# Rocky Shore

## State of the Environment Monitoring Report 2019-2024

## Technical Report 2025-34

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Taranaki Regional Council

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# Executive summary

Section 35 of the *Resource Management Act 1991* (RMA) requires local authorities to undertake monitoring of the region's environment, including land, air, marine, and freshwater domains. The rocky shore component of the State of the Environment Monitoring (SoE) programme for Taranaki was initiated by the Taranaki Regional Council in the 1994/95 monitoring year and has subsequently continued each year. This report covers the state and trends observed in intertidal hard-shore communities in Taranaki from the beginning of the monitoring record to June 2024.

As part of the SoE programme, six representative reef sites are surveyed twice a year, in spring and summer, using a fixed transect, random quadrat survey design. For each survey, a 50 meter transect is laid parallel to the shore and substrate cover, algal cover and animal cover/abundance in 25 x $0.5m^2$ random quadrats are quantified. Changes in the number of species per quadrat (species richness) and Shannon Wiener index per quadrat (diversity) have been assessed at the six reef sites over the 30 years of the SoE programme.

Of the six sites surveyed, the intertidal communities at Mānihi Road Reef (near Rahotu) were the most species rich and diverse. This is likely due to a low supply of sand, and the presence of pools that provided a stable environment with many ecological niches. The intertidal communities at Waihī Reef (near Hāwera) were the least species rich and diverse. This is most likely due to the high energy wave environment and resulting unstable habitat. The differences between sites observed during 2019-2024 generally reflected the differences seen throughout the entire monitoring record.

Sand deposition has been shown to have a strong effect on intertidal communities in Taranaki, with the sites at Orapa Reef (near Waitara), Mangāti Reef (near Bell Block) and Greenwood Road (near Ōkato) being particularly prone to periodic sand inundation. Trend analysis showed that sand cover has increased at the four northernmost SoE sites (including Tūrangi Reef near Motunui). This is likely due to an increased sand supply from Taranaki Maunga, combined with oceanographic conditions that shift this sand onshore. Although typically short lived, sand inundation events can result in significant reductions in species richness and diversity.

When accounting for observed sand cover, long-term trend analyses found evidence that the mean number of species per quadrat was 'highly likely' to 'likely' increasing at five sites, and 'likely' decreasing at one site. Although the analyses identified statistically significant long-term trends, the rate of change was very low at three sites, including the declining trend at Waihī Reef. The rate of change was highest at Orapa, Mangatī and Mānihi Reefs equating to 0.63 – 0.96% annual change based on the long-term median. This translates to the mean number of species recorded at these sites increasing by one every five to 11 years. The same long-term trend analyses also found evidence that species diversity (as measured by mean Shannon-Wiener diversity index) was 'highly likely' increasing at three sites, and 'highly likely' to 'likely' decreasing at three sites. The associated rates of change were comparable to what was observed with the mean number of species.

Despite the negative relationship demonstrated between sand cover and the ecological measures of species richness and diversity at the four northernmost sites, when comparing the sand-adjusted and unadjusted trend analyses, the observed sand cover did not appear to be having a strong influence on the current long-term trends for species richness or diversity (i.e., similar results were generally observed across both datasets). This suggests that sand cover has not remained sufficiently high for long-enough periods to drive negative trends in rocky shore communities (except the long-term trend in the mean number of species observed at Greenwood Road). It also suggests that there are other factors influencing the observed trends in rocky shore communities that require further investigation (e.g., potential changes in wave exposure at Waihī Reef).

While in the previous reporting period, seagrass (*Zostera capricorni*) was found at Orapa and Mangatī reefs, during 2019–2024 seagrass was only recorded at Orapa Reef.

Recommendations for further monitoring and investigations are provided within this report.

# Table of contents



# List of tables

## List of figures

# List of photos

# 1. Introduction

## 1.1 General

The *Resource Management Act 1991* (RMA) sets out requirements for local authorities to undertake environmental monitoring. Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment of their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

To this effect, Taranaki Regional Council (the Council) has established a state of the environment monitoring (SoE) programme for the region. A key aspect of this programme is reporting on the state and trends of coastal health to enhance the effectiveness of RMA policies and to inform decision-making in regard to the region's coastal environment.

The SoE programme is made up of a number of individual monitoring activities, many of which are undertaken and managed on an annual basis (from 1 July to 30 June). For each of these monitoring activities, regular reporting provides an overview of the most recent state and trends. These reports also provides the 'building blocks' of the regional state of the environment report, published every five years.

This report summarises the results for the sites surveyed as part of the Rocky Shore SoE programme over the 2019-2024 monitoring period. Biological communities of the rocky reefs around the Taranaki coastline have been monitored since 1983, initially by the Taranaki Catchment Commission. A more comprehensive rocky shore monitoring programme was first implemented by the Council during spring in 1994/95 as an on-going component of the SoE programme for the Taranaki region. However, this methodology was not implemented at all six sites until the summer in 1995/96.

## 1.2 Taranaki rocky shore intertidal environment

### 1.2.1 Physical environment

Rocky reefs dominate the intertidal zone of the Taranaki coastline. Around the ring plain, reefs are largely formed from lahar (volcanic derived) materials. The lahars consist of andesite cobbles and boulders bound within an ash type matrix. Selective erosion of the weaker matrix leaves the harder cobbles and boulders to form large platform reefs. These reefs are typically low in relief, but can be considerable in extent e.g., the reefs off the Waitara coastline extend as far as five kilometres offshore (TRC, 1991).

Taranaki reefs are exposed to high energy wave and wind conditions. Prevailing south westerly winds from the Tasman Sea, not weakened by land barriers or local irregularities of the coastline, can be persistent. The dominant wave direction is from the west, which results in considerable sand movement as waves strike much of the coast obliquely. The sand is supplied to the coast mainly from river/stream transport and cliff erosion, resulting in turbid conditions close to shore (TRC, 1991).

### 1.2.2 Biological communities

The organisms that live on the Taranaki rocky shore provide an important food source for humans, birds and fish, and form a significant component of marine biodiversity in the region. This ecological community is profoundly influenced by the physical characteristics of the region. The exposed weather and wave conditions, as well as the geomorphology of the shore, largely determine the structure and composition of these marine communities. However, these important geophysical factors do not uniformly influence rocky shore communities around the Taranaki coastline.

Due to the shape of the Taranaki headland, nearshore bathymetry, and the prevailing wave climate, there is a gradient of wave energy which exists around the Taranaki coastline (Johnson et al., 2008; Crofskey, 2007). Wave energy is generally higher in western Taranaki and decreases with distance in both directions around the coastline (northeast towards New Plymouth and southeast towards Hāwera). This regional wave exposure gradient, combined with local geomorphological factors (e.g., reef slope and aspect), can result in considerable differences in rocky reef communities between sites, with more wave tolerant species prevailing at high energy sites.

Another factor which has a strong influence on some rocky reef communities in Taranaki is sand supply. Erosion events on Taranaki Maunga have led to the transport of significant volumes of sand to the coast via the Hangatāhua (Stony) River. Once at the coast, littoral drift transports this sand northeast, towards New Plymouth (Cowie, 2009). Under certain conditions, this sand can be deposited in the intertidal zone, burying rocky reef habitat as a result. Due to the direction that this sand is transported when it reaches the coast, rocky reefs south of the Hangatāhua River are less likely to be inundated as a result of such events, although these sites can still be affected by sand from other rivers and streams, or eroding cliffs (Matthews, 1977). Sand movement has affected rocky reef communities in different ways around the Taranaki coastline. However, heavy inundation events have consistently resulted in sharp declines in species richness and diversity.

How wave exposure, sand movement, and other factors influence rocky reef communities in Taranaki will be discussed in more detail in Section 4 of this report, in light of the results from the current reporting period.

### 1.2.3 Cultural significance

The reefs of Taranaki provide a valuable source of kaimoana/mātaitai for Māori. This kaimoana/mātaitai is of significant cultural value, not only as a source of food, but also because it maintains tribal mana and standing (Waitangi Tribunal Reports, 1983; TRC, 2015).

The results of the Council's intertidal rocky shore surveys presented in this report are not suitable for providing robust assessment of kaimoana/mātaitai stocks, including pāua, kina and kuku/kutae (mussels) because the sites are located higher on the shore than where these species typically occur. Instead, the results of the rocky shore SoE programme provide a record of species richness, diversity and composition at representative reef sites around the region. These records can be used to assess the overall 'health' of the reef environment.

Iwi and hapū associations with the six SoE reef sites are outlined in the following section in Figures 1 to 7.

# 2. Monitoring methodology

## 2.1 Site locations

In order to have a representation of the region, six sites have been studied in total (Figure 1). These are Tūrangi Reef, Orapa Reef, Mangatī Reef, Greenwood Road Reef/Waiaua Reef, Mānihi Road Reef, and Waihī Reef.


Figure 1 State of the Environment rocky shore monitoring sites in Taranaki region and iwi rohe boundaries

### 2.1.1 Tūrangi Reef

Tūrangi Reef is the northernmost SoE rocky shore survey site, located near Motunui and the northern boundary of Taranaki's laharic coastline. The site is located approximately 7km east from the Waitara River mouth, 47km northeast of the Hangatāhua River, and 59km northeast from Cape Egmont (the western-most point in Taranaki). This reef is within the rohe of local Iwi Te Atiawa and Ngāti Rahiri hapū.

**Site code:** SEA900095 **NZTM:** 1713712/5684309


Figure 2 Tūrangi Reef SoE rocky shore survey site

### 2.1.2 Orapa Reef

Orapa Reef extends along the Waitara shoreline, in North Taranaki. The survey site is located 1.5km west of the Waitara River mouth, approximately 40km northeast of the Hangatāhua River mouth, and 52km northeast of Cape Egmont. The reef is within the rohe of local Iwi Te Atiawa, and Otaraua and Pukerangiora hapū.

**Site code:** SEA901043 **NZTM:** 1704759/5683854

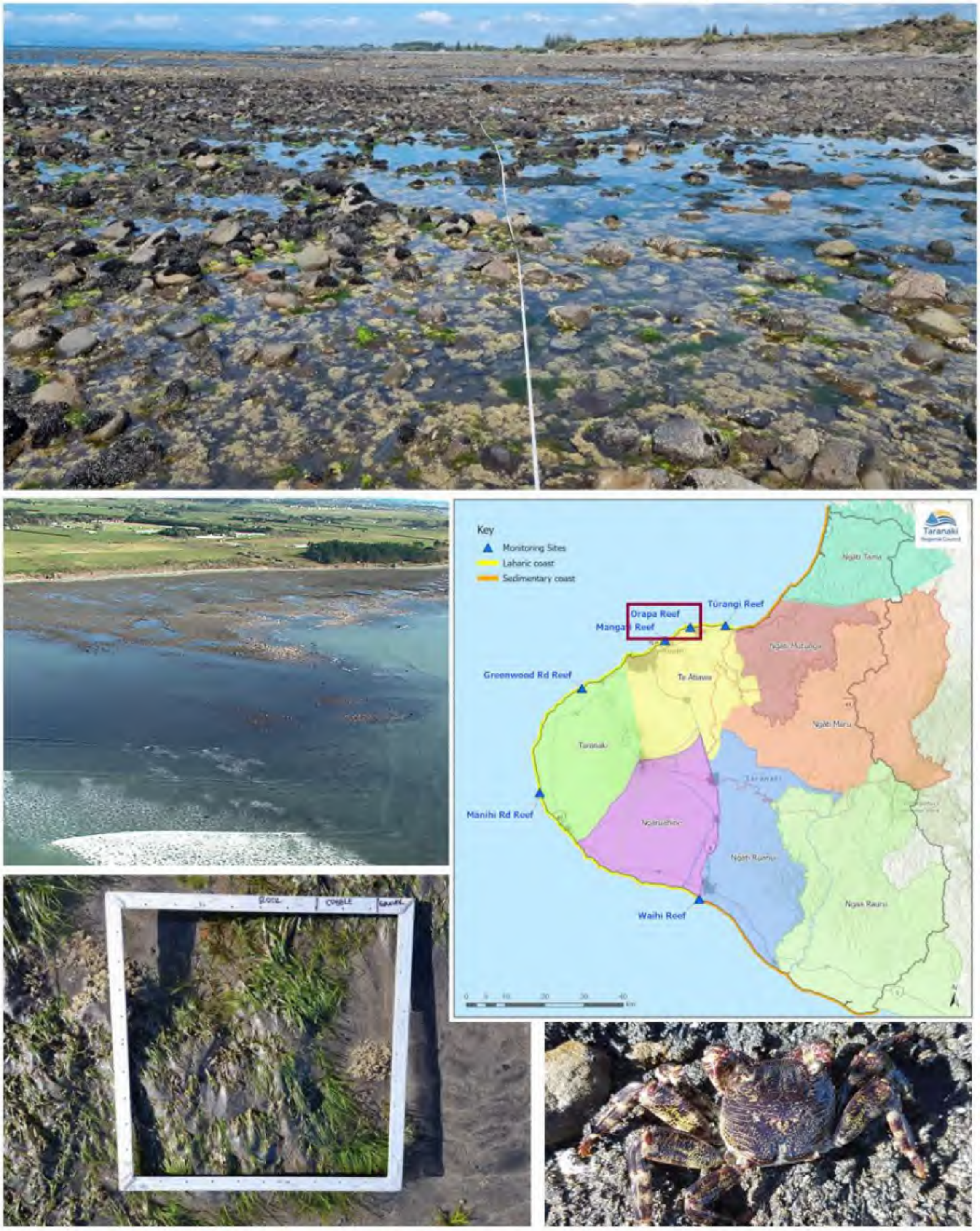


Figure 3 Orapa Reef SoE rocky shore survey site

### 2.1.3 Mangatī Reef

Mangatī Reef is found near Bell Block, just north of New Plymouth. It is positioned 3km northeast from the Waiwhakaiho River mouth, approximately 32km northeast of the Hangatāhua River mouth, and 44km northeast of Cape Egmont. This reef is within the rohe of local Iwi Te Atiawa, and Puketapu hapū.

**Site code:** SEA902005 **NZTM:** 1698314/5680510


Figure 4 Mangatī Reef SoE rocky shore survey site

### 2.1.4 Greenwood Road Reef / Waiaua Reef

Greenwood Road (or Waiaua) Reef is found west of New Plymouth, near Ōakura. It is located approximately 8km northeast of the Hangatāhua River mouth, and 21km northeast of Cape Egmont. This reef is within the rohe of local Iwi Taranaki, and Ngā Māhanga and Ngāti Tairi hapū.

**Site code:** SEA903070 **NZTM:** 1677185/5668284

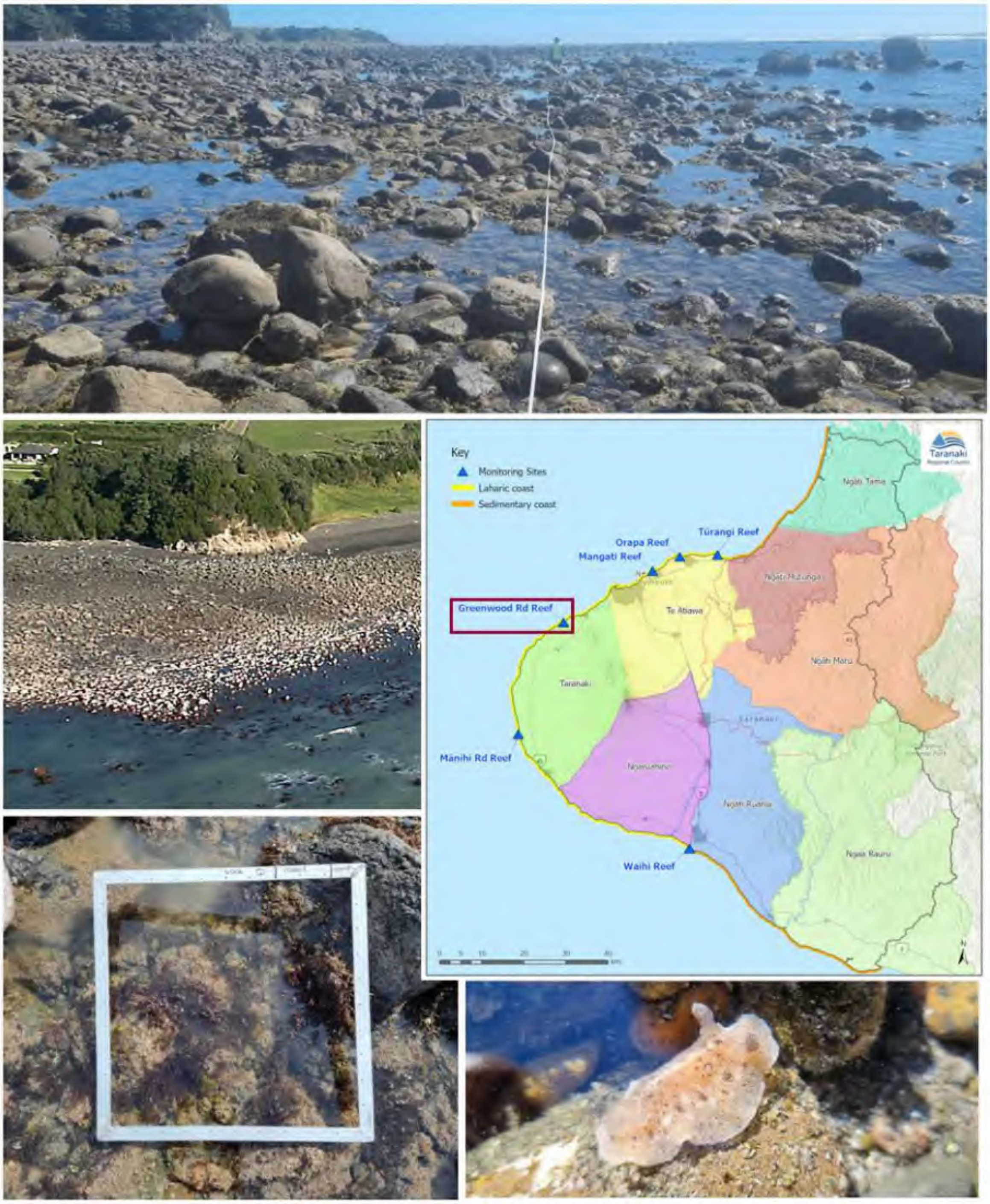


Figure 5 Greenwood Road SoE rocky shore survey site

### 2.1.5 Mānihi Road Reef

Mānihi Road Reef is found just north of Oaonui and is the western-most SoE rocky shore survey site. It is located approximately 10km south of Cape Egmont, and 22km south of the Hangatāhua River mouth. This reef is within the rohe of local Iwi Taranaki, and Ngāti Haupoto hapū.

**Site code:** SEA904065 **NZTM:** 1666415/5641780


Figure 6 Mānihi Road Reef SoE rocky shore survey site

### 2.1.6 Waihī Reef

Waihī Reef is located near Hāwera and is the southernmost SoE rocky shore survey site; positioned near the southern boundary of Taranaki's laharic coastline. Waihī Reef is located approximately 56km southeast of Cape Egmont. Immediately landward of this reef are tall, unstable cliffs reaching 20m in height. Large sections of these cliffs frequently collapse as the cliff toe is undercut by the sea. Waihī Reef is within the rohe of two local Iwi. Ngāruahine with Kanihi-Umutahi and Okahu-Inuawai hapū, and Ngāti Ruanui with Hamua, Ngāti Tanewai, Ngāti Tupaea, Hapotiki, and Ngāti Hawe hapū.

**Site code:** SEA906025 **NZTM:** 1707058/5614617


Figure 7 Waihī Reef SoE rocky shore survey site

## 2.2 Survey method

The six reef sites are monitored twice a year, in spring and summer, using a fixed transect and random quadrat survey design. The surveys are designed in a manner to provide sufficient statistical sensitivity to effectively detect change, while providing a realistic survey time to complete the survey within the low tide period (TCC, 1983; TCC, 1984).

At each site, the location of the transect is identified using GPS coordinates and photos. Generally, the start of most transects can be identified in relation to distinctive boulders and other landmark features. A 50m transect is laid parallel to the shore, at a tidal height of approximately 0.6m above chart datum. Five 5m x 3m blocks are then established along the transect. Within each block, five random 0.5$m^2$ quadrats are laid, giving a total of 25 random quadrats per site. For each quadrat, the percentage cover of algae and encrusting animal species is estimated using a grid. For all other animal species, individuals larger than 3mm are counted and identified to the lowest taxonomic level possible. Under-boulder biota are counted and identified where rocks and cobbles are easily overturned.

## 2.3 Data analysis

The survey data is used to calculate two ecological indices: species richness and the Shannon-Weiner diversity index (H'). A species richness score is derived for each survey based on the mean number of species recorded in each quadrat. A Shannon-Weiner diversity index score is calculated in the similar way but also factors in the relative abundance of each recorded species.

Diverse ecological communities are composed of a high number of species that are present in relatively even proportions, whereas communities composed of fewer species, or where one species is disproportionately more abundant than the others, are considered less diverse. Ecologically diverse communities generally include a high number of species within each functional group (e.g., primary producers, grazers, suspension feeders, predators, etc.). As a result, these communities are often more resilient when faced with stressors and disturbances. Higher levels of species diversity in rocky shore communities typically reflect optimal environmental conditions.

To maintain consistency in the data analyses through time, the survey data were filtered to only include the key taxa that were targeted when the monitoring programme was first established (i.e., algae, anemones, sea squirts, echinoderms, worms, molluscs, crustaceans, and fish). Species that have since been recorded during the surveys such as sea slug *Alloiodoris lanuginata*, snapping shrimp *Betaeopsis aequimanus*, whelk *Buccinulum sp.*, orange-tipped sea squirt *Corella eumyota*, chiton *Callochiton crocinus*, Cook's Pillbox Crab *Halicarcinus cookie*, and banded triplefin *Forsterygion malcolmi* were excluded from analyses of state and trend.

