State of the Environment
Rocky Shore Monitoring Report
2008-2015

Technical Report 2015-56

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Executive summary

Section 35 of the Resource Management Act 1991 requires local authorities to undertake monitoring of the region's environment, including land, air, marine and freshwater. The rocky shore component of the State of the Environment Monitoring (SEM) programme for Taranaki was initiated by the Taranaki Regional Council in the 1994-1995 monitoring year and has subsequently continued each year. This report covers the state and trends of intertidal hard shore communities in Taranaki. Soft shore communities will be covered in a separate, companion report.

As part of the SEM programme, six representative reef sites were monitored twice a year (spring and summer surveys) using a fixed transect, random quadrat survey design. For each survey, a 50 m transect was laid parallel to the shore (approximately 0.6 m above chart datum) and substrate cover, algal cover and animal cover/abundance in 25 x 0.25 m^2 random quadrats were quantified. Changes in the number of species per quadrat (species richness) and Shannon-Wiener index per quadrat (diversity) were assessed at the six reef sites over the 21 years of the SEM programme (spring 1994 to summer 2015).

Of the six sites surveyed over the 21 year period the intertidal communities at Manihi (west Taranaki), were the most species rich (median = 19.4 species per quadrat) and diverse (median Shannon Wiener index = 1.07 per quadrat) due to the low supply of sand and the presence of pools that provided a stable environment with many ecological niches. The intertidal communities at Waihi (south Taranaki) were the least species rich (median = 11.7 species per quadrat) and diverse (median Shannon Wiener index = 0.85 per quadrat) due to the high energy wave environment, lack of stable habitat and periodic sand inundation.

Sand deposition has been shown to have a profound effect on intertidal communities in Taranaki. The reef sites at Mangati and Greenwood Road (north Taranaki) were particularly prone to periodic sand inundation. Years of high sand accumulation at these sites resulted in lowered species richness and diversity. Trend analysis indicates that there has been a significant decrease in species richness and diversity at the Mangati and Greenwood Road reef sites, which appears to have been caused by an increased sand supply from the mountain, combined with oceanographic conditions that shift this sand onshore.

Natural environmental factors, including sand cover, wave exposure and reef geomorphology, appear to be the dominant divers of species richness and diversity at the six SEM reef sites surveyed.

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1. Introduction

1.1 State of the environment monitoring

Regional councils have responsibilities under the Resource Management Act (1991) to monitor the state of the environment. The purpose of state of the environment monitoring (SEM) is to collect sufficient data to produce information on the general health of the environment. This information is used to guide management decisions and enables the Council to assess the influence of natural processes and effectively take measures to mitigate the impacts of human activities on the coastal environment.

Biological communities of the rocky reefs around the Taranaki coastline have been monitored since 1983 by the Taranaki Catchment Commission. A more comprehensive rocky shore monitoring programme was implemented by the Taranaki Regional Council during the 1994-1995 summer as an on-going component of the SEM programme for the Taranaki region.

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, the 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. reefs off the Waitara coastline extend as far as 5 km 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 biology of the Taranaki rocky shore is profoundly influenced by the physical characteristics of the area. The exposed weather and wave conditions, as well as the geomorphology of the shore determine, to a large extent, the structure and composition of the marine communities found here. The organisms that live on these reefs provide an important food source for humans, birds and fish and also form a significant component of marine biodiversity in Taranaki.

1.2.3 Cultural significance

The reefs of Taranaki provide a valuable source of kaimoana/mātaitai for Maori. 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 paua, kina and kuku/kutae (mussels), because the sites are located higher on the shore than these species typically occur. Instead the results of the rocky shore SEM programme provide a record of species richness, diversity and composition at representative reef sites around the region which can be used to assess the 'health' of the reef environment.

Around the Taranaki coastline, particular reefs are regarded as property of particular hapu. Iwi and hapu associations with the six SEM reef sites are outlined in Table 1.

2. Monitoring methodology

2.1 Site location

The location of the six SEM rocky shore sites are shown in Table 1 and Figure 1.

Table 1 Location of SEM rocky shore sites and iwi/hapu associations

Site code	Site location	Location NZTM E/N	Iwi/hapu
SEA900095	Turangi Reef – north of Motunui	1713712 / 5684309	Te Atiawa/Ngati Rahiri
SEA901043	Orapa Reef – west of Waitara River Mouth	1704759 / 5683854	Te Atiawa/Otaraua, Pukerangiora
SEA902005	Mangati Reef – Bell Block	1698314 / 5680510	Te Atiawa/Puketapu
SEA903070	Greenwood Road Reef – south of Oakura	1677185 / 5668284	Taranaki/Nga Mahanga-a-Tairi
SEA904065	Manihi Road Reef – north of Oaonui	1666415 / 5641780	Taranaki/Ngati Haupoto
SEA906025	Waihi Reef – Hawera	1707058 / 5614617	Ngāruahine/Kanihi-Umutahi, Okahu-Inuawai Ngati Ruanui/Hamua, Ngati Tanewai, Ngati Tupaea, Hapotiki, Ngati Hawe

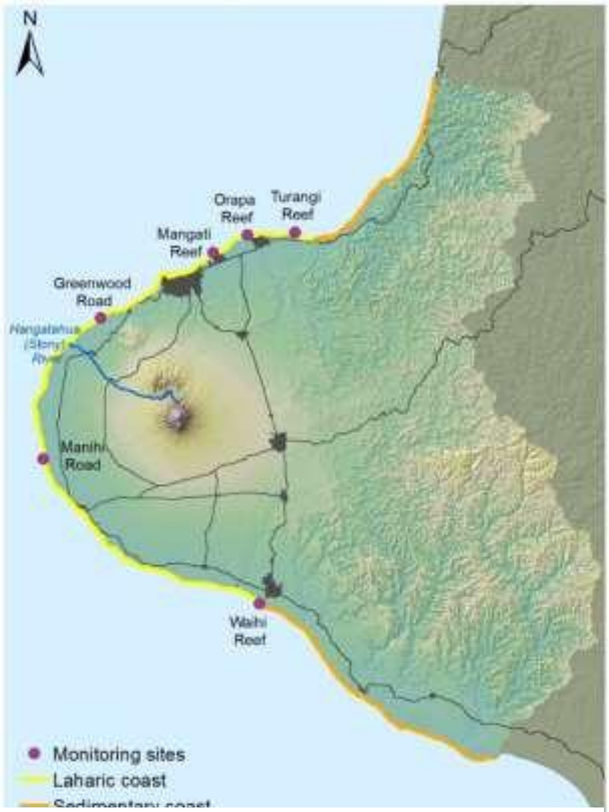

Figure 1 Location of the SEM rocky shore sites in relation to the underlying coastal geology and proximity to the Stony River (a major source of sand to the coast)

Photo 1 Turangi Reef transect (top left), kina, *Evechinus chloroticus* (bottom left), and spotted whelk *Cominella maculosa* (bottom right)

Photo 2 Orapa Reef transect (top left), polychaete tubeworm *Neosabellaria kaiparaensis* (bottom left) and oyster borer *Haustrum scobina* on *N. kaiparaensis* (bottom right)

Photo 3 Mangati Reef transect (top left), coralline algae with herbivorous gastropods cat's eyes *Turbo smaragdus* and spotted top-shell, *Melagraphia aethiops* (bottom left)

Photo 4 Greenwood Road Reef transect (bottom), reef star, *Stichaster australis* (top left), ornate limpets, *Cellana ornata*, cat's eyes, *Turbo smaragdus*, oyster borer, *Haustrum scobina*, white rock shell, *Dicathais orbita* and snakeskin chiton, *Sypharochiton pelliserpentis* (top middle)

Photo 5 Manihi Road Reef transect (top left), nudibranch *Alloiodoris lanuginata* (bottom left), duck's bill limpet, *Scutus breviculus* (bottom centre), and mottled brittle star, *Ophionereis fasciata* (bottom right)

Photo 6 Waihi Reef transect (top left), radiate limpet, *Cellana radians* (middle right), barnacles (bottom left), and Sinclair's snakeskin chiton, *Sypharochiton sinclairi* (bottom right)

2.2 Survey method

The six reef sites were monitored twice a year (spring and summer surveys) using a fixed transect, random quadrat survey design. Transect location was identified using GPS coordinates and photos (the start of most transects can be identified in relation to distinctive boulders and other landmark features). At each site, a 50 m transect was laid parallel to the shore at a tidal height of approximately 0.6 m above chart datum. The transect was used to establish five 5 m x 3 m blocks. Within each block, five random 0.25 m^2 quadrats were laid giving a total of 25 random quadrats. For each quadrat the percentage cover of algae and encrusting animal species was estimated using a grid. For all other animal species, individuals larger than 3 mm were counted. Under boulder biota was counted where rocks and cobbles were easily overturned.

