Tāmaki Makaurau / Auckland Intertidal Reef Monitoring Report: 2011 to 2024

State of the Environment Reporting

Arie Spyksma, Nick Shears

Leigh Marine Laboratory, University of Auckland

September 2025 Technical Report 2025/25

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Cover image credit
Survey site within the low tidal zone at Mathesons Bay. Photograph by Arie Spyksma.

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Executive summary

This report provides an assessment of rocky intertidal reef communities across the Auckland region, based on data collected from 22 long-term monitoring sites spanning Aotea / Great Barrier Island (GBI – east and west coast), the Mainland East Coast (MEC – outer to inner Hauraki Gulf), and the Mainland West Coast (MWC – open coast and Manukau Harbour) from 2011 to 2024. The monitoring programme captures regional and temporal variations in intertidal biodiversity and community structure and provides an evaluation of key environmental variables that may be driving change.

Overall, community structure and macroinvertebrate assemblages on Auckland rocky shores were similar, with a number of macroalgae and invertebrate species found throughout the monitoring network. Fetch (used as a proxy for wave exposure and energy) was the strongest environmental predictor of community assemblage, with the three highly exposed MWC and GBI sites dominated by sessile invertebrate communities and contained higher abundances of mobile invertebrates adapted for coping with high energy environments (e.g. limpets), while macroalgae dominated communities were common throughout the more moderately exposed and sheltered sites.

Sediment was also an important predictor of community assemblage with high sediment cover, which was particularly prevalent on expansive, gently sloping reefs, appearing to have a negative impact on overall species richness, and in particular macroinvertebrate populations. Signs of chronic sedimentation issues were apparent across the monitoring network but were particularly pronounced among inner Hauraki Gulf sites, where a potential shift in community composition from rocky reef to soft sediment is occurring (e.g., dense cockle beds recorded at Ōmana in 2023). Extreme rainfall events within the Auckland region in early 2023 resulted in sediment inundation of intertidal reefs throughout the MEC sites, which were coincidentally surveyed immediately after these events. This was associated with marked declines in species richness and macroinvertebrate abundances, especially in the low shore zone. These extreme weather events, which are being intensified by climate change, may provide a preview of future conditions likely to be experienced by Auckland's intertidal reefs.

The importance of other human impacts, including recreational harvesting, invasive species, and eutrophication, remain poorly understood. Harvesting was observed at many sites, but the current survey structure is not designed to detect impacts on target species. A number of invasive species have been recorded across the survey period, particularly in the inner Hauraki Gulf, though these have tended to only constitute minor components of the reef community. Toxic filamentous cyanobacteria, such as *Okeania* spp., have been periodically recorded at MEC and MWC sites, with blooms occurring within the inner Hauraki Gulf.

To ensure the ongoing suitability of the monitoring programme, key recommendations include reviewing the monitoring network in 2026, adopting technologies like UAVs and photogrammetry and collecting sediment for grain size analysis. Strengthening these efforts will support better understanding and management of intertidal ecosystems in the face of ongoing environmental change.

Contents

1 Introduction

Rocky shores or intertidal reefs are located at the interface between land and sea. These coastal habitats are periodically exposed to air, full sunlight, high water motion, and rapid changes in salinity and temperature. The species that occupy these physically harsh environments must tolerate rapidly changing conditions and are often at their physiological limits (Byrne, 2011; Sanford & Kelly, 2011; Sunday et al., 2014). Because of this, intertidal reefs are particularly vulnerable to additional human-induced stressors such as pollution, sedimentation, harvesting pressure and climate change (Crowe et al., 2000; Harley, 2011; Hawkins et al., 2008).

Experimental research and long-term monitoring on rocky shores in New Zealand has largely been focussed on the South Island (Menge et al., 1999; Menge et al., 2003; Schiel, 2004). This research has highlighted the complex relationship between rocky shore communities and variation in air and water temperature, wave action, and the Southern Oscillation Index (Schiel, 2011; Schiel et al., 2016). These studies have highlighted the difficulties in predicting the effects of a changing climate on ecologically important habitat-forming species in the intertidal zone. Much of this research, as well as other biogeographic studies on New Zealand's rocky shores (Mieszkowska & Lundquist, 2011) have focussed on intertidal reefs on exposed open coasts. It is likely however that the impacts of human activities, including sedimentation, harvesting and increasingly climate change, will vary across a range of environmental conditions meaning data collection spanning environmental gradients is vital.

A nation-wide study by Schiel (2011) showed that rocky shore communities were mapped into four general regions: the east and west coasts to the north and south of Cook Strait. These findings were broadly consistent with previous research (Menge et al., 1999; Menge et al., 2003; Schiel, 2004) and identified large-scale differences in intertidal reef communities between the east and west coasts of New Zealand. The low- and mid-tidal zones on west coast reefs, which are more exposed, were dominated by invertebrates, particularly mussels and barnacles. Almost all of the east coast sites were dominated by fucoid algae, particularly the low tidal zone, with a distinct shift in dominant algal species around the Cook Strait (Schiel, 2011). This shift is likely related to temperature and current patterns that occur within this region, with seasonal northerly wind creating upwelling in the upper South Island and predominant south-westerly winds pushing colder water up from the south (Schiel, 2011). Cold tolerant species such as bull kelp (*Durvillaea antarctica)* are more commonly found south of Cook Strait while species such as *Xiphophora chondrophylla* and *Carpophyllum angustifolium,* which are common in warmer regions, are only found to the north of Cook Strait.

Within the Auckland region, the eastern and western coastlines are within easy reach of the country's most populous metropolitan area, Auckland. Consequently water bodies such as the Hauraki Gulf – Tīkapa Moana – Te Moanaui-ā-Toi (from here referred to as the Hauraki Gulf), the large embayment on the east coast of Auckland (Fig. 1), provides an extremely important setting for recreational, cultural, societal and economic demands (Aguirre et al., 2016). Despite the importance of the Hauraki Gulf, nation-wide studies on rocky shore communities (e.g. Mieszkowska & Lundquist, 2011; Schiel, 2011) have generally only included a limited number of sites from the outer Hauraki Gulf. The Hauraki Gulf is protected from the prevailing south-westerly winds but is exposed to ocean swells from the northeast. Subsequently, there is a large gradient of decreasing wave exposure from the outer to inner Hauraki Gulf due to increasing protection from natural features such as Aotea / Great Barrier Island, the Coromandel Peninsula, and the many islands within the mid and inner Hauraki Gulf. The turbidity gradient across the Hauraki Gulf is opposite to that of waves, with greater inputs of fine sediments into the more sheltered parts of the inner Hauraki Gulf (Seers & Shears, 2015). Community characteristics on intertidal reefs in the outer Hauraki Gulf may therefore not necessarily reflect those in more sheltered inner areas. Auckland's population is rapidly growing and coastal land around the Hauraki Gulf continues to be developed (Hauraki Gulf Forum, 2023). In general, environmental indicators have fluctuated or shown declining trends in ecosystem health across marine habitats, with some of the main stressors including sediment runoff, toxic chemicals, nutrient inputs, microbiological contamination (pathogens), overharvesting of kai moana and introduced species (Hauraki Gulf Forum, 2023).

Auckland's west coast also includes a number of popular coastal communities and is connected to the Manukau Harbour. Auckland Council monitoring programmes in the Manukau have largely focussed on intertidal soft sediment ecosystems (Greenfield et al., 2019; Drylie, 2025), and limited information exists on intertidal reef communities and how these ecosystems may have changed over time (Hayward & Morley, 2004). Like the Hauraki Gulf, the west coast and the Manukau Harbour, particularly the sheltered inlets, are impacted by a variety of stressors including sedimentation, pollution, heavy metal contamination and overharvesting (Greenfield et al., 2019; Hayward & Morley, 2004).

Climate change is also an emerging issue, which could have particularly large impacts on intertidal communities from the combination of sea-level rise and larger and more frequent storm events, which are expected to increase coastal erosion, sediment inputs and inundation (Seers & Shears, 2015). Ocean temperatures throughout northeastern New Zealand are increasing (Shears et al., 2024) while Auckland's air temperature is projected to warm considerably into the future (Pearce et al., 2018). The number of "hot days" (days >25^{o}C) in Auckland is projected to double by 2110 (Pearce et al., 2018), adding an additional 70 hot days per annum. An increasing number of hot days over the summer will likely have a variety of effects on rocky shore communities especially when low tides occur in the afternoon (Helmuth et al., 2006) while more intense storms raise the risk of land instability, erosion (Howard & Roberts, 2024; Stone et al., 2024), and shifts in the horizontal extent of reef platforms.

The Hauraki Gulf and exposed west coast were the initial focal point of descriptions of rocky shore communities in New Zealand (Carnachan, 1952; Dellow, 1950 & 1955; Morton & Miller, 1973; Oliver, 1923; Powell, 1937). These historic descriptions have provided valuable information and allowed scientists to assess some dramatic long-term changes in Auckland's rocky shore biota, including the loss of the green-lipped mussel (*Perna canaliculus*) and the introduction of new species such as the Pacific oyster, *Crassostrea gigas* (Dromgoole & Foster, 1983). However, as Dromgoole and Foster (1983) pointed out, "replicable quantitative data are rare, and it is difficult to find the exact location of most ecological observations." Quantitative and experimental research on rocky shores increased in the 1970s and 1980s through research carried out at the University of Auckland's Leigh Marine Laboratory; however, this was primarily focussed on rocky shores within the Leigh marine reserve (Reviewed in Creese, 1988). With changes in personnel and academic research interests at the Leigh Marine Laboratory, there has been a paucity of rocky shore research at Leigh since the mid-1990s, and this trend appears to apply to the wider Auckland region as well.

There have been two, small-scale rocky shore monitoring programmes carried out in the Auckland region in more recent times. Monitoring of rocky shores was carried out sporadically by the Department of Conservation in the Long Bay-Okura Marine Reserve between 2000 and 2009 (Sivaguru, 2010). This study found that there was spatial and temporal variation in species among sites and among tidal zones, four of which were identified—upper, upper mid, lower mid, lower tidal zones—according to the dominant species found within the area. Monitoring of six intertidal sites on Meola Reef in Auckland's Waitematā Harbour has been carried out annually for the Auckland Council since 2001 (Foley & Shears, 2019). Sampling at these sites is conducted along the mid-shore, and the reef is largely dominated by oysters (both *Crassostrea gigas* and *Saccostrea glomerata*). This programme has found that there is a lot of variability in community structure along Meola Reef that is cyclical in nature. There are also community composition differences along the reef that correspond with differences in tidal height, wave exposure, and sediment cover (Foley & Shears, 2019). While these surveys provide detailed quantitative information for Long Bay and Meola Reef, systematic quantitative surveys of intertidal reef communities throughout the wider Auckland region are lacking and our knowledge of spatial and temporal variation in these communities and the processes that structure them is limited.

This report details the findings of a region wide intertidal rocky reef monitoring programme designed to contribute to Auckland Council's state of the environment monitoring and reporting responsibilities. The programme was initiated in 2011 at 14 sites across Auckland's east coast, but expanded in 2013 to include an additional four sites from Aotea / Great Barrier Island (from here GBI), and again in 2021 to include two sites on the exposed west coast and two sites within the Manukau Harbour. Thus, the sites cover a wide range of environmental conditions, from exposed coastline to sheltered embayments. All sites are now monitored biennially, providing the basis for long-term monitoring. Here we describe the broad-scale patterns in rocky shore communities across the Auckland region, provide a preliminary investigation into how these patterns vary in relation to key environmental variables among the sites and examine temporal trends in community composition among the survey regions and sites over the monitoring period. Further, we provide recommendations to ensure that the long-term monitoring programme continues to be fit for purpose in an increasingly changing world.

Supporting information

This report is one of a series of technical publications prepared in support of *Te oranga o te taiao o Tāmaki Makaurau – The health of Tāmaki Makaurau Auckland's Natural Environment in 2025: a synthesis of Auckland Council State of the Environment reporting*.

All related reports (past and present) are published on the Knowledge Auckland website.

All data supporting this report can be requested through our Environment Auckland Data Portal. Here you can also view live rainfall data and use several data explorer tools.

2 Methods

2.1 Site selection and locations

In total, twenty-two intertidal rocky reefs have been surveyed as part of the Auckland Council Intertidal Rocky Reef Monitoring Programme (Table 1, Fig. 1, Appendix 1). These include:

- Fourteen sites along Auckland's mainland east coast (MEC), surveyed in 2011, 2013, 2019, 2021 and 2023.
- Four sites around GBI surveyed in 2013, 2020 (two sites only) and 2022.
- Four sites along Auckland's mainland west coast (MWC), including two within the Manukau Harbour and two along exposed open coastline, surveyed in 2021, 2022, and 2024.

These twenty-two sites were chosen to be representative of intertidal rocky reef habitats throughout the region. The GBI sites were selected to span the island's exposure gradient as best as possible (given the challenges of sampling offshore), with three sites along the west coast and one on the east coast (Fig. 1). MEC sites were positioned approximately every 5 to 10km along the coast and spanned the mainland gradient from the outer (Echinoderm Reef-Goat Island) to inner (Ōmana) Hauraki Gulf (Fig. 1). MWC sites were chosen to represent contrasting characteristics of highly exposed open coastline and comparatively sheltered harbour conditions. Two sites were located along open coastline and two within the Manukau Harbour (Fig. 1). Suitable areas of intertidal rocky reef were rare or completely absent from within the inner Manukau Harbour, resulting in both harbour sites being located relatively close to the harbour entrance.

Monitoring sites were chosen based on the following parameters:

- Representative of intertidal rocky reef habitats throughout the region;
- Reflect a gradient in urbanisation, with decreasing eutrophication/sedimentation and increasing wave exposure from the inner sheltered waters to the more open coast of the Hauraki Gulf and GBI;
- Align with sites where existing intertidal and subtidal rocky reef monitoring and research has been carried out (e.g., Long Bay, Echinoderm Reef at Leigh, Campbells Bay, Piha and Te Henga);
- Align with the Auckland Council's existing water quality monitoring sites (e.g., Echinoderm Reef, Ōrewa, and Browns Bay);
- Follow recommended locations for monitoring in Hewitt (2000); and
- Located where a contiguous reef extending from the high to low shore was present.

Survey methods were adapted from those used by the Marine Ecology Research Group (MERG) at the University of Canterbury (Schiel et al., 2016). MERG has used the same methods to survey intertidal reef sites in southern New Zealand for more than 20 years, and this technique appears to provide a standardised and consistent approach to determining the ecological characteristics of these reefs and detecting trends and changes in benthic communities.

The MEC survey for 2019 included one site that was surveyed in 2020, while COVID restrictions throughout 2021 hampered survey efforts meaning five sites were surveyed in 2022. As climatological conditions were broadly similar within the 2019/2020 and 2021/2022 periods (NIWA, 2025) the risk of large, site level variations in community composition occurring between sites surveyed in 2019 vs 2020 or 2021 vs 2022 was considered to be no greater than the risk of variation occurring across the typical three to four month survey period required to complete the MEC sites (accounting for a limited number of suitable spring low tides each month). For this reason, the 2020 surveys were analysed as part of the 2019 survey period and 2022 surveys analysed as part of the 2021 survey period.

Table 1: Location of intertidal monitoring sites within the Auckland region. Wind fetch was calculated for each site by summing the distance to land for each 10-degree sector of the compass rose (max distance for open sea set to 300km). Reef extent was estimated by measuring the length of the reef platform at each site. See Appendix 1 for site descriptions.

Site name	Site code	Latitude	Longitude	Fetch (km)	Reef extent (m)	Description
Aotea Great Barrier Island (GBI)						
Rangiwhakaea Bay	Rangi	36°5.410'S	175°24.865'E	912.95	15	East coast – exposed
Oruapure Bay	Orua	36°7.952'S	175°19.547'E	624.66	18	West coast – exposed
Bradshaw Cove	Brad	36°10.261'S	175°19.243'E	18.17	13	West coast – sheltered
Whangaparapara Harbour	Whan	36°14.920'S	175°23.414'E	12.44	17	West coast – sheltered
Mainland – East Coast (MEC)						
Echinoderm Reef (Goat Is)	EReef	36°16.160'S	174°47.654'E	799.65	100	Outer Hauraki Gulf – exposed
Mathesons Bay	Math	36°18.034'S	174°48.139'E	611.10	78	Outer Hauraki Gulf – exposed
Ōmaha	Omah	36°20.975'S	174°47.807'E	907.08	70	Outer Hauraki Gulf – exposed
Christian Bay	Chris	36°23.352'S	174°47.558'E	412.03	60	Mid Hauraki Gulf – semi exposed
Martins Bay	Mart	36°27.501'S	174°45.970'E	222.56	100	Mid Hauraki Gulf – semi exposed

Site name	Site code	Latitude	Longitude	Fetch (km)	Reef extent (m)	Description
Waiwera	Waiw	36°32.532'S	174°43.128'E	379.83	130	Mid Hauraki Gulf – semi exposed
Fishermans Cove	Fish	36°36.124'S	174°47.527'E	383.51	100	Mid Hauraki Gulf – semi exposed
Shakespear	Shak	36°36.505'S	174°50.451'E	489.71	160	Mid Hauraki Gulf – semi exposed
Arkles Bay	Arkl	36°38.690'S	174°44.776'E	314.73	55	Mid Hauraki Gulf – semi exposed
Long Bay	Long	36°41.579'S	174°45.642'E	418.10	70	Mid Hauraki Gulf – semi exposed
Campbells Bay	Camp	36°44.879'S	174°45.952'E	427.85	42	Mid Hauraki Gulf – semi exposed
North Head	Nhead	36°49.718'S	174°48.821'E	113.68	17	Inner Hauraki Gulf – sheltered
Mellons Bay	Mell	36°52.750'S	174°55.709'E	162.11	145	Inner Hauraki Gulf – sheltered
Ōmana	Oman	36°52.492'S	175°1.334'E	156.23	200	Inner Hauraki Gulf – sheltered
Mainland – West Coast (MWC)						
Te Henga Bethells Beach	TeHen	36°53.498'S	174°26.356'E	2816.30	17	Open Coast–Exposed
Piha	Piha	36°56.094'S	174°27.423'E	2570.50	24	Open Coast–Exposed
Kaitarakihi	Kait	37°00.562'S	174°34.861'E	649.60	55	Manukau Harbour – sheltered
Huia	Huia	37°10.279'S	174°33.455'E	380.19	15	Manukau Harbour – sheltered

Figure 1: Intertidal reef monitoring sites across the Auckland region, including sites at Aotea / Great Barrier Island (GBI - Blue), along the mainland east coast (MEC - Red) and mainland west coast (MWC - Green). See Table 1 for full names of each site and Appendix 1 for a site description.

2.2 Transect and quadrat placement

The reef platform at each site was stratified into three zones, determined according to the tidal height on the shore (high, mid, and low). An area of reef representative of each tidal height was surveyed using a 30m transect line, running parallel to the shore (Fig. 2) and randomly placed quadrats. During the very first survey at each site, the high, mid, and low shore transects were permanently marked at both ends with a galvanised steel hex bolt embedded in the reef with epoxy. GPS coordinates (WGS84) were also recorded for every bolt/transect start and end positions (Appendix 1) and photographs were taken with landscape features captured in the background to allow exact relocation of transects if bolts were lost. Updated versions of these photos, alongside general photos of the site, were taken during each year's survey. At three of the GBI and all MWC sites, bolts were not installed and only GPS coordinates and photos taken. Additionally, at one site on GBI (Oruapure Bay) it was not possible to locate a 30m stretch of contiguous low shore reef so instead a 6m x 10m area was surveyed. From 2013 onwards, photos were also taken of each individual quadrat sampled.

Surveys conducted in the mid and low tidal zones used ten 1 m^2 quadrats randomly positioned along the transect tape (except for Piha and Te Henga; see below). Quadrats were alternately sampled on each side of the tape (shoreward and seaward) so that the edge of the quadrat ran along the tape. The same method was employed in the high tidal zone but used ten 0.25 m^2 quadrats. A larger quadrat size (1 m^2 vs. 0.25 m^2) was used in the mid and low tidal zones to reduce the potential effects of small-scale patchiness that characterise intertidal reefs. In addition, surveying a larger area of reef provides a better estimate of the species present and is more representative of the overall community. Smaller, 0.25 m^2 quadrats were deemed adequate for the high tidal zone due to greater homogeneity and low species diversity compared to the mid and low shores. The low tidal zones at Piha and Te Henga (exposed west coast sites) were surveyed using a 0.25 m^2 quadrat as opposed to a 1 m^2 due to the narrowness of this zone and the extreme homogeneity of the intertidal community present. It is important to note that if the location of a quadrat happened to encompass a rockpool, a new random location was selected because the species assemblages within rockpools differs from the surrounding reef platform, which the survey was primarily designed to assess.

Figure 2: An example of the sampling layout on the intertidal reef platform at Campbells Bay. Red lines indicate 30m transects at high, mid, and low shore heights. Yellow markers show bolt positions at the ends of the transects. Dark areas at the edge of the sampling area are subtidal reefs covered in large brown seaweeds.

2.3 Biological variables

Each 1m^2 quadrat was divided into one hundred 10cm x 10cm squares and each 0.25m^2 quadrat was divided into twenty-five 10cm x 10cm squares. These squares were used to visually estimate percentage cover of sessile and permanently attached organisms (such as algae, sponges, barnacles, mussels, oysters and ascidians) as well as bare rock up to a total of 100%. For canopy forming macroalgae species (predominantly *Hormosira banksii)* holdfast covers were included within the per cent cover estimates with canopy cover estimated separately. Similarly, non-biological variables such as sand and silt, which can form veneers on top of algae or sessile invertebrate species, were estimated as a separate, secondary cover. In this way the total cover within a quadrat, including algae and sessile invertebrates, algae canopy cover and sediment could be >100%. Counts of mobile invertebrates (mainly gastropods) were made for the whole quadrat. For highly abundant species (>100 per m^2, e.g. *Austrolittorina* spp.), quadrats were subsampled whereby counts of the species were made for only one or several squares then multiplied (depending on the number of squares sampled) to provide an estimate of the total abundance for the entire quadrat. All mobile species >5mm that were visible, without overturning rocks or removing sessile species, were counted in the quadrat except for small, highly mobile crustaceans, such as amphipods and isopods. *Austrolittorina* spp. and other small gastropods, which are often <5mm, were identified to a species level where possible but were grouped as "microgastropods" for analysis. Rock oysters were not identified to the species level due to difficulties separating the native oyster *Saccostrea glomerata* from the Pacific oyster *Crassostrea gigas* in the field (Dromgoole & Foster, 1983).

In the initial surveys (2011/2013) cover of barnacles, oysters and mussels was recorded as a single number and likely included dead individuals in the total per cent cover. In the 2019 – 2024 surveys data was split for these cover categories so that the per cent cover of live and dead individuals was recorded. For consistency, these two categories were combined for analysis so that accurate comparisons could be made with previous survey periods. Furthermore, due to difficulty distinguishing between the two species of *Chamaesipho* sp. *(C. columna* and *C. brunnea)* these species were combined in the 2019 - 2024 surveys. For consistency during data analysis the per cent cover of these two species were combined for the earlier surveys (2011/2013).

2.4 Non-biological variables

Vertical relief (rugosity) was estimated for each quadrat by measuring the vertical distance from the highest point within or above the quadrat as it lay on the reef to the lowest point below the quadrat. We estimate the average slope of the plot, by lifting the lowest edge of the quadrat so that it was approximately horizontal and then measured the vertical distance between the quadrat and the reef along the lowest edge. Percentage cover of bare rock was included in the estimates of invertebrates and algae cover while sediment cover was estimated as a secondary cover and broken into two main categories: silt (<0.06mm particles) and sand (0.06mm – 2.0mm particles) cover. These sediment categories were judged based on feel alone. The average depth of silt and sand was also estimated by taking the average of three depth measurements made throughout the quadrat.

In some cases, sediment was included as a primary and secondary cover. Where sediment was so thick that the underlying primary cover type could not be identified the sediment layer was recorded as a primary cover. Atop this area, along with other parts of the quadrat where a thinner layer of sediment also persisted (but the primary cover type was identifiable) a secondary silt cover was recorded. Sediment as a primary cover was mostly recorded at the low tidal zone at Piha in 2022 and 2024, due to inundation by sand, and among MEC sites in 2023, as a likely consequence of the January rain event, followed in quick succession by Cyclone Gabrielle.

2.5 Statistical analysis

Variation in the environmental conditions among sites was investigated using principal coordinates analysis (PCA). Variables included wind fetch, reef extent, reef slope, rugosity, and silt and sand cover. The PCA analysis was based on site averaged data for each environmental variable over the course of the survey period for that site. Environmental data were square root transformed and normalised prior to all analyses. Sites were then classified into significant groups based on environmental variables using similarity profile analysis (SIMPROF). Latitude and longitude were not included as variables as we were interested in the similarity in environmental conditions among sites independent of their geographic position within the Auckland region.

The cover of sediment on intertidal reefs is determined by complex physical and hydrodynamic processes. To provide insights into these processes, we used distance based linear modelling (DistLM) to investigate how variation in silt and sand cover among the sites related to environmental factors (wind fetch, reef extent, reef slope, rugosity). Although wave action can be a major influencer of intertidal communities, fine scale wave measurements are not available for the sites surveyed. We have therefore used wind fetch (here on termed fetch) as a proxy for exposure of a site to wave actions, with sites with higher fetch values likely to experience greater wave action. Silt and sand covers were square root transformed then normalised with analyses based on a Euclidean distance matrix. DistLM provides results for marginal tests, which fit each predictor variable to the matrix individually, and conditional tests, which fit all variables used in the model sequentially (Anderson, 2004). Prior to analysis, multicollinearity was tested using Draftsman's Plots. Person's r values indicated that consistently there were strong correlation ($r > 0.7$) between slope, vertical relief, and reef extent. Because reefs with a narrow extent were also likely to be more steeply sloping, we chose to exclude slope from DistLM analyses. We kept rugosity as an explanatory variable as sites that are highly rugose are more three-dimensionally complex which in turn may influence the species assemblage regardless of how wide or steep a reef platform is. The reduced Akaike's Information Criterion (AICc) and the BEST procedure was used to pick the most parsimonious combination of variables ($\triangle$AICc <2) due to each analysis being limited to one average value per environmental variable per site per survey period.