Long-term trend analyses of species richness (mean number of species per quadrat) and diversity (Shannon-Wiener diversity index per quadrat) at each site were undertaken utilising data from Taranaki Regional Council's SoE programme collected from 1994/95 (see section 1.1). These analyses were conducted using methods described by Land Water People (LWP) (Snelder & Fraser, 2019), which assume that data either increase or decrease over time. The LWP approach calculates the confidence that the analysed dataset exhibits a defined trend. For this study, the non-seasonal trend analysis function was utilised, which implements the Mann-Kendall test; a nonparametric test that detects trends without assuming a normal distribution.

The likelihood of a given trend direction was determined by the reported confidence value:

- A confidence value of 0.95 or above was deemed "Highly likely."
- A confidence value of 0.90 or above was deemed "Very likely."
- A confidence value of 0.67 or above was deemed "Likely."

- Trends with a confidence value below 0.67 were considered uncertain.

It has previously been recognised that the statistical significance of a trend does not necessarily imply a 'meaningful' trend i.e., one that is likely to be relevant in a management sense. While the method of Ballantine and Davies-Colley (2009) is commonly used, where a 'meaningful' trend is defined to be one which is found to be statistically significant, and that has a relative magnitude >1 percent change per year, it has not been adopted in this report. While this method is useful and indicative when used to analyse a short (or initial) time period, it becomes less useful as the time series being studied grows. In fact, the rate of change which may be considered meaningful is specific to each unique site. Consequently, while absolute and relative rates of change are calculated in this report, the interpretation of whether a trend is ecologically meaningful or not is made via professional judgment and scientific critique.

## 2.4 Analysis of sand cover

The level of sand cover at a site can impact both, species richness and diversity, in rocky reefs. While the reef community may tolerate some level of sand cover, above a certain threshold the community becomes impacted. Once this threshold of sand cover is exceeded, the number of species declines, before eventually bottoming out at high percentages of sand cover. In some cases, the level of sand cover can be the main driving force behind variability in species richness and diversity at a site.

To assess the influence of sand cover on species richness and diversity across the six rocky shore sites, Generalized Additive Models (GAMs) were used to model the relationship between each ecological parameter (species richness and diversity) and sand cover percentage. For sites where a strong relationship was identified—Tūrangi, Orapa, Mangatī, Greenwood Road, and Waihī Reefs—the residuals from the GAMs were used in subsequent trend analyses to account for the effect of sand cover. At Mānihi Reef, where at no point in time had there been any significant sand build up, raw data were used. To adjust for sand cover, the percentage of sand cover was plotted against species richness and diversity, and GAMs were fitted using the LWP trend packages in R Studio (version 2022.07.1). Each data point was adjusted using the formula: adjusted value = raw value – modelled value + median value. Trend analyses were then conducted on these adjusted datasets.

# 3. Results

## 3.1 Species composition and abundance

A full list of the species recorded during the SoE intertidal surveys between 2019 and 2024, including the number of records for each species, is provided in Appendix III.

The encrusting algal species, *Corallina* sp. (paint) and *Ralfsia* sp., were among the most widespread primary producers recorded between 2019 and 2024 (present in most quadrats at all sites). The geniculate algae, *Corallina* sp. (turf), was also widely found at most sites, except for Waihī Reef which had a low presence of this species. Notably fewer algal species were found at Waihī Reef compared to the remaining sites; only two green algal species (Chlorophyta) were present in any of the surveys at this site, (*Chaetomorpha aerea* and *Ulva sp).*

The barnacle, *Chaemosipho columna*, and colonial tube worms *Neosabellaria kaiparaensis* (sand), and *Spirobranchus carniferus* (calcareous) were the most widespread sedentary filter feeding species across all six sites. *Isactinia olivacea*, was the only species of anemone present at all sites.

There were 51 species of mollusc identified across the six survey sites between 2019 and 2024–the most species of any animal phyla. Of these, the most widespread mobile grazers were two top shell species, *Lunella smaragda* and *Diloma aethiops,* followed by the green chiton*, Chiton glaucus,* and the rainbow chiton, *Sypharochiton sinclairi*. The oyster boring whelk, *Haustrum scobina*, was the most widely present predatory species.

Crustacea contained the second highest number of species (24) identified of all animal phyla. The filter feeding porcelain crab (*Petrolisthes elongatus*) was the most widespread mobile crustacean surveyed between 2019 and 2024.

Figure 8 provides the average cover data (or abundance data for mobile animals) from all SoE surveys for a number of the key species discussed above, along with sand cover between 2019 and 2024.

Overall SoE surveys between 2019 and 2024 showed that the average cover of *Corallina sp.* (turf algae) was highest at Greenwood Road, similar between Mangāti, Mānihi, Orapa, and Tūrangi, and considerably lower at Waihī Reef (Figure 8). An evident north to south pattern of decreasing abundance was observed for the top shell *L. smaragdus,* while the top shell *D. aethiops* and whelk *H. scobina* did not present an obvious latitudinal pattern (Figure 8).

In contrast to turf cover, the cover of *Corallina* sp. (paint) was significantly higher at Waihī Reef compared to the rest of the sites. Cover was lowest at the Orapa and Mangatī sites. These two sites along with Greenwood Road had the lowest average abundances of *C. glaucus* and *P. elongatus.* Furthermore, Orapa Reef presented the highest average cover of sand, followed by Tūrangi, Mangatī, Greenwood Road, Waihī and Mānihi. Average cover of *N. kaiparaensis* was also significantly higher at Orapa than at any other site. Orapa Reef presented the highest average cover of sand, followed by Tūrangi, Mangatī, Greenwood Road, Waihī and Mānihi. Compared to the previous 2017 to 2019 reporting period, which had seagrass *Zostera capricorni* at two sites (Orapa and Mangatī reefs), during the 2019 to 2024 period, seagrass was only recorded at Orapa Reef (Figure 8).

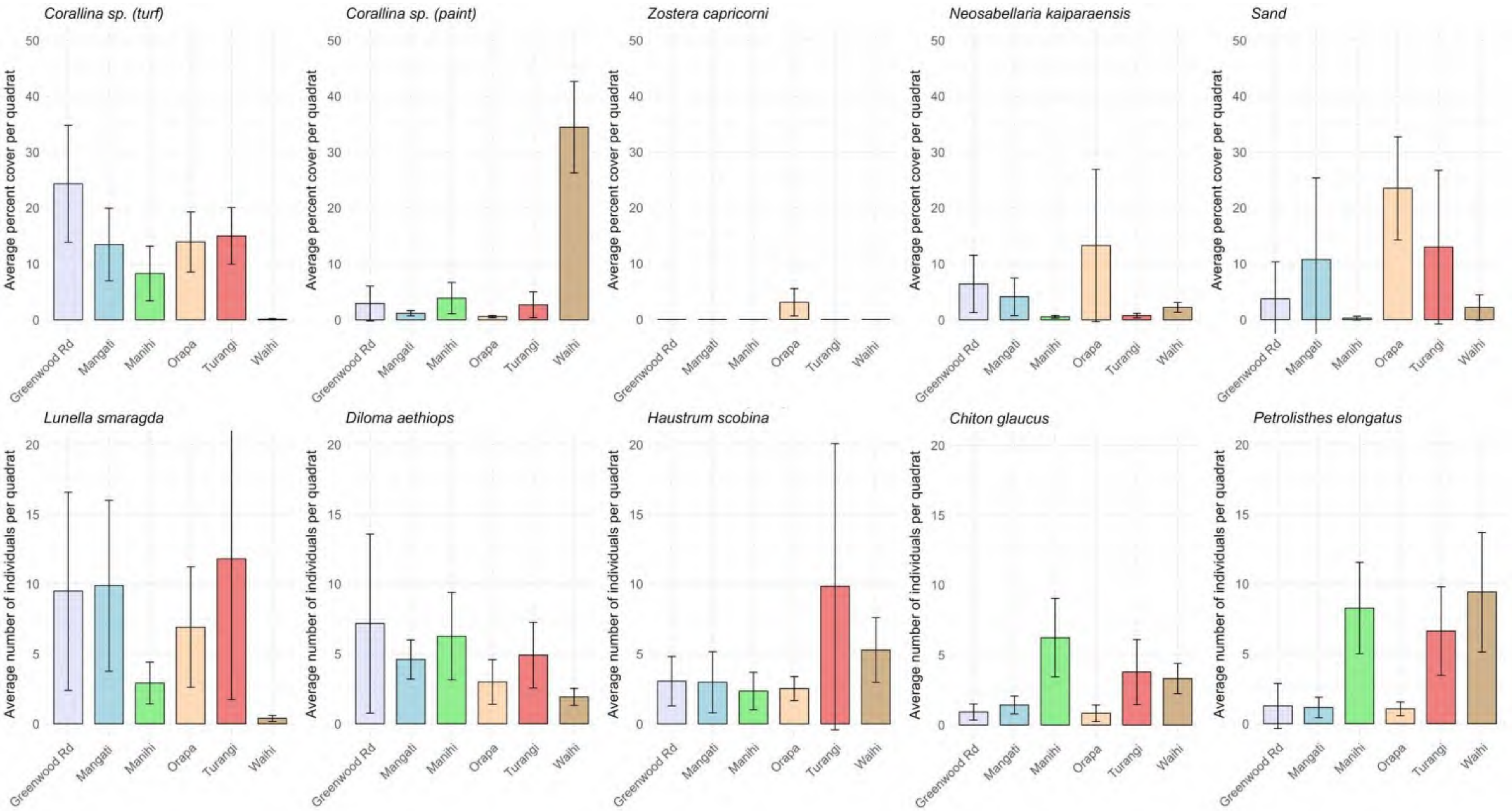


Figure 8 Average cover and abundance (±SE) of key species and sand at the six reef sites from all SoE surveys between 2019 and 2024

## 3.2 Species richness and diversity

Figure 9 shows the average number of species per quadrat (species richness) and Shannon-Wiener index per quadrat (diversity) at the six reef sites from 2019 to 2024. Different locations exhibited different patterns in species richness and diversity over time, with some being relatively more consistent, and others more variable. Species richness and diversity were consistently highest at Mānihi reef. Species richness and diversity was consistently lowest at Waihī reef. Species richness appeared more consistent at the Tūrangi, Orapa and Waihī reefs, while it was more variable at Greenwood Road, Mānihi and Mangatī. The diversity results show a similar pattern, although with slightly less variability.

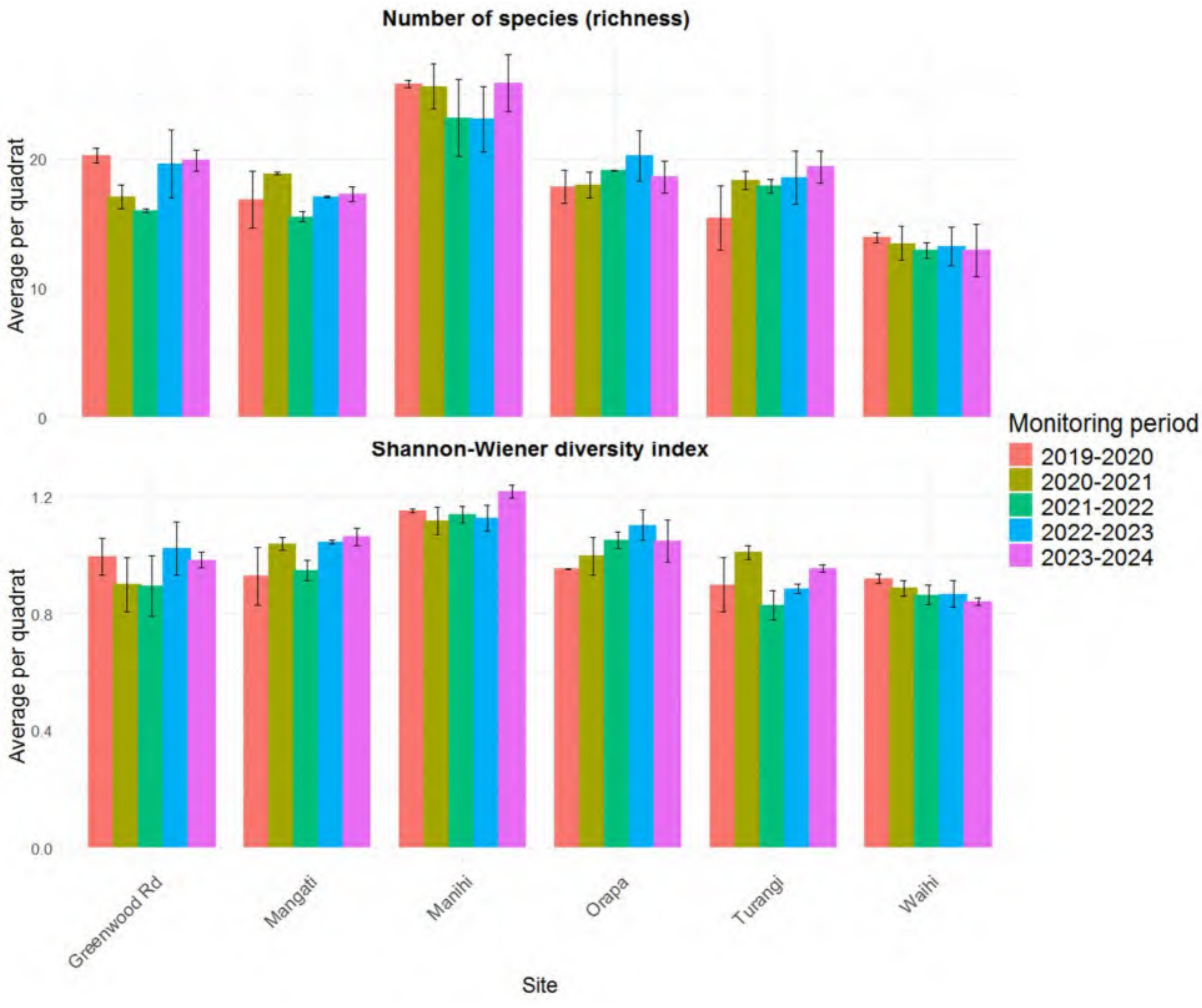


Figure 9 Average number of species (richness) and Shannon-Wiener diversity index (± SD) per quadrat at the six reef sites from 2019 to 2024

Summary statistics for species richness and diversity at the six reef sites, from the full 30-year record of SoE surveys, are provided in Table 1 along with the first (Table 2) and last five years (Table 3). Individual survey results are presented in Appendix I.

When looking at the 30-year summary statistics, Mānihi was consistently the most diverse and species-rich site, with a mean of 20.16 species per quadrat and the highest average Shannon-Wiener diversity index (1.05). Greenwood followed with a moderate species richness (mean = 16.03) and diversity (mean Shannon-Wiener index= 0.90), though it exhibited the highest variability, indicating temporal fluctuations. Tūrangi, Orapa, and Mangāti had similar species richness (means between 14.6–15.9) and moderate diversity (mean Shannon-Wiener index between 0.88–0.90), though Orapa and Mangāti showed relatively high variability in both richness (SD = 3.68 and 3.80, respectively) and diversity (SD = 0.18 and 0.16), suggesting more dynamic or unstable community structures. Waihī remained the least species-rich and least diverse site, with a mean of 11.46 species per quadrat and the lowest mean diversity index (0.84).

Table 1 Species richness and diversity summary statistics at six reef sites from 1994 to 2024

| Site | Number of surveys | Number of species per quadrat | | | | | Shannon-Wiener index per quadrat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Median | Max | Min | SD | Mean | Median | Max | Min | SD |
| Tūrangi | 67 | 15.86 | 16.16 | 20.64 | 10.72 | 2.37 | 0.90 | 0.90 | 1.04 | 0.68 | 0.07 |
| Orapa | 60 | 14.58 | 14.76 | 21.64 | 1.60 | 3.68 | 0.88 | 0.92 | 1.14 | 0.15 | 0.18 |
| Mangāti | 58 | 14.87 | 14.98 | 23.16 | 3.44 | 3.80 | 0.90 | 0.92 | 1.14 | 0.28 | 0.16 |
| Greenwood | 68 | 16.03 | 16.44 | 23.64 | 0.16 | 4.04 | 0.90 | 0.95 | 1.15 | 0.02 | 0.17 |
| Mānihi | 56 | 20.16 | 19.48 | 27.60 | 13.40 | 3.64 | 1.05 | 1.06 | 1.23 | 0.89 | 0.08 |
| Waihī | 65 | 11.46 | 11.60 | 15.92 | 4.84 | 1.96 | 0.84 | 0.84 | 0.96 | 0.40 | 0.08 |

During the first five years of the monitoring programme (Table 2), species richness and diversity varied across the six surveyed sites. Mānihi and Greenwood presented the highest mean number of species per quadrat (20.18 and 18.97, respectively) and the highest Shannon-Wiener diversity indices (1.06 and 1.03). In contrast, Waihī had the lowest mean species richness (12.97) and among the lowest diversity (0.92). Tūrangi, Orapa, and Mangāti reefs exhibited moderate richness and diversity, with mean species counts ranging from 15.69 to 16.79 and Shannon-Wiener indices from 0.92 to 0.97. Standard deviations in species richness were highest at Greenwood and Mānihi, pointing to greater temporal or spatial variability in species presence. In contrast, the standard deviation of the Shannon-Wiener index was low across all sites (ranging from 0.04 to 0.07), suggesting relatively stable community structure and evenness over time. While, Mānihi showed the most consistent diversity (SD = 0.04), Waihī and Tūrangi exhibited slightly more variability (SD = 0.07) (Table 2, Figure 10 and Figure 11).

Table 2 Species richness and diversity summary statistics at six reef sites from 1994 to 1999 (first five years)

| Site | Number of surveys | Number of species per quadrat | | | | | Shannon-Wiener index per quadrat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Median | Max | Min | SD | Mean | Median | Max | Min | SD |
| Tūrangi | 14 | 16.79 | 17.10 | 18.52 | 13.80 | 1.38 | 0.92 | 0.93 | 1.01 | 0.75 | 0.07 |
| Orapa | 10 | 15.69 | 15.96 | 17.76 | 13.16 | 1.49 | 0.96 | 0.97 | 1.02 | 0.89 | 0.05 |
| Mangāti | 8 | 15.78 | 15.98 | 17.20 | 13.88 | 1.18 | 0.97 | 0.96 | 1.05 | 0.92 | 0.05 |
| Greenwood | 13 | 18.97 | 18.96 | 22.04 | 14.80 | 1.85 | 1.03 | 1.04 | 1.12 | 0.92 | 0.05 |
| Mānihi | 8 | 20.18 | 20.08 | 23.16 | 17.24 | 1.78 | 1.06 | 1.07 | 1.14 | 1.01 | 0.04 |
| Waihī | 14 | 12.97 | 12.92 | 16.96 | 10.72 | 1.55 | 0.92 | 0.94 | 1.03 | 0.80 | 0.07 |

In the last five years of the monitoring programme, several sites showed increases in species richness and diversity, indicating potential improvements in intertidal community health. Mānihi continued to present the highest mean species richness per quadrat (24.71) and the highest Shannon-Wiener diversity index (1.15). Orapa also showed a notable increase in richness (mean = 18.76) and diversity (mean H' = 1.03), while Mangāti showed a comparatively smaller improvement. Tūrangi's species richness rose slightly to 17.92, but its diversity remained stable at 0.92, suggesting limited change in community evenness. Greenwood experienced a slight decrease in richness (18.57) and diversity (0.96), coupled with the highest standard deviation in species richness (2.05), indicating more variability over time. Waihī remained the least diverse site, with only a marginal increase in species richness (13.30) and a slight decline in diversity (mean H' = 0.88). Across all sites, the standard deviation of the Shannon-Wiener index remained low (ranging from 0.04 to 0.08), suggesting continued stability in community evenness. Mānihi again showed the most consistent diversity (SD = 0.05), while Greenwood had the highest variation in diversity (SD = 0.08), suggesting temporal fluctuations in that site's intertidal species (Table 3, Figure 10 and Figure 11).

Table 3 Species richness and diversity summary statistics at six reef sites from 2019 to 2024 (last five years)

| Site | Number of surveys | Number of species per quadrat | | | | | Shannon-Wiener index per quadrat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Median | Max | Min | SD | Mean | Median | Max | Min | SD |
| Tūrangi | 10 | 17.92 | 18.06 | 20.24 | 13.68 | 1.14 | 0.92 | 0.92 | 1.03 | 0.79 | 0.07 |
| Orapa | 10 | 18.76 | 18.80 | 21.64 | 16.96 | 1.31 | 1.03 | 1.04 | 1.14 | 0.95 | 0.07 |
| Mangāti | 10 | 17.13 | 17.10 | 18.96 | 15.28 | 1.36 | 1.01 | 1.03 | 1.085 | 0.858 | 0.07 |
| Greenwood | 10 | 18.57 | 18.54 | 21.48 | 15.91 | 2.05 | 0.96 | 0.97 | 1.09 | 0.82 | 0.08 |
| Mānihi | 10 | 24.71 | 25.08 | 27.44 | 21.08 | 2.11 | 1.15 | 1.15 | 1.23 | 1.08 | 0.05 |
| Waihī | 10 | 13.30 | 13.50 | 14.40 | 11.48 | 1.11 | 0.88 | 0.88 | 0.93 | 0.83 | 0.04 |

Comparisons of species richness and diversity at each site for the 1994-1999, 1999-2004, 2004-2009, 2009-2014, 2014-2019, and 2019-2024 SoE monitoring periods, are given in Figure 10 and Figure 11. It is notable that between 2019– 2024 both median species richness and diversity increased at all sites from the previous monitoring periods. Possible reasons for this are expanded on in the discussion section of this report.

