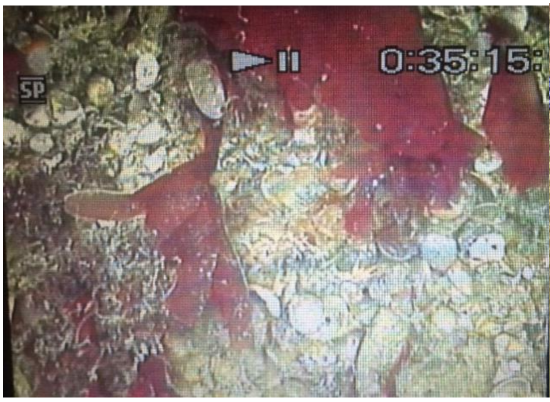
Ecological survey of Waiheke Island north-west coastline – December 2016



Prepared for Auckland Council and Hauraki Gulf Conservation Trust

by

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and Hauraki Gulf Conservation Trust
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Tim Haggitt (PhD)

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Executive Summary

The report details the results of quantitative benthic rocky reef sampling, reef fish sampling, and qualitative soft sediment sampling undertaken within the north-western coastline of Waiheke Island in December 2016. The aim of the sampling was to obtain baseline data that could be used in support of no-take marine reserves along this section of the Waiheke Island coastline. The survey followed on from a desk-top gaps analysis study that evaluated five potential marine reserves (PMRs) for Waiheke Island. Of these, three were proposed along the north-western coastline PMR-1 (2,519.1 ha); PMR-4 (23.3 ha); and, PMR 4A (170.3 ha). A further 2 marine reserves, PMR-2 (1,048.6 ha); and, PMR-3 (123.06 ha) were proposed along the southern coastline west of the existing Te Matuku Marine Reserve (690 ha). It is anticipated that these proposed no-take marine reserves would form a reserve network for Waiheke Island and argument conservation benefits for the inner Hauraki Gulf. From the gaps analysis study it was recommended that while all reserves had some conservation merit, further data gathering was necessary in order to better document and understand the habitats and species within the proposed reserves. Extensions to proposed reserves 2, 4, and 4A were also recommended.

Acting on the outcomes from the gaps analysis, a first-order subtidal ecological survey of the north-western region of the Waiheke coastline within PMRs 1, 4, and 4A in December 2017.

Main findings from the survey were:

- A diverse array of biogenic habitats represented by macroalgae; sponge and sessile invertebrate communities; and, patchily distributed bivalve beds (primarily associated with soft sediment habitat) were present within the survey area;

- Subtidal rocky reef habitat between Matiatia Bay and Hakaimango Point was predominantly macroalgal dominated, with macroalgal diversity particularly high east of Owhanake Bay > 8m depth;

- Urchin barrens habitat was negligible between Matiatia Bay and Hakaimango Point; although this habitat type increased in spatial extent within and east of Enclosure Bay.

- Sessile invertebrate diversity (sponges and ascidians) was moderate-to-high across the survey area, with species occupying the deepest depth strata surveyed (> 10 m depth) morphologically complex.

- Reef fish biodiversity was low, but consistent with assemblage compositions recorded for the inner-Hauraki Gulf elsewhere (e.g., Long Bay). Commonly targeted species such as snapper (legal and sub-legal individuals), kahawai, and kingfish were observed during the survey.

- Despite complex high quality rocky reef habitat being present at all sites surveyed, no spiny rock lobster (*Jasus edwardsii*) were recorded.

- Soft sediment habitat as surveyed by remote video ranged in type and spatial extent across the survey area. Habitats typified by coarse sediment, shell hash, and whole shell were common immediately adjacent subtidal rocky reef habitat and in the main

channel area west of Matiatia Bay and Owhanake Bay. Of these habitats coarse shell and whole shell habitats were typically associated with diverse encrusting communities, e.g., sponges and red algae. Patchily distributed low-density bivalves beds were associated with coarser sand and shell hash material; whereas, the scallop (*Pecten novaezelandiae*) was common in sandy substrates offshore from Matiatia Bay, and Hakaimango Point with sandy habitats also characterised by shrimp/worm/crab holes indicative of abundant infaunal communities.

- Collectively, the northern-western and wider northern coastline of Waiheke Island contains high-quality subtidal rocky reef and soft-sediment benthic habitats.

- Given the diverse array of physical and biological habitats within the surveyed area PMR1 would be beneficial as a no take marine reserve given its size. Furthermore, the extension of the offshore boundary out to the Noises Islands for this proposed reserve should also be considered.

- For proposed marine reserves 4 and 4A due to their large boundary relative to area, extending the eastern boundary of 4A further offshore and east to Thompsons Point would be of value. This would increase their functionality in terms of protecting larger more-mobile species and additional biogenic sponge habitat as identified in other surveys. Should boundaries remain as proposed then protection would be focused on habitat protection, e.g., macroalgal beds and sessile invertebrate communities.

While analogous biological surveys have not been done for the proposed reserves on the southern coastline of Waiheke Island (PMRs 2 and 3), based on the recommendations of the gaps analysis it is likely that protection related effects for PMR-2 would be similar to Te Matuku marine reserve. For PMR 3 (123.06 ha located within Anzac Bay), while the size of the reserve is unlikely to protect large mobile fish species, the protection of bivalve beds (cockles and pipi) and intertidal seagrass habitat (important as nursery habitat for fishes) would have certain conservation merit. Again, collection of baseline data would be of value for these two southern-coast marine reserves to formally evaluate the diversity and abundance of species and document the variety of habitats and ecotones present. Surveys of these PMRs could be done via local community groups and citizen science projects collectively with Waiheke Island High School and paralleling the monitoring that is done within Te Matuku Marine Reserve.

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1.0 Introduction

1.1 Preamble

In September 2016, a desktop gaps analysis and feasibility study that evaluated five proposed Type-1[1] marine reserves (PMRs) for Waiheke Island (Figure 1.1) was undertaken (Haggitt 2016). The analysis was largely based on summary ecological datasets available through Seasketch (2016), unpublished Auckland Council remote sensing data, together with a wide range of technical reports and scientific studies that contained relevant ecological information. For all proposed marine reserves, broad-scale data were available for dominant physical and biological habitats; however, there was very little accompanying quantitative data Specific information/data gaps identified included:

1. Absence of quantitative data on the abundance and biomass of dominant species within intertidal and subtidal rocky reef habitats (macroalgae, mussels, mobile and sessile invertebrates and reef fish), including overall community composition.

2. Lack of information on species (shellfish, fin-fish) being harvested within proposed areas (particularly PMRs 2 and 3) and types of harvesting carried out. This is ultimately critical to predicting the potential ecological value of a marine reserve.

3. Absence of quantitative data on the abundance and biomass of dominant species within intertidal and subtidal soft sediment habitat (epifauna and infauna) including overall community composition.

4. Lack of understanding on larval dispersal and connectivity between proposed reserves.

5. Paucity of environmental monitoring data for the Waiheke Island coastline.

6. Lack of information on sedimentation-related effects (direct and indirect) including effects of other stressors, pollution, and invasive species incursions etc.

For all proposed marine reserves evaluated it was recommended that focused quantitative first-order subtidal ecological sampling should be done to bridge information gaps pertaining to species occurrence and habitat distributions within each PMR. Of the five proposed marine reserves, PMR 1 and PMRs 4 and 4A combined (northern-western coastline) (Figure 1.1) were deemed as being of highest priority, in so far as obtaining baseline quantitative ecological information. Following, a meeting with Auckland Council and members of the Hauraki Gulf Conservation Trust on 30 November 2016 it was decided that the area of coastline encompassing PMR 1 and PMR4 and 4A especially areas of rocky reef between Matiatia Bay and Enclosure Bay would be of value to survey using a combined quantitative and qualitative approach.

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[1] Type-1 Marine Reserves are the highest level of marine protection established under the Marine Reserves Act 1971. The main aim of a marine reserve is to create an area free from alterations to marine habitats and life, providing a useful comparison for scientists to study. Marine reserves may be established in areas that contain underwater scenery, natural features, or marine life of such distinctive quality, or so typical, beautiful or unique that their continued preservation is in the national interest (www.doc.govt.nz).

1.2 Biological Assessment

This report details the main findings of a subtidal biological assessment focused on obtaining baseline subtidal ecological information along parts of the north-western coastline of Waiheke Island. The specific aims of the survey were to: 1) quantify the size and abundance of dominant rocky reef organisms (macroalgae, mobile and sessile invertebrates) and reef-fish; and, 2) evaluate qualitatively the nature of soft-sediment physical and biological habitat types. Information collected will be used to evaluate the potential of the area as a no-take marine reserve for this section of the Waiheke Island coastline.

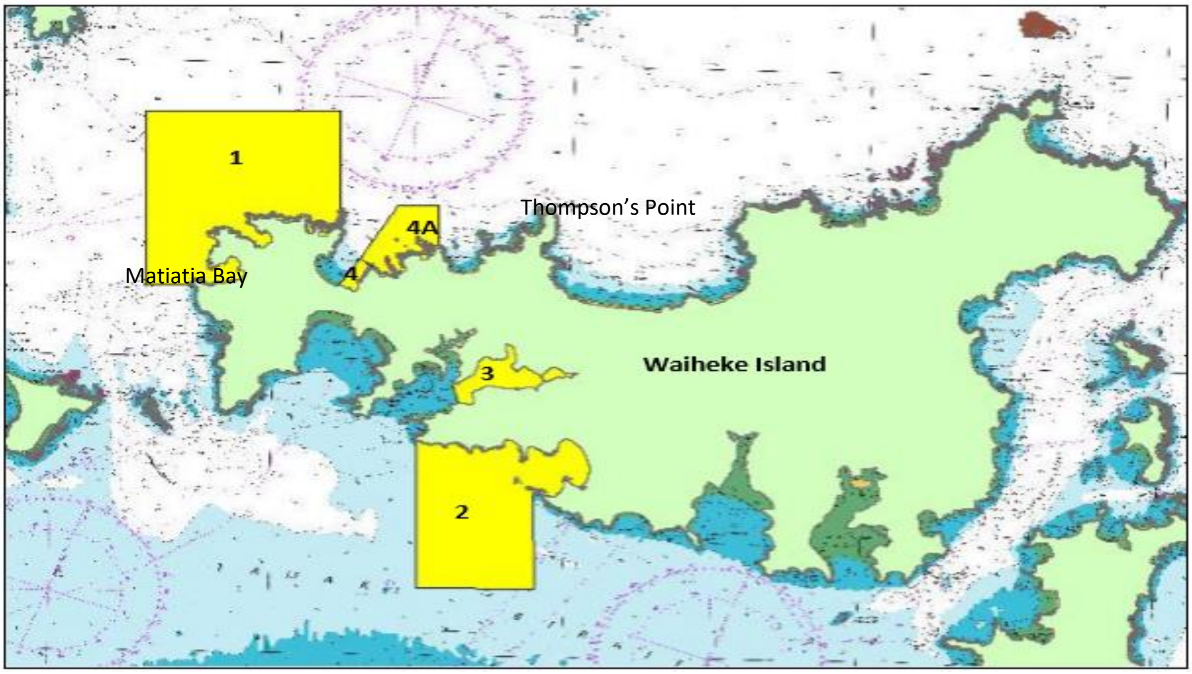

Figure 1.1 Proposed marine reserves for Waiheke Island 1-4A.

2.0 Methodology

The following survey methodology pertains to subtidal rocky reef and soft sediment sampling undertaking between 1-5 December 2016. Key aspects included depth-stratified benthic sampling and reef-fish sampling using SCUBA; and, the evaluation of soft sediment (physical and biological) habitats based on remote video sampling.

2.1 Rocky reef benthic sampling

To quantify dominant macroalgae and sessile and mobile invertebrates depth-stratified sampling was undertaken at 3 sites (Fig. 2.1) following the general sampling methods/protocols of Shears and Babcock (2007). The three sites surveyed were: Site 1 Owhanake Bay-east; Site 2 Hakaimango Bay/Point; and Site 3 an area of rocky reef habitat offshore from Enclosure Bay (Enclosure Bay-outer). Within each site, 3 depth strata were sampled classified as shallow (1-3m depth); mid-depth (5-8 m depth); and, deep (> 10m depth).

Figure 2.1. Three rocky reef and reef fish sampling sites along the north-western Waiheke Island coastline. Site 1 Owhanake Bay-east; Site 2 Hakaimango Bay/Point; and Site 3 Enclosure Bay-outer. Shaded region denotes area in which remote video transects were sampled to evaluate soft sediment physical and biological habitat types.

2.1 Rocky reef benthic sampling

To quantify dominant macroalgae and sessile and mobile invertebrate abundance and diversity, depth-stratified sampling following the general sampling methods/protocols of Shears and Babcock (2007) was undertaken at 3 sites (Fig. 2.1). The three sites surveyed were: Site 1 Owhanake Bay-east; Site 2 Hakaimango Bay/Point; and Site 3 an area of rocky reef habitat offshore from Enclosure Bay (Enclosure Bay-outer). Within each site, 3 depth strata were sampled and were classified as shallow (1-3m depth); mid-depth (5-8 m depth); and, deep (> 10m depth).

To document the depth distribution of habitats at each site, the extent of the reef from deep to shallow was videoed using a GoPro Camera (Hero 3+). To obtain quantitative information on the extent of dominant species and community composition with each depth strata, a total of 3 haphazardly deployed 1m^{2} quadrats were sampled as follows:

Macroalgae

All large brown macroalgae and turfing algal species within each quadrat were counted, measured, and their percent cover estimated. The total length (TL) of all brown algae were measured to ± 5 cm and individual measurements of stipe length (SL) and primary lamina length (PL) made to ± 5cm for the laminarian alga *Ecklonia radiata*. Macroalgal length measurements were then converted to biomass based on length-dry weight relationships presented in 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 cover was recorded in each 1m^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 10cm 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 will be recorded, unlike point-intercept methods.

Mobile invertebrates

Urchins

All urchins (*Evechinus chloroticus)* occurring within each 1m^2 quadrat were counted, their test diameter >10 mm measured to ± 5 mm. and their behavioural characteristics noted; i.e., grazing in the open (exposed behaviour) or in crevices and holes (cryptic behaviour).

Gastropods and other species

All gastropods on the substratum and on macroalgae within each 1m^2 quadrat were counted and the largest shell dimension (width or length) for each species measured ± 5 mm. For example, shell width was measured for *Cookia sulcata*, whereas shell height was measured for *Cantharidus purpureus*. The total length limpets (*Cellana stellifera*) and other chitons were also measured, whereas only counts were made for echinoderms (starfish sea cucumber).

Note: All animal taxa enumerated in the survey were checked using the New Zealand Inventory of Biodiversity (Gordon 2009).

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*, and the paddle-crab *Charybdis japonica*. All 1m^2 quadrats sampled including adjacent areas of reef were checked for the possible occurrence of these taxa.

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. *Zonariaturneriana*	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	
Codiumconvolutum	1% = 4.7 g
Others, e.g. *Ulva* sp.	1% = 1.7 g
Filamentous algae	1% = 0.2 g

Environmental variables

A range of physical variables: rock type, depth, and sediment percent cover were assessed for each site as part of the study.

Rock type

The nature of the rock type within each permanent quadrat was recorded based on 5 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 three sampling sites, a total of 6 reef fish transects were done within the 5-8m depth strata. 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 snapper (*Pagurus auratus*) 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 (where present). All UVC censuses were done between 08:00 and 16:00 NZST.

2.3 Lobster occurrence

Following reef fish sampling, areas of reef deemed suitable as lobster habitat were searched for the presence of the spiny rock lobster *Jasus edwardsii*. When encountered the size, and where possible, sex of each lobster was determined by visual estimation (see MacDiarmid, 1991). Torches were used to aid in the detection of lobster within deep holes and crevices.

