A Status Report On the Biological and Physical Information for Wellington's South Coast with Monitoring Recommendations for the Taputeranga Marine Reserve

prepared for the

Department of Conservation
Wellington Conservancy

October 20th, 2008

Tyler Eddy, Jonathan Gardner & James Bell

Centre for Marine Environmental & Economic Research
School of Biological Sciences
Victoria University of Wellington

CENTRE FOR MARINE ENVIRONMENTAL & ECONOMIC RESEARCH
Te Pūtahi Rangahau i ngā Tini a Tangaroa

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MAUI
VICTORIA
UNIVERSITY OF WELLINGTON

Table of Contents

Summary

Many studies which span a range of disciplines have been conducted on Wellington's south coast. The aim of this report is to summarise this information, particularly highlighting research that is relevant to the monitoring of the Taputeranga Marine Reserve (MR). The spreadsheet included with this report titled "Marine Reserve Monitoring References" lists the studies that have been conducted on the Wellington south coast indicating the species, sites and methodologies used.

Our report particularly highlights research from Anjali Pande's PhD thesis, which is important because it provides important baseline information for the new Marine Reserve and forms the basis of our recommendations for the species and sites to be surveyed in the future, as well as suitable methodologies to be employed. We do however, highlight problems identified from this earlier work, and the ongoing work to address these issues. There have been a number of previous studies on specific species that we recommend for continued monitoring and by using these species and the same sites, with the same methodologies, a large database will be created (couple with existing information) that can be used to detect any future changes in the Taputeranga MR.

Importantly, Gardner and colleagues reported the presence of an environmental gradient of increasing nutrient and suspended sediment concentration in the water column, from west (low concentrations) to east (high concentrations), along the south coast. This has a strong influence on the monitoring and identification of suitable "control" sites within and adjacent to the Marine Reserve. We make recommendations for future monitoring with respect these potential problems. Finally, this report discusses past and ongoing research on the Wellington south coast concerning invasive species, genetic studies, connectivity, tagging studies as well as further studies that will enhance and support monitoring in the Taputeranga MR.

Introduction

The Taputeranga Marine Reserve protects 854.79 hectares of coastal waters on the south coast of New Zealand's capital, Wellington. The reserve extends from Princess Bay on the eastern boundary to Quarry Bay on the western boundary (Figure 1). The reserve has been the result of many years of work by local residents of the south coast, scientists at Victoria University of Wellington and The Royal Forest and Bird Protection Society of New Zealand. Formal application for the reserve was made by the South Coast Marine Reserve Coalition in October 2000 and the MR was gazetted in August 2008.

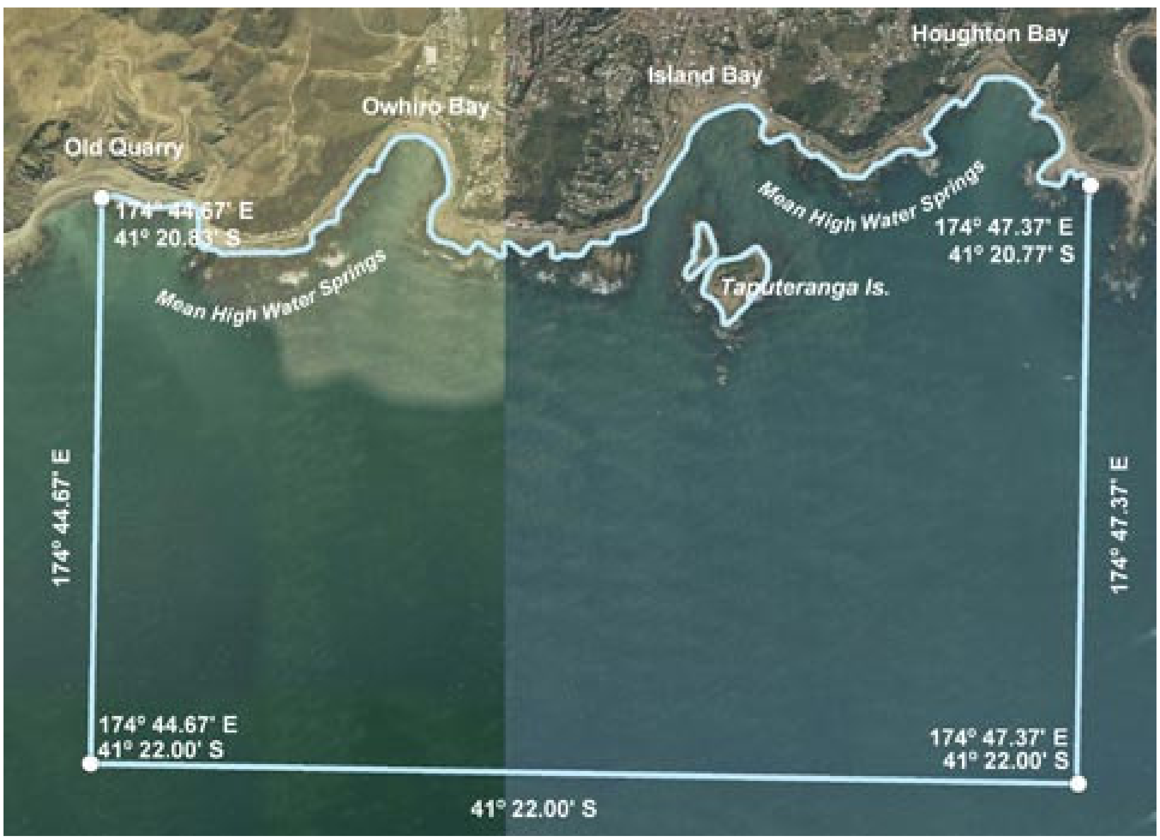


Figure 1. Map showing Taputeranga MR boundaries with GPS coordinates of boundaries (From Department of Conservation website).

The marine environment that the Taputeranga MR protects is representative of the temperate Cook Strait region. This is a highly dynamic area, receiving substantial wave energy from the south as well as the zone of convergence for the East Cape, D'Urville and Southland currents. Habitats protected by the MR include wave exposed rocky reef, wave sheltered rocky reef, cobble beach and sandy shore.

Wellington's south coast is home to a diverse assemblage of algal species including macroalgal stands, also known as "kelp forests", which provide habitat for a large number of invertebrate and vertebrate species. These algae belong to the brown algal group (Phaeophyceae), while red (Rhodophyceae) and green (Chlorophyceae) algae are also represented and speciose along the south coast. Much of the bottom type is characterized by greywacke reef, which is structurally complex with caves and gullies that provide habitat for a number of commercially and recreationally targeted invertebrates including rock lobster (*Jasus edwardsii*), paua (*Haliotis iris* and *Haliotis australis*) and kina (*Evechinus chloroticus*). The combination of macroalgae and rocky reef provide habitat for many fish species typical of Cook Strait temperate assemblages. Encrusting communities are composed of sponges, hydroids, ascidians and bryozoans. Elsewhere in the reserve, the substratum is sand with its associated, but poorly known epifaunal and infaunal assemblages.

Part I: Historic Biological and Physical Information

Summary of data contained in spreadsheet

The database titled “Taputeranga MR Monitoring References” contains five spreadsheet tabs titled “references”, “biological meta-data” and “physical meta-data”, “sites” and “baseline & monitoring”. The references tab was created by Helen Kettles (DoC) giving complete citations and abstracts of studies pertaining to the Wellington Conservancy’s management territory. From this list, the authors examined those studies that were relevant to the biological and physical characteristics of Wellington’s south coast and added further relevant references which can be found in the “biological meta-data” and “physical meta-data” tabs. In addition to the citation of the study, information is included describing the techniques or methods that were employed to gather the data, the year(s) that the study was conducted and study duration, the availability of the raw data, the location of the site(s) (Figure 1, Table 2), the general locations of the study sites, as well as the number of sites located in the MR, east of the MR and west of the MR.

The spreadsheet titled “Biological Meta-Data” contains 46 entries of studies conducted on the south coast that have been identified as important or relevant to the monitoring of the Taputeranga Marine Reserve. Of these 46 studies, 31 have at least one site located within the MR. Of these 31 studies with sites in the MR, there are 21 studies that also have at least one control site. Of these 21 studies with both reserve and control sites, 11 have at least one control site located to the east of the reserve, while 10 have at least one control site to both the west and east of the reserve (Table 1).

Of the 31 studies that use at least one site inside the marine reserve, the majority (14) of the studies address invertebrate species, which have mostly been conducted by Jonathan Gardner's research group who have published studies on mussel distribution and water column characteristics, and also size and distribution of kina, paua, and rock lobster. There are also a number of studies (nine) conducted on fish, fish larvae and tidepool fish size and abundance. The majority of these studies have been conducted sub-tidally for all major fish species. Nine studies focused on algae size, distribution and ecology; five of these concerned specifically with the growth and distribution of the invasive northern Pacific kelp, *Undaria pinnatifida*. Five studies addressed intertidal communities both at the community level (three studies) or a focusing on one specific group (two studies). Three studies addressed sponge distribution and ecology.

There have been a number of studies on water quality parameters including Gardner (2000), Gardner & Thompson (2001), Helson (2001), Gardner (2002), Helson & Gardner (2004), Helson & Gardner (2007) and Helson et al. (2007). Most of this research focuses on the environmental gradient that exists along the south coast where suspended particle and nutrient concentrations decrease from east to west (from Wellington Harbour to Sinclair Head). Information has been collected for water column characteristics describing: temperature, salinity, dissolved oxygen, total particulate matter, particulate organic matter, percentage of organic matter, chlorophyll *a*, particulate counts (per mL and for the size range 2.5 – 63 μm), percentage of carbon, percentage of nitrogen, and carbon to nitrogen ratio.

Dickie (1982) qualitatively characterized the wave exposure level of five sites on Wellington's south coast and assigned them a score from 0 to 7 depending on the degree of wave exposure (7 being most exposed, refer to Appendix 1).

Bradford et al. (1986) conducted research in the Cook Strait onboard the RV Tangaroa investigating the availability of dissolved inorganic nutrients in surface waters and their influence on phytoplankton production in 1980 and 1981. Measurements were taken for surface temperature, salinity, in vivo chlorophyll *a*, dissolved nitrate, nitrite and ammonium nitrogen as well as potential primary production. Bowman et al. (1983) determined that under certain conditions, warm, nutrient-depleted subtropical water flows into Cook Strait surface waters from western North Island, New Zealand. Coastal upwelling takes place in the southeastern region of the Cook Strait Canyon. During northerly storm winds, upwelling of nutrient rich subsurface water occurs, which is thought to be linked with phytoplankton blooms that have been observed from the Cook Strait stretching to the southeast. Bowman et al. (1983) also collected data on temperature and conductivity with depth in combination with nutrient sampling and determined that water quality characteristics are highly influenced by storms which determine how much cold, nutrient-rich water from the south, or warmer, nutrient-poor water from the northwest coast enters the Cook Strait.

Of the studies that have been conducted on fish, most are subtidal (Eddy in progress, Pande 2001, MacDiarmid & Stewart unpublished; Cole & Jackson 1989) with one further study on larval abundance (Keith 2000) and one study on the abundance of intertidal rockpool fish (Willis & Roberts 1996). Previous studies on paua size and distribution have been conducted by Byfield (in progress), Russell (2004), Pande (2001), MacDiarmid & Stewart (unpublished), Cole & Jackson (1989) and Sinclair (1963). Russell specifically addressed growth and mortality rates, as well as migration. Studies on kina have been undertaken by Byfield (in progress), Pande (2001), MacDiarmid & Stewart (unpublished) and Cole & Jackson (1989), while studies on rock lobster size and abundance have been conducted by Booth et al. (2007), Pande (2001) and MacDiarmid & Stewart (unpublished). Booth quantified settlement rates and post-settlement migration rates, while the other studies have looked at size and abundance of juveniles and adults.

Pande (2001) conducted fish surveys for eight species: banded wrasse (*Notolabrus fucicola*), blue cod (*Parapercis colias*), blue moki (*Latridopsis ciliaris*), butterfish (*Odax pullus*), red moki (*Cheilodactylus spectabilis*), spotty (*Notolabrus celidotus*), tarakihi (*Nemadactylus nacroplerus*) and trevally (*Pseudocarnax dentex*). Eddy (in progress) is the only person who has undertaken research recording the same species as Pande. MacDiarmid & Stewart collected information for blue cod, red moki, blue moki, butterfish, and tarakihi (unpublished). Cole & Jackson collected information for six of the eight species (tarakihi and trevally were not surveyed) used by Pande. Of Pande's eight species, Keith (2000) only found larvae from spotty. Willis & Roberts (1996) only reported banded wrasse and spotty in tidepools in their intertidal study.

Studies conducted on biosecurity-related issues include work by Hay & Villouta (1993) who identified *Undaria pinnatifida* in Wellington Harbour and identified morphological and seasonal characteristics of this species. Wear & Gardner (1998, 2000) and Gardner & Wear (1999) conducted subtidal and intertidal research at The Sirens and produced three reports detailing the location of *Undaria pinnatifida* in their survey sites (Appendix 2). They also recorded information on the percentage cover of other algal species and grazing invertebrates that occurred within transects and quadrats. In her Master's thesis at Victoria University of Wellington, Christian (2003) measured the abundance, morphological features and growth rates of *Undaria pinnatifida* occurring in the intertidal zone at two locations in Wellington Harbour and two locations at Island Bay. D'Archino & Nelson (2006) documented the first occurrence of *Asperococcus ensiformis* in New Zealand waters in 2006 from the sunken wreck of the frigate HMNZS Wellington in Island Bay. For her PhD thesis at Victoria University of Wellington (in progress), Bionda Morelissen is recording algal species richness and algal percentage cover from lower intertidal sites at Island Bay and at Owhiro Bay.