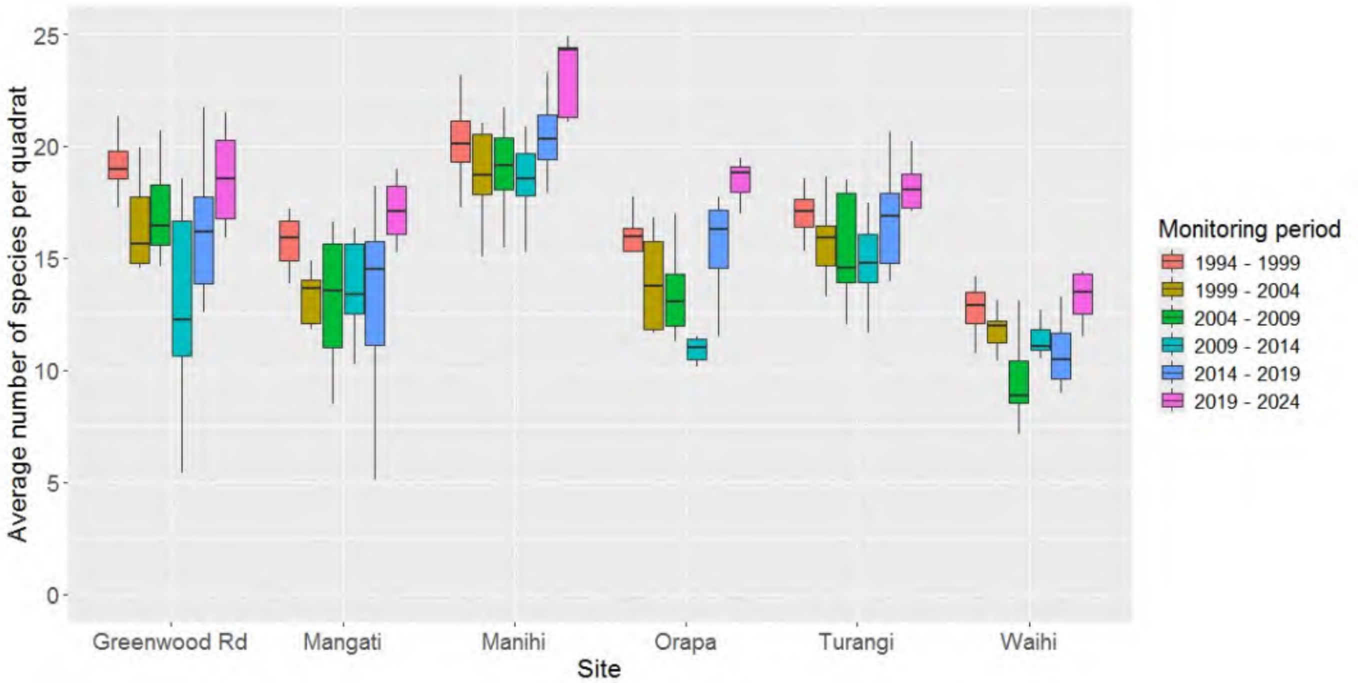


Figure 10 Box and whisker plot of number of species per quadrat (species richness) at the six reef sites for 5-year monitoring periods: 1994-1999, 1999-2004, 2004-2009, 2009-2014, 2014-2019, and current monitoring period (2019-2024)

On the other hand, the median Shannon-Wiener diversity index (species diversity) per quadrat showed a sustained growth since 2008 at most sites (Mangatī, Mānihi, Orapa, Tūrangi and Waihī reefs), except Greenwood Road that exhibited a decrease between 2014–2019, followed by an increase in 2019–2024 (Figure 11). Similarly to the species richness, the Shannon-Wiener diversity index also exhibited an increase from the previous period at all sites (Figure 11).

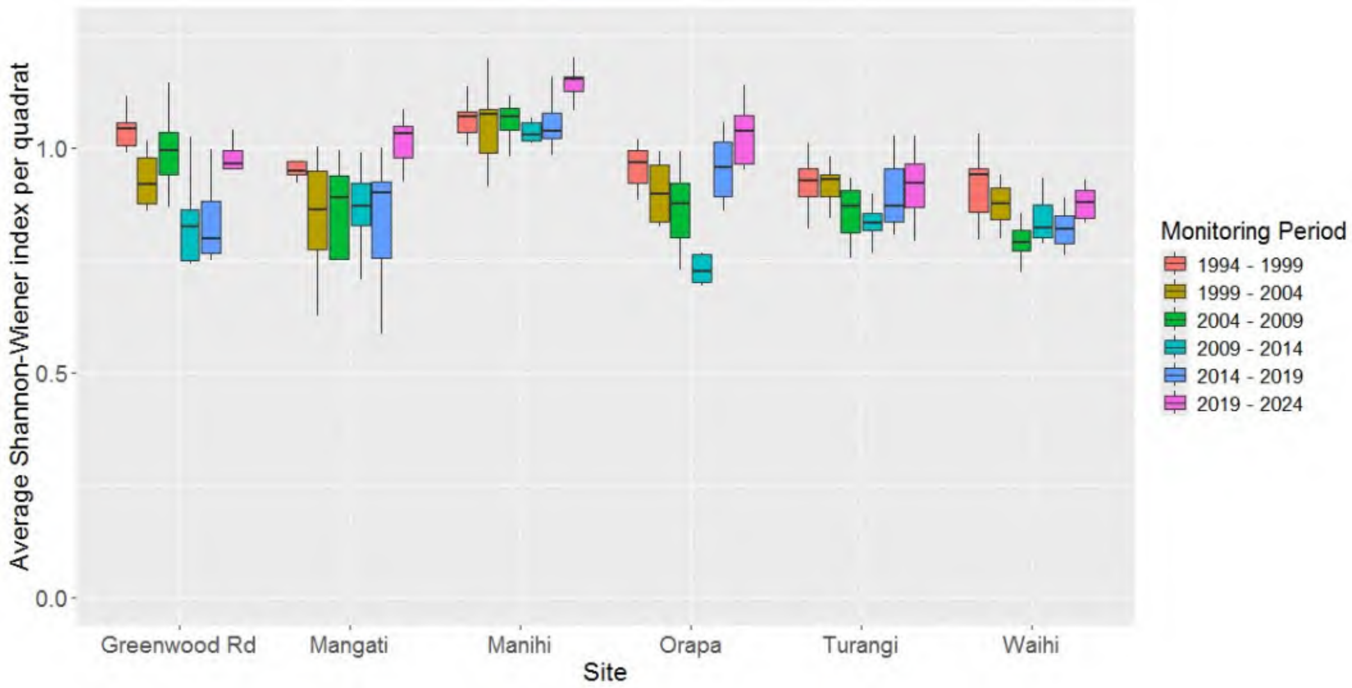


Figure 11 Box and whisker plots of Shannon-Wiener index per quadrat (diversity) at the six reef sites for 5-year monitoring periods: 1994-1999, 1999-2004, 2004-2009, 2009-2014, 2014-2019, and current monitoring period (2019-2024)

In order to compare the nature of the rocky shore communities at the different sites, a non-parametric Kuskal-Wallis test was applied, using the full 30-year dataset. Results showed that there were significant differences in species richness and diversity across the different reef locations (p-value < 0.05).

To explore where these differences were found, post-hoc paired samples Wilcoxon tests were utilised. Results showed that there are many statistically significant differences in species richness between the locations, particularly between the Waihī, Mānihi, and Tūrangi Reefs.

Highly significant differences in species richness were found between all sites except between Orapa and Mangāti, and Tūrangi and Greenwood Rd. Marginal significance (p-value close to 0.05) was found between Tūrangi and Orapa (Table 4, Figure 12).

Table 4 Paired Wilcoxon test for species richness for all six locations between 1994-2024 where p ≤ 0.05 depicts a significant statistical difference between sites

| | Greenwood Rd | Mangāti | Mānihi | Orapa | Tūrangi |
|---|---|---|---|---|---|
| Mangāti | **0.00011** | - | - | - | - |
| Mānihi | **$1.8 \times 10^{-7}$** | **$2.7 \times 10^{-16}$** | - | - | - |
| Orapa | **0.00655** | 1.0 | **$2.0 \times 10^{-14}$** | - | - |
| Tūrangi | 1.0 | **0.00071** | **$3.7 \times 10^{-13}$** | **0.05596** | - |
| Waihī | **$1.5 \times 10^{-12}$** | **$6.2 \times 10^{-7}$** | **$<2.0 \times 10^{-16}$** | **$8.2 \times 10^{-7}$** | **$<2.0 \times 10^{-16}$** |

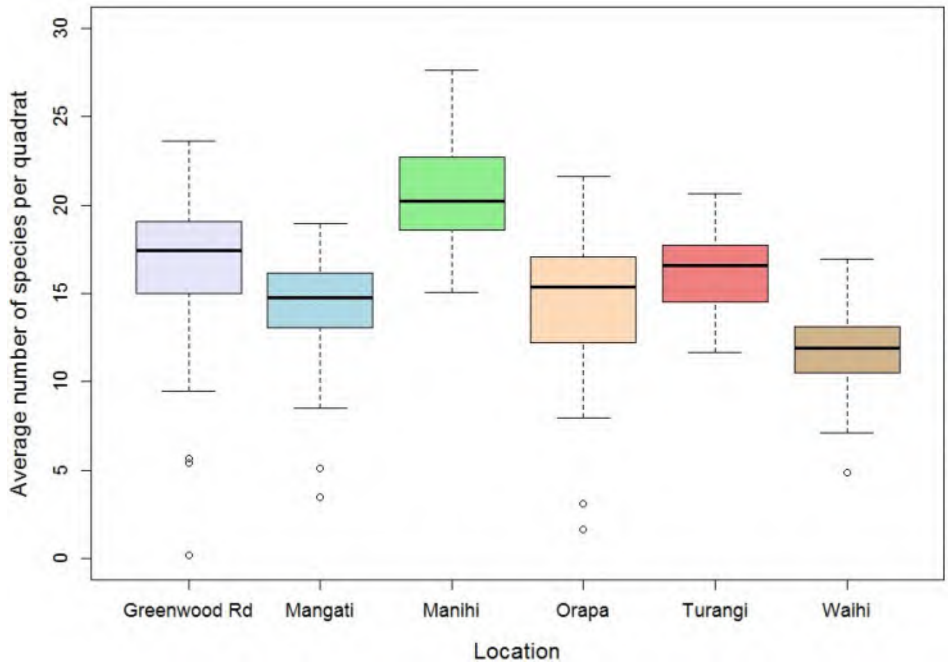


Figure 12 Average number of species per quadrat at all survey sites between 1994 and 2024

Similarly, with regards to the Shannon-Weiner diversity index, statistically significant differences were found between many of the locations, particularly between Waihī, Mānihi, and Tūrangi reefs. Waihī showed significant differences compared to all other locations, suggesting it has distinct diversity patterns compared to the rest. Tūrangi and Orapa were similar to each other in terms of diversity. No significant differences were found between Mangatī and Greenwood Rd or Orapa and Mangāti, indicating these locations have similar diversity distributions (Table 5, Figure 13).

Comparisons of Shannon-Wiener Index records between the different sites found very strong evidence that Mānihi has higher diversity than the remaining five sites (p value $<10^{-10}$). There is also evidence showing that Waihī has lower species diversity than the remaining sites (p value $< 0.05$) (Table 5, Figure 13).

Table 5 Paired Wilcoxon diversity test for species diversity for all six locations between 1994-2024 where $p \leq 0.05$ depicts a significant statistical difference between sites

| | Greenwood Rd | Mangāti | Mānihi | Orapa | Tūrangi |
|---|---|---|---|---|---|
| Mangāti | 1.0 | - | - | - | - |
| Mānihi | **$2.3 \times 10^{-10}$** | **$1.9 \times 10^{-13}$** | - | - | - |
| Orapa | 1.0 | 1.0 | **$1.7 \times 10^{-12}$** | - | - |
| Tūrangi | 0.16451 | 1.0 | **$<2.0 \times 10^{-16}$** | 1.0 | - |
| Waihī | **0.00016** | **0.01873** | **$<2.0 \times 10^{-16}$** | **0.01087** | **0.03233** |

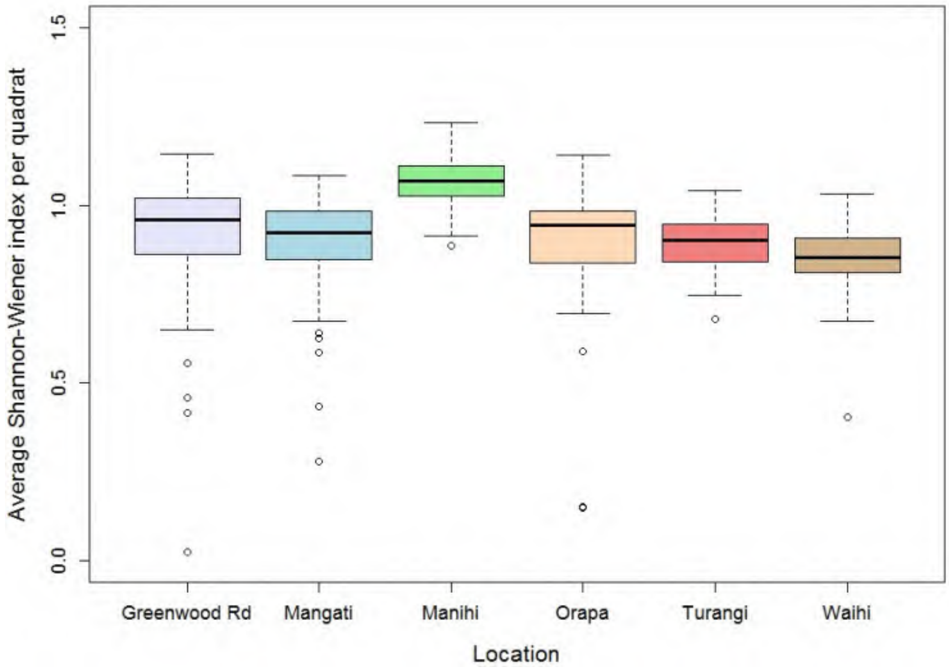


Figure 13 Average Shannon-Wiener Index per quadrat at all survey sites between 1994 and 2024

## 3.3 Long term trend analyses

Time series plots of average number of species per quadrat (species richness) and average Shannon-Wiener diversity index (species diversity) from 1994 to summer 2024 are shown in Figure 14 and Figure 15, respectively. Both parameters have experienced fluctuations over time at all monitored sites.

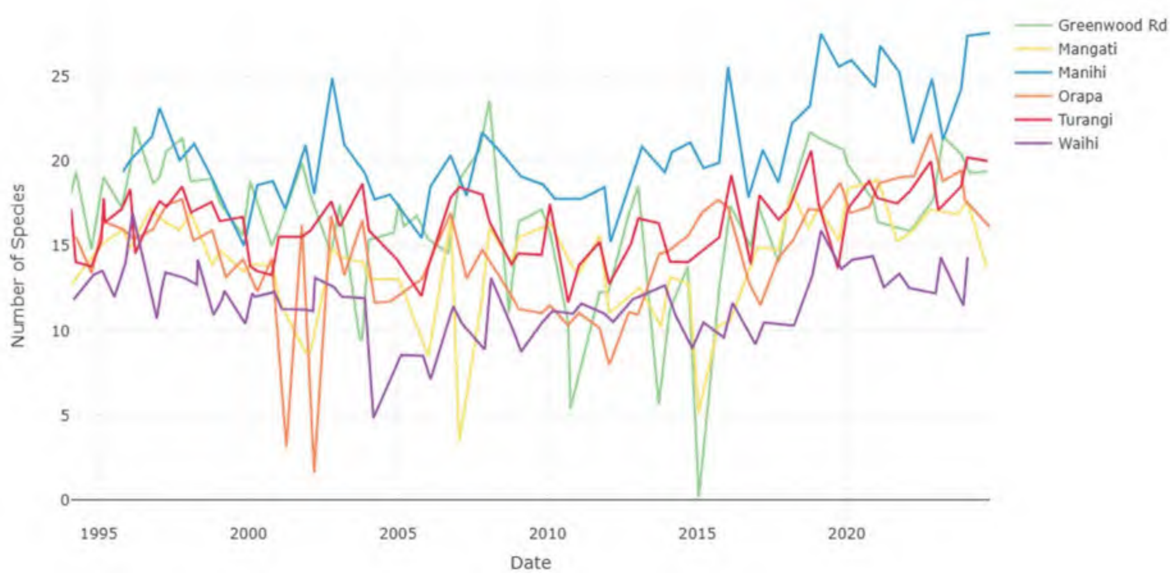


Figure 14 Average number of species per quadrat at each site between 1994 and 2024


Figure 15 Mean Shannon-Wiener Diversity Index per quadrat at each site between 1994 and 2024

Theil–Sen models were fitted to the time series to visually inspect for trends. On first inspection, species richness appears to have increased over time at most sites except for Waihī Reef (Figure 16). The most pronounced increase over time was observed at Mānihi Road Reef. While this increase in richness is seemingly matched by an increase in diversity at some sites, at others, such as Waihī, there has been no apparent increase in diversity in recent years (Figure 17).

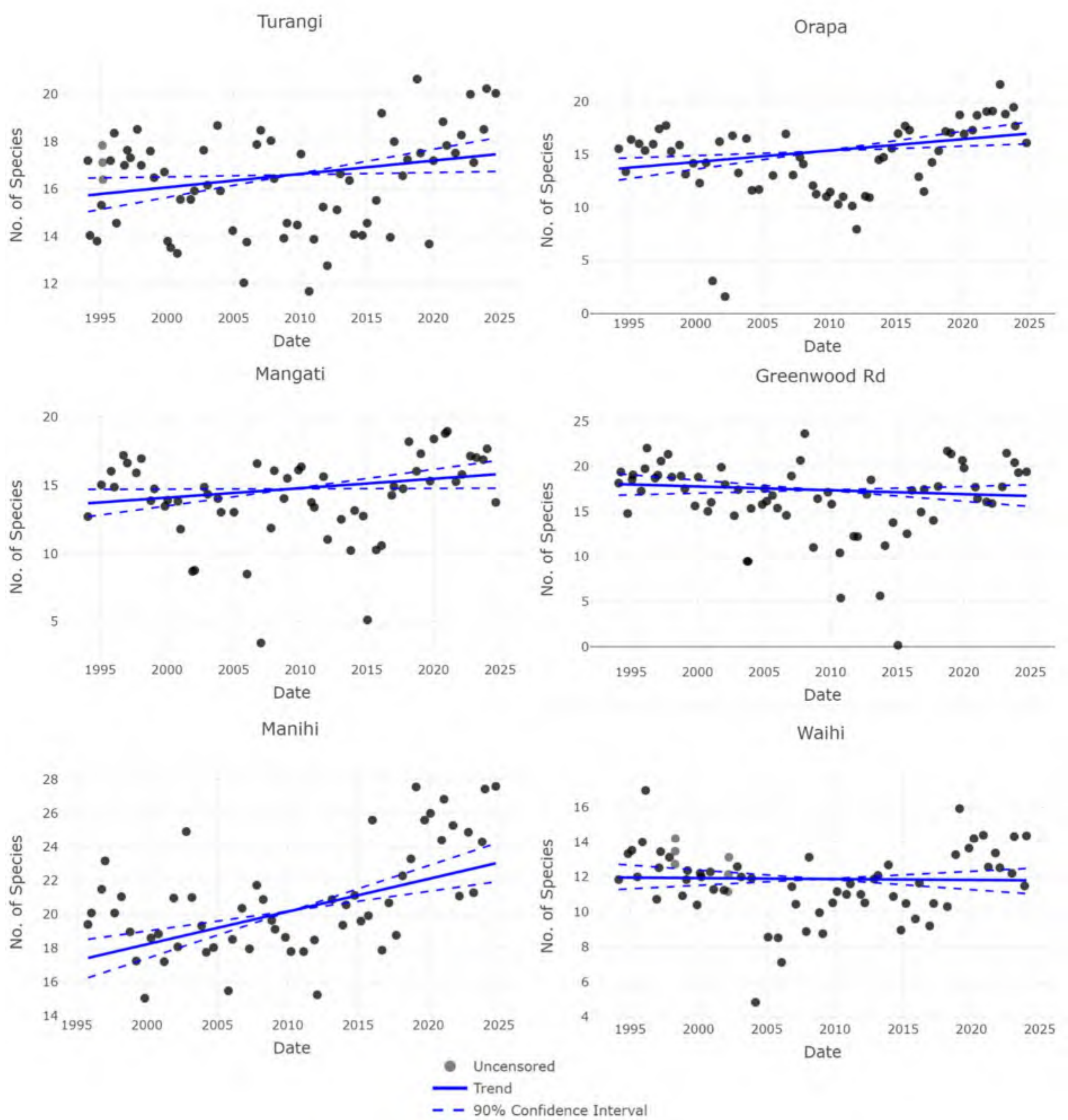


Figure 16 Time series of average number of species per quadrat (species richness) recorded at each site, for all surveys undertaken between 1994 and 2024. A Theil–Sen (Sen's) median slope line is overlaid to provide a robust, non-parametric estimate of the monotonic trend

