version
934_R1	All	20/1/20	NA	AF	1

Distribution

Copy	Format	Holder	Organisation
1	MS Word	Elissa Muller	AGL
2	MS Word	Dr Travis Dutka	La Trobe University
3	MS Word	Fathom Pacific	Library
4	MS Word	Andrew Morrison	PPW CMA

Table of Contents

Figures

1. Introduction

1.1. Bryozoan reef macrofauna and megafauna associations

Bryozoans are a diverse group of invertebrate colonial animals, with about 5700 extant (Horowitz and Pachut, 1994) and 15,000 fossil species recognised (Amini 2004). Bryozoan species occur commonly worldwide and inhabit all temperate zones (tropics to polar) and broad depth ranges from the intertidal zone to depths of at least 800 m (Wood et al. 2012). However, significant habitat-forming bryozoan structures are rare and are known from just 54 sites globally (Wood et al. 2012). Of the 54 recognised sites. only three are found in Australian waters: Coorong Lagoon and surrounding shelf waters (South Australia), Bathurst Channel (Tasmania) and in the Tasman Sea (near the New South Wales-Victorian border). Other bryozoan communities (non-habitat forming) in Australia occur on the continental shelf of Bass Strait and Tasmania (James et al. 2008) and Port Phillip Heads (Unpublished data). New Zealand is a hotspot of bryozoan diversity, especially in Foveaux Strait and on the Three Kings Plateau (Rowden et al. 2004), and the Otago shelf (Wood and Probert 2013), where they form biogenic structures.

These biogenic reef structures are known to offer a range of benefits to associating fauna (largely invertebrates). The structure of bryozoan reefs provide protection from predators and currents, attachment points for larval stage species and feeding opportunities. This often results in the reefs supporting significantly higher species assemblages than their surrounding habitat (Wood et al. 2013).

1.2. Vulnerability of bryozoan reefs

Much of what is known about the vulnerability of bryozoan reefs comes from studies related to the impacts of scallop and oyster dredging in New Zealand (Cranfield et al. 1999, 2003, Wood et al. 2012; 2013). These studies indicate that when impacts occur across biogenic bryozoan reefs that involves the incidental damage or removal of bryozoans, recovery of those reefs may take decades, if indeed they recover at all. Cranfield et al. (2003) reported that a dredge impacted bryozoan reef area showed no signs of recovery after 49 years of cessation of dredging. Whilst the bryozoan reefs of Western Port are not subject to dredging impacts, they are at risk of considerable anchor damage from recreational fishing. Remotely operated vehicle (ROV) surveys and diver observations noted apparent damage of the bryozoan reef colonies. Given the results of Cranfield et al. (2003) and the hypothesis that substrate type in the Western Port bryozoan reef area have been fundamentally altered and may not support new reef settlement (see Fathom Pacific 2020, Report 2), a precautionary assumption is made that deleterious impacts to the reef would cause localised extinction.

1.3. Bryozoan reefs of Western Port

The first indication of the existence of bryozoan biogenic reefs in Western Port came via a report by Blake et al. (2013) who used towed underwater video to describe isolated occurrences of a habitat described as "patches of low and high profile broken and solid reef colonised by dense bryozoans and sparse sponges". The potential significance of this habitat type was not fully appreciated until a 2016 biotope classification study of Western Port by the Department of Environment, Land, Water and Planning (DELWP) (Fathom Pacific 2016). This study reviewed the same towed video as was used by Blake et al. and also made use of multibeam bathymetry collected in 2009 which showed, at a coarse resolution, characteristic seabed north/south aligned linear textures that required further examination. The findings of the 2016 biotope mapping study of Western Port triggered a 2017 pilot study initiated by Fathom Pacific Pty Ltd, which would include the first visual investigation of the seabed textures. The results of this pilot study confirmed the presence of extensive reef forming bryozoan habitat made up of three bryozoan species: The fenestrate forms *Triphyllozoon moniliferum* and *Triphyllozoon munitum* and the plate-like form of *Celleporaria foliata* (Figure 1). These initial findings combined with an extensive desktop study and consultation with world experts, pointed to the existence of a significant biotope of national and potentially global significance. It was these indicators that instigated the commencement of the Western Port Bryozoan Reef Research Project in 2018.

This newly discovered habitat type was not recognised in previous major studies of Western Port (Smith et al. 1975, Kellogg Brown & Root 2010, Melbourne Water 2018).

1.4. The Western Port Bryozoan Project

The Western Port Bryozoan Reef Project was developed as an academic–industry–community partnership. The Project is intended to be a multi-disciplinary, collaborative study with strong academic support. The broad aims of the project are:

1. To quantify the typology and extent of the bryozoan reefs.
2. To document the diversity of bryozoans and co-occurring species.
3. To investigate and quantify threatening processes and vulnerability.
4. To establish conservation values; and
5. To engage citizen scientists and community stakeholders.

This report addresses Objective 2 and contributes to Objectives 3 and 4.

(a) *Triphyllozoon moniliferum*

(b) *Triphyllozoon munitum*

(c) *Celleporaria foliata*

Figure 1. The three predominant species comprising the Western Port bryozoan reefs

The Matrix Fauna Biodiversity component of the Project was developed to identify and document the range of invertebrate species associated with the reefs (termed 'matrix' fauna) and contrast this with the macrofauna/infauna of neighbouring sediment habitats. Matrix fauna was studied as part of a Bachelor of Science Honours project and subsequently upgraded to a Masters project through La Trobe University with co-supervision and field support by Fathom Pacific. The macrofauna (fauna visible in underwater imagery) addressed the bryozoan reefs only and was handled by Fathom Pacific.

The specific aims of this part of the project were:

- To collect core samples from all three bryozoan species within the linear reef zone (see Fathom Pacific 2020, Report 2) and neighbouring sediment habitats.
- To collect imagery from the linear bryozoan reef habitat.
- To catalogue the biodiversity of matrix fauna from cores and macrofauna from imagery associated with the bryozoan reefs.
- To compare the matrix macrofauna biodiversity between the three bryozoan species.
- To compare biodiversity of matrix macrofauna from cores with macrofauna from neighbouring sediment habitats.

2. Study Area

The recently discovered bryozoan reefs are located between French Island, Corinella and Rhyll in water depths ranging between 5 and 12 m, in Western Port, Victoria, Australia (Figure 2). Partner report Reef Type and Extent (Fathom Pacific 2020) describes the abiotic components of the reefs.

The reefs present as extensive physical structures in an area that is otherwise a largely featureless habitat dominated by mud banks and narrow channels. As is the case with most marine structures, an aggregation of a range of marine species either colonise, live within or regularly visit these features. Bryozoa have been described as "bioconstructors" that, when clustered together either loosely or in reef form (such as in Western Port), can enhance species richness and diversity (Jones 2006). Several recreationally and commercially targeted fish species are known to be seasonally present in the reef area making it a highly desirable fishing location. Between the 1820's and early 1920's, the area was also targeted by a commercial oyster dredge fishery (Bennett and Hannan 2010).

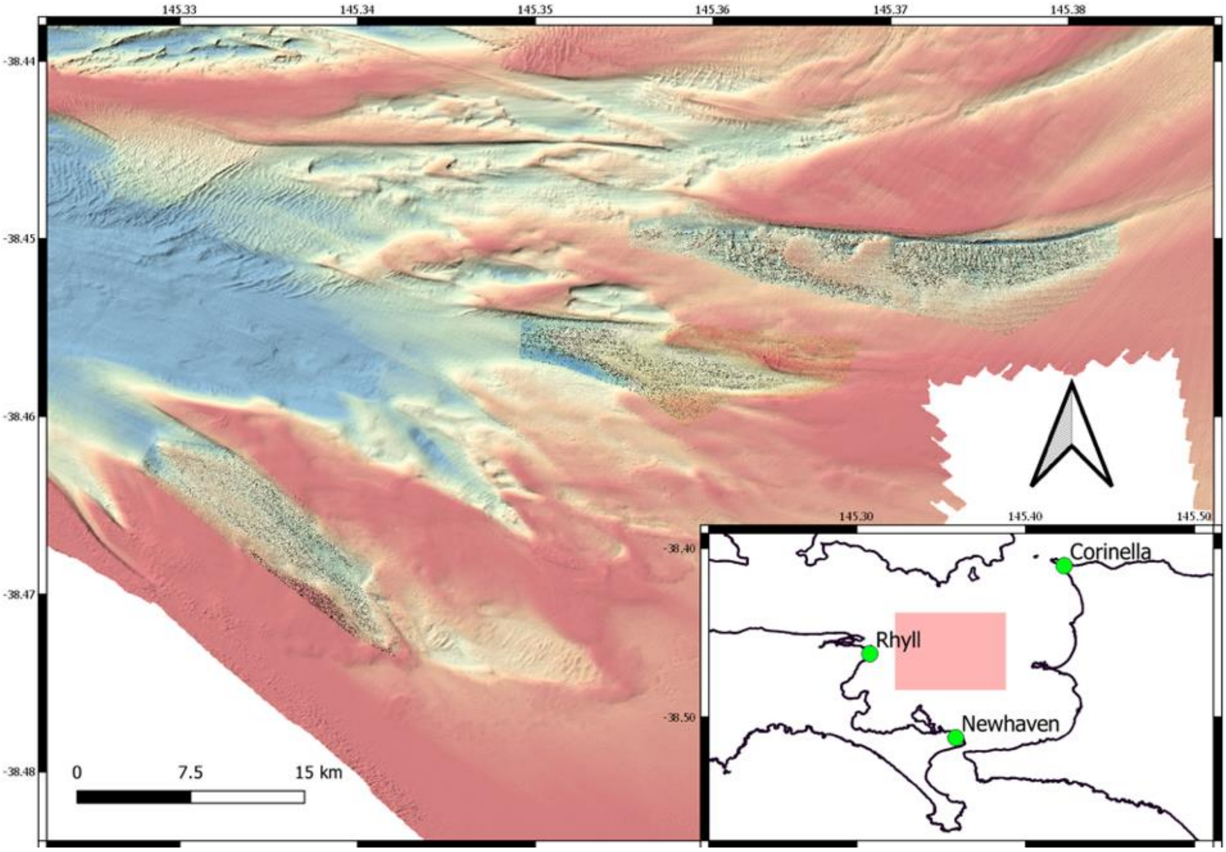


Figure 2 Location of the study area.

3. Materials and Methods

3.1. Bryozoan matrix and sediment macrofauna

3.1.1. Hand coring

Three sites were selected for sampling:

1. Bryozoan linear reef: three replicate cores from the colonies of each of the three species.
2. Sediment bed (distal): three replicate cores from sediment beds 500 m south of the bryozoan reef site.
3. *Caulerpa geminata* beds: three replicate cores from the beds, located approximately 2,100 m southwest of the bryozoan reef site.

Core sampling occurred in each season between April 2019 and January 2020 inclusive with pilot sampling occurring in February of 2019. The proximal sediment site was omitted after the second round of sampling (April 2019) as it was found to contain very fine silt, making it a difficult sample to handle at the surface. Subsequent sampling efforts targeted bryozoan colonies, distal sediment and *Caulerpa* bed sites only. Some areas of the distal sediment site had a heavy coverage of impenetrable mud oyster shells. This made core sampling extremely difficult and required the diver to search for appropriate sampling locations within the site before samples could be acquired.

The corer comprised of 30 cm tall piece of 150 mm diameter PVC pipe fitted with a tethered, removeable end cap at the base and a neck piece at the top. A 15 mm diameter handle was also fitted to assist with handling of the corer underwater. Within the neck piece was a piece of 0.5 mm mesh (the size range of macrofauna defined for this study). A cap was fitted to the top of the corer upon retrieval to the surface to contain the sample during transport. The sampling volume of the corer was 5,301 cm^3.

A total of 65 core samples were collected from 5 field excursions (pilot, Autumn, Winter, Spring and Summer) which comprised of 41 bryozoan samples (12 x *C. foliata*, 16 x *T. munitum* and 13 x *T. moniliferum*), 11 distal sediment samples, 4 proximal sediment samples and 9 samples from *Caulerpa* beds. The total number of samples analysed for this report was 35 (identification is still ongoing), comprised of: 23 bryozoan (6 x *C. foliata*, 10 x *T. munitum* and 7 x *T. moniliferum*), 5 distal sediment samples, 4 proximal sediment samples and 3 *Caulerpa* bed samples.

3.1.2. Macrofauna sample processing and analysis

Samples were gently washed through a 0.5 mm sieve (Figure 3). The corer comprised of 30 cm tall piece of 150 mm diameter PVC pipe fitted with a tethered, removeable end cap at the base and a neck piece at the top. A 15 mm diameter handle was also fitted to assist with handling of the corer underwater. Within the neck piece was a piece of 0.5 mm mesh (the size range of macrofauna defined for this study). A cap was fitted to the top of the corer upon retrieval to the surface to contain the sample during transport. The sampling volume of the corer was 5,301 cm^3.

A total of 65 core samples were collected from 5 field excursions (pilot, Autumn, Winter, Spring and Summer) which comprised of 41 bryozoan samples (12 *x C.* foliata, *16 x* T. munitum *and 13* x T. moniliferum), 11 distal sediment samples, 4 proximal sediment samples and *9* samples from *Caulerpa* beds.) to remove the majority of silt and particulate matter. All living, protected species and larger, readily identifiable fauna (i.e. teleost fishes and cephalopods) were photographed and returned to the water.

On completion of the sieving process, the sample retained on the sieve was returned to the corer, tagged with the sample number and habitat type and sealed in durable plastic bags for transport to the laboratory at La Trobe University. Details on laboratory processing are provided in Appendix 1.

Figure 3 Rinsing sieve with *T. munitum* sample in-situ.

3.2. Epifauna

Epifauna were censused using underwater imagery still photographs from diver exploration surveys (February 2018 and January 2020) and video from exploratory ROV surveys (December of 2017). This imagery was collected during opportunistic, exploratory phases of the program when environmental conditions allowed and therefore does not represent quantitative transecting. The method targeted conspicuous sessile and mobile invertebrates, but any fishes and cephalopods sighted were also documented.

Approximately 85 minutes of ROV footage and 590 still images were scored for the presence of fauna. Frames of each morphospecies were collected to accompany the catalogue of taxa (Figure 4). In order to standardise the classification process, observers used the Combined Biotope Classification Scheme (CBiCS), a morphospecies and habitat classification system used for classifying species and habitat types in Victorian waters. A second observer verified identifications.

As this was not a quantitative survey, abundance was not included in this analysis. Coleman et al. (1978) noted that presence/absence data of major representative taxa achieved good comparability to fully quantitative data and therefore this preliminary screening of epifauna biodiversity from opportunistic imagery is considered indicative of overall biodiversity.

(a) Feather worm (*Sabella sp.)*

(b) Stalked compound ascidian (*Sycozoa sp*.)

(c) Biscuit star *(Tosia australis)*

(d) Pencil urchin (*Phyllacanthus parvispinus*)

(e) Flathead sp. (*Platycephalus sp.*)

(f) Giant cuttlefish (*Sepia apama*)

Figure 4 Example of images used for the macrofauna morphospecies catalogue.

4. Results and Discussion

4.1. Matrix and sediment macrofauna

A total of 4,775 individual animals from 84 different morphospecies across 9 phyla which included crustaceans, polychaetes and molluscs with crustaceans being the most dominant taxa. To some degree this appears to be a bay wide pattern as Coleman et al. 1978 reported that crustaceans, polychaetes, and molluscs were the most abundant taxa throughout Western Port. With crustacea being the most taxonomically diverse phylum. Bryozoan reef colonies supported a much higher species richness than all other neighbouring habitats (proximal sediment, distal sediment and *Caulerpa* beds). These findings are consistent with studies of bryozoan habitats from the Otago Peninsula, New Zealand (Wood et al. 2012) when compared to adjoining habitats.

Further details and results may be found in La Trobe University Honours Thesis – Nicole Wilson (Appendix 1).

4.2. Epifauna

A total of 42 morphospecies from seven phyla were recorded from the bryozoan reefs (see Appendix 2). The seven phyla were not considered remarkable or unique to the bryozoan habitat and commonly occur in nearby reef and seagrass habitats. The seven phyla represented were Chordata, Mollusca, Porifera, Cnidaria, Echinodermata, Annelida and Phaeophyta.

The most dominant taxa across the three sample sites were from the phylum Porifera (sponges). The most abundant sponge species were *Callyspongia sp.* and *Dendrilla sp.* which occurred across all sites, almost exclusively associated with *Triphyllozoon* spp. colonies. This apparent preference for the fenestrate form of bryozoa is not confirmed quantitatively but an explanation for this may be that the tightly folded, fenestrate form provides a more favourable surface for settlement of larval biology such as sponges. These bryozoan forms may also present preferential microhabitat for settlement of larvae by slowing water movement and providing protection from currents and wave activity (Wood & Probert 2013) and providing concealment opportunities for adult and larval stages alike.

The ascidian, *Sycozoa cerebriformis* was in the top five most abundant macrofaunal species detected on the bryozoan reefs. Interestingly, this species had three colour variants (white, orange and yellow) and showed apparent preference for *Triphyllozoa* spp. colonies but was also observed on *C. foliata* colonies. The colour variations of this species noted here are consistent with descriptions given in the literature (Gowlett-Holmes 2008) but there is no information available on the taxonomic or geographic significance of this variation. Western Port mud oyster (*Ostrea angasi*) clusters were observed in in the bryozoan reef. Anecdotal observations suggest mud oysters were most commonly associated with *C. foliata* colonies (Figure 5).