The surveys were designed to provide sufficient statistical sensitivity to effectively detect change while providing a realistic survey time within the low tide period to effectively complete the survey (TCC, 1983; TCC, 1984).

2.3 Statistical comparisons between sites

Given the unequal variance between reef sites (Levene's test, $p = <0.001$), even following log transformation of the data (Levene's test, $p = <0.006$), it was not appropriate to use ANOVA to test for differences between means. Instead the Welch test (a t-test with separate variance estimates) was used to determine the statistical significant differences between sites. For both Levene's and Welch test, Statistica software was used to conduct the statistical analysis.

2.4 Trend Analysis

Trend analysis for number of species per quadrat (species richness) and Shannon Wiener Index per quadrat (diversity) was carried out using an adapted method of the water quality trend analysis developed by Scarsbrook and McBride (2007). Protocols similar to flow adjusted water quality analyses were used to analyze the effect of sand cover on rocky shore communities. The trend analysis involved an adjustment of the raw data for each variable at each site to take the degree of sand cover into account, followed by trend analysis accounting for any temporal pattern.

Sand adjustment was performed using LOWESS (LOcally WEighted Scatterplot Smoothing), within the Time Trends software, with a 30% span. Every data-point in the record was then adjusted depending on the value of percentage sand cover (adjusted value=raw value – smoothed value + median value, where the smoothed value is that predicted from the sand cover using LOWESS). The non-parametric trend analysis was then applied to the whole data for each parameter at each site which takes into account the temporal variability in the data.

This analysis is based on two key measures:

- The seasonal Kendall slope estimator (SKSE) which measures the magnitude of the trend; and
- The associated seasonal Kendall trend test which determines whether the trend is significant.

Statistically significant trends were determined using a p-value < 0.05 or <0.01. If a p-value is less than 0.05 or 0.01, then there is a less than 5% or 1% chance of finding a trend when there is not one.

The slope of the trend (SKSE) is expressed in units of change per year, and can also be expressed in terms of relative change (RSKSE) which is the percent of change per year. A positive SKSE or RSKSE indicates a positive (increasing) trend, and a negative SKSE or RSKSE indicates a negative or decreasing trend. The RSKSE allows comparisons in the slope between parameters and sites.

It is 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. Ballantine and Davies-Colley (2009) have determined a 'meaningful' trend as one for which the RSKSE is statistically significant and has an absolute magnitude > 1 percent change per year. This approach has also been adopted in this report.

The statistical analysis and approach has undergone independent peer review by NIWA staff.

3. Results

3.1 Species richness and diversity between sites

Summary statistics for the number of species per quadrat (species richness) and Shannon-Wiener index per quadrat (diversity) for the six reef sites are provided in Table 2 (raw data in Appendix I).

Table 2 Summary statistics: species richness and diversity at six reef sites from 1994 to 2015

Site	Number of surveys	*Number of species per quadrat				*Shannon-Wiener index per quadrat			
		Mean	Median	Max	Min	Mean	Median	Max	Min
Turangi	46	15.8	15.9	18.7	11.7	0.89	0.89	1.01	0.68
Orapa	40	13.3	13.8	17.8	1.6	0.84	0.90	1.03	0.15
Mangati	38	13.4	13.9	17.2	3.4	0.86	0.92	1.05	0.28
Greenwood	42	15.6	16.3	23.8	0.2	0.91	0.94	1.15	0.02
Manihi	37	19.4	19.4	24.9	15.0	1.05	1.07	1.20	0.89
Waihi	46	11.4	11.7	17.0	4.8	0.85	0.85	1.03	0.40

**Values based on means for each survey, not individual quadrats*

Figures 2 and 3 show differences in species richness and diversity between the reef sites over the 21 years of the monitoring programme (1994-2015). Both species richness and diversity were significantly higher at Manihi than at all other sites (Welch test, $p < 0.0001$). At Waihi, species richness was significantly lower than at all other sites (Welch test, $p < 0.004$), but there was no significant difference in diversity between Waihi, Orapa and Mangati (Welch test, $p > 0.05$).

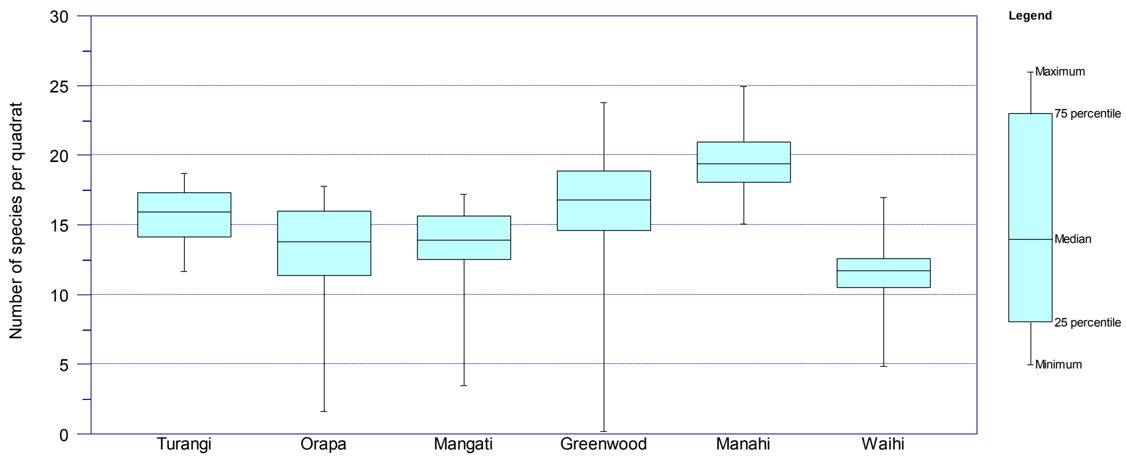

Figure 2 Box and whisker plot of number of species per quadrat (species richness) at the six reef sites from spring 1994 to summer 2015

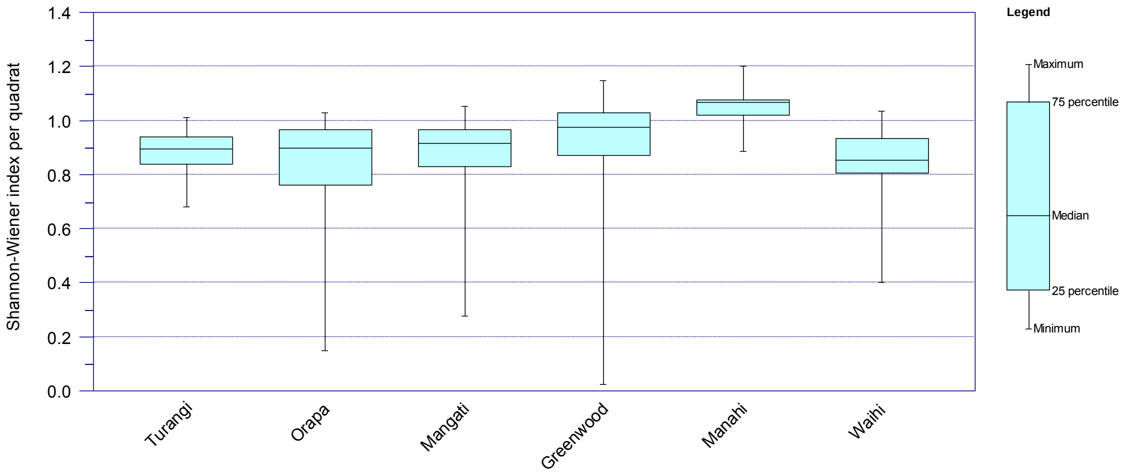

Figure 3 Box and whisker plots of Shannon-Wiener index per quadrat (diversity) at the six reef sites from spring 1994 to summer 2015

