# Subtidal Ecological Survey Noises Islands

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Executive summary

- A subtidal biological survey of rocky reef benthic habitats and dominant species was undertaken at eight sites across the Noises Islands in autumn 2021. Soft sediment sampling was also undertaken along the south-west coastline of Ōtata island to quantify tipa/scallop abundance.

- Rocky reef habitats were brown macroalgal and urchin (kina)-grazed barrens dominated, with the distribution and abundance of species and benthic habitats highly variable across sites and depth strata.

- In addition to brown macroalgal habitat, the Noises Islands group comprises an array of biogenic habitats and high diversity areas spanning multiple depth strata. Key examples include anemone beds, subtidal kūtai/green-lipped mussel beds, rhodolith beds, and sessile invertebrate communities dominated by large sponges.

- For the majority of sites surveyed there were clear impacts associated with sediment deposition, whereas expansive areas of urchin barrens habitat remain indicative of an absence of large predators such as tāmure/snapper and koura/lobster that would otherwise control kina (*Evechinus chloroticus*) densities and grazing activity.

- Reef fish biodiversity was low to moderate, but consistent with assemblage compositions recorded for the inner-Hauraki Gulf elsewhere (e.g., Long Bay, Waiheke Island, Rakino Island). Commonly, targeted species such as tāmure/snapper, kahawai, red moki, and butterfish were observed during the survey. For both tāmure/snapper and red moki, the majority of fish censused were sub-legal.

- Despite complex rocky reef habitat being present at several sites, very low numbers of kōura /spiny rock lobster (*Jasus edwardsii*) were recorded (< 0.25 individuals 500 m^{-2}).

- Tipa/scallop abundance was estimated to be 23.0 scallops (± 5.5 SE) 100 m^{-2}, which equates to very- ow abundance. Legal-sized individuals occurred at an average density of 3.1 (± 1.3 SE) 100 m^{-2}.

- However, data now exist that can serve as a platform for further information gathering and to monitor future environmental change across the Noises Islands group. This will be especially important in the context of any marine protection and habitat restoration initiatives that may take place. It is also anticipated that the data will be used for a range of educational and outreach activities that have a common goal towards whole system thinking around concepts of regeneration, restoration, and protection.

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1.0 Preamble

This report details the main findings from a subtidal ecological baseline survey of select sites encompassing the Noises Island Group within the central Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi. Specific aims of the survey were to: 1) quantify the distribution of main habitat types and the size and abundance of dominant rocky reef organisms (macroalgae, mobile and sessile invertebrates, reef fish and rock lobster) and, 2) evaluate qualitatively the densities of tipa/scallops and hururoa/horse mussels within a discrete bed.

The Noises Islands is comprised of four main islands – Ōtata, Motuhoropapa, Maria/Ruapuke and the David Rocks - that are all pest free. Additional smaller islands include Orarapa (Haystack), Ike, Scott, and Sunday, with a range of rocky pinnacles such as the Ahaaha's Tern Rock and, Zeno Reef constituting the group. Its pest free status is nationally significant, with Maria Island being New Zealand's first pest free Island. The Noises Island Group has been privately owned since the 1930's by the Neureuter family (refer to noises.co.nz for detailed history).

Historically, the Islands have been considered "islands of abundance" due to their ecological diversity and functioning. Significant effort has gone into pest-eradication, native species introductions and weed control. Collectively, these efforts have resulted in substantial ecological gains that have seen the translocation of critically threatened species such as wētāpunga (*Deinacrida heteracantha*) and more recently the Duvaucel's gecko (*Hoplodactylus duvaucelii*). However, over the last decade the Neureuter family has voiced their concern around the declining sate of the marine ecosystem – both intertidal and subtidal realms. Key observations have included:

- Reduced intertidal abundance and diversity of sessile and mobile invertebrates in particular crabs, pāua, mussels, and seaweeds;
- Lack of beach-cast seaweed through space and time;
- Reduction in several seabird species such as blue penguins/korora (*Eudyptula minor*); white fronted terns (*Sterna striata*); Tara / *Larus novaehollandiae* - Tara-punga / red-billed gull/tarāpunga (*Chroicocephalus novaehollandiae*); black-backed gull/karoro (*Larus dominicanus*); and, total loss of pārekareka/spotted shag (*Phalacrocorax punctatus*).
- Reduction in subtidal rocky reef macroalgal diversity/abundance and increase in urchin barrens spatial extent;
- Reduction in reef fish diversity;
- Collapse of kōura lobster populations;
- Reduction in intertidal and subtidal mussel reefs;
- Reduction in intertidal seaweed spatial extent and invertebrates (e.g., rock crabs);
- Increase in sediment deposition on rocky reef habitats in tandem with elevated turbidity;
- Reduction in tipa/scallop and hururoa/horse mussel distribution and abundance adjacent Ōtata and Motuhoropapa Islands. Changes consistent with harvest pressure, dredging, and anchoring;

- Presence of benthic algal blooms in warmer oceanographic periods consistent with *Ostreopsis siemensis* (Shears and Ross, 2009, 2010); and
- Accelerating erosion of areas of intertidal mudstone, e.g., south-western coastline Ōtata.

Many of these observations and findings are not Noises Islands-centric and match similar reports from nearby Rakino and Waiheke Islands and fits within the wider reported degraded state of the Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi., i.e., declining environmental state, which is rapidly occurring and, in some cases, irreversible. (Hauraki Gulf Forum, 2020). Impacts and threats to the Gulf range from highly localised (dredging, point-source pollution) to more broad-scale, (sedimentation, and those associated with climate and ocean change). The State of our Gulf 2020 report (Hauraki Gulf Forum 2020) lists the top five impacts to the Gulf as being climate change, ocean acidification, sedimentation, fishing, and pollution. Conceivably, the latter three can be controlled and managed using existing legislative frameworks; however, the State of our Gulf 2020 report acknowledges that the current weighting is tipped too far toward development and resource utilisation.

Based on personal concern and well-founded insight, the Neureuter family have spearheaded engagement with iwi and other stakeholders around whole-ecosystem thinking and identifying mechanisms for protection and restoration for the Noises Islands marine environment - with a guiding kaupapa of achieving better environmental and conservation-related outcomes. Ultimately, in doing so, an improved marine environmental state and functionality would undoubtedly translate to an improved terrestrial environmental state and functionality – acknowledging that the two are unequivocally intwined.

The Noises Islands group has had a long history of scientific study and endeavour and while the terrestrial realm has undoubtedly received the most attention a range of studies have also encompassed the marine environment as summarised in (Table 1.1). However, despite these, there remains very little quantitative baseline information from which to evaluate environmental change.

In 2019, the Neureuter's hopes for restoring the marine ecosystem received a major boost with the formation of The Noises Marine Restoration Project, a partnership between the family trust, Tāmaki Paenga Hira Auckland War Memorial Museum, and the University of Auckland. The partnership was formed in part thanks to a Gulf Innovation Fund Together (GIFT) grant from Foundation North, with the Auckland Museum and University of Auckland providing their time in-kind.

This current survey aims to build on the 2017 qualitative habitat survey undertaken by Haggitt and Shears (2017); primarily through collection of quantitative information on benthic rocky reef habitats and the abundance of key species at a range of rocky reef sites representative of the Noises Islands group. Key aspects of the sampling include:

- Collection of data on the abundance(s) and depth-distribution of key benthic organisms per unit area including the percent cover of physical variables such as fine sediment per unit area;
- Begin to spatially map subtidal, green-lipped mussel habitat at select locations;

- Repeat reef fish underwater visual census (UVC) at sites surveyed in 2017;
- Evaluate koura/lobster size and abundance at sites surveyed in 2017; and,
- Evaluate subtidal scallop density of Ōtata Island's south-western coastline.

It is anticipated that the collection of the above data will:

- Build upon the existing benthic habitat and reef-fish datasets for the Noises Islands;
- Allow for comparisons to be made to other locations (Waiheke Island, Rakino Island, Long Bay, Leigh, Tawharanui, and Te Whanganui-a-Heī);
- Support and compliment other research being done by the Auckland War Memorial Museum and the University of Auckland associated with the Noises Islands.
- Help contribute to the "voice of Ōtata" and Mātauranga Māori approach to ecosystem management and thinking.

Table 1.1. Summary of key marine related intertidal and subtidal research studies (incomplete) that have involved the Noises Islands. Note there is significant seabird research past and present that is being undertaken by Auckland War Memorial Museum and Auckland Council not reported here.

Study details	Researcher(s)
Spatial predictive modelling - invertebrate diversity and assemblage structure Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi, includes Noises Islands.	Franz Smith (2004; 2006)
Soft sediment benthic surveys quantifying benthic diversity and dog cockle (*Tucetona laticostata)* abundance biogenic structure.	Severine Dewas, Steve O'Shea (2008-2011), Auckland University of Technology
Intertidal seaweed species observations.	Mike Wilcox. Auckland Botanical Society (2008)
Ecklonia radiata removals, photosynthetic and net primary production studies	Catlin Blain, Nick Shears – University of Auckland (2016)
2017 subtidal habitat and reef fish survey	Nick Shears Tim Haggitt University of Auckland/eCoast (2017)
Intertidal sampling 2019– Ōtata Island	Tim Haggitt University of Auckland/eCoast - ongoing
Underwater soundscapes – impacts of boat noise. – Noises included as part of a wider Hauraki Gulf/ Tikapa Moana/Te Moananui ā Toi study	Louise Wilson, Craig Radford – University of Auckland - current
Kina removal Ōtata Island – Noises included as part of a wider Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi study	Kelsey Miller, Nick Shears – University of Auckland - current
Archaeological work - Ōtata Island midden analysis.	Dr. Louise Furey, Emma Ash – Auckland War Memorial Museum; Ngāi Tai ki Tāmaki - current

2.0   Methods

The following survey methodology pertains to subtidal rocky reef and soft sediment sampling undertaken over March-May, 2021 (Austral autumn). Key components of the sampling included depth-stratified benthic, kōura/lobster, reef-fish, and scallop sampling utilising SCUBA. All work was be conducted from the University of Auckland's research vessel Hawere using industry standard data acquisition methodologies as follows:

2.1   Rocky reef benthic sampling

To quantify macroalgal abundance, biomass, and diversity and sessile and mobile invertebrate abundance and diversity, depth-stratified sampling was undertaken at eight sites (Fig. 2.1); refer to Appendix 1.0 for site coordinates. Benthic sampling followed the general sampling methods/protocols of Shears and Babcock (2007). The sites surveyed were as follows: Motuhoropapa Island north-east (NE), Motuhoropapa Island south-east (SE), Ōtata Island north-east (NE), Ōtata Island south-east (SE), David Rocks (DR), Maria/Ruapuke Island (MI) Ahaaha Rocks (AA), and Orarapa Island (OI). Within each site 3 depth strata were sampled where possible classified as shallow (1-3m depth MLWS); mid (5-8 m depth MLWS); and, deep (>10 m depth MLWS).

To document the depth distribution of broad-scale habitats at each site, the extent of the reef from shallow to deep was videoed using a GoPro Camera (Hero 4+). To obtain quantitative information on the extent of dominant species and community composition a total of four haphazardly deployed 1m^2 quadrats were sampled within each of the depth strata (shallow, mid, and deep) as follows:

Rimurimu/Macroalgae

All large brown macroalgae and turfing algal species within each quadrat was counted, measured, or their percent cover estimated. The total length (TL) of all brown algae was measured to ± 5 cm and individual measurements of stipe length (SL) to ± 5 cm for the laminarian alga *Ecklonia radiata.* Macroalgal length measurements were then converted to biomass based on length-dry weight relationships presented Shears and Babcock (2003) (see Table 2.1).

Encrusting species

The primary (substratum) percent cover of foliose algae, turfing algae, encrusting algal species, encrusting invertebrates (e.g., sponges and ascidians bryozoans), as well as sediment and sand percent cover were recorded in each 1 m^2 quadrat using a visual estimation technique (see Shears and Babcock, 2003). Briefly, quadrats were divided into quarters (1/4 =25 %) to assist in estimating covers of dominant forms, while the covers of minor forms were estimated on the basis that a 10 x 10 cm area equates to 1 % cover. This technique is considered to be the most suitable for this study as it is efficient and ensures that the cover of all forms are recorded, unlike point-intercept methods. Sub-samples of any unidentifiable species were taken, preserved, and then identified accordingly.

Kina/Urchins

All urchins occurring within each 1 m^2 quadrat were counted and their behavioural characteristics noted, i.e., grazing in the open (exposed behaviour) or occupation of crevices and holes (cryptic behaviour). The test diameter of all urchins >10 mm were measured to the nearest 5 mm with replacement.

Pūpū/Gastropods and mobile invertebrates

All gastropods on the substratum and on macroalgae (stipes, fronds, and laminae) within each 1 m² quadrat were counted and the largest shell dimension (width or length) measured to the nearest 5 mm. For example, shell width was measured for *Cookia sulcata*; whereas shell height was measured for *Cantharidus purpureus*. The total length of pāua (*Haliotis* species), limpets (*Cellana stellifera*), and chitons were also measured. For echinoderm species excluding urchins encountered (seastars, holothurians) only counts were made.

Note: All animal taxa enumerated in the survey were checked using the New Zealand Inventory of Biodiversity (Gordon, 2009), New Zealand Coastal Marine Invertebrates Vol.1 (Cook, 2010) and additional UoA unpublished identification guides.
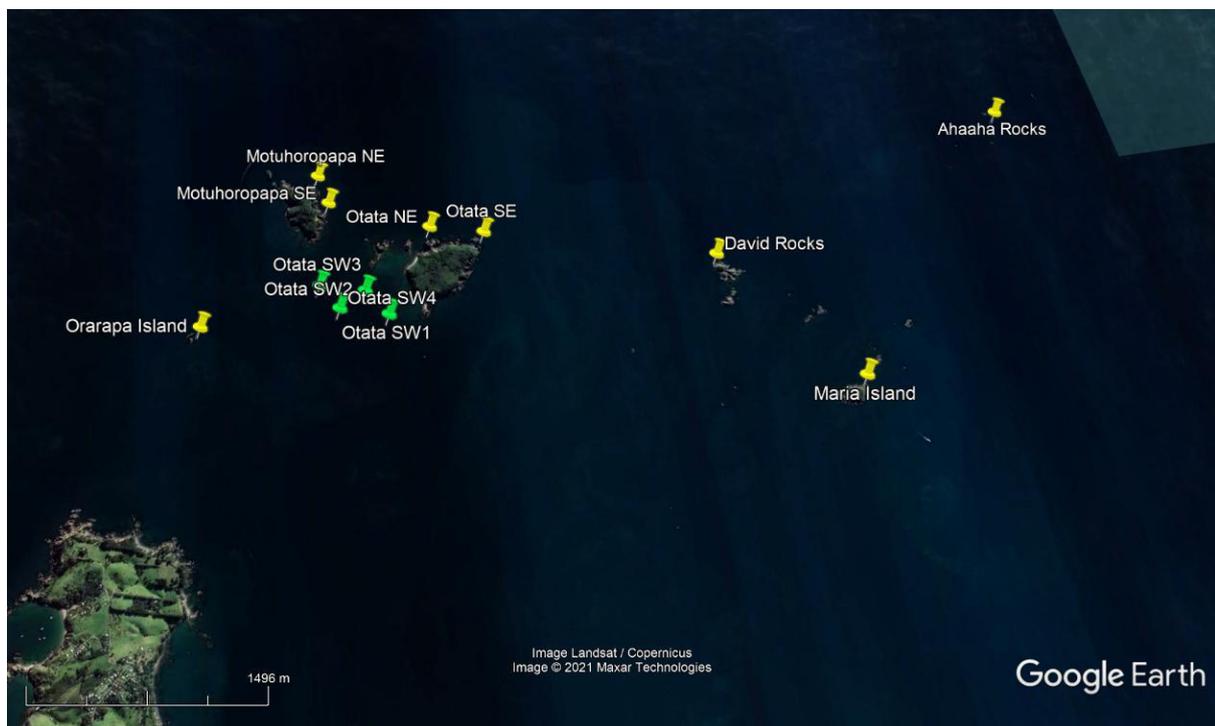

Figure 2.1. Location of eight rocky reef benthic sampling sites (yellow marks) and soft sediment sampling sites (green marks) Noises Islands group – Autumn 2021. Source: Google Earth. Refer to Appendix 1.0 for GPS coordinates.

Table 2.1. Algal species and functional groups used in analysis along with length-weight and/or percent cover-weight relationships for biomass estimates. y = dry weight (g), x = total length (cm), SL = stipe length (cm) and LL = laminae length (cm). Data are from Shears and Babcock (2003).

Brown algae	
Carpophyllum angustifolium	$y = 0.068x - 0.27$
C. maschalocarpum	$\ln(y) = 1.764\ln(x) - 4.311$
C. plumosum	$\ln(y) = 1.472\ln(x) - 3.850$
C. flexuosum	$\ln(y) = 2.049\ln(x) - 5.251$
Xiphophora chondrophylla	$y = 1.786x - 4.171$
Ecklonia radiata – Stipe	$\ln(y) = 1.671\ln(SL) - 3.787$
– Laminae	$\ln(y) = 1.177\ln(SL \times LL) - 3.879$
Sargassum sinclairii	$y = 0.075x + 0.124$
Landsburgia quercifolia	$\ln(y) = 1.971\ln(x) - 5.058$
Small brown algae,	$\ln(y) = 2.587\ln(x) - 6.443$
e.g. *Zonaria turneriana*	1% = 2.5 g
Brown turf, e.g. *Distromium*, *Dictyota* spp.	1% = 1.5 g
Brown encrusting, e.g. *Ralfsia*	1% = 0.1 g
Red algae	
Osmundaria colensoi	$\ln(y) = 1.720\ln(x) - 3.379$, 1% = 22.9 g
Pterocladia lucida	$\ln(y) = 1.963\ln(x) - 5.076$ 0., 1% = 10.0 g
Melanthalia abscissa	$\ln(y) = 1.775\ln(x) - 4.247$
Red foliose, e.g. *Plocamium* spp.	$\ln(y) = 2.649\ln(x) - 8.812$
Red turfing (< 5 cm), e.g. *Champia* spp.	1% = 1.7 g
Coralline turf, e.g. *Corallina officinalis*	1% = 4.5 g
Crustose corallines	1% = 0.1 g
Red encrusting	1% = 0.1 g
Green algae	
Codium convolutum	1% = 4.7 g
Others, e.g. *Ulva* sp.	1% = 1.7 g
Filamentous algae	1% = 0.2 g

Invasive species

In recent years, parts of the New Zealand coastline have been subject to several invasive species introductions such as the laminarian *Undaria pinnatifida,* the 'solitary' sea squirt (clubbed tunicate) *Styela clava*, Mediterranean fan-worm *Sebella spallanzanii* and the paddle-crab *Charybdis japonica*. All quadrats and adjacent areas within the sampling envelope at each site will be qualitatively checked for the possible occurrence of these taxa.

Environmental variables

Physical variables: rock type, depth, sand, and sediment percent cover were assessed for each site as part of the study. The nature of the rock type within quadrat was recorded based on 6 categories:

- Low lying platform reef;
- Boulder reef;
- Platform and boulder reef mix;
- Cobbles;
- Complex platform reef characterised by overhangs and crevices.

2.2   Reef fish abundance and diversity

To evaluate the abundance and diversity of reef fish taxa at each of the six sampling sites, a total of 9 reef fish transects were done within the 3-8 m depth range using underwater visual censuses (UVC) methodology (Willis *et al.* 2000). To census reef fish, a diver fastened a 30 m fibreglass transect tape to the substratum, then swam 5 m before commencing counts to avoid sampling any fish attracted to the diver. The transect tape was swum out to 30 m, with all fish visible 2.5 m either side of the swim direction counted. Where certain schooling species (e.g., sweep *Scorpis lineolatus*) were too numerous to be counted, numbers were estimated in their 20's. Cryptic species were not surveyed due to their small size (e.g., clinids, syngnathids, and tripterygiids other than the oblique swimming triplefin *Obliquichthys maryannae* - if present). All tāmure/snapper (*Chrysophrus auratus*) and red moki (*Cheilodactylus spectabilis*) censused were sized to ± 50 mm based on visual estimation. In instances where fish followed divers between transects, care was taken to not include previously censused individuals in subsequent replicate transects. Similarly, fish seen outside of the transect survey width were not sampled, but their presence and corresponding depth were noted. Depth (m) at the start and end of each transect and the occurrence of 7 habitat types (*Ecklonia radiata*; *Ecklonia radiata* and sponge; mixed algae; *Carpophyllum flexuosum*; urchin barrens habitat; shallow *Carpophyllum*; and sand) were recorded at 5 m intervals along each transect (as present). All UVC censuses were done between 08:00 and 16:00 NZST.

2.3   Kōura/Lobster abundance

Following reef fish sampling, areas of reef deemed suitable as kōura/lobster habitat were searched for the presence of the spiny rock lobster *Jasus edwardsii* and packhorse lobster (*Sagmariasus verreauxii)* using three 50 m x 10 m (500 m^2) haphazardly placed transects. When encountered the size and, where possible, sex of each kōura/lobster was determined by visual estimation (see MacDiarmid, 1991). Torches were used to aid in the detection of kōura/lobster within deep holes and crevices. Depth and habitat variables (as above) were also recorded.

2.4   Tipa/scallop and hururoa/horse mussel abundance

To evaluate tipa/scallop (*Pecten novaezelandiae*) and hururoa/horse mussel (*Atrina zelandica*) density, a total of ten haphazardly placed 100 m^2 transects were sampled within a predetermined area off the south-western coast of Ōtata island. The survey area, which was initially defined by the Neureuter family, is considered to be a popular tipa/scallop bed.   To survey tipa/scallop and hururoa/horse mussel density, a buoyed shot line was deployed to mark the start of each transect. Two divers then descended the shot line to the seabed. Once on the seabed one of the divers swam out a 50 m transect tape down a pre-determined compass direction. The second diver followed behind videoing the main soft sediment habitats approximately 1m above the seabed until reaching the end of the transect. Following this both divers worked their way back slowly to the transect origin sampling 1m either side of the transect counting and sizing (± 1 mm using vernier callipers) all tipa/scallops encountered. Hururoa/horse mussels both living, and dead were also recorded. To ensure the correct area was searched along each diver held a 1m length, (20 mm dia.) PVC pipe perpendicular to each transect. Depth (m) at the start and end of each transect were also recorded.