Biological data were analysed as three separate datasets:

1. Species richness – total number of species recorded at each site,
2. Benthic community structure – macroalgae and sessile invertebrates (based on percent cover measurements),
3. Macroinvertebrate assemblages – mobile macroinvertebrates, sea anemones and solitary ascidians (based on counts).

DistLM was used to examine how species richness at each site (all data) was related to environmental variables (fetch, reef extent, rugosity, and silt and sand cover). Species richness was not transformed, and the analysis was based on a Euclidean distance matrix. The same model selection procedure as above was used.

DistLM, was also used to explore environmental drivers of variation in the benthic community structure (per cent cover) and macroinvertebrate assemblage (counts) data sets. This provided a means of understanding if any of the measured environmental variables were having a negative impact on overall community structure. Per cent cover data was square root transformed, whereas count data were $\log_{10}(x+1)$ transformed prior to analysis. In both cases, DistLM was based on Bray-Curtis dissimilarities and the environmental variables included fetch, reef extent, reef slope, rugosity, silt cover and sand cover. Non-metric multidimensional scaling (nMDS) and SIMPROF analysis were then used to visualise the level of dissimilarity in benthic community structure and macroinvertebrate assemblage between sites. This was performed on site average data, across the survey period for each site.

PERMANOVA was used to test for differences in regional community structure and macroinvertebrate assemblage through time. Because each survey region (GBI, MEC, MWC) were sampled over differing time periods the data was split and PERMANOVA tests run individually for each survey region. Tests were based on site averaged data for each tidal zone and included Tidal

Zone and Year as fixed factors as well as the interaction between these factors. Post hoc testing was carried out to examine difference in each factor, or the interaction between factors where these were identified.

All statistical analysis was carried out in PRIMER v7.

3 Results

3.1 Physical reef characteristics

3.1.1 Reef profile, wave exposure and sediment characteristics

3.1.1.1 Regional characteristics

The PCA based on physical site characteristics summarised the overall variation in reef structure and physical conditions among sites (Fig. 3). The PCA demonstrated that sites within the Auckland region fell into two broad groups based largely on reef slope and rugosity, reef extent, and silt cover. Sites with extensive, gently sloping reef platforms and higher silt cover were grouped on the right-hand side of the ordination (most MEC sites and Kaitarakihi in the Manukau Harbour, Fig. 3) with less extensive, more sloping and complex reefs on the left (including all GBI sites and most MWC sites, Fig. 3).

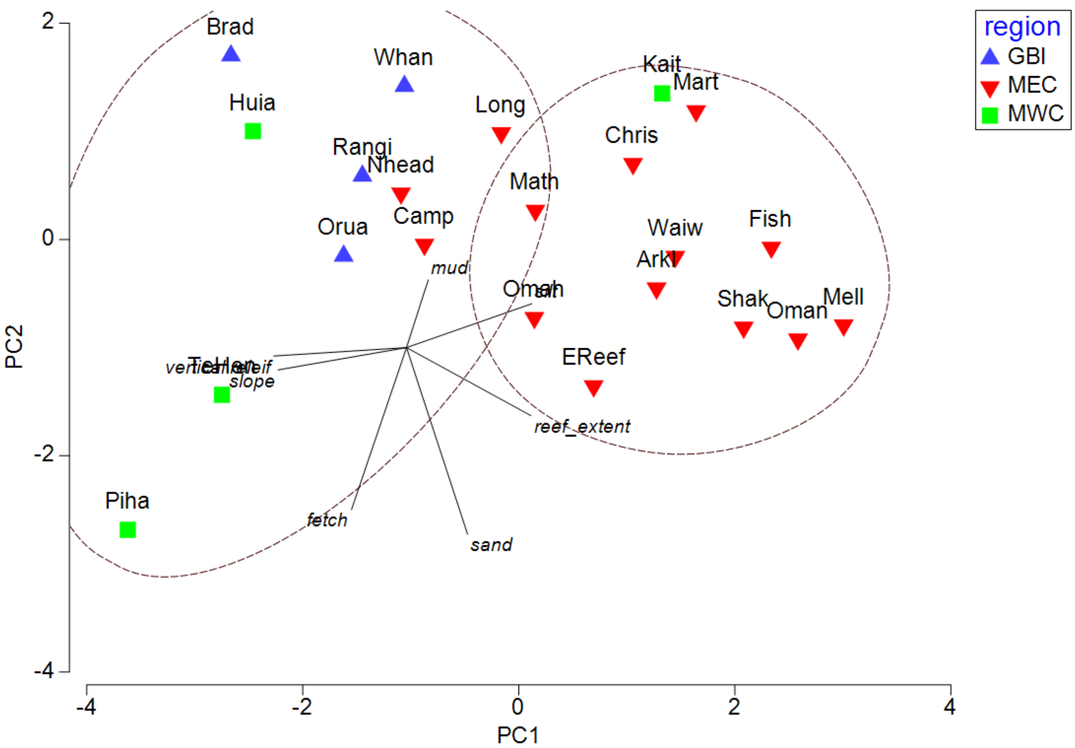

Figure 3: Principal components analysis (PCA) of physical variables recorded at each of the Auckland region intertidal monitoring sites across GBI (blue), MEC (red) and MWC (green) sites. Dashed lines indicate significant site groupings based on SIMPROF. Note latitude and longitude was excluded from PCA and SIMPROF analysis. See Table 1 for full site names.

3.1.1.2 Area specific characteristics

Aotea Great Barrier Island (GBI)

Rocky reef monitoring sites at GBI included one site on the east coast (Rangiwhakaea) and three on the west coast (Oruapure, Bradshaw Cove, Whangaparapara) positioned along a north to south latitudinal gradient (Fig. 1). Rangiwhakaea was directly exposed to fetch from the northeast, while Oruapure was exposed to fetch from the north/northwest. Bradshaw Cove, situated on Kaikoura Island, and Whangaparapara, within the Whangaparapara Harbour, were both very sheltered by comparison (Figs. 1, 4). Intertidal reefs at GBI were characteristically narrow (<30m wide) and steep (Fig. 5A). Silt and sand cover were generally low at all sites except for Whangaparapara, which is located in a narrow, sheltered harbour.

Mainland East Coast (MEC)

The 14 MEC locations spanned a north to south latitudinal gradient running approximately 120km from the outer (Echinoderm Reef) to inner Hauraki Gulf (Mellons Bay and Ōmana, Fig. 1). Fetch declined across this gradient, and the majority of reefs were characterised by wide, gently sloping intertidal reef platforms (50m – 150m wide, Fig. 4 and e.g., 5B). The exceptions were North Head and Campbells Bay, both of which had short, moderately sloping reef profiles (e.g. Fig. 5C). High silt and sand covers were common, particularly throughout the mid and low shores of sheltered, gently sloping inner Hauraki Gulf sites (e.g. Fig. 5D).

Mainland West Coast (MWC)

The MWC sites along the open coast (Te Henga and Piha) were the most exposed sites across the entire monitoring network (Fig. 4A). Both sites had high fetch (and by proxy wave action) from the northwest through to southwest. The Manukau Harbour sites were generally more sheltered than those on the open coast but were still susceptible to fetch from the southwest due to their proximity to the harbour entrance. Despite being situated further into the harbour, Kaitarakihi had greater total fetch than Huia due to the headland at Huia providing some protection from the southwest. Intertidal reefs at both exposed sites and Huia were narrow (<25m wide) and steeply sloping (e.g. Fig. 6A) while the site at Kaitarakihi, by comparison, was expansive (55m wide) and gently sloping (Fig. 6B). Silt was a major component of the intertidal reef at Kaitarakihi (Fig. 6C). Piha was the only site where sand was common on the reef, particularly within the low shore (Fig. 6D), where large sand deposits buried most of the available reef within this zone in 2022.

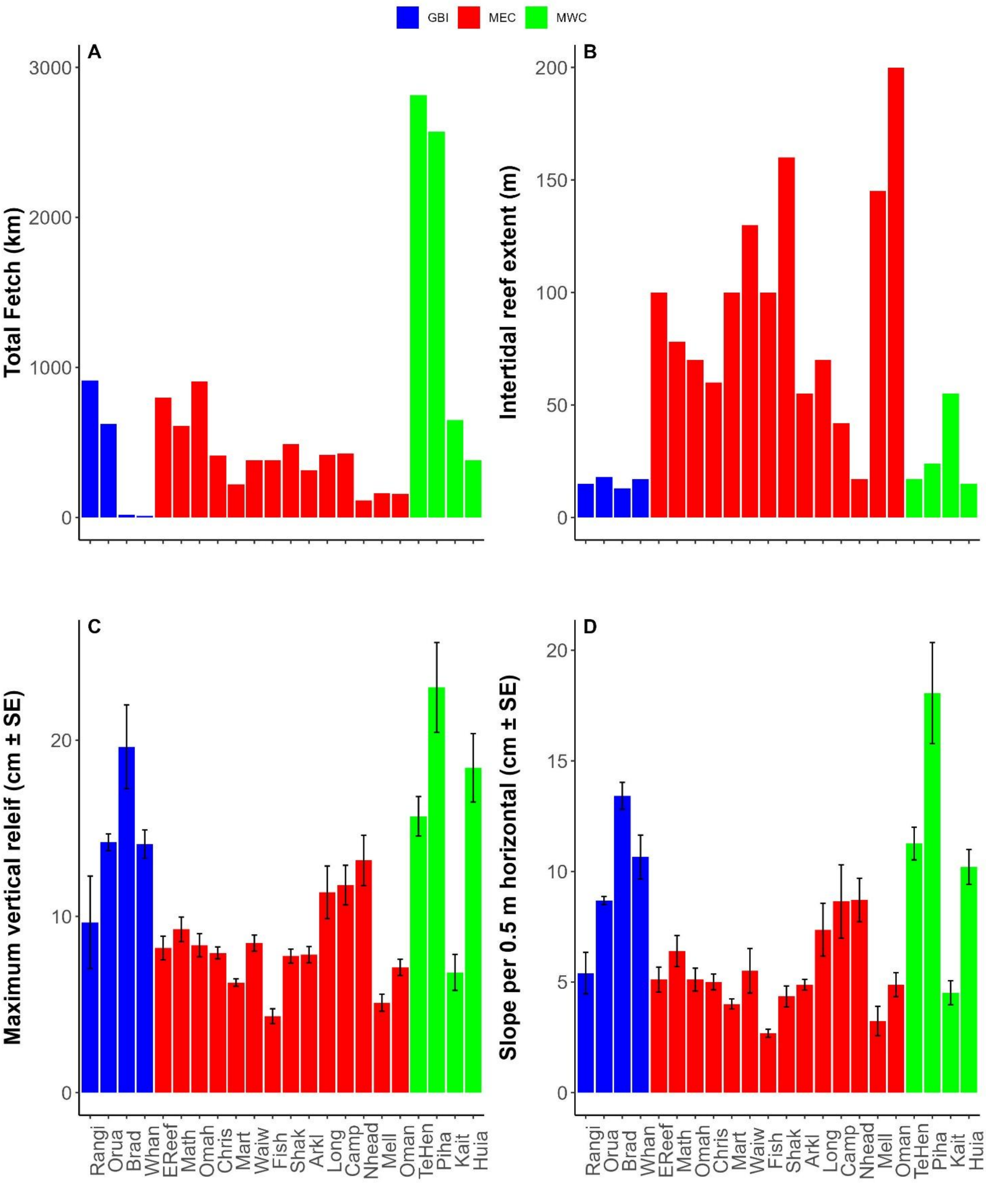

Figure 4: Physical characteristics of the Auckland region's intertidal reef monitoring sites. A) Total fetch (wave exposure), B) Intertidal reef extent, C) Maximum vertical relief, D) Site slope. Sites are arranged from north to south with Aotea Great Barrier Island (GBI) sites coloured blue, Mainland East Coast (MEC) sites coloured red and Mainland West Coast (MWC) sites coloured green. In C) and D) values are averaged across sampling events for each location. See Fig. 1 and Table 1 for site names, locations and positions.

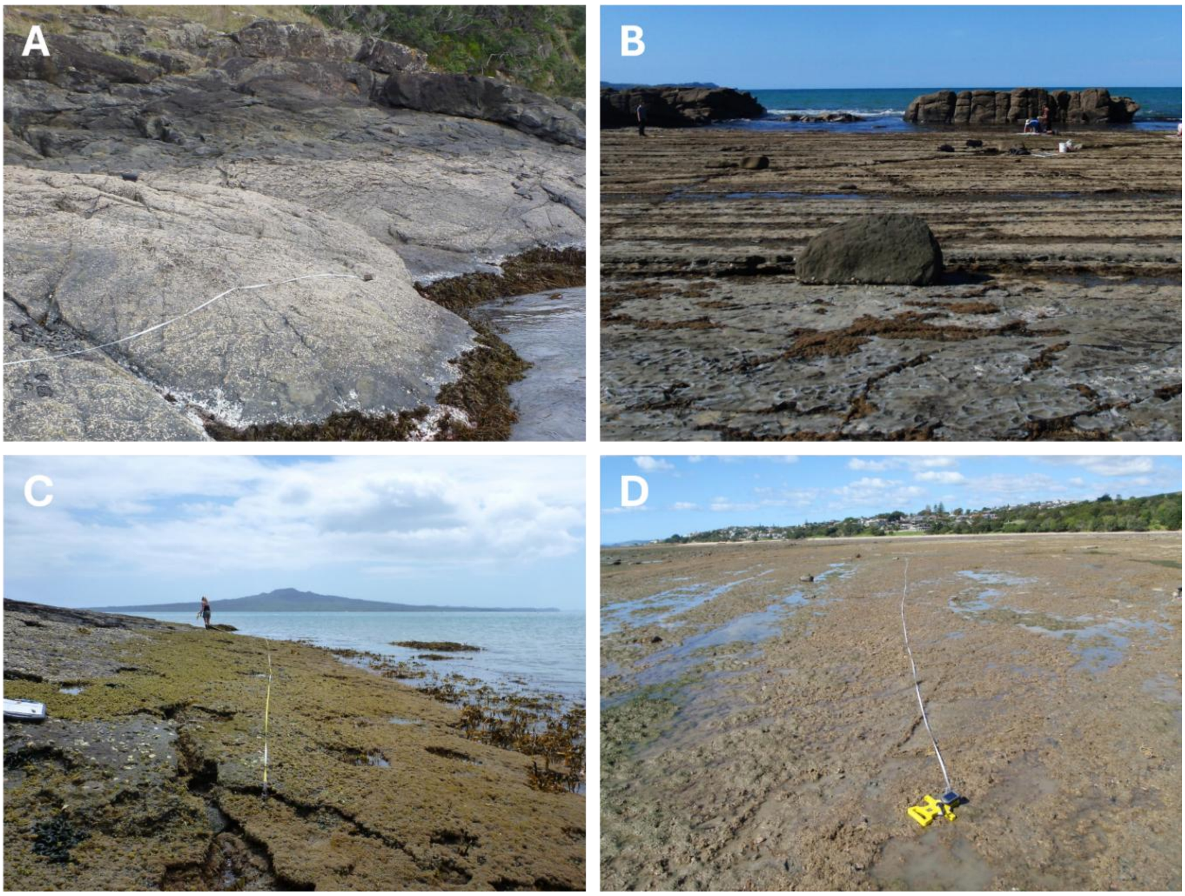

Figure 5: Examples of intertidal monitoring sites at GBI and the MEC. (A) Rangiwhakaea, a steeply sloping GBI site, (B) extensive, gently sloping reef at Ōmaha, a MEC site, (C) steeply sloping intertidal reef at North Head and (D) silt covering an inner Gulf reef at Ōmana.

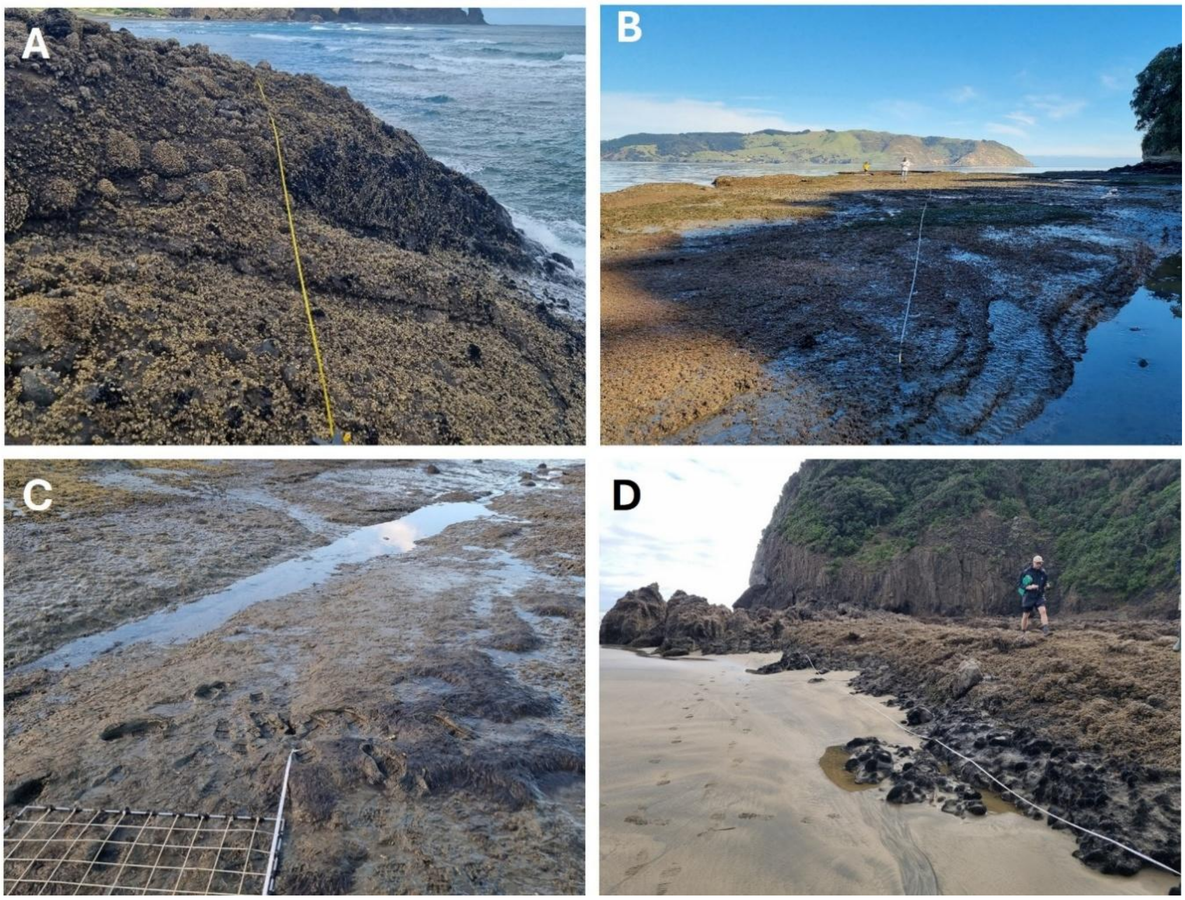

Figure 6: Example of MWC intertidal reefs at (A) Te Henga, a highly exposed, steeply sloping open coast site and (B) Kaitarakihi, a more sheltered, gradually sloping Manukau Harbour site. High sediment covers in the form of silt throughout the low shore at (C) Kaitarakihi and sand at (D) Piha. Note that at Piha sand had buried parts of the low shore reef in 2022 and 2024 that were able to be surveyed during the original survey in 2021.

3.1.2 Sediment cover

3.1.2.1 Regional patterns of sediment cover

The secondary cover of sediment, which was split into silt and sand cover, varied among tidal zones and monitoring sites (Fig. 7, Table 2A and 2B). In general, silt made up the greater component of overall sediment cover and was consistently lowest in, or entirely absent from, the high tide zone. Silt cover tended to increase across the reef platform and was highest in the low zone (Fig. 7A and 7B, Table 2A). Where low shore monitoring was conducted, particularly on MEC reefs, it was not uncommon for secondary silt cover to exceed 50% (Table 2). At GBI, silt was only a major feature on the reef at Whangaparapara, where on average >50% of the low tide reef was covered in a fine silt layer (Table 2A). Similarly, Kaitarakihi was the only MWC site with a high silt cover (Table 2A).

Across the Auckland region, DistLM results showed that silt cover was significantly related to reef rugosity, fetch, and reef extent (Table 3A). The BEST model for explaining silt cover across the region was one that included reef rugosity and extent, fetch and longitude (R^2 = 0.55, AICc 120.43), though an equally parsimonious model (R^2 = 0.55), but with a slightly lower AICc (122.72) also existed and included latitude as an explanatory variable (Table 3B).

Field observations confirm these results and show that rugosity and fetch were negatively correlated with silt cover while reef extent and silt cover were positively correlated. More exposed and/or rugose reefs such as Rangiwhakaea (GBI), E Reef, Ōmaha and North Head (MEC), Piha and Te Henga (MWC) tended to have lower silt covers compared to highly expansive reefs which were mostly found in more sheltered survey areas e.g. inner Hauraki Gulf sites (MEC), Kaitarakihi (MWC), and Whangaparapara (GBI) (Table 2A).

Secondary sand cover was generally lower than secondary silt cover but was highly variable and followed no clear pattern with respect to tidal zone (Fig. 7A and 7B, Table 2B). This was reflected in DistLM results which found that reef extent was the only environmental variable significantly, and positively, influencing sand cover (Table 4A). Overall, the BEST model for explaining sand cover included fetch, reef extent, longitude and latitude but had low explanatory power (R^2 = 0.16; Table 4B).

3.1.2.2 Temporal patterns in sediment cover

Secondary sediment covers have remained relatively consistent across the GBI sites through time, whereas some notable changes have occurred through time across MEC and MWC sites (Fig. 7). Temporal patterns in total secondary sediment as well as silt and sand cover for each site are provided in the Supporting Material.

Mainland East Coast (MEC)

Overall, the data indicates that across the MEC sites small fluctuations in secondary sediment cover have occurred through time, however there was a notable increase in cover, particularly through the mid and low shore between 2021 and 2023 (Fig. 7A). Through time silt has been the main component of total sediment cover recorded in the mid tidal zone while silt cover has decreased but sand cover increased in the low tidal zone (Fig. 7B and 7C). More detail on changes within each tidal zone are provided below.

Sediment cover has remained consistent within the high tidal zone, fluctuating between ~6% and ~14% (Fig. 7A). Silt cover, although low, has fluctuated, falling from a regional average of ~9% in 2011 to <1% in 2021, before rising again to ~6% in 2023 (Fig. 7B). Fluctuations in silt have been offset by an increase in sand cover through time, rising from ~1.5% in 2021 to ~7% in 2023, though this increase is largely attributable to increasing sand cover at Mellons Bay, where cover increased from 0% in 2011 to 82% in 2023 (see Supporting Material).

Sediment cover in the mid tidal zone decreased from ~36% to ~25% between 2011 and 2019 but then rose again to a regional high of ~46% in 2023 (Fig. 7A). This change in cover was largely mirrored by changes in silt cover (Fig. 7B). Sites with extensive, gently sloping reef platforms (Christian's Bay to Arkles Bay, Mellons Bay and Ōmana) were more prone to large fluctuations in silt cover through time, however silt cover at Mathesons Bay, extensive reef platform but relatively high wave exposure, was anomalously high in 2023 (~70%) while silt cover of >93% at Ōmana in 2023 was more than double that of any previous year surveyed (Supporting Material). Secondary sand cover in the mid tide was lower than that of silt cover and the regional average has remained relatively consistent, between a low of ~3% (2011) and high of 9% (2021) (Fig. 7C). Ōmana was the only site where high secondary sand cover was regularly recorded (32% - 86%), however sand was completely replaced by finer silt as a secondary cover in 2023 (see Supporting Material). Very high sand cover (88%) was recorded within the mid tide at Fishermans Cove in 2023 but was sparse in all previous surveys.

Sediment cover has remained relatively stable in the low tidal zone, with the highest average coverage of ~73% recorded in 2023 and a low of 62% in 2019 (Fig. 7A). Within this overall cover however, silt and sand have shown highly contrasting trends through time (Fig. 7B and 7C). There has been a steady regional decline in silt cover from ~67% in 2011 to ~39% in 2023. Over the same period secondary sand cover increased across the region, from ~3% in 2011 to ~35% in 2023. Through time, sand was the dominant secondary cover within the low tide zone at the three outer gulf MEC sites (E Reef, Mathesons Bay and Ōmaha) whereas sites further into the gulf, excluding the steeper reefs at Campbells Bay and North Head, were largely covered by silt. In 2023 a number of typically 'silty' sites were inundated by sand, lowering the average regional silt cover and dramatically increasing sand cover for this survey year (Fig. 7B and 7C; Supporting Material). Ōmana appeared to follow the opposite trend, returning to a siltier sediment composition in 2023 from a sandy one in 2021 (see Supporting Material).

While sediment has historically been recorded only as a secondary cover, with fine layers of silt and sand covering other primary cover types, in 2023 very thick sand and/or silt layers were recorded across different tidal zones at Martins Bay, Fishermans Cove, Arkles Bay, Mellons Bay and Ōmana (see Supporting Material). This sediment was so thick that any underlying benthic covers could not be quantified. Where this was the case within individual quadrats, silt and sand cover was also recorded within the primary covers and consequently in 2023 there was a spike in silt and sand recorded as primary cover across all three tidal zones (Fig. 8A-C).