3.2 Trends in species richness and diversity from 1994 to 2015

Changes in species richness, diversity and sand cover from spring 1994 to summer 2015 are shown in Figure 4. Over the 21 years of the monitoring programme, Orapa, Mangati, Greenwood and Waihi have been more prone to periodic sand inundation than Turangi and Manihi. Surveys with high sand accumulation were associated with lower species richness and diversity (Figure 4, Photos 7 and 8).

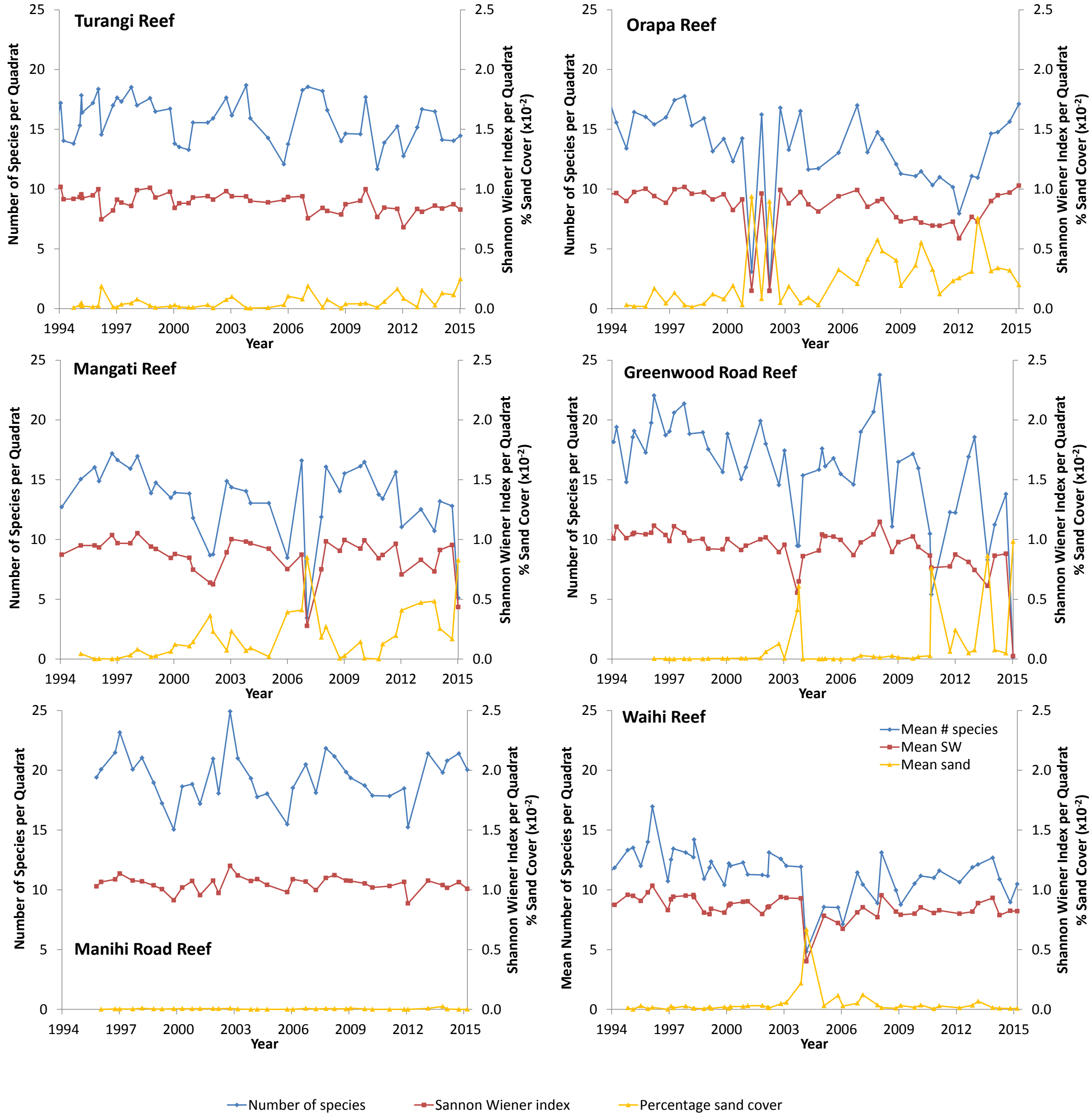

Figure 4 Number of species, Shannon-Wiener index and percentage sand cover at the six reef sites from spring 1994 to summer 2015

Photo 7 Mangati Reef with low sand cover on 25 September 2014 (left) and inundated with sand on 23 January 2015 (right)

Photo 8 Greenwood Road Reef with low sand cover on 2 February 2014 (left) and inundated with sand on 23 January 2015 (right)

Long term trend analysis showed a significant ($p < 0.05$), meaningful (>1% annual change) decrease in species richness at Mangati, Greenwood and Waihi over the 21 years (Table 3). For Mangati and Greenwood, sand adjusted trends were no longer significant ($p > 0.05$, Table 3), indicating that a decrease in species richness at these sites could be related to an increase in periodic sand accumulation (Figure 4). For Waihi, the sand adjusted trend for species richness remained significant ($p < 0.05$) and meaningful (>1% annual change), indicating additional factors were driving the decrease in species richness at this site.

Trend analysis showed a significant ($p < 0.05$) decrease in diversity at Turangi, Mangati, Greenwood and Waihi over the 21 years (Table 3). This decrease was only meaningful (>1% annual change) at Greenwood. For Mangati and Greenwood, sand adjusted trends in diversity were no longer significant ($p > 0.05$, Table 3), providing support that the decrease in diversity at these sites was related to an increase in periodic sand accumulation (Figure 4). For Turangi and Waihi, the sand adjusted trends for diversity remained significant ($p < 0.05$), indicating additional factors were driving the decrease in diversity at these sites.