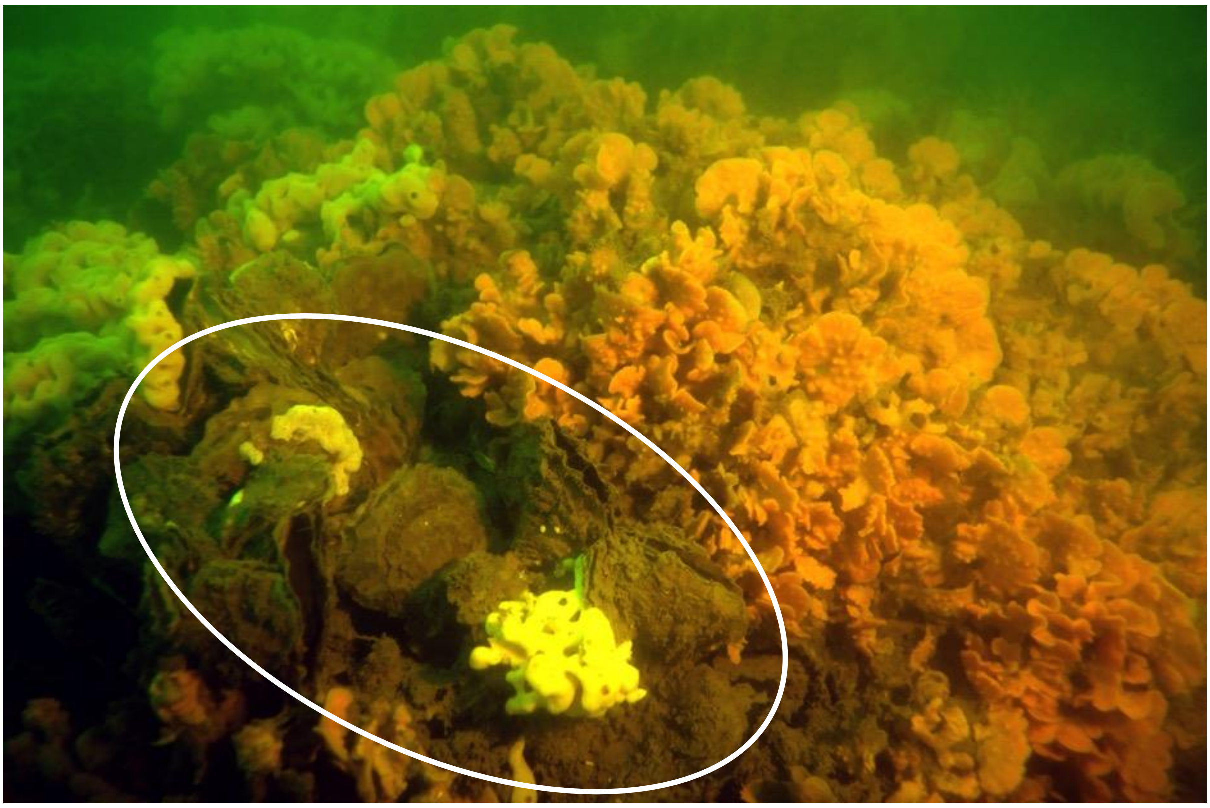


Figure 5 Mud oyster (*Ostrea angasi*, circled) amongst *Celleporaria foliata* (orange colony).

The bryozoan reef also provide habitat for tall erect, branching multi-species structures. These stalked structures are covered with multiple encrusting sponge morphospecies, hydroids, fine red algae with bivalves attached (Figure 6a). In Victorian waters, these structures have been recorded from circalittoral sediment habitats on the open coast (Flynn pers. comm. 2020) (Figure 6b). These assemblages are thought to colonise solid or semi-solid structures such as marine debris and deceased calcified marine life. The presence of these sponge-dominated structures on the bryozoan reefs appear to be representative of a deep-water form occurring in shallow water, which is a unique feature described for the bryozoan reef as a whole (Fathom Pacific 2020, Report 2). The low light, low energy and moderate current flow of this site likely provides the appropriate conditions in which these assemblages can survive. There are only two other known examples of deep-water habitats being replicated in shallow water in Victoria and both are present in Western Port at Crawfish Rock and the area between the entrance to Corinella channel and Pelican Island in the Eastern Arm of Western Port. (Flynn pers. comm. 2020). This finding is consistent with at statement made by Smith et al. 1975 referring to Crawfish Rock.

"Reduced light penetration, together with the secondary factors of shelter from deep wave movement and the presence of good current flow, has permitted the incursion into the channels and reefs of Westernport Bay some species more typical of a deeper water oceanic fauna."

(a) Western Port (6 metres)

(b) Wilsons Promontory (48 metres)

Figure 6 Examples of encrusted sponge based multispecies assemblage in Western Port (a) and at Wilsons Promontory (b).

4.3. Flora and Fauna Guarantee (FFG) Act listed species

To date, no FFG listed species were identified from hand core samples or imagery analysis. However, two listed species have been recorded from nearby sites, suggesting that these species may also occur at the bryozoan reef site. The brittle star *Amphiura triscacantha* has been reported from the French Island Marine National Park (MNP) while the stalked hydroid species *Ralpharia coccinea* has been recorded from Crawfish Rock, a site that shares similar biodiversity to the bryozoan reefs (Barton et al. 2012). We recommend that future monitoring include a focus on these species.

4.4. Marine pests

Observations on the bryozoan reefs have so far shown no marine pests to be present at the site. However, a feather worm (also known as a fan worm) tube was observed in the imagery (Figure 4a), although species identification was not able to be confirmed. Two species of feather worm from the family *Sabellidae* are known to occur in Victorian waters, *Sabella australiensis* (native) and *Sabella spallanzani* (introduced). The latter species has been introduced from Europe and occurs in high density within Corio Bay and across large sections of eastern Port Phillip (Edgar 2008). In Western Port, *S. spallanzani* has been documented in the lower reaches of the embayment at the Flinders aquaculture farms (Parry et al. 2000). There are no other validated records of this marine pest from other areas of Western Port.

5. Conclusions

The Western Port bryozoan reefs provide habitat for diverse assemblages of matrix-associated and epifaunal macrofauna. The invertebrate communities associated with the bryozoan reefs would not otherwise occur in this area of Western Port. Coleman et al. (1978) did not sample the bryozoan reefs but reported that epifauna were more diverse where sediments had a higher abundance of attachment substrate for epifauna (e.g. shell, gravel and bryozoan fragments). The findings of the present study are consistent with those from around the world showing that bryozoan dominated communities support an elevated faunal diversity when compared to surrounding habitats. (Bradstock and Gordon 1983, Wood et al. 2012, Ferdeghini and Cocito 1999, Morgado and Tanaka 2001).

Polychaete worms, molluscs, ascidians and sponges of various species were the most dominant taxa associated with the Western Port bryozoan reefs and these are among the most common taxa reported from other bryozoan habitats. The invertebrate assemblages of the Western Port bryozoan reefs include species that are important in the diets of teleost fishes such as snapper (*Pagrus auratus*) (Bradstock and Gordon, 1983). The reefs therefore represent areas of enhanced prey abundance. The local enhancement of biodiversity on the Western Port bryozoan reefs may be reflected in the popularity of the site to recreational fishers, and in the recent past, commercial fishers targeting snapper and other demersal fish species.

Scientific data collection/survey methods over time have varied considerably, therefore results may not always be directly comparable between studies. Additionally, most studies of Western Port fauna have occurred over a time space of 50+ years, during which many ecological changes are likely to have occurred. For this report we have compared studies that have used similar methods, but we have not accounted for the effects of time or methodology at these study sites. Based on selected studies (Edgar et al. 1994, Morris et al. 2007), it is reasonable to conclude that the bryozoan reefs in Western Port are comparable in species richness to seagrass beds and infralittoral rocky reefs. However, Western Port bryozoans are likely to be comprised of unique communities that are not represented in either seagrass beds or infralittoral rocky reefs.

The specific conclusions of this study are:

- The Western Port bryozoan reefs provide habitat for a highly diverse community of matrix macrofauna.
- The diversity of matrix macrofauna on the bryozoan reefs is higher than that of the surrounding sediment and *Caulerpa* beds.
- There is no overall difference in matrix macrofaunal species richness or abundance between the three habitat forming bryozoan species.
- Macrofaunal species that rely on larval settlement appear to show preference for the fenestrate form bryozoan species.
- The Western Port bryozoan reefs represent habitat for species that otherwise would not occur in this area of East Arm.
- The findings from this study show that the reefs represent localised biodiversity enhancement and, in combination with the other findings of the research project, further indicate the bryozoan reefs of Western Port are unique with national and likely global significance.

6. Recommendations for management and monitoring

Additional matrix fauna studies are underway at the time of writing that will be integrated into more detailed analysis. This section identifies initial recommendations on the basis of data available to date.

6.1. Monitoring basis and endpoints

Destructive sampling of one site in the linear bryozoan reefs was considered essential for baseline biodiversity characterisation. However, due to the sensitivity of the bryozoan habitat additional sampling and the use of destructive methods of monitoring are not recommended for future studies. Given the cryptic nature of most of the matrix macrofauna, visual monitoring will not be a tractable monitoring alternative for this faunal group. Therefore, we consider that the focus of biodiversity monitoring should be targeted at macrofauna and bryozoan reef condition, in addition to the overall reef extent monitoring discussed in Fathom Pacific (2020, Report 2).

A monitoring approach aligned with the Victorian Government's indicators of Good Environmental Status (GES) is recommended. GES as a basis for monitoring are explained in detail in Fathom Pacific (2020, Report 2). Of the 11 GES descriptors under consideration, three are applicable as a basis for monitoring bryozoan reef biodiversity and potential indicators are as follows:

GES Descriptor 1. Biodiversity is maintained

- No change in the overall distribution of key indicator species. Selection of these indicator species is under current investigation.
- No decline (beyond an error margin to-be-determined) in the abundance of key indicator species within the survey site.
- No change (beyond an error margin to-be-determined) in the abundance of red algae, a potential competitor to bryozoans.

GES Descriptor 2. Non-indigenous species do not adversely alter the ecosystem

- **Presence of marine pests**
  - No detection of a marine pest species on bryozoan reefs.
  - No advancement of any marine pest outside of known marine pest infestation areas within the broader Western Port region.
  - No detection of any new marine pest species at surveillance sites.

Descriptor 3. The abundance of recreationally fished species is healthy

- **Distribution and abundance**
  - No change in the overall distribution of key recreationally targeted species.
  - No decline (beyond an error margin to-be-determined) in the seasonal abundance of key recreational species within the survey site.

Descriptor 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem

- Changes in salinity levels remain within known natural variations.
- Turbidity levels remain within set parameters.
- Speed of currents does not increase above or below natural known variations.

Descriptor 8. Contaminants

- Concentrations of contaminants are at levels not giving rise to pollution effects.

Other GES descriptors are relevant to reef extent and these are described in Fathom Pacific (2020, Report 2). Given the strong association between matrix fauna and macrofauna and bryozoan reefs themselves and the preference to avoid destructive sampling, measures to protect reef extent and integrity will form major part of the biodiversity protection plan.

6.2. Management and monitoring

6.2.1. Formal conservation status

The bryozoan reefs are outside any existing marine protected areas in Western Port. The Project is currently investigating options to have the bryozoan reefs listed as a community under the Victorian Flora and Fauna Guarantee (FFG) Act 1988. The category under which the reefs may be listed is as a threatened community that is prone to future threats that may lead to extinction. If successful, the bryozoan reefs will be just the third such marine community to be listed, the others being the deep canyon at Port Phillip Heads and the San Remo intertidal reef. Whilst being listed under the FFG Act does not necessarily afford the reefs increased protection, it does ensure that the area will be considered as part of any future management planning and/or development plans for the area.

6.2.2. Matrix fauna

Matrix fauna is by nature generally cryptic and in the context of this study, surviving in a low visibility environment. Image-based monitoring of these species is likely to impractical. The coring method used in this study was effective but is not a preferred monitoring method. Environmental DNA (eDNA) and metagenomic techniques could provide a useful monitoring method. These techniques can sample intracellular and extracellular DNA from smaller reef samples or potentially interstitial sediment samples to screen biodiversity at the genomic sequence level (Kelly et al. 2017, Stat et al. 2017). Techniques are available for prokaryotes and eukaryotes and targeting of so-called gene barcoding regions, the sequence diversity can be linked with true taxonomic diversity over time.

6.2.3. Epifauna

Imagery used for macrofauna biodiversity assessment in the present study was collected after multiple attempts at times which were deemed to have the highest probability of achieving the best possible underwater visibility (i.e., low tidal flows, absence of rain in the period leading up to survey, absence of winds over 10 knots in the period leading up to survey). Despite this planning, underwater visibility was often less than 0.5 m, resulting in longer than planned dive times, difficulty in sampling and limitations around the collection of imagery. Therefore, a very focussed monitoring program is required.

Image-based techniques are preferred because they align with morphospecies classification approaches, provide an archival record and can be accurately georeferenced if the right equipment is used (i.e. ROV, AUV or diver tracked with USBL). Diver imagery is avoided where possible on OHS and cost grounds. However, an image-based monitoring program in this environment would need to be adequately funded to cover the expected periodic failure to collect usable imagery owing to extremely poor visibility.

It is recommended that high resolution sonar scanning methods are explored. New scanning sonar technology can resolve individual objects and textures at centimetre scale resolution. Reef structure in addition to epifaunal textures and potentially types (e.g. staked, encrusting, foliose structures) may be detectable. Deployed from an ROV, this method when targeted to key indicator species (e.g. sub-erect epifauna, algae) may generate georeferenced data that can be link to reef condition.

6.2.4. Marine pests

An increase in international and domestic commercial and passenger shipping operations in The Port of Hastings, and increasing recreational vessel activity, presents a growing risk of marine pest introductions to Western Port. Introduced species monitoring effort should be increased to include port locations, boat ramps, harbours and aquaculture farms. This approach meets with the recommendations of the research priorities of the Understanding Western Port document (Melbourne Water 2018) and addresses GES Descriptor 2.

An expanded marine pest monitoring program as it related to the bryozoan reefs would aim to detect the presence of introduced species prior to an infestation reaching the bryozoan reefs location. Monitoring at sentinel locations such as nearby boat ramps, jetties and areas where marine pests are known to occur in addition to the commercial shipping ports would aim to provide early warning of marine pests and allow time for management responses before infestation of the bryozoan reef. Species such as the Japanese kelp (*Undaria pinnatifida)* and the north Pacific seastar (*Asterias amurensis*) which are already prevalent throughout much of Port Phillip, have the potential to pose a serious threat to the bryozoan reefs and co-occurring species, particularly the rich bivalve communities associated with the reefs.

6.2.5. Water quality

Turbidity likely plays a key role in maintaining the balance between suitable conditions for bryozoa survival and suppression of algal growth. Algae is known to be a key competitor of bryozoans and is known to contribute to mortality of bryozoa (Cocito et al. 1998). The expansive growth of bryozoans in this part of Western Port is likely to be associated with the low light conditions preventing seagrass and algal growth. The red algae observed on the bryozoan reef is known to occur in the lower infralittoral zone and is adapted to lower light conditions (Tschudy 1933). Changing water quality conditions, both in the direction of increasing turbidity and sedimentation, and potentially in the direction of significantly decreased turbidity, may alter the bryozoan-algae balance.

As filter feeders, bryozoa are also likely to be sensitive to suspended sediments in the water column. Depending on particle size, bryozoans could be compromised in their ability to feed should a shift in sediment suspension occur. A study by Tjensvoll et al. (2013) demonstrated that when exposed to an increase in sediment suspension above manageable thresholds, a deep-water sponge species *Geodia barrette*, suffered a physiological shutdown. It is conceivable that a similar scenario could also be true for bryozoa. The consequences of which have the potential for bryozoan dieback and subsequent loss of bryozoan reef habitat. Other water quality related pressures such as toxicants could also have detrimental impacts on the survivorship of the reef forming bryozoa.

It is recommended that a water quality monitoring program that includes sediment deposition rates is adopted to develop an understanding of the natural variations in water quality in the bryozoan reefs area and identify the propriety monitoring indicators.

6.2.6. Reef extent

In addition to monitoring associated biology and environmental parameters, reef extent is also considered a priority for any future monitoring program to include. Baseline multibeam data has been acquired and may be used to assess the reef's health as well as to detect any changes in its extent in the future. Full details on this aspect of the project are available in Fathom Pacific (2020, Report 2 - Reef Type and Extent).

7. Future research

This study in association with its partner studies has further contextualised the significance of the unique bryozoan reefs of Western Port. Whilst much has been achieved, it is clear that further studies are required to properly understand the reefs and their ecological function in Western Port. Consequently, work to date should be considered as a starting point and by no means the endpoint.

Analysis of the remaining matrix macrofauna core samples is currently underway, the results of which will help to inform on the seasonal abundance and diversity of matrix fauna associated with the reefs. Other studies to springboard from this work will include the bryozoan growth rate study (underway), further characterisation and groundtruthing of associated macrofauna and a fish bioacoustics study. Furthermore, we recommend future studies also examine the age of colonies, formation of colonies, relatedness to other deepwater bryozoan found elsewhere and larval settlement/recruitment processes to name but a few.

8. Acknowledgements

This work was part of the Western Port Bryozoan Reefs Research Project funded by La Trobe University, AGL, Port Phillip and Western Port Catchment Management Authority and Fathom Pacific Pty Ltd. The project has benefitted greatly from the collaborations with Port of Hastings Development Authority, Victorian Fisheries Authority and the Western Port Biosphere. The Port of Hastings Development Authority and Department of Environment, Land, Water and Planning allowed access to the original 2009 multibeam data. Mr Anthony Morton and Mr Kade Mills provided diving support to the project during the final two field excursions. Ms. Nicole Wilson provided field support and completed all laboratory analysis of the core samples as part of her Honours/Masters project with La Trobe University.

9. References

Amini, Z.Z., Adabi, M.H., Burrett, C.F. and Quilty, P.G. (2004). Bryozoan distribution and growth form associations as a tool in environmental interpretation, Tasmania, Australia. *Sedimentary Geology*, 167(1-2): 1-15.

Barton, J., Pope, A. and Howe, S. (2012). Marine Natural Values Study Vol 2: Marine Protected Areas of the Victorian Embayments Bioregion, Part 2 Western Port Bay & Corner Inlet. Parks Victoria Technical Series No. 78. Parks Victoria, Melbourne.

Blake, S., Ball, D., Coots, A. and Smith, T. (2013). Marine Video Survey of Western Port Report. Victorian Fisheries Authority Report. Victoria, Australia.

Bradstock, M. and Gordon, D. P. (1983) Coral-like bryozoan growths in Tasman Bay, and their protection to conserve commercial fish stocks. *New Zealand Journal of Marine and Freshwater Research*, 17(2): 159-163, DOI: 10.1080/00288330.1983.9515993.

Cocito, S., Sgorbini, S., Bianchi. C.N. (1998). Aspects of the biology of the bryozoan *Pentapora fascialis* in the northwestern Mediterranean. *Marine Biology*, 131: 73-82.

Cohen, B.F., McArthur, M.A., and Parry, G.D. (2000). Exotic Marine Pests in Western Port. Marine and Freshwater Resources Institute Report No. 22.