2.5   Data analysis

Both multivariate (many species) and univariate (single species) statistical tests were used to analyse benthic rocky reef data with the majority undertaken using PRIMER-E statistical software (Clarke and Warwick 2001) and associated routines; particularly PERMANOVA[1] (Anderson *et al*. 2008). Unless otherwise stated, for the majority of species enumerated, means are presented ± their associated standard error (SE).

Multivariate analyses using PERMANOVA were run on either (log x+1) or square-root transformed multispecies data (macroalgae, sessile invertebrate and mobile invertebrate data) using a Bray-Curtis similarity (resemblance) measure. Analysis of macroalgae assemblage composition was based on biomass estimates, sessile invertebrate analysis was based on count and percent cover data (combined), and mobile invertebrate analysis was based on count data. Irrespective of analyses, the same model design and associated factors were examined. Of specific interest was evaluating community assemblage variation across **Sites** (Motuhoropapa north-east and SE, Ōtata Island north-east and south-east, David Rocks, Maria Island, Ahaaha Rocks and Orarapa Island); **Depth** strata (shallow; mid; and deep), and the associated **Site×Depth** interaction. Individual analyses were run on full models (all effects) using 4999 permutations. All significance levels corresponded to α = 0.05.

The multivariate null hypothesis tested was - H0: there is no statistically significant difference in the species assemblages (e.g., macroalgae, sessile invertebrate assemblages etc.) across sites; and among depth strata (shallow, mid, and deep).

Metric multi-dimensional scaling using principal coordinates analysis (PCO) (Anderson *et al*. 2008) was utilised to support multivariate PERMANOVA and visualise patterns based on the among sites and depths in multivariate space. All analyses were run either (log x+1), or square-root transformed multispecies data using a Bray-Curtis similarity measure. To further elucidate species contributions to the patterns depicted from PCO, Pearson's correlation coefficient and SIMPER analyses were undertaken (Clarke and Warwick 2001).

To test for differences in single-species (univariate) abundances –across sites and depth-strata PERMANOVA was run on log (x+1) transformed single species data using a Euclidean distance measure (which is equivalent to traditional ANOVA (see Anderson *et al*., 2008)).

The univariate null hypothesis tested was - H$_{01}$: there is no statistically significant difference in the response variable (e.g., Ecklonia radiata density) across sites; and among depth strata (shallow, mid, and deep).

A similar approach to that above was used to analysis reef fish data; however, as only one depth strata was surveyed (mid) we were only interested in among-site differences.

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[1] PERMANOVA (permutational multivariate analysis of variance) is used for the analysis of univariate or multivariate data in response to factors, groups or treatments in an experimental design.

3.0   Results

3.1   Habitat distributions

Rocky reef structure and associated biological habitats varied in accordance with location and depth. Broad physical and biological habitat descriptions at a site-specific level are summarised and presented in Table 3.1 and Figs 3.1-3.2. For those sites with continuous rocky reef habitat that extended beyond 10 m depth, there was a general pattern of macroalgal habitats being dominant in shallow and deep depth strata and urchin barrens habitat concomitant with turfing and crustose coralline habitats prevalent at mid depths. (Fig 3.2A-F). Thereafter at depths > 10 m depth, *Ecklonia radiata* and sponge habitats were universally the dominant habitat types. For those sites with only a shallow extent of rocky reef habitat, e.g., Maria Island and Orarapa Island there was trend for mixed algae and *Carpophyllum flexuosum* habitats to dominate, with urchin barrens habitat either sparse to non-existent or extremely patchily distributed. The very shallow subtidal < 1 m depth (not quantitatively sampled) at the majority of sites was often characterised by a band of oysters (native and Pacific combined) intermixed with fucalean algae such as *Hormosira banksii* and *Xiphophora chondrophylla*.

Equally, there was high variation in physical elements across the survey sites. Motuhoropapa and Ōtata Island's had a large spectrum of rocky reef architecture ranging from pinnacles, overhangs, crevices, guts, and extensive platform reef throughout mid and deeper depths. Both large and small boulder complexes were also evident at these sites providing high habitat complexity. In a similar way, Ahaaha Rocks were also notable for diverse rocky reef habitat elements including, pinnacles, platform reef with deep crevices and boulder complexes. David rocks, Maria Island and Orarapa Island all had moderate complexity comprised of platform reef with occasional crevices, guts, and boulder complexes. Typically, at the termination of rocky reef habitats across sites, coarse sediment, shell hash and dog cockle (*Tucetona laticostata*) whole shell combinations were the prevalent soft sediment habitat types. Large rhodolith (mearl) patches (10s m) in extent were also a dominant feature along the northern coastline of Maria Island.
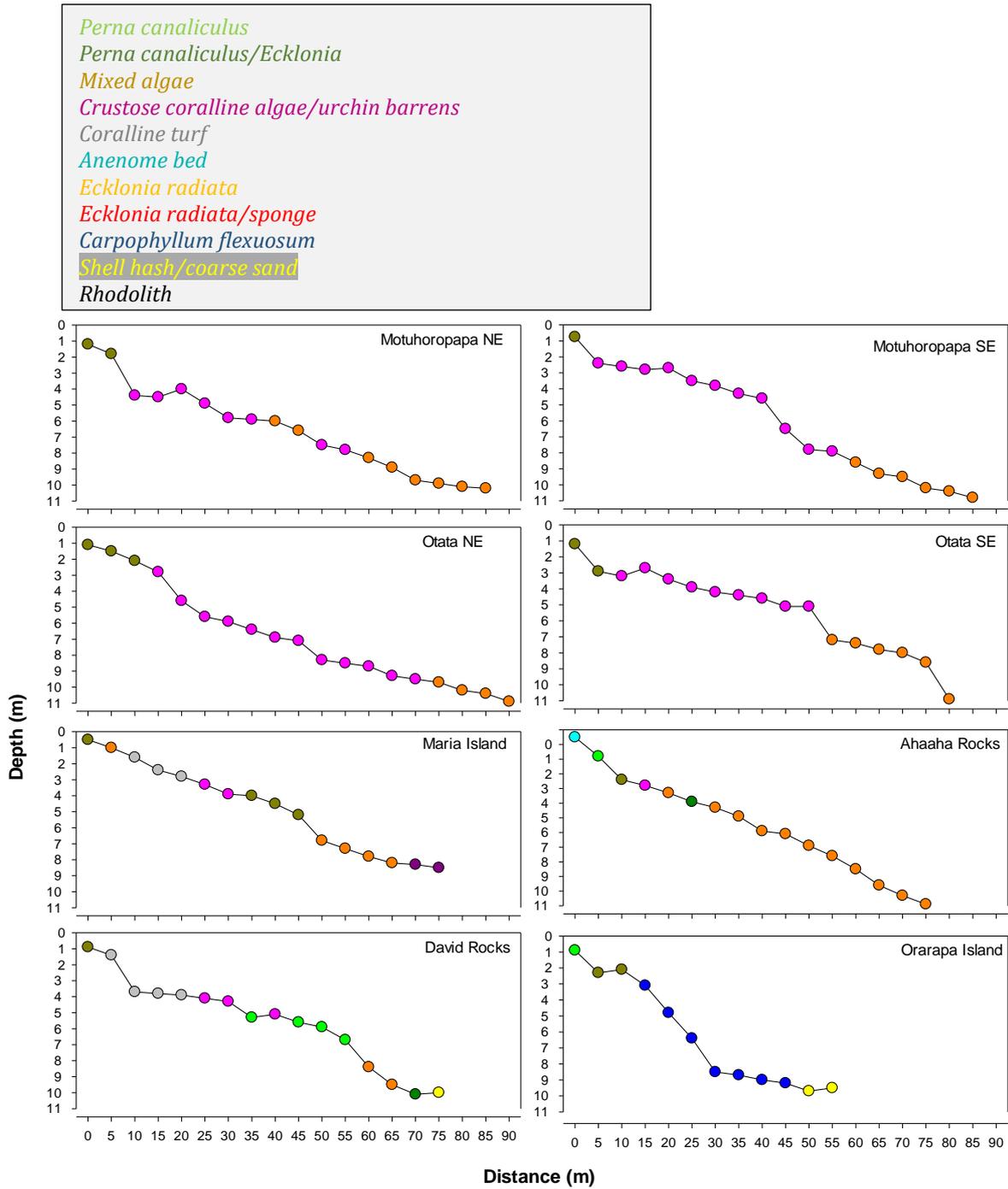
Figure. 3.1. Habitat distribution in accordance with depth (MLWS) and distance (meters) across eight rocky reef dominated sites Noises Islands March 2021. Refer to Figure 2.1 for site locations.

Table 3.1. General rocky reef site descriptions Noises Islands sampling sites March 2021.

Site	Physical habitats	Biological habitats
Motuhoropapa Island North East (MNE)	Gently sloping rocky reef (bedrock) habitat characterised by guts in shallow water < 2m depth transitioning to gently sloping large platform terraces interspersed with cobble habitat with increasing depth. Rock rubble common at reef/soft sediment interface at approximately 10m depth. Soft sediment habitat characterised by coarse sediment, shell hash, and whole-shell matrix. Reef complexity moderate. Fine sediment percent cover conspicuous and increasing with depth.	Sparse mixed algal habitat in shallow water < 2m depth dominated by *Carpophyllum maschalocarpum* transitioning rapidly into urchin barrens habitat – the dominant habitat at this site. High cover of coralline turf, fine sediment, and highly moribund *Carpophyllum flexuosum* in deeper water > 7 m depth. Sponges *Tethya burtoni* and *Raspailia topsenti* common towards rocky reef and soft sediment interface at approximately 10m depth. Sponges (*Callyspongia ramosa*) common on shell-hash adjacent reef edge.
Motuhoropapa Island South East (MNS)	Moderately sloping rocky reef (bedrock) habitat characterised by overhangs and vertical sections of reef between 1-5m depth. Beyond 5m transitioning into gently sloping large platform terraces interspersed with small boulder habitat with increasing depth. Reef extends out to approximately 12m depth transitioning into coarse sediment, shell hash and whole-shell matrix. . Reef complexity moderate to high. Fine sediment percent cover conspicuous and increases with depth.	Mixed algal habitat patchily distributed between 0-3 m depth. Small patches of green-lipped mussels < 2m depth. Narrow bands of urchin grazed barrens habitat patchily distributed between 1-10m depth. *Ecklonia radiata* and *Carpophyllum flexuosum* dominant > 5m-10m depth. *Ecklonia radiata* and diverse sponge habitat characteristic > 10m depth.
Ōtata Island North east (ONE)	Moderately sloping rocky reef characterised by overhangs and vertical sections of reef between 1-5 m deep. Beyond 5 m transitioning into gently sloping large platform terraces interspersed with small and large boulder habitat with increasing depth. Reef extends out to approximately 15m depth transitioning into coarse sediment, shell hash and whole-shell matrix. . Reef complexity moderate to high. Fine sediment percent cover conspicuous and increases with depth.	Dense mixed algal habitat between 0-3 m depth transitioning abruptly into extensive urchin-grazed barrens habitat with encrusting sponges and ascidians common. *Ecklonia radiata* and sponge habitat increases in abundance beyond 12m depth, but patchily distributed.
Ōtata Island South East (OSE)	Vertical reef and pinnacles common between 0-3m transitioning into gently sloping rocky reef (bedrock) platform habitat interspersed with small and large boulders out to 12 depth which transitions into coarse sediment, shell hash, and whole-shell matrix.	Patchily distributed mixed algal habitat between 0-3 m depth transitioning abruptly into extensive urchin-grazed barrens habitat with encrusting sponges and ascidians common. *Ecklonia radiata* and sponge habitat increases in abundance beyond 9 m depth, but patchily distributed with frequent breaks in the canopy.
David Rocks (DR)	Vertical reef and pinnacles characteristic of shallow depths , 3 m depth. Moderately sloping platform reef between 3 m-9 m depth, thereafter large boulders are common down to 12 m depth.	Coralline turf dominant between 0-3 m depth associated with vertical reef. Green-lipped mussels abundant between 3-8 m depth interspersed with urchin-grazed barrens habitat. *Ecklonia radiata* dominant beyond 9m depth, often co-occurring with low density green-lipped mussels.
Maria Island (MI)	Moderately sloping rock reef habitat with occasional overhangs and vertical sections of reef between 1-3 m deep. Boulder reef habitat common between 5-8m depth. Rocky reef habitat terminates in soft sediment matrix around 8m depth, which is comprised of coarse sediment, shell hash, and whole shell. Rhodolith patches common.	Patchily distributed green-lipped mussel habitat between 0-1m depth intwined with mixed algal habitat. Narrow areas of urchin barrens habitat between 2-4m depth which gives way to mixed *Ecklonia radiata* and *Carpophyllum flexuosum* dominated habitats down to 8m depth. Rhodolith habitat common beyond rocky reef at depth along with course shell-hash, whole shell substrate supporting dense dog-cockle beds.
Ahaaha Rocks (AA)	Complex reef system characterised by vertical reef and network of pinnacles between 0-10m depth, intermixed with areas of moderately sloping reef. Reef comprised of platform bedrock reef, small and large boulders, and cobbles. Reef terminates in fine to medium sand at approximately 15m depth.	Dense green-lipped mussel and *Anthothoe albocincta* anemone habitat between 0-3m. Rapid transition into *Ecklonia radiata* habitat beyond 3m depth becoming the dominant macroalga forming continuous monospecific cover out to the lower limit of rocky reef substratum at around 18 m depth. *Ecklonia radiata* canopy thins dramatically beyond 10m depth with large sponges increasing in abundance.
Orarapa Island (OI)	Steeply sloping reef system comprised of cobbles boulders and bedrock platform reef between 0-12m depth.	Dense, green-lipped mussel habitat between 0-3m depth followed by *Carpophyllum flexuosum* becoming the dominant macroalga forming continuous monospecific cover out to the lower limit of rocky reef substratum 8 m depth.

Figure 3.2. Examples of main biological habitat types across sites – Noises Islands March 2021. A) Mixed algal habitat- Maria Island; B) Anemone (*Anthothoe albocincta*) – Ahaaha Rocks; C) kūtai/green-lipped mussels (*Perna canaliculus*) David Rocks and D) Ahaaha Rocks; E) Urchin-grazed barrens – Ōtata Island; F) sessile-invertebrate Ōtata Island – mid depth; G) *Ecklonia radiata* – Motuhoropapa Island; H) large sponge *Ecionemia alata* – Ōtata Island.

3.2 Rimurimu/Macroalgal habitat

Three main brown macroalgal species were synonymous with highest algal abundance, biomass, and habitat structure across the eight sites surveyed. These were the laminarian alga *Ecklonia radiata* (true kelp), and the fucalean algae (rockweeds) *Carpophyllum flexuosum* and *Carpophyllum maschalocarpum*, which often formed enclosed canopies and were associated with high algal biodiversity. As is typical with macroalgal assemblages, there was high variability in both species-specific abundance, size, and biomass across the sites and depth strata surveyed (Figs 3.3-3.7; refer to Appendix 2.0 for single species analyses). However, coarse depth-distributional patterns were apparent that included the kelp *Ecklonia radiata* attaining highest abundance, size, and biomass in either shallow and/or deep depth-strata. Lower *Ecklonia radiata* abundance and biomass in the mid-depth strata, reflects the dominance of urchin-grazed barrens habitat (Figs 3.1, 3.2E) or the presence of kūtai/green-lipped mussel habitat (Figs 3.1, 3.2D).

In shallow-water, *Ecklonia radiata* was commonly intermixed with other fucalean species; whereas, at deeper depths (> 8 m) *Ecklonia radiata* stands tended to be either monospecific (only *Ecklonia*) or co-occurring with *Carpophyllum flexuosum*. Size structures based on stipe length (SL) also differed between depth strata, with smaller individual's more characteristic of shallow depths and slightly larger individuals more common in deeper water (Fig. 3.5). Canopy cover at depth was patchy at both Motuhoropapa and Ōtata sites, where there was also evidence of canopy regression and both urchin (*Evechinus chloroticus*) and amphipod (*Orchomenella ahhu*) grazing (Fig. 3.6). At Ahaaha Rocks, *Ecklonia radiata* formed a reasonably continuous monospecific stand from approximately mid-depth (6 m) out to the termination of rocky reef habitat at approximately 15 m depth. Resultantly, this site also had the highest biomass, being a representative example of continuous kelp forest habitat. Orarapa Island was also of note due to the dominance of *Carpophyllum flexuosum* forming monospecific stands from mid depth (5 m)out to deeper areas of reef > 10 m depth (Fig. 3.6). This is also reflected in size frequency distributions (Fig. 3.7).

A total of 29 algal species were enumerated across survey sites, many of which were understory in nature and equally diverse in size and architecture i.e., ranging from erect multi-branched and foliose through to filamentous, encrusting, and turfing forms. Macroalgal richness was highest in either shallow or deep depth strata (Fig. 3.10). However, it is likely that the macroalgal species diversity presented here is under-representative of maximum algal diversity across the Noises Island groups due in part to 1) the timing of the survey (Austral autumn); and, 2) the high sediment percent cover prevalent across sampling sites making species detection and identification difficult in some instances.

Common understorey species encountered during the survey were the brown algae *Carpomitra costata, Zonaria turneriana, Halopteris virgata, Colpomenia sinuosa, Zonaria turneriana, Dictyota* spp; and, red algae *Champia laingii, Pterocladia lucida*, and *Gigartina* spp. Two forms of red coralline algae – crustose (CCA) and articulated/turfing – (CT)

were also conspicuous at many of the sites; albeit exhibiting high variation across depth strata (Fig. 3.7).
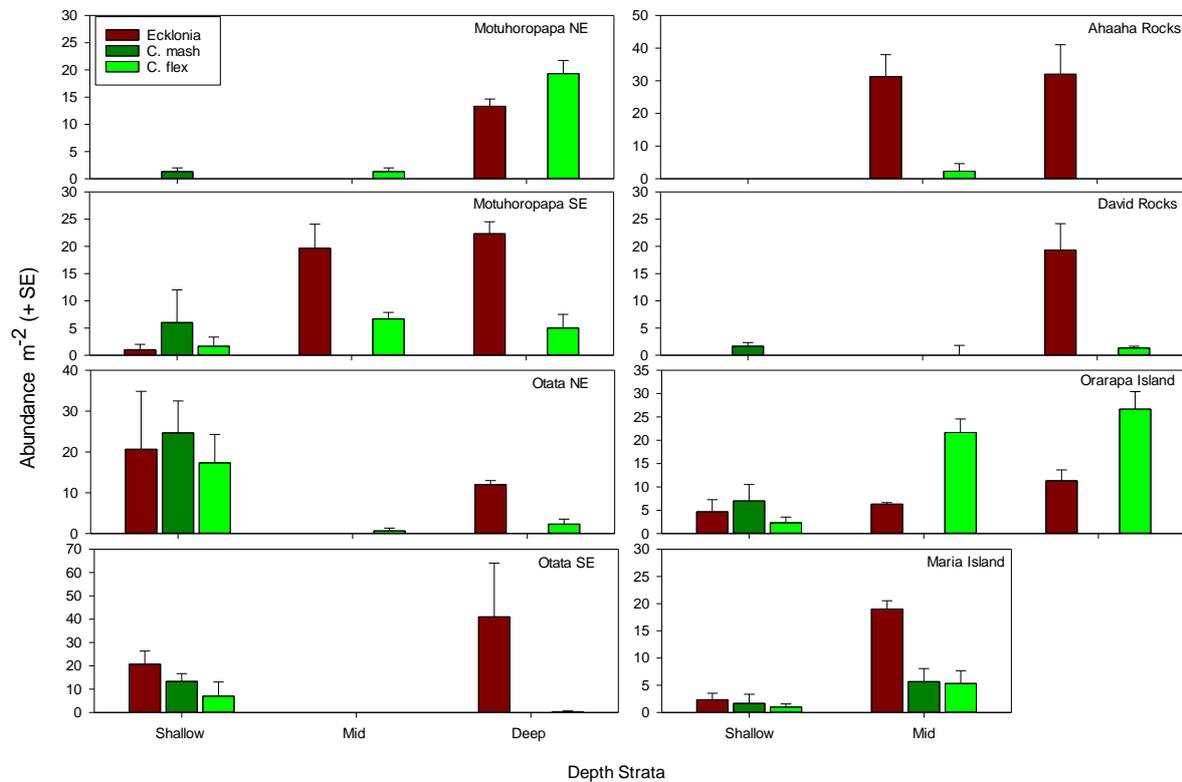
Figure 3.3. Abundance of three habitat forming brown macroalgae across eight sites in relation to depth – Noises Island, Autumn 2021. Species include the kelp *Ecklonia radiata,* and rockweeds *Carpophyllum flexuosum and Carpophyllum maschalocarpum.* Data are averages + SE. *Note:* x and y axis differ among graphs.

