Designing a programme to monitor the recovery of the benthic community between North Cape and Cape Reinga

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Spirits Bay and Tom Bowling Bay are at the northernmost tip of the North Island of New Zealand, and are of great cultural and spiritual significance to all Maori as the pathway to the spiritual world of their ancestors. The area also supports several commercial fisheries, including an important part of the Northland scallop fishery and some bottom trawling for snapper and trevally, and recreational fishing interests.

During the mid 1990s, the scallop fishery was active in an area with a large and very unusual bycatch of sponges, bryozoans, and hydroids (including a high proportion of local endemic species). In response to concerns over the bycatch, a voluntary closure to dredging was established by fishers in 1997. Ministry of Fisheries funded research in 1999 examined the nature and extent of the benthic communities in the area and identified a probable link between dredge fishing for scallops and a decline in the unique and highly diverse fauna in part of Spirits Bay. A regulated closure to all mobile bottom fishing methods in this area was introduced in 1999.

The current project has designed a programme to monitor changes in fished and unfished parts of Spirits Bay, using survey data collected in 1999 and 2006. Acoustic mapping techniques have been used in conjunction with broad-scale video transects to determine the distribution of habitats in the area, and both video and high resolution digital still images have been used to examine benthic epifaunal communities within habitats. The still images proved to be particularly useful for identification of species (in conjunction with visual identification guides developed within the project), but sea conditions limited the work possible with the available equipment. On the basis of life history characteristics, recognisable species were categorised as to their sensitivity to the effects of fishing and other disturbances. Historical patterns of fishing activity were examined to investigate gradients of fishing pressure on benthic communities, and differences in benthic faunal abundance and community composition were examined in relation to these potential fishing gradients, and other environmental data. Significant differences were identified between the “voluntary” (closed since 1997), “regulated” (closed since 1999), and “open to fishing” areas, and species contributing to differences in communities included those previously identified as being most vulnerable to the effects of fishing. However, the community differences could not be attributed specifically to fishing, owing to environmental gradients and uncertainty over the history of fishing impacts in the area. No significant differences were identified within areas between 1999 and 2006, suggesting there has been no detectable change (impact in fished areas, or recovery in closed areas) over this time.

On the basis of findings from both this and previous surveys in the area, a survey design has been developed to monitor the recovery of the benthic communities in the closed areas, and compare them with those in the area still open to fishing. This longer term monitoring work would focus on non-destructive visual sampling of communities, which appears to offer good potential to discriminate between species and community types. Future monitoring should also involve acoustic mapping approaches.

1. OBJECTIVES

1.1. Overall objective

To design a monitoring programme that will allow a quantitative examination of the recovery of the benthic community from the effects of fishing between North Cape and Cape Reinga.

1.2. Specific objectives

To design a monitoring programme that will provide the following quantitative estimates.

i) Estimates of the nature and extent of past fishing impacts on the benthic community between North Cape and Cape Reinga.

ii) Estimates of change over time in areas previously fished but subsequently closed to fishing. Estimated parameters will include indices representing biodiversity, community composition, and biogenic structure.

iii) Estimates of change over time in areas environmentally comparable to those assessed in (ii), above, but subject to ongoing fishing impacts.

iv) Estimates of change over time in areas comparable to those above, but not impacted by fishing (if any such areas can be found).

2. INTRODUCTION

The Ministry of Fisheries is required by the Fisheries Act (1996) to avoid, remedy, or mitigate any adverse effects of fishing on the aquatic environment. This requirement includes mandates that "associated or dependent species" should be maintained above a level that ensures their long-term viability, that biological diversity of the aquatic environment should be maintained, and that "habitat of particular significance for fisheries management" should be protected.

Spirits Bay (Piwhane) and Tom Bowling Bay are at the northernmost tip of the North Island of New Zealand, between North Cape and Cape Reinga (Figure 1). Ngati Kuri have been the kaitiaki of these waters for at least the last 700 years, but the area is of great cultural and spiritual significance to all Maori, as the pathway to the spiritual world of their ancestors. The area also supports several commercial fisheries including (but not restricted to) an important part of the Northland scallop fishery and some bottom trawling for snapper and trevally, as well as being important for recreational fishing interests.

The scallop grounds in the area are regularly surveyed to estimate abundance and population size frequency of scallops, and estimate potential yield on the basis of these data (Williams et al. 2007). During the 1996 northern scallop stock survey carried out by NIWA (for the Ministry of Fisheries), very unusual dredge bycatch was observed in the 40–50 m depth range in Spirits Bay. This bycatch was taken mostly in the area specified by fishers as where most scallops had been caught during 1995 (stratum 93). Specimens were taken and later identified by NIWA specialists. The fauna was so unusual (including a high proportion of local endemic species) that stratum 93 was unofficially dubbed "the sponge garden", the Ministry was alerted to the issue, and further samples were taken during the 1997 scallop stock survey. The additional samples seemed to confirm that the community was highly unusual, dominated by sponges, bryozoans, and hydroids, and had a very high proportion of new or endemic species. Given the limited sampling, it was thought unlikely that the full diversity of this unusual community had been determined. The restriction of sampling to strata designed for scallop surveys constrained our knowledge of the geographical extent of the community. Other samples in NIWA collections of macrofauna from similar depths around Northland were found to be quite different, suggesting that the community found in Spirits Bay and Tom Bowling Bay was uncommon around the mainland. Some of the rare taxa had been recorded in other areas of high current flow such as the Three King's Islands, Ranfurly Bank, and Cook Strait, but many were apparently local endemics. In response to the levels of bycatch, a voluntary closure to dredging was established by fishers in 1997 (north of a line at 34° 22' S) (Figure 1).

The encrusting nature and large size of much of the colonial, filter-feeding fauna in Spirits Bay and Tom Bowling Bay suggested that not only was the community unique, but it was also likely to be susceptible to damage through suffocation and burial during the course of bottom dredging for scallops (S. O'Shea, AUT, pers. comm.). Moreover, there was also good reason to suppose that the physically highly structured nature of the community was beneficial for spat settlement and survival (Walters & Wethey 1996, Talman et al. 2004). Similar benefits for scallops have also been identified for areas of biogenic maerl habitat (Kamenos et al. 2004). Serious curtailment of recruitment in a commercial fishery for bay scallops has been described (Peterson et al. 1987) following degradation of a "seagrass" community by mechanical clam harvesting. Destruction of the colonial, filter-feeding fauna of Spirits Bay may, therefore, lead to the demise of the scallop fishery as well as the loss of an important ecological archetype.

Because of concerns over the effects of fishing on benthic communities in the area (see Section 2.1), the Ministry of Fisheries commissioned research to examine the nature and extent of the sponge- and bryozoan-dominated community between North Cape and Cape Reinga (contract ENV9805, awarded to NIWA and conducted between October 1998 and September 2000). This was seen as a first step in assessing the extent to which fishing affected benthic community structure in the area. NIWA employed a combination of mapping (using two acoustic remote-sensing approaches verified or "ground truthed" using seabed video) and sampling of macrofauna at representative sites using dredges. Multivariate statistical analysis was used to assess the extent to which benthic community structure was related to environmental factors or fishing. The project (Cryer et al. 2000) identified a probable link between dredge fishing for scallops and a decline in the unique and highly diverse fauna in part of Spirits Bay. It was inferred that associated species, especially large, fragile, or long-lived forms, were likely to be adversely affected by fishing, that biological diversity was likely to be reduced, and that habitat of particular significance for fisheries management (e.g., that containing much "spat catching" foliose colonial fauna) was likely to be affected. On the basis of these inferences, the Ministry of Fisheries introduced a regulated closure (covering the voluntary closed area and also extending further south towards the eastern extent of the area) to mobile bottom fishing methods (trawling for finfish as well as dredging for scallops) in 1999 (Figure 1).

The Ministry has now requested further research to refine our understanding of the factors influencing the benthic invertebrate fauna, and to design a programme to monitor changes in fished and (nominally) unfished parts of Spirits Bay (current project). The programme is expected to be useful for the management of the effects of fishing between North Cape and Cape Reinga but also, by inference, in other areas subject to scallop dredging.

The preferred method of estimating the effects of fishing over time would be to monitor changes in community structure and biodiversity with respect to the location and intensity of fishing activity and other possible forcing variables. Our sketchy knowledge of the fine-scale distribution of trawling and dredging in Spirits Bay seriously limits the extent to which we will be able to employ this approach, however, and we have been limited to assessing spatial patterns in structure and biodiversity in relation to presumed fishing history (as codified in various voluntary and regulatory closures), and any "recovery" of modified areas over time. The Ministry has called for a robust experimental design to ensure that such work is carried out efficiently. This report describes work to construct such a design. We have drawn on methods, expertise, and equipment developed under a variety of other NIWA programmes, including previous work for the Ministry of Fisheries, the Foundation for Research, Science and Technology, Department of Conservation, and commercial projects.

2.1. Impacts of scallop dredging

The impacts of trawling and scallop dredging have recently been reviewed (Lokkeborg 2005, DFO 2006). Studies into the effects of scallop dredging on the seabed and benthic communities have been conducted in a range of geographic locations, on habitats ranging from sand and silt to pebbles and cobble. The physiological and ecological consequences of bivalve dredging have also recently been reviewed in a widescale European study (Lart 2003). The effects of fishing vary with fishing gear and habitat encountered, with the most severe impacts occurring in biogenic habitats in response to scallop dredging (Kaiser et al. 2006).

The most noticeable physical effect of scallop dredging on the seabed is the flattening of irregular bottom topography and the elimination of natural features such as ripples, bioturbation mounds, or faunal tubes. The teeth of scallop dredges are designed to penetrate the upper few centimetres of the sediment to dislodge scallops recessed in the seabed, and this "raking" effect tends to flatten the affected area, leaving distinct tracks. The flattening of natural features was observed immediately after fishing, but the furrows were eliminated by wave and tidal action shortly afterwards in exposed sandy areas (Eleftheriou & Robertson 1992, Thrush et al. 1995). Dredge tracks have remained visible up to one week after fishing in more sheltered sandy habitats (Pranovi et al. 2000) and one month in silty sand habitats (Currie & Parry 1996), but few observations have been carried out over the longer term, and confident conclusions cannot be drawn on dredge track persistence in sandy areas. An investigation into the effects of dredging on biogenic maerl habitat identified similar immediate effects to studies in sandy areas (distinct furrows, elimination of natural features), with tracks remaining visible for up to 2.5 years (Hall-Spencer & Moore 2000).

Immediate effects of dredging can be quite dramatic in some habitats. Where dredging for shellfish is carried out in areas with considerable epifauna, much can be uprooted, dislodged, or smothered (Caddy 1973, Butcher et al. 1981, Currie & Parry 1996). Fragile epifauna such as *Tubularia*, sponges, and bryozoans are particularly at risk (Auster et al. 1996), as are emergent infauna such as the large bivalve *Atrina fragilis* (Hall-Spencer et al. 1999) (similar to the New Zealand species *Atrina zelandica,* recorded in a number of scallop grounds), and large scale changes in areas where these are dominant can have significant implications for other dependent species and fisheries (Sainsbury 1987, 1988, Auster & Langton 1999). Other studies have examined short term effects, or compared areas subjected to different fishing pressures, which may also have involved comparison of habitats. Most studies have identified community effects, which were most commonly a reduction in the number of species and a reduced abundance for certain species in dredged areas. Effects on benthic communities in sandy habitats were observed for at least three months after a low intensity of disturbance (Thrush et al. 1995) and beyond eight months after more intensive fishing (Currie & Parry 1996). One study that detected no effects from scallop dredging was conducted at a site subject to strong tide and wave action (Eleftheriou & Robertson 1992), and several of the studies demonstrated that natural temporal and spatial variability in community structure may be more pronounced than changes caused by dredging (Currie & Parry 1996, Thrush et al. 1998, Currie & Parry 1999, Kaiser et al. 2000). Biogenic maerl habitat appears to be very sensitive to dredging impacts, with dredge activity burying the maerl, and up to 80% mortality of thalli being observed, with no indications of any recovery within four years (Hall-Spencer & Moore 2000).

Scallop dredging in *Atrina fragilis* beds caused reductions in habitat complexity (Hall-Spencer et al. 1999). Trawling through the “coral” grounds in Tasman Bay (consisting mostly of the bryozoans *Celleporaria agglutinans* and *Hippomenella vellicata*) had adversely affected fish populations to such an extent that an area was closed to trawling to conserve stocks (Bradstock & Gordon 1983). Similarly, dredging for oysters in Foveaux Strait is thought to have progressively modified biogenic reefs of the bryozoan *Cinctipora elegans* until oysters were the only epifauna remaining (Cranfield et al. 1999). More recent studies in the Foveaux Strait have linked changes in biogenic reef distributions to changes in fish distribution, density, feeding and growth (Cranfield et al. 2001, Jiang & Carbines 2002, Carbines et al. 2004). In other habitats, habitat complexity has been associated with reduced post-settlement mortality and improved recruitment of fish (Johnson 2007).

The recent reviews conclude that mobile, bottom-contact fishing gears have impacts on benthic populations, communities, and habitats, but the effects are not uniform and depend on at least the specific features of the habitats (including natural disturbance), the species present, the type of fishing gear, and the history of human activity (particularly fishing) in the area, and also that habitats exposed to natural disturbances and showing large interannual variability in their benthic assemblage are likely to be impacted less by trawling, while habitats dominated by large sessile fauna may be severely affected (Lokkeborg 2005, DFO 2006). For habitats or communities where there is potential for impacts to be large, the greatest impacts are caused by the first few fishing events (DFO 2006), suggesting that areas without histories of fishing require special consideration in managing the risks posed by bottom trawling and dredging.

The direct effects of marine habitat disturbance by commercial fishing have been well documented (see above). However, the potential ramifications for the ecological function of seafloor communities and ecosystems have yet to be fully considered. A simple ratio-based model has recently been developed to investigate the impact of disturbance at different spatial and temporal scales (Thrush et al. 2005). The model simplifies many of the complexities of disturbance-recovery dynamics, but provides a very valuable indication of disturbance regimes that, through their frequency, extent, or intensity, could result in catastrophic changes across the seafloor landscape. Increases in disturbance regime result in loss of late-successional-stage species, especially those that take 10–15 years to recover. As the age to maturity of late successional stage increases, the extent and frequency of disturbance increasingly restricts the spatial extent of the mature stage. When disturbance is infrequent relative to recovery time and only a small proportion of the landscape is affected, the system is stable and exhibits low variance over time. When frequency of disturbance is similar to recovery time and a large proportion of the habitat is affected, the system can still be stable, but exhibits higher variance. When disturbance frequency is shorter than recovery time and a large proportion of the system is disturbed, the system may flip to an altered state.

3. METHODS

Working definitions for this study

In New Zealand's Biodiversity Strategy, "Biodiversity" is defined as "… *the variety of all biological life. This includes plants, animals, fungi and microorganisms, the genes they contain and the ecosystems they live in.*" "Marine biodiversity" has an analogous meaning for the variety of all life in coastal and ocean environments. We do not feel that it would be necessary, feasible, or cost effective to monitor or assess biodiversity under such a definition and have conducted the project with the aim of assessing the following (important) components of biodiversity.

- Megafauna: large (habitat structuring) colonial epifauna (and, potentially, flora), and large non-colonial epifauna and burrowing infauna.

- Macrofauna: burrowing and infaunal macroinvertebrates.

- Habitat: composition, structure, variability, and gradients in habitat features, including three-dimensional structure.

We have not conducted any work on genetic diversity, or on those small invertebrates encompassed within the general terms microfauna, meiofauna, fungi, or other microorganisms. Previous investigations in the Spirits Bay area have focused on epifauna (Cryer et al. 2000). Within the current study, infaunal samples have been collected, but limited resources meant that these samples have not been analysed, and remain available for incorporation into a longer term monitoring programme.

Similarly, we have not examined the great variety of ecosystems that might be inferred to exist between North Cape and Cape Reinga, but concentrated on the area thought to be the most highly modified part of Spirits Bay (see Section 3.2). Our approach, therefore, focuses on relatively large animals within and on top of the sediment, and their distribution and assemblage structure within the survey area in relation to habitat, fishing activity, and (where possible) other forcing variables. Biogenic, three dimensional structure has been found to be important as a source of habitat, food, and protection from predators and can be described or estimated in various ways. We have favoured broad scale visual estimators (developed from video footage and digital photographs) over complex estimates of actual surface area because they are more applicable at the scale of the management issue (the effects of fishing on habitat structure).

Survey area

It is widely accepted that the area between North Cape and Cape Reinga is unique and of national importance for its exceptionally high diversity and high rate of local and regional endemism. This means that the area is an important one to study, but it also means that there are no true "control" sites that we can study in parallel. Thus, the monitoring programme we propose developing is restricted entirely to the area between North Cape and Cape Reinga. The ENV9805 project (Cryer et al. 2000) studied a relatively large area and a wide depth range between North Cape and Cape Reinga, and mapped a modest proportion of the area using side-scan sonar and acoustic seabed classification techniques, allied with qualitative video observations, and collected large, semi-quantitative samples using dredges. Given the scale of such an area, this is not considered to be the most suitable approach for a longer-term monitoring programme, although the work did identify a smaller area (essentially scallop survey stratum 93) within which they thought dredging for scallops had markedly affected biodiversity (for example, by reducing estimates of sponge alpha diversity by about one order of magnitude) (Cryer et al. 2000). This area and its immediate surroundings are of relatively constant depth and, we think, substrate composition. The area is also crossed, roughly parallel to depth contours, by the 1997 voluntary closure line and the southern boundary of the 1999 regulated closure (Figure 1). Thus, the area has some consistency in environmental conditions but should have considerable contrast in fishing history. If the decline in biodiversity caused by dredging and reported in ENV9805 (Cryer et al. 2000) was real, there should be large differences in the epifaunal assemblages within this area that can be assessed and monitored.

Although the emphasis of the surveys was different, since the survey area of the present project is within the area surveyed by ENV9805, there are samples and data sets from this previous work that are within the present survey area, and will be included in any analysis.

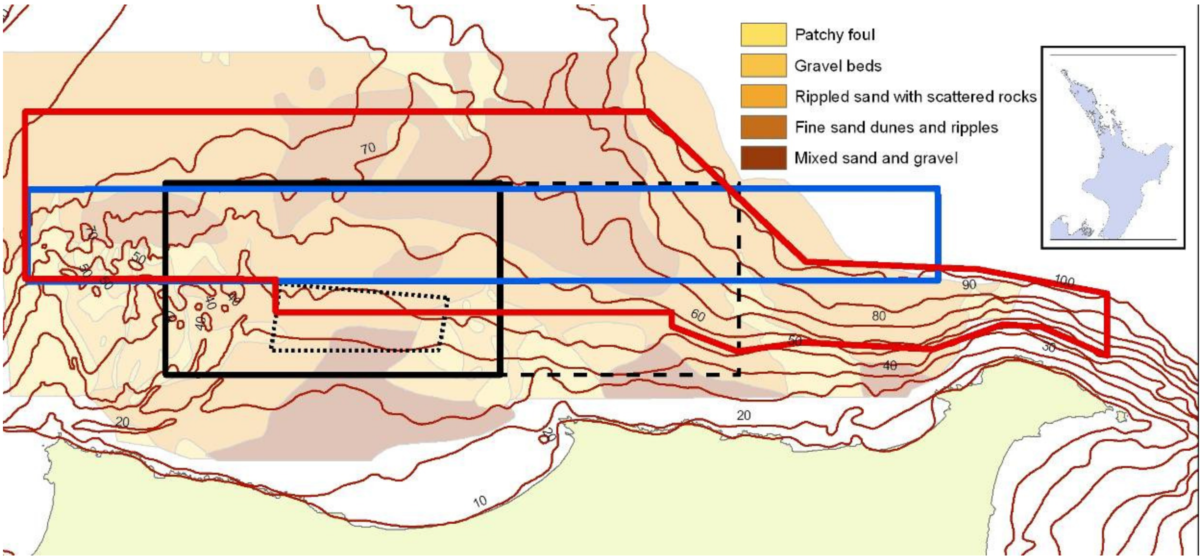


Figure 1: Map showing primary (solid black line) and secondary (dashed black line) survey areas for current work, in addition to area surveyed during ENV9805 (colours from habitat map generated from side-scan sonar in 1999), and the areas closed to fishing in the region. Area delimited by blue line – voluntary closure in 1997; red line – regulated closure in 1999; black dotted line – scallop survey strata 93 "sponge garden".

Additional work beyond accepted Ministry of Fisheries tender (ENV2005-23)

In NIWA's tender to the Ministry of Fisheries for project ENV2005-23, we proposed to deploy digital side-scan sonar from a small chartered survey launch, aiming for 100% coverage of the survey area. Following completion of this acoustic mapping, a video or combined video/still camera survey was proposed to determine what recognisable "signatures" on the acoustic map represented. Some sampling for epifauna and macro-infauna and voucher specimens was to be nested within the framework of acoustic and visual samples. A total of 14 days was costed for vessel charter.

During early 2006, before to the planned voyage, additional funds were secured from the NIWA Capability Fund (CRDJ061) and DOC (DOC06101), which allowed the project to considerably increase the data collected. The additional funding enabled the use of RV *Kaharoa* for 24 days (instead of a smaller research launch for a shorter period), extended the survey area further to the east (Figure 1), covered the cost of deployment and preliminary analysis of a multibeam echosounder during the acoustic phase of the voyage, and the hire of an ROV and operator for the video and sampling phase of the voyage.

An additional NIWA Capability Fund project (CREY073) was secured during 2006–07 to conduct analysis of the multibeam backscatter data.

3.1. Analysis of historical fishing patterns

In order to estimate the nature and extent of past fishing impacts on the benthic community between North Cape and Cape Reinga, we have attempted to estimate historic fishing patterns in the area.

Data on the spatial pattern and intensity of scallop dredging are available from the MFish Catch and Effort Landings Return (CELR) data. The CELR data records hours dredged for each day by vessel and scallop fishery statistical area. Unfortunately, while these data provide a useful source of information on the overall levels of effort and catches in the area, the entire area between North Cape and Cape Reigna is covered by a single scallop statistical area (9A), and therefore the spatial pattern of effort and disturbance within this statistical area cannot be examined from these data alone.

A thorough investigation using the CELR data to investigate depletion methods of estimating scallop biomass was conducted by NIWA as part of the MFish SCA9081 project (Cryer 2001), and this was more recently updated in MFish project ZBD200515 (Tuck et al. 2006). Both these projects specifically examined the Coromandel scallop fishery, but the data grooming conducted within the work incorporated all the scallop CELR data available at the time. The previously groomed data were augmented by a new data extraction up to the end of the 2006–07 fishing year, groomed in the same way.

As discussed above, CELR data do not provide sufficient information to examine spatial patterns of effort within area 9A, and it has not been possible to obtain detailed information from the fishery on patterns of effort. Scallops are quite habitat specific in their distribution however, and the known beds are delimited by the survey strata defined for the annual assessment surveys. In order to provide a "best estimate" of the patterns of scallop fishing activity, it has been assumed that all scallop fishing has taken place within the three defined strata, and the total effort recorded for the statistical area has been allocated to the available strata in proportion to the relative scallop density observed in the pre-season survey. This is on the assumption that fishers would preferentially target areas of higher scallop density.

As described earlier, the scallop grounds in the area are regularly surveyed to estimate absolute abundance and population size frequency, and estimate potential yield on the basis of these data (Williams et al. 2007). Data from the scallop survey time series have also been examined to identify areas of high scallop abundance.

In addition to scallop dredging, other fisheries take place in the Spirits Bay area, and are also affected by the 1999 regulated closure. As with the scallop fishery, many of the inshore fisheries record effort and landings data on the CELR system, and these data are only spatially resolved to statistical area or FMA. In this region of New Zealand, for fish species the areas are very large (e.g., for snapper, SNA 8 extends from North Cape to virtually the whole west coast of North Island), and no information on patterns of fishing disturbance can be gleaned from these data. However, some vessels have recorded to the TCEPR system, which includes location data on a haul by haul basis. A data extraction was requested from the Ministry of Fisheries (Client Services) for all fishing events recorded in the TCEPR system (1 October 1989–30 April 2007), with the start position within 34^{o}–34^{o} 30' S and 173^{o}–173^{o} 30' E. This extraction included 3800 individual haul records. Limited data grooming was conducted, examining distance towed in relation to recorded tow duration, to identify where errors may have occurred in data entry. Target species was also used as a check, with a number of records listed as targeting silver warehou (SWA) assumed to have been mis-punched, and changed to snapper (SNA). Of the target species listed within the extraction, only tows targeting barracouta (BAR), gurnard (GUR), John dory (JDO), red snapper (RSN), school shark (SCH), snapper (SNA), tarakihi (TAR), and trevally (TRE) using bottom trawl (BT) or bottom pair trawl (BPT) were considered in the analysis (reducing the number of tows to just over 3600). Most tows targeted snapper (43%), with most of the remainder targeting tarakihi (34%) and trevally (20%).

3.2. Survey design

Twenty-four days ship time was available to the project, which allowing for mobilisation, transit to and from Auckland, staff changeover at Marsden Point and demobilisation resulted in 18 days "on site". Eight days were allocated to the acoustic (first) phase of the voyage, and the remaining 10 days to a combination of visual and physical sampling.

During acoustic sampling *Kaharoa* can operate 24 hours a day. Given the size, shape, and depth contours of the area to be sampled (Figure 1), we determined that this area would be best surveyed using parallel transects oriented east-west.

During daylight hours, data were collected using three acoustic systems (multibeam echosounder, single beam echosounder, and sidescan sonar). A line spacing of 250 metres was selected to ensure overlap of the swaths ensonified by the sidescan sonar. At night time, the vessel continued logging multibeam echosounder data along transects in between the lines completed during the daytime; this ensured full coverage of the seabed by the multibeam echosounder which has a smaller swath width (in the expected water depths) than the sidescan sonar. In this fashion, the plan was to obtain complete coverage of the survey area using these acoustic tools.

The original intention of the visual and physical sampling phase of the voyage was to sample transects across the survey area (in a north-south direction), with locations of transects informed by preliminary analysis of the acoustic data (conducted at sea during the acoustic phase), to enable us to determine whether variability in acoustic signatures was reflected in habitats. Each transect was to include broad-scale video sampling (a continuous run along the whole transect), as used successfully in other New Zealand studies (Hewitt et al. 2004), with high resolution digital still and physical sampling nested within each transect. However, a computer failure early in the acoustic phase of the voyage meant that while the acoustic data were collected successfully, analysis at sea was not possible, and therefore transects were located without the benefit of these data. Also, the conditions (sea swell, strong wind, and tides) caused difficulties in navigating the vessel in a north-south direction at slow enough speeds for the camera systems to be deployed usefully. It was therefore decided to abandon the planned approach of conducting a series of continuous video runs across the survey area, and conduct sampling at point stations along nominal north-south transects. The vessel direction at each of these stations varied with local sea and wind conditions.

During the previous survey of Spirits Bay (Cryer et al. 2000), extensive dredge sampling was carried out to obtain specimens representative of this area. For this survey in 2006, it was not possible to completely avoid physical sampling; however, the intention was to keep this aspect of the work to a minimum, to avoid physical disturbance and damage to the habitats to be monitored.

To minimise the chances of foul weather or equipment breakdown interfering with the survey objectives, we commenced both the acoustic and visual sampling in the "primary" area (defined in the original survey plan), and moved into the "secondary" area (possible because of the additional funding secured) once the primary area had been completed. The weather was poor throughout most of the voyage (only improving on the last working day), and although no time was lost to the voyage, this caused difficulties with deployment and operation of the camera gear in particular, and changes in approach were required.

3.3. Position fixing, navigation, and depth sounding

A POS MV 320 system (Position and Orientation System for Marine Vessels) was used to obtain accurate position, heading, pitch, roll, and heave data. The POS MV system incorporates an inertial motion sensor (IMU) and dual GPS receivers. The POS MV was interfaced with an Omnistar 3100 LR GPS receiver to obtain differential corrections.

During the course of this survey, HydroPro Navigation software (Trimble Ltd) was used to log position data from the POS MV and Omnistar unit to record the vessel's track during deployment of a sidescan sonar, cameras, dredges, and grabsampler. Position data were recorded as latitude and longitude (WGS84), and as easting and northing coordinates (UTM Zone 59 South).

3.4. Multibeam echo sounder

A Kongsberg Simrad EM3000 multibeam echosounder (300 kHz), with a hull-mounted transducer, was used to obtain depth and backscatter data throughout the survey area. The multibeam echosounder was interfaced with the POS MV system to obtain accurate position, heading, pitch, roll, and heave data.

Sound velocity profiles of the water column were logged using a SV probe (Applied Microsystems Ltd) which was attached to a CTD winch cable and lowered over the side of the vessel. A sound velocity sensor was also installed near the echosounder transducer.

3.5. Single-beam echo sounder

A Simrad EK60 single beam echo sounder (38 kHz), interfaced with a DMS 2 motion sensor (TSS UK Ltd), was used to log depth and heave data along each of the sidescan sonar transects.

3.6. High resolution side-scan sonar

A CM2 side-scan sonar system (C-Max Ltd), operating at 100 kHz with a swath width of 150 metres each side, was also deployed throughout most of the survey area. In the northeastern corner of the secondary area, coverage was not completed owing to a combination of time constraints and difficulties in deploying the side-scan sonar at greater depth. A total of 30 transects of about 10 nautical miles each were completed in an east-west direction. Transects were conducted at 250 m intervals, to ensure overlap between adjacent runs.

The data were processed with each line read in separately using "side-scan edge detection" mode with a 3.5 m offset on the starboard channel, and with the port channel set to copy the starboard. The bottom was digitised manually where the automatic mode did not detect the seabed.

The track steamed by RV *Kahaora* during the acoustic phase of the survey is shown in Figure 2. The 30 east-west transects provided good coverage of the primary area and the southern section of the secondary area. The side-scan sonar unit was deployed over the stern of the vessel, from the dedicated side-scan sonar winch (Figure 3).