Mainland West Coast (MWC)

Among the MWC sites, silt was only a major secondary cover at Kaitarakihi, while sand was a major cover only at Piha. These two sites were primarily responsible for driving the temporal patterns in average sediment cover seen across the MWC sites in Fig. 7A -C and 8A-C). Secondary silt cover increased through time in the mid and low shore zones at Kaitarakihi from ~7% to ~16%, with a spike in primary silt cover observed in 2023 within the low shore. Sand cover fluctuated at Piha with the largest changes observed in the low shore areas where secondary and primary sand cover sharply increased between 2021 and 2022 before falling again by 2024, leading to the spikes in average MWC secondary and primary sand cover seen in Fig. 7C and 8C.

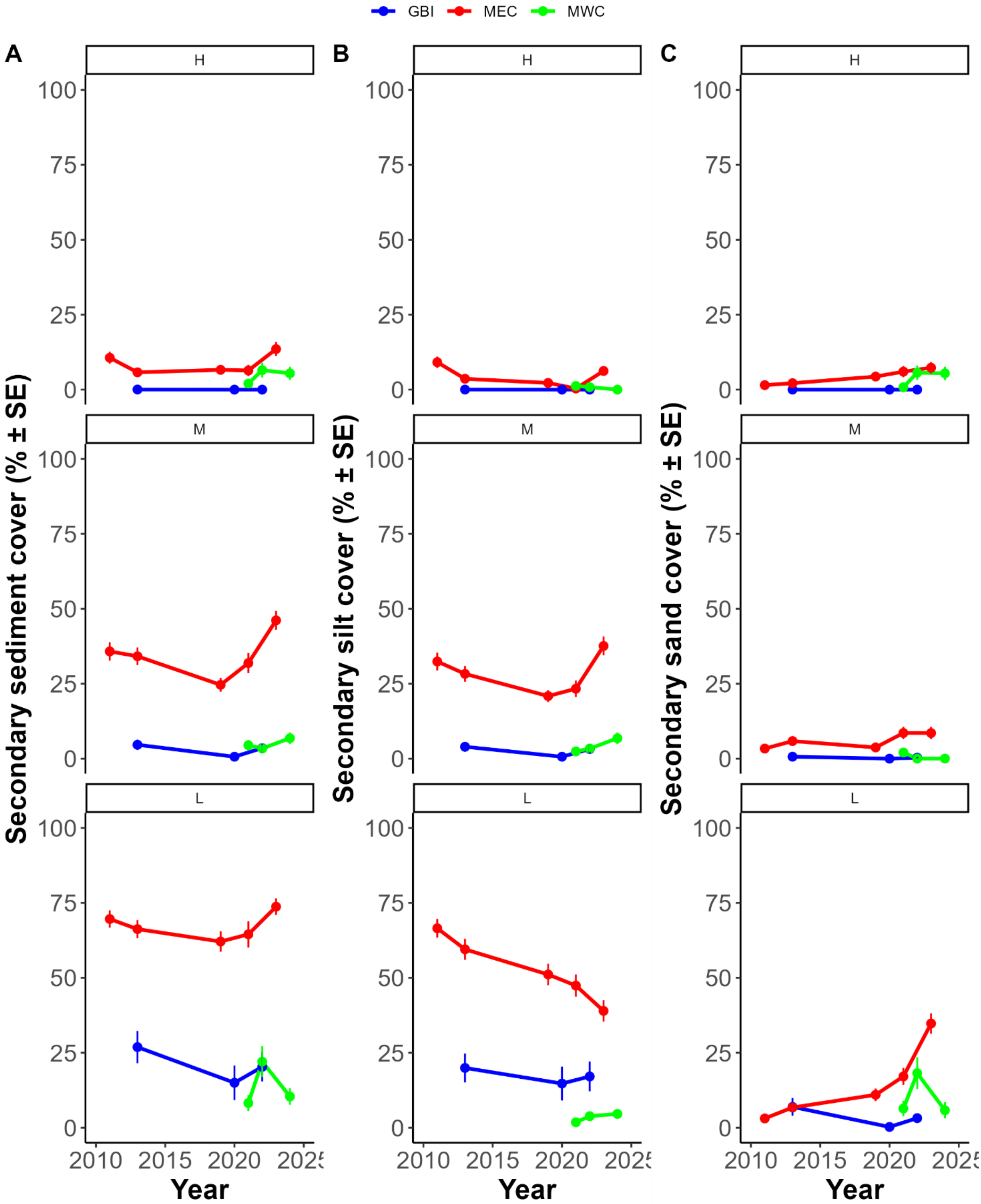

Figure 7: Average secondary (A) total sediment cover, (B) silt cover and (C) sand cover among GBI (Blue), MEC (Red) and MWC (Green) sites across the respective monitoring periods for each region at each tidal height. Values based on average secondary sediment covers across all sites within each region. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone. Secondary silt and sand covers combined equates to the total secondary sediment cover.

Table 2: Average secondary (A) silt and (B) sand cover across the high, mid and low tidal zones for each individual monitoring site. Values are averages across the respective sampling period for each site. Cells coloured red are highest average, cells coloured green are lowest average sediment cover for each sediment type at each site.

A		Tidal zone		
Region	**Site**	**H**	**M**	**L**
GBI	Rangiwhakaea	0.00	0.00	0.00
	Oruapure	0.05	5.05	1.70
	Bradshaw	0.00	0.33	5.17
	Whangaparapara	0.00	6.30	54.24
MEC	E Reef	0.00	8.61	8.84
	Mathesons Bay	3.26	24.25	22.34
	Ōmaha	0.88	3.25	8.74
	Christian's Bay	4.88	54.37	92.32
	Martins Bay	19.89	24.80	86.56
	Waiwera	1.60	47.35	66.70
	Fishermans Cove	0.00	27.78	78.78
	Shakespear	7.58	56.78	63.22
	Arkles Bay	0.98	42.28	63.10
	Long Bay	0.74	2.87	72.44
	Campbells Bay	0.13	5.08	8.61
	North Head	0.00	0.90	14.81
	Mellons Bay	14.06	59.63	72.76
	Ōmana	6.27	42.36	77.76
MWC	Te Henga	1.60	0.00	0.33
	Piha	0.00	0.00	0.00
	Kaitarakihi	1.11	12.25	12.78
	Huia	0.00	4.54	0.59

B		Tidal zone		
Region	**Site**	**H**	**M**	**L**
GBI	Rangiwhakaea	0.03	0	0
	Oruapure	0.00	0.75	12.68
	Bradshaw	0.00	0.13	0.02
	Whangaparapara	0.00	0.68	5.41
MEC	E Reef	0.00	6.08	36.35
	Mathesons Bay	0.13	0.11	3.00
	Ōmaha	3.01	0.31	14.92
	Christian's Bay	3.31	1.69	0.05
	Martins Bay	0.48	0.24	0.00
	Waiwera	0.00	0.94	16.75
	Fishermans Cove	0.90	19.68	1.64
	Shakespear	4.23	5.86	25.69
	Arkles Bay	0.08	2.62	42.80
	Long Bay	0.01	0.02	0.01
	Campbells Bay	1.75	1.53	9.76
	North Head	0.00	0.00	19.39
	Mellons Bay	45.57	3.09	17.30
	Ōmana	0.01	42.61	15.86
MWC	Te Henga	7.85	0.00	0.50
	Piha	7.98	0.04	39.76
	Kaitarakihi	0.00	2.76	0.25
	Huia	0.00	0.03	0.07

Table 3: DistLM results showing (A) Marginal tests between secondary silt cover at each site and environmental parameters, and (B) the overall best models (∆AICc <2). Results based on site averaged data for each monitoring period. In (A) bold values represent significant environmental parameters and in (B) bold values represent the model with the lowest AICc value and greatest R^2 value.

A				
Variable	**SS(trace)**	**Pseudo-F**	**P**	**Prop.**
Rugosity	273.85	60.83	**<0.01**	0.40
Fetch	98.25	15.23	**<0.02**	0.15
Reef Extent	277.60	62.24	**<0.01**	0.41
Latitude	2.22	0.30	0.58	<0.01
Longitude	1.36	0.18	0.67	<0.01

B				
AICc	**R^2**	**RSS**	**No. Variables**	**Selections**
120.43	**0.55**	303.25	4	Rugosity, Fetch, Reef Extent, Longitude
122.72	**0.55**	307.73	4	Rugosity, Fetch, Reef Extent, Latitude, Longitude

Table 4: DISTLM results showing (A) Marginal tests between secondary sand cover at each site and environmental parameters, and (B) the overall best models (ΔAICc <2). Results based on site averaged data for each monitoring period. In (A) bold values represent significant environmental parameters and in (B) bold values represent the model with the lowest AICc value and greatest R^2 value.

A				
Variable	**SS(trace)**	**Pseudo-F**	**P**	**Prop.**
Rugosity	7.22	1.97	0.18	0.02
Fetch	3.74	1.01	0.32	0.01
Reef Extent	31.29	9.21	**<0.01**	0.09
Latitude	6.70	1.83	0.16	0.02
Longitude	0.03	0.01	0.94	<0.01

B				
AICc	**R^2**	**RSS**	**No. Variables**	**Selections**
113.79	**0.16**	282.12	4	Fetch, Reef Extent, Longitude, Latitude
114.16	0.12	297.22	2	Fetch, Reef Extent
114.67	0.09	305.89	1	Reef Extent
115.18	0.13	293.46	3	Fetch, Reef Extent, Longitude
115.23	0.13	293.65	3	Fetch, Reef Extent, Longitude
115.29	0.11	300.91	2	Reef Extent, Longitude

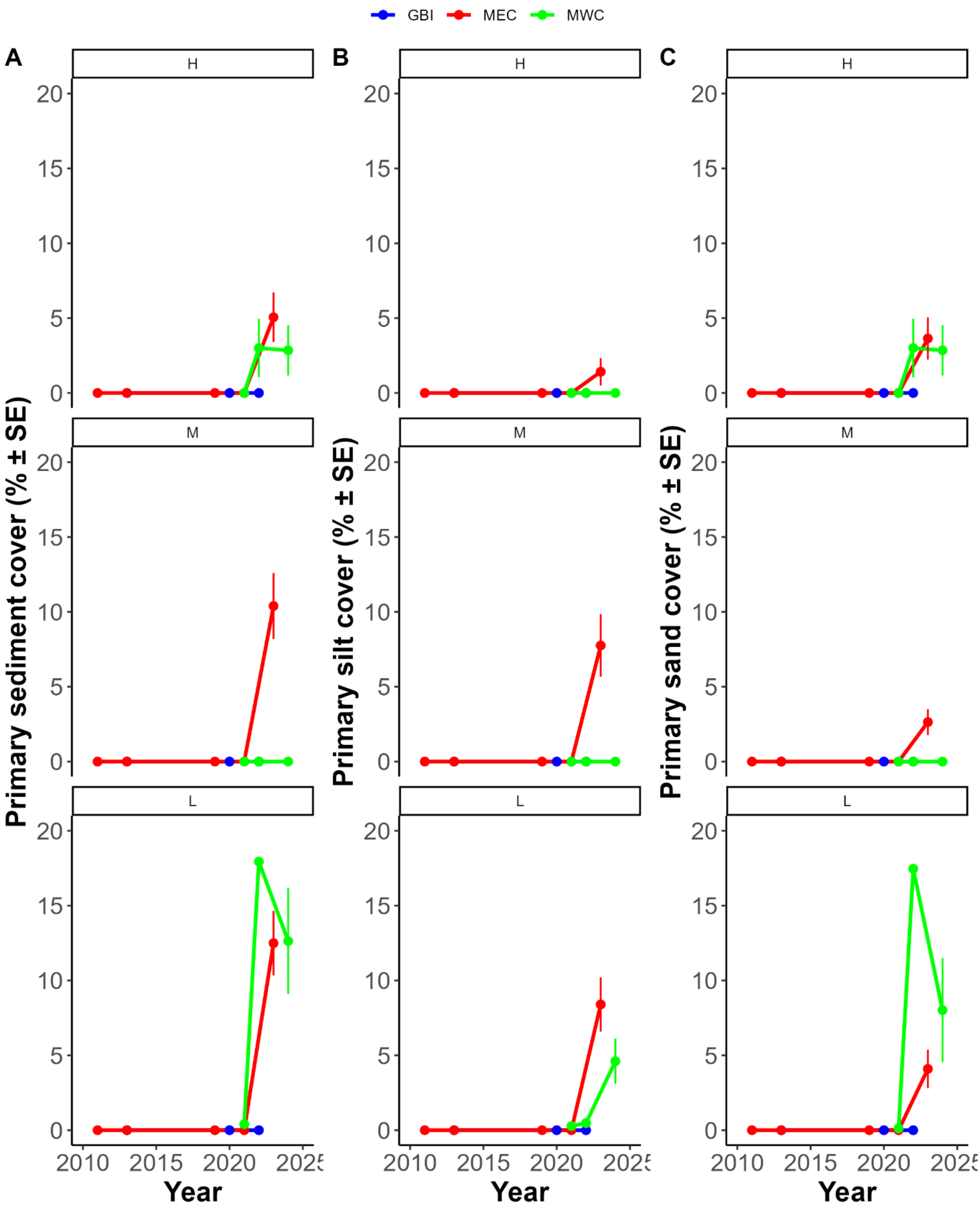

Figure 8: Average primary (A) total sediment cover (B) silt cover and (C) sediment cover at GBI (Blue), MEC (Red) and MWC (Green) sites across the respective monitoring periods for each region at each tidal height. Values based on average primary sediment covers across all sites within each region. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone. Secondary silt and sand covers combined equates to the total secondary sediment cover.

3.1.3 Bare rock

3.1.3.1 Regional patterns

Across the Auckland region bare rock followed a general pattern of declining cover down the shore (Fig. 9). Across the region bare rock averaged ~60% in the high tidal zone, ~40% in the mid tidal zone and ~15% in the low tidal zone. The cover of bare rock was similar across each survey region (GBI, MEC, MWC), except in the high shore where it was generally higher at MWC sites and lowest at GBI sites.

Overall cover of bare rock remained similar for the three survey regions over their respective survey periods, though fluctuations at individual sites were observed. The most notable shift was among MWC sites and was associated primarily with fluctuations in the cover of sessile invertebrates (barnacles and mussels) at exposed coastal sites (Fig. 9).

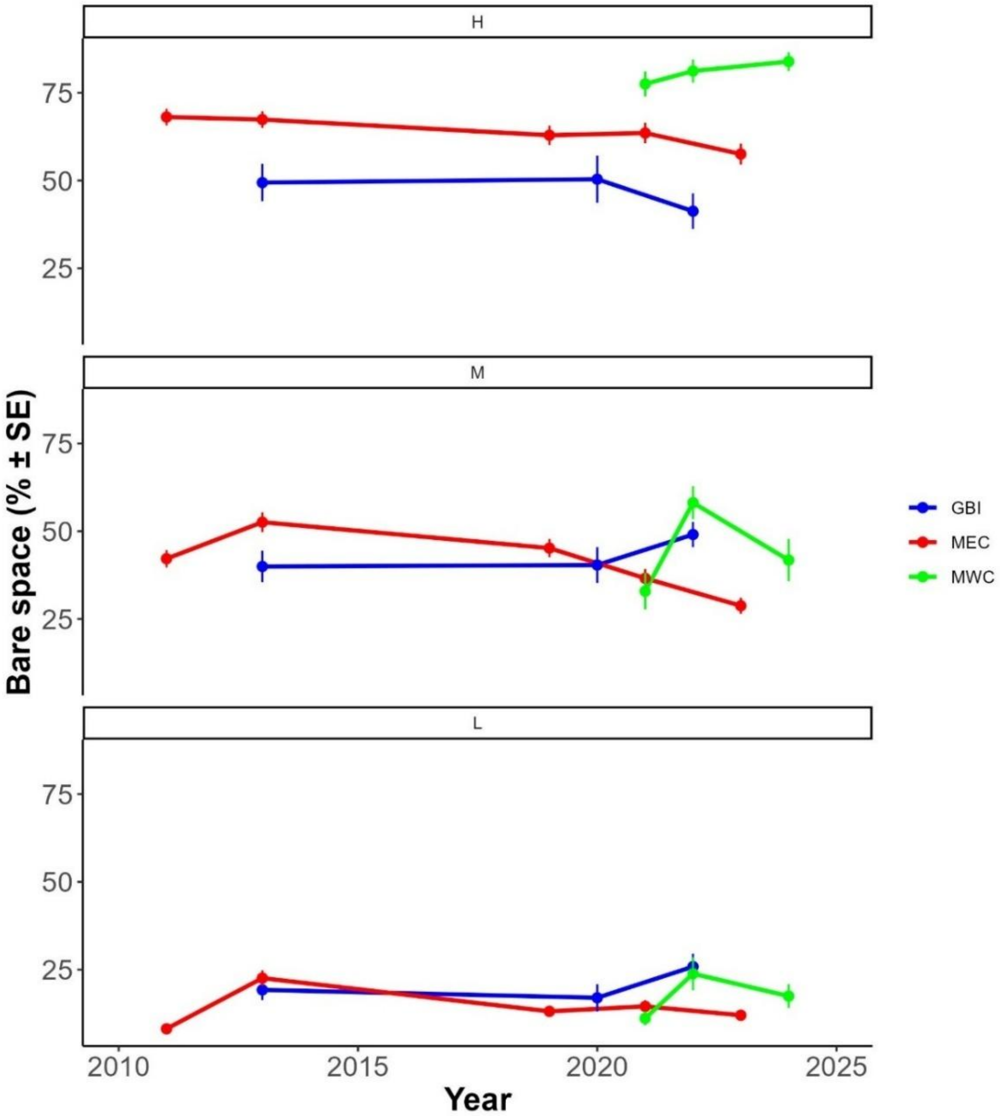

Figure 9: Average cover of bare rock across GBI (Blue), MEC (Red) and MWC (Green) over the respective monitoring periods for each region at each tidal height. Values based on average cover of bare space across all sites within each region. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone.

3.2 Biological communities

3.2.1 Species richness

3.2.1.1 Regional patterns

Across the entire Auckland region species richness, averaged across the survey period for each site, was highly variable, ranging from 25 (Te Henga) to 59 (Bradshaw Cove) species. In general, MWC sites had the lowest species richness (survey region average = 34) while GBI sites had the highest (survey region average = 53). DistLM results indicated that different environmental variables were important determinants of species richness for each survey region. At GBI, there was no environmental factor that was significantly correlated with species richness and the BEST model only included reef extent as an explanatory variable (Table 5A, B). Richness significantly correlated with silt cover, rugosity, and reef extent at MEC (Table 5A), with silt and reef extent negatively correlated and rugosity and slope positively correlated. The BEST model explaining richness included sand cover and reef extent (Table 5B). The inclusion of sand as an explanatory factor may be related to the drop in richness seen in 2023, particularly in the low tidal zone, where a large increase in sand cover occurred. Fetch was the only significant factor influencing richness among MWC sites (Table 5A). Fetch was negatively correlated with richness and this along with rugosity were included in the BEST explanatory model (Table 5B). It is unclear why rugosity has been included in the best model given its lack of correlation with species richness. It is possible that given the small sample size, individual results such as a large spike in richness at Huia in 2024, which also corresponded to a higher rugosity measure at the site, are influencing the model's performance, and resulting in inclusion of this variable.

In general, species richness was low in the high tidal zone (6 – 26 species) with mid and low tidal zones showing greater overall diversity of species (16 – 42 species, Fig. 10). Waiwera was the only site where richness was as high in the high tidal zone as it was at lower tidal heights while the highly exposed MWC sites, Te Henga and Piha, had the lowest overall species richness (see Supporting Material).

3.2.1.2 Temporal patterns

The pattern in species richness among sites and shore heights was generally consistent across the survey duration within each region (Fig. 10), however, there were a few notable changes that occurred at the MEC sites.

Mainland East Coast (MEC)

Species richness in the mid tide during the 2019, 2021, and 2023 surveys was lower than the earlier surveys in 2011 and 2013. This decrease was most noticeable at several sites including Christian's Bay, Martins Bay, Waiwera, Fishermans Cove and North Head. In contrast, Ōmaha and Campbells Bay saw large increases in mid tidal species richness between 2021 and 2023, with the highest richness recorded at both sites in 2023.

In the low shore, richness was relatively stable throughout the survey period, however a sharp decline occurred in 2023, dropping from a regional average of 30 species in 2021 to 22 species (Fig. 10). Except for North Head and Mellons Bay, all sites experienced drops in richness between 2021 and 2023.

Table 5: DistLM results showing (A) Marginal tests between species richness within each region and environmental parameter and (B) the overall BEST models (△AICc <2) explaining species richness. In (A) bold values represent significant environmental parameters and in (B) bold values represent the model with the lowest AICc value and greatest R^2 value.

A)

	Variable	SS(trace)	Pseudo-F	P	Prop.
GBI	Sand	15.94	0.45	0.53	0.05
	Silt	10.49	0.29	0.58	0.03
	Rugosity	79.72	2.87	0.12	0.26
	Fetch	42.12	1.30	0.31	0.14
	Reef extent	92.65	3.54	0.09	0.31

	Variable	SS(trace)	Pseudo-F	P	Prop.
MEC	Sand	0.31	0.01	0.95	<0.01
	Silt	280.22	7.31	**0.02**	0.10
	Rugosity	303.82	7.99	**0.01**	0.11
	Fetch	2.70	0.06	0.80	<0.01
	Reef extent	931.76	32.38	**0.00**	0.32

	Variable	SS(trace)	Pseudo-F	P	Prop.
MWC	Sand	204.68	3.20	0.10	0.24
	Silt	26.52	0.32	0.59	0.03
	Rugosity	3.92	0.05	0.84	<0.01
	Fetch	560.81	19.74	**0.00**	0.66
	Reef extent	4.03	0.05	0.81	<0.01

B)

	AICc	R^2	RSS	No.Vars	Selections
GBI	**36.13**	**0.31**	209.45	1	Reef extent
	36.73	0.264	222.38	1	Rugosity

	AICc	R^2	RSS	No.Vars	Selections
MEC	**236.55**	**0.35**	1875.80	2	Sand, Reef extent
	237.32	**0.32**	1956.90		Reeg extent
	238.48	**0.35**	1867.30	3	Sand, Fetch, Reef extent

	AICc	R^2	RSS	No.Vars	Selections
MWC	**36.37**	**0.86**	117.40	2	Rugosity, Fetch

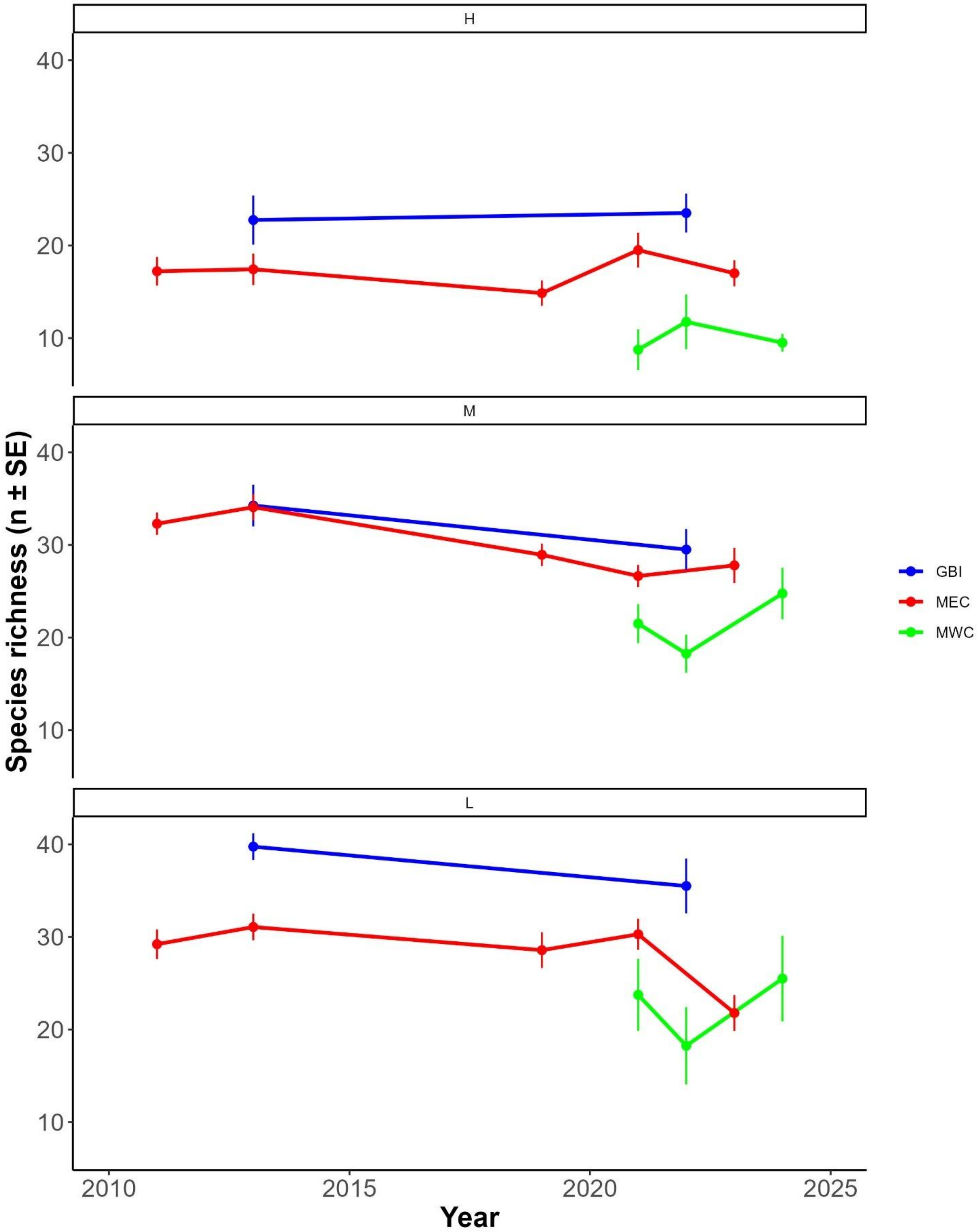

Figure 10: Average species richness across GBI (Blue), MEC (Red) and MWC (Green) sites over the respective monitoring periods for each survey region at each tidal height. Values based on average species richness across all sites within each region. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone.