Several studies have focused on tagging, connectivity and genetics of key species. Bradstock (1948) tagged rock lobster (*Jasus edwardsii*) on the south coast to determine seasonal or directed migration. Russell (2004) conducted a tagging study on both yellow-foot (*Haliotis australis*) and black-foot (*Haliotis iris*) paua where she measured seasonal migrations over small distances, indicating that these species are relatively sessile. Star et al. (2003) conducted connectivity studies for mussels in New Zealand to determine the amount of gene flow that is exchanged between populations to find if a major split between northern and southern stocks of mussels occurs in the Cook Strait region. Currently, Salinas de Leon is conducting connectivity research between three marine reserves (Kapiti, Long Island and Taputeranga) using two marine gastropods as models to determine connectivity between marine reserves, while Westfall is currently conducting research on the genetic population structure of blue mussels to determine gene flow between populations and the presence of biogeographic barriers potentially including sites on the south coast. One aspect of the current PhD research of Reisser is to examine gene flow among populations of the black nerite, *Nerita melanotragus* which has its southern distributional limit in the Wellington region. Dr Ann Wood is currently examining limpet taxonomy, systematics, population genetics and biogeography in NZ including the south coast.

Summary of previous studies

The metadata spreadsheet “Marine Reserve Monitoring References” contains information about previous and current research associated with the Taputeranga MR. The spreadsheet lists studies conducted in many disciplines (including marine biology, oceanography, fisheries management and geology), as well as informal reports conducted by local interest groups, such as a checklist of shells found in Wellington Harbour and on the south coast, by the Wellington Shell Club in 1971 (Beu & Climo 1971). This spreadsheet lists all the studies undertaken and ongoing on the Wellington south coast that are relevant to the management and monitoring of the Taputeranga MR. All studies and reports available to the authors at the time of writing were included in the spreadsheet.

What follows is a summary of studies that are considered most useful as baseline information for the Taputeranga MR. Studies included were selected if their methodology quantified either species abundance and/or size at sites inside MR boundaries or at adjacent unprotected (non-MR) sites. A summary of these studies and a map of their locations are provided in Table 1 and Figure 2.

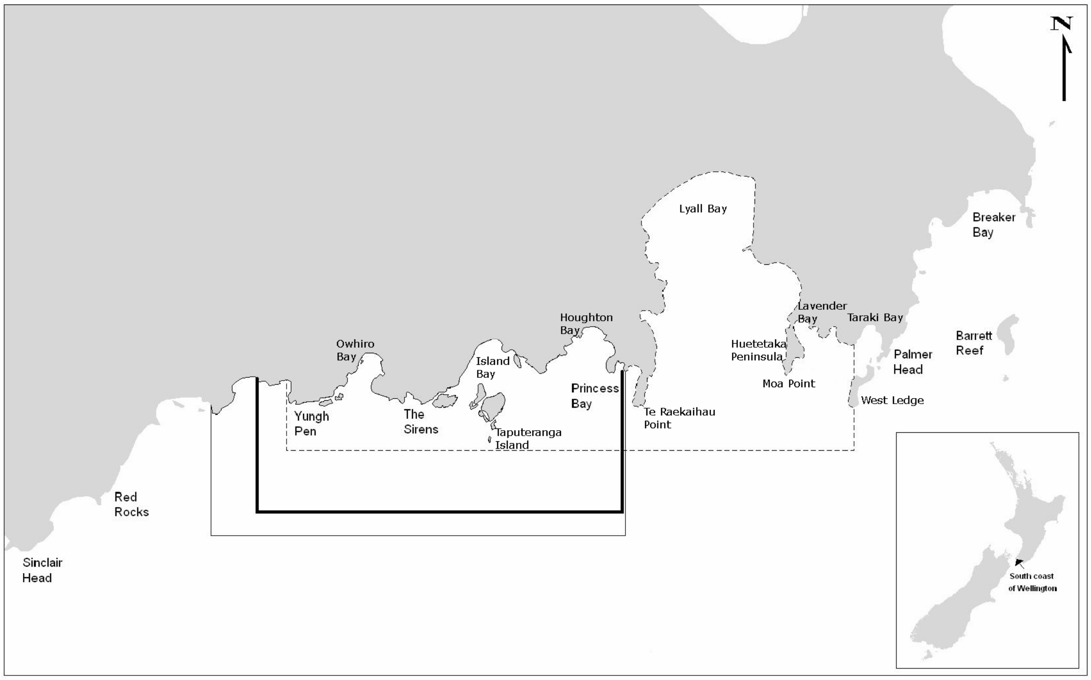


Figure 2. Map showing 1996 (dotted line) and 2004 (thin solid line) MR proposed boundaries. Dark solid line represents the present (2008) MR boundaries. South coast research sites from Table 1 are labeled. (Map adapted from Pande & Gardner 2008).

Table 1. Sites sampled along the south coast with corresponding latitude and longitude (where available) and study reference.

Site (East to West)	Latitude (S)	Longitude (E)	Studies at this site:
Pencarrow Head			MacDiarmid & Stewart unpublished
Barrett Reef	41.20.495	174.50.160	Pande 2004, Russell 2004, Byfield in progress, Eddy in progress, MacDiarmid & Stewart unpublished
Breaker Bay	41.19.992	174.49.856	Pande 2004, Russell 2004, Eddy in progress, Berman in progress
Flax Bay	41.20.168	174.49.595	Byfield in progress
Palmer Head	41.20.841	174.49.285	Pande 2004, Russell 2004, Byfield in progress, Eddy in progress, Carter & Connell 1980
Taraki Bay	41.20	174.48	Carter & Connell 1980
West Ledge	41.20	174.48	Carter & Connell 1980
Lavender Bay	41.20	174.48	Carter & Connell 1980
Huetetaka Peninsula	41.20	174.48	Carter & Connell 1980
Moa Point			MacDiarmid & Stewart unpublished, Carter & Connell 1980
Lyall Bay			Keith 2000, Booth et al. 2007
Te Raekaihau Point			MacDiarmid & Stewart unpublished
Princess Bay	41.20.955	174.47.347	Pande 2004, Russell 2004, Byfield in progress, Eddy in progress, MacDiarmid & Stewart unpublished, Cole & Jackson 1989, Berman in progress
Houghton Bay			Cotsilinis 1999, Cole & Jackson 1989
Island Bay			Keith 2000, Booth et al. 2007, Christian 2003, Berman in progress
Taputeranga Island			MacDiarmid & Stewart unpublished, Cole & Jackson 1989
The Sirens	41.21.183	174.45.916	Pande 2004, Russell 2004, Byfield in progress, Eddy in progress, MacDiarmid & Stewart unpublished, Cotsilinis 1999, Cole & Jackson 1989, Christian 2003, Berman in progress
Owhiro Bay Sewer			Cotsilinis 1999
Owhiro Bay			MacDiarmid & Stewart unpublished, Cole & Jackson 1989
Owhiro Bay West			Cotsilinis 1999
Yungh Pen	41.21.114	174.45.129	Pande 2004, Russell 2004, Byfield in progress, Eddy in progress, Cole & Jackson 1989, Berman in progress
Red Rocks	41.21.587	174.43.361	Pande 2004, Russell 2004, Byfield in progress, Eddy in progress
Sinclair Head	41.21.651	174.42.219	Pande 2004, Russell 2004, Byfield in progress, Eddy in progress
Second Wash	41.21.127	174.41.666	Byfield in progress

The Moa Point Wastewater Treatment Plant & Outfall Study (Cater & Connell 1980) described benthic community structure at six sites in the Moa Point area along vertical transects from the intertidal to subtidal zones (9 m above sea level to 14 m depth, and from 350 to 900 m distance from sewage outfall) as well as along subtidal horizontal transects (ranging in depth from 6 to 27 m and 80 to 1660 m distance from sewage outfall). This study is qualitative with most descriptions given for broad groups rather than to species level; no habitat data were collected. This study is valuable in aiding our understanding of the general community structure of benthic macroalgal, epifaunal and infaunal assemblages in the Moa Point area, although its use to the future monitoring of the MR is limited as the data were qualitative.

The Department of Conservation report titled “Marine Survey of Wellington’s South Coast” by Cole & Jackson (1989) also represents a qualitative assessment of 10 sites, eight of which will be protected by the MR. Field work for this report was conducted over a three day period in August 1989 and the study represents a snapshot of fish and invertebrate species present at shallow depth (less than 10 m). The eight sites surveyed within the Taputeranga MR boundaries represent the greatest number of sampling sites for any report currently available. However, the small number of control sites (only two east of the MR boundary), lack of seasonal sampling and the qualitative nature of the report (for example, paua not identified to species and no size estimations made) limit the usefulness of this report as a source of baseline data. It does represent an early subtidal study of fish species for the south coast, so can be used as a checklist or relative abundance gauge compared to current fish abundance data collected by a similar survey methodology. The survey technique used to count eight species of fish in this study was a three minute timed count replicated six times; this methodology has not been used on the south coast since. While this technique does produce quantitative data, it yields abundance per unit time which makes it difficult to compare with other data sets because they do not use this measure. Subsequent south coast fish surveys have used the technique of swimming a fixed distance using a transect tape to quantify fish abundance per unit area. The survey technique used by Cole & Jackson to measure invertebrate species (paua and kina) abundance involved counting all individuals in 20 haphazardly placed $1m^2$ quadrats at each site. Again, this technique has not been used subsequently for south coast surveys. While this report does describe quantitative data for fish and invertebrate abundance, the survey methodology has not been repeated and therefore makes it difficult (but not impossible) to compare with other studies. It would be possible for these surveys to be repeated in the future, although we recommend the more recent survey methods area used.

Mike Cotsilinis's MSc thesis (supervised by Drs Jonathan Gardner and Robert Wear) submitted to the Victoria University of Wellington in 1999 describes the change in intertidal community structure at Owhiro Bay following the closure of the Owhiro Bay sewage outfall pipe in December 1994. Community structure (abundance and biomass of all species) at this site was compared to other sites along the south coast to determine if the assemblage was becoming more or less similar over time to sites situated further from the outfall pipe. Data were collected for invertebrate and macroalgal species at four sites; Owhiro Bay (where the sewage outfall was present), Houghton Bay, The Sirens and Owhiro Bay West. These data are useful in understanding how community structure changes along an environmental gradient, as well as how it changed in response to the closure of the sewage outfall. Abundance and biomass estimates at control sites (all three will be protected when the MR is in place) are valuable as baseline intertidal community structure data.

For the unpublished report titled "Wellington South Coast Taiapure Project 1999 & 2000" Alison MacDiarmid and Rob Stewart from NIWA surveyed eight sites on the south coast of Wellington in 1999 and 2000. The eight sites were located such that three would fall within the MR and five were located east of the reserve boundary. Data for this report were collected on the size and abundance of five key species of fish: blue cod (*Parapercis colias*), red moki (*Cheilodactylus spectabilis*), blue moki (*Latridopsis ciliaris*), butterfish (*Odax pullus*) and tarakihi (*Nemadactylus nacroplerus*). Fish were counted using the underwater visual census (UVC) technique along a 45 m long by 5 m wide transect, yielding a survey area of 225 m^2. Data were also collected for size and abundance of rock lobsters along a 50 m long by 10 m wide transect. Data describing size and abundance of paua and kina were collected along a 20 m long by 1 m wide transect. Transects were conducted at both "shallow" (4-8 m) and "deep" (18-22 m) locations. Four replicates were conducted at both depth strata at every site. Surveys were conducted once a year for two consecutive years. We believe that these data are very useful as baseline data.

Crispin Keith's MSc thesis (supervised by Drs Peter Castle and Jonathan Gardner) submitted to Victoria University of Wellington in 2000 characterised larval ichthyofauna (fish) abundance in Wellington Harbour and on the south coast. Surveys were conducted monthly over a one year period between 1997 and 1998 by collecting larvae from Kau Bay, Lyall Bay and Island Bay. Larvae were identified and counted. This research provides a baseline survey of larval abundance and biomass, as well as a list of species presence/absence at the two south coast MR sites. It would be valuable to use for any future settlement and recruitment studies conducted in the MR.

Anjala Pande's PhD thesis (submitted 2001) was supervised by Dr Jonathan Gardner and contains three years of survey data at eight sites along Wellington's south coast for key indicator fish, invertebrate and macroalgal species. Four macroalgal species were studied: *Ecklonia radiata* (paddleweed), *Macrocystis pyrifera* (giant kelp), *Carpophyllum maschalocarpum* (narrow flapjack) and *Lessonia variegata*. Algal abundance was determined by counting the number of stipes of the four species in a 0.5 m^2 quadrat placed every 3 m along a 30 m transect, yielding 10 quadrats per transect. Three such transects were undertaken at each site during each sampling period, giving a total of 30 quadrats per site. Four macroinvertebrate species were studied: *Haliotis iris* (black-foot paua), *Haliotis australis* (yellow-foot paua), *Evechinus chloroticus* (kina), and *Jasus edwardsii* (rock lobster). Size and abundance of the four species were quantified by searching transects of 25 m length by 2 m width (= 50 m^2). Six transects were conducted at each site at each sampling period.

Pande (2001) quantified fish size and abundance using the Underwater Visual Census (UVC) technique, counting all fish that were encountered in each transect of 25 m length by 5 m width (total area = 125m^2). Eight common species of fish were included in the analysis: *Notolabrus fucicola* (banded wrasse), *Parapercis colias* (blue cod), *Latridopsis ciliaris* (blue moki), *Odax pullus* (butterfish), *Cheilodactylus spectabilis* (red moki), *Notolabrus celidotus* (spotty), *Nemadactylus nacroplerus* (tarakihi), and *Pseudocaranx dentex* (trevally). Nine replicate transects were conducted at each site during each sampling event. Records of all fish species encountered (33 different species) were made, but because most species were rare, analyses concentrated on the eight common species listed above.

All of Pande's research was conducted in the subtidal zone, between depths of 5 and 15 m. It was acknowledged by Pande & Gardner (2008) that this depth limit of 15 m may not be great enough to capture seasonal depth migrations of specific species such as the rock lobster. However, given time and funding constraints for the project, it was regarded as the most appropriate sampling technique. Pande used a team of divers to conduct all of the surveys, commonly using two buddy teams of two with one group doing fish and invertebrate surveys, while the other group conducted algal surveys. Pande had access to the Victoria University of Wellington's research vessel *Raukawa Challenger* as well as two smaller research vessels to conduct surveys. Four of the survey sites are accessible via shore diving, while the other four require boat access.

