Identification and mapping of shallow-water (<30 m) animal-dominated habitats in the Wellington Region

Valerio Micaroni, Francesca Strano, James Bell

Victoria University of Wellington

Project Report for the Greater Wellington Regional Council

October 2023

Table of Contents

Executive summary

This project aimed to characterize and map shallow animal-dominated habitats (<30 m depth) in the Wellington Region, New Zealand. Surveys were conducted using ROVs, SCUBA diving, and incorporating citizen science observations across four locations: Wellington Harbour, Wellington South Coast, Wellington West Coast, and Kāpiti Coast. The study revealed extensive sponge-dominated communities in Wellington Harbour at 7-17 m depth, particularly beds of the massive sponge *Suberites australiensis*. Other notable habitats included brachiopod beds of *Magasella sanguinea* and polychaete beds dominated by *Owenia petersenae*. On the open coast, diverse sponge gardens were found at 15-30 m depth, formed by large arborescent and massive sponges. *Ecionemia alata* was a prominent habitat-forming sponge at multiple sites. These sponge-dominated communities exhibit high biodiversity and ecological significance. Wellington Harbour showed greater anthropogenic impacts compared to the open coast, particularly in the form of marine litter and habitat alterations. Recommendations include further research to characterize biodiversity, assess ecosystem services, and quantify environmental impacts affecting these habitats in the Wellington Region. The significant ecological value of the discovered communities underscores the need for targeted monitoring and management strategies to ensure their conservation.

1. Introduction

Biodiversity in urban areas is increasingly recognised as a crucial component in the enhancement of human well-being (Reyes-Riveros et al., 2021). In addition to offering ecosystem services, biodiversity also plays a role in supporting climate change adaptation and fostering environmental education programs (Dearborn and Kark, 2010). To fully harness the benefits of biodiversity and its ecosystem functions in urban areas, effective management is important, especially considering the elevated levels of anthropogenic stressors generally found in urban environments (Marselle et al., 2021).

Marine ecosystems in urban areas are recognized as valuable sources of goods, including food, raw materials, and pharmaceutical products. They also play a crucial role in regulating local air quality, enhancing carbon sequestration, mitigating extreme weather events, and improving wastewater treatment (Lowe et al., 2022). Furthermore, these urban marine ecosystems provide cultural services, such as recreational opportunities, promoting mental and physical health, attracting tourism, and offering spiritual experiences and a sense of place (Lowe et al., 2022).

Animal-dominated habitats, often referred to as 'animal forests', are megabenthic communities where sessile invertebrates like sponges, cnidarians, and bryozoans dominate (Rossi et al., 2017). These communities primarily consist of suspension feeders, which exhibit high structural complexity. As a result, they serve as important habitats, feeding grounds, and nursery areas for many organisms, ultimately enhancing biodiversity (Rossi et al., 2017; Bell et al., *in press*). In addition, suspension feeders are known for their ability to filter substantial volumes of water, playing a key role in transferring nutrients from the water column to the benthos and influencing the overall water quality in aquatic ecosystems (Ostroumov, 2005; Bell et al., *in press*).

In temperate seas, animal-dominated habitats are mostly found at mesophotic depths (between 20 and 150 m), where low-light conditions allow animals to outcompete algae (Bell et al., 2022). Importantly, these habitats are typically comprised of slow-growing and long-lived organisms, making them particularly susceptible to environmental disturbances (Micaroni et al., 2021). However, under specific local environmental conditions generally characterised by reduced light, animal-dominated assemblages can also be found at shallower depths (<30 m) (Bell and Barnes, 2002; Micaroni et al., 2021). For example, Lough Hyne Marine Nature Reserve (Ireland) supports diverse sponge-dominated communities from 12 to 40 meters, because of sheltered conditions and high turbidity levels (Bell and Barnes, 2002; Micaroni et al., 2021). Similarly, in Fiordland National Park (New Zealand), the fiords exhibit specific light and salinity conditions that support mesophotic communities at only 5 m (Kregting and Gibbs, 2006; Harris et al., 2021; Bell et al., 2022). Baseline data for animal-dominated habitats is largely absent on a global scale at both mesophotic and shallow depths (Thurstan et al., 2017; Bell et al., 2022).

The Wellington Region is known for its rich terrestrial biodiversity and indigenous forests (Dymond and Shepherd, 2004), however, there is limited data on the distribution of subtidal habitats for this urban area (Rowden et al., 2012). Consequently, there is urgent need to characterise and map these subtidal ecosystems to ensure effective management and conservation of urban biodiversity and ecosystem functioning in the Wellington Region.

The primary objectives of this project were to characterize the types and distribution of shallow animal-dominated habitats (<30 m) in the Wellington Region, including Wellington Harbour, Wellington South, and West Coast. Additionally, we integrated scientific surveys carried out by SCUBA diving and by deploying Remotely Operated Vehicle (ROVs) with historical citizen science-based observations to identify areas of ecological significance. The project also aimed to identify and quantify sources of environmental disturbance (e.g. substrate modifications, presence of marine litter, sedimentation levels) affecting these habitats, and provide recommendations for the management of these ecosystems.

2. Methods

2.1 Study sites

In total, qualitative surveys were carried out at 137 stations across 14 sites within four locations in the Wellington Region: Wellington Harbour (WH), Wellington West Coast (WWC) and Wellington South Coast (WSC) and Kāpiti Coast (KAC) (Fig. 1; Tab. 1).

WH is characterised by elevated levels of sedimentation, primarily originating from the Hutt River estuary (Carter 1977; Gall et al., 2022), situated in the northern region of WH. WH experiences relatively sheltered conditions from the oceanic swell and reduced tidal currents (Carter and Lewis, 1995; Walters et al., 2010). The marine substrate of the area investigated consisted mainly of pebbles or rocky reefs in the initial 2–5-metre depth zone. Beyond this zone, the topography changed to a sandy-muddy substrate, often mixed with shell debris, which gradually decreased towards deeper areas. This gradient eventually gives way to large areas of fine mud (mainly of poorly sorted silty pelites with an average carbonate content of 10%), which characterises the flat bottom of WH (~18–20 m) (van der Linden, 1967). In WH, we characterised 117 sampling stations (~6500 m^2) within six sites: Eastbourne (52 stations, from Webb Point to Cap Bay and including Mākaro/Ward Island), Evans Bay (25 stations, including Shelly Bay, Shark Bay and Whale's Bay), Kaiwharawhara (16 stations), Petone (11 stations, an area comprised between Petone Wharf and Ngauranga), Eastern Miramar (9 stations, including Mahanga Bay and Point Gordon), and Kau Bay (4 stations) (Fig. 2; Tab. 1). The average depth range of the surveys in WH was between 4.7 m (Eastbourne) and 15.1 m (Evans Bay).

The sites investigated on the WWC, WSC and KAC experience strong tidal currents (Walters et al., 2010), and low to moderate sedimentation levels (originating primarily from rivers, estuaries, and inlets present along the Kāpiti Coast and the Te Awarua-o-Porirua Harbour) (de Lange, 2014). The sites on the WSC also experience frequent storms and oceanic swell (Carter and Lewis 1995). On the WWC, we characterised 15 stations (~3100 m^2) within five sites (Mana Island, Pukerua Bay, Ohau Point, Makara and Hunter's Bank), on the WSC we characterised four stations within two sites (Shark Tooth and Thoms Rocks), and on the Kāpiti Coast we characterised one station

(Tokomāpuna Aeroplane Island, 40 m). The average depth range of the sites surveyed on the WWC, WSC and KAC was between 19 and 40 m (Fig. 3; Tab. 1).

All the sites surveyed in the present study were located outside marine reserves or marine protected areas.

Table 1. Details of sampling activity.

			Survey type		Observation method			
Area/Site	**Sampling Stations**	**Avg Depth (m)**	**Transects**	**Point surveys**	**ROV**	**SCUBA**	**Citizen science/ Other projects**	**Approximate survey area (m^2)**
Wellington Harbour (WH)								
Eastbourne	52	4.7	8	44	49	2	1	1816
Eastern Miramar	9	13.8	7	2	7	1	1	665
Evans Bay	25	15.1	21	4	21	4	0	1795
Kaiwharawhara	16	12.4	15	1	15	1	0	994
Kau Bay	4	14.4	4	0	4	0	0	98
Petone	11	13.1	11	0	10	1	0	1160
Wellington South Coast (WSC)								
Shark Tooth	1	29.0	0	1	0	1	0	200
Thoms Rocks	3	27.7	0	3	0	3	0	600
Wellington West Coast (WWC)								
Hunter's Bank	1	30.8	0	1	0	0	1	150
Makara	1	19.6	0	1	0	0	1	150
Mana Island	9	22.0	4	5	3	6	0	1605
Ohau Point	1	25.9	0	1	0	0	1	150
Pukerua Bay	3	19.0	0	3	2	0	1	140
Kāpiti Coast (KAC)								
Kāpiti Island	1	40.0	0	1	0	0	1	150
Total	**137**		**70**	**67**	**111**	**19**	**7**	**9672**

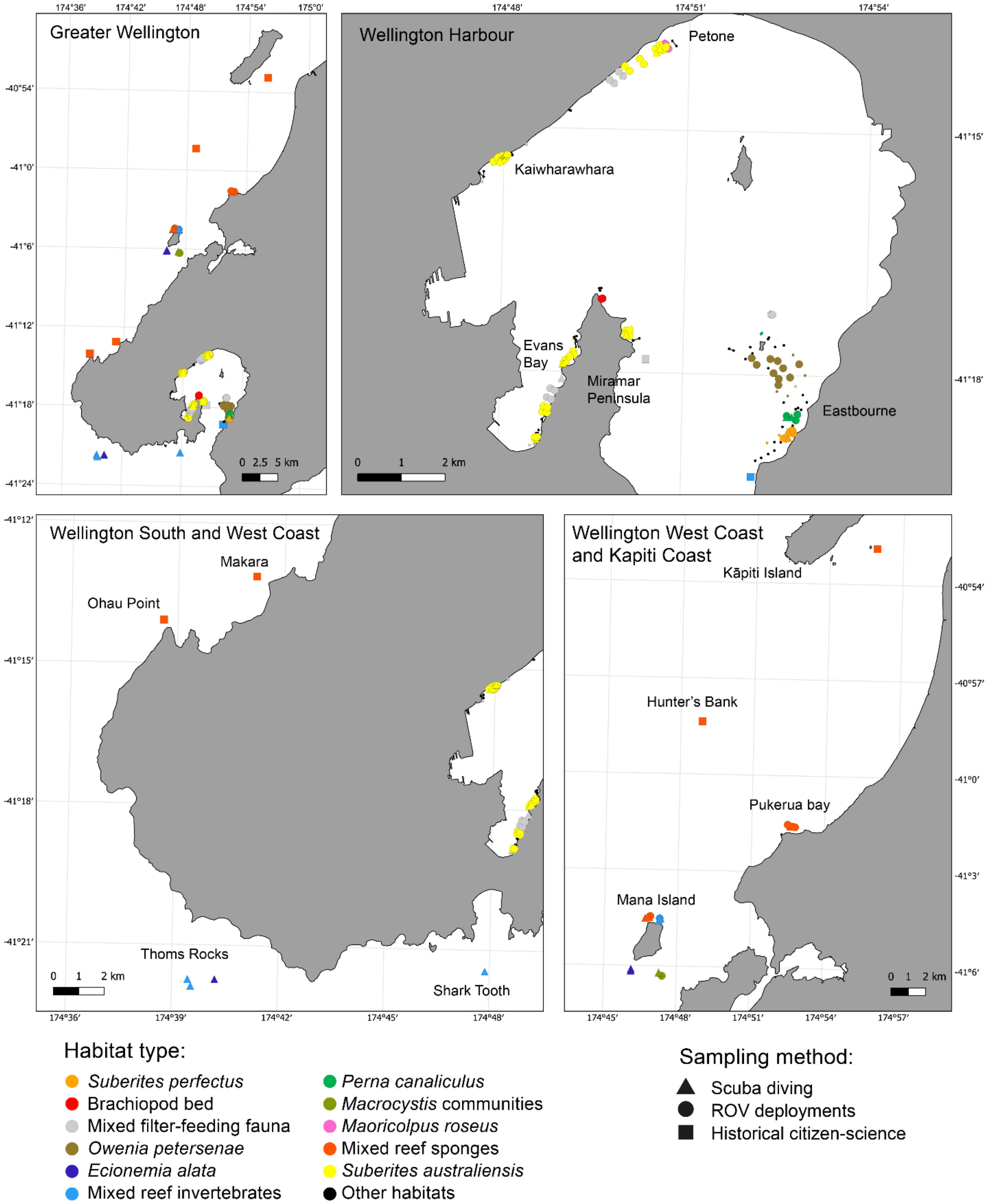


Figure 1. Map of the study areas. Sampling stations with a habitat quality score below six were represented with smaller points (see section 2.3.3).

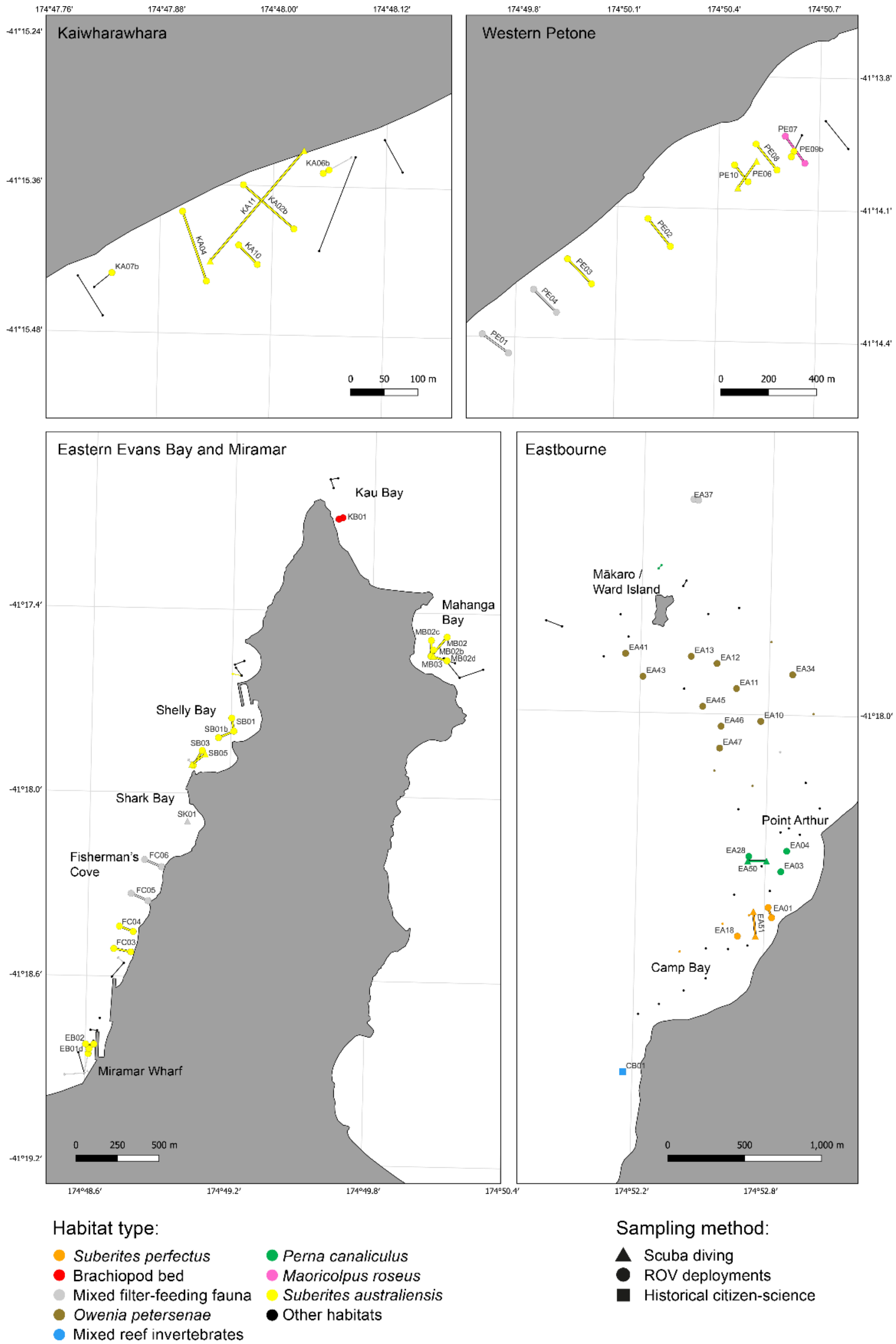


Figure 2. Details of the surveyed stations in Wellington Harbour (WH). Sampling stations with a habitat quality score below six (see section 2.3.3) were represented with smaller points. For visual clarity, station names are only reported for stations scoring six or above.