Macroalgal community composition based on biomass estimates was found to be statistically different across sites and depth strata based on PERMANOVA (Table 3.2), although the PCO ordination indicated no clear groupings with respect to either site or depth (Fig. 3.9A). This primarily reflects the high variation in macroalgal community composition and somewhat fragmented nature of algal communities across the rocky reef subtidal environs comprising the Noises Islands, supported further by the statistically significant Site×Depth interaction (Table 3.2). Macroalgal species that best explain the various site groupings across the ordination, based on corresponding Pearson's correlation coefficients are presented in Fig. 3.9B.
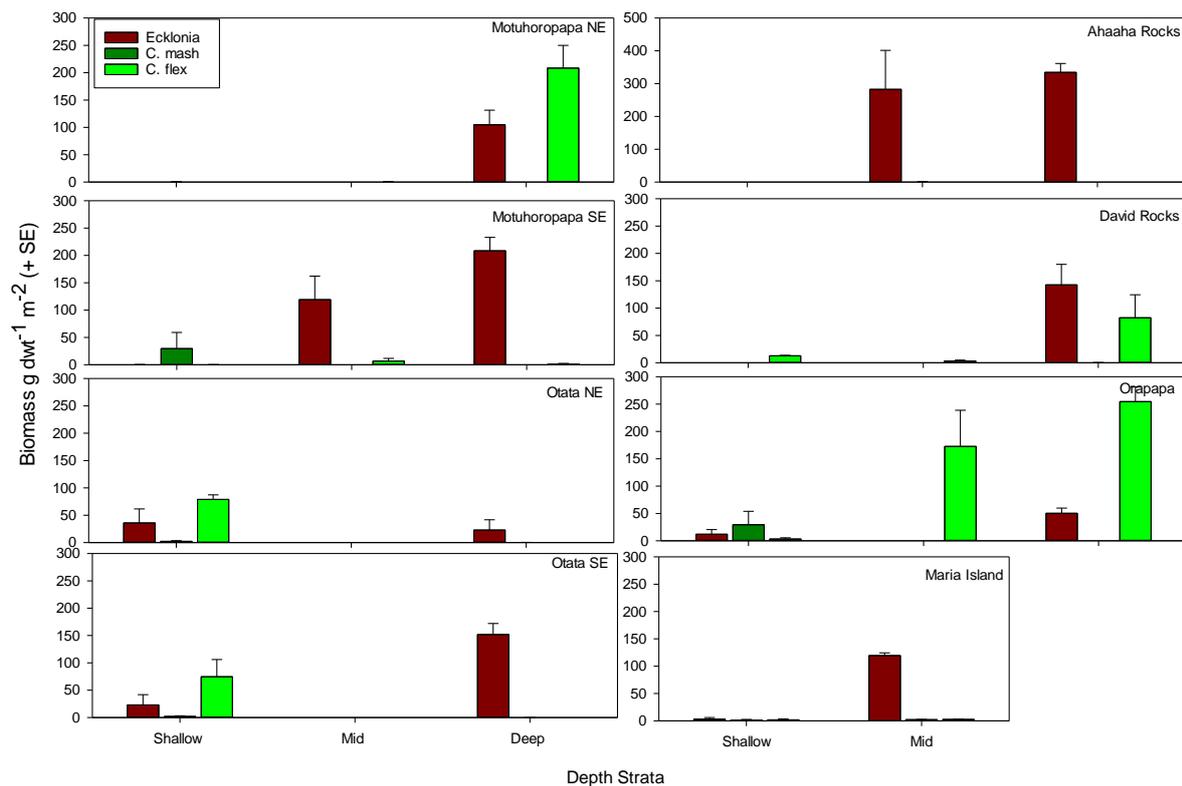
Figure 3.4. Biomass of three habitat forming brown macroalgae across eight sites in relation to depth – Noises Islands, Autumn 2021. Species include the kelp *Ecklonia radiata,* and rockweeds *Carpophyllum flexuosum and Carpophyllum maschalocarpum.* Data are averages + SE. Note: x-axis and y-axis differs among graphs.

Both coralline turf (CT) and crustose coralline algae(CCA) were the two most dominant algal groups across sites and depth strata; albeit exhibiting high variation in percent cover and biomass across depth strata (Fig. 3.8). However, coralline turf was especially dominant in shallow water at Motuhoropapa SE, Ōtata NE, Orarapa Island and both shallow and mid-depth at Ōtata SE. Brown and red turfing algae were also present across sites but tended to have low percent covers. SIMPER analysis based on dissimilarities among depth strata indicated that *Ecklonia radiata, Zonaria turneriana* and brown and red filamentous and turfing algae were more characteristic of deeper depth strata; *Carpophyllum maschalocarpum, Carpophyllum flexuosum, Carpophyllum plumosum, Xiphophora chondrophylla* and *Pterocladia lucida* more representative of shallow depth strata with coralline turf (CT) and crustose coralline algae (CCA) being intermediate across all depth strata.
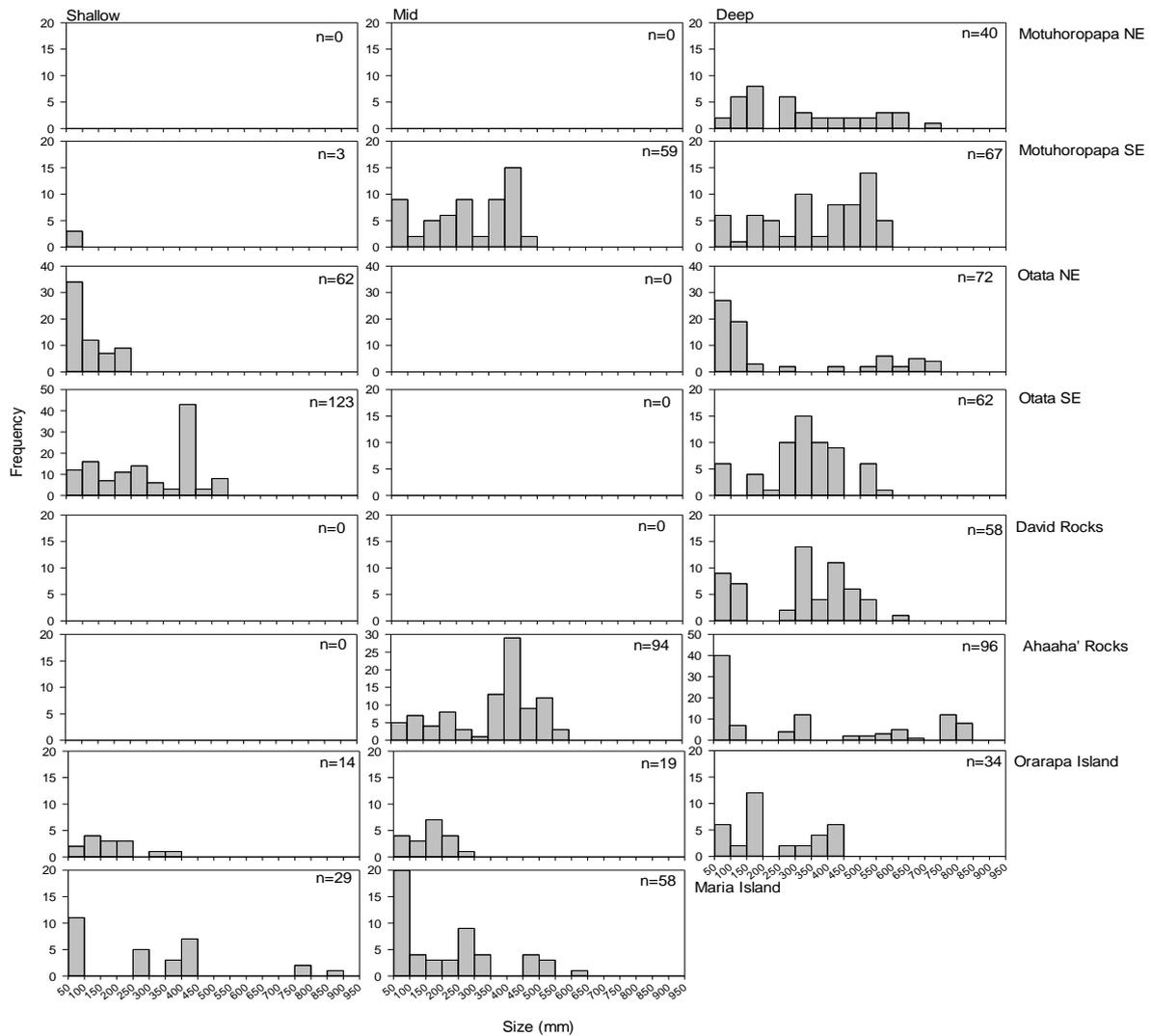
Figure 3.5. Size frequency distributions of *Ecklonia radiata* based of stipe length (SL) across eight sites in relation to depth – Noises Island, Autumn 2021. Note: x and y-axis differ among graphs.
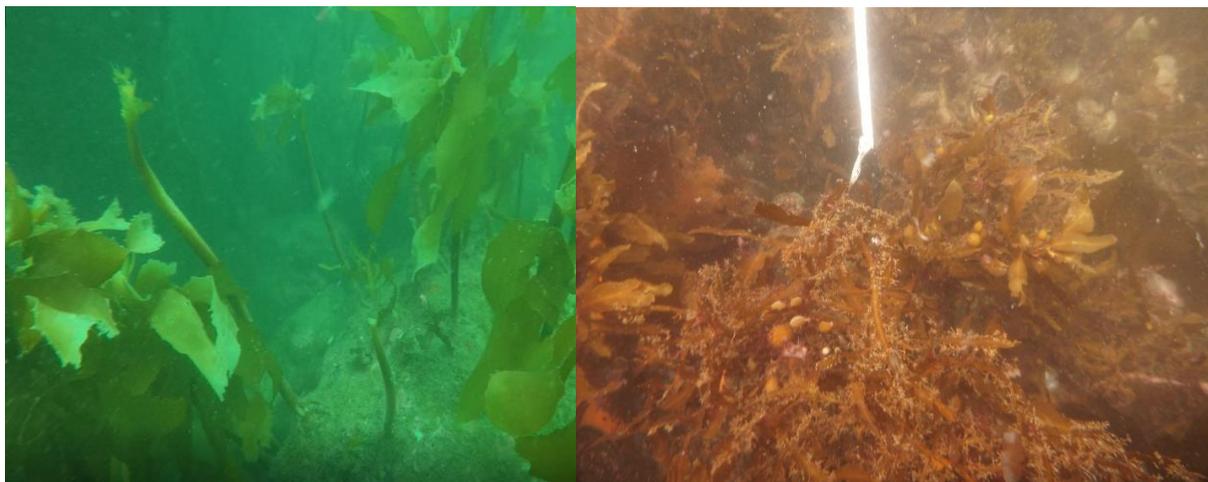
Figure 3.6. A) *Ecklonia radiata* canopy regression Motuhoropapa–SE, consistent with amphipod grazing; and, B) dense stands of *Carpophyllum flexuosum*, characteristic of Orarapa Island.
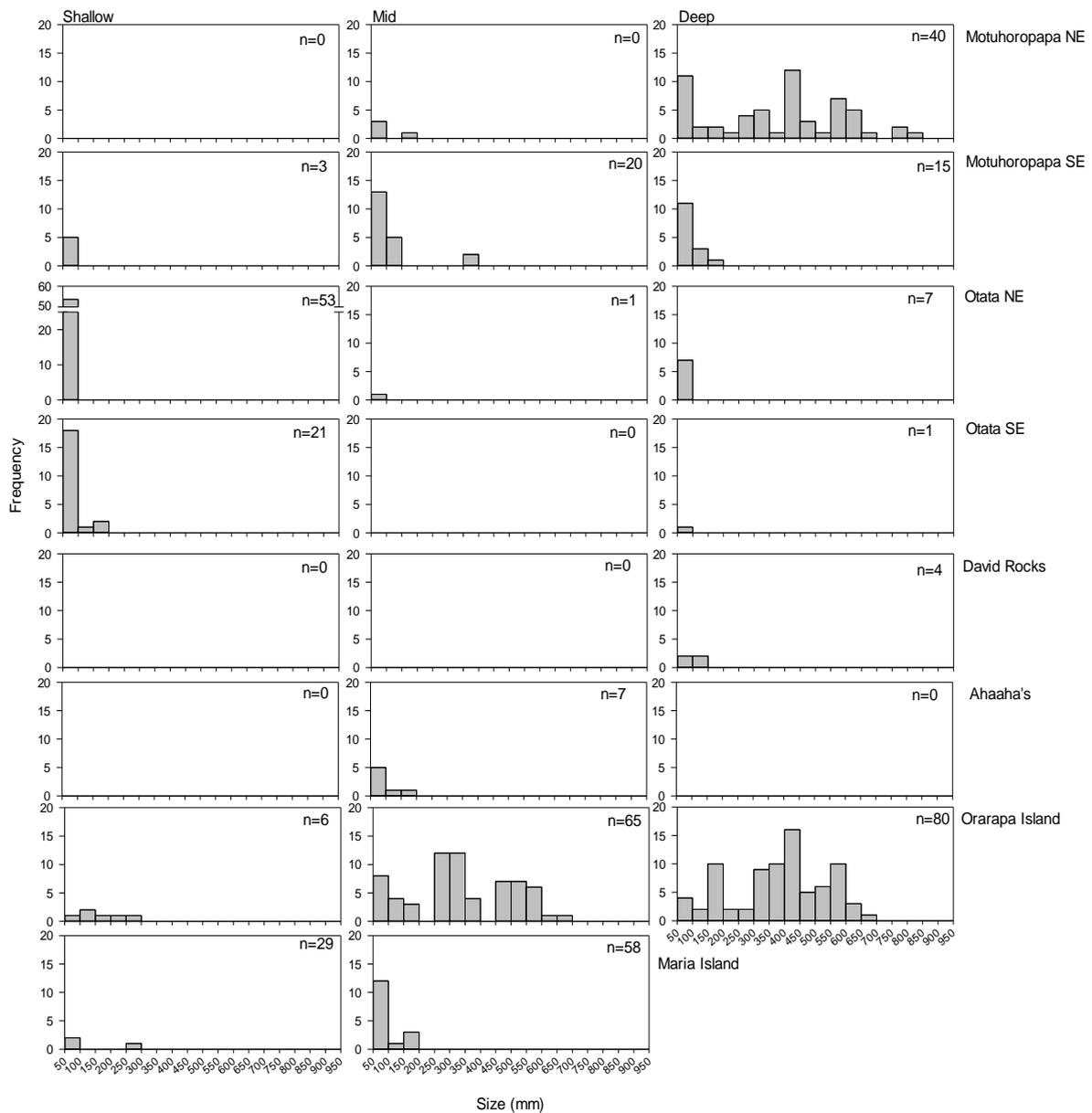
Figure 3.7. Size frequency distributions of *Carpophyllum flexuosum* based on total length (TL) across eight sites in relation to depth – Noises Island, Autumn 2021. Note: y-axis differs among plots.
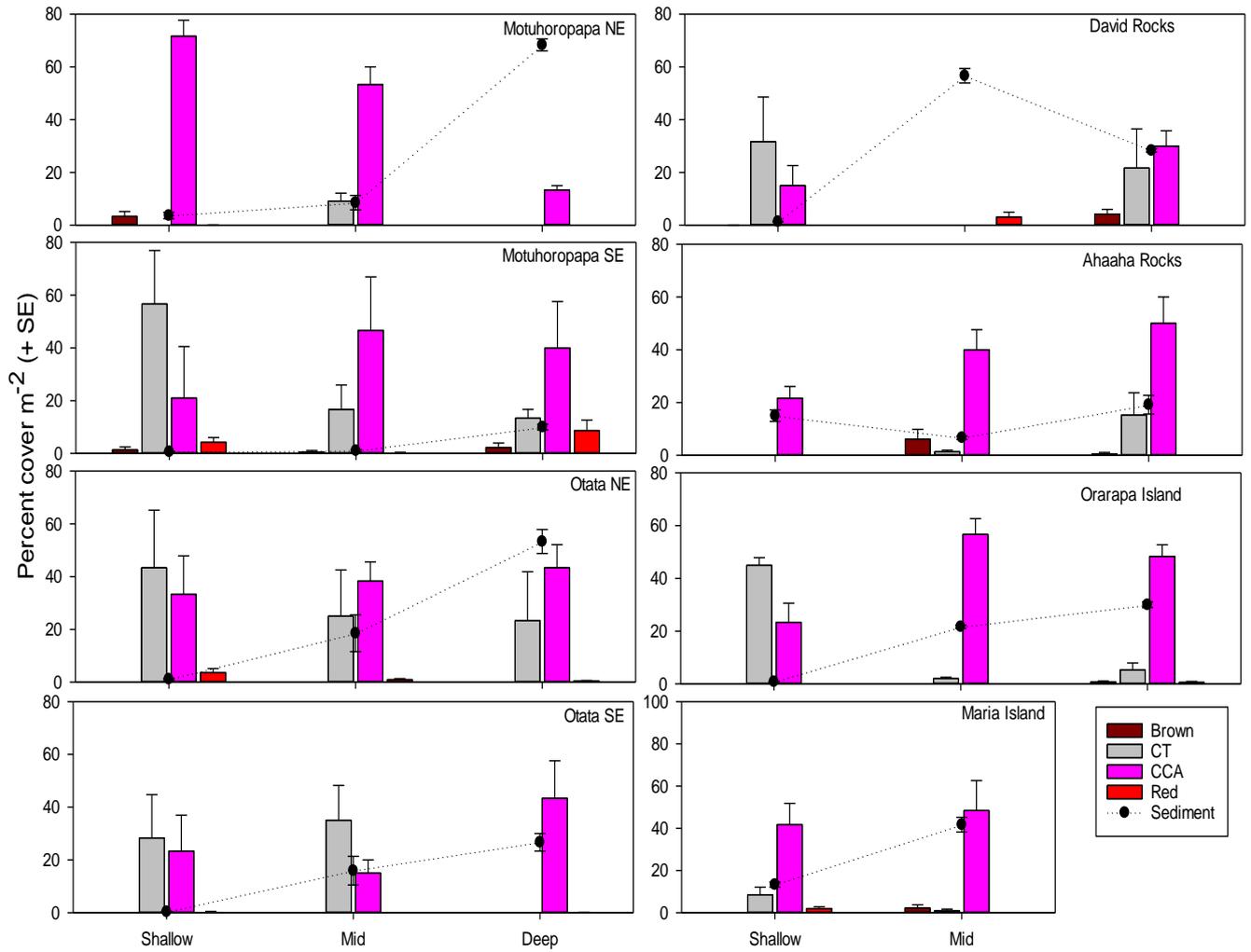
Figure 3.8. Percent cover of brown algae (foliose and crustose) CT – Coralline turf, CCA – Crustose coralline algae and additional red algae (foliose and crustose) and fine sediment across eight sites in relation to depth – Noises Islands.
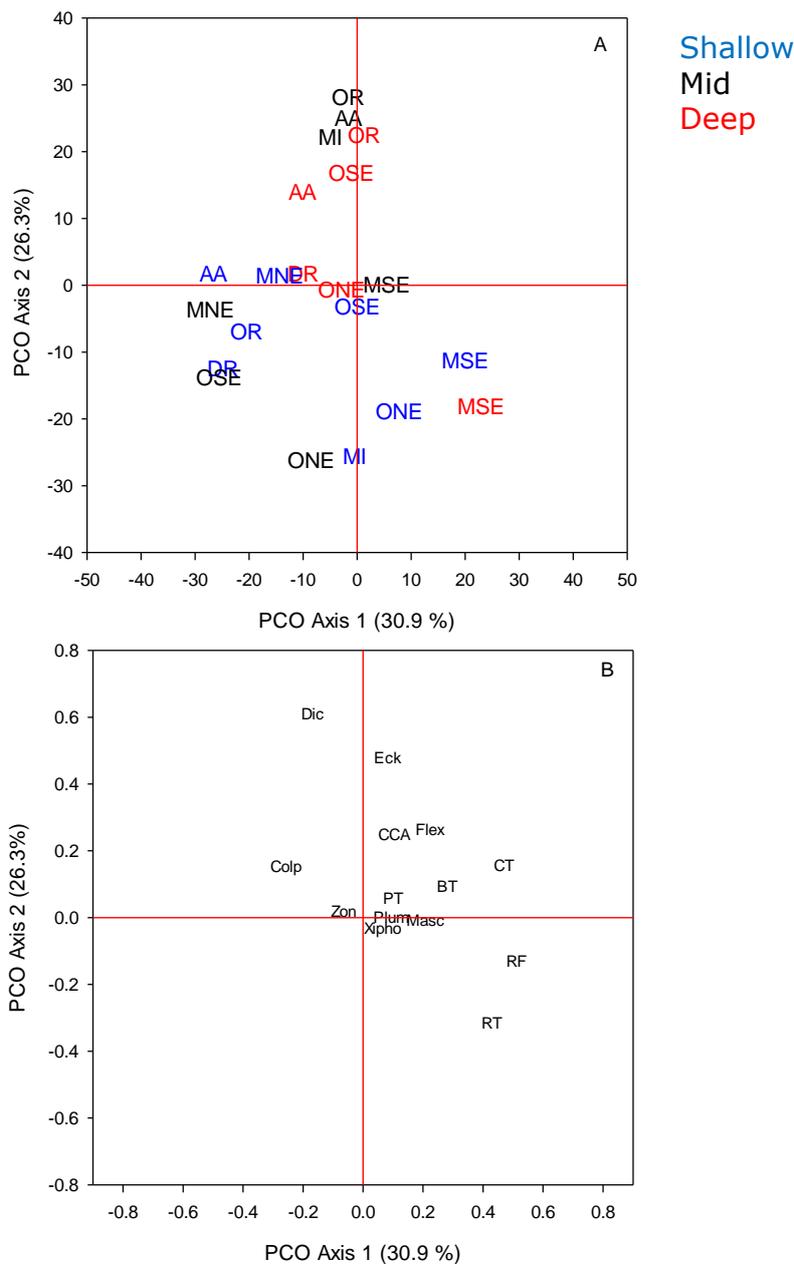
Figure 3.9. Principal coordinate analysis based on log x+1 macroalgal biomass data (27 main taxa – Appendix 3.0). A) Site-and depth-specific variation in macroalgal biomass; B) Biplot demonstrating correlation between PCO axes and each species, (>0.25 correlation). Sites as follows: AA = Ahaaha Rocks; DR = David Rocks; MI = Maria Island; MNE = Motuhoropapa north-east; MSE – Motuhoropapa south-east; ONE = Ōtata north east; OSE = Ōtata south east; OR = Orarapa Island Species and species groups as follows; BT = Brown turf; Flex = *Carpophyllum flexuosum*; Masc = *Carpophyllum maschalocarpum*; Plum = *Carpophyllum plumosum*; CT = Coralline turf; CCA = Crustose coralline algae; Colp = *Colpomenia sinuosa*; Dic= *Dictyota kunnthii*; Eck = *Ecklonia radiata*; PT = *Pterocladia lucida*; RT = Red turf; RF = Red foliose; Xipho = *Xiphophora chondrophylla*; Zon = *Zonaria turneriana*.