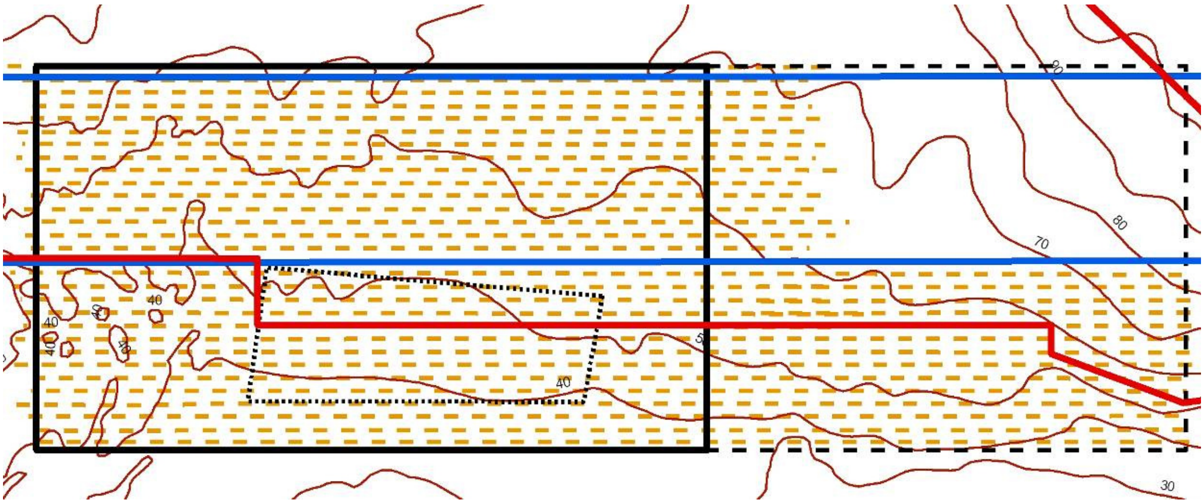


Figure 2: Side-scan survey track

Figure 3: Side-scan sonar winch (in front of blue container) with side-scan sonar cable deployed through block over stern of vessel.

3.7. Visual sampling

A range of camera systems was available for examination of the seabed. Video cameras were used for broad-scale evaluation of habitat type and fauna, with high-resolution still cameras and ROV systems used for detailed examination nested within the broad scale patterns. The camera systems varied in their sensitivity to sea conditions. The BEVIS video camera sledge was the preferred video system of choice, but the poor sea conditions combined with the size of the system meant that deployment became very difficult, and it was decided to switch to the Tritech video system, which was somewhat smaller and easier to deploy. Deployment of the middle depths digital camera system was also limited by the rough sea conditions. The ROV system was very sensitive to surface sea conditions and subsurface current (related to difficulties in station keeping), and was deployed (for examination and collection of voucher specimens) only on the last two days of the voyage when conditions had improved.

3.8. Video camera systems

BEVIS video camera sledge

The BEVIS system consists of two Benthos video cameras and lights, with two pairs of lasers, mounted on a large, stable sledge platform (Figure 4). Floats and ground contact chain were attached as required to adjust the buoyancy of the sledge.

The video sled was lowered over the stern of the vessel and towed at an altitude of about 1 m above the seabed. Video footage was recorded for about 7 to 10 minutes as the vessel drifted at a speed of about 1 knot to cover about 100 to 150 m of seabed. The start and finish position of each station and the camera track were logged using HydroPro. The sled was then towed at about 3 knots for about 300 m to the start of the next station. A total of 16 stations was completed using the BEVIS video sled.

Locations of the stations surveyed with the BEVIS video camera system are provided in the Appendix (9.1), and are shown in Figure 5. One complete north-south transect was completed with BEVIS (13 stations), running through scallop strata 93, and a second (at the western end of the primary area, 3 stations) was started, before sea conditions deteriorated, making deployment and recovery of the BEVIS system hazardous to both the system and deck crew.

Figure 4: BEVIS camera sledge.

TRITECH video camera sledge

The Tritech system consists of Typhoon video camera (Tritech International Ltd) with LED lights and dual lasers, mounted on a small sledge (Figure 6). The video sledge was lowered over the side of the vessel and suspended about 0.5 m above the seabed The start positions of each camera deployment were located about 0.5 nautical miles from each other along the north-south transects.

Video footage was recorded for about 7–10 minutes at each station as the vessel drifted at a speed of about 1 knot to cover about 150–200 m of seabed. The start and finish position of each station and the camera track were logged using HydroPro. A total of 82 stations were completed using the Tritech video sled.

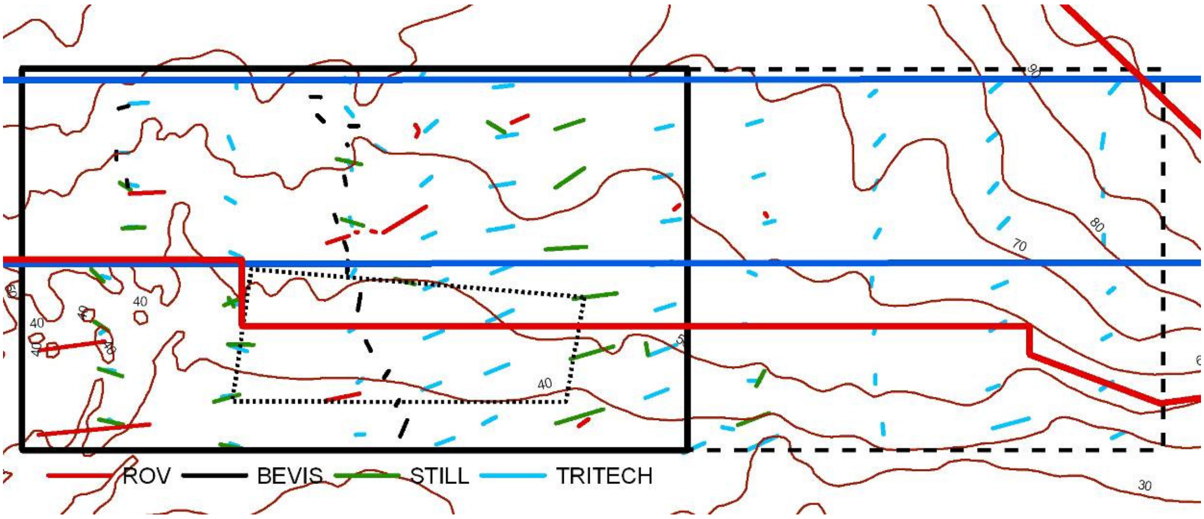


Figure 5: Station locations for TRITECH, BEVIS, STILL, and ROV camera systems. Lines represent straight line between start and finish locations of each station.

Locations of the stations surveyed with the TRITECH video camera system are provided in the Appendix (9.2), and are shown in Figure 5. The small size of the TRITECH sledge, meant that it could be deployed and recovered over the side of the vessel rather than the stern, making it far easier in rough conditions. Ten north-south transects were completed with the TRITECH system, 6 in the primary survey area, and 4 in the secondary area.

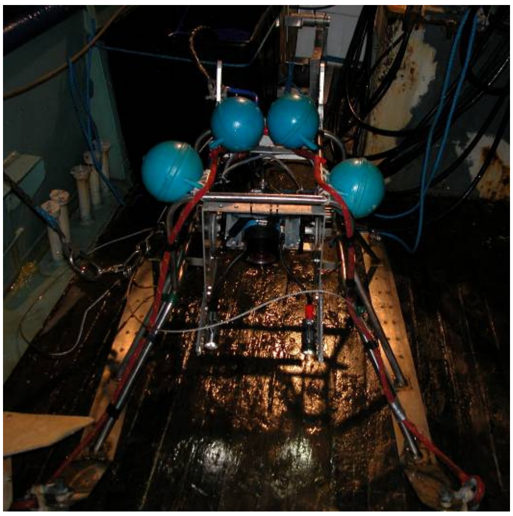


Figure 6: TRITECH video camera sledge.

3.8.1. Remotely operated vehicle

Benthos ROV

A Benthos ROV (Figure 7) was deployed at various stations to record video images of the seabed and to obtain samples of specific fauna using an articulator arm. The ROV was deployed over the side of the vessel while the vessel drifted or while the vessel was anchored using a large grapnel deployed over the stern. The start and finish position of each station and the vessel's track were logged using

HydroPro. Fourteen stations were completed using the Benthos ROV. A small manipulator arm and claw on the ROV was used to collect faunal samples on some occasions.

Figure 7: Benthos ROV system deployed during the voyage.

Locations of the stations surveyed with the Benthos ROV system are provided in the Appendix (9.3), and are shown in Figure 5. ROV deployments were conducted at the end of the survey, on the basis of the other image data collected, to examine specific locations in more detail, and to collect voucher specimens.

3.8.2. Still camera systems

Middle depths digital camera system

NIWA's high resolution middle depths digital camera system (5.0 million pixels per frame, 2560 * 1920 resolution, using Nikon Coolpix 5000 cameras) was used to take photographs 3–5 m from the seabed using a custom-built self-contained camera system deployed using a trawl warp (Figure 8). This is the current system used on scampi surveys conducted by NIWA for the Ministry of Fisheries (e.g., SCI 2005-01, SCI2006-02). This system has automatic flash exposure, which has been found to provide better exposure, better focus, and much better precision for measurements from images than systems previously used on scampi surveys.

The camera was triggered using an interval timer attached to the camera, with images taken every 20 or 40 seconds. Two parallel lasers (200 mm apart) were mounted on the camera frame, offering the potential for estimation of the linear dimensions and areas of the images. This approach works well in the scampi surveys (250–500 m depth), but a combination of ambient light and sediment/fauna colour meant the lasers were very difficult to see in this work.

At each station, the camera system was deployed over the stern of the vessel and maintained 3–4 m off the bottom using a modified CN22 acoustic headline monitor displaying distance off-bottom "real time" on the bridge. At each station, 25–30 frames were exposed as the ship drifted, using a time delay sufficient to ensure that adjacent photographs did not overlap.

Images were stored on 1 GB “flash” cards in the camera. This amount of storage allowed us to store images in Nikon raw format (NEF), which allows greater versatility in image enhancement, resulting in files of about 7 MB. After the completion of a station, the images from the flash card were downloaded through a specialised USB cable connection from the camera housing to the hard drive of a dedicated PC. The ability to download images without the need to open the housing reduced difficulties encountered on previous scampi surveys with condensation within the housing. After each station, downloaded images were briefly checked and counted to ensure that sufficient had been collected, and then backed up.

The start and finish position of each station and the camera track were logged using HydroPro. A total of 25 stations was completed using the middle depths digital camera system. Locations of the stations surveyed with the middle depths camera system are provided in the Appendix (9.4), and are shown in Figure 5. Some stations were located to coincide with video stations, while others were positioned to provide additional information between existing north-south transects. Weather conditions prevented deployment of this digital still camera system at other stations.

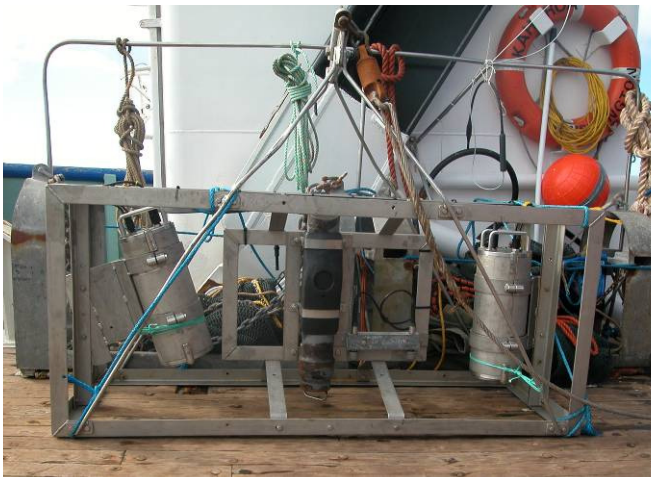


Figure 8: NIWA’s middle depths camera system.

3.9. Sampling of epifauna

Epifauna was sampled in a semi-quantitative manner using an epibenthic dredge (Figure 9) at nine stations. Locations of the stations surveyed with the epibenthic dredge are provided in the Appendix (9.5), and shown in Figure 10. Station locations were chosen to provide a semi-quantitative sample and voucher specimens from a range of contrasting habitats identified from preliminary examination of video and still images at sea. The dredge was towed for about 200 m at each station, measured using the HydroPro navigation system.

Figure 9: Epibenthic dredge used during voyage to sample epibenthos.

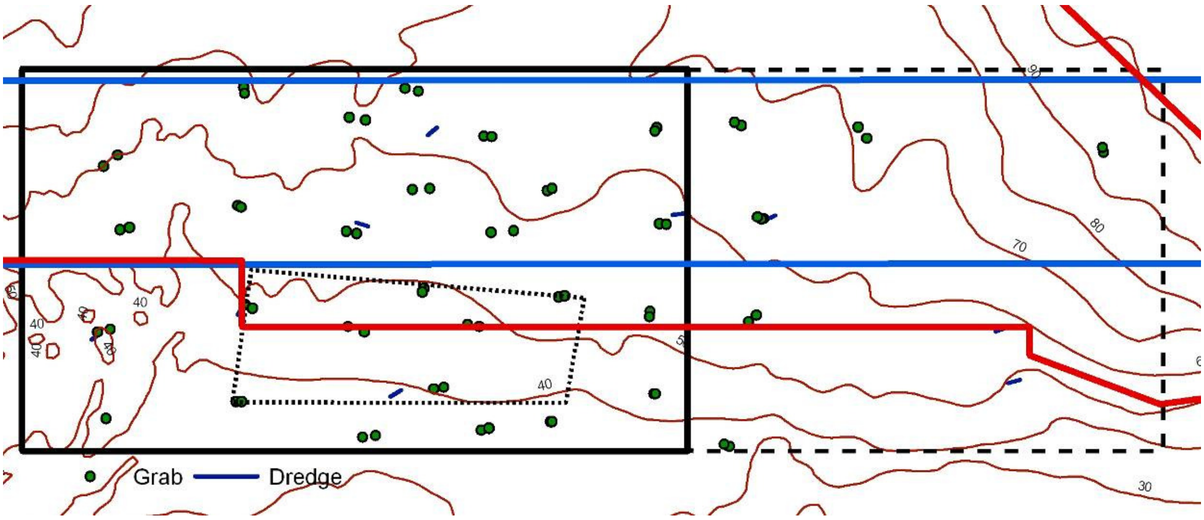


Figure 10: Station locations for epifaunal dredge and Smith-McIntyre grab sampling. Lines represent straight line between start and finish locations of each dregde station.

3.10. Sampling of infauna

A Smith-McIntyre grab sampler (Figure 11) was deployed at 35 stations. Locations of the stations are provided in the Appendix (9.6), and shown in Figure 10. Alternate camera stations along each transect in the primary survey area, and the westernmost transect of the secondary area, were sampled, with the grab being deployed at least twice at each sampled station (although two samples were not always collected), and the material processed separately from each grab.

Figure 11: Smith-McIntyre grab used during survey to collect sediment and infaunal material.

Infaunal material was generally sparse. Taxonomic identification of the infauna was beyond the scope of the current project (given its focus on visual broad scale approaches), but samples have been stored. In addition to biological samples, from each grab sample, a small sediment sample was collected for sediment grain size analysis and organic content.

3.11. Collection and curation of biological samples

From grab and dredge samples, all large fauna were retained and the fine fraction was sieved through 1 mm square aperture mesh and retained. All samples were preserved using 70% or 98% ethanol, or buffered formaldehyde in filtered seawater (final concentration 10%) as appropriate. All samples were returned to NIWA for sorting, identification, and enumeration. Sponge taxa have been identified to species level. Other species have been stored and await appropriate funding for identification.

3.12. Data from previous survey (ENV9805)

Ministry of Fisheries project ENV9805 (awarded to NIWA) examined the distribution and structure of benthic communities between North Cape and Cape Reinga, an area including the study area of the current project. This earlier project predominantly relied upon an epibenthic dredge for sampling, but also used video for ground truthing of acoustic habitat classifications, and 21 stations from this previous study were within (or very close to) the study area of the current project (15 in or adjacent to the primary area, and 6 in the secondary area (Figure 12).

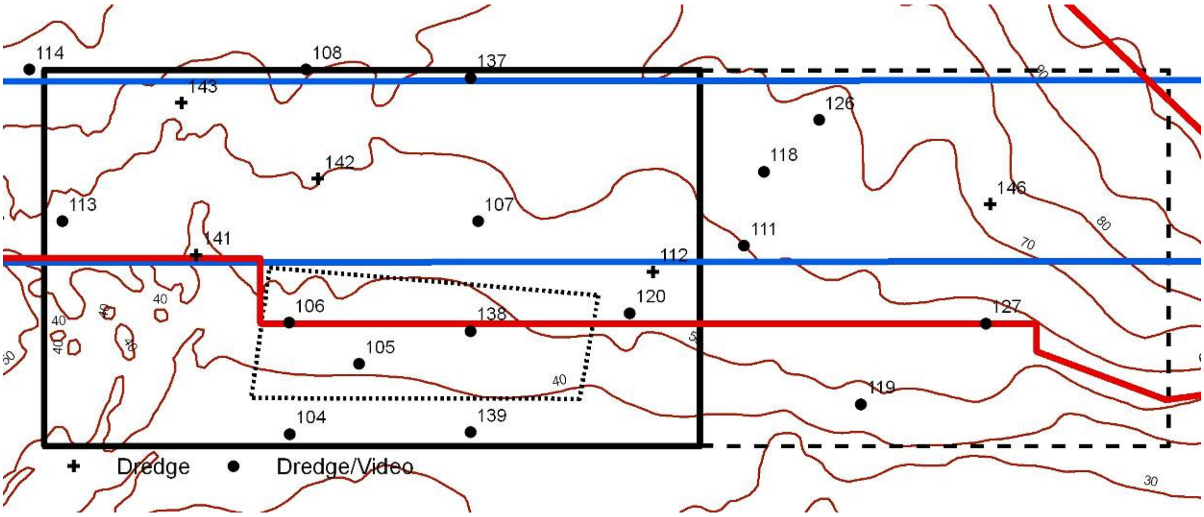


Figure 12: Locations of dredge and video sampling stations within or very close to the current study area from the ENV9805 project, surveyed in 1999.

Of these 21 stations, 16 had both dredge and video equipment deployed, with the remaining having only the epibenthic dredge deployed. Data from these stations have been examined and compared with data from the more recent survey. Dredge tows from ENV09805 were about 600 m in length (10 min duration at 1 $m.s^{-1}$).

3.13. Data analyses

3.13.1. Acoustic data analysis

Side-scan sonar and multibeam echo-sounder

Logging data from both the multibeam echo-sounder and side-scan sonar during this survey enabled us to directly compare the two datasets and will help refine options for future monitoring of the Spirits Bay area. The raw and analysed or interpreted data from the acoustic approaches employed were incorporated into data layers within the GIS developed for the Spirits Bay area within the project, for further analysis in relation to other data layers.

Side-scan sonar

Side-scan sonar produces an acoustic image of the seabed based on changes in the backscatter of the acoustic signal, and data derived from each transect can be mosaiced to provide a combined acoustic image of the survey area. Some seabed structures can be interpreted directly from the acoustic image; however, many of the observed backscatter features in the image must be ground-truthed using cameras or grab samplers to confidently determine what the features actually are.

A side-scan mosaic was produced from the data collected, and was examined and interpreted by an experienced sedimentologist and side-scan sonar technologist to identify the main seabed features.

Multibeam echo-sounder

Like side-scan sonar, multibeam echo-sounders can produce acoustic seabed images based on the backscatter data. In addition to obtaining geo-referenced backscatter data, multibeam echo sounders provide detailed bathymetry of the seabed combined with accurate positioning of underwater features. The multibeam data was used to generate a high resolution (2 m * 2 m) bathymetry surface, and also a "hill shade" surface, allowing easier visualisation of topographic features. NIWA is developing seabed classification tools for processing multibeam bathymetry and geo-referenced backscatter data to identify different types of seabed. Within this project, preliminary investigations have been undertaken with the NOAA Coastal Services Centre Benthic Terrain Modeller (BTM) package (Lundblad et al. 2006), on the original 2m* 2m bathymetric surface, and a resampled 10 m * 10 m surface. BTM was used to calculate seabed rugosity from the bathymetric surface. Rugosity is defined as the ratio of surface area to planar area, and measures the terrain complexity, or "bumpiness" of the seabed. Rugosity is calculated for each cell in a grid from its own altitude, relative to that of the eight surrounding cells (Jeness 2004). In addition, the bathymetric data are also used to calculate Bathymetric Position Index (BPI) data sets (Lundblad et al. 2006). BPI is a measure of where a location, with a defined elevation, is relative to the overall landscape. Its derivation involves evaluating elevation differences between a focal point and the mean elevation of the surrounding cells, within a user-defined radius. Both rugosity and BPI are sensitive to the scale at which they are examined (Lundblad et al. 2006). By examining rugosity at different resolutions, different spatial scales of physical complexity can be examined. Analysis of BPI over smaller neighborhoods allows the detection of smaller, localised variations in terrain, while analysis at larger scales provides detail of larger features. The creation of BPI data sets at two scales is central to the methods behind the benthic terrain classification process. The BPI grids are usually defined by their scale factors, the outer radius in map units multiplied by the bathymetric data resolution. The scales chosen should ideally reflect the size of the small and large scale features in the area considered. The two BPI data sets are then standardised, and analysed in conjunction with slope and bathymetry data to classify the seabed into zones.

The miltibeam data were collected and prepared with additional funding to that provided under ENV200523, and it has not been possible to conduct comprehensive analysis of the data using the BTM approach, particularly investigating the sensitivity of the outputs to other spatial scales of analysis, or conduct any analysis of the multibeam backscatter data. While the results of the BTM analysis presented here appear to be very informative, they can therefore only be considered preliminary.

3.13.2. Video and still image data analysis

The survey design nested still image stations within video transects, allowing the high resolution still images to provide detail of habitat and fauna, while the video provides broader scale information.

All the initial analysis of video and still images was conducted by the same individual (JD) to maintain consistency in the classification of stations to substrate, bedform, and fauna and flora categories. Habitat categories and faunal data from the video and still images were incorporated into data layers within the GIS developed for the Spirits Bay area within the project, for further analysis in relation to other data layers.

Video image data

All video footage was viewed, and each station allocated to one or more broad habitat and faunal abundance categories (Table 1). Categories were developed following preliminary examination of video and still image data, to ensure they encompassed the range of habitats observed in the survey area. Video provided a good broad-scale indication of habitat type and faunal coverage, but camera resolution and the frequently surging motion of the camera systems meant that is was difficult to quantify epifauna confidently. The still image data were considered to be the most appropriate for quantification and species identification.

Still image data

Each useable image from each of the still camera stations was categorised in terms of broad habitat substrate type and faunal abundance categories (Table 1). For each identified habitat type and faunal abundance category combination within each station, up to three representative images were selected for detailed taxonomic identification of epifauna, with abundance and attachment status recorded for each species. In addition, all other images for each habitat type recorded at a station were examined to record the other species (not observed in the three representative images), to provide a full species list for each station and habitat.

Table 1: Categories used to classify stations according to substrate and faunal abundance.

Category scale	Habitat substrate	Faunal abundance
Decreasing hardness or roughness (habitat) or abundance (fauna)	Rocky outcrop	Widespread mixed fauna
	Coarse (sand, gravel, rock)	Patches of larger fauna
	Coarse (sand, gravel, shell)	Scattered small fauna
	Sand shell (with basement substrate)	Sparse fauna
	Sand shell waves (larger wavelength & amplitude)	
	Sand shell ripples (short wavelength & amplitude)	
	Sand shell smooth	

Identification of fauna from still images was conducted by an expert in sponge taxonomy (MK), who also used these images to test and refine the faunal guides developed within this project (as described in Section 3.13.5). These guides will also be useful for future monitoring surveys.

3.13.3. Faunal data analysis

Identification of fauna from preserved samples was conducted by an expert in sponge taxonomy (MK), with other species groups being directed elsewhere within NIWA where appropriate.

The epifaunal community from the dredge and still image samples was examined in relation to the fishing area categories (as in force in 2006). This analysis was conducted within the PRIMER software package. A range of univariate measures was calculated, and the communities were analysed using the ANOSIM approach, on a Bray Curtis similarity matrix, having first excluded samples with no fauna (since these provide no information to the analysis), and transformed the data to presence/absence (for dredge samples) or root transformed abundance (for still images). A SIMPER test was used to examine overall dissimilarity between the areas, and identify the species contributing most to the dissimilarity between fishing areas.

3.13.4. Risk analysis and monitoring status of species

Over the last 10 to 20 years, risk assessment and risk management have increased in importance within fisheries management (Francis & Shotton 1997). A number of studies have investigated approaches for assessing risks from fisheries on the marine ecosystem in New Zealand and Australia (Fletcher 2005, Astles et al. 2006, Campbell & Gallagher 2007), and similar approaches have also been developed elsewhere (Hiscock & Tyler-Walters 2006). Other relevant research is also underway in New Zealand to develop risk models of fishing on seamounts (ENV2005-15 and ENV2005-16) (Rowden et al. 2007). The Ministry of Fisheries has also requested tenders for research project BEN2007-05, with the objective of developing a risk assessment framework for balancing the environmental effects of fishing on coastal seafloor ecosystems against other threats to coastal ecosystems that may influence the productivity and sustainability of fisheries.

While the approaches developed by different authors differ, they generally all include some form of risk matrix, with axes for *vulnerability* (or intolerance) to disturbance and *recoverability* from disturbance. Vulnerability is defined as "the susceptibility of a habitat, community or species to damage, or death (from an external factor)", while recoverability is "the ability of a habitat, community or species to return to a state close to that which existed before the activity or event caused change" (Hiscock & Tyler-Walters 2006). Vulnerability is associated with the sensitivity of individual species to an impact, and the likelihood or frequency of impacts, while recoverability is associated with the reproductive and dispersal capacity of the species and their growth rates. In addition to these concepts, another important aspect of risk assessment is the *representativeness* of the habitat, community, or species considered, where events affecting unique features might be considered more serious than those affecting very common features.

Following identification of the main habitat and faunal categories, and the species present within each habitat, the substrate stability has been categorised (poor, moderate, high). Individual species recorded from images were categorised by shape, size, sensitivity to a range of potential anthropogenic or natural disturbances, growth rate, and potential for reattachment following dislodgement or uprooting (Table 2). Types of disturbance considered include physical impact, wave wash, water currents, and sedimentation. Recovery was considered in terms of growth rate (time to reach typical maximum observed size) and potential for reattachment of dislodged or broken colonies if wedged on rock, of re-anchoring on sand and shell, or surviving as an unattached "roller". These categories are informative both in terms of likely recoverability from and vulnerability to physical disturbance (as part of the risk analysis) and also likely value as a monitoring species. The growth category relates to time to reach typical maximum observed size once a colony has settled. The effects of physical disturbance on the suitability of sediment for settlement by sponges is unknown, but scallop dredging is known to break down surface features (Thrush et al. 1995), leaving visible tracks that last at least a month in some areas (Currie & Parry 1996), and recovery of communities may take longer than the growth rates imply.

Species were also categorised according to ease of identification from the photographic guide developed within this project (easily recognisable, recognisable but easily confused with other species, uncertain ID and easily confused with other species), occurrence (common, moderately common, uncommon) and within each category divided into typical habitat substrate type (as categorised in Table 1).

Table 2: Definition of various categories used for fauna recorded at Spirits Bay.

Category data	Explanation
Shape	**Morphology and profile of sponge**
strappy	Tree-like with long straps
bushy	Tree-like with short bushy branches
bowl	Cup or bowl
loaf	Loaf or hemisphere
thick	Thickly encrusting
thin	Thinly encrusting
Size	**Typical observed maximum size**
large	100-1000 cm largest dimension
medium	10-100 cm largest dimension
small	<10 cm largest dimension
Dredging	**Sensitivty to human-induced physical disturbance (dredges, trawling, anchor-drag etc)**
robust	Flexible structure with tough base or very tough stony texture with broad base, or flat profile
moderate	Compressible texture with high profile & weak base of attachment, or has tough texture but weak base
sensitive	Soft papery / crumbly texture, and/or rooted basally in sediments
Wash	**Sensitivty to natural physical disturbance (multidirectional wash causing partial damage or total dislodgement)**
robust	Flexible structure with tough base or very tough stony texture with broad base, or flat profile
moderate	Compressible texture with high profile & weak base of attachment, or has tough texture but weak base
sensitive	Soft papery / crumbly texture, and/or rooted basally in sediments
Currents	**Sensitivty to natural physical disturbance (unidirectional currents causing scouring, dislodgement, and sand-dune development)**
robust	Has a very flexible structure with a tough base or very tough stony texture with a broad base, or a flat profile
moderate	Has a compressible texture with high profile and weak base of attachment, or has a tough texture but a weak base
sensitive	Has a soft papery or crumbly texture, and/or is rooted basally in sediments
Sediments	**Sensitivty to physical disturbance (terrigenous sedimentation from river flooding or industrial development)**
robust	High profile with flexible branches from previously clear-water habitat
moderate	Medium hemispherical profile from previously clear-water habitat
sensitive	Low profile with soft texture from previously clear-water habitat
Growth	**Growth rate to typical observed maximum size**
rapid	0-2 years (ephemeral)
moderate	2-10 years
slow	10-20 years
very slow	20+ years
Recovery by wedging	**Recovery potential by reattachment (to hard substrate via wedging)**
good	Will reattach if wedged
moderate	May reattach, but not very likely
poor	Unlikely to reattach if wedged
Recovery by anchoring	**Recovery potential by reattachment (burial and anchoring via agglommeration of loose substrate such as shell and sand)**
good	Will reattach if left to agglomerate loose substrate
moderate	May reattach if can be left long enough to agglomerate
poor	Unlikely to reattach as will not agglomerate to anchor
Recovery by rolling	**Recovery potential as a 'roller'**
good	Will remain viable as a roller
moderate	May remain viable as a roller
poor	Unlikely to remain viable as a roller

3.13.5. Development of identification keys

Underwater cameras are being used increasingly as cost-effective tools for seabed surveys, particularly for monitoring sensitive areas, and it seems likely they would play an important role in any long term monitoring project developed for the Spirits Bay area, since they provide a non-destructive method for observing the seabed and associated mega epifauna such as sponges, bryozoans, hydroids, gorgonians, and stony corals. It is these epifaunal species that are considered to be most sensitive to fishing disturbance.

One of the limitations of remote observation of the seabed is the difficulty of obtaining reliable identifications of most taxa. With the exception of taxa that are large and morphologically distinctive, the most marine invertebrates are difficult to differentiate to species level without physical and/or histological examination of the specimen, and this is particularly true for sponges.

On the basis of the fauna visible from the still images, and the features identifiable from the images, and in conjunction with physical samples collected both during this and previous work (ENV9805), preliminary species identification keys were developed for algae, ascidian, bryozoan, gorgonian coral, hydroid, and sponge epifauna. A similar morphological approach has been used successfully for sponge assemblages elsewhere (Bell et al. 2006, Bell 2007). Since sponges tend to be the larger and more visible epifauna in the Spirits Bay area, this key includes the most species, and has been divided into 12 morphological types. The preliminary epifaunal identification guides are provided in separate appendices to this report.