Table 3 P-values and trend slopes (% annual change) of species richness and diversity at six reef sites between spring 1994 and summer 2015, including unadjusted and sand adjusted trend results

Site	Trend Analysis							
	Number of species (species richness)				Shannon-Wiener index (diversity)			
	Unadjusted trend		Sand adjusted trend		Unadjusted trend		Sand adjusted trend	
	P value	% AC	P value	% AC	P value	% AC	P value	% AC
Turangi	0.1660	-0.7526	0.1657	-0.6576	0.0073	-0.7405	0.0496	-0.4145
Orapa	0.2757	-0.8758	0.4586	0.4232	0.2217	-0.6686	0.4074	0.3814
Mangati	0.0095	-1.7207	0.8823	0.0648	0.0218	-0.9513	0.9410	0.0303
Greenwood	0.0112	-1.7435	0.2312	-0.7068	0.0184	-1.0295	1.0000	-0.0402
Manihi	0.5551	0.6716	0.1488	0.6222	1.0000	-0.0166	0.9323	0.0508
Waihi	0.0006	-1.4712	0.0009	-1.2512	0.0131	-0.7390	0.0062	-0.7473

% AC = % annual change (also RSKSE)
Significant decreases shown in orange ($p < 0.05$ statistically significant) & red ($p < 0.01$ very statistically significant)
Meaningful trends (>1% annual change) shown in yellow

3.3 Species composition and abundance

A full list of the species recorded during the SEM intertidal surveys between 2008 and 2015, including the percentage of quadrats each species was present in, is provided in Appendix IV. In summary, species composition at the six SEM reef sites was typical of New Zealand mid-shore, wave exposed boulder reefs. The dominant primary producers were encrusting and geniculate coralline algal species (coralline paint and turf respectively). Limpets (*Cellana radians* and *Cellana ornate*) and chitons (*Sypharochiton pelliserpentis, Chiton glaucus* and *Ischnochiton maorianus*) were abundant being well adapted to the wave exposed conditions. With the exception of Waihi Reef, herbivorous gastropods *Melagraphia aethiops* and *Turbo smaragdus* thrived at all sites. Predatory gastropods *Haustrum scobina* and *Haustrum haustorium* were also abundant at most sites. The porcelain crab *Petrolisthes elongates* was often present under boulders, being able to scuttle and filter feed between the rounded rocks. The cushion star *Patiriella regularis* was one of the more common echinoderms found at the Taranaki reef sites. Unlike other echinoderm species which are generally predatory, *P. regularis* grazes on algal- and biofilms present on the surface of the boulders.

Figure 5 shows the change in abundance of three key intertidal species between spring 1994 and summer 2015. Coralline turf, largely composed of *Corallina officinalis*, was the dominant algal type at all sites with the exception of Waihi. The relatively high percentage cover of coralline turf provided an ideal habitat for juvenile cat's-eyes *T. smaragdus* which are known to feed on the small epiphytes present on the calcified surface of the coralline algae. *T. smaragdus* was also abundant at all sites with the exception of Waihi. The colonial tubeworm *Neosabellaria kaiparaensis* thrived in sand rich environments and could dominate, preventing other species from colonising. Extensive build up of *N. kaiparaensis* colonies occurred at the Orapa Reef site with mean percentage cover greater than 40% during some years.

Photo 9 Animal species commonly found on Taranaki reefs: variable chiton, *Ischnochiton maorianus* (top left), green chiton, *Chiton glaucus* (top right), half crab, *Petrolisthes elongates* (middle left), *Haustrum haustorium* with eggs (middle right), spotted top-shell, *Melagraphia aethiops* (bottom left), common cushion star, *Patiriella regularis* (bottom right)

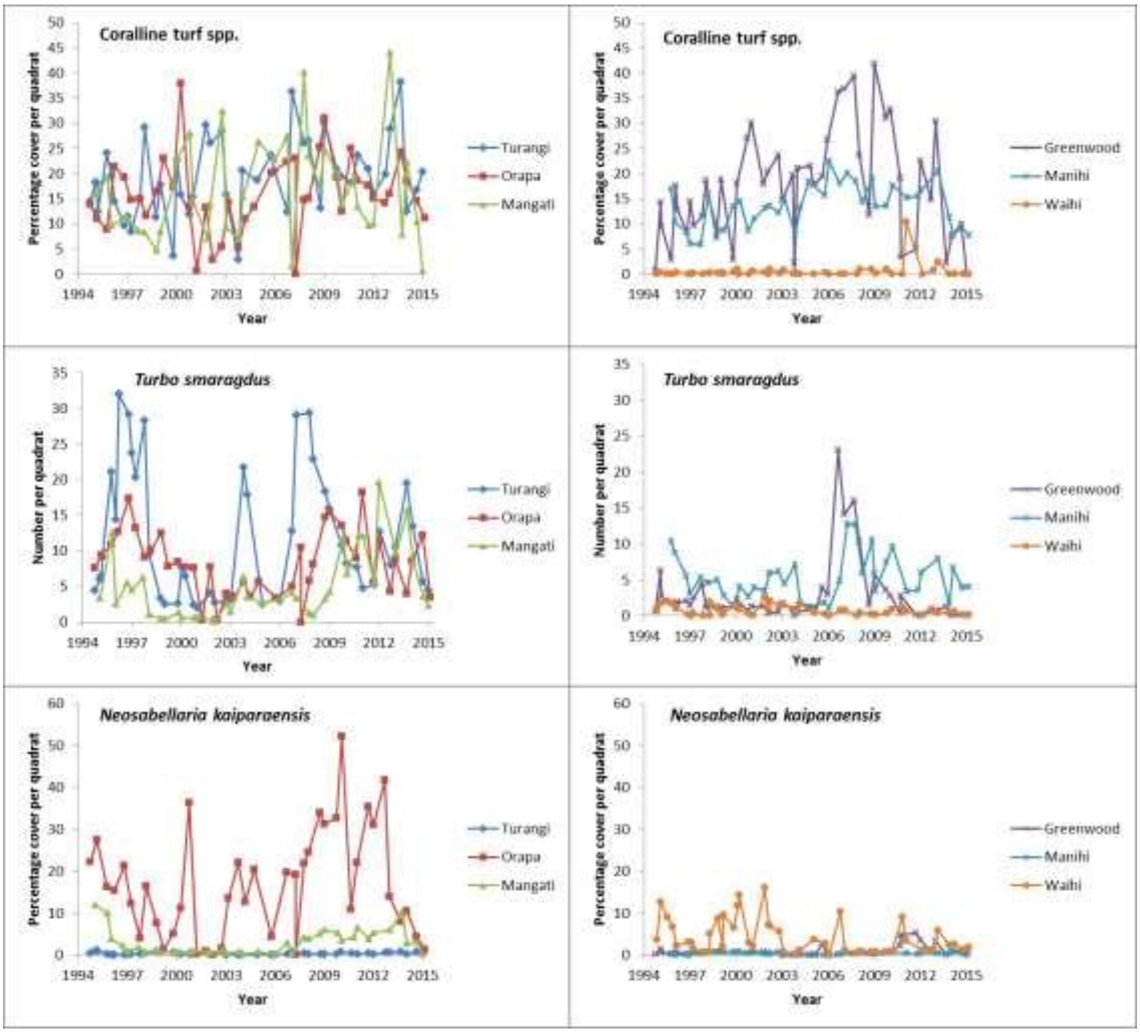

Figure 5 Abundance of three key species at six reef sites from spring 1994 to summer 2015

Photo 10 A variety of coralline algal species (left), cat's eye, *Turbo smaragdus* (centre), polychaete tubeworm, *Neosabellaria kaiparaensis* (right)

4. Discussion

In this section the main factors driving differences in diversity and species composition between sites and over time will be discussed.

4.1 Sand

Manihi, the site with the lowest sand cover (<1%), consistently had the highest species richness and diversity of all six reef sites (Figure 4). In contrast, Greenwood and Mangati have been particularly susceptible to sporadic heavy sand inundation (Photos 7 and 8), with dramatic short term effects on species richness and diversity (Figure 4). 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).

Encrusting and non-motile organisms are susceptible to smothering and burial during heavy sand inundation, often resulting in death. Motile organisms are better designed to cope, with some species having been shown to escape heavy sand accumulation altogether. For example, paua escape heavy sand cover by moving into deeper waters (Howes et al., 2000). At the Taranaki intertidal reef sites, motile gastropods (snails and limpets) have been observed concentrated on larger rocks which protrude above the sand (Photo 11). Such responses may aid rapid recovery of the reefs post sand inundation, with reefs typically recovering within a year or two providing sand accumulation is not persistent.