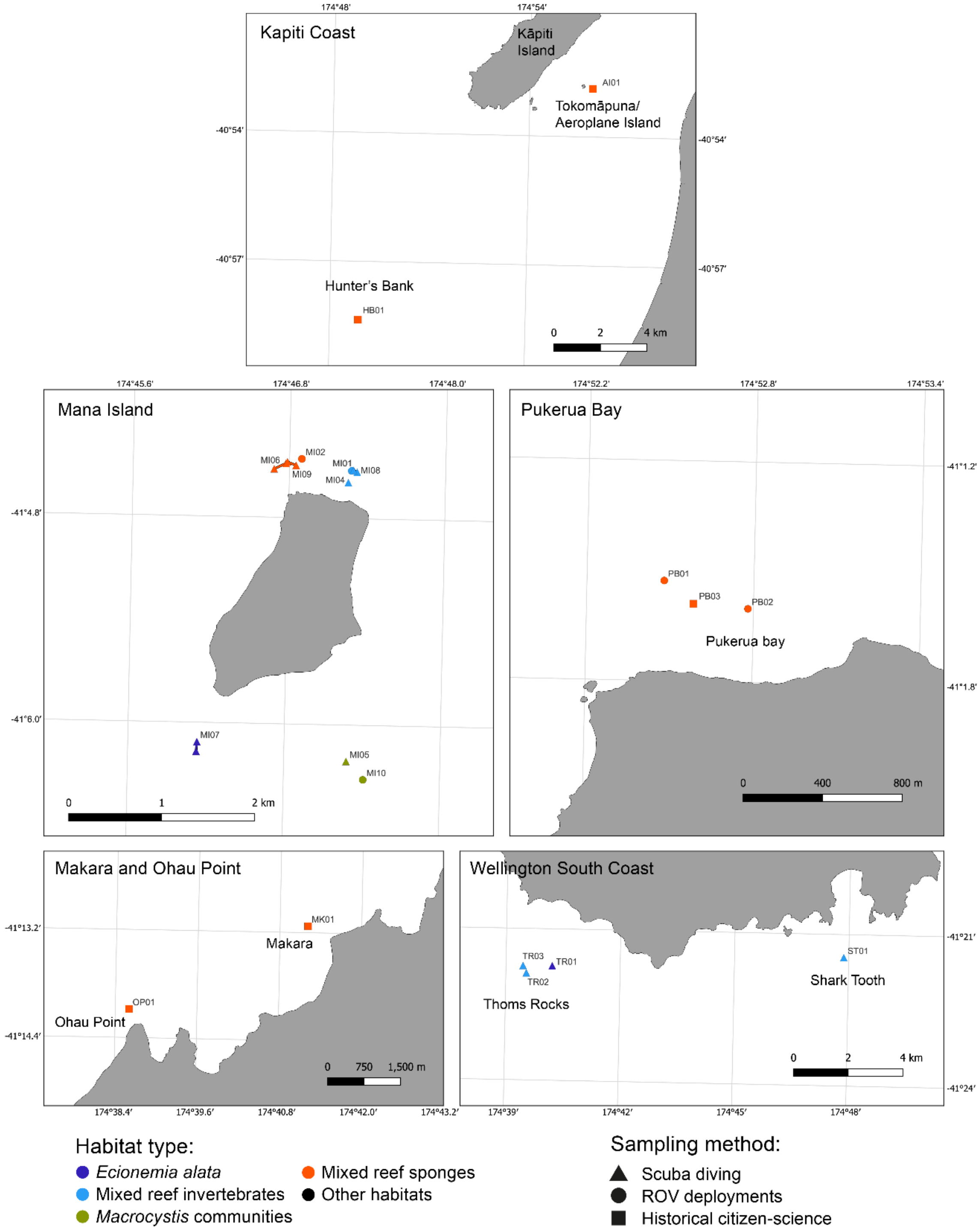


Figure 3. Details of the surveyed stations on the Wellington South Coast (WSC), Wellington West Coast (WWC) and Kāpiti Coast (KAC). Sampling stations with a habitat quality score below six (see section 2.3.3) were represented with smaller points. For visual clarity, station names are only reported for stations scoring six or above.

2.2 Observation methods

Our approach to mapping and characterising habitats in the Wellington Region was designed to optimize effort and resource utilization. We implemented surveys using three distinct methodologies:

- **ROVs:** ROVs were deployed at 106 stations in WH and five stations on the WWC for efficient exploration of large areas, repeated surveys, and reducing risks associated with diving in areas with heavy boat traffic and strong currents. The majority of surveys were conducted using a Deep Trekker DTG2, also known as "SAL", and a select few were done with a Chasing M2 Pro, (SAL II). Both ROVs were equipped with 4k cameras, LED lights, and a laser scale (2.5 cm for SAL and 10 cm for SAL II). These ROVs were solely used for collecting semi-quantitative and qualitative data.
- **SCUBA Diving:** Diving was utilised to gather high-quality qualitative data from selected sites (nine stations in WH, four on the WSC, and six on the WWC), including video transects and photoquadrats. Images and video footage were captured using a Sony a7r II (42.4 MP, 4k videos) with a Tamron 20mm f/2.8 lens and a Sony Rx100 MkV (20 MP). Photoquadrats were taken using two Ikelite DS160 strobes, while video recordings were acquired with two PowerPro 100 video lights (Diving Torches Italy, 6000 lumen each). Organisms were also collected during dives, as needed, for taxonomic identification.
- **Citizen Science:** We also incorporated historical citizen science-based observations of shallow, animal-dominated habitats by contacting local diving clubs, shops, and associations via email. Specifically, we requested historical photographic or video material and site coordinates of locations dominated by benthic animals. We received responses from the Wellington Underwater Club (WUC, Dr. Nicole Miller), Dive Wellington (Dave Drane), and Ghost Divers NZ (Rob Wilson). Dr. Nicole Miller also provided videos and metadata of explorations conducted with the WUC, which were subsequently included in our dataset. Importantly, these citizen science-based observations allowed us to add georeferenced information on animal-dominated habitats for two stations in WH, four stations on the WWC, and one station on the KAC.

2.3 Survey types

Using both ROV and SCUBA diving, we conducted a range of qualitative and quantitative surveys:

- **Qualitative surveys** (n = 97) were undertaken primarily to explore new locations and map habitat extents. These surveys yielded information on key structuring species, impacts, and associated biodiversity.
- **Quantitative surveys** (n = 20) were carried out to characterise the discovered habitats. We utilized photoquadrats (0.25 m² each, n = 10 for each site) to estimate the percentage coverage of the primary benthic organisms. In the case of photoquadrats on the WWC, WSC, and KAC, we employed a frameless method but maintained a constant distance between the camera and the substrate to cover an area close to 0.25 m². This methodology was necessitated by the need to reduce the quantity of gear transported underwater, due to challenging conditions, including strong tidal currents, significant depth, and limited bottom times. Additionally, 30-meter video transects were employed to estimate the density of key structuring species. These video transects were performed with the help of a 30-meter open reel measuring tape, ensuring the camera was kept perpendicular to the substrate and at a constant height. The area covered by the video transect was calculated from the footage using the tape measure as a reference scale. This measurement varied in accordance with the substrate's morphology, covering approximately 30 m² in WH and 38 m² on the WWC.
- **Semi-quantitative surveys** (n = 20) were performed specifically in WH, along a depth gradient, in order to characterise the depth range of habitats and principal structuring species at various sites. Transects were carried out for 70–150 m, keeping the ROV about 50 cm from the substrate and noting the depth. The categories used for these surveys were: Rare - presence of one or very few; Sparse - 1-5% coverage; Abundant - over 5% coverage.

Surveys were also classified based on the number of geographic coordinates associated with them, specifically:

- **Transect surveys.** Here, we recorded both the start and end points (66 stations in WH, and four on the WWC). Efforts were made to maintain a consistent bearing during transects as much as possible. For ROV surveys, the starting point was determined using a smartphone's integrated GPS and the Navionics App, while the end point was estimated based on the survey bearing, the length of the ROV cable utilized, and the final depth. Some deployments were divided into two or more sampling stations in cases where either the survey's bearing or the habitat changed. For SCUBA surveys, start and end points were logged using the GPS integrated into a diving computer (Garmin Descent MK2). There were instances where a single ROV deployment was split into two separate transects, and treated as independent sampling stations. This division was implemented in two circumstances: 1) when the ROV trajectory underwent a significant and intended directional change during the deployment; and 2) when a single transect showed different habitat types in distinct sections. The subdivision of transects facilitated the spatial representation of habitats on a map and to facilitate future efforts related to habitat delimitation.
- **Point surveys.** For these, we only recorded one georeferenced point (51 stations in WH, four on the WSC, 11 on the WWC and one on the KAP). This type of survey was employed when exploring a relatively confined area (~15 m^2) of the seabed, moving haphazardly around a point (e.g., stations EA01–EA49), or when the end point could not be estimated. The latter situation arose in cases such as diving at Thoms Rock, where strong tidal currents displaced us significantly beyond the ending point during the ascent.

2.3 Analyses

2.3.1 Photoquadrat analysis

We estimated the percentage cover of the dominant sessile organisms from the photoquadrats (10 randomly selected from 8 stations across the WSC and WWC, n = 80 in total) using a random point count method in Coral Point Count with Excel extensions (CPCe; Kohler and Gill, 2006). This software randomly distributes points over an image, and the user manually identifies the organism beneath each point. For each photograph, we used 120 randomly generated points (equating to 480 points/m^2) as this quantity is sufficient to reach a species accumulation curve plateau, as found in similar habitats by other works of the authors (Harris et al., 2021; Micaroni et al., 2021). When reliable identification was not possible, we made classifications at the taxon or OTU (operational taxonomic unit) level. OTUs are known for their effectiveness in identifying distribution patterns of benthic invertebrates (Brind'Amour et al., 2014) and marine sponges (Strano et al., 2020), while also avoiding the need for destructive sampling. After preliminary analyses of videos and photos, we assigned 36 categories of benthic organisms (Tab. S1) to a CPCe codefile. These subcategories were grouped under eight higher taxonomic ranks, including Sponges, Bryozoans, Cnidarians, Ascidians, Polychaetes, Algae, and Biological Matrix (no assigned subcategories). Biological matrix was used to categorise a diverse group of small and tightly packed organisms unidentifiable from the camera resolution, such as hydroids, bryozoans, small ascidians, and turf-forming algae (Bell et al., 2022). One analyst conducted all CPC image analyses to maintain consistency. Information on the OTUs, accompanied by example images, is provided in the result section (Table S1).

2.3.2 Video transect analysis

We analysed video transects in VLC media player. For WH transects (five stations, three replicates of 30-m transect per station), we recorded the number of specimens for 10 habitat-forming species per transect to estimate density (organisms/m^2). These included seven sponge species, two bivalves (*Atrina zelandica* and *Perna canaliculus*), and one brachiopod (*Magasella sanguinea*).

For the WWC transects (four stations around Mana Island, three replicates of 30-m transect per station), we recorded both the number and the maximum length of 10 habitat-forming sponges to estimate density (sponges/m^2) and size classes (maximum size in any direction measured using the transect tape as a reference scale).

2.3.3 Habitat classification (CMECS)

We used the Coastal and Marine Ecological Classification Standard (CMECS) to classify and characterize the ecological and physical attributes of the surveyed stations. The CMECS is a comprehensive framework developed by the U.S. National Oceanic and Atmospheric Administration (NOAA). It classifies habitats based on four components: water column, geoform, substrate, and biotic communities, each further subdivided into categories and subcategories for detailed descriptions.

All stations surveyed during this study, regardless of the survey method and type (including citizen-science data), were classified using the CMECS biotic classification. We found 29 biotic communities in total, 5 of which were already listed in the original biotic list, and 24 were newly created based on the habitats found in the Wellington Region. We then uploaded the classified points and transects into QGIS to visualize the distribution of the most critical habitats in the Wellington Region. Only primary biotic communities/habitats were included in the GIS analysis.

Each station was assigned a qualitative habitat quality score ranging from 0 to 10, using expert judgement based on a set of predefined criteria (Barnard and Boyes, 2013). Specifically, these criteria included: 1) density/percent cover of key structuring species like habitat-forming sponges, bivalves, and brachiopods, which provide biogenic habitat; 2) overall community diversity; 3) presence of sensitive, rare, or noteworthy species; 4) complexity of the substrate, with habitats like shell rubble considered more complex than simple soft bottoms; and 5) degree of anthropogenic impacts evident from debris and substrate alteration. Structured expert judgement incorporates the evaluated contribution from each of these objective metrics to provide a holistic habitat quality score on a continuous numerical scale. Lower scores indicate a degraded habitat with low structural complexity, diversity, and ecosystem integrity. In contrast, higher scores suggest a healthy, biodiverse, and productive habitat. While subjective, this expert judgement approach synthesises different information to assess habitat quality in a consistent manner. The limitations of this approach include the potential biases of individual assessors, so results must be interpreted with caution (Elliott et al., 2018).

2.3.4 Marine litter

The abundance and composition of marine litter were recorded from video transects at 60 stations in Wellington Harbour, and four stations around Mana Island, providing a visual survey area of 4400 m^2 in total. Litter items were classified into the following categories: plastic objects smaller or larger than 35 cm, fabric, cans, ropes, fishing gear, car parts, glass/ceramics, concrete, and large iron objects (> 100 cm). The density of litter items per 100 m^2 was calculated by dividing the counts by the estimated visual survey area covered in each video transect.

2.3.5. Statistical analysis

Permutational multivariate analysis of variance (PERMANOVA, Anderson, 2001) based on Bray-Curtis dissimilarities was employed to analyse differences in benthic community structure. The models were run using 9999 unrestricted permutations of raw data, facilitated by the R package vegan (Oksanen et al., 2022). To minimise the influence of the most abundant groups, cover data of different benthic taxa were log (x+1) transformed. The Benjamini-Hochberg procedure (Benjamini and Hochberg, 1995) was applied to correct *p*-values for all multiple comparisons, reducing the risk of Type I errors. Differences in multivariate assemblages were visually represented using non-metric multidimensional scaling (nMDS) based on Bray-Curtis dissimilarities.

All statistical analyses were conducted in R (version 4.3.1, R Core Team, 2013), with all plots generated using the R package ggplot2 (Wickham, 2016).

3. Results

3.1 Wellington Harbour (WH)

3.1.1 General overview

Wellington Harbour is largely dominated by soft-bottom habitats. Biologically and ecologically rich zones occur near the coastline at depths between 7 and 17 m. Here, biogenic substrate - largely composed of mollusc shell rubble - facilitates the proliferation of various epibenthic species, including but not limited to sponges, solitary ascidians, bivalves, brachiopods, and polychaetes.

In our study, we identified 23 distinct types of CMECS biotic communities within Wellington Harbour, with seven of these representing high-value animal-dominated communities. These communities are represented within two major CMECS biotic classes: Attached Fauna and Soft Sediment Fauna. Within the Soft Sediment Fauna class, communities of Brachiopod bed, Mixed filter-feeding fauna, *Maoricolpus roseus*, *Owenia petersenae*, and *Suberites australiensis* were identified. In the Attached Fauna class, we discovered communities of *Perna canaliculus* and *Suberites perfectus* (Fig. 2; Tab. S2).

On soft-sediments, sponges emerge as the dominant structuring species in WH, where several soft-sediment sponge beds are found. The most common sponge species was *Suberites australiensis*, a massive potato-shaped sponge that can grow up to about 40 cm in diameter and can form dense sponge beds in some areas (with up to 19 sponges per m^2). In other locations such as Petone and Fisherman's Cove, *S. australiensis* shares its dominance with a variety of other sponges (i.e., *Crella incrustans*, *C. affinis*, *Ciocalypta penicillus*, *Aaptos globosa* and branching sponges from the family Callispongiadae), filter-feeders like the horse mussel *Atrina zelandica*, the brachiopod *Magasella sanguinea*, the tower shell *Maoricolpus roseus*, solitary ascidians, and suspension feeders such as sabellid polychaetes. These communities were called "Mixed filter-feeding fauna" (Fig. 2; Tab. S2).

Table 2. CMES biotic communities found in this study. In Location: WH, Wellington Harbour; OC, Open Coast (WSC, WWC and KAC).

Biotic Subclass	Biotic Group	Biotic Community	New	Location
Benthic Macroalgae	Canopy Forming Algal Bed	*Macrocystis* Communities		WH/OC
Benthic Macroalgae	Canopy Forming Algal Bed	*Undaria pinnatifida*	✓	WH
Benthic Macroalgae	Filamentous Algal Bed	*Adamsiella*	✓	WH
Benthic Macroalgae	Filamentous Algal Bed	Mixed filamentous macroalgae	✓	OC
Benthic Macroalgae	Filamentous Algal Bed	Red filamentous algae	✓	WH/OC
Benthic Macroalgae	Sheet Algal Bed	Mixed macroalgae	✓	WH/OC
Benthic Macroalgae	Sheet Algal Bed	Red algae	✓	WH/OC
Benthic Macroalgae	Sheet Algal Bed	*Ulva*	✓	WH
Benthic Macroalgae	Turf Algal Bed	Mixed Algal Turf Communities		WH
Attached Fauna	Attached Anemones	*Anthothoe albocincta*	✓	OC
Attached Fauna	Attached Anemones	*Corynactis australis*	✓	OC
Attached Fauna	Attached Mussels	*Perna canaliculus*	✓	WH
Attached Fauna	Attached Sponges	Encrusting and low-profile sponges	✓	WH
Attached Fauna	Attached Sponges	*Suberites perfectus*	✓	WH
Attached Fauna	Diverse Colonizers	Mixed Algal Turf Communities		WH
Soft Sediment Fauna	Brachiopod Bed	Brachiopod bed	✓	WH
Soft Sediment Fauna	Diverse Soft Sediment Epifauna	Mixed filter-feeding fauna	✓	WH
Soft Sediment Fauna	Larger Deep Burrowing Fauna	Mixed burrowing fauna	✓	WH
Soft Sediment Fauna	Mobile Mollusks on Soft Sediments	*Maoricolpus roseus*	✓	WH
Soft Sediment Fauna	Small Tube Building Fauna	Mixed tube-building polychaetes	✓	WH
Soft Sediment Fauna	Small Tube Building Fauna	*Owenia petersenae*	✓	WH
Soft Sediment Fauna	Sponge Bed	Mixed soft-sediment sponges	✓	WH
Soft Sediment Fauna	Sponge Bed	*Suberites australiensis*	✓	WH
Soft Sediment Fauna	Tunicate Bed	Solitary ascidian bed	✓	WH
Mat Film Forming Microbes	Microphytobenthos	Diatom Felt		WH
Mat Film Forming Microbes	Microphytobenthos	Microbial Stain		WH
Shallow Mesophotic Coral Reef Biota	Mixed Shallow Mesophotic Coral Reef	*Ecionemia alata*	✓	OC
Shallow Mesophotic Coral Reef Biota	Mixed Shallow Mesophotic Coral Reef	Mixed reef invertebrates	✓	OC
Shallow Mesophotic Coral Reef Biota	Mixed Shallow Mesophotic Coral Reef	Mixed reef sponges	✓	OC

We also observed soft sediment sites hosting communities dominated by different organisms. Notably, we found beds of the filter-feeding gastropod *Maoricolpus roseus*, comprising hundreds of individuals per square meter, both living and deceased, embedded or laying on the sand, respectively. These gastropods further act as a secondary substrate and are colonised by sponges. Additionally, brachiopod beds of *Magasella sanguinea* with a density of hundreds of individuals per m^2 were located in Kau Bay. *Owenia petersenae* polychaete beds with a density of thousands of individuals per m^2 were identified in the shallow (4–6 m) region between Ward Island and Eastbourne (Fig. 2; Tab. S2).