4. RESULTS

4.1. Historic fishing patterns and benthic disturbance

The overall patterns of effort and catch history from scallop statistical area 9A (North Cape to Cape Reinga) are shown in Table 3 and Figure 13. The first commercial scallop activity was recorded in 1993, and landings rapidly increased, reaching about 500 t from 1995 to 1997. Survey catch rates (where available) follow a similar pattern to those estimated for the 9A fishery (covering all three survey strata) (Figure 14). The locations of the scallop survey strata (before closures reduced the area) are shown in Figure 15. Catch rates in Stratum 93 (the area identified as having a high sponge bycatch) were markedly higher than in the other local strata (and the overall survey) during 1996 and 1997, which may have attracted fishing effort to this area. Effort peaked in 1997 (over 6200 hours), with both effort and catches declining rapidly after this. Scallop catch rates were very low throughout Northland and the Coromandel fisheries in 1999 and 2000, but effort and landings increased in 2001 (catches of 130 t). Survey catch rates have declined steadily since 2002, and opportunity elsewhere in Northland (particularly Bream Bay) has meant that there has been no commercial scallop fishing recorded in 9A since the end of the 2004–05 fishing year.

Scallop effort and catch data are not available at the survey strata level. An estimate of effort distribution has been made, on the basis of assumptions that all the scallop dredge effort in 9A took place within the scallop survey area (strata previously designed to cover the extent of the fishery in the region), and that effort would be allocated in proportion to the relative abundance (density raised to area) of scallops observed in the pre-season survey (Table 3). While both of these assumptions are sources of uncertainty, the absence of other information prevents other sorts of analyses. These data suggest that the fishing intensity ($h.km^{-2}$) would generally have been highest in stratum 93, peaking at 200 $h.km^{-2}$ in the mid to late 1990s, but has declined over the time period, with no commercial scallop dredging taking place in any of the areas since 2004. For comparison, the highest levels of fishing intensity estimated (using information from industry on fishing patterns) for the Coromandel scallop fishery were in the region of 60–70 h.km^{-2} (Tuck et al. 2006).

Table 3: Annual effort (hours of fishing) and catch (tonnes greenweight by fishing year) from CELR forms for the scallop statistical area 9A (from North Cape to Cape Reinga), and pre-season survey, legal size (>= 100 mm) scallop catch rates for the three survey strata (91, 92 & 93) within 9A, and for the overall survey (all Northland strata). Effort breakdown by strata estimated on basis of assumptions that all scallop effort in 9A took place within survey strata, and was in proportion to relative scallop density observed in the pre season survey. Surveys were conducted in the May or June before the fishing season (starting 15 July), but exact dates vary between years, and no correction for dredge efficiency has been applied. Strata changed between the blocks of consecutive surveys. Estimated effort within strata calculated on the basis of the area of the strata available to the fishery during that year (i.e., area outside voluntary or regulated closure)

Year	Effort	Catch (t)	Pre-season survey density (.m^{-2})				Estimated effort (hours.km^{-2})		
			91	92	93	Northland	91	92	93
1993	11	1							
1994	1447	142							
1995	2827	499							
1996	3330	512	0.091	0.035	0.760	0.042	19.02	7.44	159.52
1997	6261	477	0.047	0.076	0.206	0.023	46.39	73.97	200.81
1998	3780	130	0.030	0.022	0.043	0.010	47.34	34.58	67.87
1999	1397	23							
2000	984	40							
2001	1241	134	0.046	0.007	0.025	0.014	24.79	3.88	13.20
2002	986	109	0.073	0.013	0.176	0.034	15.08	2.61	36.48
2003	802	70	0.056	0.025	0.134	0.018	11.34	5.01	27.16
2004	419	37							
2005	0	0	0.061	0.094		0.073	0	0	0
2006	0	0	0.024	0.038		0.096	0	0	0
2007			0.023	0.014		0.022			

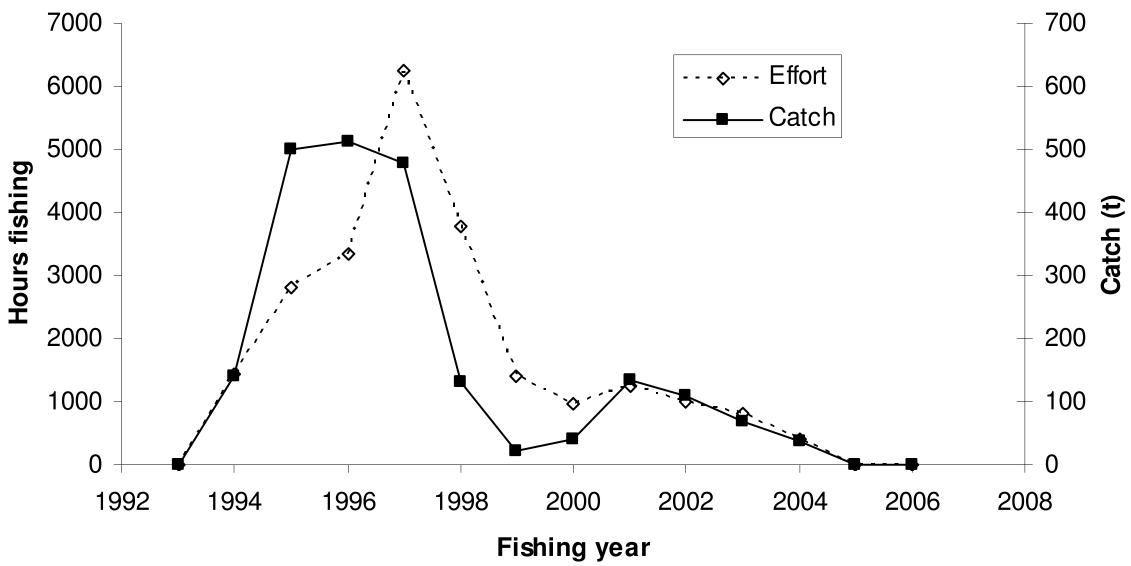


Figure 13: Annual effort (hours fished) and catch (by fishing year) from CELR forms for the scallop statistical area 9A (from North Cape to Cape Reinga).

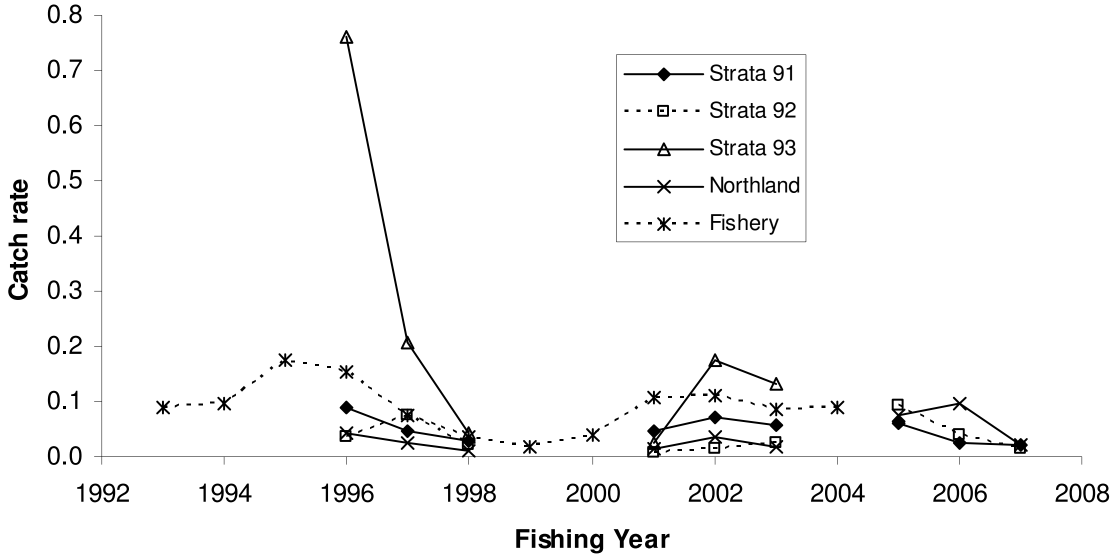


Figure 14: Catch rate from the annual pre-season scallop surveys (for the three strata within the scallop statistical area 9A and for the whole Northland survey, legal size scallops [>= 100 mm] .m^{-2}, uncorrected for dredge efficiency) and for the commercial fishery within 9A (tonnes greenweight.h^{-1} estimated from CELR data).

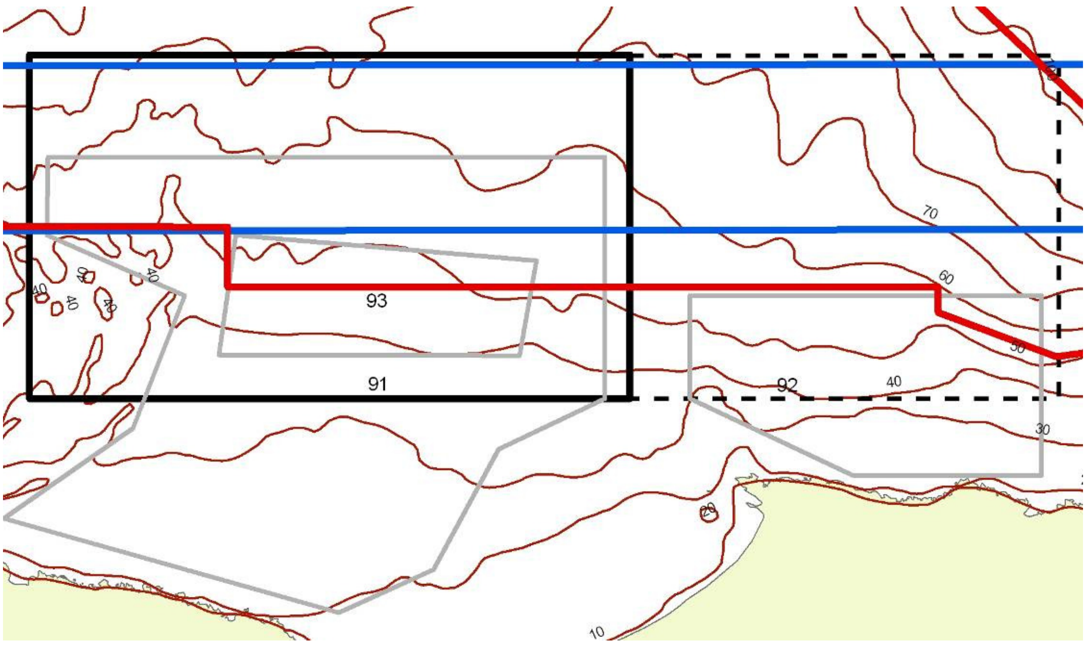
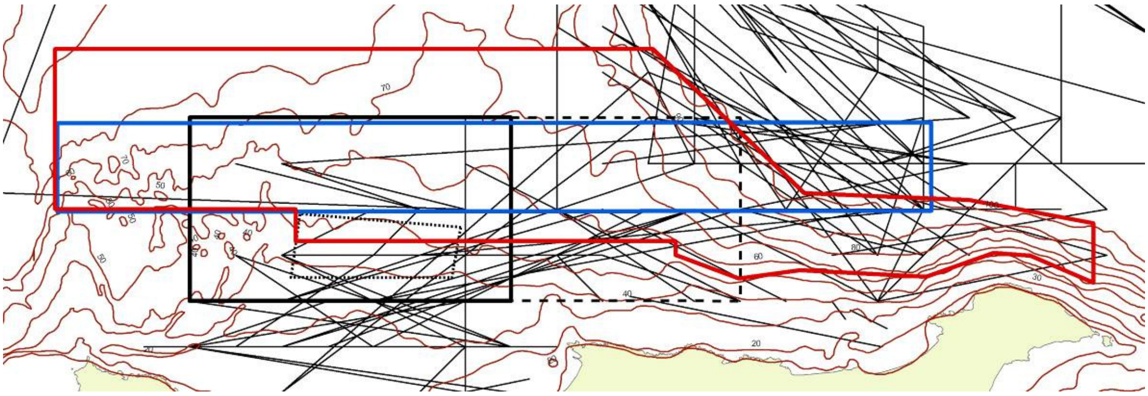


Figure 15: Location of scallop survey strata in relation to subsequent closed areas and survey areas from current investigation. Stratum 93 is within Stratum 91.

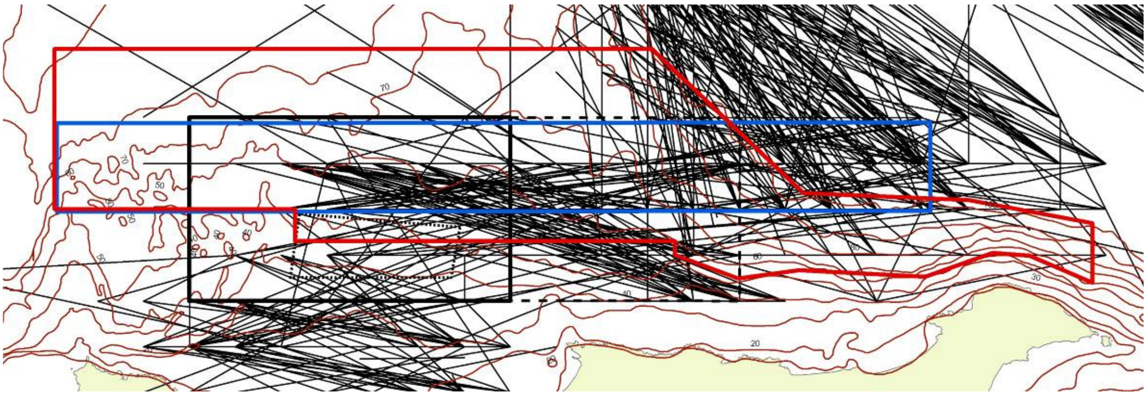
Start and end points of relevant fishing activity (groomed to exclude likely errors and non bottom contact gears) recorded on TCEPR forms were plotted to provide a general indication of the distribution of other (non scallop) fishing activity in the study area. This approach is obviously subject to some uncertainty, since it assumes fishing took place in a straight line between the recorded start and finish points, and also excludes non TCEPR data (which may have formed a significant proportion in the early years, but since about 1996, is probably less than 10% of trawling activity in this area). However, it does provide an indication of the general patterns of fishing activity over time.

The distribution of TECPR bottom trawl tows within the study area is shown in relation to year in Figure 16. It can be seen that in the early years (pre 1995) trawl tow data were quite sparse (much of the data will not have been recorded on TCEPR at this time), and trawling was quite widespread in water depths between 30–60 m in the primary area, but also extended into deeper waters in the secondary area. By 1995–96, a far greater proportion of the fishing activity is thought to have been recorded on TCEPR. Trawling was widespread in the area, with a particular concentration between 50–60 m depth in both survey areas, but also in the shallower waters (about 30 m) at the southern edge of the primary area, and in the deeper waters to the northeast of the secondary area. At the resolution available, it appears the concentrations of effort were not centred on stratum 93, but rather to the north and south of this area. The pattern recorded between 1997 and 1999 was very similar to that for the previous period, although with more fishing activity through stratum 93. Post 1999, the pattern changed quite markedly, with fishing activity within the study area limited to the southern edge of the area, outside the regulated closed area.

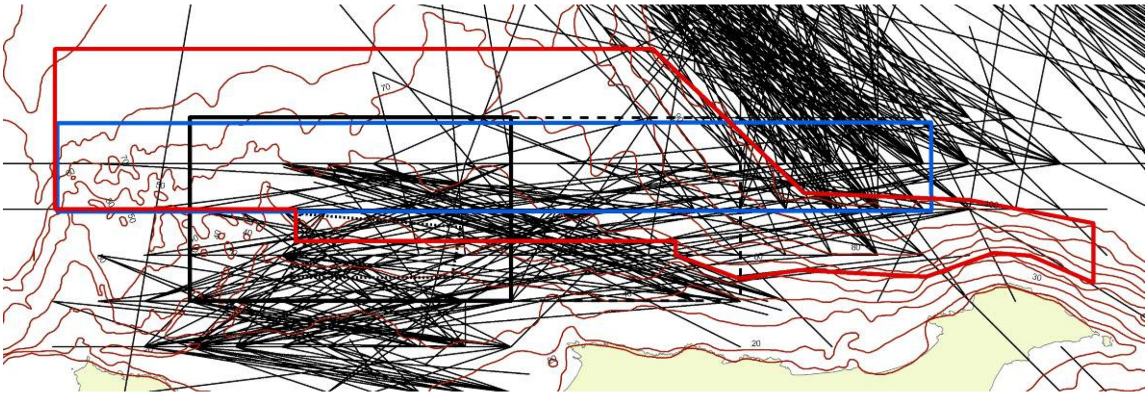
Pre 1995



1995 & 1996



1997–1999



Post 1999

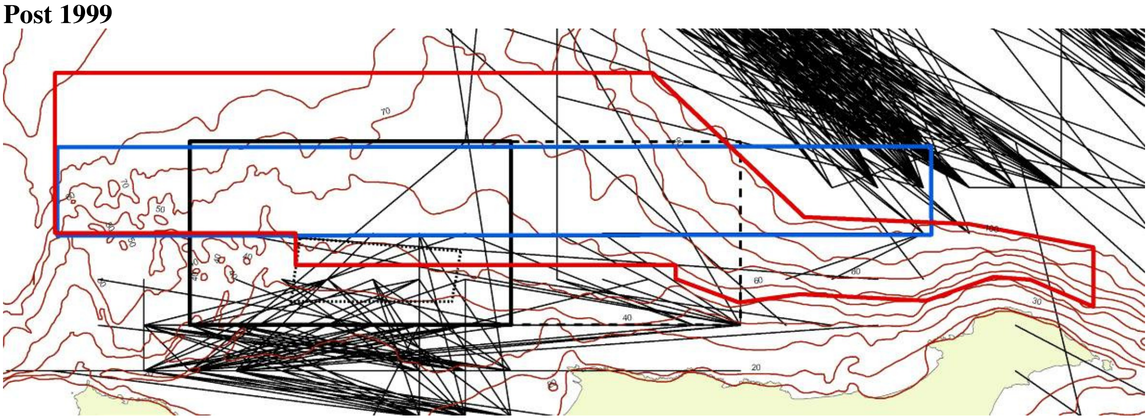


Figure 16: Distribution of bottom trawl tows recorded in TCEPR (1989–2007) in the Spirits Bay area, and depth contours, by year. From top to bottom the maps show tows for years as follows: pre 1995, 1995 & 1996, 1997–1999, post 1999.

4.2. Physical features

4.2.1. Bathymetry and derived data

The bathymetry data and 10 m contours derived from the multibeam echo sounder data are shown in Figure 17. The primary survey area appears to have some ridge type features towards its western end, extending from the southern limit of the area in about 30 m to over 60 m at the northern extent of the area. The seabed slopes more gently from 30 m to 60 m to the east of these ridges, from roughly the western limit of scallop stratum 93 to the mid point of the secondary area, although there appear to be some shallower features of complex bathymetry scattered within the 30 m to 50 m depth range. Some of these areas coincided with locations known to have extensive areas of rocky reef outcrop. In the eastern half of the secondary area, the seabed slopes away to the northeast, reaching 100 m in the northeast corner of the survey area. The multibeam data was used to generate a hill shade surface, to aid visualisation of the seabed topography (Figure 18).

The 2 m resolution bathymetry surface was used to generate a rugosity grid (Figure 19), which measures the physical complexity of the seabed, with the BTM software. The horizontal red lines in the secondary survey area are artefacts in the data, but areas of greater terrain complexity can be seen associated with the ridge-like features to the west of the primary survey area, on the southern edge of the survey area, associated with two shallower areas (see Figure 17), and in the central northern area of the secondary survey area, associated with slightly deeper areas. At this high resolution (2 m), the pattern assumed to be sand wave structure can also be clearly identified, potentially obscuring other features within the area dominated by these sand waves.

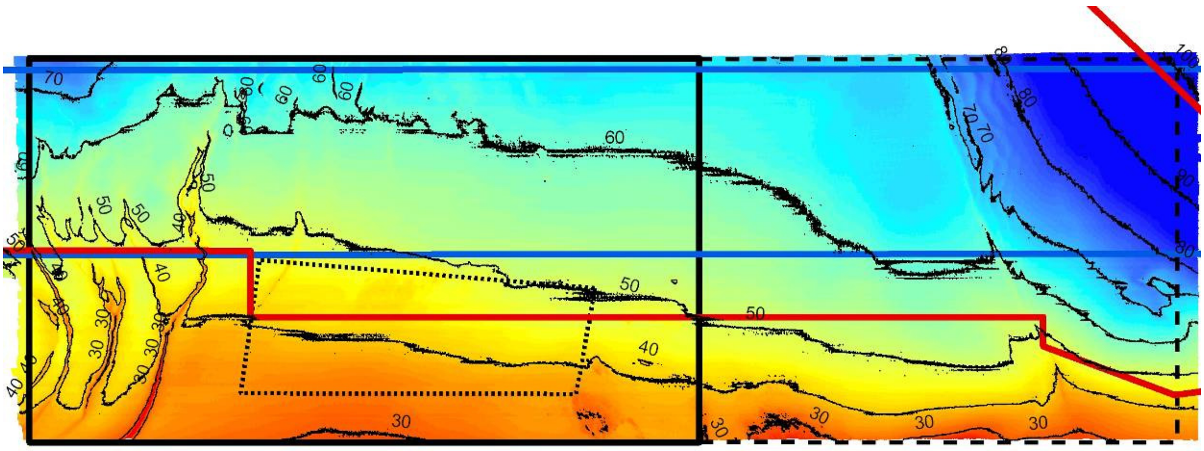


Figure 17: Bathymetry data derived from the multibeam echo sounder data, and 10 m contours calculated from the bathymetry surface. Closed areas and scallop stratum 93 as described in Figure 1.

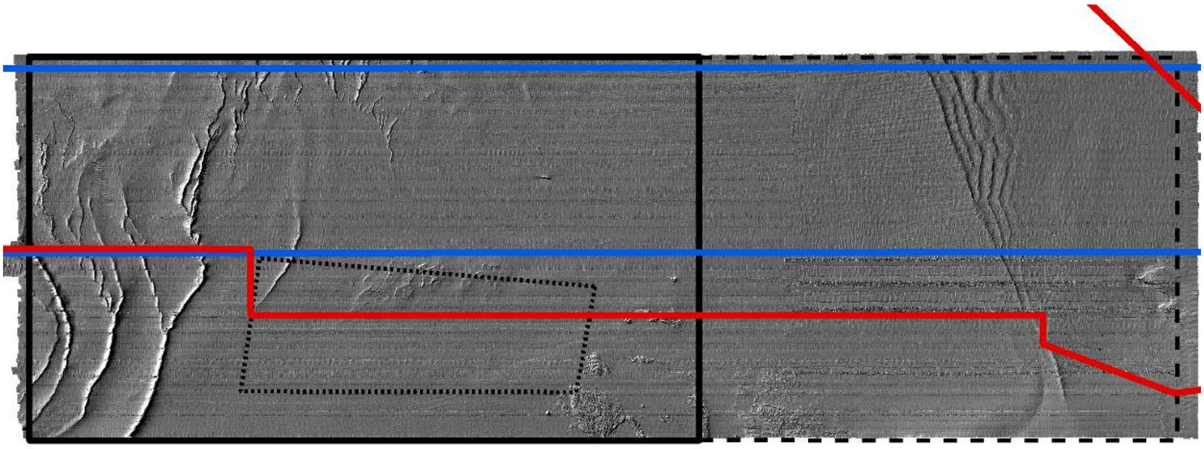


Figure 18: Hill shade surface from multibeam bathymetry data. Illumination of the surface is from an angle of 315^o, at 45^o from the horizon.

Examining rugosity at broader scales provides less detail of terrain complexity at small scales (Figure 20), and the larger features within the central area of the primary survey area become more apparent.

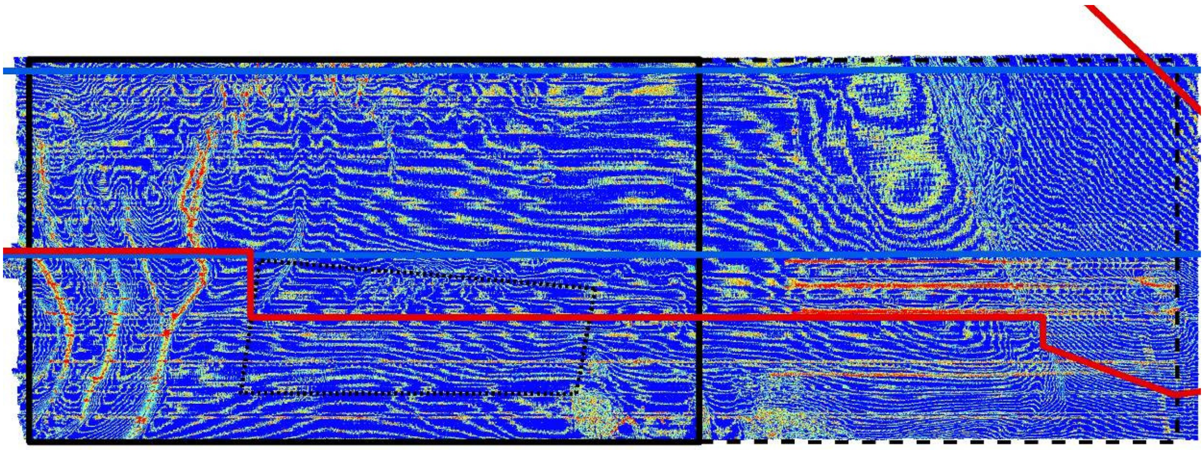


Figure 19: Terrain rugosity grid, calculated from a 2 m resolution bathymetry surface (Figure 17) with BTM. Colour scale runs from blue (low rugosity) to red (high rugosity).

BPI grids were generated at a range of scales, from the 2 m resolution bathymetry surface (scale factors of 4, 6, 10, and 20 m) and for the larger scales, from a resampled bathymetry surface (10 m resolution) (scale factors of 30, 50, 100, 250 and 500 m). Calculation of the larger scale BPI grids from the 2 m resolution bathymetry surface proved too demanding for the computer available. BPI grids were standardised (on the standard deviation of the surface), and classified into seabed zones and structures described in the Appendix (9.7) with the algorithm described in the Appendix (9.8), using different fine and broad scale BPI grids. The resulting classifications varied slightly with the scales chosen, but were generally quite consistent. Example zone (Figure 21) and structure (Figure 22) classifications are presented for the analysis using a fine-scale grid with scale factor of 30 m, and broad scale grid of scale factor 250 m. As discussed above, this analysis should be considered preliminary, and the sensitivity to spatial scales of analysis should be examined in any subsequent studies.

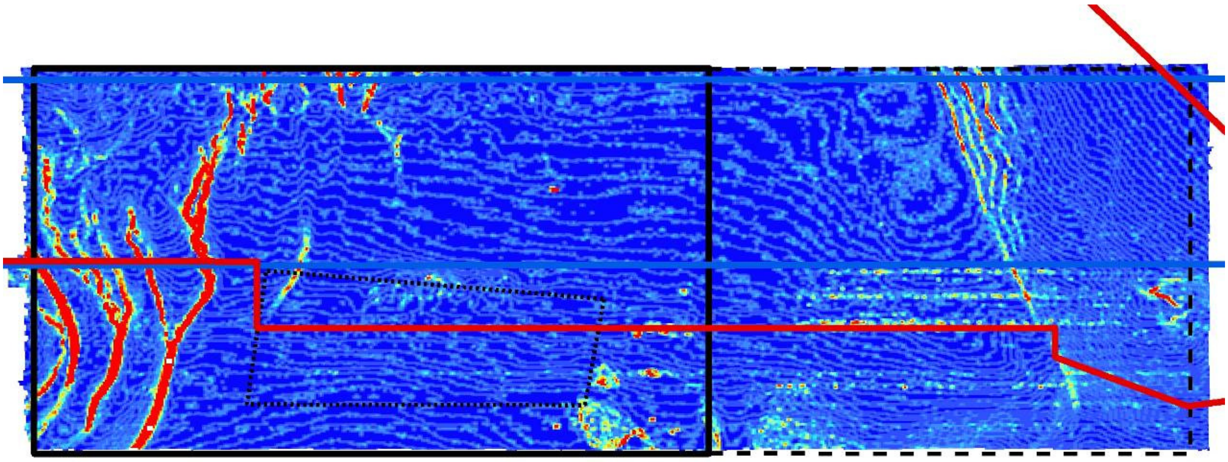


Figure 20: Terrain rugosity grid, calculated from a 30 m resolution bathymetry surface with BTM. Colour scale runs from blue (low rugosity) to red (high rugosity).

From the terrain zone map (Figure 21), the large ridge-like features to the western side of the primary survey area are clearly identified as crests. The largest ridges have depressions running alongside them, while smaller ridge features are identified as crests without the depressions. Features appearing to be large sand waves at the top of the slope in the northern half of the secondary area (Figure 18) are also identified as crests and depressions (see Figure 21). Much of the rest of both survey areas is covered by a fairly regular pattern of flat and slope (or crest) zones (distance between consecutive crests typically 100–300 m), although there are some irregularities in this pattern (e.g., northern edge and southeast corner of stratum 93), which are generally associated with slightly shallower areas (Figure 17), with higher rugosity (see Figures 19 and 20).

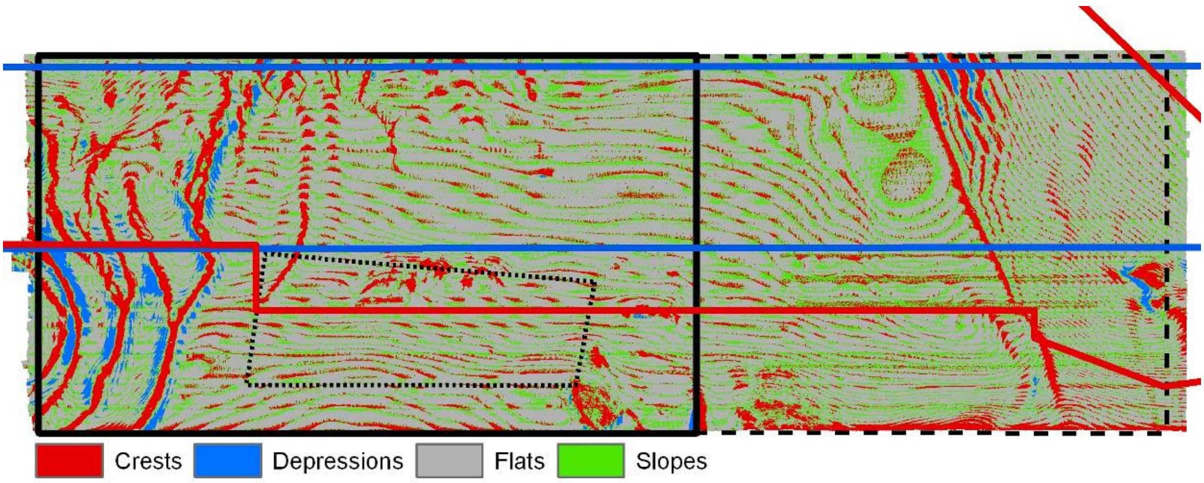


Figure 21: BPI terrain zones for the Spirits Bay survey area, calculated from fine and broad scale BPI grids using the classification and algorithm described in Appendix (9.7 and 9.8).

