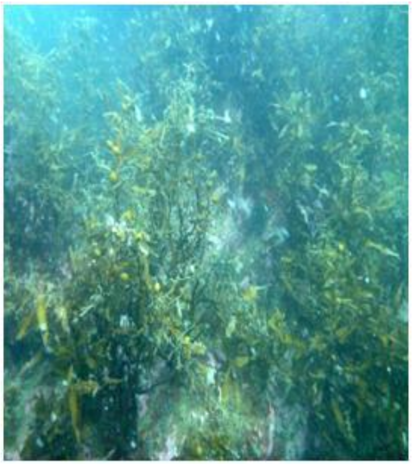
Waiheke Island Marine Reserve Network - Gaps Analysis and Feasibility Study



A report prepared for Waiheke Island Local Board

and Hauraki Gulf Conservation Trust

by

Tim Haggitt

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Executive Summary

- Five proposed no-take marine reserves (PMRs) that encompass southern, northern, and north-western sections of the coastline of Waiheke Island situated within the central Hauraki Gulf have been proposed by the Waiheke Local Board in association with the Hauraki Gulf Conservation Trust. It is anticipated that proposed marine reserves will not only form a localised network for Waiheke Island, but also compliment the protection benefits of existing marine reserves within the wider Hauraki Gulf Marine Park.

- The five proposed marine reserves are:

  1) PMR 1 (2,519.1 ha). Matiatia Harbour southern headland around to the western point of Oneroa Bay (Hakaimango Point) to a distance of 3 km stretching northwards;
  2) PMR 2 (1,048.6 ha). From the point at the end of the Te Whau Peninsula to the eastern headland of Whakanewha Bay extending south until the western corner abuts the Waiheke Local Board boundary.
  3) PMR 3 (123.06 ha). Anzac Bay from the point at the end of Wharf Rd across to the eastern end of Okoka Bay.
  4) PMR 4 (23.3 ha). Little Oneroa from the rocky outcrops between Oneroa and Little Oneroa, around to Fisherman's Rock.
  5) PMR 4A (170.3 ha) Fisherman's Rock to the western arm of Palm Beach.

- This central focus of this study was to: Identify the type of marine habitats and species contained within each PMR; Provide comment on the state of marine vegetation and potential for regrowth; Identify any biogenic habitats present and evaluate potential ecosystem productivity; Evaluate species present and potential for future species protection; Evaluate potential for spawning, larval dispersal and protection of juveniles (species-specific); Recommend ideal size and boundary lines to optimise long-term abundance; Describe the terrestrial interface bordering each proposed marine reserve; and, Identify gaps in the knowledge base. Due to the small size of PMR 4 it was combined with adjacent PMR 4A when evaluating the aforementioned attributes.

- In order to identify gaps in the knowledge base for each PMR, a desktop study was undertaken. Summary ecological datasets for Waiheke Island were available through Seasketch (2016), unpublished Auckland Council remote sensing data, together with a wide range of technical reports and scientific studies that contained relevant information. For all proposed marine reserves, broad-scale data were available for dominant physical and biological habitats; however, there was often little accompanying quantitative data.

- Based on the evaluation, it is likely all PMRs would have some merit in being designated as full no-take marine reserves, i.e., Type 1, but will likely achieve very different conservation outcomes. PMR1 and PMR 4 and 4A (combined) would have the best chance of protecting legal-sized species such as snapper and lobster. This is due to their location, and variety of habitat types contained within, but each would profit from extension of offshore boundaries. For PMR 4 and 4A the eastern boundary would need to be substantially bigger to eliminate likely edge effects. For PMR 2 and 3, protection-related benefits for fished species are less clear. Due the occurrence of horse mussel beds (PMR 2) and seagrass (PMR3) they are potentially important in enhancing fisheries and as juvenile settlement and nursery areas.

- For all PMRs in this study, focused quantitative sampling should be done to bridge information gaps pertaining to species occurrence within each PMR and evaluate further what species are commonly targeted (shellfish, fin-fish) and whether they would likely benefit from marine reserve protection.

- At this incipient stage focussing effort on the northern PMRs (1, 4 and 4A) would be prudent. To obtain quantitative data on habitats and species depth-stratified sampling within subtidal rocky reef habitat in tandem with surveying subtidal soft-sediment habitat to identify and confirm the presence/absence of biogenic habitat would be of value. Intertidal sampling of rocky reef and soft sediment habitats is also warranted and should strongly involve local community and school groups.

- Equally, there is merit in understanding the connectivity of the proposed networks in terms of larval supply beyond reserve boundaries and across the wider network. This may highlight additional benefits of the proposed areas being designated as no take marine reserves.

- Ultimately any new information will be used to underpin a much stronger application for additional marine reserve protection for Waiheke Island.

Contents

1.0 Introduction

1.1 Preamble

This report is focused on identifying gaps in the knowledge base with respect to 5 proposed no-take marine reserves that encompass southern, northern, and western sections of the coastline of Waiheke Island situated within the central Hauraki Gulf. The Waiheke Local Board in association with the Hauraki Gulf Conservation Trust desires to advance the establishment of these marine reserves (Fig.1) to form a localised reserve network around Waiheke Island.

The five areas that have been initially proposed as full no-take reserves (Type 1 as defined by MPA Policy) include:

1. Proposed MPA 1 (2,519.1 ha). Matiatia Harbour southern headland around to the western point of Oneroa Bay (Hakaimango Point) to a distance of 3 km stretching northwards. The board proposes that this marine reserve covers the full 3 km northwards and may, by negotiation, with the Noises Islands Family Trust, continue to the Noises Island.
2. Proposed MPA 2 (1,048.6 ha). From the point at the end of the Te Whau Peninsula to the eastern headland of Whakanewha Bay extending south until the western corner abuts the Waiheke Local Board boundary.
3. Proposed MPA 3 (123.06 ha). Anzac Bay from the point at the end of Wharf Rd across to the eastern end of Okoka Bay.
4. Proposed MPA 4 (23.3 ha). Little Oneroa from the rocky outcrops between Oneroa and Little Oneroa, around to Fisherman's Rock
5. Proposed MPA 4a (170.3 ha) Fisherman's Rock to the western arm of Palm Beach. In order to preserve rock fishing and shellfish gathering, the board proposes that the collective marine reserve begins 20 m from the shoreline, commencing at Fisherman's Rock (the eastern arm of Little Oneroa Beach and the start of area 4a).

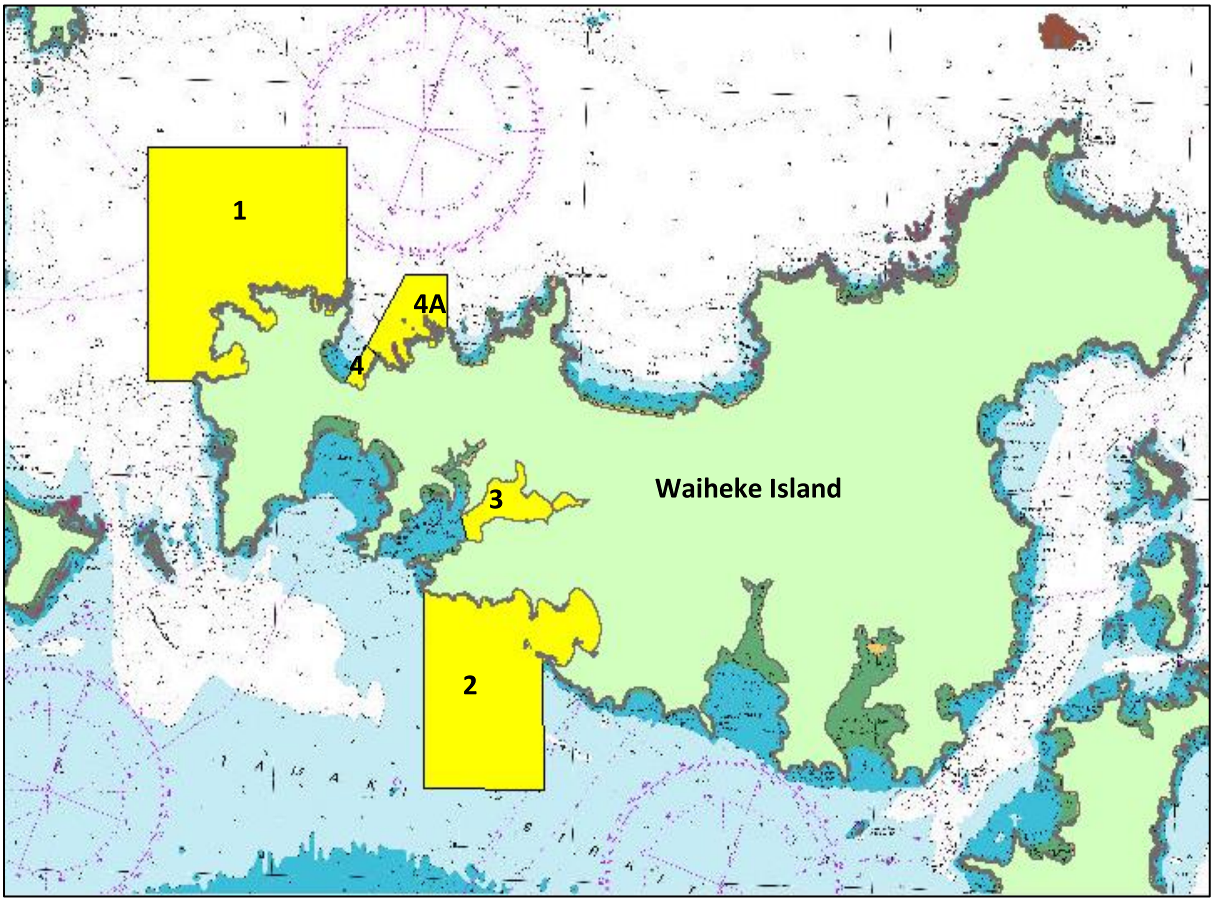

Figure 1. Location of 5 proposed marine reserves surround Waiheke Island proposed by the Waiheke Island Conservation Trust.

1.2 Report Structure

This report is divided into eight main sections that include:

Section 2: Hauraki Gulf background information and overview;

Section 3: Marine reserve network design principles;

Section 4: Key conservation goals and values pertaining to marine reserve protection;

Section 5: Gaps analysis methodology;

Section 6: Proposed marine reserve evaluation;

Section 7: Identification of information gaps; and,

Section 8: Discussion

2.0 Background Information

2.1 Hauraki Gulf

The Hauraki Gulf situated on the east coast of the North Island of New Zealand, is approximately 13,900 km^2 in extent with a coastline estimated at 2550 km in length. Its coastline frames part of New Zealand's largest urban centre and has been a focal area of importance from the early days of Māori arrival to New Zealand (Peart 2007). The Gulf is typified by a wide range of estuarine and marine habitats across its mainland and many Islands. Much of the Hauraki Gulf has been impacted through either exploitation of its natural resources, or development and intensification of its coastal catchments and associated effects e.g., habitat loss, sedimentation, nutrient enrichment, increase in pollutants and contaminants.

It has been long established that physical and biological habitats change considerably moving from the outer to inner Hauraki Gulf, primarily due to reduced wave action, increased turbidity, and reduction in the depth distribution of rocky reef habitat - predominantly along Auckland's mainland coast (Grace 1983; Walker 1999; Smith 2004, 2006; Shears 2013). The work of Grace (1983) was among the first to describe the variation in subtidal rocky reef. In addition to macroalgae, a range of rocky reef and soft sediment benthic invertebrates show accordance with this gradient either decreasing or increasing in abundance from inner to outer regions of the Gulf (Smith 2004, 2006; Shears 2013).

Water quality within the outer and central Hauraki Gulf is strongly influenced by oceanic inputs (ocean driven), whereas the southern region and Firth of Thames is largely catchment driven. The combined river inputs that drain the Hauraki Plains is the major source of sediment and nutrient input into the Gulf with sediment-related effects extending throughout the Firth of Thames and into the Tamaki Strait (Hadfield *et al*. 2014). Sediment inputs from other riverine catchments (e.g., Mahurangi Harbour, Tamaki River) while eminent, tend to invoke localised effects. Total suspended solids (TSS) in coastal waters measured by Auckland Council for 19 permanent monitoring coastal sites spanning the eastern coastline and presented in the 2014 State of the Hauraki Gulf report, indicated that 14 sites exhibited deteriorating trends in TSS between 2013 and 2014 with highest TSS recorded from the Waitemata Harbour, Tamaki River, and Mahurangi Harbour.

Interestingly, within the Auckland region, coastal nutrients are reported to be largely declining (State of the Hauraki Gulf Report 2014), yet concentrations within the Tamaki River and upper Waitemata Harbour remain elevated. Data are lacking for the Coromandel coastline and Firth of Thames region of the Gulf as coastal nutrients are not monitored by the Waikato Regional Council, although it is reported that elevated nutrient inputs into the Firth of Thames are resulting in acidification and oxygen lags in the southern region of the Gulf (Zeldis *et al*. 2014).

2.2 Management of the Hauraki Gulf

The Hauraki Gulf is one of New Zealand's coastal environments that has been under extensive planning scrutiny over the last few decades. Recognising the need for better integrated management of the wider Hauraki Gulf ecosystem, formal management of the Gulf began with the establishment of the Hauraki Gulf Marine Park Act (2000) which had the purpose of:

- Integrating the management of the natural, historic, and physical resources of the Hauraki Gulf, its islands, and its catchments;
- Establishing the Hauraki Gulf Marine Park;
- Establishing objectives for the management of the Hauraki Gulf, its islands, and catchments;
- Recognising the historic, traditional, cultural, and spiritual relationship of the tangata whenua with the Hauraki Gulf and its islands; and,
- Establishing the Hauraki Gulf Forum (HGF), which promotes and facilitates integrated management and the protection and enhancement of the Hauraki Gulf.

The HGF's current directive is focused on five priority response areas: 1) regenerating areas; 2) enhanced fisheries'; 3) mana whenua integration; 4) active land management; and, 5) knowledge utilisation. Every three years, the HGF reports on the current state of the Hauraki Gulf Marine Environment. The most recent of these presented in 2014 suggested that the wider Hauraki Gulf ecosystem is suppressed due to the effects of multiple land-based stressors such as sedimentation, nutrient enrichment, and sustained fishing pressure. With a projected increase in Auckland's population to 2 million by 2030 these pressures are unlikely to abate.

As fishing occurs in most parts of the Gulf it has historically and continues to have one of the greatest influences on the Gulf's marine ecosystem, with available data suggesting that current levels of snapper (*Pagrus auratus*) and spiny rock lobster (*Jasus edwardsii*) populations have been reduced by around 70% to 80% with the greatest loss of large, old, individuals (State of the Hauraki Gulf report 2014). In addition, the State of the Hauraki Gulf report (2014) stressed that population levels required to restore the ecosystem functions of fished species have not been evaluated in any management strategy; effects of fishing types/methods on seabed communities have not been included in fisheries stock evaluations; effects of both trawling and scallop dredging that occurs in areas that contain sensitive marine habitats to date have not been adequately addressed; and, lastly that little progress has been made towards enhancing fisheries or the creation of new marine protected areas (MPA).

In 2013, Sea Change (Tai Timu Tai Pari) was established in an effort to spatially manage the Hauraki Gulf and improve its ecology, economy, and health; a mandate will be achieved in part through improved understanding of the pressures on the Hauraki Gulf, and developing long-term solutions to reduce them. It is anticipated the Sea Change process will achieve the vision of a vibrant, resilient, and prosperous ecosystem.

Much of our understanding of the Hauraki Gulf ecosystems has stemmed from Auckland Council funded monitoring of soft sediments communities (Hailes *et al*. 2012; Haliday *et al*. 2012; Hewitt and Simpson 2012) and rocky reef (Shears 2013). More recently, in an effort to better comprehend changes that have occurred within the Hauraki Gulf as a result of human occupation and resource exploitation, MPI has commissioned a series of studies focussed on the reconstruction of historic ecosystem states within the greater Hauraki Gulf, so that ecosystems of importance can be identified, better understood and thus, managed accordingly (Pinkerton *et al*. 2015; MacDiarmid *et al*. 2016). Pinkerton *et al*. (2015)

modeled changes to the food web and identified the trophic importance for different historical epochs (present day; 1950's prior to industrial-scale fishing; 1790 late Maori phase before sealing and whaling; 1500 early to middle pre-European Maori; and, 1000 prior to human settlement). For the present day scenario in decreasing order of importance were phytoplankton, macrobenthos (small crustaceans and worms, e.g., polychaetes), mesozooplankton, bivalves, and snapper. Stemming from this study, MacDiarmid *et al*. (2016) recommend that management of the Hauraki Gulf should ensure that these trophic groups are protected, monitored, and better understood from the perspective of ecosystem resilience; that middle trophic groups are better understood in terms of their abundance, distribution, and ecological resilience within the Gulf; and, that the effects of recovery for higher trophic groups that have been made locally extinct is understood from an ecological and management viewpoint. For many marine habitats there is a poor understanding of their biodiversity and role in supporting species and fisheries production (Morrison *et al*. 2014b).