Rocky substrates in WH, which encompass rocky reefs and cobble fields, are predominantly restricted to the first few meters of water. They are largely colonised by brown algae communities, specifically *Carpophyllum* spp. and *Macrocystis pyrifera*, as well as sea-urchin barrens. Despite this, we identified two animal-dominated communities in Eastbourne: a *Suberites perfectus* bed, marking the southernmost known occurrence of this species, and a zone dominated by large specimens (10–20 cm) of *Perna canaliculus*, known as the New Zealand green-lipped mussel (Fig. 2; Tab. S2).

3.1.2 Eastbourne

Eastbourne exhibits a mosaic of habitat, with nearshore areas predominantly characterized by small boulders and offshore areas characterised by sand. Four notable biotic communities were found in some of the stations at this site: *Owenia petersenae*, *Perna canaliculus*, *Suberites perfectus* and mixed reef invertebrate community. Other stations, however, exhibited less ecological diversity, mainly presenting bare sand and small boulders covered with *Ulva* and other ephemeral algae.

A bed of *Suberites perfectus* was identified on small boulders in the rocky area north of Camp Bay (primarily within stations EA01, EA51, EA18, and intermittently present in four other stations). The sponge density at station EA51 averaged 12.6±6.9 sponges/m^2 (Fig. 4). The *S. perfectus* bed, which coexists with *Ulva* and other ephemeral macroalgae, covers an approximate area of 0.02–0.04 km^2 (Fig. 2; Tab. S2).

Approximately 200 m north of the *S. perfectus* bed, south of Arthur Point, we found a *Perna canaliculus* bed located on small boulders intermixed with macroalgae, primarily *Undaria pinnatifida* (stations: EA03, EA04, EA28, and EA50). The green-lipped mussel density in EA51 was

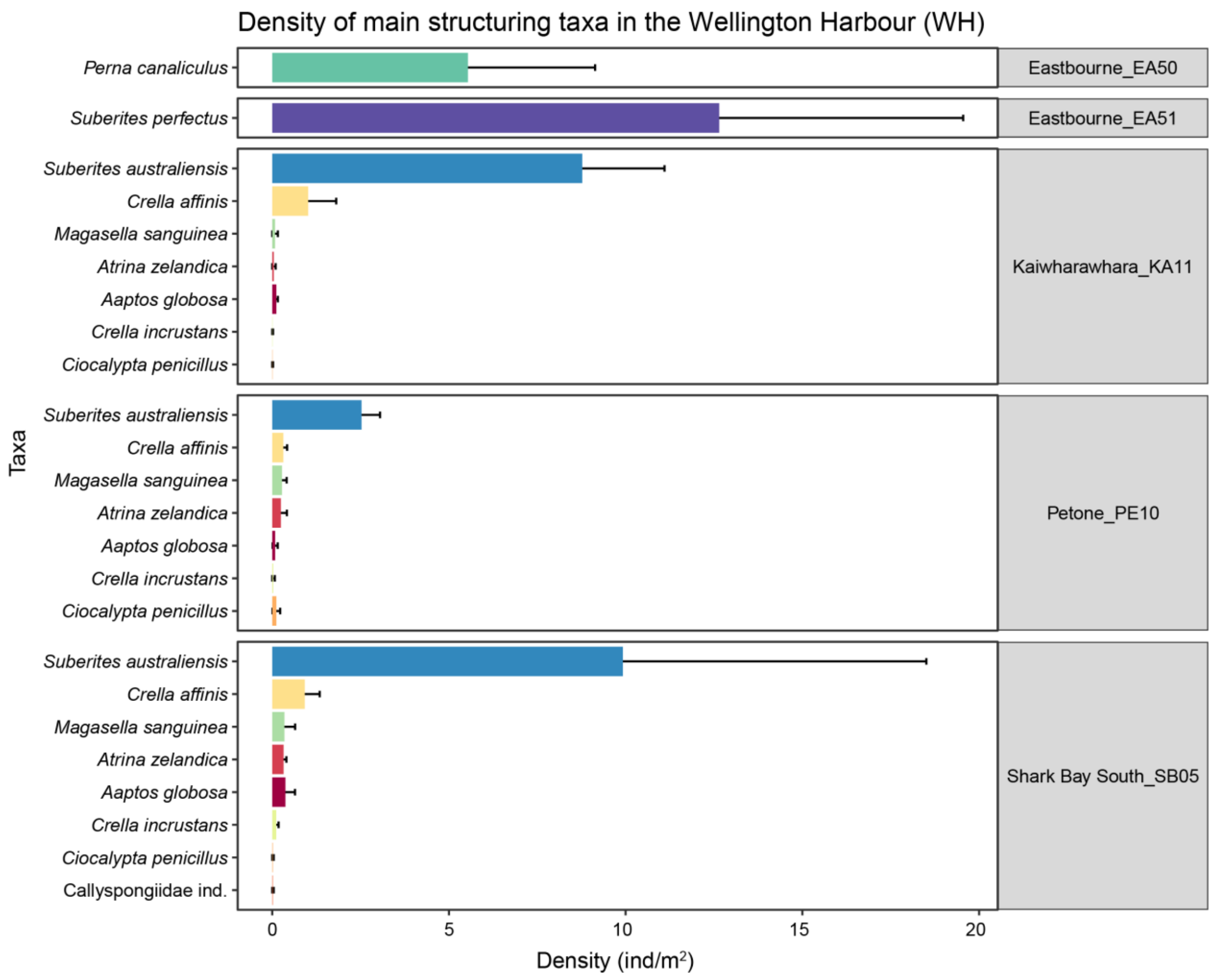


Figure 4. Density (ind/m^2) of main structuring taxa at different stations in Wellington Harbour. Error bars indicate standard deviation.

5.5±3.6 individuals/m^2, and the bed spanned an area of ~0.03–0.06 km^2 (Fig. 4). This area also had high sea urchin (*Evechinus chloroticus*) densities (Fig. 2; Tab. S2).

Between Ward Island and the shore, a sandy area (larger than 0.5 km^2) dominated by tube-building polychaetes was discovered. The principal structuring species, *Owenia petersenae*, showed densities of thousands of individuals per m^2. However, other abundant polychaetes included *Pseudobranchiomma grandis* and *Acromegalomma suspiciens*, and parchment worms, *Chaetopterus* sp. (Fig. 2; Tab. S2). Additionally, there were reports of large colonies (1–1.5 m high, 1–3 m wide) of the serpulid *Galeolaria hystrix* forming mounds northeast of Ward Island (Geoff

Read, NIWA, March 2023, personal communication). These colonies were observed in 2002, but not during this study, as the area they were previously found in was not sampled.

Distinctive to Eastbourne are the *Macrocystis pyrifera* forests south of Camp Bay (Tab. S2). These kelp forests harbour a rich and diverse understorey dominated by filter-feeding organisms, including multiple species of sponges, bryozoans, hydroids, ascidians, and mussels, alongside a high diversity of red algae. The *Macrocystis* appeared healthy, with a high canopy density and a low population of sea urchins. A diverse vagile fauna was observed, with a variety of opisthobranchs, fish, and traditionally important species such as pāua (*Haliotis* spp.) and kōura (*Jasus edwardsii*). The understorey of one of these forests (CB01) has been characterised in detail by the author (V.M.) during the LoveRimuRimu project (2022, Mountains to Sea Wellington and Victoria University of Wellington). The results will be available in LoveRimuRimu's final report.

3.1.3 Eastern Miramar and Kau Bay

In Mahanga Bay, we documented a small bed of *Suberites australiensis*, associated with the red alga *Adamsiella* and the sponge *Ciocalypta penicillus* (Fig. 2; Tab. S2). This sponge bed was notable for the presence of exceptionally large *Suberites* specimens, measuring up to 30–40 cm. Numerous egg cases of the elephant fish were also discovered within the area. The *Suberites australiensis* bed, found in stations MB02, MB02b, MB02c, and MB02d, may extend over an area of approximately 0.01–0.02 km^2. Of interest is the high abundance of the sponge *Chondropsis kirkii* and other uncommon sponge species on the ropes of the old aquaculture facility.

The most noteworthy feature of Kau Bay is a dense bed of the brachiopod *Magasella sanguinea*, with densities reaching hundreds of individuals per m^2 (Fig. 2; Tab. S2). While brachiopods are found in most sites in Wellington Harbour where shell rubble is present, station KB01 had the highest abundance. The exact extent of the brachiopod bed in this area remains uncertain, due to the limited sampling across only two stations.

3.1.4 Evans Bay

Evans Bay was surveyed mainly on the eastern side, where a variety of notable habitats were identified (Fig. 2). Extending from Shelly Bay to the inner part of Evans Bay, we observed an almost continuous band of shell rubble, starting from a depth of 7–10m and ending at around 15m. This rubble was colonized by a broad range of invertebrates, creating a rich biodiversity of soft-bottom fauna in the area. This area is characterized by communities dominated by *Suberites australiensis* (identified at nine stations) interspersed with regions wherein a mixed assemblage of benthic organisms is present. In these areas, a variety of sponge species and other invertebrates share relatively equal representation, falling under the category of 'Mixed filter-feeding fauna'. It should be noted that the area is quite heterogeneous, with each community having its own unique characteristics.

The most interesting locations on the western side of the Miramar peninsula, moving from north to south, encompass Whale's Bay (station SB05, south of Shelly Bay). Here, we discovered an *S. australiensis* bed, approximately 100–150m long and 10–20m wide, populated by a high density of *S. australiensis* (9.9±8.6 individuals/m^2) (Fig. 2, 4). Other sponges such as *Crella affinis* (0.92±0.42 individuals/m^2), *Crella incrustans* (0.11±0.07 individuals/m^2), and *Aaptos globosa* (0.37±0.27 individuals/m^2) were abundant, alongside other invertebrates such as *Magasella sanguinea* (0.34±0.3 individuals/m^2) and *Atrina zelandica* (0.32±0.08 individuals/m^2) (Fig. 4).

Shark Bay is also of interest, distinguished by its high diversity of sponge species. At this station (SK01), we identified some sponge species not found anywhere else in the harbour, including large specimens (20–35 cm) of *Chondropsis* sp., *Halichondria knowltoni*, and an unidentified white amorphous sponge (Fig. 2).

Located between Shark Bay and Burnham Wharf, an area known as Fisherman's Cove hosts a near-continuous belt (500–700 m) of interesting habitats, ranging from around nine down to 17 m in depth. This zone, abundant with shell rubble mixed with mud, is home to a variety of invertebrates, including various sponge species thriving under the more or less dominant presence of *S. australiensis* (found between 9 and 16 metres, with the greatest abundance between 11 and 14 m) (Fig. 2, 5).

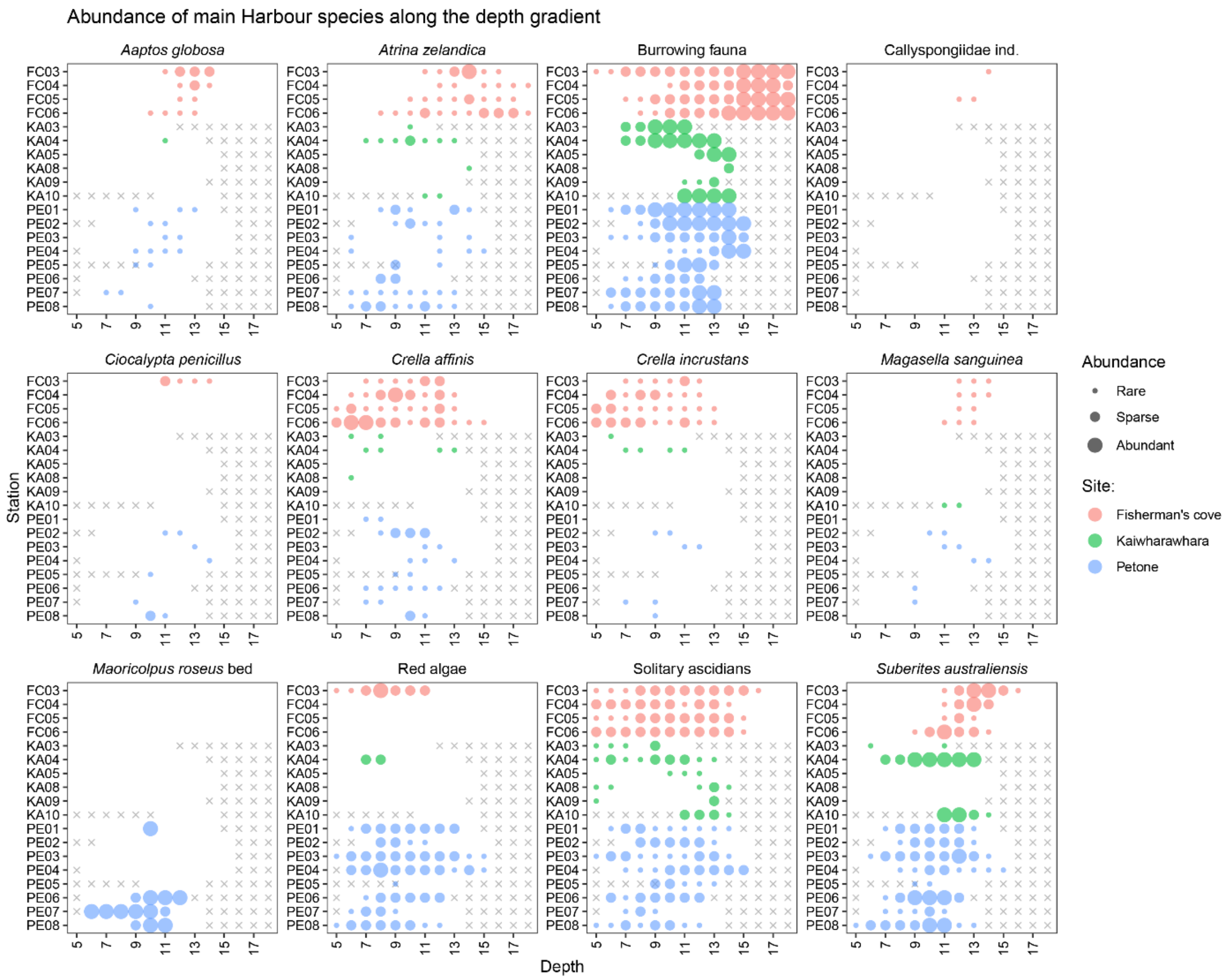


Figure 5. Semi-quantitative abundance of the main structuring species in Wellington Harbour soft-bottom communities along the depth gradient for different transects. Rare: presence of one or very few; Sparse: 1-5% coverage; Abundant: over 5% coverage (See section 2.3 for more information). The grey X indicates depths not covered by the transect.

Lastly, to the left of Miramar Wharf, we observed a small yet remarkably dense bed of *S. australiensis*. This area, populated by large specimens of *S. australiensis*, also supports populations of the sponge *C. affinis* and horse mussels (*A. zelandica*) (Fig. 2).

3.1.5 Western Harbour

Despite the large human intervention in Kaiwharawhara, its northern areas retain notable beds of *S. australiensis*. The sponge bed lies within a depth range of 7 to 14 m, with the highest density observed between 9 and 13 m (Fig. 5). Spanning approximately 350 m between stations KA07b and KA06b, this bed had a high density of *S. australiensis* (8.8±2.3 individuals/m²) (Fig. 2, 4). However, the sizes of these specimens are relatively smaller than those observed in Evans Bay and Mahanga Bay. Another sponge, *Crella affinis*, is also highly abundant, with an average density of 1±0.8 sponges/m² (Fig. 4).

Moving northward from the Kaiwharawhara sponge garden, the substrate becomes steeper and predominantly consists of anthropogenic materials (artificial gravel). There are no notable sponge beds or habitats until north of Ngauranga, around eastern Petone, where the substrate becomes less steep and shows fewer signs of human intervention. Here there is an interesting mosaic of habitats, extending for about 1500 m (Fig. 2). The area has the red alga *Adamsiella*, which is commonly found throughout the area but particularly abundant towards the southern end, between 6 and 14 m (Fig. 5). *Suberites australiensis* is dominant in the central part of the habitat, primarily found between stations PE03 and PE09b, and most abundant between depths of 9 and 12 meters (Fig. 5). The gastropod *Maoricolpus roseus* forms extensive beds, with individuals densely packed together and with the tip of the shell embedded in the sediment (between 6 and 12 m) (Fig. 2, 5).

In the northern extremity of the sponge bed (PE10), *S. australiensis* was found to have a density of 2.5±0.5 sponges/m². Other common invertebrates include the sponges *C. affinis* (0.3±0.1 sponges/m²), and *Ciocalypta penicillus* (0.12+0.1 sponges/m²), along with the brachiopod *Magasella sanguinea* (0.27±0.13 individuals/m²) and the horse mussel (0.25±0.17 individuals/m²) (Fig. 4).

3.2 Open Coast

3.2.1 General description

The open coast surrounding Wellington was explored across three key areas: Wellington South Coast (WSC), Wellington West Coast (WWC), and Kāpiti Coast (KAC) (Fig. 3). Investigations primarily focused on the upper mesophotic zone, spanning depths of 15 to 30 m, where animal-dominated habitats occur. Within these depths, three primary biotic communities were identified: Mixed Reef Invertebrates, Mixed Reef Sponges, and *Ecionemia alata*. Notably, red algae were a common co-occurring biotic community across most sites, accompanied by the anemones *Corynactis australis* and *Anthothoe albocincta*, which often dominated the substrate in terms of percentage cover, but not in terms of three-dimensional structure (Fig. S1; Tab. S3).