The terrain structure map (Figure 22) breaks down the zone features into a number of categories, although the general pattern is very similar.

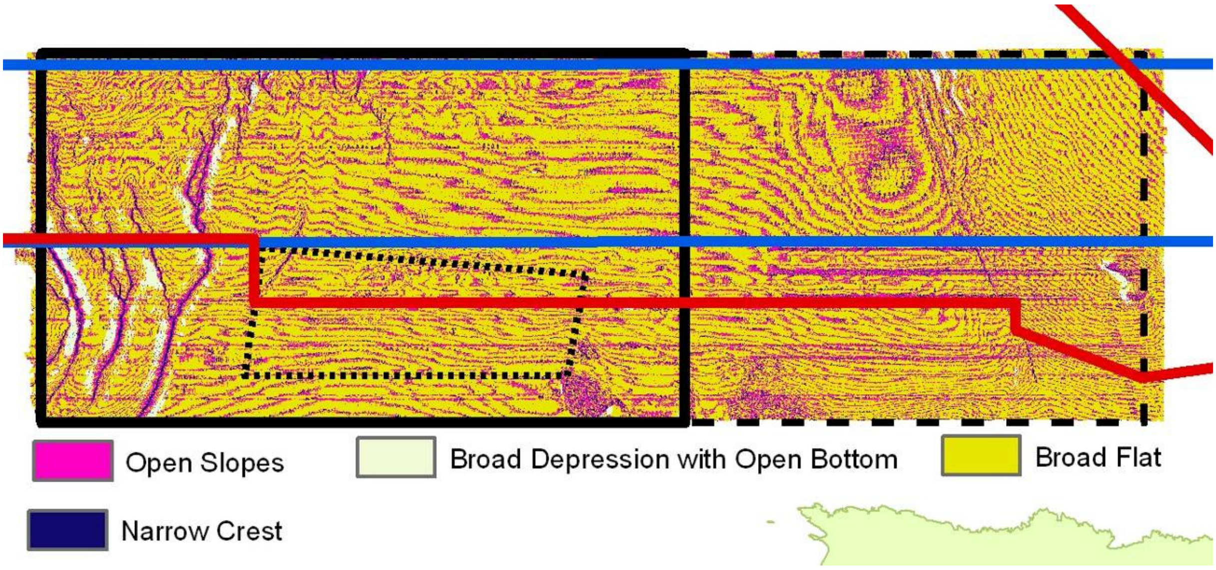


Figure 22: BPI terrain structures for the Spirits Bay survey area, calculated from fine and broad scale BPI grids using the classification and algorithm described in Appendix (9.7 and 9.8).

The preliminary analyses described above have been conducted including the whole data set. Exclusion of the ridge features from the analysis may provide more detail within the apparently more uniform central area, since this would reduce the standard deviation of the respective BPI grids.

4.2.2. Side-scan sonar

The transects of side-scan sonar data provided 100% coverage of the primary survey area, but logistical constraints meant that the deeper part of the secondary area was not surveyed (see Figure 2). The mosaic of the side-scan data is presented in Figure 23.

A number of distinct features were apparent in the side-scan mosaic, particularly to the western end of the primary area, and along the southern edge of both areas.

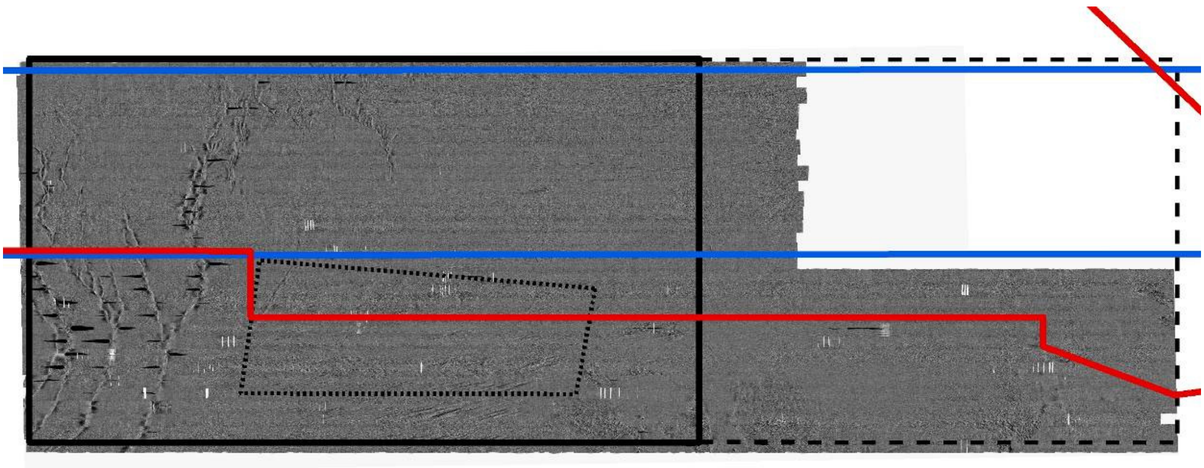


Figure 23: Mosaic of side-scan data.

The side-scan sonar mosaic was examined and interpreted by an experienced sedimentologist (T.

Hume, NIWA, pers. comm.) and side-scan sonar technologist (P.G.). Eight seabed facies were identified within the study area (Figure 24). These are as follows: 1) largely featureless flat sandy plain (probably with small wave ripples); 2) patches of rock and coarse substrate; 3) three classes of ridge features; 4) sand waves; 5) other bed forms; 6) an area of unknown sediment feature, which is not considered to be an artefact.

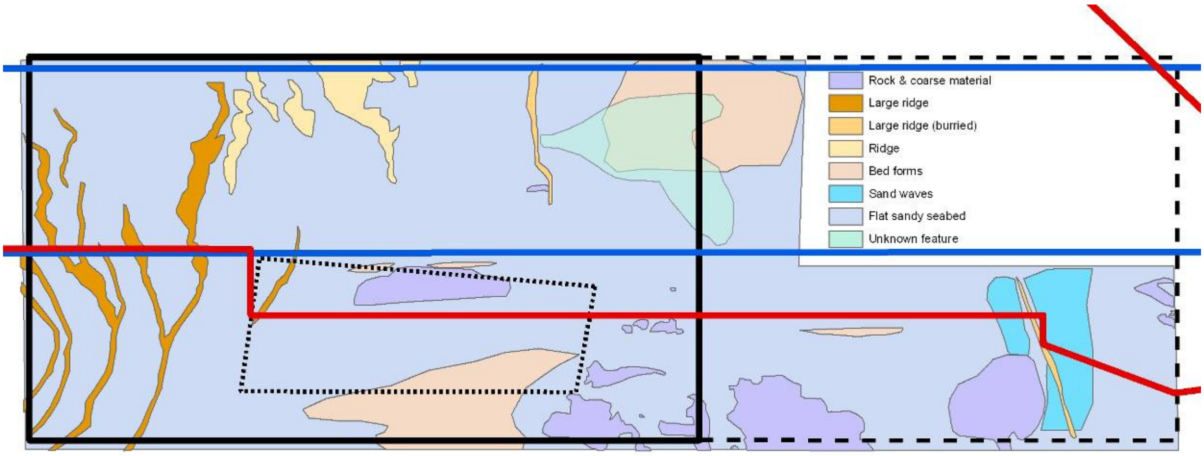


Figure 24: Digitised areas of seabed habitats interpreted from side-scan mosaic (Figure 23).

The ridge features have been split into three types, the particularly large and distinct linear features at the western end of the survey area (which have an altitude of up to 10 m), the more isolated ridges which appear less distinct (which have been interpreted as ridges being partially buried) and the broader areas of what appear to be lower altitude ridges to the north of the primary area.

The seabed habitats interpreted from the side-scan mosaic are overlayed onto the BPI terrain structure map in Figure 25. It can be seen that the ridges and areas of rock and coarse material have been relatively consistently identified as distinct features, but the areas of sand waves and other bed forms identified from the side-scan appear to be far more widespread from the BPI analysis.

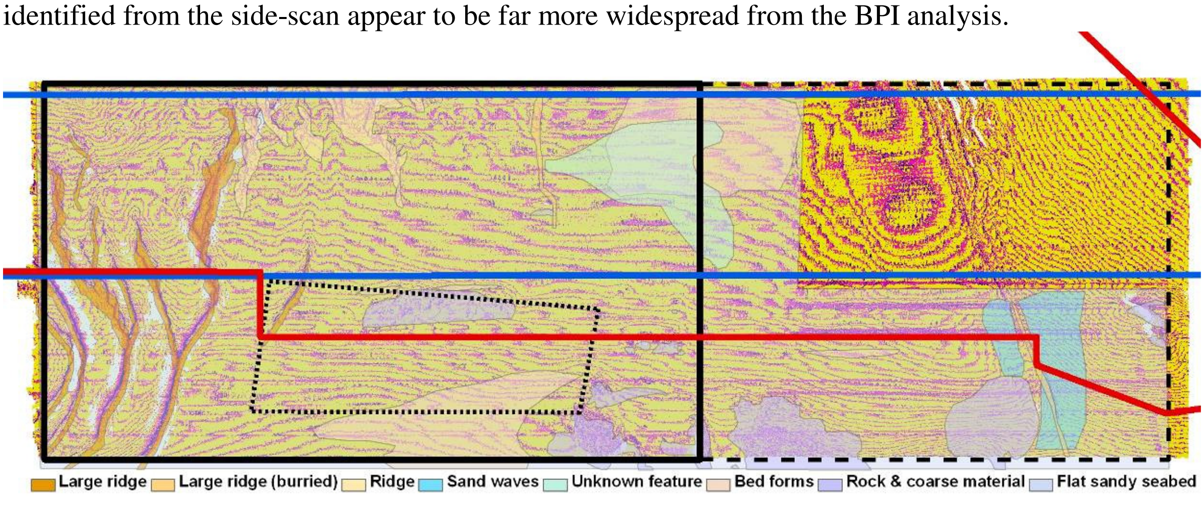


Figure 25: Digitised areas of seabed habitats (Figure 24) interpreted from side-scan mosaic (Figure 23) overlaid onto BPI terrain structures for the Spirits Bay survey area (Figure 22).

4.3. Biological features

4.3.1. Broad habitat categories

Analysis of the video and still images resulted in classification of stations to broad habitat categories.

The video transects were useful in quantifying the broad-scale habitat patterns, but image quality was variable (owing to surging and lifting of the camera systems), and identification of fine-scale features and species identification were often difficult. Each transect was viewed completely, and time specific notes were made in relation to habitat and fauna.

A summary of the total and useable images from each of the still cameras is provided in Table 4. Example images from the various habitat and faunal abundance categories are provided in Figure 26. The still images provided the most quantifiable format for analysis, owing to the high resolution and lack of movement. For almost all stations, 20 to 30 images of useable quality were available for classification, allocated to categories based on habitat and faunal factors (Table 4). Habitats within the survey area varied from rocky outcrops to smooth sand and shell substrate, and, as such, varied in their suitability for the range of epifaunal species observed in the area.

From both video and still approaches, stations were categorised by their main habitat type (or a combination of two, where one type was not considered to exceed 60–70 % of the overall station), and are mapped in Figure 27. Video stations from ENV9805 have also been included in this figure.

From the visual approaches, most of the survey area was categorised as being a sandy habitat with ripples (Figure 27), although some areas of sand waves and other habitat types were also identified. The preliminary BTM analysis (Section 4.2.1, see Figures 21 and 22) would suggest that regular wave-like features are far more widespread, but the scale of the features identified from this analysis (100–300 m wavelength) would make them impossible to detect in still images, and very difficult in video transects. The orientation of the features (generally east-west) means that north-south video transects would have the best chance of identifying them, and although such transects were the original aim, sea conditions (particularly the strong tidal currents) meant they were rarely achieved.

Table 4: Summary of images from still image stations, by habitat and faunal category.

		Habitat / faunal category											
Stn. no	Images	Unuseable images	Total useable images	Rocky / widespread fauna	Coarse sand gravel rock / sparse fauna	Coarse sand gravel shell / sparse fauna	Sand shell with basement / widespread fauna	Sand waves / scattered fauna	Sand waves / sparse fauna	Sand ripples / patches of large fauna	Sand ripples / scattered fauna	Sand ripples / sparse fauna	Sand shell smooth / scattered fauna
SC01	32	7	25	17		8							
SC02	25	1	24			21						3	
SC03	28	16	12									12	
SC04	28	4	24								24		
SC05	29	5	24								24		
SC06	31	4	27							3	24		
SC07	28	6	22						8			14	
SC08	27	3	24								24		
SC09	28	4	24						6				18
SC10	33	9	24					2			22		
SC11	28	2	26						8			18	
SC12	26	2	24						24				
SC13	28	3	25						3			22	
SC14	28	3	25						8			17	
SC15	29	5	24						9		15		
SC16	No data recorded, station abandoned												
SC17	35	11	24				19					5	
SC18	39	8	31							10	21		
SC19	38	8	30							9	21		
SC20	39	9	30							7	23		
SC21	38	6	32								29	3	
SC22	37	6	31								31		
SC23	37	5	32			32							
SC24	36	5	31	11		20							
SC25	36	7	29	15	14								
Total	763	139	624	43	14	81	19	2	66	29	258	94	18

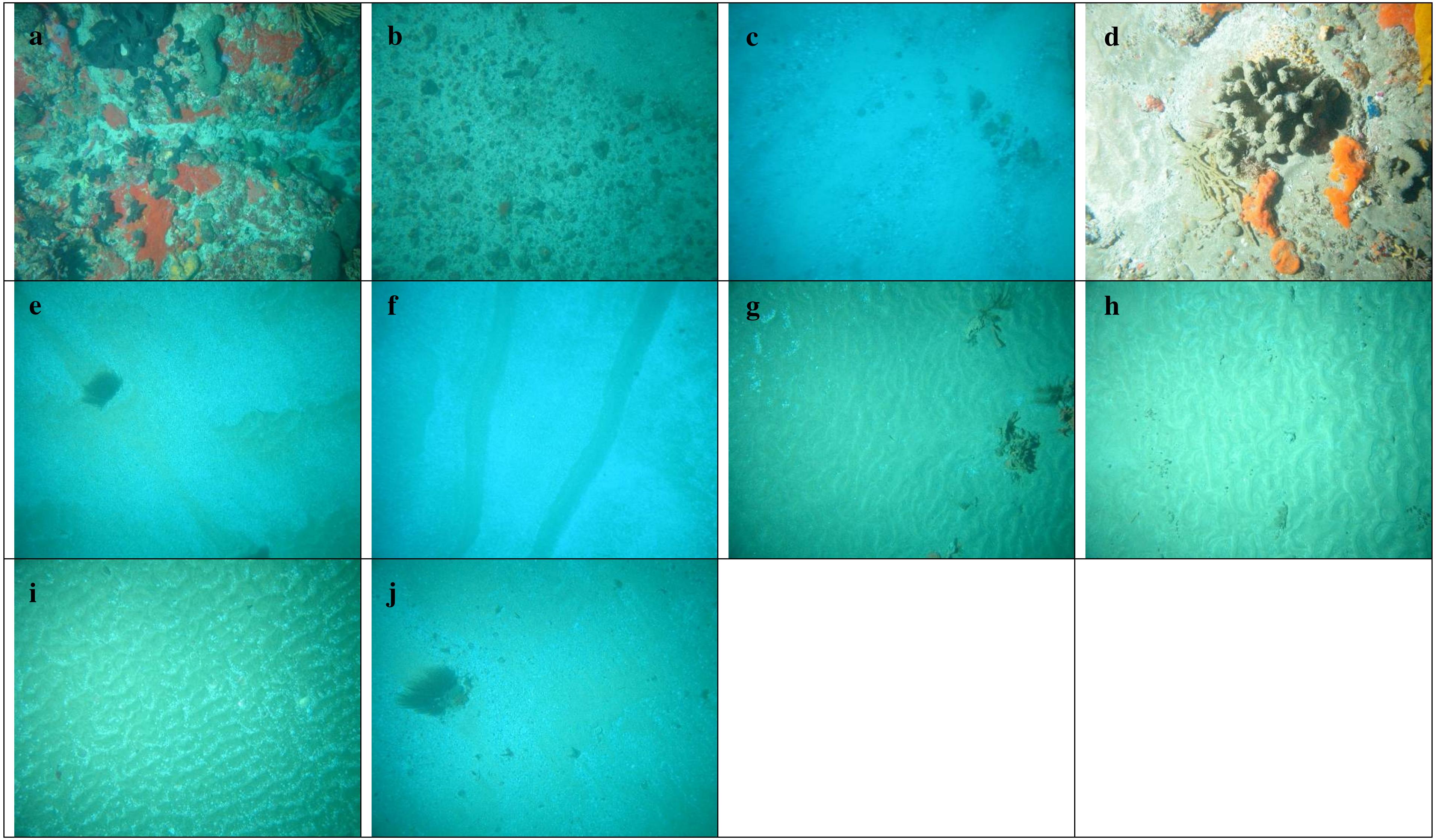


Figure 26: Example images from the habitat and faunal abundance categories. a - rocky / widespread fauna; b - coarse sand gravel rock / scattered fauna; c - coarse sand gravel shell / sparse fauna; d - sand shell with basement / widespread fauna; e - sand waves / scattered fauna; f - sand waves / sparse fauna; g - sand ripples / patches of larger fauna; h - sand ripples / scattered fauna; i - sand ripples / sparse fauna; j - sand shell smooth / scattered fauna.

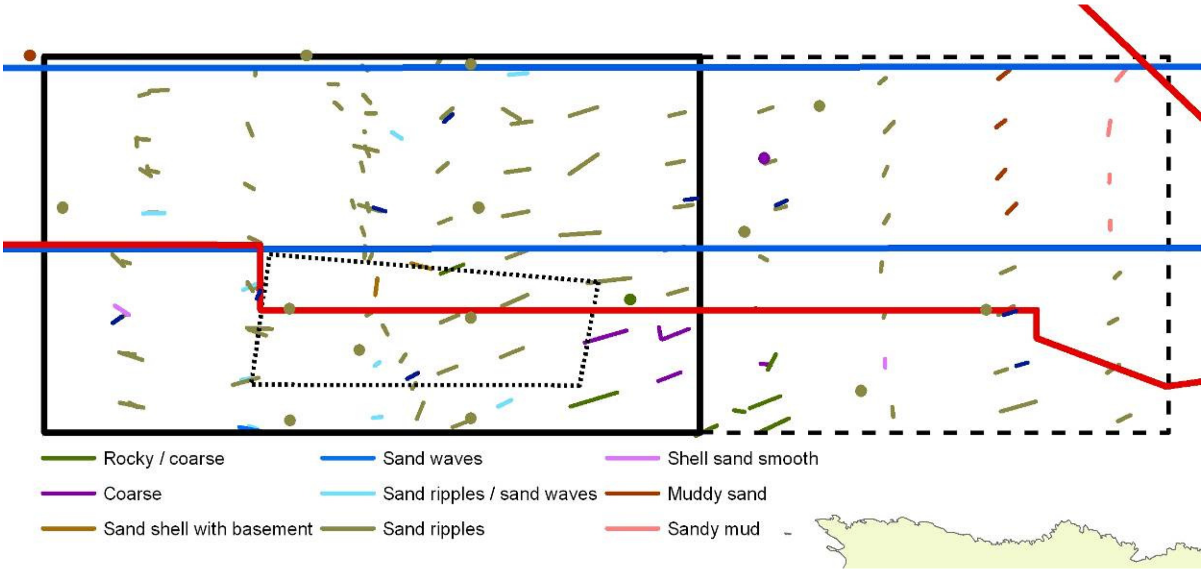


Figure 27: Habitat categories combined from all video and still camera stations. Dots represent video stations from ENV9805, same colour coding applies.

4.4. Species distributions and community analysis

Quantitative analysis from still images

The sponge and non-sponge species recorded within each habitat and faunal abundance category from the analysis of still images are summarised in Tables 5 and 6. It is clear that while some habitat types had consistently high faunal abundance and species richness (e.g., rocky outcrops or sand shell area overlying a basement substrate), others were more variable, and generally have less obvious epifauna (e.g., areas of sand waves or ripples).

The epifaunal community (as described from the analysis of the still images) was examined in relation to the habitat categories. This analysis was based on the epifauna identified and enumerated from the representative images selected from each habitat type, and conducted within the PRIMER software package. The epifaunal communities were examined at the individual image level. A range of univariate measures (number of species, number of individuals, and a suite of other diversity measures) was calculated, and the epifaunal communities were analysed using the ANOSIM approach, on a Bray Curtis similarity matrix, having first excluded images with no visible epifauna (since these provide no information to the analysis), and square root transformed the abundance data. The choice of this transformation was somewhat arbitrary, but preliminary analysis indicated that the analysis results were insensitive to the transformation approach adopted. Within the ANOSIM analysis, different combinations of levels of seabed type and faunal abundance categories were used as factors.

Table 5: Sponge species recorded in each habitat/faunal abundance category from still image stations. Numbers represent number of images on which the species was recorded, with total number of images per habitat provided at the bottom of the table.

Taxonomic identifications	Rocky / widespread	Coarse sand gravel rock / sparse	Coarse sand gravel shell / sparse	Sand shell with basement / widespread	Sand waves / scattered	Sand waves / sparse	Sand ripples / patches	Sand ripples / scattered	Sand ripples / sparse	Sand shell smooth / scattered	Total
Aaptos globosum Kelly-Borges & Bergquist, 1994							2				2
Ancorina alata Dendy, 1924	5										5
Axinella australiensis Bergquist, 1970							2	3			5
Axinella n.sp. 6 (ENV9805 like Stylotella conulos)				1							1
Axinella n.sp. 1 (Three Kings bushy club)	2										2
Biemna rufescens Bergquist & Fromont, 1988	2						1				3
Callyspongia latituba (Dendy, 1924)	4										4
Callyspongia n. sp. 16 (Spirits Bay serrated)				1			2		1		4
Callyspongia n. sp. 17 (Spirits Bay raised oscules)							1	1			2
Callyspongia ramosa (Gray, 1843)	5							1			6
Chondropsis cf n. sp. 1 (ENV9805 brown tough strappy)	2						1				3
Cinachyra n.sp. 1 (Spirits Bay large grey ball with porocalyces)				2							2
Cinachyra uteoides Dendy, 1924				3							3
Ciocalypta cf *polymastia* (Lendenfeld, 1888)			1	3			1				5
Clathria multitoxiformis Bergquist & Fromont, 1988	2										2
Crella incrustans(Carter, 1885)	3						1				4
Crella n. sp. 1 (pale blue cratered mass)	3										3
Dactylia palmata Carter 1885	2						2	1			5
Dendrilla rosea (Lendenfeld, 1883)	3			1							4
Dictyodendrilla dendyi Bergquist, 1996							2				2
Dragmacidon n. sp. 1 (Three Kings thick papillate encrustor)	1										1
Dragmacidon n. sp. 2 (Spirits Bay flanged)	1			2							3
Dysidea cf n. sp. 2 (ENV9805 blue tough + black stones)	2			1			3	1			7
Hymeniacidon n. sp. 1 (ENV9805 very rich orange mounded)				4			3				7
Hymeniacidon sphaerodigitata Bergquist, 1970								2			2
Iophon minor (Brondsted, 1924)	4	1		2			4				11
Latrunculia kaakaariki Alvarez et al., 2002	5						2				7
Latrunculia oxydiscorhabda Alvarez et al., 2002	2			3							5
Leucettusa lancifer Dendy, 1924	4										4
Oceanapia cf *aberrans* Dendy, 1924								7			7
Oceanapia cf *arcifera* Dendy, 1924				2				1			3
Oceanapia n. sp. 4 (pink translucent turnip)							1	5			6
Oceanapia n. sp. 5 (double blind fistules)								1			1
Pararhaphoxya n. sp. 1 (tiny orange branches)	4										4
Pararhaphoxya pulchra (Brondsted, 1923)				1							1
Petrosia hebes (Lendenfeld, 1888)	6										6
Polymastia aurantium Kelly-Borges & Bergquist, 1997				1							1
Polymastia croceus Kelly-Borges & Bergquist, 1997	3			1			4				8
Polymastia massalis Carter, 1886	1										1
Psammocinia cf *amodes* Cook & Bergquist, 1998	1										1

Table 5 continued

Taxonomic identifications	Rocky / widespread	Coarse sand gravel rock / sparse	Coarse sand gravel shell / sparse	Sand shell with basement / widespread	Sand waves / scattered	Sand waves / sparse	Sand ripples / patches	Sand ripples / scattered	Sand ripples / sparse	Sand shell smooth / scattered	Total
Psammocinia cf *hawere* Cook & Bergquist, 1998	1										1
Psammosinia beresfordi Cook & Bergquist, 1998	1						1				2
Pseudaxinella australis Bergquist, 1970	1			2			3				6
Pseudistoma novaezelandiae	1										1
Raspailia n. sp. 5 (Spirits Bay palmate)	5										5
Raspailia topsenti Dendy, 1924	1			1				1			3
Stelletta crater Dendy, 1924				1							1
Stelletta maori Dendy, 1924	2										2
Stylissa n. sp. 1 (Spirits Bay fingery club)							1				1
Tedania cf *connectens* (Brondsted, 1924)	4			1							5
Tedania n. sp. 1 (Spirits Bay white filmy turrets)								6			6
Tethya fastigata Bergquist & Kelly-Borges, 1991	3										3
Tethyopsis mortensoni (Burton, 1924)								8			8
Tetilla n. sp. 1 (Spirits Bay umbrella anatiaenes)				1			3				4
Trachycladus stylifer Dendy, 1924	4						1	6			11
Xestospongia coralloides (Dendy, 1924) or *Orina regius* (Brondsted, 1924)	1										1
Total images	43	14	81	19	2	66	29	258	94	18	624

A range of commonly used univariate community measures has been calculated for the epifaunal communities observed in the still images, and six of these measures are presented in box and whisker plots for habitat categories in Figure 28. The same indices are presented for habitat and faunal abundance categories in Figure 29. Other measures showed similar patterns. The notches in each plot provide roughly 95% confidence intervals of the median, and if the notches of two plots do not overlap, this can be considered strong evidence that the two medians differ (Chambers et al. 1983).

Analysis of variance identified highly significant differences in all of the univariate measures between the habitat and habitat/faunal abundance categories. There are clearly differences in the epifaunal communities between the various habitats defined here. Species richness (S) is simply the total number of species present. Hill's N1 and the Shannon H' index are measures of diversity, while the N2 index provides a measure of evenness (lower numbers associated with assemblages dominated by one or a few species). Average taxonomic distinctness is average taxonomic diversity (Warwick & Clarke 1995) divided by the Simpson diversity index, removing the dominating effect of the species abundance distribution, and is the mean path length through the taxonomic tree connecting every pair of species in a sample. Variation in taxonomic distinctness reflects the unevenness of the taxonomic tree.

Table 6: Non-sponge species recorded in each habitat/faunal abundance category from still image stations. Numbers represent number of images on which the species was recorded, with total number of images per habitat provided at the bottom of the table.

Taxonomic identifications	Rocky / widespread	Coarse sand gravel rock / sparse	Coarse sand gravel shell / sparse	Sand shell with basement / widespread	Sand waves / scattered	Sand waves / sparse	Sand ripples / patches	Sand ripples / scattered	Sand ripples / sparse	Sand shell smooth / scattered	Total
ALGAE: *Ecklonia radiata* (Ahipara variety)	1								1		2
ALGAE: Red algae sp 1 (filamentous streamers)								3			3
ASCIDIAN: Ascidian sp 1 (massive sandy foliose)				2			1	1		1	5
ASCIDIAN: SO *Aplousobranchia* sp 1 (smoked roe)							1	1			2
BRYOZOAN: Bryozoan sp 1 (feathery mass)								2			2
BRYOZOAN: *Cellaria immersa* (Tenison Woods, 1880)				2				1			3
BRYOZOAN: *Steginoporella perplexa* Livingstone, 1929							1	4			5
GORGONACEAE: *Callogorgia* sp 1 (dull brownish pink)		1					1				2
HYDROID: *Crateritheca novaezelandiae*	1						3	4	1		9
HYDROID: *Gonaxia* sp 1 (irregular multipinnate)								4	3		7
HYDROID: *Hydrodendron mirabile* (Hinks, 1866)				2			2				4
HYDROID: Hydroid sp 1 (short multipinnate red)				1							1
HYDROID: *Nemertesia elongata* Totton, 1930					1		6	7	5	1	20
Total images	43	14	81	19	2	66	29	258	94	18	624

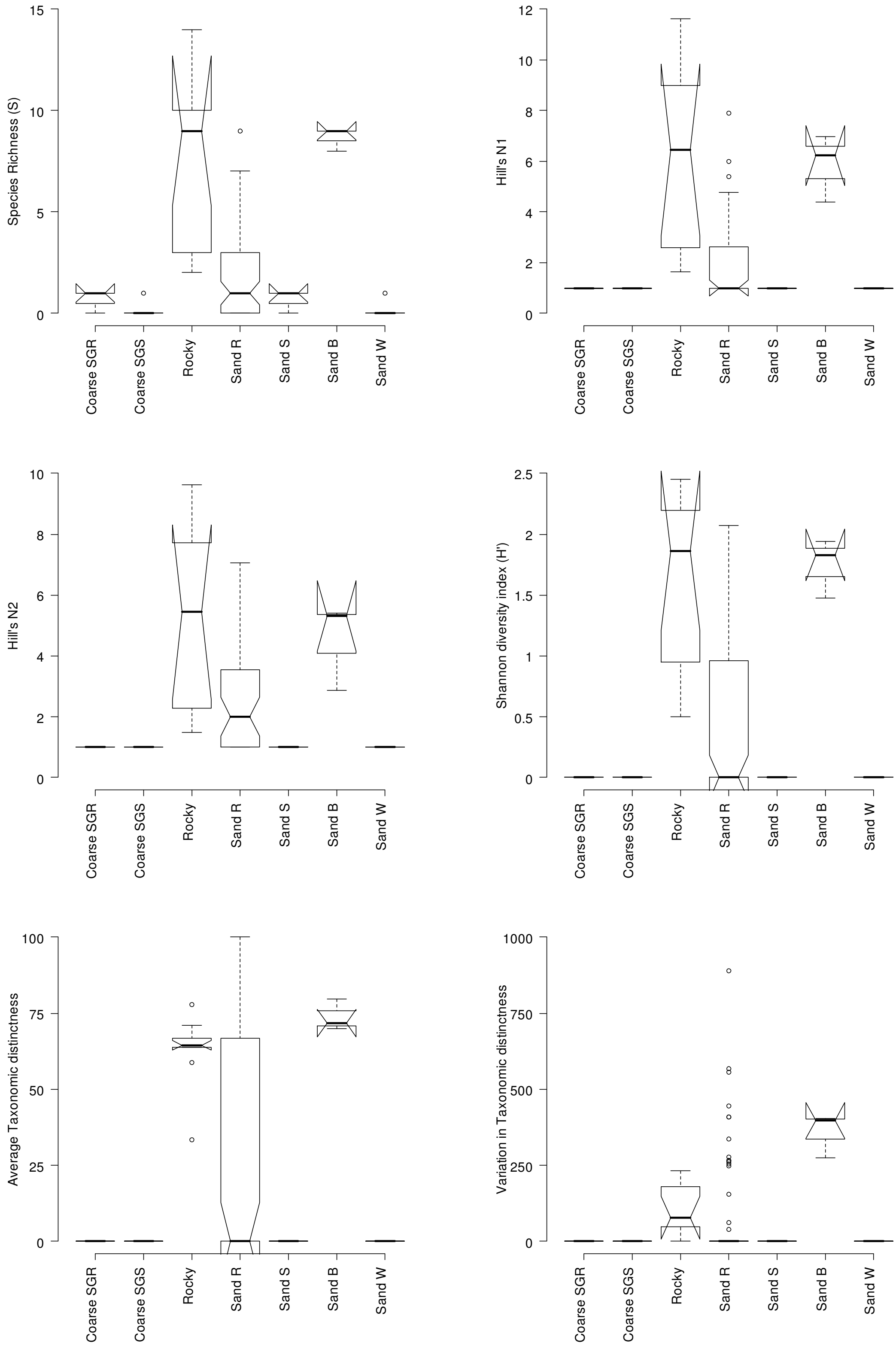


Figure 28: Box and whisker plots of the univariate community measures calculated from the still images, by habitat category. Coarse SRG – coarse sand gravel rock; Coarse SGS – coarse sand gravel shell; Rocky – rocky outcrop; Sand R – sand shell ripples; Sand S – sand shell smooth; Sand B – sand shell with basement; Sand W – sand waves.