Three sites studied by Pande will be protected by the MR when it is implemented; three sites are located to the east of the reserve and two sites are located to the west. These data were collected four times a year, capturing seasonal variation in size and abundance of species at each site. Data were collected before the implementation of the MR, specifically for the purpose of establishing a pre-protection "baseline". Sites sampled are situated to both the east and west of the MR as well as within, allowing for "inside" versus "outside" comparisons, keeping in mind an increasing environmental gradient of suspended particles and nutrients in the water column exists from west to east which has been studied extensively prior to MR implementation (Gardner 2000; Helson & Gardner 2007; Helson et al. 2007) and which is known to influence intertidal and subtidal community structure along the south coast. Pre-protection baseline data allows for "before" versus "after" comparisons to be undertaken at each site in order to observe changes in community structure after implementation. A recent paper (Pande & Gardner 2008) describes the results of this research.

Melanie Russell (MSc 2004 – supervised by Dr Jonathan Gardner) conducted research on the size, abundance, seasonal migrations, growth rate and mortality rate of both yellow-foot (*Haliotis australis*) and black-foot paua (*Haliotis iris*) at the same eight sites used by Anjali Pande and currently being used by Tyler Eddy and Tamsen Byfield (VUW PhD students – see below). During this one year study, Russell used quadrats placed along a transect tape in a similar methodology to that used by Pande to quantify size, abundance and aggregation patterns of paua in 2003. In addition to the size measurements and abundance counts, Russell also tagged individuals and measured migration rate, growth rate and mortality rate of both species.

The published article titled "Settlement indices for 2003 for the red rock lobster *(Jasus edwardsii*), and investigations into correlations between settlement and subsequent stock abundance" by Booth et al. (2007) is a New Zealand Fisheries Assessment Report and is valuable because it outlines how rock lobster population dynamics are related to larval recruitment pulses. Settling and migrating juvenile lobsters were collected from traps on the ocean floor annually at four south coast locations as well as other locations around the county, giving an indication of recruitment pulses. This information will be valuable as baseline for future studies that address the settlement and recruitment of rock lobster inside the MR as it gives an indication of the strength of yearly recruitment pulses which correspond to local population dynamics.

Tyler Eddy's PhD project (supervised by Drs Jonathan Gardner and James Bell at VUW) is an extension of Anjali Pande's research, and is conducted in collaboration with fellow VUW PhD student Tamsen Byfield (Eddy is monitoring fish species and Byfield is monitoring macroalgal and invertebrate species). Eddy is using the same sites and methodology as Pande used in her survey. Eddy's monitoring research is currently underway and will continue until 2009 and will be completed by 2010. This research is valuable because it adds to a large database and will permit testing and detection of early changes in the size and abundance of species compositions at protected and unprotected sites. Furthermore, data collected by Eddy and Byfield will add to the "baseline" dataset immediately prior to the MR being gazetted.

Eddy is also using data on biomasses of subtidal species (in collaboration with Byfield) to construct a model of trophic interactions for south coast biological communities. Ecopath and STELLA software are two modelling programmes used to describe the flow of energy and biomass through a biological system. Community structure of biological communities is modeled before and after protection to determine how energy and biomass linkages change as a consequence of protection and are impacted by extractive exploitation. This approach is valuable in understanding how species are connected within a community and how protection changes these linkages.

Tamsen Byfield's PhD research (supervised by Dr James Bell and previously by Dr Jonathan Gardner) is a subtidal habitat mapping project looking at benthic macroalgae and invertebrate communities and their associated habitats across the marine reserve. Byfield has also included a ninth site in her study (western unprotected) so that she has three eastern unprotected, three western unprotected and three protected sites. At these sites, Byfield quantifies benthic macroalgal and invertebrate cover using 1 m^2 quadrats placed six times, at 5 m intervals along a transect. Six transects are replicated at each study site. Byfield is also collecting biomass data in order to determine biomass density of each species at each site. These data are being collected to add a biological layer to a geophysical map of the south coast seabed created by NIWA using multi-beam technology. Byfield's PhD research will be completed by 2011.

Byfield's work is also examining monitoring methods to reduce the level of variability in the monitoring data set (Pande, Russell, Eddy, Byfield), by repeating the monitoring and stratifying by habitat (boulders/rubble/broken reef, vertical rock and inclined/horizontal rock). This approach will also address some of the questions surrounding the application of Power Analysis to data sets containing naturally high levels of variability in biomass and/or abundance estimates. This is a particularly important area of current research and has some important implications for the monitoring recommendations given below, with the potential for small modifications being required in the future. Stratification by habitat has significant logistic implications because it (stratification) increases the amount of time, effort and cost needed for monitoring.

The world's first Marine Bioblitz took place in Wellington in October 2007 with the aim of identifying as many species as possible in the new marine reserve in a one month period (30th September to 28th October, 2007). Five hundred and fifty one species were identified, including at least four new species; a tube anemone, a nudibranch, a bryozoan and a diatom. This effort was the result of collaboration of conservationists, scientists and divers from Forest and Bird, the Centre for Marine Environmental &

Economic Research at Victoria University of Wellington, NIWA, Wellington City Council, Department of Conservation, Dive HQ, Island Bay Divers, Splash Gordon, Te Papa and NZ Sea Adventures. Although this is an amazing achievement, it is important to note that some animal groups are under-represented in the sampling, for example, sponges, copepods and amphipods, due to the availability of taxonomic expertise. Therefore, the actual total number of species in the reserve is likely to be much higher.

Victoria University of Wellington currently has a large sponge ecology and biodiversity research group based at the Coastal Ecology Laboratory in Island Bay led by Dr James Bell. Current postgraduate students working in this group on the south coast include Jade Berman, Alejandra Perea-Blazquez, Nicholas Ward and Heather Murray. The sponge diversity in the Taputeranga Marine Reserve is considered to be relatively high and to date approximately 40 species have been reported from the reserve, although many of the sponges still remain unnamed. Although preliminary sponge biodiversity surveys have been conducted on the Wellington south coast, further surveys will be conducted over the coming years in order to determine the spatial distribution of sponges in the reserve. Prior to the establishment of the Marine Reserve replicated permanent monitoring sites have been established to specifically examine seasonal changes in sponge assemblages and establish a "sponge baseline". These include two sites at The Sirens and one site at Princess Bay. This information will be used to look at short-term and long-term changes in sponge assemblages. It is unknown if Marine Reserve status will have any effect on sponge assemblages, but it seems unlikely and was not a feature of the experimental design, although the group is currently looking for additional sites on the south coast. Nick Ward is examining morphological variability in sponge assemblages and whether a morphological approach can be used to monitor sponges in the future as has been used in other temperate reserves. Alejandra Perea-Blazquez is examining nutrient consumption and feeding rates of sponges on the south coast, while Heather Murray is examining respiration rates in response to environmental stressors (particularly sediment and UV). Although, this information will provide a better understanding of the ecology of sponges on the south coast, only the work of Nick Ward and Jade Berman are directly relevant to monitoring in the new reserve.

Drs Jonathan Gardner and James Bell are editing a forthcoming book (due October/November 2008) about the Taputeranga MR. This book contains the most up to date species lists for many different groups (macroalgae, invertebrates and vertebrates), as well as species lists compiled for the first time. As background information about the south coast region, this book will be a valuable asset.

Part II: Monitoring Recommendations

Initially, we believe a management plan needs to be developed in order to identify key aims and objectives for the reserve. A specific monitoring plan can then be developed to meet the needs of the management plan. After knowing how often and for how long monitoring will occur, as well as what are the specific objectives of the programme, appropriate recommendations regarding species and sites to be monitored using specific methodologies can be made. For the purposes of this report, and in the absence of an existing monitoring plan (to our knowledge), we believe the primary objectives of the MR monitoring should be to:

1) Detect any change in the size and abundance of key species of fish, macroinvertebrates, and macroalgae at MR and non-MR sites.
2) Detect any change in biological community structure at MR and non-MR sites.
3) Detect species that respond positively and negatively to MR protection.

Recommendations made in this report are made with regard to species and sites that should be monitored and survey methodologies that should be employed to collect such data. Recommendations are made based on our assumptions of “low to moderate”, but not “high” levels of funding being available to support the monitoring.

Baseline research that has been conducted

Pande conducted macroalgae, macroinvertebrate and fish surveys in January (summer) and September (early spring) in 1998. In 1999, surveys were conducted in January (summer), March (early autumn), May (autumn), September (early spring) and November (late spring). In 2000, surveys were conducted in February (summer), April (spring), June (early winter) and December (early summer). Eddy has conducted surveys seasonally in March 2007 (early autumn), August 2007 (late winter), January/February 2008 (summer), March 2008 (early autumn) and September 2008 (early spring). Byfield has conducted community surveys for all of Pande's algae and invertebrate species in the summers of 2007 and 2008 (due to more limited resources compared with Pande and an entire community approach rather than examining key species). Byfield and Eddy plan to continue their surveys until 2009. Drs Bell and Gardner have a new student, Daniela Diaz Guisado, who they anticipate will continue the monitoring surveys in 2010 and 2011 (annually).

Survey Methods

Similar survey methodology should be employed to that used by Pande in order to allow for compatibility of data. Although field work conducted by MacDiarmid & Stewart in 1999 and 2000 used different length transects and different widths of survey area, their abundance per unit area data can be determined to permit comparisons with Pande's data. It is therefore recommended that fish and invertebrate surveys be conducted using the underwater visual census (UVC) method for a given distance and width along a transect tape. For macroalgal surveys, using a quadrat placed at regular intervals along a transect tape counting the number of stipes of macroalgae is recommended. A high priority should be placed on continuing seasonal surveys at all of Pande's eight sites in order to add to the large baseline database that already exists and not to miss any seasonal changes.

Survey effort employed by Pande appears to be the minimum required to detect change in size and/or abundance of some key species (*Carpophyllum* sp., *Ecklonia* sp., *Lessionia* sp., paua, kina, spotty, banded wrasse and blue moki). In order to detect changes in the abundance of less abundant species (rock lobster, red moki and blue cod), an increase in sampling effort will be needed. We recommend that the sampling effort carried out by Pande with respect to the number of replicates per survey be used as a minimum. If there is particular interest in detecting change in any of these non-key species, sampling effort must be increased, in some cases quite dramatically. For several species which are low in relative abundance there is little prospect of detecting change in size and/or abundance unless they rapidly become highly abundant after protection, a prospect which we feel is unlikely.

Staff and students at VUW's Centre for Marine Environmental & Economic Research are addressing the issue of survey design and power analysis as part of ongoing projects. Currently we are unable to make specific recommendations about survey design based on power analysis. Byfield is addressing this issue in her research by investigating the effect of stratifying by habitat type in order to reduce variability in Pande's original dataset (for benthic invertebrates and macroalgae). Surveys similar to those used by Pande will be conducted on vertical, inclined/horizontal and boulder/broken rock habitats. This may reduce the level of variability in the dataset and increase the power to detect changes, but this does have time/effort considerations. This trade-off illustrates the importance of understanding the source of variability in a dataset to ensure that sampling design maximises the information that is returned.

Species to Survey

Priority indicator species should be chosen based on species expected to respond to protection. Both species of paua (black-foot and yellow-foot) are relatively sessile and highly targeted species that are expected to show a positive response to protection (Russell 2004). Rock lobster is another species that is highly targeted and has responded positively to MR protection at other sites throughout New Zealand (Pande et al. 2008). Rock lobster has been shown to migrate and show seasonal migrations to a much greater extent than paua, so the rate and trajectory of its response may be different from those of the two paua species. For these reasons it is recommended that both species of paua and rock lobster are monitored as priority indicator invertebrate species.

For fish species, Pande & Gardner (2008) have recommended that blue moki be monitored as a priority indicator species as it is highly targeted for fishing and it occurs in relatively high abundance compared to other targeted fish species. Blue moki is much more mobile than rock lobster, so we might expect higher migration rates to lead to a lower increase in local population size unless they show territorial behavior preventing individuals from leaving the MR boundaries. Nonetheless, migratory fish species have been shown to respond to MR protection in many regions of the world. A second fish species of considerable importance to be monitored is the blue cod. This species is found throughout most of New Zealand, and is also heavily targeted by recreational fishers. It is not particularly mobile, being territorial in shallow subtidal regions that are a mix of greywacke rock interspersed with sandy areas. Elsewhere in NZ, blue cod have been shown to respond rapidly and positively to MR protection.

For secondary priority species we suggest kina, which is a species that has been shown to change dramatically in abundance in response to MR protection. At the Cape Rodney - Okakari Point (Leigh) MR kina numbers dropped significantly following protection due to increased grazing pressure from snapper, which were protected from their high levels of previous exploitation. It is not clearly understood what determines kina population dynamics in the Cook Strait region, however this phenomenon is not expected to be observed on the south coast because snapper grazing pressure has not been identified as a controlling mechanism of kina population dynamics in the colder, more dynamic environment of Cook Strait. Kina in Cook Strait interact closely with key macroalgal species and for this reason we suggest that it be targeted as a secondary priority monitoring species in order to understand its interaction with macroalgae in protected and unprotected areas in a colder, high wave energy region.

We also suggest Spotty and Banded Wrasse should be used as secondary priority species because they are abundant but are not targeted commercially or recreationally (hence comparisons can be made between target and non-target species). These two species may show a change in size and/or abundance in response to community structure changes caused by protection.

For secondary priority monitoring species it is also important to monitor the spread of the invasive kelp *Undaria pinnatifida* as it moves from east to west out of Wellington Harbour and along the south coast. It is currently poorly understood what impact this species has on the endemic macroalgal species. Ultimately, *Undaria* sp. could come to monopolise areas of the shallow subtidal region of the MR and displace much of the native kelp species. We need to understand this interaction, and for that we need long-term monitoring. It is very unlikely that an eradication programme will work at this late stage, but if significant changes in benthic community structure and function occur over time these may result as a consequence of MR status and/or as a consequence of *Undaria* sp. spread and competition with *Lessonia* sp., *Ecklonia* sp., *Macrocystis* sp., *Carpophyllum* sp. and other macroalgal species.

All macroalgae, macroinvertebrate and key fish species surveyed by Pande should continue to be monitored (Table 2). These key species are relatively abundant and changes in their abundance are likely to indicate a change in overall community structure In addition to this research, Byfield and Eddy are taking a community level approach to monitoring by surveying all species, to determine if similar patterns can be identified in these species as were identified by Pande's sub-set of species. This extensive monitoring of other macroalgal, invertebrate, and fish species should be a secondary priority. By monitoring the key species, temporal and spatial changes in community structure and trophic interactions can be identified. If more in-depth information on all species of macroalgae, invertebrates and fish species exists, a greater understanding of community structure changes and site specific assemblages will be possible.