Coleman, N., Cuff, W., Drummond, M. and Kudenov, J.D. (1978). A Quantitative Survey of the Macrobenthos of Western Port, Victoria. Australian Journal of Marine and Freshwater Research Vol. 29. pp 445 - 466

Edgar, G., Shaw, C., Watson, G.F., Hammond, L.S. (1994). Comparisons of species richness, size-structure and production of benthos in vegetated and unvegetated habitats in Western Fort, Victoria. *Journal of Experimental Marine Biology and Ecology*. 176 pp 201-226

Edgar, G. (2008). Australian Marine Life: The plants and animals of temperate waters. Reed New Holland, Second Edition.

Ferdeghini, F. and Cocito S. (1999) Biologically generated diversjty in two bryozoan buildups. *Biol Mar Medit,* 6(1):191-197.

Gowlett-Holmes, K. (2008). A field guide to the marine invertebrates of South Australia. Noto Mares, Tasmania.

Horowitz, A.S. and Pachut, J.F. (1994). Lyellian bryozoan percentages and the fossil record of the Recent Bryozoan fauna. Palaios, pp.500-505.

James, N. et al. (2000). Quanternary bryozoan reef mounds in cool water, upper slope environments: Great Australian Bight. Geology, Vol 28 (7) pp. 647-650.

Jones, E.J. (2006). Bryozoan thickets on Otago shelf, New Zealand: a quantitative assessment of the epibenthos using underwater photography. Masters Thesis

Kellogg Brown & Root (2010). Western Port Ramsar Wetland Ecological Character Description. Report for Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Kelly, R.P., Closek, C.J., O'Donnell, J.L., Kralj, J.E., Shelton, A.O., Samhouri, J.F. (2017). Genetic and manual survey methods yield different and complementary views of an ecosystem. Frontiers in Marine Science, 3: 283.

Melbourne Water (2018). Understanding Western Port, A summary of research findings from the Western Port Environment Research Program 2011-2017 and priorities for future research.

Morgado, E.I. and Tanaka, M. (2001). The macrofauna associated with the bryozoan *Schizoporella errata* (Walters) in Southeastern Brazil. *Scientia Marina*, 65(3):173-181

Page, M., Kelly, M. and Herr, B. (2016). Awesome ascidians, a guide to the sea squirts of New Zealand. NIWA.

Rowden, A.A., Warwick, R.M. and Gordon, D.P. (2004). Bryozoan biodiversity in the New Zealand region and implications for marine conservation. Biodiversity and Conservation 13 pp. 2695-2721.

Smith, B., Coleman, N., Watson, J.E. (1975). The invertebrate fauna of Western Port Bay. Royal Society of Victoria Proceedings Including The Westernport Bay Symposium. Vol. 87 Part 1 Chapter 13 PP 149-155.

Smith, A.M., Stewart, B., Key Jr, M.M. and Jamet, C.M. (2001). Growth and carbonate production by Adeonellopsis (Bryozoa: Cheilostomata) in Doubtful Sound, New Zealand. Palaeogeography, Palaeoclimatology, *Palaeoecology*, 175(1-4), pp.201-210.

Stat, M., Huggett, M.J., Bernasconi, R. DiBattista, J. D., Berry, T. E., Newman, S. J., Harvey, E.S. and Bunce. M. (2017). Ecosystem biomonitoring with eDNA: metabarcoding across the tree of life in a tropical marine environment. *Nature Scientific Reports*, 7: 12240.

Tschudy, R.H. (2013). Depth Studies on Photosynthesis of the Red Algae. American Journal of Botany Vol 21, No. 9 pp. 546-556.

Tjensvoll, I., Kutti, T. and Bannister, R. J. (2013). Rapid respiratory responses of the deep-water sponge *Geodia barretti* exposed to suspended sediments. Aquatic Biology Vol. 19 pp. 65-73

Wood, A.L., Probert, P.K., Rowden, A.A. and Smith, A.M., 2012. Complex habitat generated by marine bryozoans: a review of its distribution, structure, diversity, threats and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 22(4), pp.547-563.

Wood, A.C.L. and Probert, P.K. (2013). Bryozoan-dominated benthos of Otago shelf, New Zealand: its associated fauna, environmental setting and anthropogenic threats. *Journal of the Royal Society of New Zealand*, DOI:10.1080/03036758.2012.756819

Appendix 1

La Trobe University Honours Thesis – Nicole Wilson

Appendix 2

CBiCS morphospecies list

Sponges	**Cephalopods**
Palmate sponge	Cuttlefish
Dendrilla sp.	**Echinoderms**
Callyspongia sp.	*Tosia australis*
Candelabral short sponge	*Nectria ocellata*
Alcyonarian	Sea urchin - Rounded spines
Branched fan	Sea star - Triangular tapered arms
Branching sponge	**Fishes**
Lissoclinum sp.	*Platycephalus sp.* - Flathead
Echinodathria sp.	Goby
Columnar sponge - Orange	**Bivalves**
Columnar sponge - White	Mussels
Small brown seaweed	*Ostrea angasi* - Mud oyster
Single tube - Sponge	**Gastropods**
Vase sponge	Elongate shell
Hydroids	**Worms**
Fine feathery hydroid	Polychaete worm
Bryozoa	Feather worm
Celleporaria foliata	**Substrate**
Triphyllozoon munitum	Mud channel
Triphyllozoon moniliferum	Silt
Ascidians	Burrow
Sycozoa cerebriformis	
Phallusia obesa	
Solitary ascidian - Branched, white	
Solitary ascidian	
Stalked solitary ascidian	
Algae	
Thallose red seaweed	
Red fine and filamentous	
Brown alga	
Bushy	
Spongia	
Parazoanthus sp	
Sycon sp.	

MACROFAUNA BIODIVERSITY ASSOCIATED WITH THE WESTERN PORT BIOGENIC BRYOZOAN REEFS

NICOLE WILSON

A thesis submitted in partial fulfilment of the requirements
for the degree of BSc1 (Hons)

in the

Department of Ecology, Environment & Evolution
La Trobe University
Bundoora, Victoria

28th November 2019

Statement of Authorship

Declaration

I certify that the attached document is my original work. No other person's work has been used without due acknowledgement. Except where I have clearly stated that I have used some of this material elsewhere, it has not been presented by me for examination in any other course or subject at this or any other institution. I understand that the work submitted may be reproduced and/or communicated for the purpose of detecting plagiarism.

The research undertaken in connection with this thesis was approved by La Trobe University Animal Ethics Committee (Approval No: AEC19007) and Victoria Fisheries (Permit Number RP1363).

Nicole Wilson

BSc1 (Hons) thesis

Student number: 18335706

28th November 2019

1 Table of Contents

Abstract

Biogenic reefs are important marine habitats as they provide food, attachment opportunities for sessile organisms, shelter from wave action and strong currents, and concealment from predators for both adult and larval stages alike. Consequently, these complex habitats are often biodiversity hotspots compared to surrounding habitats. Although most biogenic reef types are well represented, biogenic bryozoan reefs are extremely rare. Recently, large areas of biogenic bryozoan reef were discovered in Western Port at depths of 5-8 m. These unique reefs represent a new biotope in Victoria and are potentially globally significant due to their structure and extent. In this study, we aimed to examine the infauna and epifauna biodiversity associated with these reefs by collecting cores from the three dominant bryozoan species within the reefs; *Triphyllozoon munitum*, *Triphyllozoon moniliferum* and *Celleporaria foliata*, and three neighbouring habitats (proximal sediment, distal sediment and *Caulerpa cactoides* bed). Within the bryozoan reef, 84 different species across 9 phyla were identified and the assemblage was dominated by crustaceans (72% of the total abundance of taxa). The reef had significantly higher species richness and abundance of annelids and crustaceans than all neighbouring habitats. There was no difference in species richness or abundance between the bryozoan species, although *C.foliata* harboured a significantly higher number of annelid species. This ecosystem is potentially under threat from anthropogenic activities and further research is required to establish the conservation value of these reefs and determine what protection they require.

Acknowledgments

Firstly, I'd like to extend my sincere gratitude to my co-supervisor's Dr Travis Dutka and Dr Adele Harvey for their support, guidance and understanding throughout the year.

A very special thanks to Fathom Pacific Pty Ltd. for field execution and support; Dr Adrian Flynn and David Donnelly in particular. This research was co-funded by La Trobe University, Fathom Pacific and AGL.

I would also like to thank Lynda Avery from Infaunal Data Pty Ltd for her expert assistance with faunal identification, Dr Angie Haslem for her assistance with the data analysis, and my colleagues that assisted with the initial sorting of samples in the laboratory. Additionally, I could not have completed this thesis without the unwavering support of my family and friends. Lastly, thanks to Victoria Fisheries for allowing us to collect and undertake research on the bryozoans and associated species.

1. Introduction

Studies of biodiversity in marine habitats, such as the intertidal zone, reefs and seagrass meadows, are complex undertakings given the diversity of these habitats. Nevertheless, understanding habitat communities and their role in ecosystems is essential for making informed management and conservation decisions.

1.1. Biogenic reefs

Biogenic reefs are ecologically important marine habitats. They are typified by rigid skeletal frameworks that are topographically higher than surrounding sediments and composed of biological deposits produced over geological time (Hallock 1997). These structures form biodiversity hotspots with the number of associated species per unit of habitat often exceeding that of adjacent non-biogenic habitat by 10-fold or more (Lenihan and Peterson 1998, Jackson and Sala 2001). Most biogenic habitats, such as seagrass meadows (Heck and Wetstone 1977, Kirkman 2013), rhodolith beds (Steller et al. 2003, Harvey et al. 2017), macroalgae turfs (Holbrook et al. 1990), tube-building polychaetes (Moore et al. 1998) and molluscan beds (Lenihan et al. 2001, Grabowski and Powers 2004) are relatively well represented in the literature. Despite being well represented in the fossil record (Taylor et al. 2015) and literature as early as the 19th century (Hincks 1880), reef-forming bryozoan habitats are rarely encountered. Consequently, there is a lack of studies that describe these habitats and document their importance and usage by other organisms.

Coorong Lagoon (South Australia), Bathurst Channel (Tasmania) and the Tasman Sea (near Victoria-New South Wales border) represent three out of 54 sites globally that support significant habitat-forming bryozoans (Wood et al. 2012), however, very few sites are considered true biogenic reefs. The most noteworthy is located on the Otago shelf, NZ, where habitat-forming bryozoans, occurring at depths of 70-120 m, extend across an area of >500 km^2 (Probert et al. 1979, Batson and Probert 2000). Incidentally, the Otago shelf thicket-like bryozoan site has suffered extensive damage due to scallop dredging and has not recovered after 30 years of protection (Cranfield et al. 2003), which is potentially indicative of how old and slow- growing these colonies may be (Hageman et al. 2003). Extensive shallow water (3-50 m) *Celleporaria* reefs occur in the South Australian gulfs, though no formal studies have targeted them yet (Cook et al. 2018). Continuous carbonate sediments dominated by bryozoan skeletons on the southern continental shelf of Australia are paleoecologically significant and reveal that bryozoans from the order Cheilostomata have been a dominant taxon since the Ordovician (Conolly and von der Borch 1967, Wass et al. 1970). It was established by Hageman et al (2003), however, that despite live frame-building bryozoans colonies occurring here as well, they are not in habitat-forming densities. The discovery of these modern bryozoan reefs provided the impetus for many ecological studies.

1.2. Bryozoan biology

Bryozoans are aquatic, non-photosynthesizing, filter-feeding, invertebrates found in all oceans from the sublittoral zone to the deep sea and in all major benthic habitat types including; soft sediments, seagrass meadows, temperate reefs and hard bottoms (McKinney and Jackson 1989, Wood et al. 2012, Cook et al. 2018). They form colonies that vary widely in growth habits, and, ranging from 1 mm to more than 1 m they are often mistaken for corals (commonly referred to as lace corals), ascidians or hydroids (Cook et al. 2018). They are rigid, but fragile, and generally live attach to a substratum like rock, algae or shell, though they often colonise other animals such as gorgonians, hydroids and other bryozoans (Cocito et al. 2000, Wood et al. 2012, Cook et al. 2018). Bryozoans are generally considered large or 'frame-building' if the species typically grow to 50 mm in three dimensions, as defined by Batson and Probert (2000). The term 'habitat-forming' is generally reserved for cases where frame-building bryozoans dominate large areas of the seafloor and are a significant contributor to habitat complexity (Wood et al. 2012). They are considered complex habitat for macroinvertebrates (Attrill et al. 2000).

1.3. Western Port

Western Port (WP) is a temperate bay located in Victoria, Australia, fringed by mangroves and silty mudflats and subdivided into segments based on physical features; the Lower North Arm, Upper North Arm, Corinella Segment, Rhyll Segment and Western Entrance Segment (Jenkins and Conron 2015). Between French Island, Corinella and Rhyll, extensive patches of potentially globally significant bryozoan biogenic reefs have been discovered in depths of 5 to 8 m. The WP bryozoan reefs are in the Rhyll Segment which is a broad subtidal sedimentary plain characterised by communities of seagrass, macroalgae and sessile invertebrate isolates (Blake et al. 2013). It represents a key region for biodiversity and commercially important fish species including snapper (*Pagrus auratus*) and gummy shark (*Mustelus antarcticus*) (Keough and Bathgate 2011). The area is historically known to recreational fishers as "The Corals"; a misnomer given that bryozoans belong to a different phylum. The habitat was not represented in literature, however, until Blake et al (2013) identified it as isolated occurrences of "patches of reef colonised by dense bryozoans and sparse sponges". The ecological significance of the habitat was not appreciated until a biotope mapping study of WP revealed extensive, contiguous mounds of bryozoan reef; a new biotope in Victoria (Flynn et al. 2018).

Textures in multibeam bathymetry indicate that the area these reefs occupy is possibly as large as 3 km^2 and the mounds are arranged in a linear, north-south orientation with a vertical relief of 1-2 m (Flynn et al. 2018). Preliminary surveys reveal that there are three dominant species in the reef; *Triphyllozoon munitum* (fenestrate folded sheets), *Triphyllozoon moniliferum* (fenestrate tightly folded sheets) and *Celleporaria foliata* (non-fenestrated branching plates), with the *Triphyllozoon species* making up approximately 95% of the composition (Flynn et al. 2018). No *Triphyllozoon*-dominant biogenic reefs have been documented anywhere else (Appendix A).

Effectively nothing is known about the WP bryozoan-reef habitat (i.e. the extent, age, growth, recolonization processes and importance as biogenic engineers), however, based on previous biodiversity studies on biogenic reef habitats worldwide, bryozoan-dense habitats, and other WP habitats, it is highly likely that these reefs will harbour rich assemblages across a wide range of phyla. The Westernport Bay Environmental Study 1973-74 (Coleman et al. 1978) revealed that unvegetated mud and sand sediments are dominated by polychaetes, crustaceans and molluscs. The distribution and composition of assemblages strongly indicated habitat preference. A more recent study reported on epibenthic macroinvertebrates in WP where assemblages consisted of porifera, tunicates, cnidarians, brachiopods and hydroids (Watson et al. 2009).

Bryozoan-dominated habitats support diverse assemblages of macroinvertebrates at the centimetre to kilometre scale (Wood et al. 2012). A variety of mobile and sessile infauna and epifauna phyla have been associated with bryozoan reefs in New Zealand (Bradstock and Gordon, 1983, Wood et al. 2012) and elsewhere (Ferdeghini and Cocito 1999, Morgado and Tanaka 2001) including echinoderms, crustaceans, molluscs, hydroids, tunicates, annelids, brachiopods and other bryozoans. The bryozoan communities in New Zealand are hotpots for biodiversity especially on the Otago shelf where total of 130 non-bryozoan species are associated to three habitat-forming bryozoan species (Wood 2005, Wood and Probert 2013). Bryozoan-dominated communities elsewhere have demonstrated similarly high inter-species richness. For instance, 115 species in Brazil (Morgado and Tanaka 2001) and 84 species in the Ligurian Sea (Italy) (Ferdeghini and Cocito 1999) are associated to a single bryozoan species. Many of these habitats also demonstrate high levels of intra-phyla richness; the highest of which occur in molluscs (Willan 1981, Ferdeghini and Cocito 1999), annelids (Morgado and Tanaka 2001), arthropods (Lindberg and Stanton 1988) and epibiotic bryozoans (Bradstock and Gordon 1983). Colony spaces have also been known to provide shelter and concealment to larvae and juvenile fish alike (Bradstock and Gordon 1983, Wood et al. 2012).

1.4. Potential threatening processes to the bryozoans of WP

Increasing coastal urbanisation and recreational use of marine spaces are considered serious threats to global marine biodiversity (Halpern et al. 2007, Stuart-Smith et al. 2015). Our ability to make predictions about the vulnerability of bryozoan biogenic reefs is severely limited by our lack of historical information and most of what we do know comes from oyster dredging impact studies from other parts of the world such as New Zealand (Cranfield et al. 1999, Wood et al. 2012). These unique reefs are currently not protected under any act nor are they within any marine park.

Sedimentation in WP is viewed as the primary threatening process to most habitats within the port (Hancock et al. 2001) and it is likely that regimes in the bay have changed dramatically over the past century due primarily to anthropogenic impacts (Wilkinson et al. 2016). Sediments from coastal erosion and agricultural run-off enter the bay north of French Island (Wallbrink and Hancock 2003) and are resuspended by tidal, wind and wave action, resulting in highly turbid waters (Jenkins et al. 2013). Resuspended sediments are then redistributed by tidal currents from north of French Island in a clockwise direction to the Corinella and Rhyll sector of the port which are currently experiencing high levels of deposition (Hancock et al. 2001, Jenkins and Conron 2015). High turbidity and sedimentation levels have been known to impact negatively on bryozoans (Best and Thorpe 1996) and other biogenic habitats such as rhodolith beds (Harvey and Bird 2008). Filter-feeding is less effective in increased ambient water flow and this could greatly reduce suitable feeding periods (Cook et al. 2018). Perhaps more importantly, the feeding structures may become clogged, the soft integuments scraped or scoured, and colonies smothered, which may impact on their growth potential (Gordon 2003). Additionally, it is possible that the silty mud substrate that now characterise the area is unsuitable for bryozoan recolonization (Flynn et al. 2018).