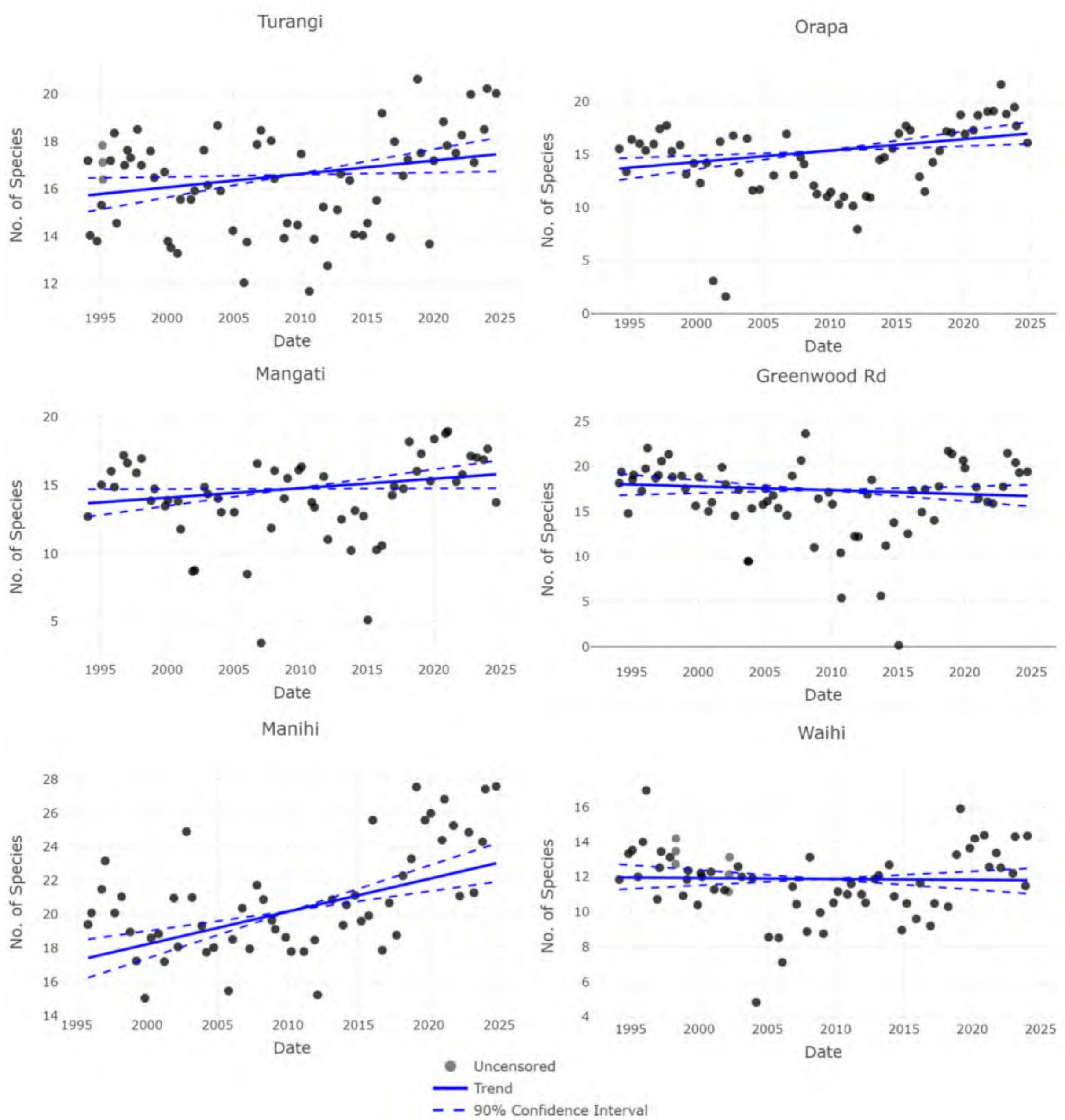


Figure 17 Time series of average Shannon Wiener Index per quadrat (species diversity) recorded at each site, from 1994 to 2024. A Theil–Sen (Sen's) median slope line is overlaid to provide a robust, non-parametric estimate of the monotonic trend

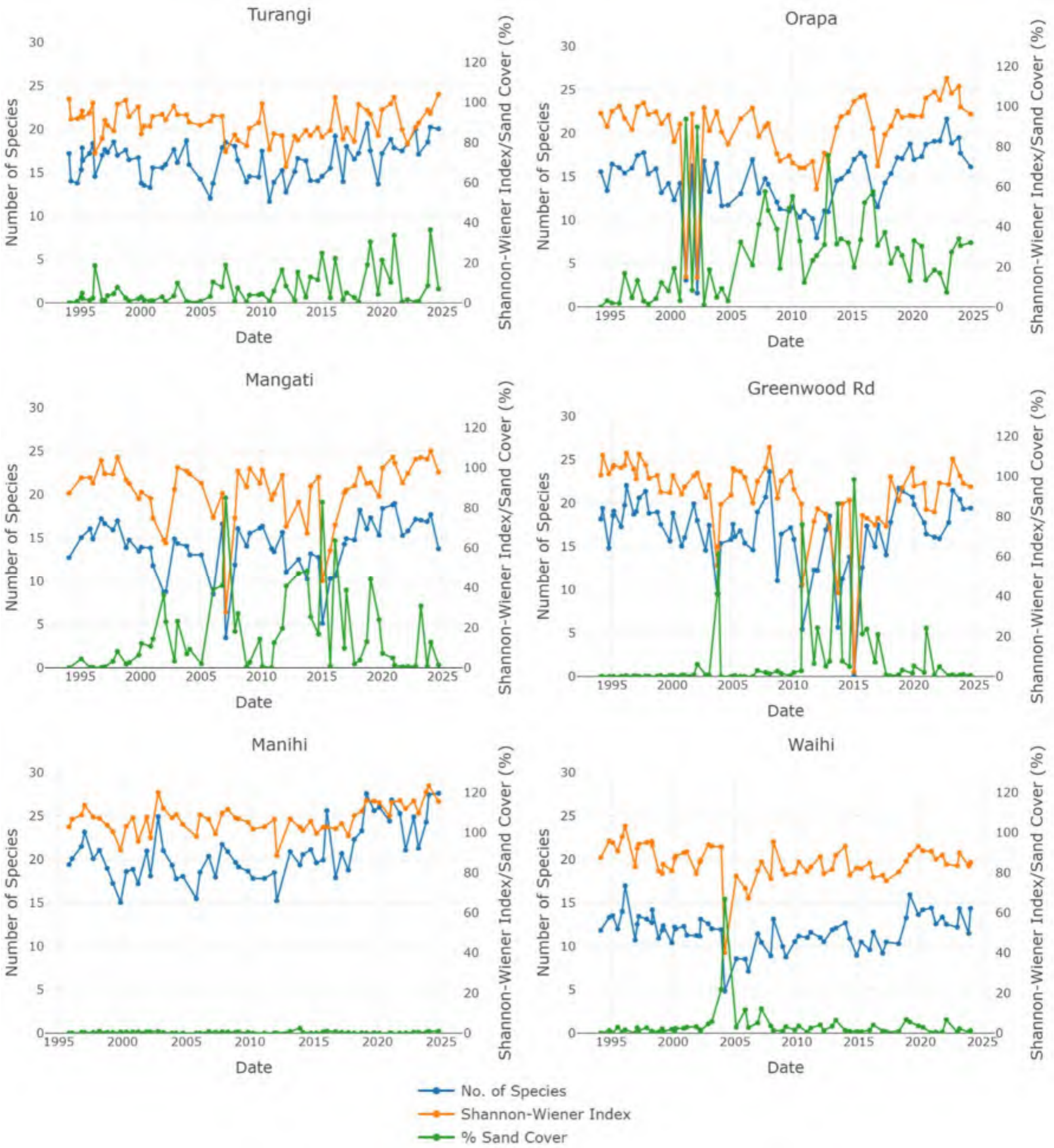


Figure 18 Number of species, Shannon-Wiener index and percentage sand cover at the six reef sites from 1994 to 2024

A comparison of sand cover with species richness and diversity shows that over the 30 years of the monitoring programme Orapa, Mangāti, Greenwood and Waihī have experienced periodic sand inundation events (Figure 18). It is apparent that surveys undertaken in periods of high sand accumulation are associated with lower species richness and diversity. In addition to discrete sand inundation events, there may be long-term changes in sand cover at some sites. Trend analysis found that long-term trends were highly likely increasing at Turangi (5.83% annual change), Orapa (3.63% annual change), and Greenwood Reefs (11.9% annual change), and very likely increasing at Mangati Reef (1.76% annual change) (Figure 19, Table 6). There does not appear to be an increasing or decreasing trend in long-term sand cover at Mānihi and Waihī reefs, where sand cover is typically lower.

The rate of change in these trends is expressed relative to the long-term median for each site based on the entire SoE monitoring record. Therefore, in real terms, the annual increase in sand cover is higher at sites with a higher median coverage, and lower at sites with a lower median coverage. This is shown by the slope and intercept of the trend lines in Figure 19.

Table 6 Key outputs of long-term trend analyses for mean observed sand cover at six SoE sites from 1994 to 2024

| Site | Median | Annual Sen Slope | Percent Annual Change | Direction | Likelihood |
|---|---|---|---|---|---|
| **Tūrangi** | 3.08 | 0.179 | 5.83 | Increasing | Highly likely (0.99) |
| **Orapa** | 22.5 | 0.817 | 3.63 | Increasing | Highly likely (0.99) |
| **Mangatī** | 8.66 | 0.152 | 1.76 | Increasing | Very likely (0.93) |
| **Greenwood** | 0.75 | 0.089 | 11.9 | Increasing | Highly likely (0.99) |
| **Mānihi** | 0.32 | 0.000 | 0.00 | Decreasing | Uncertain (0.58) |
| **Waihī** | 1.8 | 0.007 | 0.41 | Increasing | Uncertain (0.62) |

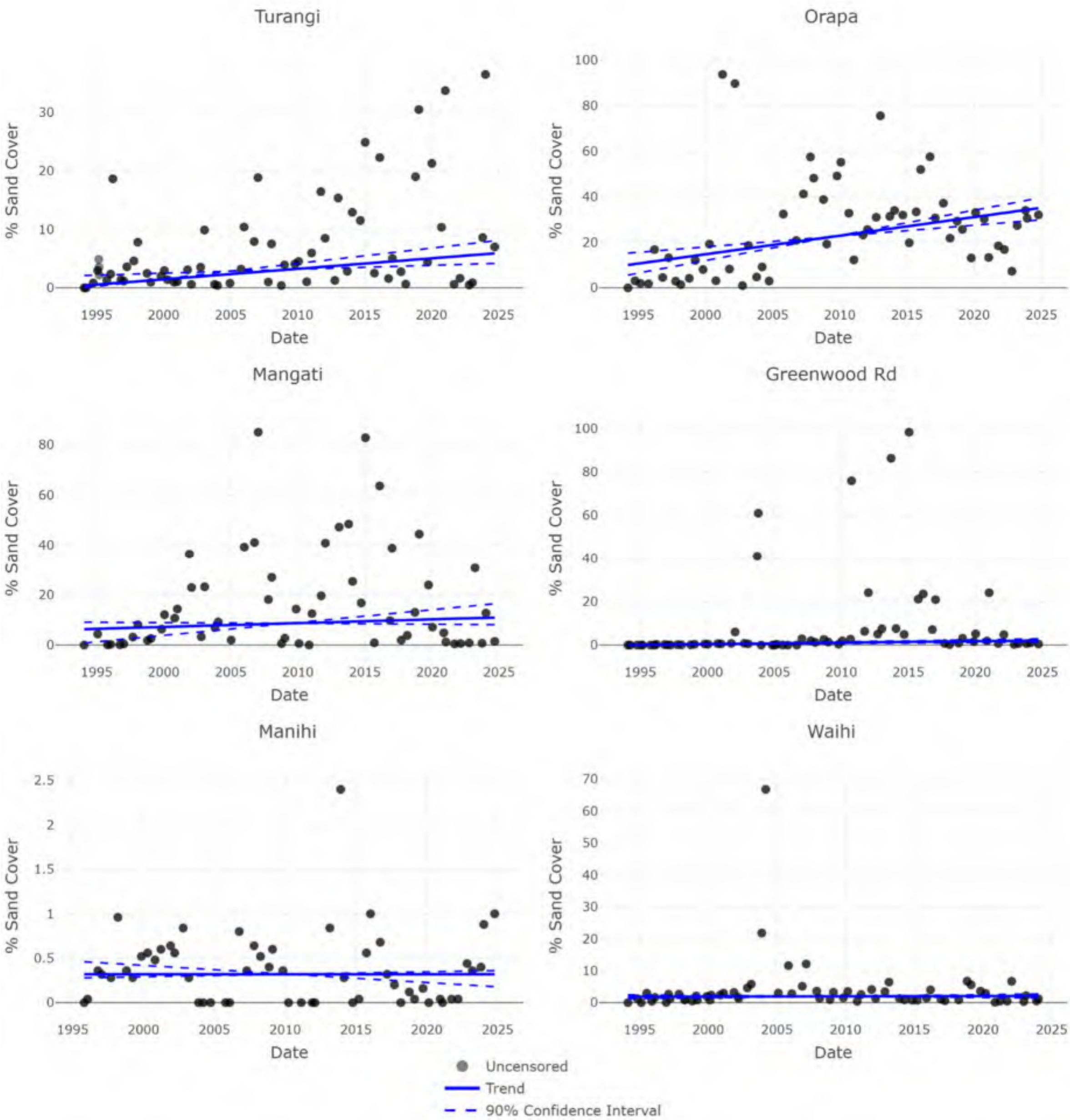


Figure 19 Time series of sand cover % at each site, between 1994 and 2024

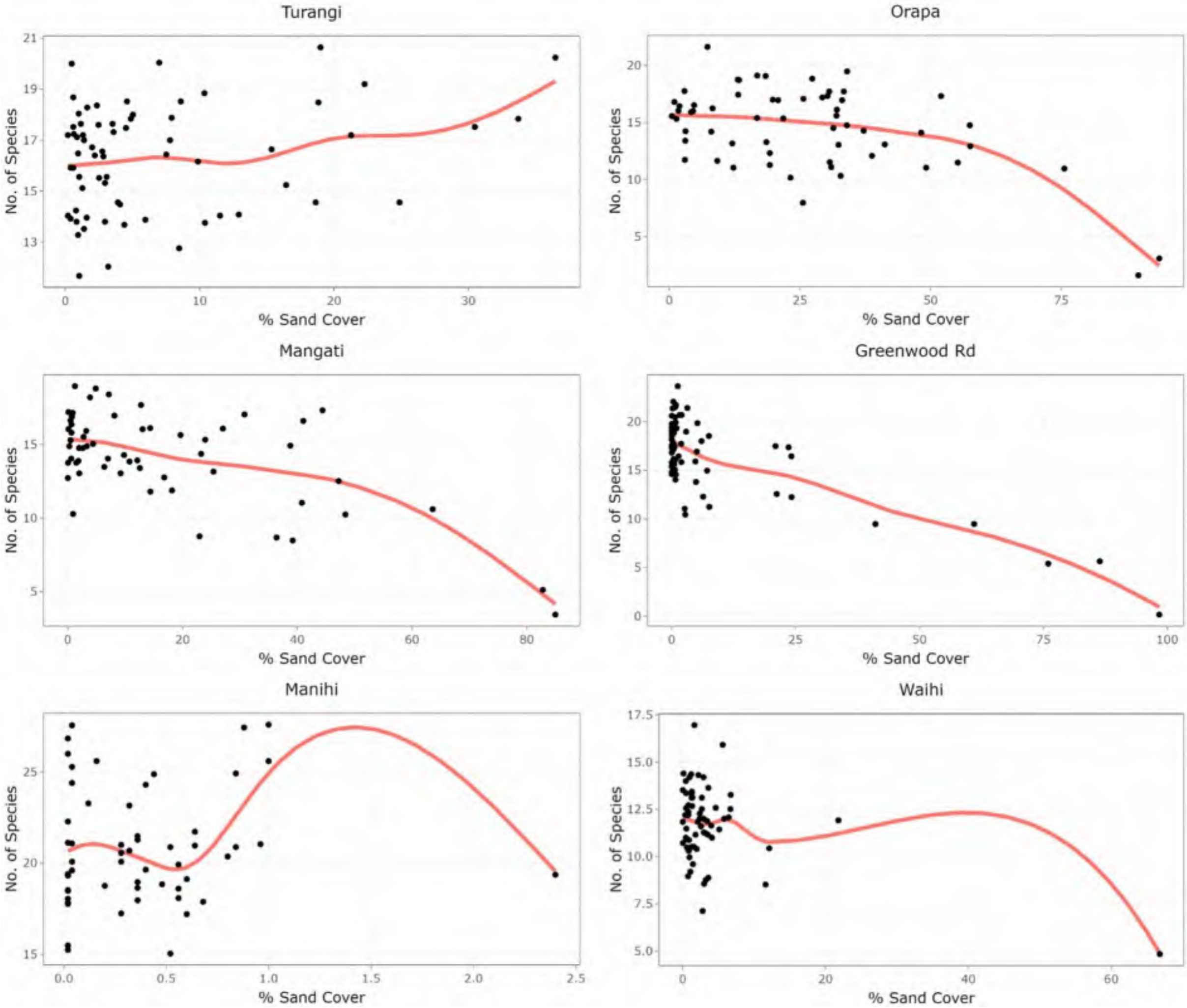


Figure 20 Sand cover vs mean number of species recorded per quadrat, at each site, for the full 30 years of monitoring. GAM models are used to estimate the relationship between the two variables at each site, and to adjust data for sand cover

The relationship between sand cover and species richness at each site is shown in Figure 20. Above a certain threshold of sand cover (which is different for each site), species richness is negatively impacted. While it appears this threshold has not been reached at the Tūrangi and Mānihi sites, the other four sites show instances in which sand cover has impacted species richness. The relationship between sand cover and Shannon-Wiener (species diversity) at each site is shown in Figure 21.

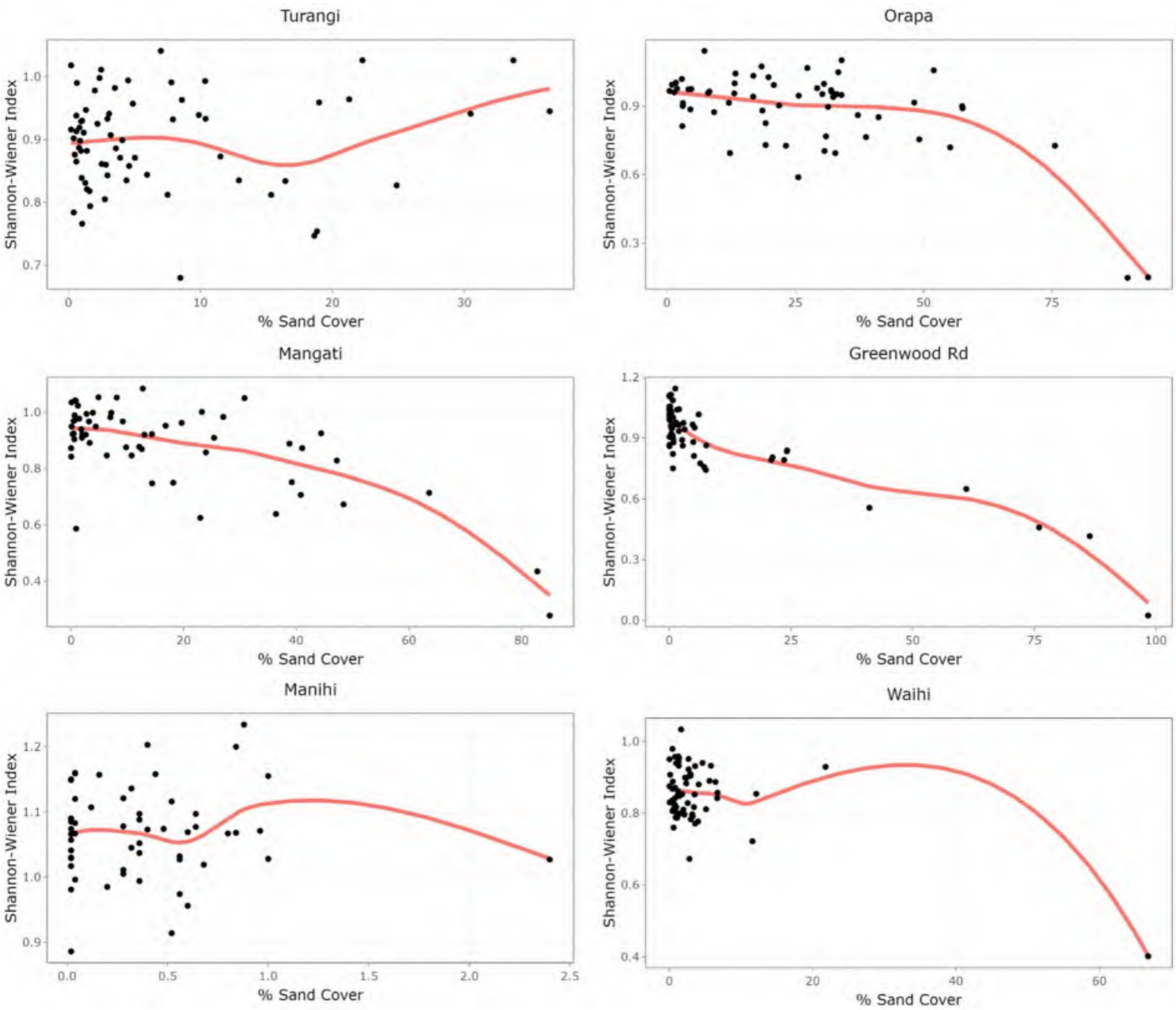


Figure 21 Sand cover vs mean Shannon-Wiener Index recorded per quadrat, at each site, for the full 30 years of monitoring. GAM models are used to estimate the relationship between the two variables at each site, and to adjust data for sand cover

Based on the relationships observed between sand cover, mean number of species and Shannon-Wiener diversity index (Figure 18, Figure 20 and Figure 21), sand adjusted trend analyses were performed for all sites except for Mānihi Reef. The purpose of assessing the sand-adjusted datasets at these sites was to examine the underlying long-term trends of these rocky shore communities that may be influenced by factors other than observed sand cover. The results of the Mann-Kendall trend analyses are provided in Table 7.

The analyses found that long-term trends in the mean number of species were highly likely increasing at Orapa (0.81% annual change), Mangatī (0.63% annual change), and Mānihi (0.96% annual change). Long-term trends in the mean number of species were likely increasing (i.e., increasing with less statistical confidence in the trend direction) at Tūrangi (0.18% annual change) and Greenwood Road (0.13% annual change). At Waihi Reef, the long-term trend in the mean number of species was likely decreasing (-0.11% annual change). The rate of change in these trends is expressed relative to the long-term median for each site based on the entire SoE monitoring record. This can be translated to the following:

- the mean number of species recorded at Orapa Reef is highly likely increasing by one every eight years.
- the mean number of species recorded at Mangatī Reef is highly likely increasing by one every 11 years.
- the mean number of species recorded at Mānihi Reef is highly likely increasing by one every five years.

- the mean number of species recorded at Tūrangi Reef is likely increasing by one every 35 years.
- the mean number of species recorded at Greenwood Reef is likely increasing by one every 45 years.
- the mean number of species recorded at Waihī Reef is likely decreasing by one every 77 years.

For the Shannon-Wiener diversity index, the analysis found that long-term trends were highly likely increasing at Orapa (0.38% annual change), Mangatī (0.35% annual change) and Mānihi (0.27% annual change). Long-term trends were highly likely decreasing at Greenwood (0.19% annual change) and Waihi reefs (0.23% annual change). At Tūrangi Reef, the long-term trend in the mean number of species was likely decreasing (0.17% annual change). The rates of change associated with these trends are very similar to those observed in the trends for mean number of species.