It is important to recognise the trade-off between time and money invested in monitoring versus the data return. If funds (and therefore time) are limited then it makes sense to monitor those key species that respond most rapidly and most dramatically to MR status. However, changes in a few key species do not necessarily represent changes in

Table 2. Baseline and monitoring studies for the Taputeranga MR on Wellington's south coast.

Baseline Studies	Study Sites	Species Surveyed	Habitat Studied	Years Surveyed
Carter & Connell 1980	Lavender Bay, Taraki Bay, Palmer Head, West Ledge, Moa Point, Huetetaka Peninsula	benthic algal and invertebrate community groups	subtidal reef and intertidal zone	1980
Cole & Jackson 1989	Yungh Pen x 2, Owhiro Bay, The Sirens, Taputarenga Island x 2, Houghton Bay, Princess Bay x 3	butterfish, blue moki, blue cod, scarlet wrasse, red moki, marblefish, paua and kina	subtidal reef	1989
Cotsilins 1999	Owhiro Bay Sewer, Houghton Bay, The Sirens, Owhiro Bay West	all intertidal algal species	intertidal zone	1995 - 1996
Wear & Gardner 1998	The Sirens	Undaria pinnatifida & other algal species	subtidal reef & intertidal zone	1997 - 1998
Gardner & Wear 1999	The Sirens	Undaria pinnatifida & other algal species	subtidal reef & intertidal zone	1998 - 1999
Wear & Gardner 2000	The Sirens	Undaria pinnatifida & other algal species	subtidal reef & intertidal zone	1999 - 2000
MacDiarmid & Stewart, unpublished	Owhiro Bay, Sirens, Taputeranga Island, Palmer Head, Raekaihau, Moa Point, Barrett Reef, Pencarrow Head	blue cod, red moki, blue moki, butterfish, tarakihi, rock lobster, paua and kina	subtidal reef	1999 - 2000
Pande 2001	Sinclair Head, Red Rocks, Yungh Pen, The Sirens, Princess Bay, Palmer Head, Breaker Bay, Barrett Reef	banded wrasse, blue cod, blue moki, butterfish, red moki, spotty, tarakihi, trevally, black-foot paua & yellow-foot paua, kina, rock lobster, Ecklonia radiata (paddleweed), Macrocystis pyrifera (giant kelp), Carpophyllum maschalocarpum (narrow flapjack) and Lessonia variegata	subtidal reef	1998 - 2000
Russell 2004	Sinclair Head, Red Rocks, Yungh Pen, The Sirens, Princess Bay, Palmer Head, Breaker Bay, Barrett Reef	black-foot paua & yellow-foot paua	subtidal reef	2003
Byfield, in progress	Second Wash, Sinclair Head, Red Rocks, Yungh Pen, The Sirens, Princess Bay, Palmer Head, Flax Bay, Barrett Reef	black-foot paua & yellow-foot paua, kina, rock lobster, Ecklonia radiata (paddleweed), Macrocystis pyrifera (giant kelp), Carpophyllum maschalocarpum (narrow flapjack) and Lessonia variegata	subtidal reef	2006 - 2008
Eddy, in progress	Sinclair Head, Red Rocks, Yungh Pen, The Sirens, Princess Bay, Palmer Head, Breaker Bay, Barrett Reef	banded wrasse, blue cod, blue moki, butterfish, red moki, spotty, tarakihi, trevally and others	subtidal reef	2007 - 2008
Berman, in progress	The Sirens, Yung Pen, Princess Bay, Island Bay, Breaker Bay	sponges	subtidal reef	2007 - 2008
Taputeranga MR Studies				
Eddy, in progress	Sinclair Head, Red Rocks, Yungh Pen, The Sirens, Princess Bay, Palmer Head, Breaker Bay, Barrett Reef	banded wrasse, blue cod, blue moki, butterfish, red moki, spotty, tarakihi, trevally and others	subtidal reef	2008 - 2009
Byfield, in progress	Second Wash, Sinclair Head, Red Rocks, Yungh Pen, The Sirens, Princess Bay, Palmer Head, Flax Bay, Barrett Reef	black-foot paua & yellow-foot paua, kina, rock lobster, Ecklonia radiata (paddleweed), Macrocystis pyrifera (giant kelp), Carpophyllum maschalocarpum (narrow flapjack) and Lessonia variegata	subtidal reef	2008 - 2009
Morelissen, in progress	The Sirens, Owhiro Bay	all algal species	intertidal zone	2007 - 2009
Berman, in progress	The Sirens, Yung Pen, Princess Bay, Island Bay, Breaker Bay	sponges	subtidal reef	2008 - 2009

community structure, and depending on the monitoring goals, may not represent conservation “success” in a broad sense.

Sampling Interval

There was a period of six years (2001 to 2006) when sites previously monitored by Pande were not monitored. While research has been resumed by Eddy and Byfield in 2006/2007, it is important, as far as possible to collect data seasonally each year because Pande (2001) found seasonal variation size and/or abundance in some but not all species of macroalgae, invertebrates and fish during her quarterly surveys. This allows for a much greater understanding of how species compositions at each site change in response to differing environmental and oceanographic conditions (for example, the effects of an El Niño year such as occurred during Pande’s period of sampling).

If a monitoring programme is established, our recommendation is for data to be collected seasonally (4 times a year) every year (once each season). As weather determines the accessibility of diving and conducting surveys in the Cook Strait, it is more feasible to adopt a flexible timeframe to conduct these surveys in each season. At the very least it would be important that if this was not possible that any annual sampling were conducted in the same season. In this case, we recommend summer as the with the best weather conditions to conduct the surveys as well as it is the season used by Byfield to conduct her yearly invertebrate and algae surveys.

Macroalgal species observed to show seasonal variation in abundance by Pande & Gardner (2008) are *Carpophyllum maschalocarpum* and *Ecklonia radiata*. The macroinvertebrate species yellow-foot paua shows seasonal variation in abundance as well as the fish species, banded wrasse, blue cod, blue moki, red moki, spotty, and trevally. Rock lobster has been identified by MacDiarmid (1991) to show seasonal migrations at some locations in New Zealand, however seasonality was not observed by Pande & Gardner (2008) for the south coast.

Of the species identified as those that undergo seasonal migration including blue moki and yellow-foot paua have been identified as primary and secondary priority species. Yellow-foot paua is expected to respond similarly to black-foot paua to protection as they share many life-history and biological characteristics. For these reasons we prioritise seasonal surveys for fish species, followed by seasonal surveys for macroinvertebrate species and lastly, for macroalgal species.

Sites to sample

It is of course very important that sites should be monitored both inside the MR as well as outside to the east and west of the boundaries. We recommended that the same sites used by Pande, Russell, Eddy and Byfield continue to be surveyed because this represents the largest baseline dataset for macroalgae, invertebrate and fish species (Table 1, Figure1). We also recommend that the extra western control site currently being surveyed by Byfield is included from now on to bring the total to nine sites (three eastern unprotected, three western unprotected and three protected) to provide a balanced design. Gardner (2000), Helson & Gardner (2007) and Helson et al. (2007) have identified an environmental gradient of increasing nutrients and suspended particles moving from Sinclair Head (low values) towards Wellington Harbour (high values). These factors have to be considered when comparing sites as western unprotected sites are different from unprotected eastern sites in community structure mostly likely due to this environmental gradient. Despite this, however, adding the ninth site is recommended, if it is feasible (bearing in mind this is a difficult site to work at), allowing for the site's greater distance from Island Bay, its access only via boat, and the attendant narrow weather windows to conduct surveys.

Because habitat plays a strong role in the determining species composition it is important to understand species composition at each site on the Wellington south coast prior to MR protection in order to objectively quantify changes at these sites resulting from MR protection. Pre-MR differences have been identified between eastern and western sites and these will be taken into consideration in the baseline dataset in order to quantify changes in size, abundance and distributions arising as a consequence of protection.

Stratification by Depth

Following the first two priorities of community level surveys (recording as many species as possible for fish, invertebrate and macroalgal groups) conducted seasonally and the addition of new sites, the next priority is to conduct depth-stratified surveys. With the exception of the unpublished report "Wellington South Coast Taiapure Report 1999/2000" by MacDiarmid & Stewart, all surveys have been conducted at relatively shallow depths (less than 15 m). It is not clear from the literature whether or not this approach will yield different results, although depth is well known to influence benthic community structure elsewhere (as light is reduced and algal communities decline and as surface wave action is reduced). There was no analysis undertaken by MacDiarmid & Stewart for their depth-stratified surveys to provide any guidance on this matter.

If funds permit, then we recommend that a depth-stratified approach to monitoring be employed. This research may be valuable in further understanding population dynamics of species that show seasonal depth stratification and also differences in community structure/species abundances based on depth stratification. A review (quantitative data analysis) should be conducted as soon as possible (within the first three years of monitoring) to determine if the depth-stratified approach is worth including. This currently represents a gap in our knowledge of the Marine Reserve. We note that monitoring at depths greater than 10-15 m has logistic considerations because dive time is reduced and because a higher diving experience level is required. Furthermore, this type of survey is not always possible with weather windows on the south coast being unpredictable and often short for subtidal research, which is why it has not been included in previous research by Victoria University of Wellington.

Intertidal Sites

We recommend that intertidal research continue at sites established by Wear & Gardner (1998, 2000) and Gardner & Wear (1999) at The Sirens to monitor the distribution of *Undaria pinnatifida* as well as seasonal changes in distribution of algal and invertebrate communities. In addition to this site, Cotsilinis's sites at The Sirens and others at Owhiro Bay Sewer, Owhiro Bay West and Houghton Bay should continue to be monitored to determine intertidal algal community structure after protection. Morelissen is currently surveying all algal species at The Sirens and Owhiro Bay and this research should be coordinated with the Department of Conservation's intertidal monitoring programme (more follows in Biosecurity section). Of these studies that have been undertaken, the only controls that exist are at sites within the Wellington Harbour. We recommend that at least one eastern and one western control site be monitored by the Department of Conservation seasonally. Researchers at Victoria University of Wellington anticipate establishing permanent replicated intertidal monitoring stations as part of Jamie Tams and Tim Jones PhD research in 2009 (supervised by Drs Bell and Gardner) to address the current gap in our understanding of temporal variability in intertidal assemblages.

Deep Sites

It has not yet been determined whether depth stratification is responsible for explaining differences in community structure on the south coast, however it has been suggested that certain species (such as rock lobster) may undergo seasonal depth migrations in which case it would be valuable to survey at greater depths then undertaken by Pande, Byfield and Eddy. It would be useful to survey each of Pande's sites at deeper depth (greater than 15 m) in order to compare community structure to shallower depths. It should be noted that resource investment will increase significantly with deeper surveys as dive time is decreased.

Habitat and Biosecurity

The habitat along the south coast is characterized by both horizontal and vertical greywacke reef which extends from the intertidal zone to depths of 30 m (Figure 3). This reef is structurally complex with cracks, crevices and caves which provide habitat for many different species of algal, invertebrates and fish. Sections of rocky reef on the south coast are interspersed in sections by both sandy and boulder areas. All of Pande's eight study sites use greywacke reef as the habitat studied. From our observations, all of the intertidal and subtidal habitats represented within the MR can also be found outside of the boundaries, on both western and eastern sides.

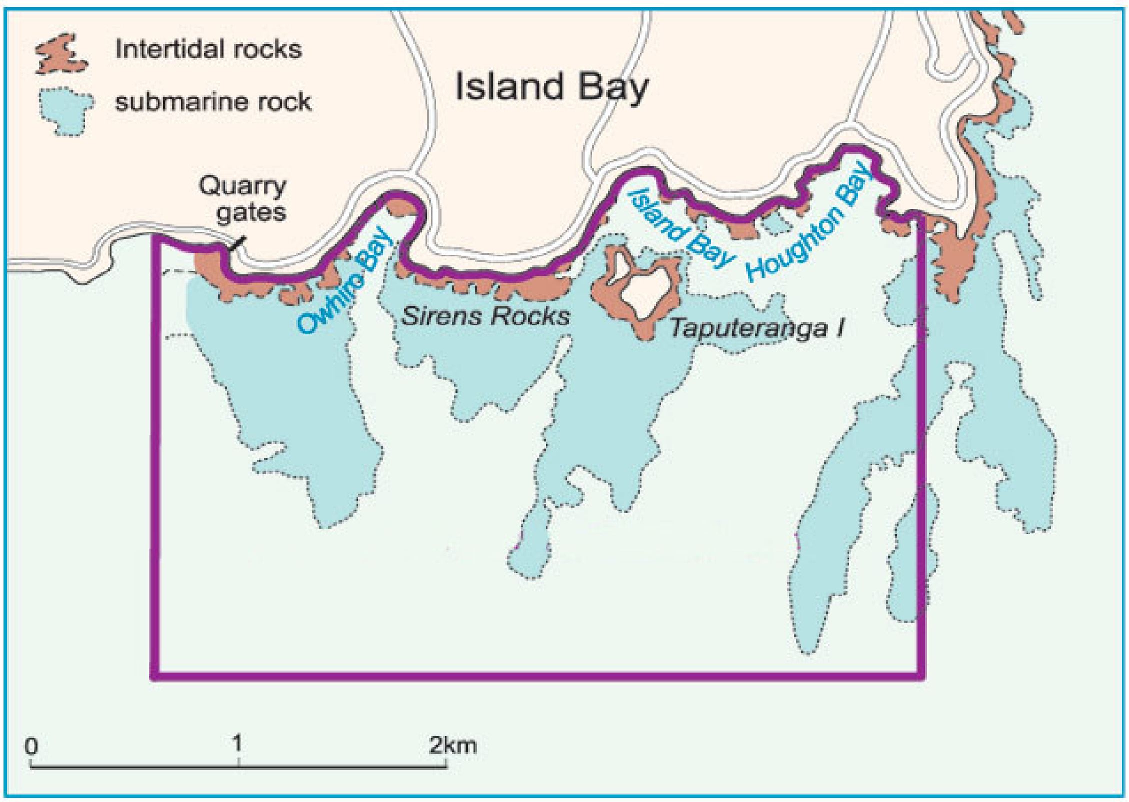


Figure 3. Map showing Taputeranga MR boundaries and location of intertidal and subtidal rocks (reefs) (From NIWA website).