Table 3.2. Results from PERMANOVA analysis of macroalgal biomass data (27 taxa). Analysis was run on log (x+1) transformed data using a Bray Curtis similarity measure and 4999 permutations. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	34594	4941.9	10.53	***0.0002***
Depth	3	16927	5642.3	12.03	***0.0002***
SixDe	10	47876	4787.6	10.21	***0.0002***
Res	48	22523	469.2		
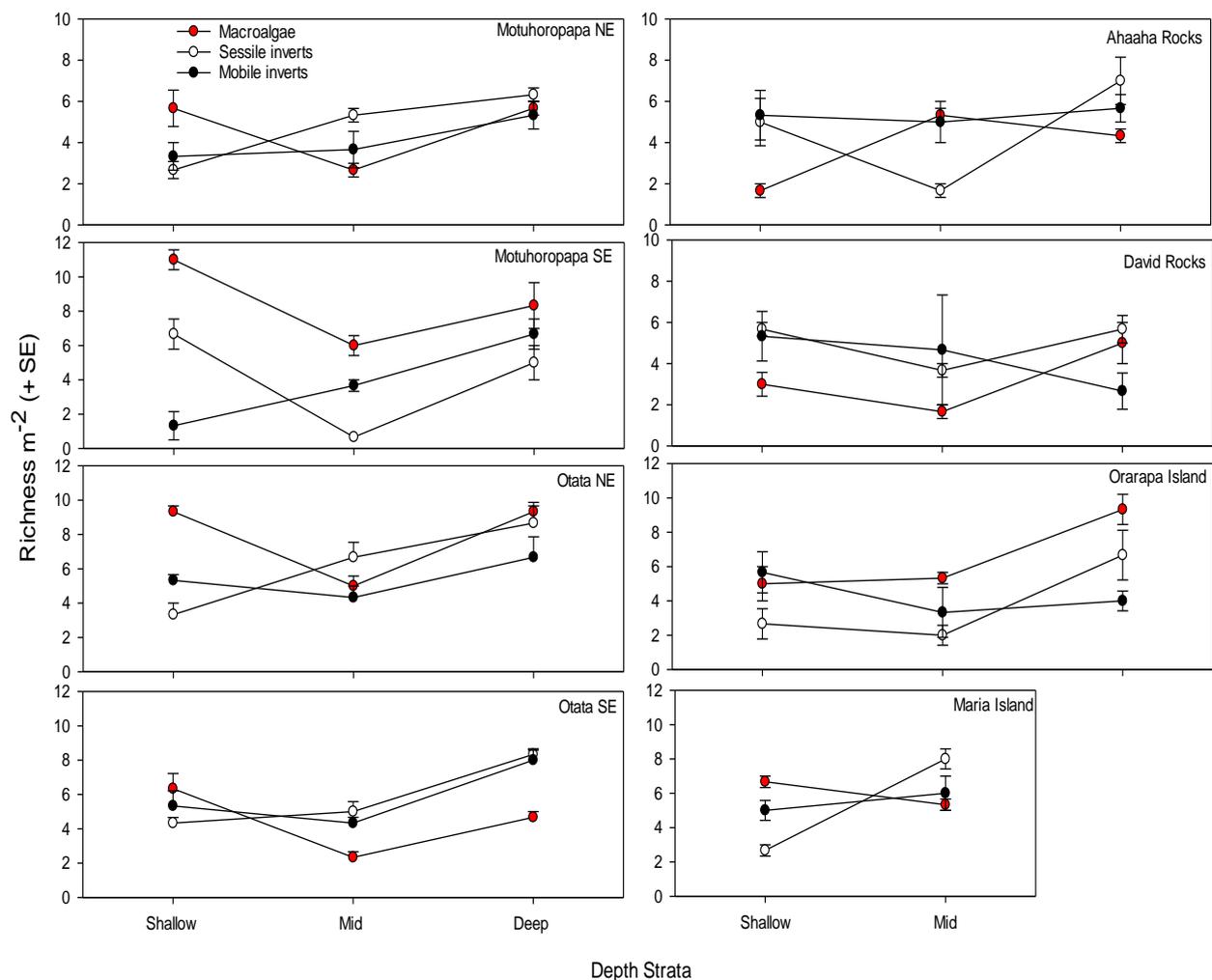
Figure 3.10. Average species richness of macroalgae, sessile invertebrates, and mobile invertebrates across eight sites in relation to depth – Noises Islands Autumn 2021. Data are averages ± SE. Note: x-axis and y-axis differs among graphs.

The percent cover of fine sediment varied considerably among sites and depth strata. For Motuhoropapa Island, Ōtata Island, Maria Island, and Orarapa Island sites there was a trend for higher sediment percent cover in deeper water relative to shallow and mid-depths. At David Rocks the percent cover of fine sediment was higher in the mid depth strata. Sites with the highest percent cover of fine sediment were Motuhoropapa north-

east, and Ōtata north-east where percent cover exceeded 50 % m^{-2}. At these sites there was also evidence of sediment impacted large sponges such as *Ecionemia alata*.

3.2 Sessile invertebrates

In addition to macroalgae, sponges, ascidians, encrusting bryozoans, hydroids, and hard coral were common components of rocky reef sessile invertebrate communities across the 8 survey sites. Species richness was found to be generally lower in shallow and mid-depths averaging around 4-5 species m^{-2}; whereas, in deeper water species richness commonly ranged between 8-9 species m^{-2} (Fig 3.10). Dominant species encountered included, the large grey sponge, *Ecionemia alata* , the golf ball sponges *Tethya burtoni*, with erect branched sponges such as *Callyspongia ramosa* and *Raspailia* spp synonymous at rocky reef/soft sediment transitions at depth. Encrusting species were commonly represented by the sponges *Cliona celata, Clathria rubens*; ascidians *Cnemidocarpa bicornuta*, *Asterocarpa coerulea*, *Aplidium* spp, and *Didemnum* spp.; and, the hard coral *Culicia rubeola*. Encrusting forms were particular dominant in urchin barrens habitat (Fig. 3.2F), whereas larger sponges with more complex architectures such as *Ecionemia alata, Apatos globosum,* and *Raspailia topsenti,* were more common in deeper depth strata (Fig. 3.2H).

Several unique sessile invertebrate assemblages were also encountered for example shallow regions around the Ahaaha Rocks were particularly notable for the high percent cover of kōtore tāhekeheke ma/anemones (*Anthothoe albocincta*) intermixed with mosaics of subtidal kūtai/green-lipped mussel (*Perna canaliculus*) habitat. High density kūtai/*Perna canaliculus* patches were also a conspicuous component throughout David Rocks (Fig. 3.11A), Maria Island and Orarapa Island shallow and mid-depth regions (0.5-5 m depth). Typically, where present, kūtai/*Perna canaliculus* beds were comprised of large individuals > 100 mm (Fig. 3.11B) that generally supported a large diversity of sessile invertebrates themselves. Within high density areas, kūtai/*Perna canaliculus* ranged between 25-50 m^{-2}. Average densities within those sites where high-density beds were evident are presented in Fig 3.11A). Very sparse subtidal patches of kūtai/*Perna canaliculus* were observed at Motuhoropapa south-east during the survey, which contrasts the 2017 habitat survey that identified numerous discrete, high-density, patches at shallow depths along much of Motuhoropapa eastern coastline (Haggitt and Shears, 2017).
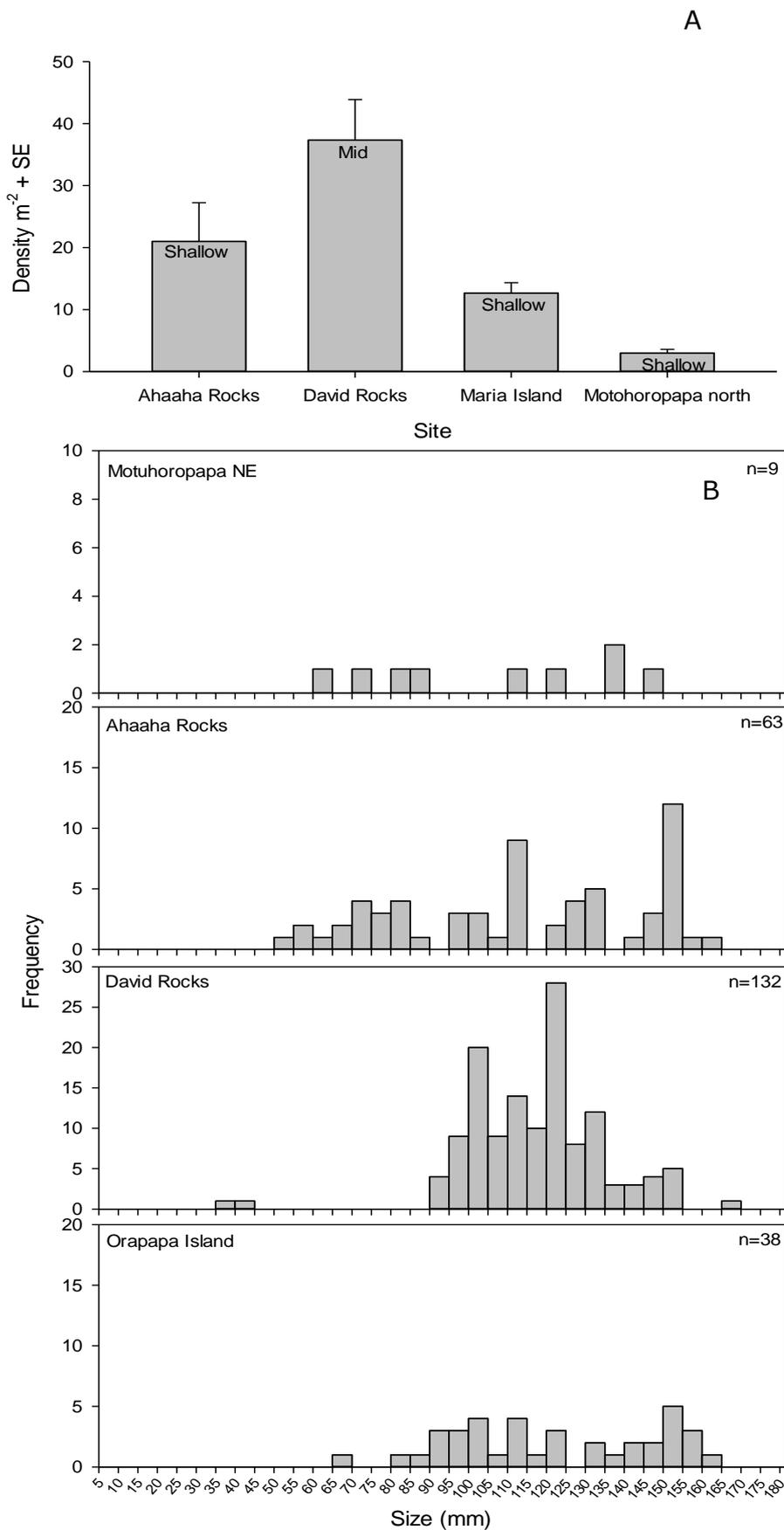
Figure 3.11. A density and B size frequency distributions of kūtai/*Perna canaliculus* across four sites– Noises Island March 2021. Note: y-axis differs among plots.

Sessile invertebrate community assemblage analysis indicated clear differences with regard to depth along PCO Axis 2 (Fig. 3.12) with deep-water sites typically negatively associated with PCO Axis 2 and mid- and shallow-water sites positively associated with PCO-Axis 2. However, there was no clear gradient in species composition across sites consistent with an environmental gradient. Differences in sessile invertebrate community composition was found to be statistically significant across sites and among depth strata based on PERMANOVA (Table 3.3).

Species contributing to the various site and depth groupings across the ordination based on Pearson's correlation coefficients are presented in Fig. 3.11B. Main species responsible for depth-related differences (dissimilarity) were as follows - the sponges *Ecionemia alata, Tethya bergquistae*, *Plakina monolopha,* and *Raspailia topsenti*; ascidians *Cnemidocarpa bicornuta* and, the solitary cup coral *Monomyces rubens* were more-characteristic of deeper strata; whereas, the anemone *Anthothoe albocincta;* mussels *Perna canaliculus* and the hard coral *Culicia rubeola* were more prevalent/typical of shallow water habitats. Species with more prevalence in mid depths were the encrusting forms such as *Aplidium* spp, and *Cliona celata*. Refer to Appendix 3.0 for presence/absence data.

Table 3.3. Results from PERMANOVA analysis of sessile count and percent cover data (32 taxa). Analysis was run on log (x+1) transformed data using a Bray Curtis similarity measure and 4999 permutations. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

| Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	74954	10708	7.8299	***0.0002***
Depth	3	39421	13140	9.6088	***0.0002***
SixDe	10	87777	7314.8	5.3489	***0.0002***
Res	48	62906	1367.5		
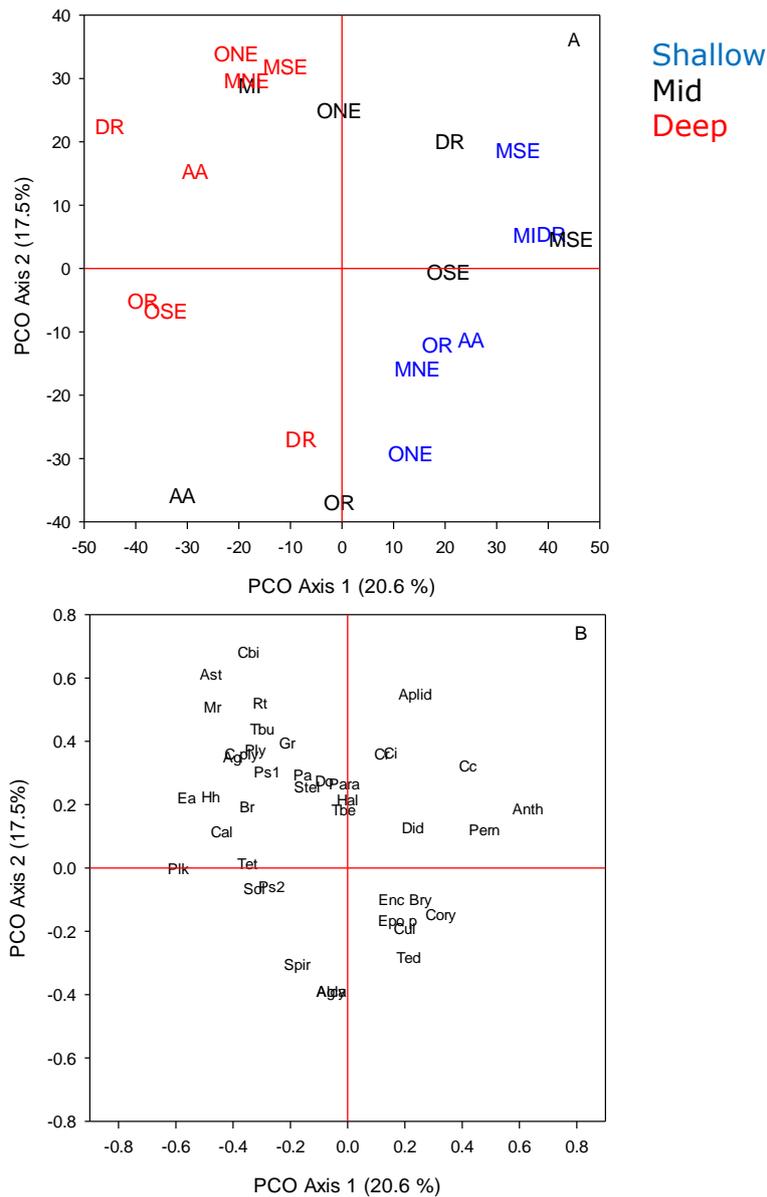
Figure 3.12. Principal coordinate analysis based on square-root transformed sessile invertebrate abundance and percent cover data (37 taxa) across eight sites – Noises Islands - March 2021. A) Site- and depth-specific variation in assemblage biomass; B) Biplot demonstrating correlation between PCO axes and sessile invertebrate species, (>0.25 correlation). Sites as follows: AA = Ahaaha Rocks; DR = David Rocks; MI = Maria Island; MNE = Motuhoropapa north-east; MSE – Motuhoropapa south-east; ONE= Ōtata north east; OSE = Ōtata south east; OR = Orarapa Island Species and species groups as follows: Apli=*Aplidium scabellum*; Ag=*Aaptos globosum*; Agla= *Aglaophenia laxa*; Alcy=*Alcyonium aurantiacum*; Anth=*Anthothoe albocincta*; Ast=*Asterocarpa coerulea*; Br=*Biemna rufescens*; Cal=*Callyspongia ramosa*; Cbi=*Cnemidocarpa bicornuta*; Cc=*Cliona celata*; Ci=*Crella incrustans*; Cory=*Corynactis australis*; C ply=*Ciocalypta polymastia*; Cr=*Clathria rubens*; Cul=*Culicia rubeola;* Did= Didemnum species; Do=*Darwinella oxeata*; Ea=*Ecionemia alata*; Enc Bry=Encrusting bryozoan; Gr= *Geodia regina*; Hal=*Halichondria moorei*; Hh= *Hymeniacidon hauraki*; Mr=*Monomyces rubrum*; Pa=*Pseudodistoma aureum*; Para=*Parasmittina delicatula*; Pern=*Perna canaliculus* Plk=*Plakina monolopha;* Ply=*Polymastia* species; Ps1=*Psammocinia* species 1; Ps2 = *Psammocinia* species 2; Rt=*Raspailia topsenti*; Sol=*Solanderia* sp.; Spir=Spiorbid tube worms; Stel=*Stelletta crater*; Tbe=*Tethya bergquistae*; Tbu= *Tethya burtoni;* Ted=*Tedania sp*; Tet=*Tetrapocillon novaezealandiae.*

3.3   Mobile invertebrates

Dominant mobile invertebrates across survey sites were represented by gastropods (pūpū/karikawa *Cookia sulcata*; pūpū kōrama/*Lunella smaragdus*; hopetea/*Dicathais orbita*; the green top shell pūpū *Trochus viridis;* and purple top shell pūpū/*Cantharidus purpureus* (Fig. 3.13; Appendix 2.0)); and, to a lesser degree, echinoderms (see below). For the main gastropod species, there was again high variation in densities across sites and depths, although broader scale depth-related and habitat related relationships were apparent.   For example, the cat's eye pūpū kōrama/*Lunella smaragdus* was generally restricted to the shallowest depth strata, whereas the green top shell *Trochus viridis* was more common in the mid depth strata associated with urchin barrens habitat, and the purple top-shell *Cantharidus purpureus* strongly associated with macroalgal habitat – particularly *Ecklonia radiata* – and was thus more prevalent in either shallow or deep depth strata (Fig 3.13). pūpū/karikawa *Cookia sulcata* was found to be highly variable among sites and among depth strata, but also attained very large sizes > 70 mm particularly in shallow water. Statistical analyses for main gastropod species in relation to depth are presented in Appendix 2.0.
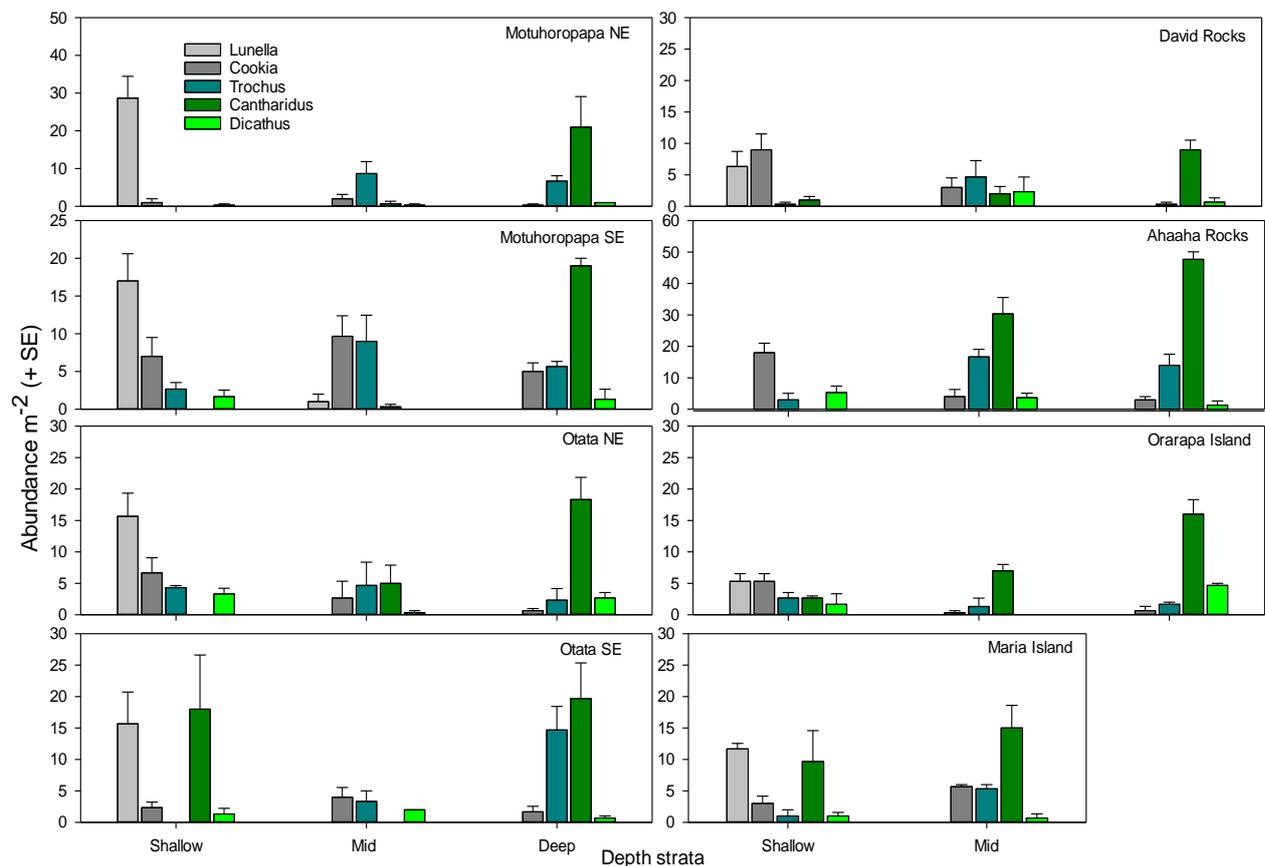

Figure 3.13. Abundance of five main gastropod species across eight sites in relation to depth – Noises Islands, Autumn 2021. Species include the cat's eye *Lunella smaragdus;* Cook's turban *Cookia sulcata*, green topshell *Trochus viridis*; purple topshell *Cantharidus purpureus,* and whelk *Dicathais orbita*. Data are averages + SE. Note x-axis differs among graphs.