Table 7 Key outputs of long-term trend analyses for mean number of species and Shannon-Wiener Diversity Index at six SoE sites from 1994 to 2024

| Site | Variable | Median | Annual Sen Slope | Percent Annual Change | Trend Direction | Likelihood |
|---|---|---|---|---|---|---|
| **Tūrangi** ***sand-adjusted*** | **No. species** | 16.6 | 0.0300 | 0.18 | Increasing | Likely (0.86) |
| | **SW index** | 0.90 | -0.0015 | -0.17 | Decreasing | Likely (0.89) |
| **Orapa** ***sand-adjusted*** | **No. species** | 15.3 | 0.1241 | 0.81 | Increasing | Highly likely (0.99) |
| | **SW index** | 0.94 | 0.0036 | 0.38 | Increasing | Highly likely (0.99) |
| **Mangatī** ***sand-adjusted*** | **No. species** | 14.8 | 0.0936 | 0.63 | Increasing | Highly likely (0.99) |
| | **SW index** | 0.92 | 0.0032 | 0.35 | Increasing | Highly likely (0.99) |
| **Greenwood** ***sand-adjusted*** | **No. species** | 17.4 | 0.0233 | 0.13 | Increasing | Likely (0.70) |
| | **SW index** | 0.96 | -0.0018 | -0.19 | Decreasing | Highly likely (0.97) |
| **Mānihi** ***unadjusted*** | **No. species** | 20.2 | 0.1931 | 0.96 | Increasing | Highly likely (0.99) |
| | **SW index** | 1.07 | 0.0029 | 0.27 | Increasing | Highly likely (0.99) |
| **Waihī** ***sand-adjusted*** | **No. species** | 11.9 | -0.0126 | -0.11 | Decreasing | Likely (0.73) |
| | **SW index** | 0.85 | -0.0020 | -0.23 | Decreasing | Highly likely (0.98) |

For reference, unadjusted trends are presented alongside the sand-adjusted trends in Appendix III. Of the 10 applicable comparisons, there was only one instance where trend direction differs between the datasets. At Greenwood Road, the mean number of species is likely increasing based on the sand-adjusted data, and likely decreasing based on the unadjusted data. There were six instances where the confidence in trend direction was greater based on the adjusted dataset, two instances where it was lower, and one instance where there was no change. The rates of annual change in both sets of long-term trends were comparable. Therefore, although there is a relationship between sand cover and the species richness and diversity observed at these sites, in most cases it does not appear to be having a significant influence on the current long-term trends.

# 4. Discussion

The main findings from this report, which includes all SoE survey data collected up until 2024, are summarised below:

- Differences in species richness and diversity across sites during the 2019-2024 monitoring period reflected those seen over the entire duration of the monitoring programme.
- Mānihi Reef remained significantly more species rich and diverse than any other site, and Waihī Reef was significantly less species rich and diverse than any other site.
- Analysis of coverage and abundance of key intertidal reef species highlighted differences between sites, likely related to key environmental factors.
- While in the previous reporting period seagrass (*Zostera capricorni*) was found at Orapa and Mangatī reefs, during the 2019 to 2024 period, seagrass was only recorded at Orapa Reef. Further research is needed to characterise the extent of seagrass in Taranaki and monitor changes over time.
- Long-term trend analyses found evidence that when adjusting for sand cover, the mean number of species per quadrat was highly likely increasing at three sites, likely increasing at two sites, and likely decreasing at one site. Nevertheless, despite the analyses showed statistically significant evidence of long-term trends, the rate of change was very low at three sites, including the declining trend at Waihī Reef. The rate of change was highest at Orapa, Mangatī and Mānihi Reefs equating to 0.63 – 0.96% annual change based on the long-term median. This translates to the mean number of species recorded at these sites increasing by one every five to 11 years.
- Long-term trend analyses also evidenced that when adjusting for sand cover, the mean Shannon-Wiener diversity index was highly likely increasing at three sites, highly likely decreasing at two sites, and likely decreasing at one site. The associated rates of change were comparable to what was observed with the mean number of species.
- Long-term trend analyses of observed sand cover found evidence of highly likely increasing trends at the four northernmost sites (Greenwood Road, Mangatī, Orapa and Tūrangi reefs). No likely trends were observed at the remaining two sites (Waihī Reef and Manihi Reef).
- A negative relationship was demonstrated between sand cover and the ecological measures of richness and diversity at the same four northernmost sites. However, when comparing the sand-adjusted and unadjusted trend analyses, observed sand cover did not appear to be having strong influence on the current long-term trends for species richness or diversity at most sites (i.e., similar results were seen using both datasets). Greenwood Road was the one exception to this, where sand cover appears to be negatively influencing the long-term trend in the mean number of species.
- It is possible that changes in sand cover may be influencing trends in species richness and diversity indirectly, in ways that are not readily observable (e.g., through reductions interstitial and under boulder habitat where observed sand cover can still be low). The relationship between sand and rocky shore communities is discussed further in the next section.
- Overall, rocky shore communities at these six locations around the Taranaki coastline have remained relatively stable over the 30-year monitoring record, with short-term influence of occasional sand inundation events. There is statistical evidence of increasing and decreasing long-term trends in species richness and diversity at all sites. However, based on the associated rates of change, the most meaningful trends are the increases in species richness and diversity observed at Mānihi, Orapa and Mangatī Reefs.

There are several factors, both abiotic and biotic, which can influence the diversity and composition of intertidal rocky reef communities. However, in this local context, it is a subset of these factors which appear to be significantly influencing patterns in intertidal communities across sites and over time. These factors are discussed in the following sections.

## 4.1 Sand

Sand deposition has been shown to have profound effects on intertidal hard-shore communities in Taranaki (Walsby, 1982). The presence of high quantities of sand results in reduced diversity due to sand scour and temporary sand burial (Walsby, 1982; Airoldi et al., 1996; Howes et al., 2000). Sand scour impacts on reef organisms causing removal from the substrate, physiological stress and increased metabolic demand (Airoldi et al., 1996; Howes et al., 2000). Sand inundation results in reduced light, oxygen and food availability (Airoldi et al., 1996; Howes et al., 2000). Mānihi Reef, the SoE site with lowest average sand cover (<1%), consistently had the highest species richness and diversity of all six reef sites (Figure 12 and Figure 13). In contrast, the Greenwood (Photo 1), Mangatī and Orapa sites have all been subjected to sporadic heavy sand inundation (Figure 18), which has resulted in dramatic short-term effects on species richness and diversity.

Photo 1 Greenwood Road Reef inundated with sand on 23 January 2015 (left) and with low sand cover on 30 September 2024 (right)

Encrusting and non-motile organisms are particularly susceptible to smothering and burial during heavy sand inundation, often resulting in death. Motile organisms are better designed to cope, with some species shown to escape heavy sand accumulation altogether. For example, pāua escape heavy sand cover by moving into deeper waters (Howes et al., 2000). At the SoE survey sites, motile gastropods (including snails and limpets) have been observed aggregating on larger rocks which protrude above the sand (Photo 2). Such responses may aid rapid recovery of the reefs post sand inundation, with reefs typically recovering within a year or two providing sand accumulation does not persist.

Photo 2 *Lunella smaragda* (left), and *Cellana radians* (right), aggregating on protruding rocks during sand inundation of the reef

Unlike at Greenwood Road, Tūrangi, Mangatī and Orapa typically retain higher levels of sand between the short-lived inundation events (Figure 18). As a result, the average sand cover recorded between 2019 and 2024 at Tūrangi, Orapa, and Mangatī was 13%, 23.5% and 10.8%, respectively, while it was just 3.7% at Greenwood Road (Figure 8). This persistent sand coverage has had demonstrable effects on the biota that occur at these sites. The green chiton, *C. glaucus* and porcelain crab, *P. elongatus* are two species which exist in the spaces beneath and between boulders rocks and cobbles. While *C. glaucus* grazes on the biofilms growing on rock surfaces, *P. elongatus* filter feeds from the water in the interstitial spaces. Of all six SoE sites, these two species were least abundant at Mangatī and Orapa, and this is most likely due to sand filling the spaces beneath and between the hard substrates; reducing the amount of available habitat (Figure 14). Conversely, other species appear resilient to the elevated sand coverage. For example, Mangatī and Orapa were two of four sites with the highest average coralline turf cover (Figure 8). Other species even appear to thrive on the increased sediment availability. Seagrass (which relies on an optimal supply of sediment to form root mats) has only been recorded within the Orapa survey site between 2019–2024, while the sandy tube worm, *N. kaiparaensis* (which also requires sediment for tube formation), has a significantly higher average cover at Orapa than at any other site (Photo 3, Figure 8).

Photo 3 Dense seagrass patches (left) and *N. kaiparaensis* colonies (right) on Orapa Reef

The main sources of sand to the Taranaki coastline comes from rivers, streams and eroding cliffs (Matthews, 1977; Cowie, 2009). In North Taranaki one source has provided an increase in sand supply to the coastline since the late nineties. In 1998, a scarp at the headwaters of the Hangatāhua River collapsed, leading to a massive input of sand and gravel down the river and into the coastal system (Photo 4). Erosion has been ongoing since 1998, including another significant event which occurred in 2008. These erosion events have been linked to a possible increasing trend in storm intensity, based on increasing flood peaks observed in stream flow monitoring data (Betts et al., 2010). Prior to 1998, the coastline extending from Cape Egmont to Ōakura was described as 'sand starved' being mainly comprised of cobble and boulder beaches and reefs. Since 1998, this influx of black sand derived from Mount Taranaki has been transported along the coast in a north easterly direction resulting in beach sediment nourishment. What were previously cobble and boulder beaches have now changed to sandy beaches (Cowie, 2009).

Boulder reefs along the North Taranaki coastline have also been affected by this increase in sand supply, with an increased likelihood of sand inundation. Large volumes of sand wash ashore at times when there are persistent long-period swells combined with prolonged calm periods with no storms (McComb pers. comm, 2015). Trend analyses suggest that an increase in these conditions, together with a greater sand supply from the mountain, may have impacted reef species richness and diversity at certain sites (Figure 16, Figure 17 and Figure 18). Analysis of sand cover data found increasing trends at four sites, all located north of the Hangatāhua River (Figure 19).

The current long-term trends in sand cover show an annual increase of 3.63% at Orapa Reef, 1.76% at Mangāti Reef, 11.9% at Greenwood and 5.83% at Tūrangi Reef. However, these increases are related to the overall median coverage at each site. Therefore, sites with higher median sand coverage (e.g., 23.5% at Orapa Reef) see bigger increases in sand cover compared to sites with lower median sand coverage (e.g., 3.7% at Greenwood Reef). The comparatively low overall increase in sand cover at Greenwood Road suggests that it is the frequency and magnitude of the discrete inundation events that is influencing the decrease in species richness at this site, rather than a gradual accumulation of sand over time. Whilst the trend analyses do not provide clear evidence of observed sand cover influencing the Shannon-Wiener diversity index at this site, it is possible that the periodic inundation events are having lasting effects on under-boulder habitat complexity that are not reflected in observed sand cover. The comparatively lower numbers of *C. glaucus* and *P. elongatus* recorded at the three sites most impacted by periodic sand inundation events provide some evidence of reduced under-boulder habitat (Figure 8). Under-boulder habitat is discussed further in Section 4.3. Gradual accumulation of sand appears to be occurring at the Orapa and Mangatī sites, however, the current levels of sand coverage at these sites have not yet reached the threshold at which significant declines in species richness and diversity occur (although this threshold has been temporarily exceeded during historic inundation events as shown in Figure 18).

It is important to note that just as natural processes deliver sand to intertidal reef habitats, the same processes are also responsible for taking it away. Therefore, sand supply and oceanographic conditions will continue to play an important role in shaping Taranaki's rocky reef communities into the future.

Photo 4 Pyramid Stream gully, at the headwaters of the Hangatāhua River: a major source of sand to the North Taranaki coastline

## 4.2 Wave exposure

On rocky shores in general, the extent of wave exposure can have a dramatic influence on species composition. Waves eliminate organisms that cannot withstand strong wave action, either by preventing settlement, or by limiting growth once settlement has occurred (Little *et al*., 2010). All six of the Taranaki SoE reef sites can be described as exposed and this is reflected in the community composition at these sites. Encrusting and geniculate coralline algal species (referred to as coralline paint and turf respectively) typically dominate all the Taranaki sites, with these species being more tolerant to drag forces and sedimentation compared to larger seaweed species. Herbivorous gastropod species, including *D. aethiops* and *L. smaragda*, are abundant, in part due to the low abundance of predators in exposed areas (Little *et al*., 2010).

Differences in wave exposure between the Taranaki reef sites, related to the location and topography of each reef, can significantly affect the diversity of the communities at those sites. Due to the prevailing wave climate and nearshore bathymetry, wave energy is generally higher in western Taranaki and decreases with distance in both directions around the coastline (northeast towards New Plymouth and southeast towards Hawera). In addition to location on the coast, reef morphology can also be an important factor determining a site's level of wave exposure. Specifically, intertidal reef sites are exposed to higher wave forces when the angle of wave approach is direct, or 'head on', when the seaward reef slope is steeper, and when there are less obstacles in the path of the wave approach (Helmuth and Denny, 2003).

Given its location and relatively steep and short gradient, Waihī Reef appears to be the most exposed of the six sites monitored. Photographic evidence indicates that relatively large boulders at this site shift in position from one survey to the next. Wave exposure is likely to be the main factor resulting in lower species richness at Waihī relative to other Taranaki reef sites. Community composition at this site reflects the exposed conditions with coralline paint and encrusting animals dominating (Photo 5, Figure 8). Trend analysis found evidence of declining trends in both species' richness and diversity at this site, unrelated to sand cover (Figure 18). It is possible that this declining trend is related to a change in wave exposure over time however, further investigation is required before this can be attributed as a causal factor.

Orapa Reef appears to be one of the least wave exposed sites, due to its location in North Taranaki, as well as the considerable seaward reef extent which effectively dissipates the incoming wave energy. This is reflected by the intertidal community that inhabits the reef, in particular, the presence of seagrass (Figure 8). In addition to the sediment requirement mentioned in the previous section, seagrasses are also better suited to more sheltered environments, hence why in New Zealand they are most typically found in estuaries, harbours and embayments (Anderson et al., 2019). Therefore, the considerable extent of seagrass at Orapa suggests that the intertidal reef platform provides an adequate level of shelter.

## 4.3 Other factors affecting habitat complexity

Habitat complexity is an important factor resulting in differences in diversity between the reef sites in Taranaki. Although it is intrinsically linked to sand cover and wave exposure, other geomorphological and biotic factors can also influence habitat complexity.

Photo 5 Contrasting habitat between the exposed Waihī site (left) and stable Mānihi site (right)

At Tūrangi, Orapa and Mangāti, previously free rock and cobble has been found locked, or 'cemented', in place with sand and rubble. These cemented substrates do not provide under-boulder habitat, and this reduction in habitat complexity can result in decreased species richness and diversity. Moreover, interstitial sediments between the cemented substrates often become anoxic, rendering them unsuitable even to organisms that are otherwise adapted to these habitats (e.g. some worms and bivalves). Although substrates are not often cemented in place at Waihī Reef, the high proportion of large rocks and boulders may also lead to lower estimates of species diversity at the site. This is because under-boulder biota can only be surveyed where the substrate is easily overturned; where there is a higher proportion of large rocks and boulders, there may be more instances where those substrates cannot be overturned and surveyed. Conversely, the geomorphology of the Mānihi Reef site comprises very little cemented reef, and a broad range of substrate sizes. This habitat heterogeneity ultimately provides many different ecological niches for a large variety of species to occupy, with habitats including stable pools, under-boulder habitat and crevices within rocks (Photo 5).

Biotic factors have also been shown to have considerable effects on habitat complexity at Orapa. When large colonies of the sand tube worm *N. kaiparaensis* build up over the reef, the diversity of microhabitats available for other species can be significantly reduced (Figure 22). Although these tube worm mounds may provide cryptic habitat for small invertebrates between the tubes and mounds, this habitat provision does not compensate for the decrease in species diversity that occurs due to the reduction in under boulder, above boulder and pool habitat. Furthermore, any increases in species diversity that may be attributed to the tube worms can only be realised if the animals are visible and large enough to be recorded in the survey (i.e., the animals are larger than 3mm). Accordingly, increases in tube worm cover in recent years have corresponded to considerable declines in diversity at Orapa (Figure 22). Notably, the changes in *N. kaiparaensis* cover that have occurred in recent years corresponded to pronounced, contrasting changes in species diversity. For future analyses, multivariate statistics are recommended to objectively assess the proportional influence of sand tube worm colonies on species diversity at this site compared to other factors (e.g., sand cover).

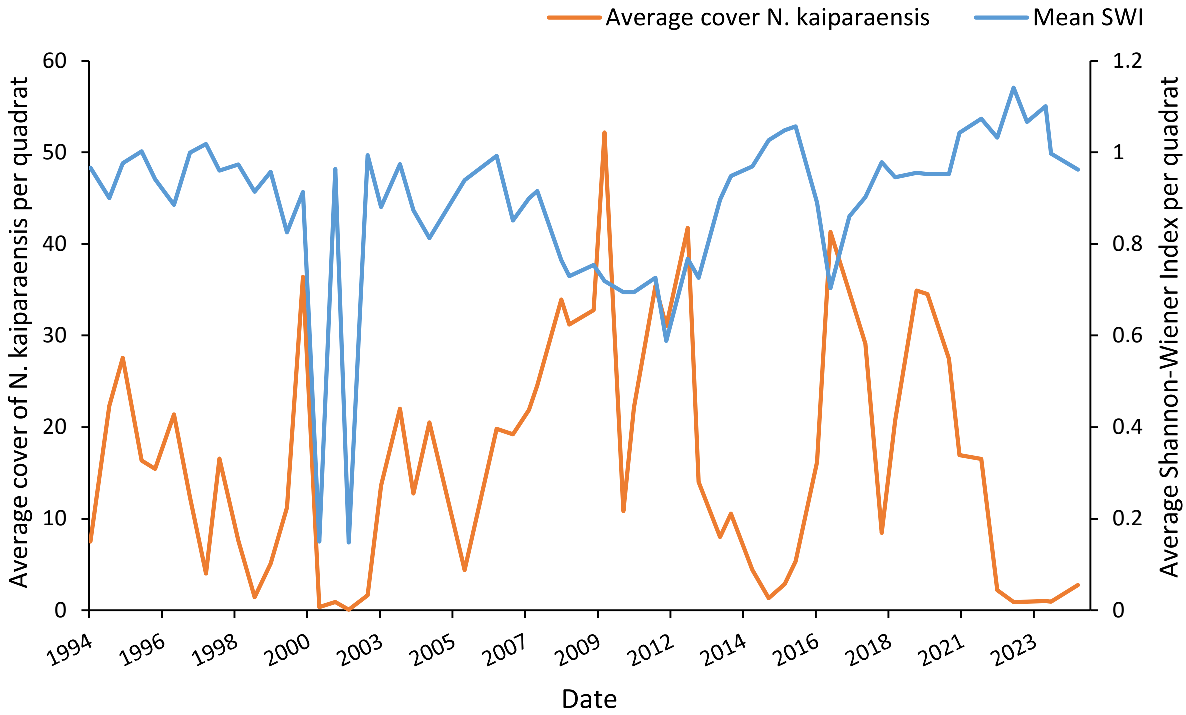


Figure 22 Average cover of *N. kaiparaensis* and average Shannon-Wiener Index over time at Orapa Reef

## 4.4 Anthropogenic factors

The diversity and composition of intertidal communities at the SoE reef sites are largely driven by the natural physical factors discussed thus far i.e. the effects of sand and sediment cover, wave exposure and geomorphology. As a result of these overriding natural drivers, underlying subtle ecological changes resulting from human activities can be difficult to detect (Clark *et al.*, 2013). However, more noticeable impacts that may arise can be evident. For example, prior to 1997, dairy factory wastewater discharged through the nearshore outfall off the Hawera coastline was having significant adverse effects on the local intertidal community. This was clearly detectable in the results of the intertidal surveys undertaken as part of the consent compliance monitoring programme for the discharge (TRC, 2014). In 1997 the dairy company installed a long outfall to discharge the wastewater nearly 2km offshore. This resulted in a stepwise improvement in intertidal species richness and diversity at the sites affected by the previous discharge. No such noticeable anthropogenic impacts have been detected at any of the SoE reef sites.

Except for Orapa and Mangāti, the SoE reef sites are located outside of the influence of wastewater discharges (in the case of Orapa, the nearby wastewater outfall is now only used as a contingency measure during rare, high rainfall events). Norovirus analysis of mussels collected from Orapa and (close to) Mangātī indicate that previously these sites have had shoreline contact with wastewater discharged from the Waitara and New Plymouth wastewater treatment plants, respectively. Although there is evidence that these wastewater discharges have resulted in microbial contamination of shellfish at these sites, adverse impacts of the wastewater discharges on intertidal species richness and diversity have not been detected through the associated consent compliance monitoring programmes.

Erosion on land increases the amount of fine sediment that is transported to the coast via rivers and streams. This sediment can have a range of adverse effects on the coastal environment, including effects on water quality and near-shore rocky reef communities. Since European settlement, increased land development has led to some catchments becoming more erosion prone, resulting in more sediment being transported to the coast. In Taranaki, sediment loads in many of the region's larger rivers have been estimated to be two to six times higher than in their predicted natural state (Robertson, 2019).

Average annual sediment loads discharged to the coast have recently been estimated using SedNetNZ under baseline and future scenarios accounting for soil conservation measures and potential impacts of climate change (Neverman et al., 2021, Neverman and Smith, 2023). The modelling highlights the gains that have likely been achieved through implementation of soil conservation measures such as riparian fencing, planting and space planting and scrub reversion of steep slopes. The measures that had been implemented at the time the model was developed in 2018 were estimated to have achieved a 29% reduction in the overall average annual sediment load discharged to the coast compared to the pre-mitigation baseline (Neverman et al., 2021). The modelling also highlights the further sediment load reductions that can be achieved with completion of planned soil conservation works (Neverman et al., 2021). However, increased storm intensity and frequency based on recent climate change projections may also lead to an increased likelihood of mass erosion events which may create additional challenges for managing sediment loads in the future (Neverman and Smith, 2023).