Physical damage, from fishing gear and anchors, is a key threat to bryozoan habitats due to the fragility of colonies (Cranfield et al. 2003). In Torrent Bay, NZ, a bryozoan biogenic reef of more than 300 km^2 was destroyed in the 1960's by commercial fishing (Saxton 1980). Although the WP reefs are not commercially fished now, photographs from Flynn et al (2018) show extensive damage and appear to be representative of recreational fishing gear and anchor damage. It is common for large volumes of recreational fishing boats to anchor in the area around the reefs throughout the spring-summer fishing season when *P. auratus* enter the port to spawn, and the area is relatively easy to locate due to access to GPS coordinates in the grey literature, coupled with the features being recognisable on recreational echosounders (Flynn et al. 2018).

Toxicants and pollution are potential threats not only to the bryozoans themselves, but also the faunal assemblages. Bioaccumulation of heavy metals can affect the entire benthic food web (Waring et al. 2006). Agriculture, industry and urban development can impact on the water quality in WP (Wilkinson et al. 2016). Surprisingly, levels of toxicants such as pesticides in sediments in WP were found to be low and relatively harmless to many biota (ANZECC and ARMCANZ 2000). Future tests should consider the impacts that these toxicants have on other local communities, such as the bryozoan reefs.

Future research is needed to determine the extent of, the biodiversity associated with, and the threats that are facing the WP bryozoan reefs as they are expected to be ecologically important and harbouring rich biodiversity over a range of phyla. There are no other occurrences of *Triphyllozoon*-dominant biogenic bryozoan reefs of this kind and it is therefore likely that they are globally significant and requiring protection of some kind. Essentially nothing is known about this newly discovered biotope and it could be lost if its significance is not understood or highlighted and appropriate protection is not considered.

1.5. Aims of this study

Given the very recent discovery of, and paucity of data associated with the WP bryozoan reefs, the current project aims to provide an understanding of the biodiversity and conservation values of these reefs. In this study, the infauna and epifauna biodiversity of the WP bryozoan reefs will be examined by collecting samples from the reefs and comparisons made to neighbouring habitats. Specifically, the aims are to;

1) Determine the biodiversity associated with the bryozoan reefs compared to neighbouring habitats including proximal sediment, distal sediment and *C.cactoides* bed, and

2) Compare the biodiversity of bryozoan species as separate entities to explore whether the morphology of each species plays a role in the composition of the associated faunal assemblages.

It was predicted that species richness and abundance would be greater in the bryozoan reefs compared to all neighbouring habitats, and that each bryozoan species harbours a similar faunal assemblage. The study was broken down into four parts; Part A) Faunal assemblage of the bryozoan reefs, Part B) Species richness - inter-habitat comparisons, Part C) Abundance - inter-habitat comparisons, and Part D) Species richness and abundance - inter-bryozoan species comparisons

2. Materials and Methods

2.1. Survey Area

The WP bryozoan reefs are in an area between French Island, Corinella and Rhyll in water depths of 5 to 8 m. The substrate is characterised by silty muds and the water column is highly turbid with wind-waves contributing to sediment resuspension and mobilisation (Wallbrink and Hancock 2003). The bryozoan reefs form North-South oriented linear features that are acoustically discernible. Textures in multibeam bathymetry suggest that they potentially occupy an area of approximately 3 km^2 and the >70 sites that have been verified with a drop-camera/scuba diver. To date, they are associated with banks and not channels (Flynn et al. 2018). Our bryozoan reef study site was previously verified and the GPS waypoints (-38.451043°, 145.376471´) recorded so that the same reef patch can be returned to each season. It is approximately 16 km's South-East of Stony Point boat ramp (launch point). Proximal sediment samples were taken at the same site between the bryozoan columns. The *C.cactoides* bed site (-38.458500°, 145.358462´) was discovered when ground-truthing for bryozoan reef and the distal sediment site (-38.455453°, 145.376220´) was located by travelling approximately 500 m South of the bryozoan site (Figure 1).

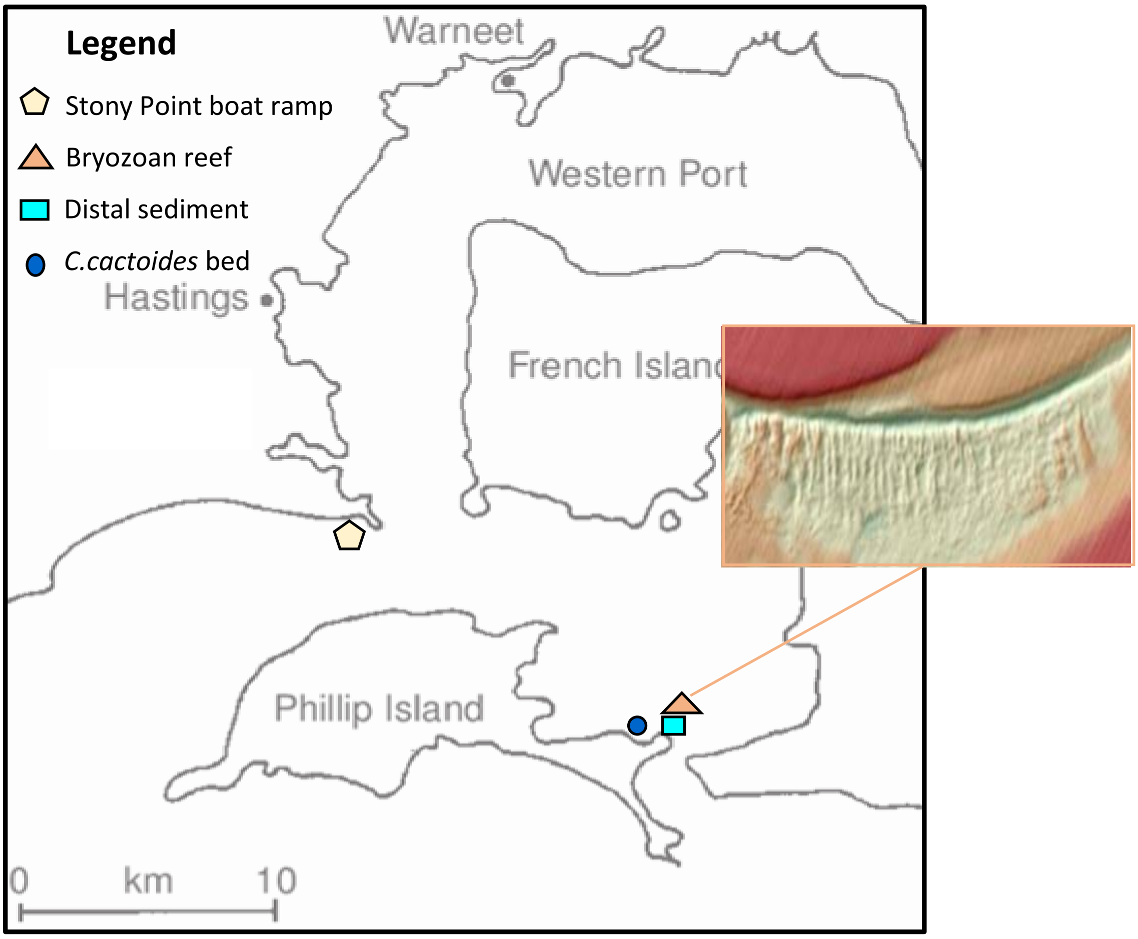


Figure 1. Map of Western Port indicating the sampling sites and launch point. Inset is multibeam imagery showing the typical North-South linear orientations of the rows of the bryozoan reefs. Map adapted from Bird and Poore (1999).

2.2. Equipment and dive execution

Fathom Pacific provided a boat, equipment and staff for the field execution. There were four members on-board including a coxswain, two scientific scuba divers and a rescue diver. When the boat reached the study site, an echosounder (Simrad Evo 3 NSS9) and a transducer (Lowrance TotalScan Transducer) were utilised to visualise the columns of bryozoans and choose an optimal position to place the shot line to avoid damaging the bryozoans. The shot-line consisted of a marker buoy, a ballast weight at the end, and knots along the rope approximately 1m apart with a lead weight attached to each so that the rope rested in a line along the sea bed once deployed. Heavy duty catch-bags containing 2 coring cylinders per bag were attached to each knot in the shot line using carabiner clips. Polyvinyl chloride (PVC) cylinders were used to craft the 15 sampling corers (height = 30 cm, radius = 7.5 cm, and total volume, v = 5301 cm^3). The initial pilot study corers were larger with a height of 33 cm and a radius of 13 cm (v = 17520 cm^3). A pole was inserted near to the top of the cylinder to act as handles to allow the diver to control the corer. The tops of the cylinders were lined with a 0.5 mm^2 wire mesh (our biodiversity screening minimum limit). The bottom of each corer was open with an attached cap to seal it off once the sample was collected (Appendix B).

Once the shot line was deployed and the boat was optimally positioned, the primary diver (in contact with the boat via an underwater communications unit) entered the water and descended the shot line. When the diver reached the first knot, they attached a guideline reel for added safety when working in poor visibility and then unclipped the catch-bag. The diver then went in searched perpendicular to the shot line and collected samples by thrusting thecorer into the sample, capping off the cylinder and returned it to the catch-bag. Once two samples were collected, the diver followed the guideline reel back to the shot line, reattached the catch-bag and repeated the process until all samples were collected. The diver then ascended the shot-line and both the diver and shot-line were collected by the boat. The bryozoan and proximal sediment samples were collected in one dive, and the distal sediment and *C.cactoides* bed samples were collected in subsequent dives on the same tide change on the same day (Appendix C)

2.3. Study design

Within the largest bryozoan reef patch, there are between 15 to 20 linear columns of bryozoan mounds. Bryozoan samples were collected from a central column to remove edge effects. To minimise damage to the ecosystem and prevent pseudo-replication, samples were collected from different columns of reef during each season.

Sample collections occurred in April (pilot- Autumn), May (Autumn) and July (Winter) 2019. Future sampling will extend into late Spring (2019) and Summer (2020) to examine potential seasonality changes in biodiversity and abundance. Sampling days were planned based on the smallest tidal movements for the month, optimal tide changes in the middle of the day and then on days with the least wind. Where possible, three samples from each of the bryozoan species (*T.munitum, T.moniliferum* and *C.foliata*), proximal sediment (silty mud between the bryozoan columns) and distal sediment (a site approximately 500 m away from the bryozoan patch) were collected (Appendix C). It quickly became apparent that the proximal sediment did not harbour much biodiversity or abundance at all so a decision was made to sample a different neighbouring habitat (*C.cactoides* bed) during the Winter survey. The distal sediment and *C.cactoides* bed sites were found to be predominantly dead shell-bed substrate.

Visibility for the diver was extremely poor due to the highly turbid water column and agitation of the fine silt on the seafloor by the diver's activities. It was often necessary for them to use touch to find and identify the bryozoans. This meant that although the samples were collected randomly, the distance between each sample was impossible to quantify.

2.4. Sample processing

Upon completion of the sample collection, the contents of each cylinder one-by-one was placed onto a 0.5 mm^2 mesh filtering system on the side of the boat and rinsed carefully with seawater using a bilge pump fitted with a hose to remove as much mud from the samples as possible before replacing the contents back into their cylinders. This process was also used to screen for and liberate any protected and potentially dangers species (i.e. seahorses and blue-ringed octopus respectively). The cylinders were then transported from Stony Point Boat Ramp, Crib Point, to a laboratory at La Trobe University Bundoora, Victoria, where they were refrigerated overnight at 4-8 ^{o}C to reduce specimen decay.

On the following day, samples were placed into a shallow container and sorted through with a magnifying glass to pick out fauna. Owing to the amount of fine silt and mud, samples were rinsed throughout the sorting process with the filtrate being collected at all stages using a 0.5 mm^2 sieve to ensure no smaller fauna were lost during the entire processing procedure. This sorting process took on average one hour per sample and pickers checked each other's samples to eliminate observer biases. Specimens were placed into jars containing 70% ethanol for later counting and identifying.

Specimens were photographed and the small fauna in the filtrate was counted using a stereomicroscope (Zeiss Stemi SV 11) and microscope digital camera (Olympus DP 27). This secondary sorting process took approximately one week per sample as each was meticulously picked through and each animal counted rather than sorting for a set time and giving an estimate. Only the head ends of annelids and crustaceans were recorded. Many of the tunicates were encrusting species and regardless of the size, each separate piece observed was counted as one individual. All bivalves that were whole were counted as one individual, while all half bivalves were counted as half an individual. All crushed or damaged molluscs that could not be positively identified were not counted.

2.5. Fauna identification

Relevant literature (Glasby 2000, Gowlett-Holmes 2008) was used to assist with identifying taxa to the lowest possible taxonomic level. Samples were then sent to an infauna specialist for clarification and further identification. Some taxa were difficult to classify down to family level, and as such, higher taxonomic levels were often applied. This was especially the case for brachiopods and tunicates.

2.6. Statistical analysis

Part A - The fauna found in the three bryozoan samples were pooled and the total number of different morphospecies and total abundance of taxa from each phylum was calculated.

Parts B & C –To account for high (n) in pooled bryozoans relative to the other habitats, each sample was randomly allocated into one of three groups (B1, B2, & B3) so that each group represented a random subset of the total bryozoan pool. The same analysis was used across all 3 groups to gauge whether the results were similar across models and could therefore be reasonably applied. Two-tailed unpaired t-tests were used to assess whether there were significant differences in species richness and abundance between the bryozoan reefs and each neighbouring habitat.

Part D - A one-way ANOVA was used to examine whether there were significant differences in species richness and abundance between the three species of bryozoans. The difference in annelid richness and abundance between the bryozoan species were analysed using two-tailed unpaired t-tests.

It is important to note that all mean species richness and mean abundance data were standardised by dividing them by the volume of the corer that was used to collect each sample. In this way, data from the pilot study could be included.

3. Results

3.1 Part A: Faunal assemblage of the bryozoan reefs

In total, 4,775 individuals were captured representing 84 different morphospecies across 9 phyla. Crustaceans were the most dominant taxa making up 72% of the total abundance and 37% of the total number of morphospecies. Annelids, molluscs and tunicates were also common while rare taxa like brachiopods, Sipuncula, chordates, cnidarians and accounted for less than 1% each (Table 1). See *Appendix D* for a full list of families present in each habitat type.

Table 1. Overall faunal assemblage of the pooled bryozoan species (*T.munitum*, *T.moniliferum* and *C.foliata*) including the abundance and number of morphospecies present within each phylum in descending order.

	Total Abundance	**Abundance %**	**Total Morphospecies**	**Morphospecies %**
Crustaceans	3422	72	31	37
Annelids	801	17	22	26
Molluscs	289	6	19	23
Tunicates	235	5	5	6
Brachiopods	19	< 1	1	1
Sipuncula	4	< 1	1	1
Chordates	3	< 1	3	3.5
Cnidarians	1	< 1	1	1
Echinoderms	1	< 1	1	1
Total =	4775		84	

The most common conspicuous taxa were Pilumnidae (hairy crabs), Alpheidae (snapping shrimp), Arcidae (ark clams), Ostreidae (oysters), Flabelligeridae (polychaetes), Eunicidae (polychaetes) and Ascidacea (sea squirts). Approximately 80% of fauna were inconspicuously small and could only be observed under a microscope. Eunicidae and Tanaidacea were very common in *C.foliata*, making up 52% of the total annelid abundance and 48% of the total crustacean abundance observed. Tanaidacea and Corophiidae were relatively common in all bryozoan species (Table 2).

Table 2. The three most common families across the bryozoan reef habitat. The percentages represent the contribution to the total abundance of the associated phylum in each bryozoan species.

Phylum	**Family**	*C.foliata*	*T.munitum*	*T.moniliferum*
Annelida	Eunicidae	161 (52%)	26 (7%)	2 (2%)
Crustacea	Tanaidacea	275 (48%)	515 (32%)	191 (15%)
Crustacea	Corophiidae	83 (14%)	423 (26%)	551 (44%)

3.2 Part B: Species richness – habitat comparisons

The species richness of the bryozoan reefs was compared to neighbouring habitats. Given that the distal sediment and *C.cactoides* bed habitats were comprised mainly of dead bivalves and gastropods, the total numbers of morphospecies were further broken down into ‘molluscs’ and ‘all other phyla’ to provide a fairer representation of actual known living biodiversity.

The bryozoan reefs demonstrated the highest biodiversity with a total species richness of 84, while the proximal sediment demonstrated the lowest with a species richness of 26. Molluscs dominated the *C.cactoides* bed making up 85% of the assemblage. The distal and proximal sediments were comprised of 65% and 54% molluscs respectively. All three neighbouring habitats exhibited high mollusc diversity, but low diversity within other phyla (Figure 2).

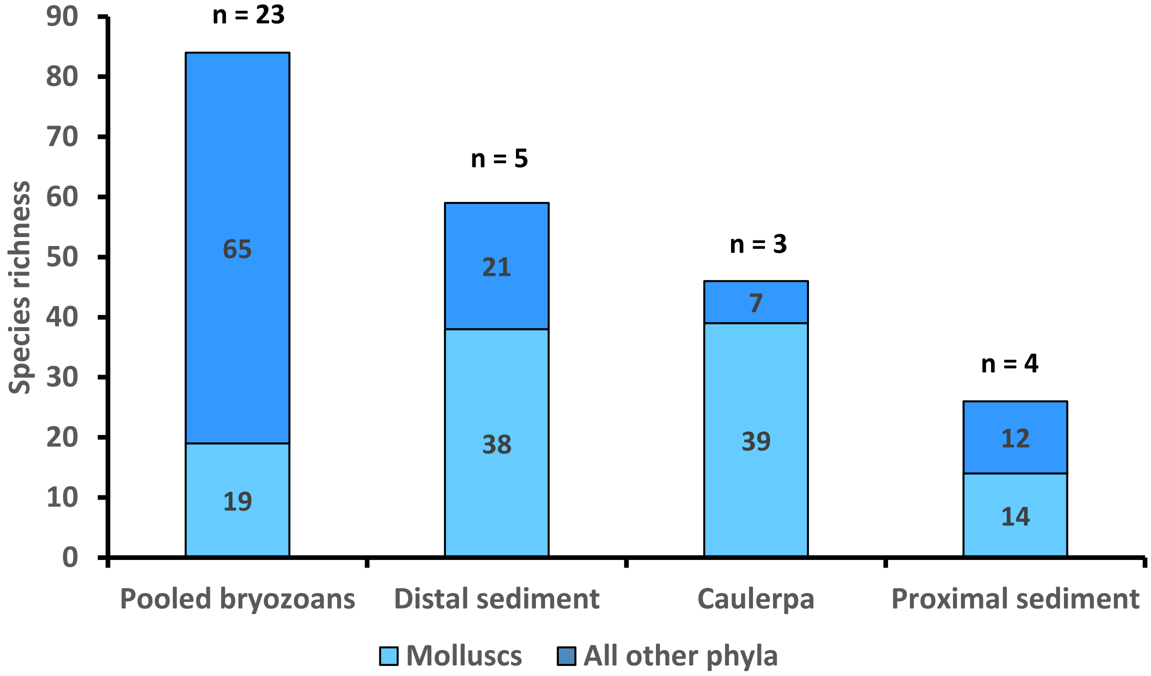


Figure 2. Total species richness found in each habitat type presented as molluscs only and all other phyla. Pooled bryozoans includes all fauna found in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6).

