Benthic habitats, macrobenthos and surficial sediments of the nearshore South Taranaki Bight

Prepared for Trans-Tasman Resources Ltd

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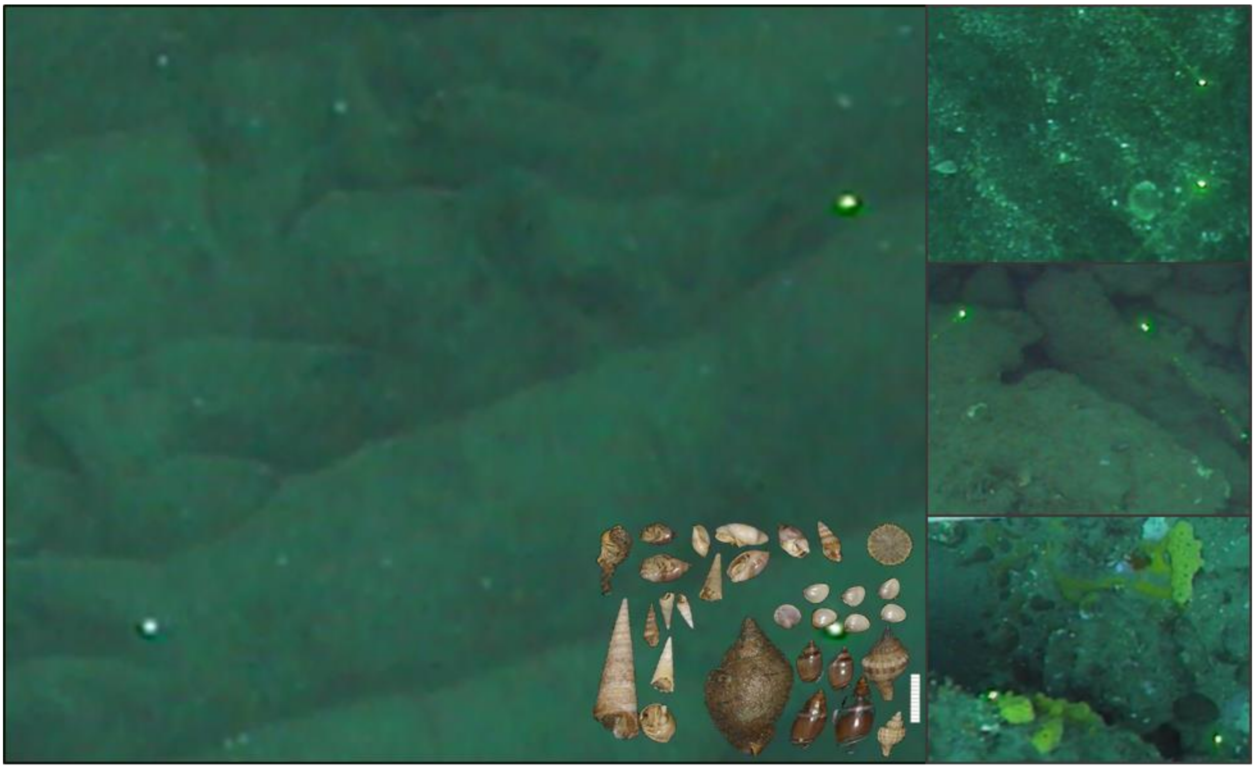

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Executive summary

Trans-Tasman Resources Ltd (TTR) is applying for consents for iron sand extraction in the South Taranaki Bight (STB). NIWA modelling predicts that activities associated with extraction of seabed sediments will produce down-current plumes of suspended sediments and deposition of fine-sediment within the nearshore marine environment directly offshore from the Whanganui River estuary. This has potential implications for the benthic assemblage, particularly benthic primary production and suspension feeding organisms. As very little was known about the types of habitats and organisms that occur in the nearshore region of the STB, NIWA was contracted by TTR to survey and describe the benthic flora and fauna within this region. This report presents the finding of these investigations.

Seabed sampling of the nearshore region of the STB was conducted during a 3-day field survey undertaken from the 28th February to the 2nd March 2013. Seabed habitats were characterised at 36 sites (26 nearshore sites and 10 cross-shelf sites), using underwater video footage and still images (photo-quadrats). Representative habitats were then sampled using a benthic grab for surficial sediments (surface sediments) and a benthic dredge to collect surficial macrobenthic specimens.

Several soft-sediment and rocky outcrop habitats were recorded within the nearshore region of STB. The exposed areas in the north and central regions of the STB were characterised by well-sorted fine sands in dynamic rippled bedforms, while the more protected southern sites were characterised by flat or subtly rippled bedforms with higher proportions of mud. The amount of shell debris associated with soft-sediment habitats also increased offshore, with coarse-shell debris habitats recorded in water depths > 20 m. Rocky outcrops occurred at five of the 36 sites surveyed, with two types of rocky outcrops recorded. Hard rock outcrops of low to moderate relief were recorded at three sites in the northern sections of the STB in water depths of 12-22 m, while two mudstone outcrops were recorded: one south of Hawera as a low-lying outcrop at 14 m and another offshore of Whanganui as a moderate-relief outcrop at 13.5 m.

Video observations of the seabed along with dredge collections at representative sites found that most soft-sediment sites supported very low numbers of surficial macrobenthos (16.64 ± 6.2 specimens and 6.8 ±1.5 species p/150 m dredge). These assemblages were characterised by deposit feeders, predators/scavengers and suspension feeders. Rocky outcrops, although much rarer in spatial extent (8% of available habitats), supported much more abundant and diverse macrobenthic assemblages (38.7 ± 18.3 specimens and 22.9 ± 9.2 species p/150 m dredge), dominated by suspension-feeders (66%) and primary producers (19%). These assemblages were characterised by bryozoans, macroalgae and sponges, as well as more motile species, such as crabs, amphipods, starfish, brittle stars, gastropods and polychaetes worms. In contrast to mudstone outcrops, which supported low or negligible amounts of macrobenthos (<2.5% of specimens), hard rock outcrops (dredges at Sites 5 and 6) accounted for more than 25% of all specimens and 61% of all species collected during the survey. Most species recorded during this survey have been reported previously from the broader Patea Shoals or STB region, with six of these species purported as common. No records of new species were found.

Nine soft-sediment sites (6 nearshore and 3 cross-shelf sites) and one mudstone outcrop (Site CS1) lie within the most concentrated suspended sediments (CSS) area, predicted to

occur directly offshore from the Whanganui River estuary. These soft-sediment sites were characterised by fine rippled sands with low and variable numbers of small motile epifauna - mostly hermit crabs, gastropods, and a few suspension-feeding bivalves. These species are presently subjected to regular sediment disturbances from storm events and river runoff and are likely to be tolerant to deposition of sediments. The mudstone outcrop (CS1) present in this area is covered in fine silt with few macrobenthic organisms. Other habitats and organisms likely to be affected by a CSS plume are macroalgal and suspension-feeding species associated with hard rock outcrops, particularly their diverse bryozoan and sponge dominated assemblages.

Information relating to TTR's additional scientific work undertaken since 2014 has been provided and the conclusions is this report remain valid.

1 Introduction

1.1 Background

1.1.1 Iron ore and seabed extraction

Shelf sediments within the South Taranaki Bight (STB) on the West Coast of the North Island contain a rich source of magnetic iron ore, and the oxides of titanium and vanadium, collectively known as Vanadium Titano-Magnetite (VTM). These sediments have terrigenous origins resulting from eroded volcanic rock washed down from Mount Taranaki and the Central Plateau. Trans-Tasman Resources Ltd (TTR) is seeking consent to extract seabed material from the STB. The proposed project area (PPA) is located in an area of seabed known as “Patea Shoals”, approximately 15-40 km offshore in water depths of 25-45 m (Figure 1 and Figure 2). Extraction of seabed sediments and deposition of de-ored sands back to the seabed has the potential to produce down-current plumes of suspended sediments. This could alter water clarity and increase sediment deposition to the seabed with implications for the benthic assemblage, including benthic primary production and suspension feeding organisms.

1.1.2 Plume modelling

In 2011, NIWA was contracted by TTR to model the transportation of resuspended sediments from sand extraction activities based on three potential extraction scenarios (A-inshore, B-midshore and C-offshore) all located within TTR’s original PPA boundary (Hadfield, 2012). Worst case assumptions predicted that sediment plumes from extraction activities would be carried by the prevailing east and southeast currents in all three model scenarios resulting in i) elevated levels of suspended sediments in the nearshore coastal region of the STB between Hawera and south of Whanganui, and ii) fine-sediment deposition on the seabed immediately offshore of the Whanganui River estuary (*model output for Source B is shown in Figure 1; but see Hadfield, 2012 for a complete description of all three models*). The predicted concentration of sediment in the plumes and amount of fine-sediments deposited on the seabed, significantly decreased in scenarios where the extraction sites were located further offshore (Hadfield, 2012). TTR subsequently reduced the boundary of the PPA to only include the area beyond the 12 nautical mile territorial limit (Figure 1).

Based on the outcomes of the suspended sediments plume models (Hadfield, 2012) and because little was known about the benthic habitats and assemblages within the coastal regions of the STB - potentially affected by changes in suspended sediment and sediment deposition concentrations -TTR contracted NIWA to characterise benthic habitats, surficial sediments and surficial macro-fauna and macro-flora in the nearshore region of the STB.

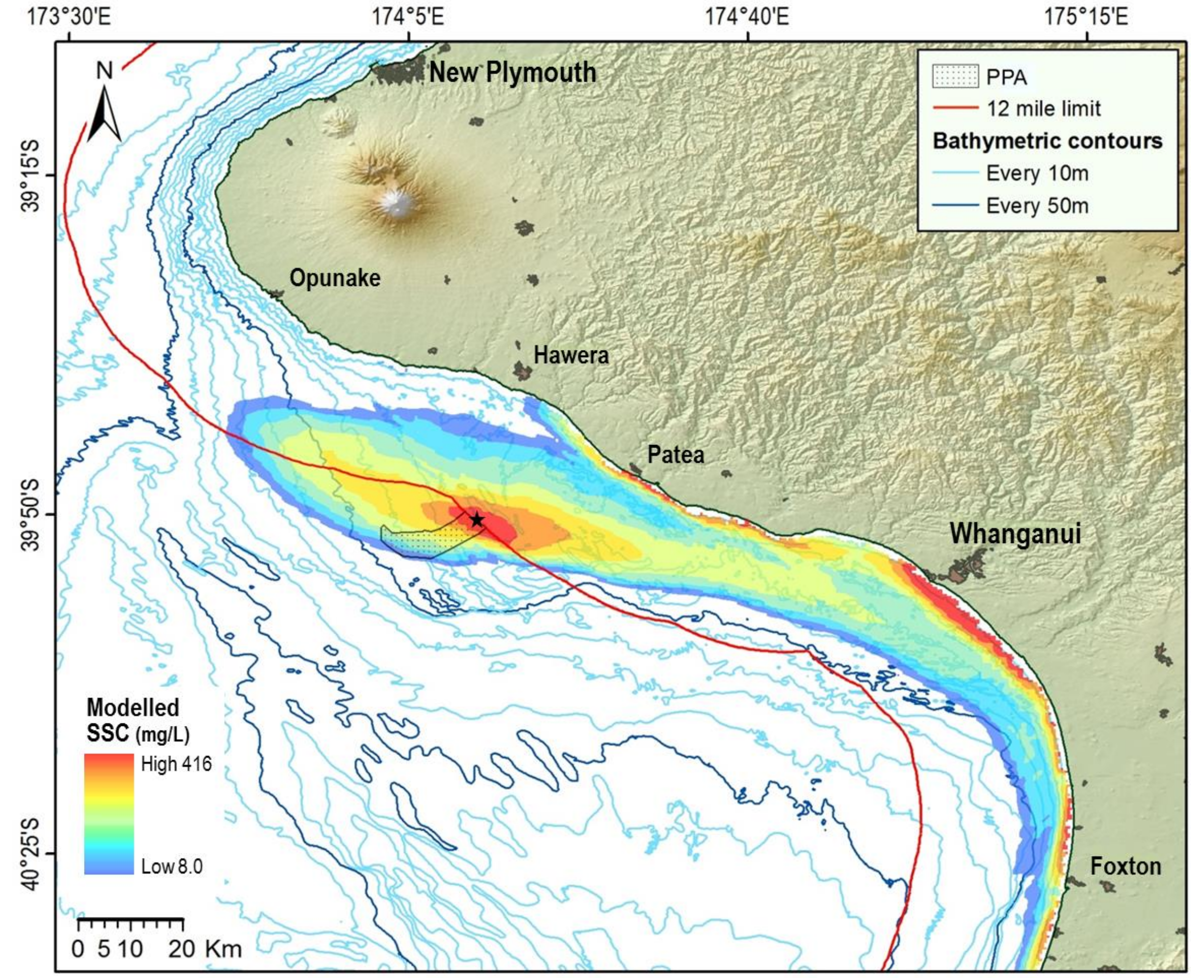

Figure 1: Map of the South Taranaki Bight with predicted near-bottom suspended sediment concentrations (SSC) of extraction-derived sediment. SSC values represent 95th percentile for releases from the dredging source (black star = Source B in Hadfield, 2012) within the proposed project area (PPA).

1.1.3 NIWA's understanding of TTR's requirements

NIWA was commissioned by TTR under Work Schedule AB to characterise the inshore benthic habitats, macro-fauna and macro-algae, and to collect and analyse surficial sediments along the coast from Hawera to Foxton. Sampling areas were prioritised to those sites i) adjacent to Whanganui River where the highest amount of sediment was predicted to accumulate on the sea floor based on the suspended sediment plume models in Hadfield (2012), ii) northern and southern sites along the nearshore from Hawera to Foxton, and iii) sites along a cross-shelf transect that would traverse the plume gradient offshore of Whanganui. Characterising the inshore benthic habitats and macro-fauna and flora was to be undertaken using video transects and photo-quadrating methods with representative habitats sampled using dredges to collect surficial macrobenthic specimens, and grab samples to describe the surficial sediments. This report presents the findings of this study.