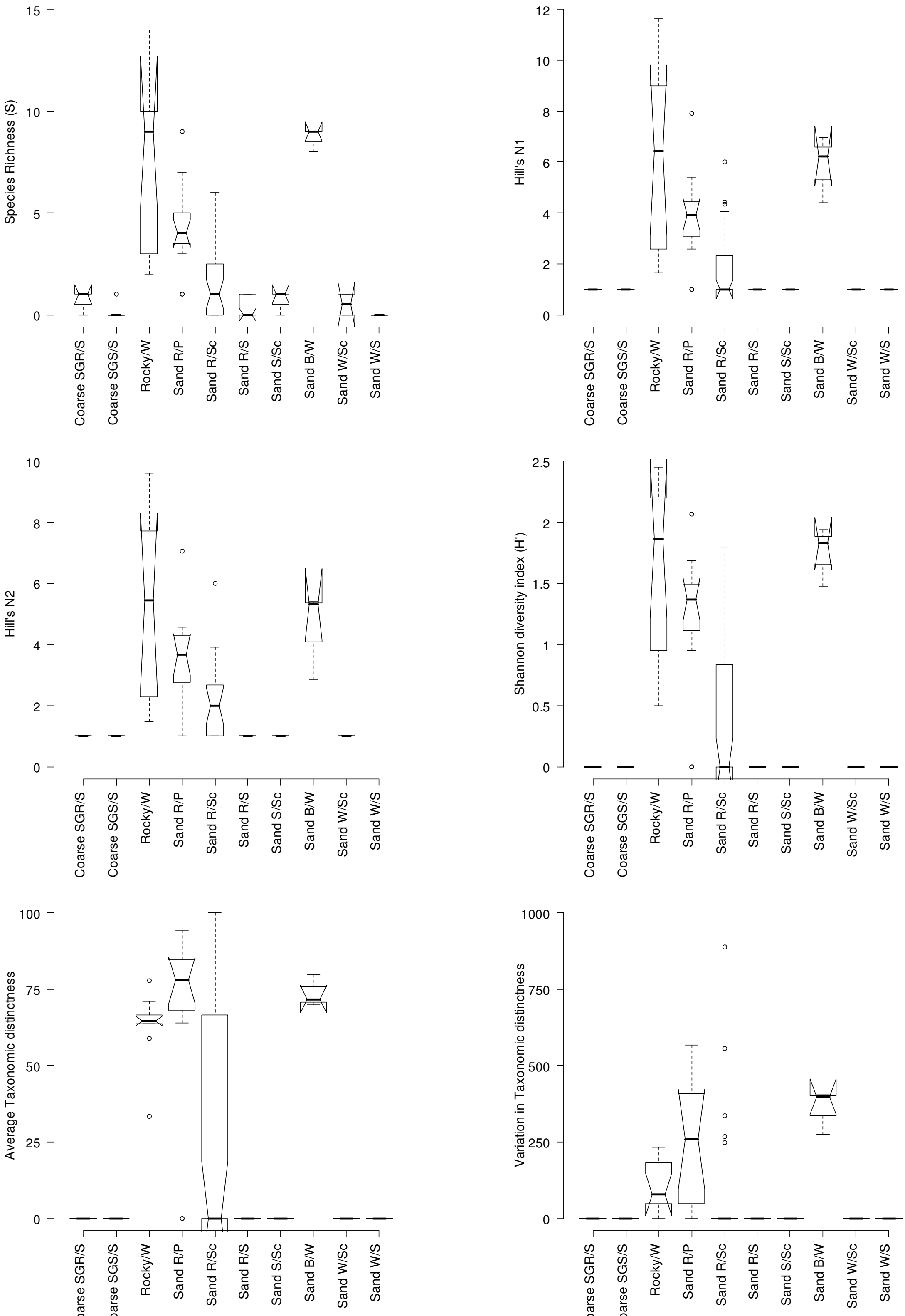


Figure 29: Box and whisker plots of the univariate community measures calculated from the still images, by habitat and faunal abundance category. Habitat labels/faunal abundance categories as follows. Habitat; Coarse SRG – coarse sand gravel rock; Coarse SGS – coarse sand gravel shell; Rocky – rocky outcrop; Sand R – sand shell ripples; Sand S – sand shell smooth; Sand B – sand shell with basement; Sand W – sand waves. Faunal abundance; W – widespread; P – patches of larger fauna; Sc – scattered; S - sparse.

The rocky and sand shell with basement habitats consistently had the highest values for all the indices. Values S, N1, H' N2 and were not significantly different between these two habitats, although observations from the rocky habitat were more variable. For the measures based on taxonomic distinctiveness, the box plots (see Figure 28) indicate that the median values for the sand shell with basement habitats were significantly greater than for the rocky habitat. The sand ripple habitat had intermediate median levels of the various indices, and showed considerable variability in the measures based on taxonomic distinctiveness, while the other habitats generally had very low values (see Figure 28).

Categorising the images by habitat and faunal abundance provided a similar overall picture (rock and sand with basement habitats generally having higher values than other categories) (Figure 29), and as might have been anticipated (although still reassuring), within habitat types, richness, diversity, and evenness indices decreased as abundance categories changed from patchy to scattered and finally scarce. Values for the sand ripple habitat with patches of larger fauna were not significantly different from the rock or sand with basement habitats for some indices.

A non-metric multi-dimensional scaling (MDS) plot of the similarity matrix of the root transformed epifaunal abundance data is shown in Figure 30. Within this plot, individual images with a similar epifaunal community are plotted closer together than images with dissimilar communities. It can be clearly seen that most of the images form a single cluster, with two separate groups composed of one (sand shell ripples, sparse fauna) and three (sand shell ripples, scattered small fauna) images respectively, each having images from only one station.

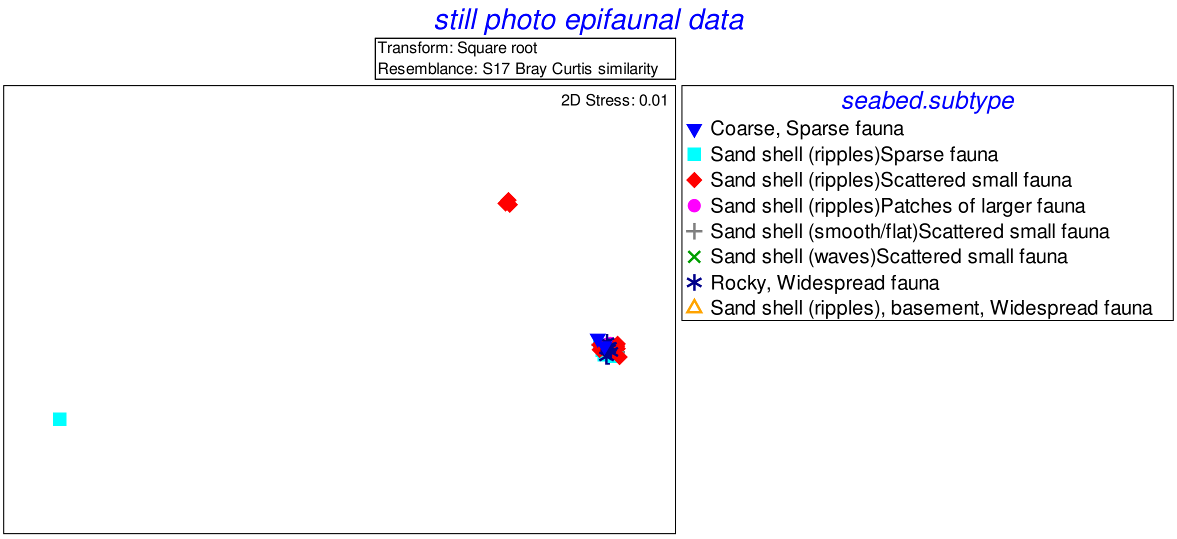


Figure 30: Non-metric MDS plot of the epifaunal communities, from Bray Curtis similarities computed from root transformed abundance data from the still images. Symbols represent combinations of seabed type and faunal abundance category.

A dendrogram of the similarity data is presented in Figure 31, and the two groups of separate stations can be seen clearly at the right hand end of the plot, having zero similarity with each other and the main cluster. These two groups each have a single, different species of alga as their only epifauna/flora, which is unique to that group within this data set. Closer examination of the data identified that alga at SC02 was in fact unattached to the substrate, and therefore may not be representative of the community at that station. The complete dissimilarity of stations SC02 and SC15 from each other and the rest of the images dominated Figure 30 and hides any pattern within the main cluster of images. Therefore, an MDS plot of the main cluster of images (excluding SC02 and SC15) has been generated from a subset of the data (Figure 32).

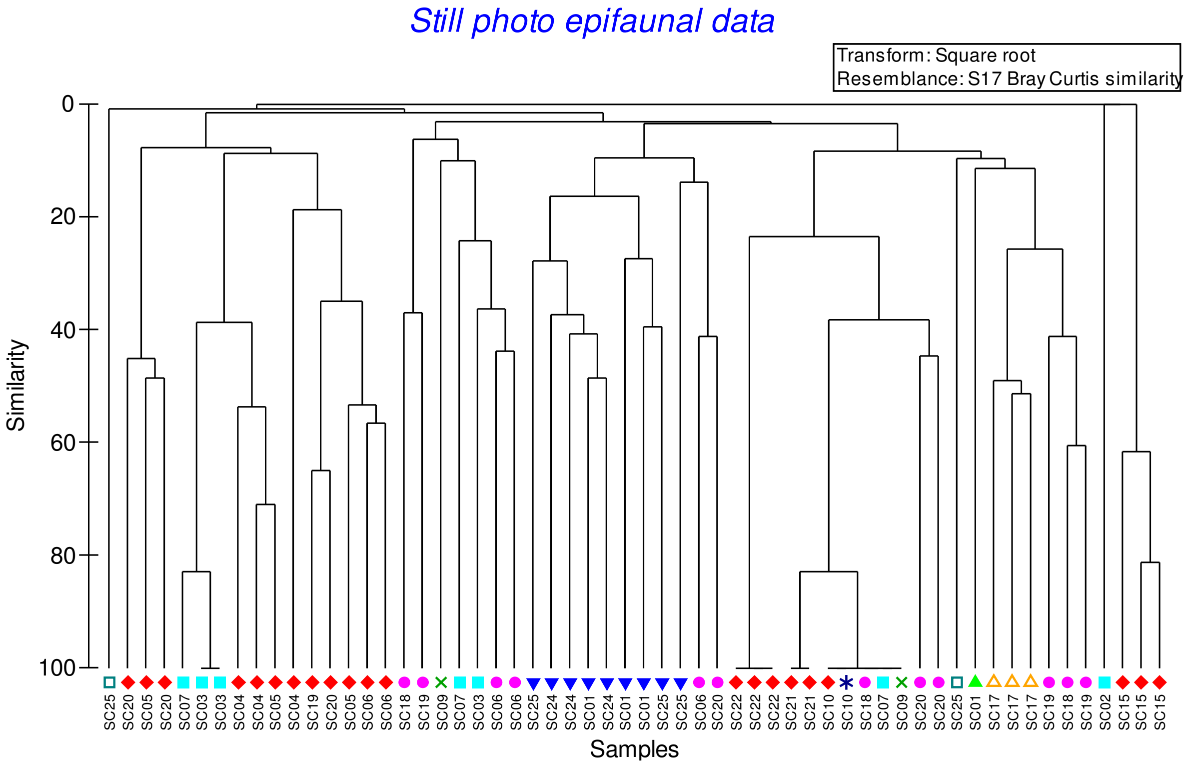


Figure 31: Dendrogram of epifaunal communities, from Bray Curtis similarities computed from root transformed abundance data from the still images. Sample numbers represent photographic stations. Symbols represent combinations of seabed type and faunal abundance category. See Figure 30 for explanation of symbols.

Distinct clustering of the images can be seen, suggesting that the communities recorded within the habitat and epifaunal abundance categories are different. This was confirmed with a one way ANOSIM test, which calculated that the significance of the global test between seabed categories (ignoring faunal abundance) was highly significant (0.4%). The global test for differences between seabed / faunal abundance categories was also highly significant (0.1%).

Pairwise tests within the ANOSIM procedure also allowed examination of differences between habitats and faunal abundance categories (Table 7). The ANOSIM approach is based upon randomisation of stations among factors, and the power of the test is related to the number of samples within any factor, and the number of permutations possible. For this reason, both the significance and the number of permutations tested are presented in Table 7.

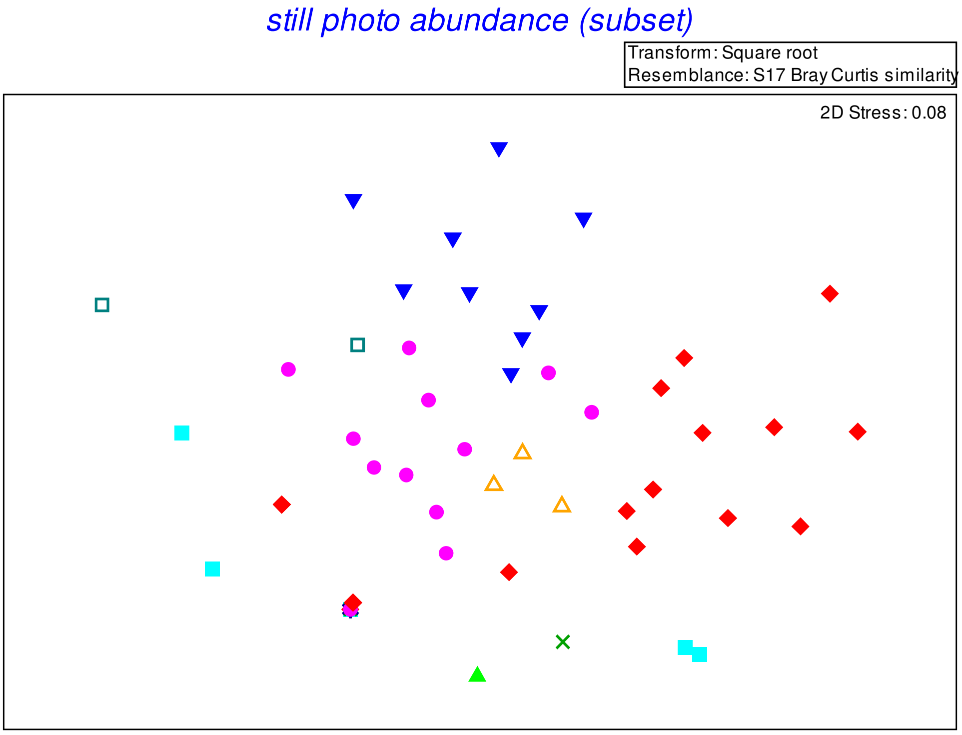


Figure 32: Non-metric MDS plot of the main cluster of epifaunal communities (from Figure 30), from Bray Curtis similarities computed from root transformed abundance data from the still images. See Figure 30 for explanation of symbols.

Where samples were available to provide sufficient permutations, the pairwise tests showed significant differences between each of the broad habitat types (rock, coarse, and sand). However, there were no differences in the communities observed between habitat categories within the broad types (i.e., no difference between sand ripples, waves, flat areas, or the sand over basement). It is perhaps not surprising that there are no differences between the sand ripples, waves, and flat areas, given that the BPI analysis (see Figure 22) suggested that much of the area appeared to be covered by large wave-like features, and the visual classification (ripples, waves, flat) may simply have been an artifact of the scale and orientation of the video and still image transects. Although there were no significant differences in the community structure between the sand over basement and the other sand habitats, there were significant differences in the univariate community statistics between these habitats (see Figure 28). The lack of difference between the community structure may have been due to the lack of available permutations for the wave and flat areas (partly due to the number of images with no visible fauna), and the variability within the sand ripple habitat, since the basement habitat was significantly different from the sand ripple/sparse and sand ripple/scattered categories.

Table 7: Significance levels and number of permutations (in parentheses) from pairwise ANOSIM tests, examining differences between habitats, and between abundance categories within the different sand habitats. Bold font signifies significance at the 5% level.

	Coarse material (sand gravel shell)	Sand shell (ripples)	Sand shell (ripples)Scattered small fauna	Sand shell (ripples)Patches of larger fauna	Sand shell (smooth/flat)	Sand shell (waves)	Sand shell (some ripples) with basement substrate	Coarse material (sand gravel rock)
Rocky outcrop	10 (10)	**0.6 (999)**			**1.8 (55)**	10 (10)	**0.5 (220)**	**3.6 (55)**
Coarse material (sand gravel shell)		**4.9 (41)**			100 (3)		25 (4)	100 (3)
Sand shell (ripples)					35.7 (861)	73.2 (41)	30.4 (999)	**3.1 (861)**
Sand shell (ripples)Sparse fauna			**1.8 (999)**	**0.3 (999)**	41.7 (36)	62.5 (8)	**5 (120)**	
Sand shell (ripples)Scattered small fauna				**0.8 (999)**	14.2 (253)	68.2 (22)	**0.1 (999)**	
Sand shell (smooth/flat)				18.7 (91)		100 (3)	10 (10)	100 (3)
Sand shell (waves)				69.2 (13)			25 (4)	100 (3)
Sand shell (some ripples) with basement substrate				21.8 (455)				10 (10)

Qualitative analysis from all visual data

Although the sea conditions meant that it was not considered possible to collect detailed quantitative data on faunal communities and abundance from the video transect data, each transect was assigned to a broad faunal abundance category (sparse, scattered, widespread) in the same way as the individual images. The spatial distribution of the abundance categories is shown in Figure 33.

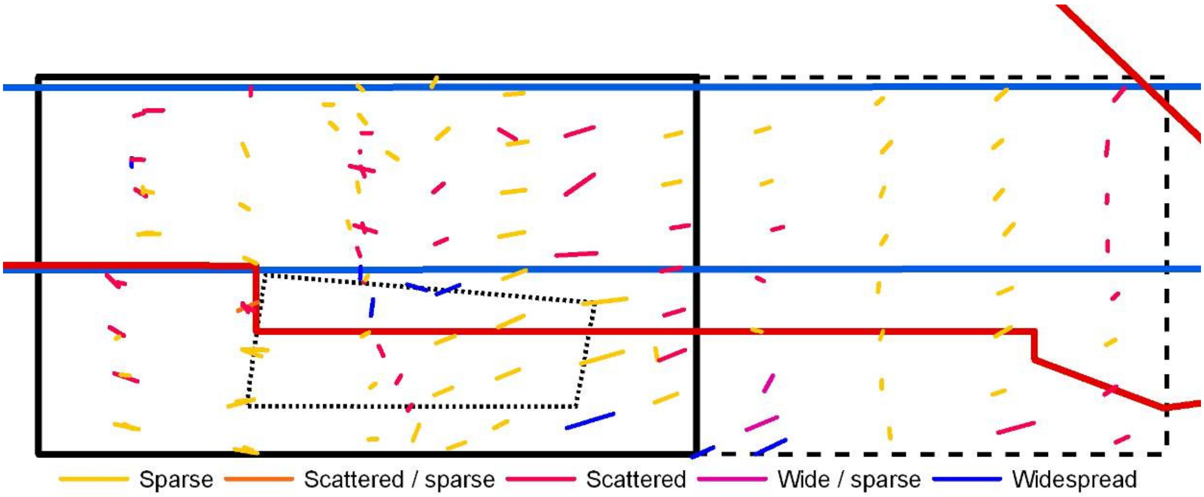


Figure 33: Faunal abundance categories combined from all video and still camera stations.

Some stations (or very close locations) were surveyed with both the video and still methods, enabling comparison of the categories between approaches (assuming faunal abundance is uniform over the spatial scales of comparison). A matrix of comparisons is provided in Table 8, suggesting that while there was reasonable general agreement between the methods, at intermediate levels of abundance (scattered), the still method approach estimated greater abundance than the video method. Given that the analyses were all conducted by the same individual, this is considered to be related to the image quality, and the different scales over which the sampling was conducted. The categories allocated to pairs of observations were ranked and tested with a Wilcoxon matched pairs sign rank test and the two approaches (still and video) were found to be not significantly different.

Quantitative analysis of the still images showed that there were significant differences between the univariate community measures of the different abundance categories for the still image data (see Figure 29). Such analysis is not possible for the video data.

Table 8: Comparison of abundance categorisation of repeat stations between video and still images.

Video categories	Still categories		
	Sparse	Scattered	Widespread
Sparse	7	5	
Scattered	1	4	
Widespread			3

Examining community differences between areas of different potential fishing pressure

Given the lack of difference in community measures and structure between the sandy ripple, wave, and flat areas (from the analysis of the still images, see Figure 28, Table 7), and the suggestion from the preliminary BPI analysis (see Figure 22) that the visual classification into these categories may partly be an artifact of the scale of the visual sampling, differences between fishing areas have been examined across the three sand habitats (ripples, waves, flat) combined.

Given the nature of the data available, examination of fishing effort patterns has been over quite a broad scale. Trawling for a range of inshore species occurs in the area, and TCEPR data suggests effort was widespread across much of the study area until 1999 (see Figure 16). Since the introduction of the regulated closure there appears to have been little trawl fishing effort in the study area, most of the activity being to the south, closer to the land. Making inferences about the patterns of scallop dredge effort is harder. Overall dredge effort in the area has declined considerably since the mid 1990s (see Figure 13), but since the scallop density (from the pre-season survey) within stratum 93 has been consistently higher than the Northland average, and often higher than the other local strata (see Table 3), it is certainly possible that when fishing has taken place in the region, it may have been at a high intensity within stratum 93, probably higher than in other areas within the region.

Within the study area, we therefore have an inferred gradient of availability to the fishery, going on a relative scale from low (voluntary closed area, some of which may have been dredged before 1997, and trawled before 1999) to high (still open, and last dredged in 2004). Stratum 93 overlaps the boundary of the regulated closure, and so if our interpretations of fishing pattern are correct, then the northern half of the stratum may have been fished heavily up to 1999, while in the southern half, effort has probably continued to be higher than in adjacent areas until 2004. Since the area closed by the 1999 regulation includes the voluntarily closed area, for this analysis, we consider the regulated area to be the additional area closed. Historically, areas outside the voluntary but within the regulated closure may have experienced far greater fishing pressure than areas still open to fishing. An attempt to provide a summary of the relative levels of fishing in the different areas has been made in Table 9.

Table 9: Summary of estimated relative levels of fishing by gear, interpreted from broad patterns of scallop effort (Table 3) and TCEPR records (Figure 16). vol – area covered by voluntary closure introduced in 1997; reg – additional closed area covered by regulated closure in 1999; open – area outside closures; 91 to 93 represent scallop survey strata; out – area outside scallop strata.

	pre 1997		1997–1999		post 1999	
Area	scallop	trawl	scallop	trawl	scallop	trawl
vol 91	mod	low	-	low	-	-
vol out	-	mod	-	mod	-	-
reg 91	mod	mod	mod	mod	-	-
reg 93	v.high	low	v.high	low	-	-
reg out	-	mod	-	mod	-	-
open 91	mod	mod	mod	mod	mod	mod
open 92	low/mod	mod	mod	mod	low	low
open 93	v.high	low	v.high	mod	mod	low
open out	-	low	-	low	-	low

Unfortunately, the length of closure increases with distance from the coast, and hence depth, resultings in potential confounding of closure duration with depth. Taking this and our uncertainty over the patterns of fishing into account, any examination of effects of fishing are likely to be more reliable when comparing areas over time, rather than between areas.

The same suite of univariate community measures was examined for the still image data set for the combined sand habitats (ripples, waves, and flat) in relation to fishing gradient (Figure 34). Unfortunately, still images were not collected on sand habitat from within stratum 93, and so only three levels of fishing availability (voluntary closure since 1997, regulated closure since 1999, still open) can be compared. Also, the level of sampling was unbalanced, with fewer images from the regulated area than the other two treatments, although all six community measures showed a consistent pattern, with the highest diversity recorded in the area closed since 1997.

As discussed above, simple comparison of these three areas may be confounded by depth. Investigations into sponge communities off Australia (in deeper water) have found species richness to decline as depth increases (Schlacher et al. 2007), and this is what was anticipated within the Spirits Bay area (M.K. pers. comm.). Examining some of the univariate measures within a GAM framework (Figure 35), with area as a factor and depth as a covariate (with a smoother), suggested that depth was the most important driver of the community measures (with values increasing with depth). Values did not vary significantly between the fishing areas, although the values in the regulated area were often lower (not significantly) than the other areas (although the unbalanced nature of the sampling reduces confidence in this difference).

A non-metric multi-dimensional scaling (MDS) plot of the similarity matrix of the root transformed epifaunal abundance data for the sand habitats is shown in Figure 36. The images from the area closed on a voluntary basis in 1997 form a distinct cluster, with the images from the open area in particular being quite scattered. A one way ANOSIM test, calculating the significance of the global test between fishing areas, confirmed the difference was significant (1.5%). Significance levels of the pairwise tests within the ANOSIM are shown in Table 10. The epifaunal community within the area closed by regulation since 1999 (Reg) was significantly different from that in the other areas, while the communities in the open and voluntarily closed areas were not quite significantly different (5.6%).

Table 10: Significance levels and number of permutations (in parentheses) from pairwise ANOSIM tests, examining differences between fishing area for the sand habitats. Bold font signifies significance at the 5% level.

	Reg sand	Vol sand
Open sand	**1.4 (364)**	5.6 (999)
Reg sand		**3.1 (999)**

A SIMPER test was used to examine overall dissimilarity between the areas, and identify the species contributing most to the dissimilarity between fishing areas (Table 11). The regulated area was marginally more dissimilar than the other areas (between area dissimilarity 100% and 94.37%, compared to 92.04 %). Species contributing to the between-area dissimilarity varied, but the hydroids *Nemertesia elongata*, *Gonaxia* sp. 1 and *Crateritheca novaezelandiae*, and sponges *Tethyopsis mortensoni*, *Tedania* n. sp. 1, *Callyspongia* n. sp. 16, and *Oceanapia* n. sp. 4 appeared to contribute more to dissimilarity, more frequently than other species.

Of these species, *Nemertesia elongata* and *Crateritheca novaezelandiae* were most abundant in the open area and were absent from the regulated area. *Gonaxia* sp. 1 and *Callyspongia* n. sp. 16 were most abundant in the regulated area, and absent from the open area. *Tethyopsis mortensoni*, *Tedania* n. sp. 1, and *Oceanapia* n. sp. 4 were recorded only in the voluntary area.

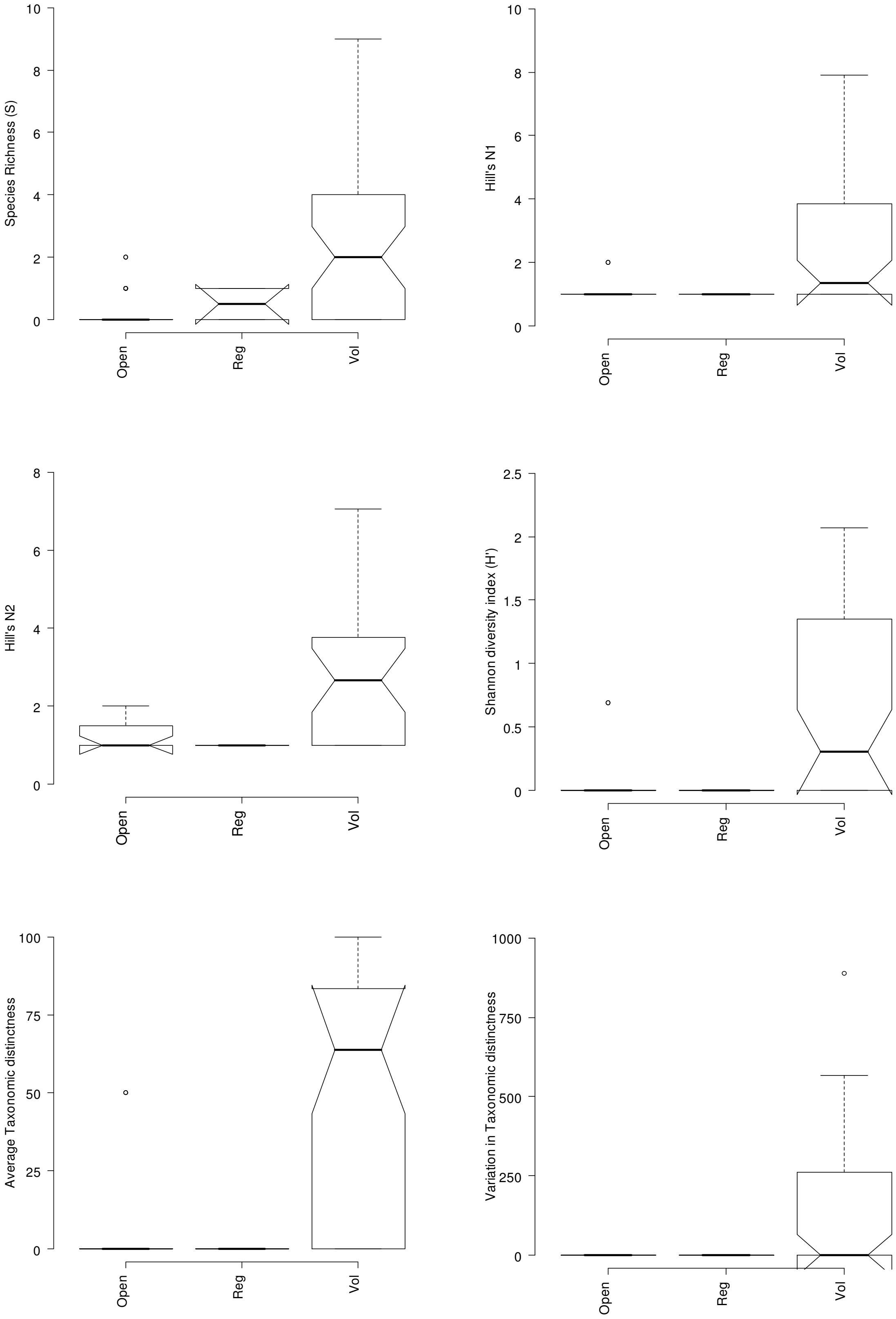


Figure 34: Box and whisker plots of the univariate community measures calculated from the still images for the sand habitats, by relative fishing intensity.