2.3 HGMP Marine Reserves

Five no-take (Type 1) marine reserves occur within the Auckland regional boundary of the HGMP. From oldest to newest these are: Cape Rodney to Okakari Point Marine Reserve (CROP, est. 1975 – 518 ha); Tawharanui Marine Reserve (TMR, – est. 1981 – 588 ha)[1]; Long Bay-Okura Marine Reserve (est. 1995 – 980 ha); Motu Manawa (Pollen Island); Marine Reserve (est. 1995 – 500 ha); and, Te Matuku Marine Reserve (Waiheke Island est. 2005 – 690 ha). One marine reserve occurs within the Waikato regional boundary of the HGMP, Te Whanganui-a-Hei (Hahei) Marine Reserve (est. 1993 – 680 ha). Of these, 3 are truly marine (CROP, TMR, Hahei); 2 have estuarine and marine habitats (Long Bay-Okura, Te Matuku), with Motu Manawa located within Waitemata Harbour and sharing both estuarine and marine elements. Each marine reserve has its own conservation merits and collectively they protect a diverse range of habitats across a wide range of exposure scales, yet only equate to 0.3 % of the HGMP being fully protected.

To varying degrees, temporal monitoring of habitats (rocky reef communities) and select species vulnerable to fishing (snapper, reef-fish, lobster) has been undertaken with CROP and TMR (Sivaguru 2007; Haggitt *et al*. 2014); Hahei (Haggitt *et al*. 2006-2016) and Long Bay-Okura marine reserves (Haggitt and Shears 2011; Shears 2013), whereas data for Motu Manawa and Te Matuku are relatively sparse or remains unpublished.

2.3.1 Responses of targeted species and marine habitats following no-take protection

Due to often rapid increases in abundance and size of both snapper and lobster following marine reserve protection in north-eastern New Zealand (see Freeman *et al*. 2012; Willis 2013) these two species are typically used as the "poster-species" promoting the benefits of no-take marine reserve protection. Both are considered iconic species and hold immense value/taonga for all fisheries sectors (customary, recreational, and commercial). Responses of targeted (fished) species and benthic habitats following complete no-take protection have been examined within the context of direct and indirect effects at both global (Babcock *et al.* 2012; Edgar *et al*. 2014) and national scales (Babcock *et al.* 1999; Shears and Babcock 2003; Freeman *et al*. 2012; Willis 2013). Babcock *et al*. (2010) suggest that direct effects on fished (target) species are likely manifest on average 5.13 ± 1.9 years following protection.

[1] Prior to 2011, Tawharanui Marine Reserve was known as Tawharanui Marine Park and managed by Auckland Council and the Department of Conservation. The management of the reserve is now the sole responsibility of DoC.

Conversely, indirect effects on other taxa and habitats (particularly macroalgae) can be much longer at approximately 13.1 ± 2.0 years, mediated through cascading trophic interactions (top down) principally associated with increased predation on herbivores (urchins and molluscs) (Shears and Babcock 2002, 2003; Langlois *et al*. 2005; Shears *et al*. 2006). High rates of predation, particularly on the urchin, *Evechinus chloroticus* (kina) has been demonstrated to lead to increased diversity, abundance, and biomass of macroalgae (fucalean species and *Ecklonia radiata*). Predation-related effects on bivalves due to greater lobster predation may also extend to soft sediment habitats adjacent rocky reef habitats leading to reduced abundance of bivalve species (Langlois *et al*. 2005).

Snapper (*Pagurus auratus*)
Snapper recovery in north-eastern New Zealand marine reserves (CROP; TMR and Hahei), quantified using baited underwater video (see Willis and Babcock 2000) has demonstrated marked increases in legal sized (≥ 270 mm FL) individuals being on average 14.3 times more abundant than in fished areas. While pre-protection abundance estimates were unavailable for these three reserves, sampling of the Poor Knights Island marine reserve (est. 1981 – 2,800 ha) prior to and after protection, measured a 300% increase in legal-sized snapper within the first year of protection and snapper numbers were 8.3 times higher the than control sample area 3 years following protection demonstrating very rapid recovery. Generally, because snapper are a highly mobile species and heavily targeted by customary, recreational, and commercial fishers, responses of snapper to marine reserve protection may be variable through space and time.

For snapper, the Hauraki Gulf has regularly been the backbone of the SNA 1 fishery comprising the largest biomass and producing the largest commercial and recreational harvest (Walsh *et al*. 2013; Parsons *et al*. 2014). The inner Hauraki Gulf has long been recognised as an important spawning and recruitment area (Cassie 1956; Francis 1994, Francis *et al*. 1995 Zeldis and Francis 1988; Zeldis *et al.* 2005) and there has been a strong focus on understanding snapper movement patterns relative to fisheries dynamics within the Hauraki Gulf since the late 1960s. The incipient tagging work of Paul (1967) and Crossland (1982) established that generally snapper do not move long distances within the Hauraki Gulf, the majority being resident in a particular area and making only localised movements associated with feeding and spawning, although individuals have been known to make long distance migrations away from the Gulf > 400 km. Movements from outer to inner parts of the Gulf appear strongly-linked to water temperature and spawning activity. Further, tagging studies have suggested that SNA 1 is comprised of three separate biological sub-stocks: east Northland, Hauraki Gulf, and Bay of Plenty with mixing occurring between the Hauraki Gulf and the BoP stock and is often treated as one stock in modelling scenarios (Walsh *et al*. 2013).

Pagrus auratus tagging studies undertaken in and around CROP reserve have described snapper movement in relation to protection identifying high site fidelity for some individuals, (but this may not be universal), as well as variable habitat utilisation within the reserve (Egli and Babcock 2004). More recently, Parsons *et al*. (2010) has provided valuable reserve and non-reserve comparisons for snapper. In that study, non-reserve snapper were found to have larger home ranges and utilised more than one main area (bi-modal home ranges), whereas reserve snapper had higher site fidelity with only one main area of use (uni-modal home ranges). Two central explanations given for such differences included: 1) increased shelter offered by higher abundance of *Ecklonia radiata* inside CROP reserve; and, 2) that snapper inside CROP reserve may be subject to different rates of fishery induced selection due to their different movement behaviour, i.e., because individuals within the centre of the reserve were less likely to cross the reserve boundary (high site fidelity), probabilistically they were less likely to be removed by fishing activities (see Parsons *et al*. 2010).

Spiny rock lobster (*Jasus edwardsii*)

Freeman *et al*. (2012) compared rates of recovery of the spiny rock lobster *Jasus edwardsii* from eight New Zealand marine reserves for up to 34 years of protection. Inter-reserve responses were identified as being highly variable (as for snapper) and often location-specific, with several reserves demonstrating immediate increases in population abundance and biomass within 1-2 years of protection, several having negligible initial increases followed by a sudden augmentation after 5-6 years of protection, while others reserves displayed significant declines following initial periods of increased abundance. Supplementary analysis of life history stages inferred that marine reserves located in areas with initial high densities of juveniles tended to have rapid recovery and that variability in recovery trajectories across reserves evaluated was likely related to supply of recruits with recruitment being a key driver of lobster recovery.

In addition to increased abundance and biomass of fished species, as a general rule recovered populations of fished species are more stable in reserves than in fished areas, suggesting increased ecological resilience. This is an important benefit of marine reserves with respect to their function as a tool for conservation and restoration (Babcock *et al*. 2010). However, populations protected within reserves are not immune to fishing related effects where rocky reef habitat extends beyond the reserve boundary (Freeman *et al*. 2009), or reserve boundaries are not large enough to protect the full adult movement range of lobster (Kelly *et al*. 2001, 2003). Recent monitoring results suggest that boundary fishing may be negatively impacting lobster numbers in both CROP and TMR for this very reason (Haggitt *et al*. 2014).

2.4 Waiheke Island

Waiheke Island is located within the central Hauraki Gulf separating the mid Gulf and Firth of Thames northern boundary. Waiheke Island is bounded to the west by Motutapu and Motuihe Islands forming the Motuihe Channel and to the south-east by Pakatoa, Rotoroa, and Ponui Islands forming the Waiheke Channel. It is the largest Island within the central Hauraki Gulf and second largest within the HGMP with approximately 133 km of coastline. It is the most inhabited of all Hauraki Gulf Islands with a population of 8,340 (2013 Census). The coastline is considerably varied comprised of a variety of physical habitat types that reflect exposure regimes and localised oceanographic climates. The northern coastline is more wave exposed relative to southern, western, and eastern regions and is punctuated by small embayments, sandy beaches, extensive intertidal rocky coastline and deep subtidal rocky reef. The southern coastline (Tamaki Strait) is characterised by rocky coastline, shallow subtidal rocky reef, and complex headlands that frame small and large sheltered embayments, and contains a variety of estuarine areas (Awaararoa Bay, Te Matuku Bay). Similarly, eastern and western coastlines are predominantly rocky also intersected with small and larger embayments, with channel regions typified by high tidal currents. Relative to the outer Hauraki Gulf which is semi-exposed, collectively the Waiheke Island coastline ranges from moderately sheltered to very sheltered.

Due to its central position within the Gulf, a distinct turbidity gradient exists with high turbidity along the southern, western, and eastern coastlines influenced by the Tamaki River, Wairoa embayment and far-field effects of sediment inputs stemming from the Firth of Thames. In contrast the northern coastline is reported to have higher water clarity (Auckland Council 2014). Tidal currents are particularly strong within the Motuihe Channel (western coastline) and Waiheke Channel (eastern coastline).

2.4.1 Land use

Soils of Waiheke Island are principally fine grained with clay and clay loam that overlay sand and sandstone and deeply weathered greywacke rock. Much of Waiheke Island was actively logged in the late 1800's and converted to exotic pastureland. Today, large areas of regenerating manuka/kanuka exist predominantly along the southern coast and headlands. Modified land use ranges from residential to light commercial and industrial that blankets much of the western Waiheke landmass between Oneroa and Onetangi with small pockets of horticulture, viticulture, and exotic forest scattered across the Island. The majority of the island is classified as high producing exotic grassland.

2.4.2 Te Matuku Marine Reserve

Te Matuku marine reserve is located on the southern coastline of the Island (686 ha). The boundaries include the entire Te Matuku estuary with the western boundary extending from the western headland of Whites Bay out into the Waiheke Channel. The offshore southern boundary extends to Kauri Point on Ponui Island with the eastern boundary to Otakawhe Bay and encompasses Passage Rocks. Established in 2005, the reserve contains ecologically significant estuarine vegetation (saltmarsh, and mangroves) that form complete ecological sequences. Other prominent habitat types include a large sand-spit at the mouth of Pearl Bay, intertidal and subtidal rocky reef, and large expanses of intertidal and subtidal soft sediment (mud and sandy mud). It is described by Enderby and Enderby (2005) as the largest and most undisturbed estuary on Waiheke Island. Sediment deposition and increased muddiness of the estuary through time has been hypothesised to be partially due to its proximity to Wairoa embayment (Hewitt *et al*. 2009).

With the exception of surveys undertaken by local school groups, monitoring data for Te Matuku marine reserve is limited in temporal extent. Based on *ad hoc* studies further data exists for intertidal biota (Haywood *et al*. 1997); infaunal species diversity, abundance and corresponding sediment texture/grain size (3 surveys – DoC *unpublished data 2005*); and fishes (2 surveys – DoC *unpublished data in 2009 and 2011*). The survey of Haywood *et al.* (1997) identified Ninety-seven Mollusca (7 chitons, 52 gastropods, 38 bivalves), 33 Crustacea (8 amphipods, 4 barnacles, 18 decapods) 10 Echinodermata (3 echinoids, 3 asteroids, 3 ophiuroids, 1 holothurian), 21 Polychaeta and the majority of these species were recorded in the Department of Conservation's 2005 survey.

Fish abundance and diversity was quantified in 2009 and 2010 utilising drift underwater video (Breen *et al. unpublished data*) and evaluated abundance and diversity against primary and secondary substratum types. Collectively, the DUV surveys identified 13 fish species within Te Matuku marine reserve (Table 1) with dominant species including snapper, jack mackerel, anchovies, and kahawai. There was a weak but positive correlation between species diversity and habitat complexity. Snapper enumerated ranged from 26-350 mm fork length (FL), with the majority < 200 mm (1-2 years old), findings which aligns with onteongenic-habitat relationships identified by Compton *et al*. (2012) for this species.

Table 1. Fish species recorded within Te Matuku Marine Resave based on dropped underwater video (DUV) surveys undertaken in 2009 and 2011.

Species	Species name	Total count
Snapper (SNA)	*Pagrus auratus*	124
Jack mackerel (JMA)	*Trachurus novaezelandiae*	63
Anchovies (ANC)	*Engraulis australis*	24
Kahawai (KAH	*Arripis trutta*	16
Goatfish (RMU)	*Upeneichthys lineatus*	8
Trevally (TRE)	*Pseudocaranx dentex*	4
Flounder sp. (FLA)	*Rhombosolea plebeia*	4
Red cod (RCO)	*Pseudophycis bachus*	3
Pilchard (PIL)	*Sardinops neopilchardus*	2
Spotty (STY)	*Notolabrus celidotus*	1
Yellow eyed mullet (YEM)	*Aldrichetta forsteri*	1
Conger eel (CON)	*Conger verreauxi*	1
Red scorpion fish (RRC)	*Scorpaena* sp.	1

3.0 Marine Reserve network design principles

An increase in the number and age of marine protected areas (MPAs) both nationally and globally (> 25 years for many) has allowed evaluation and comparison of responses over multiple temporal and spatial scales. Recently, the synthesis of data obtained through monitoring has facilitated analysis and commentary on protection-related effects for species and habitats, extending to broader design principles and MPA networks Seminal reviews include those of Babcock *et al*. (2010); Willis (2013); Edgar *et al*. (2014); Jackson (2014); and, Thomas and Shears (2014). Several have a focus on providing timescales with respect to direct and indirect responses and using these to establish key criteria to ensure MPAs are able to meet various conservation goals and aspirations.

The review of Thomas and Shears (2014) provides a comprehensive evaluation of NZ MPA Policy guidelines (2005) against international guidelines and provides additional recommendations to align the NZ MPA Policy guidelines with those. Some of the key recommendations for effective MPA network design as defined in that study include:

1) All habitats are represented in the network. The appropriate habitat classification should match the spatial scale of the conservation planning efforts and ecosystem processes should be represented.

2) Enough of each specific habitat should be included in the network to be functionally protected.

3) MPAs should be large enough to cover the majority of species adult movement distances. Based on case studies it is recommended that MPAs have a minimum coastline length of 5-10 km, preferably 10-20 km, and should extend along the depth gradient from intertidal to deeper offshore waters (preferably to the 12 nautical mile limit).

4) Several examples of each habitat should be included within separated MPAs. A precautionary number of replicates would be 3, with 2 habitat replicates being the minimum.

5) The spacing between MPAs should allow larval dispersal to occur. It is recommended that MPAs, with similar habitats where possible, should be placed within 50-100 km of each other.

In his recent commentary and identification of a network of MPAs for the wider HGMP, Grace (2014) reiterates the views of Thomas and Shears (2013) with respect to representation, replication and connectivity adding that MPAs within the HGMP should be permanent and of sufficient quantity arguing for > 10 % of the HGMP as Type 1 MPAs.

A global review Edgar *et al*. (2014) suggest that MPAs may be unsuccessful to reach their full conservation and restorative potential as a consequence of factors such as illegal harvesting, regulations that legally allow detrimental harvesting (partial take), or emigration of animals outside boundaries because of continuous habitat or inadequate size of reserve. Resultantly, 5 key planning and management attributes are provided as a framework to achieve better MPA network design and conservation outcomes. These are: (1) degree of fishing permitted within MPAs; (2) level of enforcement; (3) MPA age; (4) MPA size; and, (5) presence of continuous habitat allowing unconstrained movement of fish across MPA boundaries. It is argued that conservation outcomes increase exponentially when reserves are no-take; well enforced; >10 years old; >100 km^2; and are isolated by deep water and/or sand.

4.0 Key conservation goals and values pertaining to the network of no-take marine reserves around Waiheke Island

Auckland’s population is projected to increase by 500,000 people to reach almost 2 million by 2038. (MacPherson 2015). Presumably this will not only add considerable pressure to Auckland’s aging infrastructure but also to coastal environments and the resources within. Considering the conclusions that have stemmed from the 2014 State of the Hauraki Gulf report it is clear that further protection such as that afforded by no-take marine reserves alongside habitat restoration is required within the wider Hauraki Gulf.

A survey of the general public of Waiheke Island commissioned by the Waiheke Island Local Board (Bing 2015) indicated that there was general support for further marine protected areas along the Waiheke coastline. The proposed MPA network put forward by the Local Board seeks to create a localised network of marine reserves around Waiheke Island that invariably would add to the existing MPA networks already in existence with the HGMP. Key conservation goals and values associated with the proposed marine reserve network include:

- Protection, maintenance and enhancement of marine biodiversity;

- Increasing the density, size, biomass and reproductive output of commonly exploited species;
- Maintenance of population stability and strengthening of both species and ecosystem resilience against common stressors, e.g., sedimentation, climate change.
- Protection of important biogenic habitats;
- Protection and maintenance of ecological function;
- Provide baseline data from, which threats to the Waiheke Island marine environment can be identified and managed accordingly Monitoring tool;
- Educational purposes.