2.4 Soft sediment sampling

In addition to quantitative rocky reef sampling, a video survey using drop camera targeting soft sediment habitat across the survey area was done on 5 December 2016 (Fig 2.2). Sampling used a Splashcam® underwater camera unit connected to Sony® digital videocassette recorder (GV-D800E) on the surface and was deployed from a 5.4 m Stabicaft vessel. Sampling involved filming the seabed along haphazard transects for around 5 minutes at each sampling site. GPS coordinates were taken at the start and end of each transect including at various points along each transect. In total,> 2 hrs footage of the seabed across the survey area was obtained. The survey primarily focused on evaluating the physical and biological nature of soft sediment habitat including the presence of biogenic habitat such as horse mussels, and bivalve beds. Following each video transect was evaluated and descriptions of the substratum characteristics and biological features made (refer to Appendix 1).

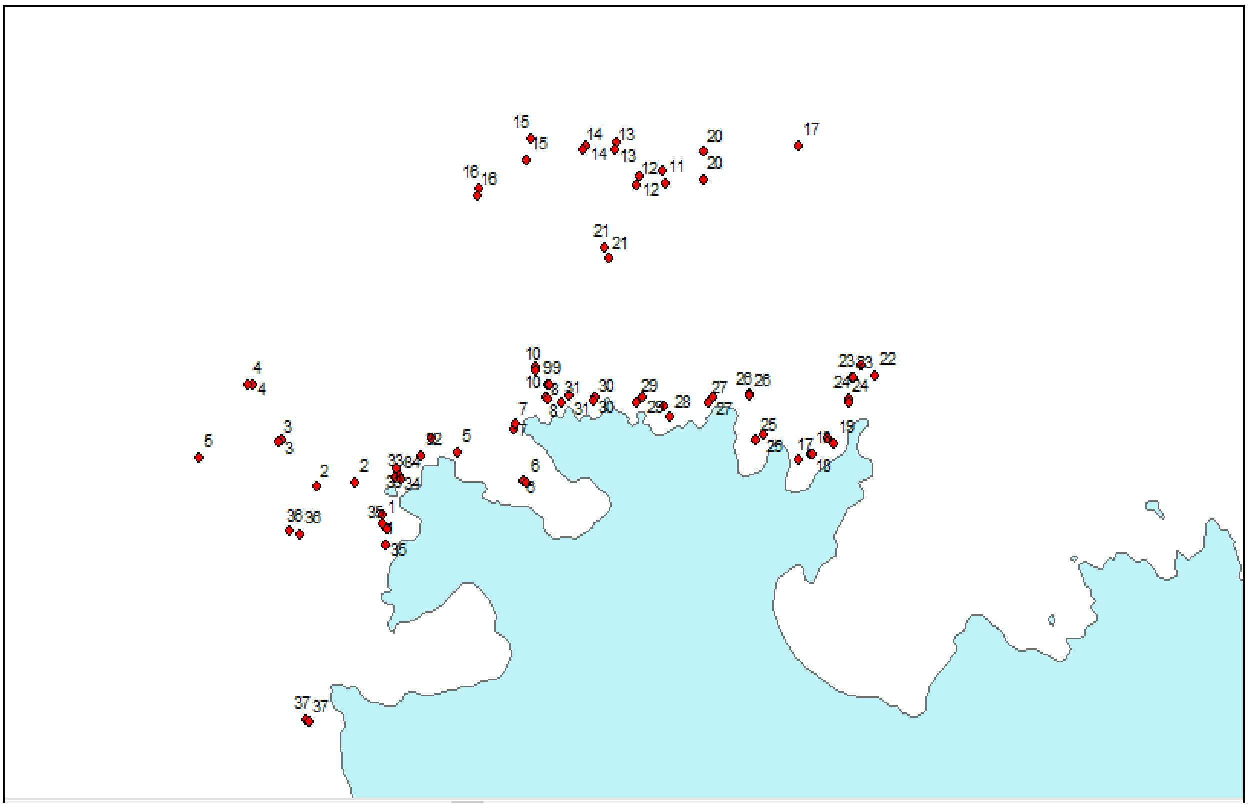

Figure 2.2. Location of remote video drops and transects sites along the north-western Waiheke Island coastline.

2.5 Data analysis

Unless otherwise stated, for the majority of species enumerated, means are presented + their associated standard error (SE). Multivariate statistical tests were used to analyse benthic rocky reef data with the majority of statistical analyses undertaken using PRIMER-E statistical software (Clarke and Warwick 2001) and associated routines; particularly PERMANOVA[2] (Anderson *et al*. 2008).

Multivariate analyses using PERMANOVA were run on either (log x+1) or square-root transformed multispecies data (macroalgae, sessile invertebrate and mobile invertebrate) using a Bray-Curtis similarity (resemblance) measure. Analysis of macroalgae assemblage composition was based on biomass data, 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 for the factor Site (Owhanake Bay-east; Hakaimango Bay; and, Enclosure Bay-outer); Depth (shallow, mid, and deep), and the associated Site×Depth interaction. Individual analyses were run on full models (all effects) using 4999 permutations. Additional pair-wise tests using

[2]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.

PERMANOVA were employed to further examine differences for statistically significant main effects (Site or Depth). All significance levels corresponded to $\alpha = 0.05$.

The multivariate null hypothesis tested was - $H_{0:}$ *there is no statistically significant difference in the species assemblages (e.g., macroalgae sessile invertebrate assemblages) across sites; and among depth strata (shallow versus deep).*

Metric multi-dimensional scaling using principal coordinates analysis (PCO) (Anderson *et al*. 2008) was utilised to support multivariate PERMANOVA results and visualise patterns based on the factor Depth among all sites in multivariate space. All analyses were run either (log x+1) or square-root transformed multispecies data using a Bray-Curtis similarity measure

3.0 Results

Results obtained from the quantitative and qualitative survey of the north-western coastline of Waiheke Island undertaken in December 2016 are presented for dominant macroalgae, macroalgal assemblages, sessile invertebrates, mobile invertebrates (gastropods, echinoderms), and reef fish.

3.1 Macroalgae

All rocky reef sites sampled across the survey area were typically algal dominated. A total of 22 macroalgal species were enumerated across sites ranging from large brown macroalgae, to fine filamentous turfing species (Refer to Appendix 1 for species list). Based on PERMANOVA analysis, there was statistically significant variation in assemblage biomass across sites and among depth strata surveyed (Table 3.1). The statistically significant Site×Depth interaction reflects disparate algal biomasses among depth strata across sites, i.e., both Owhanake Bay-east and Hakaimango Bay were macroalgal dominated for all depth strata surveyed, whereas the mid-depth region of Enclosure Bay was urchin-barrens dominated with low algal biomass. Urchin barrens habitat was observed (anecdotally) to increase in spatial extent east of Enclosure Bay. Results of PERMANOVA analysis are supported by the principle components ordination (PCO) (Fig. 3.1A) with deep-water samples clustered to the top left of the ordination and shallow-water samples located to the mid and right of the ordination. Patterns of this nature infer a moderate to high degree of similarity in macroalgal composition for these depth strata across sites surveyed. In contrast, mid-depth samples were highly variable with no clear across-site similarity (Fig 3.1A). Species responsible for the various site-specific groupings across the ordination are presented in Fig. 3.1B.

Table 3.1. Results from PERMANOVA analysis of macroalgal biomass data (22 species) for 3 sites (Owhanake Bay-east; Hakaimango Bay; and Enclosure Bay-outer) and 3 depth strata (shallow, mid, and deep). Analysis was run on Log (x+1) transformed data using a Bray Curtis similarity measure. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Source	df	SS	MS	Pseudo-F	P (perm)
Site	2	10092	5046.1	10.9	***0.0001***
Depth	2	9123.7	4561.8	9.8	***0.0001***
Site × Depth	4	11501	2875.2	6.2	***0.0001***
Residual	18	8346	463.7	10.9	
Total	26	39062	5046.1		

Algal habitat at Owhanake Bay-east was dominated by the laminarian alga *Ecklonia radiata* and to a lesser-degree the fucalean alga *Carpophyllum flexuosum* (Figs 3.2-3.5). At depths > 5 m, both species often co-occurred in dense stands concomitant with a diverse understorey of mixed algae. Common understorey species were the red algae *Plocamium angustum*, *Asparagopsis armata*, *Pterocladia lucida*, *Hummbrella hydra*, *Gigartina* spp, filamentous turf red and the brown alga *Zonaria turneriana.* Large (> 1 m^2) patches of the green alga *Caulerpa germinata* were conspicuous between larger stands of brown algae > 8 m depth. The fucalean alga *Sargassum sinclairii* was also present in low density clumps (3-4 plants) in this depth stratum with fine sediment often present on algal canopies. With decreasing depth *Carpophyllum flexuosum*, while still present, decreased in abundance, size, and biomass (Figs

3.4, 3.5). Conversely, *Ecklonia radiata* exhibited peak size and abundance in the mid-depth range (Figs 3.2, 3.3, 3.7) where it formed large predominantly monospecific stands with filamentous red turf and crustose coralline algae (CCA) prevalent understorey species. Fine sediment was less apparent on algal canopies with decreasing depth.

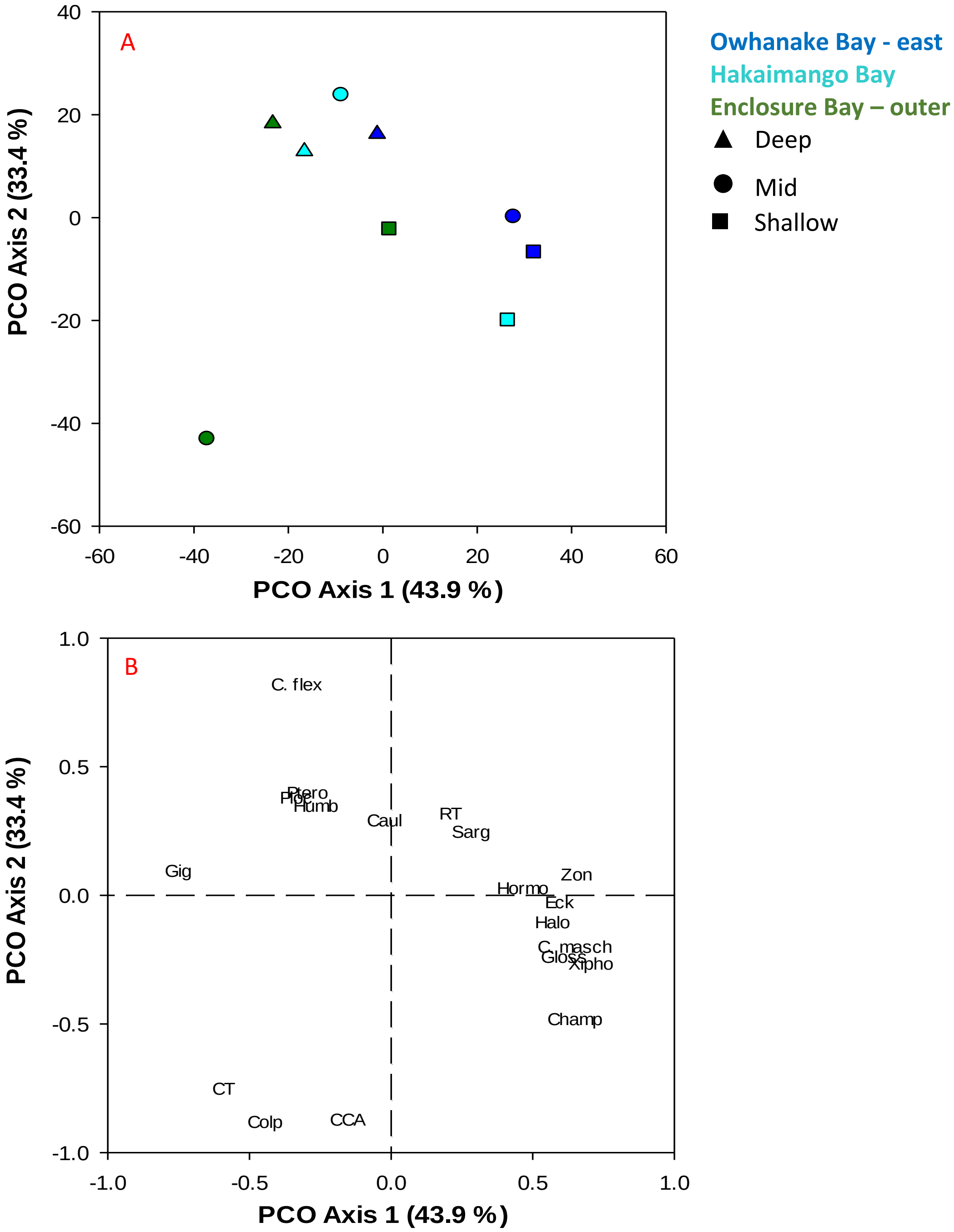

Figure 3.1. Principle coordinate analysis based on log x+1 macroalgal biomass data A) Site- and depth-specific variation in macroalgal biomass – Waiheke Island north-western coastline. B) Biplot demonstrating correlation between PCO axes and each macroalgal species. C. flex = *Carpophyllum flexuosum*; C. masch = *Carpophyllum maschalocarpum*; Caul = *Caulerpa germinata*; Champ = *Champia novaezelandiae*; CT = Coralline turf; CCA = Crustose coralline algae; Colp = *Colpomenia sinuosa*; Eck = *Ecklonia radiata*; Gloss = *Glossophora kunthii*; Halo = *Halopteris* spp; Hormo = *Hormosira banksii*; Humb = *Hummbrella hydra*; Ploc = *Plocamium angustum*; Ptero = *Pterocladia lucida* RT = Red turf; Sarg = *Sargassum sinclairii*; Xipho = *Xiphophora chondrophylla*; Zon = *Zonaria turneriana*.

In shallow water (2-3 m depth) *Ecklonia radiata* while still common, occurred in discrete monospecific stands alternating with similar sized patches of *Xiphophora chondrophylla. Carpophyllum flexuosum* and *Carpophyllum maschalocarpum* added to the brown algal assemblage within this shallow depth range. In very shallow water < 1 m depth, the fucalean alga *Hormosira banksii* co-occurred with *Xiphophora chondrophylla* before giving way to dense bands of the Pacific oyster, *Crassostrea gigas* (Fig. 3.7).

Within Hakaimango Bay, the macroalgal community between 5-10m depth (mid to deep depth strata) tended to be exclusively dominated by *Carpophyllum flexuosum*. *Carpophyllum flexuosum* attained highest abundance (20 sporophytes m^{-2}) in the mid-depth stratum and highest biomass (300 g m^{-2}) in the deep-stratum (Fig. 3.4). The *Carpophyllum flexuosum* canopy > 8m depth was typically comprised of sporophytes > 500 mm TL with laminae (vegetative parts) often covered by fine sediment; which was also evident on the substratum beneath the canopy. Filamentous red turf and CCA were the dominant substratum algae with occasional brown (*Zonaria turneriana*) and red (*Plocamium angustum*, *Asparagopsis armata*) foliose species present. As for Owhanake Bay-east, *Hormosira banksii* and *Xiphophora chondrophylla* were common species, occupying rocky reef habitat < 1 m depth.

Sharing commonality with Hakaimango Bay, *Carpophyllum flexuosum* was the dominant alga between 8-10m depth at the Enclosure Bay-outer sampling site (Figs 3.4, 3.5, 3.7), with sporophyte abundance around 22 individuals m^{-2}; and biomass equating to around 300g m^{-2}. Canopy sporophytes were generally > 600 mm TL, again with high sediment cover event on laminae. *Carpophyllum flexuosum* recruit stages were common beneath canopy sporophytes. *Carpophyllum flexuosum* and other large brown macroalgae were largely absent or occurred at very low abundances in the mid-depth stratum. Here, the substratum was typified by turfing coralline algae, CCA, occasional patches of red algal turf, and the brown alga *Colpomenia sinuosa*. Shallower regions of the sampling site (1-3 m depth) were punctuated by dense stands of *Ecklonia radiata* (550-600 mm SL) occurring at around 30 sporophytes m^{-2} with biomass around 600 g m^{-2} (Figs 3.2, 3.3). Recruit stages 50-100 mm SL were common beneath the *Ecklonia radiata* canopy at this site. As for the other sites, *Hormosira banksii* co-occurred with *Xiphophora chondrophylla*<1m depth. No invasive species, e.g., *Undaria pinnatifida* were observed at any of the sampling locations.