2 Methods

2.1 Study sites

NIWA's sediment plume model based on a worst case scenario at an extraction site 12 nm offshore (location depicted by a black star in Figure 1 and Figure 2) indicated a potential impact-area of approximately 35 km alongshore centred off the Whanganui River (Hadfield, 2012). This region of coastline is exposed to high energy conditions, with persistent south-westerly swells (period of 9–12 s) from the Southern Ocean coupled with storm-generated waves (1–3 m and 6–8 s) driven by southerly, westerly, and north-westerly wind events (Pickrill and Mitchell, 1979; Harris, 1990). These conditions cause bed stress across much of the shelf within the South Taranaki Bight (informally known as the Whanganui shelf), which has a shallow slope (<1^{o}) extending 100 km offshore to a depth of around 110 m (Gillespie et al., 1998). Mean significant wave height decreases in a south-easterly direction down the coast in relation to increased shelter from the prevailing south-westerly swell (MacDiarmid et al., 2010). Sediment samples and seabed photographs collected from various locations across the Whanganui shelf (mostly around Patea Shoals region) have recorded dynamic high-energy benthic environments dominated by sand rippled and mega-rippled iron-rich bedforms, comprising coarse grained sands that are largely devoid of mud (Gillespie and Nelson, 1996; *review in* MacDiarmid et al., 2010; Beaumont et al., 2013). Bed resuspension is high in these areas resulting in very mobile sediments (Orpin et al., 2009), and persistently high levels of water turbidity in nearshore areas (MacDiarmid et al., 2010). Mobile shelf sediments, particularly on the mid-shelf around Patea shoals, generally support low species abundances and relatively poor species richness compared to other coastal locations around New Zealand (MacDiarmid et al., 2010; Beaumont et al., 2013). However, little is known about the biota within the nearshore regions of the STB (*but see* Gillespie and Nelson, 1996).

2.2 Survey design

To describe the physical composition of the seabed and its surficial macrobenthos (macrofauna and macroflora), a total of 36 sites (26 nearshore and 10 cross-shelf transect sites) were sampled along the coastline, using combinations of video transects, benthic dredges and sediment grabs (Table 1; Figure 2). Seabed sampling was conducted during a 3-day field survey (28th February to the 2nd March 2013) on board the *R.V. Ikatere*. The 26 nearshore sites were sampled at approximately 6 km intervals in depths of 3-28 m along a 35 km section of coastline from Hawera in the west to Foxton in the south, with a higher concentration of sites sampled at approximately 3 km intervals in and around the Whanganui River - the area where the highest concentrations of sediment (estimated 2-10 mm) is predicted to accumulate (Figure 2; Table 1). To determine how seabed habitats and biota changed with distance offshore of Whanganui, 10 cross-shelf transect sites were sampled at approximately 80 m intervals in water depths spanning 13 to 32 m (Table 1; Figure 2).

Table 1: Summary of the physical and biological samples collected during the nearshore and cross-shelf survey on the R.V. *Ikatere*. Location denote the four zones: 3 nearshore (North, central and south coast locations) and 1 cross-shelf (located offshore of Whanganui) zone; cam=Splashcam, stn= station and reflects the order in which samples were collected.

Area	*Site*	*Splashcam Lander*	*Dietz Grab*	*Agassiz Dredge*	*Oklemann Dredge*	*Location*
Nearshore	1	cam26	*stn26*		*stn54*	South (Foxton)
Nearshore	2	cam29	*stn29*			South (Foxton)
Nearshore	3	cam32	*stn32*		*stn51*	South (Foxton)
Nearshore	4	cam11	*stn11*			Central (Whanganui)
Nearshore	5	cam08	*stn08*		*stn42*	North (Hawera/Patea)
Nearshore	6	cam05	*stn05*	*stn40*		North (Hawera/Patea)
Nearshore	7	cam01				North (Hawera/Patea)
Nearshore	8	cam27	*stn27*			South (Foxton)
Nearshore	9	cam30	*stn30*		*stn52*	South (Foxton)
Nearshore	10	cam20	*stn20*			Central (Whanganui)
Nearshore	11	cam12	*stn12*		*stn44*	Central (Whanganui)
Nearshore	12	cam09				North (Hawera/Patea)
Nearshore	13	cam06		*stn41*		North (Hawera/Patea)
Nearshore	14	*cam02*	*stn02*	*stn38*		North (Hawera/Patea)
Nearshore	15	cam28	*stn28*		*stn53*	South (Foxton)
Nearshore	16	cam31	*stn31*			South (Foxton)
Nearshore	17	cam19	*stn19*		*stn50*	Central (Whanganui)
Nearshore	18	cam13	*stn13*			Central (Whanganui)
Nearshore	19	cam10		*stn43*		Central (Whanganui)
Nearshore	20	cam07	*stn07*			North (Hawera/Patea)
Nearshore	21	cam03-04		*stn39*		North (Hawera/Patea)
Nearshore	22	cam16			*stn45*	Central (Whanganui)
Nearshore	23	cam16	*stn16*		*stn46*	Central (Whanganui)
Nearshore	24	cam17	*stn17*			Central (Whanganui)
Nearshore	25	cam14	*stn14*			Central (Whanganui)
Nearshore	26	cam14	*stn14*			Central (Whanganui)
Cross-shelf	CS1	cam37	*stn37*			Cross-shelf Transect
Cross-shelf	CS2	cam36	*stn36*			Cross-shelf Transect
Cross-shelf	CS3	cam35	*stn35*		*stn47*	Cross-shelf Transect
Cross-shelf	CS4	cam34	*stn34*			Cross-shelf Transect
Cross-shelf	CS5	cam33	*stn33*			Cross-shelf Transect
Cross-shelf	CS6	cam25	*stn25*			Cross-shelf Transect
Cross-shelf	CS7	cam24	*stn24*		*stn48*	Cross-shelf Transect
Cross-shelf	CS8	cam23	*stn23*			Cross-shelf Transect
Cross-shelf	CS9	cam22	*stn22*			Cross-shelf Transect
Cross-shelf	CS10	cam21	*stn21*		*stn49*	Cross-shelf Transect
Total	**37**	**38**	***30***	***5***	***12***	

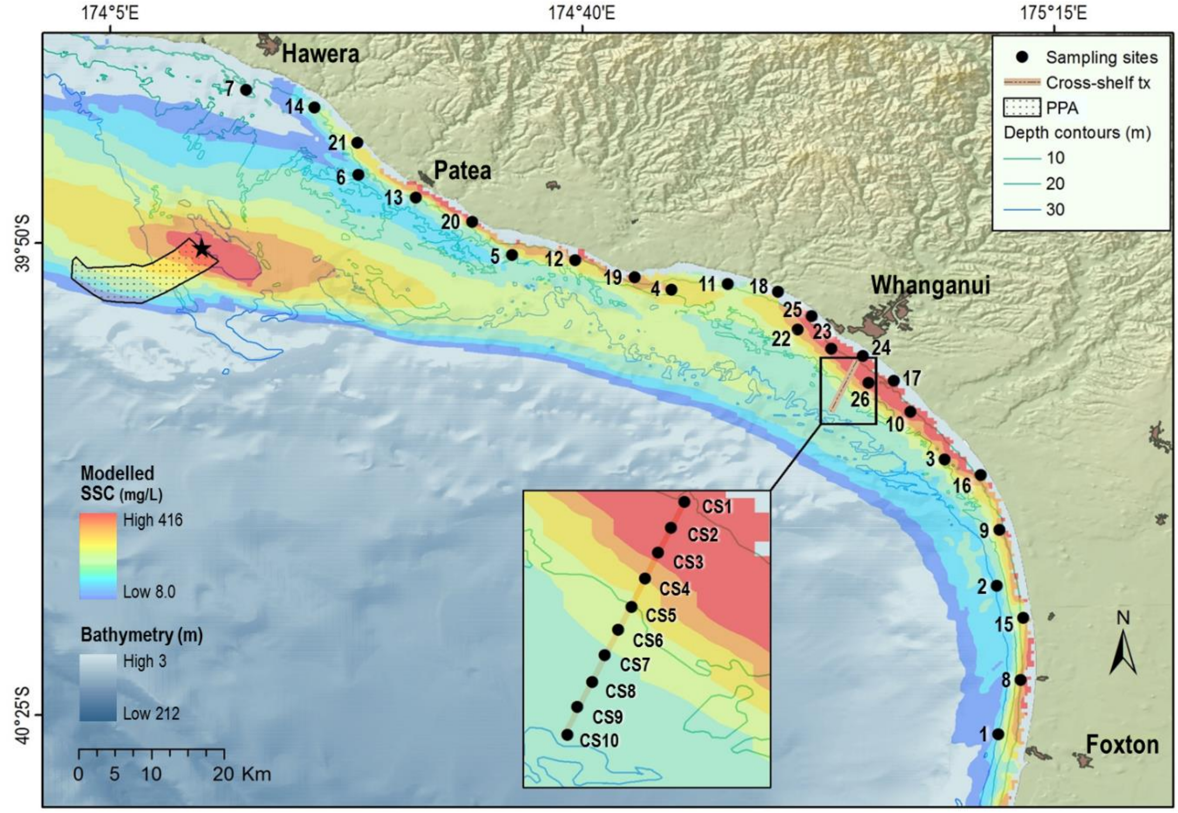

Figure 2: Location of sampling sites relative to the predicted bottom suspended sediment concentrations (SSC) of extraction-derived sediment within the South Taranaki Bight (STB). SSC values represent 95th percentile for releases from the dredging source (black star = Source B in Hadfield, 2012) within the proposed project area (PPA). Sites 1-26 = nearshore sites (main figure), Sites CS1-CS10 = cross-shelf transect sites (insert).

2.3 Splashcam transects and seabed characterisations

Benthic habitats and macro-organisms were surveyed at each of the 26 nearshore and 10 cross-shelf sites using NIWA's Splashcam Lander (Table 1; Figure 2; Figure 3a, b; Appendix A). The Splashcam Lander (from here simply referred to as the Splashcam) comprises a small galvanised frame fitted with a downward-looking low-light video camera (Deep Blue Pro, 0.1 lux sensitivity, 3.6 mm wide angle lens). The camera, positioned 420 mm above the base frame, viewed an area of 40 x 30 cm when the Splashcam was positioned on the seabed. As the low-light camera functions well in continental shelf water depths (i.e. <100 m) no extra lights were fitted to the lander. Paired green lasers, positioned 20 cm apart and projected onto the seabed, were used to quantify the area seen in photo-quadrats and to quantify the percent cover and size of habitat features and organisms.

At each site, the Splashcam was deployed from the stern of the *RV Ikatere* and lowered slowly to the seabed, and recorded continuous video footage and captured ~12 replicate photo-quadrats along the length of a single transect (~100 m). Photo-quadrats were captured by carefully lowering the Splashcam down onto the seabed and after a clear view of the seabed was visible on the ships splash-cam video monitor, the Splashcam was left for a further 5-8 seconds to capture a good video sequence of the seabed. The Splashcam was then lifted 1-2 m off the seabed and allowed to drift for 15 seconds (~5 m) before being lowered again to the seabed. This was repeated ~12 times, so that for each site a sequence of 12 photo-quadrats were captured to video. Video footage along the transect was transmitted in real-time, via coaxial cable, to a ship-board video-monitor enabling real-time observations of the seabed environment, while an axillary feed to a second video-monitor enabled the hydraulic winch operator to regulate the Landers altitude above the seabed. The spatial position of the Splashcam, along each transect, was recorded using the ships GPS. A Furuno RD-30 display was linked to the video-system to enable researchers to co-monitor the ships GPS position, speed over ground and heading. Real-time video footage was then fed through a Horita time stamp (GPT-50) device that stamped GPS and UTC date and time information onto the video image as it was being recorded to digital mini-DV tape (Figure 3c,d). Mini-DV tapes were backed up to digital hard drives and are stored at NIWA, Greta Point Wellington.

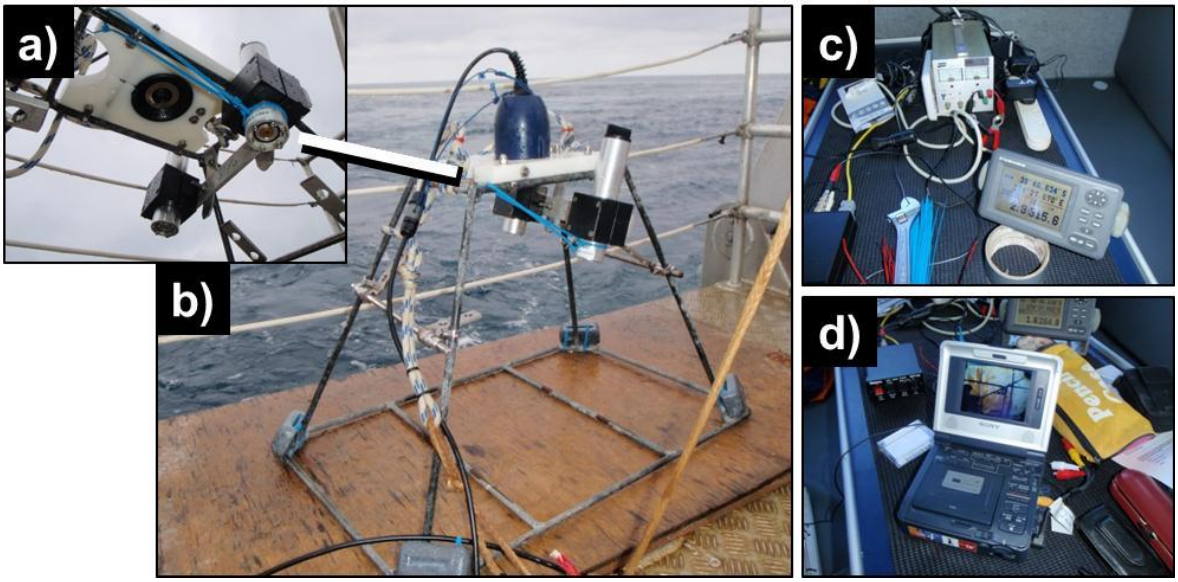

Figure 3: NIWA's Splashcam Lander and video recording system. a) Close-up view looking up at the video-camera and paired laser system, b) Side view of the Splashcam showing the entire camera frame with downward facing video-camera and paired lasers, b) Power supply, GPS and Horita time stamp (GPT-50) device, c) Sony video recorder.

Back in the laboratory, the continuous video footage was viewed for each site and for each of the 12 photo-quadrats a still image (framegrab) in jpg format was captured using OFOP (Ocean Floor Observation Protocols software v3.3.3). All photo-quadrat images per site were then imported in batch mode into Image-J (Image processing software v1.46) for quantitative analysis. Here, each photo-quadrat image was first rectified in space using the known distance between the lasers, using ImageJ's area function tool, and then the seabed and biota within the image was systematically quantified using a three-tiered characterisation scheme of substratum, geomorphology, and macrobenthos. First, percent cover of each substratum type (bedrock, boulders (>25.6 cm), cobbles (6.4-25.6 cm), shell-hash (angular shell fragments >3 mm), coquina (white specks of shell ≤ 3 mm), sand, and mud) was recorded as percent cover. Second, the geomorphology (or shape) of the seabed was classified by the 'bedform type' of soft-sediments (e.g. sediment waves, sediment ripples, subtle ripples or sediment flats) or by the 'vertical relief' of hard substrata (e.g. flat [0-0.3 m], low [0.3-1 m], moderate [1-3 m] or high relief [>3 m]). Thirdly, macro-flora and -fauna (organism visible to the eye) were quantified by either recording the % cover of sessile taxa (e.g. macroalgae, bryozoans, and sponges), or by counting the number of individuals from motile taxa (e.g. gastropods and hermit crabs) or different lebensspuren activity (*cf* signs of life, such as burrows, pits, mounds and faecal casts) within the image. Taxa were identified to lowest taxonomic resolution possible. Percentage cover estimates were quantified by drawing polygons around each substratum or taxa type and then calculating the total area for that category as a percentage of the total area within the photo-quadrat.

