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Underwater Imagery Reveals Bryozoan Habitat in Western Port, South-East Australia

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ABSTRACT

Large erect bryozoan colonies significantly enhance habitat complexity and associated biodiversity. Globally, bryozoan habitats are rare and at risk from anthropogenic disturbance. This paper presents two newly described bryozoan habitats in Western Port (~70 km south-east of Melbourne, Australia) and further expands our current knowledge of bryozoan habitats in other parts of the bay. These previously unknown bryozoan habitats discovered in the North and Western Arms of Western Port are comprised of laminar forms that develop erect plates, growing large (up to 1 m in circumference and vertical relief) robust colonies and structure on cobble and shelly sand substrates in areas of high current and moderate wave energy. These bryozoan habitats are composed of two main species: *Adeonellopsis sulcata* (Milne Edwards, 1836) and *Celleporaria foliata* (MacGillivray, 1888). Colonies of *A. sulcata* and *C. foliata* were in approximately equal proportional abundance at the North Arm site, while *A. sulcata* dominated the Western Arm site. These bryozoan habitats support a variety of marine life, with sponges, ascidians, molluscs, echinoderms, fishes, cnidarians, smaller, non-habitat-forming bryozoan species and macroalgae recorded. The North and Western Arm bryozoan habitats differ from previously described bryozoan reefs in the Eastern Arm, which are dominated by fenestrate species forming erect rounded foliose colonies arranged in continuous linear rows and patch reefs in shallower areas of the bay. The new findings add to an emerging understanding of bryozoan habitats in Western Port (a Ramsar site of international significance), which are unique in their ecophysical setting and one of only four known such habitats in Australia. Further research is needed to determine the extent of these habitats in Western Port, the biodiversity of associated species and ecological function.

1 | Introduction

Bryozoans are benthic aquatic invertebrates which form colonies of variable morphology, generally on hard surfaces. The phylum Bryozoa comprises approximately 6535 species according to the World Register of Marine Species (WoRMS 2025). Cheilostomatid bryozoans (of the order Cheilostomata) comprise the largest proportion of extant species and are almost exclusively marine (Cook et al. 2018). Bryozoan colonies can also be classified as erect, with variable forms both fixed-rigid or flexible (Bock et al. 2018). The fixed-rigid bryozoans produce carbonate skeletons and can provide habitat stabilisation by encrusting loose substrate (Hageman et al. 1998) and potentially baffle near-bottom currents. Where bryozoan colonies are densely aggregated, bryozoan habitats are formed that can represent enhanced structural complexity and associated biodiversity (Dutka et al. 2022; Mello et al. 2021, 2023; Smith 2014; Wood et al. 2012). Larger colonies have been reported to support higher

species richness (Wood and Probert 2013) but habitat-forming bryozoans have been defined as those which are greater than 5 cm in three dimensions (Wood et al. 2012). Colonies formed by notable habitat-forming bryozoans can usually grow from a few centimetres to 0.5 m, but the largest bryozoan colonies reported worldwide reach 70 cm to 1 m across (Barnes and de Grave 2002; Cocito et al. 2004).

Habitat-forming bryozoans are those that regularly grow to more than 50 mm in three dimensions, with colonies that dominate the benthic habitat (areas greater than a few square meters) and contribute significantly to the habitat complexity of a locality (Wood et al. 2012). These bryozoans mostly belong to the order Cheilostomata (Cook et al. 2018) and can exhibit a range of growth forms (e.g., encrusting runners, laminar, patch- and sheet-like colonies, erect foliaceous, branching) (Bock et al. 2018). Wood et al. (2012) listed habitat-forming bryozoans across the world, which include colonies forming erect horn-like structures, masses of repeatedly dividing sheets in an open honeycomb structure, stiff but flexible bushy clumps and dense tufts composed of cylindrical branches.