The effects of fine sediment on coastal water quality vary throughout the region due to fundamental differences between river catchments (including size, geology and land class). When standardised by catchment area, SedNetNZ sediment load estimates clearly demonstrate how the sediment loads generated in steep, erosion prone hill country catchments are generally much higher than those generated in volcanic ring plain catchments (TRC, 2024). In North Taranaki, a gradient of turbidity in coastal waters has been demonstrated, increasing from Cape Egmont to Waitara/Motunui (Crofskey, 2007). This gradient has been largely attributed to the high suspended sediment loads that are delivered to the coast by the Waitara River.

Humans can also have localised impacts on intertidal rocky reef communities when exploring rock pools and collecting kaimoana species (i.e., pāua and kina). Specifically, these communities can be adversely affected when rocks and boulders are overturned and not returned to their original position afterwards. Algal species are generally found attached to the top side of these substrates as they require light to photosynthesise, whereas many invertebrate species are found on the underside of rocks and cobbles to remain sheltered and avoid predation. Therefore, when exploring the reef, rocks must be turned back over to how they were found to preserve these intertidal communities. Although this issue has not been associated with the sites in this monitoring programme, it has been observed at various locations around Taranaki, typically lower down the intertidal zone where pāua and kina are gathered.

After increasing concerns from mana whenua followed by public consultation, a customary rāhui under section 186A of the Fisheries Act 1996 requested by Taranaki iwi and hapū was established along the Taranaki coast between Herekawe stream in New Plymouth and Taungatara stream in Ōpunake in December 2022 (Figure 23). In December 2024, the rāhui was extended until 15 December 2026. These protection measures temporarily close a vast area Western Taranaki to the take of shellfish (excluding rock lobster), seaweed (except beach cast seaweed), sea anemones, stingrays, and two species of conger eel (*Conger wilsoni* and *Conger verreauxi*). Two SoE monitoring sites (Greenwood Road and Mānihi Road reefs) are located within the rāhui area. Long-term data sets from this monitoring programme could shed light on potential effects of the rāhui on species richness and diversity at these sites.

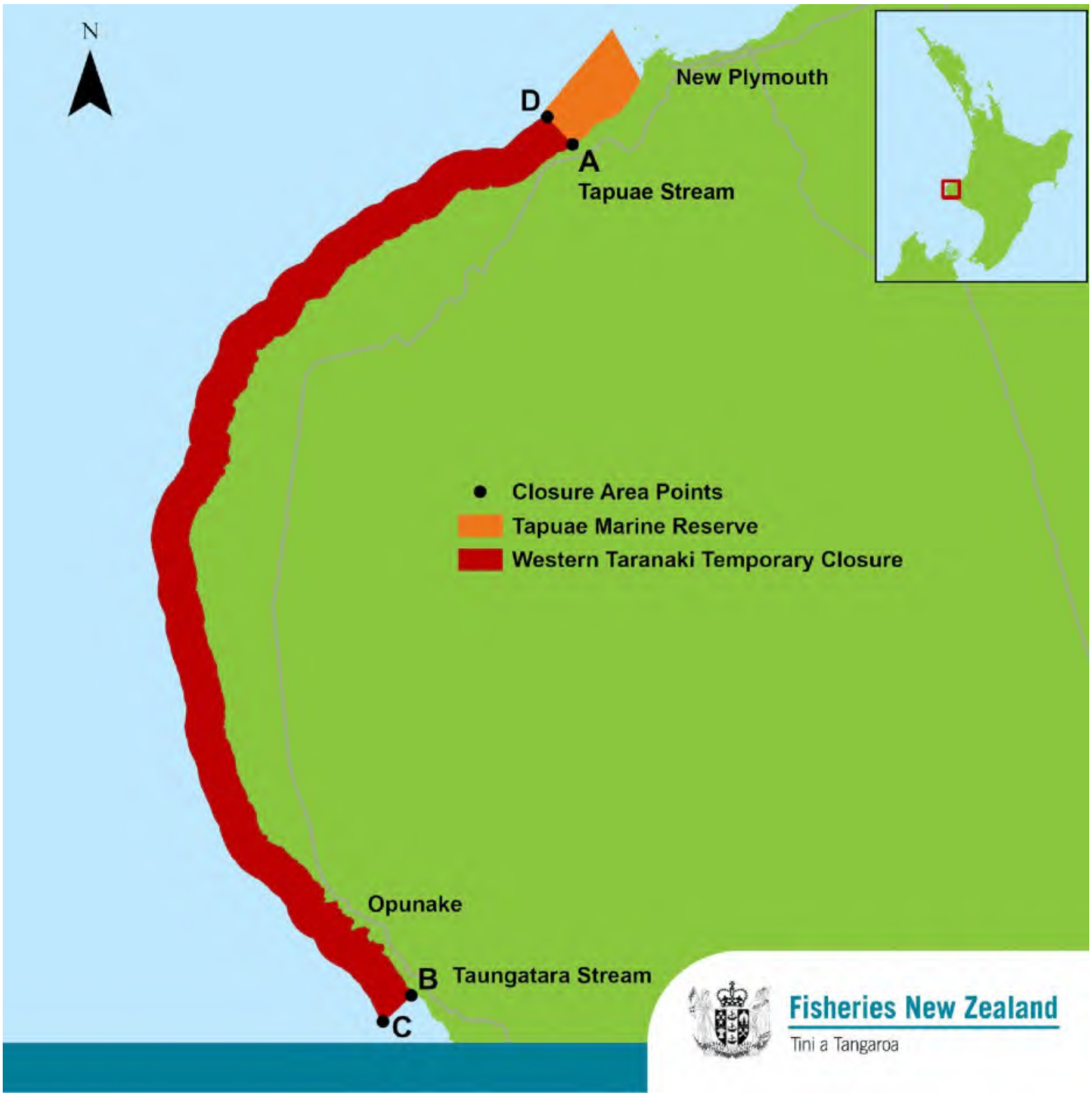


Figure 23 Area of customary rāhui in place since December 2022 until December 2026

The impacts of climate change on intertidal rocky reef habitats are also likely to increase in the future. In some instances, these impacts may exacerbate existing processes. For example, more frequent, intense rainfall events could accelerate erosion in the headwaters of the Hangatāhua River (and elsewhere in the region), introducing more sand to the coast which may eventually be deposited on rocky reef habitat (Cowie, 2009, Betts et al., 2010 and Neverman and Smith, 2023). Other facets of climate change may have a more selective effect on rocky reef communities. For example, the intertidal species that are most resilient to heat and desiccation stress may be better suited to cope with increasing ocean and atmospheric temperatures. Increased dissolved carbon dioxide associated with ocean acidification may potentially hold some benefit for photosynthesising seaweeds, whilst hindering calcification processes for shell forming molluscs, including mussels and pāua. Eventually, intertidal reef habitat may be permanently reduced, and in some cases eliminated, in coastal areas with hard protection structures preventing landward shoreline migration to compensate for rising sea levels. With many factors potentially affecting these important habitats, ongoing monitoring and management of the coastal environment will be critical for their protection.

# 5. General summary

Rocky reefs dominate the intertidal zone of the Taranaki coastline, particularly around the ring plain. In spring 1994, the Council began conducting biannual surveys of intertidal communities at six rocky reef sites as a part of its SoE programme. The information gained through these surveys is used to guide management decisions, enabling the Council to assess the influence of natural processes, and effectively take measures to mitigate the impacts of human activities on the coastal environment.

Natural environmental factors, in particular sand cover, wave exposure, and habitat complexity appear to be important factors influencing species richness and diversity at the six SoE reef sites. No noticeable anthropogenic impacts have been detected at any of the SoE reef sites to date, although subtle changes resulting from human activities can be difficult to identify due to the impact of natural factors.

Of the six sites surveyed during a 30-year period of monitoring, the intertidal communities at Mānihi Reef are the most species rich and diverse, likely due to the low supply of sand and the presence of pools that provide a stable environment with many ecological niches. The intertidal communities at Waihī Reef are the least species rich and diverse. This is likely related to the high energy wave environment and resulting unstable habitat.

Periodic sand deposition has been shown to have a profound effect on intertidal communities in Taranaki, with the sites at Orapa, Mangatī and Greenwood Road being particularly prone to periodic sand inundation. Trend analysis shows that sand cover has increased at the four northern-most SoE sites. This is likely due to an increased sand supply from the mountain, combined with oceanographic conditions that shift this sand onshore. Although typically short lived, sand inundation events result in significant reductions in species richness and diversity.

Despite the negative relationship demonstrated between sand cover and the ecological measures (species richness and diversity) at the four northernmost sites, when comparing the sand-adjusted and unadjusted trend analyses, the observed sand cover did not appear to be having strong influence on the current long-term trends for species richness or diversity (i.e., similar results were generally observed across both datasets). This suggests that sand cover has not remained sufficiently high for long-enough periods to drive negative trends in rocky shore communities (except the long-term trend in the mean number of species observed at Greenwood Road). It also suggests that there are other factors influencing the observed trends in rocky shore communities that require further investigation (e.g., potential changes in wave exposure at Waihī Reef).

Recommendations are provided in the following section for additional monitoring and investigations to further characterise these rocky shore reef communities and attempt to identify key drivers in long-term trends.

# 6. Recommendations

1. THAT monitoring of the six SoE reef sites is extended from that carried out in 2019-2024 to also include habitat mapping techniques to gather broad scale information on reef topography, sand coverage, seagrass and other key habitat forming species.
2. THAT further work is undertaken to investigate the drivers behind observed trends in species richness and diversity at the six SoE reef sites.
3. THAT seagrass at Orapa reef is surveyed regularly based on methods recommended by Shanahan et al. (2023) "Guidance on council seagrass monitoring" to early detect changes in its extent and/or condition.

# 7. Glossary of common terms and abbreviations

The following abbreviations and terms may be used within this report:

| | |
|---|---|
| Anthropogenic | Caused or produced by humans. |
| Biomonitoring | Assessing the health of the environment using aquatic organisms. |
| Community | An ecological unit composed of a group of organisms or a population of different species occupying a particular area, usually interacting with each other and their environment. |
| Gastropods | Snails and slugs within a large taxonomic class (Gastropoda) within the phylum Mollusca. |
| Intertidal | The intertidal zone, also known as the littoral zone, is the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide, i.e. the area between tide marks. |
| Littoral | The intertidal zone. |
| Microhabitat | A habitat which is of small or limited extent and which differs in character from some surrounding more extensive habitat. |
| Niche (ecological) | An ecological niche is the role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' niche includes all of its interactions with the biotic and abiotic factors of its environment. |
| Physicochemical | Measurement of both physical properties (e.g. temperature, clarity, density) and chemical determinants (e.g. metals and nutrients) to characterise the state of an environment. |
| Population | A group of organisms of one species that interbreed and live in the same place at the same time. |
| Resource consent | Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15). |
| Ring plain | On the Taranaki peninsula, a line of three cone volcanoes (Taranaki, Pouākai, and Kaitake) is surrounded by a ring plain of avalanche, lahar, and tephra deposits. |
| RMA | *Resource Management Act* 1991 and including all subsequent amendments. |
| Species | Regarded as the basic category of biological classification, composed of related individuals that resemble one another, are able to breed among themselves, but are not able to breed with members of another species. |

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# Appendix I

## Survey summary data

Table 8 Tūrangi Reef mean number of species, Shannon-Wiener Diversity Index and sand cover data

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 5 Oct 1994 | 13.80 | 0.918 | 0.84 |
| 2 Feb 1995 | 15.32 | 0.933 | 2.96 |
| 3 Mar 1995 | 17.84 | 0.956 | 4.88 |
| 18 Mar 1995 | 16.40 | 0.924 | 2.20 |
| 10 Oct 1995 | 17.20 | 0.947 | 1.32 |
| 21 Jan 1996 | 18.36 | 0.998 | 2.36 |
| 21 Mar 1996 | 14.56 | 0.746 | 18.64 |
| 28 Oct 1996 | 17.00 | 0.820 | 1.40 |
| 14 Jan 1997 | 17.64 | 0.911 | 1.16 |
| 8 Apr 1997 | 17.31 | 0.886 | 3.60 |
| 15 Oct 1997 | 18.52 | 0.858 | 4.59 |
| 31 Jan 1998 | 17.00 | 0.991 | 7.80 |
| 9 Oct 1998 | 17.60 | 1.010 | 2.48 |
| 18 Jan 1999 | 16.48 | 0.929 | 0.96 |
| 27 Oct 1999 | 16.72 | 0.977 | 2.00 |
| 25 Jan 2000 | 13.80 | 0.842 | 2.96 |
| 20 Apr 2000 | 13.52 | 0.881 | 1.40 |
| 17 Oct 2000 | 13.28 | 0.882 | 0.96 |
| 8 Jan 2001 | 15.56 | 0.929 | 1.04 |
| 19 Oct 2001 | 15.56 | 0.940 | 3.08 |
| 29 Jan 2002 | 15.92 | 0.912 | 0.60 |
| 9 Oct 2002 | 17.64 | 0.982 | 7.52 |
| 23 Jan 2003 | 16.16 | 0.939 | 9.88 |
| 25 Oct 2003 | 18.68 | 0.938 | 0.60 |
| 12 Jan 2004 | 15.92 | 0.901 | 0.40 |
| 16 Dec 2004 | 14.28 | 0.888 | 0.80 |
| 15 Oct 2005 | 12.08 | 0.909 | 3.20 |
| 5 Jan 2006 | 13.76 | 0.933 | 10.40 |
| 8 Oct 2006 | 18.28 | 0.939 | 7.92 |
| 21 Jan 2007 | 18.55 | 0.755 | 18.84 |
| 28 Oct 2007 | 18.20 | 0.842 | 1.00 |
| 24 Jan 2008 | 16.60 | 0.816 | 7.52 |
| 18 Oct 2008 | 14.00 | 0.787 | 0.40 |
| 11 Jan 2009 | 14.64 | 0.873 | 3.92 |
| 21 Oct 2009 | 14.60 | 0.902 | 4.08 |
| 31 Jan 2010 | 17.68 | 0.998 | 4.52 |
| 10 Sep 2010 | 11.68 | 0.766 | 1.04 |

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 21 Jan 2011 | 13.88 | 0.844 | 5.96 |
| 29 Sep 2011 | 15.24 | 0.834 | 16.44 |
| 24 Jan 2012 | 12.76 | 0.680 | 8.48 |
| 15 Oct 2012 | 15.16 | 0.833 | 1.33 |
| 14 Jan 2013 | 16.68 | 0.810 | 15.36 |
| 19 Sep 2013 | 16.48 | 0.861 | 2.84 |
| 3 Feb 2014 | 14.12 | 0.837 | 12.92 |
| 10 Sep 2014 | 14.04 | 0.873 | 11.52 |
| 20 Jan 2015 | 14.46 | 0.828 | 24.88 |
| 28 Sep 2015 | 15.68 | 0.864 | 2.52 |
| 22 Feb 2016 | 19.52 | 1.032 | 22.28 |
| 17 Oct 2016 | 14.12 | 0.821 | 1.60 |
| 31 Jan 2017 | 18.12 | 0.875 | 5.73 |
| 22 Sep 2017 | 16.80 | 0.812 | 2.76 |
| 30 Jan 2018 | 17.44 | 0.993 | 0.70 |
| 24 Oct 2018 | 20.92 | 0.965 | 19.00 |
| 22 Jan 2019 | 17.52 | 0.941 | 30.48 |
| 16 Sep 2019 | 13.68 | 0.840 | 4.40 |
| 1 Dec 2020 | 17.2 | 0.970 | 21.28 |
| 10 Jan 2020 | 18.84 | 0.996 | 10.36 |
| 1 Dec 2021 | 17.84 | 1.027 | 33.72 |
| 8 Sep 2021 | 17.52 | 0.874 | 0.60 |
| 17 Feb 2022 | 18.28 | 0.795 | 1.64 |
| 25 Oct 2022 | 20 | 0.881 | 0.48 |
| 23 Jan 2023 | 17.12 | 0.902 | 0.88 |
| 28 Oct 2023 | 18.52 | 0.965 | 8.60 |
| 12 Jan 2024 | 20.24 | 0.947 | 36.48 |
| **Mean** | **16.35** | **0.89** | **7.00** |
| **Median** | **16.64** | **0.90** | **3.14** |
| **Max** | **20.92** | **1.03** | **36.48** |
| **Min** | **11.68** | **0.68** | **0.40** |

Table 9 Orapa Reef mean number of species, Shannon-Wiener Diversity Index and sand cover data

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 6 Oct 1994 | 13.40 | 0.899 | 3.08 |
| 2 Mar 1995 | 16.44 | 0.975 | 1.96 |
| 7 Oct 1995 | 16.04 | 1.002 | 1.76 |
| 18 Mar 1996 | 15.40 | 0.941 | 16.80 |
| 26 Oct 1996 | 16.00 | 0.885 | 4.56 |
| 7 Apr 1997 | 17.44 | 0.998 | 13.20 |
| 14 Oct 1997 | 17.76 | 1.017 | 2.92 |
| 3 Mar 1998 | 15.32 | 0.960 | 1.40 |
| 19 Oct 1998 | 15.92 | 0.972 | 4.20 |
| 1 Apr 1999 | 13.16 | 0.913 | 12.08 |
| 29 Oct 1999 | 14.20 | 0.956 | 8.03 |
| 20 Apr 2000 | 12.32 | 0.824 | 19.23 |
| 14 Oct 2000 | 14.24 | 0.913 | 3.12 |
| 10 Apr 2001 | 3.08 | 0.149 | 93.76 |
| 17 Oct 2001 | 16.23 | 0.962 | 8.27 |
| 16 Mar 2002 | 1.60 | 0.148 | 89.76 |
| 7 Oct 2002 | 16.80 | 0.993 | 5.00 |
| 18 Mar 2003 | 13.28 | 0.880 | 18.60 |
| 24 Oct 2003 | 16.52 | 0.974 | 4.76 |
| 23 Mar 2004 | 11.64 | 0.872 | 9.19 |
| 29 Sep 2004 | 11.72 | 0.812 | 3.00 |
| 19 Oct 2005 | 13.04 | 0.939 | 32.40 |
| 7 Oct 2006 | 17.00 | 0.992 | 20.84 |
| 20 Apr 2007 | 13.08 | 0.851 | 41.24 |
| 26 Oct 2007 | 14.76 | 0.899 | 57.52 |
| 25 Jan 2008 | 14.16 | 0.916 | 48.20 |
| 16 Oct 2008 | 12.08 | 0.764 | 40.42 |
| 13 Jan 2009 | 11.28 | 0.729 | 19.24 |
| 19 Oct 2009 | 11.08 | 0.755 | 36.16 |
| 1 Feb 2010 | 11.48 | 0.719 | 55.20 |
| 7 Sep 2010 | 10.32 | 0.694 | 32.80 |
| 20 Jan 2011 | 11.00 | 0.693 | 12.28 |
| 28 Sep 2011 | 10.16 | 0.726 | 23.20 |
| 25 Jan 2012 | 7.96 | 0.588 | 25.60 |
| 19 Sep 2012 | 11.08 | 0.767 | 31.00 |
| 11 Jan 2013 | 10.96 | 0.726 | 75.60 |
| 23 Sep 2013 | 14.64 | 0.899 | 31.40 |

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 29 Jan 2014 | 14.76 | 0.948 | 34.00 |
| 11 Sep 2014 | 15.64 | 0.970 | 32.00 |
| 6 Mar 2015 | 17.12 | 1.029 | 19.80 |
| 14 Sep 2015 | 17.72 | 1.048 | 33.40 |
| 11 Jan 2016 | 17.36 | 1.057 | 52.00 |
| 20 Sep 2016 | 12.92 | 0.890 | 57.60 |
| 10 Feb 2017 | 11.52 | 0.703 | 30.72 |
| 18 Sep 2017 | 14.36 | 0.863 | 37.20 |
| 19 Mar 2018 | 15.68 | 0.908 | 21.84 |
| 27 Sep 2018 | 17.28 | 0.979 | 29.28 |
| 18 Feb 2019 | 17.12 | 0.946 | 25.68 |
| 16 Oct 2019 | 18.92 | 0.958 | 13.12 |
| 13 Feb 2020 | 17.24 | 0.958 | 33.08 |
| 2 Oct 2020 | 17.52 | 0.957 | 30.28 |
| 2 Feb 2021 | 19.28 | 1.054 | 13.36 |
| 21 Oct 2021 | 19.40 | 1.080 | 18.44 |
| 2 Apr 2022 | 19.68 | 1.042 | 16.84 |
| 26 Oct 2022 | 21.80 | 1.145 | 7.32 |
| 20 Mar 2023 | 19.16 | 1.073 | 27.36 |
| 30 Oct 2023 | 19.64 | 1.103 | 34.04 |
| 14 Dec 2023 | 18.00 | 1.005 | 30.60 |
| **Mean** | **14.59** | **0.887** | **26.49** |
| **Median** | **15.32** | **0.941** | **23.20** |
| **Max** | **21.8** | **1.145** | **93.76** |
| **Min** | **1.60** | **0.148** | **1.00** |

Table 10 Mangati Reef mean number of species, Shannon-Wiener Diversity Index and sand cover data