2.4 Sediment sampling

To determine the composition of surficial seabed sediments, a total of 26 sites (16 nearshore and 10 cross-shelf transect sites) were sampled using NIWA's small (16 cm wide x 50 cm tall grab, with a 15 x 10 cm grab-gape) Deitz sediment grab (Table 1; Figure 4; Appendix B). Sediment samples at each site were collected by deploying the Deitz grab off the aft port side of the *R.V. Ikatere*. Upon hitting the seabed the jaws of the grab closed collecting a small sediment sample (~ 2000 ml although amounts varied between locations). Once back on board the vessel, the jaws of the grab were carefully opened and where a sufficient amount of sample had been collected a sediment sample (approximately 500 ml) was bagged, labelled and retained in a cool store at 4^{o} C until laboratory analysis. Where a grab failed to collect enough sample a second grab deployment was undertaken.

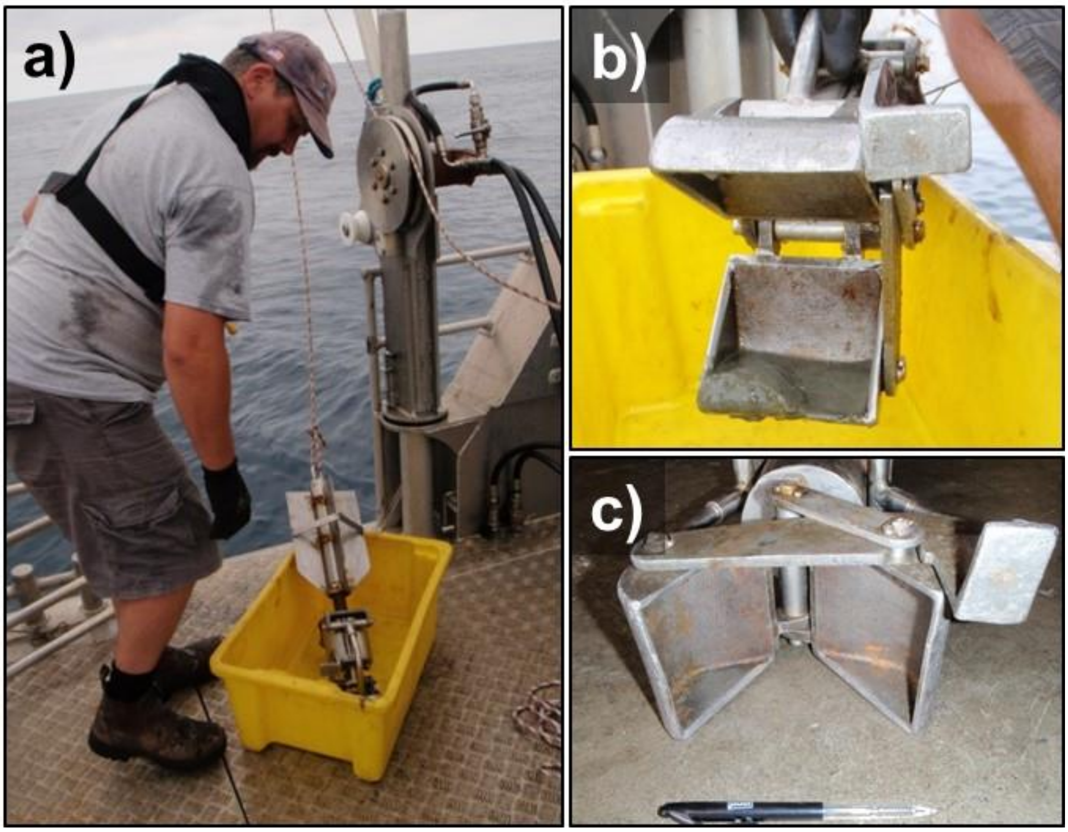

Figure 4: Sediment sampling using NIWA's small Deitz grab. a-b) Sediment sample being retrieved (jaws open), c) The jaws of the grab in the open position (15 cm apart).

Back in the laboratory, each sediment sample was analysed to determine grain size distributions of the mud and sand fractions using a Beckman Coulter LS 13 320 Dual

Wavelength Laser Particle Size Analyser. To do this the sediment sample was homogenised, whereby 0.5 cm^3 of sediment was re-suspended in distilled water in a 50 ml container, invigorated using ultrasound, and then washed through a 1.6 mm sieve into the laser-sizer where it was analysed for 90 seconds. Several sites (e.g. CS1, CS7, CS8, CS9 and CS10) contained visible shell or gravel fractions (≥1.6 mm), but only two sites (Sites 6 and CS8) contained enough to be analysed using the laser sizer. For these two samples, the proportions of gravel, sand and mud were determined using dry sieves and are tabulated separately. Standard granulometric statistics (mean grain size, sorting, skewness and kurtosis) were then calculated for each site from the 'percent by volume' laser data using GRADISTAT (Blott and Pye, 2001) and provided standard textural descriptions (e.g. Folk, 1974).

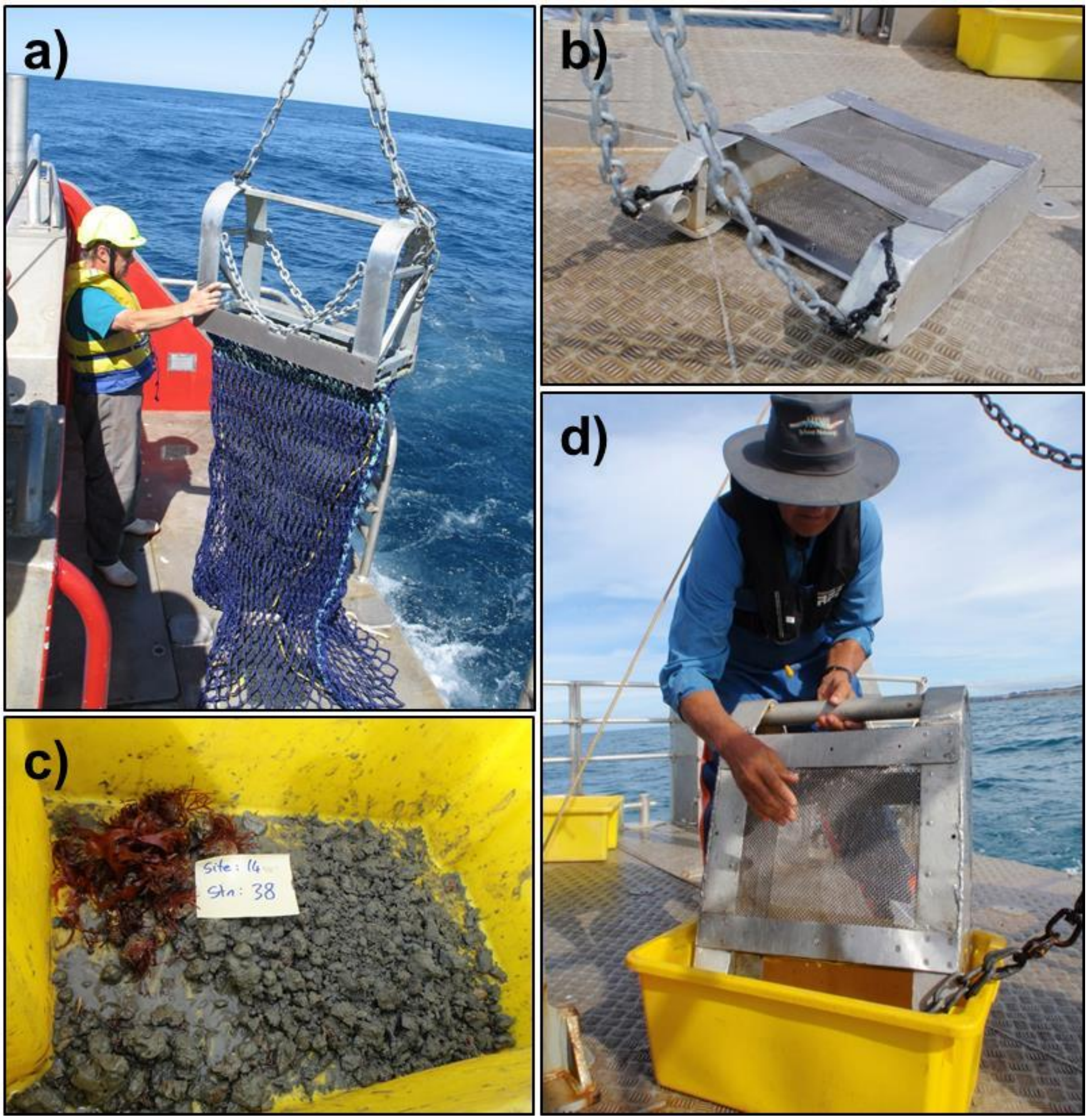

Figure 5: Benthic dredge sampling. a) NIWA's Agassiz dredge used over hard rocky reefs, b,d) NIWA's Oklemann dredge used in soft-sediments, c) contents of a dredge from site14 (red algae and small fragments of pale grey mudstone) emptied into a sorting bin.

2.5 Macrobenthic collections

A representative selection of sites (17 of the 36 sites: 14 nearshore and 3 cross-shelf sites) were sampled for macrobenthic organisms using one of two dredges (Table 1; Figure 5, Appendix C). At sites with reef, boulders or broken bedrock habitats (n=5), NIWA's small (80 cm wide by 25 cm high) Agassiz dredge fitted with a 2 m long and 28 mm diagonal mesh net (enveloped in a 100 mm chaffing mesh to protect the internal cod end from damage) was used (Table 1; Figure 5a). Conversely, in soft-sediment sites (n=12), NIWA's small (40 cm wide by 12 cm high) Oklemann dredge with a 4 mm aluminium mesh grate was employed (Table 1; Figure 5b, d). No dredge samples were attempted over the two most complex reef sites (sites 7 and CS1) as the reef topography of these two sites was deemed too dangerous for either dredge to safely sample. Each dredge was deployed from the stern of the *R.V. Ikatere* and towed along the seabed at 2 knots for 2 minutes, covering a linear distance of approximately 150 m. Dredge distance was recorded using the ships GPS. This sampling approach enabled taxonomic specimens to be collected from all habitat types across the spatial extent of the survey. However, different dredges sampled over different habitat and relief types will have different sampling efficiencies. This means that different sites may not be directly comparable in terms of quantities, but will be indicative of species occurrences, assemblage structure and trophic function.

Upon retrieval, the dredge net was emptied into a plastic container (Figure 5c-d), which was then transferred to a sorting bench where researchers carefully separated specimens into broad taxonomic groups (e.g. bryozoans, sponges, brittle stars, algae, worms, and crustaceans). In dredge samples where large number of specimens of the same species were collected, representative specimens were retained for taxonomic identification while the remaining specimens were counted (e.g. sand dollars) or a total weight was estimated (e.g. sponges and bryozoan) and then excess specimens were returned to the sea. Retained specimens were then preserved in either 99% ethanol (e.g. most taxa), 4% buffered formalin (e.g. algae and worms), dried (bryozoan) or refrigerated and then frozen at -20^{o}C (e.g. sponges, bivalves and gastropods). Upon completion of the survey, biological specimens were transported to NIWA Greta Point where specimens were catalogued and then transferred to taxonomic specialists for identification to species or operational taxonomic unit (OTU's). Once identified, specimens were returned and archived in NIWA's Museum Collection at Greta Point. The exception to this were sponges, which are housed in the Sponge collection at NIWA Auckland. All benthic samples were collected under NIWA's special permit (505) with the Ministry for Primary Industries (MPI).

2.6 Data analyses

Mean and standard errors for percentage cover of each substratum type and sessile biota categories and for counts of motile taxa and lebensspuren activity were calculated for each site, and for each habitat type and are presented in graphical and tabulated forms. Similarly, sediment variables (mean grain size, sorting, skewness and kurtosis) attained from grain size analyses are presented as mean and standard errors per site and per habitat type. To examine the importance and relative contribution of different functional groups ,macrobenthic species were classed into one of seven feeding guilds (predators, scavengers, deposit feeders, primary producers and suspension feeders), following Hewitt et al. (2008). Mean and standard error values of feeding guilds were then calculated for sites and habitat types.

To examine the location of rocky outcrops relative to known and predicted reef and rocky outcrops for the region, site locations were overlaid on a shape file that showed the positions of known and predicted hard substratum habitats around New Zealand (MacDiarmid et al., 2013). The reefs data layer was based on the initial data layer created by Smith (2008) where all seabed features with abrupt changes in vertical relief were assumed to be reef structures. This data layer was then adapted by MacDiarmid et al (2013) for the STB region using a combination of existing TTR data (i.e. visual, acoustic sidescan or backscatter, and drilling information collected from the study region during 2010-2012), along with chart data and other published information to eliminate non-reef areas, but no attempt was made to locate and identify all rock outcrops in the STB (*details in* MacDiarmid et al., 2013).

3 Results

3.1 Seabed composition and geomorphology.

A total of 417 photo-quadrats were recorded from 35 sites (25 nearshore and 10 cross-shelf sites) with approximately 12 photo-quadrats recorded per site (Table 1) and an estimated 2.65 line-km's of seabed visually surveyed. The majority of sites (31 out of the 36 sites and 92% of all photo-quadrats) were characterised by expansive soft-sediment habitats in either rippled (71.2% of photo-quadrats) or flat (20.6 %) sediment bedforms (Figure 6 and Appendix A). In contrast, rocky outcrop habitats occurred at only five sites (Sites 5, 6, 7, 14 and CS1, and only 8.2% of all photo-quadrats), composed of either mixtures of hard and soft substrata (Sites 5, 6 and 14) or contiguous bedrock (Sites 7 and CS1) (Figure 6 and Appendix A).