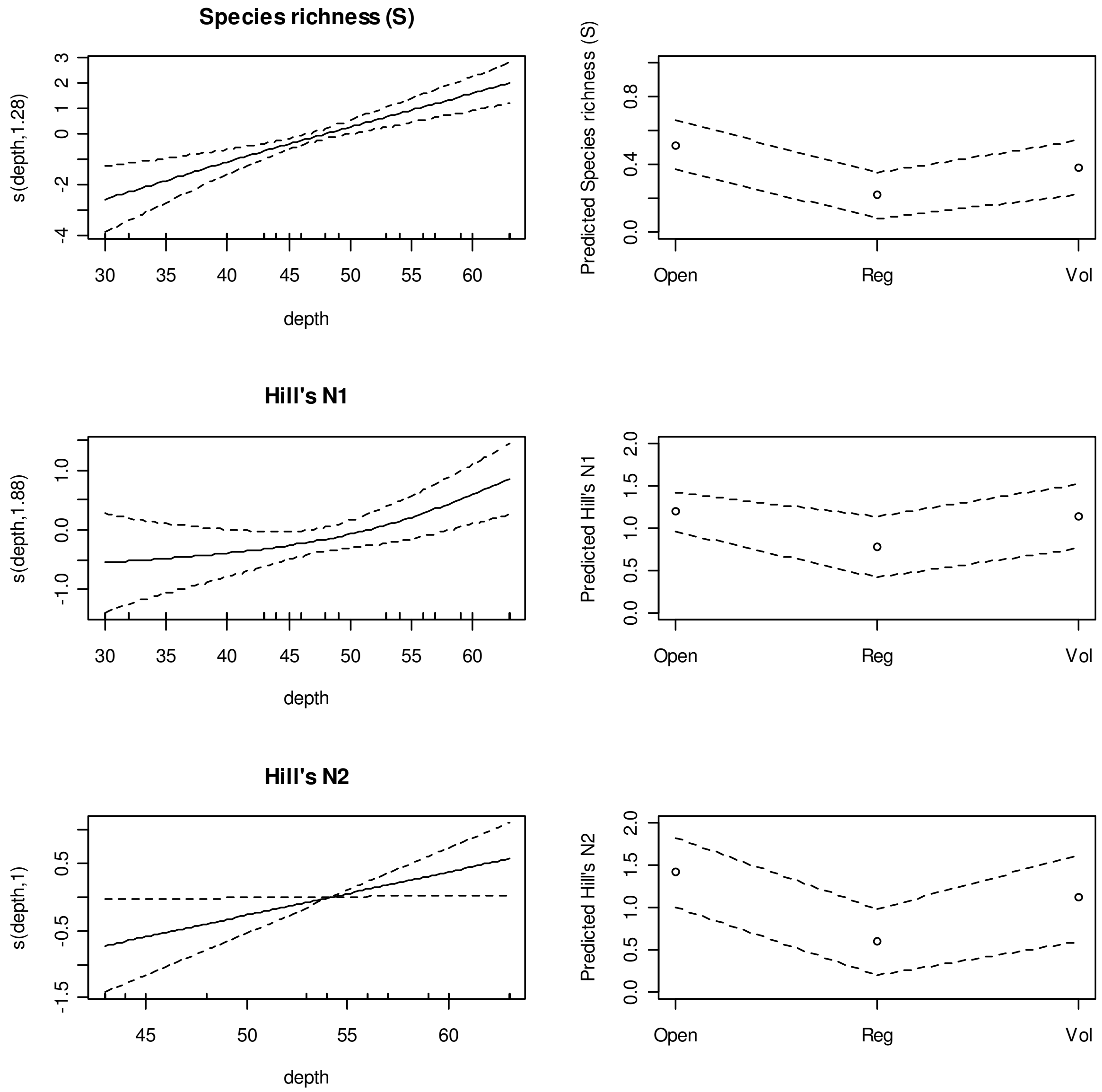


Figure 35: Effect of depth and predicted diversity measures for area factors from GAM of univariate measures (Species richness, Hill's N1, Hill's N2) on depth and area. Dashed lines represent ±standard error ranges.

Analysis of sponge communities from epifaunal dredge sampling

Over the two studies, sponge community data were available from 26 dredge samples within the ENV200523 study area (no sponge catch was recorded from dredge station 8 of the present study, and stations 7, 9, 11, and 53 of ENV9805). All but one of these stations was on sand habitat.

The univariate community measures are presented in box and whisker plots for fishing area and year combinations in Figure 37. Within each survey's data, a general increase in the measures is apparent as the potential recovery time since fishing increases (open < regulated < voluntary). As with the earlier analysis of the image data, the measures also increase with depth. Comparison of the areas between the two surveys suggests lower values in the later survey for the species richness and diversity measures, but not for those based on taxonomic distinctness. Tow length in 1999 was three times that in 2006, and the taxonomic measures are less sensitive to sample size (Warwick & Clarke 1995).

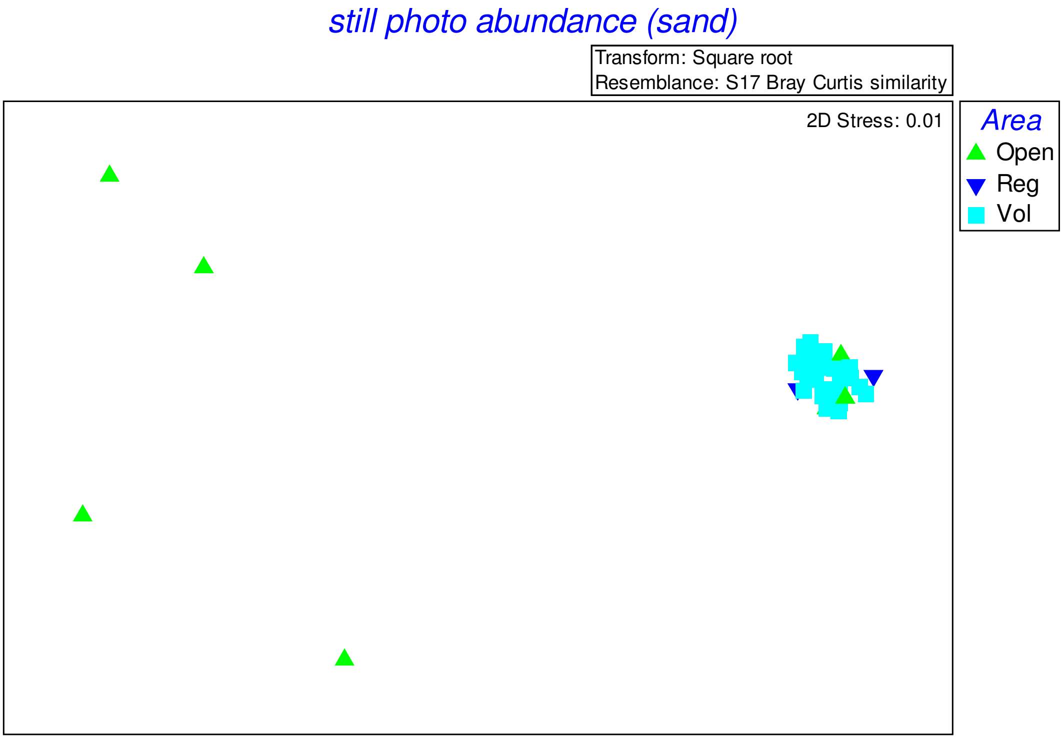


Figure 36: Non-metric MDS plot of the epifaunal communities from sand habitats, from Bray Curtis similarities computed from root transformed abundance data from the still images. Symbols represent fishing history area (see text for details).

Analysis of variance identified significant differences in all the univariate measures except variation in taxonomic distinctness between fishing area (voluntary, regulated, or open), but year and interaction terms were not significant at the 5% level, suggesting no evidence of change between surveys in any of the areas.

ANOSIM was used to examine differences in sponge communities between areas and surveys (Table 12). From the 1999 survey the pairwise ANOSIM tests identified a significant difference between the sponge communities in the voluntary and open areas. The pattern was similar in 2006, although the difference was not significant at the 5% level (P = 6.7%). Comparing the communities within areas between years did not identify any significant differences, although the difference for the voluntary area was almost significant at the 5% level (P = 7.4%). The low number of samples from the 2006 survey will have limited the statistical power to detect differences (although more for the open and regulated areas than for the voluntary area).

Table 11: Overall dissimilarity between recorded epifaunal communities from still images from open, regulated and voluntarily closed areas, and individual species contribution to the dissimilarity. AvAbund – average abundance of species in respective group; AvDiss – average contribution of species to dissimilarity between groups; Diss/SD – ratio of contribution to dissimilarity to its standard deviation; Contrib % - percentage of total dissimilarity; Cum % - cumulative % dissimilarity.

Groups OpenSand & RegSand

Average dissimilarity = 100.00

	Group OpenSand	Group RegSand				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib %	Cum %
HYDROID: *Nemertesia elongata* Totton, 1930	1.49	0	25.9	1.08	25.9	25.9
HYDROID: *Gonaxia* sp 1 (irregular multipinnate)	0	0.67	22.4	1.04	22.4	48.3
ALGAE: Red algae sp 1 (filamentous streamers)	0.72	0	19.15	0.6	19.15	67.45
HYDROID: *Crateritheca novaezelandiae*	1.22	0	12.27	0.6	12.27	79.71
Callyspongia n. sp. 16 (Spirits Bay serrated)	0	0.33	11.2	0.59	11.2	90.91

Groups OpenSand & VolSand

Average dissimilarity = 92.04

	Group OpenSand	Group VolSand				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib %	Cum %
HYDROID: *Nemertesia elongata* Totton, 1930	1.49	0.43	17.27	1.09	18.76	18.76
HYDROID: *Crateritheca novaezelandiae*	1.22	0.17	11.7	0.72	12.71	31.47
ALGAE: Red algae sp 1 (filamentous streamers)	0.72	0	11.38	0.54	12.36	43.83
Tethyopsis mortensoni (Burton, 1924)	0	0.35	5.13	0.37	5.58	49.41
Tedania n. sp. 1 (Spirits Bay white filmy turrets)	0	0.36	4.19	0.48	4.55	53.96
HYDROID: *Gonaxia* sp 1 (irregular multipinnate)	0	0.26	4.07	0.38	4.42	58.38
Oceanapia n. sp. 4 (pink translucent turnip)	0	0.27	3.2	0.42	3.48	61.86
ASCIDIAN: Ascidian sp 1 (massive sandy foliose)	0.09	0.07	2.84	0.34	3.09	64.94
Polymastia croceus Kelly-Borges & Bergquist, 1997	0	0.15	2.84	0.31	3.08	68.03
Trachycladus stylifer Dendy, 1924	0	0.21	2.53	0.46	2.75	70.77
BRYOZOAN: *Steginoporella perplexa* Livingstone, 1929	0	0.19	2.44	0.3	2.65	73.42
Oceanapia cf *aberrans* Dendy, 1924	0	0.13	2.27	0.29	2.47	75.89
ALGAE: *Ecklonia radiata* (Ahipara variety)	0.09	0	2.2	0.27	2.39	78.28
Hymeniacidon n. sp. 1 (ENV9805 very rich orange mounded)	0	0.15	1.8	0.32	1.95	80.23
Iophon minor (Brondsted, 1924)	0	0.14	1.72	0.36	1.87	82.1
Pseudaxinella australis Bergquist, 1970	0	0.13	1.62	0.31	1.76	83.87
Tetilla n. sp. 1 (spirits Bay umbrella anatiaenes)	0	0.17	1.45	0.32	1.57	85.44
Dysidea cf. sp. 2 (ENV9805 blue tough + black stones)	0	0.1	1.26	0.3	1.37	86.8
Axinella australiensis Bergquist, 1970	0	0.07	1.13	0.24	1.23	88.03
Callyspongia n. sp. 16 (Spirits Bay serrated)	0	0.07	0.98	0.26	1.06	89.09
GORGONACEAE: *Callogorgia* sp 1 (dull brownish pink)	0	0.06	0.96	0.18	1.05	90.14

Table 11 continued

Groups RegSand & VolSand
Average dissimilarity = 94.37

Species	Group RegSand Av.Abund	Group VolSand Av.Abund	Av.Diss	Diss/SD	Contrib %	Cum %
HYDROID: *Gonaxia* sp 1 (irregular multipinnate)	0.67	0.26	16.71	1.06	17.7	17.7
HYDROID: *Nemertesia elongata* Totton, 1930	0	0.43	11.45	0.6	12.13	29.83
Callyspongia n. sp. 16 (Spirits Bay serrated)	0.33	0.07	8.47	0.61	8.97	38.81
Tethyopsis mortensoni (Burton, 1924)	0	0.35	6.71	0.39	7.11	45.92
Tedania n. sp. 1 (Spirits Bay white filmy turrets)	0	0.36	5.25	0.5	5.56	51.48
Oceanapia n. sp. 4 (pink translucent turnip)	0	0.27	4.02	0.44	4.26	55.74
HYDROID: *Crateritheca novaezelandiae*	0	0.17	3.99	0.36	4.23	59.97
Polymastia croceus Kelly-Borges & Bergquist, 1997	0	0.15	3.86	0.33	4.1	64.06
Trachycladus stylifer Dendy, 1924	0	0.21	3.2	0.48	3.39	67.45
BRYOZOAN: *Steginoporella perplexa* Livingstone, 1929	0	0.19	3.08	0.31	3.27	70.72
Oceanapia cf aberrans Dendy, 1924	0	0.13	3.03	0.31	3.21	73.92
Hymeniacidon n. sp. 1 (ENV9805 very rich orange mounded)	0	0.15	2.24	0.33	2.37	76.3
Iophon minor (Brondsted, 1924)	0	0.14	2.18	0.38	2.31	78.61
Pseudaxinella australis Bergquist, 1970	0	0.13	2.04	0.33	2.16	80.77
Tetilla n. sp. 1 (spirits Bay umbrella anatiaenes)	0	0.17	1.74	0.33	1.84	82.61
Dysidea cf. sp. 2 (ENV9805 blue tough + black stones)	0	0.1	1.59	0.32	1.69	84.3
Axinella australiensis Bergquist, 1970	0	0.07	1.5	0.25	1.59	85.89
GORGONACEAE: *Callogorgia* sp 1 (dull brownish pink)	0	0.06	1.26	0.19	1.34	87.23
HYDROID: *Hydrodendron mirabile* (Hinks, 1866)	0	0.07	1.15	0.27	1.22	88.46
ASCIDIAN: Ascidian sp 1 (massive sandy foliose)	0	0.07	1.05	0.26	1.12	89.57
Chondropsis cf n. sp. 1 (ENV9805 brown tough strappy)	0	0.06	0.97	0.19	1.03	90.6

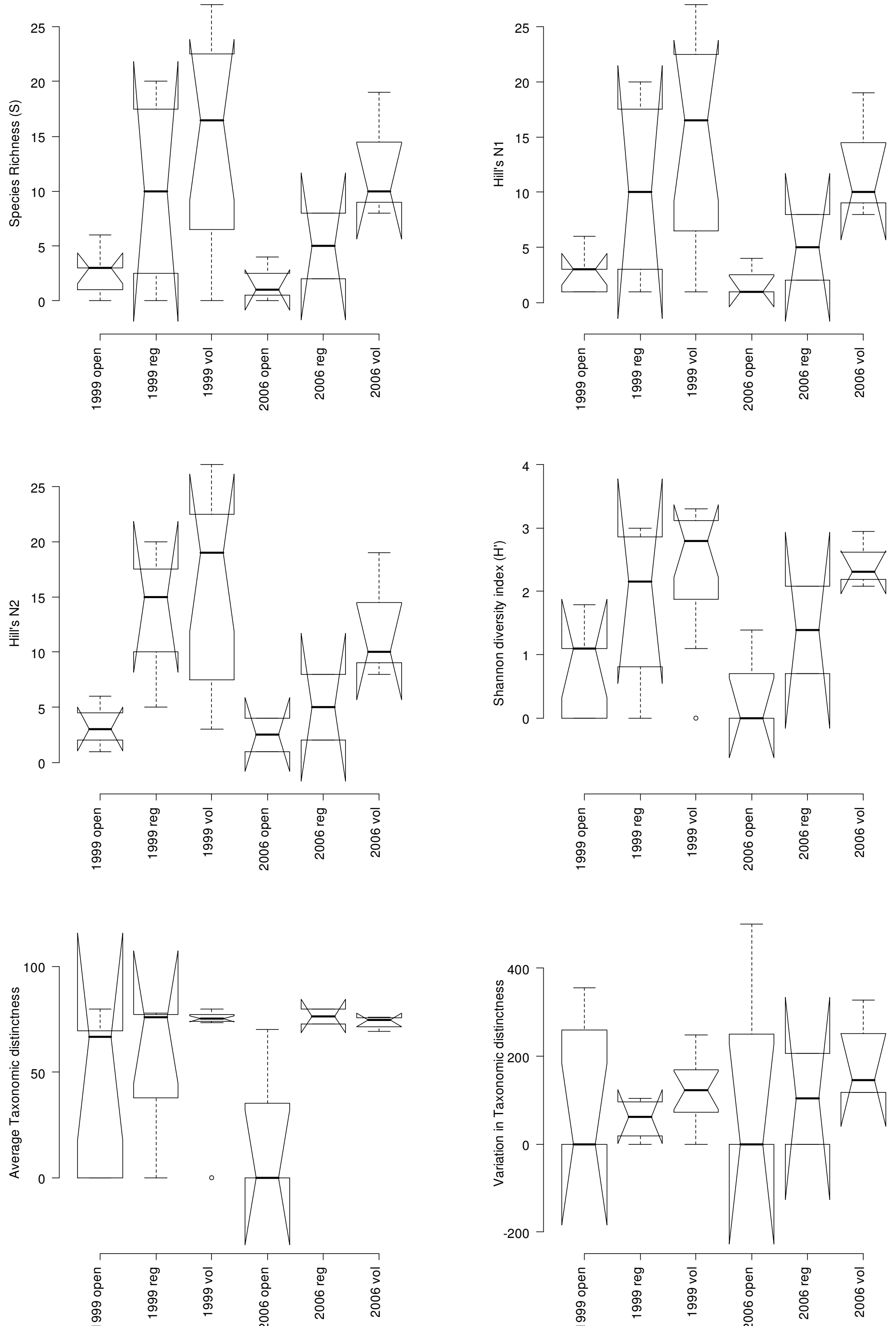


Figure 37: Box and whisker plots of the univariate community measures calculated from the dredge catches of sponges from sand habitats, by fishing area and year.

Table 12: Significance levels and number of permutations (in parentheses) from pairwise ANOSIM tests, examining differences in sponge community structure between fishing areas within and between surveys, from dredge catches on sand habitat. Bold font signifies significance at the 5% level.

1999		reg	vol
	open	100 (10)	3.5 (286)
	reg		84.8 (66)

2006		reg	vol
	open	100 (3)	6.7 (15)
	reg		20 (15)

	1999 v 2006
open	100 (10)
reg	100 (3)
vol	7.4 (999)

Analysis of qualitative faunal abundance from visual sampling

The qualitative data on faunal abundance recorded from the video transects was examined in relation to main habitat, camera type, depth, survey, and fishing area within a tree based model. The pruned regression tree (pruned on basis of cross-validation error) is shown in Figure 38. Important splits that provide the best discrimination between classes are those with the longest branches.

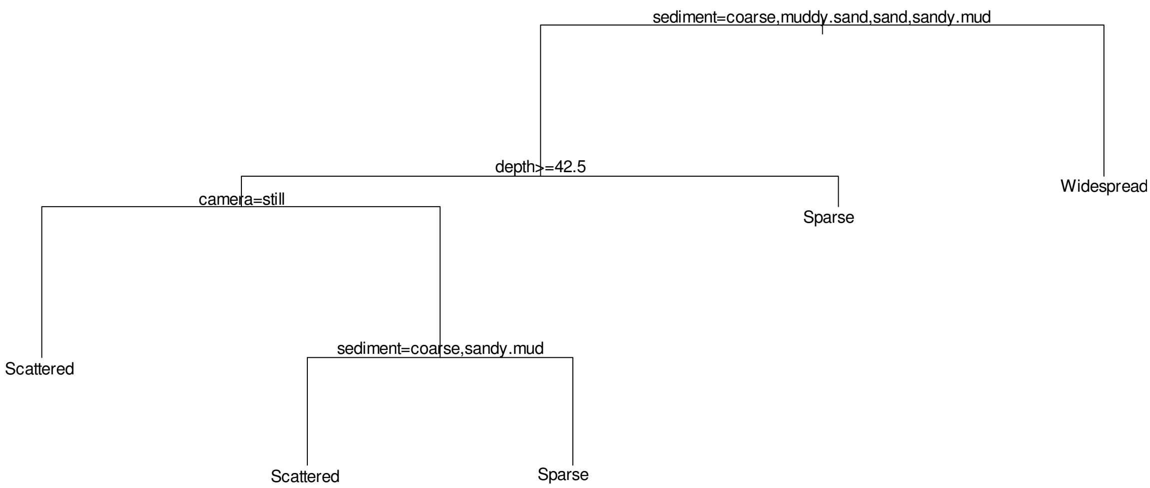


Figure 38: Pruned regression tree of analysis of qualitative faunal abundance data from visual sampling. Factors listed at each split are those for the left limb.

The main habitat type was the most important factor, with the rocky and sand with basement habitats having widespread abundance. Of the remaining habitats, depth was an important factor (sparse fauna shallower than 42.5 m), camera type influenced the classification of faunal abundance (still images tending to be categorised as scattered), and of the video stations, the coarse and sandy mud habitat stations had greater faunal abundance (scattered) than the sand and muddy sand habitats (sparse). The discrepancy between faunal classification from still and video data was identified earlier (see Table 8), and probably relates to image quality. Neither fishing area (open, regulated, voluntary) or survey year (1999, 2006) were retained in the pruned tree, suggesting these were not important factors in determining abundance class in these data.

5. Development of risk assessment methodology

Vulnerability (sensitivity and recoverability)

The sensitivity of the sponges and other species identified from images to various sources of physical disturbance, and factors influencing recoverability following disturbance, have been categorised following Table 2 (independently of the examination of species contributing to the differences between fishing areas). This is a relatively new field of research for marine communities (Hiscock & Tyler-Walters 2006), and is somewhat subjective. Some aspects of the categories have had to be interpreted from knowledge of life histories, since specific investigations into species sensitivities have not been conducted. However, we are confident that our categorisations are on the basis of the best available information. The data are presented in Table 13 for rocky habitat and Table 14 for sand, sand with basement, and coarse habitats.

Sensitivities and recoverability factors (Table 13 and 14) are traffic light colour coded (red – more sensitive to damage, less potential to recover; green – less sensitive to damage, more potential to recover) to aid visualisation. Species rows in the tables with more red (particularly in sensitivity to dredging and potential for recoverability) are likely to be less abundant in areas impacted by dredging.

Within the rocky habitats (Table 13), most species recorded in the images are considered relatively robust to the natural disturbances considered (wash and currents). Sensitivity to dredge impact ranged from robust to sensitive, with the vast majority of species split evenly between moderately sensitive and sensitive. Growth ranged from very slow to rapid, but potential for recovery by reattachment was generally poor. The species (all sponges) likely to be most vulnerable (combining sensitivity to impact with poorer growth and recoverability) are the various *Callyspongia* spp., *Iophon minor*, *Tethya fastigata*, *Petrosia hebes*, *Xestospongia coralloides*, *Psammocinia* cf *hawere*, and *Tetilla* n. sp. 1.

All but one of the species identified from images in the sandy habitats were categorised as sensitive to dredging (Table 14), but were mostly moderately sensitive to current and wave disturbance. Growth varied between species, but of the species observed in the sandy habitats, a higher proportion than other habitats were categorized with rapid growth (reaching typically observed maximum size in 0–2 years). Potential for recovery was poor for some species, but overall, (of those recorded) species from sandy habitats appeared to have better scope for recovery than those in rocky habitats (smaller proportion of species with poor potential). The species likely to be most vulnerable (combining sensitivity to impact with poorer growth and recoverability) are the sponge *Tethyopsis mortensoni,* the unidentified ascidian sp. 1, and the bryozoan *Steginoporella perplexa*.

Within the sand with basement habitat most species were considered sensitive to dredging (Table 14), but were generally robust to wash, currents, and sediments. Growth varies between species, with just over half the recorded species having moderate growth. Potential for recovery was generally poor, although two *Cinachyra* species were considered to have good potential for recovery by re-anchoring.

The species likely to be most vulnerable (combining sensitivity to impact with poorer growth and recoverability) are the unidentified gorgonial coral *Callogorgia* sp. 1 and the hydroid *Hydrodendron mirabile*. Of the sponges recorded, *Dictyodendrilla dendyi*, *Pararhaphoxya pulchra*, and *Polymastia aurantium* are all considered to have poor potential for recovery, but the former is categorised as having rapid growth, while the latter two are considered to be moderately sensitive to dredging.

Table 13: A summary of the sensitivity and recoverability factors for the rocky habitat species identified from images. Species are grouped by recognisability, and within the easily recognisable group, by frequency of occurrence in the Spirits Bay data set (common – C; moderately common – Mc; uncommon – U). Sensitivity and recoverability categories have been colour coded to aid visualisation (red – sensitive and slow to recover; green – robust and fast growing). Size categories, L – large; Md – medium; Sm – small. Sensitivity categories; R – robust; M – moderate; S – sensitive. Growth categories, VS – very slow; Sl - slow; M – moderate; Ra – rapid. Recovery categories, G – good; M – moderate; P – poor.

Species	**Frequency**	**Shape**	**Size**	**Dredging**	**Wash**	**Currents**	**Sediments**	**Growth**	**Recovery by wedging**	**Recovery by anchoring**	**Recovery by rolling**
Easily recognisable											
Ancorina alata Dendy, 1924	C	loaf	L	R	R	R	R	Sl	M	P	G
Callyspongia latituba (Dendy, 1924)	C	strapp	L	S	R	R	R	M	P	P	P
Callyspongia ramosa (Gray, 1843)	C	strapp	L	S	R	R	R	M	P	P	P
Dactylia palmata Carter 1885	C	palmat	L	S	S	M	M	M	M	P	M
Iophon minor (Brondsted, 1924)	C	strapp	L	M	R	R	R	Sl	P	P	P
Latrunculia kaakaariki Alvarez et al., 2002	C	loaf	Md	S	R	R	M	M	M	P	P
Latrunculia oxydiscorhabda Alvarez et al., 2002	C	thick	Md	M	R	R	M	M	P	P	P
Leucettusa lancifer Dendy, 1924	C	spheric	Sm	M	M	M	M	Ra	P	P	P
Polymastia croceus Kelly-Borges & Bergquist, 1997	C	loaf	Md	S	R	R	R	Ra	P	P	P
Trachycladus stylifer Dendy, 1924	C	bushy	Md	M	R	R	R	Sl	P	P	P
ALGAE: *Ecklonia radiata* (Ahipara variety)	Mc	strapp	L	M	M	M	R	M	P	P	P
Chondropsis cf n. sp. 1 (ENV9805 brown tough strappy)	Mc	strapp	Sm	S	S	R	R	Ra	P	P	P
Clathria multitoxiformis Bergquist & Fromont, 1988	Mc	palmat	Sm	M	R	R	R	M	P	P	P
Dendrilla rosea (Lendenfeld, 1883)	Mc	bushy	Md	M	M	M	S	Ra	P	P	P
Petrosia hebes (Lendenfeld, 1888)	Mc	thick	Md	S	R	R	R	Sl	P	P	P
Stelletta maori Dendy, 1924	Mc	bowl	Md	R	R	R	R	**VS**	M	P	M
Tethya fastigata Bergquist & Kelly-Borges, 1991	Mc	spheric	Sm	S	R	R	M	M	P	P	P
Biemna rufescens Bergquist & Fromont, 1988	U	loaf	Md	S	M	M	M	M	P	P	M
Callyspongia n. sp. 16 (Spirits Bay serrated)	U	strapp	Md	S	R	R	R	M	P	P	P
Callyspongia n. sp. 17 (Spirits Bay raised oscules)	U	strapp	Md	S	R	R	R	M	P	P	P
Dragmacidon n. sp. 1 (Three Kings thick papillate	U	thick	Sm	M	R	R	M	Ra	P	P	P
Dragmacidon n. sp. 2 (Spirits Bay flanged)	U	fan	Sm	M	R	R	R	M	P	P	P
HYDROID: *Crateritheca novaezelandiae*	U	strapp	Md	S	R	R	M	M	M	P	P
Polymastia massalis Carter, 1886	U	loaf	Md	M	R	R	R	M	P	P	P
Psammosinia beresfordi Cook & Bergquist, 1998	U	palmat	Md	M	R	R	R	Ra	P	P	P
Pseudaxinella australis Bergquist, 1970	U	thick	Sm	R	R	R	M	M	P	P	P
ASCIDIAN: *Pseudistoma novaezelandiae*	U	spheric	Sm	M	R	R	R	Ra	P	P	P
Raspailia topsenti Dendy, 1924	U	bushy	Sm	M	R	R	R	M	P	P	P
Stelletta crater Dendy, 1924	U	bowl	L	M	R	R	R	**VS**	M	P	M
Xestospongia coralloides (Dendy, 1924)	U	fan	L	S	R	R	M	Sl	M	P	P
Recognisable but easily confused with other species											
Axinella n. sp. 6 (ENV9805 like *Stylotella conulose*)		loaf	Sm	M	R	R	M	M	P	P	P
Crella n. sp. 1 (pale blue cratered mass)		thick	Sm	M	R	R	M	Ra	P	P	P
Psammocinia cf *amodes* Cook & Bergquist, 1998		palmat	Sm	M	R	R	R	Ra	P	P	P
Psammocinia cf *hawere* Cook & Bergquist, 1998		fan	Md	S	R	R	R	M	P	P	P
Tetilla n. sp. 1 (spirits Bay umbrella anatiaenes)		spheric	Sm	S	R	R	M	M	P	P	P
ID uncertain and easily confused with other species											
Axinella sp. 1 (Three Kings bushy club)		bushy	Sm	M	R	R	R	M	P	P	P
BRYOZOAN: Bryozoan sp 1 (feathery mass)		feather	Sm	S	M	M	M	Ra	P	P	P
BRYOZOAN: *Cellaria immersa* (Tenison Woods, 1880)		feather	Sm	S	S	M	M	Ra	P	P	P
Crella incrustans (Carter, 1885)		thick	Md	M	R	R	M	Ra	P	P	P
HYDROID: Hydroid sp 1 (short multipinnate red)		feather	Sm	S	R	R	M	M	M	M	P
Oceanapia cf *aberrans* Dendy, 1924		spheric	Sm	S	M	M	R	Ra	P	M	P
Pararhaphoxya n. sp. 1 (tiny orange branches)		bushy	Md	M	R	R	R	Ra	P	P	P
Raspailia n. sp. 5 (Spirits Bay palmate)		strapp	Sm	S	M	M	R	Ra	P	P	P

Of the species recorded from the coarser gravel habitats, most were considered sensitive to dredging (Table 14), but generally not sensitive to wash, currents, or sediment. Growth rates were moderate or rapid, and although potential for recovery varied, it appeared generally better than for the other habitats. The species likely to be most vulnerable (combining sensitivity to impact with poorer growth and recoverability) is *Axinella australiensis*.