As reported in Wood et al. (2012), based on the morphology and dimensions of the involved species, various terms have been used to describe bryozoan-dominated habitat such as bryozoan 'reefs', 'meadows', 'thickets' and 'forests'. In line with our previous work, we use the term 'bryozoan habitat' when referring to areas where bryozoan colonies are a dominant feature. We use the term 'bryozoan reefs' when referring to bryozoan-dominated habitats where colonies are large (> 5 cm in three dimensions), colonies are tightly clustered or co-mingled to form areas of continuous seafloor coverage of biogenic structure, and where that structure forms a substantial area (> 10 m^2) of vertical relief compared to the surrounding seafloor and is detectable as an elevated seafloor feature using common marine mapping techniques that such as that described by Dutka et al. (2022).

Bryozoan habitats and reefs tend to occur in mesophotic or aphotic zones. When they occur in shallow waters, they are associated with turbid waters, which reduce competition with light-dependent algae (Cumming et al. 2018; Dutka et al. 2022). Only about 54 extant bryozoan habitats are known throughout the world and extant bryozoan habitats have been reported between 59° N and 77° S, and nearly 25% are reported to occur in New Zealand and Australia (Wood et al. 2012). In Australia, bryozoan habitats have been reported in the Coorong Lagoon (Bone and Wass 1990), in the Great Australian Bight (James et al. 2004), on the Lacepede Shelf (Bone and James 1993; Hageman et al. 1995), in Bass Strait and the Tasmanian shelf (James et al. 2008), and in the Port Davey region in South-West Tasmania (Barrett et al. 2007; Edgar et al. 2010).

Recently, Dutka et al. (2022) described an extensive bryozoan reef system (~1.7 km^2), ranging in depth from 4.5 to 8.5 m, in the Eastern Arm of Western Port, a Ramsar site of international significance ~70 km south-east of Melbourne, Australia. Dutka et al. (2022) used high-resolution multibeam echosounding in conjunction with ground-truthing surveys to quantify the typology, extent and species composition of the bryozoan reefs. Following this work, the newly discovered bryozoan reef community was listed as threatened under the *Victorian Flora and Fauna Guarantee (FFG) Act 1988* (Department of Energy, Environment and Climate Action 2024). Since then, further work has been completed to investigate the distribution of bryozoan habitats in other parts of Western Port based on features detected in available multibeam bathymetry (Victorian Department of Energy, Environment and Climate Action, pers. comm.). Here, we report on inspections at two new areas in Western Port that aimed to further investigate the presence of bryozoan habitats and the associated biodiversity.

2 | Materials and Methods

Western Port is a shallow embayment of approximately 680 km^2 located south-east of Melbourne, Australia and is a Ramsar site (an internationally significant coastal wetland) of high biodiversity value linked to a wide range of habitats and recognised by UNESCO (Blake and Ball 2001). The bay comprises a large area of intertidal mudflats occupying approximately 1/3rd of the embayment and dendritic channels (depth to 30 m). Western Port's shores are fringed by mangroves, saltmarshes and seagrasses (Costa et al. 2022). Seafloor sediments and terrigenous sediments transported from the catchment, predominantly entering the bay in the North Arm segment, are reworked and resuspended daily as a result of tides, wind and wave action and are transported clockwise around the embayment (Wallbrink and Hancock 2003).

Tidal range is 2.3–3.1 m and Marsden et al. (1979) delineated five segments of the bay based on topography and tidal flow. Tidal flow is predominantly in a clockwise direction through the bay, with the highest exchange occurring through the Western Entrance (Kellogg Brown & Root 2010). The southern area of the bay near the Western Entrance is exposed to moderate wave energy entering the bay from Bass Strait swells, while the central and northern areas of the bay are exposed to low wave energy that is predominantly wind-generated.

Sites of potential bryozoan habitats were identified on the basis of inspection of seafloor textures in the North Arm and Western Arm that are apparent in existing multibeam bathymetry available via the Victorian Department of Energy, Environment and Climate Action data repositories. Areas of interest were further inspected using vessel-based recreational grade echosounders on research vessels; particular sites for underwater imaging were identified based on the presence of bathymetric relief and increased seafloor rugosity compared to the surrounding sediments.