3.1.1 Soft-sediment habitats

Soft sediment habitats occurred in depths of 2.5 m down to at least 30.5 m (max. depths sampled) and were dominated by sandy sediments in rippled bedforms (Figure 7 and Appendix A), consistent with the high-energy depositional environment of the STB. Surficial sediments were characterised by moderate to well sorted fine sands (mean grain size: 202.5 ± 29.4, sorting: 1.8 ± 0.12) that were mostly devoid of mud (8.5% ± 4.7%) (Figure 9, Appendix B). However, seabed geomorphology and sediment composition differed subtly alongshore in a southerly direction (Figure 6-10). In the north, between Whanganui and Hawera, soft-sediments were characterised by linearly-shaped rippled sands (Figure 7, e.g. Figure 8a-c), characteristic of unidirectional water flow. Central sites adjacent to Whanganui were also characterised by rippled sands, albeit in more complex rippled bedforms with combinations of sinuous-, lunar-, catenary- and linguoid-shaped ripples (Figure 8e.g. Figure 8d-f), indicative of more locally dynamic multidirectional flow. In contrast, the more protected southern sites, down towards Foxton, were characterised by either subtly-rippled or flat sediments and comprised higher proportions of mud (6-14% mud) (e.g. Figure 8g-I, Appendix A), indicative of less energetic water flow. Sediment characteristics also varied with depth (Figure 6-10). Cross-shelf sites located in water depths < ˜20 m, were characterised by moderately-sorted fine sands (nearshore sites) or fine muddy sands (i.e. CS1-05, 6-18% mud) (e.g. Figure 6-10), while sediments in water depth > 20 m (e.g. cross-shelf Sites CS6-10 and nearshore Sites 1, 2, 3, 5 and 6) were characterised by increased amounts of coarse shell hash material (Figure 6-10 and Appendix C).

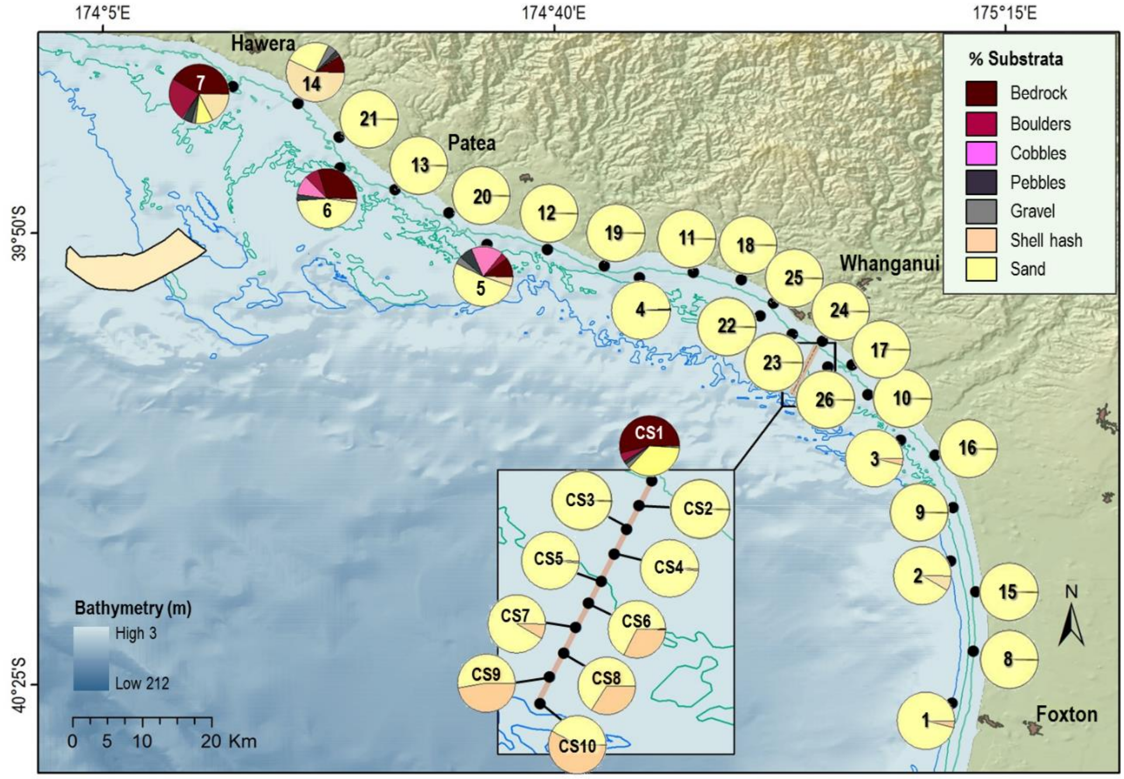

Figure 6: Seabed substratum types at nearshore (1-26) and cross-shelf transect (CS1-CS10) sites within the STB. Figure captions are provided in See Figure 2.

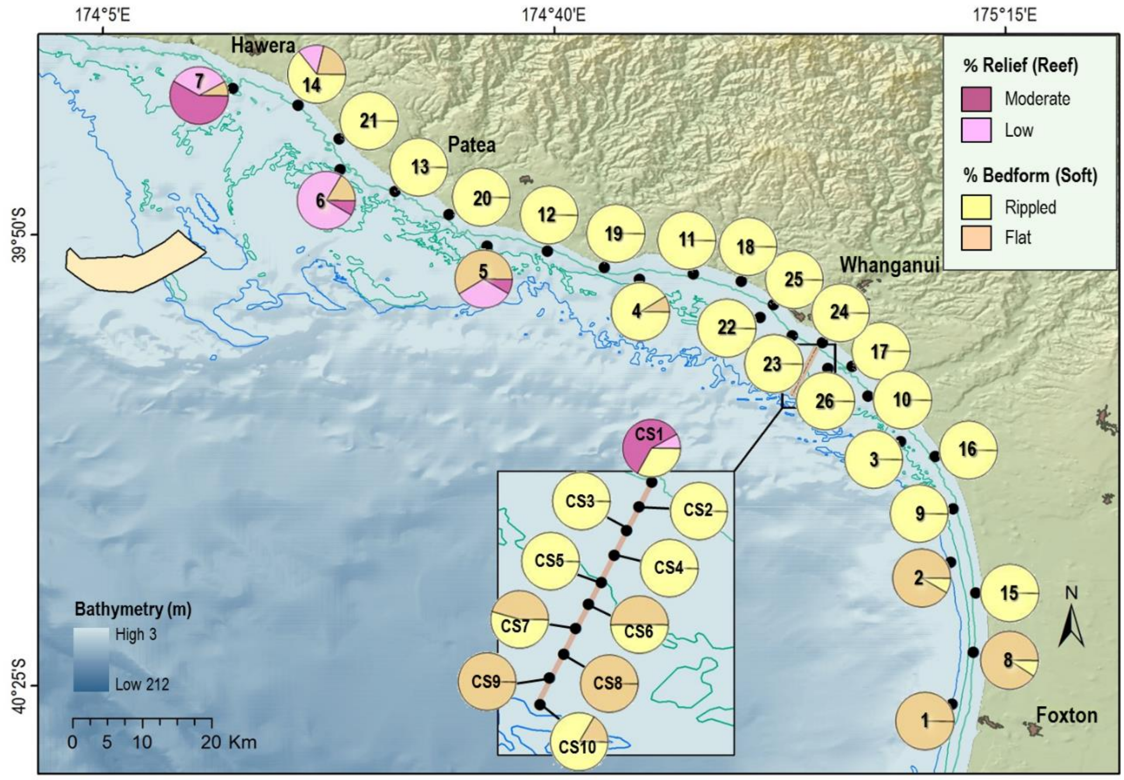

Figure 7: Seabed relief and bedform structure at nearshore (1-26) and cross-shelf transect (CS1-CS10) sites within the STB. Figure captions are provided in See Figure 2.

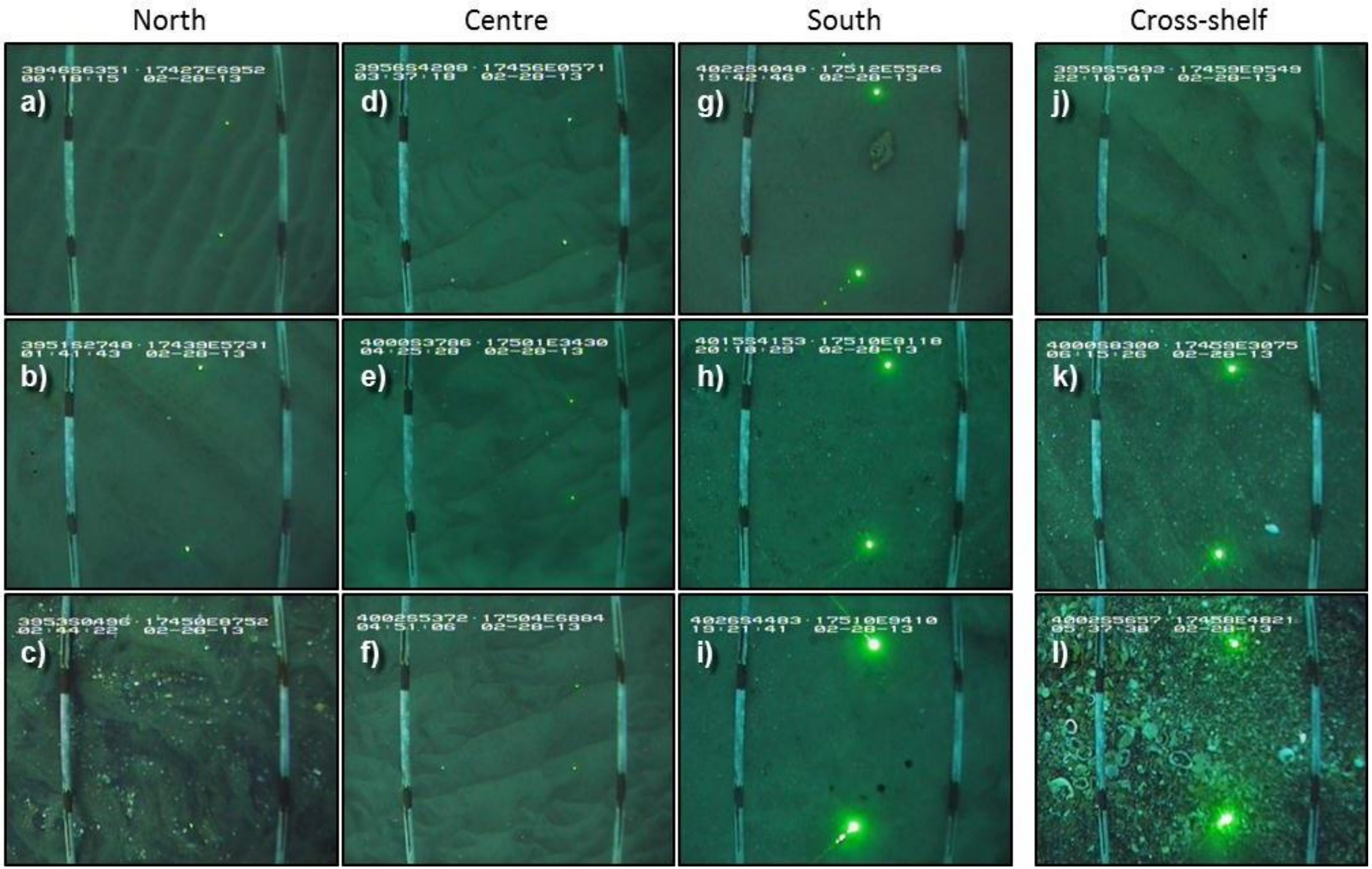

Figure 8: Splashcam images of soft-sediment habitats within the STB. Northern Sites: a) Site 13 (12.5 m depth) – linear rippled bedforms; b) Site12 (14 m) – linear ripples, c) site 11 (8 m) - linguoid-shaped ripples. Central sites: d) Site 22 (16.5 m) – mixed-ripple formations, e) Site 26 (16 m) – mixed-ripples, f) Site 10 (10 m) – mixed-ripples. Southern sites: g) Site 8 (11.5 m) – flat sediment and gastropod, h) Site 2 (25 m) – flat sediment, i) Site 1 (28 m) – flat sediment and small burrows. Cross-shelf transect: j) site CS3 (16.5 m) – rippled sediment, k) Site CS6 (22 m) – rippled sediment, l) Site CS10 (30 m) – shell-hash dominated sediment. Green lasers are 20 cm apart.

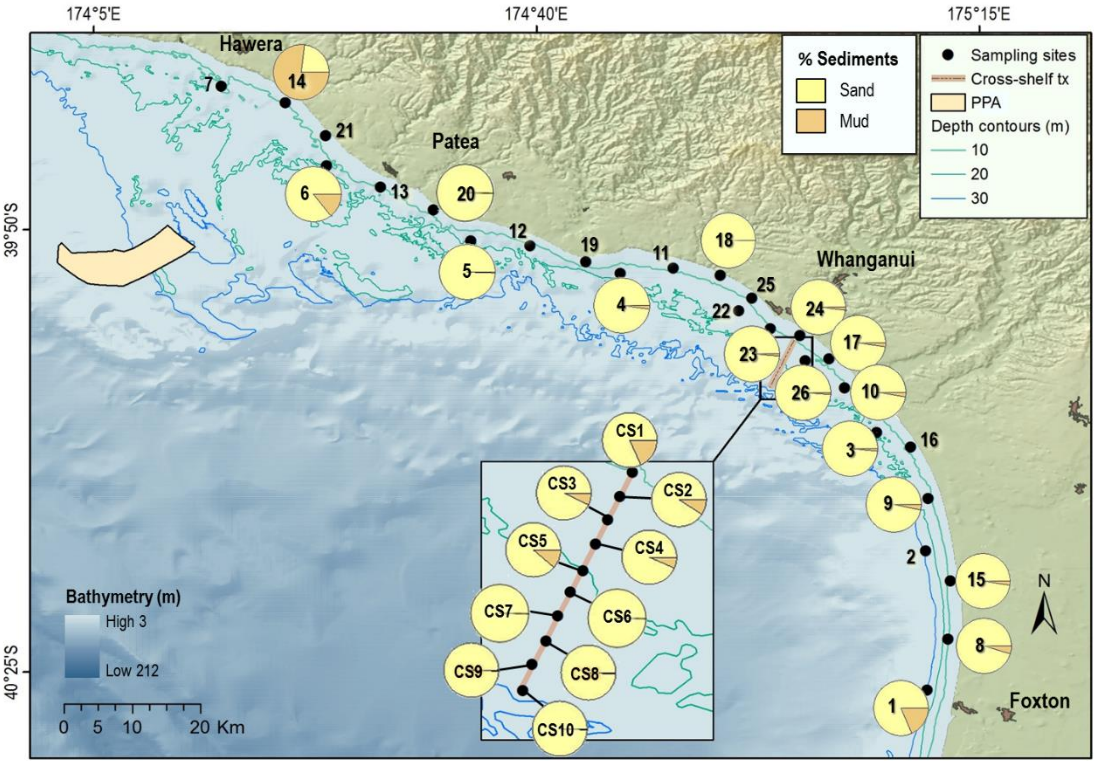

Figure 9: Sediment composition from nearshore (1-26) and cross-shelf (CS1-CS10) grab sites within the STB. Figure captions are provided in Figure 2.