The Mixed Reef Invertebrates community was identified in areas where substrate utilization was equally distributed among various invertebrate groups, including sponges, bryozoans (primarily catenicellids), ascidians (ranging from the large *Pyura pachydermatina* to smaller colonial ascidians), and cnidarians. At other locations, sponges emerged as the dominant benthic component. In cases where several three-dimensional species had the same abundance, these communities were classified as mixed reef sponges (mainly on the WWC). However, two sites on the WSC and WWC (TR01 and MI07) displayed a notable dominance of *Ecionemia alata*. There, this species stood out not only as the most prominent, but also in terms of area occupied, surpassing that of any other sponge within these areas (Tab. S3).

When comparing the composition of the benthic communities (measured by percentage coverage) across three sites within the WSC and WWC, we observed a distinct divergence between Shark Tooth and Mana Island. Thoms Rocks, however, demonstrated intermediate characteristics, lying somewhere between the two sites mentioned above (Fig. 6). Statistical analyses affirm these observations, with significantly different benthic communities found at each site (PERMANOVA, $p < 0.0001$, $F = 13.3$). Furthermore, pairwise PERMANOVA tests revealed distinct differences in benthic community compositions across individual stations ($p = 0.0001$–0.003), with the exception of two stations at Mana Island North (MI04, MI05). Collectively, these

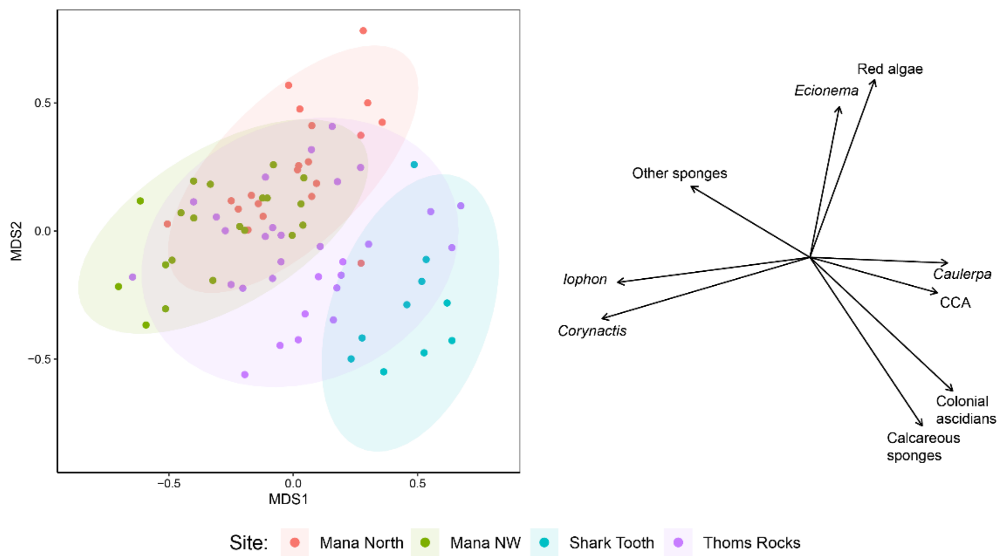


Figure 6. Multidimensional scaling (MDS) plot of benthic sessile communities for a combination of site (represented by symbol colour) with overlaid vector of species contribution to spatial separation.

results highlight the high heterogeneity within these marine communities, not only at broader spatial scales (e.g., between sites) but also at a local scale (e.g., between stations within a site).

3.2.2 Wellington South Coast (WSC)

Two locations were examined on the Wellington South Coast (WSC): Thoms Rocks and Shark Tooth. The shoal of Thoms Rocks, located approximately 2.5–3 km offshore, was explored over three stations (Fig. 3). In terms of habitats, the primary biotic communities observed at stations TR02 and TR03 fell under the Mixed Reef Invertebrates category, whereas at TR01 the main structuring species was *Ecionemia alata*. It's noteworthy that TR03, being shallower than the other two sites (26 m compared to 29–30 m), had a greater presence of red algae. When considering the overall coverage, the rocky substrate at Thoms Rocks, averaged across the three sites, was primarily composed of cnidarians (35.8±14.2 %, primarily *Corynactis australis*), algae

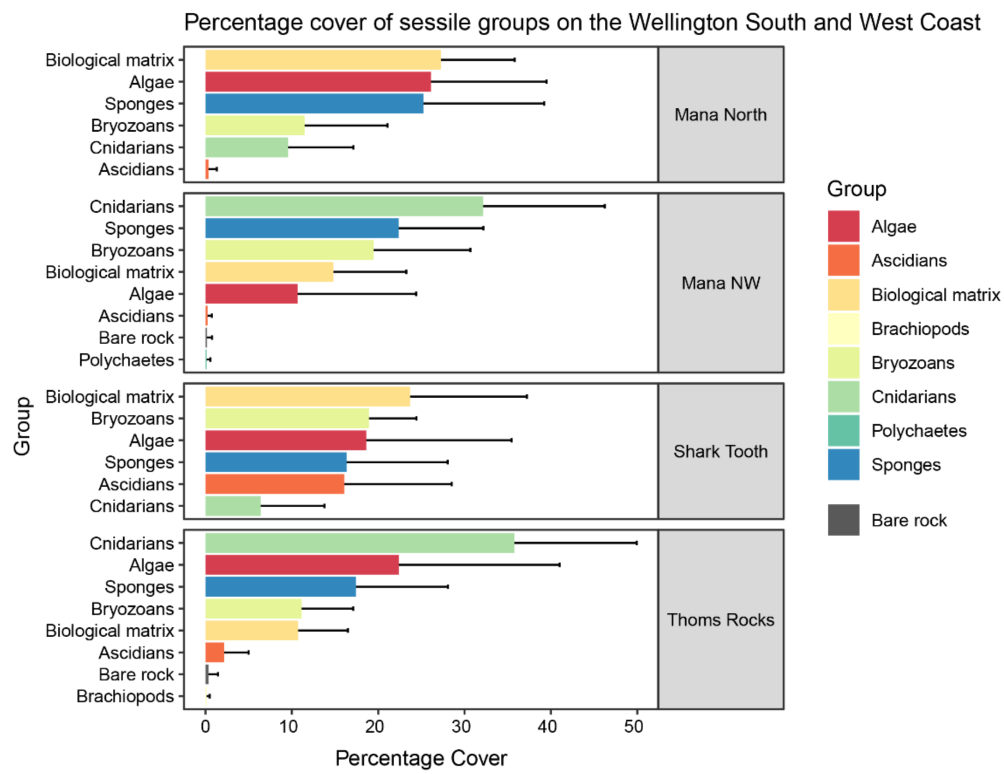


Figure 7. Percentage cover of sessile groups and bare rock at different sites on the Wellington South and West Coast. Sampling stations within the same site were pooled. Error bars indicate standard deviation.

(22.4±18.6%, predominantly red algae), sponges (17.4%±10.7 %, largely *Ecionemia alata*), and bryozoans (11.1±6 %, mostly catenicellids) (Fig. 7–8; Fig. S1–S2).

At Shark Tooth, the communities were largely dominated by Mixed Reef Invertebrates and algae. A significant portion of the substrate was occupied by a biological matrix (23.7±13.6 %), comprising invertebrates and filamentous algae, which could not be identified from the photos (refer to Materials and Methods 2.3.1). Other important organisms were bryozoans (18.9±5.5 %, primarily catenicellids), algae (18.6±16.8 %, chiefly red algae and *Caulerpa*), sponges (16.3±11.7 %, various species), and ascidians (16.1±12.4 %) (Fig. 7–8; Fig. S1–S2).

3.2.3 Wellington West Coast (WWC)

The most thoroughly explored site within the Wellington West Coast (WWC) was Mana Island, where both ROV and SCUBA surveys were conducted at a total of nine stations (Fig. 3). Each side

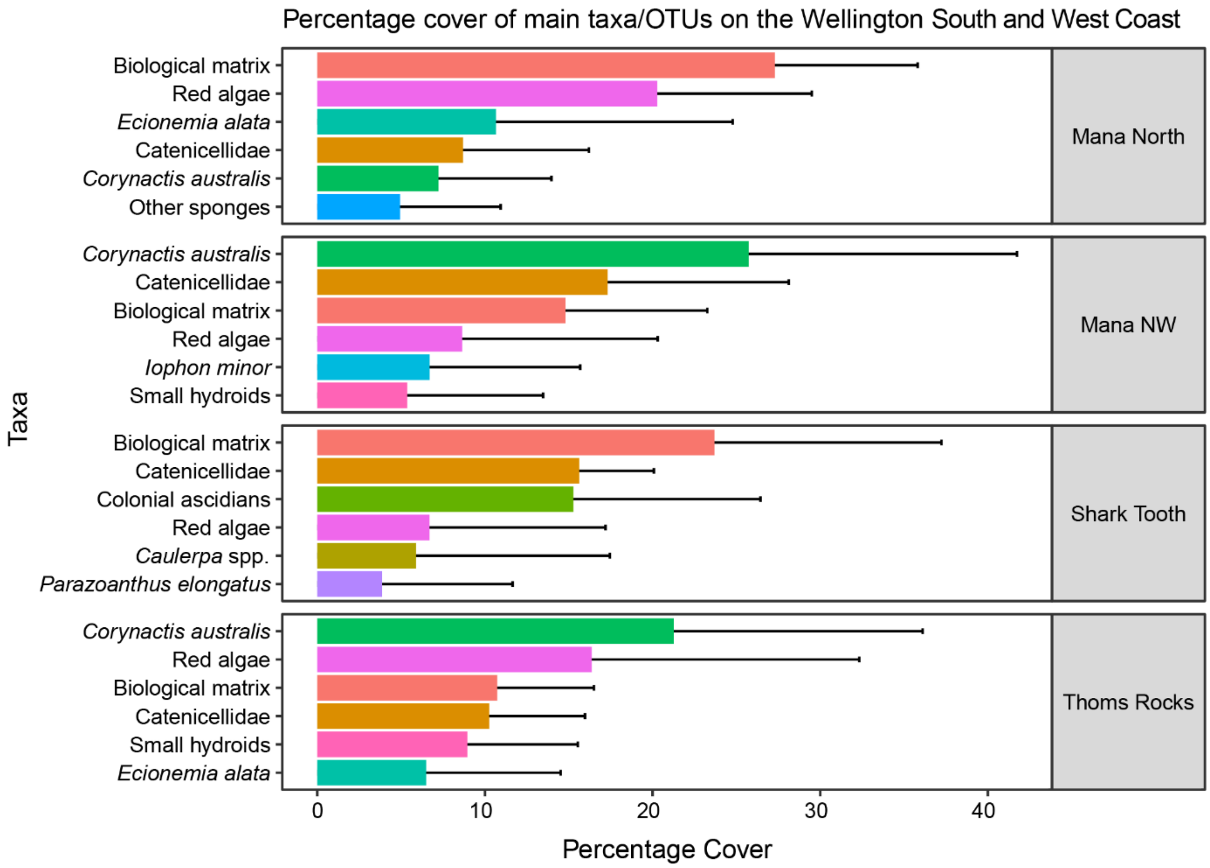


Figure 8. Percentage cover of the main sessile taxa/OTUs at different sites on the Wellington South and West Coast. Sampling stations within the same site were pooled. Error bars indicate standard deviation.

of the island had its own distinct biotic communities. The most diverse communities were those on the island's northwestern side. This side was characterised by strong tidal currents and minimal sediment accumulation, conditions that seem to support a rich and dense sessile community. Sponges were particularly dominant here, with a diversity of large, massive and arborescent species, some of which could not be found in existing taxonomic guides, warranting further investigation. In terms of substrate coverage, cnidarians dominate (32.2±14.1%, largely comprised of *Corynactis australis*), followed by sponges (22.4±9.8%), and bryozoans (19.5±11.2%, almost exclusively catenicellids) (Fig. 7–8; Fig. S1–S2). As for sponges, the most prevalent structuring species, in order, were *Iophon minor*, *Crella incrustans*, *Ecionemia alata*, and various branching sponges, with densities ranging from 1.0±0.4 ind/m^2 to 0.2±0.2 ind/m^2 (Fig. 9).

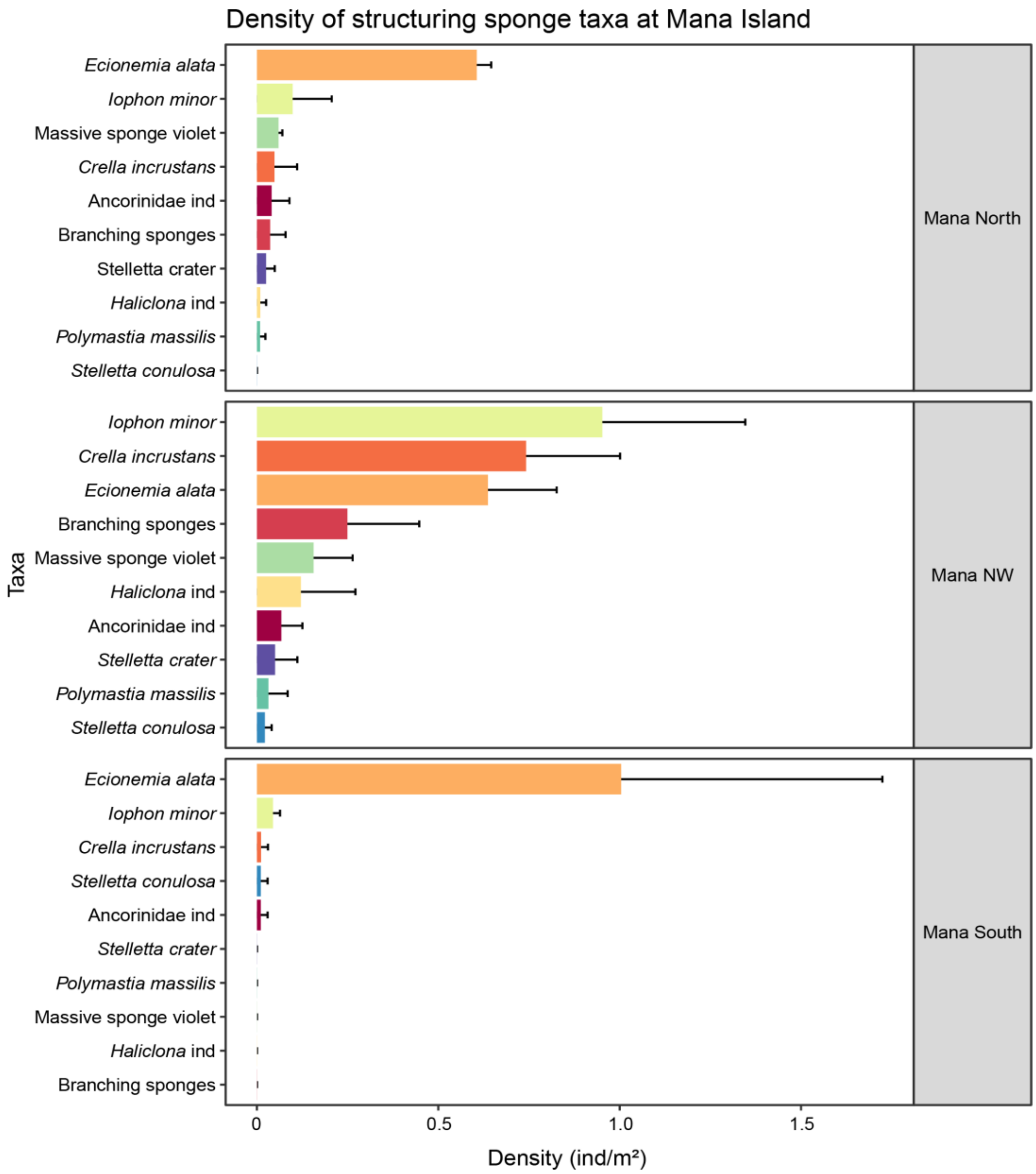


Figure 9. Density (ind/m^2) of main structuring sponge taxa at different stations at Mana Island. Error bars indicate standard deviation. Data from the two sampling stations at Mana NW were pooled.

Conversely, the northern side of Mana Island, which was more sheltered from tidal currents and receiving more sediment from the Porirua Harbour, had a different community. While sponges were abundant and diverse, other invertebrates, especially bush-forming hydroids and bryozoans capable of withstanding higher sedimentation, made a greater contribution. As such, this community has been classified as 'Mixed Reef Invertebrates'. With regard to percentage cover, biological matrix dominated the substrate (27.3±8.5%), followed by algae (26.1±13.4%, mostly red algae) and sponges (25.2±14.0%) (Fig. 7–8; Fig. S1–S2). The most common structuring sponges in this area were *Ecionemia alata* (0.6±0.3 sponges/m^2) and *Iophon minor* (0.1±0.1 sponges/m^2) (Fig. 9).

The southern side of Mana Island, which is also sheltered from currents and has higher sediment accumulation compared to the northwestern area, was dominated by *Ecionemia alata*. This species is found in high density (1.0±0.7 sponges/m^2), with particularly large specimens (>130 cm of diameter) observed (Fig. 9–10).

In contrast, the inner side of Mana Island, known as 'The Bridge', is home to *Macrocystis* forests extending from shallow waters (4–5 m) down to 15–18 m depths. Below this, the substrate flattens and is primarily composed of pebbles and cobbles colonised by the anemone *Anthothoe albocincta*. Of the two sites examined in this area, one (MI10) displayed a high density of sea urchins grazing on *Macrocystis* (Fig. 3).

Pukerua Bay represents another unique and highly heterogeneous site. The three stations explored all experienced high sedimentation and were classified under the 'Mixed Reef Sponges' community, yet they featured remarkably distinct communities (Fig. 3). The deepest station (22–24 m, PB01) supported many unidentified branching sponges, bushy hydroids and bryozoans, as well as high densities of the cup coral *Monomyces rubrum*. At PB02, the seafloor was characterised by large boulders resting on sand, populated by large branching sponges (*Callyspongia ramosa* along with other unidentified species) set within fields of anemone (*Anthothoe albocincta*). In contrast, PB03, the shallowest site (15–16 m), consisted of a mixed platform reef and large boulders. This station hosted a unique sponge garden with a high density of arborescent forms, as well as a population of *Polymastia crocea*. The density and specimen size of the sponge *Polymastia crocea* at PB03 were much higher compared to any other locations around Wellington.