Other gastropod and mollusc species that were encountered less frequently were the whelks kawari/*Cominella virgata*; *Muricopsis* spp, *Xyeme* spp, *Buccinulum linea linea, Penion sulcatus, Calliostoma punctulatum* and *Maoricolpus roseus roseus* butterfly chiton *Cryptoconchus porosus* and noble chiton *Eudoxochiton nobilis.* Pāua/*Haliotis iris* were only encountered at Ōtata north-east in the shallowest depth strata (2 sublegal individuals approximately 70 mm in length).

Echinoderms were numerically dominated by the common urchin kina/*Evechinus chloroticus* and the holothurian *Stichopus mollis.* Kina/*Evechinus chloroticus,* were present at all sites with abundances highly variable according to depth. Typically, highest densities occurred within shallow or mid-depth strata with much low densities associated with deeper depth strata (Fig 3.14). Very high densities, i.e., > 8 m^{-2} were enumerated at Motuhoropapa north-east – shallow, Motuhoropapa south-east – mid, and Ōtata south-east – mid. Active grazing of *Ecklonia radiata* was observed at Motuhoropapa north-east in both mid and deep depth strata. There was also variation across sites with respect to urchin size, with a greater frequency of larger individuals occurring at Motuhoropapa and Ōtata sites (Figs 3.15, 3.16).
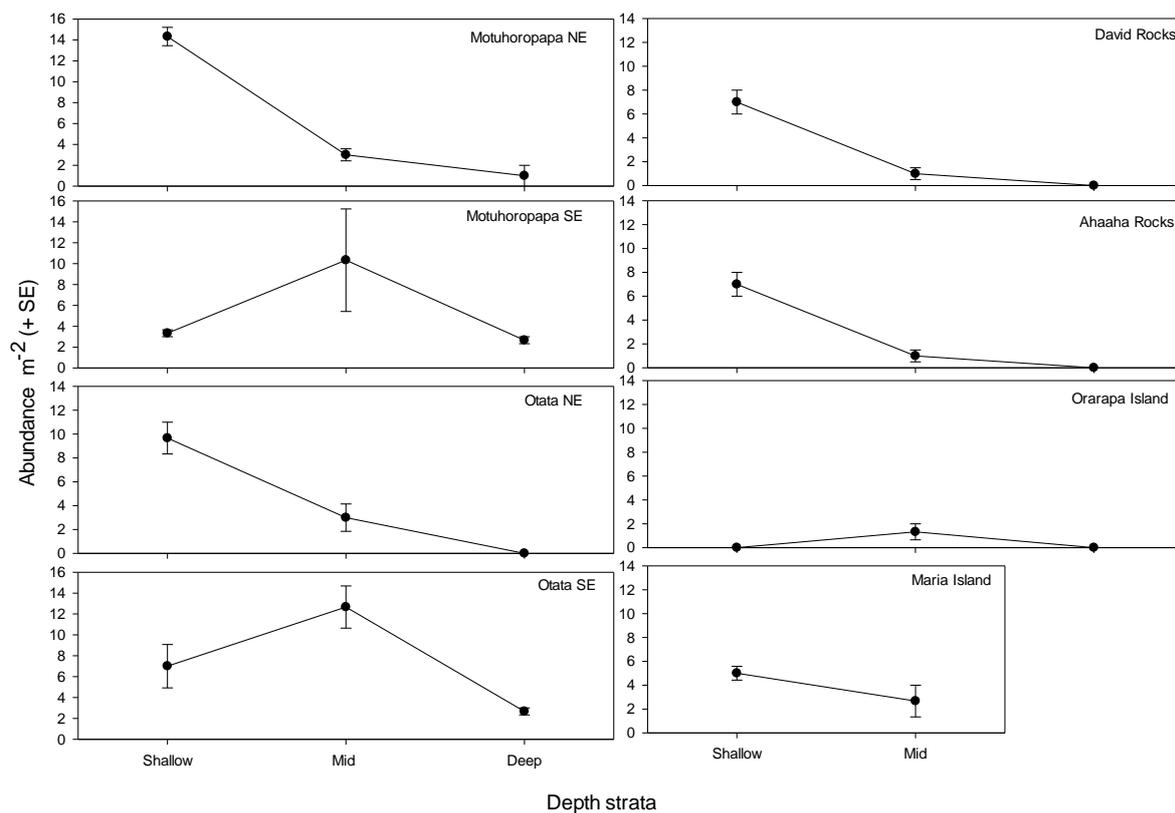
Figure 3.14. Abundance of the common sea urchin *Evechinus chloroticus* (kina) across eight sites in relation to depth – Noises Islands, Autumn 2021. Note *y*-axis differs among plots.
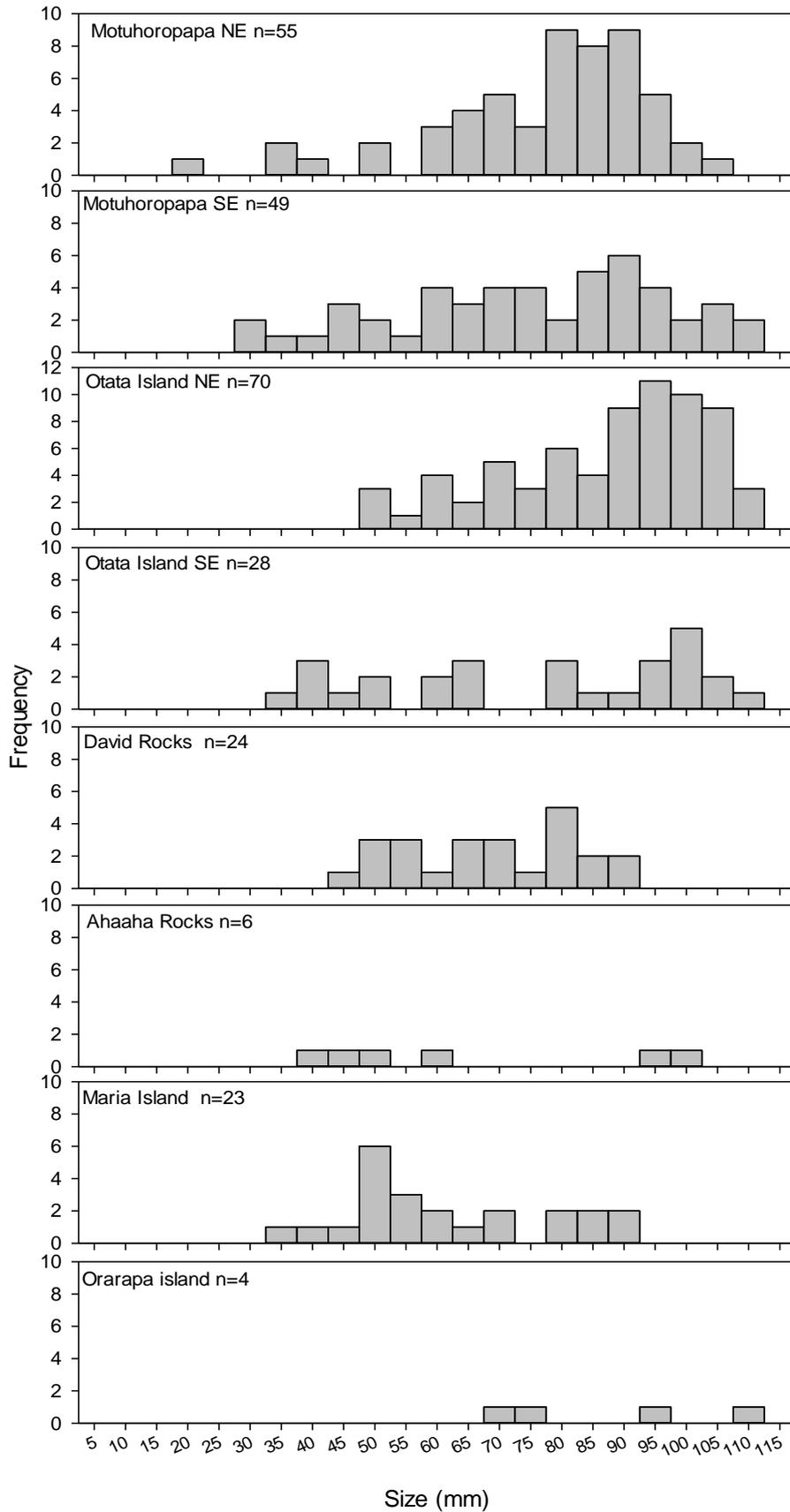
Figure 3.15. Size frequency distributions of the urchin *Evechinus chloroticus* (kina) across eight sites – Island, March 2020. *Note:* data are pooled across depth strata.
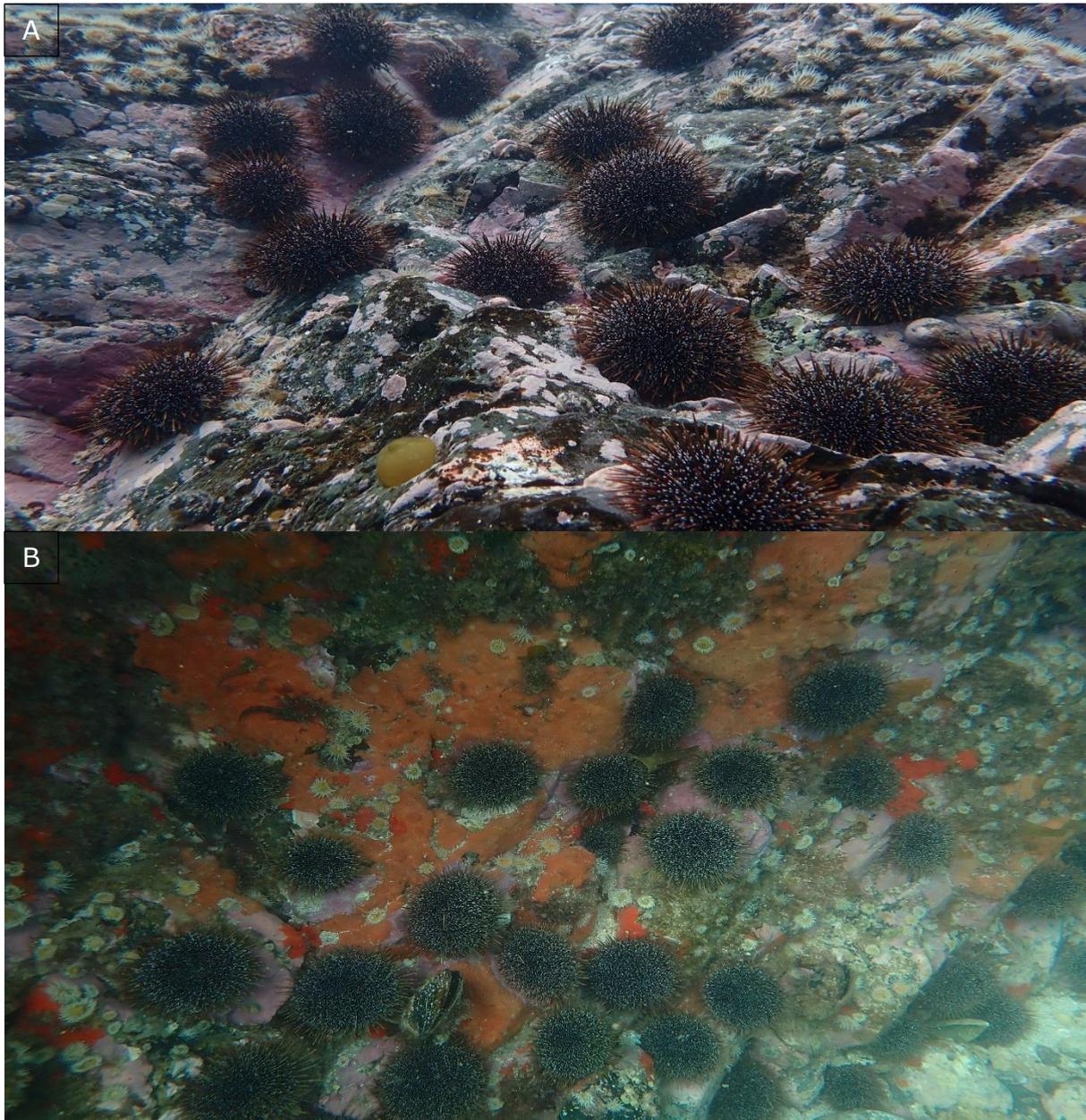
Figure 3.16. Example of *Evechinus chloroticus* densities – A) 1m depth, B) 5m depth Motuhoropapa Island 2021.

At a community level, mobile invertebrate assemblage composition exhibited clear depth-related variation, evident from the PCO ordination (Fig. 3.17A) with shallow-water sites grouped to the left of the ordination negatively associated with PCO-Axis 1, mid-depth sites grouped to the right of the ordination positively associated with PCO-Axis 1, and deeper sites both negatively and positively associated with PCO-Axis 1. Species responsible for depth-related variation, based on Pearson's correlation coefficients are presented in Fig. 3.17B. SIMPER analysis supported the broad-scale depth-related differences described above with pūpū kōrama/*Lunella smaragdus*, and *Cookia sulcata* more abundant at shallow depths, and the green topshell *Trochus viridis*; purple topshell and *Cantharidus purpureus* associate with deeper depth strata. Refer to Appendix 3.0 for presence/absence data.
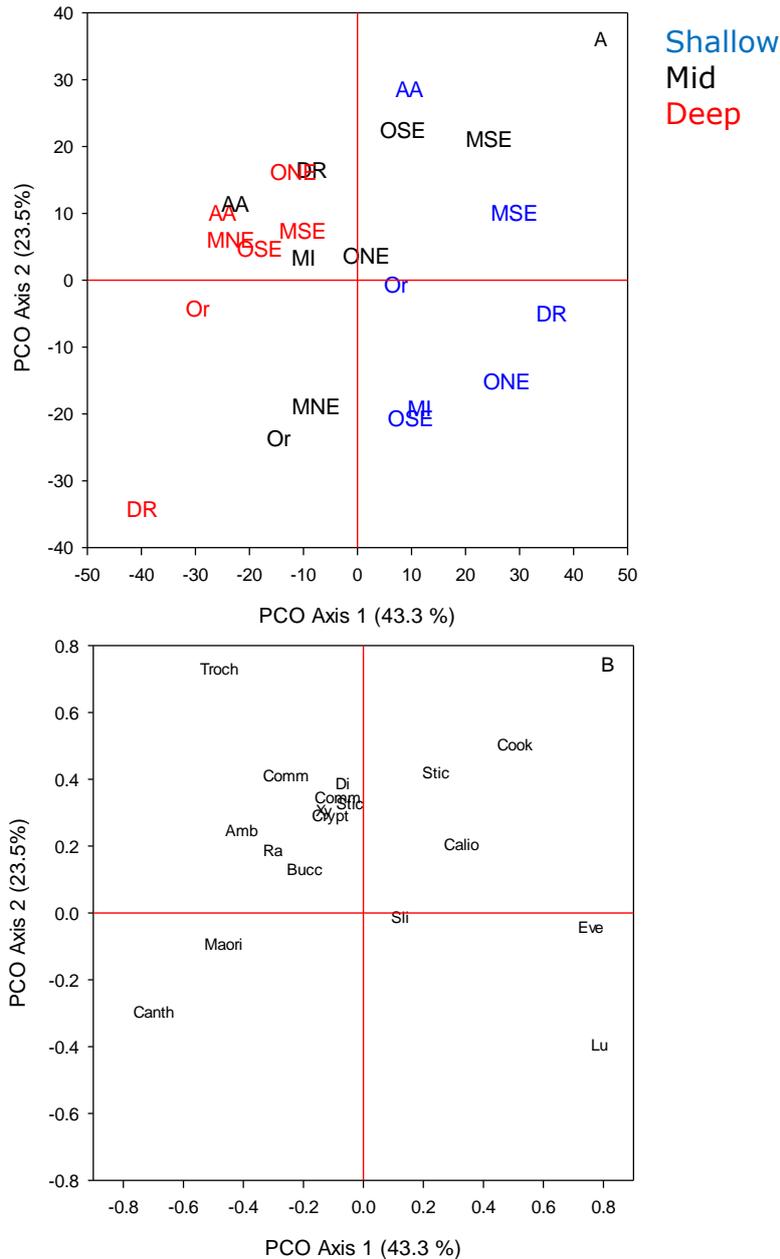
Figure 3.17. Principal coordinate analysis based on log (x+1) transformed mobile invertebrate abundance data (26 taxa) across eight sites – Noises Islands - March 2021. A) Site- and depth-specific variation in assemblage biomass; B) Biplot demonstrating correlation between PCO axes and sessile invertebrate species, (> 0.25 correlation). Sites as follows: AA = Ahaaha Rocks; DR = David Rocks; MI = Maria Island; MNE = Motuhoropapa north-east; MSE – Motuhoropapa south-east; ONE= Ōtata north east; OSE = Ōtata south east; OR = Orarapa Island Species and species groups as follows: Amb= *Amblypneustes elevates*; Canth=*Cantharidus purpureus*; Cook=*Cookia sulcata*; Com= *Cominella quoyana* Bucc= *Buccinulum linea linea*; Cryp=*Cryptoconchus porosus;* Bucc= *Buccinulum linea linea;* Di=*Dicathias orbita*; Eve=*Evechinus chloroticus*; Maori= *Maoricolpus roseus roseus*; Lun=*Lunella smaragdus*; Ra= *Ranella australasia australasia*; Stic=*Stichopus mollis*; TD= *Taron dubius*; Troch=*Trochus viridis*; Xym=*Xymene ambiguous.*

Table 3.4. Results from PERMANOVA of mobile invertebrate count data (26 taxa) across eight sites – Noises Islands, Autumn 2021. Analysis was run on log (x+1) transformed data using a Bray Curtis similarity measure and 4999 permutations. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	22391	3198.7	5.1368	***0.0002***
Depth	3	35065	17533	28.156	***0.0002***
SixDe	10	30872	2374.8	3.8136	***0.0002***
Res	48	28645	622.71		

3.4   Reef fish

A total of 18 reef fish species were censused across the 8 sites within the Noises Islands Group. Of these, parore (*Girella tricuspidata*), goatfish *(Upeneichthys lineatus)*, spotty (*Notolabrus celidotus*), red moki (*Cheilodactylus spectabilis*) and tāmure/snapper (*Chrysophrus auratus*) were numerically dominant although across site-specific variation was notable (Fig. 3.18-3.20). Common trends were for parore to occur in large schools in and around Motuhoropapa and Ōtata Islands (Figure 3.18), whereas spotty and goatfish were common all sites. Tāmure/snapper occurred at their highest abundance at the Ahaaha Rocks, David Rocks and Ōtata north-east– albeit the majority of tāmure/snapper censused were sublegal (Fig's 3.20). Similarly, red moki were observed at the majority of sampling sites, but again were predominantly sublegal (Fig. 3.20). Other commonly fished species such as butterfish (*Odax pullus*) and blue cod (*Parapercis colias*) were only occasionally observed, but in all cases were juveniles < 250 mm TL.
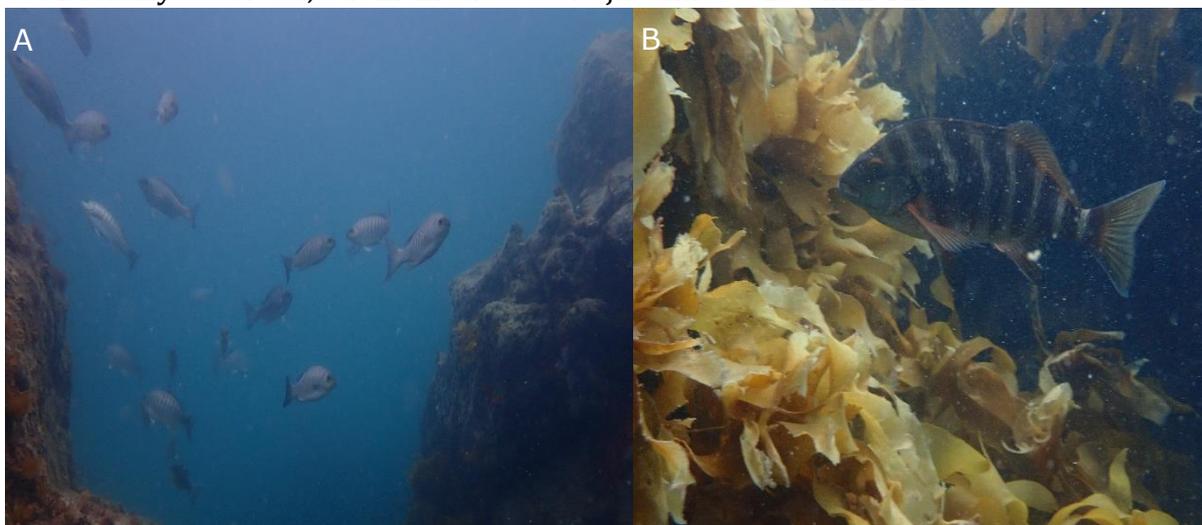
Figure 3.18. A) Parore (*Girella tricuspidata*), and B) juvenile red moki (*Cheilodactylus spectabilis*) – common reef fish across the Noises Island group.