3.2.2 Benthic community structure (cover)

3.2.2.1 Broad-scale variation in benthic community structure across the Auckland region

The majority of sites surveyed across the Auckland region had broadly similar benthic community structure, as evident in Fig. 11 by the clustering of 18 of 22 sites, including sites from all three survey regions to the left of the ordination plot. SIMPROF analysis found three distinct groupings within this main cluster. The largest of these contained most MEC sites as well as Huia, a MWC site. These sites were characterised by high covers of the turfing algae *Corallina officinalis*, while crustose coralline algae (CCA), encrusting brown algae (*Ralfsia* complex), encrusting and filamentous (*Okeania* spp.) cyanobacteria, *Capreolia implexa* (red turf) and the canopy forming brown algae *Hormosira banksii* were all common. The barnacle *Chamaesipho* spp. was generally the most abundant encrusting invertebrate, while other barnacle species such as *Epopella plicata* and *Austrominius modestus* were common, as were rock oysters (*Magallana gigas* and *Saccostrea glomerata)* and the tubeworm *Spirobranchus cariniferus*.

The three west coast GBI sites (Oruapure Bay, Whangaparapara, Bradshaw Cove) were grouped together and were characterised by higher CCA cover than most MEC and all MWC sites. The two most exposed MEC sites (E Reef, Mathesons Bay) were also separated from the main MEC grouping (Fig. 11.). These two sites were also characterised by greater CCA cover than other MEC sites and also generally lower *H. banksii* canopy cover. Ōmaha, the remaining outer gulf MEC site was not included in this small grouping due to high encrusting brown algae (*Ralfsia* complex) cover relative to other sites.

Kaitarakihi, which featured a wide, gently sloped intertidal zone, was the only site which consistently contained a significant cover of thick silt. This likely allows the native seagrass (*Zostera muelleri*) to form in the low tidal zone, the presence of which has made this site characteristically dissimilar from any of the others (Fig. 11).

The exposed east coast GBI site, Rangiwhakaea, differed from other GBI sites, or MEC sites, by having a very low cover of *C. officinalis* and high cover of the barnacles *Chamaesipho* spp. and *E. plicata*. The highly exposed MWC sites, Te Henga and Piha, formed their own group (Fig. 11). These two sites were the most exposed monitoring sites within the Auckland region (Fig. 4C; Table 1). Both had narrow, steep intertidal zones dominated by sessile invertebrate species. Barnacles (*Chamaesipho* spp. and *E. plicata)* and the green-lipped mussel (*Perna canaliculus*) were common, as was the black mussel (*Xenostrobus pulex*) at Te Henga (Table 5). The canopy forming macroalgae *H. banksii* was absent from these sites and in the low tide zone barnacles and black mussels were growing over green-lipped mussels as a secondary cover. These sites had the lowest overall benthic community richness and many of the species common at other sites were missing from these highly exposed sites.

DistLM results were consistent with spatial variation observed among sites (Fig. 11), with most environmental factors significantly related to community composition at MEC and MWC sites (Table 6A). At GBI, silt, slope and fetch all significantly related to community composition (Table 6A). The BEST models for all survey regions included fetch as an explanatory variable with rugosity and reef extent also important at GBI; sand, silt, rugosity and reef extent also important among MEC sites and silt important among MWC sites (Table 6B). Models for GBI and MWC provided much greater explanatory power ($r^2 = 0.6$ and 0.75 respectively) than the BEST model for MEC ($r^2 = 0.23$).

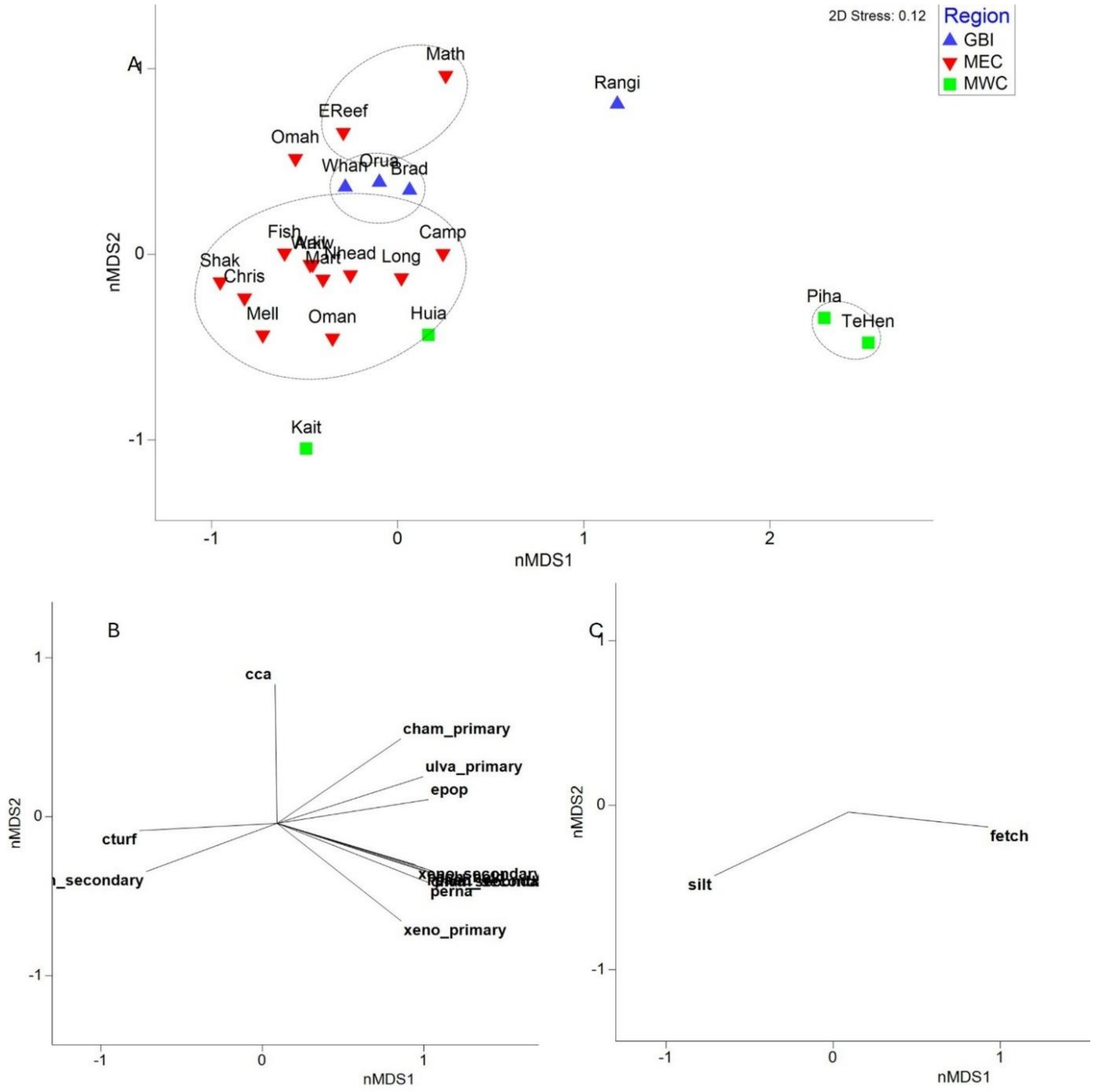

Figure 11: Variation in benthic community structure (percent cover of algae and sessile invertebrates) among rocky shore monitoring sites. (A). nMDS ordination based on square-root transformed, site averaged cover data. (B) Correlations between nMDS axes and taxa. (C) Correlations between nMDS axes and environmental parameters. Taxa and environmental parameters with correlation > 0.7 with axis are shown. In A. Blue = GBI sites; Red = MEC sites; Green = MWC sites. Black dotted lines indicate significant site groupings based on SIMPROF. See Table 1 for full site names.

Table 6: DistLM results showing (A) Marginal tests between benthic community structure (cover) within each region and environmental parameter and (B) the overall BEST models explaining species richness. In (A) bold values represent significant environmental parameters and in (B) bold values represent the model with the lowest AICc value and greatest R^2 value.

A)

	Variable	SS(trace)	Pseudo-F	P	Prop.
GBI	Sand	1295.80	1.33	0.22	0.14
	Silt	2966.80	3.87	**0.02**	0.33
	Rugosity	1230.20	1.25	0.30	0.14
	Fetch	3435.60	4.86	**<0.01**	0.38
	Reef extent	1098.10	1.10	0.36	0.12

	Variable	SS(trace)	Pseudo-F	P	Prop.
MEC	Sand	1557.60	1.47	0.13	0.02
	Silt	8535.10	8.90	**<0.01**	0.12
	Rugosity	4549.40	4.47	**<0.01**	0.06
	Fetch	8274.80	8.60	**<0.01**	0.11
	Reef extent	4865.50	4.81	**<0.01**	0.07

	Variable	SS(trace)	Pseudo-F	P	Prop.
MWC	Sand	5186.80	2.95	**0.05**	0.23
	Silt	7442.50	4.85	**<0.01**	0.33
	Rugosity	6375.40	3.88	**0.03**	0.28
	Fetch	13207.00	13.78	**<0.01**	0.58
	Reef extent	5777.70	3.40	**0.05**	0.25

B)

	AICc	R^2	RSS	No.Vars	Selections
GBI	**68.99**	0.60	3646	2	Fetch, Reef extent
	70.49	**0.74**	2324	3	Rugosity, Fetch, Reef extent

	AICc	R^2	RSS	No.Vars	Selections
MEC	**477.79**	0.23	57011	3	Sand, Silt, Fetch
	478.46	**0.27**	53804	5	Sand, Silt, Rugosity, Fetch, Reef extent

	AICc	R^2	RSS	No.Vars	Selections
MWC	**82.75**	**0.75**	5602	2	Silt, Fetch

3.2.2.2 Variation in benthic community structure (cover) across tidal zones

At GBI and MEC the overall primary benthic cover of algae and invertebrate species progressively increased with position down the shore (Fig. 12A). The high tidal zone consistently had the lowest overall biotic cover, while the low tidal zone had the highest. Primary biotic cover at MWC was lowest in the high tidal zone, but similar in the mid and low tidal zones, owing primarily to the high encrusting invertebrate cover found in these zones at the two highly exposed MWC sites, Te Henga and Piha (Fig. 12A). Across all locations, very little secondary biotic cover (algae and/or sessile invertebrates) was found in the high or low tidal zone, with secondary cover peaking in the mid tidal zone. This was particularly true at MEC sites (Fig. 12B) where the canopy forming brown algae, *H. banksii*, was common. Within the mid and low tidal zones of the two exposed MWC sites, secondary cover largely consisted of encrusting invertebrates, in particular *Chamaesipho* spp., growing on other encrusting invertebrates such as mussels.

In the high tidal zone, the barnacle *Chamaesipho* spp., rock oysters and brown encrusting algae (*Ralfsia* complex) were the most commonly encountered biotic cover types (Table 7A; Fig. 13 and 14). The barnacle *A. modestus* was also locally abundant at Whangaparapara, GBI, within the high tidal zone (see Supporting Material).

Mid tidal zones saw an increase in the cover of a broad suite of macroalgae and encrusting invertebrates (Fig. 13 and 14). This included *C. officinalis* (particularly at MEC sites with expansive reef platforms), the barnacles *A. modestus* and *E. plicata,* and CCA. High *E. plicata* cover among MWC sites was driven by high abundances of this species in the mid tidal zones at Piha and Te Henga, while encrusting cyanobacteria cover was notably high in the mid tidal zone at all GBI sites (Fig. 14). Rock oyster cover was similar between the high and mid tidal zones, but low in the low tidal zone (Fig. 14D). *Chamaesipho* spp. cover generally decreased between the high and mid tidal zone at GBI and MEC sites but increased between these zones at MWC (Fig. 13). This increase was driven primarily by comparatively high abundances of *Chamaesipho* spp. in the mid tidal zone at Te Henga and Piha. *Hormosira banskii* canopy cover was highest in the mid tidal zone at MEC sites and declined in the low tidal zone (Fig. 13). It occurred at lower covers at GBI and was rare or absent at most MWC sites.

Cover of *C. officinalis* peaked across the entire Auckland region in the low tidal zone (Fig. 13) as did the cover of CCA (Fig. 14). High cover of several encrusting invertebrates, including *P. canaliculus*, *X. pulex* and the calcareous tube worm *S. cariniferus* were recorded at exposed MWC sites, while at the more sheltered Kaitarakihi site, the seagrass Z. *muelleri* was found growing in areas of thick silt/mud present on the low shore. Among MEC sites, high covers of encrusting brown algae were common in the low tidal zone. Filamentous cyanobacteria (*Okeania* spp.) were also present, and associated with areas of flat, expansive reef, through MEC.

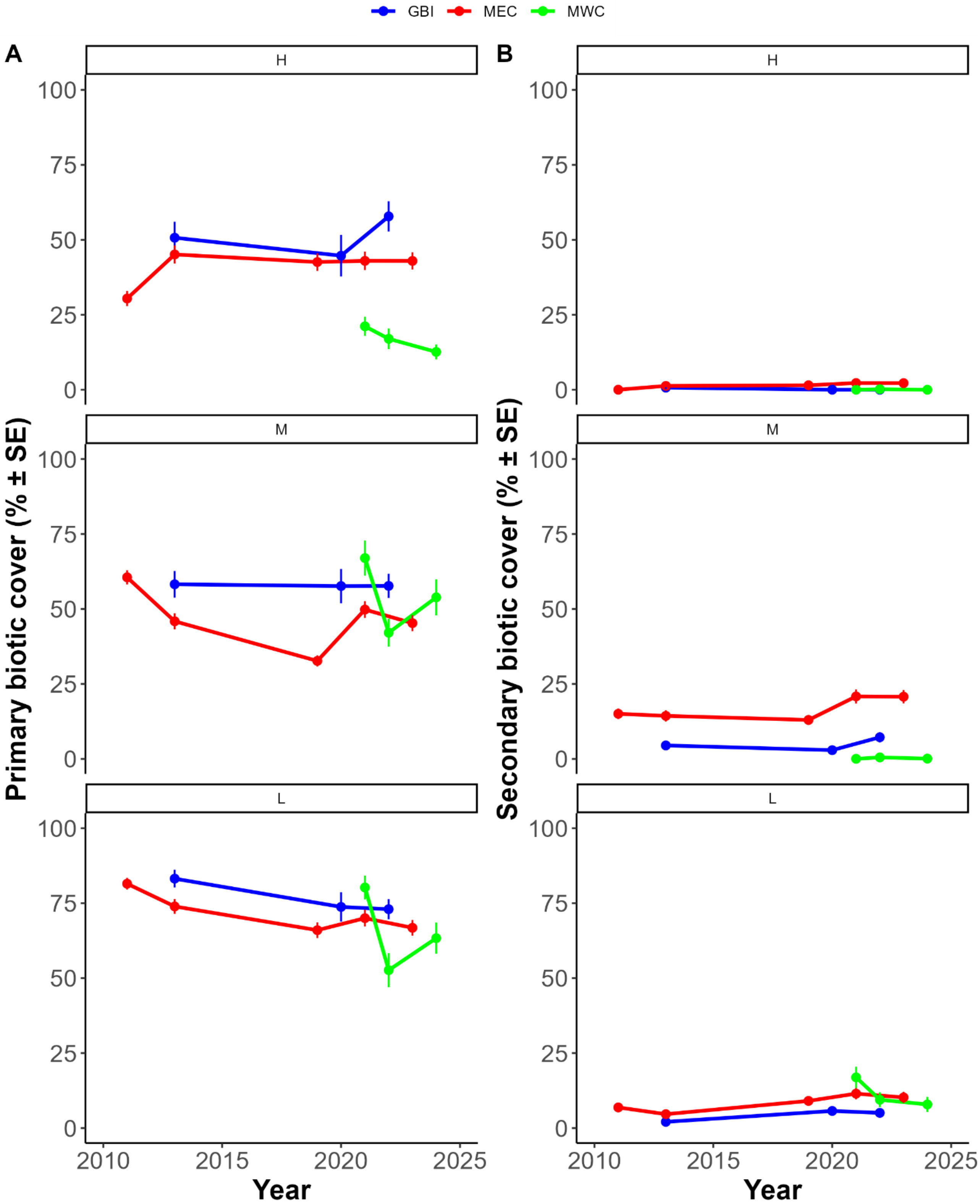

Figure 12: Average (A) primary and (B) benthic community compositions (covers) among GBI (Blue), MEC (Red) and MWC (Green) sites across the respective monitoring periods for each region at each tidal height. Values based on average covers across all sites within each region. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone. Values based on algae and encrusting animal species only, excludes non-biotic covers. 2020 data from GBI excluded as only two of four sites were surveyed.

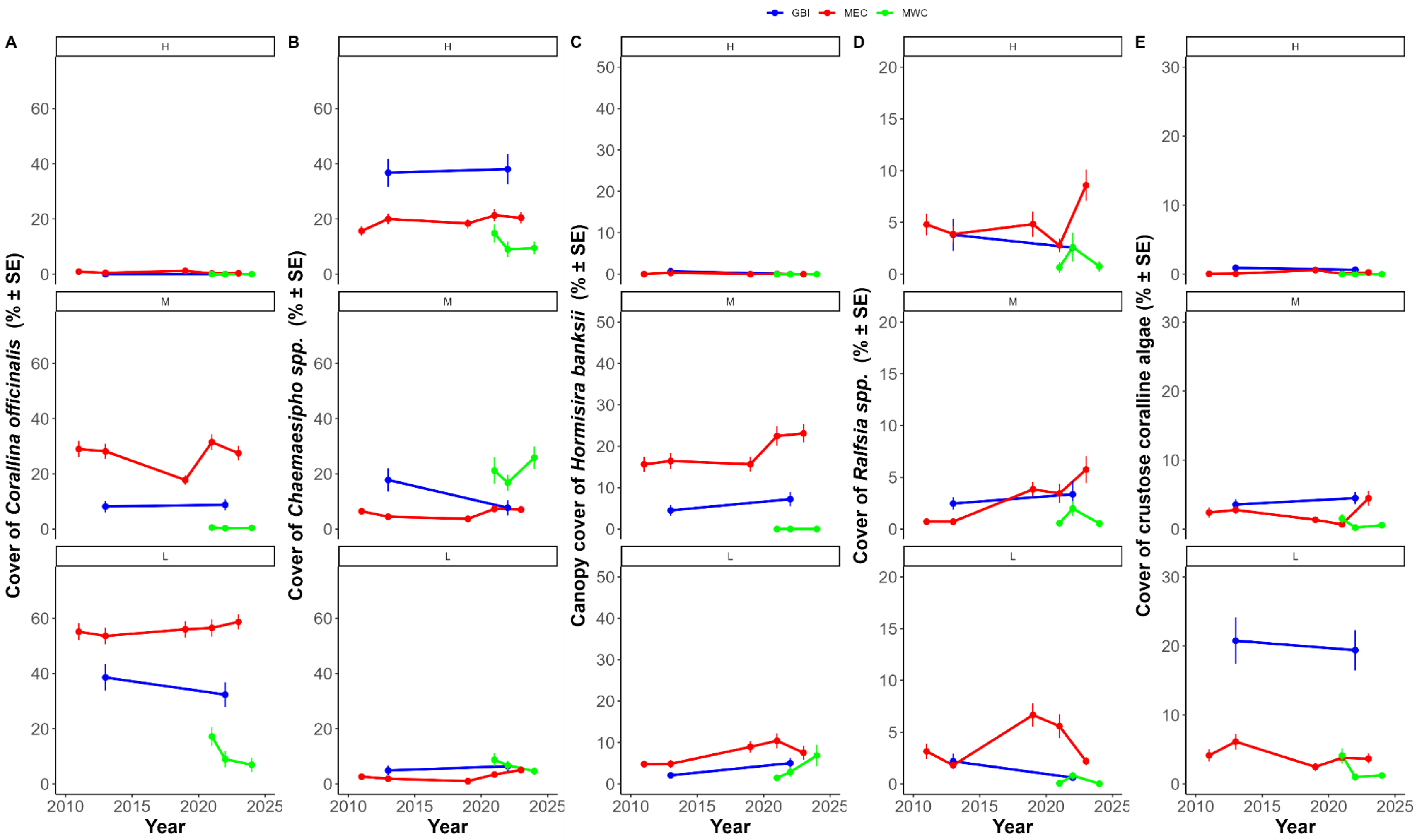

Figure 13: Average cover of (A) *Corallina officinalis* (B) *Chamaesipho* spp., (C) *Hormosira banksii* canopy cover, (D) *Ralfsia* spp. (and other brown encrusting algae) and (E) crustose coralline algae among GBI (Blue), MEC (Red) and MWC (Green) sites across the respective monitoring periods for each region at each tidal height. Values based on average covers across all sites within each region. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone. In (C), H. banksii cover is of canopy cover, not holdfast cover, making it a secondary cover, all others are primary covers. 2020 data from GBI excluded as only two of four sites were surveyed.

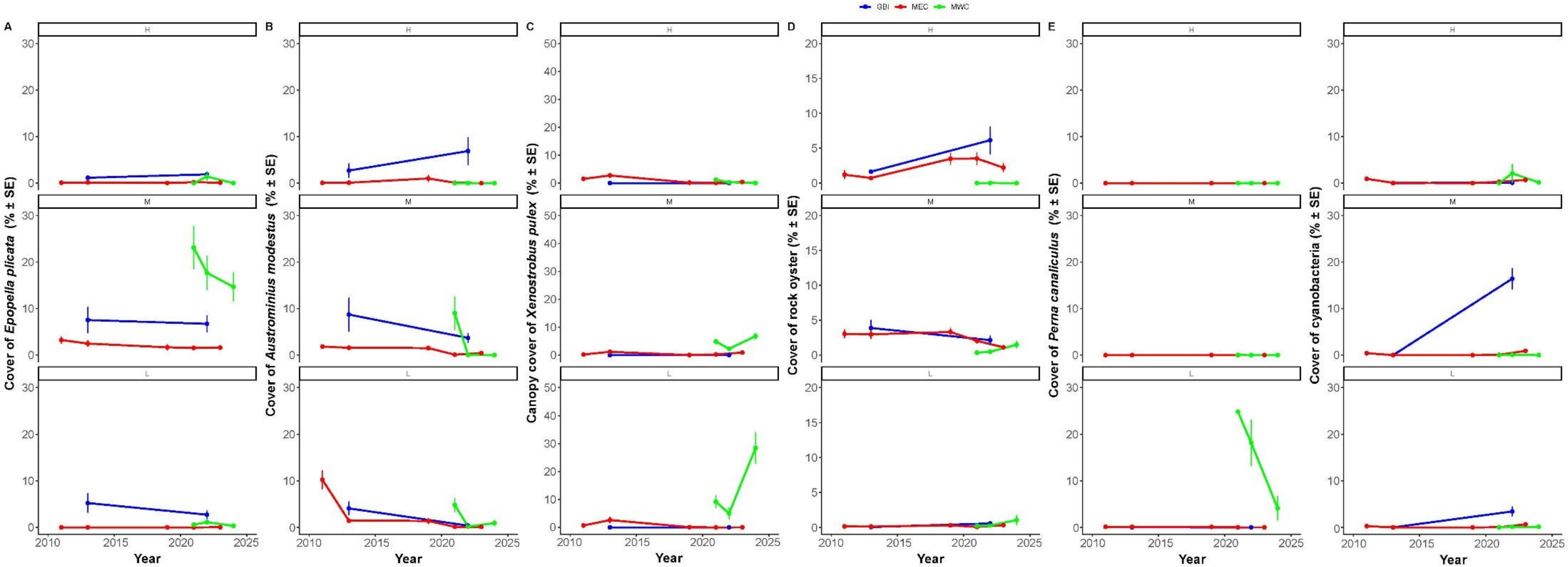

Figure 14: Average cover of (A) *Epopella plicata* (B) *Austrominius modestus*, (C) *Xenostrobus pulex*, (D) rock oysters (*Saccostrea glomerata* and *Magallana gigas*), (E) *Perna canaliculus* and (F) cyanobacteria among GBI (Blue), MEC (Red) and MWC (Green) sites across the respective monitoring periods for each region at each tidal height. Values based on average covers across all sites within each region. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone. All covers are primary covers. 2020 data from GBI excluded as only two of four sites were surveyed.

3.2.2.3 Temporal variation in benthic community structure (cover) among sites and tidal zones

Great Barrier Island (GBI)

Average benthic community structure did not significantly change at GBI between the 2013 and 2022 sampling periods, when all four sites were surveyed (Table 7A). As expected, community structure differed between each tidal zone, but the changes remained relatively consistent through time (there was no interaction between time and tidal zone), with the most notable change a large increase in encrusting cyanobacteria within the mid tidal zone at all sites between the two survey periods (Fig. 14F). In the high tidal zone, a large increase in *A. modestus* occurred at Whangaparapara, where the species was common, while rock oyster cover increased at all three GBI west coast sites (see Supporting Material).

Whangaparapara and Bradshaw Cove were both sampled in 2020. This sampling period showed that the community composition significantly changed at these two sites between 2013 and 2020, before returning to a similar composition to the initial survey by 2022. At Bradshaw Cove, *Chamaesipho* spp. cover declined sharply in the high and mid tidal zones between 2013 and 2020 but recovered in the high tidal zone by 2022. Cover of CCA and *C. officinalis* also dropped in the mid tidal zone between 2013 and 2020 before recovering by 2022. At Whangaparapara, changes to three key species were also driving the temporal changes seen. Firstly, *Chamaesipho* spp. was present in 2013 but not the 2020 and 2022 surveys. Secondly, *A. modestus* cover increased between 2013 and 2020 but declined between 2020 and 2022. Finally, *C. officinalis* declined between the 2013 and 2020 surveys but increased markedly between 2020 and 2022 (see Supporting Material).

Mainland East Coast (MEC)

Benthic community composition changed significantly over survey years across the MEC sites, and this change was consistent across all tidal zones (Table 7A and 7B). These changes were driven by region wide shifts in species abundances, as well as site specific fluctuations in individual species through time.