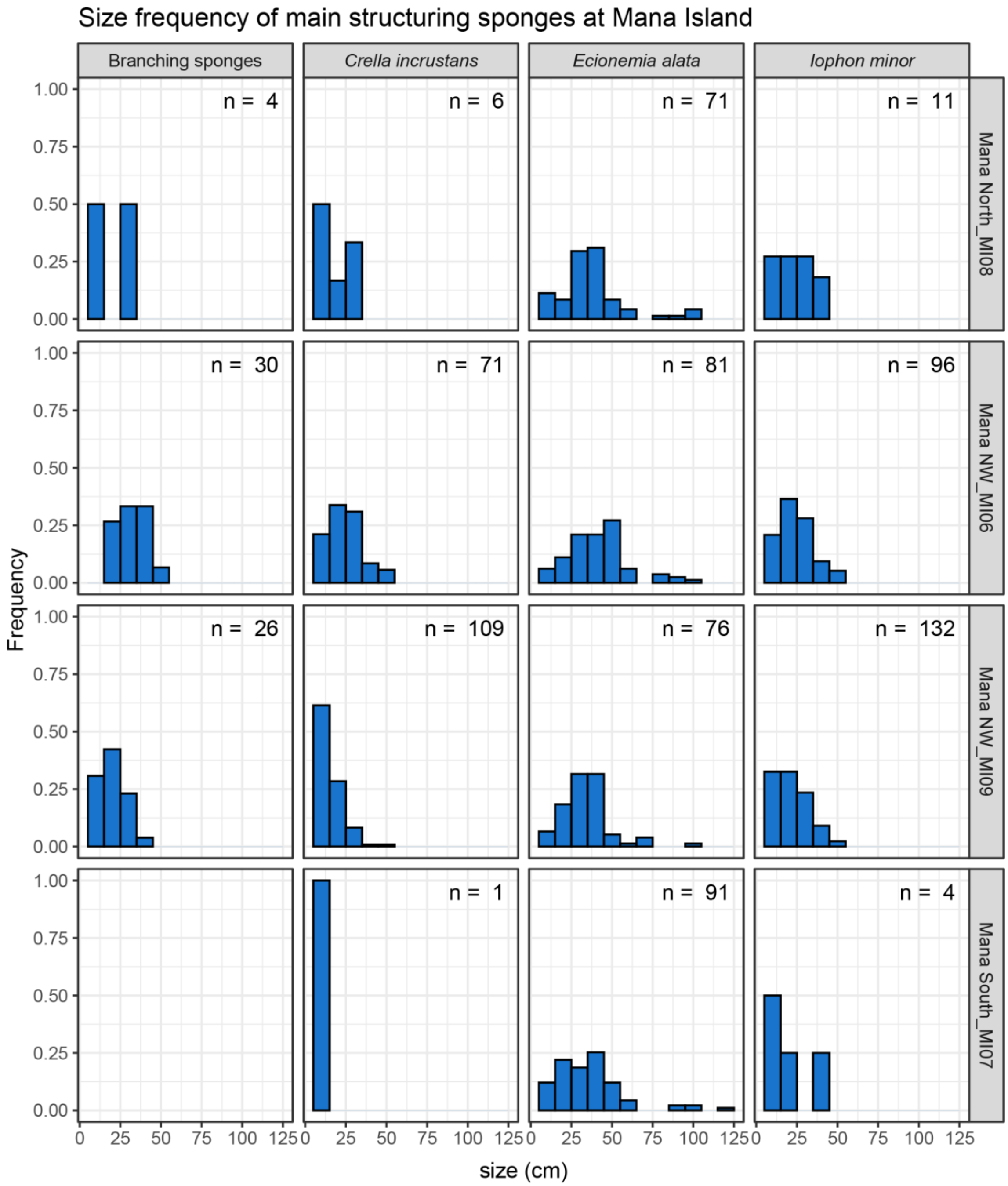


Figure 10. Relative size frequency of main structuring sponge taxa at four stations at Mana Island. The sample size is indicated in the top right-hand corner of each graph.

The remaining stations on the WWC and KAC were explored with information from the Wellington Underwater Club. Notably, an investigation was conducted on the western side of the southern plateau at Hunter's Bank (HB01), a site presenting stark differences from other locations surveyed (Fig. 3). The station features a rocky reef, populated with sponges, encrusting invertebrates, and crustose coralline algae. While a few abundant sponge species (*Ecionemia alata* and *Iophon minor*) contribute significantly to the three-dimensional structure of the reef, the diversity of sponge species is not remarkably high. A noteworthy feature of this location is the high abundance of brachiopods, which are overlaid with crustose coralline algae. This site also has a high level of fish abundance and diversity.

The survey station at Makara (MK01) featured platform reefs, gullies, and swim-throughs. This area was at the upper limits of the mesophotic zone (16–19 m) and it was characterised by the presence of large specimens of *Ecionemia alata* and *Iophon minor*, in addition to a variety of mixed algae, including filamentous reds and *Ecklonia radiata* (Fig. 3).

Heading south, at Ohau Point (OP01), the ocean floor was complex, with high pinnacles, reaching up to 5 m in height, and a series of small and large boulders interspersed with coarse sediments. The area hosted a remarkable sponge garden amongst fields of the anemones *Anthothoe albocincta* and *Corynactis*. The 3-dimensional structure of the reef is primarily shaped by various sponge species, such as *Ecionemia alata*, *Callyspongia ramosa*, *Iophon minor*, and *Crella incrustans* (Fig. 3).

On the Kāpiti Coast, one site was explored nearby Tokomāpuna (Aeroplane) Island (AI01) at mesophotic depths (Fig. 3). Along all depths, the reef's three-dimensional structure was primarily formed by sponges, with *Ecionemia alata*, *Iophon minor*, *Crella incrustans*, and an unidentified orange chimney sponge dominating the community. The rest of the biotic communities varied according to depth. In the deepest areas explored, between approximately 30 and 40 m, the substrate was predominantly occupied by barnacles of two or more species, including *Calantica villosa* and *Notomegabalanus decorus*. Ascending from the barnacle zone, a distinct band primarily inhabited by *Corynactis* was noted at approximately 25 m. Above this, a mixed community of *Anthothoe albocincta* and filamentous red algae was present, giving way, in the shallowest region, to *Ecklonia* and *Caulerpa*.

3.3 Anthropogenic impacts and marine litter

Comparatively, we observed a greater degree of anthropogenic impacts within Wellington Harbour than along the open coast. The only anthropogenic debris identified along Wellington's open coast was a fishing line located at Mana Island. Examination of video transects revealed the presence of marine litter and anthropogenic alterations in most of the seabed observations in Wellington Harbour (Fig. 11A). Specifically, the area southeast of Evans Bay was the most heavily impacted, recording the highest litter density (3.1±7.0 pieces per m^2) (Fig. 11A). This was followed by Kaiwharawhara (1.1±3.0 pieces per m^2), Shelly Bay (0.5±2.0 pieces per m^2), and Mahanga Bay (0.5±1.2 pieces per m^2) (Fig. 11A). The most frequent types of debris were small plastic items and fragments measuring less than 35 cm (e.g., bottles, packaging, plastic cups), which were most densely concentrated in Evans Bay. Aluminium cans, ropes, and large plastic objects were also commonly found in Evans Bay, Kaiwharawhara, Shelly Bay, and Mahanga Bay. Fishing gear, such as weights and lines, was only identified at Evans Bay, Fisherman's Cove, and Kaiwharawhara (Fig. 11B). Overgrown concrete blocks were present in Evans Bay, Kaiwharawhara, and Mahanga Bay, colonised by branching sponges and other filter feeders. Automobile parts, such as tyres, were frequently encountered in Evans Bay, Shelly Bay, Kaiwharawhara, and Petone.

Based on our data, the areas least impacted by marine litter and substrate modifications within Wellington Harbour were Fisherman's Cove, Kau Bay, and Eastbourne. Notably, we identified areas of artificial gravel between Kaiwharawhara and Petone and to the south of Kaiwharawhara, which showed no signs of recolonization and very low diversity.

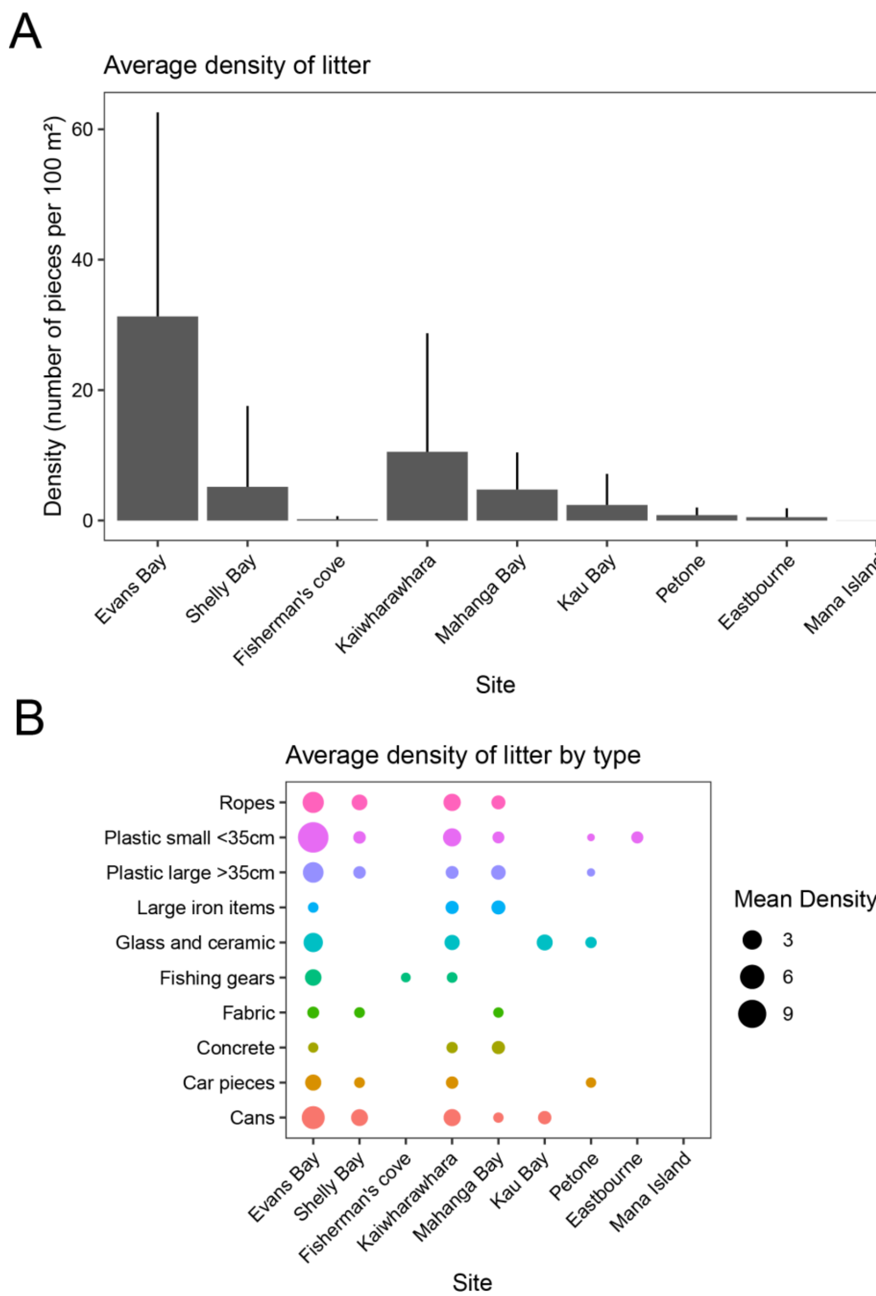


Figure 11. Abundance (number of pieces per m^2) of marine litter at different sites in Wellington Harbour and Mana Island. Panel **A** shows the overall density of litter, while panel **B** shows the average density for different types of marine litter. Several stations at the same site were pooled.

4. Discussion

This study explored the shallow marine habitats in the Wellington Region, identifying a considerable range of animal-dominated communities distributed throughout the area, which were previously unreported. Our findings highlight the biological and ecological significance of this coastal region, underscoring its potential role in the maintenance of biodiversity and nutrient cycling in the Wellington Region (Costanza et al., 1997). However, these ecosystems are facing many threats that could jeopardise their ecological integrity and economic value if not appropriately managed.

4.1 Animal-dominated communities in the Wellington Region

The detailed documentation and mapping of marine communities are critical steps in their conservation (Naidoo et al., 2008). Prior to our study, Wellington Harbour was studied mainly from a hydrogeological perspective (Van der Linden, 1967; Carter, 1977; Gall et al., 2022), while knowledge of associated benthic communities was extremely limited (Rowden et al., 2012; D'Archino et al., 2021). Comprehensive surveys, such as those carried out in this study, serve as a fundamental resource for understanding the ecological dynamics of these habitats, providing the necessary baseline information for effective management and conservation strategies (Halpern et al., 2008).

Our results revealed that one of the most common animal-dominated habitats in Wellington Harbour were the sponge beds dominated by *Suberites australiensis*. *Suberites australiensis* were found on mud and biogenic substrate mainly composed of empty bivalve shells, which served as anchoring points for these sponges and other organisms. Those habitats were often populated by mixed-borrowing fauna and other filter feeders such as horse mussels (*Atrina zelandica*), and other sponges, such as *Crella affinis* and *Aaptos globosa*. Our results suggest that biogenic habitats composed of empty shells on fine sand and mud are important for the occurrence of sponge beds in Wellington Harbour. Moreover, our results indicate that sponge beds are the major contributors to subtidal habitat heterogeneity in Wellington Harbour, similar to deep-sea environments (Buhl-Mortensen et al., 2010; Maldonado et al., 2017). In addition, the large size and wide distribution of *S. australiensis* suggest a significant role in nutrient cycling within the harbour ecosystem (Morganti et al., 2019), which should be the subject of future studies. Our study also documented the existence of brachiopod beds (*Magasella sanguinea*) in Wellington Harbour, particularly in Kau Bay, Shelly Bay, and Fisherman's Cove. These findings contribute to the known distribution of *M. sanguinea*, previously reported to be more common in the South Island of New Zealand (Robinson et al., 2016).

Some stations in the Petone area were found to be dominated by the mollusc *Maoricolpus roseus*. This species is an endemic filter-feeding mollusc in New Zealand (Donald and Spencer, 2015), and a well-known invasive species in the soft bottoms of Tasmania and Australia (Reid et al., 2018). As it stands, the ecological role of this abundant organism within Wellington Harbour remains unstudied.

Another significant finding within the harbour was the presence of the sponge *Suberites perfectus*. This species is typically associated with harbours and low-intertidal reefs and has previously only been reported in northern New Zealand, from Northland to the Bay of Plenty (Kelly 2022). Our study documented the first occurrence for the Wellington Region, and notably, the southernmost record for this species.

In Wellington Harbour, one of the most interesting areas from a biological and ecological perspective was the eastern Miramar peninsula. In particular, the sponge beds situated south of Shelly Bay (SB03), were characterised by an exceptionally high density of *S. australiensis*; Shark Bay (SK01) emerged as another area of interest due to its diverse sponge community; Fisherman's Cove (FC03, FC04) and the area adjacent to Miramar Wharf (EB01d, EB02) were characterized by a notable abundance and diversity of filter-feeding invertebrates. On the eastern side of the Miramar Peninsula, Mahanga Bay was characterised by the presence of large specimens of *S. australiensis*. Meanwhile, the stations in western Petone were distinguished by small-scale habitat heterogeneity. Lastly, Camp Bay (CB01) hosted a well-established *Macrocystis* forest that supported a rich and diverse understorey, that could not be found in other forests on the Wellington South or West coasts (author's personal observation).

The Open Coast of Wellington has very different communities to the Wellington Harbour, largely influenced by the strong tidal currents (Walters et al., 2010). These currents bring food that supports a large biomass and biodiversity of filter-feeders, particularly sponges, bryozoans, cnidarians and ascidians. We observed extensive sponge gardens, which included large specimens (> 1 m) of *Ecionema alata*, along with various other species, the majority of which could not be identified due to their absence from available identification guides and biodiversity monographs. Further studies focusing on taxonomic identification will be needed to reveal the true biodiversity of this area, which is probably home to several undescribed species.

Notably, there is a considerable degree of variation among communities in different areas, underscoring the large diversity of habitats within the Wellington Region. While all explored stations on the open coast exhibited high biodiversity and substantial ecological value, the most interesting sites were Mana NW and Ohau Point, because of their diversity and biomass of sponges and other filter-feeders; Pukerua Bay, for the small-scale heterogeneity of its benthic habitats; and Airplane Island, distinguished by the uniqueness of its communities, such as cirriped beds.

4.2 Impacts, threats, and vulnerability

Anthropogenic impacts were predominantly observed in Wellington Harbour, most notably in the form of marine litter and habitat alterations. Evans Bay was found to be particularly affected, with the highest density of litter observed in this study. This is not surprising, given that Wellington Harbour is located in a highly urbanised area, but it is a source of concern for the health of these ecosystems (Jambeck et al., 2015). This marine litter comprised a diverse array of materials, including plastic objects, car tyres, traffic cones, and discarded fishing gear. Such a wide assortment of litter has the potential to considerably alter local habitats and negatively impact associated fauna. In particular, plastic debris, given its durability and persistence, can lead to physical damage, entanglement, ingestion, and potentially toxic effects in a variety of marine species (Derraik, 2002; Rochman et al., 2013). For instance, car tyres, fishing gear and other large objects can alter the seafloor habitat and smother benthic organisms, causing local declines in biodiversity (Gall and Thompson, 2015).

Habitat alteration is a well-documented impact of human activities (Halpern et al., 2008), and is distinctly evident in Wellington Harbour. Our observations suggest that in Eastern Miramar, animal-dominated communities likely formed a continuous belt extending from Shelly Bay to Evans Bay in the past. However, the seabed surrounding Burnham and Miramar wharfs appeared depauperated and highly degraded. This degradation is potentially a consequence of wharf construction, or the water turbulence caused by the propellers of large vessels (Airoldi and Beck, 2007).