Photo 11 Cat's eyes, *Turbo smaragdus* (left), and radiate limpets, *Cellana radians* (right), concentrating on protruding rocks during sand inundation of the reef

At Greenwood and Mangati, trend analysis implies that species richness and diversity have decreased at these sites over time (Table 3). Sand adjusted trend analysis and sand cover data (Table 3, Figure 4) indicate that these decreases could be related to an increase in periodic sand accumulation. The main sources of sand to the Taranaki coastline come from rivers, streams and eroding cliffs (Matthews, 1977; Cowie, 2009). In North Taranaki one source in particular has provided an increase in sand supply to the coastline since the late nineties: In 1998, a scarp at the headwaters of the Stony River collapsed, leading to a massive input of sand and gravel down the river and into the coastal system. Erosion has been ongoing since this event, including a number of other large erosion events. Prior to 1998, the coastline extending from Cape Egmont to Oakura 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 risk 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 personal communication). An increase in these conditions, together with a greater sand supply from the mountain, appear to have impacted on reef species richness and diversity at certain sites, particularly at Greenwood and Mangati.

Photo 12 Pyramid Stream gully, at the headwaters of the Stony 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 large accelerational forces, either by preventing settlement or by limiting growth once settlement has occurred (Little *et al*., 2010). All six of the Taranaki SEM 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 at all of the Taranaki sites with these species being more tolerant to drag forces and sedimentation relative to larger seaweed species. Herbivorous gastropod species, including *Melagraphia aethiops* and *Turbo smaragdus*, are abundant, in part due to the low abundance of predators in exposed areas (Little *et al*., 2010).

Wave exposure is also likely to drive differences in diversity between the Taranaki reef sites. Waihi is the most exposed of the six sites. Photographic evidence indicates that relatively large boulders at this site shift in position from one survey to the next. Community composition at this site reflects the exposed conditions with coralline paint and encrusting animals dominating (Photo 13). Wave exposure is likely to be the main factor resulting in lower species richness at Waihi relative to other Taranaki reef sites.


Photo 13 Species composition at the Taranaki reef sites is affected by wave exposure: Wave exposed Waihi Reef dominated by a limited number of encrusting algae and animals (left) and sheltered pools at Manihi Road Reef with abundant and diverse intertidal communities (right)

4.3 Habitat complexity

Reef geomorphology and associated habitat complexity is another major factor resulting in differences in diversity between the reef sites in Taranaki. The site at Manihi provides many different ecological niches for a broad range of species to occupy, with habitats including stable pools, under-boulder habitat and crevices within rocks.

At Turangi, Orapa and Mangati rocks have been observed cemented into the substrate, reducing the amount of under-boulder habitat. This reduction in habitat availability results in a decrease in diversity and species richness.

At Orapa, large colonies of the tubeworm *Neosabellaria kaiparaensis* can build up over the reef, reducing the diversity of microhabitats available for other species (Photo 14). A build up of tubeworms occurred at Orapa between 2006 and 2012 (Figure 5), resulting in a reduction in species richness and diversity at the reef site (Figure 4). Since 2012, the tubeworm beds have largely broken down (Figure 5), exposing more diverse substrate for habitation. This increase in habitat complexity has been associated with a clear increase in species richness and diversity, evident between 2012 and 2015 (Figure 4).


Photo 14 Orapa Reef in 2006 with build up of tubeworm colonies (left) and in 2015 with a much lower cover of tubeworms (right)

4.4 Human versus natural effects

The diversity and composition of intertidal communities at the SEM reef sites are largely driven by the natural physical factors discussed thus far i.e. effects of sand and sediment, wave exposure and geomorphology of the reefs. 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, off the Hawera coastline, prior to 1997 dairy factory wastewater discharged through the nearshore outfall was having significant adverse effects on the local intertidal community, which was clearly detectable in the results of the intertidal surveys undertaken as part of the consent compliance monitoring programme (TRC, 2014). In 1997 the dairy company installed a long outfall to discharge the wastewater nearly 2 km offshore, which 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 SEM reef sites.

With the exception of Orapa and Mangati, the SEM reef sites are located outside of the influence of wastewater discharges. Norovirus analysis of mussels from Orapa and (close to) Mangati indicate that previously these sites have had shoreline contact with wastewater discharged from the Waitara and New Plymouth wastewater treatment plants respectively (TRC, *in prep.*). Although there is evidence that these wastewater discharges have resulted in microbial contamination of shellfish at these sites (covered in TRC, *in prep*.), deleterious impacts of the wastewater discharges on intertidal species richness and diversity have not been detected through the Council's Rocky Shore SEM programme (Figure 4).

Poor land management practices have the potential to accelerate stream- and river bank erosion, increasing the volume of sediment reaching the coast. The extent that sediment is deposited onto the SEM reef sites as a result of this anthropogenic source is difficult to detect/separate from deposition occurring through natural processes. However the adoption of good land management practices e.g. riparian fencing and planting, will aid to reduce anthropogenic impact of this nature.

5. General summary

Rocky reefs dominate the intertidal zone of the Taranaki coastline, particularly around the ring plain. Since spring 1994, the Council has conducted biannual surveys of intertidal communities at six rocky reef sites using a fixed transect random quadrat design as part of the SEM programme. This information is used to guide management decisions and enables 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, including sand cover, wave exposure and reef geomorphology, appear to be the dominant drivers of species richness and diversity at the six SEM reef sites surveyed. Although subtle changes resulting from human activities can be difficult to identify, no noticeable anthropogenic impacts have been detected at any of the SEM reef sites to date.

Of the six sites surveyed over the 21 year period the intertidal communities at Manihi were the most species rich and diverse due to the low supply of sand and the presence of pools that provided a stable environment with many ecological niches. The intertidal communities at Waihi were the least species rich and diverse due to the high energy wave environment, lack of stable habitat and periodic sand inundation. A summary of the main factors affecting diversity and species composition at the six reef sites is provided in Table 4.

Sand deposition has been shown to have a profound effect on intertidal communities in Taranaki. The reef sites at Mangati and Greenwood Road were particularly prone to periodic sand inundation. Years of high sand accumulation at these sites resulted in lowered species richness and diversity. Trend analysis indicates that there has been a significant decrease in species richness and diversity at the Mangati and Greenwood Road reef sites, which appears to have been caused by an increased sand supply from the mountain, combined with oceanographic conditions that shift this sand onshore.

Table 4 Factors affecting diversity and species composition at the SEM reef sites

	Turangi	Orapa	Mangati	Greenwood	Manihi	Waihi
Sand cover	Sand cover low. Not prone to inundation.	Consistent high sand cover. Occasional inundation.	Prone to periodic sand inundation: Increasing in frequency.	Prone to periodic sand inundation: Increasing in frequency.	Very low sand cover. Not prone to inundation.	Prone to occasional inundation.
Wave exposure	Moderately wave exposed.	Moderately wave exposed.	Moderately wave exposed.	Moderately wave exposed.	Moderately wave exposed.	Very exposed, high energy wave environment.
Habitat complexity	Mix of different sized substrates.	Larger boulders and rocks less common.	Larger boulders and rocks less common.	Mix of different sized substrates.	Most diverse mix of substrates.	Rocks and boulders dominate.
Pools	Shallow pools.	Shallow pools.	Shallow pools.	Shallow and deeper pools when not inundated with sand.	Variety of shallow and deeper pools.	Fast draining site with few pools.
Under-boulder habitat	Rocks can become cemented to the substrate reducing the availability of under-boulder habitat.	Rocks can become cemented to the substrate reducing the availability of under-boulder habitat.	Rocks can become cemented to the substrate reducing the availability of under-boulder habitat.	Good availability of under-boulder habitat when not sand inundated.	Excellent availability and variety of under-boulder habitat.	Under-boulder habitat not stable due to high wave energy environment.
Tubeworm cover	Low tubeworm cover.	Large tubeworm colonies can cover reef at times, reducing habitat complexity.	Tubeworms present but not significantly impacting habitat complexity.	Tubeworms present but not significantly impacting habitat complexity.	Low tubeworm cover.	Occasional past high tubeworm cover.
Summary	Moderately diverse site. Under-boulder habitat can be reduced when rocks become cemented to the substrate.	Sand cover and dense colonies of tube worms can reduce biodiversity at this site. Recent increase in diversity due to degeneration of tubeworm beds, freeing substrate for other species.	Sand affected site. Sand inundation increasing in frequency following increased supply from the Stony River.	Diverse site when not inundated with sand. Sand inundation increasing in frequency following increased supply from the Stony River.	Most diverse SEM reef site due to low sand cover and high habitat complexity.	Least diverse SEM reef site, likely due to the high energy wave environment.