Underwater imaging inspections were performed at the identified sites of interest in the North and Western Arm of Western Port between May 2021 and March 2024. In 2021 and 2024, inspections were completed at the Western Arm and North Arm sites using a Remotely Operated Vehicle (ROV) (Figure 1, Table 1). The 2024 ROV surveys were georeferenced using an ultra-short baseline (USBL) acoustic tracking system. A SCUBA diving inspection was undertaken in 2022 at the Western Arm site to acquire additional images of the bryozoan habitats to determine the bryozoan species present and investigate the

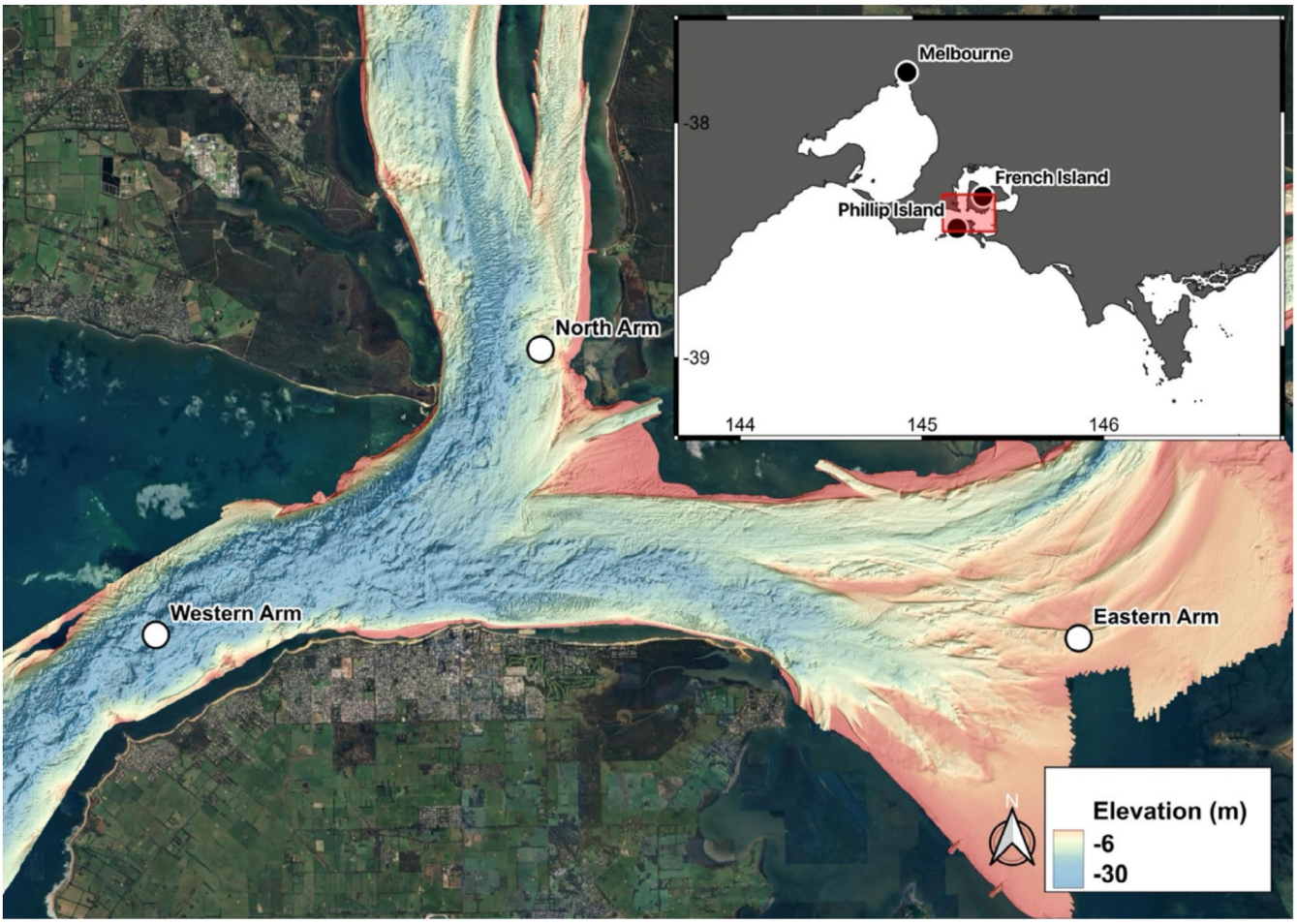

FIGURE 1 | Locations of bryozoan habitats situated in Western Port (~70 km south-east of Melbourne, Australia) and described in the present study in the North Arm and Western Arm, in relation to the previously described bryozoan reefs in Eastern Arm (see Dutka et al. 2022).

TABLE 1 | Summary of surveys undertaken to qualitatively describe bryozoan habitats in the North Arm and Western Arm of Western Port between May 2021 and March 2024.

Location	Date	Latitude	Longitude	Average depth (m)	Imaging method
North Arm	21 May 2021	38°23′46.3″ S	145°15′16.2″ E	13.8	ROV