Byfield's PhD research seeks to develop a method to assess the marine environment, which is useful for topographically complex environments, such as those found in the Taputeranga Marine Reserve. Various acoustic (e.g. multibeam, side-scan and swath sonar), remote (camera observations), and direct (diver observations) survey techniques can be used to explore, classify, analyse, and represent a region's marine diversity. Byfield's methodology employs a remote survey method (a drop camera) to map Wellington's nearshore benthic community as part of a larger mapping project involving VUW, NIWA and DoC. The drop camera is now being used in two ways: firstly, to identify the types of plants and animals associated with the physical habitats identified by NIWA's work; secondly, to provide habitat mapping protocols, as acoustic mapping of an area of conservation interest is not always feasible. This project which is currently underway and due to be completed by 2010 will provide an overview of the south shore's nearshore benthic community and correlation to underlying physical structure and will include the new MR.

VUW PhD student Bionda Morrelison (supervised by Dr Nicole Phillips) is investigating whether or not the introduced macroalgal species *Undaria pinnatifida* and *Colpomenia bullosa* affect patterns of competition and community composition in rocky intertidal communities in the Wellington region. She is investigating if rocky intertidal assemblage composition differs in the presence or absence of these introduced algae and will examine the effects of their removal on native assemblages. Also, to investigate whether increased nutrient concentrations in coastal seawater facilitates the success of these introduced algae, Morrelison is employing a regime of artificial nutrient additions in rocky intertidal environments around the Wellington coast. Results will be compared to surveys and experiments conducted at two sites in proximity of sewage outfalls, and will be used as a proxy for future nutrient conditions in coastal waters.

Investigation of the effects of increasing nutrient concentrations on key species of intertidal ecosystems and possible cascading effects through trophic levels will give insight into the consequences of anthropogenic impacts on rocky intertidal zones and can help to set up appropriate environmental management and conservation strategies. This research will contribute to a better understanding of factors that underlie invasion dynamics, the distribution, and ecological role of *Undaria pinnatifida* and *Colpomenia bullosa* at distinct locations in the Wellington region. The outcomes will allow the establishment of strategic environmental protection and conservation plans to maintain rocky intertidal biodiversity. This work builds on a 3-year monitoring programme of the abundance and spread of *Undaria* at sites within the new MR compared to sites to the west where *Undaria* was absent, carried out during the period September 1997 to June 2000 (see Wear & Gardner 1998, 2000; Gardner & Wear 1999, Appendix 2) and the 2003 VUW thesis by Sheree Christian (supervised by Dr Bob Wear).

Oceanographic Conditions and Physical Parameter Monitoring

VUW PhD student Jeremy Helson (supervised by Dr Jonathan Gardner) transplanted mussels from Wellington Harbour to the Island Bay Marine Laboratory on the south coast and found that these mussels experienced a decrease in body condition compared with mussels from the collection site in Wellington Harbour. This and other research by Helson (e.g., Helson & Gardner, 2007; Helson et al. 2007) confirmed earlier work that an environmental gradient exists along the south coast (Gardner, 2000; Gardner & Thompson 2001; Gardner 2002), which influences intertidal and subtidal community structure (Pande & Gardner 2008). This gradient has been previously addressed in the report and makes treatment of “control” sites more difficult because western control sites have lower nutrient availability compared to eastern control sites. This has implications for the organization of community structures at these sites (Pande & Gardner 2008). This gradient will continue to be studied and monitored by a new PhD student (starting February 2009) in order to improve our understanding regarding whether it changes over time and how it may impact biological communities.

In addition, seasonal collection of water samples from each of Pande's eight sites to be analysed for suspended sediments and nutrient concentrations along with temperature and Secchi readings taken will provide a record of how the gradient changes and may help to how community structure is affected by it.

Part III: Tagging, Genetic & Connectivity Research

Russell (VUW MSc, 2004) tagged paua along the south coast and found that their migration rate was relatively small (no individuals were found to migrate between survey sites) suggesting that this relatively sessile species will respond positively to MR protection on the south coast.

Dr Jeff Shima at Victoria University of Wellington and his students Anna Smith and Philipp Neubauer are examining recruitment of triplefin fish in the harbour and along the south coast. This project uses the otolith as a "flight recorder" to track the movement of larvae and juveniles. The otolith shows chemical signatures specific to water characteristics of specific locations which can be used to determine patterns of settlement, recruitment and connectivity between populations.

We are unaware of any "genetic studies" specific to the Cook Strait region. There are many NZ-wide studies which have relevance to Cook Strait, some which suggest that the Cook Strait does not provide a significant geographic boundary to gene flow.

Pelayo Salinas de Leon is a PhD student at Victoria University of Wellington working with Drs James Bell and Jonathan Gardner. His research is using microsatellite markers for two common species of marine gastropods, *Austrolittorina cincta* and *Austrolittorina antipodium*, to investigate population connectivity within New Zealand. These markers will be used to determine the relative levels of isolation and the potential role of Cook Strait as a barrier to dispersal between populations separated by similar distances, including three marine reserves (Taputeranga, Kapiti and Long Island). The markers will also be used to determine if there are any barriers to gene flow between these marine reserves.

VUW PhD student Smita Apte (2000) and VUW MSc student Bastiaan Star (2001) (both supervised by Dr Jonathan Gardner) examined genetic connectivity in New Zealand greenshell mussels using a variety of different genetic markers. Recent additional work by Dr Kaijian Wei (VUW Post-Doctoral Fellow working with Dr Jonathan Gardner) has added to this work. In all cases, the genetic markers (both mitochondrial and nuclear) clearly indicate a split between northern and southern stocks of greenshell mussels, with the genetic break occurring at approx 42º South. Thus, all of Cook Strait including the Marlborough Sounds, Golden Bay and Tasman Bay fall into a generally homogenous northern group. This research suggests that gene flow within this region is extensive and sufficient to prevent genetic differences developing over scales of 100s of km (Apte & Gardner 2002).

VUW PhD student Kristen Westfall (supervised by Dr Jonathan Gardner) is presently looking at genetic population structuring in blue mussels of the genus *Mytilus*. This work involves the use of mitochondrial DNA markers to quantify gene flow among populations and to test the generality of the north-south split observed for greenshell mussels described above, as well as to identify putatively invasive blue mussels. Kristen's research will be completed in 2009.

While both greenshell and blue mussels are rare in the region of the Taputeranga Marine Reserve, these species are excellent model organisms to examine gene flow on small to large spatial scales. When coupled with the markers being developed by Pelayo Salinas for *Austrolittorina cincta* and *Austrolittorina antipodium*, the results from all of these studies will be applicable to other species with similar life-history characteristics (planktonic larval phases of two to four weeks duration) which are abundant in the reserve.

VUW PhD student Celine Reisser (supervised by Drs Jonathan Gardner and James Bell) is quantifying gene flow among North Island populations of the black nerite, *Nerita melanotragus*, and VUW Post-Doctoral Research Fellow Dr Ann Wood (working with Dr Jonathan Gardner) is examining limpet taxonomy, systematics, biogeography and population genetics within New Zealand.

Conclusions

The large amount of research that has been conducted on Wellington's south coast has been the product of many studies by students and scientists from a number of universities, research groups and government organisations. The extensive research in this area will be invaluable when developing a management plan for the Taputeranga Marine Reserve, which will inform how biological communities that occur in subtidal and intertidal habitats should be monitored.

We believe that the body of research conducted by Pande (2001) represents the most comprehensive baseline of subtidal abundance and distribution for algae, invertebrate and fish for the Taputeranga Marine Reserve. When surveys by Byfield and Eddy cease, it should be a priority to make sure these surveys are conducted at least once per year (summer), although seasonally if possible due to identified seasonality in some species. Surveys that have been undertaken by Gardner & Wear and also by Cotsilinis for algae and invertebrate species should be continued after consultation with Morelissen about the availability of her survey data as well as the addition of at least two new additional sites (one eastern control and one western control) in order to monitor intertidal communities. Secondary survey priorities should be for subtidal surveys of all species, not just identified key species in order to be able to detect community level changes. Following these initial priorities, consideration should be given to using Byfield's ninth western control site as well as the addition of deep sites to the survey.

Monitoring physical characteristics such as temperature, suspended sediment, nutrient concentrations and water column characteristics (Secchi readings) will add to the existing understanding of the environmental gradient that exists along the south coast and should be continued in the future.

We believe that the creation of the Taputeranga Marine Reserve will have significant impacts on many specific species and potentially overall community structure for subtidal and intertidal populations. Monitoring is critical in order to detect these changes. We hope this document has provided the insight and basis for the creation of an effective monitoring programme for the new reserve.

References

Anon, E.S. 1979. Notes on some shell collecting localities about Wellington. Cookia, Journal of the Wellington Shell Club **3(2)**: 16-17.

Anon, E.S. 1974. Notes on some shell collecting localities about Wellington. Wellington Shell Club, Bulletin **35**.

Apte, S., Star, B., Gardner, J.P.A. 2003. A comparison of genetic diversity between cultured and wild populations, and a test for genetic introgression in the New Zealand greenshell mussel *Perna canaliculus* (Gmelin 1791). Aquaculture **219**: 193-220.

Arron, E.S., Lewis, K.B. 1993. Wellington South Coast substrates; side scan sonographs of Southern Wellington Harbour. 1:15000. New Zealand Oceanographic Institute Chart, Miscellaneous Series **69**.

Berman, J. **In progress.** Temporal Variability of Sponge Assemblages and Quantitative Biodiversity of Sponges on the Wellington South Coast. Thesis – PhD. Victoria University of Wellington.

Beu, A.G., Climo, F.M. 1971. Marine Mollusca of Wellington Harbour and approaches. Wellington Shell Club Bulletin **29**: 1-8.

Booth, J.D., Forman, J.S., Stotter, D.R., Bradford, E., Renwick, J. and Chiswell, S.M. 1999. Recruitment of the red rock lobster, *Jasus edwardsii*, with management implications. N.Z. Fisheries Assessment Research Document **99/10**. 102 p.

Booth, J.D., McKenzie, A., Forman, J.S., Stotter, D.R. 2007. Settlement indices for 2003 for the red rock lobster (*Jasus edwardsii*), and investigations into correlations between settlement and subsequent stock abundance. New Zealand Fisheries Assessment Report **2007/42**. 48p.

Bowman, M.J., Kibblewhite, A.C., Murtagh, R.A., Chiswell, S.M., Sanderson, B.G. 1983. Circulation and mixing in greater Cook Strait, New Zealand. Oceanologica Acta. **6.4**: 383-391.

Bradford-Grieve, J.M. 1999. New species of benthopelagic copepods of the genus *Stephos* (Calanoida: Stephidae) from Wellington Harbour, New Zealand. New Zealand Journal of Marine and Freshwater Research: **33**. 13-27.

Bradford, J.M., Lapennas, P.P., Murtagh, R.A., Chang, F.H., Wilkinson, V. 1986. Factors controlling summer phytoplankton production in greater Cook Strait, New Zealand. New Zealand Journal of Marine and Freshwater Research **20**: 253-279.

Bradstock, C.A. 1948. A study of the marine spiny crayfish *Jasus lalandii* (Milne - Edwards). Thesis - M.Sc. in Zoology, Victoria University of Wellington.

Byfield, T. **In progress.** Methods of benthic habitat assessment for conservation and management: Wellington's South Coast. Thesis – PhD. Victoria University of Wellington.

Buchanan, J. 2005. The crustose brown algae of New Zealand: a taxonomic study. Thesis - M.Sc. Victoria University of Wellington.

Carter, B., Connell, C. 1980. Moa Point Wastewater Treatment Plant & Outfall Study. Moa Point Wastewater Treatment Plant & Outfall Study. Chapter 9. 87-100.

Choat, J.H., Schiel, D.R. 1982. Patterns of distribution and abundance of large brown algae and invertebrate herbivores in subtidal regions of northern New Zealand. Journal of Experimental Marine Biology and Ecology **60**: 129-162.

Cole, R., Jackson, B. 1989. Marine survey of Wellington's south coast. Unpublished report to the Department of Conservation, Wellington, New Zealand.

Cotsilinis, M. E. 1999. Intertidal community responses following the decommissioning of a sewer outfall: Owhiro Bay, Wellington, December 1994 - March 1996. Thesis - M.Sc. in Zoology, Victoria University of Wellington.

D'Archino, R., Nelson, W.A. 2006. Marine brown algae introduced to New Zealand waters: first record of *Asperococcus ensiformis* (Phaeophyta, Ectocarpales, Chordariaceae). New Zealand Journal of Marine and Freshwater Research **40**: 599-604.

Dickie, B.N. 1982. Aspects of the ecology of three species of *Cellana* in the Wellington area. Thesis - M.Sc. in Zoology, Victoria University of Wellington.

Eagar, S.H. 1999. Distribution of Ostracoda around a coastal sewer outfall: a case study from Wellington, New Zealand. Journal of The Royal Society of New Zealand **29** (3): 257-264.

Eddy, T.D. , **In progress.** Marine Reserves as Conservation and Management Tools in New Zealand. Thesis - PhD, Victoria University of Wellington.

Gardner, J.P.A. 2002. Effects of seston variability on the clearance rate and absorption efficiency of the mussels *Aulacomya maoriana*, *Mytilus galloprovincialis* and *Perna canaliculus* from New Zealand. Journal of Experimental Marine Biology and Ecology **268**: 83-101.

Gardner J.P.A., Thompson R.J. 2001. Naturally low seston concentration and the net energy balance of the greenshell mussel (*Perna canaliculus*) at Island Bay, Cook Strait, New Zealand. New Zealand Journal of Marine & Freshwater Research **35**: 457-468..

Gardner, J.P.A. 2000. Where are the mussels on Cook Strait (New Zealand) shores? Low seston quality as a possible factor limiting multi-species distributions. Marine Ecology Progress Series **194**: 123-132.

Gardner, J.P.A. & Wear, R.G. 1999. *Undaria pinnatifida* Monitoring Programme Island Bay, Wellington South Coast: Second Progress Report (July 1998 – June 1999). Coastal Marine Research Unit Report No. 30. 21 pp.

Hay, C.H., Villouta, E. 1993. Seasonality of the Adventive Asian Kelp *Undaria pinnatifida* in New Zealand. Botanica Marina **36**: 461-476.