6. Recommendation

1. THAT monitoring of the six SEM reef sites continue at the same level as in 2014-2015.

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

Species richness and diversity:
Raw data & statistical summary

Turangi Reef

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
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
Mean	15.76	0.89	5.41
Median	15.92	0.89	3.02
Max	18.68	1.01	24.88
Min	11.68	0.68	0.40

Orapa Reef

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
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
Mean	13.25	0.84	24.84
Median	13.78	0.90	19.24
Max	17.76	1.03	93.76
Min	1.60	0.15	1.40

Mangati Reef

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
19 Jan 2015	5.12	0.435	82.80
Mean	13.37	0.86	18.30
Median	13.90	0.92	11.44
Max	17.20	1.05	85.00
Min	3.44	0.28	0.04

Greenwood Road Reef

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
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
Mean	15.64	0.91	10.91
Median	16.30	0.94	0.74
Max	23.76	1.15	98.40
Min	0.16	0.02	0.00

Manihi Road Reef

Date	Number of species per quadrat	Shannon Wiener index per quadrat	Percentage sand cover per quadrat
25 Oct 1995	19.40	1.029	-
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	-
22 Feb 2011	17.84	1.031	-
29 Nov 2011	18.48	1.066	-
9 Feb 2012	15.24	0.886	-
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
Mean	19.39	1.05	0.46
Median	19.36	1.07	0.36
Max	24.92	1.20	2.50
Min	15.04	0.89	0.00

Whaihi Reef

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
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
Mean	11.42	0.85	4.38
Median	11.72	0.85	2.04
Max	16.96	1.03	66.80
Min	4.84	0.40	0.00

Appendix II

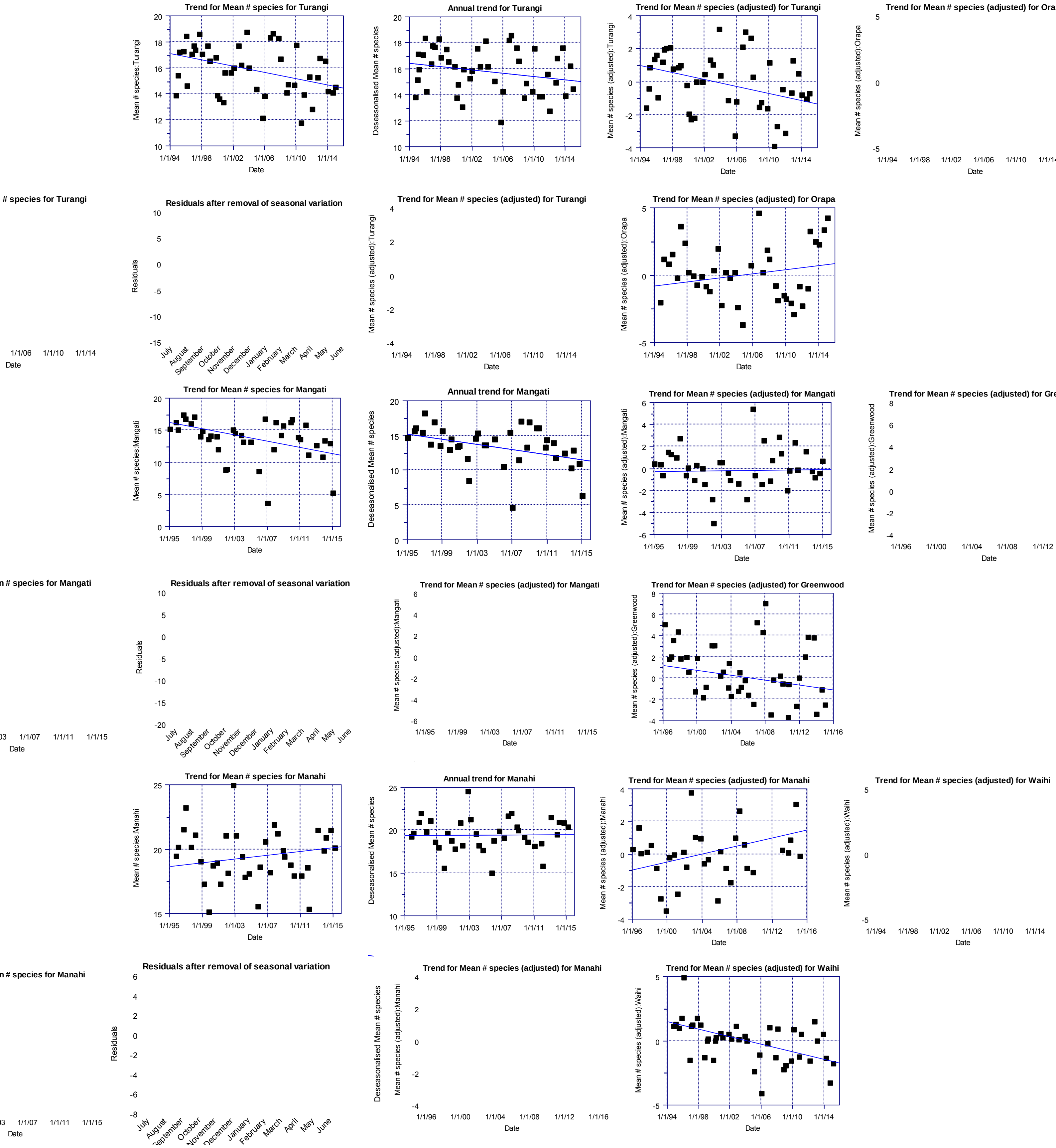
Trends for unadjusted, seasonally adjusted and sand adjusted species richness and diversity data