Macroalgal diversity presented as species richness varied across sites and depth strata surveyed. Highest species richness occurred at Owhanake Bay-east deep (Fig. 3.6) with mid- and shallow-depth strataat this site also having higher diversity than both Hakaimango Bay and Enclosure Bay-outer. For the latter two sites, macroalgal richness was generally higher in the shallow depth stratum (> 8 species m^{-2}), lowest in mid-depth stratum (< 6 species m^{-2}); and, intermediate in the deepest stratum (Fig. 3.6).

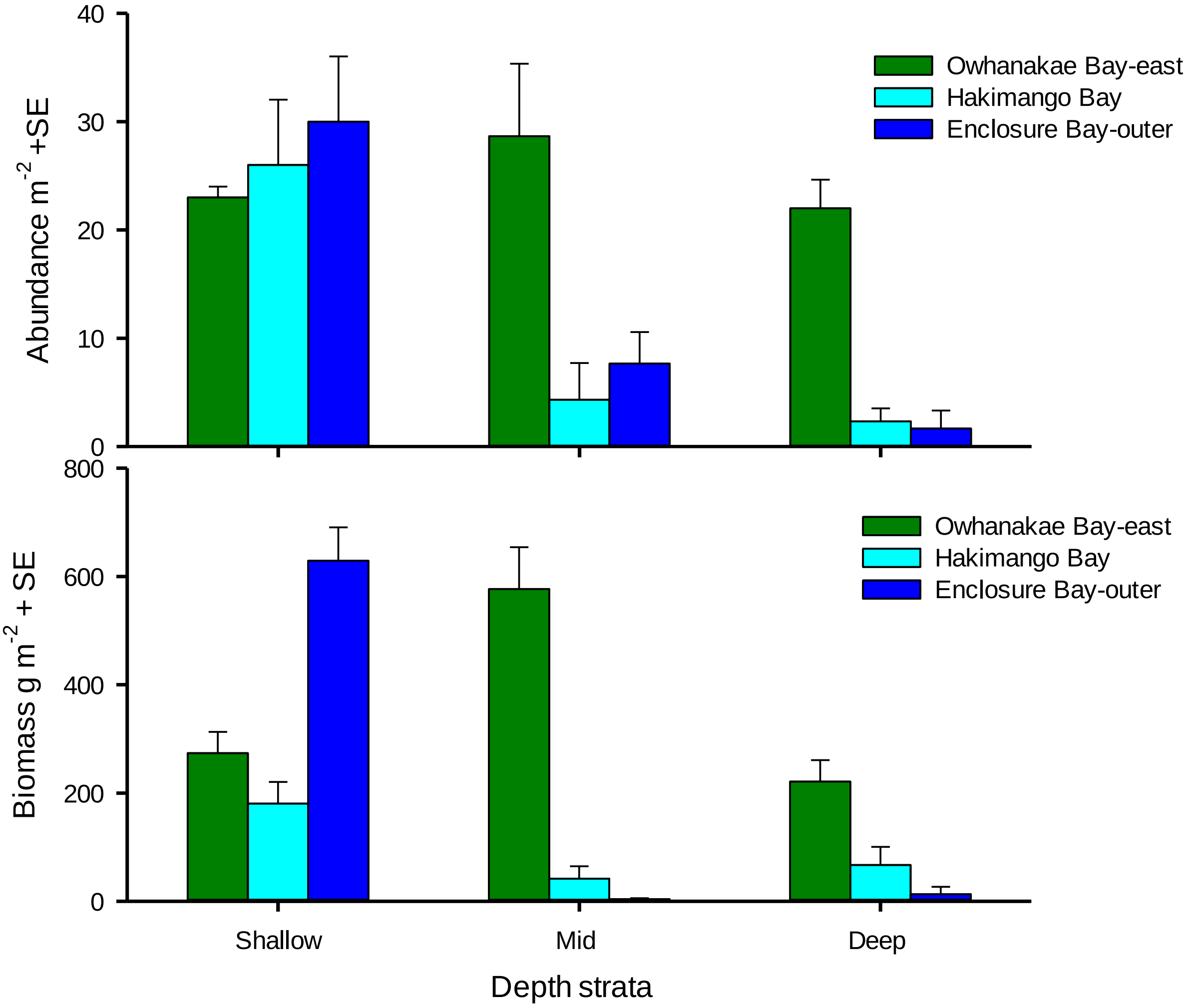

Figure 3.2. Abundance and biomass of *Ecklonia radiata* within three depth strata – shallow (1-3 m); mid (5-8 m); and, deep (>10 m depth), at 3 sites along the north-western coastline of Waiheke Island.

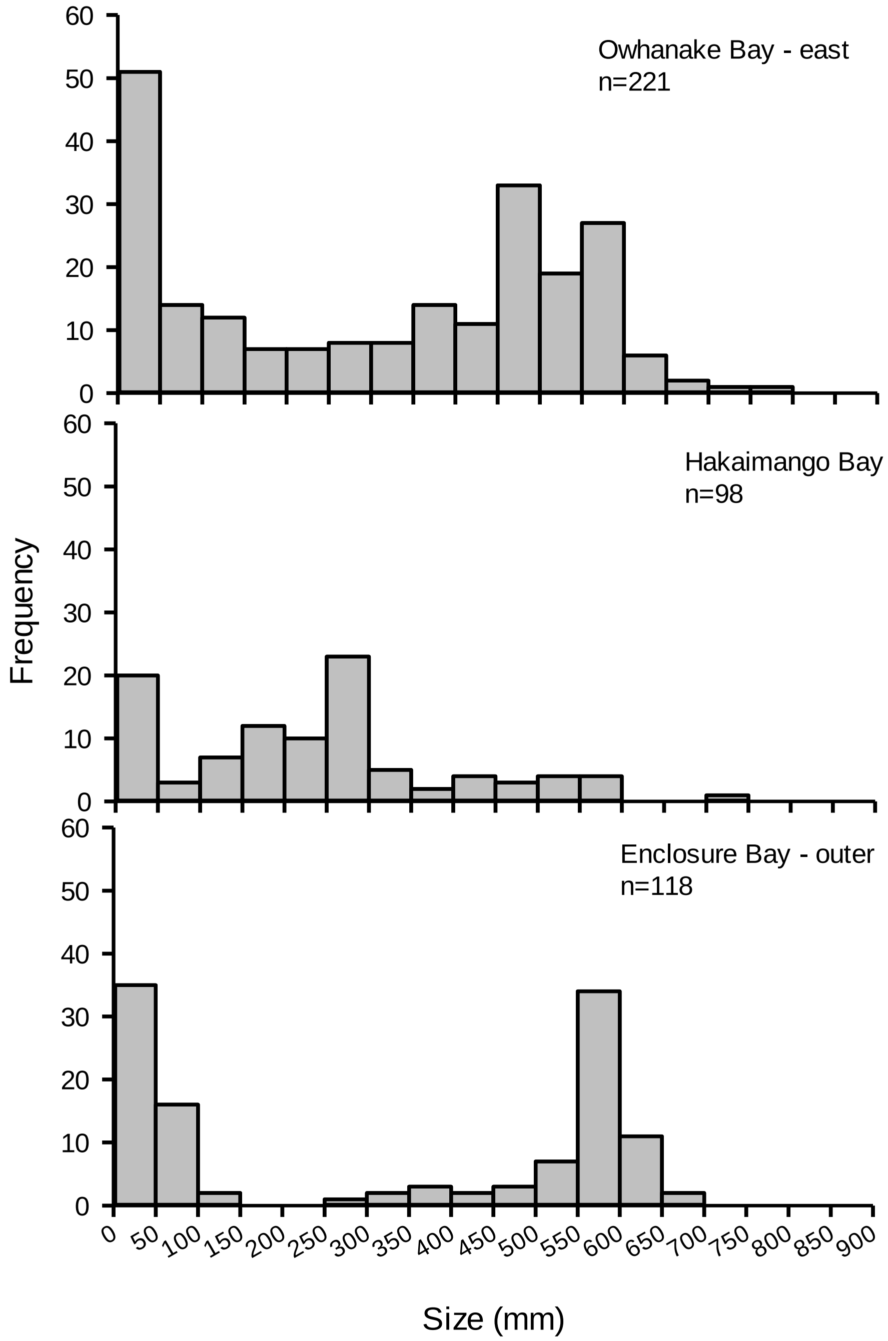

Figure 3.3. Size frequency of *Ecklonia radiata* pooled across depth strata for three sites surveyed along the north-western coastline of Waiheke Island.

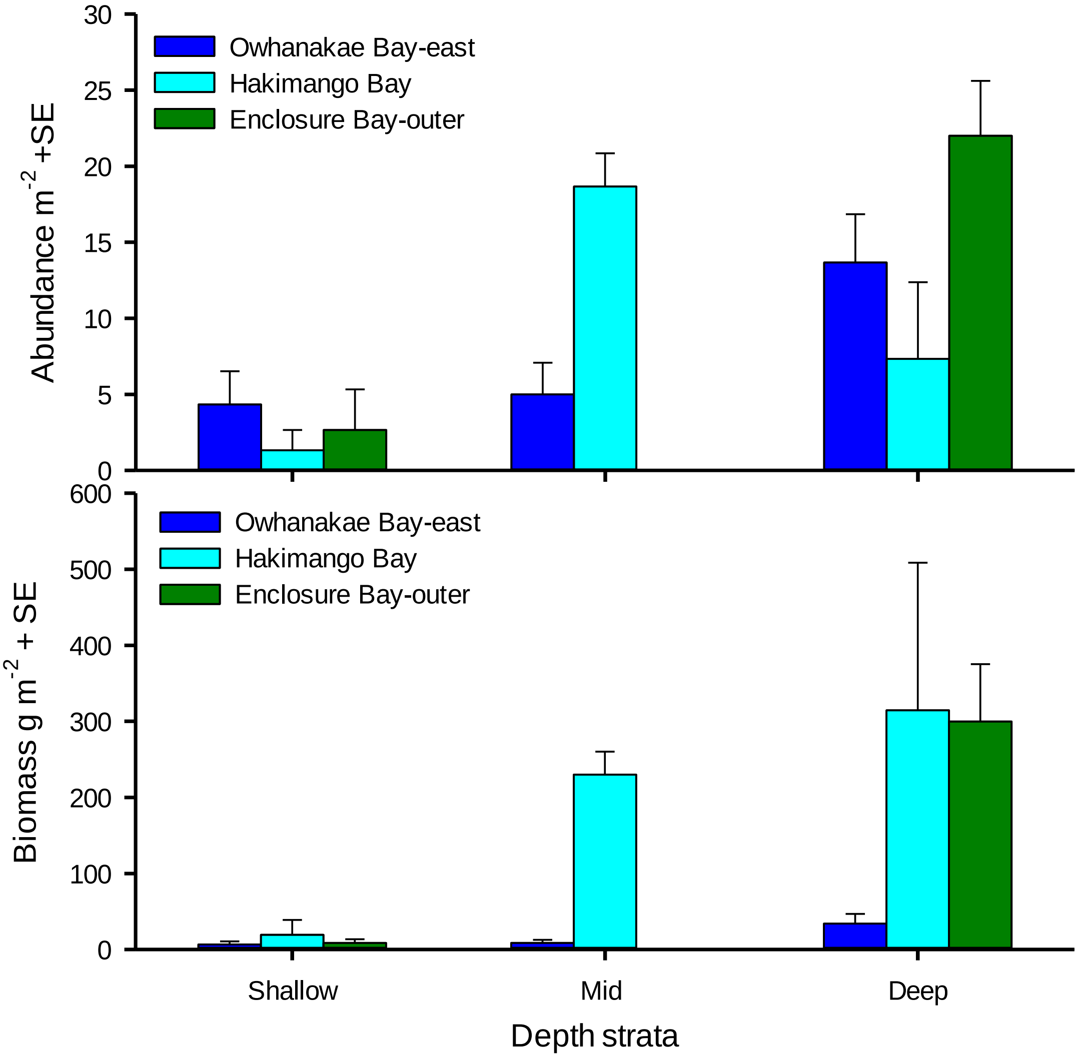

Figure 3.4. Abundance and biomass of *Carpophyllum flexuosum* within three depth strata – shallow (1-3 m); mid (5-8m); and, deep (>10 m depth), at 3 sites along the north-western coastline of Waiheke Island.

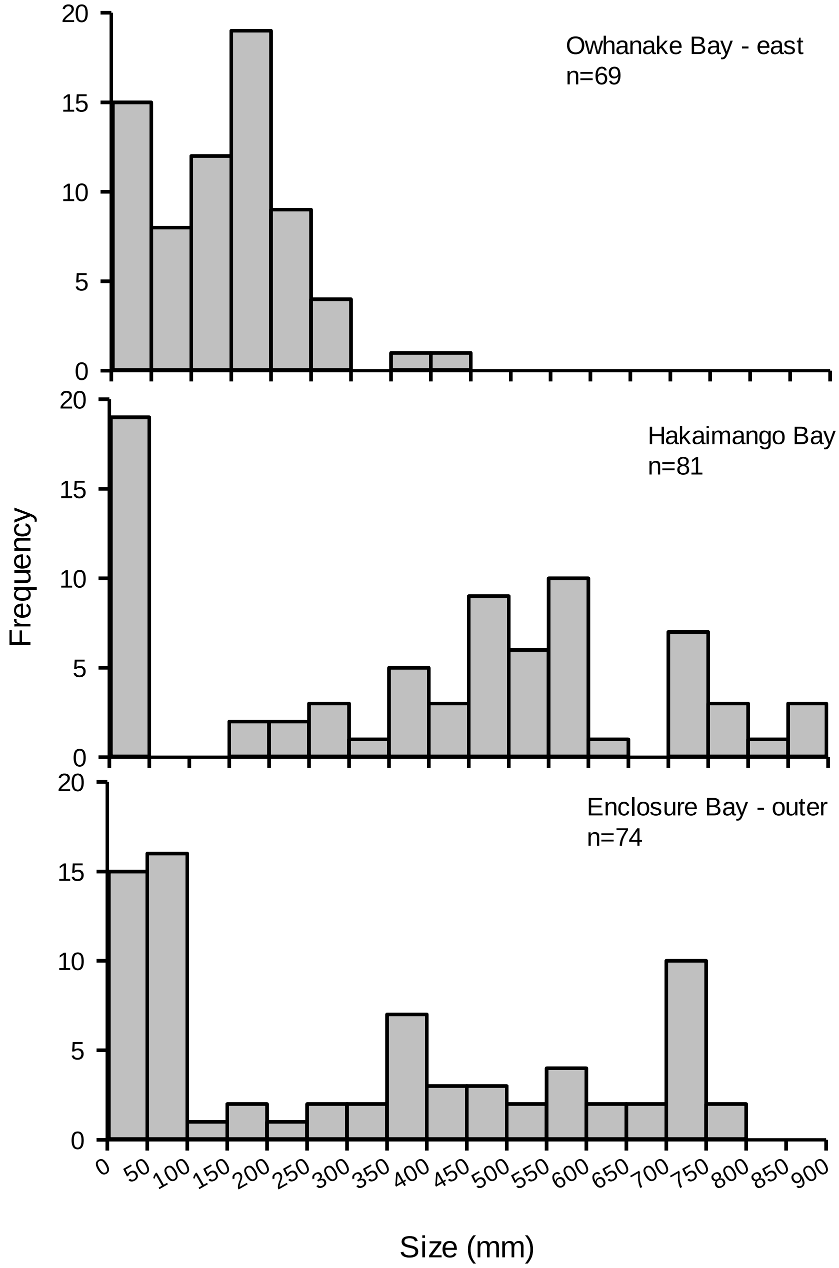

Figure 3.5. Size frequency of *Carpophyllum flexuosum* pooled across depth strata for three sites surveyed along the north-western coastline of Waiheke Island.