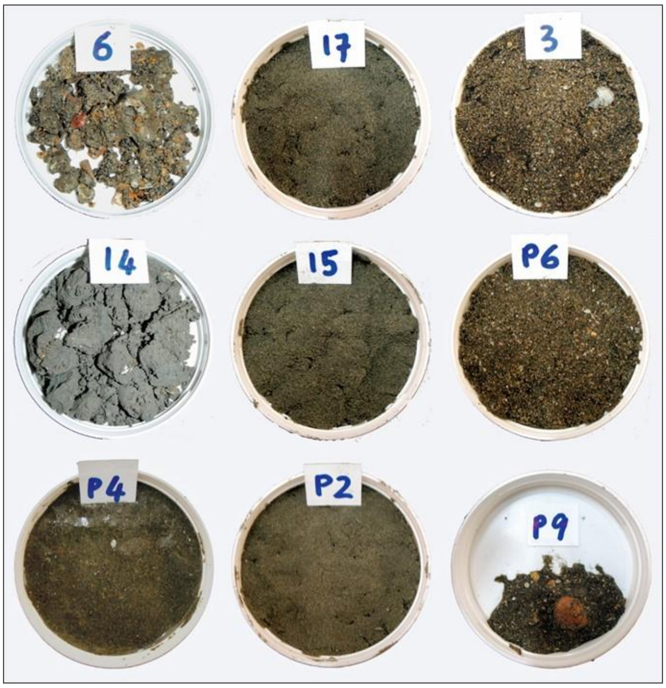

Figure 10: Examples of the surficial sediments collected using the Dietz grab within the STB. Numerical labels = site numbers (e.g. Sites 6, 17 and 3), while P2-9 = Cross-shelf Sites CS2-9, respectively. Site 6 (rocky outcrop site) contained high proportions of gravel and shell material; Site 14 comprised mostly semi-consolidated, pale grey mudstone; Sites 17, 15, CS2 and CS4 depict well-sorted fine sands, representative of the majority of nearshore and inshore cross-shelf sites; while Sites 3, CS6 and CS9 depict the coarser grained sediments found in water depths deeper than 20 m. Each container is 85 mm wide.

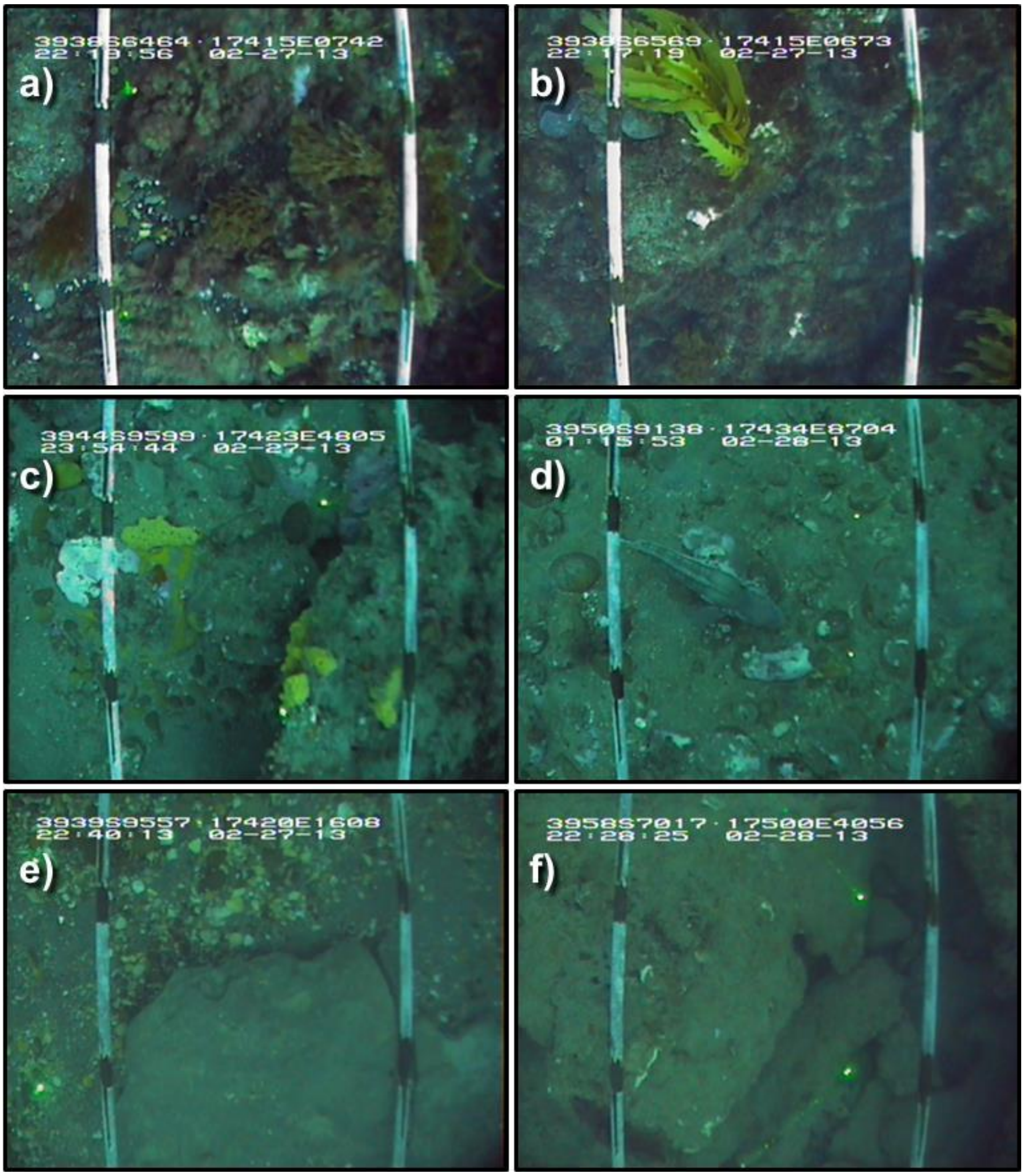

Figure 11: Splashcam images of hard substratum habitats within the STB.
a-b) Site 7 (13 m depth) – contiguous, moderate relief rocky outcrop with diverse sessile assemblages of bryozoans, kelp (*Ecklonia radiata*) and sponges (e.g. *Ecionemia alata*); c) Site 6 (20 m) - moderate relief rocky outcrop with characteristic bright yellow sponges (*Halichondria* sp.); d) Site 5 (22 m) - low relief rocky outcrop (here boulder cobbles and sand) with encrusting sponges and a blue cod; e) Site 14 (14 m) - pale grey mudstone and sediments with gravel and shell material, but no visible biota; f) Cross-shelf site CS1 (13 m) – mudstone outcrop of moderate relief (here bedrock and boulders) with patches of benthic diatoms and red filamentous algae.

3.1.2 Rocky outcrop habitats

Of the 36 sites surveyed, only five sites (Sites 5, 6, 7, 14 and CS1) contained hard substratum (8% of all photo-quadrats), represented by low to moderate relief hard rock (6%) or variable relief mudstone (2.2%) outcrops. Four of the five outcrops (Sites 5, 6, 7 and 14) occurred in the northern sections of the study area in water depths of 12 to 22 m, while the fifth outcrop (CS1) occurred at a depth of 13 m on the inner-most section of the cross-shelf transect (Figure 6). The composition and rugosity (relief) of these features, however, varied between locations (Figure 6-7 and Figure 11). The most rugose outcrops were found at Sites 7 and CS1. Video observations at Site 7 confirmed this feature to be hard rock with moderate relief bedrock and boulders (e.g. Figure 11a-b) abutting coarse sandy sediments with pebbles and shell-hash (Figure 6, 7 and 11a-b). CS1 was also characterised by moderate relief bedrock and boulder, but abutted rippled muddy sands (Figure 6-7 and Figure 11f) and was composed of mudstone (locally known as Papa Rock). Sites 5 and 6 were characterised by lower relief hard rock outcrops, comprising varying mixtures of bedrock, boulders, cobbles and soft substrata (Figure 6-7 and Figure 11c-d), while Site 14 contained the least amount of hard substratum (mean 10.35% ± 5.35%), characterised by low-lying slabs of pale grey weathered mudstone partially covered in coarse sands with shell hash and gravel, along with small cobble-sized mudstone fragments (Figure 11e). Both dredge and sediment grab samples collected at this site, returned high proportions of semi-consolidated, pale grey mudstone (see Figure 5c and Figure 10 and Appendix B and D). In addition, the dissolution of soft mudstone fragments during the wet-sieve grain-size analyses accounted for the very high proportion of mud (77%) recorded for this site (Figure 9-10 and Appendix B), and identified the very crumbly and fragile nature of this mudstone substratum.

3.2 Macrobenthic assemblages

Seventeen sites were sampled with benthic dredges, collecting a total of 94 species/OTU's and 349 individual specimens from 68 families (1.38 ± 0.09 species per family) (Appendix E). Of these, 61 species had been recorded previously from the Patea Shoals region, with 6 species recorded as common to the region (Appendix E; *also see* Beaumont et al., 2013), while several additional species have also been recorded for the great STB region by other sources (Appendix E). Although only two of these species, the hermit crab, *Areopaguristes setosus*, and the predatory gastropod, *Amalda australis*, were common to both areas. In this survey, dredges sampled representative habitats, including rocky outcrops (Sites 5, 6, 14) and a variety of soft-sediment habitats from northern, central, southern and cross-shelf locations (Figure 13). Very few macrobenthic specimens were collected from most sites. Overall, samples yielded 20.5 ± 6.1 individuals and 9.5 ± 2.4 species per site, with functional groups dominated by suspension feeders (39.5%), deposit feeders (23.3%), predators/scavengers (21.6%) and primary producers (12.7%) with only a few grazers (2.9%). However, the number of specimens and the composition of benthic assemblages varied markedly between, and within, soft-sediment and rocky outcrop habitats (Figure 12-16).

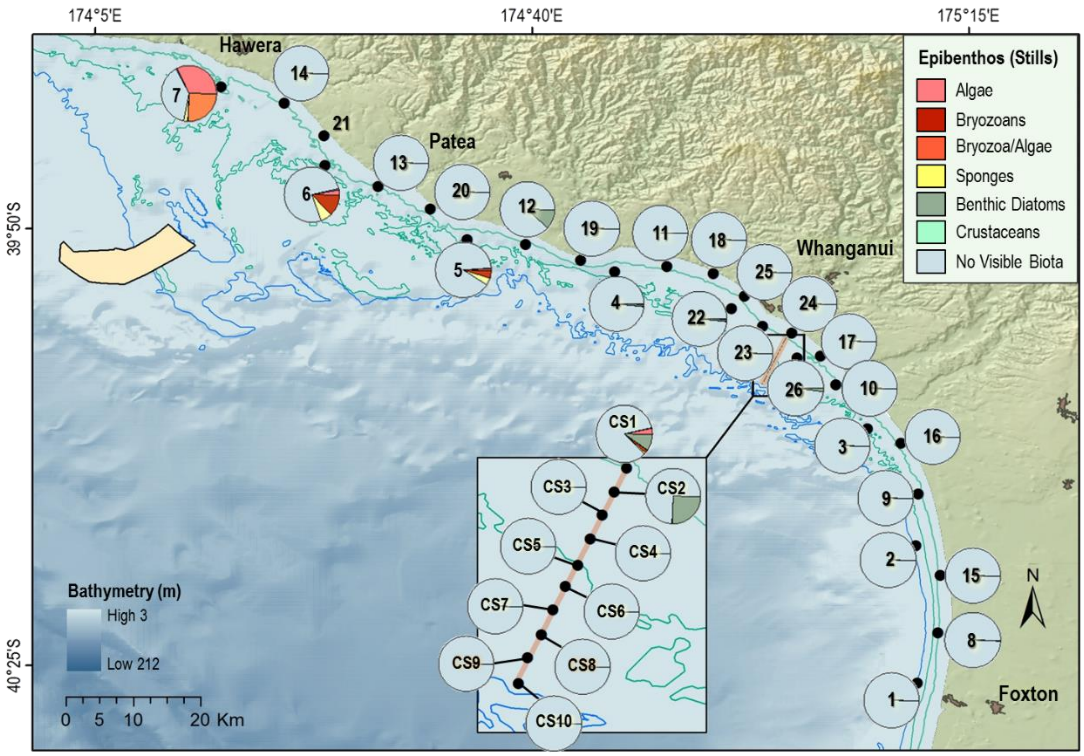

Figure 12: Macrobenthic assemblages recorded from Splashcam photo-quadrats in nearshore and cross-shelf sites within the STB. Figure captions are provided in Figure 2.

3.2.1 Soft-sediment macrobenthos

Soft-sediment sites were characterised by very few visible organisms (mean 0.19% ± 0.32% cover, range 0-43% per photo-quadrats) (Figure 8 and Figure 12; Appendix D-E). The only abundant organism seen in soft-sediments was occasional surface films of benthic diatoms (mean 1.5% ± 0.3%, range 0-40% per photo-quadrat) recorded at several central sites - mostly notably at Sites CS2, CS1, and to a lesser extent Sites 4, 12, 22, and 26 (Figure 12), and which bind and stabilised surface sediments. Lebensspuren activity (i.e. visible signs of life) was also extremely rare across the extent of the survey (mean 0.37 ± 0.06, range 0-7 per photo-quadrat), with only 15 of the 36 sites (14.6% of all soft-sediment photo-quadrats) having some form of lebensspuren activity. These were mostly represented by small burrows (0.30 ± 0.04 burrows, range 0-7; e.g. Figure 8b,i), with much rarer occurrences of pits (0.005 ± 0.04, range 0-2) and faecal casts (0.07 ± 0.04, range 0-15). Although burrows are indicative of infaunal activity, the animals within these burrows were never observed.

Benthic dredge samples were collected from a total of 14 soft-sediment sites covering a broad range of locations across the spatial extent of the survey. Although video footage of soft-sediment sites revealed few to no macrobenthos, dredges collected a total of 233 specimens from 47 species, representing a variety of mostly small motile taxa (e.g. Figure 16b-f). Overall, macrobenthic assemblages at soft-sediment sites were characterised by various combinations of echinoids (a single sand dollar species, *F. zelandiae*), molluscs (i.e. bivalves and gastropods) and crustaceans (dominated by hermit crabs), with occasional macroalgae (likely drift weed) and polychaete worms (Figure 13, Figure 16b-f, Appendix D-E). Here species reflected an even mixture of deposit-feeders (dominated by *F. zelandiae*), predatory/scavengers (e.g. Hermit crabs and gastropods) and suspension feeding species (e.g. bivalves and polychaete worms) (Figure 15).