Trends: Number of species per quadrat

Unadjusted

Seasonally adjusted

Sand adjusted

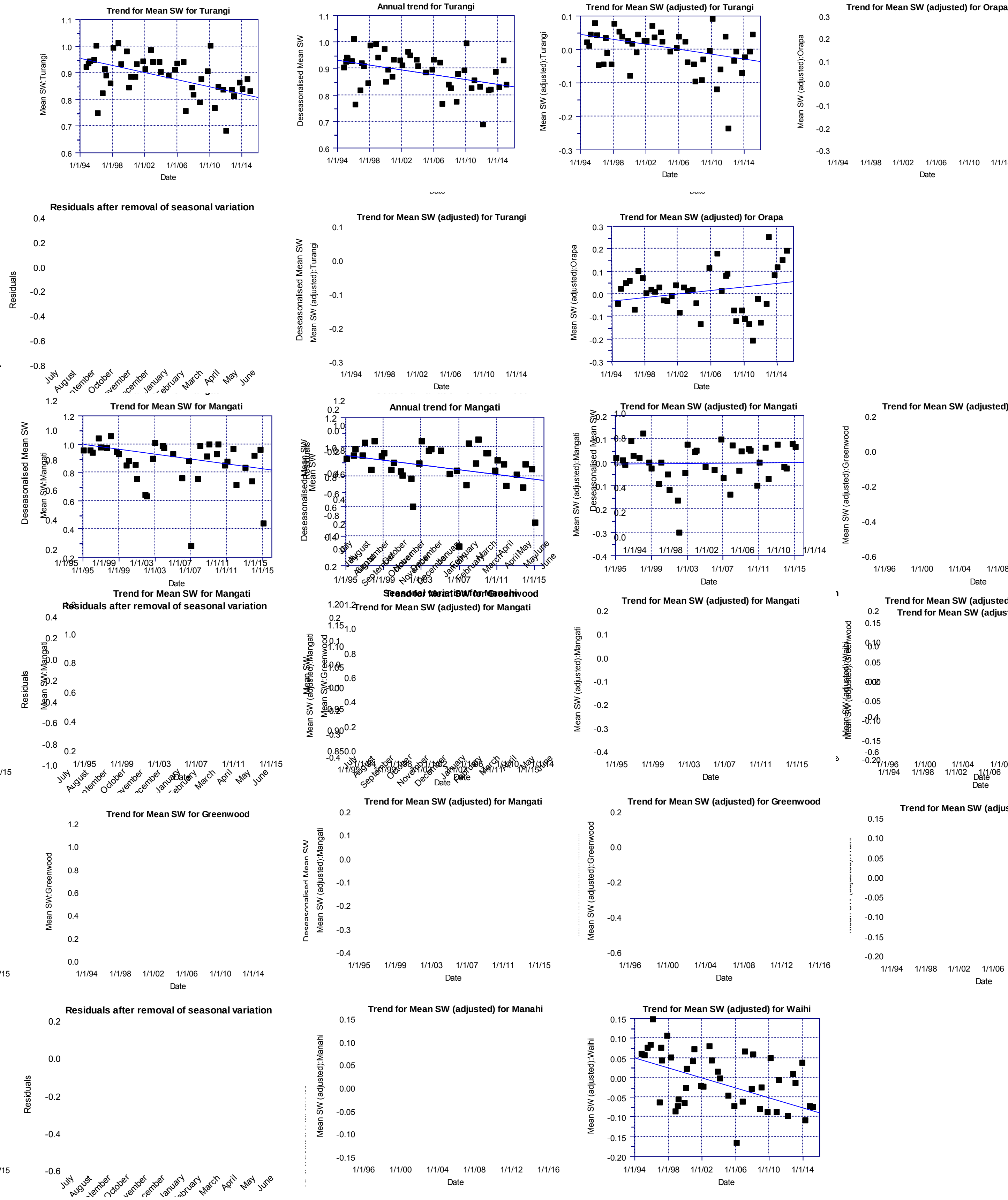


Trends: Shannon Wiener index per quadrat

Unadjusted

Seasonally adjusted

Sand adjusted



Appendix III

Seasonal Kendall test results: Unadjusted & sand adjusted species richness and diversity data

Seasonal Kendall test results showing unadjusted and sand adjusted trends analysis for number of species per quadrat and Shannon Wiener index per quadrat

Site/Variable	Samples used	Sampling period	Mean	Maximum	Minimum	Median	Kendall statistic	Variance	Z	P	Sen slope (annual)	5% confidence limit for slope	95% confidence limit for slope	Percent annual change
Number of species per quadrat														
Turangi	44	5/10/94-20/1/15	15.73	18.68	11.68	15.92	-49	1201	-1.3850637	0.1660	-0.1198	-0.2338	0.0138	-0.7526
	Adjusted for Mean Sand 14.1% variance explained						-49	1199	-1.3862184	0.1657	-0.1047	-0.2020	0.0211	-0.6576
Orapa	39	6/10/94-6/3/15	13.25	17.76	1.6	13.78	-26	526	-1.0900518	0.2757	-0.1207	-0.3264	0.0687	-0.8758
	Adjusted for Mean Sand 65.2% variance explained						18	526	0.7412352	0.4586	0.0761	-0.0778	0.2416	0.5524
Mangati	37	1/2/95-19/1/15	13.37	17.2	3.44	13.9	-71	728	-2.5937789	0.0095	-0.2392	-0.4313	-0.0970	-1.7207
	Adjusted for Mean Sand 65.4% variance explained						5	730	0.1480129	0.8823	0.0090	-0.0868	0.1099	0.0648
Greenwood	38	17/3/96-23/1/15	15.64	23.76	0.16	16.3	-73	806	-2.5355676	0.0112	-0.2842	-0.5667	-0.1198	-1.7436
	Adjusted for Mean Sand 66.3% variance explained						-35	806	-1.1973514	0.2312	-0.1152	-0.2320	0.0726	-0.7068
Manahi	31	23/1/96-20/3/15	19.65	24.92	15.04	19.82	8	141	0.5902044	0.5551	0.1331	-0.0786	0.2811	0.6716
	Adjusted for Mean Sand 39.2% variance explained						18	139	1.4436532	0.1488	0.1233	-0.0601	0.3321	0.6222
Waihi	43	4/11/94-19/3/15	11.36	16.96	4.84	11.72	-109	990	-3.4318876	0.0006	-0.1724	-0.2565	-0.1075	-1.4712
	Adjusted for Mean Sand 37.1% variance explained						-105	988	-3.3081228	0.0009	-0.1466	-0.2178	-0.0713	-1.2512
Shannon Wiener Index per quadrat														
Turangi	44	5/10/94-20/1/15	0.88	1.01	0.68	0.888	-94	1200	-2.6846788	0.0073	-0.0066	-0.0102	-0.0026	-0.7405
	Adjusted for Mean Sand 30.1% variance explained						-69	1199	-1.9638093	0.0496	-0.0037	-0.0070	-0.0005	-0.4145
Orapa	39	6/10/94-6/3/15	0.84	1.029	0.148	0.899	-29	525	-1.2220202	0.2217	-0.0060	-0.0114	0.0027	-0.6686
	Adjusted for Mean Sand 74.3% variance explained						18	526	0.7412352	0.4586	0.0040	-0.0036	0.0112	0.4395
Mangati	37	1/2/95-19/1/15	0.86	1.052	0.277	0.9165	-63	730	-2.2941992	0.0218	-0.0087	-0.0186	-0.0030	-0.9513
	Adjusted for Mean Sand 72.0% variance explained						3	730	0.0740064	0.9410	0.0003	-0.0038	0.0039	0.0303
Greenwood	38	17/3/96-23/1/15	0.91	1.147	0.024	0.9425	-68	807	-2.3580248	0.0184	-0.0097	-0.0200	-0.0025	-1.0295
	Adjusted for Mean Sand 66.0% variance explained						-1	806	0	1.0000	-0.0004	-0.0055	0.0067	-0.0402
Manahi	31	23/1/96-20/3/15	1.06	1.2	0.913	1.069	0	141	0	1.0000	-0.0002	-0.0036	0.0039	-0.0166
	Adjusted for Mean Sand 25.8% variance explained						2	139	0.0849208	0.9323	0.0005	-0.0044	0.0054	0.0508
Waihi	43	4/11/94-19/3/15	0.85	1.033	0.402	0.8465	-79	988	-2.4810921	0.0131	-0.0063	-0.0100	-0.0023	-0.7390
	Adjusted for Mean Sand 52.2% variance explained						-87	988	-2.7355631	0.0062	-0.0063	-0.0086	-0.0021	-0.7473

Appendix IV

Species list

Algal and plant species identified during the July 2008 to June 2015 surveys, showing the percentage of quadrats each species were present in.