5.0 Gaps analysis methodology

In order to identify any gaps and evaluate the feasibility of each proposed marine reserve, physical and ecological data were gleaned from available datasets, published studies, and technical reports that contained relevant information (quantitative, semi quantitative and qualitative) pertaining to each marine reserve.

Unpublished data on broad rocky reef habitat types were made available by Auckland Council for the entire Waiheke Island coastline derived from unpublished remote sensing done in 2013. This allowed for determination of broad habitat type extents for each proposed MPA (intertidal rocky reef, subtidal rocky reef, algal habitat and bare rock/urchin barrens) within ArcGIS v 10.0.

Seminal reports and data sources that provided additional information were the broad-scale study of the Tamaki Strait and Motuihe Channel region (Chiaroni *et al.* (2010); various ecological, physical habitat and fisheries and data layers, including metadata contained within Seasketch (2016); a recent side-scan sonar survey and *ad hoc* descriptions of the northern coastline of Waiheke Island (Kerr and Grace 2013); and, spatially predicted rocky reef and soft sediment invertebrate diversity across the Hauraki Gulf (Smith 2004; 2006). It is worth noting that the data presented in Smith (2004, 2006) and much of the data within Seasketch (2016) is derived from spatial prediction analysis, which invariably assigns values (abundance, diversity, nutrient cycling *etc*) across the entire HGMP (including Waiheke Island) based on physical and biological relationships (depth, substrate type *etc*) derived from much smaller subsets of empirical data.

Where possible, data collated for each of the proposed marine reserves were evaluated with regard to seven main attributes of interest:

1) Type of marine habitats and species contained within the proposed reserve
Summary of physical and biological habitat types based on relevant habitat classifications (e.g., MFish and DoC 2008; Jackson 2014); Summary of dominant species within habitats.

1) State of marine vegetation and potential for regrowth
Evaluation of the distribution (spatial extent) of macroalgae, seagrass and mangrove habitat (if present) within each proposed marine reserve.

2) Biogenic habitats present and potential ecosystem productivity
Of the range of habitats common to coastal regions those biogenic in nature often play a pivotal role in enhancing biodiversity through the provision of habitat/structure for other

colonising species and in enhancing fish survival, (particularly juveniles). Common examples within estuarine and nearshore coastal zones include seagrass meadows, macroalgal forests, *Caulerpa* beds (green algae), sponge gardens, green-lipped mussel reefs, oyster reefs, horse mussel beds, bryozoan fields, maerl/rhodolith beds (red algae that form nodules of calcium carbonate), tubeworm mounds, and dog cockle beds (Morrison *et al*. 2012, 2014b).

3) Species present and potential for future species protection

Summary of key species present that are likely to benefit from no-take marine reserve protection.

4) Potential for spawning, larval dispersal and protection of juveniles (species-specific)

Evaluation of potential for increased spawning, larval dispersal and juvenile protection with each proposed marine reserve.

5) Ideal size and boundary lines to optimise long term abundance

Consideration of boundary size relative to species movements and habitat requirements for different life-history stages.

6) Terrestrial interface

Description of the terrestrial interface surrounding each proposed marine reserve advantages and disadvantages to habitat quality and (e.g. marine reserve abuts a DOC or council reserve, stormwater run-off, adjacent wet lands, possible pollutants, stream discharges *etc*).

Due to the small size of PMR 4, it was combined with adjacent PMR 4A when evaluating the above attributes. Following the assessment of these attributes of interest, key gaps across proposed marine reserves were evaluated (Section 7.0) and ways to bridge these identified.

6.0 Proposed Marine Reserve Evaluation

The following section provides an assessment of each proposed marine reserve. Each assessment describes where possible: 1) dominant marine habitats (physical and biological) and species of note; 2) state of current marine vegetation with each proposed marine reserve; 3) species present and potential for protection; 4) potential for spawning, larval dispersal and protection of juveniles (species-specific); 5) Ideal size and boundary lines to optimise long term abundance; and, 6) Terrestrial interface boarding each marine reserve and potential catchment-related. Gaps identified throughout this review including ways to bridge these information gaps are discussed in a section 7.0.

6.1 Proposed Marine Reserve 1

Proposed Marine Reserve 1 encompasses Matiatia Harbour southern headland around to the western point of Oneroa Bay (Hakaimango Point) to a distance of 3 km stretching northwards. The board proposes that this marine reserve covers the full 3 km northwards and may by negotiation with the Noises Islands Family Trust, continue to the Noises Island. Boundary lengths are: 1.5 km southern boundary; 4.3 km western boundary; 4.5 km northern boundary; 3 km eastern boundary (Fig. 2).

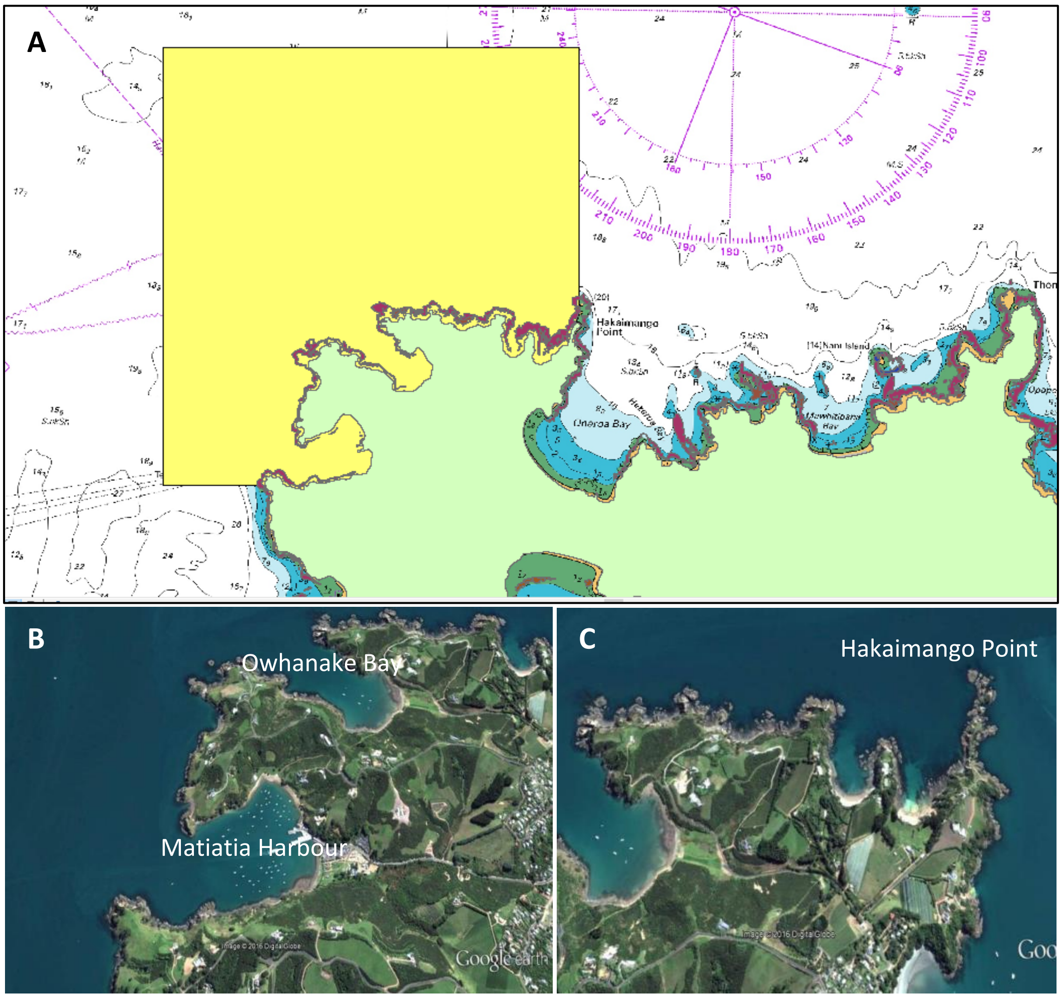

Figure 2. A: Proposed marine reserve 1 (yellow area). B) Main embayments within proposed marine reserve – north-western coastline; and, C) northern coastline.

6.1.1 Type of marine habitats and species contained within the proposed reserve

Proposed marine reserve 1 (PMR 1) encompasses parts of the western and northern coastline of Waiheke Island (Fig. 2). The southern boundary of the reserve extends approximately 1.5 km into the Motuihe Channel. The channel region is described as moderate-to-high current > 0.75 m s^{-1} (Chiaroni *et al.* 2010; Seasketch 2016) and is relatively shallow < 25 m. Moderate to high current speeds continue around the eastern headland of Owhanake Bay dissipating rapidly to < 0.25 m s^{-1} past Hakaimango Point. Similarly, towards the northern boundary current speeds decrease adjacent Rakino Island (Seasketch 2016).

The section of coastline encapsulated by the reserve is typified by a diverse range of intertidal and subtidal marine habitats. Intertidal habitats include rocky reef, sheltered gravel and mud beaches framed by headlands associated with Matiatia Bay and Owhanake Bay, and small sandy beaches (e.g., Double U Bay) along the northern coastline. Subtidal habitats include rocky reef and large expanses of subtidal soft sediment that range from sand, sand and mud matrices, and shell hash and gravel patches

Rocky reef

The western coastline of Waiheke Island is predominately intertidal rocky reef ranging in gradient from steep, moderate-flat, to flat and often characterised by distinct zonation bands (barnacles, oysters, and macroalgae) from high to low tide (Chiaroni *et al*. 2010). Within the proposed marine reserve intertidal rocky reef is approximately 0.24 km^2 in extent. Matiatia Bay is classified as containing gently sloping rough sedimentary rocks and boulders with many crevices, and narrow rocky intertidal reefs at the base of vertical cliffs. Data for intertidal rocky reef substrate types and zonation patterns are limited for the northern stretch of coastline immediately west of Ohanake Bay to Hakaimango Point, but are likely to share many of the physical elements described by Chiaroni e*t al*. (2010) for the western coastline. Intertidal rocky reef platforms are of particular note between the eastern point of Owhanake Bay and the western point of Oneroa Bay.

Subtidal reefs typically extend down to a depth of 10-15 m and are predominant north of Matiatia Point and along much of the northern coastline within the proposed reserve boundary (Kerr and Grace 2013). Five rocky reef habitat types according to the classification of Shears *et al*. (2004) occur within the proposed reserve (synthesised from Kerr and Grace (2013)). These are shallow *Carpophyllum*, mixed algae, *Carpophyllum flexuosum*, urchin-grazed barrens, and, sponge flats. Based on remote sensing analysis (Auckland Council *unpublished data*), algal habitat equates to around 0.22 km^2 and bare rock/urchin barrens 0.03 km^2 within the proposed reserve.

Subtidal marine vegetation along the northern Waiheke coastline is dominated by fucalean species (Kerr and Grace 2013). In the immediate subtidal (sub-littoral fringe) *Carpophyllum maschalocarpum* forms a thin fringing algal band in tandem with *Xiphophora chondrophylla* and occasional *Ecklonia radiata*, the latter of which increases in occurrence with increasing wave exposure. Beyond the fringing algal band, *Carpophyllum flexuosum*[2] becomes the dominant macroalga either forming monospecific patches down to around 5 m depth, or co-occurring with *Carpophyllum plumosum* and occasional *Ecklonia radiata* with the red foliose alga *Pterocladia lucida* often a prevalent understorey species. The sea-urchin *Evechinus*

[2]Also described as tangle weed in Kerr and Grace 2013)

chloroticus is also described as common in this mixed algal habitat occupying holes, crevices, and depressions within the reef i.e., displaying cryptic behaviour. A wide variety of grazing molluscs are reported to occupy this shallow mixed algal habitat (Smith 2004; Kerr and Grace (2013).

Beyond the mixed algal zone between 3-15 m depth two disparate habitat types commonly occur, urchin barrens (3-10 m depth) or *Carpophyllum flexuosum* (3-15 m depth) (Kerr and Grace 2013). The former is characterised a high cover of crustose coralline algae (CCA), interspersed with turfing and articulated coralline and sporadic large macroalgae. *Evechinus chloroticus* occurs at moderate-to-high density 5-10 m^2 and in some instances higher. The *Carpophyllum flexuosum* forest habitat is dominated by a high cover of *Carpophyllum flexuosum*, which forms monospecific stands in sheltered water and co-occurs with *Ecklonia radiata* with increasing wave exposure or currents. Typically, this habitat is associated with high levels of sediment (Shears *et al*. 2004). In instances where subtidal rocky reef extends beyond 10 m depth, urchin barrens or *Carpophyllum flexuosum* habitat rapidly gives way to sponge dominated areas with the large sponge *Ancorina alata*, the finger sponge *Raspailia* sp., large yellow sponge *Polymastia granulosa*, and the orange golf ball sponge *Tethya aurantium*[3] all common components of this habitat type (Kerr and Grace 2013).

While quantitative data are lacking for much of the proposed marine reserve, Smith (2004) surveyed Hakaimango Point as part of a wider survey that included 36 other sampling sites throughout the Hauraki Gulf. In that study, Hakaimango Point was described as a shallow reef flat characterised by sparse *Ecklonia radiata* and large hydroid colonies with sponges *Tethya* spp and *Ancorina alata* common. Areas of high density *Ecklonia radiata* were observed along the lower extent of the reef with the western extension typified by a steep wall with many bryozoans, solitary corals, and hydroids equating to high biodiversity.

Cryptic reef fishes for this area of coastline compared to other sites in the Hauraki Gulf Smith (2004) were: the spectacled triplefin, *Ruanoho whero* (moderate abundance); blue-eyed triplefin, *Notoclinops segmentatus* (low to moderate abundance); mottled triplefin, *Forsterygion malcolmi* (low to moderate abundance); the variable triplefin *Forsterygion varium* (low to moderate abundance); the yellow-black triplefin, *Forsterygion flavonigrum* (low abundance); the slender roughy, *Optivus elongatus* (low to moderate abundance); the scorpion fish, *Scorpaena papillosus* (low abundance); crested blenny, *Parablennius laticlavius* (low abundance); and, the common triplefin, *Forsterygion lapillum* (high abundance).

Mobile invertebrates recorded by Smith (2004) were represented by the cooks turban, *Cookia sulcata* (low abundance); ribbed rock shell, *Dicathais orbita* (low abundance); spotted topshell, *Calliostoma punctulatum* (low abundance); green topshell, *Trochus viridis* (low abundance); large hermit crabs (moderate abundance); clown nudibranch, *Ceratosoma amoenum* (moderate abundance); butterfly chiton, *Cryptochonchus porosus* (low abundance); sea cucumber, *Stichopus mollis* (moderate to high abundance); and, the whelk, *Axymene corticatus* (low abundance).

[3] Recorded as *Tethya aurantium* in (Kerr and Grace 2013)

Soft sediment

Intertidal soft sediment habitats (0.1km^2) within the proposed reserve are typified by beaches comprised of gravel pebbles and rocks e.g., Matiatia Bay, that support infaunal communities of low biological diversity and abundance (Chiaroni *et al*. 2010; Seasketch 2016). Of these, Owhanake Bay has flat topography, whereas Matiatia Bay is steeply sloping with small swales present. Both are characterised by gravel, pebble and cobble sediment matrices becoming increasingly sandy near low tide. Macrofauna of these beaches are described as being of low abundance and diversity supporting infaunal communities (Chiaroni *et al*. 2010). Comparative descriptions are not available on the biological makeup of the soft sediment beaches along the northern coastline within the proposed reserve.

Subtidal soft sediment habitat diversity within the proposed marine reserve and beyond is summarised for the western (Chiaroni *et al*. (2010) and northern coastline (Kerr and Grace 2013) and available in its entirety in Seasketch (2016) based on MPA Policy Habitat Classifications (MFish and DoC 2008; Jackson 2014) classifications. Habitats are varied within the proposed marine reserve and include sandy and muddy substrates within the embayments proper, transitioning to shallow subtidal gravel fields at the mouth of Matiatia Bay, high-current gravel fields and mud throughout the Motuihe channel, high current shallow mud and shallow coarse sand/shell/gravel matrices[4]. The sand/shell/gravel matrix described in Kerr and Grace (2013) typically occurs directly beyond subtidal rocky reef and is common to both northern and western regions of the proposed reserve, extending approximately 1 km seaward from the reefs along the northern coastline and forming a narrow elbow 2 km offshore from Owhanake Bay in the north western region of the proposed reserve. This extension presumably reflects the influence of the strong tidal currents within the area. Kerr and Grace (2013) further suggest that in channel regions, soft sediment habitat is more typically coarse shelly sand or gravel rather than mud and sandy environments are strewn with small rocks and boulders that amplifies the diversity and complexity of the physical habitat types (where present). Mud and sandy mud becomes the common habitat beyond coarser substratum types - approximately 2 km offshore.