North Arm	28 Mar 2024	38°23′38.8″ S	145°15′19.1″ E	13.7	ROV
North Arm	29 Mar 2024	38°23′45.2″ S	145°15′12.2″ E	16.0	ROV
North Arm	31 Mar 2024	38°23′38.8″ S	145°15′19.1″ E	10.2	ROV
Western Arm	14 Jan 2022	38°26′48.8″ S	145°10′21.0″ E	17.6	SCUBA Diver
Western Arm	28 Mar 2024	38°26′46.7″ S	145°10′18.1″ E	17.8	ROV

associated biodiversity, with footage recorded using a GoPro Hero 4 and video lights. Due to relatively strong tidal currents at the sites, underwater imaging was restricted to slack tide periods.

Imagery across both sites was reviewed to identify the bryozoan species and the main components of the associated macroscopic biodiversity. Bryozoan taxonomic experts (Drs Phil Bock and Jan Carey) were also consulted to confirm the identification of the bryozoan species present.

3 | Results

A selection of the footage collected is available in the Supporting Information.

The dominant bryozoan species were the multilaminar orange-coloured *Adeonellopsis sulcata* (Milne Edwards, 1836), and purple-coloured *Celleporaria foliata* (MacGillivray, 1888) (P. Bock, pers. comm.), both forming large and robust laminar colonies (Figures 2 and 3). *Adeonellopsis sulcata* dominated