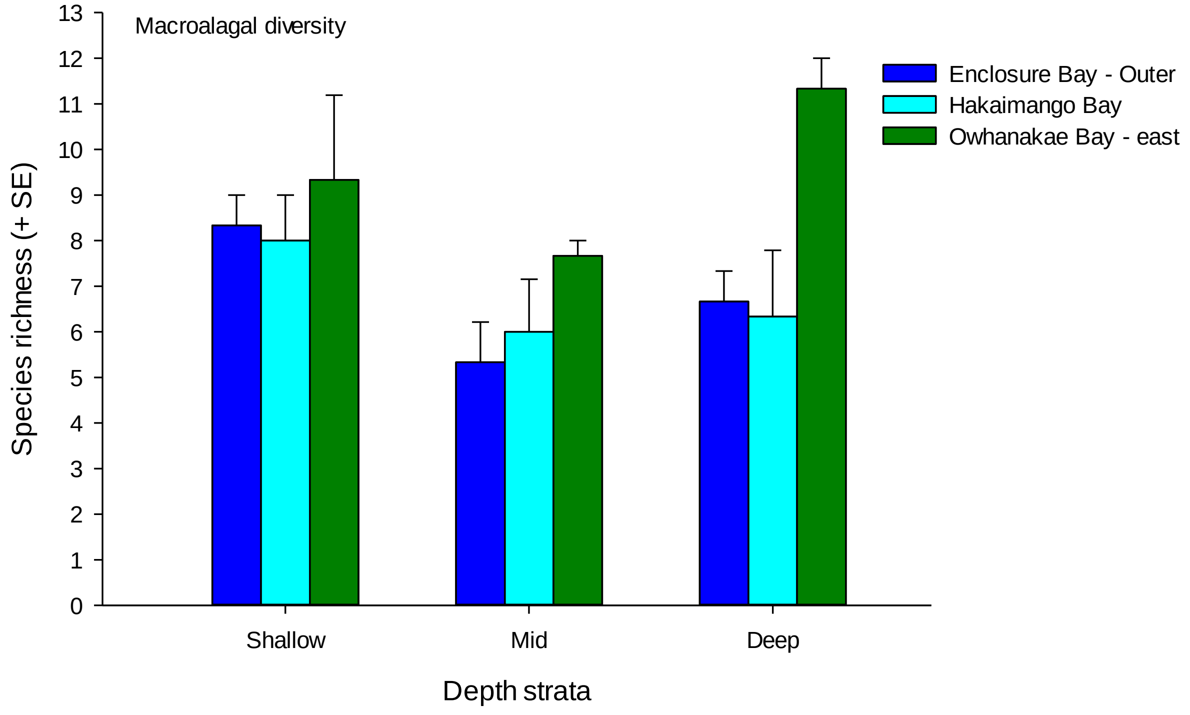

Figure 3.6. Macroalgal diversity based on species richness within three depth strata – shallow (1-3 m); mid (5-8m); and, deep (>10 m depth), at 3 sites along the north-western coastline of Waiheke Island.

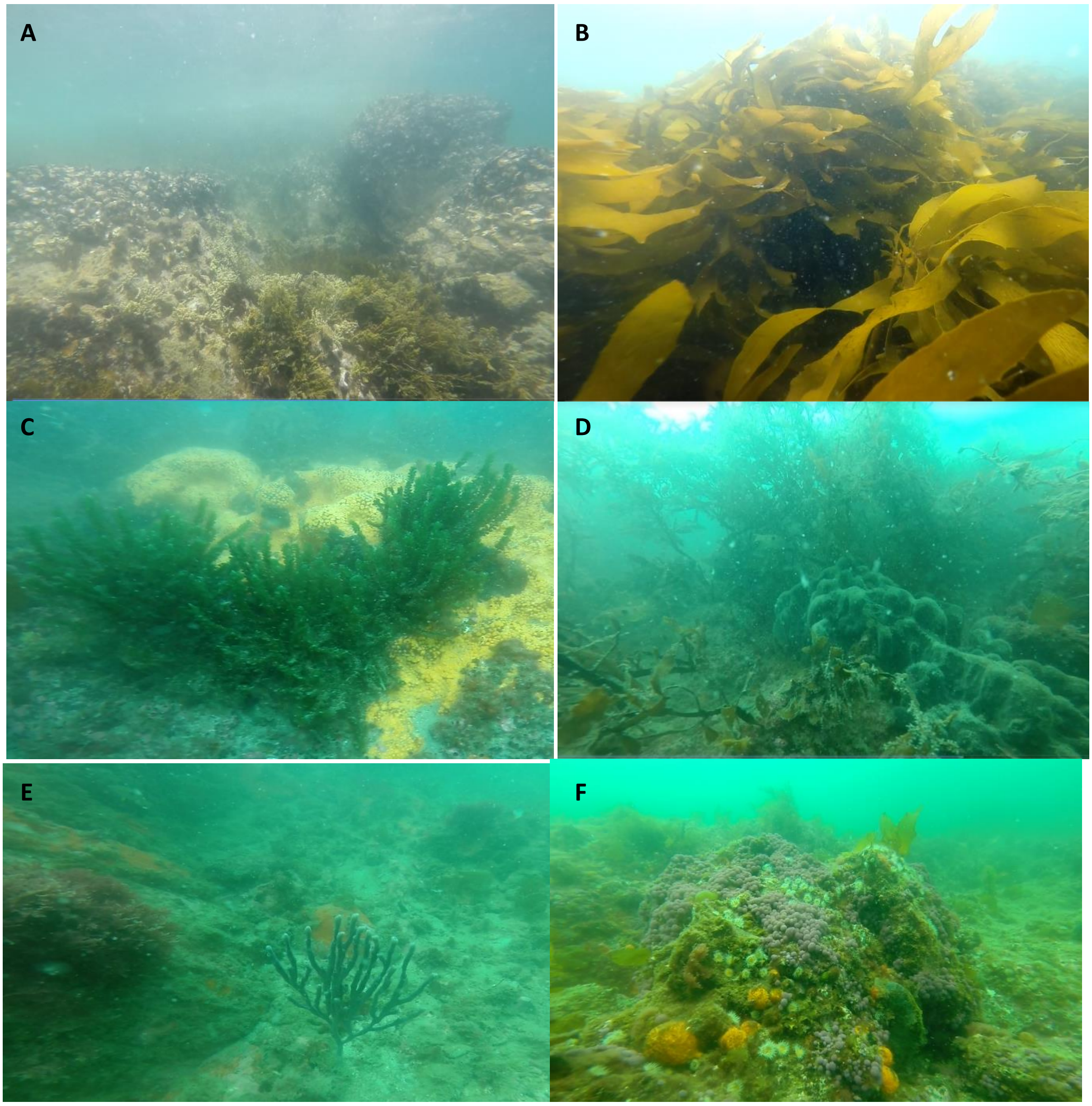

Figure 3.7a. Examples of rocky reef biological habitats characteristic of the north-western Waiheke Island coastline. A) Oyster, *Crassostrea gigas* and algal (*Hormosira banksii* and *Xiphophora chondrophylla* mix) habitat; 0-1 m depth – Hakaimango Bay; B) Dense monospecific *Ecklonia radiata* canopy; 6 m depth – Owhanake Bay-east; C) *Caulerpa germinata* patch; 11m depth – Owhanake Bay-east; D) *Carpophyllum flexuosum* habitat and large *Ancorina alata* sponge; 9 m depth – Hakaimango Bay; E) Erect, branched, sponge *Callyspongia* sp on reef edge – 12 m depth Hakaimango Bay; F) Ascidian *Hypsistozoa fasmeriana*, sponge *Tethya burtoni*, and anemone *Actinothoe albocincta* mix adjacent urchin barrens habitat; 3m depth – Enclosure Bay-outer.

Figure 3.7 continued. Examples of rocky reef biological habitats characteristic of the north-western Waiheke Island coastline. G) Urchin barrens habitat east of Enclosure Bay; H) *Ecklonia radiata* canopy and diverse sponge and ascidian communities >10 m depth east of Enclosure Bay.

3.2 Sessile invertebrates

Sponges, ascidians, encrusting bryozoans, and hard coral were dominant sessile invertebrates inhabiting rocky reef habitat across survey sites. Species richness was lowest in shallow-water at around 5 species m^{-2}, whereas at mid- and deep-water sites, species richness ranged between 8-9 species m^{-2} (Fig 3.8; refer to Appendix 1 for species list). Dominant species encountered included the golf ball sponge *Tethya burtoni*, the large grey sponge, *Ancorina alata*, with erect branched sponges *Callyspongia ramosa* and *Raspailia* spp also dominant. Encrusting sponges were represented by *Cliona celata*, *Clathria rubens*, and the ascidians *Cnemidocarpa bicornuta*, *Asterocarpa coerulea*, *Hypsistozoa fasmeriana*, *Aplidium* spp, and *Didemnum* spp. In very shallow water at each site (< 1m depth) dense patches of the pacific oyster *Crassostrea gigas* (Fig. 3.7) and isolated, small patches of the green-lipped mussel *Perna canaliculus* (3-5 individuals) were present.

PERMANOVA analysis (Table 3.2) indicated that sessile invertebrate community composition was statistically different across sites and among depth strata. Again this is supported in part by the principle coordinate ordination (Fig. 3.9),with deep-water samples clustered to the bottom of the ordination, mid-depth samples to the center of the ordination, and shallow-water samples (while highly variable among sites) were located to the top of the ordination. The Hakaimango Bay sample was an obvious outlier negatively associated with PCO Axis 1 and 2 (Fig 3.1A) and reflects its low sessile invertebrate diversity relative to other shallow-water samples. Species synonymous with shallow-water sites were the hard coral *Culicea rubeola*, solitary ascidian *Asterocarpa coerulea* and encrusting sponge *Cliona celata*. The golf ball sponge *Tethya burtoni*, encrusting sponge *Halicondria moorei*, solitary ascidian *Cnemidocarpa bicornuta* and solitary coral *Monomyces rubrum* were characteristic species of the deep stratum (Fig 3.8B). The urchin barrens habitat sampled at Enclosure Bay outer was also notable for the diverse sponge and ascidian assemblages particularly on complex reef with vertical topography; - in particular, the often prominent cover of the ascidian *Hypsistozoa fasmeriana* (Fig. 3.7).

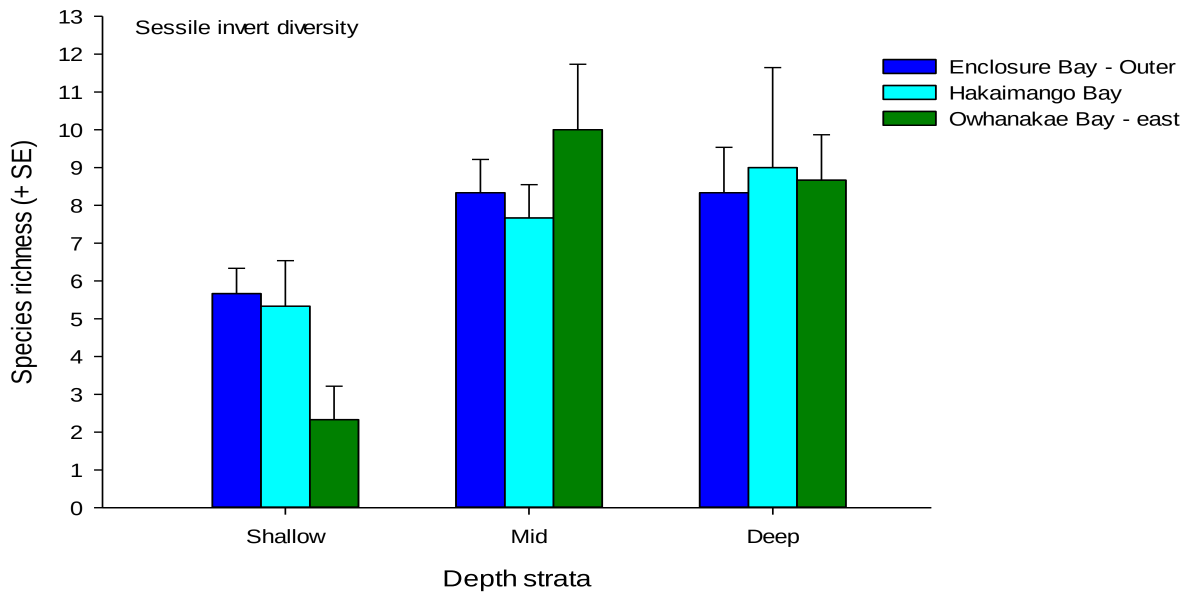

Figure 3.8. Sessile invertebrate diversity based on species richness within three depth strata – shallow - (1-3m); mid- (3-8m); and, deep - (>10m depth) for 3 sites along the north-eastern coastline of Waiheke Island.

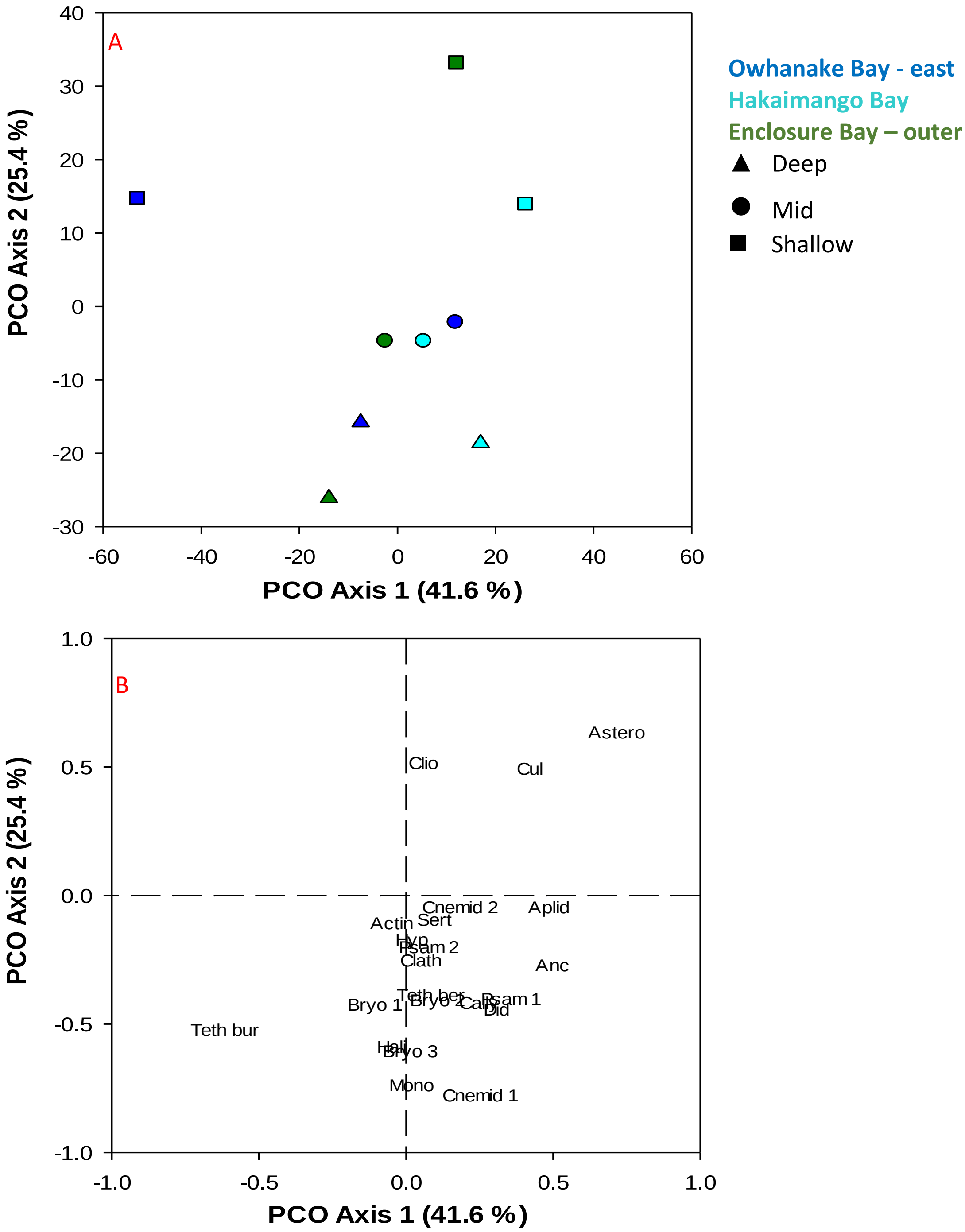

Figure 3.9. A) Site- and depth-specific variation in sessile invertebrate assemblage composition– Waiheke Island north-western coastline. Principle coordinate analysis based on square root transformed abundance and percent cover data combined. B) Biplot demonstrates correlation between PCO axes and each species. Teth bur = *Tethya burtoni*; Teth ber = *Tethya bergquistae*; Anc = *Ancorina alata*; Clio = *Cliona celata*; Psam 1 = Psammocinia sp1; Psam 2 = Psammocinia sp2; Clath = *Clathria rubens*; Hali = *Halicondria moorei*; Cnemid 1 = *Cnemidocarpa bicornuta*; Astero = *Asterocarpa coerulea*; Cnemid 2 = *Cnemidocarpa nisiotis* (novaezelandia); Aplid = *Aplidium* (orange); Did = Didemnum(pink); Hyp = *Hypsistozoa fasmeriana*; Sert = Sertularia sp.; Mono = *Monomyces rubrum*; Cul = *Culicea rubeola*; Actin = *Actinothoe albocincta*; Bryo 1 = orange encrusting bryozoan; Bryo 2 = black encrusting bryozoan; and Bryo 3 = brown encrusting bryozoan