Biological communities reportedly show strong accordance with the range of soft sediment habitat types described for this area of Waiheke Island. For coarse sand/shell/gravel habitat, mobile epifauna (starfish, gastropods, and hermit crabs) and ecological significant high current communities and dominated by *Heteromastus* and *Onuphid* polychaetes, and the file shell *Limaria* are often present. In addition, filter feeding sessile invertebrates (sponges and ascidians) and mobile scavengers (*Patiriella*) are described as widespread along the western inshore boundary immediately adjacent subtidal rocky reef habitat (Chiaroni *et al*. 2010; Kerr and Grace 2013). Similar biological communities are likely to occur within this substrate type for the north-western and northern Waiheke Island coastline. Kerr and Grace (2013) suggest that where sediment with high complexity occurs adjacent to rocky reef habitat it represents an important habitat sequences with many species crossing regularly to feed or shelter between the two. Beds of the dog cockle *Tucetona laticostata*, and the scallop *Pecten novaezealandiae* are reported to occur along the northern coastline of Waiheke Island (Kerr and Grace 2013), although their occurrence within the proposed reserve area is unknown.

Modelled benthic community richness across the proposed reserve is regarded by Smith (2006) as moderate (8-9 species grab^{-1}) with high (western coastline) to moderate (northern

[4] Note: Among these various studies/reviews there is discrepancy between the various habitat type classifications

coastline) species turnover. The abundance (average) of the heart urchin *Echinocardium*, Sigalionidae and Oenodiae polychaetes and brittle stars are all predicted to be low within the proposed reserve area, whereas Lumbrineridae polychaetes and the invasive bivalve *Theora lubrica* are predicted to have moderate abundance.

6.1.2 State of marine vegetation and potential for regrowth

The rocky reef area within the proposed reserve is likely to be punctuated by mixed algae, and extensive monospecific stands of *Carpophyllum flexuosum* interdispersed with bare rock/urchin barrens. Where present along the northern coastline, *Carpophyllum flexuosum* stands are described as dense, and often large in vertical height (> 1m in total length) (Kerr and Grace 2013), although quantitative data on abundance, biomass, including algal diversity per unit area are non-existent. Based on remote sensing data bare rock largely occurs along the western region of the proposed reserve.

In terms of regrowth, should the area become a no-take marine reserve, there is potential that urchin barrens habitat would reduce through time following the recovery of snapper and crayfish and transition to macroalgal habitat. Successional processes would depend on the depth distribution of macroalgal habitat and ultimately species present adjacent urchin barrens habitat. Most macroalgal species likely to be present have limited dispersal (5-10 m; Schiel 1988) and certainly this process would not expected to be immediate, being largely conditional on the reduction in *Evechinus chloroticus* by larger predators through space and time (Babcock *et al*. 2010). *Carpophyllum flexuosum* is typically associated with high secondary productivity (Taylor 1994), and any increase in its density will augment localised coastal productivity to a degree.

6.1.3 Biogenic habitats present and potential ecosystem productivity

In terms of area, macroalgal stands dominated by *Carpophyllum flexuosum* are likely to be the most prominent biogenic habitat within the proposed reserve associated with rocky reef habitat, followed by sponge and sessile invertebrate habitat (Smith 2004; Kerr and Grace 2013). Primary productivity values are unavailable for *Carpophyllum flexuosum*, although secondary production associated with *Carpophyllum* habitat is regarded as being significant (Taylor and Cole 1994; Taylor 1998). This is largely due to the 3-D morphological complexity afforded by multiple laminae that support diverse epifaunal assemblages dominated by crustaceans (Gammarid amphipods and isopods) and gastropods. Both are an important component in the diets of either juvenile and adult red moki (*Cheilodactylus spectabilis*), juvenile and adult snapper (*Pagurus auratus*), juvenile spotty (*Notolabrus celidotus*), juvenile banded wrasse (*Notolabrus fucicola)*, juvenile leatherjacket (*Parika scaber*), adult bigeye (*Pempheris adspersus)*, and adult goatfish *(Upeneichthys lineaus*) (see Jones 1988) of which the majority would be expected to occur within the propose reserve (Francis 1996).

Sponge habitat that is present on deeper reef areas is also a biogenic habitat of note within the proposed marine reserve. While Smith (2014) describes the diversity of sponge and sessile invertebrates in and around Hakaimango Point, other biodiversity hotspots are unknown and again there is a paucity of quantitative data. Sponge habitat in tandem with ascidians and other incrusting invertebrates are considered to play an important role in so far as provision of nursery habitat for juvenile snapper (Battershill 1987; Morrison *et al*. 2014a,b) Shears and

Usmar (2006) describe a diverse fauna of 20 fish species associated with incrusting invertebrate communities (sponges, ascidians, bryozoans *etc*) in the inner Hauraki Gulf cable zone that included juvenile blue cod, leatherjacket, pigfish, snapper, golden snapper and carpet sharks. A similar suite of species was identified by Williams *et al.* (2008) corresponding to sponge habitat with CROP reserve.

Based on available data the occurrence of soft sediment biogenic species have been reported within the general area of the proposed reserve. Given the descriptions of *Tucetona laticostata* within the northern coastline and around the Noises Islands where it co-occurs with a secondary rhodolith habitat (Dewas 2008; Dewas and O'Shea 2012), it is feasible that this biogenic habitat is present within the proposed marine reserve. Ecologically, *Tucetona laticostata* provide a range of functions and services that includes benthic-pelagic coupling, nutrient exchange, regulation of phytoplankton abundance, carbon sequestration, to food provision and their presence is considered as being a good indicator of high primary production areas (Morrison *et al.* 2014b). Moreover, their dead shells modify the benthos where they often accumulate in shell-drifts forming biogenic reefs and increase benthic complexity (three dimensional). This in turn affords attachment surfaces of macroalgae and sessile invertebrates (sponges and ascidians) resulting in localised increases in biological diversity. However, Morrison *et al*. (2009; 2014a,b) suggests that the role of dense infaunal shellfish beds, in so far as supporting fisheries species in New Zealand remains unknown.

The horse mussel *Atrina zelandica* is another biogenic habitat present in medium density (0.5-1 individual m^{-2}) below the southern boundary in the main channel region of the proposed marine reserve and around the northern coastline of Motuihe Island. (Chiaroni *et al*. 2010; Crompton *et al*. 2012). Again, due to an absence of quantitative data within the proposed reserve the occurrence of this significant biogenic habitat is presently unknown.

Based on summary goods and services data within Seasketch (2016) the majority of the proposed reserve is considered to be of medium-to-high productivity and nutrient cycling is classified as high for the entire reserve inferring high exchange of organic and inorganic material between pelagic and benthic habitats (Table 2).

6.1.4 Species present and potential for future species protection

Benthic species

The area encapsulated by the proposed marine reserve contains a diverse range of physical and biological habitat types and thus has the potential to protect a range of species (summarised in Table 1). Rocky reef areas will undoubtedly contain numerous species (macroalgae, mobile and sessile invertebrates) that are protected in other HGMP marine reserves elsewhere (Te Matuku, Long Bay, CROP, TMR, and Hahei). The large monospecific expanses of *Carpophyllum flexuosum* is one habitat type not well represented in existing marine reserves other than Long Bay (Shears 2013).

Reef fish richness is described as moderate within the proposed reserve (13-15 species) and is likely to comprise many of those species recorded within Te Matuku Marine Reserve (Table Table 2). Based on the study of Compton *et al*. (2012), adult snapper are considered particularly abundant along the western and northern coastline of Waiheke Island and throughout the Motuihe Channel region. Resultantly, it is feasible that snapper numbers would respond positively to protection afforded by the reserve, presuming that similar behavioural characteristics noted in Willis *et al*. (2000) and Parsons *et al.* (2010), i.e., high site fidelity of large individuals occurs. It is conceivable that juvenile snapper will be less-abundant within the western region of the proposed marine reserve as they tend to be associated with low current areas, although the sheltered embayments of Matiatia Bay and Owhanake Bay (not sampled in the study of Compton *et al*. 2012), could potentially serve as important areas for juvenile snapper. Other species of fisheries interest that have the potential to benefit from marine reserve protection along this stretch of Waiheke Island include sand flounder, john dory, and red gurnard (Stevenson 1998; Morrison *et al*. 2003). Based on representations in Seasketch (2016) the central area of Motuihe Channel is classified for reef fish as top 10% of conservation prioritization effort and the southern boundary of the proposed reserve abuts this high-priority area. Both 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.

Due to a paucity of data on lobster abundance and population size structure within the inner Hauraki Gulf it is unknown what densities and life history stages may be present within the proposed reserve area (if any). Crayfish would be expected to recover in the proposed area over time given the extensive subtidal reef in northern parts of the proposed area. However, the timing will be dependent on recruitment and recovery may take longer than in areas with higher recruitment (Freeman *et al*. 2012).

Table 1. Main species likely to be present within Proposed Marine Reserve 1. Data are extrapolated from available literature.

Component	Species/community	Abundance	Source
Rocky reef			
Macroalgae	*Carpophyllum flexuosum* *Carpophyllum plumosum* *Ecklonia radiata*	High Low to moderate Low	Smith (2004); Kerr and Grace (2013); Auckland Council unpublished data.
Sessile invert	*Ancorina alata* *Raspailia topensoi* *Polymastia* spp *Tethya* spp	Moderate?	Smith (2004); Kerr and Grace (2013)
Mobile invert	*Evechinus chloroticus* *Sticopus mollis* *Cookia sulcata* *Trochus viridis* *Calliostoma punctulatum* *Jasus edwardsii*	Moderate to high Moderate to high Low to moderate Low to moderate Low to moderate Unknown	Smith (2004); Kerr and Grace (2013
Benthic - Soft sediment			
Mobile invert	*Heteromastus-Onuphid- Limaria* Mobile epifauna Infauna	Moderate to high Unknown Unknown	Chiaroni *et al*. (2010)
Bivalves	*Pecten novaezelandiae* *Tucetona laticostata* *Atrina zelandica*	Unknown Unknown Unknown	Kerr and Grace (2013)
Fishes (non-cryptic)	Snapper -adult Snapper - juvenile Red gurnard John dory Rig Trevally Sand flounder Kahawai	High Low to moderate Moderate to high Moderate to high Moderate to high Low to moderate Low to moderate Moderate	Compton *et al*. (2010) Morrison *et al*. (2003)

6.1.5 Potential for spawning, hatching, protection of juveniles and of which species

One of the central principles of marine reserves is to allow adult spawning biomass of many fished species to increase in the absence of fishing pressure. As a result, egg production and larval production should also increase and depending on larval duration there is a high probability that propagules are transported beyond reserve boundaries into adjacent unprotected areas of coastline.

While studies on egg and larval export from marine reserves are limited, Willis *et al*. (2003) calculated that on average snapper egg production within marine reserves can be up to 18 times greater compared to outside. This combined with their long larval phase 17–33 days (Sim-Smith *et al*. 2012) suggest any build up of adults within marine reserves will enhance the larval supply to unprotected areas of coastline. Stephens *et al*. (2004) modelled larval dispersal from the Te Tapuwae O Rongokako Marine Reserve for a range of benthic species many likely to occur within and adjacent to Waiheke Island (cat's eye, kina, *Cookia,* and limpets – *Cellana* sp). In that study, larval dispersal was lowest during calm weather and related to tidal forces with most larvae settling 2 km away from spawning sites, regardless of species. Unsurprisingly, larval dispersal was much greater in storm events. Ultimately dispersal was related to larval duration with kina and paua having the highest dispersal distances, with limpets, gastropods and macroalgae (bull kelp) having more localised dispersal. Depending on location within the reserve and proximity to dominant currents and frequency of storm events, all had the potential to disperse larvae beyond the reserve boundary, particularly during storm events.

Due to high tidal currents associated with the western and northern region of the reserve (Chiaroni et al; 2010; Seasketch 2016) larval export from the reserve to non-reserve areas is likely to be routinely high for many species (gastropods, kina, fishes) in both a northward and eastward direction (Fig. 3). Moreover, snapper eggs and larvae have been demonstrated as being abundant throughout the proposed marine reserve (Zeldis and Francis 1988; Zeldis *et al*. 2005). In addition to snapper, other juvenile species that have been recorded from trawl survey data within, and adjacent to, the proposed marine reserve and will likely benefit to some degree from marine reserve protection include: red gurnard (moderate to high abundance); john dory (moderate to high abundance); trevally (low to moderate abundance); and, sand flounder (high abundance) (Kendrick and Francis 2002; Morrison *et al.* 2003).

6.1.6 Ideal size and boundary lines to optimise long term abundance

Given that the southern and western boundaries of the reserve will encompass high current and high productivity areas that are synonymous with moderate to high adult snapper abundance, the proposed marine reserve size is likely to be moderately beneficial to this species assuming high site fidelity occurs, as is observed in other marine reserves. On balance, while marine reserves with sizes similar to Leigh and Tawharanui (*c*. 5 km^2) can achieve significant levels of protection for snapper, they are often too small to fully protect resident reserve snapper populations. The boundary lines proposed for PMR 1 would be adequate to enhance many other species (e.g., lobster) that occur along this stretch of the Waiheke Island coastline through protection of multiple habitats including those likely important for spawning, settlement and on-growth. The majority of the criteria suggested by Edgar *et al*. (2014) would be met within the currently proposed marine reserve area, the exception being size. As such, 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 (Dewas 2008) would be of value.

Table 2. Select data summaries from Seasketch (2016) for physical, biological, and recreational fishing and snapper catch within the Proposed Marine Reserve 1.

Proposed Marine Reserve1			
Physical attributes	**Details**	**Biological attributes**	**Details**
Tidal current	Western Coastline offshore – High Northern Coastline offshore – Moderate	Biogenic	Western Coastline offshore – High Northern Coastline offshore – High inshore low offshore
Wave height	Low < 0.75 m	Historic mussel beds	Historically dredged area Historically dredged dense mussel beds adjacent eastern boundary
Productivity Nutrient Cycling	Medium (4.2-8.00) to High (8.01 to 14.67) with small pockets of high productivity surrounding rocky reef habitat) High	Reef fish richness Reef fish conservation prioritisation	Low to moderate (13 to 17 species) Western Coastline offshore – Top 10% to 10-30% Northern Coastline 30-50%; 50-100%
Habitat types	Intertidal – rocky reef Intertidal – very sheltered shallow mud and soft sediment Subtidal – High current shallow rocky reef Subtidal – Very sheltered shallow gravel Subtidal – High current shallow gravel Subtidal – High current shallow mud Very sheltered intertidal soft sediment Very sheltered intertidal shallow mud	Rec Fishing Effort (2004-2005) Rec Fishing Effort (2011-2012)	Western Coastline offshore – (21-50 to 151-200) Northern Coastline –(21-50 to 51-100) Western Coastline offshore – (151-200 to 701-1000) Northern Coastline – (21-50 to 201-300)
Main Substrates	Mud and sandy mud Mixed sediment Intertidal soft sediment Intertidal and subtidal rocky reef	Snapper catch intensity kg/km^2 1 October 2011 to 30 September 2012	Western Coastline 2000-14000 Northern Coastline 2000-7000

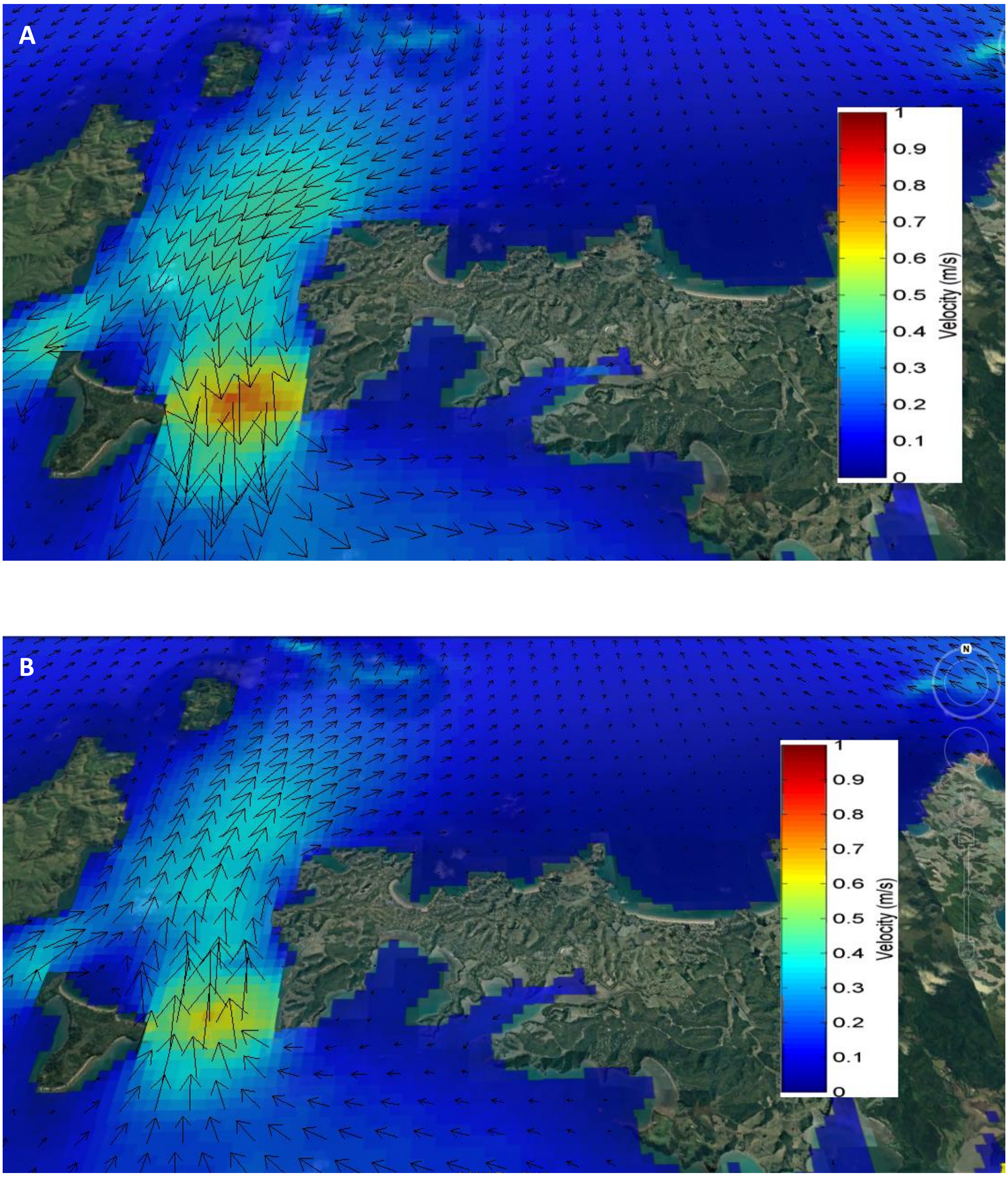

Figure 3. A: Flood; and B: ebb dominated tidal velocity and direction for the western region of Waiheke Island; Source: eCoast Hauraki Gulf tidal model.