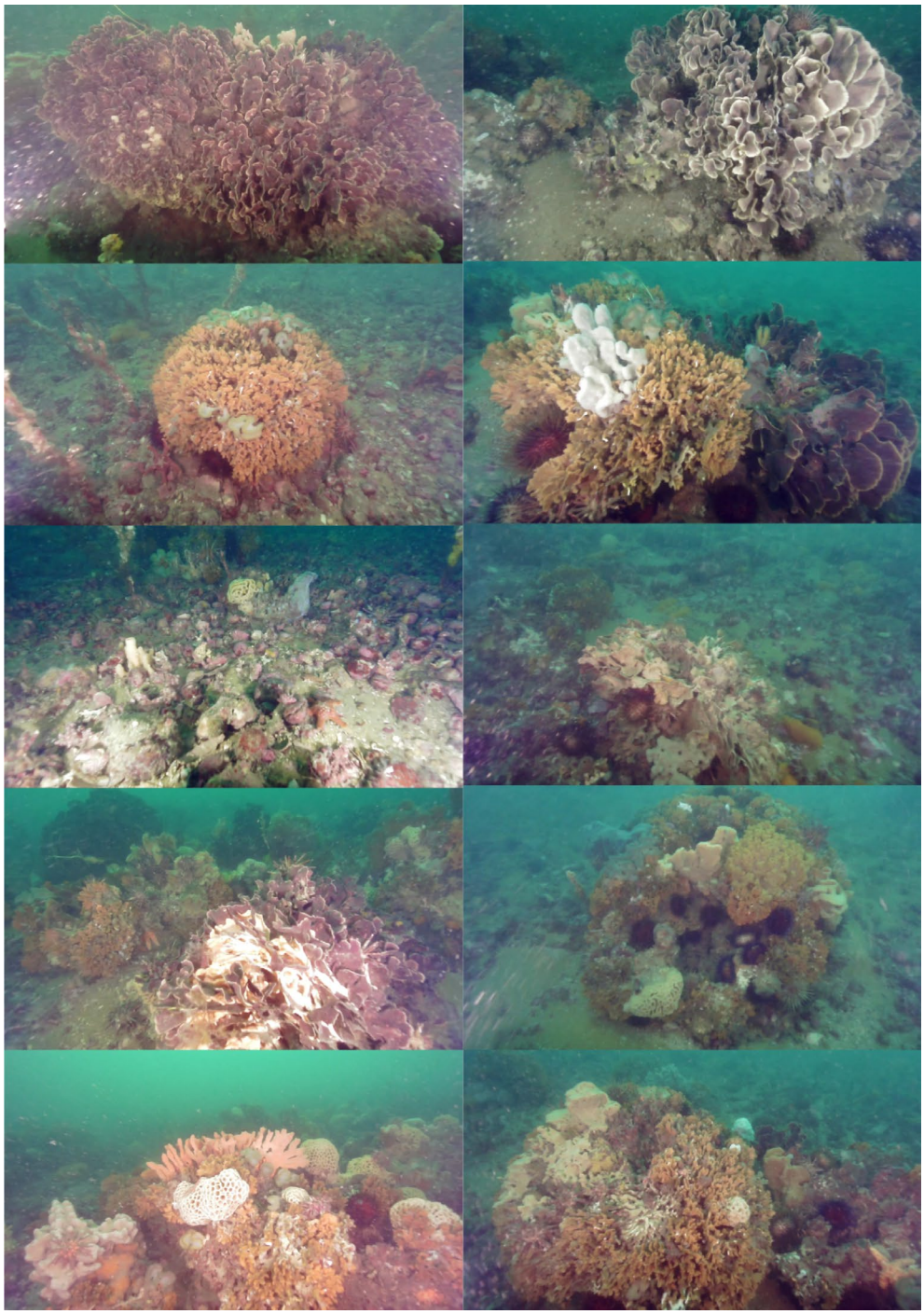

FIGURE 2 | Representative images of the North Arm bryozoan habitat from ROV footage obtained on the 21 May 2021 (left column) and on 28, 29 and 31 March 2024 in the North Arm (right column) in Western Port, Australia. The images showcase the main bryozoan species *Adeonellopsis sulcata* (purple-coloured) and *Celleporaria foliata* (orange-coloured) and associated biodiversity.

the site in Western Arm, which was deeper than the North Arm site. The two species were present in approximately equal proportions in the North Arm. At the North Arm site, the shallower areas generally had more intact, contiguous colonies compared to the deeper areas which had more isolated, smaller bryozoan colonies interspersed with cobbles and finer sediments.

At both sites, many bryozoan colonies were over 50 cm in three dimensions and thus can be reliably classed as habitat-forming. However, the expression of the habitat was not observed in continuous or co-mingled seafloor covering a substantial area and thus the sites are categorised as bryozoan habitat and not bryozoan reef at this time. A wide range of associated biodiversity was observed in the bryozoan habitat. A list of the detected associated biodiversity is provided in Table 2. Sea urchins were most abundant at the North Arm site and brachiopods (lamp shells) were also observed at this site. Red algae and sponge morphotypes were more prominent at the Western Arm site.