A similar deleterious impact of human intervention is evident on the western side of the harbour. In certain areas, such as Kaiwharawhara and Ngauranga, the natural substrate was overlaid with artificial gravel, drastically altering the original habitat. The community in these locations exhibited low diversity with minimal signs of recolonization, underscoring the potential long-term impacts of such human-induced alterations (Bulleri and Chapman, 2010). These observations confirm that habitat alterations compromise the capacity of these areas to support native and diverse communities (Lotze et al., 2006), and can facilitate the establishment of invasive species (Tyrrell and Byers, 2007).

Assessing the health status of the marine communities in the Wellington Region is challenging due to a lack of baseline ecological data, an issue that impedes our understanding of the original or pristine state of these communities (Knowlton and Jackson, 2008). While it is possible that the open–coast sponge- and invertebrate-dominated reefs have remained relatively untouched, the harbour communities have likely been more affected by anthropogenic impacts. For example, it is possible that increased sedimentation, a common consequence of urbanization and changes in land use (Warrick et al., 2009), has gradually shaped the communities within Wellington Harbour. This process may have promoted the proliferation of sediment-tolerant organisms such as sponges and caused a decrease in other organisms such as bryozoans and horse mussels (Airoldi, 2003; Thrush et al., 2004; Bell et al., 2015; Schönberg, 2016). In addition, other stressors such as heavy metal contamination, recreational fishing, and climate change may have contributed to the changes.

Ocean warming poses an imminent and future threat to Wellington's marine ecosystems, particularly in Wellington Harbour. This semi-enclosed shallow basin is especially vulnerable, as its waters tend to accumulate heat during the summer months, a phenomenon observed in similar environments (Lima and Wethey, 2012). Wellington Harbour has already been subject to heatwaves in recent years, and the potential for more severe events is a growing concern (Oliver et al., 2018). Many sessile organisms, including sponges, are particularly susceptible to such thermal anomalies (see Strano et al., 2022, 2023) and could undergo mass mortalities in the coming years, as observed in other regions around New Zealand (Bell et al., 2023). In contrast, Wellington's open coast, under the influence of upwelling currents from the Cook Strait (Bowman et al., 1983), likely represents a climate change refugia (Keppel et al., 2012). The influx of colder, deeper waters makes it less likely for these areas to experience heatwave-driven mass mortality events (Lourenço et al., 2016). Therefore, particular attention should be given to conserving communities on Wellington's open coast, considering the critical role this area may play in preserving New Zealand's biodiversity in the face of future climate change (Morelli et al., 2016).

Fortunately, most of the communities on the open coast benefit from a certain degree of natural protection due to harsh weather conditions, tide rips, and the relative inaccessibility of this coastal area. Nonetheless, certain vulnerable species could still face threats from anchoring and fishing activities (Bell et al., 2023), especially in areas that are easier to access, such as Mana Island, Kāpiti Island and Pukerua Bay. Sponges are particularly susceptible to eradication from these direct physical impacts, and they may also suffer from infections and necrosis as a result of inflicted wounds (Bell et al., *in press*). This vulnerability is exacerbated by ocean warming, which promotes the proliferation of pathogenic microorganisms, further increasing the risk of infection (Wulff, 2006).

It is worth noting that many mesophotic sponges are slow-growing and show limited resilience to impacts (Montero-Serra et al., 2018; authors' unpublished data). Given the large size of some of the sponges we found (in particular *Ecionemia alata*, which can exceed 1 m in length), these specimens may indeed be centuries old (Petralia et al., 2014). This raises the possibility that the Wellington coastline is surrounded by ancient animal forests. From a conservation perspective, this underlines the urgency of further research and the implementation of conservation measures for these potential pristine habitats.

4.3 Conclusive remarks

This study revealed that Wellington's coastline hosts extensive animal-dominated communities of high ecological significance. The filter-feeding organisms forming these habitats likely provide critical ecosystem services that benefit both marine life and humans. For example, the sponges and bivalves documented play an important role in filtering large volumes of water, thereby enhancing water quality, clarity, and availability of nutrients for other species (Ostroumov, 2005; Bell et al., *in press*). These complex three-dimensional habitats also provide crucial nursery grounds, refuges, and feeding areas that enhance biodiversity (Rossi et al., 2017). While the open-coast communities remain relatively pristine, Wellington Harbour exhibited concerning impacts from marine litter and habitat degradation that threaten ecological integrity. Targeted monitoring and management strategies focused on reducing anthropogenic threats are needed to safeguard these habitats (Bell et al., 2022). Findings from this baseline study can inform future marine spatial planning to allow respectful and sustainable use of the sea while conserving these unique shallow-animal forests for generations to come.

Acknowledgements

Our deepest appreciation goes to Megan Oliver and the Greater Wellington Regional Council (GWRC) for generously funding this research project. We extend our gratitude to Dr. Geoff Read (NIWA) for his expertise in the identification of polychaetes, and to Dr. Dennis Gordon (NIWA), for his assistance with bryozoan identification. Our thanks go to John van der Sman for his invaluable technical support and training with our boating operations, and Daniel McNaughtan and Simon Maddalena for their advice on conducting safe underwater operations. Fieldwork was made possible by the excellent seamanship of Don Nelson and Dave Drane (Dive Wellington). This research benefited greatly from the generous contributions of citizen scientists. In particular, we thank Dr. Nicole Miller of the Wellington Underwater Club for sharing invaluable video footage and site information. We also thank Rob Edwards, Rob Wilson (Ghost Divers NZ), and other local divers for providing key observations that expanded our understanding of Wellington's marine animal forests. This work would not have been possible without the knowledge and assistance of many passionate local divers willing to share their underwater discoveries.

References

Airoldi, L., & Beck, M. W. (2007). Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology: An Annual Review, 45, 345-405.

Anderson, M. J. (2001). A new method for non-parametric multivariate analysis of variance. Austral ecology, 26(1), 32-46.

Barnard, S., & Boyes, S. (2013). Review of case studies and recommendations for the inclusion of expert judgement in marine biodiversity status assessments. Joint Nature Conservation Committee.

Bell, J. J., & Barnes, D. K. (2002). The relationship between sedimentation, flow rates, depth and time at Lough Hyne Marine Nature Reserve. The Irish Naturalists' Journal, 106-116.

Bell, J. J., McGrath, E., Biggerstaff, A., Bates, T., Bennett, H., Marlow, J., & Shaffer, M. (2015). Sediment impacts on marine sponges. Marine pollution bulletin, 94(1-2), 5-13.

Bell, J. J., Micaroni, V., Harris, B., Strano, F., Broadribb, M., & Rogers, A. (2022). Global status, impacts, and management of rocky temperate mesophotic ecosystems. Conservation Biology, e13945.

Bell, J. J., Smith, R. O., Micaroni, V., Strano, F., Balemi, C. A., Caiger, P. E., Miller, K.I., Spyksma, A.J. & Shears, N. T. (2023). Marine heat waves drive bleaching and necrosis of temperate sponges. Current Biology, 33(1), 158-163.

Bell, J. J., Strano, F., Broadribb-Payne, M., Wood, G., Harris, B., Resende, A. C., Novak, E., Micaroni, V. (2023) Sponge functional roles in a changing world. Advances in Marine Biology

Benjamini, Y., and Hochberg, Y. 1995. "Controlling the false discovery rate: a practical and powerful approach to multiple testing." Journal of the Royal statistical society: series B (Methodological) 57: 289–300.

Bowman, M. J., Kibblewhite, A. C., Murtagh, R. A., Chiswell, S. M., & Sanderson, B. G. (1983). Circulation and mixing in greater cook strait, new-zealand. Oceanologica acta, 6(4), 383-391.

Brind'Amour, A., Laffargue, P., Morin, J., Vaz, S., Foveau, A., & Le Bris, H. (2014). Morphospecies and taxonomic sufficiency of benthic megafauna in scientific bottom trawl surveys. Continental Shelf Research, 72, 1-9.

Bulleri, F., & Chapman, M. G. (2010). The introduction of coastal infrastructure as a driver of change in marine environments. Journal of Applied Ecology, 47(1), 26-35.

Carter, L. (1977). Sand transport, Wellington Harbour entrance, New Zealand. New Zealand journal of geology and geophysics, 20(2), 335-351.

Carter, L., & Lewis, K. (1995). Variability of the modern sand cover on a tide and storm driven inner shelf, south Wellington, New Zealand. New Zealand journal of geology and geophysics, 38(4), 451-470.

D'Archino, R., Nelson, W., Neill, K., & Pallentin, A. (2021). Characterisation of the Evans Bay *Adamsiella* algal bed. NIWA Client Report 2021306WN, for Wellington Regional Council

de Lange, W. (2014). Kapiti Coast coastal hazard assessment. Executive summary for Kapiti Coast District Council, 25.

Dearborn, D. C., & Kark, S. (2010). Motivations for conserving urban biodiversity. Conservation biology, 24(2), 432-440.

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. Marine pollution bulletin, 44(9), 842-852.

Donald, K. M., & Spencer, H. G. (2015). New Zealand screw shells Maoricolpus roseus (Gastropoda: Turritellidae): two species, two subspecies or a single variable species?. Molluscan Research, 35(2), 123-127.

Dymond, J. R., & Shepherd, J. D. (2004). The spatial distribution of indigenous forest and its composition in the Wellington region, New Zealand, from ETM+ satellite imagery. Remote sensing of Environment, 90(1), 116-125.

Elliott, M., Boyes, S. J., Barnard, S., & Borja, Á. (2018). Using best expert judgement to harmonise marine environmental status assessment and maritime spatial planning. Marine pollution bulletin, 133, 367-377.

Gall, M. P., Davies-Colley, R., Milne, J., & Stott, R. (2022). Suspended sediment and faecal contamination in a stormflow plume from the Hutt River in Wellington Harbour, New Zealand. New Zealand Journal of Marine and Freshwater Research, 56(3), 389-409.

Gall, S. C., & Thompson, R. C. (2015). The impact of debris on marine life. Marine pollution bulletin, 92(1-2), 170-179.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., & Watson, R. (2008). A global map of human impact on marine ecosystems. Science, 319(5865), 948-952.

Harris, B., Davy, S. K., & Bell, J. J. (2021). Benthic community composition of temperate mesophotic ecosystems (TMEs) in New Zealand: sponge domination and contribution to habitat complexity. Marine Ecology Progress Series, 671, 21-43.

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768-771.

Kelly, M. (2022) Splendid Sponges, a guide to the sponges of New Zealand. Version 4 (2022), 124 pp. https://niwa.co.nz/coasts-and-oceans/marine-identification-guides-and-fact-sheets

Keppel, G., Van Niel, K. P., Wardell-Johnson, G. W., Yates, C. J., Byrne, M., Mucina, L., Schut, A.G., Hopper, S.D. & Franklin, S. E. (2012). Refugia: identifying and understanding safe havens for biodiversity under climate change. Global Ecology and Biogeography, 21(4), 393-404.

Knowlton, N., & Jackson, J. B. C. (2008). Shifting baselines, local impacts, and global change on coral reefs. PLoS biology, 6(2), e54.

Kohler, K. E., & Gill, S. M. (2006). Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers & geosciences, 32(9), 1259-1269.

Kregting, L. T., & Gibbs, M. T. (2006). Salinity controls the upper depth limit of black corals in Doubtful Sound, New Zealand. New Zealand Journal of Marine and Freshwater Research, 40(1), 43-52.

Lima, F. P., & Wethey, D. S. (2012). Three decades of high-resolution coastal sea surface temperatures reveal more than warming. Nature Communications, 3(1), 1-13.

Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., Kidwell, S. M., Kirby, M. X., Peterson, C. H., & Jackson, J. B. C. (2006). Depletion, degradation, and recovery potential of estuaries and coastal seas. Science, 312(5781), 1806-1809.

Lourenço, C. R., Zardi, G. I., McQuaid, C. D., Serrão, E. A., Pearson, G. A., Jacinto, R., & Nicastro, K. R. (2016). Upwelling areas as climate change refugia for the distribution and genetic diversity of a marine macroalga. Journal of biogeography, 43(8), 1595-1607.

Lowe, E. C., Steven, R., Morris, R. L., Parris, K. M., Aguiar, A. C., Webb, C. E., ... & Pinto, M. M. (2022). Supporting urban ecosystem services across terrestrial, marine and freshwater realms. Science of the Total Environment, 817, 152689.

Maldonado, M., Aguilar, R., Bannister, R., Bell, J., Conway, J., Dayton, P., ... & Young, C. (2017). Sponge grounds as key marine habitats: a synthetic review of types, structure, functional roles, and conservation concerns. Marine animal forests: The ecology of benthic biodiversity hotspots.

Marselle, M. R., Lindley, S. J., Cook, P. A., & Bonn, A. (2021). Biodiversity and health in the urban environment. Current Environmental Health Reports, 8(2), 146-156.

Micaroni, V., McAllen, R., Turner, J., Strano, F., Morrow, C., Picton, B., Harman, L. & Bell, J. J. (2021). Vulnerability of temperate mesophotic ecosystems (TMEs) to environmental impacts: rapid ecosystem changes at Lough Hyne Marine Nature Reserve, Ireland. Science of The Total Environment, 789, 147708.

Montero-Serra, I., Linares, C., Doak, D. F., Ledoux, J. B., & Garrabou, J. (2018). Strong linkages between depth, longevity and demographic stability across marine sessile species. Proceedings of the Royal Society B: Biological Sciences, 285(1873), 20172688.

Morelli, T. L., Daly, C., Dobrowski, S. Z., Dulen, D. M., Ebersole, J. L., Jackson, S. T., Lundquist, J.D., Millar, C.I., Maher, S.P., Monahan, W.B. and Nydick, K.R., Redmond, K. T., Sawyer, S. C., Stock, S., & Beissinger, S. R. (2016). Managing climate change refugia for climate adaptation. PLoS One, 11(8), e0159909.

Morganti, T. M., Ribes, M., Yahel, G., & Coma, R. (2019). Size is the major determinant of pumping rates in marine sponges. Frontiers in physiology, 10, 1474.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R. E., Lehner, B., ... & Ricketts, T. H. (2008). Global mapping of ecosystem services and conservation priorities. Proceedings of the National Academy of Sciences, 105(28), 9495-9500.

Oksanen, J., Simpson, G. L., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. P., O'Hara, R. B., Solymos, P., Stevens, M. H. H., and Szöecs, E. 2022. vegan: Community Ecology Package. R package version 2.6-2. https://CRAN.R-project.org/package=vegan

Oliver, E. C. J., Donat, M. G., Burrows, M. T., Moore, P. J., Smale, D. A., Alexander, L. V., Benthuysen, J. A., Feng, M., Gupta, A. S., Hobday, A. J., Holbrook, N. J., Perkins-Kirkpatrick, S. E., Scannell, H. A., Straub, S. C., Wernberg, T. (2018). Longer and more frequent marine heatwaves over the past century. Nature Communications, 9(1), 1-12.

Ostroumov, S. A. (2005). Suspension-feeders as factors influencing water quality in aquatic ecosystems. In The Comparative Roles of Suspension-Feeders in Ecosystems: Proceedings of the NATO Advanced Research Workshop on The Comparative Roles of Suspension-Feeders in Ecosystems Nida, Lithuania 4–9 October 2003 (pp. 147-164). Springer Netherlands.

Petralia, R. S., Mattson, M. P., & Yao, P. J. (2014). Aging and longevity in the simplest animals and the quest for immortality. Ageing research reviews, 16, 66-82.

R Core Team 2013. R: A language and environment for statistical computing.

Reid, A. P., Johnson, C. R., & Ross, D. J. (2018). Impacts of the New Zealand screwshell Maoricolpus roseus on growth and condition of juvenile commercial scallops Pecten fumatus. Marine Ecology Progress Series, 604, 173-185.

Reyes-Riveros, R., Altamirano, A., De La Barrera, F., Rozas-Vásquez, D., Vieli, L., & Meli, P. (2021). Linking public urban green spaces and human well-being: A systematic review. Urban Forestry & Urban Greening, 61, 127105.

Robinson, J. H., Donald, K. M., Brandt, A. J., & Lee, D. E. (2016). Magasella sanguinea (Leach, 1814) and Magasella haurakiensis (Allan, 1931): resolving the taxonomic placement of these endemic New Zealand brachiopods using morphological and molecular traits. Journal of the Royal Society of New Zealand, 46(2), 139-163.

Rochman, C. M., Hoh, E., Kurobe, T., & Teh, S. J. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific reports, 3(1), 1-7.

Rossi, S., Bramanti, L., Gori, A., & Orejas Saco del Valle, C. (2017). Marine animal forests: the ecology of benthic biodiversity hotspots. Springer, Cham.

Rowden, A. A., Berkenbusch, K., Brewin, P. E., Dalen, J., Neill, K., Nelson, W., Oliver, M.D. & Probert, P. K. (2012). A review of the marine soft-sediment assemblages of New Zealand. NZ Aquatic Environment and Biodiversity Report.

Schönberg, C. H. L. (2016). Happy relationships between marine sponges and sediments–a review and some observations from Australia. Journal of the Marine Biological Association of the United Kingdom, 96(2), 493-514.

Strano, F., Micaroni, V., Costa, G., Bertocci, I., & Bertolino, M. (2020). Shallow-water sponge grounds along the Apulian coast (central Mediterranean Sea). Marine Biodiversity, 50, 1-12.

Strano, F., Micaroni, V., Davy, S. K., Woods, L., & Bell, J. J. (2022). Near-future extreme temperatures affect physiology, morphology and recruitment of the temperate sponge Crella incrustans. Science of The Total Environment, 823, 153466.

Strano, F., Micaroni, V., Thomas, T., Woods, L., Davy, S. K., & Bell, J. J. (2023). Marine heatwave conditions drive carryover effects in a temperate sponge microbiome and developmental performance. Proceedings of the Royal Society B, 290(2000), 20222539.