6.1.7 Terrestrial interface

The terrestrial interface between Matiatia Bay and Hakaimango Point is dominated by high producing exotic grassland with small areas of broadleaf indigenous hardwood, indigenous forest and pockets of manuka and kanuka and herbaceous freshwater vegetation associated within Owhanake Bay. In terms of Landcare's Threatened Environments Classifications (2012), the majority of the landmass is classified as > 30 % indigenous vegetation remaining and 10-20 % protected, however the majority of the coastal fringe is classified as chronically threatened with 10-20% indigenous cover left. Small pockets of > 30 % indigenous vegetation left and > 20% protected occur in and around Hakaimango Point, Double U Bay and the southern coastline of Matiatia Bay. The area encompassing Hakaimango Point to Oneroa Bay; Double U Bay; and Island Bay along the northern coastline is classified as having outstanding natural characters, features, and landscapes. Matiatia Historic Reserve encompasses the coastal headland between the northern side of Matiatia Bay and southern side of Oneroa Bay.

Matiatia Bay is the focal area for visitors arriving from Auckland City as such it experiences very high boat traffic. Two large mooring areas 54 m^2 and 45m^2 occur either side of the existing ferry terminal and much of Matiatia Bay is classified as a no-anchor zone. A wastewater treatment plant was constructed at Owhanake in 2001 to serve the commercial area of Oneroa Village and Wharf area. Properties that are connected to the treatment plant are required to still retain a septic tank system with the liquid portion of the wastewater diverted to the treatment plant. Eventually effluent from the treatment plant is discharged into Matiatia wetland in order to reduce nutrient (nitrite, nitrate and phosphate concentrations) which eventually flows into the southern end of Matiatia Bay. Resultantly there is potential for Matiatia Bay to be negatively affected through nutrient enrichment and nuisance algal blooms in tandem with contamination of shellfish beds and reduced water quality. Equally, poorly maintained or performing septic tanks are likely to be an issue for the area.

Water quality data for the wider reserve are not available; although, turbidity is often elevated along much of the western and north-western coastline (Dan Breen *personal communication*). The high turbidity often experienced within the proposed reserve is likely to be due to larger-scale sediment inputs into the inner Hauraki Gulf rather than associated with immediate land use.

6.2 Proposed Marine Reserve 2

Proposed boundaries for Marine Reserve 2 span from the eastern headland of Whau Point to the end of the Te Whau Peninsula extending offshore south until the western corner abuts the Waiheke Local Board boundary within Tamaki Strait. Proposed boundary lengths are: 2.5 km southern (offshore) boundary; 2 km western boundary; 3 km northern (landward boundary); and 3 km eastern boundary (Fig. 4).

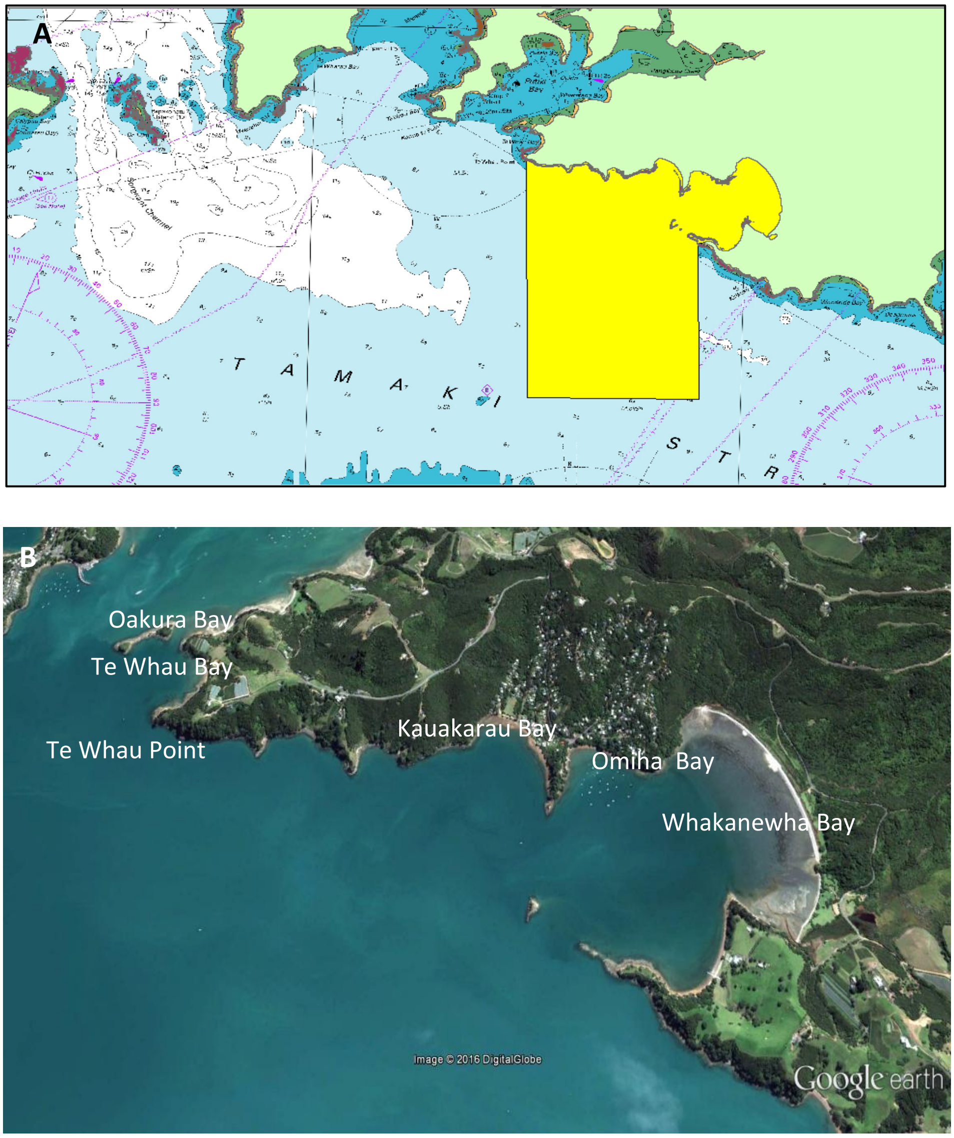

Figure 4. A: Proposed marine reserve 2 (yellow area); B) Main embayments within proposed marine reserve - southern Waiheke Island coastline.

6.2.1 Type of marine habitats and species contained within the proposed reserve

Marine reserve 2 (southern coastline of Waiheke Island) encompasses Whakanewha (Rocky) Bay, Kauaroa Bay, Hitapa Bay, and Kauakarau Bay including Koi Island. A variety of broad marine habitats are contained within the proposed boundaries (Chiaroni *et al*. 2010; Seasketch 2016). These include intertidal beaches (variety of substrates), intertidal rocky reef platforms and headlands, subtidal rocky reef and both intertidal and subtidal muddy and sandy substrates. Of these, subtidal sand and mud is the most extensive habitat type. The area encompassed by the reserve is shallow and gently sloping with maximum depth on the offshore boundary ranging between 9-12m (MLWS). The majority of the proposed reserve is classified as low current (< 0.25 m/s) with offshore areas towards the centre of Tamaki strait classified as a mid-current (> 0.5 m/s). Ecological survey data albeit limited are available for Kauaroa Bay, Whakanewha Bay, and Hitapa Bay including the benthic subtidal offshore from Te Whau Point (see Chiaroni *et al*. 2010; Compton et al. 2012). Species occurrence is summarised in Table 3.

Rocky reef

Intertidal rocky reef habitat along the stretch of coastline contained within the proposed reserve boundaries is described as rough platform and is generally low gradient with boulders often prominent. Large boulders are associated with high complexity with prominent zonation bands of barnacles, oysters, and intertidal macroalgae (*Hormosira banksii*) and fucalean algae dominated by *Carpophyllum maschalocarpum* is conspicuous within the sub-littoral fringe. Subtidal rocky reef, where present, is limited in spatial extent relative to the northern coastline typically terminating in < 5m depth. Where present, it is predominantly colonised by fucalean algae (*Carpophyllum flexuosum* dominated), interdispersed with numerous areas of bare rock and urchin barrens (Auckland Council unpublished remote sensing data). Chiaroni *et al*. (2010) describe the presence of *Ecklonia radiata* forest along the Kauakarau Bay coastline.

Smith (2004) predicted mobile invertebrate density for this area of Tamaki Strait as moderate at approximately 12 species per 0.25 m^2. The gastropods *Dicathis orbita* and *Calliostoma punctulatum* were predicted to have moderate to high abundance, whereas *Cookia sulcata* and *Trochus viridis* ranged from low to moderate. *Evechinus chloroticus,* hermit crabs and *Stichopus mollis* were all predicted to occur at low abundances.

Reef fish are estimated to be of low richness across much of the proposed reserve, nevertheless much of the offshore region is classified in the top 10% importance of conservation value (Seasketch 2016). Due to equivalent habitat types between proposed marine reserve 2 and Te Matuku marine reserve fish communities are likely to be similar between these two areas. Cryptic reef fish as described by Smith (2004) are purported to occur at low to moderate abundance, the exception being the mottled triplefin, *Forsterygion malcolmi* which has moderate to high abundance.

Soft sediment

Intertidal soft sediment habitats are varied within the proposed reserve and range from steep, flat-to-moderate and flat sloping beaches comprised of mud, gravel, pebbles, and rock. Flat, exposed intertidal areas are typically dominated by sediment matrices of pebbles, cobbles, and sand. Whakanewha Bay, the largest of the embayments within the proposed reserve, is typified by steep slopes comprised of a mix of sand, shell, and gravel. Similar sediment types are present at Kauaroa Bay which is flatter (flat to moderate slope). Neither Whakanewha nor Kauaroa Bay have visible signs of biological features with biological communities within these areas classified as infaunal dominated (Chiaroni *et al*. 2010). Bioturbators dominate the faunal community at Kauakarau Bay and patches of oysters and mussels (*Mytilus*) have been recorded as present along this stretch of coastline (Table 3). Macrofauna in the intertidal soft sediment areas are of low abundance and species diversity (3-5 species per sample core) (Chiaroni *et al*. 2010). Mangrove habitat is present at the southern end of Whakanewha Bay and the entire stretch is classified within Seasketch (2016) as a potential site of shorebird significance.

Subtidally, large areas of sandy and muddy substrate occur adjacent the rocky reef habitat and extend out to the offshore boundary. Biological communities adjacent rocky reef habitat include low density *Atrina* beds (< 0.5 m^{-2}), mobile epifauna, and patches of the introduced Asian date mussel *Musculista senhousia*. Deeper regions of the proposed reserve towards the southern boundary are reported to be *Echinocardium cordatum* dominated, which is an important bioturbator. Much of the area historically supported dense mussel (*Perna canaliculus*) beds. Based on predictive models, Smith (2006) reports that soft sediment macrofaunal diversity is low (5-6 species per grab) across the proposed reserve area together with low turnover diversity. The average abundance of Lumbrineridae and Oenoidae polychaetes were predicted to be high with Siglanoidea polychaetes and the brittlestar *Amphiura rosea* moderate. The invasive bivalve *Theora lubrica* was predicted to have high abundance. Compton *et al*. (2012) documented areas of alternating high and low benthic diversity and burrows at the sediment surface offshore from Te Whau Peninsula (within the proposed marine reserve boundary).

6.2.2 State of marine vegetation and potential for regrowth

Based on analysis of remote sensing data, algal habitat within the proposed reserve occupies 0.06 km^2 of subtidal rocky reef with the remainder (0.02 km^2) classified as bare rock. As for PMR 1 the density, size structure, biomass and diversity of subtidal algal communities are unknown as is the level at which these are overgrazed by sea urchins. With respect to regrowth of macroalgal habitat, it is unlikely in this highly turbid and sheltered embayment that these are influenced by sea urchins and indirectly fishing.

6.2.3 Biogenic habitats present and potential ecosystem productivity

Four biogenic habitat types occur within the proposed reserve – mangrove, macroalgae, horse mussel, and bivalve (oysters, mussels). Mangrove habitat is approximately 28,865 m^2 in spatial extent and isolated to the upper intertidal of Whakanewha Bay. Macroalgal habitat is dominated by *Carpophyllum* species and occasional stands of *Ecklonia radiata* and bivalve habitats are represented by *Atrina* beds and intertidal *Mytilus* beds. In terms of spatial extent macroalgal beds are limited to depths < 5 m consistent with the termination of subtidal rocky reef and zonation patterns are likely less discrete than for the northern coastline. Where they occur, bivalve beds are described as patchily distributed and of low abundance (Chiaroni *et al*. 2010). Due to the limited spatial extent of vegetative habitats and high turbidity, primary and secondary production associated with macroalgae is likely much lower than for other parts of the Waiheke coastline. Equally, the low density of *Atrina* and other bivalves would likely translate into limited fisheries productivity. Historically the presence of dense mussel beds throughout the proposed reserve would have translated into a highly productive area of the Tamaki Strait.

Based on the goods and services outputs in Seasketch (2016) derived from Ecosystem Principle Scores (Townsend and Thrush 2010), ecosystem productivity for much of the proposed reserve area is classified as "medium" with small pockets of high productivity corresponding to subtidal rocky reef habitat. Nutrient cycling is classified as high for the entire reserve inferring high exchange of organic and inorganic material between pelagic and benthic habitats.

Table 3. Main species likely to be present within proposed Marine Reserve 2. Data are extrapolated from available literature.

Component	Species/community	Occurrence	Source
Rocky reef			
Macroalgae	*Carpophyllum maschalocarpum* *Carpophyllum flexuosum* *Carpophyllum plumosum* *Ecklonia radiata*	High Low to moderate? Moderate?	Chiaroni *et al*. (2011) Auckland Council unpublished data
Mobile invertebrate	*Evechinus chloroticus* *Sticopus mollis* *Cookia sulcata* *Trochus viridis* *Calliostoma punctulatum* *Dicathais orbita* *Hermit crabs*	Low to moderate Low Moderate Low to moderate High to moderate Moderate to high Moderate	Smith (2004)
Soft sediment			
Mobile invertebrate.	*Echinocardium* sp Mobile epifauna Infauna	Moderate to high Unknown Unknown	Chiaroni *et al*. (2010)
Sessile invertebrate	*Mytilus* *Oysters* *Atrina zelandica* -subtidal	Low Low Low	Chiaroni *et al*. (2010) Smith (2006)
Fishes (non-cryptic)	Snapper -adult Snapper - juvenile red gurnard john dory Sand flounder	Low to moderate Low to moderate Moderate Moderate to high High	Compton *et al*. (2010) Morrison *et al*. (2003)

6.2.4 Species present and potential for future species protection

Data are very limited on the type of fish and shellfish present along this stretch of coastline. More in-depth knowledge of the type of harvested species would be required to effectively evaluate the potential of the proposed reserve area to protect various species. Fishing effort is estimated to range from low to moderate within much of the proposed reserve area with snapper take estimated to range from 1,000-2,000 kg/km^2 between 2011-2012 (Seasketch 2016; Table 4.). Much of the offshore region of the proposed reserve is classified as top 10 % of fish conservation prioritisation (Seasketch 2016; Table 4). The study of Compton *et al*.