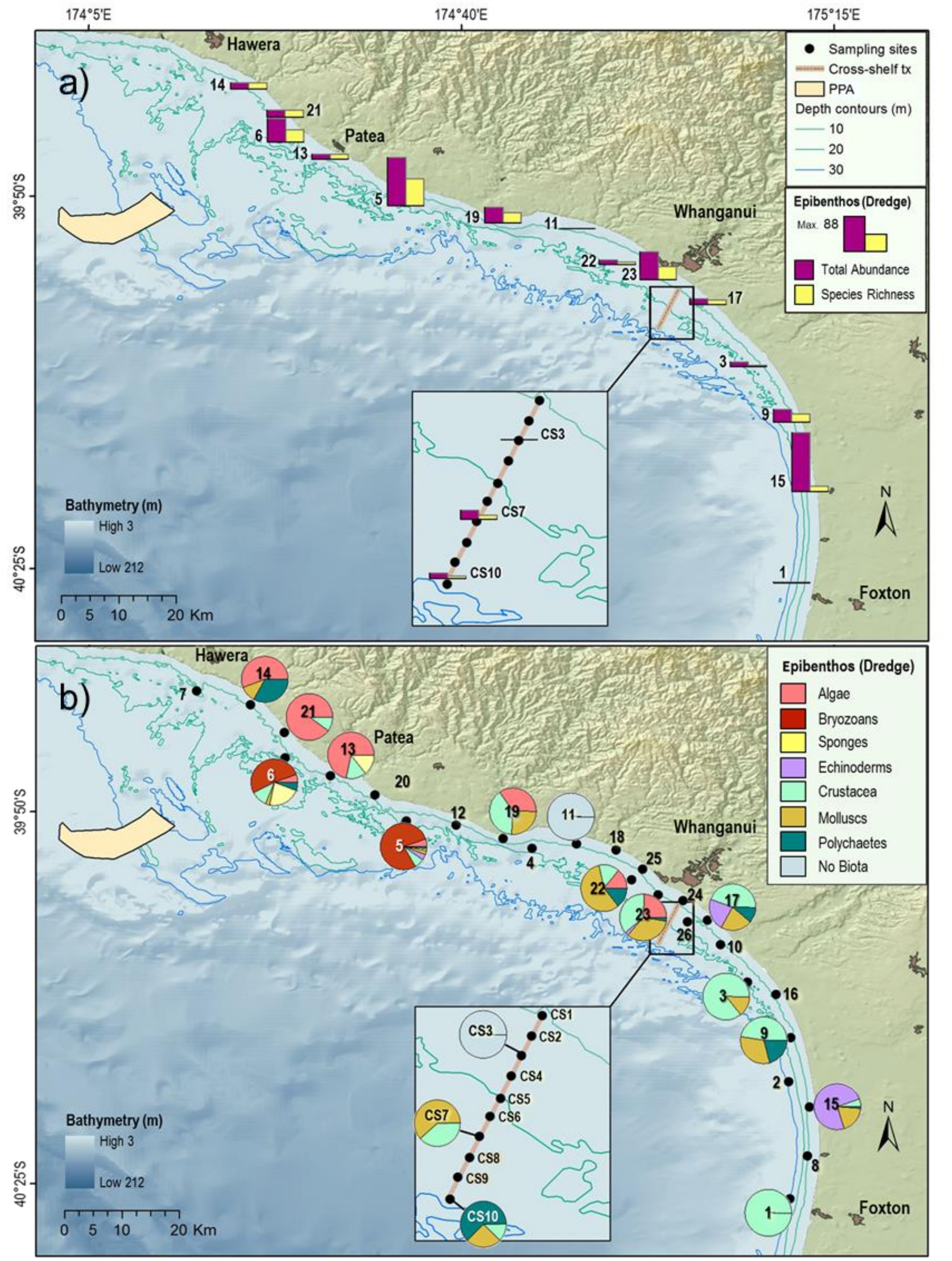

Figure 13: Macrobenthic assemblages collected in dredges at nearshore and cross-shelf sites within the STB. a) Histograms of total abundance and species richness at each dredge site, b) The proportion of major taxonomic groups collected at each dredge site. PPA = Proposed Project Area. Numbers depict sites.

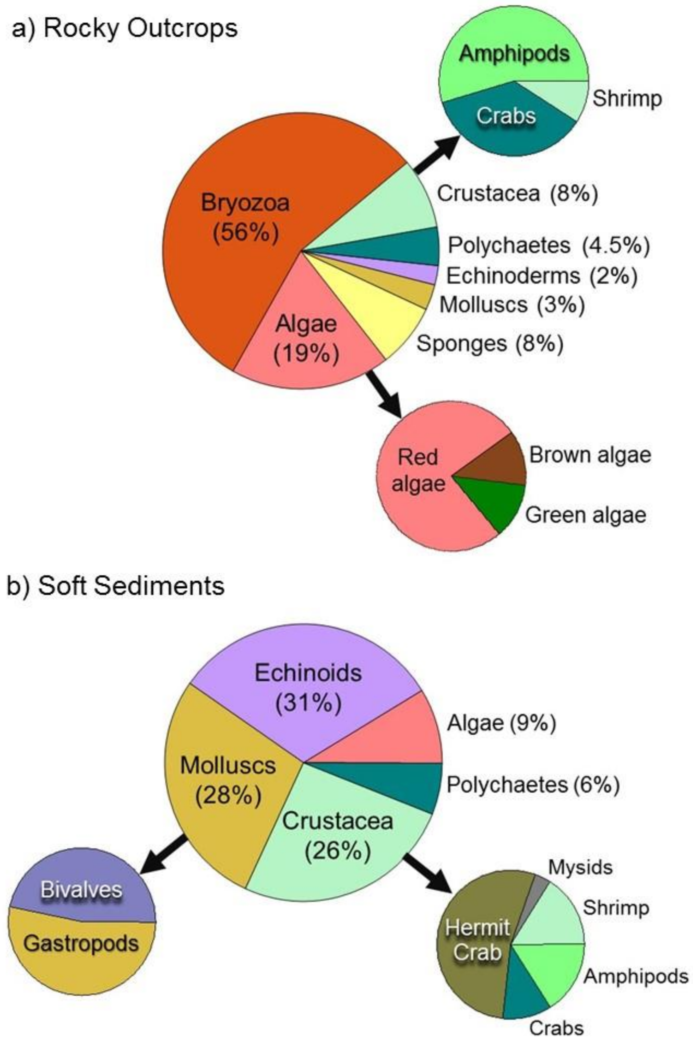

Figure 14: The proportion of major taxonomic groups collected in benthic dredges from rocky outcrop and soft-sediment habitats in the STB. Pie charts represent dedges from a) rocky outcrops (116 specimens from 56 species), and b) soft-sediment habitats (233 individuals from 47 species). Echinoids were represented here by a single species (the sand dollar, *F. zelandiae*) found at three sites. The relative contribution of algae may be underestimated here, as macroalgae collected in the dredges were recorded as presence/absence only, not amount collected.

Hermit crabs (e.g. *A. setosus,* and to a lesser extent *Lophopagurus cookie*) were the most frequently collected taxa in soft-sediment habitats, along with shrimps (*Philocheras australis*), gastropods (*A. australis*), fragments of macroalgae (e.g. *Acrosorium ciliolatum, Caulerpa flexilis*, *Halopteris novaezelandiae*) and bivalves (*Mactra ordinaria* and *Dosinia anus*) (Figure 14, Figure 16c-f, and Appendix E). The sand dollar, *F. zelandiae*, was the single most abundant species recorded across the entire survey, but this reflected high abundance (65 specimens) at a single location (Site 15), with only 1 and 2 specimens collected at two other locations (sites 23 and 17, respectively) (Figure 16b,d and Appendix E).

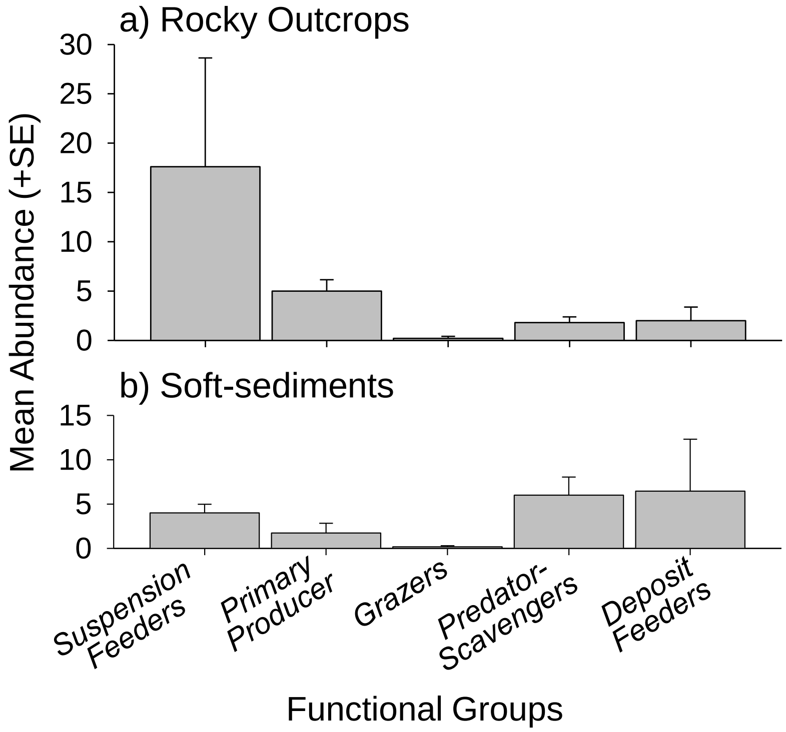

Figure 15: Mean abundance of macrobenthic functional groups (feeding guilds) by habitat type. a) rocky outcrops (Sites 5, 6 and 14), b) soft-sediments (all other sites).

Most soft-sediment sites (12 of the 14 sites dredged) supported relatively depauperate assemblages (8.3 ± 2.0 specimens, range 0-25; 5.7 ±1.4 species, range 0-15 species) (Figure 13a; Figure 16e-f). In contrast, two relatively distant soft-sediment sites (Sites 15 and 23 - approx. 40 km apart) were characterised by locally abundant assemblages (Figure 13; Figure 16b-d). Site 15 (*subtly-rippled muddy-sands*) supported the highest abundance (88 specimens) of all sites surveyed, but this was driven by high numbers of the sand dollars, *F. zelandiae* (65 specimens), along with a few gastropods (*A. australis*), bivalves (*M. ordinaria*) and crustaceans Figure 13, Figure 16b,d, and Appendices D-E). Site 23 (*subtly-rippled fine-sands*) had less than half the abundance of Site 15 (41 specimens), but comprised a numerically more even assemblage of hermit crabs (*A. setosus*), bivalves (*Nucula nitidula* and *D. anus*) and gastropods (*A. australis*, *Austrofusus glans* and *Cominella adspersa*), along with a single *F. zelandiae* specimen Figure 13, Figure 16c and Appendices D-E). Rippled sediments, characteristic of the nearshore (< 20 m depth) supported more macrobenthos (20.4 ± 8.5 specimens, range 0-88 specimens and 8.2 ± 1.9 species, range 0-19) than the coarser shell-debris sediments in water depth > 20 m, which supported very few visible biota (0.34% ± 0.08%, range 0-4% biotic cover per photo-quadrat) and represented the lowest mean number of specimens (mean 7.3 ± 2.5 specimens, range 1-13) and species (mean 3.3 ±1.1 species, range 1-6) collected over all habitats (Figure 13 and Appendix D).

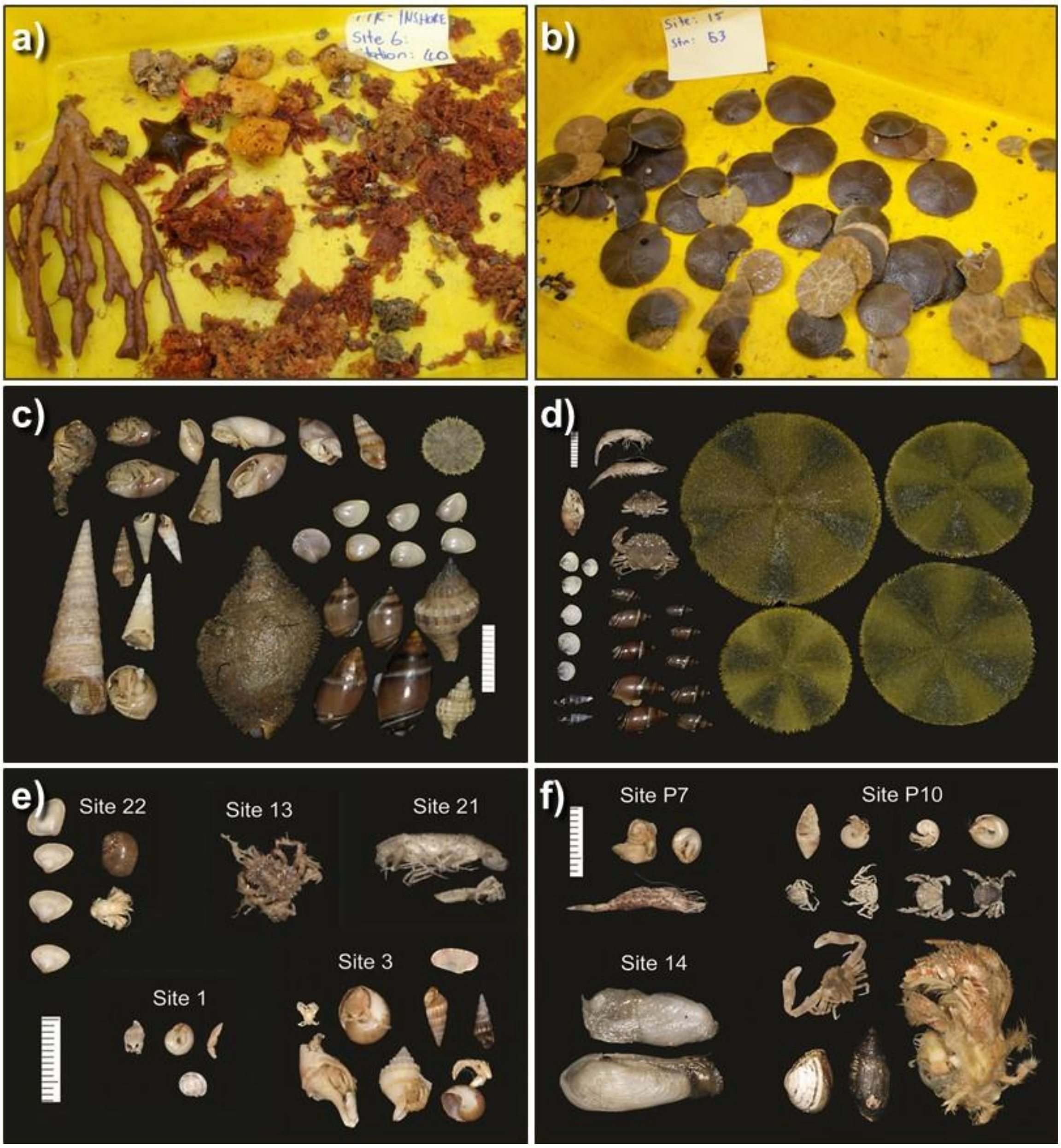

Figure 16: Types of biota collected in the benthic dredges from the nearshore and cross shelf regions of the STB. a) Site 6 (rocky outcrop, 19 m water depth) - dominated by mixed sponges (including *Halichondria* sp*.* and *C. ramose*), bryozoan and red macroalgae, with starfish (*P. mortensoni*) and other smaller taxa (worms and crustaceans); b,d) Site 15 (rippled sands, 7.5 m) - dominated by sand dollars (*F. zelandiae*), with gastropods (*A. australis*), bivalves (*M. ordinaria*), shrimp, crabs and a hermit crab; c) Site 23 (rippled sands, 14 m) - characterised by hermit crabs (*A. setosus*), gastropods (*A. australis*, *A. glans* and *C. adspersa*) and bivalves (*N. nitidula* and *D. anus*), with a small sand dollar; e-f) examples of taxa from various sites where only a few specimens were collected, including the rock-boring bivalve, *Barnea similis*, collected from site 14. Scale bars are in mm.