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 1 Feb 1995 | 15.04 | 0.950 | 4.40 |
| 26 Oct 1995 | 16.04 | 0.950 | 0.12 |
| 20 Jan 1996 | 14.88 | 0.933 | 0.28 |
| 27 Sep 1996 | 17.20 | 1.036 | 0.12 |
| 10 Jan 1997 | 16.64 | 0.969 | 0.48 |
| 15 Sep 1997 | 15.92 | 0.968 | 3.20 |
| 30 Jan 1998 | 16.96 | 1.052 | 8.11 |
| 20 Oct 1998 | 13.88 | 0.940 | 1.84 |
| 22 Jan 1999 | 14.75 | 0.921 | 2.62 |
| 8 Nov 1999 | 13.48 | 0.846 | 6.36 |
| 25 Jan 2000 | 13.92 | 0.878 | 12.12 |
| 30 Oct 2000 | 13.84 | 0.847 | 10.76 |
| 9 Jan 2001 | 11.80 | 0.747 | 14.40 |
| 3 Dec 2001 | 8.68 | 0.638 | 36.40 |
| 1 Feb 2002 | 8.76 | 0.625 | 22.96 |
| 22 Oct 2002 | 14.88 | 0.892 | 7.32 |
| 22 Jan 2003 | 14.36 | 1.002 | 23.24 |
| 30 Oct 2003 | 14.04 | 0.982 | 7.00 |
| 25 Jan 2004 | 13.04 | 0.967 | 9.19 |
| 13 Jan 2005 | 13.04 | 0.922 | 2.00 |
| 6 Jan 2006 | 8.48 | 0.752 | 39.20 |
| 9 Oct 2006 | 16.60 | 0.873 | 41.04 |
| 20 Jan 2007 | 3.44 | 0.277 | 85.00 |
| 24 Oct 2007 | 11.88 | 0.750 | 18.16 |
| 22 Jan 2008 | 16.08 | 0.984 | 27.04 |
| 14 Oct 2008 | 14.04 | 0.905 | 0.60 |
| 14 Jan 2009 | 15.52 | 0.995 | 2.76 |
| 16 Nov 2009 | 16.12 | 0.923 | 14.36 |
| 2 Feb 2010 | 16.48 | 0.993 | 0.64 |
| 6 Nov 2010 | 13.76 | 0.843 | 0.04 |
| 22 Jan 2011 | 13.40 | 0.870 | 12.56 |
| 1 Oct 2011 | 15.64 | 0.963 | 19.64 |
| 23 Jan 2012 | 11.04 | 0.707 | 40.80 |
| 30 Jan 2013 | 12.52 | 0.829 | 47.20 |
| 18 Oct 2013 | 10.71 | 0.733 | 48.40 |
| 1 Feb 2014 | 13.20 | 0.912 | 25.40 |
| 25 Sep 2014 | 12.80 | 0.954 | 16.80 |

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 19 Jan 2015 | 5.12 | 0.435 | 82.80 |
| 15 Sep 2015 | 10.28 | 0.587 | 1.00 |
| 9 Feb 2016 | 10.60 | 0.714 | 63.60 |
| 16 Nov 2016 | 14.28 | 0.876 | 9.80 |
| 11 Jan 2017 | 14.92 | 0.889 | 38.80 |
| 19 Sep 2017 | 14.76 | 0.908 | 1.96 |
| 28 Feb 2018 | 18.20 | 0.999 | 3.88 |
| 25 Sep 2018 | 16.04 | 0.921 | 13.04 |
| 20 Jan 2019 | 17.32 | 0.926 | 44.40 |
| 1 Oct 2019 | 15.32 | 0.858 | 23.96 |
| 15 Jan 2020 | 18.52 | 1.001 | 7.16 |
| 19 Nov 2020 | 18.84 | 1.055 | 4.88 |
| 15 Jan 2021 | 19.12 | 1.027 | 1.24 |
| 9 Sep 2021 | 15.36 | 0.928 | 0.48 |
| 20 Feb 2022 | 15.80 | 0.972 | 0.64 |
| 12 Oct 2022 | 17.25 | 1.044 | 0.85 |
| 20 Mar 2023 | 17.12 | 1.053 | 30.80 |
| 27 Sep 2023 | 17.08 | 1.046 | 0.72 |
| 12 Jan 2024 | 18.32 | 1.100 | 12.76 |
| 4 Sep 2024 | 13.84 | 0.980 | 1.48 |
| **Mean** | **14.22** | **0.89** | **16.72** |
| **Median** | **14.76** | **0.92** | **9.20** |
| **Max** | **19.12** | **1.10** | **85.00** |
| **Min** | **3.44** | **0.28** | **0.04** |

Table 11 Greenwood Road Reef mean number of species, Shannon-Wiener Diversity Index and sand cover data

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 17 Mar 1996 | 22.04 | 1.115 | 0.36 |
| 25 Oct 1996 | 18.72 | 1.037 | 0.24 |
| 9 Jan 1997 | 19.04 | 0.987 | 0.12 |
| 6 Apr 1997 | 20.60 | 1.110 | 0.00 |
| 16 Oct 1997 | 21.36 | 1.056 | 0.20 |
| 28 Jan 1998 | 18.84 | 0.990 | 0.08 |
| 8 Oct 1998 | 18.96 | 1.004 | 0.12 |
| 21 Jan 1999 | 17.55 | 0.922 | 0.40 |
| 26 Oct 1999 | 15.64 | 0.918 | 0.52 |
| 24 Jan 2000 | 18.84 | 1.003 | 0.44 |
| 14 Oct 2000 | 15.04 | 0.912 | 0.68 |
| 12 Jan 2001 | 16.04 | 0.948 | 0.56 |
| 18 Oct 2001 | 19.92 | 1.001 | 0.80 |
| 28 Jan 2002 | 18.00 | 1.017 | 6.04 |
| 8 Oct 2002 | 14.56 | 0.894 | 12.76 |
| 22 Jan 2003 | 17.44 | 0.956 | 0.60 |
| 25 Sep 2003 | 9.48 | 0.555 | 41.12 |
| 23 Oct 2003 | 9.48 | 0.649 | 61.04 |
| 10 Jan 2004 | 15.36 | 0.860 | 0.00 |
| 12 Nov 2004 | 15.84 | 0.907 | 0.00 |
| 13 Jan 2005 | 17.60 | 1.041 | 0.00 |
| 14 Mar 2005 | 16.12 | 1.028 | 0.40 |
| 18 Aug 2005 | 16.80 | 1.024 | 0.00 |
| 4 Jan 2006 | 15.48 | 0.996 | 0.00 |
| 7 Sep 2006 | 14.60 | 0.869 | 0.00 |
| 23 Jan 2007 | 19.00 | 0.975 | 2.92 |
| 26 Sep 2007 | 20.68 | 1.042 | 2.00 |
| 23 Jan 2008 | 23.76 | 1.147 | 1.24 |
| 16 Sep 2008 | 11.08 | 0.895 | 2.64 |
| 12 Jan 2009 | 16.48 | 0.978 | 1.40 |
| 20 Oct 2009 | 17.16 | 1.025 | 0.46 |
| 30 Jan 2010 | 15.96 | 0.937 | 1.96 |
| 11 Sep 2010 | 10.48 | 0.865 | 2.76 |
| 7 Oct 2010 | 5.40 | 0.764 | 76.00 |
| 30 Sep 2011 | 12.28 | 0.775 | 6.36 |
| 11 Jan 2012 | 12.24 | 0.874 | 24.20 |
| 21 Sep 2012 | 16.92 | 0.812 | 5.08 |

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 13 Jan 2013 | 18.56 | 0.744 | 7.52 |
| 20 Sep 2013 | 8.29 | 0.612 | 86.40 |
| 2 Feb 2014 | 11.24 | 0.864 | 7.60 |
| 9 Sep 2014 | 13.80 | 0.881 | 4.92 |
| 23 Jan 2015 | 0.16 | 0.024 | 98.40 |
| 30 Sep 2015 | 12.56 | 0.805 | 23.04 |
| 12 Feb 2016 | 17.88 | 0.802 | 23.60 |
| 18 Oct 2016 | 14.96 | 0.758 | 7.16 |
| 13 Jan 2017 | 17.48 | 0.792 | 20.96 |
| 21 Sep 2017 | 14.04 | 0.751 | 0.79 |
| 31 Jan 2018 | 18.04 | 1.003 | 0.24 |
| 9 Oct 2018 | 21.72 | 0.879 | 0.88 |
| 21 Jan 2019 | 21.48 | 0.944 | 3.16 |
| 25 Nov 2019 | 20.72 | 1.041 | 1.60 |
| 11 Jan 2020 | 19.96 | 0.954 | 5.20 |
| 17 Nov 2020 | 17.96 | 0.972 | 1.92 |
| 14 Jan 2021 | 16.80 | 0.842 | 24.16 |
| 20 Sep 2021 | 16.44 | 0.829 | 0.74 |
| 18 Feb 2022 | 15.95 | 0.969 | 4.81 |
| 26 Nov 2022 | 18.36 | 0.971 | 0.32 |
| 23 Mar 2023 | 22.08 | 1.099 | 0.72 |
| 29 Oct 2023 | 20.68 | 1.008 | 0.68 |
| 11 Feb 2024 | 19.48 | 0.968 | 1.00 |
| Mean | 16.35 | 0.90 | 9.42 |
| Median | 17.04 | 0.95 | 0.94 |
| Max | 23.76 | 1.15 | 98.40 |
| Min | 0.16 | 0.02 | 0.00 |

Table 12 Mānihi Reef mean number of species, Shannon-Wiener Diversity Index and sand cover data

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 23 Jan 1996 | 20.08 | 1.066 | 0.04 |
| 14 Oct 1996 | 21.48 | 1.087 | 0.36 |
| 12 Jan 1997 | 23.16 | 1.136 | 0.32 |
| 16 Sep 1997 | 20.07 | 1.077 | 0.28 |
| 12 Mar 1998 | 21.04 | 1.070 | 0.96 |
| 21 Oct 1998 | 18.96 | 1.037 | 0.36 |
| 31 Mar 1999 | 17.23 | 1.005 | 0.28 |
| 9 Nov 1999 | 15.04 | 0.913 | 0.52 |
| 19 Apr 2000 | 18.64 | 1.019 | 0.56 |
| 27 Oct 2000 | 18.84 | 1.073 | 0.48 |
| 26 Mar 2001 | 17.20 | 0.956 | 0.60 |
| 30 Nov 2001 | 20.96 | 1.076 | 0.64 |
| 15 Mar 2002 | 18.07 | 0.973 | 0.56 |
| 21 Oct 2002 | 24.92 | 1.200 | 0.84 |
| 17 Mar 2003 | 21.00 | 1.120 | 0.28 |
| 23 Nov 2003 | 19.32 | 1.073 | 0.00 |
| 22 Mar 2004 | 17.76 | 1.089 | 0.00 |
| 27 Sep 2004 | 18.04 | 1.041 | 0.00 |
| 18 Oct 2005 | 15.48 | 0.981 | 0.00 |
| 1 Feb 2006 | 18.52 | 1.088 | 0.00 |
| 6 Oct 2006 | 20.48 | 1.068 | 0.80 |
| 18 Apr 2007 | 18.12 | 0.997 | 0.36 |
| 25 Oct 2007 | 21.84 | 1.099 | 0.64 |
| 7 Apr 2008 | 21.16 | 1.122 | 0.52 |
| 15 Nov 2008 | 19.84 | 1.077 | 0.40 |
| 10 Feb 2009 | 19.36 | 1.074 | 1.00 |
| 6 Nov 2009 | 18.72 | 1.053 | 0.36 |
| 31 Mar 2010 | 17.88 | 1.019 | 0.00 |
| 22 Feb 2011 | 17.84 | 1.031 | 0.00 |
| 29 Nov 2011 | 18.48 | 1.066 | 0.00 |
| 9 Feb 2012 | 15.24 | 0.886 | 0.00 |
| 28 Feb 2013 | 21.40 | 1.076 | 0.84 |
| 4 Dec 2013 | 19.80 | 1.039 | 2.50 |
| 28 Feb 2014 | 20.80 | 1.016 | 0.28 |
| 10 Oct 2014 | 21.40 | 1.064 | 0.00 |
| 20 Mar 2015 | 20.04 | 1.008 | 0.05 |
| 29 Sep 2015 | 20.04 | 1.029 | 0.70 |

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 12 Jan 2016 | 26.24 | 1.042 | 1.00 |
| 19 Sep 2016 | 17.92 | 1.020 | 0.77 |
| 13 Mar 2017 | 21.20 | 1.054 | 0.38 |
| 20 Sep 2017 | 18.80 | 0.986 | 0.20 |
| 5 Mar 2018 | 22.52 | 1.090 | 0.00 |
| 8 Oct 2018 | 23.36 | 1.108 | 0.12 |
| 20 Feb 2019 | 27.72 | 1.162 | 0.04 |
| 27 Sep 2019 | 25.84 | 1.161 | 0.16 |
| 25 Feb 2020 | 26.24 | 1.153 | 0.00 |
| 14 Dec 2020 | 24.72 | 1.086 | 0.04 |
| 12 Feb 2021 | 27.28 | 1.155 | 0.00 |
| 5 Oct 2021 | 25.32 | 1.161 | 0.04 |
| 18 Mar 2022 | 21.08 | 1.120 | 0.04 |
| 7 Nov 2022 | 25.00 | 1.160 | 0.44 |
| 22 Mar 2023 | 21.44 | 1.100 | 0.36 |
| 30 Oct 2023 | 24.35 | 1.203 | 0.40 |
| 13 Jan 2024 | 28.00 | 1.243 | 0.88 |
| **Mean** | **20.84** | **1.07** | **0.36** |
| **Median** | **20.28** | **1.07** | **0.32** |
| **Max** | **28.00** | **1.24** | **2.40** |
| **Min** | **15.04** | **0.89** | **0.00** |

Table 13 Waihi Reef mean number of species, Shannon-Wiener Diversity Index and sand cover data

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 4 Nov 1994 | 13.32 | 0.958 | 1.24 |
| 15 Feb 1995 | 13.52 | 0.949 | 0.00 |
| 12 Jul 1995 | 12.00 | 0.907 | 2.96 |
| 24 Nov 1995 | 14.00 | 0.978 | 0.44 |
| 18 Feb 1996 | 16.96 | 1.033 | 1.64 |
| 10 Dec 1996 | 10.72 | 0.830 | 0.04 |
| 9 Feb 1997 | 12.52 | 0.921 | 2.68 |
| 25 Mar 1997 | 13.44 | 0.942 | 1.28 |
| 16 Nov 1997 | 13.12 | 0.951 | 2.68 |
| 14 Apr 1998 | 12.72 | 0.956 | 0.80 |
| 24 Apr 1998 | 14.20 | 0.938 | 0.96 |
| 2 Nov 1998 | 10.92 | 0.809 | 0.52 |
| 15 Feb 1999 | 11.84 | 0.796 | 2.12 |
| 16 Mar 1999 | 12.36 | 0.841 | 0.80 |
| 26 Nov 1999 | 10.40 | 0.809 | 1.96 |
| 18 Feb 2000 | 12.20 | 0.870 | 0.80 |
| 21 Mar 2000 | 12.00 | 0.883 | 2.36 |
| 15 Nov 2000 | 12.28 | 0.899 | 2.40 |
| 12 Feb 2001 | 11.28 | 0.903 | 2.96 |
| 17 Nov 2001 | 11.24 | 0.797 | 3.20 |
| 2 Mar 2002 | 11.16 | 0.853 | 1.80 |
| 26 Mar 2002 | 13.12 | 0.860 | 1.24 |
| 8 Nov 2002 | 12.58 | 0.939 | 4.62 |
| 19 Feb 2003 | 12.00 | 0.932 | 5.80 |
| 25 Nov 2003 | 11.92 | 0.928 | 21.80 |
| 8 Mar 2004 | 4.84 | 0.402 | 66.80 |
| 8 Feb 2005 | 8.56 | 0.782 | 3.00 |
| 3 Nov 2005 | 8.52 | 0.722 | 11.60 |
| 3 Feb 2006 | 7.12 | 0.673 | 2.80 |
| 6 Nov 2006 | 11.44 | 0.811 | 5.12 |
| 20 Feb 2007 | 10.44 | 0.853 | 12.12 |
| 26 Nov 2007 | 8.88 | 0.771 | 3.60 |
| 11 Feb 2008 | 13.12 | 0.954 | 1.36 |
| 13 Nov 2008 | 9.96 | 0.817 | 0.96 |
| 12 Feb 2009 | 8.76 | 0.791 | 3.24 |
| 3 Nov 2009 | 10.52 | 0.800 | 1.56 |
| 2 Mar 2010 | 11.16 | 0.852 | 3.52 |

| Date | Number of species per quadrat | Shannon Wiener index per quadrat | Percentage sand cover per quadrat |
|---|---|---|---|
| 8 Nov 2010 | 11.00 | 0.806 | 0.44 |
| 18 Feb 2011 | 11.60 | 0.828 | 2.91 |
| 11 Mar 2012 | 10.64 | 0.800 | 1.28 |
| 12 Nov 2012 | 11.88 | 0.817 | 3.44 |
| 27 Feb 2013 | 12.12 | 0.888 | 6.71 |
| 3 Dec 2013 | 12.68 | 0.932 | 1.38 |
| 15 Apr 2014 | 10.88 | 0.788 | 0.88 |
| 4 Nov 2014 | 8.96 | 0.824 | 0.76 |
| 19 Mar 2015 | 10.48 | 0.821 | 0.75 |
| 24 Nov 2015 | 9.60 | 0.848 | 1.44 |
| 9 Mar 2016 | 11.64 | 0.777 | 4.00 |
| 12 Dec 2016 | 9.20 | 0.787 | 1.08 |
| 27 Mar 2017 | 10.48 | 0.760 | 0.60 |
| No Spring 2017 survey | - | - | - |
| 29 Mar 2018 | 10.55 | 0.812 | 1.00 |
| 8 Nov 2018 | 13.27 | 0.857 | 8.42 |
| 21 Feb 2019 | 15.92 | 0.890 | 5.60 |
| 29 Oct 2019 | 13.64 | 0.931 | 3.60 |
| 11 Mar 2020 | 14.20 | 0.909 | 2.92 |
| 16 Nov 2020 | 14.40 | 0.907 | 0.12 |
| 30 Mar 2021 | 12.56 | 0.868 | 0.48 |
| 6 Oct 2021 | 13.36 | 0.888 | 0.48 |
| 3 Feb 2022 | 12.52 | 0.842 | 6.68 |
| 23 Dec 2022 | 12.24 | 0.836 | 0.36 |
| 22 Feb 2023 | 14.40 | 0.900 | 2.20 |
| 26 Nov 2023 | 11.52 | 0.835 | 0.52 |
| 16 Jan 2024 | 14.44 | 0.853 | 1.20 |
| **Mean** | **11.72** | **0.85** | **3.81** |
| **Median** | **11.90** | **0.85** | **1.88** |
| **Max** | **16.96** | **1.03** | **66.80** |
| **Min** | **4.84** | **0.40** | **0.00** |

# Appendix II

# Species list

Table 14 Full list of species recorded during SoE rocky shore surveys between 2019 and 2025

| Species name | Class name | Feed group | 2019/2020 | 2020/2021 | 2021/2022 | 2022/2023 | 2023/2024 | 2024/2025 | Total |
|---|---|---|---|---|---|---|---|---|---|
| *Acanthochitona zelandica* | Molluscs/ Shells | Herbivore | 64 | 57 | 55 | 99 | 86 | 21 | 382 |
| *Actinia tenebrosa* | Coelenterates/ Anemones | Predator/ scavenger | 1 | | | 1 | 1 | | 3 |
| *Actinothoe albocincta* | Coelenterates/ Anemones | Predator/ scavenger | | | | | | 2 | 2 |
| *Acutigebia danai* | Crustaceans/ Crabs | Predator/ scavenger | | | 1 | | | | 1 |
| *Alloiodoris lanuginata* | Molluscs/Shells | N/A | 2 | | | | | | 2 |
| *Alope spinifrons* | Crustaceans/ Crabs | Predator/ scavenger | 4 | 4 | 5 | 20 | 15 | 1 | 49 |
| *Anthopleura aureoradiata* | Coelenterates/ Anemones | Predator/ scavenger | | 1 | | | | | 1 |
| *Atalacmea fragilis* | Molluscs/Shells | Herbivore | 8 | 13 | 5 | 10 | 3 | 3 | 42 |
| *Austrominius modestus* | Crustaceans/ Crabs | Filter feeder | 66 | 54 | 30 | 31 | 17 | 2 | 200 |
| *Berthellina citrina* | Molluscs/Shells | Predator/ scavenger | 3 | | | | | | 3 |
| *Betaeus aequimanus* | Crustaceans/ Crabs | Predator/ scavenger | 1 | | 4 | 1 | | | 6 |
| *Borniola reniformis* | Molluscs/Shells | Filter feeder | | 7 | 13 | | | | 20 |
| *Buccinulum sp.* | Molluscs/Shells | Predator/ scavenger | 8 | 10 | 3 | 1 | | | 22 |
| *Callochiton crocinus* | Molluscs/Shells | Herbivore | 2 | 1 | | | | | 3 |
| *Cantharidella tesselata* | Molluscs/Shells | Herbivore | 108 | 93 | 75 | 108 | 62 | 63 | 509 |
| *Cantharidus sp.* | Molluscs/Shells | Herbivore | 2 | | | | | | 2 |
| *Cellana ornata* | Molluscs/Shells | Herbivore | 23 | 19 | 20 | 48 | 38 | 7 | 155 |
| *Cellana radians* | Molluscs/Shells | Herbivore | 162 | 143 | 116 | 129 | 123 | 46 | 719 |
| *Chamaesipho columna* | Crustaceans/ Crabs | Filter feeder | 233 | 214 | 219 | 180 | 184 | 69 | 1099 |
| *Chiton glaucus* | Molluscs/Shells | Herbivore | 175 | 156 | 166 | 195 | 183 | 40 | 915 |
| *Clingfish* | Chordates/Fish | Predator/ scavenger | 7 | 5 | 3 | 3 | 21 | 3 | 42 |
| *Cnemidocarpa bicornuta* | Chordates/Fish | Filter feeder | 9 | 11 | 9 | 6 | 2 | | 37 |
| *Cominella maculosa* | Molluscs/Shells | Predator/ scavenger | 40 | 40 | 38 | 30 | 26 | 12 | 186 |
| *Cookia sulcata* | Molluscs/Shells | Herbivore | | | | | 2 | | 2 |
| *Corella eumyota* | Chordates/Fish | Filter feeder | 14 | 12 | 6 | 2 | | | 34 |
| *Coscinasterias muricata* | Echinoderms/ Starfish | Predator/ scavenger | 11 | 3 | 5 | 1 | 3 | | 23 |
| *Crested Blenny* | Chordates/Fish | Predator/ scavenger | | | | | 2 | | 2 |
| *Dicathais orbita* | Molluscs/Shells | Predator/ | 18 | 5 | 8 | 6 | 9 | 2 | 48 |