(2012) infers that juvenile snapper have low to moderate occurrence within Whakanewha Bay, with patches of high juvenile and adult occurrence inside of Kauaroa Bay suggesting that the area could be beneficial for as a nursery habitat. Juvenile John dory have also been reported to be present within the reserve boundary (Stevenson 1998). As proposed marine reserve 2 contains many of the physical and biological habitats characteristic of Te Matuku Marine Reserve located 6 km to the west and assuming targeted species are protected within Te Matuku Marine Reserve, any protection-related effects are likely to be similar between the two areas. Presently it is unclear as to the real value of complete marine reserve protection for this area of the Waiheke coastline, but if it is an important nursery area it should be protected against activities that may influence this, i.e., protection against dredging may be of value. Protection of bivalves from harvesting may also be important.

6.2.5 Potential for spawning, hatching, protection of juveniles and of which species

The occurrence of sedimentary structures (burrows) and horse mussels within the proposed reserve have the potential to provide settlement and juvenile habitat for snapper (Thrush *et al*. 2001; Compton *et al*. 2012) and John dory (Stevenson 1998). However, if snapper settlement coincides with periods of high turbidity and total suspended solids then there is potential for this to inhibit larval survival (Partridge and Michael 2010). Similar effects are likely to be apparent for many other marine species. As previously discussed the area will likely be important for species that require sheltered embayments such as that afforded by Whakanewha Bay either for spawning, settlement, foraging and nursery habitat. Species that are often seasonally abundant within sheltered embayments include kahawai (juveniles), mullet (juveniles, adults), sand flounder (juveniles, adults) and yellow-bellied flounder (juvenile, adults) (Morrison *et al*. 2009, 2014a).

Due to lower tidal currents within the proposed reserve larval dispersal for many benthic species is likely to be more limited than for PMR 1. Again, the transport of larvae beyond the reserve boundary will depend on the larval settlement rates and proximity to the reserve boundary. For many species with short larval phases recruitment is likely to be localised along this stretch of coastline.

6.2.6 Ideal size and boundary lines to optimise diversity and long term abundance

Again, without knowing the key species that are fished it is difficult to provide a robust assessment of whether the proposed boundaries are adequate to protect their long term abundance. In terms of biodiversity, biogenic habitat in the form of macroalgae and horse mussels will be protected by the existing reserve. 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.

In terms of modifications to the proposed boundary to enhance biodiversity, extending the western boundary to include Te Whau Bay, Oakura Bay and associated Islands would be beneficial. This area of coastline contains unique environments, particularly the sand-spit that extends from Okura Bay out to the Islands immediately offshore, which has a high diversity of sessile invertebrates (sponges/ascidians) (Dan Breen *personal communication*).

Table 4. Select data summaries from Seasketch (2016) for physical, biological, and recreational fishing and snapper catch within the Proposed Marine Reserve 2.

Proposed Marine Reserve 2			
Physical attributes	**Details**	**Biological attributes**	**Details**
Tidal current	Rocky Bay Inshore – Low Coastal embayment – Moderate Offshore Tamaki Strait –High	Biogenic	High inshore Low offshore
Wave height	Low < 0.5 m	Historic mussel beds	Historically dredged area Historic dense mussel beds adjacent coastal embayment beyond Koi Island and Te Whau
Productivity Nutrient Cycling	Medium (4.2-8.00) to High (8.01 to 14.67) with small pockets of high productivity surrounding rocky reef habitat High (7.70-12.28)	Reef fish richness Reef fish conservation prioritisation	Low to moderate (14 to 15 species) Much of the reserve – Top 10% to 10-30%
Habitat types	Intertidal – very sheltered rocky reef Intertidal – very sheltered shallow mud and soft sediment Subtidal – Sheltered shallow rocky reef Subtidal – Sheltered shallow mud and soft sediment	Rec Fishing Effort (2004-2005); boats per km^2 Rec Fishing Effort (2011-2012); boats per km^2	(2-60) (60-150)
Main Substrates	Mud and sandy mud Mixed sediment Intertidal soft sediment Intertidal and subtidal rocky reef	Snapper catch intensity kg/km^2 1 October 2011 to 30 September 2012	1500 -1750

6.2.7 Terrestrial interface

Whau Point and Te Whau Point are designated as being areas of outstanding natural coastal character and Pohutukawa Point and Whakanewha Bay notable for containing outstanding natural landscape features. Furthermore, Whakanewha Bay is classified as a significant ecological area within the Auckland Region.

The catchment surrounding Whakanewha Bay is predominantly regenerating native vegetation comprised of manuka/kanuka and broadleaf indigenous hardwoods. A thin band of exotic grassland run divides the native vegetative sequences and the foreshore of Whakanewha Bay. Residential development occurs within Omiha Bay and Kauakarau Bay catchments with the majority of land between Kauakarau Bay and Te Whau steep and covered in manuka/kanuka scrub. Small horticultural areas occur in and around Te Whau Point and the southern region of Whakanewha Bay.

The majority of the land adjacent the reserve has a low threat category of > 30% native vegetation left and 10-20% protected. Residential areas are classified as chronically threatened with 10-20 % indigenous cover remaining. The coastal vegetation threat rankings for Whakanewha Bay range from acutely threatened < 10% indigenous cover left (southern region) and pockets of chronically threatened (10-20%; 20-30% indigenous cover remaining) (Landcare Threatened Environment Classification 2012). Three streams located in forested catchments discharge into Whakanewha Bay.

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 total suspended solids of the wider Tamaki Strait attributable to far-field effects of sediment inputs in the Firth of Thames and Tamaki River Tamaki Strait, effectiveness of marine reserve protection and enhancement of productivity and biodiversity is likely to be constrained for some species. Other water quality characteristics (nutrients, DO, TSS) within the proposed marine reserved are unknown.

6.3 Proposed Marine Reserve 3:

Proposed MPA 3 (123.06 ha). Anzac Bay from the point at the end of Wharf Rd across to the eastern end of Okoka Bay. The offshore boundary between these two points is 0.5 km in length (Fig. 5).

6.3.1 Type of marine habitats and species contained within the proposed reserve

Proposed marine reserve 3 Anzac Bay is a very sheltered coastal embayment characterised by extensive intertidal sand- and mud-flats, subtidal sand and sandy mud, with vegetation dominated by a large seagrass bed, mangroves and coastal shrubland. Intertidal reef is limited in spatial extent forming narrow bands along the eastern coastline north of Okoka Bay and subtidal rocky reef is entirely absent. The subtidal region encompassed by the reserve is shallow < 0.5 m, and of low tidal current < 0.25 m^{-2}. Oyster farming is undertaken within the southern region of Anzac Bay (1.683 ha).

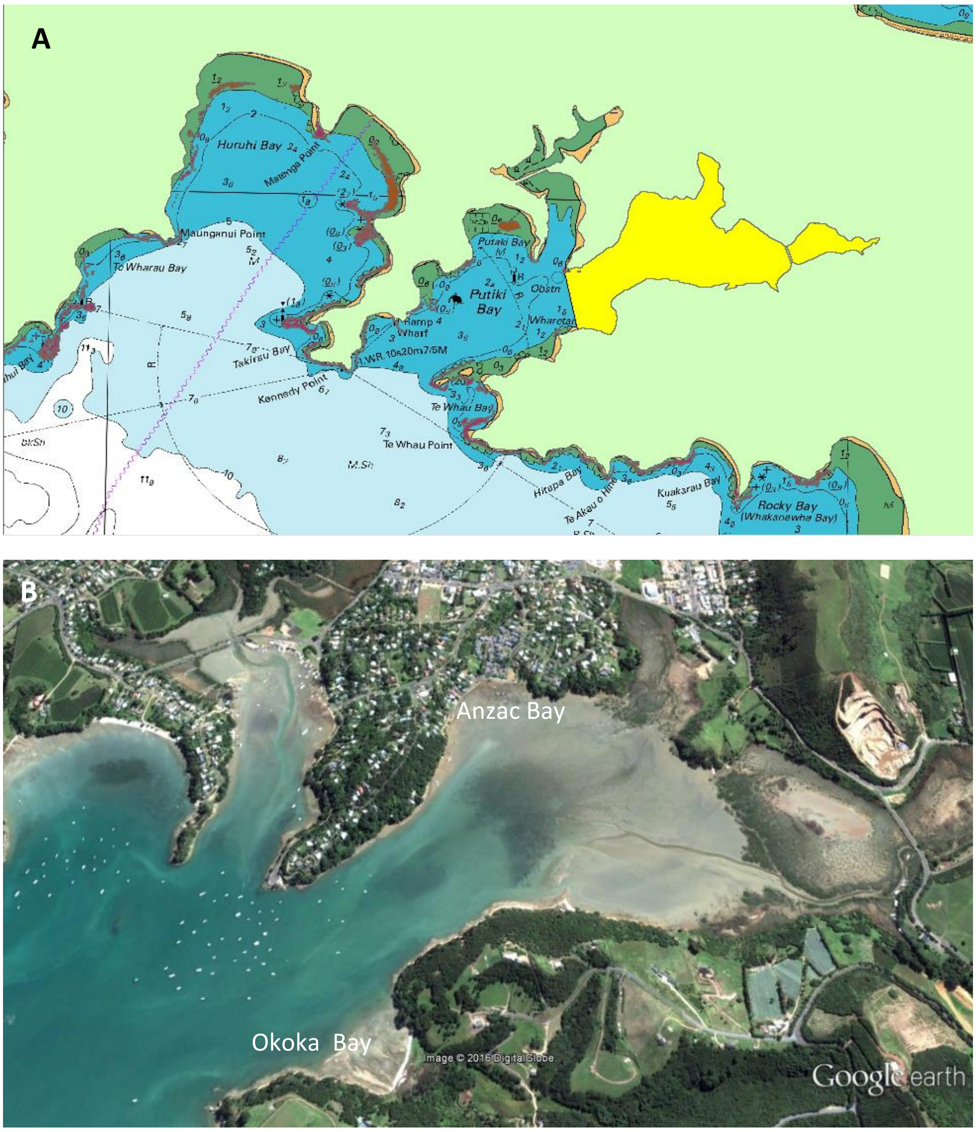

Figure 5. A: Proposed Marine Reserve 3 (yellow area). B: Main embayments within proposed marine reserve - south-eastern Waiheke Island coastline.

Soft sediment

Ecological data for this area of Waiheke Island are relatively limited – although the region is classified by Chiaroni *et al*. (2010) as having important coastal wetlands and cockles are present in Wharetana and Putaki Bays immediately adjacent the proposed reserve. Anzac Bay has two main inlets (Tawaipareira Creek and Rangihoua Creek) and an outer region fringed with mangroves. The embayment is flat and muddy with numerous crab burrows and several patches of abundant cockles and isolated patches of dense oysters (Chiaroni *et al*. 2010). Cockles are also present in Wharetana and Putaki Bays immediately adjacent the proposed reserve. Putiki Bay, further west of the proposed marine reserve, is described as flat to moderate in slope being comprised of occasional small rocks and shell hash sediment. The bay is inhabited by low densities of cockles with pipi increasing in abundance from mid tide to low tide where they occur at very high densities (Chiaroni *et al*. 2010).

6.3.2 State of marine vegetation and potential for regrowth

Intertidal marine vegetation within the proposed reserve is represented by mangroves, saltmarsh, and a 185 m^2 seagrass bed is a dominant feature across Anzac Bay. Within Tawaipareira Creek mangrove habitat and saltmarsh equate to around 76, 800 m^2 and 3,2846 m^2 respectively and within Rangihoua Creek mangrove is particularly dominant covering 285,5000 m^2 with saltmarsh lining the terrestrial boundary, albeit patchily distributed (100 m^2). Large brown macroalgae is non-existent due to the general absence of rocky reef habitat.

Data are not available regarding how vegetative habitats within the proposed reserve have or have not changed through space and time. Mangrove and saltmarsh variation is likely to be governed more by land-based effects such as sedimentation, nutrient enrichment, pollution, reclamation, and direct disturbance e.g., trampling. Equally, seagrass patch dynamics can be influenced by the aforementioned elements, together with exposure to wind-generated waves, tidal currents, and storm events. The presence of mangrove habitat adjacent seagrass habitat is likely to be very important in so far as protecting/buffering the seagrass from effects associated with sedimentation.

None of these habitats are likely to experience changes in abundance due to the area being designated as a no-take marine reserve *per se*. Rather marine reserve protection is likely to ensure that these habitats are better-protected from stressors, particularly those diffuse in nature associated with sedimentation, nutrient enrichment and stormwater. Moreover, seagrass habitat is not widely protected by marine reserves regionally or nationally.

6.3.3 Biogenic habitats present and potential ecosystem productivity

Main biogenic habitats within the proposed reserve are intertidal seagrass and mangrove habitat with bivalve beds potentially less significant due to their reported patchy distribution. In New Zealand, seagrass is represented by one species, *Zostera capricorni*. *Zostera capricorni* typically occurs in monospecific beds and is predominantly intertidal (to about mid-tide level) occurring subtidally in limited locations (Kaipara Harbour). Seagrass habitat is considered to be ecologically significant due to its contribution to primary productivity and detrital food webs and through its structural complexity, which provides critical habitat for a range of species (Turner and Schwarz 2006). Seagrass habitat is considered as being important for fish settlement and juvenile enhancement, particularly where it occurs subtidally (Morrison *et al*. 2014a,b). Seagrass meadows have also been demonstrated to enhance bottom stability, reduce sediment accumulation, and enhance nutrient cycling (Ruiz *et al*. 2001; Turner and Schwarz 2006). Typically, shoot density and above ground biomass and productivity is highest in summer and lowest in winter in north-eastern New Zealand (Turner and Schwartz 2006). The presence of *Zostera capricorni* within the proposed reserve is undoubtedly important in enhancing local productivity (primary and secondary) within the embayment. Its role in fisheries enhancement remains unknown.

The mangrove *Avicennia marina* is one biogenic habitat that has increased in cover throughout the Auckland region in many locations (Morrisey *et al.* 2007). *Avicenna marina* habitat is generally considered an important coastal habitat due to its productivity, and the provision of structure afforded to a variety of birds and marine organisms; although, there does not appear to be any evidence for "exclusive mangrove-dependency" for any native fishes, marine invertebrates, or birds (Morrisey *et al*. 2007). Estimates of mangrove productivity suggest similar or slightly higher rates than coastal phytoplankton or benthic microalgae and may enter the estuarine food webs by direct grazing or as detritus, but it is expected that the largest proportion enters as detritus and this appear to be important to a range of organisms via the detrital food web (Morrisey *et al*. 2007). Mangroves as biogenic habitat and their contribution to fisheries production is not well understood within New Zealand (Morrison *et al.* 2014a,b), but is considered as being beneficial at some point in the life history of grey mullet, parore, and short-fin eels.

Where they obtain high biomasses cockle (*Austrovenus stutchburyi*) beds and oyster reefs are considered important biogenic habitats although as for many habitats their immediate role in enhancing fisheries production is unknown (discussed in Morrison *et al*. 2014b). Cockle beds are ubiquitously associated with high biodiversity and abundance across Auckland's estuarine environments (Hewitt *et al*. 2009) and similar biodiversity enhancement is likely to be true throughout the wider embayment. In some estuaries e.g., Mahurangi Harbour, cockle habitat supersedes seagrass with respect to biodiversity (Hewitt *et al*. 2009). As for many bivalves they can strongly influence the nutrient dynamics and phytoplankton abundance and are an important food source for a variety of species – oyster catcher, sand flounder and mud whelks (Hewitt *et al*. 2009)

6.3.4 Species present and potential for future species protection

While various bivalve fauna are reported within and immediately adjacent to the proposed reserve, the lack of quantitative data make it exceedingly difficult to evaluate the effects of marine reserve protection on the species present (Table 5). On one hand if species such as pipi and cockle occur prolifically and are commonly harvested (recreationally and customarily) then any protection afforded by the reserve is likely to ensure some stability and result in population increases. For example, a rāhui placed on cockle harvesting at Umupuia in 2007 was effective in restoring abundances to historic (1998) levels (Hauraki Gulf State of the Environment Report 2014). Alternatively, should numbers of predators, e.g., sand flounder *etc* increase (which is unlikely in the short term), then predation pressure on these beds is likely to be greater, which could reduce numbers. For many other benthic species characteristic of intertidal mud-flat habitat, responses to marine reserve protection remain largely unknown.

Table 5. Main species likely to be present within Proposed Marine Reserve 3. Data are extrapolated from available literature

Component	Species/community	Occurrence	Source
Soft sediment			
	Seagrass	Abundant	Auckland Council *unpublished data*
Mobile invertebrates	Unknown	Unknown	
Bivalves	Cockle - *Austrovenus* Pipi – *Paphies australis*	Unknown Unknown	Chiaroni *et al*. (2010)
Fishes (non-cryptic)	Snapper -adult Snapper - juvenile Sand flounder	Unknown Unknown Unknown	Compton *et al*. (2010)

While the occurrence of juvenile snapper and other fish species may be enhanced by the presence of seagrass, based on summary data within Seasketch (2016) the main areas of the reserve experience low snapper catch (Table 6) presumably attributable to its largely intertidal nature and low-current flow, i.e., less-preferred habitat for adults (Compton *et al*. 2012). Snapper catch is, however, estimated to increase substantially beyond Okoka Bay and Ostend Peninsula, i.e., outside of the proposed reserve.