Representativeness

A further consideration in relation to the risk assessment process is a species' representativeness (are they widespread, or only found in this particular location). Although our knowledge of the distribution of sponge species is far from complete, the sponges of the Spirits Bay region have been the subject of a number of studies (both between North Cape and Cape Reinga, and at the Three Kings Islands and Pandora Bank).

From the studies to date, 310 sponge species are known from Spirits Bay and the surrounding region. Of these, 87 (28%) are known from Spirits Bay only. An additional 95 (31%) are known from the Spirits Bay region only. Of the 117 genera represented, within New Zealand, 38 (32%) are only found in the Spirits Bay region, and 5 are unique globally to the Spirits Bay region. Two genera (*Crambe* and *Lithoplocamia*) are found elsewhere only in fossil taxa. For each of the sponge species from projects ENV9805 and ENV200523, distribution of recorded New Zealand occurrence is summarised in Appendix 9.9.

The genus and species diversity of marine sponges in the Spirits Bay region is unprecedented in New Zealand, as it is known at present, although little is known about sponge communities at the Poor Knights Islands, and these are expected to be equally diverse and unusual (Kelly et al. 2009).

Table 14: A summary of the sensitivity and recoverability factors for the sand, sand with basement and coarse habitat species identified from images. Species are grouped by recognisability, and within the easily recognizable group, by frequency of occurrence in the Spirits Bay data set (common – C; moderately common – Mc; uncommon – U). Sensitivity and recoverability categories have been colour coded to aid visualisation (red – sensitive and slow to recover; green – robust and fast growing). Size categories, L – large; Md – medium; Sm – small. Sensitivity categories; R – robust; M – moderate; S – sensitive. Growth categories, VS – very slow; Sl - slow; M – moderate; Ra – rapid. Recovery categories, G – good; M – moderate; P – poor.

Species	Frequency	Shape	Size	Dredging	Wash	Currents	Sediments	Growth	Recovery by wedging	Recovery by anchoring	Recovery by rolling
Sand											
Easily recognisable											
ALGAE: Red algae sp 1 (filamentous streamers)	C	strappy	Md	S	M	M	M	Ra	P	P	P
HYDROID: *Gonaxia* sp 1 (irregular multipinnate)	C	feathery	Sm	S	R	R	M	Ra	P	P	P
HYDROID: *Nemertesia elongata* Totton, 1930	C	feathery	Md	S	R	R	R	Sl	M	M	P
Oceanapia n. sp. 4 (pink translucent turnip)	C	spherical	Sm	S	M	M	R	M	P	M	P
Tedania n. sp. 1 (Spirits Bay white filmy turrets)	C	loaf	Sm	S	M	M	R	Ra	M	M	P
Tethyopsis mortensoni (Burton, 1924)	C	spherical	Sm	S	M	S	R	M	P	P	P
ASCIDIAN: Ascidian sp 1 (massive sandy foliose)	U	foliose	L	S	R	R	R	**VS**	P	M	P
ASCIDIAN: SO *Aplousobranchia* sp 1 (smoked roe)	U	spherical	Sm	S	M	M	M	Ra	P	P	P
BRYOZOAN: *Steginoporella perplexa* Livingstone,	U	fan	Sm	S	M	M	R	M	P	P	P
Dysidea cf. n. sp. 2 (ENV9805 blue tough + black stones)	U	palmate	Sm	M	R	R	R	Ra	G	G	M
Hymeniacidon n. sp. 1 (ENV9805 very rich orange	U	loaf	Md	S	M	M	M	Ra	M	M	G
Hymeniacidon sphaerodigitata Bergquist, 1970	U	loaf	Md	S	M	M	M	Ra	M	M	G
Oceanapia cf arcifera Dendy, 1924 (purple brown tipped papery fistules; cf NIWAKD 056 aberrans)	U	spherical	Sm	S	M	M	R	Ra	P	M	P
Tedania cf *connectens* (Brondsted, 1924)	U	loaf	Md	S	M	M	M	Ra	G	G	G
Sand with basement											
Easily recognisable											
Dictyodendrilla dendyi Bergquist, 1996	Mc	bushy	Md	S	M	M	S	Ra	P	P	P
Aaptos globosum Kelly-Borges & Bergquist, 1994	U	spherical	Sm	S	R	R	R	M	P	P	M
Cinachyra n. sp. 1 (Spirits Bay large grey ball with	U	spherical	Sm	S	M	M	R	M	M	G	P
Cinachyra uteoides Dendy, 1924	U	spherical	Sm	S	S	S	R	M	M	G	P
GORGONACEAE: *Callogorgia* sp 1 (dull brownish	U	feathery	L	S	R	R	R	Sl	P	P	P
HYDROID: *Hydrodendron mirabile* (Hinks, 1866)	U	feathery	L	S	R	R	M	Sl	P	P	P
Pararhaphoxya pulchra (Brondsted, 1923)	U	bushy	Md	M	R	R	R	M	P	P	P
Polymastia aurantium Kelly-Borges & Bergquist, 1997	U	loaf	Md	M	R	R	R	Ra	P	P	P
Stylissa n. sp. 1 (Spirits Bay fingery club)	U	fan	Sm	S	M	M	R	M	M	M	M
Coarse material (sand gravel shell)											
Recognisable but easily confused with other species											
Axinella australiensis Bergquist, 1970		strappy	Md	M	R	R	R	M	P	P	P
Ciocalypta cf *polymastia* (Lendenfeld, 1888)		loaf	Md	S	S	M	M	M	M	G	G
Hymeniacidon n. sp. 1 (ENV9805 very rich orange		loaf	Md	S	M	M	M	Ra	M	M	G
Oceanapia n. sp. 5 (double blind fistules)		spherical	Sm	S	M	M	R	Ra	P	M	P

Likelihood

Scallops are observed in habitats ranging from gravelly to muddy areas, and may therefore occur in some of the areas categorized as coarse in this study, in addition to the sandy areas. Scallop dredgers rarely operate in depths exceeding 60 m in this area, but trawling occurs in all depths greater than about 20 m. Trawling with lighter trawl gears in the coarse sand gravel rock (see Figure 26b) might cause gear damage, and so such areas may be avoided by some fishers, but such habitat would not inhibit heavier scallop dredges.

The sandy habitats recorded in the area are more likely to be fished by both gears, and given that the basement appears to be relatively low lying, this is likely to include the sand with basement habitat. The rocky areas would generally be avoided by all mobile fishing gear in the area, and are therefore unlikely to be impacted. Within the study area, the muddier habitats are relatively deep (> 70 m), and are outside the recognized scallop grounds (as defined by scallop survey strata, see Figure 15), and it is very unlikely these areas would have been scallop dredged. Prior to the introduction of the regulated closure in 1999, however, the muddy areas will have been trawled (see Figure 16).

Overall, the habitats most likely to be impacted by bottom trawl and scallop dredge gear are the sandy and gravelly areas. Within these habitats, the species recorded from photographs in the gravelly habitats appear (from our classification of sensitivities) to be more robust to the effects of dredging than those from sandy habitats. The most vulnerable species appear to be the sponge *Tethyopsis mortensoni,* the unidentified ascidian sp. 1 and the bryozoan *Steginoporella perplexa* (from sandy habitats), the unidentified gorgonial coral *Callogorgia* sp. 1 and the hydroid *Hydrodendron mirabile* (from the sand with basement habitat), and the sponge *Axinella australiensis* (from the gravelly habitats). There may be other equally or more vulnerable species, but the pool of species considered within this work is limited to those identifiable from still photographs, the sampling approach adopted as the most appropriate for the study, and longer term monitoring of the Spirits Bay area.

In examining the epifaunal communities from seabed images, only sandy habitats were sampled across the range of fishing areas (open, regulated closure since 1999, voluntary closure since 1997). Of the species identified above as being most sensitive, *Tethyopsis mortensoni* was previously identified as being one of the species contributing most to the dissimilarity between areas, being recorded only in the area voluntarily closed since 1997. General absence from the open and regulated area was also a feature of the other species identified as being most sensitive (Table 15). Species listed from each of the more vulnerable habitats have been included in Table 15, but only their presence or absence on sandy habitats is recorded. Only the ascidian was recorded outside the voluntary closed area.

Table 15: Presence/absence on sandy habitats of species identified as likely to be most vulnerable to the effects of dredging, by fishing area.

Species	Open area	Regulated closure	Voluntary closure
Tethyopsis mortensoni	✗	✗	✓
Ascidian sp. 1	✓	✗	✓
Steginoporella perplexa	✗	✗	✓
Callogorgia sp 1	✗	✗	✓
Hydrodendron mirabile	✗	✗	✓
Axinella australiensis	✗	✗	✓

6. MONITORING PROGRAMME DESIGN

There are no other “Spirits Bays” in New Zealand (or elsewhere) for comparison or control, so we propose a monitoring programme based entirely in Spirits Bay. To improve tractability and essentially remove some environmental factors as co-variables, we propose that future monitoring in relation to the effects of fishing and the recovery of benthic communities is restricted to the main survey areas of the present investigation, effectively a “box” surrounding scallop survey stratum 93, previously called the “sponge garden”. Depth within the primary survey area within the present study varies between about 35 and 70 m, and the substrate type probably comprises a modest subset of the types represented in the larger area surveyed in 1999 (Cryer et al. 2000). Most importantly, we think there has probably been marked heterogeneity in the distribution of fishing within the area, although more detailed data would be very useful in determine this more accurately. Assuming that the voluntary and regulated closed areas have been observed, the levels of fishing effort vary from an area closed to scallop dredging since 1997, to an area still open to fishing. Availability to the fleet does not necessarily reflect fishing history, however, or its cumulative impact. Scallop stock assessment surveys have consistently found scallop density to be highest in stratum 93, and it is therefore likely that what fishing effort has taken place in the area (which has declined overall since 1997) may have been concentrated in the available part of this area (some being affected by the regulated closure enforced since 1999). More detailed spatial information on the patterns of fishing activity over time may be available from the scallop fleet (Tuck et al. 2006), and would inform any interpretation of recovery levels.

The previous survey in the area (Cryer et al. 2000) was conducted to characterise the community structure and species diversity of benthic sponge and bryozoan communities, and used a combination of acoustic approaches (sidescan and QTC analysis of echo sounder signal) to classify habitat types, and epibenthic dredge samples to collect fauna. Underwater video was used to verify interpretation of sidescan habitat types, but not as a main sampling tool.

The current survey used both high resolution side-scan sonar and a multibeam echo sounder to map the overall survey area. It was originally intended that analyses of these data would inform the later sampling, but computer failure early in the voyage meant this was not possible. However, both approaches provided valuable maps of the survey area, which were later analysed and interpreted. Although still only preliminary in nature, the analysis of the multibeam data suggests this approach may be more powerful in detecting some broad scale features, since the regular patterns of crests and slopes evident across much of the area from the BPI terrain zones (Figure 21) were simply not visible in the side-scan mosaic (Figure 23). Any future analysis of the multibeam backscatter (not yet possible within existing projects) is also likely to be very informative. Given its location, the sedimentary environment of the Spirits Bay area is likely to be strongly influenced by wave exposure and strong tidal currents. It is unknown whether the ridge-like features to the west, or the more widespread crests and slope features are mobile, but if they were, their movement over time might expose other areas of sand with basement habitat, or smother epifauna. It would therefore be useful if future surveys incorporated some degree of acoustic mapping using multibeam. It is currently unclear whether 100% coverage would be required, or if some lower level of coverage would be sufficient.

Given the potential sensitivity of the habitats and species concerned, and the levels of dedicated sampling and opportunistic collection previously conducted in the area, we specifically avoided a survey design involving wide-scale physical sampling, and would recommend that any future monitoring programme would do the same. Our original plan within the survey conducted for this project was to conduct broad-scale video transects (100s of metres long), stratified partly on the basis of an acoustic survey, using an approach used successfully elsewhere (Hewitt et al. 2004). These video transects would provide qualitative and quantitative data on the broader scale patterns of habitat and epifauna, and nested within them, high resolution still images would be used to collect more detailed quantitative data. The use of video transects has proved very successful in relatively sheltered waters (Hewitt et al. 2004), but we found (as did the previous work in the area) that the ability to collect reliable quantitative data on epifauna from video is very sensitive to sea conditions, and cannot be relied upon in the Spirits Bay area. Although no time was lost to weather, sampling procedures had to be modified owing to difficulties in deploying equipment, and this is an important consideration for cost-effective operations in an exposed area like Spirits Bay. The video data were useful for broader scale examination of habitat types. In contrast, the still images proved very useful in examining and identifying epifaunal communities. The preliminary identification guides developed during the project proved to be very useful, and are being developed further within a NIWA Capability Fund project. An optimal approach might be to save survey time by fitting both video and high resolution still cameras to a relatively small system that is “flown” above the seabed. This would provide a continuous video transect for examination of broader scale patterns in habitat (and fauna when conditions were suitable), and high resolution still images, which can be used to provide quantitative data on fauna and are relatively independent of sea conditions. For work in areas like Spirits Bay, having a small system that is deployable in poor sea conditions is an important consideration.

The voluntary closure was introduced by the scallop fishery in 1997, although it is unclear how much scallop dredging took place within this area before the closure. The area was extended, and also closed to all mobile gear in 1999. The survey conducted in 2006 may therefore have been examining communities in their ninth (or more) year of recovery from any scallop dredging in the voluntary area, and in their seventh year of recovery from all mobile fishing in the area covered by the regulated closure. Fishing is permitted outside the closed areas, and trawling has continued within the study area (particularly to the south of stratum 93), but there has been no recorded commercial scallop dredging in any of statistical area

9A since 2004. The species identified as potentially being the most vulnerable (of those recorded from images) typically had moderate or slow growth (taking 2–10 or 10–20 years to reach typical observed maximum size, Table 2), and only one of these species was recorded outside the voluntary closed area (Table 15). Some of the other species contributing most to the dissimilarity between the areas have faster growth (taking up to 2 years to reach observed maximum size), although some were more frequent in the open area, and others in the regulated area, which may reflect different responses to disturbance, or successional change. If fishing disturbance is the reason the more vulnerable species are absent from the open and regulated areas, one might expect some recovery within the regulated closure area over the timescale of 2 to 10 years, depending on any effects on settlement success. Although somewhat subjective, a monitoring frequency of 3 to 5 years would appear to provide a realistic timescale for observable recovery given the species concerned.

We propose a survey design based on sampling a number of "corridors" running north-south across the main survey area examined in the current study. Each of these corridors would cross a gradient of depth and availability to fishing (although it may be possible to be more quantitative about fishing history if data on previous fishing patterns can be gathered), and by monitoring these corridors over time, any changes in communities can be examined. The area of sand with basement at the northern edge of stratum 93 appears to be unique within the study area, and particularly high in sponge diversity (Figure 28), despite its potential vulnerability to disturbance from fishing, and the survey design should ensure this area is adequately monitored.

Within each corridor, multibeam echosounder data would be collected to map seabed features and habitats, and visual sampling would be conducted over broad and finer scales within corridors with high resolution still images nested within a series of longer video transects. Multibeam surveys are usually carried out with survey lines running parallel to depth contours (keeping the swath width relatively constant on a transect), but there is no reason why they could not be run perpendicular to contours (Ian Wright, NIWA., pers. comm.) if 100% coverage of the overall survey area was not required. If this was the case, then some additional east-west survey lines would also be required to monitor any changes in sedimentary features across the area. While costly, multibeam echo sounder data has proved to be particularly useful within this project as an acoustic habitat mapping tool. Exclusion of this approach from future surveys would prevent any examination of changes in spatial distribution of these habitats, which may have knock-on effects for the distribution of the epifaunal and infaunal communities examined through photographic and physical sampling.

As discussed above, the most cost-effective approach to visual sampling would be to combine video and high resolution camera systems into a single system which is "flown" along transects, recording continuous video for broad-scale patterns of habitat and faunal communities, and still images for detailed faunal identification and quantification. The identification guides developed within this project, based on morphological features from photographs, are being developed further, and would form the basis of analysis for the images, avoiding the need to collect physical sponge samples.

The current study has focussed on visual sampling approaches, as these are considered most appropriate for the large epifaunal species of most concern in this area. Infaunal samples are typically time consuming and expensive to analyse, but are the only appropriate approach to examine any changes in infaunal component of the benthic communities. Some infaunal samples have been collected within the current study (although limited resources have meant it has not been possible to work these up), and future monitoring work should also conduct some infaunal sampling on the visual sampling transects.

Future monitoring surveys (on the basis of potential sponge growth rates, every three to five years initially) would therefore include the following stages.

1. Mapping corridors and lines across the survey area (or all survey area) using a multibeam echo sounder.

2. Within each corridor, establish series of sampling transects running north-south. Within these transects, we would make extensive use of high resolution video and digital still photography to provide quantitative estimates of the density of large, distinctive epifauna and determine community types.

3. At each transect, sampling for smaller epifauna and macro-infauna using quantitative corers or grabs. We do not anticipate the need to sample with larger epifaunal dredges in the future.

Differences in community composition between areas and over time would be examined with both univariate and multivariate approaches. A suite of univariate biodiversity indicators has been examined here, and this should be continued with the monitoring as different indices monitor different aspects of diversity. Multivariate approaches may identify changes in community structure that would be missed by the univariate techniques.

Analysis of variance of the univariate community measures within the current study identified significant differences between the fishing areas, showing that the sampling level was sufficient to detect what would be classed as large effect sizes (Cohen 1988). Power analysis based on the sand habitat image community data suggests that realistic levels of sampling are also likely to be able to detect moderate effects (effect size about 0.25), but detecting small effects (effect size about 0.1) would require a considerable increase in sampling effort (see for example Figure 39 for average taxonomic diversity, other measures produced similar figures). Adopting a repeated measures type analysis through repeated monitoring of the area over time would improve the power to detect small effects. The PRIMER software package does not currently include an approach to estimate statistical power, but an approach suitable for analyses based on randomisation of similarity matrices (like the ANOSIM technique) has recently been applied to salt marsh vegetation data (James-Pirri et al. 2007). It has not been possible to apply this approach to the data collected within this project, but such an investigation should be conducted before any monitoring survey.

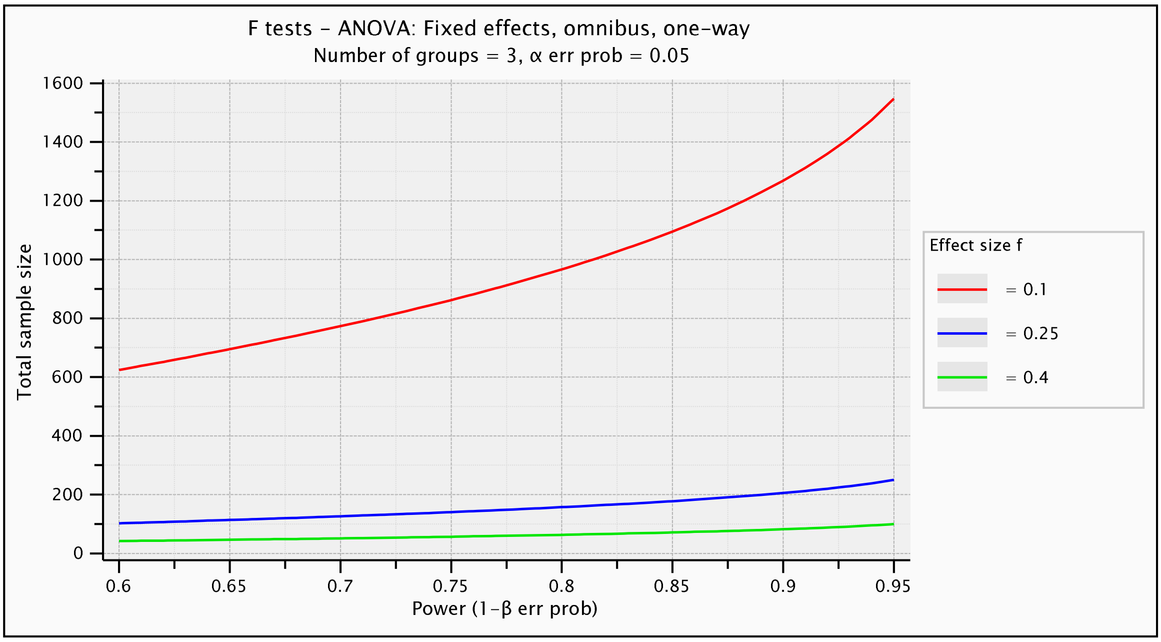


Figure 39: Plot of power against sample size for average taxonomic diversity, based on still image community data from sand habitats. Effect size conventions, 0.1 – small, 0.25 – medium, 0.4 – large effect). Analysis conducted using G*Power 3 (Faul et al. 2007).

7. ACKNOWLEDGMENTS

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9. Data appendices

9.1. Locations of stations sampled with BEVIS video camera sledge.

S no.	Easting	Northing	CS no.
B1	663947.7	6192715	1
B2	663832.6	6193142	2
B3	663670.4	6193909	3
B4	663444	6194200	4
B5	663266.9	6194944	5
B6	663087	6195632	6
B7	663065.2	6196034	7
B8	662910.4	6196576	8
B9	663078.3	6197303	9
B10	663126.1	6198002	10
B11	663234.9	6198361	11
B12	662698.9	6198522	12
B13	662626.2	6198944	13
B14	659525.9	6198794	14
B15	659395.1	6197860	15
B16	659562.7	6197313	16

9.2. Locations of stations sampled with TRITECH video camera sledge.

S no.	Easting	Northing	CS no.	S no.	Easting	Northing	CS no.	S no.	Easting	Northing	CS no.
T1	669162.1	6192382	33	T29	661246.8	6194970	61	T56	663172	6198644	87
T2	669607.1	6193296	34	T30	661299.4	6194072	62	T57	663150.2	6199253	88
T3	669540.6	6194383	35	T31	661095.3	6193152	63	T58	663652.8	6197914	89
T4	669615.4	6195383	36	T32	661199.9	6192206	64	T59	671671.3	6192319	90
T5	669910.5	6196375	37	T33	659249.7	6192678	65	T60	671560.7	6193286	91
T6	669754.4	6197281	38	T34	659212.2	6193687	66	T61	671573.3	6194251	92
T7	669704	6198314	39	T35	659104.6	6194427	67	T62	671536.6	6195182	93
T8	668247.2	6198251	40	T36	659178.5	6195494	68	T63	671643.2	6196120	94
T9	668204.4	6197299	41	T37	659634.9	6196470	69	T64	671638.6	6197067	95
T10	668320.8	6196439	42	T38	659642.5	6197281	70	T65	671716.2	6197937	96
T11	668159.1	6195607	43	T39	659484.4	6197910	71	T66	671622.2	6198849	97
T12	668193.4	6194755	44	T40	659769.7	6198871	72	T67	675352.3	6194897	98
T13	668146.5	6193921	45	T41	665659.7	6199093	73	T68	675306.6	6194045	99
T14	668029.1	6193082	46	T42	665700	6198134	74	T69	675288	6193100	100
T15	668610.5	6192010	47	T43	665619.7	6197184	75	T70	675456.7	6192131	101
T16	669720.9	6192090	48	T44	665570.5	6196338	76	T71	673731	6192390	102
T17	664599.7	6192212	49	T45	665600.9	6195549	77	T72	673458.7	6193092	103
T18	664397.8	6193279	50	T46	665520.8	6194626	78	T73	673557.5	6194284	104
T19	664453	6194290	51	T47	665464.6	6193605	79	T74	673604.6	6195083	105
T20	664508.1	6195270	52	T48	665320.2	6192607	80	T75	673688.7	6196292	115
T21	664412.4	6196219	53	T49	663234.3	6192363	81	T76	673534.3	6196973	116
T22	664387	6197268	54	T50	663250.6	6193416	82	T77	673539.6	6197965	117
T23	664480.8	6198340	55	T51	663152.3	6194417	83	T78	673615	6198938	118
T24	664357.1	6199347	56	T52	663144.8	6195447	84-1	T79	675537.9	6198903	119
T25	661323.3	6198632	57	T53	663185.5	6195534	84-2	T80	675320.9	6197851	120
T26	661248.1	6198074	58	T54	663155	6196506	85	T81	675303.4	6196852	121
T27	661219	6196956	59	T55	663156.9	6197610	86	T82	675296.4	6195934	122
T28	661293.5	6195896	60								

9.3. Locations of stations sampled with Benthos ROV.

S no.	Easting	Northing	CS no.
R1	663238.8	6194728	85
R2	662957.3	6193096	2
R3	662942.7	6196162	85
R4	663518.8	6196301	85
R5	664024.5	6196530	85
R6	665912	6198452	74
R7	668418.6	6196694	42
R8	659872.4	6197125	70
R9	658623.3	6194166	6
R10	658940.3	6192534	27, 65
R11	666840.2	6192534	17
R12	664258.8	6198177	55
R13	664253.3	6198321	55
R14	669856.8	6196520	37

9.4. Locations of stations sampled with Middle depths digital still camera system.

S no.	Easting	Northing	CS no.
SC01	666781.3	6192650	17
SC02	666999	6193887	18
SC03	667068	6194995	19
SC04	666617.4	6195920	20
SC05	666702.1	6197296	21
SC06	666712.5	6198331	22
SC07	659645.5	6196449	23
SC08	659045.8	6195535	24
SC09	659092.9	6194546	25
SC10	659225	6193641	26
SC11	659219.2	6192672	27
SC12	661155.9	6192167	28
SC13	661092.8	6193110	29
SC14	661332.7	6194148	30
SC15	661241.4	6194998	31
SC16	661376.7	6195870	32
SC17	664006.2	6195331	106
SC18	663181.1	6196491	107
SC19	663141	6197669	108
SC20	665531.4	6198300	109
SC21	659523.2	6197257	110
SC22	661196.5	6194976	111
SC23	667887	6193941	112
SC24	669708.7	6193344	113
SC25	669582.8	6192551	114

9.5. Locations of stations sampled with epibenthic dredge.

S no.	Easting	Northing
D1	673799.7	6193221
D2	673624.1	6194237
D3	669918.5	6196469
D4	668446.5	6196577
D5	664503.3	6198246
D6	663343.8	6196462
D7	661334.8	6194818
D8	659011.3	6194364
D9	663823	6193172

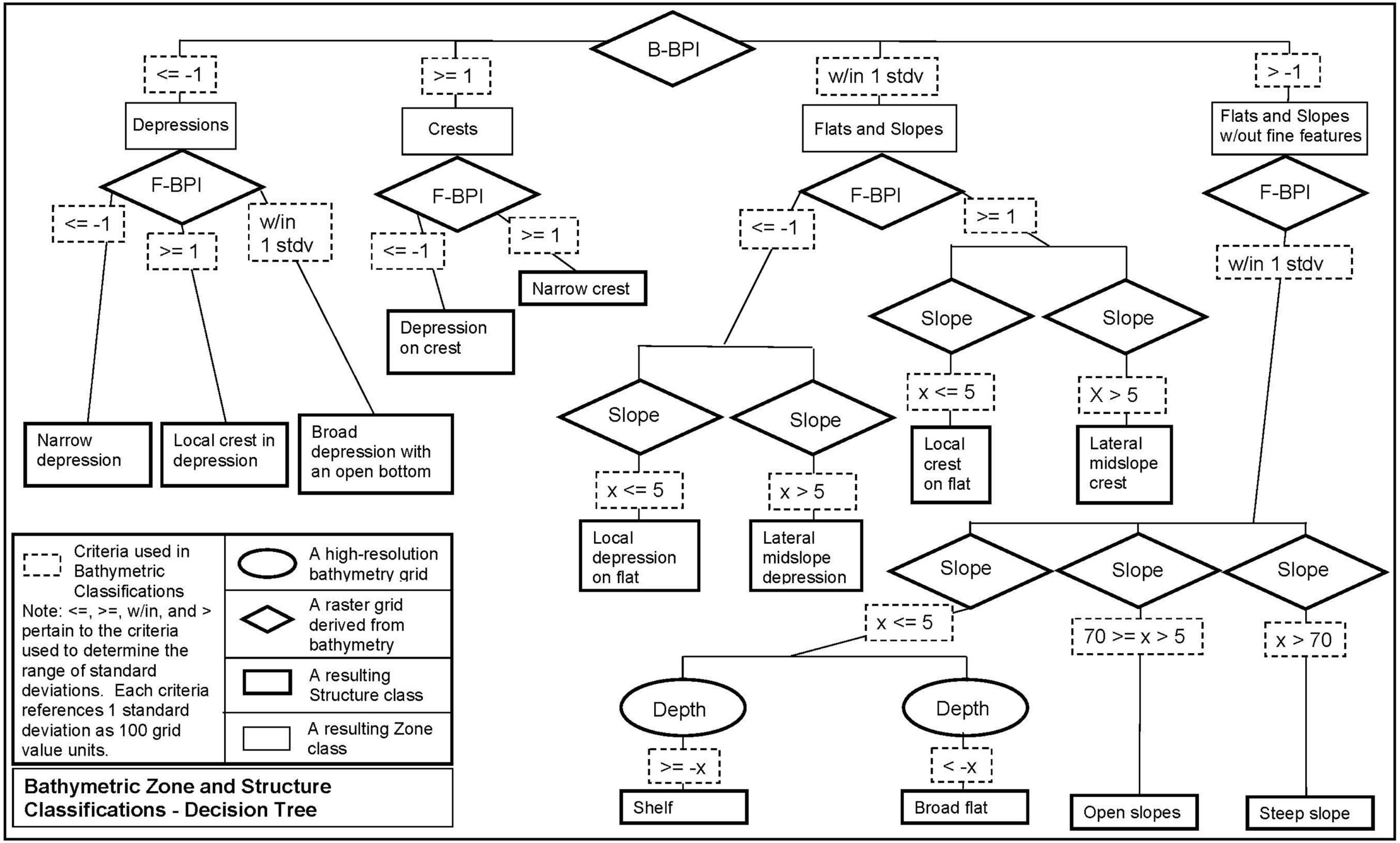
9.6. Locations of stations sampled with Smith-McIntyre grab