Helson, J.G., Gardner, J.P.A. 2007. Variation in mussel scope for growth: a test of intertidal community structure. Hydrobiologia **586**: 373-392.

Helson, J.G., Pledger, S., Gardner, J.P.A. 2007. Does differential particulate food supply explain the presence of mussels in Wellington Harbour (New Zealand) and their absence on neighbouring Cook Strait shores? Estuarine Coastal and Shelf Science **72**: 223-234.

Helson, J.G., Gardner, J.P.A. 2004. Contrasting patterns of mussel abundance at neighbouring sites: does recruitment limitation explain the absence of mussels on Cook Strait (New Zealand) shores? Journal of Experimental Marine Biology and Ecology **312** (2): 285-298

Helson, J.G. 2001. An investigation into the absence of mussels (*Perna canaliculus*, *Aulacomya maoriana* & *Mytilus galloprovincialis*) from the south coast of Wellington, New Zealand. PhD Thesis, Victoria University of Wellington.

Hicks, G.RF. 1971. Checklist and ecological notes on the fauna associated with some littoral corrallinacean algae. Victoria University Biological Society Bulletin of Natural Sciences **2**: 47-58.

Keith, C. M. 2000. Fish larvae of the Wellington Harbour and south coast, 1997-1998. Thesis - M.Sc. In Zoology, Victoria University of Wellington. 164 pp.

Livingston, M., Berben, P. 1987. East coast spawning hoki confirmed. Catch **14.10**: 7-9.

MacDiarmid, A.B, Stewart, R. 2000. Wellington South Coast Taiapure Project 1999 & 2000. **Unpublished report**.

Morrelison, B. **In progress.** Ecological effect of an introduced macroalga on native rocky intertidal communities in NZ and the role of nutrient enrichment on its success. Thesis – PhD. Victoria University of Wellington.

Pande, A. 2001. Evaluating biological change in New Zealand marine reserves. Thesis - PhD. in Zoology. Victoria University of Wellington.

Pande, A., Gardner, J.P.A. 2008. A baseline biological survey of the proposed Kupe / Kevin Smith Marine Reserve (Wellington, New Zealand): spatial and temporal variability along a natural environmental gradient. Aquatic Conservation: Marine & Freshwater Ecosystems DOI: 10.1002/aqc.984.

Pande A, MacDiarmid AB, Smith PJ, Davidson RJ, Cole RG, Freeman D, Kelly S & Gardner JPA. 2008. Marine reserves increase the abundance and size of blue cod and rock lobster. Marine Ecology Progress Series **366**: 147-158.

Perea-Blazquez, A. **In progress.** Bentho-pelagic coupling in New Zealand sponge assemblages. Thesis – PhD. Victoria University of Wellington.

Reisser, C. In progress. Genetic connectivity among populations of isolated island marine molluscs. Thesis – PhD. Victoria University of Wellington.

Russell, M. K. 2004. Population biology of paua (*Haliotis iris* and *Haliotis australis*) along the Wellington South Coast, New Zealand. Thesis - M.Sc. In Marine Biology, Victoria University of Wellington. 136 pp.

Sinclair, M. 1963. Studies on the paua *Haliotis iris* Martyn in the Wellington district, 1945-46. Zoology Publications from Victoria University of Wellington **35**. 16 pp.

Star, B., Apte, S., Gardner, J.P.A. 2003. Genetic structuring among populations of the greenshell mussel *Perna canaliculus* revealed by analysis of randomly amplified polymorphic DNA. Marine Ecology Progress Series **249**: 171-182.

Taputeranga Marine Reserve: Marine Reserve Application South Coast Marine Reserve Coaltion & Royal Forest and Bird Protection Society of New Zealand. 2000.

Trumpeter, N. **In progress**. Life history trade-offs and spatial dynamics of an aggregating species, *Petrolisthes elongatus*. Thesis – PhD. Victoria University of Wellington.

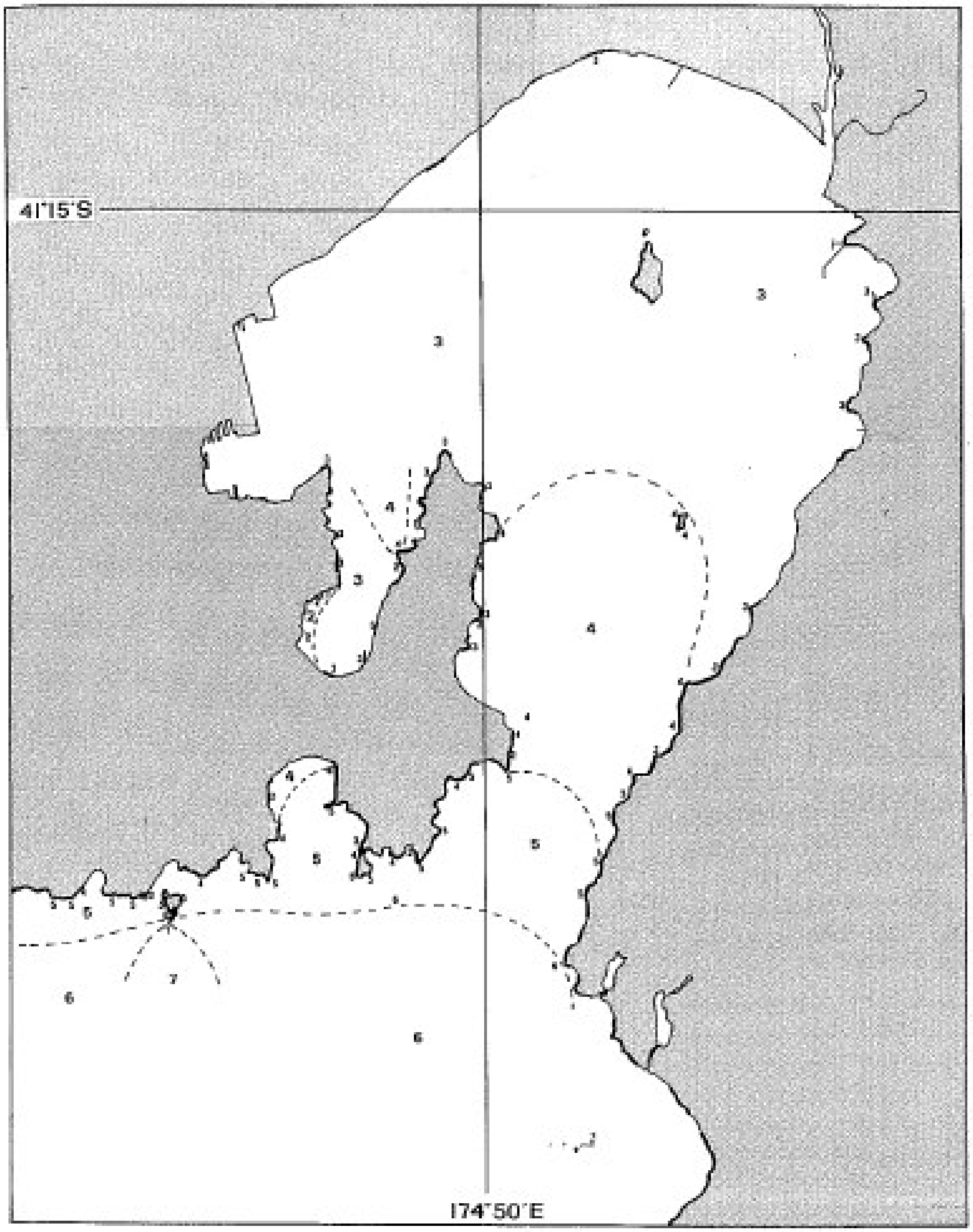
Tunbridge, B. 1961. Special Fisheries Report - Paua Survey of Wellington Coast, September 1961. 14p.

Wear, R.G. & Gardner, J.P.A. 2000. *Undaria pinnatifida* Monitoring Programme Island Bay, Wellington South Coast: Final Progress Report (01 January – 30 June 2000). 16 pp.

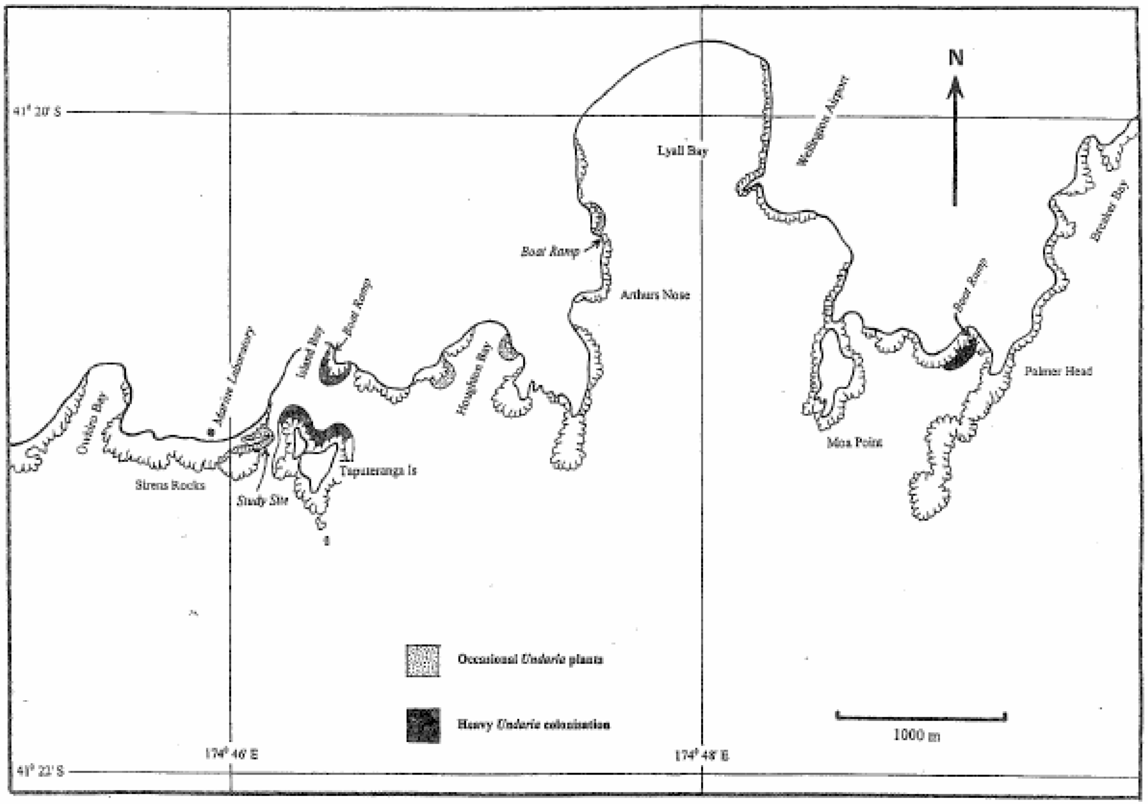
Wear, R.G. & Gardner, J.P.A. 1998. *Undaria pinnatifida* Monitoring Programme Island Bay, Wellington South Coast: First Progress Report (Sept 1997 – June 1998). Coastal Marine Research Unit Report No. 29. 26 pp.

Willis, T.J., Roberts, C.D. 1996. Recolonisation and recruitment of fishes to intertidal rockpools at Wellington, New Zealand. Environmental Biology of Fishes **47**: 329-343.

Appendix 1. Map of Wellington area showing the maximum Exposure Index of inner harbour and south coast shores. Index: 7 – extremely exposed, 6 – very exposed, 5 – exposed, 4 – semi-exposed, 3 – mainly sheltered, 2 – sheltered. Figure from Dickie 1982.

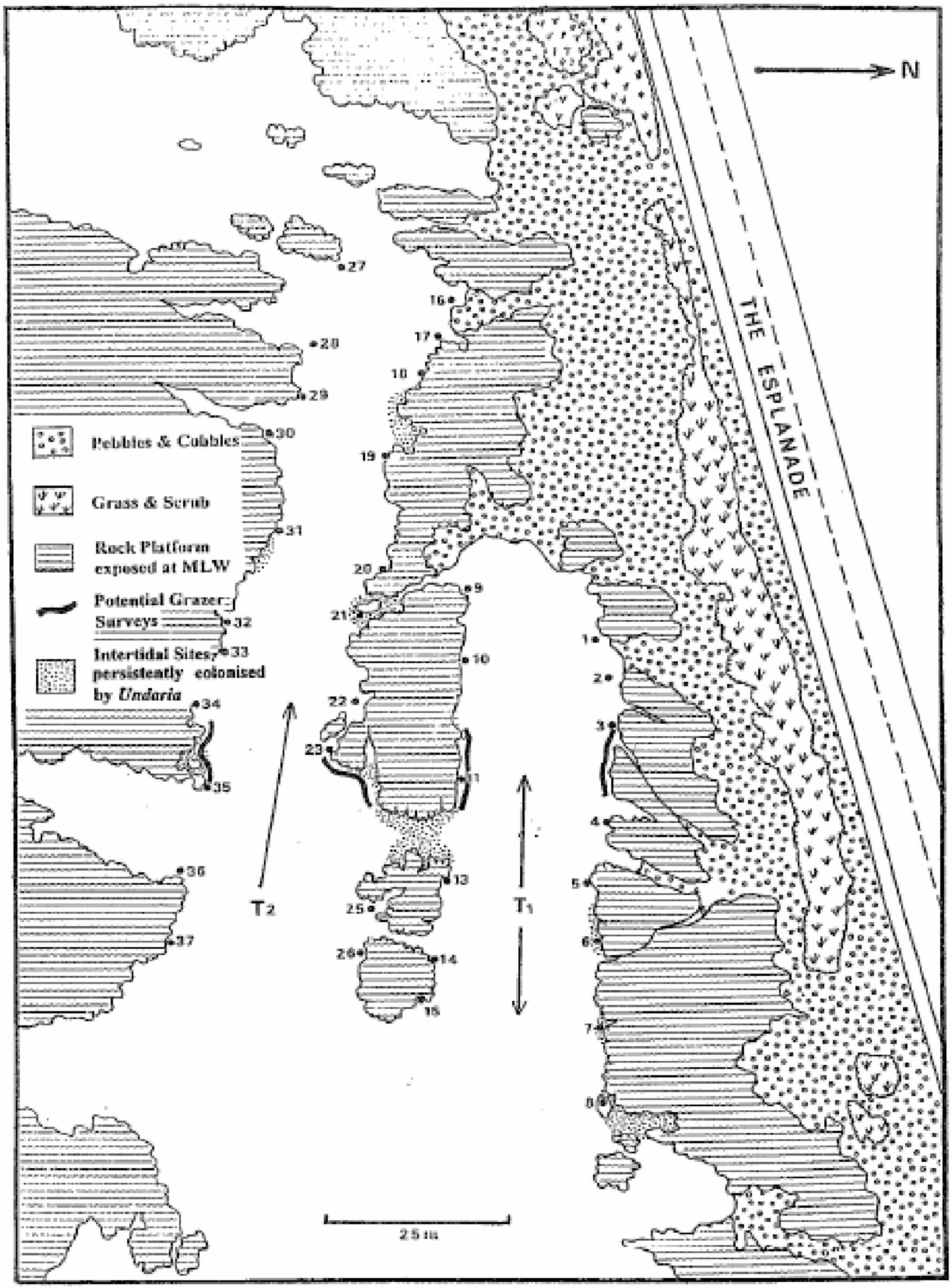


Appendix 2. Figures from Wear & Gardner 1998, Gardner & Wear 1999 and Wear & Gardner 2000.