While the distal sediment and *C.cactoides* bed habitats were comprised mainly of dead molluscs, species richness and abundance including the mollusc data was still examined. When including all phyla, the mean species richness was significantly greater in pooled bryozoans than in proximal sediments (df = 25, t = 2.434, $p < 0.05$), however, bryozoan subsets B1 (df = 9, t = 1.917, $p > 0.05$) and B3 (df = 10, t – 1.741, $p > 0.05$) were not significant. Mean species richness was significantly lower in pooled bryozoans than in distal sediment (df = 26, t = -2.653, $p < 0.05$) and *C.cactoides* (df = 24, t = -2.684, $p < 0.05$). This was true for all bryozoan subsets B1-B3 (Figure 3).

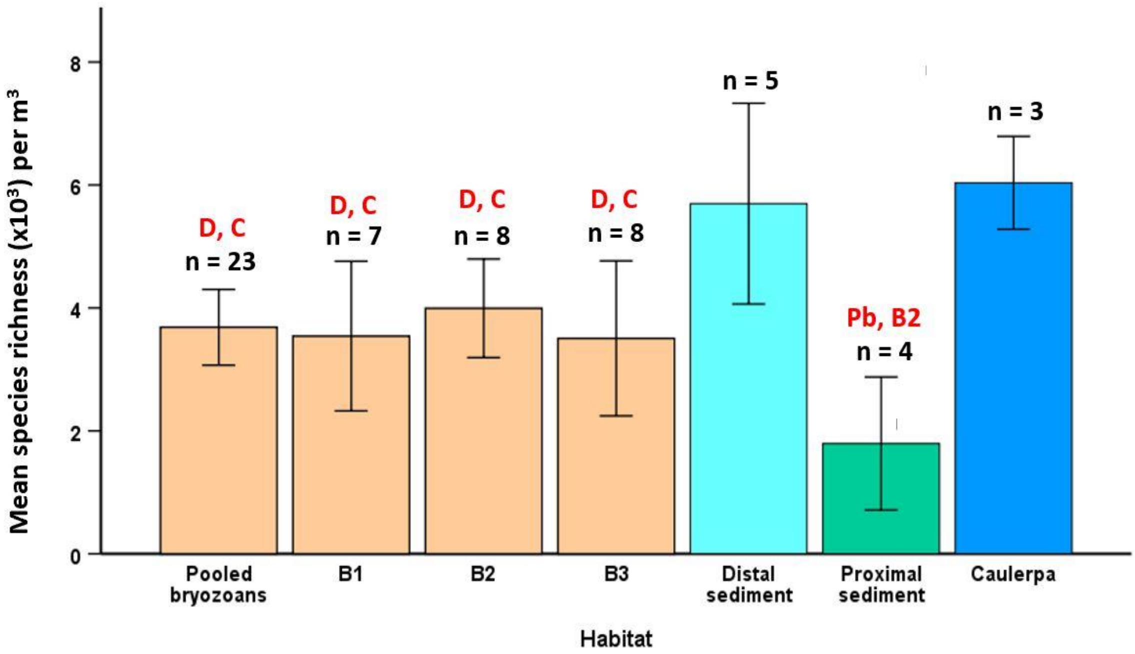


Figure 3. Mean species richness per m^3 across habitats including taxa from all phyla. Pooled bryozoans includes taxa observed in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6). B1-B3 are random subsets from the pooled bryozoans. Error bars represent $\pm$ 2 standard errors. The codes above the bars represent a significantly higher value in the code-associated habitat than the bar-associated habitat beneath. Pb = Pooled bryozoans, B1-B3 = B1-B3, D = Distal sediment, P = Proximal sediment, and C = *C.cactoides.*

When excluding molluscs which are problematic (discussed earlier), there was a significantly higher mean species richness in the pooled bryozoans than proximal sediment (df =25, t = 3.664, $p < 0.05$), distal sediment (df = 26, t = 2.763, $p < 0.05$), and *C.cactoides* bed (df = 24, t = 3.385, $p < 0.05$). This was true for all subsets of bryozoans B1-B3 (Figure 4).

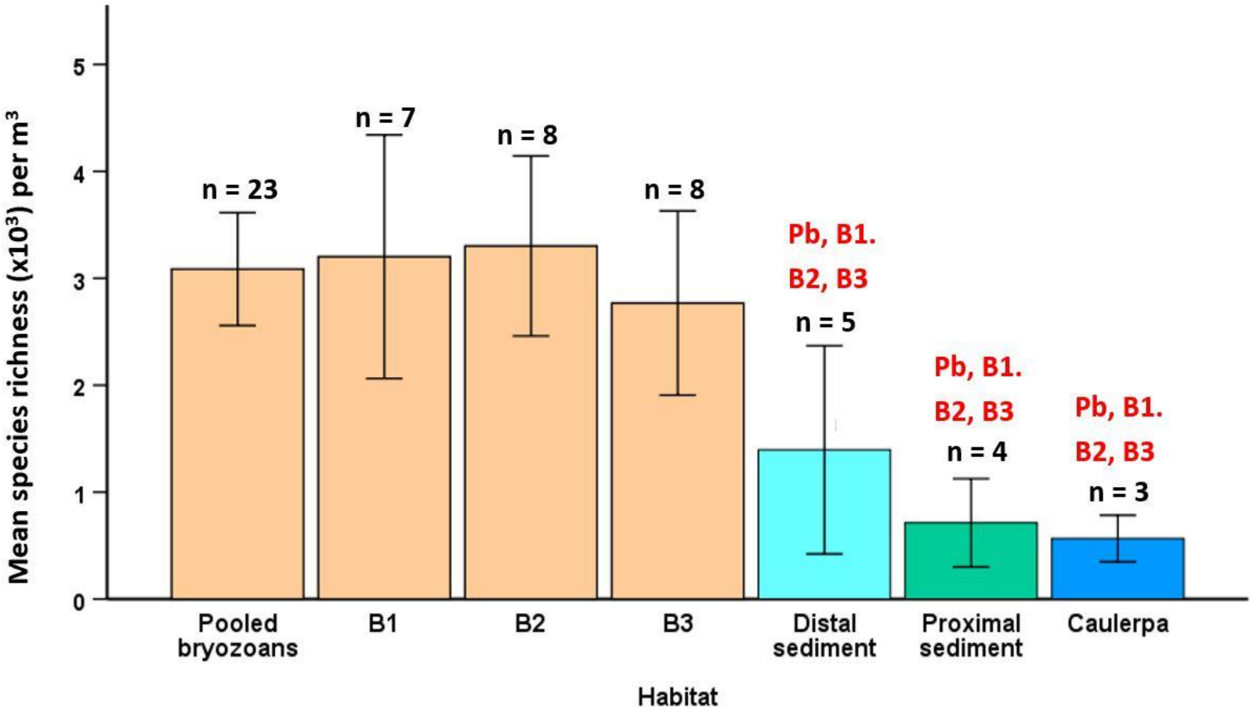


Figure 4. Mean species richness per m^3 across habitats including taxa from all phyla except molluscs. Pooled bryozoans includes taxa observed in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6). B1-B3 are random subsets from the pooled bryozoans. Error bars represent ± 2 standard errors. The codes above the bars represent a significantly higher value in the code-associated habitat than the bar-associated habitat beneath. Pb = Pooled bryozoans, B1-B3 = B1-B3, D = Distal sediment, P = Proximal sediment, and C = *C.cactoides.*

The number of annelid and crustacean morphospecies observed in the bryozoan reefs was compared to the numbers found in the neighbouring habitats. The mean number of annelid morphospecies was significantly greater in pooled bryozoans than in proximal sediment (df = 25 , t = 2.373, $p < 0.05$), distal sediment (df = 26, t = 2.213, $p < 0.05$) and *C.cactoides* bed (df = 24, t = 3.389, $p < 0.05$). This was true for all bryozoan subsets B1-B3 (Figure 5).

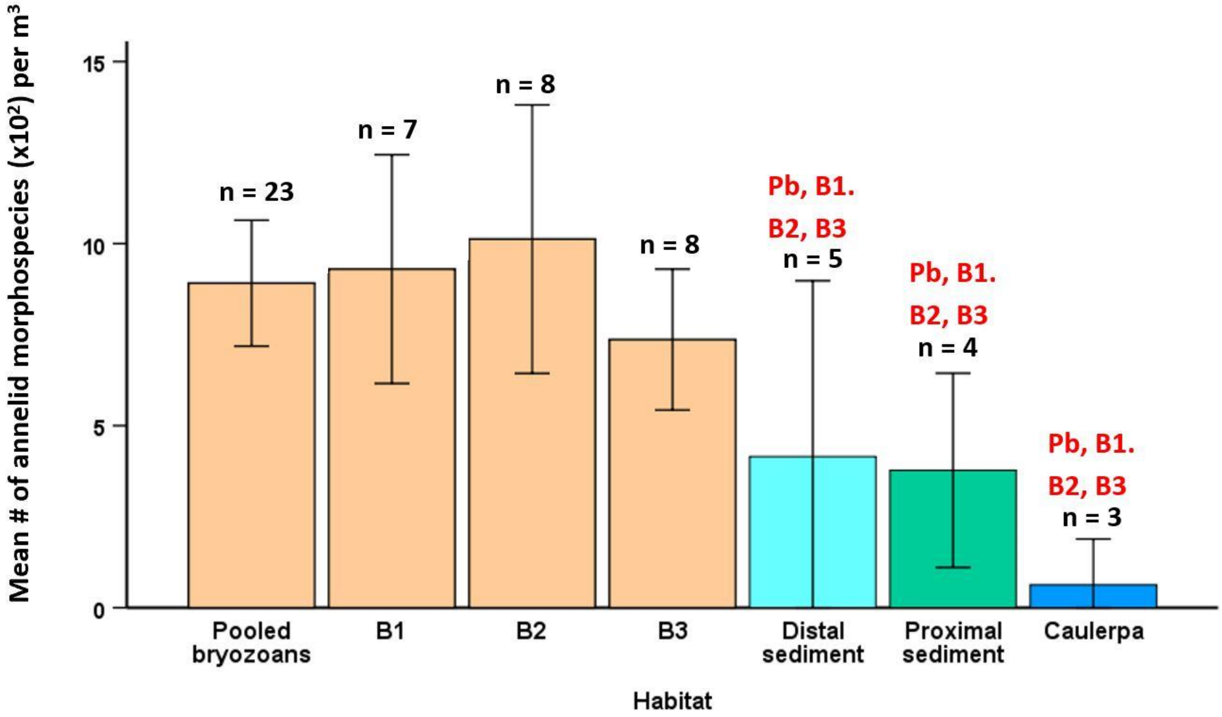


Figure 5. Mean number of annelid morphospecies per m^3 across habitats. Pooled bryozoans includes taxa observed in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6). B1-B3 are random subsets from the pooled bryozoans. Error bars represent $\pm$ 2 standard errors. The codes above the bars represent a significantly higher value in the code-associated habitat than the bar-associated habitat beneath. Pb = Pooled bryozoans, B1-B3 = B1-B3, D = Distal sediment, P = Proximal sediment, and C = *C.cactoides.*

The mean number of crustacean morphospecies was significantly greater in bryozoans than in distal sediment (df = 26, t = 2.575, $p < 0.05$), proximal sediment (df = 17, t = 7.454, $p < 0.05$) and *C.cactoides* (df = 24, t = 3.451, $p < 0.05$). This was true for all bryozoan subsets B1-B3 (Figure 6).

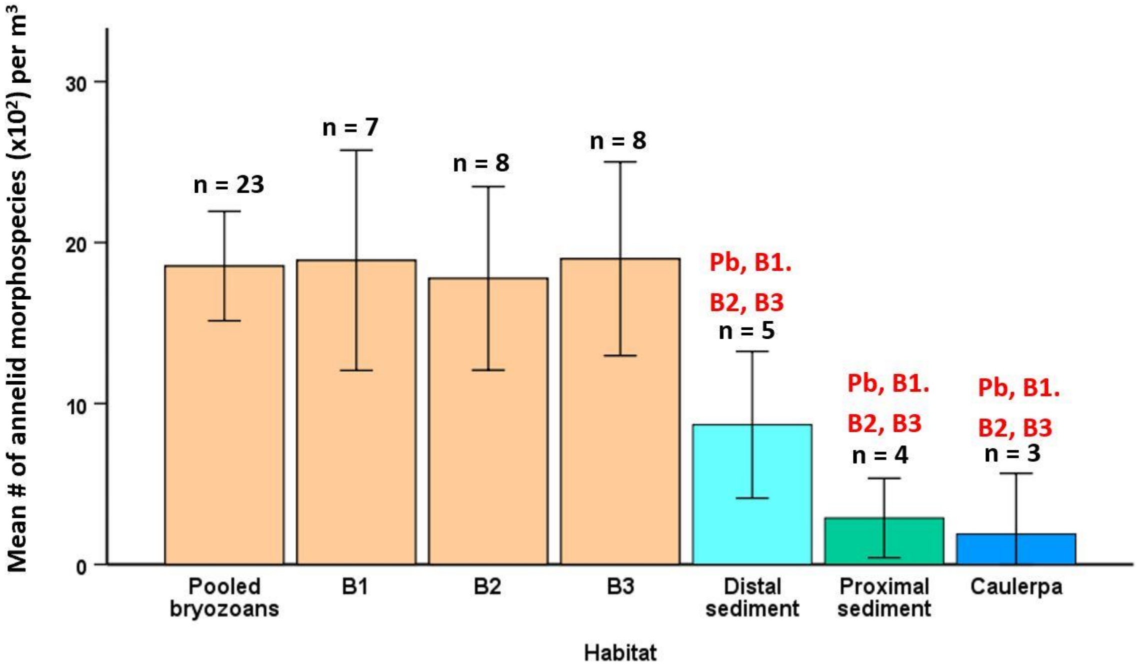


Figure 6. Mean number of crustacean morphospecies per m^3 across habitats. Pooled bryozoans includes taxa observed in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6). B1-B3 are random subsets of all samples from the pooled bryozoans. Error bars represent ± 2 standard errors. The codes above the bars represent a significantly higher value in the code-associated habitat than the bar-associated habitat beneath. Pb = Pooled bryozoans, B1-B3 = B1-B3, D = Distal sediment, P = Proximal sediment, and C = *C.cactoides.*

3.3 Part C: Faunal abundance – habitat comparisons

The total abundance of taxa observed in the bryozoans was compared to that observed within the neighbouring habitats. When including all phyla, there was a significantly greater abundance of fauna in the pooled bryozoans than the proximal sediments (df = 25, t = 4.762, $p < 0.05$). This was true for all bryozoan subsets B1-B3. There were no significant differences in the abundance of fauna between the pooled bryozoans and distal sediment (df = 4.184, t = -1.582, $p > 0.05$) or *C.cactoides* (df = 2.08, t = -2.537, $p > 0.05$) (Figure 7).

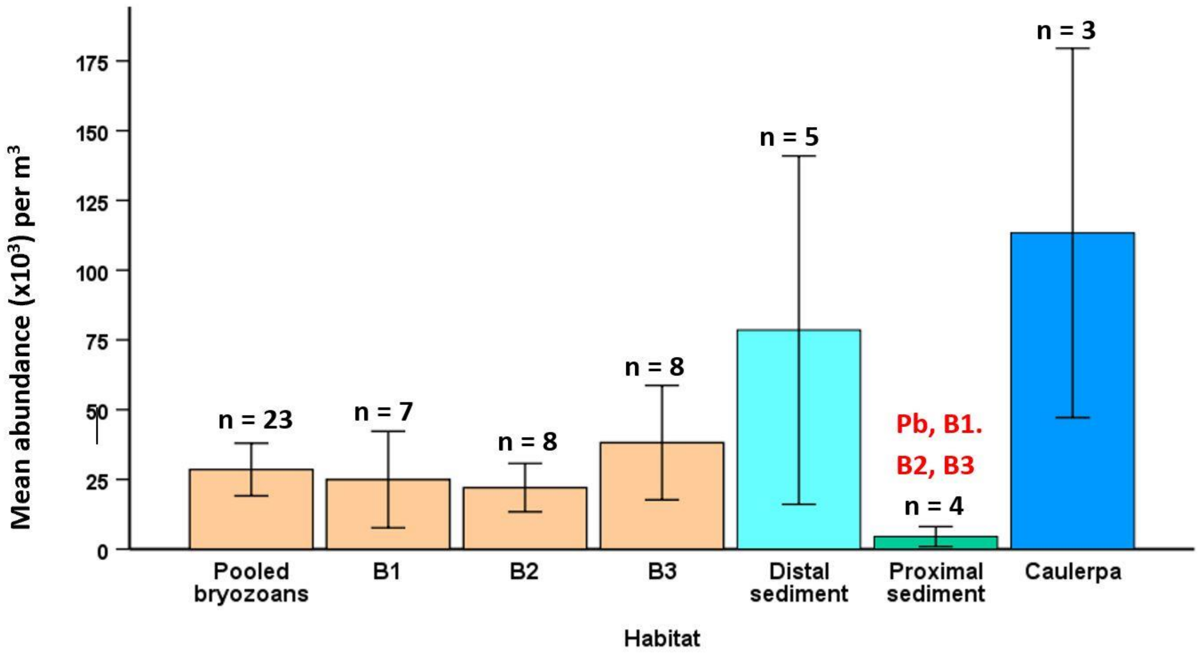


Figure 7. Mean abundance per m^3 across habitats including taxa from all phyla. Pooled bryozoans includes taxa observed in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6). B1-B3 are random subsets of all samples from the pooled bryozoans. Error bars represent $\pm$ 2 standard errors. The codes above the bars represent a significantly higher value in the code-associated habitat than the bar-associated habitat beneath. Pb = Pooled bryozoans, B1-B3 = B1-B3, D = Distal sediment, P = Proximal sediment, and C = *C.cactoides*.