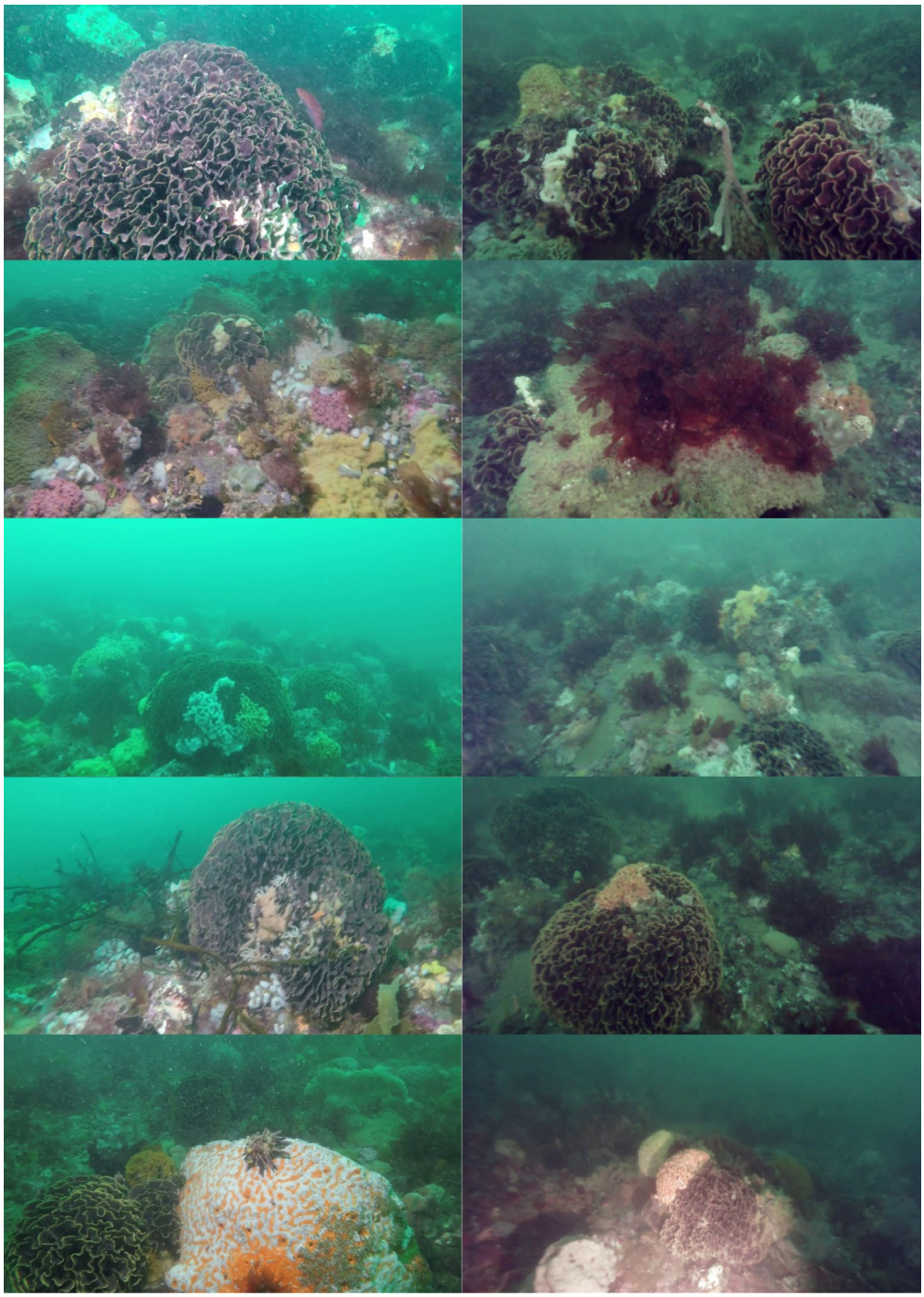

FIGURE 3 | Representative images of the Western Arm bryozoan habitat extracted from the footage recorded during a diver survey on 14 January 2022 (left column) and from ROV footage obtained on 27 March 2024 (right column) in Western Port, Australia. The images showcase the main bryozoan species, *Adeonellopsis sulcata* (purple-coloured) and associated biodiversity.