3.2.2 Rocky outcrop macrobenthos

In contrast to soft-sediment sites, rocky outcrops (Sites 5, 6, 7, 14 and CS1), although rare in spatial extent, supported much higher biotic cover (36.71 ± 4.51 % cover; range 0-83% cover per photo-quadrats) and species richness (3.92 ± 0.52 species, range 0-7 species/per photo-quadrat) (Figure 11 and Figure 12). Benthic dredge samples were collected from 3 rocky outcrop sites, 2 hard rock sites (Site 5 and 6) and one mudstone site (Site 14), while the two most rugose outcrops (Site 7 and CS1) were deemed too dangerous to dredge. However, dredge collections at rocky outcrop sites reflected similar assemblage structure to those seen in the video footage, characterised by moderately abundant (38.7 ± 18.3 specimens; range 9-72 specimens) and diverse (22.9 ± 9.2 species, range 9-40 species) assemblages (total of 116 specimens from 56 species collected) (Figure 13). The composition of rocky outcrops (mudstone vs. hard rock) and the level of rugosity were important factors in describing assemblage abundance and composition.

Based on video footage, mudstone outcrops (Sites 14 and CS1) supported low amounts of biota (mean 12.8% ± 3.9% cover, range 0-35%, per photo-quadrat) (Figure 11e-f and Figure 12). The low-lying mudstone outcrops at Site 14 displayed heavily eroded surfaces with no visible macrobenthos (Figure 14e), while the benthic dredge at this site collected only a few organisms (9 specimens from 9 species), including fragments from five red algal species, two polychaete species (Family Nereididae), a Sipuncula worm and the rock-boring bivalve, *Barnea similis* – associated with soft rock formations (Figure 13, Figure 16f and Appendices D-E). Large amounts (~ 5 kg) of semi-consolidated mudstone were also collected (see Figure 5c and Figure 10), identifying the very fragile and erodible nature of this mudstone habitat. Although no dredge sampling was undertaken across the mudstone outcrop at CS1 (13 m), video footage identified this moderate-relief feature to be heavily silted with relatively low biotic cover (total mean 14% ± 4.0% cover, range 0-35% per photo-quadrat) (Figure 11f and Figure 12), composed of small patches of filamentous red macroalgae (mean 5% ±1.9%, range 0-14%), surface films of benthic diatoms (4.4% ± 2.2%, range 0-15%), small encrusting yellow sponges (1.6% ±1.2%, range 0-10%) and high localised densities of some unidentified taxa (3% ± 2.5%, range 0-20%), possibly small colonial ascidians. Rippled sediments adjacent to this outcrop supported more abundant surface films of benthic diatoms (mean 20% ± 11.6%, range 0-40%), but no other visible biota.

In contrast, video footage of the more consolidated and rugose hard rock habitats at Sites 5, 6 and 7, supported much higher amounts of biotic cover (overall mean of 45% ± 5.0% cover, range 4-83% per photo-quadrat) (Figure 11a-d and Figure 12). Dredges collected at Sites 5 and 6 recorded the highest abundance (53.5% ± 18.5 specimens, range 35-72) and diversity (29 ± 11 species, range 18-40) of all dredge sites (Figure 13a). These more diverse assemblages, were characterised by sessile habitat-forming biota, dominated by bryozoans (74 specimens from 27 species), macroalgae (mostly red algal species) and sponges, as well as more motile species, such as crabs, amphipods, starfish, brittle stars, gastropods and polychaetes worms (Figure 13b, Figure 16a, and Appendices D-E). Some assemblage differences were recorded between these two sites, with more than three times the number of bryozoan collected from the lower-relief outcrop at Site 5 (56 specimens from 27 species) than the slightly more extensive and rugose outcrop at Site 6 (18 specimens from 8 species), although eight bryozoan species - including the three most abundant species (*Pterocella vesiculosa*, *Catenicella* sp A and *Orthoscuticella innominata*) - occurred at both sites (Figure 13a,b and Appendices D-E). Conversely, Site 6 was characterised by more frequent occurrences of *Halichondria* sp., a small bright yellow ball sponge (e.g. Figure 11c and Figure 16a), along with larger erect sponge species (e.g. *C. ramose*, e.g. Figure 16a, Appendices D-E). Although no dredge sampling was able to be undertaken at site 7 (13 m), video footage identified a similar mixed algal and suspension feeding assemblage, dominated by bryozoans, red macroalgae and sponges (Figure 11a, b) - including several shared sponge species (e.g. *Haliclona venustina*, *Leucettusa lancifera* and *I. proximum, and the encrusting Hymedesmia* cf *microstrongyla*) (Appendices D-E). Comparisons between video footage at all three hard rock sites, identified that Site 7, the most rugose (moderate-relief) outcrop surveyed, had the highest biotic cover (mean 66.9% ± 4.4% cover, range 35-83% cover/per photo-quadrat), compared to the low to moderate relief outcrop at Site 6 (mean 34.3% ± 5.7% cover, range 16-64%), and the low-relief patchy outcropping at Site 5 (mean 21.3% ± 6.0% cover, range 4-43%). Site 7 also appeared to support a more advanced assemblage structure with the addition of sparsely distributed kelp (*Ecklonia radiata*) and massive sponges (e.g. *Ecionemia alata*) - not seen or collected from Sites 5 and 6 (Appendices A,E).

3.3 Predicted Reefs and Rocky outcrops

Based on MacDiarmid et al. (2013) reefs and rocky outcrop map layers, 4 coastal reefs (0.2 – 8.5 km^2) and 13 rocky outcrops (0.34 - 2.45 km^2 size range) were predicted to occur on the shelf between Hawera and Foxton (Figure 17). These consisted of three relatively extensive coastal reefs (˜4.3 – 5.1 km^2 size range) in the northern section of the study area around Patea and Hawera, one small coastal reef immediately north of the Whanganui river mouth (˜0.2 km^2), and 13 rocky outcrops (˜0.3 - 2.5 km^2 size range) in the northern section of the study area, located at distances of 2 to 10 km offshore (Figure 17; *also see Figure 1-2 in MacDiarmid et al., 2013 for broader scale view of the spatial occurrence of reefs and rocks*). However, of the rocky outcrops sampled during this survey, only Site 7 was mapped, indicating that the number and possible extent of mudstone and hard rock outcrops within this region has been underestimated. Site 7 traversed the NW side of the largest of the rocky outcrops (approx. 3.8 x 0.8 km, 2.45 km^2), which from the video footage and map layer appears to be an extensive consolidated reef. Although the mudstone outcrop at Site CS1 was not present on the Reefs and Rocks data layer, a strip of Multibeam acoustic imagery collected along the cross-shelf transect (Pallentin et al., 2013) identified that CS1 sampled the edge of a small (38 x 85 m, 0.0024 km^2) discrete rock outcrop, which video observations confirmed as being consolidated mudstone of moderate relief (Figure 17 – insert). Adjacent to this outcrop are smaller patches of low-lying outcrops that are likely part of the same basement mudstone. The occurrence of these sub-surface mudstone features may explain the higher proportions of muds in the sediments at these sites (i.e. CS1-5 and Site 26, Figure 9). The rocky outcrops at Sites 5 and 6, along with the low-lying mudstone outcrop at Site 14, were also unmapped. Sites 5 and 6 occur within an area of complicated bathymetry, which extends along much of this northern inner-shelf region, indicating that hard rock outcrops may be more common throughout this region. This region also includes the North and South Traps, both relatively large (1.2 x 0.2 km - 0.52 km^2 and 1.8 x 0.1 km - 0.94 km^2, respectively) high relief outcrops (MacDiarmid et al., 2013). These two features are located approximately 2 km apart, and less than 2.5 km away from site 5 (Figure 17), indicating that they may be part of the same basement feature. Of the 13 rocky outcrops predicted to occur on the shelf between Hawera and Foxton, 10 occur either inshore or south-east of the PPA, in areas predicted to be lightly affected by CSS (Figure 17). Hard rock outcrops, sampled during this survey, either occur within these same lightly affected areas (Sites 5 and 6) or beyond the plume range (Site 7).

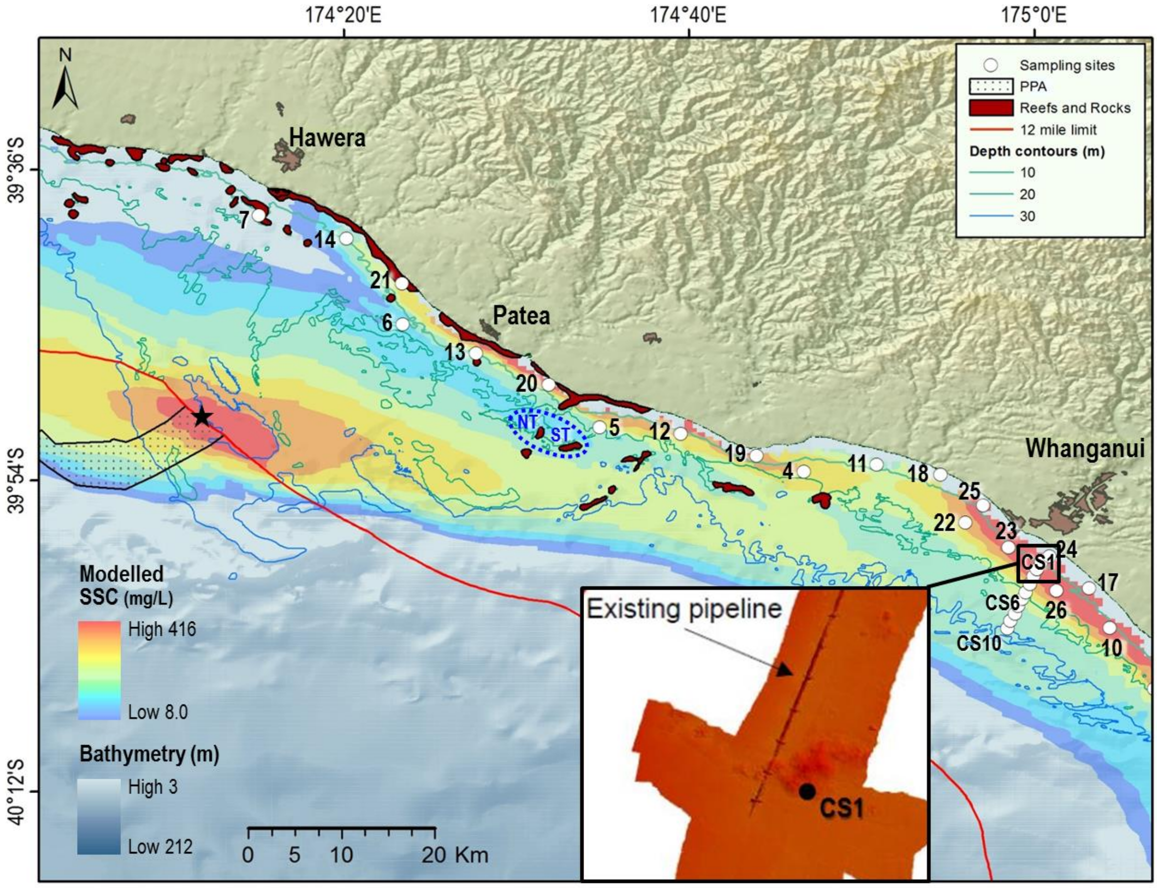

Figure 17: The location of coastal reefs and rocky outcrops within the STB (based on MacDiarmid et al., 2013) relative to predicted near-bottom suspended sediment concentrations (SSC) of extraction-derived sediment. (NT = North Trap and ST = South Trap) locally named Rocky Outcrops. Insert shows the multibeam bathymetry for the inner-section of the cross-shelf transect. Red area depict the mudstone outcrop at CS1 and the Whanganui waste water outfall; Orange depicts the surrounding soft-sediments. See Figure 2 for additional caption descriptions.

Several additional sites occurred in close proximity to either coastal reefs (e.g. Sites 20 and 21) or rocky outcrops (e.g. Site 13) (Figure 17). Site 13 was located between 465-510 m NNW of a small (0.36 km^2) unnamed rocky outcrop. Video observations of the seabed at this site identified a dynamic soft-sediment habitat of rippled sands with no visible macrobenthos (Appendix A). However, a benthic dredge sampled within 20 m of the video transect collected small fragments of red (*A. ciliolatum*, *Aphanocladia delicatula* and *Ceramium* sp), green (*C. flexilis*) and brown (*H. novaezelandiae*) macroalgae, as well as a decorator crab (*Notomithrax peronii*) and a small reef sponge (*I. proximum*, present on the hard rock outcrops at Sites 5, 6 and 7) (Appendix D-E), and returned with a bent spreader, indicating that some rocky habitat was also sampled. Similarly, Site 21 was located on the outer edge of an extensive (8.5 km^2) coastal reef. This site was too turbid to collect video footage, but like Site 13 a benthic dredge collected a range of macroalgal fragments, including red (*Anotrichium crinitum*, *A. ciliolatum*, *Ceramium* sp1 and sp2, *Plocamium cirrhosum* and *Rhodymenia* sp), brown (*H. novaezelandiae* and *Sporochnus moorei*) and green (*C. flexilis*) macroalgal species (Appendices D-E).