Thrush, S. F., Hewitt, J. E., Cummings, V. J., Ellis, J. I., Hatton, C., Lohrer, A., & Norkko, A. (2004). Muddy waters: elevating sediment input to coastal and estuarine habitats. Frontiers in Ecology and the Environment, 2(6), 299-306.

Thurstan, R. H., Pandolfi, J. M., & zu Ermgassen, P. S. (2017). Animal forests through time: historical data to understand present changes in marine ecosystems. Marine animal forests: The ecology of benthic biodiversity hotspots, 947-964.

Tyrrell, M. C., & Byers, J. E. (2007). Do artificial substrates favor nonindigenous fouling species over native species?. Journal of Experimental Marine Biology and Ecology, 342(1), 54-60.

Van der Linden, W. J. (1967). A textural analysis of Wellington Harbour sediments. New Zealand journal of marine and freshwater research, 1(1), 26-37.

Walters, R. A., Gillibrand, P. A., Bell, R. G., & Lane, E. M. (2010). A study of tides and currents in Cook Strait, New Zealand. Ocean dynamics, 60, 1559-1580.

Walters, R. A., Gillibrand, P. A., Bell, R. G., & Lane, E. M. (2010). A study of tides and currents in Cook Strait, New Zealand. Ocean dynamics, 60, 1559-1580.

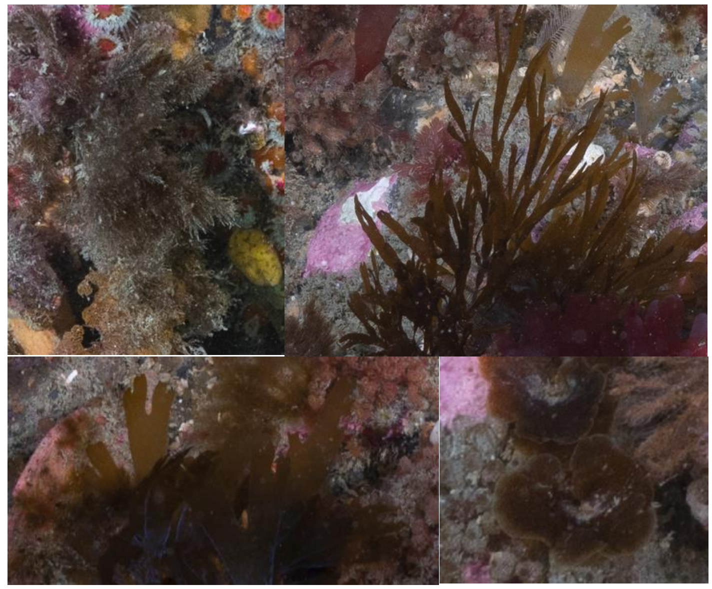
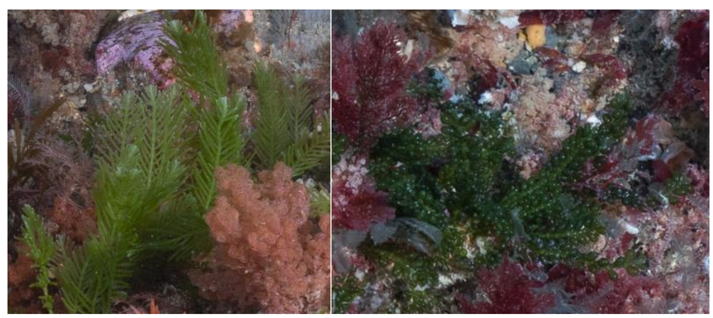
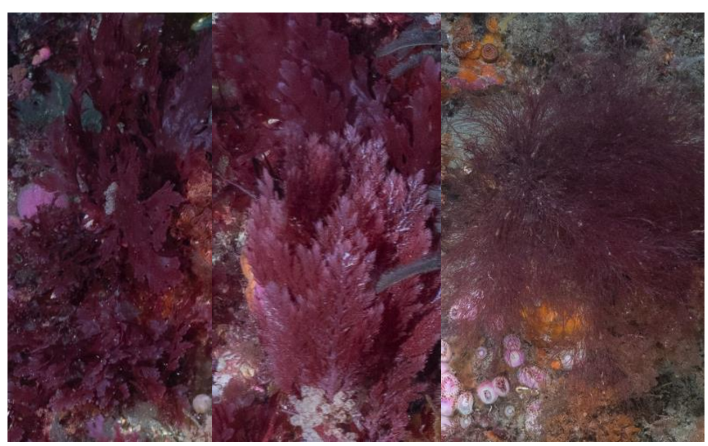
Warrick, J. A., Farnsworth, K. L., Lee, H. J., & Normark, W. R. (2009). Sources of sediment to the coastal waters of the Southern California Bight. Geological Society of America Special Papers, 454, 39-52.

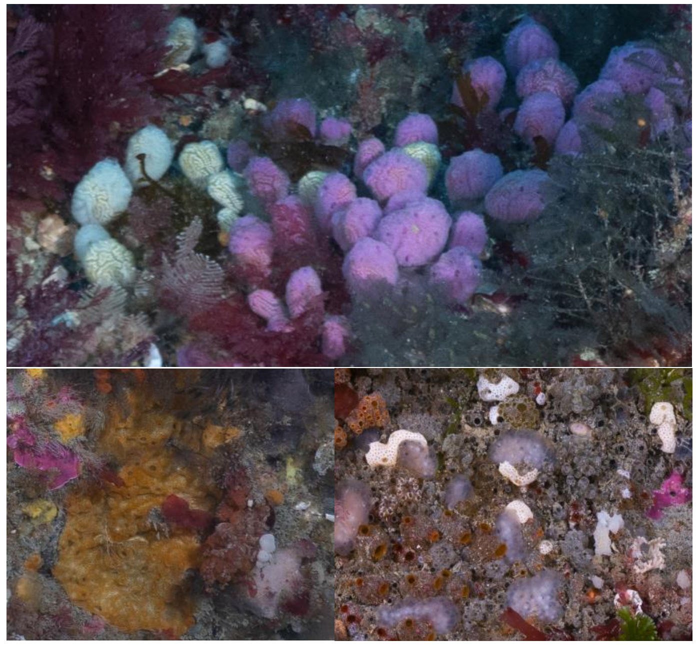
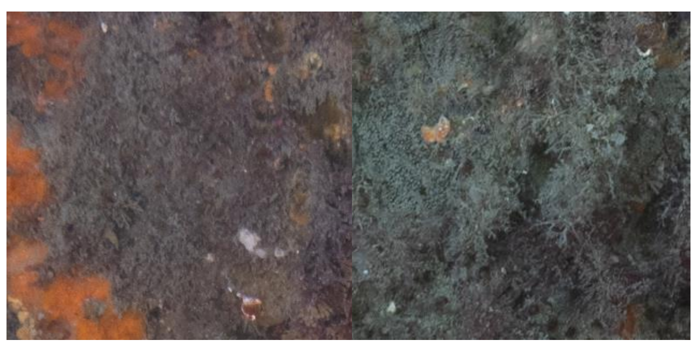
Wickham, H. (2011). ggplot2. Wiley interdisciplinary reviews: computational statistics, 3(2), 180-185.

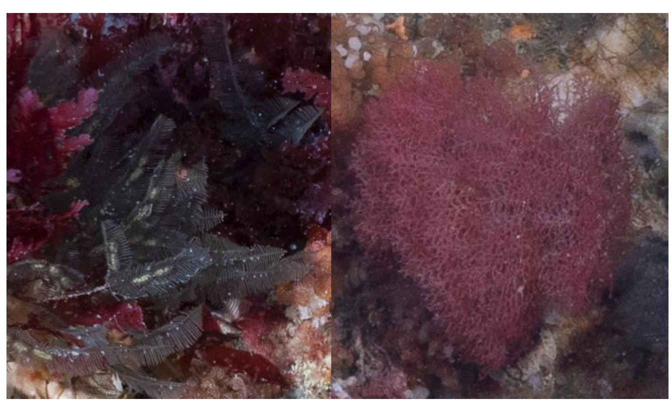
Wulff, J. L. (2006). Ecological interactions of marine sponges. Canadian Journal of Zoology, 84(2), 146-166.

Appendix

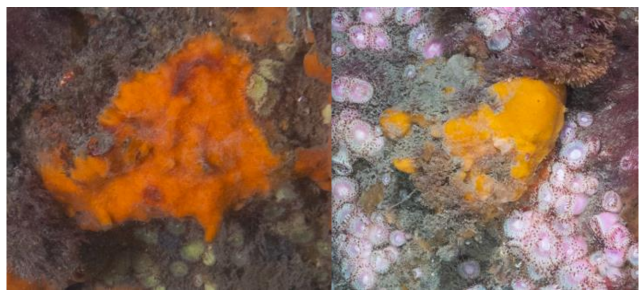
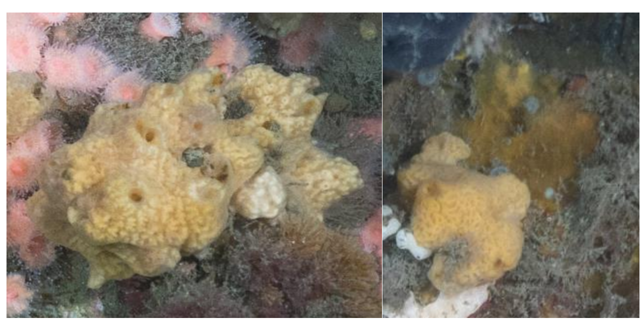
Table S1. OTUs used in the photoquadrat analysis with description and photos

Operational taxonomic unit (OTU)	Comments/Location	Photos
Brown algae	Non-kelp brown algae, including *Halopteris*, *Dictyota* and other species. More common in the shallowest stations, such as Mana North MI04 and MI08.	
Caulerpa spp.	Mainly *Caulerpa articulata* and, to a lesser extent, *Caulerpa geminata*.	
Red algae	Many species of conspicuous, filamentous red algae.	

Operational taxonomic unit (OTU)	**Comments/Location**	**Photos**
Colonial ascidians	Small colonial ascidians, such as *Hypsistozoa fasmeriana* and other unidentified species.	
Solitary ascidians	Large solitary ascidians, including *Cnemidocarpa* and other unidentified species	
Biological matrix	A mixture of hydroids, bryozoans, and filamentous algae.	

Operational taxonomic unit (OTU)	**Comments/Location**	**Photos**
Encrusting Bryozoans	Various species of calcifying encrusting bryozoans, including *Celleporaria agglutinans.*	
Erect bryozoans	Many species of erect branching bryozoans, including *Margaretta barbata,* cf. *Menipea vectifera,* and *Caberea* ind.	
Catenicellidae	Various species of moss bryozoans. Very abundant, especially at Mana NW and Shark Tooth.	
Hydroids	Many species, such as *Halopteris campanula, Aglaophenia*, and an unidentified Sertulariidae.	

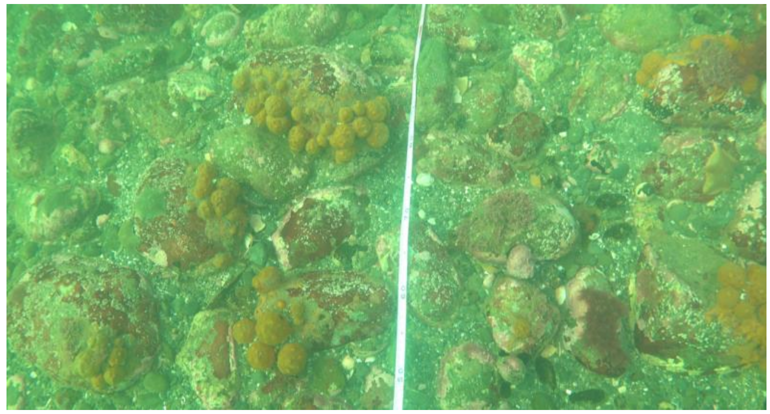
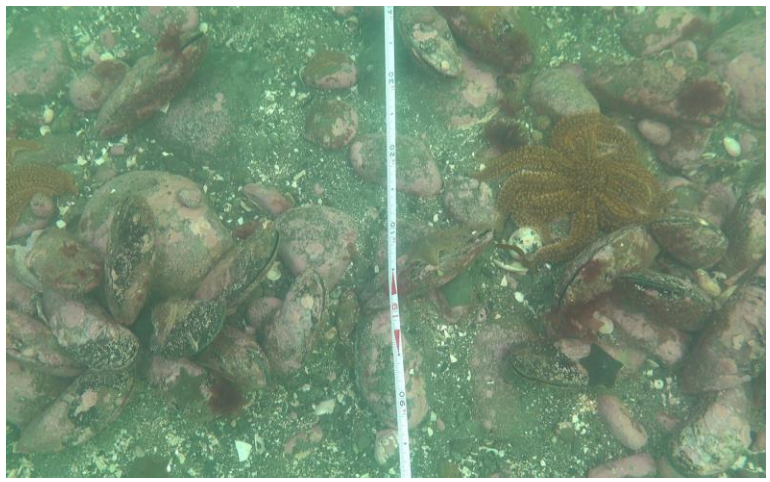
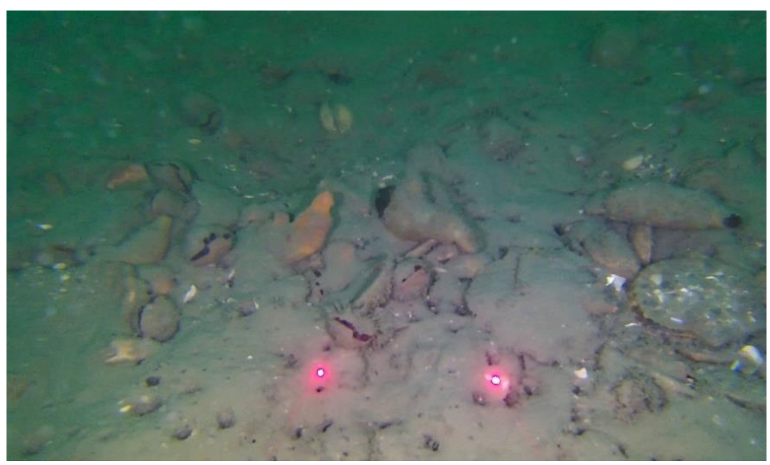
Operational taxonomic unit (OTU)	**Comments/Location**	**Photos**
		
Ancorinidae ind.	An unidentified species belonging to the family Ancorinidae. This species is more sinuous than *Ecionema alata* and has a velvety appearance.	 
Calcareous sponges	Unidentified calcareous sponges.	 

Operational taxonomic unit (OTU)	Comments/Location	Photos
Branching sponges	Several species of branching sponges, the most common of which is *Callyspogia ramosa*.	
Encrusting orange sponge	Unidentified encrusting sponges that cannot be identified from photographs. Especially common at Mana NW.	
Encrusting red sponge	Unidentified encrusting sponges which cannot be identified from photographs.	
Encrusting yellow sponge	Unidentified encrusting sponges which cannot be identified from photographs.	

Operational taxonomic unit (OTU)	**Comments/Location**	**Photos**
Massive violet sponge	Massive white to purple sponge (probably hosting cyanobacteria), common around Mana North and NW. It does not appear in the guides.	
Other sponges	Various unidentified sponges of different morphologies that cannot be identified from the photographic material.	

Table S2. Main habitats found in Wellington harbour with description and photos

CMECS Classification	Description/Location	Photo
Faunal Bed > Soft Sediment Fauna > Sponge Bed: ***Suberites australiensis***	Sponge bed dominated by *Suberites australiensis,* often associated with other filter-feeding organisms, such as other sponges, ascidians, bivalves and brachiopods. The most common sponge bed in the harbour.	
Faunal Bed > Soft Sediment Fauna > Diverse Soft Sediment Epifauna: **Mixed filter-feeding fauna**	Diverse epifauna consisting of sponges, horse mussels (*Atrina zelandica*), brachiopods, solitary ascidians, and suspension feeders such as sabellid polychaetes.	
Faunal Bed > Soft Sediment Fauna > Small Tube Building Fauna: ***Owenia petersenae***	Large fields of the small tube-forming polychaete *Owenia petersenae.* This habitat hosts several other species of tube-forming worms. This habitat was only found in Eastbourne between Ward Island and Robinson Bay.	

CMECS Classification	**Description/Location**	**Photo**
Faunal Bed > Attached Fauna > Attached Sponges: ***Superites perfectus***	Clusters of the colonial sponge *Suberites perfectus* on beds of bare boulders with CCA. This community was only found in Eastbourne near Camp Bay.	
Faunal Bed > Attached Fauna > Attached Mussels: ***Perna canaliculus***	Clusters of large specimens of *Perna canaliculus* on beds of bare boulders with CCA and sparse *Undaria pinnatifida*. This community was only found in Eastbourne, near Point Arthur.	
Faunal Bed > Soft Sediment Fauna > Brachiopod bed: **Brachiopod bed**	Shell rubble and mud with a high density of brachiopods mostly (or exclusively) belonging to the species *Magasella sanguinea*. This community was only found at one station in Kau Bay, but there are anecdotal observations in other areas of the Harbour, such as Shelly Bay.	