4 | Discussion

The current paper describes bryozoan habitats additional to those described by Dutka et al. (2022) and provides further insights into the existence of bryozoan habitat in Western Port. Historical accounts from the mud oyster *Ostrea angasi* Sowerby, 1871 dredge fishery indicated the presence in Western Port of bryozoans (termed "corals" at that time and in recreational fisher parlance) from the early 19th century to the early 20th century. However, there were no dedicated investigations until Dutka et al. (2022).

The newly discovered biogenic bryozoan habitats located in both the North Arm and the Western Arm of Western Port reported here are very different to the predominantly delicate foliose colonies reported in Dutka et al. (2022). The North Arm and the Western Arm bryozoan habitats are exposed to relatively stronger tidal currents than those of the Eastern bryozoan reefs. Consequently, the bryozoan habitats of the North Arm and Western Arm are more rounded and robust with thicker plates. As revealed in the underwater imagery obtained, the sites provide habitat for various species, and biodiversity is likely to be much greater when considering the fauna living within the

TABLE 2 | List of some of the taxa associated with bryozoan habitats derived from qualitative examination of imagery (ROV and scuba diving) in the North Arm and Western Arm of Western Port between 2021 and 2024.

Taxon	Examples of representative species, when identification was possible
Sponges	Range of plate, erect, encrusting and seafloor spreading forms
Cnidarians	Feathery hydroids, *Melithaea zimmeri* Kükenthal, 1908, *Anthothoe albocincta* (Hutton, 1879)
Crustaceans	*Paguristes frontalis* (H. Milne Edwards, 1836)
Molluscs	*Mimachlamys asperrima* (Lamarck, 1819), *Haliotis rubra* Leach, 1814, *Pterochelus triformis* (Reeve, 1845)
Serpulid tubeworms	
Non-habitat- forming bryozoans	*Orthoscuticella ventricosa* (Busk, 1852)
Feather stars	*Cenolia trichoptera* (Müller, 1846)
Sea urchins	*Heliocidaris erythrogramma* (Valenciennes, 1846), *Goniocidaris tubaria* (Lamarck, 1816), *Amblypneustes ovum* (Lamarck, 1816)
Sea stars	*Nectria* sp., *Tosia* spp., *Pentagonaster duebeni* Gray, 1847, *Uniophora granifera* (Lamarck, 1816), *Meridiastra gunnii* (Gray, 1840), *Coscinasterias muricata* (Verrill, 1867)
Ascidians	*Pyura* sp., *Sycozoa* sp. *Ritterella* sp., *Phallusia obesa* (Herdman, 1880)
Fishes	*Bovichtus angustifrons* Regan, 1913, *Notolabrus tetricus* (Richardson, 1840), *Caesioperca rasor* (Richardson, 1839), *Pseudogoniistius nigripes* (Richardson, 1850), *Pictilabrus laticlavius* (Richardson, 1840), *Aracana ornata* (Gray, 1838)
Macroalgae	Brown algae (e.g., fucoids), red algae

interstices that are not detectable in imagery. The findings have state, national and international significance and are particularly important for the evaluation of Ramsar ecosystem values.

The North Arm bryozoan habitat is composed of *A. sulcata* and *C. foliata* in approximately equal proportions while at the Western Arm site, *A. sulcata* is most abundant. The differences in bryozoan assemblages between the Eastern Arm, Western Arm and the North Arm are most likely due to differences in the prevailing local environmental factors such as tidal flow, wave energy, water depth, nutrient availability and substrate types. At the North Arm site, the bryozoan habitat in shallower areas is comprised of more intact and contiguous colonies compared to the deeper part of the North Arm where more isolated and smaller bryozoan colonies are found. This difference may reflect a difference in exposure to anchor damage in this area which is frequented by recreational fishers, or natural erosive forces associated with scouring by currents.