6.3.6 Potential for spawning, hatching, protection of juveniles and of which species

The presence of the large seagrass habitat within PMR 3 is potentially important for settlement or enhancement of juvenile fish species e.g., snapper, although subtidal seagrass habitat is considered to be of much greater importance (Morrison *et al.* 2014 a,b). Its real value is likely in protecting various bivalve species and maintenance of biodiversity. As cockles can be long lived (up to 20 years) and have been demonstrated to respond positively to harvest restrictions elsewhere (Umupuia) protection afforded by marine reserve designation is likely to translate into increased biomass and reproductive output for this species (Thrush *et al.* 2006). Similar positive effects are likely for pipi should they occur within the proposed reserve boundary and harvested. Both are predicted to have an extended larval duration of 2-3 weeks (Lundquist *et al*. 2009), thus there is potential for larvae to be transported beyond the reserve boundary and enhance adjacent non-reserve areas of coastline. This enhancement will be contingent on the suitability of physical elements such as substrate mud content, salinity, and wave exposure (Lundquist *et al*. 2009).

6.3.7 Ideal size and boundary lines to optimise long term abundance

Given the location, physical makeup (primarily intertidal), and size of PMR 3 it is only likely to be effective in protecting those fishes (mullet, flounder, flat fish, parore) that may enter the embayment for foraging and spawning. To have a greater probability of optimising protection the marine reserve would have to be substantially larger to include a variety of subtidal habitats. As the reserve extends into the shallow subtidal region it will likely be effective in protecting bivalves (cockles and pipi).

The proposed marine reserve still has substantial merit in so far as protecting biogenic habitat especially seagrass that is poorly represented in marine reserves elsewhere and undoubtedly plays a beneficial role in terms of productivity, estuarine biodiversity, and provision of habitat for a range of invertebrates that may be otherwise absent along this section of the Waiheke Island coastline.

6.3.8 Terrestrial interface

The terrestrial interface surrounding PMR 3 is varied being comprised of moderate density residential and light industrial dwellings associated with Ostend township bordering the northern and north-western region of the proposed reserve and Tawaipareira Creek. A causeway dissects both Tawaipareira and Rangihoua Creek inlets and the upper northern reaches of Rangihoua Creek is bounded by a quarry and various horticultural areas. The south-western and southern coastline of Ostend and Anzac Bay is lined with a narrow fringe of native vegetation dominated by manuka/kanuka forest. This is relatively continuous from the mouth of Rangihoua Creek to Okoka Bay on the eastern coastline. Beyond this, pockets of exotic grassland mixed exotic shrubland, and indigenous forest occur. A saltmarsh and swamp area immediately adjacent Okoka Bay increases the vegetative diversity of the coastline. Based on Landcare's Threatened Environment Classification (2012), both Tawaipareira Creek and Rangihoua Creek inlets are classified as acutely threatened with < 10% indigenous cover remaining, Okoka Bay estuary – chronically threatened with 10-20% indigenous cover remaining, with the majority of the land cover classified as either 20-30% indigenous cover left; and the remaining > 20-30% left and 10-20 % protected.

Given the proximity of the proposed reserve to Ostend township, there is the potential for the reserve to be impacted by stormwater-related contaminants (nutrients, heavy metals, PAHs). Sedimentation from the main catchments draining directly into both inlets is also a likely stressor. Considering the importance of the seagrass habitat to wider biodiversity ways to control sediment, e.g., additional riparian planting in and around the Tawaipareira and Rangihoua Creek inlets should be considered alongside marine reserve protection.

Table 6. Select data summaries from Seasketch (2016) for physical, biological, and recreational fishing and snapper catch within the Proposed Marine Reserve 3.

Proposed Marine Reserve3			
Physical attributes	**Details**	**Biological attributes**	Details
Tidal current	Low	Biogenic	High inshore Low offshore
Wave height	Low < 0.25 m	Historic mussel beds	Historically dredged area
Productivity Nutrient Cycling	Medium (4.2-8.00) to High (8.01 to 14.67) with small pockets of high productivity surrounding rocky reef habitat High (7.70-12.28)	Reef fish richness Reef fish conservation prioritisation	No data No data
Habitat types	Intertidal – very sheltered shallow mud and soft sediment Subtidal – Sheltered shallow mud and soft sediment	Rec Fishing Effort (2004-2005); boats per km^2 Rec Fishing Effort (2011-2012); boats per km^2	(2-12) (0-19)
Main Substrates	Mud and sandy mud Mixed sediment Intertidal soft sediment Intertidal and subtidal rocky reef	Snapper catch intensity kg/km^2 1 October 2011 to 30 September 2012	18 -159.8

6.4 Proposed Marine Reserves 4 and 4A

Proposed MPA 4 (23.3 ha). Little Oneroa from the rocky outcrops between Oneroa and Little Oneroa, around to Fisherman's Rock. In order to preserve rock fishing and shellfish gathering, the board proposes that the collective marine reserve begins 20 m from the shoreline, commencing at Fisherman's Rock (the eastern arm of Little Oneroa Beach and the start of area 4a). Proposed MPA 4a (170.3 ha) extends from Fisherman's Rock to the western arm of Palm Beach (Fig. 6).

Boundary lengths for both PMRs are: western boundary 2 km from Little Oneroa to the offshore boundary; offshore boundary 0.75 km in length; and, eastern boundary 1km off the western arm of Palm Beach.

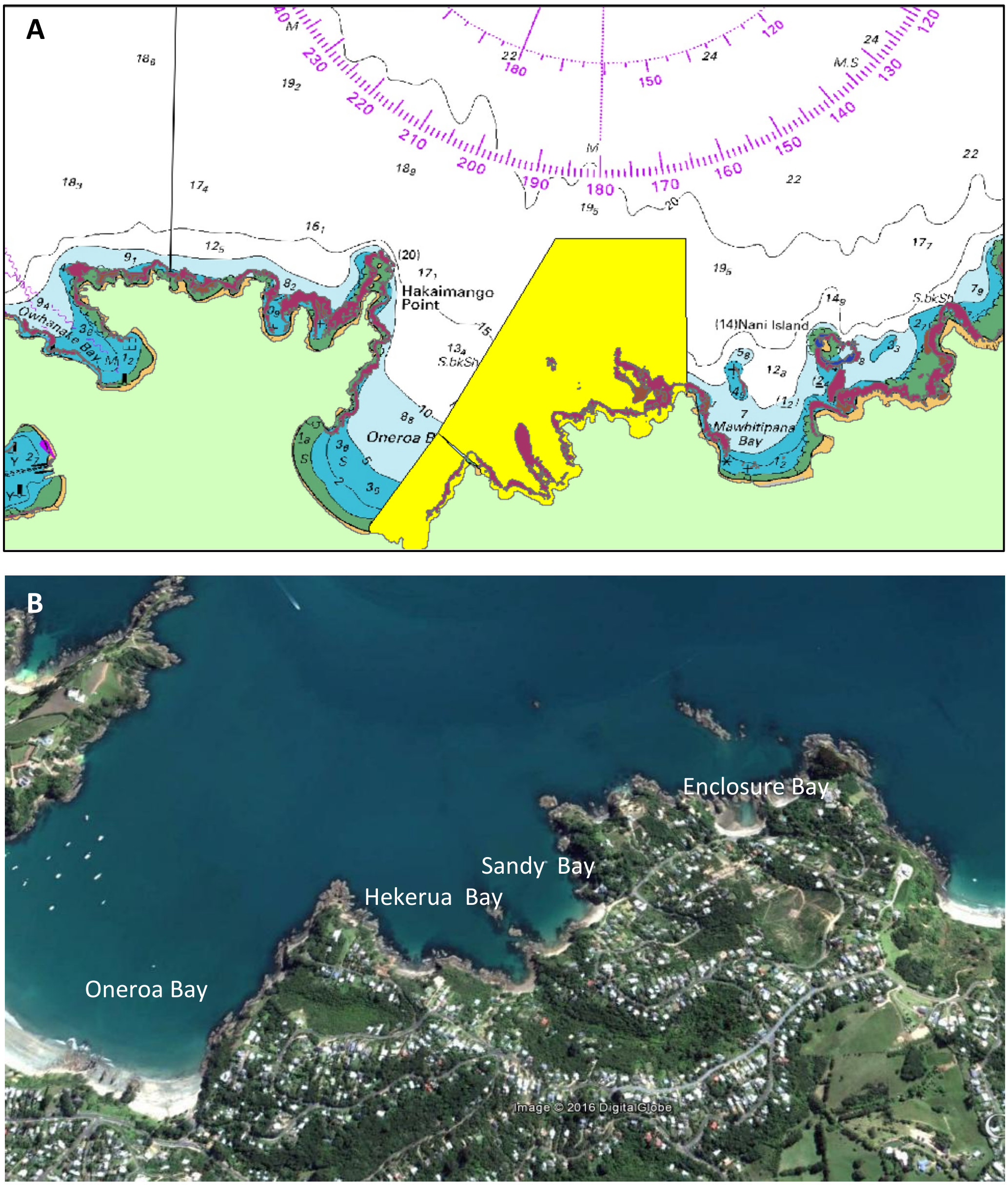

Figure 6. A: Proposed marine reserve 4 and 4A (yellow area); B: Main embayments within proposed marine reserve - northern Waiheke Island coastline.

6.4.1 Type of marine habitats and species contained within the proposed reserve

Proposed marine reserves 4A and to a much lesser degree 4, enclose similar intertidal and subtidal rocky reef and soft sediment habitats types identified along the northern coastline of PMR 1 (Kerr and Grace 2103). Proposed marine reserve 4A is dominated intertidally by complex rocky reef platforms and small (< 150m in extent) sandy embayments (Hekerua Bay, Sandy Bay, and Enclosure Bay). Enclosure Bay is physically unique being characterised by a hem of intertidal rocky reef approximately 80m offshore creating a shallow lagoon.

Intertidal and subtidal rocky reef habitat is present in a series of 3 narrow fingers that extend for approximately 450-475 m offshore across the PMR 4A. The first of these divides Hekerua Bay and Sandy Bay, the second runs out offshore from the western side of Enclosure Bay, and the third encompasses a small offshore rocky outcrop to the east of Enclosure Bay. Sand is the dominant substrate between rocky reef fingers, which transitions into shelly coarse sand/shell gravel substrates immediately beyond rocky reef habitat - approximately 15 m depth (Kerr and Grace 2013).

PMR 4 will exclude the nearshore intertidal and subtidal rocky reef habitat that divides Oneroa Bay from little Oneroa Bay with the inshore boundary commencing at Fisherman's Rocks out to the eastern Point of Hekerua Bay. The eastern coastline of Little Oneroa Bay is predominantly subtidal sandy substrate with shallow subtidal rocky reef present in a narrow continuous band out to the western tip of Hekerua Bay.

The section of the Waiheke Island coastline encompassed by both proposed reserves is semi-sheltered with mean wave height below 0.5 m and is of low tidal current < 0.05 m/s. Contact recreational water quality is monitored by Auckland Council at Oneroa, Little Oneroa and Palm Beach where it is classified as "Excellent", i.e., occurs below the amber level of the Ministry of the Environment marine bathing water quality guidelines (below 140 enterococci $100ml^{-1}$) > 90 %.

Based on aerial imagery macroalgae is conspicuous throughout both reserves associated within subtidal rocky reef. The occurrence and diversity of sponge habitat remains unknown, but is likely to be found on rocky reef > 12m depth. In addition to macroalgal and sponge habitat the proposed marine reserves will more than likely contain the suite of rocky reef and soft sediment marine invertebrates described by Smith (2004, 2016) and Kerr and Grace (2013) for the northern Waiheke coastline. For rocky reef habitat this would include low to moderate abundances of *Cookia sulcata*, *Trochus viridis*, *Calliostoma punctulatum*, *Dicathis orbita*, and *Evechinus chloroticus* (Table 7) and high to moderate abundances of the clown nudibranch *Ceratosoma amonena* and butterfly chiton *Cryptochonchus porosus* (derived from spatial predictive modeling of Smith 2004). Soft sediment macrofauna is likely to be of moderate species richness (diversity) predicted to be around 8 species (per sampling grab) and moderate turnover diversity. Species predicted to have moderate abundance include the heart urchin *Echinocardium cordatum,* the brittle star *Amphiura rosea,* the invasive bivalve *Theora lumbrica*, Siglanoidea polychaetes, Oenoidae polychaetes, whereas Lumbrineridae polychaetes are predicted to be found in high abundance.

Due to lower tidal currents along this section of coastline, it is probable that a different macrobenthic community to the high-current community described for the western area of

PMR 1 (Chiaroni *et al*. 2010). While the composition of soft sediment benthic communities are largely undescribed within the proposed reserve there is a high probability that scallop and dog-cockle beds are present within or at least, adjacent to, the proposed reserve associated with coarse, sandy, gravel habitat (Kerr and Grace 2013).

As for PMR 1, the variety of cryptic fish described by Smith (2004) and the majority of benthic and pelagic fish identified in the unpublished survey of Te Matuku Marine Reserve (Table 1) are all likely to occur across the proposed reserve Morrison *et al.* (2003) infer that snapper, jack mackerel, sand flounder, red gurnard, and john dory are all likely to occur in moderate to high abundance within and adjacent to the proposed reserve area. Reef fish richness based on Seasketch (2006) is reasonably low within the area with snapper take low to moderate (Table 8).

6.4.2 State of marine vegetation and potential for regrowth

Macroalgae is the dominant marine vegetation across both proposed marine reserves occupying 0.31 km^2 of rocky reef habitat with bare rock and urchin barrens encompassing < 0.03 km^2 (Auckland Council *remote sensing estimate*). While data on macroalgal diversity, abundance, and biomass are unavailable for PMA 4 and 4A, it is likely that similar species composition to that described for Hakaimango Point and the north-western coastline of proposed marine reserve 1 is present (Smith 2004; Kerr and Grace 2013). This would include shallow *Carpophyllum* habitat in the sub-littoral fringe, mixed algal habitat dominated by fucalean species down to 3-5m and *Carpophyllum flexuosum* or urchin-grazed barrens habitat down to 10-12 m depth. It is unclear as to the presence/extent of *Ecklonia radiata* habitat across the proposed area.

Given the presence of barrens habitat within the proposed reserve there is potential for re-growth of macroalgae should the recovery trajectories of large predators follow that observed in the outer Hauraki Gulf marine reserves and urchins numbers decline in response to this (Shears and Babcock 2002, 2003). Sharing commonality with PMA 1, successional processes of macroalgal recovery will be contingent on the depth distribution of barrens habitat and the presence of macroalgae adjacent this habitat.

6.4.3 Biogenic habitats present and potential ecosystem productivity

Macroalgae is the main biogenic habitat contained with proposed marine reserves 4 and 4A and would collectively contribute significantly to primary and secondary productivity across this section of coastline (Taylor 1994; Shears and Babcock 2007; Seasketch 2016). Sponges associated with deeper reef habitat within PMA 4A are likely to be represented by *Ancorina alata*, *Polymastia* sp, and *Tethya* spp (Kerr and Grace 2013). As previously mentioned scallop, dog-cockle and horse mussel beds are a potential biogenic habitat (Kerr and Grace 2013). Indeed, scallops, dog cockles and horse mussels *Atrina zelandica* have been known to wash up in large numbers following storm events across this stretch of coastline.

6.4.4 Species present and potential for future species protection

A range of commonly targeted reef fish could potentially respond positively to, or benefit in some way to, no-take protection along this stretch of the Waiheke coastline. This will however be contingent on whether the reserve is large enough to accommodate adult movement and multiple habitat utilisation. Species that could potentially benefit include those common to trawl surveys, e.g., snapper, sand flounder, red gurnard, john dory (Morrison *et al*. 2003) and tarakihi and other species associated with rocky reef habitat that are common targets for spearfishers red moki, leatherjacket, butterfish.

Spiny rock lobster (*Jasus edwardsi*) presence within the proposed reserve is unknown. As for PMR 1, should lobster occur along this stretch of coastline and rocky reef habitat is suitable for settlement, survival and ongoing retention (which is highly likely) then protection afforded by the reserve could be significant.

Table 7. Main species likely to be present within Proposed Marine Reserve 4 and 4A (combined). Data are extrapolated from available literature.

Component	Species/community	Occurrence	Source
Rocky reef			
Macroalgae	*Carpophyllum flexuosum* Mixed algae *Ecklonia radiata*	High High Moderate?	Extrapolated from Smith (2004); Kerr and Grace (2013)
Sessile invert	Sponge	Moderate?	Extrapolated from Kerr and Grace (2013)
Mobile Invert	*Evechinus chloroticus* *Stichopus mollis* *Cookia sulcata* *Trochus viridis* *Calliostoma punctulatum* *Jasus edwardsii*	High Low to moderate Low to moderate Low to moderate Low to moderate Unknown	Extrapolated from Smith (2004)
Soft sediment			
Mobile invertebrates	Unknown	Unknown	
Bivalves	*Pecten novaezelandiae* *Tucetona laticostata*	Unknown Unknown	Extrapolated from Kerr and Grace (2013)
Fishes (non-cryptic)	Snapper -adult Snapper - juvenile red gurnard – juvenile and adult john dory - juvenile	Low to moderate Low to moderate Low Low to moderate Moderate	Compton *et al*. (2012) Stevenson (1998)

6.4.5 Potential for spawning, hatching, protection of juveniles and of which species

The studies of Zeldis and Francis (1988) and Zeldis *et al*. (2005) infer that the northern coastline of Waiheke Island, has moderate to high egg production (forming an arc to the Noises, Tiritiri and Kawau island - see Morrison *et al*. 2014a) and moderate to high snapper larvae in the water column. Therefore intuitively the northern coastline is likely beneficial to both juvenile and adult snapper. Should they occur, habitats that offer three-dimensional structure and those biogenic in nature within the proposed reserve will be likely important for tarakihi, blue cod, and leatherjacket (Morrison *et al*. 2014a,b).