When excluding molluscs, there was a significantly higher mean abundance of taxa in the pooled bryozoans than in proximal sediment (df = 22.32, t = 5.425, $p < 0.05$), distal sediment (df = 26, t = 4.432, $p < 0.05$), and *C.cactoides* bed (df = 24, t = 5.478, $p < 0.05$). This was true for the B1 and B2 subsets, however, there were no significant differences in abundance between B3 and neighbouring habitats (Figure 8).

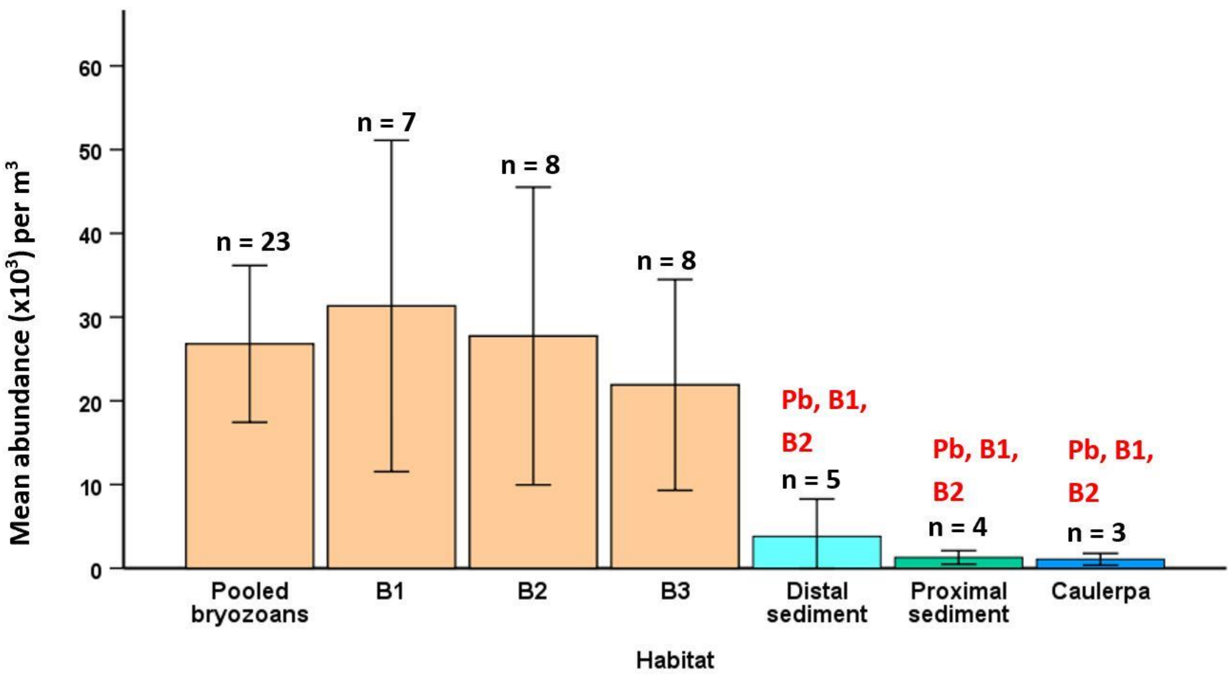


Figure 8. Mean abundance per m^3 across habitats including taxa from all phyla except molluscs. Pooled bryozoans includes taxa observed in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6). B1-B3 are random subsets of all samples from the pooled bryozoans. Error bars represent $\pm$ 2 standard errors. The codes above the bars represent a significantly higher value in the code-associated habitat than the bar-associated habitat beneath. Pb = Pooled bryozoans, B1-B3 = B1-B3, D = Distal sediment, P = Proximal sediment, and C = *C.cactoides*.

The abundance of annelids and crustaceans observed in the bryozoans were compared to the abundances found in the neighbouring habitats. There was no significant difference in the mean abundance of annelids between the pooled bryozoans and distal sediment (df = 26, t = 0.969, $p > 0.05$), proximal sediment (df = 25, t = 1.691, $p > 0.05$) or *C.cactoides* (df = 24, t = 1.660, $p > 0.05$). The bryozoan subsets B1 & B2 were in line these results. B3, however, had a significantly greater abundance of annelids than proximal sediment and *C.cactoides* (Figure 9).

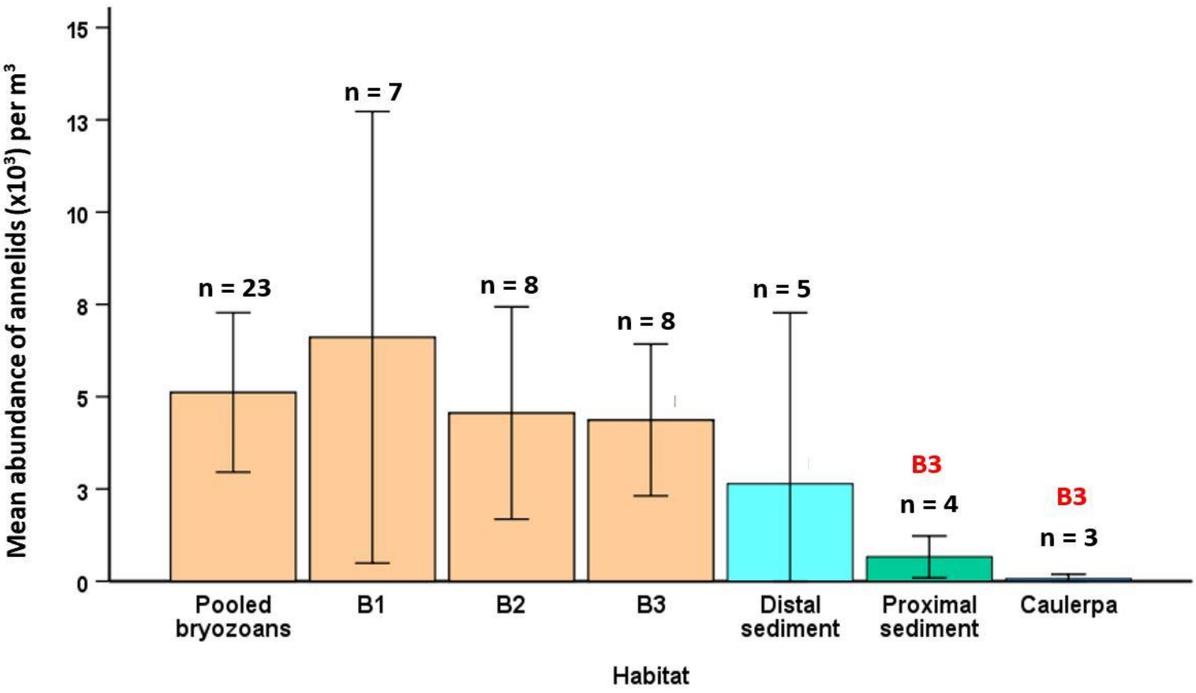


Figure 9. Mean abundance of annelids per m^3 across habitats. Pooled bryozoans includes taxa observed in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6). B1-B3 are random subsets of all samples from the pooled bryozoans. Error bars represent $\pm$ 2 standard errors. The codes above the bars represent a significantly higher value in the code-associated habitat than the bar-associated habitat beneath. Pb = Pooled bryozoans, B1-B3 = B1-B3, D = Distal sediment, P = Proximal sediment, and C = *C.cactoides.*

The mean abundance of crustaceans was significantly greater in the bryozoans than in distal sediment (df = 23, t = 4.478, $p < 0.05$), proximal sediment (df = 22.18, t = 4.845, $p < 0.05$), and *C.cactoides* (df = 22.17, t = 4.918, $p < 0.05$). This was true for all bryozoan subsets B1-B3 (Figure 10).

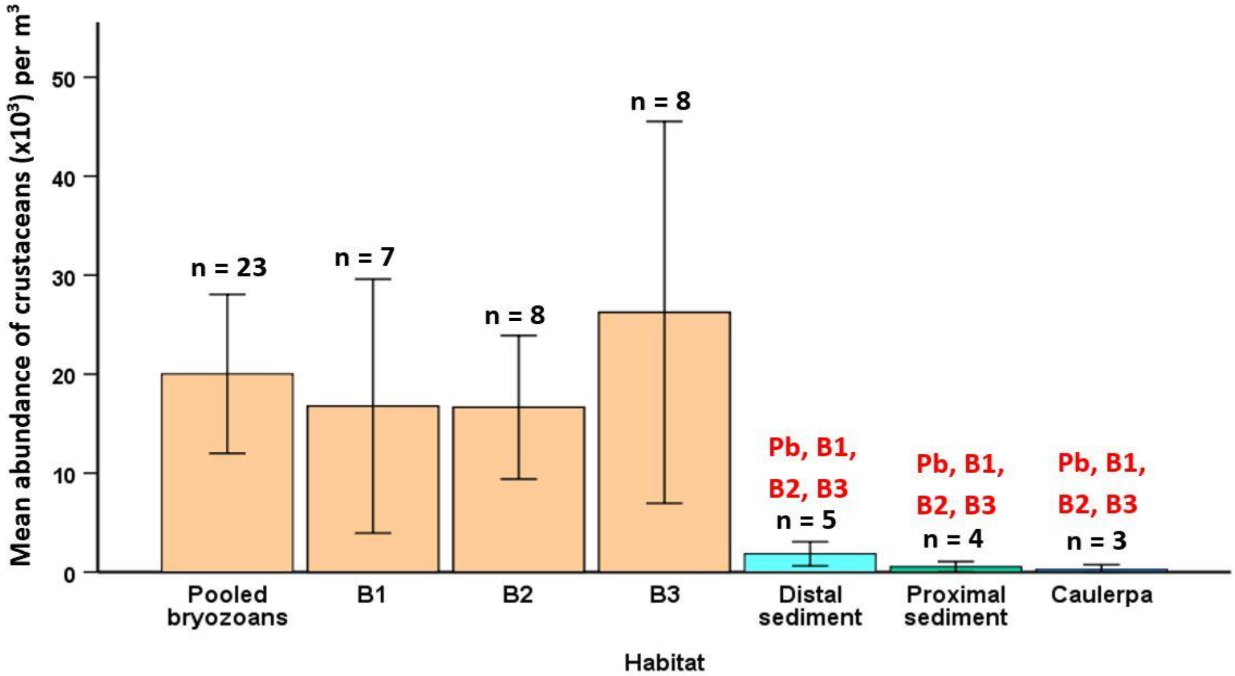


Figure 10. Mean abundance of crustaceans per m^3 across habitats. Pooled bryozoans includes taxa observed in *T.munitum* (n = 10), *T.moniliferum* (n = 7) and *C.foliata* (n = 6). B1-B3 are random subsets of all samples from the pooled bryozoans. Error bars represent $\pm$ 2 standard errors. The codes above the bars represent a significantly higher value in the code-associated habitat than the bar-associated habitat beneath. Pb = Pooled bryozoans, B1-B3 = B1-B3, D = Distal sediment, P = Proximal sediment, and C = *C.cactoides*.

3.3 Part D: Species richness and abundance – comparisons between bryozoans

Species richness and abundance of taxa observed in each bryozoan species as separate entities were compared. There was no significant difference in the mean species richness (df = 2, F = 1.141, $p > 0.05$) (Figure 11a) or mean abundance of taxa (df = 2, F = 1.045, $p > 0.05$) (Figure 11b) per m^3 between the different bryozoan species.

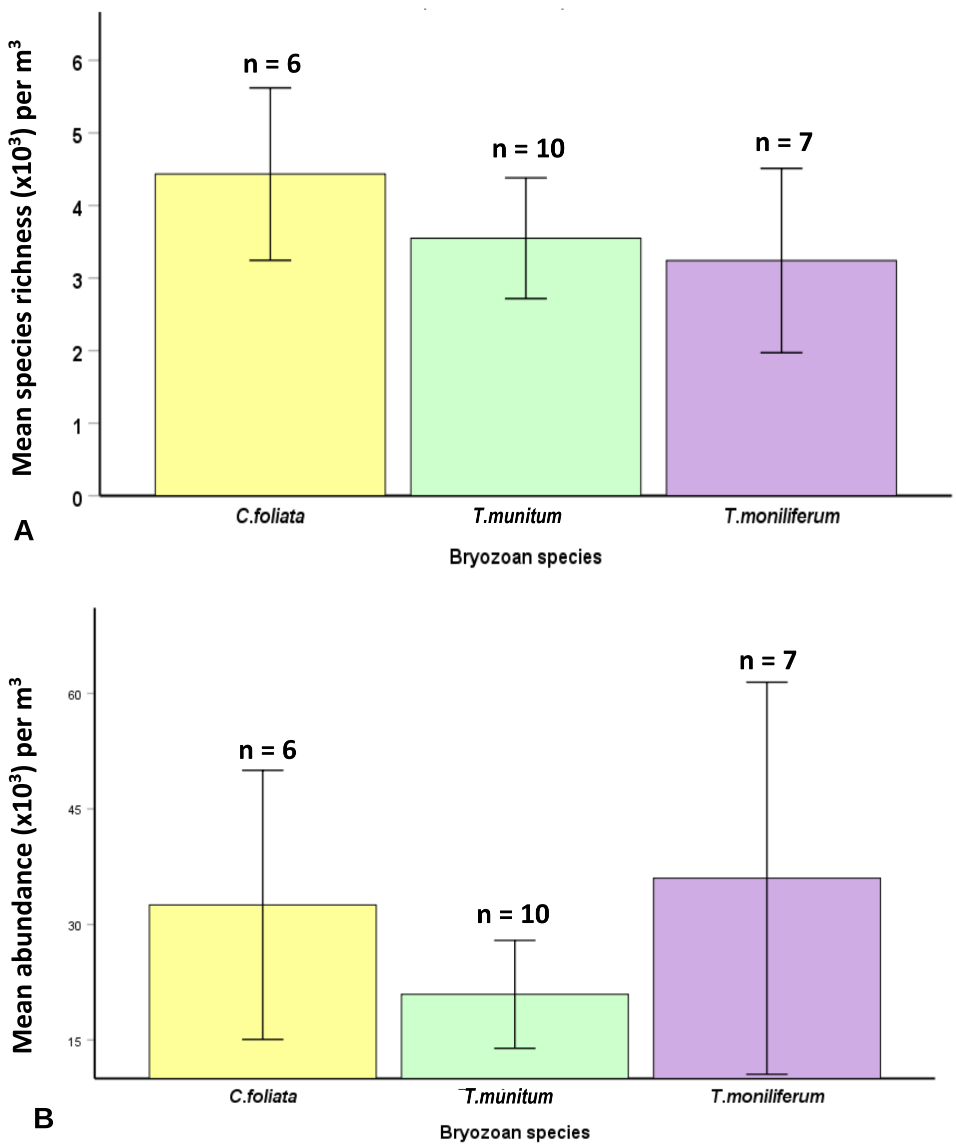


Figure 11. Comparisons of biodiversity between bryozoan species. A) Mean species richness per m^3, and B) Mean abundance of fauna per m^3. Error bars represent $\pm$ 2 standard errors.

Although there was no significant difference in overall species richness between each of the bryozoan species, there was a significantly greater mean number of annelid morphospecies found in *C.foliata* than in *T.munitum* (df = 14, t = 2.80, $p < 0.05$) and in *T.moniliferum* (df = 11, t = 2.624, $p < 0.05$) (Figure 12a). The abundance of annelids was not significantly different between *C.foliata* and *T.munitum* (df = 5.53, t = 1.621, p >

0.05) or *T.moniliferum* (df = 5.48, t = 2.057, p > 0.05) or between *T.munitum* and *T.moniliferum* (df = 15, t = -1.340, p > 0.05) (Figure 12b).

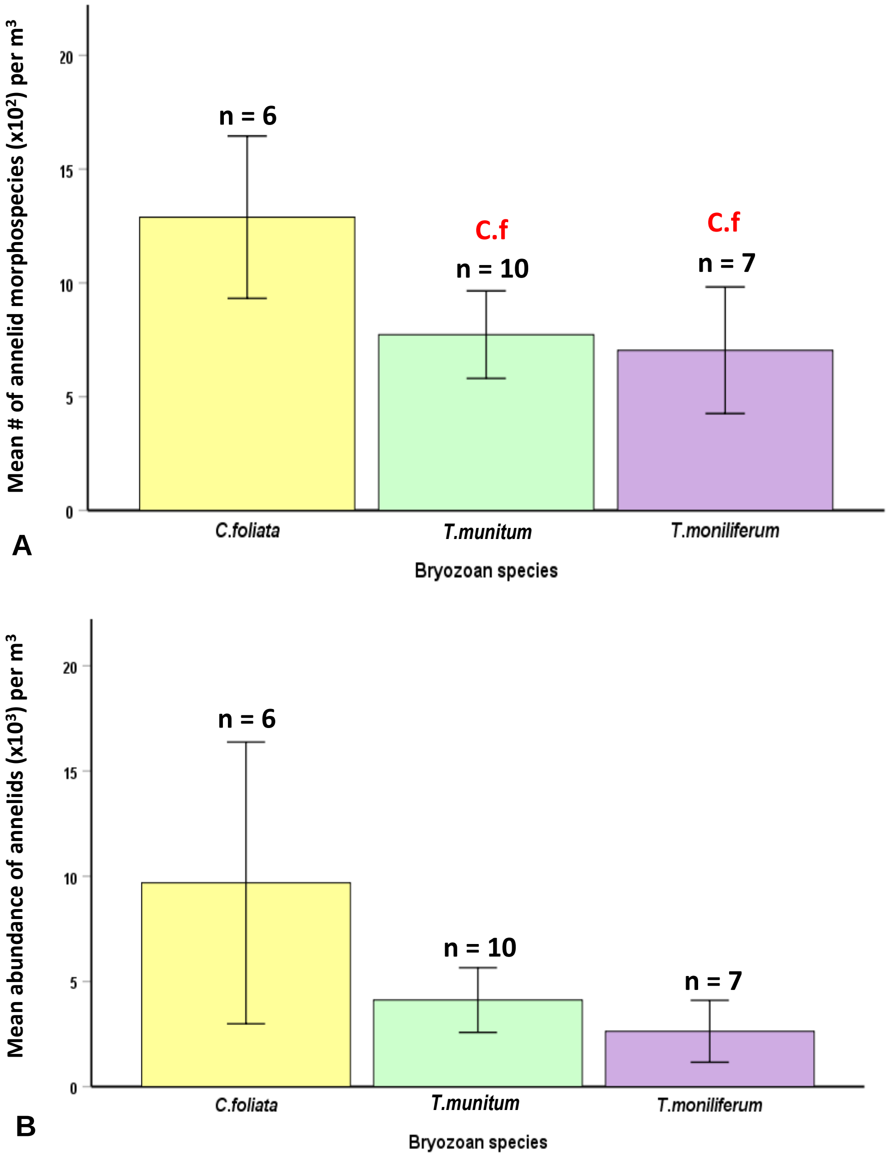


Figure 12. Comparisons of annelid biodiversity between bryozoan species. A) Mean species richness per m^3, and B) Mean abundance of annelids per m^3. Error bars represent $\pm$ 2 standard errors. The code C.f represents a significantly higher value in *C.foliata* than the bryozoan species below it.