S no.	Easting	Northing	S no.	Easting	Northing
GS1	659142.1518	6192771.347	GS19a	665415.9659	6196274.791
GS2a	659242.0884	6194497.606	GS19b	665782.9303	6196302.247
GS2b	659026.5896	6194445.815	GS20a	665331.4064	6198145.093
GS3a	659582.4198	6196470.143	GS20b	665452.2752	6198124.627
GS3b	659428.5033	6196435.795	GS21a	666339.8522	6197073.256
GS4a	659407.1364	6197878.32	GS21b	666417.1608	6197108.858
GS4b	659182.9816	6197673.211	GS22a	666482.5318	6195001.641
GS5a	661468.8253	6199155.641	GS22b	666579.1599	6195016.595
GS5b	661482.241	6199044.473	GS23a	666305.7388	6192580.784
GS6a	661337.22	6196865.229	GS23b	666336.3838	6192580.237
GS6b	661382.5686	6196827.466	GS24a	667985.0006	6193091.605
GS7a	661426.5936	6194940.778	GS24b	668016.203	6193086.325
GS7b	661532.5959	6194864.985	GS25a	667953.225	6194696.112
GS8a	661240.7286	6193058.062	GS25b	667940.7365	6194580.659
GS8b	661332.6665	6193056.472	GS26a	668137.1294	6196393.899
GS9a	663273.8598	6192330.342	GS26b	668242.2774	6196377.445
GS9b	663481.5413	6192353.401	GS27a	668124.7608	6198261.629
GS10a	663074.3814	6194486.853	GS27b	668099.4586	6198193.241
GS10b	663332.9717	6194371.389	GS28a	669177.6564	6192048.346
GS11a	663080.6375	6196334.062	GS28b	669101.7181	6192086.705
GS11b	663245.42	6196293.953	GS29a	669668.406	6194591.108
GS12a	663160.7834	6198553.064	GS30a	669824.0162	6196454.541
GS12b	663420.4595	6198493.055	GS31a	675330.0653	6197639.671
GS13a	664075.121	6199091.736	GS31b	675313.4221	6197738.382
GS13b	664288.8088	6199032.511	GS32a	671505.1064	6197983.102
GS14a	664163.3366	6197130.277	GS32b	671372.7561	6198214.702
GS14b	664439.5998	6197143.904	GS33a	669543.9963	6194459.29
GS15a	664308.8993	6195212.362	GS34a	669788.7996	6196444.063
GS15b	664281.4873	6195131.302	GS34b	669718.3616	6196494.71
GS16a	664432.159	6193242.682	GS35a	669483.0544	6198276.831
GS16b	664601.3701	6193276.676	GS35b	669386.7668	6198342.115
GS17a	665184.2482	6192434.317			
GS17b	665307.4815	6192469.112			
GS18a	665005.7326	6194490.6			
GS18b	665189.2979	6194449.633			

9.7. Classification scheme for BPI Zones and Structures. Source (Lundblad et al. 2006)

Zones	
Crest	High points in the terrain where there are positive bathymetric position index values greater than one standard deviation from the mean in the positive direction.
Depressions	Low points in the terrain where there are negative bathymetric position index values greater than one standard deviation from the mean in the negative direction.
Flats	Flat points in the terrain where there are near zero bathymetric position index values that are within one standard deviation of the mean. Flats have a slope that is <=5^{o}.
Slopes	Sloping points in the terrain where there are near zero bathymetric position index values that are within one standard deviation of the mean. Slopes have a slope that is >5^{o}.
Structures	
Narrow depression	A depression where both fine and broad scale features within the terrain are lower than their surrpoundinGS.
Local depression on flat	A fine scale depression within a broader flat terrain
Lateral midslope depression	A fine scale depression that laterally incises a slope.
Depression on crest	A fine scale depression within a crested terrain.
Broad depression with an open bottom	A broad scale depression with a U-shape where any nested, fine scale features are flat or have constant slope.
Broad flat	A broad flat area where the terrain contains few, nested, fine scale features.
Shelf	A broad flat area where the terrain contains few, nested, fine scale features. A shelf is shallower than 22m.
Open slope	A constant slope where the slope values are between 5^{o} and 70^{o} and there are few, nested, fine scale features within the broader terrain.
Local crest in depression	A fine scale crest within a broader depressed terrain.
Local crest on flat	A fine scale crest that laterally divides a slope. This often looks like a ledge in the middle of a slope.
Narrow crest	A crest where both fine and broad features within the terrain are higher that their surroundinGS.
Steep slope	An open slope with a slope value greater than 70^{o}.

9.8. Flowchart of the decisions made by the algorithms that derive the zone and structure classes from the broad (B-BPI) and fine (F-BPI) scale BPI, slope and depth. Source (Lundblad et al. 2006)



9.9. Summary of Spirits Bay sponge species distribution of recorded occurrence.

Identification	Order	SPIRITS BAY ONLY	SPIRITS BAY REGION	NORTHLAND	SOUTH ISLAND
Ancorina alata Dendy, 1924	Astrophorida		X	X	
Ancorina n. sp. 1 (streptasters, oxyasters 80, tridents, 3Kings)	Astrophorida		X		
Ancorina n. sp. 2 (amphiasters, oxyasters 30, dichotriaenes, 3Kings	Astrophorida		X		
Ancorina novae-zelandiae Dendy, 1924	Astrophorida		X	X	
Ancorina stalagmoides	Astrophorida		X		
Asteropus simplex	Astrophorida		X		
Geodia rex	Astrophorida		X	X	
Geodinella vestigifera	Astrophorida		X	X	X
Holoxea n. sp. 1 (trichodragmata)	Astrophorida		X	X	X
Jaspis n. sp. 2 (vermetid yellow ball, Cape Reinga)	Astrophorida		X		
Jaspis novae-zelandiae	Astrophorida		X		
Lamellomorpha n. sp. 1	Astrophorida	X			
Lamellomorpha strongylata Bergquist, 1968	Astrophorida		X		
Pachastrella incrustata	Astrophorida		X		
Pachastrissa (?) n. sp. 1 (black chimney sponge)	Astrophorida		X		
Penares tylotaster Dendy, 1924	Astrophorida		X	X	
Poecillastra laminaris	Astrophorida		X	X	X
Stelletta cf purpurea (Ridley, 1884) (lemon yellow)	Astrophorida		X	X	
Stelletta columna	Astrophorida		X	X	
Stelletta communis (Sollas, 1886)	Astrophorida		X	X	
Stelletta conulosa Bergquist, 1968 (+ dysideid)	Astrophorida		X	X	
Stelletta crater Dendy, 1924 + Desmacella dendyi de Laubenfels, 1936	Astrophorida		X	X	
Stelletta maori Dendy, 1924	Astrophorida		X	X	
Stelletta maxima Thiele, 1898	Astrophorida		X	X	
Stelletta n. sp. 1 (huge fat oxeas)	Astrophorida	X			
Stelletta n. sp. 2	Astrophorida	X			
Stelletta n. sp. 7 (Tethya amplexa mimic 3 Kings)	Astrophorida		X		
Stelletta novae-zelandiae	Astrophorida		X	X	
Stelletta sandalinium Bronsted, 1924	Astrophorida		X	X	
Stryphnus n. sp. 1 (sanidaster egg)	Astrophorida		X		
Tethyopsis (Monosyringia) mortenseni (Brondsted, 1924)	Astrophorida		X	X	
Clathina n. sp. 1 (cream thin encruster, 3 Kings)	Clathrinida		X		
Leucetta n. sp. 1 (pink, shperical clathrous 3Kings)	Clathrinida		X		
Leucetta n. sp. 1(single thick bulb)	Clathrinida		X		
Leucettusa lancifer Dendy, 1924	Clathrinida		X	X	
Leucettusa n. sp. 1 (pale pink mass 3 Kings)	Clathrinida		X		
Leucettusa n. sp. 2 (encrusting tubes)	Clathrinida		X		
Leucettusa tubulosa Dendy, 1924	Clathrinida		X	X	
Chelonaplysilla violacea (Lendenfeld, 1883)	Dendroceratida		X	X	
Darwinella gardineri Topsent, 1905	Dendroceratida		X	X	
Darwinella oxeata Bergquist, 1961	Dendroceratida		X	X	
Dendrilla rosea Lendenfeld, 1883	Dendroceratida		X	X	
Dictyodendrilla dendyi Bergquist, 1996	Dendroceratida		X	X	
Dictyodendrilla n. sp. 1 (grey blue)	Dendroceratida	X			
Dictyodendrilla n. sp. 2 (fawn)	Dendroceratida	X			
Dictyodendrilla n. sp. 3 (black soft tight mesh)	Dendroceratida	X			
Aplysinopsis n. sp. 1	Dictyoceratida	X			
Cacospongia n. sp. 1	Dictyoceratida	X			
Cacospongia n. sp. 2 (digitate, ramose)	Dictyoceratida	X			
Cacospongia n. sp. 3	Dictyoceratida	X			
Cacospongia n. sp. 4 (tough stellate club)	Dictyoceratida	X			
Dysidea cf sp. 2 (ENV9805 blue tough palmate black stones)	Dictyoceratida		X	X	

Identification	Order	SPIRITS BAY ONLY	SPIRITS BAY REGION	NORTHLAND	SOUTH ISLAND
Dysidea cf sp. 6 (ENV9805 sandy ridges, clear)	Dictyoceratida		X	X	
Dysidea cf sp. 7 (ENV9805 ramosa + black stones)	Dictyoceratida		X	X	
Dysidea n. sp. 1 (tough grey ridged - on S. crater)	Dictyoceratida		X	X	
Dysidea n. sp. 2 (blue tough + black stones)	Dictyoceratida		X	X	
Dysidea n. sp. 3	Dictyoceratida		X	X	
Dysidea n. sp. 4	Dictyoceratida		X	X	
Dysidea n. sp. 5 (like G. fibulata)	Dictyoceratida		X	X	
Dysidea n. sp. 6 (ridges sand tent)	Dictyoceratida		X	X	
Dysidea n. sp. 7 (ramosa + black stones)	Dictyoceratida		X	X	
Dysidea n. sp. 8 (Spirits Bay super cavernous)	Dictyoceratida		X		
Narrabeena n. sp. 1 (Pandora Bank)	Dictyoceratida		X		
Psammocinia amodes	Dictyoceratida		X	X	
Psammocinia hawere	Dictyoceratida		X	X	
Sarcotragus n. sp. 2 (North cape lobed)	Dictyoceratida		X		
Spongia (Heterofibria) gorgonocephalus	Dictyoceratida		X	X	
Spongia (Heterofibria) irregularis	Dictyoceratida		X	X	
Spongia (Heterofibria) manipulatus	Dictyoceratida		X	X	
Taonura ?marginalis	Dictyoceratida		X		
Aaptos confertus	Hadromerida		X	X	
Aaptos globosum Kelly-Borges & Bergquist, 1994	Hadromerida		X	X	
Aaptos n. sp. 1 (cream)	Hadromerida	X			
Aaptos rosacea	Hadromerida		X	X	
Cliona celata	Hadromerida		X	X	
Cliona n. sp. 1	Hadromerida	X			
Cliona n. sp. 2	Hadromerida	X			
Cliona n. sp. 3 (yellow in bryo)	Hadromerida	X			
Homaxinella erecta (Brondsted, 1924)	Hadromerida		X	X	
Latrunculia duckworthi Alvarez, Bergquist & Battershill, 2002	Hadromerida		X	X	
Latrunculia kaakaariki Alvarez, Bergquist & Battershill, 2002	Hadromerida		X	X	
Latrunculia n. sp. 3 (large vase papillae)	Hadromerida	X			
Latrunculia n. sp. 4	Hadromerida	X			
Latrunculia n. sp. 5	Hadromerida	X			
Latrunculia oxydiscorhabda Alvarez, Bergquist & Battershill, 2002	Hadromerida		X	X	
Polymastia aurantium Kelly-Borges & Bergquist, 1997	Hadromerida		X	X	
Polymastia cf massalis Carter, 1886	Hadromerida		X	X	
Polymastia crocea Kelly-Borges & Bergquist, 1997	Hadromerida		X	X	
Polymastia echinus	Hadromerida		X	X	
Polymastia hirsuta Bergquist, 1968	Hadromerida		X	X	
Polymastia lorum Kelly-Borges & Bergquist, 1997	Hadromerida		X	X	
Polymastia n. sp. 1	Hadromerida	X			
Polymastia n. sp. 2	Hadromerida	X			
Polymastia n. sp. 3	Hadromerida	X			
Polymastia n. sp. 4	Hadromerida	X			
Polymastiidae n. g. n. sp. 1	Hadromerida	X			
Polymastiidae n. g. n. sp. 2	Hadromerida	X			
Spirastrella n. sp. 1 (rusty ridged 3 Kings)	Hadromerida		X		
Suberites cf axinelloides Brondsted, 1924	Hadromerida		X	X	
Suberites n. sp. 1 (golden aromatic Cape Reinga)	Hadromerida		X		
Suberites n. sp. 2 (erect thin blade)	Hadromerida	X			
Suberites n. sp. 3 (cartilag fungi)	Hadromerida	X			
Suberites perfectus Ridley & Dendy, 1886	Hadromerida		X	X	
Tentorium n. sp. 2 (Spirits Bay hollow base and fistule)	Hadromerida	X			

Identification	Order	SPIRITS BAY ONLY	SPIRITS BAY REGION	NORTHLAND	SOUTH ISLAND
Tethya amplexa Bergquist & Kelly-Borges, 1991	Hadromerida		X	X	
Tethya bergquistae Hooper & Wiedenmayer, 1994	Hadromerida		X	X	
Tethya burtoni	Hadromerida		X	X	
Tethya fastigata Bergquist & Kelly-Borges, 1991	Hadromerida		X	X	
Trachycladus n. sp. 3 (dirty mint feather 3 Kings)	Hadromerida		X		
Trachycladus stylifer Dendy, 1924	Hadromerida		X	X	
Acanthoclada n. sp. 1	Halichondrida	X			
Acanthoclada prostrata Bergquist, 1970	Halichondrida		X		
Axinella australiensis, Bergquist, 1970	Halichondrida		X	X	
Axinella cf richardsoni Bergquist, 1970	Halichondrida		X	X	
Axinella n. sp. 1 (floppy multiple branches)	Halichondrida		X		
Axinella n. sp. 1 (slippery club-bush, Northland)	Halichondrida		X		
Axinella n. sp. 10 (smooth plump serial oscules)	Halichondrida		X		
Axinella n. sp. 2 (brownish orange convoluted surface, Cape Reinga))	Halichondrida		X		
Axinella n. sp. 3 (corrugated flesh conulose, Phakellia dendyi mimic	Halichondrida		X		
Axinella n. sp. 4	Halichondrida	X			
Axinella n. sp. 5	Halichondrida	X			
Axinella n. sp. 6 (like stylotella)	Halichondrida	X			
Axinella n. sp. 7 (encrusting)	Halichondrida	X			
Axinella n. sp. 8 (Ptilocaulis-like)	Halichondrida	X			
Axinella n. sp. 9 (whip-like + Carmia encr)	Halichondrida	X			
Bubaris n. sp. 1	Halichondrida	X			
Bubaris oxeata Dendy, 1924	Halichondrida		X		
Ciocalypta cf polymastia (Lendenfeld, 1888)	Halichondrida		X	X	
Ciocalypta cf sp. 7 (ENV9805 smooth volcano turret)	Halichondrida		X		
Ciocalypta n. sp. 1 (tough blunt fingers)	Halichondrida		X		
Ciocalypta pencillus Bowerbank, 1864	Halichondrida		X	X	
Ciocalypta polymastia (Lendenfeld, 1888)	Halichondrida		X	X	
Ciocalypta sp. 1 (agg base, pale lem, styles + styles)	Halichondrida	X			
Ciocalypta sp. 2 (white, style 5-700, oxeas 170)	Halichondrida	X			
Ciocalypta sp. 3	Halichondrida	X			
Ciocalypta sp. 4 (fibrous orange huge)	Halichondrida	X			
Ciocalypta sp. 5 (orange - thick skin)	Halichondrida	X			
Ciocalypta sp. 6	Halichondrida	X			
Ciocalypta sp. 7 (lemon-grey styles + styles)	Halichondrida	X			
Dragmacidon n. sp. 2 (Spirits Bay flanged)	Halichondrida	X			
Halichondria cf n. sp. 1 (white cake 3 Kings)	Halichondrida		X		
Halichondria n. sp. 1 (mustard mamillate)	Halichondrida		X		
Higginsia n. sp. 1 (floppy cylindrical)	Halichondrida	X			
Higginsia n. sp. 2 (soft apricot encrustor, 3Kings)	Halichondrida		X		
Hymeniacidon hauraki	Halichondrida		X	X	
Hymeniacidon n. sp. 1 (very rich orange mounded)	Halichondrida	X			
Hymeniacidon sphaerodigitata Bergquist, 1970	Halichondrida		X	X	
Pararaphoxya n. sp. 2 (Raspaila topsenti mimic)	Halichondrida		X		
Pararhaphoxya n. sp. 1	Halichondrida		X		
Pararhaphoxya pulchra (Brondsted, 1923)	Halichondrida		X	X	
Phakellia dendyi Bergquist, 1970	Halichondrida		X		
Phakellia n. sp. 1	Halichondrida	X			
Pseudaxinella australis Bergquist, 1970	Halichondrida		X	X	
Pseudaxinella n. sp. 1 (yellow)	Halichondrida	X			
Stylinos n. sp. 1	Halichondrida	X			
Stylissa n. sp. 1 (Spirits Bay fingery club)	Halichondrida	X			

Continuation of summary of Spirits Bay sponge species distribution of recorded occurrence.

Identification	Order	SPIRITS BAY ONLY	SPIRITS BAY REGION	NORTHLAND	SOUTH ISLAND
Topsentia n. sp. 1 (fistular tan)	Halichondrida		X		
Amphimedon n. sp. 1	Haplosclerida	X			
Amphimedon n. sp. 2	Haplosclerida	X			
Callyspongia diffusa (Ridley, 1884) sensu Bergquist& Warne(1980)	Haplosclerida		X	X	
Callyspongia latituba	Haplosclerida		X	X	
Callyspongia n. sp. 1 (bulbous branched, soft)	Haplosclerida	X			
Callyspongia n. sp. 16 (Spirits Bay serrated)	Haplosclerida	X			
Callyspongia n. sp. 17 (Spirits Bay raised oscules)	Haplosclerida	X			
Callyspongia ramosa (Gray, 1843)	Haplosclerida		X	X	
Callyspongiidae n.g., n. sp. 1	Haplosclerida	X			
Calyx imperialis (Dendy, 1924)	Haplosclerida		X		
Calyx n. sp. 1 (pedunculate, mucous, North Cape)	Haplosclerida		X		
Chalinopsilla n. sp. 1 (like Callyspongia)	Haplosclerida	X			
Dactylia n. sp. 1 (branching tangle)	Haplosclerida		X		
Dactylia n. sp. 2 (springy blade, rough)	Haplosclerida		X		
Dactylia palmata Carter, 1885	Haplosclerida		X	X	X
Gellius (Orina) petrocalyx	Haplosclerida		X	X	
Haliclona (Gellius) n. sp. 4 (rose keyhole oscules 3 Kings)	Haplosclerida		X		
Haliclona n. sp. 1 (oxeas 100, digitate)	Haplosclerida		X		
Haliclona n. sp. 10 (pink pad, raised oscules, 110, 3Kings)	Haplosclerida		X		
Haliclona n. sp. 2	Haplosclerida		X		
Haliclona n. sp. 3 (soft dk grn)	Haplosclerida		X		
Haliclona n. sp. 4 (agglutin)	Haplosclerida		X		
Haliclona n. sp. 5 (soft encrust shaggy)	Haplosclerida		X		
Haliclona n. sp. 6 (soft smooth, biggish strap)	Haplosclerida		X		
Haliclona n. sp. 7 (branch, big raised oscules)	Haplosclerida		X		
Haliclona n. sp. 8	Haplosclerida		X		
Neopetrosia n. sp. 1 (thick fleshy plate Great Barrier)	Haplosclerida		X	X	
Neopetrosia n. sp. 1 (thin brittle ear, 3Kings)	Haplosclerida		X		
Neopetrosia n. sp. 3 (volcano ridges, 3Kings)	Haplosclerida		X		
Neopetrosia n. sp. 4 (pocked plate, 160-190 North Cape)	Haplosclerida		X		
Oceanapia cf aberrans Dendy, 1924 (purple tip fistules)	Haplosclerida		X		
Oceanapia n. sp. 1 (turnip)	Haplosclerida	X			
Oceanapia n. sp. 2	Haplosclerida		X		
Oceanapia n. sp. 3 (short digits false halichondrid)	Haplosclerida		X		
Oceanapia n. sp. 4 (brown chunky)	Haplosclerida		X		
Oceanapia n. sp. 4 (pink translucent turnip)	Haplosclerida		X		
Oceanapia n. sp. 5 (double blind fistules)	Haplosclerida		X		
Oceanapia n. sp. 6 (transl windows)	Haplosclerida		X		
Oceanapidae n.g. n. sp. 1 (smooth turrets)	Haplosclerida		X		
Orina n. sp. 1 (toxa feet)	Haplosclerida	X			
Pachypellina n. sp. 2 (red/yellow soft)	Haplosclerida		X		
Petrosia australis Bergquist & Warne, 1980	Haplosclerida		X	X	
Petrosia hebes Lendenfeld, 1888	Haplosclerida		X	X	
Sigmadocia fragilis Berguist & Warne, 1980	Haplosclerida		X	X	
Sigmadocia glacialis (Ridley & Dendy, 1886)	Haplosclerida		X	X	
Xestospongia coralloides (Dendy, 1924)	Haplosclerida		X	X	
Xestospongia n. sp. 1 (purple convoluted plate)	Haplosclerida	X			
Xestospongia n. sp. 2 (crumbly massive)	Haplosclerida	X			
Xestospongia n. sp. 3 (transl golden)	Haplosclerida	X			
Xestospongia novaezelandiae Bergquist & Warne, 1980	Haplosclerida		X	X	
Aciculites pulchra	Lithistid		X	X	

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Aciculites manawatawhi	Lithistid Demospongiae		X		
Homophymia stipitata	Lithistid Demospongiae		X		
Symplectella rowi	Lyssacinosida		X	X	
Amphiastrella kirkpatricki Dendy, 1924	Poecilosclerida		X	X	
Antho (Acarnia) n. sp. 1 (brondstedi with acanthotylotes)	Poecilosclerida		X	X	
Antho (Acarnia) n. sp. 2 (megatoxas 3Kings)	Poecilosclerida		X		
Biemna (Sigmaxinella) flabellata Bergquist, 1970	Poecilosclerida		X	X	
Biemna n. sp. 1	Poecilosclerida		X		
Biemna rufescens Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Chondropsis cf n. sp. 1 (ENV9805 brown tough strappy)	Poecilosclerida	X			
Chondropsis kirkii Carter, 1881	Poecilosclerida		X	X	X
Chondropsis n. sp. 1	Poecilosclerida	X			
Chondropsis n. sp. 2 (amorphous grey)	Poecilosclerida	X			
Chondropsis n. sp. 3 (yellow on hydroid)	Poecilosclerida		X		
Chondropsis n. sp. 5 (Spirits Bay grey spaghetti)	Poecilosclerida	X			
Chondropsis n. sp. 6 (iophon fan mimic Cape Reinga)	Poecilosclerida		X		
Clathria (Axociella) macrotoxa (Bergquist & Fromont, 1988)	Poecilosclerida		X	X	
Clathria (Axociella) toxitenuis (Bergquist & Fromont, 1988)	Poecilosclerida		X	X	
Clathria (Axosuberites) multitoxaformis (Bergquist & Fromont, 1988)	Poecilosclerida		X	X	
Clathria (Clathria) n. sp. 1 (cf axinellid, Dictyociona-like)	Poecilosclerida		X		
Clathria (Clathria) atoxa (Bergquist & Fromont, 1988)	Poecilosclerida		X	X	
Clathria (Clathria) lissosclera	Poecilosclerida		X	X	
Clathria (Clathria) terraenovae	Poecilosclerida		X	X	
Clathria (Microciona) n. sp. 1	Poecilosclerida		X		
Clathria (Microciona) coccinea Bergquist, 1961	Poecilosclerida		X	X	
Clathria (Thalysias) coriocrassus Bergquist & Fromont, 1988	Poecilosclerida		X		
Clathria n. sp. 1 (like Pseudaxinella)	Poecilosclerida		X		
Crambe n. sp. 1	Poecilosclerida	X			
Crella affinis Brondsted, 1924	Poecilosclerida		X	X	
Crella fristedi	Poecilosclerida		X	X	
Crella incrustans (Carter, 1885)	Poecilosclerida		X	X	X
Crella n. sp. 1 (Spirits Bay pale cratered mass)	Poecilosclerida	X			
Desmacella cf dendyi de Laubenfels, 1936	Poecilosclerida		X	X	X
Desmacidon mammilatum Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Ectyodoryx n. sp. 1	Poecilosclerida		X		
Eurypon n. sp. 1	Poecilosclerida		X		
Grantessa poculum (Polejaeff, 1883)	Poecilosclerida		X		
Guitarra fimbriata Carter, 1874	Poecilosclerida		X		
Hamigera macrostrongyla Bergquist & Fromont, 1988	Poecilosclerida		X		
Hamigera n. sp. 1	Poecilosclerida	X			
Histodermella n. sp. 1 (thin papery fist, agglu)	Poecilosclerida	X			
Histodermella n. sp. 2 (incrusting)	Poecilosclerida	X			
Hymedesmia anisostrongyloxea Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Hymedesmia lundbecki Dendy, 1924	Poecilosclerida		X	X	
Iophon laevistylus Dendy, 1924	Poecilosclerida		X	X	
Iophon minor (Brondsted, 1924)	Poecilosclerida		X	X	
Iophon proximum (Ridley, 1881)	Poecilosclerida		X	X	
Isodictya cavicornuta Dendy, 1924	Poecilosclerida		X		
Latrunculia procumbens	Poecilosclerida		X	X	
Lissodendoryx (Lissodendoryx) n. sp. 3 (soft fleshy mustard mucus 3K	Poecilosclerida		X		
Lithoplocamia n. sp. 1 (blue sand Cake, North Cape)	Poecilosclerida	X			
Mycale (Carmia) cf macilenta (Bowerbank, 1866)	Poecilosclerida		X	X	

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Mycale (Carmia) hentscheli Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Mycale (Carmia) n. sp. 1	Poecilosclerida		X		
Mycale (Carmia) n. sp. 2 (soft mystard agglutinator}	Poecilosclerida		X		
Myxilla (Ectyomyxilla) kerguelensis	Poecilosclerida		X	X	
Myxilla (Ectyomyxilla) ramosa	Poecilosclerida		X	X	
Myxilla columna Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Naniupi novaezelandiae Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Neofibularia n. sp. 1	Poecilosclerida		X		
Paracornulum n. sp. 1 (yellow to brown agglut)	Poecilosclerida	X			
Paracornulum n. sp. 2 (bullhorn toxas)	Poecilosclerida	X			
Phorbas areolata Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Phorbas intermedia Bergquist, 1961	Poecilosclerida		X	X	
Poecilosclerida n. fam. n. g. n. sp.	Poecilosclerida	X			
Poecilosclerida n. fam. n. g. n. sp.	Poecilosclerida	X			
Pronax anchorata Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Pronax n. sp. 1 (agglutinating)	Poecilosclerida		X		
Psammoclemma n. sp. 1 (must brown digitate)	Poecilosclerida		X		
Psammoclemma n. sp. 2 (golden birdsnest, 3 kings)	Poecilosclerida		X		
Psammoclemma n. sp. 3 (encrusting hydroid)	Poecilosclerida		X		
Psammoclemma n. sp. 4 (transl green fibrous)	Poecilosclerida		X		
Psammoclemma n. sp. 5 (thick smooth sandy)	Poecilosclerida		X		
Raspailia (Raspailia) flaccida Bergquist, 1970	Poecilosclerida		X	X	
Raspailia (Raspailia) agminata Hallman, 1914	Poecilosclerida		X	X	
Raspailia (Raspailia) compressa Bergquist, 1970	Poecilosclerida		X	X	
Raspailia n. sp. 1	Poecilosclerida		X		
Raspailia n. sp. 2 (thin blade)	Poecilosclerida	X			
Raspailia n. sp. 3 (black fan)	Poecilosclerida	X			
Raspailia n. sp. 4 (frilly blades)	Poecilosclerida	X			
Raspailia n. sp. 4 (Spirits Bay thin yellow frond)	Poecilosclerida	X			
Raspailia topsenti Dendy, 1924	Poecilosclerida		X	X	
Rhabderemia stelletta Bergquist, 1961	Poecilosclerida		X	X	
Stylopus australis Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Tedania battershilli Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Tedania connectens (Brondsted, 1924)	Poecilosclerida		X	X	
Tedania diversiraphidiophora Brondsted, 1923	Poecilosclerida		X	X	
Tedania n. sp. 1 (Spirits Bay white filmy turrets)	Poecilosclerida	X			
Tedania spinistylota Bergquist & Fromont, 1988	Poecilosclerida		X	X	
Tedaniopsis turbinatum Dendy, 1924	Poecilosclerida		X	X	
Tetrapocillon novaezelandiae	Poecilosclerida		X	X	
Thrinacophora n. sp. 1 (massive)	Poecilosclerida		X		
Thrinacophora n. sp. 2 (Spirits Bay fuzzy stalk)	Poecilosclerida	X			
Thrinacophora n. sp. 2 (stringy)	Poecilosclerida		X		
Cinachyra uteoides Dendy, 1924	Spirophorida	X			
Cinachyrella n. sp. 1 (thick flat)	Spirophorida	X			
Cinachyrella n. sp. 2 (big crypts)	Spirophorida	X			
Cinachyrella n. sp. 3	Spirophorida	X			
Craniella n. sp. 1	Spirophorida	X			
Tetilla n. sp. 1 (Spirits Bay umbrella anatriaenes)	Spirophorida	X			
Stelletta cf maori	Stellettidae		X	X	
Pseudoceratina cf n. sp. 1 (agglutinating purple)	Verongida		X		