| Species name | Class name | Feed group | 2019/2020 | 2020/2021 | 2021/2022 | 2022/2023 | 2023/2024 | 2024/2025 | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | scavenger | | | | | | | |
| *Diloma aethiops* | Molluscs/Shells | Herbivore | 255 | 220 | 233 | 241 | 233 | 91 | 1273 |
| *Diloma bicanaliculata* | Molluscs/Shells | Herbivore | 8 | 16 | 18 | 25 | 24 | 4 | 95 |
| *Diloma aridum* (yellow spotty) | Molluscs/Shells | Herbivore | 39 | 19 | 17 | 55 | 21 | 1 | 152 |
| *Doris wellingtonensis* | Molluscs/Shells | Predator/ scavenger | | | 1 | | | | 1 |
| *Epitonium jukesianum* | Molluscs/Shells | Predator/ scavenger | 2 | 5 | 1 | | | | 8 |
| *Epopella plicata* | Crustaceans/ Crabs | Filter feeder | 2 | 4 | 2 | 4 | 11 | 1 | 24 |
| *Evechinus chloroticus* | Echinoderms/ Starfish | Herbivore | 7 | 2 | 12 | 3 | 33 | 12 | 69 |
| Flatworm | Annelids/ Worms | Herbivore | 36 | 32 | 12 | 28 | 36 | 4 | 148 |
| *Halicarcinus cookii* | Crustaceans/ Crabs | Predator/ scavenger | | | | 28 | | | 28 |
| *Halicarcinus sp.* | Crustaceans/ Crabs | Predator/ scavenger | 17 | 17 | 21 | 59 | 44 | 16 | 174 |
| *Haliotis iris* | Molluscs/Shells | Herbivore | 1 | 3 | 1 | | | | 5 |
| *Haustrum haustorium* | Molluscs/Shells | Herbivore | 84 | 79 | 79 | 31 | 9 | 5 | 287 |
| *Haustrum scobina* | Molluscs/Shells | Predator/ scavenger | 185 | 166 | 188 | 197 | 179 | 54 | 969 |
| *Heterozius rotundifrons* | Crustaceans/ Crabs | Predator/ scavenger | 10 | 8 | 8 | 16 | 8 | | 50 |
| *Hiatella arctica* | Molluscs/Shells | Filter feeder | 4 | 3 | | | | | 7 |
| *Irus reflexus* | Molluscs/Shells | Filter feeder | 4 | | | | | | 4 |
| *Isactinia olivacea* | Coelenterates/ Anemones | Predator/ scavenger | 94 | 90 | 92 | 91 | 93 | 21 | 481 |
| *Ischnochiton maorianus* | Molluscs/Shells | Herbivore | 98 | 107 | 99 | 93 | 118 | 34 | 549 |
| *Isocradactis magna* | Coelenterates/ Anemones | Predator/ scavenger | 1 | 3 | 1 | 2 | | 1 | 8 |
| *Isoparactis ferax* | Coelenterates/ Anemones | Predator/ scavenger | 8 | 5 | 3 | 5 | 5 | | 26 |
| Isopod | Crustaceans/ Crabs | N/A | 50 | 40 | 29 | 48 | 18 | 8 | 193 |
| *Jorunna sp.* | Molluscs/Shells | Herbivore | | 3 | 2 | | 1 | | 6 |
| Large sand tube-worm | Annelids/Worms | Filter feeder | 2 | | | | | | 2 |
| *Leptograpsus variegatus* | Crustaceans/ Crabs | Predator/ scavenger | 1 | 2 | 1 | 5 | 5 | 3 | 17 |
| *Lissocampus filum* | Chordates/Fish | Predator/ scavenger | | | 1 | | | | 1 |
| *Lunella smaragdus* | Molluscs/Shells | Herbivore | 219 | 202 | 226 | 222 | 203 | 85 | 1157 |
| *Macroctopus maorum* | Molluscs/Shells | Predator/ scavenger | | 1 | | | | | 1 |

| Species name | Class name | Feed group | 2019/2020 | 2020/2021 | 2021/2022 | 2022/2023 | 2023/2024 | 2024/2025 | Total |
|---|---|---|---|---|---|---|---|---|---|
| *Maoricolpus roseus* | Molluscs/Shells | Filter feeder | 3 | | | | | | 3 |
| *Metacarcinus novaezelandiae* | Crustaceans/ Crabs | N/A | | 2 | 1 | | | | 3 |
| Nemertine worm | Annelids/Worms | N/A | 4 | 12 | 9 | 16 | 25 | 1 | 67 |
| *Neohymenicus pubescens* | Crustaceans/Crabs | Predator/ scavenger | | | | 1 | | 1 | 2 |
| *Neosabellaria kaiparaensis* | Annelids/Worms | Filter feeder | 238 | 204 | 218 | 251 | 252 | 85 | 1248 |
| *Notoacmea daedala* | Molluscs/Shells | Herbivore | 146 | 145 | 113 | 182 | 189 | 52 | 827 |
| *Notomithrax sp.* | Crustaceans/ Crabs | Predator/ scavenger | 5 | 3 | 3 | 3 | 5 | | 19 |
| *Onchidella nigricans* | Molluscs/Shells | Herbivore | 14 | 8 | 13 | 5 | 4 | 1 | 45 |
| *Ophionerias fasciata* | Echinoderms/ Starfish | Filter feeder | 21 | 12 | 23 | 6 | 3 | 5 | 70 |
| *Ostreidae sp.* | Molluscs/Shells | Filter feeder | 2 | | | | | | 2 |
| *Oulactis muscosa* | Coelenterates/ Anemones | Predator/ scavenger | 23 | 19 | 23 | 15 | 12 | 1 | 93 |
| *Ozius truncatus* | Crustaceans/ Crabs | Predator/ scavenger | 5 | 13 | 17 | 11 | 7 | 1 | 54 |
| *Pagurus sp.* | Crustaceans/ Crabs | Predator/ scavenger | 112 | 95 | 79 | 66 | 69 | 40 | 461 |
| *Palaemon affinis* | Crustaceans/ Crabs | N/A | 4 | 22 | 9 | 6 | 1 | | 42 |
| *Patelloida corticata* | Molluscs/Shells | Herbivore | 14 | 9 | 4 | 14 | | | 41 |
| *Patiriella regularis* | Echinoderms/ Starfish | Predator/ scavenger | 65 | 77 | 88 | 88 | 77 | 13 | 408 |
| Peanut worm | Annelids/Worms | N/A | 6 | 13 | 4 | 15 | 1 | | 39 |
| *Perna canaliculus* | Molluscs/Shells | Filter feeder | 4 | | 2 | | 3 | 1 | 10 |
| *Petrolisthes elongatus* | Crustaceans/ Crabs | Predator/ scavenger | 140 | 149 | 151 | 175 | 157 | 36 | 808 |
| *Phidiana milleri* | Molluscs/Shells | Predator/ scavenger | 1 | 2 | | 2 | | | 5 |
| *Plagusia chabrus* | Crustaceans/ Crabs | Predator/ scavenger | 23 | 17 | 8 | 3 | 26 | 18 | 95 |
| *Polychaete sp.* | Annelids/Worms | Predator/ scavenger | 22 | 22 | 17 | 48 | 39 | 6 | 154 |
| *Protothaca crassicosta* | Molluscs/Shells | Filter feeder | 59 | 66 | 44 | 84 | 29 | 2 | 284 |
| *Sypharochiton sinclairi* (Rainbow chiton) | Molluscs/Shells | Herbivore | 146 | 132 | 148 | 211 | 190 | 42 | 869 |
| *Rhyssoplax aerea* | Molluscs/Shells | Herbivore | | | 3 | 1 | | | 4 |
| Rockfish | Chordates/Fish | Predator/ scavenger | 5 | 2 | 2 | | 2 | | 11 |
| *Saccostrea cucullata* | Molluscs/Shells | N/A | | | | | | 1 | 1 |

| Species name | Class name | Feed group | 2019/2020 | 2020/2021 | 2021/2022 | 2022/2023 | 2023/2024 | 2024/2025 | Total |
|---|---|---|---|---|---|---|---|---|---|
| *Saccostrea glomerata* | Molluscs/Shells | Filter feeder | 2 | | | | | | 2 |
| *Scale worm spp.* | Annelids/Worms | N/A | 5 | 5 | 2 | 2 | | | 14 |
| *Scutus breviculus* | Molluscs/Shells | Herbivore | 5 | 7 | 9 | 4 | 10 | | 35 |
| *Siphonaria australis* | Molluscs/Shells | Herbivore | 17 | 30 | 49 | 25 | 74 | 28 | 223 |
| *Spirobranchus cariniferus* | Annelids/Worms | Filter feeder | 201 | 215 | 216 | 225 | 218 | 65 | 1140 |
| *Spirorbis sp.* | Annelids/Worms | Filter feeder | 69 | 106 | 127 | 132 | 141 | 39 | 614 |
| *Stichaster australis* | Echinoderms/ Starfish | Predator/ scavenger | | | | 1 | | | 1 |
| *Sypharochiton pelliserpentis* | Molluscs/Shells | Herbivore | 90 | 87 | 109 | 105 | 88 | 28 | 507 |
| *Taeniogyrus dunedinensis* | Echinoderms/ Starfish | Predator/ scavenger | | | 2 | | | | 2 |
| *Tethya aurantium* | Porifera | Filter feeder | | | | | 1 | | 1 |
| *Tethya sp.* | Porifera | Filter feeder | | 2 | 3 | 6 | 2 | 1 | 14 |
| *Tetraclitella purpurascens* | Crustaceans/ Crabs | Filter feeder | 29 | 28 | 15 | 19 | 7 | 3 | 101 |
| *Trachelochismus pinnulatus* | Chordates/Fish | Predator/ scavenger | 8 | 10 | 4 | 1 | | | 23 |
| Triplefin | Chordates/Fish | Predator/ scavenger | 6 | 7 | 4 | 4 | 14 | 3 | 38 |
| Tunicate | Chordates/Fish | Filter feeder | 2 | | | 16 | 11 | 6 | 35 |
| Unidentified anemone | Coelenterates/ Anemones | Predator/ scavenger | 10 | 1 | 3 | 17 | 2 | 2 | 35 |
| Unidentified Bivalve | Molluscs/Shells | Filter feeder | 6 | 2 | 3 | 1 | | | 12 |
| Unidentified tunicate (orange) | Chordates/Fish | Filter feeder | | | | 2 | | | 2 |
| Unidentified crab | Crustaceans/ Crabs | N/A | | | | 13 | 4 | | 17 |
| Unidentified hydrozoan | Hydrozoans | Filter feeder | | | | | 2 | | 2 |
| Unidentified nematode | Annelids/Worms | N/A | 1 | | 3 | 11 | 3 | 2 | 20 |
| Unidentified Nudibranch | Molluscs/Shells | Predator/ scavenger | | | 1 | 11 | 1 | | 13 |
| Unidentified shell | Molluscs/Shells | Herbivore | 2 | 1 | 6 | 3 | 5 | 1 | 18 |
| Unidentified shrimp | Crustaceans/ Crabs | N/A | | 4 | | | | | 4 |
| Unidentified calc tube worm | Annelids/Worms | Filter feeder | 1 | | | | | | 1 |
| Unidentified sponge | Porifera | Filter feeder | 10 | 28 | 21 | 25 | 47 | 11 | 142 |
| Unidentified sponge 2 | Porifera | Filter feeder | 4 | 10 | 6 | 10 | 1 | 3 | 34 |
| Unidentified terebellid | Annelids/Worms | Filter feeder | 1 | 1 | 1 | | | | 3 |

| Species name | Class name | Feed group | 2019/2020 | 2020/2021 | 2021/2022 | 2022/2023 | 2023/2024 | 2024/2025 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Unidentified worm | Annelids/Worms | Filter feeder | 1 | 6 | 5 | 6 | 1 | | 19 |
| Unidentified amphipod | Crustaceans/Crabs | Herbivore | 64 | 63 | 46 | 106 | 106 | 26 | 411 |
| Unidentified crab | Crustaceans/ Crabs | Predator/ scavenger | | | 1 | 1 | | | 2 |
| Unidentified fish | Chordates/Fish | Predator/ scavenger | 3 | 2 | 1 | | 3 | | 9 |
| Unidentified pink anemone | Coelenterates/ Anemones | Predator/ scavenger | | 1 | | | 2 | | 3 |
| Xenostrobus pulex | Molluscs/Shells | Filter feeder | 44 | 35 | 36 | 54 | 52 | 22 | 243 |
| Zeacumantus lutulentus | Molluscs/Shells | Herbivore | | | | | 6 | 1 | 7 |
| Zeacumantus subcarinatus | Molluscs/Shells | Herbivore | 53 | 55 | 54 | 4 | | | 166 |
| *Acrosorium venulosum* | Algae | Algae | | | | 0 | 0 | | 0 |
| *Asparagopsis armata* | Algae | Algae | | | | | 1 | | 1 |
| *Carpophyllum sp.* | Algae | Algae | | | 1 | 2 | 1 | 1 | 5 |
| *Centroceras clavulatum* | Algae | Algae | | | | | | 13 | 13 |
| *Ceramium sp.* | Algae | Algae | 1 | | | | | | 1 |
| *Chaetomorpha aerea* | Algae | Algae | 140 | 170 | 143 | 163 | 114 | 120 | 850 |
| *Champia sp.* | Algae | Algae | 5 | 18 | 14 | 9 | 73 | 57 | 176 |
| *Chondria macrocarpa* | Algae | Algae | | 17 | 11 | 5 | | | 33 |
| *Cladophora sp.* | Algae | Algae | | | | | 19 | | 19 |
| *Cladophoropsis herpestica* | Algae | Algae | 15 | | | | | 1 | 16 |
| *Cladostephus spongiosus* | Algae | Algae | 2 | 3 | 1 | | | | 6 |
| *Cladostephus spongiosus (Rope)* | Algae | Algae | 2 | | | | | | 2 |
| *Codium species* | Algae | Algae | | | | 1 | 14 | 1 | 16 |
| *Colpomenia sp.* | Algae | Algae | 106 | 86 | 54 | 98 | 120 | 104 | 568 |
| *Corralina officinalis paint* | Algae | Algae | 261 | 270 | 276 | 221 | 237 | 209 | 1474 |
| *Corralina officinalis turf* | Algae | Algae | 241 | 238 | 228 | 246 | 235 | 211 | 1399 |
| *Cystophora torulosa* | Algae | Algae | 1 | 4 | | 1 | 1 | 8 | 15 |
| *Dasyclonium sp.* | Algae | Algae | 1 | | | | 2 | | 3 |
| *Dictyota sp.* | Algae | Algae | | 7 | | | 2 | 1 | 10 |
| *Distromium skottsbergii* | Algae | Algae | | | | | 1 | | 1 |
| *Endarachne* | Algae | Algae | | | | 1 | 3 | 14 | 18 |

| Species name | Class name | Feed group | 2019/2020 | 2020/2021 | 2021/2022 | 2022/2023 | 2023/2024 | 2024/2025 | Total |
|---|---|---|---|---|---|---|---|---|---|
| *binghamiae* | | | | | | | | | |
| *Enteromorpha sp.* | Algae | Algae | 15 | 17 | 3 | 1 | 50 | 35 | 121 |
| *Gelidium caulacantheum* | Algae | Algae | 72 | 98 | 142 | 124 | 150 | 158 | 744 |
| *Gigartina sp.* | Algae | Algae | 121 | 64 | 55 | 13 | 94 | 88 | 435 |
| *Grateloupia turuturu* | Algae | Algae | | 40 | 30 | 3 | 1 | | 74 |
| *Grateloupia urvilleana* | Algae | Algae | | 1 | | | | | 1 |
| *Halopteris sp.* | Algae | Algae | | | 5 | | 1 | | 6 |
| *Hormosira banksii* | Algae | Algae | 47 | 43 | 45 | 47 | 43 | 47 | 272 |
| *Hymenena sp.* | Algae | Algae | 14 | 5 | 14 | 9 | 1 | 2 | 45 |
| *Jania sp.* | Algae | Algae | 34 | 64 | 71 | 78 | 51 | 76 | 374 |
| *Laurencia distichophylla* | Algae | Algae | 15 | 12 | 9 | 42 | 17 | 24 | 119 |
| *Laurencia thryisifera* | Algae | Algae | 58 | 44 | 23 | 45 | 65 | 57 | 292 |
| *Leathesia sp.* | Algae | Algae | 9 | | | | 16 | 42 | 67 |
| *Lophothamnion hirtum* | Algae | Algae | | 3 | 3 | | | | 6 |
| *Lophurella sp.* | Algae | Algae | 16 | 36 | 35 | 15 | 61 | 52 | 215 |
| *Notheia anomala* | Algae | Algae | 4 | 4 | 2 | | | | 10 |
| *Petalonia fascia* | Algae | Algae | | | | | | 4 | 4 |
| *Plocamium angustum* | Algae | Algae | | 1 | 2 | | 2 | | 5 |
| *Polysiphonia strictissima* | Algae | Algae | | | | 1 | | 6 | 7 |
| *Porphyra columbina* | Algae | Algae | 21 | | | | 7 | | 28 |
| *Pterocladia sp.* | Algae | Algae | | | | 5 | | | 5 |
| *Pterocladiella capillacea* | Algae | Algae | 30 | 18 | 18 | 7 | 8 | 5 | 86 |
| *Ralfsia sp.* | Algae | Algae | 239 | 266 | 247 | 230 | 230 | 201 | 1413 |
| *Sarcothalia marginifera* | Algae | Algae | 37 | 149 | 23 | 5 | 14 | 4 | 232 |
| *Scytothamnus australis* | Algae | Algae | 15 | 39 | 42 | 7 | 14 | 34 | 151 |
| *Splachnidium rugosum* | Algae | Algae | | | | | | 2 | 2 |
| *Spongoclonium pastorale* | Algae | Algae | | | 2 | 2 | 10 | 38 | 52 |
| Unidentified algae 2 | Algae | Algae | | 3 | | 2 | 8 | 47 | 60 |
| Unidentified algae 3 | Algae | Algae | | | | | 12 | 6 | 18 |
| Unidentified algae 4 | Algae | Algae | | 1 | | | 4 | 3 | 8 |
| Unidentified | Algae | Algae | | | | | 7 | 4 | 11 |

| Species name | Class name | Feed group | 2019/2020 | 2020/2021 | 2021/2022 | 2022/2023 | 2023/2024 | 2024/2025 | Total |
|---|---|---|---|---|---|---|---|---|---|
| algae 5 | | | | | | | | | |
| Unidentified algae 6 | Algae | Algae | | | | | 2 | 1 | 3 |
| Unidentified algae 7 | Algae | Algae | | | | | 2 | | 2 |
| Unidentified brown algae 1 | Algae | Algae | 28 | 33 | 7 | 6 | 27 | 8 | 109 |
| Unidentified brown algae 2 | Algae | Algae | 2 | 6 | | | 2 | | 10 |
| Unidentified green algae 1 | Algae | Algae | 3 | 5 | 6 | 5 | 24 | 11 | 54 |
| Unidentified red algae 1 | Algae | Algae | 34 | 51 | 33 | 55 | 48 | 34 | 255 |
| Unidentified red algae 2 | Algae | Algae | 33 | 26 | 6 | 9 | 19 | 24 | 117 |
| Unidentified red turf | Algae | Algae | | 14 | | 1 | | | 15 |
| *Ulva sp.* | Algae | Algae | 129 | 163 | 83 | 75 | 108 | 61 | 619 |
| Unidentified algae | Algae | Algae | 4 | 3 | 2 | | 1 | | 10 |
| *Zostera sp.* | Algae | Algae | 7 | 7 | 12 | 9 | 8 | 5 | 48 |

# Appendix III

## Unadjusted long-term trend analyses

Table 15 Key outputs of long-term trend analyses for mean number of species and Shannon-Wiener Diversity Index at six SoE sites from 1994 to 2024

| Site | Variable | Unadjusted | | | | | Sand-adjusted | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Median | Annual Sen Slope | Percent Annual Change | Trend Direction | Likelihood | Annual Sen Slope | Percent Annual Change | Trend Direction | Likelihood |
| **Tūrangi** | **No. species** | 16.6 | 0.0564 | 0.34 | Increasing | Highly likely (0.97) | 0.0300 | 0.18 | Increasing | Likely (0.86) |
| | **SW index** | 0.90 | -0.0011 | -0.13 | Decreasing | Likely (0.81) | -0.0015 | -0.17 | Decreasing | Likely (0.89) |
| **Orapa** | **No. species** | 15.3 | 0.1077 | 0.70 | Increasing | Highly likely (0.99) | 0.1241 | 0.81 | Increasing | Highly likely (0.99) |
| | **SW index** | 0.94 | 0.0024 | 0.26 | Increasing | Very likely (0.92) | 0.0036 | 0.38 | Increasing | Highly likely (0.99) |
| **Mangatī** | **No. species** | 14.8 | 0.0689 | 0.47 | Increasing | Highly likely (0.95) | 0.0936 | 0.63 | Increasing | Highly likely (0.99) |
| | **SW index** | 0.92 | 0.0021 | 0.24 | Increasing | Very likely (0.94) | 0.0032 | 0.35 | Increasing | Highly likely (0.99) |
| **Greenwood** | **No. species** | **17.4** | **-0.0423** | **-0.24** | **Decreasing** | **Likely (0.78)** | **0.0233** | **0.13** | **Increasing** | **Likely (0.70)** |
| | **SW index** | 0.96 | -0.0052 | -0.55 | Decreasing | Highly likely (0.99) | -0.0018 | -0.19 | Decreasing | Highly likely (0.97) |
| **Mānihi** | **No. species** | 20.2 | 0.1931 | 0.96 | Increasing | Highly likely (0.99) | n/a | n/a | n/a | n/a |
| | **SW index** | 1.07 | 0.0029 | 0.27 | Increasing | Highly likely (0.99) | n/a | n/a | n/a | n/a |
| **Waihī** | **No. species** | 11.9 | -0.0054 | -0.05 | Decreasing | Uncertain (0.56) | -0.0126 | -0.11 | Decreasing | Likely (0.73) |
| | **SW index** | 0.85 | -0.0019 | -0.22 | Decreasing | Highly likely (0.97) | -0.0020 | -0.23 | Decreasing | Highly likely (0.98) |

NB: trends in bold denote instances where trend direction differs from adjusted trend