Table 3.2. Results from PERMANOVA analysis of sessile invertebrate data for 3 sites and 3 depth strata (shallow, mid, and deep). Analysis was run on Log (x+1) transformed data using a Bray Curtis similarity measure. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Source	**df**	**SS**	**MS**	**Pseudo-F**	**P (perm)**
Site	2	5617.3	2808.6	2.5	***0.0022***
Depth	2	6596.2	3298.1	2.9	***0.0012***
Site × Depth	4	9357.9	2339.5	2.1	***0.0026***
Residual	18	20158.0	1119.9	2.5	
Total	26	41730.0	2808.6		

3.3 Mobile Invertebrates

There was high variation in mobile invertebrate abundance across sites and depth strata surveyed. Common gastropod species encountered during the survey included the cook's turban *Cookia sulcata*, green top shell *Trochus viridis* the red opal top shell *Cantharidus purpureus,* and the catseye *Turbo smaragdus* (Fig. 3.10). Of these dominant species, *Turbo smaragdus* exhibited clear distributional patterns in accordance with depth being the dominant species in shallow-water particularly at Owhanake Bay and Hakaimango Bay (Fig 3.10).

Cookia sulcata occurred in all depth strata at each survey site (Fig. 3.10) being present within algal canopies and on the immediate substratum. Highest abundance occurred at Hakaimango Bay in shallow water (Fig 3.10). *Trochus viridis* attained highest abundances at Enclosure Bay-outer relative to the other two sampling sites; however, there was a general trend for slightly higher abundance in the mid-depth strata for all sites surveyed. Both *Cookia sulcata* and *Trochus viridis* were encountered on algal fronds and the substratum across sites. *Cantharidus purpureus* is predominantly associated with algal canopies and at a site-specific level was numerically dominant in the mid-depth strata at Owhanake Bay-east (Fig. 3.10), mid-depth strata a Hakaimango Bay, and shallow depth strata at Enclosure Bay-outer. Other gastropod species encountered during the survey were *Dicathais orbita*, *Buccinulum linea linea*, *Calliostoma punctulatum* and *Xymenella spp* (Refer to Appendix 1 for species list).

Echinoderms characteristic of survey sites were the urchin *Evechinus chloroticus*, sea cucumber *Stichopus mollis* and cushion star *Patriella regularis.* Of these, *Evechinus chloroticus* was present at all sites in all depth strata being particularly abundant in the mid-depth range at Enclosure Bay – outer grazing in the open, i.e., displaying exposed behavior (Fig. 3.11). At the other sites surveyed *Evechinus chloroticus* commonly displayed cryptic behavior, occurring in crevices and reef hollows beneath macroalgal canopies. Rarely were they observed out in the open, the exception being Hakaimango Bay – east deep, where > 50 % of urchins displayed exposed behaviour. Urchin size frequencies based on test-diameter (Fig. 3.12) infer that sample populations were comprised of both large and small individuals. Mean size for each site were Owhanake Bay-east 69 mm ± 9.1 ($CI^{95\%}$); Hakaimango Bay 73.7 ± 8.3 ($CI^{95\%}$); and, Enclosure Bay-outer 80.1 ± 6.6 ($CI^{95\%}$) respectively.

The sea cucumber *Stichopus mollis* was abundant in the deepest depth-strata at all survey sites, generally associated with high sediment areas of the reef and at the base of rocky reef soft sediment habitat transitions. In contrast, *Patriella regularis* was common in all habitat types and depth strata surveyed, the exception being Hakaimango Bay deep (Fig. 3.11).

Results for mobile invertebrate community analysis (PERMANOVA; Table 3.3) indicated that community composition was not statistically different among sites but was among depth strata. Again this is supported by the PCO analysis (Fig 3.13) where there was clear separation of samples based on depth strata with shallow-depth samples clustering to the right, mid-depth to the middle and deep sites grouping to the left of the ordination negatively associated with PCO Axis 1. Species correlations indicate that the separation of deep sites relative to other depth strata is primarily due to the occurrence of *Stichopus mollis*. Species characteristic of shallow water sites were *Turbo smaragdus*, *Dicathais orbita* and *Patriella regularis*.

Table 3.3. Results from PERMANOVA analysis of mobile invertebrate data for 3 sites and 3 depth strata (shallow, mid, and deep). Analysis was run on Log (x+1) transformed data using a Bray Curtis similarity measure. Statistically significant *P*-values at the 5% level are shown italicised and in bold.

Source	df	SS	MS	Pseudo-F	P (perm)
Site	2	3555	1777.5	2.1466	0.0862
Depth	2	22777	11389	13.754	***0.0002***
Site × Depth	4	6688.5	1672.1	2.0193	0.0516
Residual	18	14905	828.06	2.1466	
Total	26	47926	1777.5		

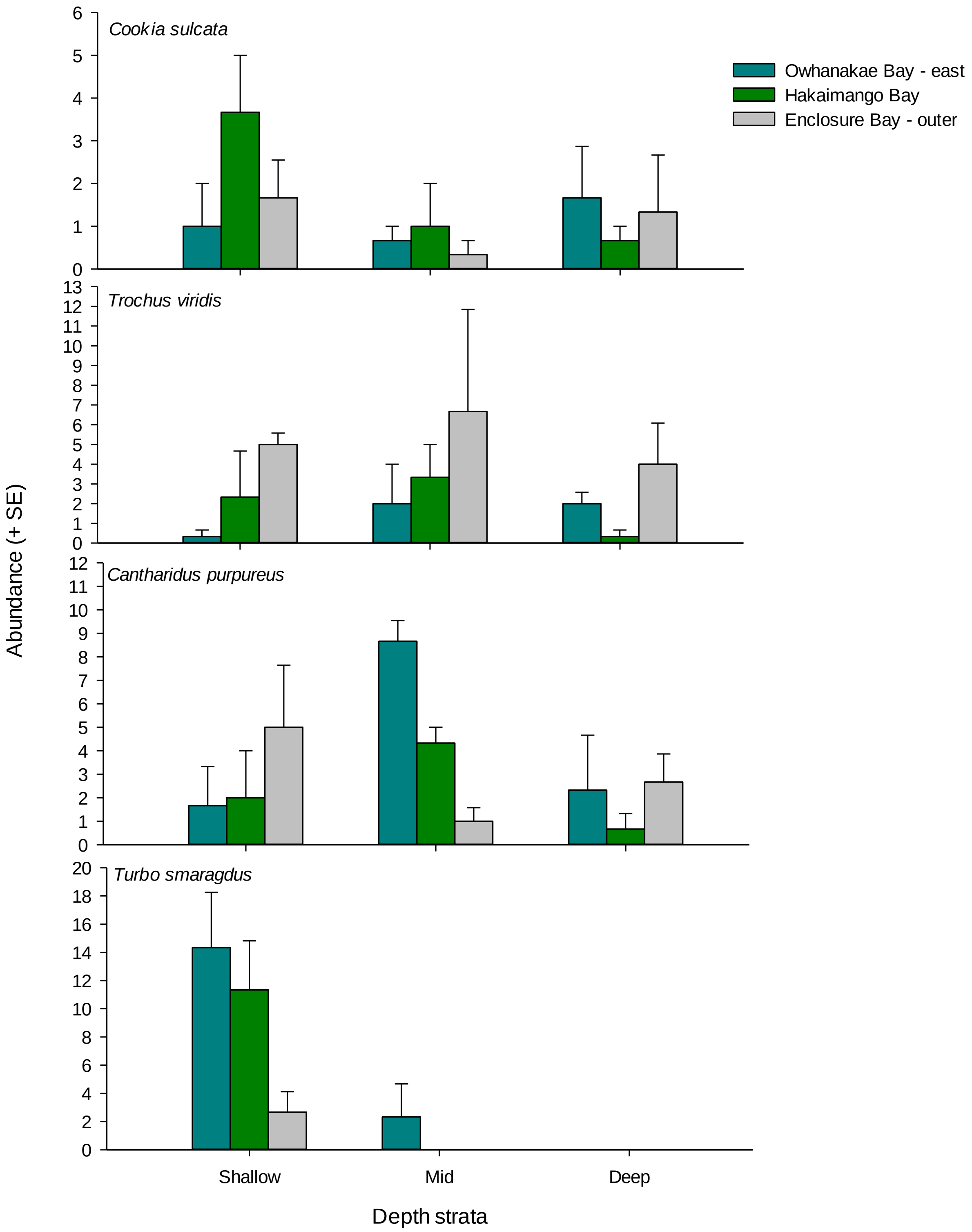

Figure 3.10. Abundance of dominant gastropods within three depth strata – shallow (1-3 m); mid (5-8m); and, deep (>10 m depth), at 3 sites along the north-western coastline of Waiheke Island.

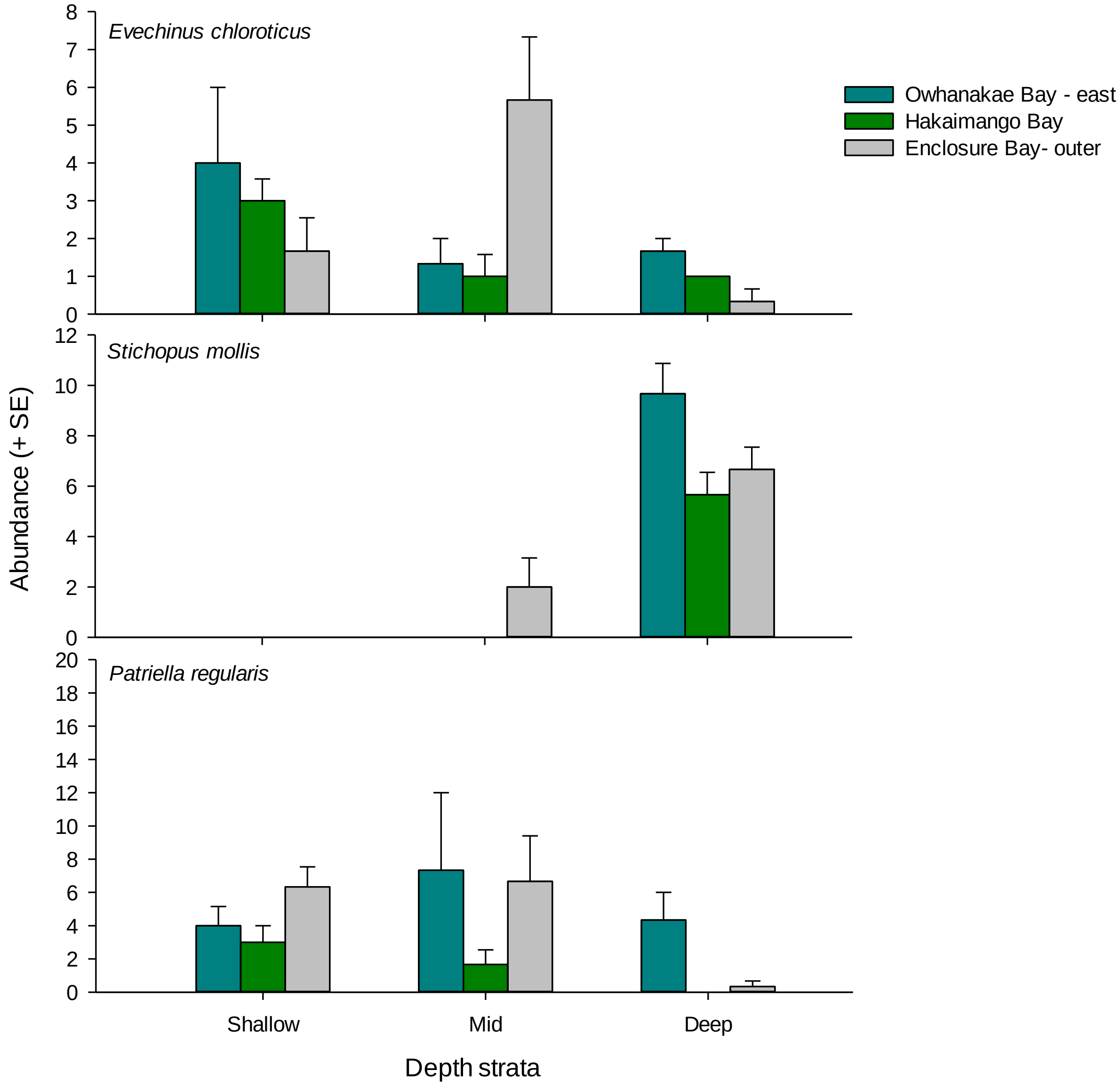

Figure 3.11. Abundance of dominant echinoderms within three depth strata – shallow (1-3 m); mid (5-8 m); and, deep (>10 m depth), at 3 sites along the north-western coastline of Waiheke Island.