Phylum	Species	Presence in quadrats (%)					
		Turangi	Orapa	Mangati	Greenwood	Manihi	Waihi
Chlorophyta (green algae)	*Codium convolutum*	-	-	-	1	0.3	-
	Chaetomorpha coliformis	40	80	53	47	13	1
	Cladophoropsis herpestica	-	0.3	-	-	-	-
	Ulva intestinalis	-	5	5	3	9	-
	Ulva spp.	11	51	39	28	22	3
Phyaeophyta (brown algae)	*Carpophyllum maschalocarpum*	-	-	-	1	2	4
	Colpomenia spp.	16	16	11	21	46	-
	Cystophora torulosa	-	-	-	-	8	-
	Dictyota spp.	-	1	-	2	0.3	3
	Glossophora kunthii	0.3	0.3	-	1	0.3	-
	Hormosira banksii	-	-	-	31	92	-
	Mesogloea intestinalis	-	-	-	0.3	-	-
	Notheia anomala	-	-	-	-	6	-
	Petalonia fascia	-	-	-	-	-	0.3
	Ralfsia verrucosa	49	34	34	62	88	78
	Sargassum sinclairii	-	-	-	2	-	-
	Scytothamnus australis	5	-	2	28	41	2
	Splachnidium rugosum	1	-	-	0	3	4
	Xiphophora gladiata	-	1	-	-	1	-
	Zonaria turneriana	-	-	-	1	0.3	-
Rhodophyta (red algae)	*Champia* sp.	9	6	2	7	27	3
	Encrusting coralline spp. (coralline paint)	91	45	56	79	94	96
	Geniculate coralline spp. including *Corallina officinalis* (coralline turf)	95	91	86	79	92	13
	Echinothamnion spp.	1	0	1	4	-	4
	Gelidium caulacantheum	53	18	37	27	7	51
	Gigartina spp.	18	27	6	18	6	18
	Hildenbrandia crouani	-	1	2	-	2	-
	Hymenena spp.	1	-	-	3	-	2
	Jania spp.	1	3	11	-	-	1
	Laurencia thyrsiflora	14	9	4	12	13	12
	Lophurella caespitosea	0.3	-	1	0.3	17	-
	Polysiphonia strictissima	1	0.3	0.3	-	1	-
	Porphyra columbina	-	-	-	2	1	-
Unidentified algae	Unidentified algal species (at least 7 different species)	18	20	7	38	30	9
Anthophyta	*Zostera* sp.	-	5	-	-	-	-

Animal species identified during the July 2008 to June 2015, showing the percentage of quadrats each species were present in

Phylum	Class	Species	Presence in quadrats (%)					
			Turangi	Orapa	Mangati	Greenwood	Manihi	Waihi
Annelida	Polychaeta	*Neosabellaria kaiparaensis*	47	91	83	55	52	87
		Scale worm spp.	1	1	-	-	2	-
		Spirobranchus cariniferus	84	53	75	41	59	86
		Spirorbis sp.	37	34	12	35	76	13
		Unidentified polychaete spp.	1	1	1	0.3	2	1
		Polyp Tubeworm	0.3	0.3	0.3	-	2	8
Crustacea	Malacostraca	*Alope spinifrons*	3	1	1	1	4	2
		Callianassa filholi	1	-	-	-	-	-
		Halicarcinus spp.	1	1	0.3	1	2	-
		Hemigrapsus sexdentatus				1	0.3	0.3
		Heterozius rotundifrons	1	-	1	1	2	1
		Isopod spp.	2	2	2	8	5	2
		Leptograpsus variegatus	-	-	1	-	-	0.3
		Notomithrax ursus	1	0	1	1	1	-
		Ozius truncatus	4	1	2	0.3	1	-
		Pagurus spp.	43	19	24	20	25	3
		Palaemon affinis	3	2	2	2	4	1
		Petrolisthes elongatus	58	17	27	9	67	48
		Plagusia chabrus	1	1	0	2	0.3	1
		Squilla armata	0.3	-	-	-	0.3	-
		Tetraclitella purpurascens	1	-	-	0.3	2	1
		Amphipod spp.	6	4	2	6	7	3
Crustacea	Maxillopoda	*Austrominius modestus*	4	-	0.3	1	2	22
		Chamaesipho columna	69	33	83	42	61	72
		Epopella plicata	3	1	2	-	2	2
Brachiopoda		Unidentified brachiopod sp.	0.3	-	-	-	-	-
Chordata	Tunicata	Tunicate spp.	6	2	2	1	22	2
Chordata	Vertebrates	Clingfish spp. including *Haplocylix littoreus* and *Trachelochismus pinnulatus*	2	-	3	8	8	2
		Parablennius laticlavius	-	-	-	2	0.3	-
		Acanthoclinus littoreus	1	1	-	-	2	-
		Triplefin spp. including *Forsterygion lapillum*	2	1	-	1	3	0.3
		Unidentified fish spp.	-	-	-		1	-
Cnidaria	Anthozoa	*Actinia tenebrosa*	-	-	-	0.3	2	-
		Isactinia olivacea	29	25	31	33	16	7
		Isocradactis magna	1	0.3	1	9	9	2
		Oulactis muscosa	-	-	-	-	3	0.3
Echinodermata	Asterozoa	*Coscinasterias muricata*	11	-	0.3	-	5	0.3
		Ophionerias fasciata	3	1	1	1	31	-
		Patiriella regularis	12	17	8	4	36	3
	Echinozoa	*Evechinus chloroticus*	13	5	1	0.3	2	-
Mollusca	Bivalvia	*Barnea similis*	0.3	-	-	-	-	-
		Perna canaliculus	3	1	1	1	0.3	0.3
		Protothaca crassicosta	3	2	5	6	8	3
		Saccostrea cucullata	0.3	-		-	-	-
		Xenostrobus pulex	3	19	43	4	2	0.3
	Gastropoda	*Alloiodoris lanuginata*	1	0.3	-	-	1	-
		Aphelodoris luctuosa	-	-	-	-	0.3	-
		Atalacmea fragilis	-	-	-	-	9	1
		Buccinulum spp.	1	1	-	1	7	2
		Cantharidella tesselata	13	12	17	58	13	9
		Cantharidus sp.	-	-	-	-	0.3	-
		Cellana ornata	9	5	18	20	27	3
		Cellana radians	10	20	42	40	74	75
		Cominella maculosa	18	18	11	2	17	2
		Cookia sulcata	-	-	-	0.3	-	-
		Dendrodoris sp.	1	0.3	1	1	2	-
		Dicathais orbita	1	1	0.3	1	0.3	2
		Diloma bicanaliculata	7	1	6	3	13	1

Phylum	Class	Species	Presence in quadrats (%)					
			Turangi	Orapa	Mangati	Greenwood	Manihi	Waihi
		Diloma nigerrima	1	3	1	37	3	3
		Diloma zelandica	1	-	1	18	2	11
		Epitonium jukesianum	1	0.3	-	3	4	-
		Haustrum haustorium	13	2	6	3	25	24
		Haustrum scobina	68	65	51	9	52	57
		Jorunna sp.	0.3	0.3	0.3	-	-	-
		Margarella sp.		0		3	0.3	0.3
		Melagraphia aethiops	75	65	78	38	95	67
		Notoacmea daedala	47	16	43	25	48	27
		Notoacmea parviconoida	3	6	1	1	2	6
		Onchidella nigricans	8	8	6	2	26	1
		Patelloida corticata				1	-	-
		Pleurobranchaea novazelandiae				1	-	
		Scutus breviculus	1	-	1	-	4	-
		Siphonaria australis	7	1	4	17	4	1
		Turbo smaragdus	88	89	79	38	72	23
		Xymene sp.				3	-	-
		Zeacumantus lutelentus	5	16	2	2	8	-
	Polyplacophora	*Acanthochitona zelandica*	18	19	18	3	31	1
		Chiton glaucus	66	27	40	31	81	39
		Ischnochiton maorianus	27	16	23	8	62	9
		Notoplax violacea	0.3	-		-	0.3	-
		Rhyssoplax aerea	1	-	1	1	1	-
		Sypharochiton pelliserpentis	33	33	34	6	24	20
		Sypharochiton sinclairi	41	30	38	12	40	14
Nemertea		Nemertine worm spp.	1	1	-	1	4	3
Platyhelminthes		Flatworm spp.	13	3	9	2	9	2
Porifera		*Tethya butoni*	0.3	0	-	0.3	-	-
Sipuncula		Peanut worm	0.3	-	0.3	1	0.3	-