Reef fish diversity was low to moderate across sites (Fig. 3.22) with Ahaaha Rocks having the highest richness of all sites and species such as jack mackerel (*Trachurus novaezelandiae*), leatherjacket (*Parika scaber*), and kahawai (*Arripis trutta*) were only observed at Ahaaha Rocks.

Community composition was found to be statistically different across sites (Table 3.5) with among-site pairwise tests provided in Appendix 2.0. In summary Motuhoropapa, Ōtata, and David Rocks sites had very similar reef fish communities and were not statistically different; however, there were statistically significant differences between the Ahaaha Rocks, Orarapa and Maria Island communities from those aforementioned sites.

Table 3.5. Results from PERMANOVA of reef fish count data (18 taxa) across eight sites – Noises Islands, Autumn 2021. Analysis was run on log (x+1) transformed data using a Bray Curtis similarity measure and 4999 permutations. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Source	df	SS	MS	Pseudo-*F*	P(perm)
Site	7	45781	6540.1	3.1169	***0.0002***
Residual	64	1.34E+05	2098.3		
Total	71	1.80E+05			

This is supported by the community ordination indicating a gradient across the Noises Island Groups with Ōtata and Motuhoropapa sites grouped to the right of the ordination and across-site serration evident from right to left across PCO Axis 1. Ahaaha Rocks was distinct from the other sites reflecting its distinct fish fauna being driven by the high abundance of jack mackerel, and snapper and presence of kahawai. Other species responsible for driving site related differences include parore, goatfish, and red moki (Motuhoropapa and Ōtata) and eagle ray (David rocks). Other species censused tended to be intermediate across all sites. Several species of note were observed outside of sample transects as follows – kingfish (Ahaaha Rocks), short-tailed ray (Motuhoropapa NE) and juvenile butterfish (Ōtata south/David Rocks).
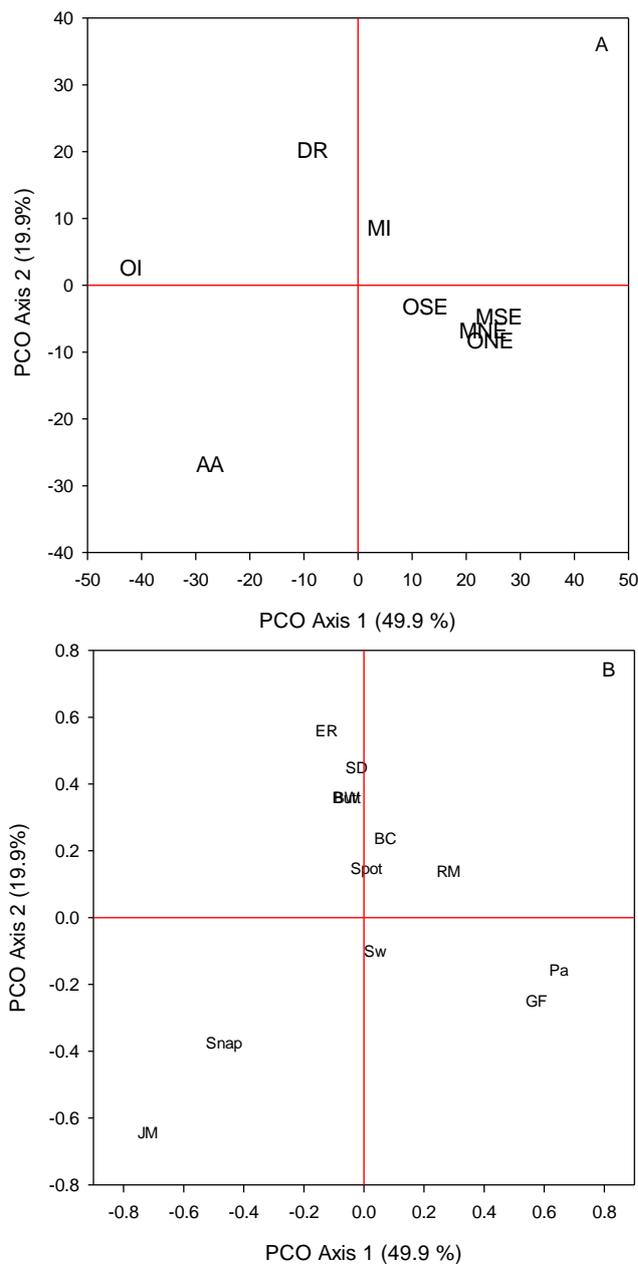
Figure 3.19. Principal coordinate analysis based on log (x+1) transformed reef-fish data (18 taxa) across eight sites – Noises Islands - Autumn 2021. A) Site- specific variation in community composition; B) Biplot demonstrating correlation between PCO axes and reef-fish species, (>0.25 correlation). Sites as follows: AA = Ahaaha Rocks; DR = David Rocks; MI = Maria Island; MNE = Motuhoropapa north-east; MSE – Motuhoropapa south-east; ONE= Ōtata north east; OSE = Ōtata south east; OR = Orarapa Island. Species as follows: BC= Blue cod (*Parapercis colias*); *But*=Butterfish(*Odax pullus*); BW=banded wrasse (*Notolabrus fucicola*); ER=eagle ray (*Myliobatis tenuicaudatus*); GF=goatfish *(Upeneichthys lineatus)*; JM=jack mackerel *(Trachurus novaezelandiae)*; LJ=leatherjacket (*Parika scaber*); Pa=parore (*Girella tricuspidata*); SW=sweep (*Scorpis lineolatus*); SD=silver drummer (*Kyphosus sydneyanus*); Snap=(*Chrysophrus auratus*)*;* RM=Red moki (*Cheilodactylus spectabilis*); Spot=spotty (*Notolabrus celidotus*).
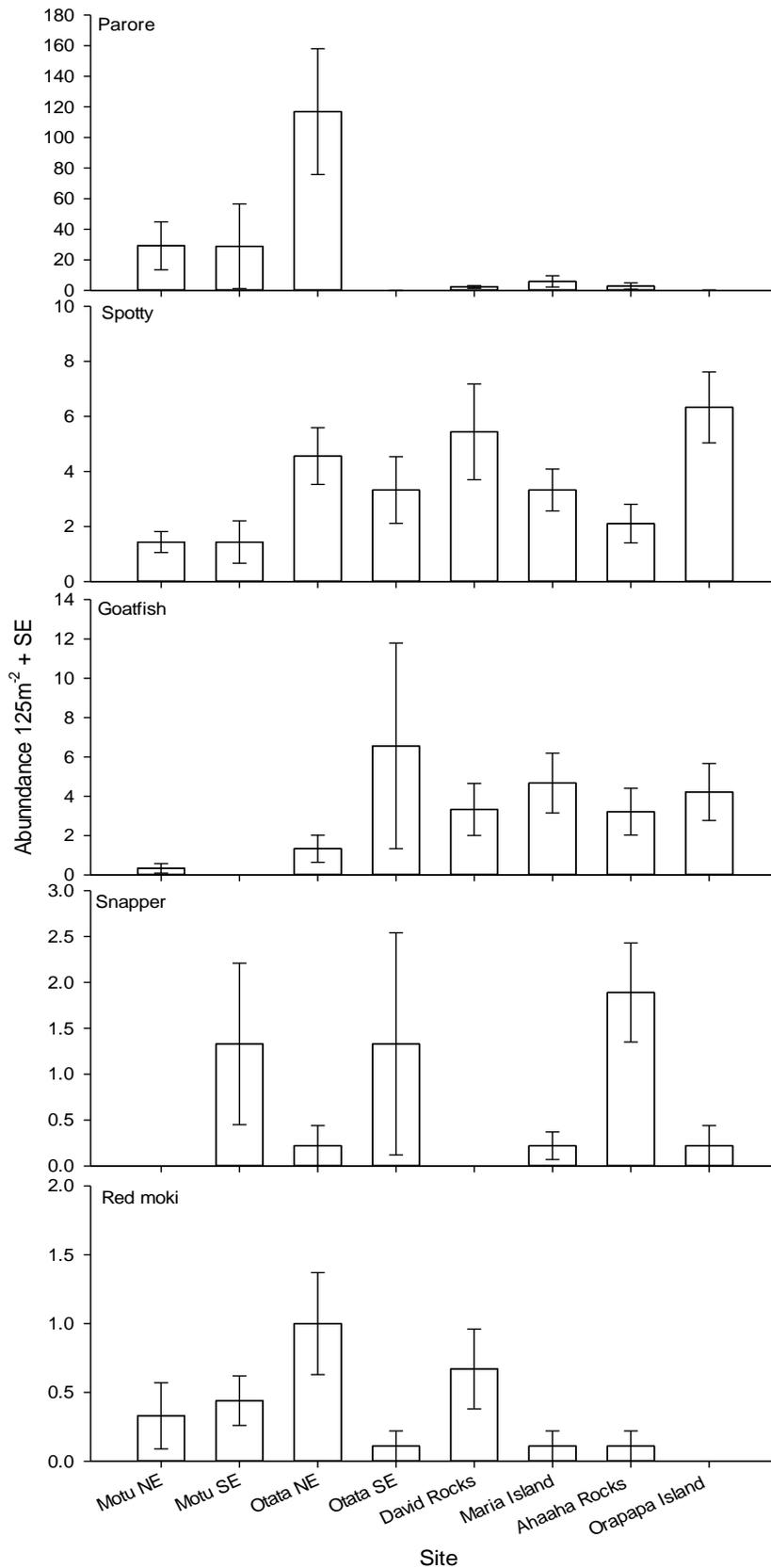
Figure 3.20. Densities of parore (*Girella tricuspidata*), spotty (*Notolabrus celidotus*), goatfish *(Upeneichthys lineatus)*, tāmure/snapper (*Chrysophrus auratus*) and red moki (*Cheilodactylus spectabilis*), across eight sites – Noises Islands, Autumn 2021.
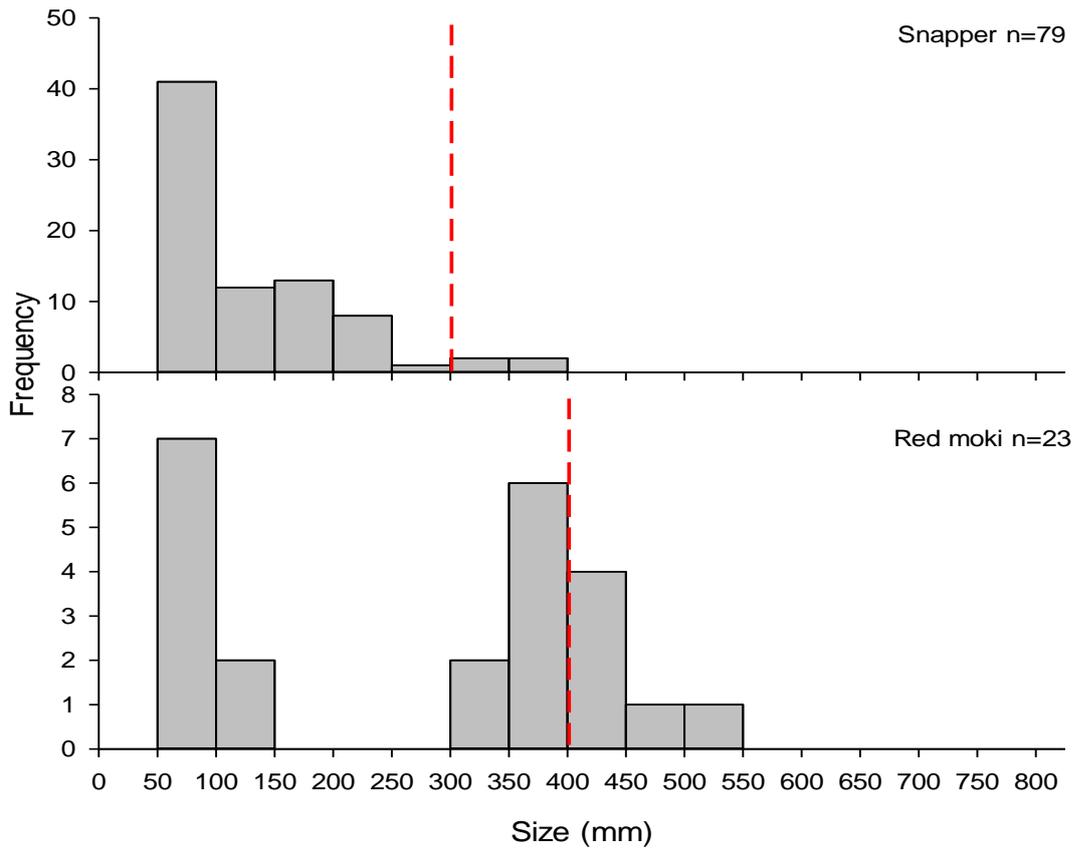
Figure 3.21. Size frequency distributions of tāmure/snapper and red moki fork length (FL). Vertical dashed lines denote division between sub-legal and legal-sized individuals.
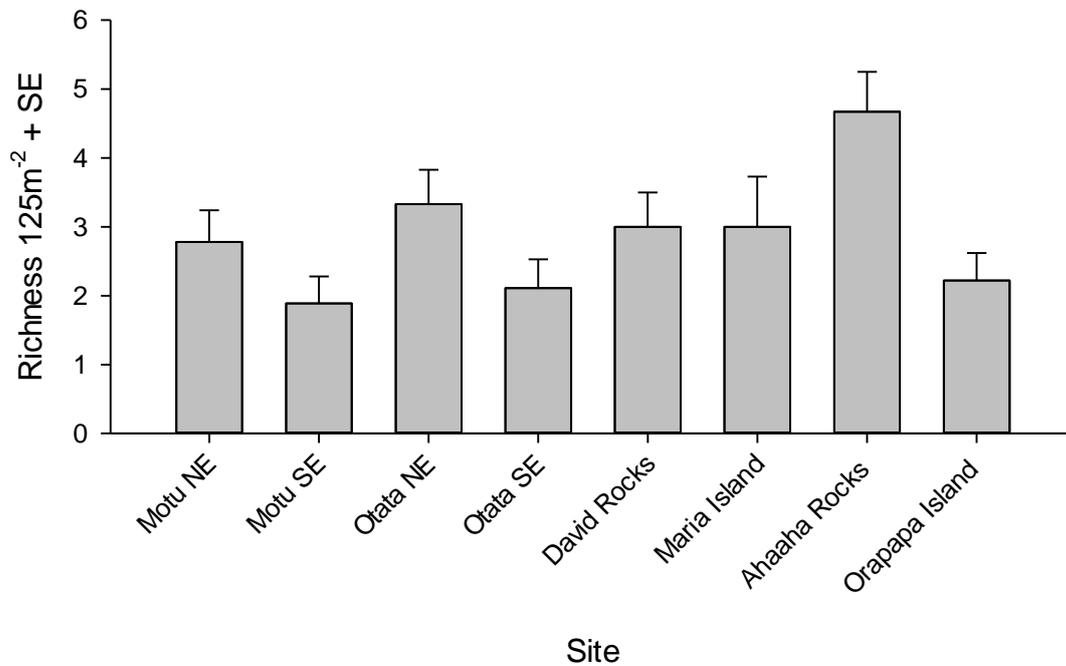
Figure 3.22. Reef fish diversity based on average species richness + SE.

3.5   Kōura/Lobster

Despite high quality habitat for rock lobster and extensive searches only three kōura/*Jasus edwardsii* were censused in total across the eight survey sites equating to an average density of 0.13 lobster per 500m^{-2} (± 0.1 SE). All were deemed to be sublegal, i.e., carapace length < 95 mm.

3.6   Soft sediment bivalves

Tipa/*Pecten novaezelandiae* average abundance derived from ten transects was 23 scallops (± 5.5 SE) 100 m^{-2}, which translates to very-low abundance. The majority of tipa/*Pecten novaezelandiae* sampled (87 %) were sub-legal with individuals between 85-95 mm the most frequently encountered (Fig. 3.23). A total of 31 legal-sized individuals were censused over 1 km^2 of seabed surveyed equating to an average density of 3.1 (± 1.3 SE) 100 m^{-2}. Juvenile tipa/scallops < 50 mm were present across the sampling area, albeit at very low densities and were patchily distributed.

Soft sediment habitats across the survey site were highly variable ranging from soft muds, fine sand, through to coarse shell hash, dog cockle shells and rhodolith patches (Fig. 3.24). Tipa/scallops were found across all habitat types; however, further sampling would be required to evaluate density and habitat-specific relationships and it is likely that much higher densities would be required to evaluate these types of relationships. Within the scallop survey area, horse mussel *Atrina zelandica* were also present, although the majority were dead (Fig. 3.24). Live *Atrina zelandica* equated to only 12 individuals over 1 km^2 of seabed surveyed (Fig. 3.25).
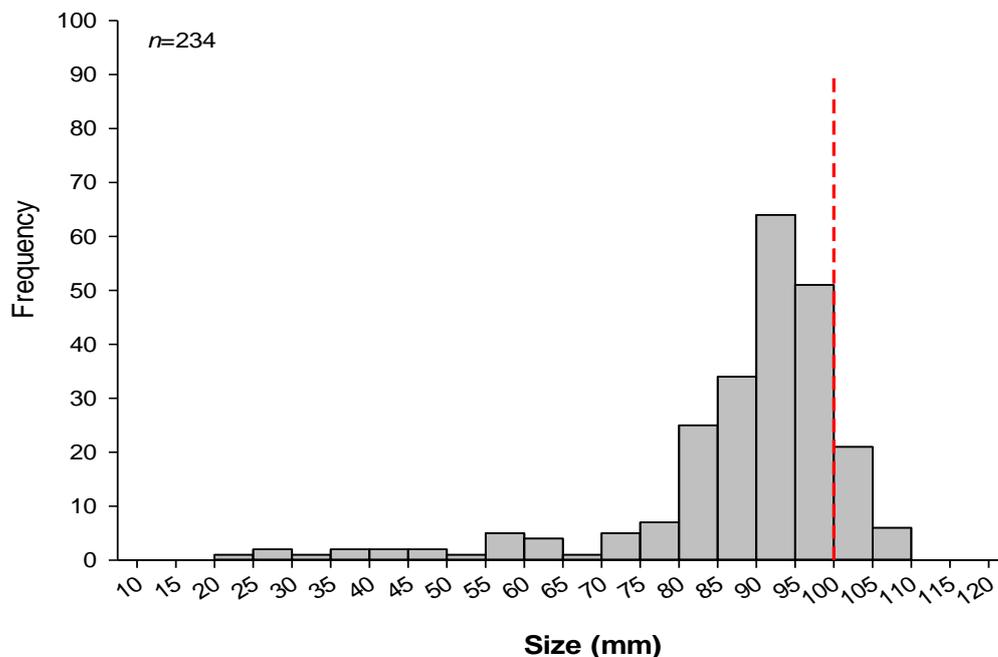
Figure. 3.23 Size frequency distribution of tipa/*Pecten novaezelandiae*. Data are derived from ten 100m^2 transects – SW Ōtata Island – May 2021. Horizontal vertical line denotes the division between sublegal and legal-sized individuals.

Figure 3.24. Example of soft sediment habitat types encountered during the tipa/scallop and hururoa/horse mussel survey – SW Ōtata Island – May 2021.
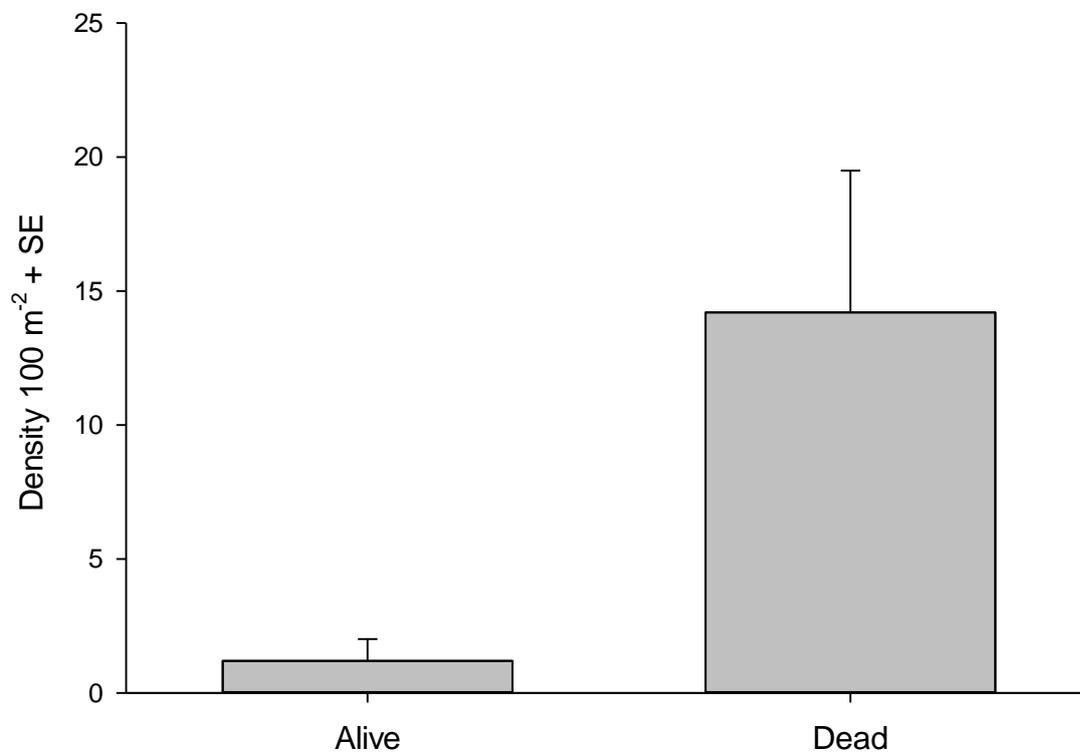
Figure. 3.24. Average density (+ SE) of hururoa/horse mussel *Atrina zelandica*, SW Ōtata Island May 2021. Data are derived from ten 100m^2 transects – May 2021.
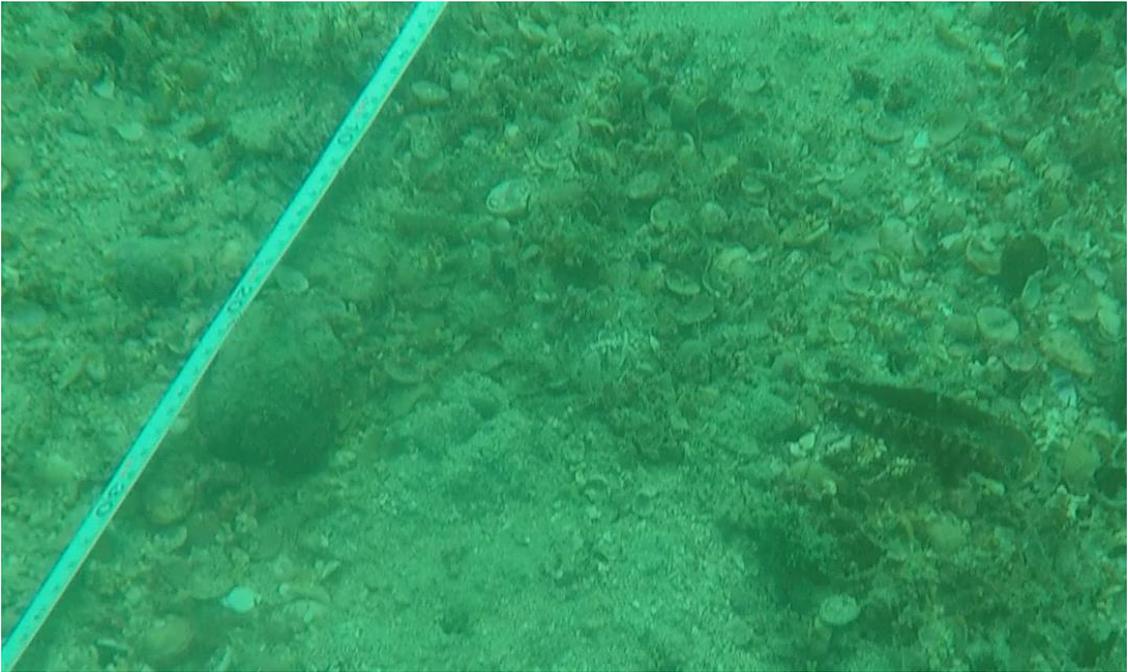
Figure. 3.25. Example of living hururoa/horse mussel, *Atrina zelandica* – bottom right – SW Ōtata Island May 2021.