4. Discussion

The WP bryozoan reefs are a newly documented biotope in Victoria and are potentially globally significant based on their structure, composition and extent (Flynn et al. 2018). To our knowledge, this biotope is the only one of its kind predominantly composed by *Triphyllozoons*. As this is the first study of any nature to examine this unique reef system, there is no historic data and little comparative data available. The samples collected from the reefs have been compared to samples collected from neighbouring habitats, as well as data drawn from studies of other WP habitats and global research on bryozoan-associated fauna. In this study, the reefs demonstrated significantly high species richness and abundance compared to immediately neighbouring habitats.

Habitat-forming bryozoan colonies commonly harbor a diverse range of fauna (McKinney and Jaklin 2000, Cocito et al. 2002) including even the crudely associated fauna that live around scattered patches of bryozoa (Jones and Lockhart 2011). It was predicted that the bryozoan reefs would harbour abundant taxa across a range of phyla. The principal reasoning behind that prediction is the positive relationship between habitat complexity and resource availability (Bruno et al. 2003). One example of this is prey favouring complex habitat to seek refuge from predation (Pederson and Peterson 2002) and this stabilisation of predator-prey interactions can lead to high biodiversity across all trophic levels within biogenic habitats (Menge and Sutherland 1976).

In this study, 31 crustacean morphospecies, 22 annelid morphospecies and 19 mollusc morphospecies were all found within a single patch of bryozoan reef. A total of 84 morphospecies across 9 phyla is indicative of a reef that is harbouring a highly diverse community of epifauna and infauna. This assemblage composition is consistent with that of a patchy thicket-like bryozoan-dominated habitat on the Otago Shelf (NZ), where 36 crustacean morphospecies, 19 mollusc morphospecies, 31 annelid morphospecies and a total of 11 phyla were observed (Wood 2005).

The most abundant phyla observed in the bryozoan reefs were crustaceans (72%), followed by annelids (17%) and then molluscs (6%). Macrofauna biodiversity studies of WP habitats have produced a range of results. For instance, a comprehensive survey by Coleman et al. (1978) found that mud and sand sediments were dominated by annelids (54%), while Edgar et al. (1994) found that vegetated and unvegetated habitats within the bay (including seagrass habitats) all had relatively the same compositions and were dominated by crustaceans (39%) and annelids (33%). Rhodolith beds were found to be dominated by polychaete worms, both in abundance (89% of the total assemblage) and number of morphospecies (Terebellidae being the most common family) (Harvey and Bird, 2008). Like bryozoans, biogenic rhodolith beds provide a substratum for invertebrates such as crustaceans, polychaetes and molluscs to attach to, burrow into or hide within (Harvey and Bird 2008). Biodiversity in rhodolith beds has proven to be remarkably higher than in surrounding habitats (Foster 2001). An exceptional example of this comes from the Gulf of California where rhodolith-associated benthic species richness was 1.7 times higher and abundance was approximately 900 times than adjacent sand flats (Steller et al. 2003). Consistent with the finding of this current study, the shallow biogenic rhodolith beds in WP display high levels of biodiversity compared to soft sediment communities elsewhere in the bay (Harvey and Bird 2008).

All the bryozoan species exhibited a high inter- phylum and intra- phylum richness, except for within the tunicates and brachiopods, which may be the result of them only being classified down to Class. The number of morphospecies' counted within these phyla could be underestimates as a conservative approach was used when considering whether an individual was likely to be a different morphospecies to one that had already been identified.

It was expected that the distal sediment and *C.cactoides* bed would have a relatively high number of individuals and a low number of morphospecies. The assemblages were mainly comprised of dead Veneridae (venus clams) and Arcidae (ark clams). *T.munitum* had the highest species richness and abundance of non-molluscan taxa suggesting that it is the most biodiverse of all the habitats sampled. This fenestrate species has a much larger surface area and hence complexity of laminal interstices relative to the plate-like features of *C.foliata*. This is not surprising as a positive relationship between the complexity of habitat and infauna richness has been demonstrated in bryozoans (McKinney and Jaklin 2000), coralligenous communities (Cocito et al. 2002), seagrass meadows (Heck and Wetstone 1977) and biogenic polychaete worm communities elsewhere (Woodin 1978). *C.foliata*, was relatively high in species richness and abundance as well as having a low average number of individuals per morphospecies. This is indicative of a reef that is serving many functions and providing a variety of resources to a wide range of taxa.

The bryozoan reefs had a much higher total species richness than all neighbouring habitats. Given that the majority of species present were from phyla other than molluscs, it was reasonable to assume that the number was a good estimate of actual biodiversity. In contrast, the *C.cactoides* bed and distal sediments were hard-bottomed shell-bed making the measure of biodiversity problematic; not only because it was difficult to discern between living and dead gastropods, but also because of the damage caused to bivalves as a result of the sampling corer being pushed through the sediment. The mean abundance of taxa within the bryozoan reefs was significantly greater than proximal sediment, however, not different to distal sediment or *C.cactoides* bed. This is due to the high number of molluscs being counted as living animals when it is quite possible that the majority of the sediment collected in the samples was dead shell-bed. When the molluscs were excluded, the total abundance of taxa and total abundance of crustaceans within the bryozoan reefs was greater than all other habitats, strongly suggesting that they provide habitat and resources for a significantly higher number of fauna compared to less complex habitats. The number of annelid and crustacean morphospecies was greater in the bryozoan reefs than all neighbouring habitats and is in accord with bryozoan biodiversity studies elsewhere (Lindberg and Stanton 1988, Morgado and Tanaka 2001, Wood and Probert 2013).

Despite the morphological differences between the fenestrate (*T.munitum* and *T.moniliferum*) and non-fenestrate (*C.foliata*) bryozoan species, there was no difference in the overall abundance or species richness of the assemblages. Interestingly, it was obvious during the initial sorting process that there was a high presence of Eunice worms in *C.foliata* compared to other bryozoan species and neighbouring habitats. Although, only the number of annelid morphospecies (and not the overall abundance) was significantly greater in *C.foliata*, more than half of the total annelid abundance was composed of Eunicidae. This infers that the plate-like structure of the species offers a resource that is preferable to this family of annelids over the fenestrate species. *Ex-situ* observation of eunicid behaviour within *C.foliata* could shed some light on the function of the habitat for these worms. Some interesting relationships have been observed between eunicid worms and habitat-forming organisms. For instance, Roberts (2005) discovered reef-aggregating behaviour in eunicid worms; potentially demonstrative of a symbiotic relationship with cold-water corals.

The results of this study have answered some questions around the types of fauna that the WP bryozoan reefs may be harbouring, however, there is a lot more research to be undertaken to understand the reefs and what kind of protection they require.

5. Future research

Identifying the taxa observed in this study to a lower classification could possibly reveal undescribed or unique species associated with the bryozoan reefs. In the immediate future, species data from other Victorian marine habitats will be collected, collated and compared to the species data from this study. Using presence/absence data, similarities and dissimilarities will be measured to understand the uniqueness of the bryozoan reefs.

Additionally, highly mobile and large macrofauna will need to be targeted specifically in an intensive way. Apart from the obvious physical exclusion of large invertebrates and fish from the small corer, poor visibility limits the techniques that can be utilised to accurately record fish biodiversity. Two of the most common methods utilize 1) BRUVs - but that is only possible with excellent visibility and 2) fine mesh netting and poisoning of a patch of reef - not a palatable option for the purposes of this study. Line fishing is an option but may miss many species owing to restrictions in their diet, size and competitive exclusion by other species. The more practical approach will be to extensively survey the bryozoan reef with sophisticated bioacoustics sonar at various stages of tide, on multiple days and during all seasons. This would be a large undertaking in itself and is beyond the scope of this current honours project.

The data collected in this study could be used to place species into functional groups, and this, in conjunction with future research on the mobile macrofauna associated with the reefs (such as chordates and echinoderms), could be used to examine the trophic composition of the reefs and further our understanding of how the bryozoan reef community functions as an ecosystem.

Although seasonality was not possible to be studied here, it will be a focus moving forward in order to examine whether there are changes in the assemblages or appearances/disappearance of different life stages. Two juvenile *Genypterus sp.* (rockling) were found during the preliminary sorting of Spring data (data not included) indicating that seasonal changes might well be observed.

This study is a discrete unit contributing to a much larger over-arching project and sought to establish conservation its values in readiness to be list the bryozoan community under the Flora and Fauna Guarantee (FFG) Act. In the near future aspects of its conservation value will become clearer by 1) measuring the season biodiversity associated with the reefs 2) comprehensively mapping the extent of the reefs in fine scale 3) identifying and assessing potential threats, and 4) educating and creating partnerships with the various stakeholders.

6. Conclusions

This study of the biodiversity associated with the recently discovered WP bryozoan biogenic reefs demonstrates that there is a wide range of taxa that rely on these reefs for habitat, attachment opportunities, food, and protection from predators and wave action. After 30 years of protection, the bryozoan reefs on the Otago Shelf have not recovered from the damage they sustained from oyster dredging and the WP bryozoan reefs may also be under threat from anthropogenic activities. Understanding the role of these reef communities in ecosystems is essential for making informed management and conservation decisions. The results of this study will provide crucial knowledge about the biodiversity associated with them and contribute to future studies that will highlight their significance and address what protection they require (i.e. either spatial or temporal restrictions). There are, however, still many unanswered questions that need to be addressed in order to establish the full extent of conservation value of these unique reefs.

References

Attrill, M. J. Strong, J. A. & Rowden, A. A. (2000) Are macroinvertebrate communities influenced by seagrass structural complexity? Ecography, 23(1), 114-121.

Australia and New Zealand Environment and Conservation Council, and Agriculture and Resources Management Council of Australia and New Zealand. (2000) National Water Quality Management Strategy: Australia and New Zealand Guidelines for Fresh and Marine Water Quality. Australian Water Association, Artarmon, NSW.

Batson, P. B. & Probert, P. K. (2000) Bryozoan thickets off Otago Peninsula. Wellington: Ministry of Fisheries, 31.

Best, M. A. & Thorpe, J. P. (1996) The effect of suspended particulate matter (silt) on the feeding activity of the intertidal ctenostomate bryozoan Flustrellidra hispida (Fabricius). Bryozoans in Space and Time: Wellington, New Zealand, National Institute of Water and Atmospheric Research (NIWA), 39-45.

Blake, S. Ball, D. Coots, A. & Smith, T. H. (2013) Marine video survey of Western Port. Department of Primary Industries.

Bradstock, M. & Gordon, D. P. (1983) Coral-like bryozoan growths in Tasman Bay, and their protection to conserve commercial fish stocks. New Zealand journal of marine and freshwater research, 17(2), 159-163.

Bruno, J. F., Stachowicz, J. J., & Bertness, M. D. (2003) Inclusion of facilitation into ecological theory. Trends in Ecology & Evolution, 18(3), 119-125.

Cocito, S. Bedulli, D. & Sgorbini, S. (2002) Distribution patterns of the sublittoral epibenthic assemblages on a rocky shoal in the Ligurian Sea (NW Mediterranean). Scientia Marina, 66(2), 175-181.

Cocito, S. Ferdeghini, F. Morri, C. & Bianchi, C. N. (2000) Patterns of bioconstruction in the cheilostome bryozoan Schizoporella errata: the influence of hydrodynamics and associated biota. Marine Ecology Progress Series, 192, 153-161.

Coleman, N. Cuff, W. Drummond, M. & Kudenov, J. D. (1978) A quantitative survey of the macrobenthos of Western Port, Victoria. Marine and Freshwater Research, 29(4), 445-466.

Conolly, J. R. & Von der Borch, C. C. (1967) Sedimentation and physiography of the sea floor south of Australia. Sedimentary Geology, 1, 181-220.

Cook, P. Weaver, H. Bock, P. & Gordon, D. (Eds.). (2018) Australian Bryozoa Volume 2: Taxonomy of Australian Families, 2. CSIRO Publishing.

Cranfield, H. J. Michael, K. P. & Doonan, I. J. (1999) Changes in the distribution of epifaunal reefs and oysters during 130 years of dredging for oysters in Foveaux Strait, southern New Zealand. Aquatic Conservation: Marine and Freshwater Ecosystems, 9(5), 461-483.

Cranfield, H. J. Manighetti, B. Michael, K. P. & Hill, A. (2003) Effects of oyster dredging on the distribution of bryozoan biogenic reefs and associated sediments in Foveaux Strait, southern New Zealand. Continental Shelf Research, 23(14-15), 1337-1357.

Edgar, G. J. Shaw, C. Watsona, G. F. & Hammond, L. S. (1994) Comparisons of species richness, size-structure and production of benthos in vegetated and unvegetated habitats in Western Port, Victoria. Journal of Experimental Marine Biology and Ecology, 176(2), 201-226.

Fathom Pacific (2020) Western Port Bryozoan Reefs Project: 2020 Macrofauna Biodiversity Report Annual Report. Report to AGL and La Trobe University by Fathom Pacific Pty Ltd.

Ferdeghini, F. & Cocito, S. (1999) Biologically generated diversity in two bryozoan buildups. Biologia Marina Mediterranea, 6(1), 191-197.

Flynn, A.J, Bock, P, Gordon, D, Gowlett-Holmes, K, Edmunds, M, Dutka T.L & Donnelly, D.M. (2018) Unique bryozoan reefs in Western Port, a southern temperate embayment. Abstract.

Foster, M. S. (2001) Rhodoliths: between rocks and soft places. Journal of phycology, 37(5), 659-667..

Glasby, C. J. (2000) Polychaetes & allies: the southern synthesis (4). CSIRO publishing.

Gowlett-Holmes, K. L. (2008) A field guide to the marine invertebrates of South Australia. Notomares.

Grabowski, J. H. & Powers, S. P. (2004) Habitat complexity mitigates trophic transfer on oyster reefs. Marine Ecology Progress Series, 277, 291-295.

Hageman, S. J. Lukasik, J. McGowran, B. & Bone, Y. (2003) Paleoenvironmental significance of Celleporaria (Bryozoa) from modern and Tertiary cool-water carbonates of southern Australia. Palaios, 18(6), 510-527.

Hallock, P. (1997) Reefs and reef limestones in earth history. Life and death of coral reefs, 13-42.

Halpern, B. S. Selkoe, K. A. Micheli, F. & Kappel, C. V. (2007) Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conservation Biology, 21(5), 1301-1315.

Hancock, G. J. Olley, J. M. & Wallbrink, P. J. (2001) Sediment transport and accumulation in Western Port. Report on Phase, 1.

Harvey, A. S. & Bird, F. L. (2008) Community structure of a rhodolith bed from cold-temperate waters (southern Australia). Australian journal of botany, 56(5), 437-450.

Harvey, A. S. Harvey, R. M. & Merton, E. (2017) The distribution, significance and vulnerability of Australian rhodolith beds: a review. Marine and Freshwater Research, 68(3), 411-428.

Heck Jr, K. L. & Wetstone, G. S. (1977) Habitat complexity and invertebrate species richness and abundance in tropical seagrass meadows. Journal of Biogeography, 135-142.

Hincks, T. (1880) A history of the British marine Polyzoa (1) J. Van Voorst.

Holbrook, S.J, Schmitt, R.J & Ambrose, R.F. (1990) Biogenic habitat structure and characteristics of temperate reef fish assemblages. Australian Journal of Ecology, 15(4), 489-503.

Jackson, J. B. & Sala, E. (2001) Unnatural oceans. Scientia Marina, 65(S2), 273-281.

Jenkins, G. & Conron, S. (2015) Characterising the status of the Western Port recreational fishery in relation to biodiversity values: Phase. Technical Report. School of Biosciences. Melbourne University.

Jenkins, G. Kenner, T. & Brown, A. (2013) Determining the Specificity of Fish–Habitat Relationships in Western Port. Melbourne Water: Melbourne.

Jones, C. D., & Lockhart, S. J. (2011) Detecting Vulnerable Marine Ecosystems in the Southern Ocean using research trawls and underwater imagery. Marine Policy, 35(5), 732-736.

Keough, M. J & Bathgate, R (2011) Understanding the Western Port Environment. A summary of current knowledge and priorities for future research. A report for Melbourne Water, Department of Sustainability and Environment and the Port Phillip and Westernport CMA. Melbourne Water Corporation.

Kirkman, H. (2013) Near-Coastal Seagrass Ecosystems. Ecology and the Environment, 1-23.

Lenihan, H. S. & Peterson, C. H. (1998) How habitat degradation through fishery disturbance enhances impacts of hypoxia on oyster reefs. Ecological applications, 8(1), 128-140.

Lenihan, H. S. Peterson, C. H. Byers, J. E. Grabowski, J. H. Thayer, G. W. & Colby, D. R. (2001) Cascading of habitat degradation: oyster reefs invaded by refugee fishes escaping stress. Ecological Applications, 11(3), 764-782.

Lindberg, W. J. & Stanton, G. (1988) Bryozoan-associated decapod crustaceans: community patterns and a case of cleaning symbiosis between a shrimp and crab. Bulletin of Marine Science, 42(3), 411-423.

McKinney, F. K. & Jackson, J. B. (1991) Bryozoan evolution. University of Chicago Press.

McKinney, F. K. & Jaklin, A. (2000) Spatial niche partitioning in the Cellaria meadow epibiont association, northern Adriatic Sea. Cahiers de biologie marine, 41(1), 1-18.

Menge, B. A., & Sutherland, J. P. (1976) Species diversity gradients: synthesis of the roles of predation, competition, and temporal heterogeneity. The American Naturalist, 110(973), 351-369.

Moore, C. G. Saunders, G. R. & Harries, D. B. (1998) The status and ecology of reefs of Serpula vermicularis L.(Polychaeta: Serpulidae) in Scotland. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(5), 645-656.