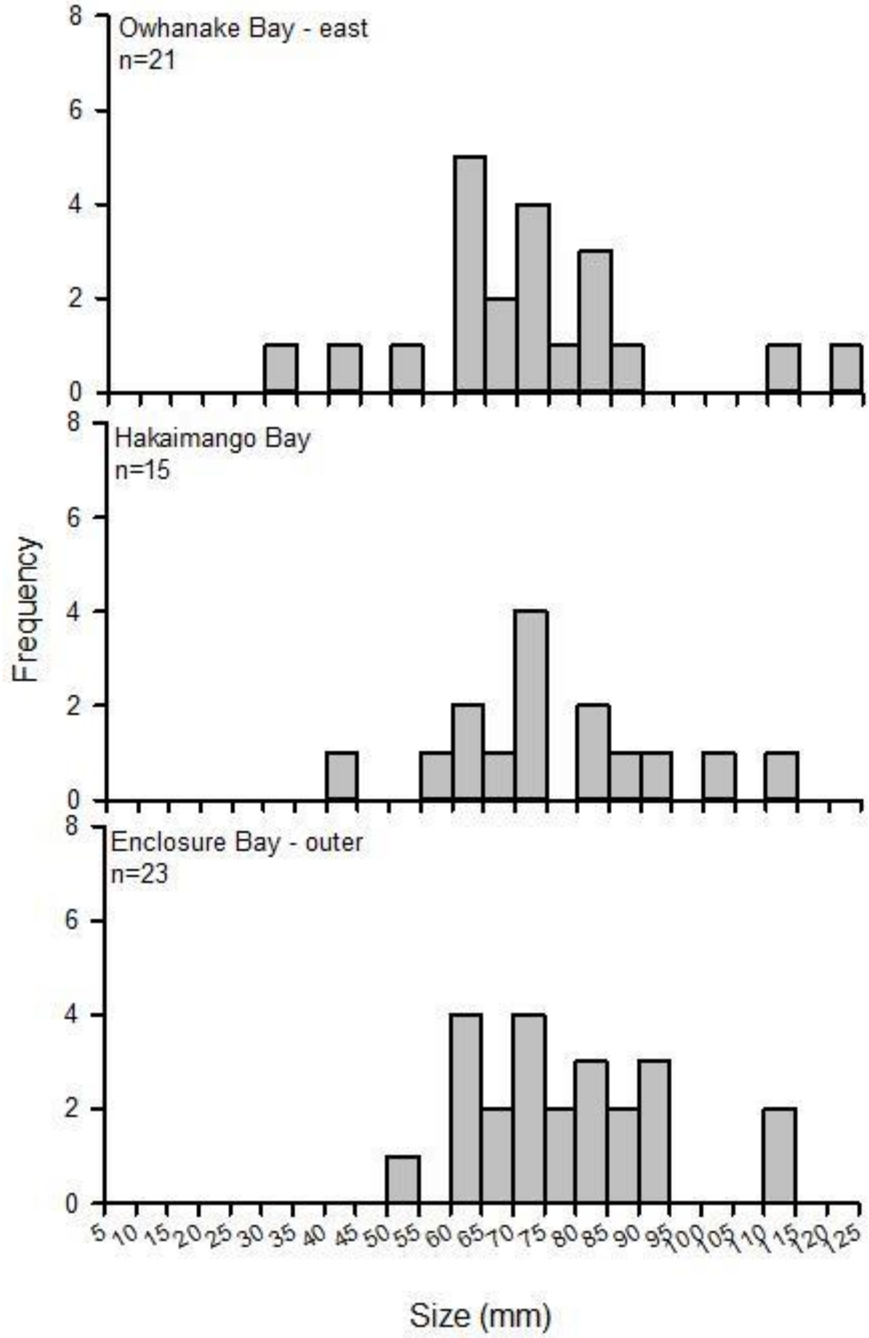

Figure 3.12 *Evechinus chloroticus* size frequency based on test-diameter for 3 sites along the north-western coastline of Waiheke Island. Data are pooled across depth strata for each site.

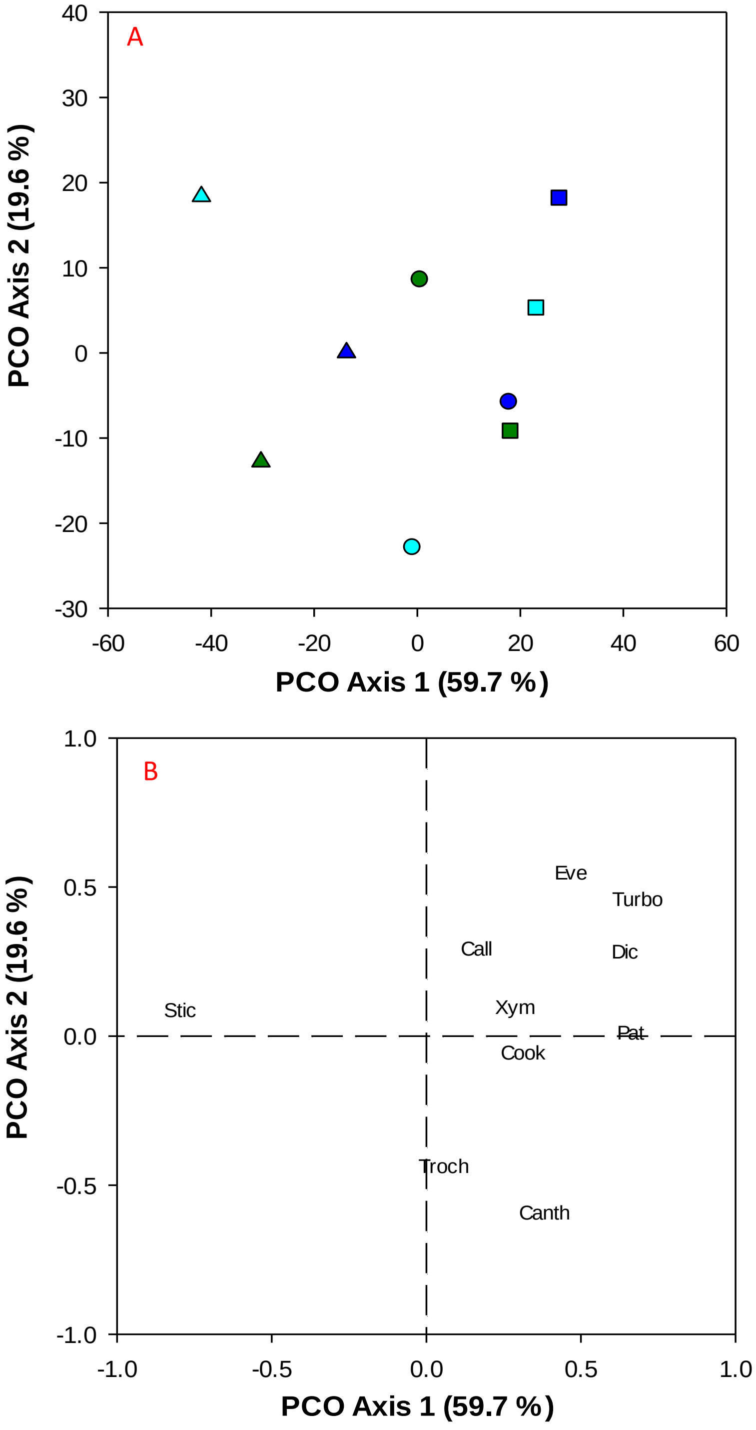

Figure 3.13. Principle coordinate analysis based on log x+1 count data A) Site- and depth-specific variation in mobile invertebrate abundance – Waiheke Island north-western coastline. B) Biplot demonstrating correlation between PCO axes and each species. Call = *Calliostoma punctulatum*; Canth = *Cantharidus purpureus*; Cook = *Cookia sulcata; Dic = Dicathais orbita;* Eve = *Evechinus chloroticus*; Pat = *Patriella regularis*; Stic = *Stichopus mollis*; Troch = *Trochus viridis*; Xym = *Xymenella spp.*

3.4 Reef fish

Reef fish abundance and diversity enumerated by underwater visual census (UVC) across sites was low (Fig. 3.14). Of the species encountered, spotty (*Notolabrus celidotus*) were typically common occurring at all sites surveyed, particularly at Hakaimango Bay (Fig 3.15) associated with *Carpophyllum flexuosum* habitat. Other species that were encountered at all sites were goatfish (*Upeneichthys lineatus)*, parore (*Girella tricuspidata*), and snapper (*Pagrus auratus)*. Red moki (*Cheilodactylus spectabilis*) were observed at Hakaimango Bay and Enclosure Bay-outer (Fig. 3.15). For snapper, 3 legal-sized individuals were observed (1 individual at Owhanake Bay; and, 2 individuals at Hakaimango Bay) all being around 300 mm fork length (FL). Discrete schools of snapper ranging from 10-20 individuals (< 150 mm FL, i.e., 0+ and 1+ age classes) were also observed outside of sample transects at Owhanake Bay-east and Enclosure Bay-outer. Analysis of assemblage composition (PERMANOVA) indicated statistically significant differences among survey sites (Table 3.4). Based on additional pair-wise analysis Owhanake Bay-east and Hakaimango Bay reef fish assemblages were not statistically different from another, but were both statistically different to Enclosure Bay-outer.

Other reef fish species observed during the survey outside of the sample transects included kingfish (*Arripis trutta* – Enclosure Bay-outer – 12m depth; Fig. 3.15); kahawai (Owhanake Bay-east – 8 m depth); koheru (*Decapterus koheru* – Owhanake Bay 4-5 m depth); leather jacket (*Parika scaber* – Owhanake Bay 3m depth); butterfish (*Odax pullus* – Enclosure Bay-outer 2m depth), banded wrasse (*Notolabrus fucicola* -Owhanake Bay-east – 2 m depth); and, sweep (*Scorpis lineolatus* - Owhanake Bay-east – 6 m depth). Main trends for reef fish observed are summarised in Table 3.5.

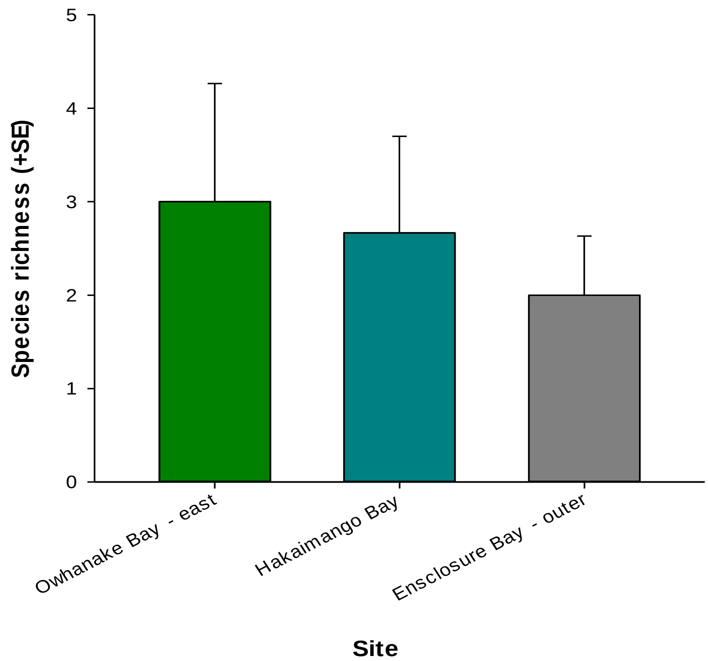

Figure 3.14. Reef fish diversity based on species richness as measured by UVC for 3 sites along the north-western coastline of Waiheke Island. Data are mean values + associated standard error (SE).

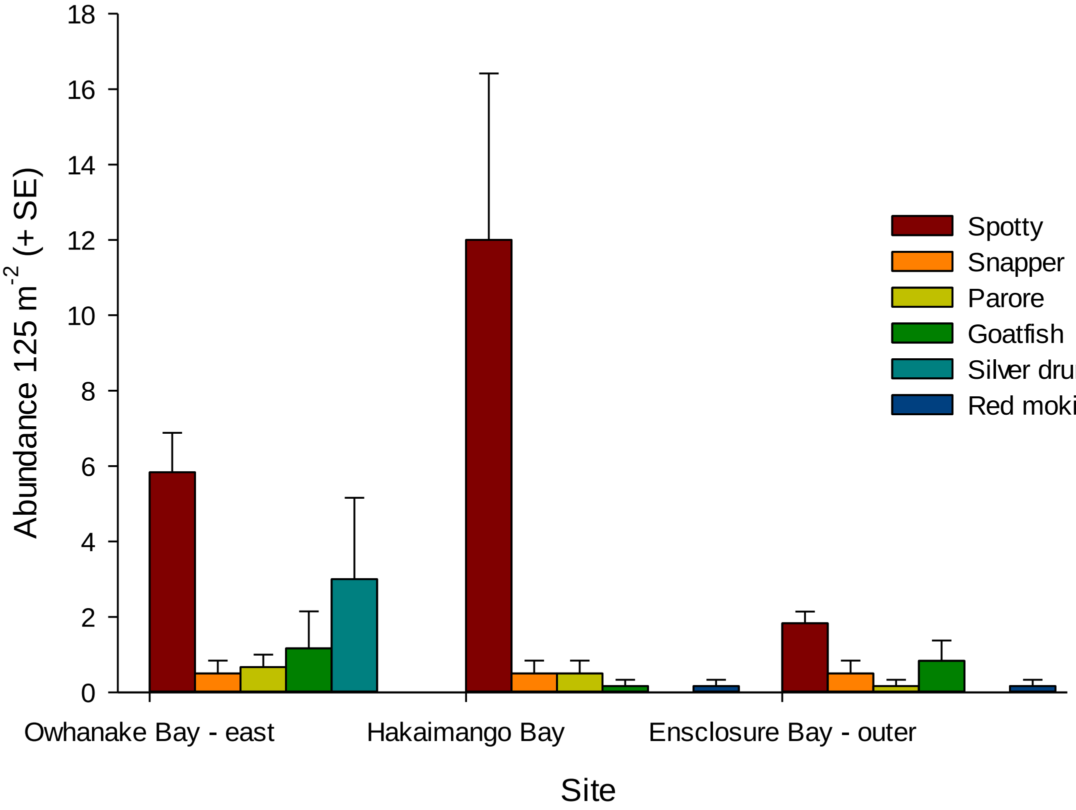

Figure 3.15. Reef fish abundance by UVC for 3 sites along the north-western coastline of Waiheke Island. Data are mean values + associated standard error (SE).

Table 3.4. Results from PERMANOVA analysis of reef fish assemblage composition for 3 sitessurveyed within the north-western coastline of Waiheke Island. Analysis was run on Log (x+1) transformed data using a Bray Curtis similarity measure. Statistically significant *P*-values at the 5% level are shown italicised and in bold. Pair wise tests indicated which sites were statistically different from one another.

Source	**df**	**SS**	**MS**	**Pseudo-F**	**P (perm)**
Site	2	5369	2684.5	2.35	***0.0194***
Res	15	17120	1141.3		
Total	17	22489			

Pairwise for site		
Sites	***t***	**P (perm)**
Owh - Haka	0.89	0.673
Owh- Encl	1.74	***0.022***
Haka-Encl	1.75	***0.023***

Table 3.5. Summary of main fish species observed from both UVC sampling and general observations while undertaking additional benthic sampling.

Species	Description
Spotty	Numerically dominant across survey sites commonly associated with dense macroalgal canopies. Abundances quantified here support the notion of higher spotty abundance within the inner Hauraki Gulf relative to outer areas.
Snapper	Legal sized individuals (approx. 300 mm FL) observed at Owhanake Bay-east and Hakaimango Bay. Juvenile shoals (< 150m FL) present at all sites particularly common on rocky reef and soft sediment interfaces.
Sweep	Small school (10 individuals) above *Ecklonia radiata* canopy Owhanake Bay-east.
Kahawai	Small school (3-5) individuals observed at Owhanake Bay-east moving rapidly through area mid-water.
Kingfish	Small school (5-8) individuals observed at Enclosure Bay-outer moving through area above algal canopy.
Koheru	School of +100 individuals near surface - Owhanake Bay-east.
Goatfish	Present at all sites particularly common on rocky reef and soft sediment interface and areas of low algal abundance.
Red moki	Observed in shallow-water (Hakaimango Bay and Enclosure Bay-outer; associated with macroalgal habitat.
Silver drummer	Small school – 4 individuals observed at Owhanake Bay-east moving fairly rapidly through area mid-water.

3.5 Lobster abundance

All sites surveyed were characterised by what could be considered suitable rocky reef habitat for occupation by spiny rock lobster *Jasus edwardsii*; e.g., crevices, ledges, and areas of boulder reef. Despite rigorous searches no lobster were observed at any of the sampling sites.

3.6 Soft sediment habitat types

Consistent with previous survey work undertaken by Kerr and Grace (2013), there was a clear gradient in soft sediment habitat types within the survey area. Based on remote video survey transects coarse sand and whole shell habitat was the dominant immediately adjacent rocky reef habitat between Matiatia Bay and Enclosure Bay and the main channel area between 10-20m depth along the western Waiheke coastline. With increasing distance offshore along the north-west and northern coastline the physical nature of the soft sediment changed from coarser material to finer muddy sand.

Biological habitats changed in accordance with the variation in soft sediment substratum types and are summarized in Table 3.6. Briefly, where whole shell and coarse sand content was content was high encrusting and erect sponges and red algae were common. Patchy, very low density areas of the horse mussel, *Atrina zelandica* were observed in the main channel region along the western coastline of the survey area as were occasional scallops, *Pecten novaezelandiae* and unidentified bivalve beds. As the substratum became increasingly muddier (> 15m depth) biological features were less apparent being represented by occasional crab/shrimp/worm holes. Scallop dominated areas of seabed were a distinct component of the subtidal adjacent Matiatia Bay and Hakaimango Bay.