In the high tidal zone, a region wide increase in encrusting brown algae (*Ralfsia* complex) occurred between 2021 and 2023 (Fig. 13D), while fluctuations in other common species such as *Chamaesipho* spp. were more apparent at a site level. For example, *Chamaesipho* spp. cover at Arkles Bay rose from ~35% to ~54% between 2019 and 2021 before dropping to a site low of ~19% in 2023, whereas *Chamaesipho spp.* cover at nearby Fishermans Cove remained stable (~20 – 32%) across the survey period.

In the mid tidal zone, fluctuations in cover of *C. officinalis* and canopy forming *H. banksii* were apparent (Fig. 13A, C). *Corallina officinalis* cover declined across the survey region between 2013 and 2019 (~28% to 18%) but increased again to ~31% by 2021. *Hormosira banksii* cover was relatively stable between 2011 and 2019 before increasing from ~16% to ~22% between 2019 and 2021. It remained higher through to 2023 (Fig. 13C). *Ralfsia* spp. cover steadily climbed throughout the survey period from ~1% to ~6% (Fig. 13D), while CCA cover declined between 2013 and 2021 before increasing in 2023. Rock oyster cover was stable between 2011 and 2019 and gradually declined since then. As well as regional trends, large site level fluctuations have also occurred for some species. *Epopella plicata* for example was only common at four sites and at three of these (Ōmaha, Long Bay and Campbells Bay) it has fluctuated considerably through time (see Supporting Material).

As with the mid tidal zone, several species in the low tidal zone underwent regionwide population fluctuations over the course of the survey period. Most notable was the sharp decline of *A. modestus* cover between 2011 and 2013 (Fig. 14B). This species was found at most sites in 2011, with high cover (10% to 70%) recorded at E Reef, Ōmaha, Martins Bay and Cambell's Bay. Following the large population decline between 2011 and 2013 regional cover dropped from ~10% to ~1%. Cover of *Ralfsia* spp. increased significantly between 2013 and 2019 before falling back to similar levels to 2013 by 2023 (Fig. 13D), while *H. banksii* canopy cover increased between 2013 and 2021 (Fig. 13C). Regional crustose coralline algae cover peaked in 2013 and was at its lowest in 2019 (Fig. 13E), while at a site level, *Chamaesipho spp.* cover varied greatly at E Reef and Campbells Bay, as did *X. pulex* cover at Ōmaha and *S. cariniferus* cover at E Reef and Christian's Bay (see Supporting Material).

Mainland West Coast (MWC)

The community structure at west coast sites varied considerably between exposed open coast sites (Te Henga and Piha) and the more sheltered Manukau Harbour sites (Huia and Kaitarakihi; Fig. 11, Table 7A). Despite these differences among exposed and sheltered sites, the general characteristics of the benthic community remained relatively stable across the survey period (2021 – 2024; Table 7A) with expected difference occurring among the three tidal zones (Table 7A).

The most obvious changes in community composition were in the low tidal zone where a large decline in the cover of *P. canaliculus* occurred between 2021 and 2024 (Fig. 14E). This species was highly abundant at Te Henga and Piha, but rare or absent at the two sheltered harbour sites. At Piha, the initial population loss (~44% to ~11%) occurred in 2022 and coincided with much of the low tidal zone being buried by sand. At Te Henga, this loss occurred between 2022 and 2024 when cover declined from ~62% to ~11%. In 2024, *X pulex* replaced *P. canaliculus* as the primary mussel species present within the low tidal zone at both of these locations (Fig. 14C).

Other changes were largely driven by site specific shifts in species abundances, for example, an overall decline in *A. modestus* cover in the mid and low tidal zones were primarily due to large declines at Huia, where the species was common in 2021. Similarly, *H. banksii* canopy cover increased between 2021 and 2024 at Kaitarakihi, but the species was rare or absent at the other three sites (Fig. 13C and Supporting Material). The non-native barnacle *Austromegabalanus nigrescens* was first recorded at Te Henga in 2022 and had increased to ~10% cover in 2024.

Table 7: (A) Results from PERMANOVA tests examining the effects of Tidal zone and Year on the benthic community composition at GBI, MEC and MWC. (B) Pairwise comparisons for the effects of Year on the benthic community composition at MEC. Tests based on yearly site averaged data for each tidal zone. For GBI 2020 data excluded as only two sites were surveyed. In (B) pairwise analysis only conducted for year as no Tidal Zone x Year interaction was present.

A)

Location	Source	df	SS	MS	Pseudo-F	*P*	perms
GBI	Tidal zone	2	18510.00	9255.10	6.25	**<0.01**	999
	Year	1	2960.90	2960.90	2.00	0.08	999
	Tidal zone x year	2	1307.60	653.78	0.44	0.93	997
	Res	18	26653.00	1480.70			
	Total	23					

Location	Source	df	SS	MS	Pseudo-F	*P*	perms
MEC	Tidal zone	2	173000.00	86499.00	54.31	**<0.01**	999
	Year	1	22976.00	5744.00	3.61	**<0.01**	998
	Tidal zone x year	2	10904.00	1363.00	0.86	0.82	998
	Res	18	310560.00	1592.60			
	Total	23					

Location	Source	df	SS	MS	Pseudo-F	*P*	perms
MWC	Tidal zone	2	24019.00	12010.00	4.23	**<0.01**	999
	Year	1	3558.30	1779.10	0.63	0.89	999
	Tidal zone x year	2	4480.60	1120.10	0.39	1.00	999
	Residuals	18	76651.00	2838.90			
	Total	23					

B)

Location	Pairwise comparisons	t	*P*	perms
MEC	2011, 2013	2.13	**<0.01**	999
	2011, 2019	2.41	**<0.01**	999
	2011, 2021	2.00	**<0.01**	999
	2011, 2023	2.13	**<0.01**	999
	2013, 2019	1.78	**<0.01**	999
	2013, 2021	1.53	**0.01**	999
	2013, 2023	1.87	**<0.01**	999
	2019, 2021	1.27	0.09	999
	2019, 2023	2.20	**<0.01**	999
	2021, 2023	1.44	**0.02**	999

3.2.3 Macroinvertebrate assemblages (counts)

3.2.3.1 Broad-scale variation in mobile macroinvertebrate assemblages across the Auckland region

The mobile invertebrate assemblage was broadly similar at many sites across the Auckland region (Fig. 15A), with 15 of 22 surveyed sites clustered in the central area of the ordination plot. This cluster contains sites from GBI, MEC and MWC. Within this, three smaller groupings existed. The largest of these comprised MEC sites from Mathesons Bay to Arkles Bay and was characterised by high abundances of the herbivorous gastropods *Lunella smaragdus* and *Nerita melanotragus,* as well as high but variable abundances of microgastropods. Other species which were generally common in this group included the herbivorous gastropod *Diloma aethiops,* predatory whelks *Haustrum scobina* and *Cominella virgata*, the chiton *Sypharochiton pelliserpentis,* and the limpet *Siphonaria* sp.

A smaller grouping within this main cluster comprised the most exposed MEC site, E Reef, as well as two of the most rugose, sloping MEC sites, Long Bay and Campbells Bay (Fig. 15A). These sites had higher abundances of *S. pelliserpentis,* and the limpets *Cellana ornata* and *C. radians,* than other sites within the cluster (Fig. 15B). The other small cluster contained the three west coast GBI sites (Oruapure Bay, Bradshaw Cove and Whangaparapara), as well as North Head (MEC) and Huia (MWC). These sites were all characterised by narrow intertidal reefs with high rugosity and slope (Fig. 4). Among these sites, *S. pelliserpentis, Diloma aethiops* and *Haustrum scobina* were generally more abundant than other sites within the main cluster. Microgastropods were uncommon at the GBI sites and North Head but were abundant at Huia.

Kaitarakihi, the MWC site with the most extensive reef platform, as well as the highest silt cover, sat slightly apart from the main grouping (Fig. 15A). Interestingly this site was lacking a number of common species found at nearby Huia, and throughout the MEC sites.

Mellons Bay and Ōmana (MEC sites) in the inner gulf formed their own group (Fig. 15A) and were characterised by extensive, gently sloping reefs with high silt cover. These sites had very few microgastropods compared to other MEC sites. *Zeacumantus* spp. were common at both sites, while mudflat anemones *Anthopleura aureoradiata* were common at Ōmana.

The two MWC sites on the open coast also formed their own group (Fig. 15A). These sites were very similar in their macroinvertebrate composition and had the lowest overall macroinvertebrate diversity (see Supporting Material). At both sites, microgastropods were relatively common, with *Austrolittorina cincta* attaining comparatively large sizes (up to ~15mm) at Te Henga and extending down into the low tidal zone (which was atypical throughout the sites surveyed). Species such as *L. smaragdus, N. melanotragus* and *Zeacumantus* spp., which were common at other sites, were very rare or entirely absent at these sites, but *H. scobina* abundance was very high. Limpets, including *Cellana spp.* (so weathered it was not possible to tell species apart) and *Notoacmea sp.* were all regularly recorded at Te Henga. Piha had a high abundance of the anemone *Isactinia olivacea.*

Rangiwhakaea, the most exposed and only site on the east coast of GBI, was an outlier in terms of its macroinvertebrate assemblage. Here the most common marine snails were *H. scobina* and *Risellopsis varia*. *Sypharochiton pelliserpentis* and the limpets *Siphonaria* sp., *Notoacmea* sp. and *Cellana* spp., were also common, as was the predatory whelk *Dicathais orbita*.

DistLM results indicated that all environmental factors played a significant role in shaping the macroinvertebrate communities among MEC sites, but the BEST model, which included sand, silt, reef extent and fetch, only resulted in modest explanatory power (r^2 = 0.23; Table 8A, B). For GBI and MWC, rugosity and fetch were significant drivers of macroinvertebrate composition with only fetch included in the BEST models. Like MEC, the predictive power of these DistLM models was only modest (r^2 = 0.31 and 0.43 respectively; Table 8A and 8B). A second model with a notably higher r^2 value (0.54) was also suggested for MWC, containing fetch and reef extent as explanatory variables (Table 8B).

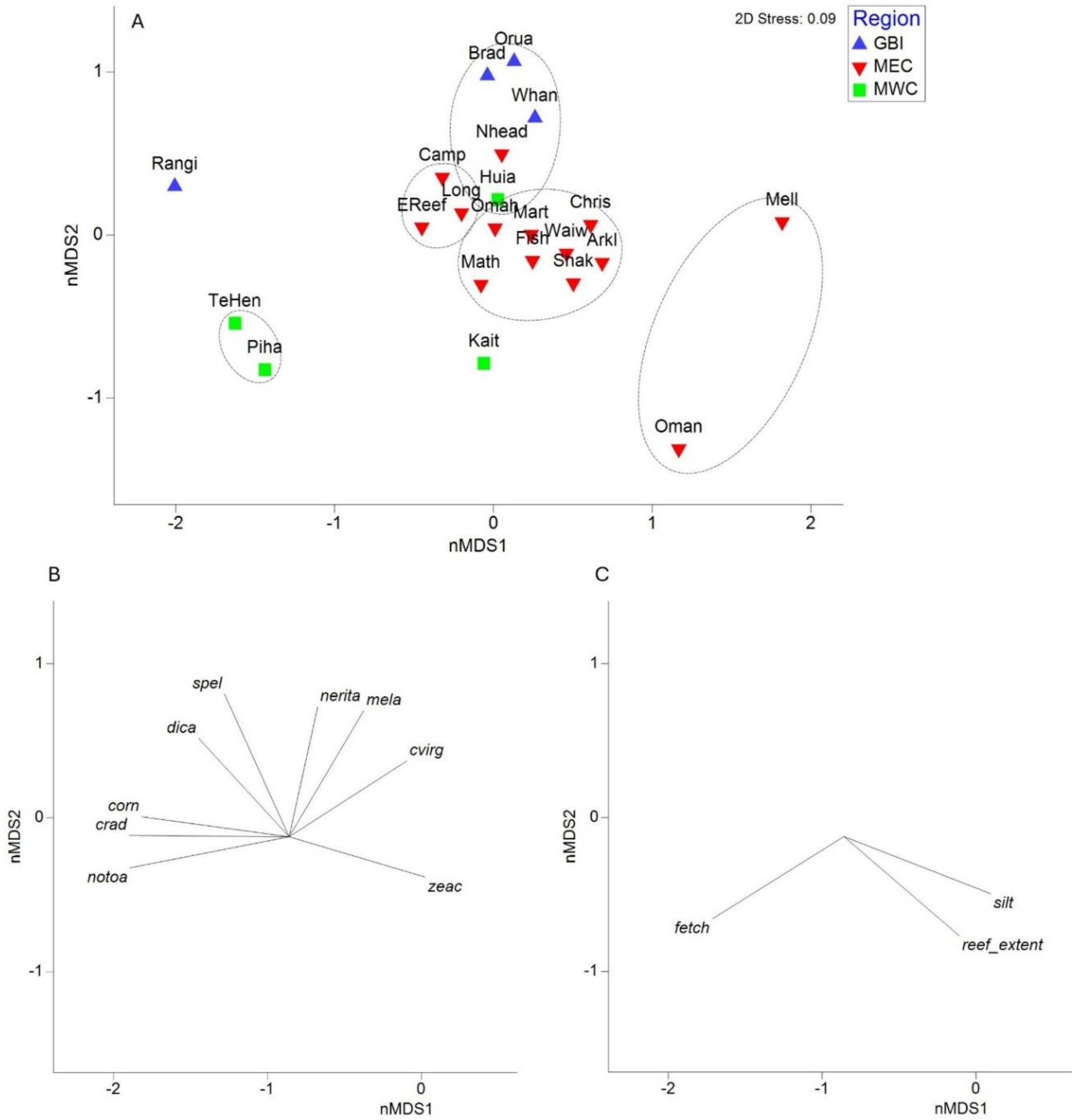

Figure 15: Variation in mobile macroinvertebrate assemblage among rocky shore monitoring sites. (A). nMDS ordination based on log (x+1) transformed, site averaged count data. (B) Correlations between nMDS axes and taxa. (C) Correlations between nMDS axes and environmental parameters. Taxa and environmental parameters with correlation > 0.7, with axis are shown. In A. Blue = GBI sites; Red = MEC sites; Green = MWC sites. Black dotted lines indicate significant site groupings based on SIMPROF. See Table 1 for full site names.

Table 8: DistLM results showing (A) Marginal tests between macroinvertebrate assemblage within each region and environmental parameter and (B) the overall BEST models explaining species richness. In (A) bold values represent significant environmental parameters and in (B) bold values represent the model with the lowest AICc value and greatest R^2 value.

A)

	Variable	SS(trace)	Pseudo-F	P	Prop.
GBI	Sand	767.19	0.95	0.40	0.11
	Silt	1213.50	1.61	0.14	0.17
	Rugosity	1909.90	2.87	**0.04**	0.26
	Fetch	2207.70	3.51	**0.01**	0.31
	Reef extent	512.59	0.61	0.69	0.07

	Variable	SS(trace)	Pseudo-F	P	Prop.
MEC	Sand	1977.00	2.67	**0.02**	0.04
	Silt	6211.60	9.16	**<0.01**	0.12
	Rugosity	4298.90	6.09	**<0.01**	0.08
	Fetch	6739.50	10.06	**<0.01**	0.13
	Reef extent	8070.70	12.40	**<0.01**	0.15

	Variable	SS(trace)	Pseudo-F	P	Prop.
MWC	Sand	1828.4	2.3	0.09	0.2
	Silt	2052.1	2.6	0.06	0.2
	Rugosity	2142.6	2.8	**0.05**	0.2
	Fetch	4270.9	7.6	**<0.01**	0.4
	Reef extent	1692.4	2.1	0.10	0.2

B)

	AICc	R^2	RSS	No.Vars	Selections
GBI	**67.91**	**0.31**	5025.60	1	Fetch
	68.49	0.26	5323.40	1	Rugosity

	AICc	R^2	RSS	No.Vars	Selections
MEC	**446.59**	0.32	35317.00	4	Sand, Silt, Fetch, Reef extent
	447.13	**0.34**	34393.00	5	Sand, Silt, Rugosity, Fetch, Reef extent

	AICc	R^2	RSS	No.Vars	Selections
MWC	**79.14**	0.43	5629.20	1	Fetch
	80.24	**0.54**	4544.50	2	Fetch, Reef extent

3.2.3.2 Variation in mobile macroinvertebrate communities across tidal zones

Microgastropods were extremely abundant and highly variable among sites (Fig 16A). The two most commonly identifiable microgastropod species were *Austrolittorina antipodum* and *A. cincta,* which were most often found in the high tidal zone, except at MWC exposed sites, where *A. cincta* were across all tidal zones. Other non-identifiable microgastropod species were found in the low and mid shore zones but were typically less abundant than populations found in the high shore zone.

Aside from microgastropods, *N. melanotragus*, *H. scobina* and to a lesser extent *D. aethiops*, were the only macroinvertebrates commonly recorded within the high tidal zone, with most other species either absent, particularly among MWC sites, or very rare (Fig. 17 and 18). On GBI, *R. varia* was also common in the high tidal zone, and was recorded within the high tidal zone at several MEC sites in 2011, but not during later survey dates (Fig. 18C).

Overall abundance of other mobile macroinvertebrates (excluding microgastropods) was highest in the mid tidal zone (Fig, 16B). This was due to several commonly recorded species being most abundant here, and a generally higher diversity of species occupying this section of the intertidal platform. *Nerita melanotragus*, *H. scobina* and *D. aethiops* were most abundant among all survey regions within the mid tidal zone (Fig. 17A, C, 18A). Additionally, at GBI, *S. pelliserpentis*, *R. varia*, *Siphonaria* sp. and *Cellana* spp. were most abundant within the mid tidal zone. This was also the case for *Cellana* spp. and *Zeacumantus* spp. among MEC sites, while *Notoacmea* sp. and *Onchidella nigricans* were common within this zone at MWC (see Supporting Material).

The same general suite of macroinvertebrates found in the mid tidal zone was also found in the low tidal zone, however *L. smaragdus* was the only common species whose abundance peaked within the low shore across all three survey regions (Fig. 17B). At GBI, *N. melanotragus* and *S. pelliserpentis* remained at high abundances, while predatory whelks such as *D. orbita*, *Taron dubius* and *C. virgata* were all common. *Cominella virgata* abundance were similar in the mid and low tidal zones at MEC sites, while *Zeacumantus* spp. remained common, particularly at sites with greater sediment cover, and *Siphonaria* sp. abundances peaked. Among MWC sites, *Cellana* spp. abundance was highest in the low tidal zone, though this was mostly due to its presence on the exposed coastal sites, while *S. pelliserpentis* and *H. scobina,* in particular, remained common.

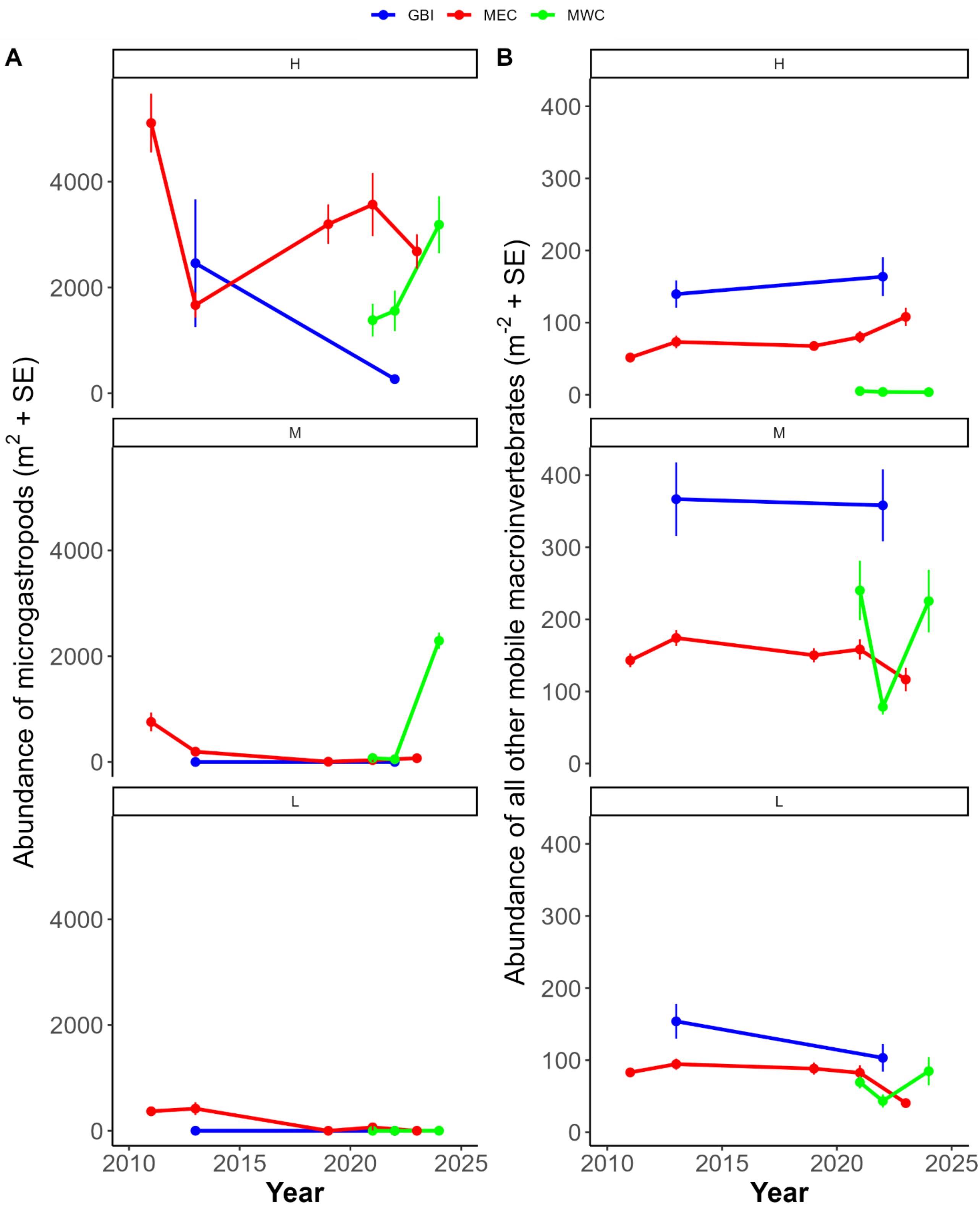

Figure 16: Average abundance of (A) microgastropods and (B) all other macroinvertebrates among GBI (Blue), MEC (Red) and MWC (Green) sites across the respective monitoring periods for each survey region at each tidal height. Values based on average covers across all sites within each region. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone. 2020 data from GBI excluded as only two of four sites were surveyed.

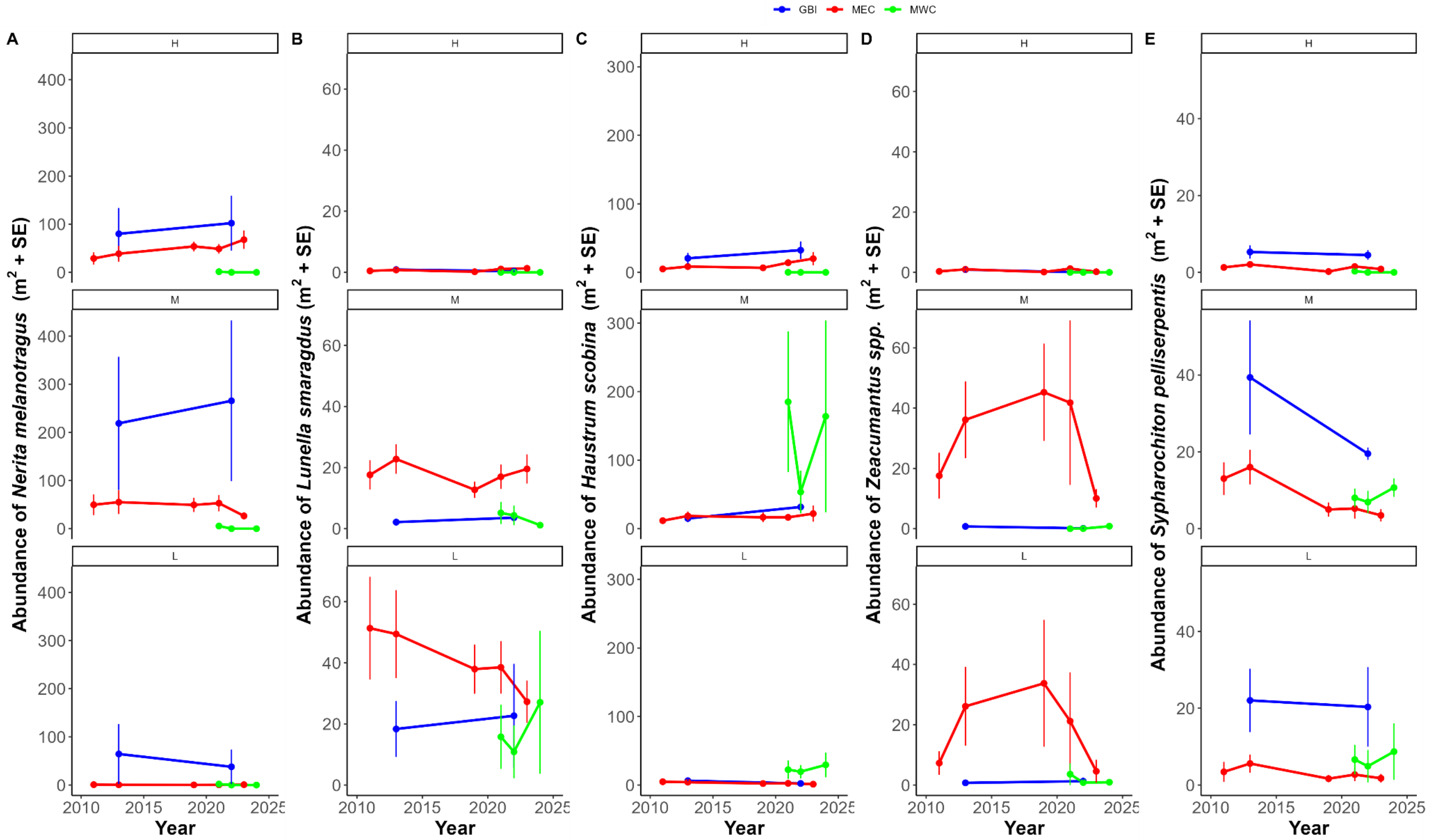

Figure 17: Average abundances of (A) *Nerita melanotragus* (B) *Lunella smargdus*, (C) *Haustrum scobina*, (D) *Zeacumantus* spp., and (E) *Sypharochiton pelliserpentis* among GBI (Blue), MEC (Red) and MWC (Green) sites across the respective monitoring periods for each region at each tidal height. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone. 2020 data from GBI excluded as only two of four sites were surveyed.