4.0   Discussion

This report details a quantitative biological survey of the Noises Islands group using a depth stratified sampling approach. The methods used here are directly comparable to other surveys done at adjacent Rakino Island (Haggitt, 2020); Waiheke Island (Haggitt, 2016); and both the inner and outer Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi (Shears, 2017 – 2019 published and unpublished data). The data also represent robust baseline information from which ecological change in response to future restorative and protection-related initiatives can be gauged. Moreover, the dataset will empirically build on qualitative and semi-quantitative data that were obtained in an earlier habitat survey done in 2017 (Haggitt and Shears, 2017). On balance, due to the lack of any temporal monitoring at the Noises Islands over the last few decades the broad-scale descriptions of habitats, marine invertebrates, and reef-fish communities presented here are a snapshot in time. As such, the lack of any robust long-term monitoring has created an obvious shifting baseline scenario. This is not unique to the Noises Islands but also applies to much of the Hauraki Gulf Marine Park (HGMP). Resultantly, any quantitative assessment of long-term ecosystem change for the Noises Islands Group is not possible (see Gatti, *et al.* 2015). The vast wealth of information held by the Neureuter family does however provide valuable insight into what has been lost and where, including sources of pressure impacting the marine environs.

4.1   General findings - biological habitat and species distribution

The distributional pattern of key biological rocky reef habitats characteristic of the Noises Islands Group display variability consistent with depth and location. Deeper reef areas (> 10m depth) were characteristically macroalgal dominated with either *Ecklonia radiata*, *Ecklonia radiata*/sponge, *Carpophyllum flexuosum* or various combinations of these habitat types. Mid-depths were either urchin-barrens dominated, macroalgal dominated, or kūtai/green-lipped mussel dominated with shallow depths either *Ecklonia radiata* or mixed macroalgal dominated, urchin barrens dominated, anemone dominated, or green-lipped mussel dominated. Of the surveyed habitats within this study, the majority were biogenic in nature (Refer to Box 1). The variation in biological habitats across sites in addition to depth also reflects the interplay between physical and biological process including, but not necessarily limited to, exposure, sedimentation, grazing and competition for space. Future planned analyses of the existing datasets will examine the importance of these physical processes further.

The deeper *Ecklonia radiata* beds at Motuhoropapa, and Ōtata survey sites were patchy in nature and were often bordered by extensive shallower urchin barrens habitat. The patchy nature of *Ecklonia radiata* at these sites particularly at depth is likely due to a combination of high sediment cover (evident on algal fronds and the immediate substratum) and elevated turbidity and corresponding reduced photosynthetic ability. Sustained sedimentation and resultant high suspended sediment concentrations

(increase in turbidity) can impact significantly on both kelp abundance, distribution, and morphology (Airoldi, 2003). Morphological traits of *Ecklonia radiata* in low light conditions include short stipes and longer primary laminae that also extend to reduced surface area to volume ratios (SA:V) of vegetative tissues (Blain, *et al.* 2020). Experiments undertaken by Blain, *et al.* (2020) that included the Noises Islands demonstrated that under low light (turbid) conditions, *Ecklonia radiata* typically loses significant vegetative biomass and has lower Net Primary Production (NPP) compared to *Carpophyllum flexuosum* (Blain and Shears, 2019; Blain, *et al.* 2020; Blain and Shears, 2020). Further, it has been suggested that in low light conditions, habitats can shift from kelp dominated to fucalean dominated which, may in-part, explain why *Carpophyllum flexuosum* can occur in higher densities at turbid locations and *Ecklonia radiata* often attains high abundance in shallow depth strata, i.e., < 5 m depth. This distributional pattern, which differs considerably from less-turbid locations, has been demonstrated to occur at some sites at the Noises Islands (this study; Blain and Shears, 2019), Rakino Island (Haggitt, 2020), Waiheke Island (Haggitt, 2016) and much of the inner Hauraki Gulf/ Tikapa Moana/Te Moananui ā Toi. (Grace, 1983; Shears, 2017; Blain and Shears, 2020). Small-scale canopy reduction of *Ecklonia radiata* due to herbivory – primarily amphipod (Haggitt and Babcock, 2003) and urchin grazing incursions as observed at Motuhoropapa south-east and Ōtata north-east sites is also likely a structuring factor at depth.

Ahaaha Rocks was the only site surveyed where there was a dense, and continuous expanse of *Ecklonia radiata* from mid depth out to the termination of rocky reef habitat at depth. This distributional pattern likely reflects the more exposed nature of this site, which has the potential to reduce sediment deposition and urchin grazing, both of which can limit kelp distribution. Finally, the deep depth strata at David Rocks was notable for the co-occurrence of *Ecklonia radiata* and *Perna canaliculus* at the lower limit of the reef margin. The extent of this association across the Noises Islands is unknown but is likely to occur elsewhere and warrants further investigation.

The 2017 habitat-distribution survey documented areas of high sessile invertebrate diversity, comprised by an assortment of sponges, ascidians, bryozoans, and anemones. Focal points included Ōtata Island (south-eastern and southern coastline), shallow regions of Maria Island (anemone dominated) and both shallow and deeper regions of the Ahaaha Rocks (*Perna canaliculus* dominated, anemone dominated) with the current survey supporting these earlier findings in a quantitative manner. Of particular note across multiple surveys has been the wide occurrence of large *Ecionemia alata* sponges present throughout the Noises Island group. This also extends to multiple areas of diverse erect and branching species and large swathes of the anemone *Anthothoe albocincta* and jewel anemone *Corynactis australis*. The importance of sessile invertebrate of communities to ecological function are similar to bivalves in terms of benthic-pelagic coupling through suspension feeding, as well as providing structure for recruiting organism and refuge from predation. Similarly, the spatial prevalence of anemone beds at the Noises Islands are undoubtedly important as food for some fishes (Russell, 1983), in tandem with augmenting habitat complexity, structure and rocky reef biodiversity.

Mobile invertebrates in this study were dominated by gastropods and echinoderms (primarily urchins). Densities of the dominant species were similar to nearby Rakino Island (Haggitt, 2020) and Auckland's sheltered east coast (north shore) (Grace, 1987; Walker, 1999; Shears, 2017) with clear association with depths and habitats. Collectively these animals play a crucial role in food-webs being a source of food for predatory fishes and benthic predators such as kōura/lobster (Freeman and Creese, 2011) and octopus. Equally they themselves rely on healthy macroalgal dominated environments for shelter and protection. As such, their abundance can be impacted greatly by macroalgae loss, which has undoubtably been the case at the Noises Islands. In addition, future comparisons between present-day gastropod diversity and size to those found in historic middens currently being analysed by Dr. Louise Fury – Auckland Museum may provide important insights into historical kaimoana selection and take.

The prevalence of expansive urchin-grazed barrens habitat along the eastern coastline of Motuhoropapa and Ōtata Islands, including other locations and corresponding high urchin abundances is a major feature of the Noises Islands subtidal landscape. There is some evidence to suggest that the urchin-grazed barrens habitat has extended into even shallower depths at Motuhoropapa since 2017 and the section of subtidal reef immediately adjacent Sunday Island (between Motuhoropapa and Ōtata Island TRH personal observation). The prevalence and potential persistence of urchin barrens habitat is symptomatic of an absence of large higher-order predators (snapper and lobster) that would naturally control urchin abundances (Shears and Babcock, 2002, 2003). In particular, kōura/lobster have been considered functionally extinct within the Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi for some time (Pinkerton, *et al.* 2015), i.e., koura/lobster biomass has been reduced to such an extent that it is no longer of trophic importance within the wider Gulf's marine food web. The exception to this being within the Hauraki Gulf Marine Park's three eminent marine reserves Cape Rodney to Okakari Point (Leigh), Tawharanui, and Te Whanganui-a-Hei (Hahei) (Haggitt *et al.* 2019; Haggitt 2020). Within these reserves, kōura/lobster and tāmure/snapper densities are currently sufficient to restrict urchin abundance and grazing, with the upshot being higher macroalgal abundance, biomass, and net primary productivity.

Ultimately, the prevalence of urchin-grazed barrens habitat signifies reduced primary productivity, diversity, altered food-web dynamics and reduction in biological structure. Collectively, these elements equate to reduced ecosystem function including resilience to various stressors e.g., climate driven oceanographic processes, wave action, sedimentation, pollution etc (see Graham *et al.* 2004). Persistent reduction of macroalgal habitat through time can also lead to a lack of reproductive source populations being able to provide adequate densities of spores for post-grazing or post-disturbance recruitment (Filbee-Dexter and Scheibling, 2014). Equally, the presence of coralline turf, which may increase macroalgal canopy regression in sediment-prone locations may further retard further macroalgal colonisation (Layton, *et al.* 2019).

At the time of writing, large-scale urchin removal experiments are being conducted by the University of Auckland (N.T. Shears, K. Miller) across the Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi, including the Noises Islands (Ōtata). It is hoped that the results of the study will provide insight into recovery rates and feasibility of such

measures. Notwithstanding, these efforts remain a poor surrogate for urchin control that would otherwise exist in a naturally functioning ecosystem, whereby larger predators naturally carry out this role. An additional University of Auckland study led by Dr. Catlin Blain is seeking to empirically measure differences in primary productivity between urchin barens and macroalgal dominated habitats. Such data will be useful in reconstructing the "historic value" of macroalgal habitats lost through grazing through a productivity lens as well as informing the merits of macroalgae restoration efforts taking place at the Noises Islands.

The diverse range of shallow-water habitats across the Noises Islands group was also a notable finding of this baseline study. Of these, kūtai/green-lipped mussel beds are of high ecological significance due to their prevalent spatial coverage (intertidal/subtidal) and size and density. Examples of intact subtidal beds were evident at David Rocks, Maria Island, and the Ahaaha Rocks: however, there has been increased concern by the Neureuter family over the loss of kūtai/green-lipped mussel habitat across the Islands in recent years – primarily due to harvesting. Indeed, there has been a notable decrease in intertidal and subtidal kūtai/green-lipped mussel extent at Ōtata (south-western and northern coast), Sunday Island and Motuhoropapa Islands (eastern coast) since 2017 (personal observation). This is of some concern given the significant ecological role mussels play in terms of nutrient cycling, provision of biogenic structure, fisheries enhancement and as a food source amongst others (Morrison *et al.* 2014).

In spite of localised declines of mussels at Ōtata and Motuhoropapa the current intact nature of mussel habitat at other locations throughout the Noises should be upheld as very significant when placed in the context of the large-scale, resource intensive, mussel restoration initiatives taking place across the Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi (reviveourgulf.org.nz). In essence, these initiatives have used aquaculture-based source populations to investigate the merits of kūtai/green-lipped mussel restoration. While such initiatives are of immense value, it must be stressed that the provision for the protection of existing wild stocks is left severely wanting. As such, the safeguarding of these remnant stocks that are an undoubtedly important source of genetic heterogeneity and supply of spat should be seen as an upmost priority within the Gulf. Of equal importance is the need to spatially map and monitor demographic changes in both intertidal and mussel beds at the Noises through space and time given they can be impacted by sedimentation and changes in oceanographic climate e.g., periods of hot/dry weather (intertidal) or algal blooms etc aside from harvesting. Data of this nature will help better identify any changes including rates of change and potential causes of change. Equally similar efforts should be placed into quantifying blue mussel (*Mytilus edulis*) and pāua abundance, which to date have not been collected with any degree of rigour.

A notable finding from the study, albeit synonymous with degradation, was the high percent cover of fine sediment across survey sites particularly at depth. Fine sediment, which is primarily derived from land-based activities such as farming, forestry, and urban development, is considered to be the third largest threat to the Hauraki Gulf's marine flora and fauna behind climate change and ocean acidification (Hauraki Gulf Forum, 2020). Subsequent impacts that relate to elevated sediment and suspended sediment concentrations within the marine environment – some of which have been evident at the

Noises Islands – include increased turbidity (Seers and Shears, 2015), reduced macroalgal photosynthetic ability (Blain, *et al.* 2020 – discussed above), direct smothering and scour, and reduced filtering efficacy of suspension feeders such as sponges and bivalves (Airoldi, 2003).

Common effects for sessile invertebrate communities associated with persistent sediment exposure are primarily relate to reduced feeding, condition (health) and reproduction (Roberts, *et al.* 1998), with long-term exposure resulting in reduced diversity and pronounced shifts from mature and stable communities to unstable and less-diverse communities through time (Carballo, 2006). However, there is also evidence in the ecological literature to suggest that some sponge species can tolerate long-term exposure to high suspended sediment concentration (Cummings *et al.* 2020). Again, the lack of any monitoring precludes our ability to comment on rates of change through space and time attributable to sediment, but the very high percent cover of fine sediment at some sites suggests this is a major issue and is of on-going concern.

It is not only rocky reef habitats and species that have been in decline or exhibited signs of degradation at the Noises Islands with soft sediment species such as tipa/scallops and hururoa/horse mussels also described as "being shadows of their former high abundance" by the Neureuter family. The Neureuter's describe the use of dredges that can impact species distributions and seafloor structure dramatically as frequent in this area of the Noises Islands group. This survey was the first to quantify tipa/scallop and hururoa/horse mussel abundance along the south-western coastline of Ōtata Island. Current densities of both are very low and in the case of tipa/scallops only 31 legal-sized individuals were encountered over 1 km^2 of seabed surveyed. The tipa/scallop data collected here will be placed into the context of the wider Hauraki Gulf Marine Park by Dr. James Williams (NIWA), who is in the process of completing a status update of both commercial and recreational beds throughout the Gulf. In addition, there is current discussion around governmental bans on the use of recreational dredges within the Gulf that can only be seen as a positive outcome for soft-sediment benthic habitats.

Dr. William's study is timely given that the wider status of tipa/scallop densities and habitats in the Hauraki Gulf/Tikapa Moana/Te Moananui ā Toi is currently unknown, albeit there has been concern around declining densities and bed size across the Hauraki Gulf/ Tikapa Moana/Te Moananui ā Toi for some time. Due in part to government inaction over this issue rahui's on tipa/scallop harvest have been placed at Opito Bay – Coromandel (Nāgti Hei) and Waiheke Island (Ngāti pāoa). Of equal concern due to their ecological significance is the large number of dead – hururoa/horse mussels quantified by the survey. While causes of hururoa/horse mussel mortality remain unknown, potential sources include fishing induced damage, i.e., by dredges, sedimentation, water quality, and toxic algal blooms such as *Ostreopsis siemensis* (as observed by the Neureuter's in 2019). Further surveys of the soft sediment habitats off Ōtata Island will build on the findings of this incipient study and allow for some of these aspects to be explored further. Additional sampling of soft-sediment habitats across the Noises Islands group to identify the presence and health of horse mussel beds is also warranted. Focal areas to target as a starting point include the Ahaaha Rocks, David Rocks, and stretch of seabed between Maria Island and the Ahaaha Rocks.

BIOGENIC HABITATS

Where dense aggregations of a species occur, a three-dimensional living habitat is created. These biogenic habitats provide shelter, protection, and food for other species, increasing biodiversity and helping to stabilise marine ecosystems. Biogenic habitats are under threat by bottom fishing methods, pollution, increased sediment loads, global warming, and ocean acidification. Loss of these habitats will cause a decrease in biodiversity, degradation of our waterways, erosion, ecosystem changes, ecosystem collapse, and loss of resources. There are four biogenic habitats surrounding Rakino Island. Macroalgae; Sponge gardens; Horse mussel beds and Dog cockle beds.

SPONGE GARDENS

Sponges are found all around New Zealand coastlines from the shallow intertidal zones, beyond the kelp forests and down into the Abyss. Sponges are asymmetrical and come in many different shapes and forms. These structures provide micro-habitats for marine animals and bacteria to live on and are a food source to some marine species. Sponges are suspension feeders filtering the water and removing nitrogen and organic particles, including viral particles, and play an important role in the carbon flow of the surrounding water to the benthos.

Sponge gardens have a high aesthetic value for marine tourism and the chemicals in sponges are important in biochemistry research.   Threats to sponges include bottom fishing activities such as dredging and bottom trawling, increased suspended sediment and sedimentation, ocean acidification and global warming.

MACRO ALGAE

Algae are primary producers and are an important source of food for many marine species. Their structures provide habitat and refuge for a vast number of other plants and animals and are important nursery grounds for fish. They can act as a buffer against wave action and lessen strong bottom currents. Beach cast seaweed can provide additional food sources for marine invertebrates and birds. Through photosynthesis they remove carbon dioxide from surrounding water, as well as long term sequestering of carbon to the deep sea. Main threats to macroalgal habitat include increased sedimentation causing turbidity in the water, which reduces the algae's ability to photosynthesise, pollution, invasive species, and global warming.

HORSE MUSSEL Beds

The valves (shells) of horse mussels protrude from the soft sediment modifying the seabed and creating biogenic habitats for other marine organisms to grow on or to find shelter amongst, thereby increasing the biodiversity of the area. The filter feeding mechanisms of mussels clarify the water by removing organic matter from the surrounding sea. They also modify the flow of water over the beds and stabilise the sediment. Their shells can also accumulate and sequester carbon. Bottom fishing activities such as dredging and bottom trawling destroys shellfish beds and has greatly reduced existing horse mussel populations. Other threats include increased suspended sediment and sedimentation, pollution, ocean acidification and global warming.
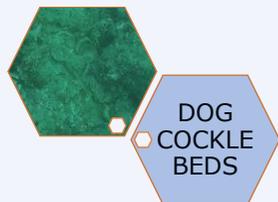
DOG COCKLE BEDS

Dog cockles turn the soft sediment as they move and create sediment stability. Dog cockle habitats also include a multitude of their empty shells after they die. These thick shells remain for many years providing a multilayered surface for colonising invertebrates such as bryzoans, erect sea sponges and other species to grow on. As filter feeders they increase the water clarity of the surrounding waters by removing suspended organic matter and nutrients.

Threats to dog cockles beds include pollution, increased suspended sediments, sedimentation and ocean acidificaiton. Also, bottom fishing activities, such as dredging and trawling would impact on the habitats created by the dead shells.

Reef-fish abundance and diversity match surveys done in 2017 (Appendix 4) and equivalent surveys done at Rakino Island (2020), Waiheke Island (2016) and Long Bay (Haggitt and Shears, 2011; Haggitt, 2016). While both the 2017 and 2021 survey identified few legal-sized snapper, additional legal-sized individuals were observed outside of sample transects around Ōtata Island, and the Ahaahas along with low density schools of kingfish and kahawai. To provide further information on snapper densities across the Noises Island group future surveys should incorporate Baited Underwater Video (BUV) techniques (Willis *et al.* 2000). Parsons *et al.* (2014) provide a detailed overview of snapper demography and vulnerabilities, many of these are pertinent to the Noises Islands.

4.2   Where to from here?

The use of the baseline quantitative data obtained here is multifaceted and is intended to provide information from a certain time and place while acting as a scaffold from which further initiatives can be established that have the *net result* of improved environmental understanding and conservation-related outcomes.

Marine protection

Based on: 1)the low overall density and lack of legal-sized kōura/lobster, 2) low densities of legal-sized reef-fish; 3) low density of tipa/scallops; 4) recent evidence of significant mussel harvest (anecdotally observed); and 5) extensive urchin grazed barrens habitat, all collectively point to the need for protective measures to be established around the Noises Islands group to help stem further declines. The framework for protection while presently undecided needs to be based on an ecosystems approach that recognises Island to sea linkages and places iwi-led aspirations on an equal footing as other stakeholders. Current legislation is not fit for purpose to achieve these goals.