Table 3.6 Soft sediment substratum types and main biological features as identified by remote video survey – north-western coastline Waiheke Island.

Substratum type	Location	Biological features
Coarse sand and whole shell	Adjacent subtidal rocky reef habitat and areas of western channel	Encrusting and erect sponges and red algae. Bivalve beds evident occasional low density horse mussels and scallops
Muddy sand	>15m depth throughout survey area	Occasional crab/shrimp/worm holes in sediment surface
Fine sand	Hakaimango Bay	Occasional crab/shrimp/worm holes in sediment surface, scallops common.

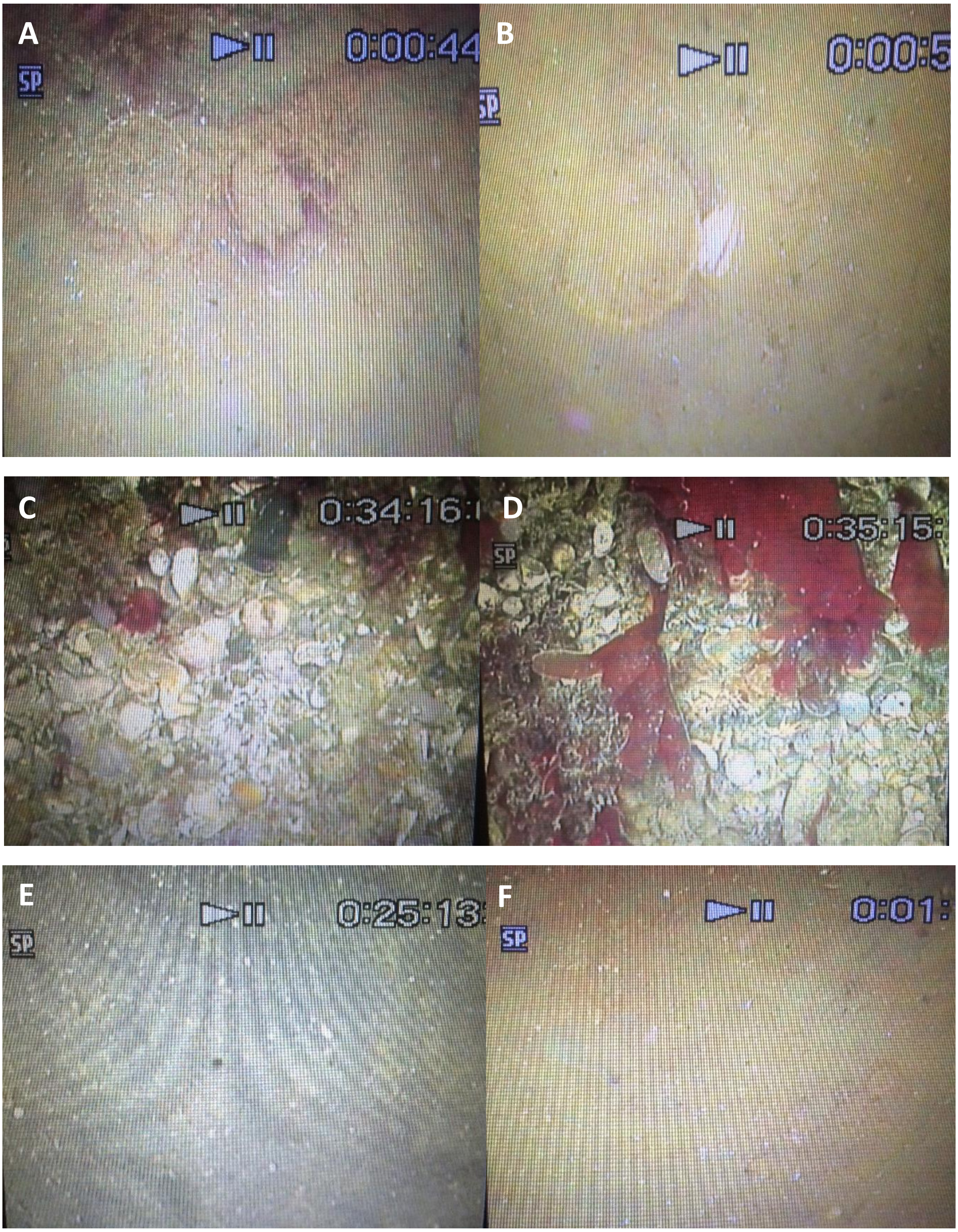

Figure 3.16. Features of soft sediment habitat within the survey area. A and B: scallop *Pecten novazealandiae* beds; C: coarse sediment and shell hash; D: red algae on coarse sediment and whole shell material; E fine sand (Owhanake Bay); F) fine sand adjacent Hakaimango Bay – Note: worm/crab/shrimp holes in sediment surface.

Figure 3.16. ***continued*** Features of soft sediment habitat within the survey area. G: red turfing algae on sediment surface: and, H: sponge habitat on soft sediment habitat in central channel area west of Matiatia Bay and Owhanake Bay.

4.0 Discussion

This report details the results of a baseline first-order biological survey undertaken along the north-western coastline of Waiheke Island using both a quantitative and qualitative sampling approach. The aims and purpose of the survey were to: 1) document the size and abundance of dominant rocky reef organisms (macroalgae and mobile and sessile invertebrates) and reef-fish; and, 2) evaluate qualitatively the nature of soft-sediment physical and biological habitat types. Information collected in this survey will be used to underpin proposed no-take marine reserve along this section of the Waiheke Island coastline.

4.1 Rocky reef habitats

The majority of rocky reef habitats surveyed in this study were macroalgal dominated. The exception to this was Enclosure Bay–outer where urchin barrens habitat was the prevalent habitat type between 3-8m depth. While variation in macroalgal habitats was broadly consistent with depth, there was a high degree of variation in species composition across the three survey sites. Moving from shallow (<1 m) to deep (> 10 m) all survey sites were characterised by a mix of *Hormosira banksii,* and *Xiphophora chondrophylla* between 1-2m depth and beyond this very shallow zone, large brown macroalgae became dominant. At the Owhanake Bay-east site between 3-5m depth, the laminarian alga *Ecklonia radiata* was the dominant macroalgal species. Beyond 5m depth *Ecklonia radiata* habitat was often intermixed with patchy stands of the fucalean *Carpophyllum flexuosum* and this combination (with *Ecklonia radiata* the most dominant), continuing to the end of the reef in approximately 12 m depth. Sediment was a common feature on algal fronds and the substratum > 8m depth at this site. At Hakaimango Bay, *Carpophyllum flexuosum* was the dominant alga from around 5 m depth, and formed a continuous canopy to the termination of rocky reef habitat at around 10 m depth, which also coincided with high sediment cover on algal fronds and the immediate substratum. A similar species composition with high sediment cover was evident at Enclosure Bay–outer, with *Carpophyllum flexuosum* forming monospecific stands between 8 m- 12m depth. In shallow water (2-5 m depth), *Ecklonia radiata* was the dominant canopy forming macroalga with urchin barrens habitat prevalent between 3-8m depth. The high sediment cover on algal canopies across sites invariably reflects terrigenous-derived sediment settling in deeper areas of reef, a common feature of sheltered and semi-sheltered habitats (Walker 1999; Shears 2013). Despite elevated sediment levels the deep-water strata > 8 m depth at Owhanake Bay-east this site was of particular note due to the high diversity of macroalgal species present that, in addition to large brown macroalgae, included large patches > 1 $m^2$of the green alga *Caulerpa germinata,* and a rich assemblage of ephemeral and perennial red foliose algae.

The depth-related pattern in macroalgal assemblages quantified in this study, mirrors broad-scale qualitative descriptions of the north-west and northern coastline done previously (Kerr and Grace 2013) and also shares elements of both shallow-water rocky reef habitats characteristic of the inshore mainland Hauraki Gulf (Grace 1983; Walker 1999; Shears 2013) and the northern coast of Kawau Island, in the outer Hauraki Gulf (Walker 1999). At these locations there is often a continuous band of macroalgae (both mixed and monospecific guilds) from shallow to deep, with urchin barrens habitat either absent or patchily distributed.

Due to a general paucity of temporal monitoring in the Waiheke Island region of the Hauraki Gulf the depth-related patterns in macroalgal communities presented here merely present a snap-shot in time. Although algal assemblages within the inner Hauraki Gulf are considered to be more-stable than the outer Hauraki Gulf (see Shears 2013), it is worth emphasisingthey are not static entities and are in turn influenced by a suite of physical (wave exposure, turbidity, rocky reef extent, oceanographic climate) and biological (grazing, inter- and intra-competition for space) processes. For example, at inner Hauraki Gulf rocky reef sites surveyed by Shears (2013) as part of Auckland Council's State of the Environment Monitoring (e.g., Meola Reef, Torbay, and Whangaparaoa),over the last 9 yearsthere has been a notable increase in the abundance and biomass of *Ecklonia radiata* together with an increase in the invasive kelp *Undaria pinnatifida*. While the increase in *Undaria pinnatifida* reflects the longevity of its gametophyte stage and its ability to rapidly colonise bare space and outcompete slower growing native species, mechanisms underpinning the increase in *Ecklonia radiata* remain largely unknown. Given the broad-scale nature of the expansions, current investigations are evaluating the role of El-Nino and La-Nina climatic events (variability and intensity) and their role in influencing turbidity and nutrient regimes (Shears 2013). In other Hauraki Gulf Marine Park monitoring studies, expansion of *Carpophyllum flexuosum* together with a decline in urchin barrens habitat have also been documented along the Leigh and Hahei coastlines. Changes of this nature have been hypothesised to be the result of outbreaks of toxic microalgae *Ostreopsis siamensis* affecting the movement, feeding rates, and survival of the urchin *Evechinus chloroticus* (Shears and Ross 2010; TH personal observation). In the absence of grazing pressure *Carpophyllum flexuosum* a species largely unpalatable to *Evechinus chloroticus* (Cole and Haggitt 2001) is able to become established and proliferate.

Evechinus chloroticus while present at all sites and depth-strata surveyed was, not-surprisingly, of low density and cryptic in nature where macroalgae and sediment was prevalent. This fits with and supports recent remote sensing of subtidal habitatsalong the northern Waiheke coastline (Auckland Council unpublished data) that identified negligible urchin barrens habitat between Matiatia Bay and Hakaimango Point. Urchin barrens habitat however, increases notably in spatial extent with increasing distance east of Oneroa Bay and is particularly prevalent from Enclosure Bay to Thompson's Point. The urchin grazed barrens habitats surveyed in this study (Enclosure Bay-outer; mid depth) typically corresponded with a high abundance of urchins displaying "exposed' behaviour. While urchin barrens habitat also coincided with a high percent cover of crustose coralline algae, both turfing algae and sessile invertebrates were also conspicuous on areas of reef with high vertical complexity.

Encrusting assemblages beneath algal canopies were broadly similar across sites, with greatest variation consistent with depth. Species richness and assemblage composition was also comparable to rocky reef habitat within Te Whanganui-a-Hei Marine Reserve (Haggitt *et al*. 2015). Species characteristic of the deep depth strata were morphologically complex e.g., the sponges *Ancorina alata* and *Callyspongia ramosa*, whereas species such the sponge *Tethya burtoni* and solitary ascidians e.g., *Cnemidocarpa bicornuta* were numerically dominant across all depth strata surveyed. As a further point of reference Shears (2013) has documented an increase in *Cnemidocarpa bicornuta* at multiple sampling sites within the Hauraki Gulf, particularly in locations where *Ecklonia radiata* has increased over recent years, inferring that the presence of *Ecklonia radiata* may be beneficial to this particular species.

Sessile invertebrate communities dominated by sponges and ascidians such as those identified here are particularly important to ecosystem functioning due to their filtering capacities and provision of biogenic habitat (Morrison *et al*. 2014). The presence of dense narrow bands of oysters and occasional patches of *Perna canaliculus* in very shallow water are also representative of additional sessile invertebrate biogenic habitat. Given the low abundance and narrow distribution of these bivalves their functional role is likely to be very limited, especially *Perna canaliculus.*

Gastropod species enumerated in this study are all species commonly found in inner and outer Hauraki Gulf rocky reef habitats (Walker 1999; Shears 2013, Haggitt *et al*. 2015). Of these, the cats-eye *Turbo smaragdus* was present in shallow depth strata, with other main species (*Cookia sulcata*, *Trochus viridis*, *Cantharidus purpureus*) highly variable across depth strata but not survey sites. Densities enumerated for Waiheke Island fall within the temporal ranges recorded by Shears (2013) and Haggitt *et al*. (2015), as does the high among-depth variability. Both of these temporal monitoring studies have documented recent declines in multiple gastropod species through time, and when evaluated on the basis of spatial-scale, infer that regional processes (throughout the HGMP) are likely to be influential rather any than local-scale factors*per se*. Cause of declines are presently unknown but again may reflect the variability and intensity of El Nino and La Nina climatic events (Shears 2013; Haggitt *et al*. 2015).

4.2 Reef-fish

As for the benthic survey component, the survey of reef-fish using UVC provides a coarse assessment of fish abundance and diversity for the north-western coastline of Waiheke Island. The high abundance of spotty across sites within the 5-8m depth strata and occurrence of goatfish, parore, and snapper (legal and sub-legal) closely matches patterns identified with and outside Long Bay-Okura Marine reserve (Haggitt and Shears 2011). This similarity also extends to the occurrence of schooling juvenile snapper (10-20 individuals) (< 150 mm FL, i.e., 0+ and 1+ age classes) observed at Owhanake Bay-east and Enclosure Bay, and supports further the findings of snapper habitat associations identified by Compton *et al*. (2011). The numerical dominance of spotty along the north-western coastline reflects the prevalence of macroalgal habitat particularly *Carpophyllum flexuosum* (Jones 1988) and further supports the pattern of higher abundance within the inner Hauraki Gulf relative to the outer Hauraki Gulf (Haggitt and Shears 2011; Haggitt *et al*. 2011).

Other reef fish species observed during the survey outside of the sample transects included kingfish (*Arripis trutta* – Enclosure Bay-outer – 12m depth; Fig. 3.15); kahawai (Owhanake Bay-east – 8m depth); koheru (*Decapterus koheru* – Owhanake Bay 4-5m depth); leather jacket (*Parika scaber* – Owhanake Bay 3m depth); butterfish (*Odax pullus* – Enclosure Bay-outer 2m depth), banded wrasse (*Notolabrus fucicola* -Owhanake Bay-east – 2m depth); and, sweep (*Scorpis lineolatus* - Owhanake Bay-east – 6m depth).

4.3 Soft sediment habitats

The range of soft sediment habitats identified from the remote video survey matches the general patterns described by Kerr and Grace (2013) for the north-western coastline of Waiheke Island. Biological communities associated with soft sediment habitats include: sponge/sessile invertebrates and red algae present on coarse and whole shell material; patchily distributed low-density scallop (*Pecten novaezealandiae*), horse mussel (*Atrina* *zelandica*) and other bivalves were primarily associated with coarse sand; and, small worm/crab/shrimp holes evident across large areas of seabed comprised of sandy mud. Typically, coarser sand material adjacent rocky reef and in the main channel west of Matiatia Bay and Owhanake Bay. was biologically diverse.

4.4 Summary

Main findings from undertaking the baseline benthic survey for the north-western coastline of Waiheke Island were:

- A diverse array of biogenic habitats represented by macroalgae, sponge and sessile invertebrate communities, and, bivalve beds (the latter associated with both rocky reef and soft sediment);

- Subtidal rocky reef habitat between Matiatia Bay and Hakaimango Point was predominantly macroalgal dominated, with macroalgal diversity particularly high within the deepest depth stratum east of Owhanake Bay;

- Urchin barrens habitat was negligible between Matiatia Bay and Hakaimango Point, although this habitat type increased in spatial extent east of Enclosure Bay;

- Sessile invertebrate diversity was moderate to high across the survey area, with species characteristic of the deepest depth strata surveyed (> 10 m depth) morphologically complex;.