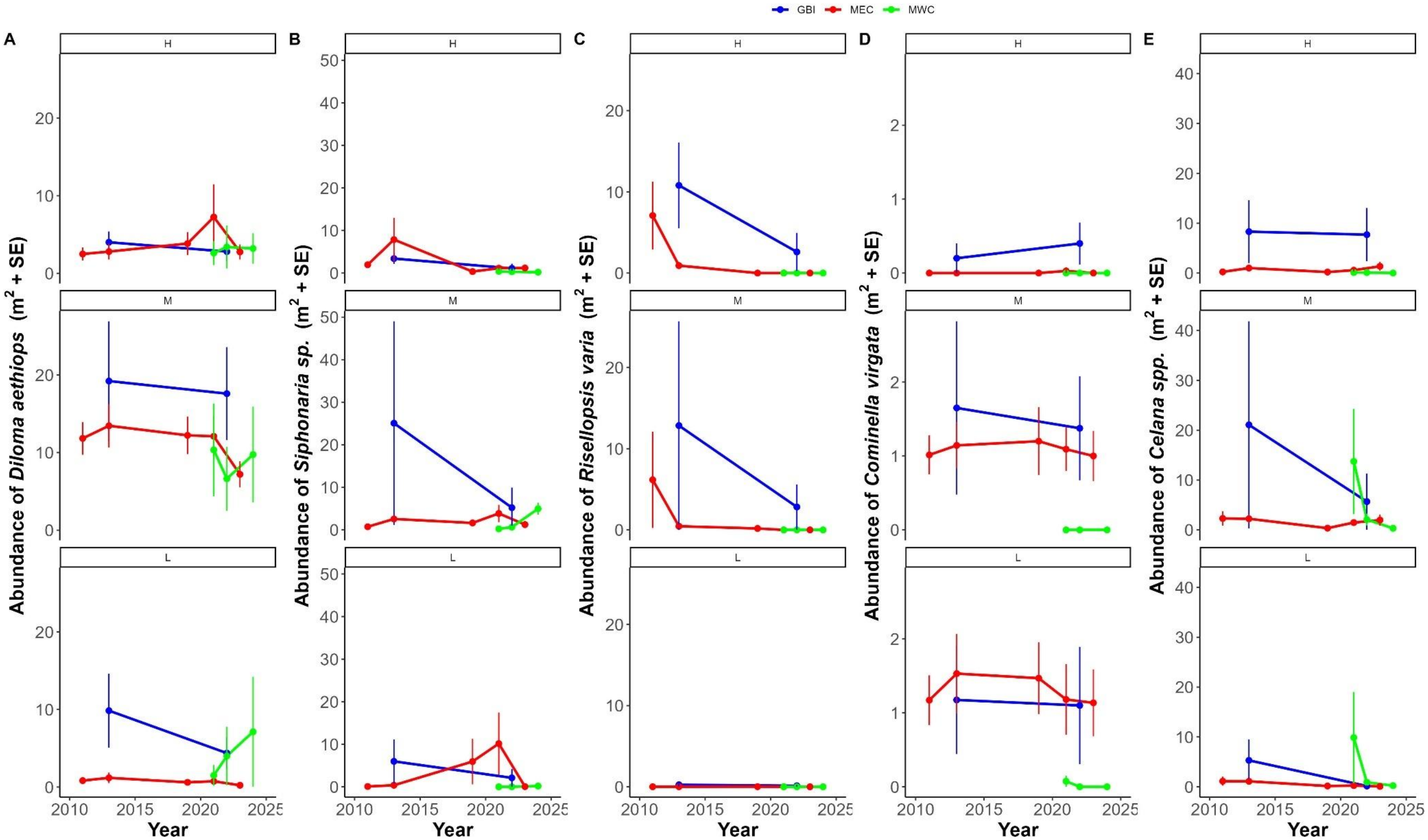

Figure 18: Average abundances of (A) *Diloma aethiops* (B) *Siphonaria* spp., (C) *Risellopsis varia*, (D) *Cominella virgata*, and (E) *Cellana* spp. among GBI (Blue), MEC (Red) and MWC (Green) sites across the respective monitoring periods for each region at each tidal height. H = High tidal zone, M = Mid tidal zone, L = Low tidal zone. 2020 data from GBI excluded as only two of four sites were surveyed.

3.2.3.3 Temporal variation in macroinvertebrate communities among sites and tidal zones

Overall macroinvertebrate assemblages have remained temporally similar at GBI and MWC but have significantly varied through time at MEC (Table 7A). These changes have been due to fluctuations in individual species through time, and although overall changes were not detected at GBI and MWC, there have been some species that have changed in abundance through time.

Great Barrier Island (GBI)

All GBI sites showed a modest degree of fluctuation through time, however there was no general trend in terms of the macroinvertebrate community (Fig. 16, Table 7A). At Rangiwhakaea, overall macroinvertebrate abundances were lower in 2022 than in 2013. The largest single decline was in microgastropods where density in the high shore went from ~6651 per m^2 in 2013 to 25 per m^2 in 2022. In the mid tidal zone there were also notable declines in the small gastropod *Risellopsis varia* and limpets, *Notoacmea* sp. and *Siphonaria* sp., but large increases in *H. scobina. Haustrum scobina* also increased across all tidal heights, at Oruapure Bay, while most other species remained relatively stable. At Bradshaw Cove several species went through large fluctuations in abundance. For example, *H. scobina*, which was common at all tidal heights, remained relatively stable in the high- and mid-tidal zones, but went from ~1 per m^2 in 2013 in the low tidal zone to ~97 per m^2 in 2020, before dropping back to 1.3 per m^2 in 2022. *Lunella smaragdus* densities increased through the sampling period, while predatory species such as *C. virgata* and *T. dubius* increased in 2020 and remained more common through to 2022. Microgastropods declined in the high tidal zone at Whangaparapara as did *L. smaragdus* and *H. scobina* in the low tidal zone and *S. pelliserpentis* in the low and mid tidal zones. *Neritia melanotragus* on the other hand, increased in the high tidal zone across the survey period.

Mainland East Coast (MEC)

The greatest overall changes appeared to occur between the earlier survey periods (2011, 2013 and 2019) along the MEC coast (Table 7A and 7B), however as with GBI, individual species and sites experienced fluctuations in abundance across the duration of the monitoring period.

Microgastropods were most abundant in the high tidal zone and experienced large fluctuations in abundances at many sites, with a general decline among sites between 2011 and 2013, before populations increased through to 2021, declining again in 2023 (Fig. 16A).

There was more stability in the overall assemblage of other macroinvertebrates, though an overall increase in abundance was seen on the high tidal zone between 2019 and 2023 and a notable decline in abundances in the low tidal zone between 2021 and 2023 (Fig. 16B). In the high tidal zone, *N. melanotragus* was the main driver of this change with average abundance increasing from ~39 per m^2 in 2013 to ~54 per m^2 in 2019 and peaking at ~68 per m^2 in 2023

(Fig. 17A). *Haustrum scobina* abundances also peaked in 2023 at ~20 per m^2 (Fig. 17C), while most other species were only found in low numbers, and populations remained relatively stable over the course of the survey period (Fig. 17 and Fig. 18). The one exception was *R. varia*, which was recorded at high abundances at several sites in 2011 (average regional abundance ~7 per m^2), was rare in 2013 and then not recorded again (Fig. 18C).

This same pattern with *R. varia* was also seen in the mid tidal zone. While most species experience relatively little change at a regional level within the mid tidal zone, a few notable exceptions were recorded. Firstly, *N. melanotragus* abundance halved between 2021 – 2023 from ~53 per m^2 to ~26 per m^2, having been stable up to that point (Fig. 17A). Secondly, *Zeacumantus* spp. populations fluctuated greatly (Fig 17D). This species was common at a number of sites, but appeared to thrive, particularly between 2013 and 2021, at Arkles Bay, where abundances ranged from ~100 per m^2 to ~340 per m^2 (see Supporting Material). This species experienced a relatively consistent decline in abundance across MEC sites in 2023. In addition, *S. pelliserpentis* declined through time within the mid tidal zone (Fig. 17E) while *D. aethiops,* which was stable through 2011 to 2021, then declined significantly in 2023 (Fig. 18A). At a site level, the most noticeable shift was at Ōmana, where a large recruitment of the cockle *Austrovenus stutchburyi*, more synonymous with soft sediment environments, occurred between 2021 and 2023. Although this species was recorded at this site during all previous surveys, abundances jumped abruptly from ~1.1 per m^2 in 2021 to ~28 per m^2 in 2023.

In the low tidal zone the same general fluctuations in *Zeacumantus* spp. abundances occurred, with lowest densities occurring in 2023, but similar to those recorded in 2011 (Fig 17D). *Lunella smaragdus*, which was the most abundant macroinvertebrate, declined through time, with the lowest overall densities also occurring in 2023 (Fig. 17B). The limpet *Siphonaria* sp. declined to near zero in 2023 after initial population increases between 2013 and 2021 (Fig. 18B).

Mainland West Coast (MWC)

Overall macroinvertebrate assemblages did not significantly differ across the MWC survey region between 2021 and 2024 (Table 7A), however, there were some notable changes in the abundance of specific species at each site, which drove changes in abundances at a survey region scale (e.g. Fig. 16, 17, 18).

Microgastropod abundance increased across the survey period in both the high and mid tidal zones (Fig. 16A). At Te Henga, abundance in the high tidal zone increased from ~38 per m^2 in 2019 to ~1990 per m^2 in 2024, while no microgastropods were recorded at Huia's mid shore in 2022, but abundances were ~1860 per m^2 in 2024. *Haustrum scobina* was very abundant at Te Henga and Piha in 2021, dropping significantly at both sites in 2022 and then recovering at Piha by 2024 (Fig 17C). In the low tidal zone changes in *L. smaragdus, S. pelliserpentis* and *D. aetheopis* (Fig. 17B, 17E and Fig. 18A) reflected increases in abundance at Huia between 2021 - 2024, while *Cellana* spp. declined significantly at Te Henga between 2021 and 2022, resulting in the large drop in abundance in the low and mid tides in Fig. 18E.

Table 7: (A) Results from PERMANOVA tests examining the effects of Tidal zone and Year on the macroinvertebrate assemblage at GBI, MEC and MWC. (B) Pairwise comparisons for the effects of Year on the benthic community composition at MEC. Tests based on yearly site averaged data for each tidal zone. For GBI 2020 data excluded as only two sites were surveyed. In (B) pairwise analysis only conducted for year as no Tidal Zone x Year interaction was present.

A)

Region	Source	df	SS	MS	Pseudo-F	*P*	perms
GBI	Tidal zone	2	15094.00	7547.10	5.60	**<0.01**	999
	Year	1	3793.90	1896.90	1.41	0.20	999
	Tidal zone x year	2	1581.30	395.33	0.29	1.00	997
	Res	18	28278.00	1346.60			

Region	Source	df	SS	MS	Pseudo-F	*P*	perms
MEC	Tidal zone	2	183850.00	91927.00	67.64	**<0.01**	999
	Year	4	20515.00	5128.80	3.77	**<0.01**	996
	Tidal zone x year	8	9083.50	1135.40	0.84	0.80	998
	Res	195	265020.00	1359.10			

Region	Source	df	SS	MS	Pseudo-F	*P*	perms
MWC	Tidal zone	2	42436.00	21218.00	15.19	**<0.01**	999
	Year	2	3666.20	1833.10	1.31	0.89	999
	Tidal zone x year	4	1897.30	474.33	0.34	1.00	999
	Res	27	37708.00	1396.60			

B)

Region	Pairwise comparisons	t	*P*	perms
MEC	2011, 2013	1.50	**0.04**	999
	2011, 2019	2.69	**<0.01**	999
	2011, 2021	2.61	**<0.01**	998
	2011, 2023	2.52	**<0.01**	999
	2013, 2019	1.90	**<0.01**	997
	2013, 2021	1.81	**<0.01**	999
	2013, 2023	2.11	**<0.01**	998
	2019, 2021	1.09	0.30	999
	2019, 2023	1.33	0.07	998
	2021, 2023	1.05	0.33	999

4 Discussion

The intertidal rocky shore monitoring programme was initiated in 2011, spanning 14 sites along Auckland's east coast (MEC), from the outer to inner Hauraki Gulf. The programme was expanded in 2013 to include four additional offshore sites around Great Barrier Island (GBI) and again in 2021 to include four sites along Auckland's west coast (MWC). This series of twenty-two rocky shore monitoring sites spans a large environmental gradient in terms of physical reef characteristics (e.g. reef slope, rugosity and extent), wave exposure and sedimentation.

4.1 Regional drivers of rocky shore communities

Variation in species richness, benthic community structure (algae/sessile invertebrates) and mobile macroinvertebrate assemblages across the Auckland region were highly correlated with several measured environmental parameters, however the overall relationship between community composition and environmental parameters was only modest and many sites shared broadly similar ecological communities despite widely variable environmental characteristics. For benthic community structure and macroinvertebrate assemblages, monitoring results centred around one main grouping of sites which included sites from all three survey regions (GBI, MEC, MWC). Within this main grouping subclusters and outliers were present, and these were usually associated with specific environmental conditions or ecological characteristics. For example, Rangiwhakaea on the wave exposed east coast of GBI was dissimilar from other GBI and MEC sites. Similarly, the two exposed west coast sites (Te Henga and Piha) were distinct from all other sites, having the lowest species richness and a benthic community structure dominated by sessile invertebrates. Previous ecological studies have demonstrated characteristic differences between the intertidal communities existing on the exposed east and west coastlines of northern New Zealand (which includes the Auckland region; Schiel, 2011), however it is interesting to note that the intertidal communities within the Manukau Harbour at Huia and Kaitarakihi were more similar to the MEC and GBI sites than they were the exposed MWC sites.

4.1.1 Fetch

Fetch was perhaps the most influential environmental parameter measured. Fetch was consistently and significantly related to benthic community structure and macroinvertebrate assemblages and was a component of most best performing (lowest AICc or R^2) DistlM models. The three most exposed sites (Te Henga, Piha and Rangiwhakaea) were all characteristic outliers, both within their respective survey regions and across the Auckland region overall. Increased fetch (as a proxy for wave energy and exposure) has been shown, on a global scale, to increase the biomass of suspension feeding organisms occupying space on rocky intertidal reefs (Ricciardi & Bourget, 1999) and these three sites were characteristic of this. Benthic community structure at all three sites was dominated by the barnacles *Chamaesipho* sp. and *E. plicata* and, in the case of the low shore zone at Te Henga and Piha, green-lipped mussels *P. canaliculus*. This is consistent with previous west coast New Zealand surveys which have shown that highly exposed rocky shores often contain dense, green-lipped mussel communities in the low shore zone, over which barnacles, other mussel species (e.g., *X. pulex*) and algae grow as secondary cover (Hayward and Morley, 2004; Schiel, 2011). As fetch decreases macroalgae becomes the dominant habitat forming component of the mid and low rocky shore community throughout the Auckland region. For example, expansive reef platforms are largely dominated by articulated coralline turf and canopy forming *H. banksii* (e.g. Waiwera, Fishermans Cove, and Arkles Bay). Some exceptions were found within this pattern, with conditions at Kaitarakihi (MWC) supporting small areas of seagrass.

Macroinvertebrate assemblages also varied strongly in relation to fetch. This was particularly apparent among the MWC, where the contrast in wave exposure at the open coast sites, Te Henga and Piha, versus the more sheltered Manukau Harbour sites, Kaitarakihi and Huia, was pronounced. The two exposed MWC sites had the lowest overall macroinvertebrate species richness with microgastropods, and the predatory whelk *Haustrum scobina* was the only mobile species commonly recorded. The latter likely benefits from the high cover of sessile invertebrate prey. The sites at GBI followed a similar pattern with the exposed east coast site, Rangiwhakaea having lower species richness and a higher abundance of species such as chitons and limpets, which can suction onto the rock surface, than less exposed sites on the western side of the island.

4.1.2 Sedimentation

Sediment also likely plays an important role in structuring the intertidal community across the survey region. Sediment cover, particularly that of silt, was largely determined by reef characteristics (slope, rugosity and reef extent) and is further influenced by local and regional hydrodynamics (wave exposure and currents) and sediment loads in the surrounding waters (Airoldi, 2003). In general, sediment cover was low on GBI reefs, whereas large variations in the cover of sand and silt occurred across the surveyed MEC and MWC reefs. Both recorded sediment types (silt and sand) were strongly related to species richness, benthic community structure and macroinvertebrate assemblages among MEC sites, with silt also important in determining benthic community structure among MWC, primarily through the facilitation of small patches of seagrass at Kaitarakihi.

Flat, expansive reefs are characteristic of the mid/inner Hauraki Gulf and it is not surprising that many of the MEC sites were inundated with sediment given the higher turbidity and greater inputs of sediment in the mid/inner Hauraki Gulf compared to the outer gulf (Seers & Shears, 2015). Long Bay, Campbells Bay and North Head (inner Hauraki Gulf sites) are the exceptions to this, and across the time series have routinely had low silt covers. This is most likely due to the physical structure of the reefs at these sites, which are narrow and steep compared to other inner gulf sites. These features make these reefs less conducive to deposition of sediment compared to extensive low profile reef platforms. Sediment cover and thickness is generally highest at the inner-most sites (Mellons Bay and Ōmana) where reefs are extensive, water movement is comparatively low and turbidity is greatest. Sediment loading may be responsible for the consistently lower species richness and is likely a key indicator of ecological health at these sites. At Ōmana, sediment cover was so thick in the mid tidal zone in 2023 that large quantities of cockle were recorded, a species that is associated with soft sediment environments (Fig. 19A). While further investigation is required this may indicate that the rocky reefs at Ōmana are transitioning to a predominantly soft sediment environment.

Throughout the Auckland region sediment cover was consistently highest in the low shore zone, where over time there has been an apparent shift in sediment characteristics, with a regional decrease in fine silt and increase in coarser sand. It should however be noted that the assessment of sediment characteristics is made *in-situ* which can be extremely difficult to do visually (Assallay et al., 1998). In the future, collection of sediment samples from representative MEC sites and subsequent grain size analysis may improve the ability to correctly define sediment characteristics and capture changes in sediment composition across this region.

Despite these potential limitations, major sand and silt inundation was evident across many of the sites surveyed in 2023. Increases in sand and silt were recorded across all tidal heights at most MEC sites in 2023. This inundation was a likely consequence of the significant weather events that occurred early in the year (Fig. 19B). On 10-11 January 2023 ex Cyclone Hale hit New Zealand, with significant rainfall impacting northern Auckland (NIWA, 2023). Two weeks later Auckland experienced an unprecedented rainfall event referred to as the "Auckland Anniversary Weekend floods", which saw as much as 300mm of rainfall occurring across the region within a 24-hour period between 27-28 January (Auckland Council, 2023). Overall, Albert Park in central Auckland recorded 539mm of rainfall across the month of January, the most since records began in 1853 (NIWA, 2023). These events were then followed by Cyclone Gabrielle on 14 February, which resulted in up to an additional 230mm of rainfall across the Auckland region in a 24 hour period (Auckland Council, 2023). As well as significant flooding, these rainfall events were the primary trigger for widespread land instability which resulted in at least 140,000 landslides occurring across the North Island of New Zealand, of which approximately 50,000 were within Auckland (Howard & Roberts, 2024). These landslides, either directly or via runoff entering water ways, are likely to have contributed to the increased sediment loads seen on many MEC shorelines. Increased sedimentation on rocky shores is known to have a variety of impacts on the benthic assemblages that occupy these zones (Airoldi, 2003; Schiel et al., 2006). Worst impacted in 2023 was the low shore zone and here there was a notable decline in species richness in 2023 compared to other years, with macroinvertebrate diversity and abundances declining. Although we cannot definitively attribute these declines to the weather events and/or sediment inundation it is highly likely that these factors have played a role. Surveys scheduled for 2025 will be important in determining whether these reefs remain heavily inundated in sediment and if any recovery of species richness and macroinvertebrate abundances has occurred.

The effects of the 2023 weather events on GBI sites is unknown, owing to the most recent surveys being conducted in 2022 prior to these events. There were no obvious impacts evident among MWC sites surveyed in 2024. In general sediment cover was low on GBI reefs, which were characteristically steep and narrow. The only GBI site with a high sediment cover, primarily silt, was Whangaparapara, which was more expansive and gently sloping, and situated within a small, enclosed harbour. The silt layer present did not appear to be adversely affecting the site, with species richness, benthic community composition and macroinvertebrate composition similar to other GBI sites. This may be due to the nature of the catchment feeding into the Whangaparapara Harbour, which is relatively small and almost exclusively covered in native vegetation. Forested catchments are less prone to erosion and have lower flow rates than deforested catchments (Sanhueza et al., 2024), which may limit the potential for large pulses of sediment smothering the reefs and leading to declines in richness or abundance.

Among MWC sites only Kaitarakihi had a high silt cover. This site, which was also more expansive and gently sloping than other MWC sites, was situated away from the main Manukau Harbour channel and further back from the harbour entrance. Here thick silt deposits have facilitated the presence of seagrass, a unique habitat type among the 22 surveyed reefs. Benthic community composition and macroinvertebrate assemblage at Kaitarakihi was different to nearby Huia, which was more characteristically similar to many of the MEC sites. A number of species common on rocky shores were rare or absent from Kaitarakihi, while species tolerant of high silt, such as the mud whelk *Cominella glandiformis* (Donald et al., 2020), were common.

While silt was not a major factor on the exposed west coast rock shorelines, Piha did experience large fluctuations in coarse sand cover, particularly in the low tidal zone, where much of the low shore reef was buried by sand between 2021 and 2022. Not surprisingly, this had a major impact on the species assemblage within this zone. Piha has undergone periods of erosion and accretion since the 1940s but has seen an overall increase in beach widening and sand levels (Blue and Kench, 2016; Boyle, 2016). If this trend continues, we may expect to see further loss of the low shore reef and associated flora and fauna at this site. The 2024 survey found that the site had been partially uncovered, but full recovery of the benthic community or macroinvertebrate assemblage was yet to be seen. The little black mussel *X. pulex* had colonised the reef and was the only species that appeared to be as abundant in 2024 as it was in 2021. Further sampling of this site will be important to understand the long-term impact of sand inundation on these reefs, particularly if further beach widening and greater sand deposition is forecast.

4.2 Differences in community structure between tidal zones

We found differences in the community structure between tidal zones within all three survey regions (GBI, MEC, MWC) with the most visually pronounced differences occurring between the high and mid tidal zones. The high tidal zone at almost every site was dominated by bare rock and high densities of littorinid snails (mainly periwinkles and microgastropods – collectively grouped) and overall had low species diversity and abundance. This is typical of rocky shores in Australasia (Morton & Miller, 1973; Underwood, 1981) and globally (Garbary, 2007). Species such as periwinkles are able to cope with the extreme environmental stresses that comes with prolonged exposure to air, highly variable temperature and regular salinity changes, that occur in the high tidal zone (Garbary, 2007) through adaptations such as the presences of gills that are capable of efficiently extracting oxygen from the air during the low tide period (Smith, 2013). Other commonly found species such as barnacles (mostly *Chamaesipho* spp. and *E. plicata*) which were regularly recorded in the high tidal zone, have the ability to tightly close their opercular valves when the tide is out to prevent themselves from drying out, while light colourations help to reduce internal temperature increases (Foster, 1971).

The large fluctuations in population abundance seen within microgastropods within the high tidal zone is likely due to recruitment, and in periwinkle species such as *Littorina obtusata,* high and low recruitment phases occur on a 3-4 year cycle (Kozminsky, 2012).

There was considerably more variability in mid-shore communities among sites than in the high- and low-zones. As noted previously, large seaweeds are rare in the mid-shore zone in northern New Zealand, which contrasts the situation in many other parts of the world (Morton & Miller, 1973; Underwood, 1981). The fucoid *H. banksii* was the dominant, and in most cases only large seaweed found in the mid-intertidal zone and was most commonly associated with coralline turf (*Corallina officinalis*) on flat platform reefs in the mid/inner gulf. Cover was variable among these MEC sites, and across the survey years, but there was a general increase in cover between 2019 and 2021. Despite this increase, cover at most sites was generally <50%, which is in contrast to South Island locations where it can cover 100% of mid- and low-shore reef platforms (Lilley & Schiel, 2006; Schiel, 2011). In southern New Zealand, *H. banksii* is considered to facilitate a range of other species through positive interactions (Lilley & Schiel, 2006). Despite greater exposure to air than in the low tidal zone, we found that among MEC sites macroinvertebrate abundances were highest in the mid tidal zone. Macroalgae canopies can provide refuge for organisms occupying the intertidal zone, reducing temperature extremes, light levels and desiccation (Bulleri et al., 2002; Ørberg et al., 2018) and it is likely that despite lower canopy covers than in the South Island, *H. banskii* is playing an important role in structuring the mid tidal macroinvertebrate community among MEC sites. Crucially, *H. banksii* is considered to be extremely hardy, capable of withstanding high summer air and water temperatures and varying salinity (Kain, 2015). Despite northeastern New Zealand experiencing an unprecedented marine heatwave in the summer of 2021/2022, and continued marine heatwave conditions throughout much of 2022 (Shears et al., 2024) there was no detectable decline in *H. banksii* cover among MEC sites (those most directly impacted by marine heatwave conditions) between surveys in 2021 and 2023. This would indicate that *H. banksii* is currently tolerant of anomalous warm water conditions and its continued presence as temperatures, both water and atmospheric, increase will likely provide some form of refuge for other species which are less temperature tolerant.