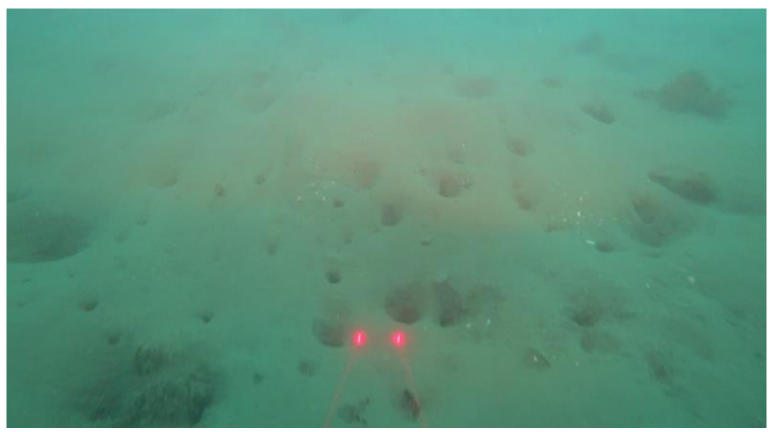
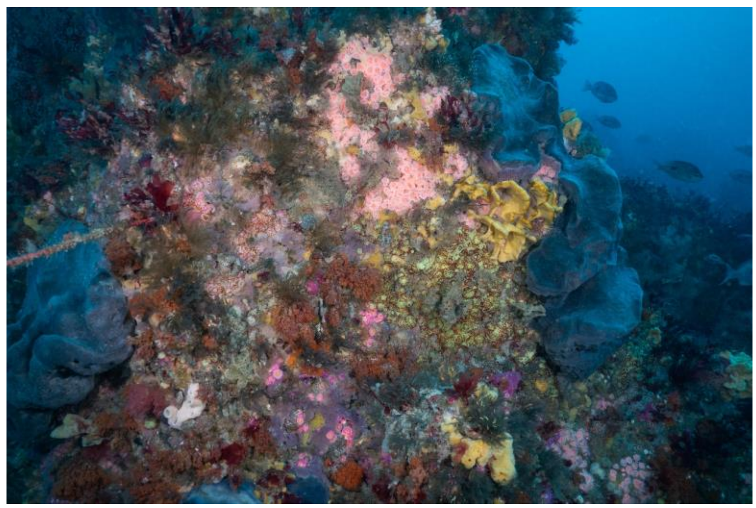
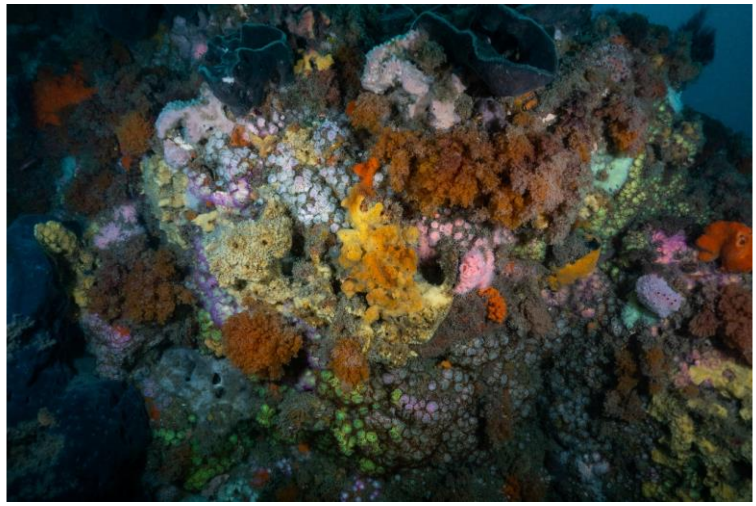
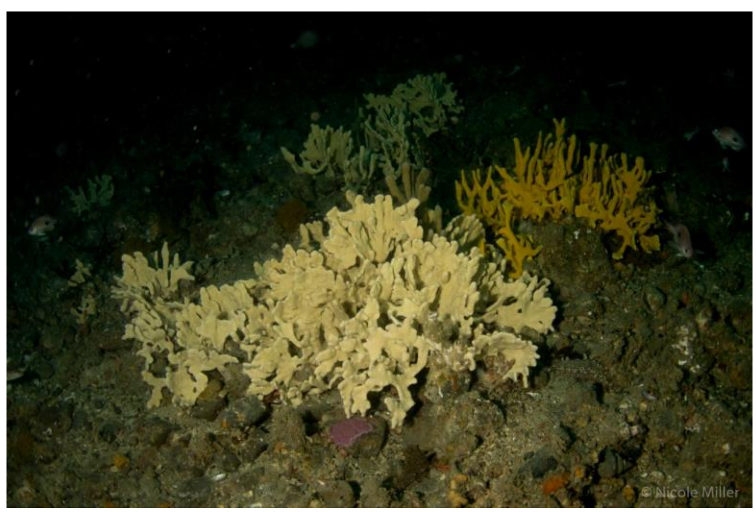
CMECS Classification	Description/Location	Photo
Faunal Bed > Soft Sediment Fauna > Mobile Mollusks on Soft Sediments: ***Maoricolpus roseus***	Fields of the filter-feeding gastropod *Maoricolpus roseus*. This species is common throughout Wellington Harbour, but is only found in such high densities in the north-western part of the harbour, near Petone.	
Faunal Bed > Soft Sediment Fauna > Larger Deep Burrowing Fauna: **Mixed borrowing fauna**	Includes bivalves, worms, crustaceans and fish that burrow into the mud. Common all around the harbour.	
Faunal Bed > Soft Sediment Fauna > Sponge Bed: **Mixed soft-sediment sponges**	Mixed sponges, including *Suberites australiensis, Crella incrustans, C. affinis, Ciocalypta penicillus, Aaptos globosa* and branching sponges from the family Callispongiadae.	

Table S3. Main biotic communities found in Wellington's open coast with description and photos.

CMECS Classification	Description/Location	Photo
Reef Biota > Shallow Mesophotic Coral Reef Biota > Mixed Shallow Mesophotic Coral Reef: **Mixed reef invertebrates**	Communities dominated by a mixture of sessile invertebrates, including sponges, bryozoans, hydroids, and ascidians. Shark Tooth (ST01, 27 m)	
	Thoms Rocks (TR02, 30 m)	
	Mana North (MI08, 21 m)	

CMECS Classification	Description/Location	Photo
Reef Biota > Shallow Mesophotic Coral Reef Biota > Mixed Shallow Mesophotic Coral Reef: **Mixed reef sponges**	Communities dominated by sessile invertebrates, but where sponges (several species) are the main structuring organisms. Mana NW (MI09, 21 m)	
	Ohau Point (OP01, 24 m)	
	Airplane Island (AI01, 38 m)	

CMECS Classification	**Description/Location**	**Photo**
	Hunter's Bank (HB01, 26 m)	
	Pukerua Bay (PB03, 16 m)	
Reef Biota > Shallow Mesophotic Coral Reef Biota > Mixed Shallow Mesophotic Coral Reef: ***Ecionemia alata***	Communities dominated by sessile invertebrates, but where the sponge *Ecionemia alata* is the main structuring species. Mana South (MI07, 19 m)	

CMECS Classification	Description/Location	Photo
	Thoms Rocks (TR01, 28 m)	

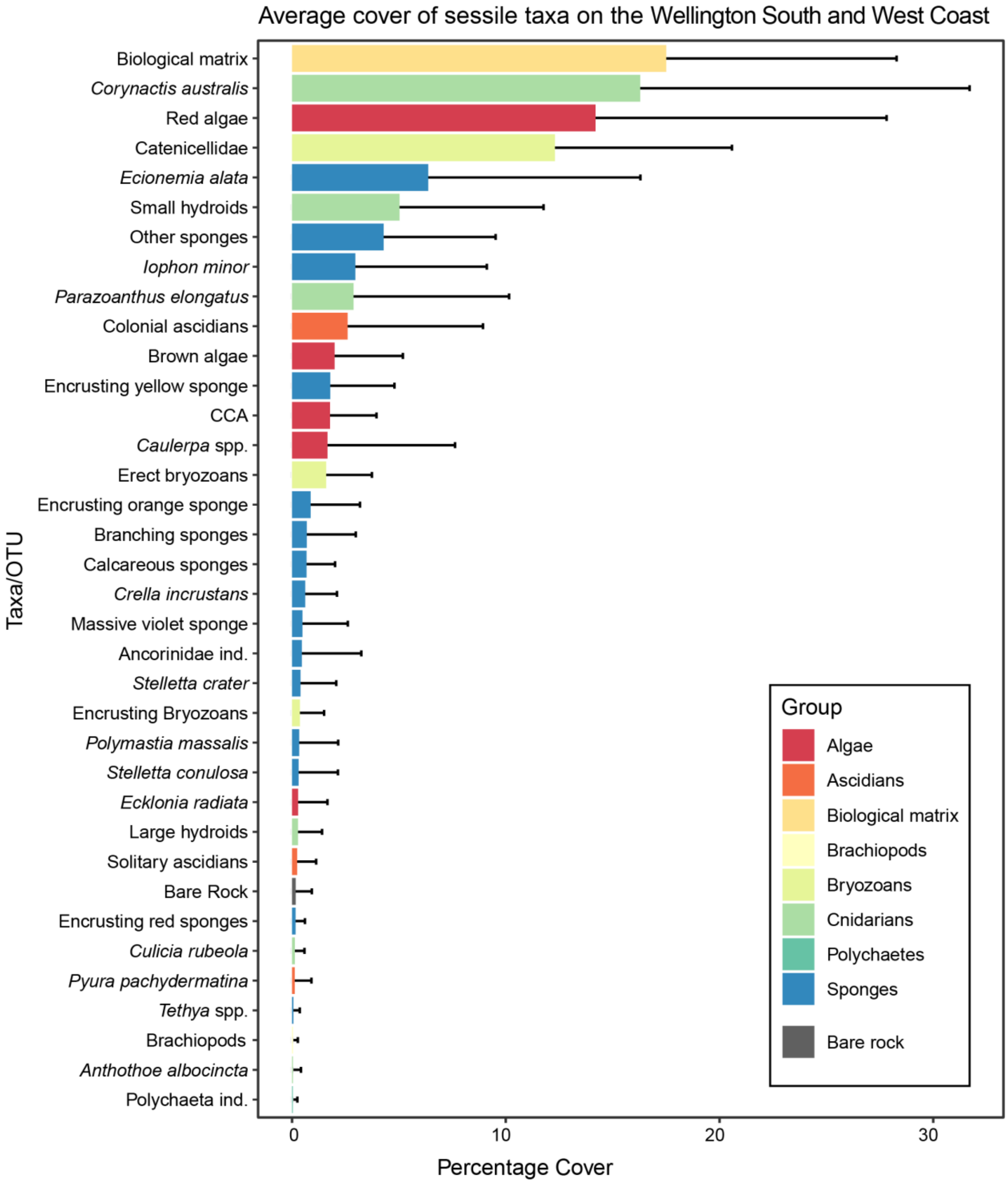


Figure S1. Average percentage cover of sessile organisms and bare rock on the Wellington South and West Coast. All the stations are pooled. Error bars indicate standard deviation.

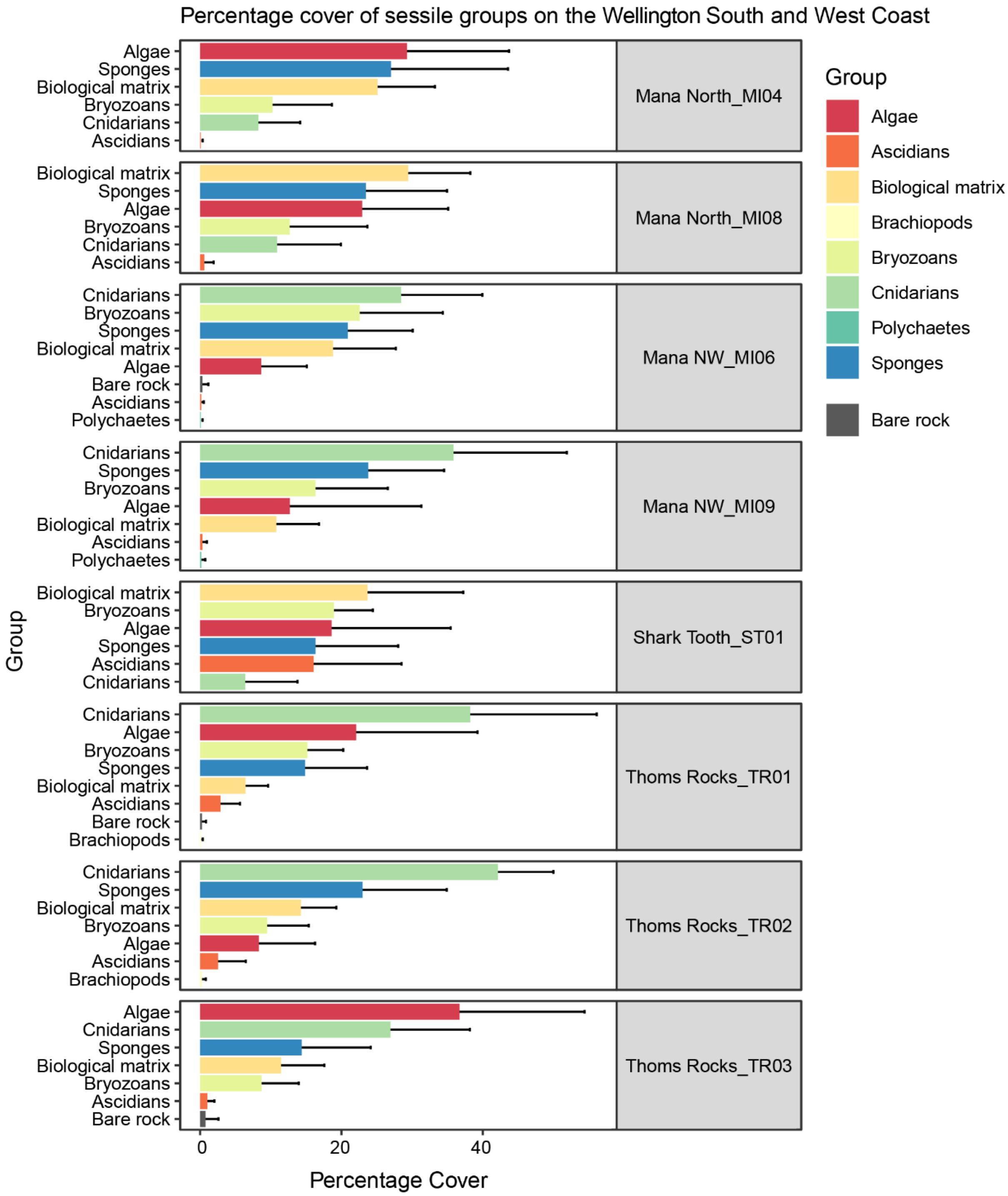


Figure S2. Percentage cover of sessile groups and bare rock at different stations on the Wellington South and West Coast (*n* = 10). Error bars indicate standard deviation.

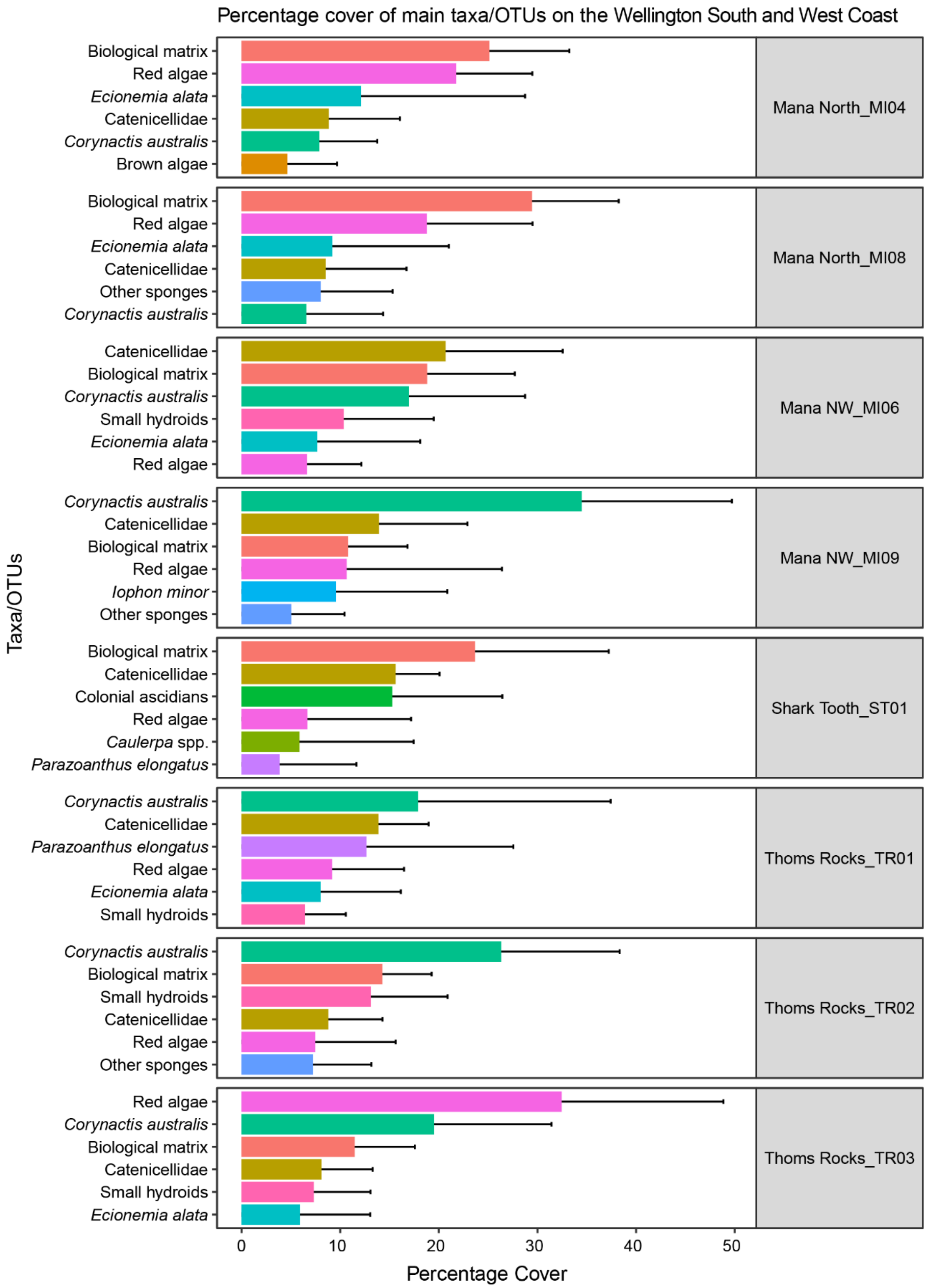


Figure S3. Percentage cover of the main sessile taxa/OTUs at different stations on the Wellington South and West Coast. Error bars indicate standard deviation.