Owing to the higher current regime and exposure of the northern coastline relative to the southern there is likely to be wide larval dispersal, i.e., beyond the proposed marine reserve boundaries for many species. In addition, due to the proximity of PMR 4 and 4A to PMR 1, there is likely to be a high degree of connectivity between these two proposed marine reserves.

6.4.6 Ideal size and boundary lines to optimise long term abundance

As the proposed reserves 4 and 4A (combined) represent the smallest reserve being considered within the localised network and will have a high boundary to area ratio they are not likely to be effective in protecting and enhancing the long term abundance of commonly target species like snapper and lobster. While much of the rocky reef fingers extending offshore from Sandy Bay and Enclosure Bay will be protected by the proposed marine reserve, the continuous rocky reef that extends past Enclosure Bay into the western region of Palm Beach may reduce any protection-related benefits (Edgar *et al*. 2014). The effect of fishing on longshore boundaries (i.e., edge effects) for snapper and crayfish will likely extend ~1 km into a reserve (Freeman *et al.* 2009; Willis *et al*. 2003), so this reserve being ~2 km long will have minimal area that is effectively protected. The limited offshore extent will also greatly exacerbate these edge effects. It would therefore be beneficial to expand the eastern boundary so at the bare minimum the continuous rocky reef habitat within Mawhitipana Bay is protected. In addition, the offshore boundary should be extended at least 1 km offshore to encompass offshore movements of key species and ensure that additional soft sediment habitat types (muddy substrates) and potential soft sediment biogenic habitats are protected. It is author's preference that the eastern boundary is extended as far as Thompson Point to include Nani Island. A larger reserve will ensure that a higher diversity of coastal habitats unique to the northern Waiheke coastline and Hauraki Gulf will be protected. It will also ensure that the reserve is effective at mitigating the effects of fishing on key species. As it stands the proposed reserve will only be effective at protecting reef species that have limited mobility.

6.4.7 Terrestrial interface advantages and disadvantages

The area surrounding Little Oneroa adjacent the southern boundary of proposed marine reserve 4 is predominantly built-up residential which transitions to broadleaf indigenous hardwoods and low-density residential land cover towards Hekerua Bay. Similar terrestrial habitats boarder proposed marine reserve 4A. The entire terrestrial interface for both reserves has a threatened environmental classification of chronically threatened with 20-30% indigenous cover remaining (Landcare Threatened Environment Classification 2012)**.**

Given the proximity of the western boundary to Oneroa, there is the potential for western parts of the reserve to be periodically impacted by stormwater-related contaminants (nutrients, heavy metals, PAHs). Similarly there is always the potential for localised impacts from poorly maintained or performing septic tanks, effects which may be acerbated during peak visitor periods (summer).

Table 8. Select data summaries from Seasketch (2016) for physical, biological, and recreational fishing and snapper catch within the Proposed Marine Reserve 4 and 4A.

Proposed Marine Reserve 4 and 4A			
Physical attributes	**Details**	**Biological attributes**	**Details**
Tidal current	Moderate	Biogenic	High inshore Low offshore
Wave height	Low < 0.5 m	Historic mussel beds	Historically dredged dense mussel beds throughout
Productivity Nutrient Cycling	Medium (4.2-8.00) to High (8.01 to 14.67) with small pockets of high productivity surrounding rocky reef habitat) High (7-12.2)	Reef fish richness Reef fish conservation prioritisation	Low 13-14 species 50-100% (low priority)
Habitat types	Intertidal – rocky reef Intertidal – soft sediment - sand Subtidal – rocky reef Subtidal – shallow sand Subtidal – shallow mud	Rec Fishing Effort (2004-2005) boats per km^2 Rec Fishing Effort (2011-2012) boats per km^2	30-41 68-128
Main Substrates	Mud and sandy mud Mixed sediment Intertidal soft sediment Intertidal and subtidal rocky reef	Snapper catch intensity Kg/Km2 1 October 2011 to 30 September 2012	825.3-1157.7

7.0 Identification of information gaps

For all proposed marine reserves qualitative descriptions of broad habitat types are available from remote sensing (Auckland Council *unpublished data*), broad-scale surveys (e.g., Chiaroni *et al*. 2010), and synthesis of summary data layers within Seasketch (2016). While much of the data is derived from spatial predictive modelling, a technique that provides an estimate of species occurrence/abundance and is useful in its own right, unfortunately there is a distinct lack of quantitative data for many intertidal and subtidal habitats and species across proposed reserves.

Another major information gap for the majority of PMRs evaluated is in understanding the types of extractive activities taking place in each area - primarily what species are being caught? Once this is understood more compressively, better-judgements on what the effects of fishing are on the proposed area and whether these could be improved or reversed by marine reserve protection can be made.

The efficacy of a marine reserve will be dependent on the species within and their movement patterns, relative to the size of the reserve. For the most part, we have a reasonable understanding on how marine reserves will benefit reef ecosystems on more exposed reefs such as PMR 1, but we have a very limited understanding of their value for sheltered habitats such as Te Matuku. e.g., are snapper that are being caught in PMR 2 likely to take up residence if they are not caught, or are they merely moving through the area to more-preferred habitat?

Specific information gaps include:

1. Lack of information on species (shellfish, fin-fish) being harvested within proposed areas (particularly PMR 2 and 3) and types of harvesting carried out. This is ultimately critical to predicting the potential ecological value of a marine reserve.
2. Absence of quantitative data on the abundance and biomass of dominant species within intertidal and subtidal rocky reef habitat (macroalgae, mussels, mobile and sessile invertebrates and reef fish), including overall community composition.
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 and effects of other stressors, pollution, invasive species incursions *etc*.

Due to the deficiency of hard data for Waiheke Island, it would be extremely beneficial to the overall marine reserve network process to undertake quantitative sampling of rocky reef and soft sediment habitat types and generate baseline data. For PMRs 1, 2, 4, and 4A we recommend that for subtidal rocky reef environments, depth-stratified sampling at 2-3 rocky reef sampling sites per reserve is undertaken with a focus on recording habitat types and measuring dominant benthic organisms and sediment cover (e.g., Shears 2013). Subtidal soft sediment areas can be effectively surveyed using drop camera deployments and dredge tows. Should underwater visibility allow, assessments of common reef-fish could occur jointly with depth-stratified rocky reef sampling.

Ultimately this will provide information on biodiversity and build on the work of Kerr and Grace (2013) for northern areas, and Chiaroni *et al*. (2010) for southern areas of the coast. To provide further context data can also be compared quantitatively to benthic sampling undertaken in Long-Bay Okura, Tawharanui, CROP and Hahei marine reserves. For intertidal rocky reef and intertidal soft sediment habitats within all proposed reserves it would be entirely feasible to incorporate citizen-based monitoring (school groups and wider public) under guidance of a suitable qualified marine ecologist. Data generated on dominant habitats and species within these can be compared to the datasets in existence for Te Matuku marine reserve. For PMR 3, sampling of seagrass habitat and intertidal bivalve beds particularly cockles are strongly warranted. These habitats could again be sampled by community and school groups to better understand the diversity and abundance of species within the proposed marine reserve and will share commonality with other community-driven bivalve censuses (e.g., Whangateau Harbour).

In addition to a lack of quantitative data, wider information gaps exist with respect to habitat preferences for different life history stages of commonly targeted fishes (Morrison *et al*. 2014a), the degree and effectiveness of larval dispersal across marine reserve boundaries and between adjacent reserves (connectivity). As such it would be a useful exercise to evaluate the re-seeding potential and connectivity (sources or sinks) of the marine reserves proposed for Waiheke Island, as well as identify other sites within the Gulf that may be important to Waiheke Island. This could be achieved through basic dispersal modelling and hydrodynamic models already in existence for the Gulf.

8.0 Discussion

Based on the information synthesised from existing studies/data sources and presented in Section 6.0, and presuming modifications can be made to proposed boundaries the 5 marine reserves proposed by the Waiheke Local Board and Hauraki Gulf Conservation Trust all have some merit in being designated as full no-take marine reserves, i.e., Type 1, but are likely to have different conservation merit. Should these reserves become established then together with Te Matuku marine reserve, collectively they will form an important first step towards developing a network of protected areas across Waiheke Island. Main attributes and gaps in the knowledge base are summarised in Table 9.

The array of habitats the proposed marine reserves would protect range from sheltered estuarine (PMR 3), complete marine (PMR 1, 4 and 4A), with PMR 2 having both estuarine and coastal elements. A variety of biogenic habitats and species span these areas including mangroves, intertidal seagrass, macroalgae, sponge communities, horse mussel beds, and other bivalve species. While presently data are lacking for abundance, size and biomass for the majority of species, many habitats and species of high ecological function identified will likely be completely protected within the proposed marine reserve boundaries. Replicated habitats (including Te Matuku) will include mangroves, macroalgal habitat, sponge habitat, intertidal rocky reef, intertidal mud and sand flats, and a wide range of subtidal soft sediment (mud and sandy mud and coarse sediment shell and gravel) and fulfils many of the requirements of network design put forward by Thomas and Shears (2013). It must be stressed that these habitats do vary in spatial extent and quality across Waiheke Island and it would be misleading to assume equivalent ecological importance or ecological function for a particular habitat where it across multiple reserve areas.

For one of the proposed marine reserves (PMR 4A) considerable modification of the boundaries will be essential to ensure that is effective in protecting and restoring the ecosystems found along this part of the Waiheke Island coastline. Extensive urchin barrens are found in this area (Fig. 7) and an adequately sized marine reserve would be necessary to restore macroalgal habitat. Smaller boundary modifications are also recommended for PMR1 and PMR2. For PMR 1 extension of the offshore boundary to include, or be within, close proximity to the proposed Noises Island Marine Reserve would of value in so far as protecting deepwater soft sediment habitat. This habitat is not well represented in either existing or the other proposed Waiheke Island marine reserves (see Jackson 2014). For PMR 2, extension of the north-western boundary to include Te Whau Bay and all, or part of, Oakura Bay to encompass the natural sand-spit that divides the two bays including offshore Islands would be beneficial for biodiversity enhancement.

Larval dispersal for many of the species contained within the proposed reserves is more than likely to transverse reserve boundaries, thereby enhancing adjacent unprotected areas. Larval dispersal is likely to be greatest for the northern PMRs due to their proximity to higher tidal currents and greater wave exposure and less for southern coastline PMRs. Larval connectivity across all PMRs is highly feasible, again this will likely to be more pronounced between northern reserves than southern, but will ultimately be contingent on larval duration. To effectively predict larval transport from proposed MPAs hydrodynamic modeling analogous to that done for Te Tapuwae O Rongokako Marine Reserve would be required. Such an approach would likely be very beneficial to our understanding of marine reserve connectivity (sources/sinks) surrounding Waiheke Island including the potential value of Waiheke Island as a larval source to other areas of the Gulf.

Figure 7. Urchin-grazed barrens habitat along the northern coastline of Waiheke Island (adjacent Enclosure Bay).

Because much of our understanding of marine reserve functioning within the HGMP has stemmed from repeat surveys of CROP, TMR, and Hahei, three coastal environments that differ physically (water quality, exposure, habitats) and biologically (habitats) from Waiheke Island, determining exact responses of fished species or various sections of the marine community to complete no-take protection is intrinsically difficult. This is further amplified by a lack of comprehensive baseline data. Furthermore, marine reserves within the HGMP that have estuarine components (Pollen Island, and Te Matuku) are comparatively less well studied and thus understood from protection-related perspectives (maintenance of biodiversity, resilience).

Should recommended boundary modifications occur, in terms of protection of fished species PMR 1 and PMR 4 and 4A (combined) are likely to be the most effective and effort should be placed on evaluating these areas further. For PMR 2 and PMR3 there is doubt as to whether these would be effective in protecting highly mobile fish species. The benefit from complete no-take protection for these reserves may lie in the protection of bivalve species that are harvested (cockles and pipi); the protection of important biogenic habitats from the direct effects of fishing, e.g., dredging; and, provision of nursery habitat for a range of fishes. Resultantly, core conservation goals are likely to differ across these proposed reserves.

The catchments of proposed marine reserves considered here range from residential, exotic pasture and horticulture to native scrub and forest. The area adjacent PMR 2 is the most natural with much of the catchment adjoining Whakanewha Bay and west of Kauakarau Bay covered in regenerating native scrub, whereas other reserves have more modified catchments. The main catchments adjacent PMR 3 is characterised by light industrial, residential, and horticulture 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 including other regions of the catchment that remain unvegeteted could be enhanced significantly through riparian planting – an initiative that has been widely adopted on Waiheke Island.

Importance of marine protection for Waiheke Island

The most recent State of the Hauraki Gulf Report (2014) identified that demands on the Gulf environments are significant and are likely to exacerbate given that Auckland's population is experiencing high growth. Population growth has many direct and indirect effects on marine resources and coastal amenities and striking a balance between coastal development and resource use while ensuring environmental integrity is fraught with difficulty and uncertainties. Many of the pressures highlighted within the State of the Hauraki Gulf Report (2014) are directly attributable to Waiheke Island, therefore additional marine protected areas proposed here would be a valuable contribution to meeting the conservation goals, preserving and restoring the size and abundance of many targeted species, concomitant with eliminating indirect effects of fishing (habitat disturbance). Moreover, as monitoring of physical and biological components are severely lacking for Waiheke Island the designation of marine reserves is likely to draw greater attention to protecting the habitats within in tandem with providing monitoring opportunities that can increase the understanding of these systems.

Where to from here?

The central focus of this report was to evaluate gaps in the knowledge base proposed Waiheke Island marine reserves. Of these, the most obvious gap surrounds the lack of quantitative data within the proposed marine reserve areas evaluated, which is common to much of the wider Hauraki Gulf. Obtaining quantitative data will allow for better evaluation of each marine reserve in terms of biodiversity, species abundance and size and any protection- and conservation-related benefits. Moving forward it will be important that the marine reserve network development for Waiheke Island is an inclusive process and it is anticipated that much of the data collection required could be done by a consortium that includes both qualified researchers and community/school groups. Equally, there is merit in understanding the connectivity of the proposed networks in terms of larval supply beyond reserve boundaries and across the wider network. This exercise may highlight additional benefits of the proposed areas being designated as a marine reserve. Ultimately, this information will be used to present a much stronger application for marine reserve network protection for Waiheke Island.

Table 9. Summary of key attributes for each proposed marine reserve for Waiheke Island.

Attribute	Proposed Marine Reserve			
	PMR 1	**PMR2**	**PMR 3**	**PMR 4 and 4A**
Main Conservation Value	Protection of fished species: Snapper, Lobster, and bivalves. Regrowth of macroalage	Protection of biogenic habitat, and potential nursery habitat from indirect effects of fishing. Protection of bivalves from harvesting.	Protection of biogenic habitat, nursery habitat and protection of bivalves (*Cockles*) from harvesting.	Protection of fished species: Snapper, Lobster, and bivalves. Regrowth of macroalage
Limitations to achieve conservation goals	Size	Location – high turbidity	Location – high turbidity	Size
Replicated habitats	Intertidal rocky reef Complex subtidal rocky reef Sheltered embayments Sandy beaches Extensive subtidal soft sediment (mud, sand, coarse shell and gravel)	Intertidal rocky reef Subtidal rocky reef Sheltered embayments Extensive subtidal soft sediment (mud, sandy-mud)	Sheltered embayment Intertidal mud and sand-flats Subtidal soft sediment (mud, sandy-mud)	Complex subtidal rocky reef Intertidal rocky reef Sheltered embayments Sandy beaches Extensive subtidal soft sediment (mud, sand, coarse shell and gravel)
Biogenic habitat	Macroalage Sponge Bivalve beds?	Mangrove Horse mussel (*Atrina*) Microalgae	Seagrass Macroalgae Bivalve beds?	Macroalage Sponge Bivalve beds?
Dominant terrestrial interface	Exotic pasture and horticulture	Regenerating native scrub Small areas of residential dwellings	Residential, light industrial and exotic pasture and horticulture	Residential, and exotic pasture
Change to proposed boundaries	Extension of offshore boundary recommended	Extension of western boundary to include Te Whau Bay and Oakura Bay	N/a	Extend offshore boundary and eastern boundary to include Thompsons Point.
Gaps in knowledge base	Lack of information on rocky reef and soft sediment species diversity, abundance, and size. Lack of information on reef-fish distribution, abundance and community composition. Lack of information on larval dispersal between and among proposed marine reserves, including wider Hauraki Gulf.			

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