The geniculate coralline turf *C. officinalis* was the dominant non-canopy forming algae present among the mid-shore zone on flat platform reefs throughout most mid/inner Hauraki Gulf sites. Coralline turf provides habitat for a range of macro- and microfauna (Brown & Taylor, 1999; Walsby, 1977). It also binds up and traps large amounts of sand and silt on rocky shores. The amount of fine sediment in subtidal coralline turf can have a large influence on the faunal assemblages found within the turf (Berthelsen et al., 2015), but this has not been examined on intertidal reefs. It is also unknown whether high silt loads may limit the coralline turf itself, as suggested by the low covers at the two inner most Hauraki Gulf sites.

Coralline turf became the most dominant biotic cover in the low-shore across the MEC and GBI sites where cover typically ranged from ~30%– 90%. Coralline turf was only abundant at Huia among the MWC sites with Te Henga and Piha likely too exposed (with encrusting invertebrates the dominant cover) and Kaitarakihi too silty. High sediment loads have been reported to impact survival, growth and recruitment of other intertidal algae species (Schiel & Gunn, 2019) but it is unclear whether this impact extends to coralline turf. Certainly, the reef characteristics at Kaitarakihi, along with Mellons Bay and Ōmana (MEC sites with low or absent coralline turf within the low tidal zone), were similar to other locations where coralline turf was abundant, having wide, gently sloping reef platforms, however at all three sites sediment loads were very high. Thick silt deposits at Kaitarakihi did however support seagrass, with beds remaining a consistent feature across the three survey periods for this site.

The catseye snail *L. smaragdus* was generally the most abundant gastropod species in the low zone across the Auckland region and was only absent from the three most exposed sites (Te Henga, Piha and Rangiwhakaea). Across the MEC sites there was a general decline in abundance through time, which may be associated with a number of stressors, including elevated temperature (Mortensen & Dunphy, 2016), though the relative stability within mid tidal zone populations make this unlikely to be the causation on its own. Although there is limited information, its relatively large size (~20mm) and abundance may increase its vulnerability to harvesting pressure. With a small larval dispersal range (~3m) (Grange, 1976) localised depletions could lead to continued declines due to a lack of recruitment to replace harvested individuals, or those lost to other stressors.

4.3 Impact of human activities on rocky shores in the Auckland region

With the largest population and a wide range of land uses, the potential for human activities to impact rocky reefs within the Auckland region is high. Despite this, most potential impacts remain poorly understood. Few studies directly investigating human impacts have been conducted within the Auckland region, and while long-term monitoring is useful for capturing spatial and temporal changes in community structure, which may be linked to human impacts, the sporadic sampling frequency of intertidal rocky reefs at GBI and short duration in which MWC sites have been monitored currently makes this difficult.

4.3.1 Sedimentation

Sedimentation is currently the most apparent human impact within the Auckland region, with the effects of chronic and acute sediment loading seen across the survey sites. Long-term sediment deposition likely heightens the risk of a loss of biodiversity, and it appears that expansive, gently sloping intertidal reefs with limited fetch are most susceptible. The apparent transition from rocky reef to soft sediment habitat observed at Ōmana and the presence of seagrass patches within thick silt deposits at Kaitarakihi may serve as precursors to more broad-scale ecological change associated with continued sediment accumulation. In addition, as the impacts of climate change worsen, severe storms are predicted to become more frequent, delivering more intense rainfall (Stone et al., 2024) which in turn has the potential to lead to more frequent pulses of sediment inundation associated with runoff and coastal erosion. The extreme weather events in early 2023 indicated that many sites were susceptible to acute sediment loading with suggestions that this resulted in a decline in macroinvertebrate abundances and overall species richness among MEC sites, particularly in the low tidal zone. Further work is needed on understanding the mechanisms of sediment deposition on these reefs, as well as research projecting how sites that are less sediment laden may be impacted in the future.

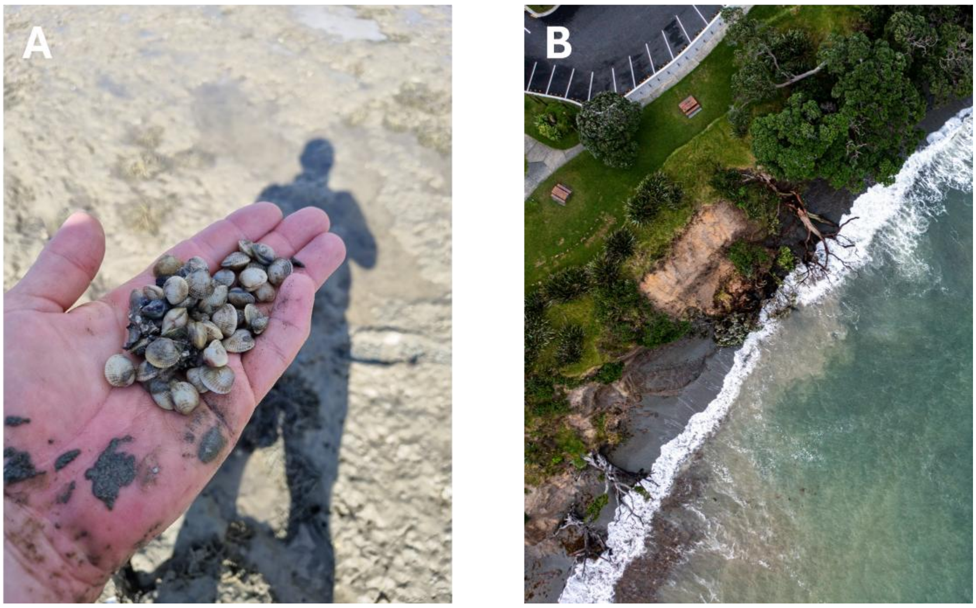

Figure 19: Potential sediment impacts to rocky intertidal shores. A) Dense cockle (A. stutchburyi) beds recorded in the mid-shore at Ōmana in 2023, with thick silt visible in the background. B) Landslide above Echinoderm Reef, the outermost MEC survey site, following the January 27 rainfall event.

4.3.2 Overharvesting

In recent years, there have been increasing concerns regarding the potential impact of recreational harvesting on a wide range of intertidal plants and animals. This has included increasing coverage by media as well as petitions for the closure and/or placement of rāhui across large areas of intertidal reef to allow harvested species to recover. While these concerns have been anecdotal in nature, the potential for overharvesting has previously been raised as a potential stressor for rocky reefs within the Auckland region, particularly as Auckland's population grows (Hayward & Morley, 2004). Across the entire survey period (2011 – 2024) it was not uncommon to observe people collecting intertidal species from MEC and MWC. Many potentially harvestable intertidal species are regulated only under a combined mixed-species bag limit, and no reporting is required for recreational harvest, making it difficult to assess the current impact of harvest on the intertidal zone.

Further to this, the survey protocols used in the current monitoring programme are not specifically designed to capture the impacts of harvesting on intertidal species or disentangle these impacts from other human impacts such as sedimentation. Declines in species such as *L. smaragdus* among many MEC sites (though not obviously within the Marine Reserve at Long Bay), and green-lipped mussel at Te Henga and Piha, may in part be attributable to the impacts of harvesting, but equally impacts such as temperature stress may be implicated in these declines (e.g. Venter et al., 2023) as well as sedimentation (both fine sediment and in the case of Piha, large changes in sand levels). An in-depth evaluation of data inside and outside of the Cape Rodney-Okakari Point and Long Bay Marine Reserves would be beneficial for trying to assess the impacts of harvesting from the existing data. Additional information in the form of questionnaires about harvester habits, target species and target habitat types is required to help inform more specific research into this potential issue.

4.3.3 Invasive Species

Invasive taxa have the potential to impact rocky shore communities, and a large number of invasive species are known to occupy rocky shores in the Auckland region (Hayward, 1997). In general, invasive species were relatively rare among the rocky shore monitoring sites and were only minor contributors to the overall communities structure. However, we did not separate the native oyster *Saccostrea glomerata* from the Pacific oyster *Magallana gigas* in the field. *M. gigas* is widely thought to have taken over *S. glomerata* on intertidal reefs in the Waitematā Harbour (Dromgoole & Foster, 1983; Hayward, 1997) and there has been a general assumption among marine ecologists that *M. gigas* has outcompeted *S. glomerata* on rocky shores in northern New Zealand (Morton, 2004). However, identification of oysters on Echinoderm Reef and Meola Reef using anatomical descriptions by Dromgoole and Foster (1983) indicated that the majority of these sites were in fact the native oyster (N.S. per. obs., September 2018). Morton (2004) has suggested that the two species can hybridise, which further complicates identification. Given the abundance of oysters in the mid-shore at some sites, further investigation is needed to determine the relative abundance of these species and whether there is in fact any evidence that *M. gigas* has outcompeted *S. glomerata.*

A number of other invasive species were recorded that have previously been documented in the Hauraki Gulf (Hayward, 1997). The Asian date mussel *Musculista senhousia* was recorded in the mid shore at Ōmana and Mellons Bay in 2023 with thick mats of up to 80% cover occurring within some quadrats. The encrusting bryozoan *Watersipora arcuata* was recorded across the Auckland region during all survey periods but cover was typically low (<2%) and only occurred in the mid and low zone. Three individuals of the clubbed ascidian *Styela clava* were recorded at Ōmana in 2011 and 2013 but has not been recorded since. The green seaweed *Codium fragile tomentosoides*, which was expected to invade most sheltered shores in New Zealand (Trowbridge, 1995), was only recorded in low numbers at six sites, being most common at Ōmana and Mellons Bay. New species such as the colonial ascidian *Symplegma brachenhielmii* and the brown macroalgae *Cladostephus spongiosus*, were detected for the first time in 2023 at North Head and Long Bay respectively. *Symplegma brachenhielmii* was first detected in the Auckland region in 2016, as part of the Auckland Council Meola Reef Subtidal Monitoring Programme, has subsequently spread and recently proliferated as a consequence of marine heatwave conditions during the summer of 2021/2023 (Spyksma et al., 2024). This species was also observed in rockpools at several sites in 2021 and 2023, including Fishermans Cove, Long Bay and Campbells Bay. *Cladostephus spongiosus* has also proliferated at some subtidal monitoring sites in recent years (see Shears, 2025) but was only a very minor constituent of the Long Bay intertidal reefs.

In general, the number of invasive species was higher in the inner gulf, and this is likely due to the closer proximity to the port of Auckland (particularly North Head), but it is also possible that the high sediment sites at Ōmana and Mellons Bay made these sites more vulnerable to invasion. As seen in the subtidal reef ecosystems in the Hauraki Gulf, increased anthropogenic and environmental stress can increase the vulnerability to marine invasion (James & Shears, 2016) and although most invasive species remain at low levels, it is important to continue monitoring as their spread and proliferation can have devastating impacts on local ecosystems (Palomo et al., 2016).

4.3.4 Eutrophication

The impacts of eutrophication on rocky shores in the Auckland region are also poorly understood but likely interact with the effects of sedimentation at inner gulf sites as well as at Kaitarakihi in the Manukau Harbour. Increased occurrence of blooms of the blue-green alga *Okeania* spp. (previously *Lyngbya* spp.) have been reported worldwide and are generally considered to be associated with anthropogenic eutrophication and other forms of human disturbance (e.g., dredging and land development) (Nelson et al., 2015). These species are known to be toxic and can cause skin, eye and respiratory irritation (Osborne et al., 2001). In 2011, *Okeania* spp. was highly abundant in the low zone at Ōmana, and previous studies have reported frequent and large blooms in this area (Nelson et al., 2015). In 2013, *Okeania* was rare at Ōmana but had been replaced by clumps of the yellow-green algae *Vaucheria velutina* which bind up sediments (Fig. 20). This phenomenon was described by Wilcox (2012) and has not previously been reported on “rocky” shores. *Vaucheria velutina* was again noted at the low tide edge at Ōmana in 2023 but was not recorded within the survey area. The occurrence of such species is a likely indicator of high sediment and nutrient loads and are likely to become more common without reductions in both. *Okeania* spp. is now a regular cover at many mid and inner gulf sites, and also occurs in high concentrations at Kaitarakihi, though it has rarely been recorded in the monitoring data as prolific as it was at Ōmana in 2011.

5 Conclusions and recommendations

This report presents the first quantitative description of rocky shore communities using a systematic survey method across the Auckland region. A total of 22 sites including locations at GBI, MEC and MWC have been surveyed at various temporal intervals over the past 12 years. In general, many of the intertidal communities across the Auckland region show similar characteristics in both the community composition of benthic covers and macroinvertebrate assemblages. Fetch (wave exposure) and sediment cover are likely to be the largest environmental drivers of differences among sites. There is limited evidence of large-scale changes in community composition over time across the three survey regions, though site specific fluctuations in benthic cover and species abundances have frequently occurred.

High sedimentation, particularly at mid and inner Hauraki Gulf and sheltered Manukau Harbour sites, is likely to be having the largest adverse effect on intertidal reef communities, however further targeted studies investigating the effects of chronic and acute sediment loading are required to disentangle sedimentation from other potential impacts such as eutrophication or increased harvest pressure.

As the impacts of climate change intensify, a number of changes are also predicted to have more severe consequences for intertidal communities. The increasing number of hot days forecast in the Auckland region over the next century (Pearce et al. 2018) will increase the levels of thermal stress in the intertidal. To begin understanding such impacts, temperature loggers have recently been installed in the mid-tidal zone at a number of MEC and MWC locations to track daily, seasonal and yearly trends in intertidal reef temperature. Rising sea level will alter tidal heights, accelerate cliff-face erosion and redefine the horizontal extent of many intertidal reefs. A preview of some of these impacts were observed in 2023 where the impacts of multiple extreme weather events, exacerbated by climatic warming, resulted in significant land instability, erosion and sediment deposition on the intertidal shore. This is likely to have contributed to an increase in sediment cover and a decline in species richness and macroinvertebrate abundances across many MEC sites surveyed that year.

Continued long-term monitoring, combined with targeted investigations of the impacts of human activities, is needed to understand the current magnitude and extent of anthropogenic impacts, particularly as the effects of climate change become more prevalent. From a management perspective it is important that steps are taken to minimise sedimentation and nutrient inputs, understand the consequences of harvesting and track the occurrence of invasive species to ensure these ecosystems are as resilient as possible to the long-term changes and stressors that are present throughout the Auckland region. Below are a number of recommendations that would help to improve the long-term intertidal rocky reef monitoring programme, ensuring it is fit for purpose going forward.

Additionally, recommendations aimed at better understanding the role human activities have on structuring intertidal reef communities are given.

General monitoring programme

- Conduct a thorough review of the intertidal monitoring network to ensure that all sites remain suitable for continued monitoring. This review should be conducted in 2026 following the survey of MEC sites in 2025 and MWC and GBI sites in 2026. This would allow evaluation of trends over five years for MWC sites and ~15 years for MEC and GBI.
  - Site characteristics, accessibility (particularly GBI sites) and location relative to other Council monitoring initiatives, should all be considered when assessing continuation suitability.
- Assess opportunities for iwi, hapu and/or community lead monitoring. Community action in the marine environment is increasing throughout the Auckland region, with increased desire for preservation and restoration of rocky reef (including intertidal) ecosystems.
  - Empowering tangata whenua and local communities to take on an active role in intertidal monitoring will provide greater mātauranga regarding long-term ecosystem change and may also provide a means to more proactively monitor rapid changes as they occur.
- Consider adopting greater use of technology to enhance the monitoring methodology. Aerial surveys conducted by unmanned aerial vehicles (UAV, i.e. drones) are increasingly used in a range of ecological monitoring programmes, as is close range photogrammetry. These methods can be relatively low-cost ways of increasing spatial and temporal coverage and can also leverage the growing capacity of artificial intelligence to streamline data analysis. When well setup, many technologies can also be easily implemented by community groups.
  - As part of the general review in 2026, suitability of current monitoring methodologies should be considered, as well as what technological adaptations could be made to improve the project objectives.

Understanding sedimentation impacts

- Collect sediment samples suitable for grain size analysis at a range of sites when monitoring occurs. This will provide greater insights into sedimentation dynamics through time, e.g. understanding of wave induced deposition of sand vs. silt.
- Undertake research investigating the acute and chronic impacts of increases in sediment load on intertidal reef platforms.
  - This could include proactively surveying intertidal communities immediately before and, in the period following, forecasted extreme weather events.
  - It could also include increased temporal frequency of monitoring at select sites to capture seasonal variations in sediment fluxes.

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7 Appendix 1 – Site descriptions and GPS positions

A description of each site within the monitoring network along with the location of each survey pin recorded in the high, mid, and low tidal zones.

7.1.1 Site name: Rangiwhakaea Bay

Location: Aotea / Great Barrier Island

Transect coordinates (WGS84):

RA-H0	175°24.857'E	36°5.419'S
RA-H17	175°24.864'E	36°5.411'S
RA-H30	175°24.871'E	36°5.407'S
RA-M0	175°24.857'E	36°5.414'S
RA-M30	175°24.872'E	36°5.407'S
RA-L0	175°24.859'E	36°5.413'S
RA-L27	175°24.872'E	36°5.405'S
RA-L31	175°24.874'E	36°5.406'S

Site description:

Located on the eastern side of Aotea approximately 5km north of Whangapoa Bay. The most exposed Aotea Great Barrier Island site, open to the northeast. Reef characterised by a narrow sloping intertidal zone with moderate rugosity. Very low sediment cover.

Characteristically different from other Great Barrier Island or Auckland east coast sites due to its high cover of barnacles (*Chamaesipho brunnea, Epopella plicata*), low cover of coralline turf cover and high abundances of limpets (*Cellana radians, C. ornata, Siphonaria* sp., *Notoacmea* sp.).

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2013	16	0.05	0.00	0.05
High	2022	21	0.00	0.00	0.00
Mid	2013	29	0.00	0.00	0.00
Mid	2022	34	0.00	0.00	0.00
Low	2013	43	0.00	0.00	0.00
Low	2022	41	0.00	0.00	0.00

7.1.2 Site name: Oruapure Bay

Location: Aotea / Great Barrier Island

Transect coordinates (WGS84):

OR-H0	175°19.554'E	36°7.904'S
OR-H30	175°19.549'E	36°7.916'S
OR-M0	175°19.564'E	36°7.977'S
OR-M30	175°19.574'E	36°7.993'S
OR-L0	175°19.552'E	36°7.949'S
OR-L10	175°19.547'E	36°7.952'S
OR-L6	175°19.555'E	36°7.952'S

Site description:

Located within the outer limits of Katherine Bay on the western side of Aotea. Moderately exposed to the north and northwest. Reef characterised by a narrow, highly rugose intertidal zone. Very low sediment cover.

Site typically has very low abundances of microgastropods compared to others but high abundances of black nerite (*Nerita melanotragus*)and very high relative abundances of snakeskin chiton (*Sypharochiton pelliserpentis*). Cover of coralline turf is high for Aotea (average across all years/tide heights - 22%), primarily in the mid and low shore zones, while crustose coralline algae cover is high (average across all years/tide heights - 10%) for the Auckland region.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2013	21	0.10	0.10	0.00
High	2022	28	0.00	0.00	0.00
Mid	2013	34	5.70	5.50	0.20
Mid	2022	24	5.90	4.60	1.30
Low	2013	36	16.25	2.30	13.95
Low	2022	40	12.50	1.10	11.40

7.1.3 Site name: Bradshaw Cove

Location: Aotea / Great Barrier Island

Transect coordinates (WGS84):

BS-H0	175°19.252'E	36°10.212'S
BS-H15	175°19.260'E	36°10.201'S
BS-H23	175°19.257'E	36°10.197'S
BS-H30	175°19.249'E	36°10.197'S
BS-M0	175°19.246'E	36°10.276'S
BS-M16	175°19.249'E	36°10.265'S
BS-M30	175°19.243'E	36°10.261'S
BS-L0	175°19.251'E	36°10.276'S
BS-L24	175°19.251'E	36°10.264'S
BS-L30	Photos only, no position	

Site description:

Located on the northern side of Kaikoura Island, at the entrance of Port Fitzroy, Aotea. The site is relatively sheltered by Kaikoura Island and Aotea to the north. Reef characterised by a narrow, steep intertidal zone with high rugosity. Low silt cover.

Site typically has low coralline turf cover and a minimal canopy cover of Neptune's necklace (*Hormosira banksii*). Very high abundance of black nerite (*N. melanotragus*) occurred in the high and mid tidal zones, while predatory oyster borers (*Haustrum scobina*) were also common. Very high relative abundances of snakeskin chiton (*Sypharochiton pelliserpentis*).

Highest overall species richness (59) has been recorded at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2013	27	0.00	0.00	0.00
High	2020	29	0.00	0.00	0.00
High	2022	19	0.00	0.00	0.00
Mid	2013	40	1.40	1.00	0.40
Mid	2020	45	0.00	0.00	0.00
Mid	2022	32	0.00	0.00	0.00
Low	2013	40	15.50	15.50	0.00
Low	2020	44	0.00	0.00	0.00
Low	2022	32	0.05	0.00	0.05

7.1.4 Site name: Whangaparapara

Location: Aotea / Great Barrier Island

Transect coordinates (WGS84):

WHP-H0	175°23.399'E	36°14.948'S
WHP-H11.2	175°23.403'E	36°14.942'S
WHP-H27	175°23.413'E	36°14.939'S
WHP-H30	175°23.413'E	36°14.936'S
WHP-M0	175°23.414'E	36°14.920'S
WHP-M30	175°23.407'E	36°14.905'S
WHP-L0	175°23.413'E	36°14.899'S
WHP-L30	175°23.422'E	36°14.886'S

Site description:

Located within the Whangaparapara Harbour on the western side of Aotea. A very sheltered site with a high rugosity and slightly wider intertidal zone than other Aotea sites. As a consequence, silt cover is typically higher, particularly in the low tidal zone.

High relative abundances of snakeskin chiton (*S. pelliserpentis*), dark rock shells (*Haustrum haustorium*) and red-mouthed whelk (*Cominella virgata*). High cover of coralline turf for Aotea (average across all years/tide zones - 20%), primarily in the mid and low shore zones, and highest cover of the modest barnacle (*Austrominius modestus*) recorded across all surveyed sites (average across all years/tide heights - 20%).

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2013	27	0.00	0.00	0.00
High	2020	24	0.00	0.00	0.00
High	2022	26	0.00	0.00	0.00
Mid	2013	34	11.45	9.40	2.05
Mid	2020	33	1.30	1.30	0.00
Mid	2022	28	8.20	8.20	0.00
Low	2013	40	75.83	62.00	13.83
Low	2020	33	31.67	31.11	0.56
Low	2022	29	68.65	67.30	1.35

7.1.5 Site name: Echinoderm Reef

Location: Mainland – East Coast

Transect coordinates (WGS84):

ER-H0m	174°47.822'E	36°16.141S
ER-H30m	174°47.808'E	36°16.132'S
ER-M0m	174°47.656'E	36°16.193'S
ER-M30m	174°47.637'E	36°16.199'S
ER-L0m	174°47.676'E	36°16.182'S
ER-L30m	174°47.660'E	36°16.172'S

Site description:

Located within the Cape Rodney – Okakari Pt. Marine Reserve, this is the most northern survey site along Auckland's east coast. A wide (100 m) intertidal platform that is exposed to the north, northwest and partially to the northeast. One of the most exposed survey sites along the east coast. Moderate to high sediment cover in the mid and low tidal zones with a high sand component. Moderate cover of coralline turf (average across all years/tide zone- 23%), primarily in the mid and low tidal zones but very little Neptune's necklace (*H. banksii*) canopy cover. High relative cover of brown encrusting algae (*Ralfsia* complex). High abundances of cat's eye snails (*Lunella smaragdus*) and the limpet *Siphonaria* sp.

A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
H	2011	15	0.00	0.00	0.00
H	2013	17	0.00	0.00	0.00
H	2019	11	0.00	0.00	0.00
H	2021	16	0.00	0.00	0.00
H	2023	20	0.00	0.00	0.00
M	2011	30	8.60	1.65	6.95
M	2013	40	10.60	0.00	10.60
M	2019	34	19.66	7.00	12.66
M	2021	32	0.51	0.40	0.11
M	2023	31	34.10	34.00	0.10
L	2011	33	39.40	1.50	37.90
L	2013	40	32.25	0.40	31.85
L	2019	30	27.32	9.00	18.32
L	2021	25	42.70	0.00	42.70
L	2023	24	84.30	33.30	51.00

7.1.6 Site name: Mathesons Bay

Location: Mainland – East Coast

Transect coordinates (WGS84):

Math-H0m	174°48.010'E	36°18.019'S
Math-H25m	174°48.024'E	36°18.013'S
Math-M30m	174°48.045'E	36°18.028'S
Math-M0m	174°48.037'E	36°18.0042'S
Math-L0m	174°48.108'E	36°18.018'S
Math-L30m	174°48.127'E	36°18.014'S

Site description:

Located towards the southern end of the Leigh township. A moderately wide (78 m), gently sloping intertidal reef with moderate rugosity. Variable sediment cover through time with silt as the primary sediment type.

High cover of crustose coralline algae but low cover of crustose coralline algae. The canopy forming algae Neptune's necklace (*H. banksii*) has not been recovered at this site.