Morgado, E. H. & Tanaka, M. O. (2001) The macrofauna associated with the bryozoan Schizoporella unicornis in southeastern Brazil. Scientia Marina, 65(3), 173-181.

Pederson, E. & Peterson, M. (2002) Bryozoans as ephemeral estuarine habitat and a larval transport mechanism for mobile benthos and young fishes in the north-central Gulf of Mexico. Marine Biology, 140(5), 935-947.

Probert, P.K, Batham, E.J. & Wilson, J.B. (1979) Epibenthic macrofauna off southeastern New Zealand and mid-shelf bryozoan dominance. New Zealand Journal of Marine and Freshwater Research 13, 379-392.

Saxton, F. L. (1980). The coral beds of Tasman and Golden Bay. Ministry of Agriculture and Fisheries Unpublished Report.

Steller, D. L. Riosmena-Rodríguez, R. Foster, M. S. & Roberts, C. A. (2003) Rhodolith bed diversity in the Gulf of California: the importance of rhodolith structure and consequences of disturbance. Aquatic conservation: marine and freshwater ecosystems, 13(S1), S5-S20.

Stuart-Smith, R. D. Edgar, G. J. Stuart-Smith, J. F. Barrett, N. S. Fowles, A. E. Hill, N. A. & Thomson, R. J. (2015) Loss of native rocky reef biodiversity in Australian metropolitan embayments. *Marine pollution bulletin*, *95*(1), 324-332.

Taylor, P. D. Lombardi, C. & Cocito, S. (2015) Biomineralization in bryozoans: present, past and future. Biological Reviews, 90(4), 1118-1150.

Wallbrink, P. J. & Hancock, G. (2003) Western Port sediment study: Background and literature review. CSIRO Land and Water.

Waring, J. S. Maher, W. A. & Krikowa, F. (2006) Trace metal bioaccumulation in eight common coastal Australian polychaeta. Journal of Environmental Monitoring, 8(11), 1149-1157.

Wass, R. E. Conolly, J. R. & MacIntyre, R. J. (1970) Bryozoan carbonate sand continuous along southern Australia. Marine Geology, 9(1), 63-73.

Watson, D. L. Harvey, E. S. Fitzpatrick, B. M. Langlois, T. J. & Shedrawi, G. (2009) Assessing reef fish assemblage structure: how do different stereo-video techniques compare? Marine Biology, 157(6), 1237-1250.

Wilkinson, S. N. Anstee, J. M. Joehnk, K. D. Karim, F. Lorenz, Z. Glover, M. & Coleman, R. (2016) Western Port sediment supply, seagrass interactions and remote sensing. Report to Melbourne Water.

Willan, R. C. (1981) Soft-bottom assemblages of Paterson Inlet, Stewart Island. New Zealand Journal of Zoology, 8(2), 229-248.

Wood, A. C. L. (2005) The Macrofaunal Communities Associated with Bryozoan Thickets on Otago Shelf, South-eastern New Zealand: A Thesis Submitted for the Degree of Master of Science at the University of Otago, Dunedin, New Zealand (Doctoral dissertation, University of Otago).

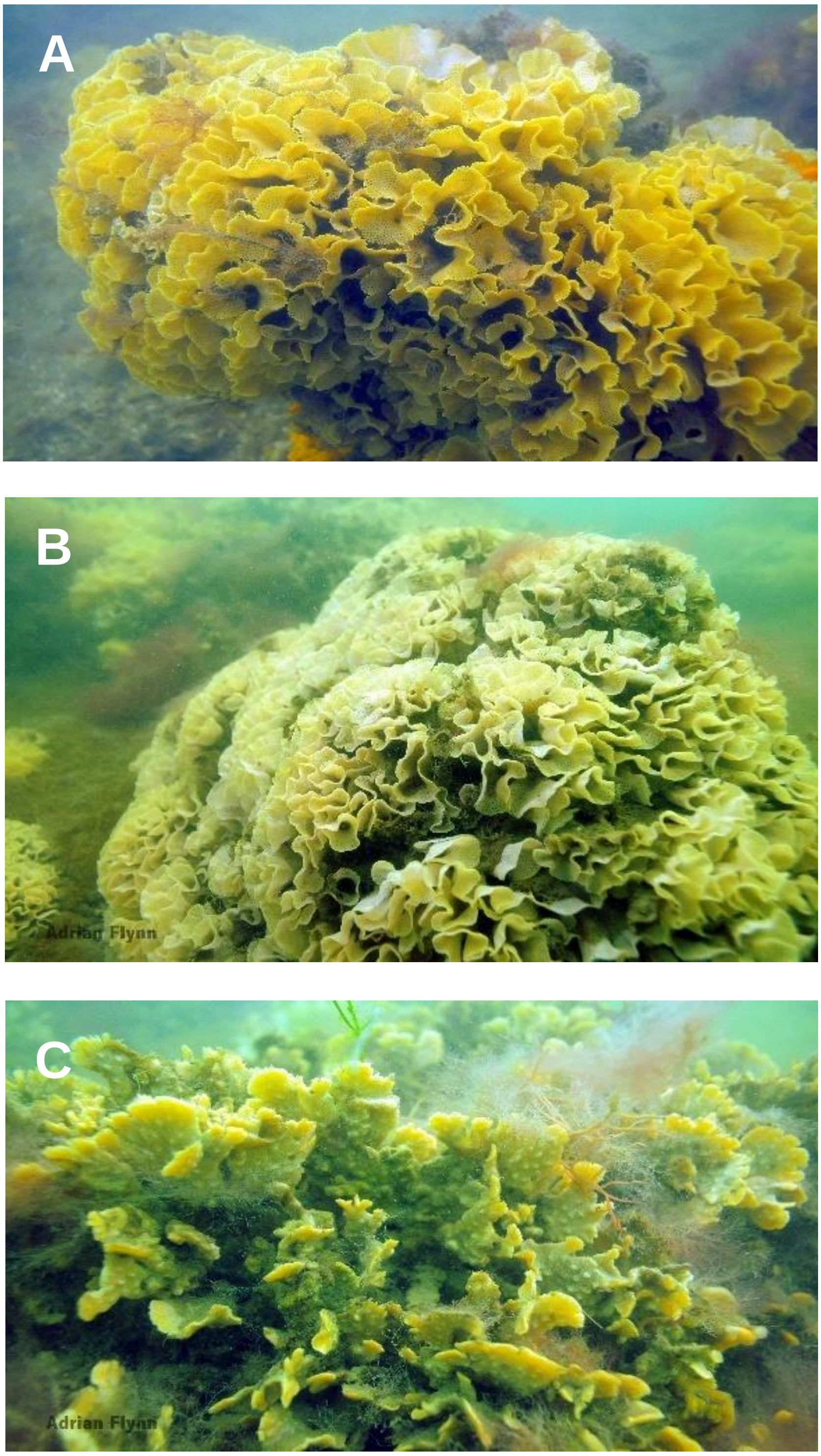
Wood, A. L. Probert, P. K. Rowden, A. A. & Smith, A. M. (2012) Complex habitat generated by marine bryozoans: a review of its distribution, structure, diversity, threats and conservation. Aquatic Conservation: Marine and Freshwater Ecosystems, 22(4), 547-563.

Wood, A. C. L. & Probert, P. K. (2013) Bryozoan-dominated benthos of Otago shelf, New Zealand: its associated fauna, environmental setting and anthropogenic threats. Journal of the Royal Society of New Zealand, 43(4), 231-249.

Woodin, S. A. (1978). Refuges, disturbance, and community structure: a marine soft-bottom example. Ecology, 59(2), 274-284.

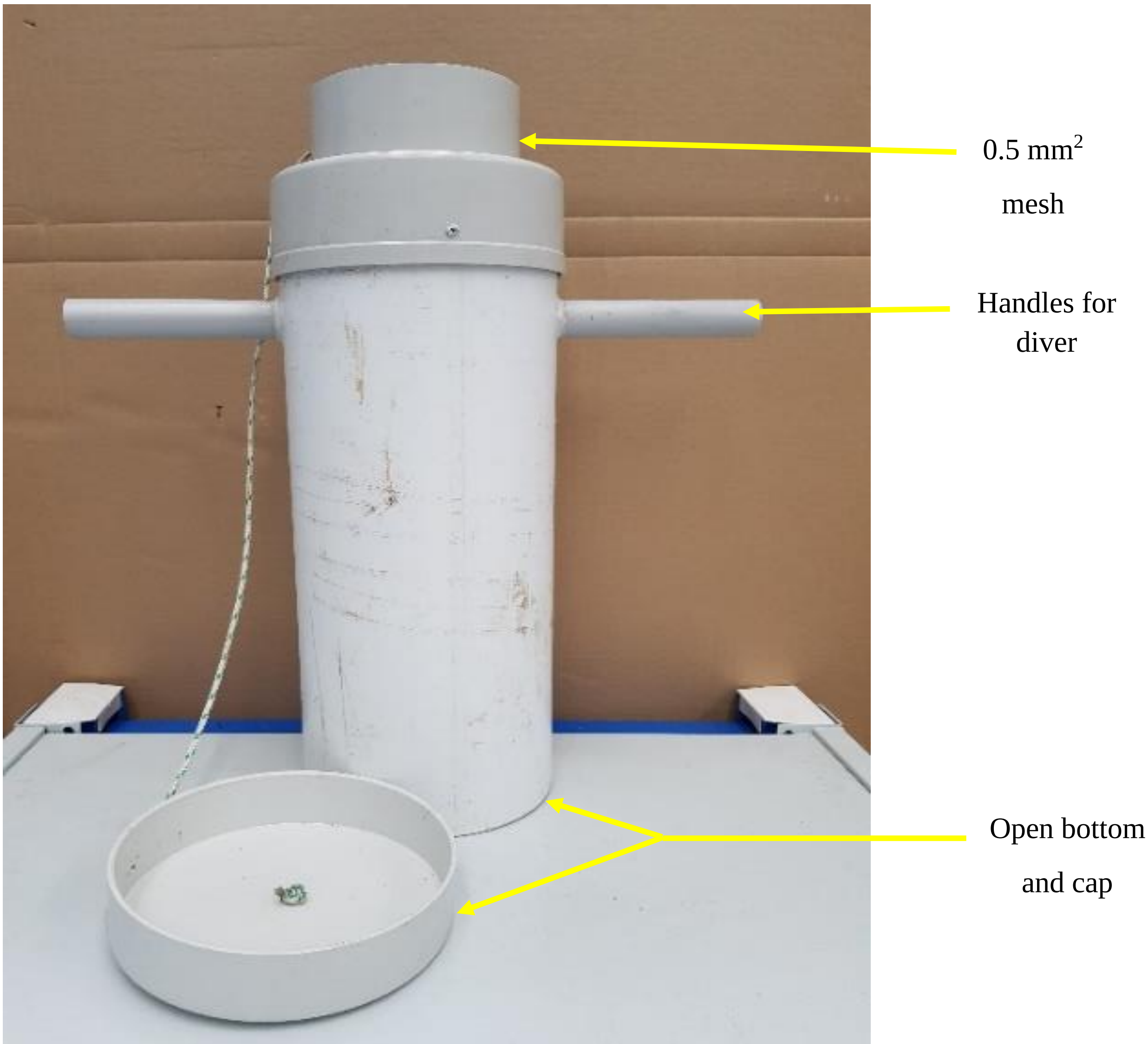
Appendices

Appendix A



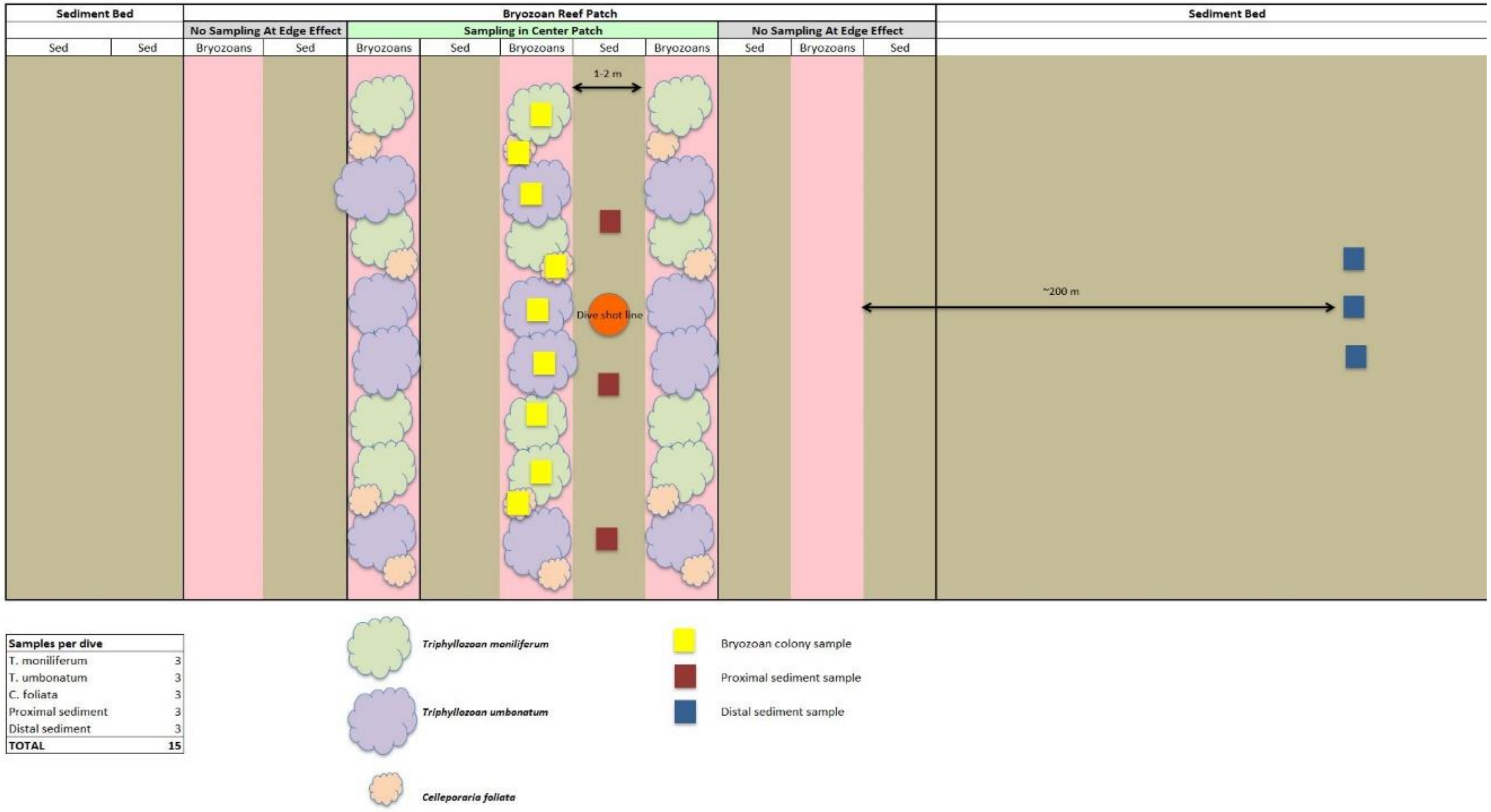
Appendix A. Dominant bryozoan species in the Western Port bryozoan reefs. a) *Triphyllozoon munitum* b) *Triphyllozoon moniliferum* c) *Celleporaria foliata*

Appendix B



Appendix B. PVC sampling corer design illustrating the 0.5mm^2 mesh top of the cylinder, the handles the diver uses to push the corer into the bryozoan or sediment, and the open bottom of the cylinder and cap that is used to seal it off.

Appendix C



Appendix C. Original sample collection design. The beige represents sediment, while the pink lines represent 15- 20 linear columns of bryozoan mounds. Each bryozoan species is denoted by a different colour, as are the distal sediment, proximal sediment and bryozoan sample replicates. *C.cactoides* habitat was added to the study after designing this plan.

Table 3. Presence/absence table of all families present in each habitat type listed in alphabetical order. When classification down to Family level was not possible, taxa are listed as a Phyla, Order, or Class.

Family	*C.foliata*	*T.munitum*	*T.moniliferum*	Proximal sediment	Distal sediment	*C.cactoides*
Acanthochitonidae	x		x			
Alpheidae	x	x	x			
Amaryllidae	x	x	x			
Ampharetidae		x				
Amphiuridae	x					
Antennariidae		x				
Anthuriidae	x	x	x		x	
Arcidae	x	x	x	x	x	x
Ascidian	x	x	x			
Brachiopoda	x	x	x		x	x
Callianassidae		x		x	x	
Calyptraeidae	x	x			x	x
Capitellidae			x	x	x	
Carditidae		x		x	x	x
Certhiidae					x	x
Corophiidae	x	x	x	x	x	x
Columbellidae				x	x	x
Cnidarian				x		
Cumacea	x	x	x	x	x	
Cypraeidae					x	x

Epitoniidae		x		x	x	x
Eunicidae	x	x	x		x	x
Flabelligeridae	x	x	x			
Galatheidae	x	x	x			
Gammaridea		x				
Gobiidae		x	x			
Golfingiida	x					x
Goniadidae			x		x	
Haminoeidae		x		x	x	x
Octopodidae		x				
Hipponicidae						x
Hydrozoa	x					
Imphimediidae		x	x			
Joeropsidae	x	x	x	x		
Liljebergiidae	x	x	x	x		
Lottiidae					x	x
Lysianassidae					x	
Munididae	x	x	x			
Muricidae					x	x
Mysida	x	x	x	x	x	
Mytilidae					x	x
Nassariidae	x	x	x	x	x	x
Nereididae	x	x	x			
Nuculidae		x	x	x	x	x
Opheliidae	x	x	x		x	
Ostreidae	x	x	x		x	x
Orbiniidae		x		x	x	

Paranebaliidae	x	x	x		x	x
Paranthuridae		x	x			x
Pectinidae			x		x	
Phoxochelidae	x	x	x	x	x	
Pilumnidae	x	x	x			
Polynoidae	x	x	x			
Pyramidellidae	x	x		x	x	x
Rissoidae					x	x
Sigalionidae	x	x		x		
Syllidae	x	x	x		x	
Tanaidacea		x	x	x	x	
Tellinidae	x	x	x	x	x	
Trochiidae	x	x	x	x	x	x
Trichobranchidae		x	x	x		
Turbinidae						x
Turritellidae						x
Veneridae	x	x	x	x	x	x