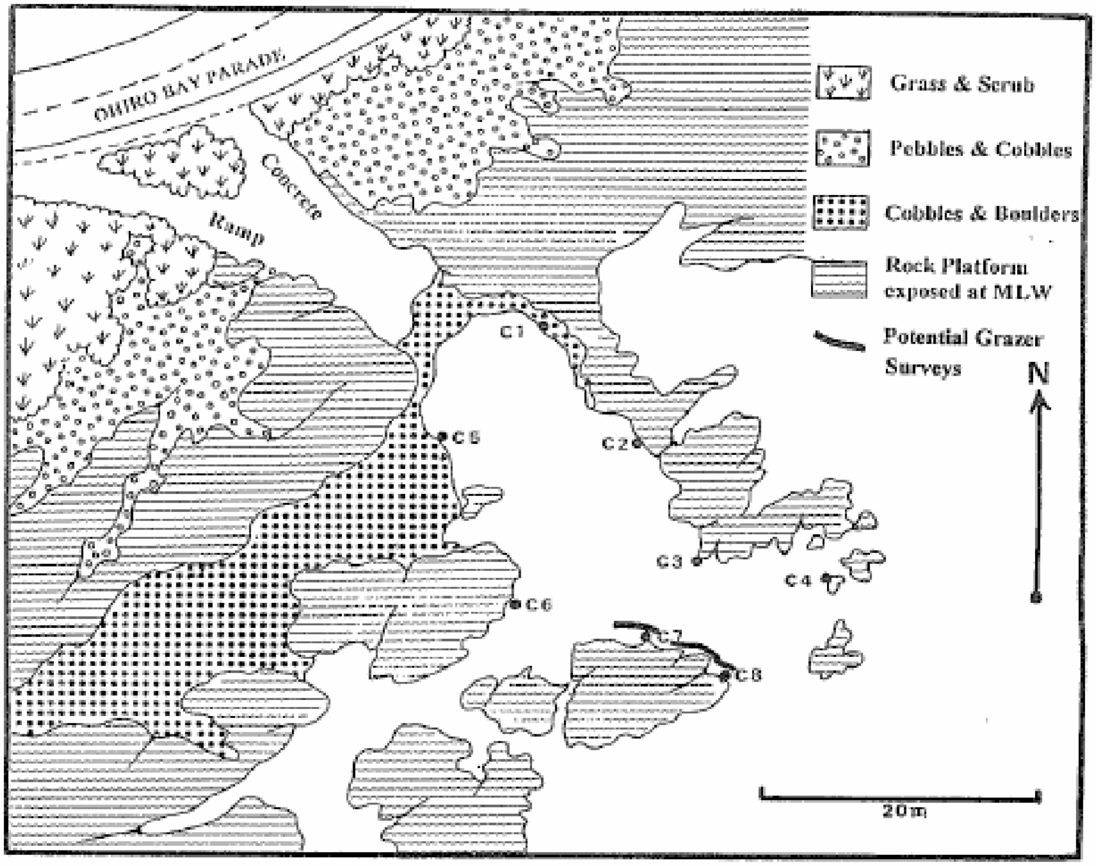
Distribution of *Undaria pinnatifida* along the Wellington South Coast, 15 December, 1997

Wear & Gardner 1998.



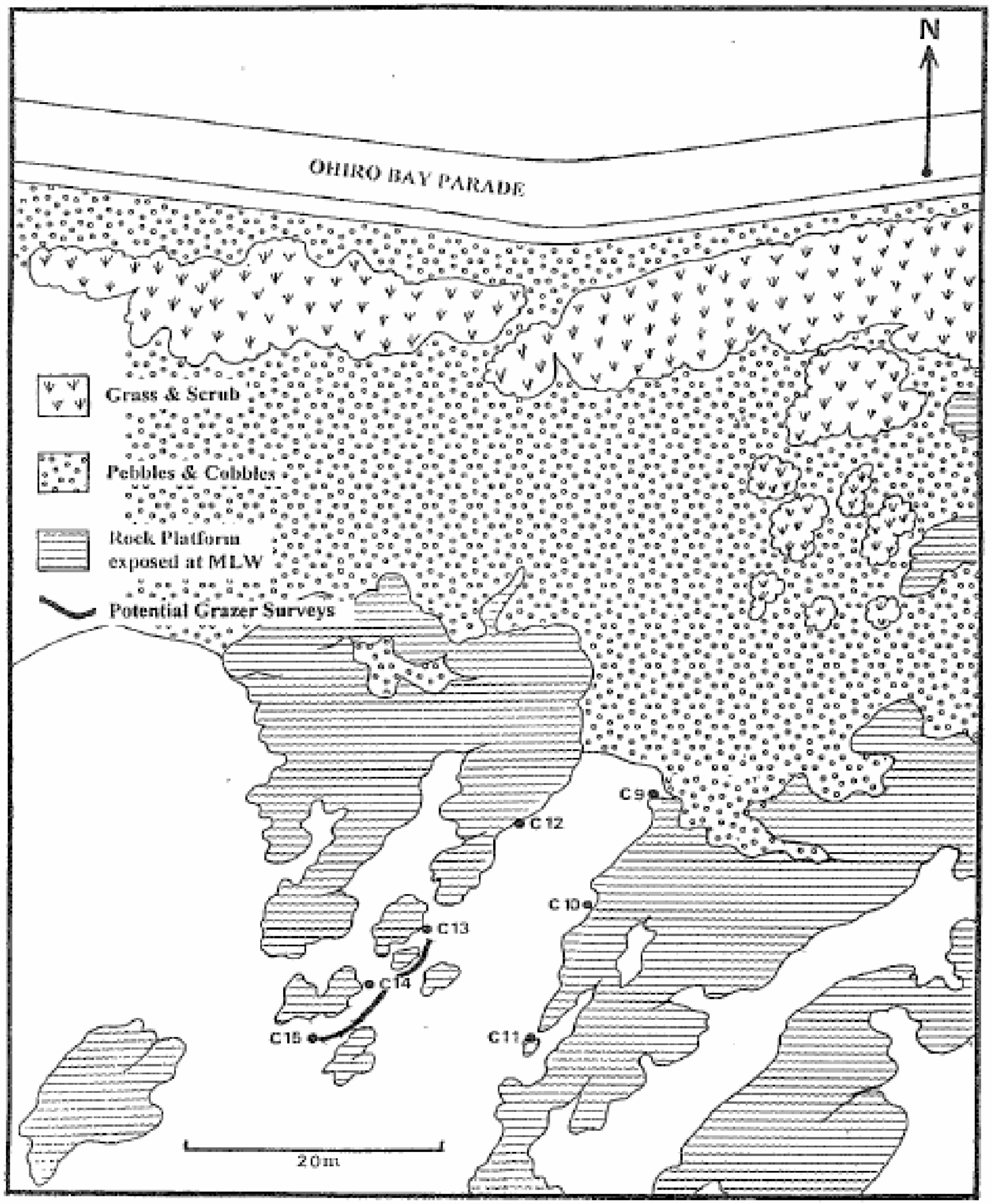
Study Site at Island Bay: Transects 1 & 2 showing Fixed Quadrat Locations, main areas of *Undaria* Colonisation 1997 - 98, and Potential Grazer Survey Transects

Wear & Gardner 1998.



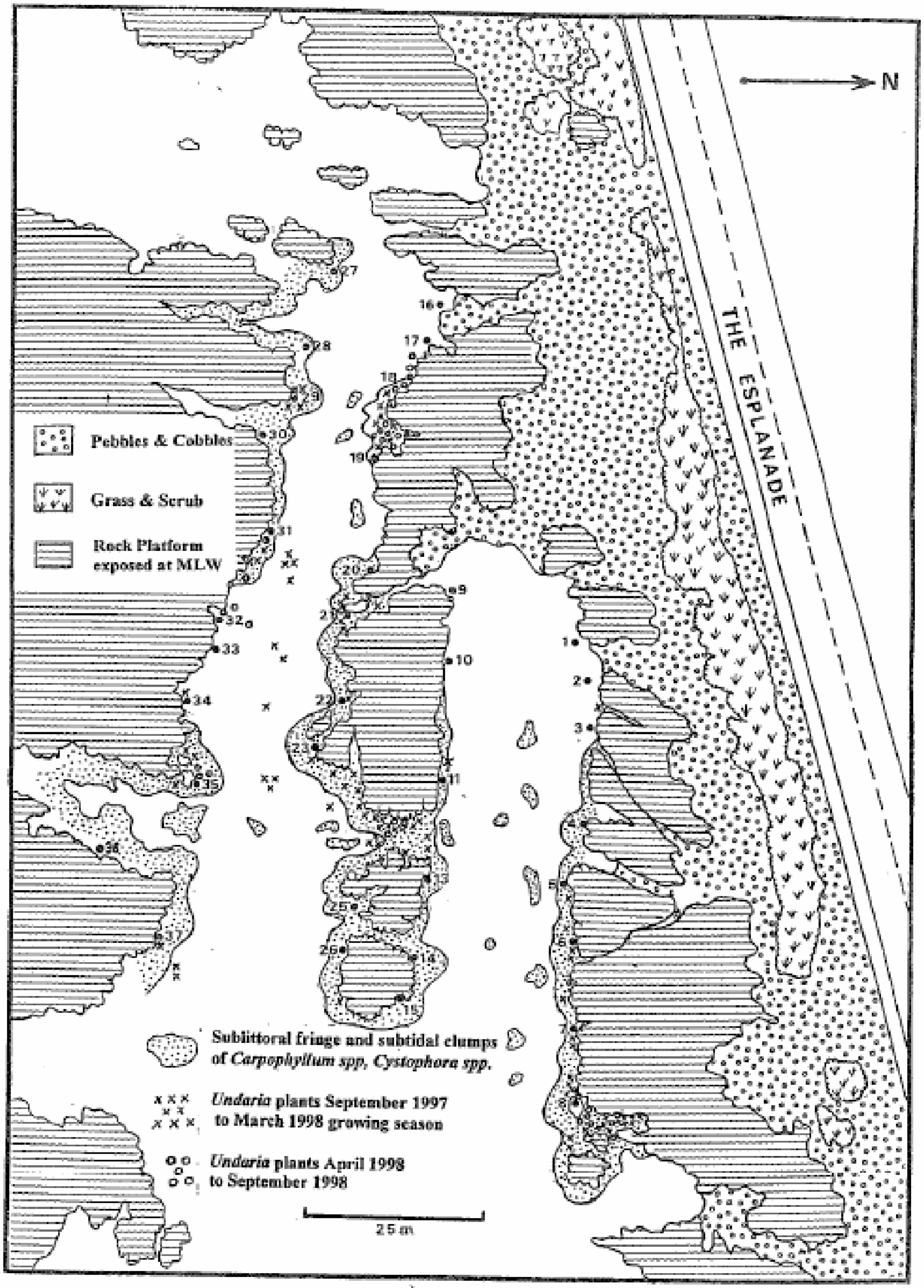
Control Site 2 showing Fixed Quadrat Locations and Potential Grazer Survey Transect

Wear & Gardner 1998.