A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	23	9.12	9.01	0.11
High	2013	23	0.40	0.00	0.40
High	2019	18	0.00	0.00	0.00
High	2021	16	0.05	0.00	0.05
High	2023	17	7.41	7.30	0.11
Mid	2011	32	11.41	11.40	0.01
Mid	2013	28	2.95	2.50	0.45
Mid	2019	29	33.50	33.50	0.00
Mid	2021	26	2.38	2.31	0.07
Mid	2023	23	69.35	69.35	0.00
Low	2011	27	50.90	50.50	0.40
Low	2013	32	0.95	0.45	0.50
Low	2019	27	12.52	2.89	9.63
Low	2021	27	51.51	46.50	5.01
Low	2023	16	9.51	9.40	0.11

7.1.7 Site name: Ōmaha

Location: Mainland – East Coast

Transect coordinates (WGS84):

OH-H0	174°47.687'E	36°21.003'S
OH-H30	174°47.669'E	36°20.996'S
OH-M0	174°47.692'E	36°20.991'S
OH-M30	174°47.691'E	36°20.975'S
OH-L0	174°47.792'E	36°20.999'S
OH-L30	174°47.778'E	36°20.988'S

Site description:

Located at the southern end of Ōmaha Beach. A moderately wide intertidal (70 m) reef. The most exposed monitoring site along Auckland's east coast. Low overall sediment cover with sand a significant component of cover, particularly on the lower shore.

Low covers of crustose coralline turf and Neptune's Necklace (*H. banksii*) compared to many other east coast sites. Very high densities of black nerite (*N. melanotragus*) in the mid tidal zone and cat's eye snails in the low tidal zone.
A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	15	16.60	3.50	13.10
High	2013	10	0.32	0.03	0.29
High	2019	13	0.00	0.00	0.00
High	2021	20	0.82	0.50	0.32
High	2023	14	1.71	0.36	1.35
Mid	2011	31	0.93	0.92	0.01
Mid	2013	29	0.11	0.02	0.09
Mid	2019	18	3.10	2.00	1.10
Mid	2021	22	0.58	0.25	0.33
Mid	2023	35	12.72	12.72	0.00
Low	2011	37	4.70	2.60	2.10
Low	2013	32	27.98	18.17	9.81
Low	2019	30	23.46	5.86	17.60
Low	2021	26	5.57	0.00	5.57
Low	2023	20	57.00	18.00	39.00

7.1.8 Site name: Christian Bay

Location: Mainland – East Coast

Transect coordinates (WGS84):

CH-H0m	174°47.503'E	36°23.329'S
CH-H30m	174°47.507'E	36°23.311'S
CH-M0m	174°47.512'E	36°23.357'S
CH-M31m	174°47.525'E	36°23.343'S
CH-L0m	174°47.529'E	36°23.369'S
CH-L30m	174°47.533'E	36°23.353'S

Site description:

Located on the southern side of the Tawharanui Peninsula. Open to the northeast, put some shelter provided by Tawharanui Peninsula and surrounding offshore islands. Gently sloping reef with modest rugosity. Intertidal platform ~60 m wide. High sediment cover, particularly on the lower shore where it is associated with high coralline turf cover.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	26	12.60	9.00	3.60
High	2013	22	11.05	3.60	7.45
High	2019	15	5.25	5.05	0.20
High	2021	17	5.55	0.25	5.30
High	2023	20	6.50	6.50	0.00
Mid	2011	43	60.05	59.90	0.15
Mid	2013	46	33.43	33.23	0.20
Mid	2019	31	35.60	35.60	0.00
Mid	2021	36	72.30	64.20	8.10
Mid	2023	27	78.90	78.90	0.00
Low	2011	34	91.85	91.60	0.25
Low	2013	28	92.20	92.20	0.00
Low	2019	20	95.90	95.90	0.00
Low	2021	34	86.90	86.90	0.00
Low	2023	20	95.00	95.00	0.00

7.1.9 Site name: Martins Bay

Location: Mainland – East Coast

Transect coordinates (WGS84):

MT-M0m	174°45.920'E	36°27.537'S
MT-M30m	174°45.918'E	36°27.522'S
MT-H0m	174°45.903'E	36°27.552'S
MT-H30m	174°45.907'E	36°27.537'S
MT-L0m	174°45.941'E	36°27.517'S
MT-L30m	174°45.943'E	36°27.499'S

Site description:

Located at the southern end of Martins Bay. A wide (100 m), gently sloping reef with high sediment cover, particularly silt, in the low shore zone. One of the least exposed sites along Auckland's east coast owing to the protection offered by surrounding offshore islands and the Tawharanui Peninsula.

High coralline turf cover found throughout the mid and low tidal zones. In the mid shore this supports dense horn snail (*Zeacumantus sp.*) populations. Black nerite (*N. melanotragus*) are abundant in the high and mid tidal zones.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	22	14.72	12.40	2.32
High	2013	24	21.05	20.95	0.10
High	2019	12	1.60	1.60	0.00
High	2021	13	3.50	3.50	0.00
High	2023	13	61.00	61.00	0.00
Mid	2011	30	23.61	23.40	0.21
Mid	2013	36	26.30	26.30	0.00
Mid	2019	27	12.30	12.30	0.00
Mid	2021	27	8.80	7.80	1.00
Mid	2023	23	54.20	54.20	0.00
Low	2011	30	89.70	89.70	0.00
Low	2013	29	81.50	81.50	0.00
Low	2019	25	90.50	90.50	0.00
Low	2021	27	84.10	84.10	0.00
Low	2023	17	87.00	87.00	0.00

7.1.10 Site name: Waiwera

Location: Mainland – East Coast

Transect coordinates (WGS84):

W2-H30m	174°42.990'E	36°32.533'S
W2-H0m	174°42.973'E	36°32.542'S
W2-M0m	174°42.982'E	36°32.555'S
W2-M30m	174°42.997'E	36°32.547'S
W2-L0m	174°43.043'E	36°32.565'S
W2-L30m	174°43.053'E	36°32.552'S

Site description:

Located on the northern side of the mouth of the Waiwera River. A wide (130 m), gently sloping intertidal reef with moderate rugosity. More open to the northeast than Martins Bay but remains reasonably sheltered. High sediment load in the mid and low shore zones.

High covers of coralline turf in the mid and low tidal zones, with a moderate (average – 40%) Neptune's necklace (*H. banksii*) canopy forming in the mid shore zone. Barnacle cover (*Chamaesipho* spp.) high along the high tidal. High abundances of horn snail (*Zeacumantus* spp.) and cats eye snails (*L. smaragdus*) in amongst the coralline turf.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	23	1.14	1.14	0.00
High	2013	23	6.31	6.31	0.00
High	2019	22	0.00	0.00	0.00
High	2021	30	0.05	0.05	0.00
High	2023	23	0.50	0.50	0.00
Mid	2011	32	55.25	55.10	0.15
Mid	2013	35	48.47	48.20	0.27
Mid	2019	25	23.88	23.13	0.75
Mid	2021	21	55.50	55.50	0.00
Mid	2023	18	53.50	50.00	3.50
Low	2011	21	76.90	75.80	1.10
Low	2013	25	85.25	85.00	0.25
Low	2019	14	87.10	83.70	3.40
Low	2021	18	86.00	86.00	0.00
Low	2023	16	82.00	3.00	79.00

7.1.11 Site name: Fishermans Cove

Location: Mainland – East Coast

Transect coordinates (WGS84):

FC-H0m	174°47.530'E	36°36.200'S
FC-HC12m	174°47.532'E	36°36.195'S
FC-H30m	174°47.543'E	36°36.187'S
FC-M0m	174°47.527'E	36°36.168'S
FC-M30m	174°47.547'E	36°36.170'S
FC-L0m	174°47.550'E	36°36.142'S
FC-L30m	174°47.568'E	36°36.142'S

Site description:

A wide (100m), gently sloping intertidal reef on the northern side of the Whangaparāoa Peninsula. Exposed to some wind and swell from the north and northeast. High sediment covers in the low tidal zone.

Coraline turf cover is very high on the low shore. A canopy of Neptune's necklace (*H. banksii*) is typical present within the mid tidal zone, with coralline turf occurring under this. Cat's eye snails (*L. smaragdus*) were common in the mid and low tidal zones while microgastropods were abundant in the high shore zone.

Temperature loggers are located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	13	1.32	0.00	1.32
High	2013	11	0.70	0.00	0.70
High	2019	14	0.00	0.00	0.00
High	2021	19	0.00	0.00	0.00
High	2023	18	2.50	0.00	2.50
Mid	2011	39	40.30	38.20	2.10
Mid	2013	37	48.30	47.90	0.40
Mid	2019	27	29.90	23.33	6.57
Mid	2021	27	29.00	29.00	0.00
Mid	2023	20	88.00	0.00	88.00
Low	2011	36	80.07	79.60	0.47
Low	2013	32	73.70	73.60	0.10
Low	2019	26	73.75	66.50	7.25
Low	2021	26	89.40	89.00	0.40
Low	2023	16	85.20	85.20	0.00

7.1.12 Site name: Shakespear

Location: Mainland – East Coast

Transect coordinates (WGS84):

WGP-H0m	174°50.309'E	36°36.491'S
WGP-H30m	174°50.325'E	36°36.480'S
WGP-L0m	174°50.392'E	36°36.503'S
WGP-L30m	174°50.400'E	36°36.488'S
WGP-M30m	174°50.348'E	36°36.474'S
WGP-M0m	174°50.345'E	36°36.492'S

Site description:

An expansive (160 m) reef platform with gentle slope and moderate rugosity at the eastern tip of the Whangaparāoa Peninsula. Very high sediment loads in the mid and low tidal zones, mostly comprised of silt. Exposed to the north and northeast, more so than Fishermans Cove.

Lowest abundance of oyster borers (*H. scobina*) recorded here. High coralline turf cover in the mid and low tidal zones with a solid cover of canopy forming Neptune's necklace typically found in the mid tidal zone.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	18	12.43	11.92	0.51
High	2013	23	8.95	8.20	0.75
High	2019	16	22.20	17.40	4.80
High	2021	23	0.80	0.00	0.80
High	2023	12	14.70	0.40	14.30
Mid	2011	30	76.30	76.30	0.00
Mid	2013	34	68.15	59.60	8.55
Mid	2019	31	40.02	40.00	0.02
Mid	2021	27	83.20	62.50	20.70
Mid	2023	27	45.53	45.50	0.03
Low	2011	25	90.61	90.60	0.01
Low	2013	28	80.20	79.70	0.50
Low	2019	34	83.20	70.90	12.30
Low	2021	25	93.60	74.90	18.70
Low	2023	19	96.96	0.00	96.96

7.1.13 Site name: Arkles Bay

Location: Mainland – East Coast

Transect coordinates (WGS84):

AR-M0m	174°44.747'E	36°38.683'S
AR-M30m	174°44.762'E	36°38.673'S
AR-H0m	174°44.754'E	36°38.668'S
AR-H30m	174°44.767'E	36°38.658'S
AR-L30m	174°44.749'E	36°38.693'S
AR-L0m	174°44.734'E	36°38.702'S

Site description:

Located on the southern side of the Whangaparāoa Peninsula. A comparatively narrow but gently sloping intertidal reef platform with high sediment cover occurring in the low tidal zone. Exposed to the southeast.

High cover of coralline turf persists through the mid and low shores however Neptune's necklace canopy cover in the mid shore has been variable through time. Barnacle cover (*Chamaesipho* spp.) is high in along the high shore. Horn snail populations have been highly variable in the mid and low tidal zones, fluctuating from~4 to ~400 ind. m^2. Black nerite (*N. melanotragus*) are abundant but only along the high shore.

A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	19	0.00	0.00	0.00
High	2013	25	4.90	4.90	0.00
High	2019	27	0.40	0.00	0.40
High	2021	22	0.00	0.00	0.00
High	2023	18	0.00	0.00	0.00
Mid	2011	31	73.70	73.70	0.00
Mid	2013	32	68.10	68.10	0.00
Mid	2019	32	17.50	17.40	0.10
Mid	2021	30	28.10	23.10	5.00
Mid	2023	32	37.10	29.10	8.00
Low	2011	26	97.81	97.10	0.71
Low	2013	28	93.84	92.50	1.34
Low	2019	29	100.25	20.50	79.75
Low	2021	33	173.80	86.90	86.90
Low	2023	15	63.80	18.50	45.30

7.1.14 Site name: Long Bay

Location: Mainland – East Coast

Transect coordinates (WGS84):

LB-H0m	174°45.629'E	36°41.613'S
LB-H30m	174°45.610'E	36°41.609'S
LB-M0m	174°45.642'E	36°41.605'S
LB-M13m	174°45.633'E	36°41.600'S
LB-M35m	174°45.618'E	36°41.600'S
LB-L0m	174°45.647'E	36°41.592'S
LB-L30m	174°45.627'E	36°41.592'S

Site description:

Located towards the southern end of the Long Bay – Okura Marine Reserve. Intertidal platform is ~70 m wide and characterised by high rugosity and a comparatively steep slope. Open to the north and northeast, but position within the Hauraki Gulf offers some protection. Silt is typically a major feature of the low tidal zone.

High coralline turf cover but only in the low tidal zone while barnacle cover is high along the high shore (*Chamaesipho* spp.) and mid shore (*E. plicata*). High abundances of black nerite (*N. melanotragus*) occur in the high and mid shore while cats eye snail (*L. smaragdus*) abundances are also high in the low shore but variable in the mid shores. Very high abundances of microgastropods in the high tidal zone.

A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	9	0.10	0.10	0.00
High	2013	16	0.44	0.40	0.04
High	2019	12	3.20	3.20	0.00
High	2021	17	0.00	0.00	0.00
High	2023	21	0.00	0.00	0.00
Mid	2011	32	0.61	0.61	0.00
Mid	2013	32	9.09	9.09	0.00
Mid	2019	35	0.90	0.80	0.10
Mid	2021	28	3.85	3.85	0.00
Mid	2023	27	0.00	0.00	0.00
Low	2011	24	90.70	90.70	0.00
Low	2013	29	97.86	97.80	0.06
Low	2019	27	81.70	81.70	0.00
Low	2021	36	0.00	0.00	0.00
Low	2023	23	92.00	92.00	0.00

7.1.15 Site name: Campbells Bay

Location: Mainland – East Coast

Transect coordinates (WGS84):

C4-H30m	174°45.915'E	36°44.885'S
C4-H0m	174°45.930'E	36°44.897'S
C4-M30m	174°45.958'E	36°44.903'S
C4-M0m	174°45.973'E	36°44.913'S
C4-L0m	174°45.952'E	36°44.887'S
C4-L30m	174°45.938'E	36°44.877'S

Site description:

A relatively narrow, sloping and rugose reef platform at the southern end of Campbells Bay. This site has typically had very little sediment cover.

Barnacle cover (*Chamaesipho* spp, *E. pilcata*) uncharacteristically occurs throughout all shore zones, though remains highest in the high tidal zone. Neptune's necklace and coralline turf conspicuously rare compared to other sites. High abundances of oyster borer (*H. scobina*) and snakeskin chiton (*S. pelliserpentis*) typically found at this site.

A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	10	0.11	0.11	0.00
High	2013	13	7.80	0.50	7.30
High	2019	17	0.00	0.00	0.00
High	2021	18	0.00	0.00	0.00
High	2023	25	1.24	0.00	1.24
Mid	2011	31	9.22	9.22	0.00
Mid	2013	37	7.86	7.01	0.85
Mid	2019	32	3.10	2.35	0.75
Mid	2021	23	0.00	0.00	0.00
Mid	2023	46	12.85	6.80	6.05
Low	2011	29	11.85	11.85	0.00
Low	2013	32	28.80	20.80	8.00
Low	2019	36	15.73	10.40	5.33
Low	2021	40	0.00	0.00	0.00
Low	2023	33	35.48	0.00	35.48

7.1.16 Site name: North Head

Location: Mainland – East Coast

Transect coordinates (WGS84):

NH-H0m	174°48.800'E	36°49.723'S
NH-H30m	174°48.814'E	36°49.710'S
NH-M0m	174°48.806'E	36°49.722S
NH-M30m	174°48.816'E	36°49.709'S
NH-L0m	174°48.808'E	36°49.723'S
NH-L16.6m	174°48.815'E	36°49.717'S
NH-L29m	174°48.819'E	36°49.710'S

Site description:

Situated at the eastern tip of North Head, this site is uncharacteristic of Auckland east coast sites with a steep narrow (~17 m) intertidal reef. Very little sediment compared to most other Auckland east coast reefs.

Typically, a high cover of coralline turf occurs along the low shore as does Neptune's Necklace, which is unusual (normal found in the mid shore zone). Oysters are conspicuous in the mid shore zone. Very high abundances of cat's eye snails can be found in the low tidal zone, though these have declined through time. Spotted black topshells (*Diloma aethiops*) are common in the mid shore while black nerite (*N. melanotragus*) abundances have been highly variable through time.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	24	0.03	0.02	0.01
High	2013	20	0.00	0.00	0.00
High	2019	13	0.00	0.00	0.00
High	2021	31	0.00	0.00	0.00
High	2023	16	0.00	0.00	0.00
Mid	2011	37	2.60	2.60	0.00
Mid	2013	32	1.58	1.58	0.00
Mid	2019	28	0.00	0.00	0.00
Mid	2021	19	0.23	0.23	0.00
Mid	2023	25	0.00	0.00	0.00
Low	2011	40	70.70	70.35	0.35
Low	2013	44	42.90	0.60	42.30
Low	2019	45	0.30	0.20	0.10
Low	2021	35	3.50	2.90	0.60
Low	2023	39	53.60	0.00	53.60

7.1.17 Site name: Mellons Bay

Location: Mainland – East Coast

Transect coordinates (WGS84):

MB-H0m	174°55.732'E	36°52.895'S
MB-H30m	174°55.717'E	36°52.882'S
MB-M0m	174°55.695'E	36°52.812'S
MB-M30m	174°55.678'E	36°52.802'S
MB-L0m	174°55.707'E	36°52.775'S
MB-L31m	174°55.697'E	36°52.763'S

Site description:

An expansive (~150 m), gently sloping intertidal reef at the northern end of Mellons Bay. Very sheltered within the inner Waitemata Harbour. Characterised by high sediment load throughout all shore heights, with sand prevalent in the high shore and silt lower down.

High coralline turf cover in the mid tidal zone but Neptune's necklace is typically sparse. Horn snails (*Zeacumantus* spp.) and oyster borer (*H. scobina*) are common, but abundances can be highly variable.

A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	9	70.32	70.32	0.00
High	2013	5	13.04	0.00	13.04
High	2019	6	55.20	0.00	55.20
High	2021	4	77.50	0.00	77.50
High	2023	4	82.10	0.00	82.10
Mid	2011	28	69.33	69.33	0.00
Mid	2013	34	62.86	62.70	0.16
Mid	2019	32	52.00	51.50	0.50
Mid	2021	26	63.60	63.10	0.50
Mid	2023	32	66.50	52.50	14.00
Low	2011	26	87.40	87.40	0.00
Low	2013	32	87.70	87.70	0.00
Low	2019	30	85.00	85.00	0.00
Low	2021	34	98.10	97.90	0.20
Low	2023	29	92.10	5.80	86.30

7.1.18 Site name: Ōmana

Location: Mainland – East Coast

Transect coordinates (WGS84):

OM-H0m	175°1.258'E	36°52.629'S
OM-H30m	175°1.241'E	36°52.624'S
OM-M0m	175°1.308'E	36°52.595'S
OM-M31m	175°1.292'E	36°52.583'S
OM-L0m	175°1.323'E	36°52.541'S
OM-L30m	175°1.305'E	36°52.534'S

Site description:

The southern most site within the Auckland east coast survey region. A very expansive (200 m) intertidal platform with gentle slope. Very limited exposure to wind and wave action. Sediment cover is high throughout the mid and low tidal zones

Low species diversity, with few mobile invertebrates typical of the Auckland east coast found at high abundances at this site. In 2023 high densities of the cockle *Austrovenus stutchburyi* were recorded. Modest covers of coralline turf found in the low tidal zone while barnacles (*Chamaesipho* spp.) were abundant along the high shore.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2011	15	10.35	10.35	0.00
High	2013	12	5.80	5.80	0.00
High	2019	12	3.80	3.80	0.00
High	2021	27	1.00	1.00	0.00
High	2023	17	10.45	10.40	0.05
Mid	2011	26	72.40	35.20	37.20
Mid	2013	25	87.00	27.00	60.00
Mid	2019	24	79.17	46.72	32.44
Mid	2021	29	92.40	10.00	82.40
Mid	2023	23	93.30	93.30	0.00
Low	2011	21	92.20	92.20	0.00
Low	2013	24	98.60	98.60	0.00
Low	2019	27	87.80	87.80	0.00
Low	2021	38	90.78	4.44	86.33
Low	2023	18	98.40	98.40	0.00

7.1.19 Site name: Te Henga Bethells Beach

Location: Mainland – West Coast

Transect coordinates (WGS84):

BETH HIGH START	174.4395	-36.8917
BETH HIGH END	174.4393	-36.8916
BETH MID END	174.4392	-36.8917
BETH MID START	174.4394	-36.8919
BETH LOW START	174.4394	-36.8919
BETH LOW END	174.4392	-36.8917

Site description:

Located on the western side of Ihumoana Island at Te Henga Bethells Beach. A gently sloping high tidal zone gives way to a steep mid and low tidal zone. Extremely exposed to wind and swell from the west and southwest. Very little sediment cover.

High covers of numerous encrusting invertebrates, in particular barnacles (*Chamaesipho* spp. and *E. plicata*) and mussels (*Perna canaliculus and Xenostrobus pulex*). These species are very prevalent in the mid and low tidal zones. Very high densities of oyster borers (*H. scobina*) and several limpet species. Regionally common species such as black nerite (*N. melanotragus*) and cats eye snails (*L. smaragdus*) were absent from this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2021	4	7.30	4.80	2.50
High	2022	6	10.50	0.00	10.50
High	2024	8	10.54	0.00	10.54
Mid	2021	16	0.00	0.00	0.00
Mid	2022	13	0.00	0.00	0.00
Mid	2024	21	0.00	0.00	0.00
Low	2021	19	0.00	0.00	0.00
Low	2022	14	0.00	0.00	0.00
Low	2024	19	2.50	1.00	1.50

7.1.20 Site name: Piha

Location: Mainland – West Coast

Transect coordinates (WGS84):

Piha H0	No GPS points, just photos	
Piha H30		
PIHA M0	174.4574	-36.9349
PIHA M30	174.4571	-36.9349
PIHA L0	174.4574	-36.935
PIHA L29	174.4571	-36.935

Site description:

Located at the southern end of Piha Beach. Mid tidal zone is relatively flat, with high rugosity while high shore and low tidal zones are steep. Extremely exposed to wind and swell from the west and southwest. Low shore zone is prone to periodic burial and uncovering while high shore is prone to sand inundation.

High covers of numerous encrusting invertebrates, in particular barnacles (*Chamaesipho* spp. and *E. plicata*) and mussels (*P. canaliculus and X. pulex*). These species are very prevalent in the mid and low tidal zones. Very high densities of oyster borers (*H. scobina*) and several limpet species. Regionally common species such as black nerite (*N. melanotragus*) and cats eye snails (*L. smaragdus*) were rare or absent from this site.

A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2021	6	0.60	0.00	0.60
High	2022	8	12.15	0.00	12.15
High	2024	10	11.20	0.00	11.20
Mid	2021	23	0.00	0.00	0.00
Mid	2022	21	0.11	0.00	0.11
Mid	2024	30	0.00	0.00	0.00
Low	2021	18	24.90	0.00	24.90
Low	2022	11	72.57	0.00	72.57
Low	2024	20	21.80	0.00	21.80

7.1.21 Site name: Kaitarakihi

Location: Mainland – West Coast

Transect coordinates (WGS84):

KHISTART	174.581	-37.0091
KHIEND	174.5809	-37.0093
KMIDEND	174.5813	-37.0087
KMIDSTART	174.5816	-37.0086
KLOWSTART	174.5818	-37.009
KLOWEND	174.5817	-37.0092

Site description:

A wide (55 m), gently sloping intertidal reef situated to the west of Kaitarakihi Beach. This site is within the Manukau Harbour and is sheltered compared to the open coast sites at Piha and Te Henga. High sediment covers in the mid and low shore zones, particularly around seagrass (*Zostera muelleri*) patches on the low shore.

This is the only site to have seagrass within the survey area. Macroinvertebrate and algae diversity generally low.

A temperature logger is located at this site.

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2021	13	0	0	0
High	2022	14	0.65	0.65	0
High	2024	8	0	0	0
Mid	2021	26	23.575	15.3	8.275
Mid	2022	22	73.5	73.5	0
Mid	2024	19	45	45	0
Low	2021	23	9.14	5.95	0.74
Low	2022	18	78.33	75.63	0
Low	2024	24	88.3	88.3	0

7.1.22 Site name: Huia

Location: Mainland – West Coast

Transect coordinates (WGS84):

HUIA HIGH START	174.559	-37.0194
HUIA HIGH END	174.559	-37.0192
HUIA MID START	174.5591	-37.0195
HUIA MID END	174.5592	-37.0192
HUIA LOW2 END	174.5593	-37.0192
HUIA LOW2 START	174.5592	-37.0193

Site description:

A steep, rugose intertidal platform to the south of the Huia boat ramp. Within the Manukau Harbour and closer to the entrance than Kaitarakihi, but more sheltered due to surrounding topography. Very little sediment cover.

High abundances of a number of macroinvertebrates not seen, or rare at other west coast sites including cat's eye snails (*L. smaragdus*), spotted black topshells (*D. aethiops*), oyster borer (*H. scobina*) and snakeskin chiton (*S. pelliserpentis*).

Species Richness and Secondary Sediment cover (percentage) across tidal zones and years:

Tidal zone	Year	Species richness	Total Sediment	Silt	Sand
High	2021	12	0.00	0.00	0.00
High	2022	19	0.00	0.00	0.00
High	2024	12	0.00	0.00	0.00
Mid	2021	21	0.00	0.00	0.00
Mid	2022	17	0.20	0.20	0.00
Mid	2024	29	13.53	13.43	0.10
Low	2021	35	0.20	0.20	0.00
Low	2022	30	0.23	0.03	0.20
Low	2024	39	1.55	1.55	0.00

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