While present-day reef fish abundance, size and diversity portrays an impacted system, the array of biogenic habitats, coupled with the existing geological and hydrodynamic settings, unequivocally point to a system that can recover substantially if given the chance - even more so if the area to be protected is large (> 50 km^2).

From a global perspective, we understand that for marine protected areas to be effective and meet basic conservation outcomes they require five attributes: 1) be no-take; 2) be old; 3) be large; 4) have outer boundaries terminating in either deep-water or sand and, 5) be well enforced (Edgar *et al.* 2014). A draft Marine Protected Area was put forward as part of the Sea Change Process and has been developed further by Associate Professor N.T. Shears (University of Auckland) that equates to approximately 70km^2. The proposed 70km^2 area contains large areas of soft sediment habitat that would profit from further biological mapping and sampling.

In terms of aligning mana whenua/moana knowledge and thought processes around concepts of no-take marine protection, recent discussions with iwi have highlighted the

paradox of how excluding the human dimension from harvesting in-effect stimies knowledge flow needed to inform Mātauranga Māori and maramataka itself. The author is sympathetic to this viewpoint. Albeit there is enormous scope to build cultural knowledge into the wider Noises kaupapa around regeneration, restoration, and protection. Key starting points could include Mātauranga Māori.

- Establish indicators of change that have cultural meaning and significance – tohu of change.
- Use tohu of change to develop iwi led monitoring protocols and practice for restoration and protection opportunities that inform maramataka and
- Provide support for rangitahi experiences that can integrate into the wider Noises restoration and protection kaupapa
- Maintain constant dialogue that builds on the sharing of traditional knowledge and science around concepts of resource protection and use as initiatives develop.

Should some level of agreed protection be achieved, then increases in habitats and species that would inviably occur can be viewed through a cultural lens simultaneously alongside science. This equality and duality of knowledge has the potential to be transformative for the Noises Islands and wider Hauraki Gulf/ Tikapa Moana/Te Moananui ā Toi.

Some of the above concepts have started to be explored with the Auckland Museum's excavation of a predominant midden along the south-western coastline of Ōtata that will shed light on historical kaimoana species. Mahi is also being done with Tāmaki Makaurau rangitahi around kina barrens cause and effect using experiential learning opportunities.

Restoration

In tandem with protection of the Noises Islands group there is enormous scope for restoration initiatives spanning rocky reef and soft sediment benthic habitats. Focal species such as tipa/scallops, hururoa/horse mussels, kūtai/green-lipped mussel through to seaweed regeneration (currently being explored) all warrant investigation.

Ongoing monitoring and education opportunities

Baseline data has now been collected for intertidal and subtidal areas of the Noises Islands group with the Auckland Museum expressing a desire to establish terrestrial and marine monitoring initiatives that span the next 50 years. This has an overarching focusing on building a marine and terrestrial biodiversity dataset for the Noises, with nearby locations such as Rakino Island that have been surveyed in the same way acting as comparative sites. The sampling techniques presented in this survey will be integrated into the Auckland Museum monitoring plan. There is always further scope for additional marine-based monitoring across the Noises Island Groups. This may be as simple as increasing the number of sampling sites thereby increasing spatial resolution, incorporating techniques such as Baited Underwater Video (BUV) to compliment UVC fish sampling, through to water quality and climate monitoring. Finally, developing multi-layered education tools that enable participants to contribute, learn and experience

the Noises Islands ecology will be a core priority in the near future. It is anticipated that both monitoring and education elements when used in concert, will support the Neureuter's aspirations for the Noises to become a model to inspire further conservation initiatives.

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Appendix One

Table A1.1 Site locations, Noises Island group – Autumn 2021 survey.

Site	Type	Latitude	Longitude
Motuhoropapa NE	Rocky reef	36°41'14.97"S	174°57'54.01"E
Motuhoropapa SE	Rocky reef	36°41'23.58"S	174°57'56.73"E
Ōtata NE	Rocky reef	36°41'34.28"S	174°58'26.07"E
Ōtata SE	Rocky reef	36°41'37.94"S	174°58'41.91"E
David Rocks	Rocky reef	36°41'53.47"S	174°59'49.28"E
Ahaaha Rocks	Rocky reef	36°41'24.81"S	175° 1'27.16"E
Maria Island	Rocky reef	36°42'30.32"S	175° 0'22.90"E
Orarapa Island	Rocky reef	36°41'52.30"S	174°57'17.45"E
Ōtata SW1	Soft sediment	36°41'56.39"S	174°58'11.50"E
Ōtata SW2	Soft sediment	36°41'49.17"S	174°58'5.30"E
Ōtata SW3	Soft sediment	36°41'46.04"S	174°57'52.21"E
Ōtata SW4	Soft sediment	36°41'52.87"S	174°57'57.56"E

Appendix Two

A2.1 Macroalgae

Table A2.1 Results from PERMANOVA for two dominant macroalgal species across eight sites – Noises Islands, Autumn 2021. Analysis was run on log (x+1) transformed data using a Euclidean distance measure. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Ecklonia radiata- biomass

Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	29.008	4.144	8.9827	***0.0002***
Depth	3	9.2516	3.0839	6.6846	***0.0018***
Si x De	10	12.444	1.2444	2.6975	***0.0132***
Res	48	22.144	0.46134		
Total	68	78.707			

Carpophyllum flexuosum - biomass

Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	24.556	3.5079	10.943	*0.0002*
Depth	3	1.3943	0.46475	1.4498	*0.235*
Si x De	10	14.32	1.432	4.4674	*0.0014*
Res	48	15.387	0.32056		
Total	62	55.042			

A2.2   Gastropods

Table A2.2 Results from PERMANOVA for dominant gastropod species across eight sites – Results from PERMANOVA for dominant macroalgal species across eight sites – Noises Islands, Autumn 2021. Analysis was run on log (x+1) transformed data using a Euclidean distance measure. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Lunella smaragdus: - abundance

Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	8.2874	1.1839	14.252	***0.0002***
Depth	2	74.748	37.374	449.9	***0.0002***
Si x De	13	14.79	1.1377	13.695	***0.0002***
Res	46	3.8213	0.083072		
Total	68	102.99			

Cookia sulcata: - abundance

Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	14.815	2.1165	5.1699	***0.0006***
Depth	2	7.5207	3.7604	9.1855	***0.0008***
Si x De	13	11.962	0.92016	2.2477	***0.0216***
Res	46	18.832	0.40938		
Total	68	53.737			

Trochus viridis: - abundance

Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	16.646	2.378	5.541	***0.0002***
Depth	2	32.627	16.314	38.013	***0.0002***
Si x De	13	22.832	1.7563	4.0924	***0.0006***
Res	46	19.741	0.42916		
Total	68	91.629			

Cantharidus purpureus: - abundance

Source	df	SS	MS	Pseudo-F	P(perm)
Site	7	20.334	2.9049	8.4319	***0.0002***
Depth	2	30.604	15.302	44.417	***0.0002***
Si x De	13	48.524	3.7326	10.835	***0.0002***
Res	46	15.847	0.34451		
Total	68	111.16			

Table A2.3 Results from PERMANOVA pairwise comparisons for reef-fish community composition across eight sites – Results from PERMANOVA for dominant macroalgal species across eight sites – Noises Islands, Autumn 2021. Analysis was run on log (x+1) transformed data using a Euclidean distance measure. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Site	t	P(Perm)
Motu NE, Motu SE	1.1825	0.2242
Motu NE, Ōtata NE	0.89359	0.5704
Motu NE, Ōtata SE	0.79571	0.6182
Motu NE, David Rocks	1.4933	***0.0482***
Motu NE, Maria Island	1.8222	***0.0258***
Motu NE, Ahaaha Rocks	2.9428	***0.0006***
Motu SE, Ōtata NE	1.1217	0.2794
Motu SE, David Rocks	0.89304	0.6232
Motu SE, Ahaaha Rocks	2.1652	***0.0002***
Ōtata NE, Ōtata SE	1.0365	0.3798
Ōtata NE, Maria Island	1.7424	***0.0084***
Ōtata NE, Ahaaha Rocks	2.6909	***0.0004***
Ōtata NE, Orarapa	2.3014	***0.0002***
Ōtata SE, David Rocks	0.83554	0.682
Ōtata SE, Maria Island	0.89101	0.5044
David Rocks, Maria Island	1.1276	0.28
David Rocks, Orarapa	1.5857	***0.0138***
Maria Island, Ahaaha Rocks	3.0753	***0.0002***
Maria Island, Orarapa	1.9004	***0.0204***
Ahaaha Rocks, Orarapa	2.9908	***0.0038***

Appendix Three

Macroalgae

Table A3.1 Presence (+) and absence (blank) of dominant macroalgal taxa within sample quadrats across eight sites Noises Islands group, Autumn 2021.

Taxa	M-NE	M-SE	O-NE	O-SE	DR	AA	MI	OI
Ecklonia radiata	+	+	+	+	+	+	+	+
Carpophyllum maschalocarpum	+	+	+	+			+	
Carpophyllum plumosum								+
Carpophyllum flexuosum	+	+	+	+	+	+	+	+
Sargassum sinclairii		+	+					+
Cystophora torulosa	+				+			
Xiphophora chondrophylla			+	+			+	+
Colpomenia sinuosa	+	+						+
Halopteris spp.		+						
Zonaria turneriana		+	+		+	+		
Dictyota sp.	+		+	+		+	+	
Carpomitra costata		+		+			+	
Ralfsia sp.		+						
Osmundaria colensoi	+	+						
Melanthalia abscissa			+					
Pterocladia lucida	+	+	+	+			+	+
Pterocladia capillacea		+	+					
Champia sp.		+	+				+	
Curdiea coriacea		+						
Asparagopsis sp			+	+			+	
Coralline turf/Articulated coralline	+	+	+	+	+	+	+	+
Codium convolutum	+	+						
Crustose coralline algae	+	+	+	+	+	+	+	+
Brown turfing algae		+						+
Brown crust forming algae						+		+
Gelidium spp			+					
Red turfing algae	+	+						
Rhodymenia novaehollandica		+		+			+	
Sporolithon durum							+	

Note: Macroalgal quantification as above was targeted at abundant species. To quantify additional macroalgal biodiversity spring surveys would be required to ensure annual species are also encapsulated within the dataset.

Table A3.2 Presence of intertidal macroalgae (Wilcox, 2008).

Species	Enviro
Apophlaea sinclairii	Intertidal – high, shade and sheltered
Capreolia implex	Intertidal – high, shade and sheltered
Carpophyllum maschalocarpum	Intertidal – sublittoral fringe of N. Ōtata Is.
Caulacanthus ustulatus	Intertidal – low tide turf
Corallina officinalis	Intertidal – shallows
Cystophora torulosa	Intertidal – sheltered
Derbesia novae-zelandiae	Intertidal – pools
Dictyota kunthii	Intertidal – Ōtata Is.
Gelidium caulacantheum	Intertidal
Hormosira banksii	Sparse
Laurencia thyrsifera	Intertidal
Liagora harveyana	Intertidal – shallows esp NE of Scott Is.
Pterocladia lucida	Intertidal – Ōtata Is.
Pterocladia capillacea	Intertidal – low tide turf
Sporolithon durum	Probably see Seaweeds of Auckland
Xiphophora chondrophylla	Intertidal – Ōtata & Scott Is.
Jania rosea	Intertidal – pools
Asparagopsis armata	Intertidal – low
Rhodymenia novaehollandica	Intertidal – pools and channels
Champia novae-zelandiae	Intertidal – upper
Splachnidium rugosum	Intertidal – rock

Sessile Invertebrates

Table A3.3 Presence (+) and absence (blank) of sessile invertebrate taxa within sample quadrats across eight sites Noises Islands group, Autumn 2021.

Taxa	M-NE	M-SE	O-NE	O-SE	DR	AA	MI	OI
Tethya burtoni	+		+		+	+	+	
Tethya bergquistae		+					+	
Aaptos globosum	+		+			+	+	
Ecionemia alata	+	+	+	+	+	+		
Cliona celata	+	+	+	+	+	+	+	+
Crella incrustans		+	+		+			
Psammocinia sp1	+			+		+	+	
Psammocinia sp2			+					
Polysmastia spp		+		+		+		
Ciocalypta polymastia		+	+	+		+		+
Clathria rubens		+		+	+			
Tedania sp			+	+				+
Plakina monolopha	+	+	+	+				
Raspailia topsenti	+	+				+		
Geodia regina							+	
Biemna rufescens					+			
Tetrapocillon novaezealandiae	+				+		+	+
Callyspongia ramosa			+	+				+
Darwinella oxeata		+						+
Stelletta crater	+					+		
Stelletta maori						+		
Hymeniacidon hauraki						+	+	
Cnemidocarpa bicornuta	+	+	+	+	+	+	+	+
Asterocarpa coerulea	+	+	+	+	+	+	+	+
Aplidium sp.		+	+		+			
Halchondria moorei			+	+	+			
Psuedodistoma aureum	+							
Didemnum species		+		+	+			+
Hypsistozoa fasmeriana						+		
Aglaophenia laxa		+				+		
Sertularia marginata			+					
Alcyonium sp.						+		
Monomyces rubrum	+	+	+	+	+		+	
Culicia rubeola			+	+	+		+	
Anthithoe albocincta		+	+	+	+	+	+	
Corynactis australis			+	+		+	+	
Hornera sp.		+				+		
Parasmittina delicatula		+	+	+			+	
Ostrea chilensis	+	+					+	
Spiorbid tube worms	+	+	+	+		+		
Perna canaliculus		+			+	+	+	+
Epopella plicata	+	+						

Note: Hydrozoa associated with vertical rocky canyons and high current areas have been observed and would profit from further examination. Due to the high percent cover of sediment on rocky reef habitat, the occurrence of encrusting species (sponges, ascidians, bryozoa) are likely to be underrepresented.

Mobile invertebrates (mollusc and echinoderm)

Table A3.4 Presence (+) and absence (blank) of mollusc and echinoderm taxa within sample quadrats across eight sites Noises Islands group, Autumn 2021.

Taxa	M-NE	M-SE	O-NE	O-SE	DR	AA	MI	OI
Lunella smaragdus	+	+		+	+		+	+
Cookia sulcata	+	+	+	+	+	+	+	+
Trochus viridis	+	+	+	+	+	+	+	+
Cantharidus purpureus	+	+	+	+	+	+	+	+
Calliostoma punctulatum	+					+		+
Buccinulum linea	+	+	+	+		+		
Cellana stellifera		+	+		+			
Haliotis iris			+					
Haliotis australis			+					
Xymene ambiguus	+		+	+	+	+	+	
Ranella australasia australasia					+			
Cominella quoyana	+		+	+				+
Maoricolpus roseus	+		+		+			
Cabestana spengleri								
Dicathais orbita	+	+	+	+		+		+
Penion sulcatus	+		+	+				
Scutus breviculus		+						
Cryptoconchus porosus	+	+		+	+	+		
Stichopus mollis	+	+		+	+			
Patiriella regularis					+			
Amblypneustes elevatus	+		+	+		+		
Evechinus chloroticus	+	+	+	+	+	+	+	+
Ostrea chilensis	+	+					+	

Note: In addition to the above species the following mobile species have been observed at the Noises – yellow-foot pāua (*Halotiis iris*); virgin pāua *Haliotus viriginia* green chitin (*Chiton glaucus*); noble chiton (*Eudoxochiton nobilis*); chiton (*Notoplax violacea*); octagonal murex (*Muricopsis octogonus*); clown nudibranch (*Ceratosoma amonenum*); nudibranch (*Drendodoris denisoni*);

Appendix Four

Reef fish
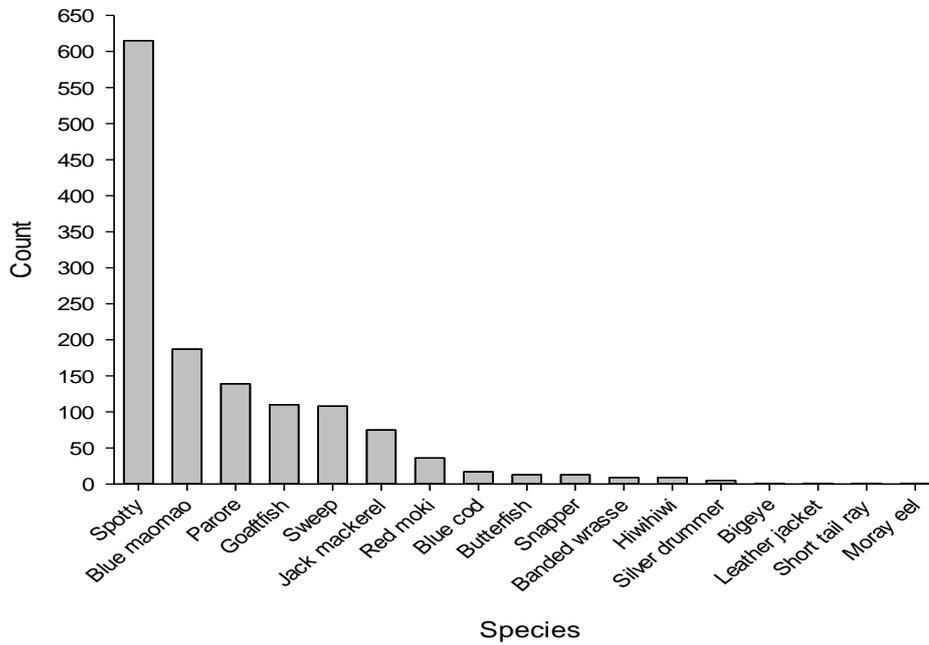
Figure A4.1. Count of reef fish (17 species). Data are pooled across sample transects for 8 sites - Noises Island group, October 2017.
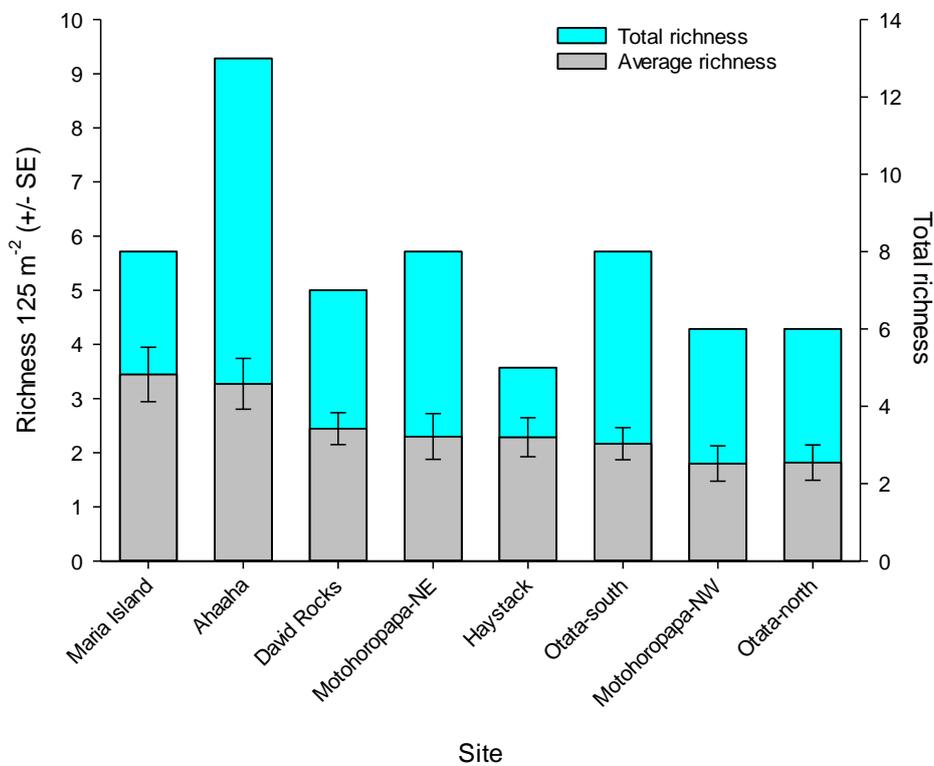

Figure A4.2. Average reef fish richness and total # of species (richness) enumerated at 8 sites across the Noises Island group, October 2017.
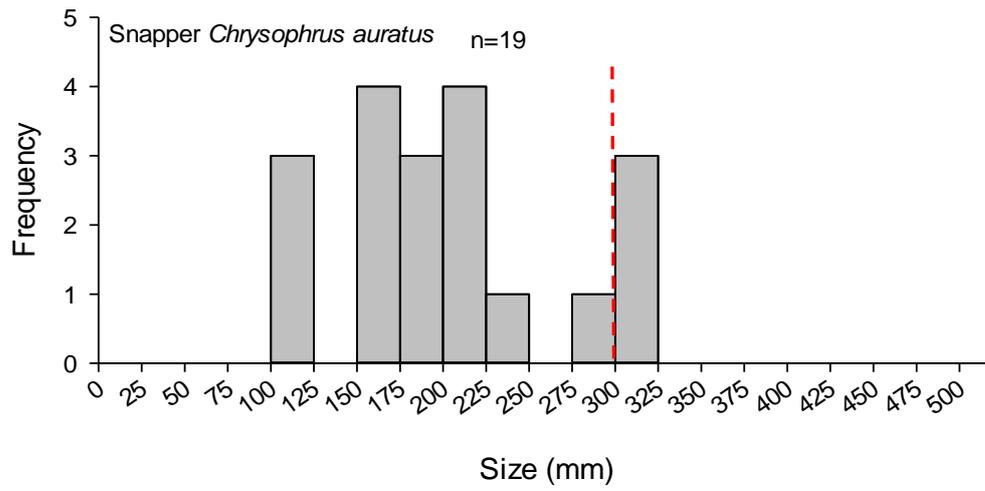
Figure A4.3. Size frequency of snapper *Chrysophrus auratus* based on fork length recorded at Ahaaha Rocks – Noises Island group, October 2017. Vertical dashed line denotes division between sub-legal and legal-sized individuals.