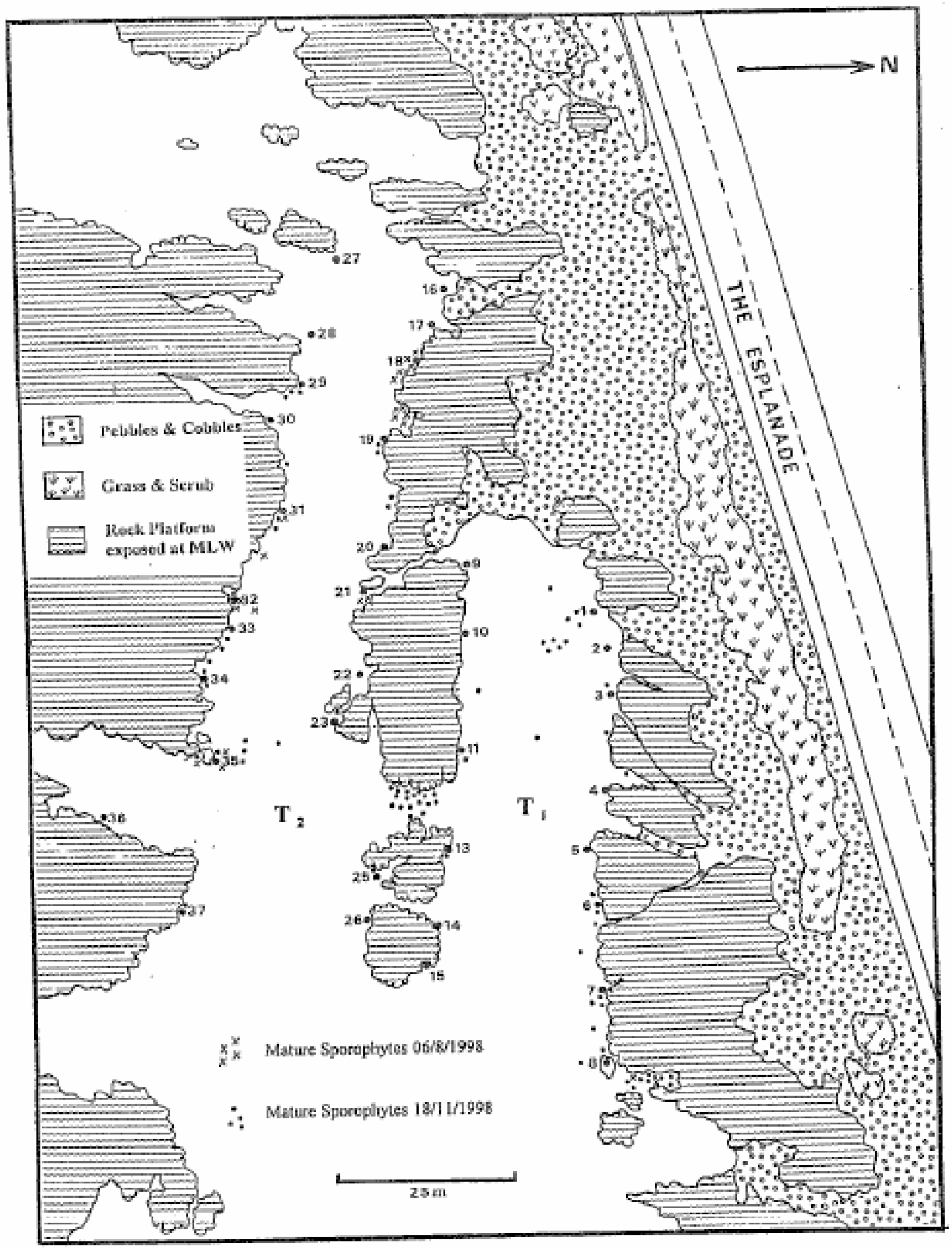
Control Site 1 showing Fixed Quadrat Locations and Potential Grazer Survey Transect

Gardner & Wear 1999



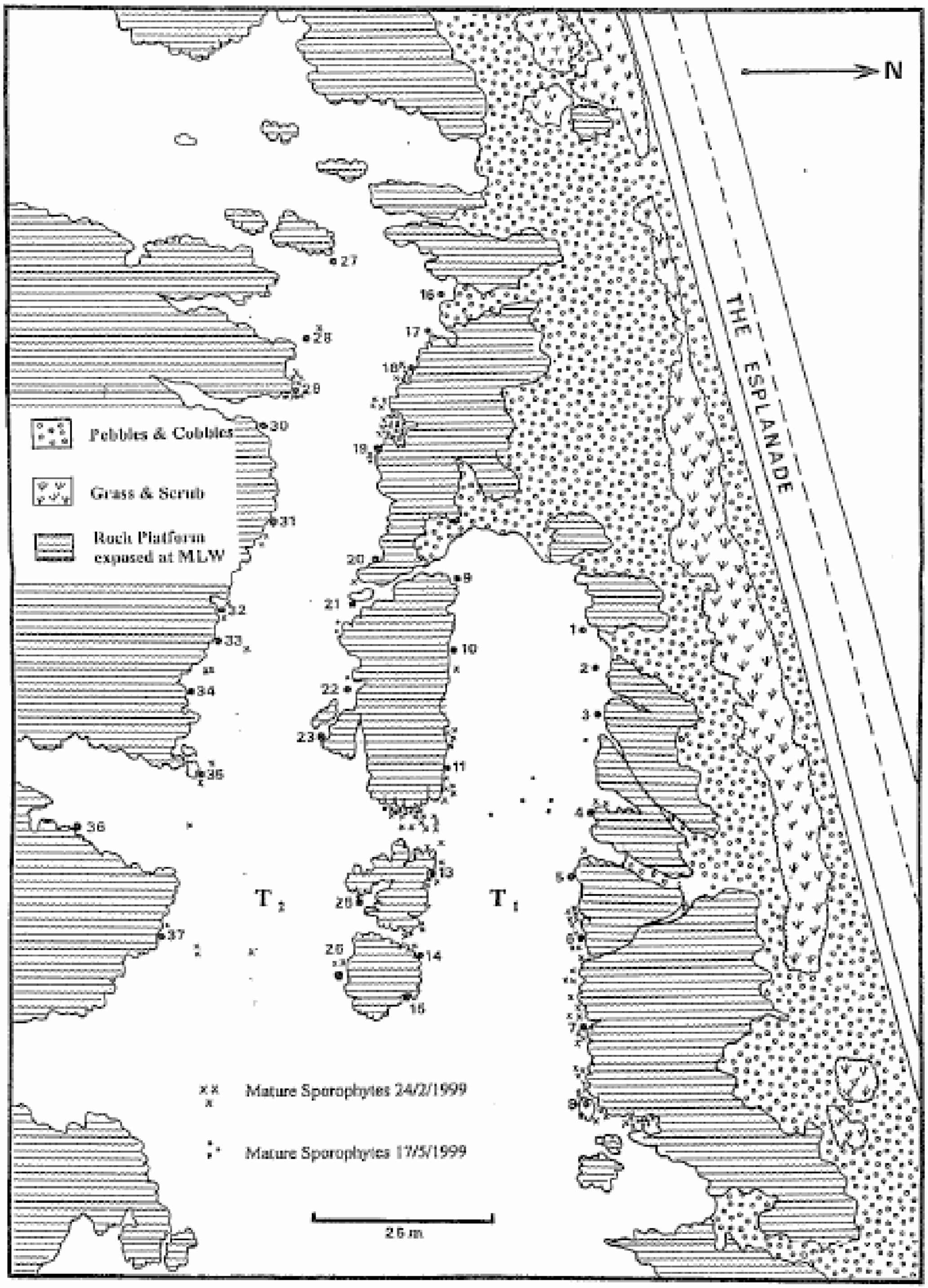
Study Site at Island Bay: Transects 1 and 2 showing distribution of Mature *Undaria* plants and position of the dense macro-algal fringe September 1997 to September, 1998

Gardner & Wear 1999



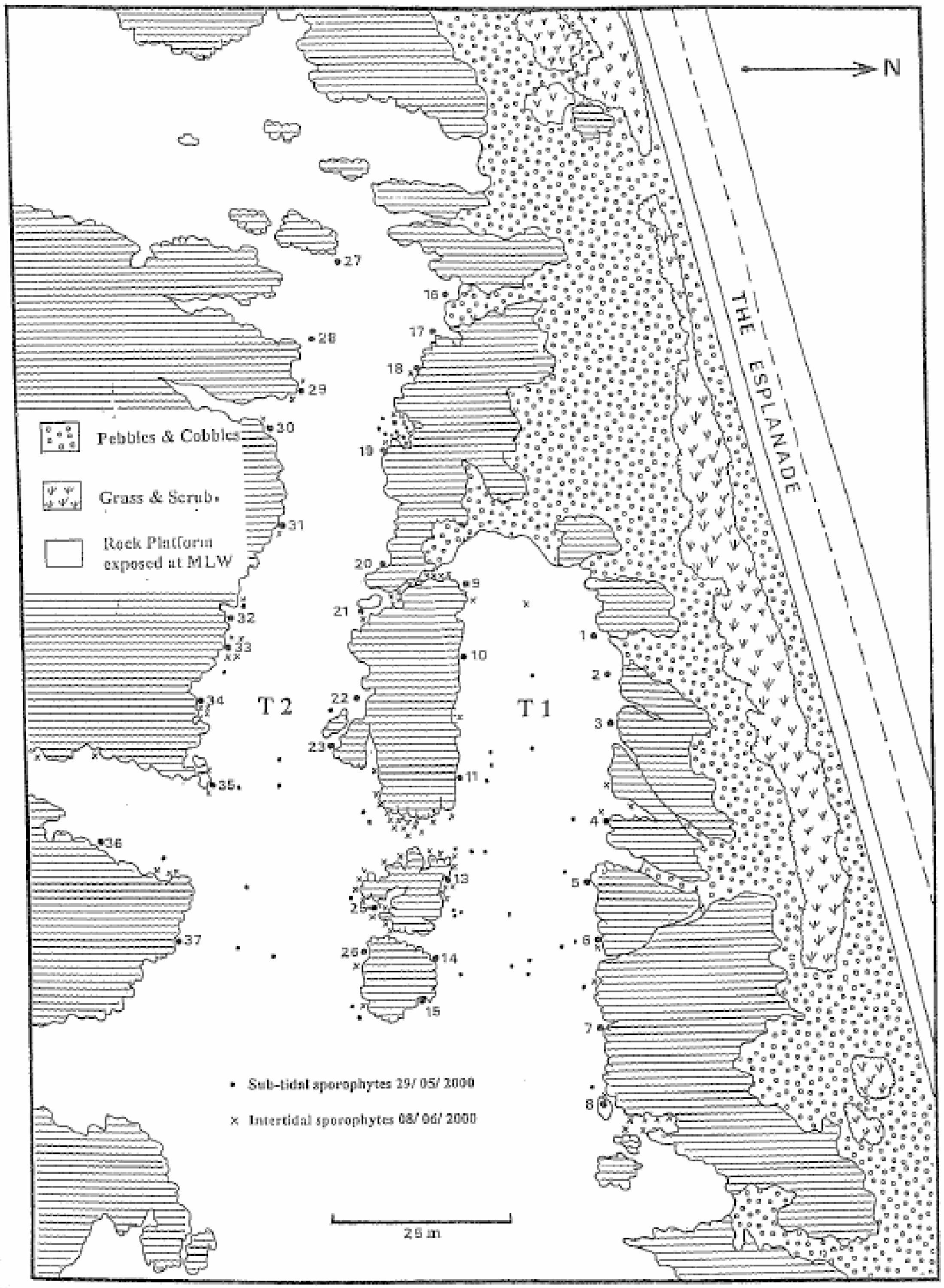
Study site at Island Bay: transects T1 and T2 showing positions of individual *Undaria pinnatifida* sporophytes in relation to the fixed quadrats on 06/08/1998 and 18/11/1998.

Gardner & Wear 1999.



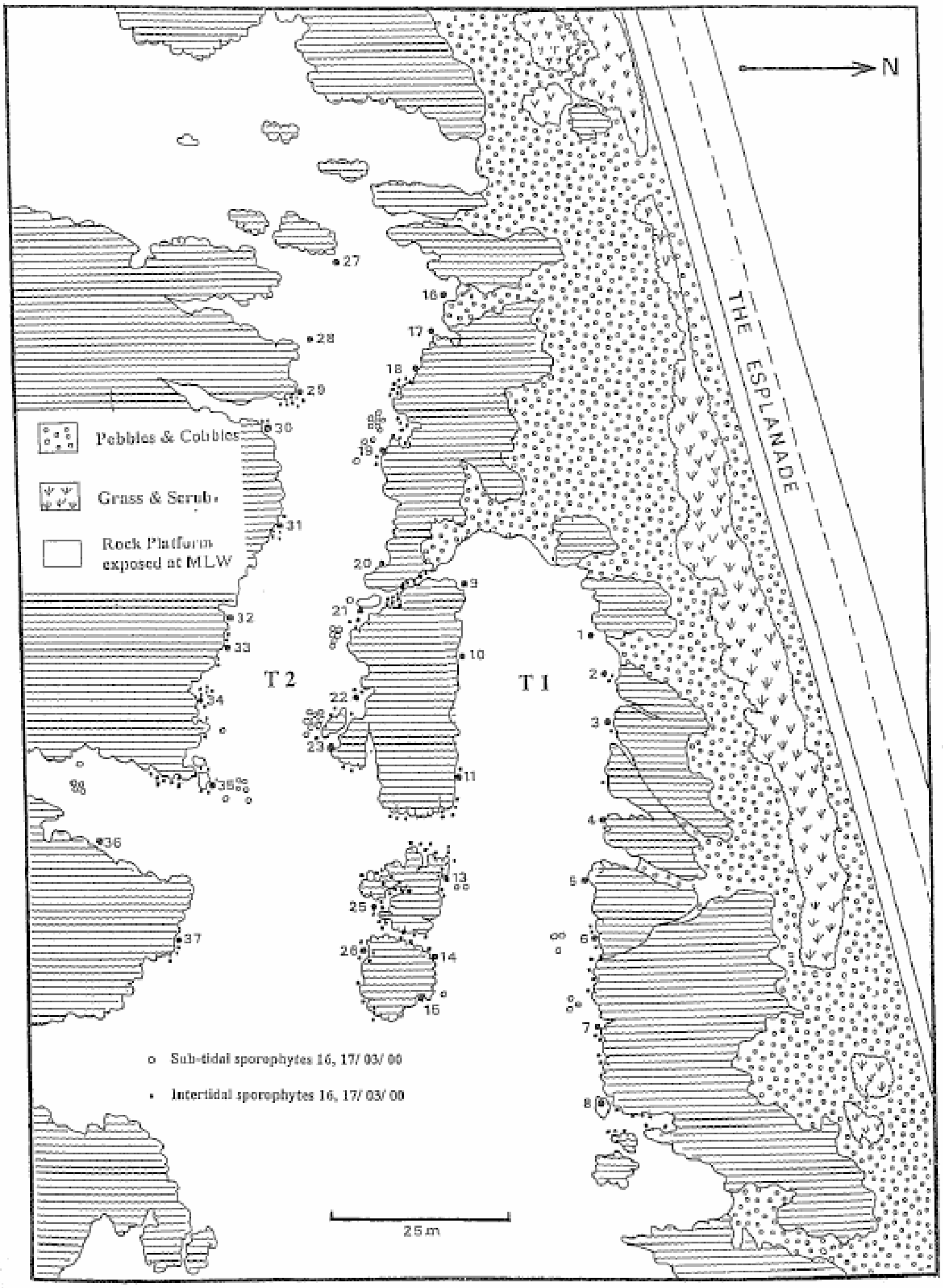
Study site at Island Bay: transects T1 and T2 showing positions of individual *Undaria pinnatifida* sporophytes in relation to the fixed quadrats on 24/02/1999 and 17/05/1999.

Gardner & Wear 1999.



Study site at Island Bay. Transects T 1 and T 2 showing positions of individual mature sporophytes of *Undaria pinnatifida* in relation to the fixed quadrats, 29 May and 08 June, 2000.

Wear & Gardner 2000.



Study site at Island Bay. Transects T 1 and T 2 showing positions of individual mature sporophytes of *Undaria pinnatifida* in relation to the fixed quadrats, 16, 17 March, 2000

Wear & Gardner 2000.