- Reef fish biodiversity was low, but consistent with assemblage compositions recorded for the inner-Hauraki Gulf elsewhere (e.g. Long Bay). Commonly targeted species such as snapper (legal and sub-legal), kahawai and kingfish were observed during the survey;

- Despite complex rocky reef habitat being present at all sites, no lobster (*Jasus edwardsii*) were recorded; and

- Soft sediment habitat, as identified by remote video ranged in type and spatial extent across the survey area. Coarse sediment, shell hash and whole shell was common immediately adjacent rocky reef habitat and in the main channel area west of Matiatia and Owhanake Bays'. Coarse shell and whole shell habitats were typically associated with diverse encrusting communities, e.g., sponges and algae. With increasing depth soft sediment habitat transitioned into finer sand and mud. These gradients in soft-sediment habitat types are depicted spatially in Kerr and Grace (2013).

4.5 Suitability of area for no-take marine reserves

Based on the findings of the current first-order biological survey, the area encompassing the north-western region of Waiheke Island encompassing PMRs 1, 4, and 4A (see Figure 1.1) would be suitable for no-take (Type-1) marine reserves. Within the context of Waiheke Island and inner Hauraki Gulf the area has the following attributes:

- Diversity of physical habitats (open coast, embayments, intertidal and subtidal rocky reef and soft sediment habitats);
- High macroalgal biodiversity;
- Complex subtidal rocky reef;
- High sessile invertebrate diversity (Hakaimango Point – see Smith 2004);
- Range of biogenic habitats (this study; Smith 2004; Kerr and Grace 2013);
- The area is considered as being highly productive. Both the western and north-western areas of the Waiheke Coastline experiences very high recreational fishing effort, which has increased over the last 5-6 years and snapper catch is especially high within the Motuihe Channel region.

Benefits of having parts of the north-western coastline of Waiheke Island as a no-take marine reserve include:

- Supporting and enhancing conservation values and aspirations on Waiheke Island;
- Protection of high-quality habitat within the inner Hauraki Gulf;
- Providing a refuge from line-fishing, spear-fishing, and dredging within the inner Hauraki Gulf. Typically this area of the Hauraki Gulf experiences some of the greatest fishing pressure;
- Allowing for recovery of spiny rock lobster *Jasus edwardsii* populations;
- Protection of scallop beds;
- Protection of a diverse range of soft sediment habitats and associated biological communities; and,
- Enhanced larval export due to the strong tidal currents associated with the western and northern region of the reserve (see Chiaroni *et al.* 2010; Seasketch 2016).

Boundary lines

The boundary lines and collective size of PMR 1 would be adequate to protect the variety of species that occur along this stretch of the Waiheke Island coastline through protection of multiple physical and biological habitats including those likely to be important for settlement and on-growth for many species. The majority of the criteria for effective marine reserve protection suggested by Edgar *et al*. (2014) would be met within the currently proposed marine reserve area. Extending the reserve to include or be within close proximity to the proposed Noises Island Marine Reserve that contains additional biogenic habitat of importance, particularly dog cockle *Tucetona laticostata* beds (see Dewas 2008) would be of value.

For proposed marine reserves 4 and 4A due to their large boundary to area ratio and the small size of the reserves themselves (combined), extending the eastern boundary of 4A further offshore and east to Thompsons Point would increase the functionality of the reserve in terms of increasing protection-related benefits for larger mobile species and ensuring that additional biogenic sponge habitat as identified by Kerr and Grace (2013) would be protected. The extensive urchin barrens habitat conspicuous along this section of coastline would undoubtedly persist until numbers of larger predators such as snapper and lobster increased markedly a scenario that would be unlikely considering the currently proposed boundaries. That being said, currently proposed boundaries would still protect high-quality biogenic habitat including shallow-water macroalgal beds and sessile invertebrate communities.

4.6 Evaluation of proposed southern Waiheke marine reserves 2 and 3

Proposed Marine Reserve 2

Due to both its position and size, protection-related effects for PMR 2 would likely be analogous to those within Te Matuku Marine Reserve. PMR 2 is predominantly subtidal muddy sand with rocky reef limited in spatial extent and depth i.e., < 5m. The gaps analysis study recommended modifications to the proposed boundary to enhance biodiversity through the extension of the western boundary to include Te Whau Bay, Oakura Bay and their associated Islands immediately offshore. This area of coastline contains unique environments, particularly the sand-spit that extends from Okura Bay out to the Islands that is punctuated by a high diversity of sessile invertebrates (sponges/ascidians) (Dan Breen personal communication).

As for Te Matuku Marine Reserve, the area is unlikely to be overly significant for adult snapper (Compton *et al*. 2002) or lobster (recruitment and substrate limited), therefore to a large extent adult abundance of these species are unlikely to increase rapidly within the reserve. The reasonably natural state of the catchments adjacent the proposed marine reserve is advantageous as there will likely be low to negligible effects from land-based stressors (sedimentation and contaminants associated with runoff). However, due to the high turbidity and high total suspended solids of the wider Tamaki Strait attributable to far-field effects of sediment inputs in the Firth of Thames and Tamaki River, enhancement of productivity and biodiversity is likely to be constrained for some species. Biological sampling of this area is however, warranted and could be initiated as part of a wider citizen-science programme for the Island.

Proposed Marine Reserve 3

Due to its location and size, the sheltered predominantly estuarine environment of PMR 3 would unlikely be effective in protecting highly mobile fish species; however, the benefit from complete no-take protection for this proposed area may lie in the protection of bivalve species that are harvested (cockles and pipi); the protection of important biogenic habitats from disturbance, e.g., dredging; and thus ensuring the provision and protection of nursery habitat.

The main catchments adjacent PMR 3 are typified by light industrial, residential, and horticulture. To some degree these all pose a threat to the ecological integrity of this area of coastline through runoff, particularly stormwater and associated contaminants and sedimentation. Should this area become a reserve then the foreshore areas and areas of the main catchments that remain unvegetated could be enhanced significantly through riparian planting – an initiative that has been widely adopted on Waiheke Island.

PMR 3, like PMR 2 would profit from biological sampling in order to evaluate the abundance and diversity of shellfish beds and the spatial extent of seagrass habitat and help increase our understanding of the proposed area.

For PMR 2 and PMR 3 there is some doubt as to whether these would be effective in protecting highly mobile fish species. The benefit from complete no-take protection for these reserves however, may lie in the protection of bivalve species that are commonly harvested (cockles and pipi); and the protection of important biogenic habitats from disturbance.

4.7 Where to from here?

To date the north-western coastline has been surveyed with side-scan sonar (Kerr and Grace 2013), remote video (Kerr and Grace 2013; this study) and diver surveys (this study). Collectively this information will be sufficient to underpin a proposal for marine reserve protection for the north-western coastline of Waiheke Island. Following on from the data acquisition key steps should include:

- Use information to determine final boundaries for north-western coastline marine reserves;
- Integrate the findings of this study with that of Kerr and Grace (2013);
- Use this information to inform further discussions with the Department of Conservation and wider Waiheke Island community; and,
- Cement pathway forward to achieve marine reserve protection.

Other initiatives that should be undertaken include:

- Undertaking fish sampling using Baited Underwater Cameras along the north-western coastline - this will build on the findings of similar studies done on the southern coastline;

- Evaluating the biological makeup of PMR-2 and PMR-3 - to help better-define reserve boundaries and derive much needed biological inventories. Surveys of these PMRs could be done via local community groups, and citizen science projects together with Waiheke Island High School, paralleling the monitoring that is done within Te Matuku Marine Reserve.

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Appendix 1.0

Table A1. Presence (+) and absence (blank) of main macroalga taxa across sites and among depth strata –north-western coastline Waiheke Island.

Site	Owhanake Bay-east			Hakaimango Bay			Enclosure Bay-outer		
Taxa	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Ecklonia radiata	+	+	+	+	+	+	+	+	+
Carpophyllum maschalocarpum	+	+		+			+		
Carpophyllum flexuosum	+	+	+	+	+	+	+		+
Xiphophora chondrophylla	+			+	+		+		
Hormosira banksii	+			+			+		
Halopteris spp.	+	+	+	+			+	+	
Zonaria turneriana	+	+	+	+	+	+	+	+	+
Colpomenia sinuosa	+							+	
Dictyota sp.			+				+		
Sargassum sinclairii			+						
Ralfsia sp.	+	+					+		
Pterocladia lucida	+	+	+			+	+		+
Curdiea coriacea	+				+		+		
Champia sp.	+			+	+				
Coralline turf	+	+	+						
CCA	+	+	+	+	+	+	+	+	+
Hummbrella hydra			+			+			+
Asparagopsis armata		+	+		+	+			
Plocamium angustum			+			+			+
Gigartina spp		+	+			+			
Caulerpa germinata		+	+			+			
Codium convolutum	+			+		+			

Table A2. Presence (+) and absence (blank) of main sessile invertebrate taxa across sites and among depth strata –north-western coastline Waiheke Island.

Site	Owhanake Bay-east			Hakaimango Bay			Enclosure Bay-outer		
Taxa	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Tethya burtoni	+	+	+	+	+	+	+	+	+
Tethya bergquistae		+						+	
Ancorina alata		+	+		+	+		+	+
Cliona celata	+	+		+	+		+	+	+
Psammocinia sp1		+	+	+	+	+	+	+	
Psammocinia sp2	+	+	+	+			+	+	
Clathria rubens			+		+			+	
Halicondria moorei		+	+		+	+			+
Callyspongia ramosa			+				+		
Cnemidocarpa bicornuta	+	+	+	+	+	+	+	+	+
Asterocarpa coerulea	+	+		+			+		
Cnemidocarpa nisiotis (novaezelandia)	+	+		+			+		
Aplidium (orange)		+	+	+	+	+	+	+	+
Didemnum(pink)		+	+		+	+			+
Hypsistozoa fasmeriana	+	+	+		+			+	
Sertularia sp.	+	+	+		+	+	+		+
Monomyces rubrum			+			+			+
Culicea rubeola		+	+		+	+			
Actinothoe albocincta	+		+	+		+	+	+	+
orange encrusting bryozoan		+	+			+			
black encrusting bryozoan		+	+			+			+
brown encrusting bryozoan	+			+		+			+

Table A3. Presence (+) and absence (blank) of main mobile invertebrate taxa across sites and among depth strata –north-western coastline Waiheke Island.

Site	Owhanake Bay-east			Hakaimango Bay			Enclosure Bay-outer		
Taxa	Shallow	Mid	Deep	Shallow	Mid	Deep	Shallow	Mid	Deep
Evechinus chloroticus	+	+	+	+	+	+	+	+	+
Stichopus mollis			+			+		+	+
Patriella regularis	+	+	+		+	+	+	+	+
Cookia sulcata	+	+	+	+	+	+	+	+	+
Trochus viridis	+	+	+	+	+	+	+	+	+
Cantharidus purpureus	+	+	+	+	+	+	+	+	+
Turbo smaragdus	+	+		+			+		
Calliostoma punctulatum		+	+	+	+	+	+	+	+
Buccinulum linea	+	+	+	+	+		+	+	
Xymenella spp	+	+		+	+		+	+	+
Cominella quoyana			+		+				
Cominella virgata	+			+			+		
Dicathais orbita	+	+		+			+		

Table A4. Description of biological and physical features of the north-western region of Waiheke Island based on a remote video survey.

Transect #	Biological features	Sediment/physical features
1	Scallops (abundant) Cushion star Sponges/ascidians Worm/shrimp/crab holes conspicuous	Fine sand occasion shell patches Hollows depressions
2	Red turfing algae Sponges/ascidians *Patriella regularis* *Evechinus* on sand	Coarse sediment and shell hash Mega-rippled sand
3	Sponges/ascidians *Patriella regularis* *Coscinasterias murcata* Bivalves unknown	Coarse sediment and shell hash Mega-rippled sand
4	Sponges and ascidians *Atrina zelandica* Patriella Coscinasterias	Whole shell and coarse sediment
5	Sponges and ascidians *Patriella regularis* *Coscinasterias murcata*	Whole shell and coarse sediment /fine mud
6	Tube worms Turfing algae *Patriella regularis* *Coscinasterias murcata*	Coarse sand
7	Worm/shrimp/crab holes conspicuous	Fine sand
8	Sponges/ascidians (common and diverse) *Carpophyllum flexusosm* ' *Ecklonia radiata* *Evechinus* (sparse)	Cobbles, coarse sand
9	Red turfing algae Sponges (common and diverse) *Carpophyllum flexusosm* ' *Ecklonia radiata*	Cobbles, coarse sand
10	Red turfing and foliose algae (high diversity) *Coscinasterias murcata*	Coarse sediment and shell hash
11	Red algal (high diversity) Sponges (high biodiversity)	Coarse sediment and shell hash
12	Sponges/ascidians (erect forms) Infauna abundant Microbenthic algae	Fine sand/mud
13	Sponges/ascidians (erect) Worm/shrimp/crab holes conspicuous Microbenthic algae	Fine sand/mud
14	Sponges/ascidians (erect) Worm/shrimp/crab holes conspicuous Microbenthic algae	Fine sand/mud
15	Worm/shrimp/crab holes conspicuous	
16	Sponges/ascidians (erect) Worm/shrimp/crab holes conspicuous Scallops (sparsely distributed) *Patriella regularis* *Coscinasterias murcata*	High biodiversity Fine sand and shell hash transitioning into coarse sand Hollows depressions
17	Sponges/ascidians (erect) Worm/shrimp/crab holes conspicuous	High biodiversity Coarse sand and shell hash Hollows depressions

	Scallops (sparsely distributed) *Patriella regularis* *Coscinasterias murcata*	
18	Worm/shrimp/crab holes sparse	Fine sand
19	Turing red algae Sponges (common and diverse) *Carpophyllum flexusosm* ‘ *Ecklonia radiata*	Bedrock, rock rubble Cobbles, coarse sand
20	Turing red algae Sponges (common and diverse) *Carpophyllum flexusosm ‘* *Ecklonia radiata*	Bedrock, rock rubble Cobbles, coarse sand
21	Turing red algae Sponges (common and diverse) *Carpophyllum flexusosm ‘* *Ecklonia radiata* *Evechinus chloroticus*	Bedrock, rock rubble Cobbles, coarse sand
22	Infauna Microbenthic algae Bivalves – unknown	Fine sand and mud
23	Scallops (sparsely distributed) *Patriella regularis* *Coscinasterias murcata* Microbenthic algae Sponges – diverse Worm/shrimp/crab holes	Fine sand transitioning into shell hash
24	Sponges Red turfing algae/green algae *Ecklonia radiata*	Rocky reef – high diversity 16:02
25	Sponges Red turfing algae/green algae *Carpophyllum flexuosum*	Rocky reef – high diversity 16:02
26	Tube worms and red algal beds Sponges (Chaetopterus) *Patriella regularis* *Coscinasterias murcata* *Evechinus chloroticus*	Coarse sand and shell hash
27	*Ecklonia radiata* and sand	Rocky reef and sand
28	Red foliose algae	Coarse sand and shell hash
29	Sponge red algae *Carpophyllum/ Ecklonia*a	Bed rock coarse sand
30	Sponge red algae *Carpophyllum/ Ecklonia*a	Bed rock
31	Sponge red algae *Carpophyllum/ Ecklonia*a	Coarse sand and sediment and rock rubble
32	Sponge red algae *Carpophyllum/ Ecklonia*a	Coarse sand and sediment and rock rubble transitions into bed rock
33	Sponge red algae *Carpophyllum/ Ecklonia*a	Coarse sand and sediment and rock rubble transitions into bed rock
34	Sponge, turfing red algae *Carpophyllum*/*Ecklonia* in shallow Urchin barrens	Coarse sand sediment Rock rubble transitions into bedrock with decreasing depth
35	Sponge, turfing red algae *Carpophyllum/ Ecklonia* in shallow	Bedrock transitions into coarse sand followed by fine sand.
36	Worm/shrimp/crab holes conspicuous Scallops (sparsely distributed) *Patriella regularis* *Coscinasterias murcata*	Fine sediment and patches of coarse sand
37	Worm/shrimp/crab holes conspicuous Scallops (sparsely distributed) *Patriella regularis* *Coscinasterias murcata*	Fine sediment and patches of coarse sand