Where documented in Australian waters, bryozoan habitats occur at depths of 30 to 425 m (Dutka et al. 2022; Wood et al. 2012). James et al. (2008) described bryozoan-rich shelf sediments composed predominantly of thin branching stalked forms, in Bass Strait and the Tasmanian shelf at depths of down to 400 m. At similar depths, bryozoans have been reported as a major constituent of the Lacepede Shelf fauna in South Australia and exhibit a high diversity (> 200 species) (Hageman et al. 1995). In the Great Australian Bight, bryozoan-rich mounds of Pliocene-Pleistocene origin have been documented at paleo-seafloor depths (i.e., depths at which the mounds originated rather than present-day depths) of ~100 and ~240 m by James et al. (2004).

In contrast to those deeper environments, a Cheilostomatid bryozoan (either *Membranipora aciculata* (Mac Gillivray 1891) or *Conopeum aciculatum* (Mac Gillivray, 1891)) forms buildups comprised of intergrowing bryozoans and serpulids in the shallow (down to 3 m water depth) and hypersaline Coorong Lagoon in South Australia (Bone and Wass 1990). In the Bathurst Channel, where dark tannin-stained surface waters severely restrict light penetration and the presence of fast-growing algae competing against invertebrate species, bryozoans are amongst the characteristic benthic invertebrates dominating space on rock surfaces (Barrett et al. 2007; Edgar et al. 2010). It is unclear whether these bryozoans can be classed as habitat-forming as defined by the criteria used in the present study (Barrett et al. 2007; Edgar et al. 2010). The presence of bryozoan habitats in Western Port is likely due to high water column turbidity reducing light penetration and limiting competition with macroalgae (Dutka et al. 2022). In addition, relatively strong tidal currents, like those exhibited in Western Port, have elsewhere been associated with relatively high bryozoan abundance (Cuffey 1974; Stebbing 1971; Wood et al. 2012).

The bryozoan habitats described here are associated with a range of species, in agreement with findings from other studies suggesting that sponges, molluscs, echinoderms, cnidarians, arthropods and fishes are amongst the most frequently recorded taxa associated with habitat-forming bryozoans (Mello et al. 2021; Wood et al. 2012). Bryozoan colonies provide attachment substrate for larval stage species, food, shelter from currents, as well as concealment from predators for both adult and larval stage organisms (Dutka et al. 2022). The methods used here only allowed identification of the epifaunal macrofauna

associated with bryozoan habitats. More research is needed to identify other types of species benefiting from the presence of habitat-forming bryozoans, including smaller species not detectable with ROVs.

Locally and globally, an understanding of the ecology of habitat-forming bryozoans is lacking (Mello et al. 2021; Wood and Probert 2013). Bryozoan habitats in Western Port are difficult to detect and sample due to turbid waters and strong currents, which complicate access to the sites for imaging and physical sampling. Detailed acoustic mapping is needed to determine the vertical and horizontal extent of the bryozoan habitats.

Threats to bryozoan habitats across the world have been identified, including burial due to sediment smothering, breakage and mechanical destruction during severe weather events, because of bottom fishing or other human activities, mortality or inhibited growth, settlement or survival due to anoxic events, low-salinity shock, pollution in general and sewage in particular, and due to introduced species (Bradstock and Gordon 1983; Cranfield et al. 2003; Mello et al. 2021, 2023; Wood et al. 2012). Bryozoan habitats can be slow to recover from disturbances and there is evidence that physical impacts to underlying substrate may be irreversible (Cranfield et al. 2004; Grange et al. 2003; Mello et al. 2021). More research is needed to further understand the specific risks to Western Port bryozoan habitats from climate change, recreational fishing activity, sediment processes, industrialisation and commercial and passenger shipping operations.

Author Contributions

Elodie C. M. Camprasse: visualization, writing – original draft, writing – review and editing. **Adrian J. Flynn:** conceptualization, investigation, methodology, writing – review and editing. **Travis L. Dutka:** conceptualization, methodology, project administration, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Underwater imagery collected in Western Port showing bryozoan habitats and associated biodiversity. URL: https://doi.org/10.6084/m9.figshare.28510361.v3.