4 Discussion

Sediment plumes can impede available light to the seabed limiting photosynthetic organisms, such as microalgae (e.g. benthic diatoms - Holland et al. 1974, Grant et al. 1986, Delgado et al. 1991) and macroalgal (e.g. kelps and seaweeds - Connell, 2005; Eriksson and Johansson, 2005; Balata et al., 2007) species that require light to survive and grow, while deposition of suspended fine-sediments can choke benthic suspension-feeding organisms, such as sponges, bryozoans, bivalves and filter feeding worms that filter their food from the water column (e.g. Grant and Thorpe, 1991; Ellis et al., 2002; Lohrer et al., 2006; Schwarz et al., 2006). Accumulation of fine-sediments on the seabed may also bury susceptible species, such as sessile or slow moving organisms (e.g. Hinchey et al., 2006;), and surface films of benthic diatoms, many of which exude polymeric substances that bind and stabilise surface sediments and are a food source for other benthic species (Holland et al. 1974, Grant et al. 1986, Delgado et al. 199l; Gillespie et al. 2000). As little was known about the benthic habitats and organisms within the nearshore region of STB, TTR contracted NIWA to characterise benthic habitats, surficial sediments and benthic macro-fauna and macro-flora in the nearshore region of the STB.

Ninety-two percent of the seabed along the nearshore region of the STB was characterised by extensive soft-sediments that supported few macrobenthic organisms. The remaining 8% of the seabed (five sites) comprised hard substratum in the form of either low to moderate relief hard rock (6%) or variable relief mudstone (2%) outcrops. In contrast to mudstone outcrops, which supported low or negligible amounts of macrobenthos, hard rock outcrops supported abundant and diverse assemblages, with the two dredges sampled at Site 5 and 6 accounting for more than 25% of all specimens and 61% of all species collected during the survey.

4.1.1 Soft-sediments

Within the STB, high wave energies create strong oscillatory currents that shape and modify the seabed (Orpin et al., 2009), mobilise and resuspend sediments leading to persistently high levels of water turbidity in nearshore areas (MacDiarmid et al., 2010). Consequently, in areas already affected by high levels of natural sediment disturbance and suspended sediments, such as the dynamic sediment rippled bedforms within the nearshore STB region, the resilience of the naturally occurring benthic community to suspended sediments is likely to be high (e.g. Lohrer, 2004). However, we would expect that functional groups, such as suspension feeding bivalves, would be more susceptible to impacts of suspended sediments than other more tolerant species, such as motile deposit feeders and to a lesser extent predatory/scavengers.

Small suspension-feeding bivalves were a characteristic component of the soft-sediment assemblages within the nearshore region, albeit with low diversity and abundance across the study region. Previous surveys within the region by Gillespie and Nelson (1996) found that large suspension-feeding bivalves (*Glycymeris modesta* and *Tucetona laticostata*) dominated sediments offshore of Whanganui in water depths of approximately 25-50 m, indicating that bivalve populations, at least in the past, have been common in deeper habitats further offshore. However, these deeper offshore habitats would also be subjected to much lower CSS levels than nearshore habitats (Figure 1). One of the two Geoduck species found in New Zealand, *Panopea smithae* (deep water clams, found to 130 m water depth), has also been collected from two offshore habitats within the STB (MacDiarmid et al., 2007; Te Papa Museum records, searched July 2013). A sandy sediment site ~18 km offshore in 40 m water depth SW of Patea (3 specimens - 39^o 56.0 S, 174^o 26.0 E, *RV Acheron* March 1976), and a bryozoan/shell sediment site ~30 km offshore of the Whanganui River in 59-64 m water depth (4 specimens - 40^o 11.0 S, 174^o 49.0 E, *RV Acheron* March 1976). In contrast, the shallower commercially-harvested species, *P. zelandica* (5–25 m depth range mostly within harbours), has only been recorded from fossils collected from the Whanganui cliffs. No geoduck were collected during this survey, however standard sampling gear rarely collect clams, which require specialised hydraulic dredging or water blasting to remove them from the sediment (e.g. Cranfield and Michael, 2001; MacDiarmid et al., 2007). Although a few dual burrows were observed in the video footage and still imagery at some sites (e.g. site 8), no characteristic "shows" (i.e. characteristic dual siphon holes surrounded by a distinct raised circle of sediment) were ever seen at any of the nearshore or cross-shelf sites, nor was there any geoduck shell debris observed at these sites that would be indicative of an underlying population (e.g. Collingwood beds in Golden Bay).

Mobile and frequently disturbed sediments, generally support low species abundances and relatively poor species richness, dominated by smaller and more motile species that are tolerant to these harsh benthic conditions (McLachlan and Dorvlo, 2005). Nearshore habitats directly offshore of Whanganui, expected to be impacted by the highest CSS, comprised low numbers of mostly small motile predatory/scavengers (hermit grabs and gastropods), larger and variable numbers of sub-surface deposit feeders (a single sand dollar species), and sparse occurrences of several small suspension feeding bivalves. Species occurring in the nearshore rippled soft-sediments are presently subjected to regular sediment disturbances resulting from tides, currents and storm events, which in turn increases local turbidity and mobilise sediments that expose and bury them periodically. Gastropods, bivalves and motile crustaceans such as hermit crabs are able to right and unbury themselves quickly after physical displacement and burial (Hinchey et al., 2006). However, some species may be especially tolerant. For example, species such as the Spionid polychaete, *Paraprionospio pinnata* (a burrowing species recorded from Site 23) are known to be highly tolerant to severe hypoxic or anoxic conditions. Sturdivant et al. (2012) in a laboratory experiment found that *P. pinnata* continued to burrow and extend polyps into the water column at a dissolved oxygen levels of 0.1 mg l^{-1}, and was the only species in their study collected from anoxic field environments. *P. pinnata* is a widely distributed species often found in disturbed habitats (Dauer, 1985), and has the ability to switch between suspension feeding and deposit feeding modes making it more durable to changing benthic conditions (Sturdivant et al., 2012). Increased abundance through time of indicator species, such as *P. pinnata*, particularly relative to other more vulnerable taxa may highlight a shift in environmental conditions at the sediment-water interface.

The focus of this survey was to characterise macrobenthic assemblages using underwater video, stills and benthic dredges. Although several infauna (animals living in the sediments) were collected in benthic dredges during this study (e.g. sand dollars [sites 15, 17 and 23], bivalves and infaunal polychaete worms), most infauna are not well sampled using these sampling methods. No sediment cores or grabs were sampled for infauna during this study. Consequently the abundance and composition of the broader infaunal assemblage, including geoduck species, is not addressed in this study. However, while there is little information on the abundance and composition of infaunal assemblages from the nearshore regions offshore of Whanganui, intensive infaunal surveys across the broader Patea shoals region found dynamic soft-sediment habitats generally supported low diversity and abundance of both epifaunal (animals living on the surface of the seabed) and infaunal assemblages (Beaumont et al., 2013).

4.1.2 Rocky outcrops

In comparison to the expansive soft sediments, rocky outcrops comprised only a small amount of the available seabed. Yet, due to low species diversity and abundance in soft-sediment areas, hard rock habitats represented a substantive component of the overall abundance and biodiversity of the region. Hard rock assemblages were characterised by high proportions of sessile suspension feeders (dominated by bryozoans and sponges) and primary producers (mostly turf-forming red macroalgae with sparser occurrences of brown and green macroalgae). Of the numerous rocky outcrops predicted to occur within the broader STB region (see MacDiarmid et al., 2013) most lay beyond the range of the predicted plume (e.g. site 7). At least 10 outcrops (e.g. North and South Traps) plus those not mapped (e.g. Sites 5 and 6 and Site 13 and 21) occur in an area predicted to be only lightly affected by CSS (Figure 17). Outcrop-associated species, especially bryozoans, erect sponges and large canopy-forming species, such as kelps and seaweeds, however, are likely to be susceptible to small increases in CSS. In contrast, turf-forming macroalgae (such as filamentous reds) have sediment-trapping morphologies that enable them to dominate space under high depositional conditions (Airoldi, 2003; Connell, 2005).

The two mudstone outcrops identified were variable in their relief and supported few macrobenthic organisms. The very low-lying eroded mudstone at Site 14, supported an impoverished assemblage. Site 14 lies in the northern inshore region of the study area (1.5 km offshore, approximately 15 km NW of Patea) within an area predicted to be lightly affected by the CSS plume. In contrast, the mudstone outcrop at Site CS1 lies within the area predicted to have the most concentrated suspended sediments, directly offshore of Whanganui. A predicted worse-case mean deposition rate of extraction-derived silts adjacent to the Whanganui coast is estimated at approximately 15 mm per year, with a maximum 5-day accumulation of ≤5 mm. In the plume SS model, natural accumulation of sediments off Whanganui are estimated in the order of 10-20 mm per year, with an estimated maximum 5-day accumulation of ≤10 mm (Hadfield, *pers. comm*.). This outcrop is already draped in fine depositional sediment and supported very few macrobenthic organisms - mostly small patches of turf-forming red macroalgae. However, surface films of benthic diatoms were common on both the adjacent rippled sediments, and to a lesser extent on the outcrop itself.

Information relating to TTR's additional scientific work undertaken since 2014 has been provided and the conclusions is this report remain valid.

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Appendix A Splashcam survey locations and seabed descriptions

Area: S=Southern, N=Northern, C=Central, CS=Cross-shelf transect regions within the survey area, Depth: SOL = start of line; EOL = end of line; No. of photo-quadrats: defined as the number of times the Splashcam was dropped to the seabed to quantify seabed habitats and biota. Seabed descriptions are a summary description of habitat types and biota based on video observations at each site.

Site	*Area*	*Start Latitude S*	*Start Longitude E*	*End Latitude S*	*End Longitude E*	*Depth (m) SOL-EOL*	*Distance (m)*	*No. Photo-quadrats*	*Seabed Description*
1	S	40° 26.436	175° 10.926	40° 26.458	175° 10.944	28	44	12	**Shell-hashed sediments** (flat bedform); burrows, but no visible biota
2	S	40° 15.415	175° 10.812	40° 15.441	175° 10.798	25 - 26	41	12	**Shell-hashed sediments** (flat bedform); faecal trails, but no visible biota
3	S	40° 06.049	175° 06.937	40° 06.075	175° 06.924	18.7 – 19.1	58	12	**Rippled sediments** (subtle lunar-shaped ripples with shell-hash); no visible biota
4	N	39° 53.486	174° 46.646	39° 53.482	174° 46.696	16.0 – 16.4	82	11	**Rippled sediments** (linear-shaped); burrows and benthic diatoms
5	N	39° 50.914	174° 34.824	39° 50.908	174° 34.927	21.7 – 22.3	190	12	**Rocky outcrop** (low-relief mix of boulders, cobbles, sand), mixed algae, bryozoans, anemones and blue cod
6	N	39° 44.949	174° 23.428	39° 44.953	174° 23.492	21 – 20.3	85	12	**Rocky outcrop** (moderate/low relief, bedrock, boulders, cobbles and sands with shell gravel); bryozoans, mixed algae, yellow sponges (*Halichondria*).
7	N	39° 38.638	174° 15.094	39° 38.638	174° 15.094	12.8 – 13.0	35	12	**Rocky outcrop** (contiguous moderate relief bedrock with boulders, adjacent to coarse sediments); *Ecklonia*, red algae, bryozoans and sponges.
8	S	40° 22.395	175° 12.552	40° 22.417	175° 12.549	11.5	50	11	**Flat sediments**; hermit crabs, gastropods and a crab
9	S	40° 11.282	175° 10.979	40° 11.299	175° 10.998	15.5 – 15.7	48	12	**Rippled sediments** (subtle sinuous/lunar-shaped); burrows, but no visible biota
10	C	40° 02.533	175° 04.688	40° 02.565	175° 04.757	9.9 – 11.5	98	13	**Rippled sediments** (mixed linear/linguoid shaped and coquina); burrows, but no visible biota
11	C	39° 53.046	174° 50.858	39° 53.049	174° 50.882	8.0 – 8.3	70	12	**Rippled sediments** (linguoid-shaped and coquina); no visible biota
12	N	39° 51.280	174° 39.524	39° 51.278	174° 39.590	13.7 – 14.2	110	11	**Rippled sediments** (linear-shaped); burrows and benthic diatoms
13	N	39° 46.635	174° 27.688	39° 46.629	174° 27.705	12.7 – 12.5	38	12	**Rippled sediments** (linear-shaped); no visible biota
14	N	39° 39.959	174° 20.177	39° 39.957	174° 20.167	14.2 – 13.8	26	14	**Mudstone outcrop** (Low-lying partially covered in coarse sands), no visible biota
15	S	40° 17.813	175° 12.745	40° 17.813	175° 12.745	5.5 – 5.7	28	12	**Rippled sediments** (subtle bedform); gastropods and hermit crabs
16	S	40° 07.195	175° 09.598	40° 07.205	175° 09.612	5.0 – 5.2	30	12	**Rippled sediments** (lunar-shaped); no visible biota
17	C	40° 00.240	175° 03.164	40° 00.268	175° 03.239	4.0 – 4.2	92	12	**Rippled sediments** (catenary –linguoid shaped); no visible biota
18	C	39° 53.640	174° 54.576	39° 53.654	174° 54.632	2.5 – 3.0	84	8	**Rippled Sediments**; poor visibility
19	N	39° 52.533	174° 43.926	39° 52.519	174° 44.012	6.9 – 7.4	109	12	**Rippled sediments** (linear-shaped); no visible biota (*poor viz*.)
20	N	39° 48.438	174° 31.875	39° 48.490	174° 31.874	6.0 – 6.5	100	13	Rippled sediments (catenary-shaped), no visible biota
21	N	39° 42.561	174° 23.382	39° 42.561	174° 23.394	7.3 – 7.5	45	-	*Two tows both aborted due to poor viz*
22	C	39° 56.417	174° 56.020	39° 56.424	174° 56.082	16.0 – 16.7	102	13	**Rippled sediments** (catenary-shaped); hydroid and negligible benthic diatoms
23	C	39° 57.859	174° 58.516	39° 57.888	174° 58.602	12.4	106	13	**Rippled sediments** (subtle bedform); *poor viz.*

Site	*Area*	*Start Latitude S*	*Start Longitude E*	*End Latitude S*	*End Longitude E*	*Depth (m) SOL-EOL*	*Distance (m)*	*No. Photo-quadrats*	*Seabed Description*
24	C	39° 58.364	175° 00.862	39° 58.370	175° 00.939	4.7 – 3.7	109	12	**Rippled sediments** (linear-shaped); no visible biota
25	C	39° 55.427	174° 57.055	39° 55.434	174° 57.090	4.8 – 5.0	27	9	**Rippled sediments** (sinuous-linguoid shaped with coquina); no visible biota
26	C	40° 00.378	175° 01.278	40° 00.379	175° 01.352	15.6 – 15.9	149	13	**Rippled sediments** (catenary-shaped with coquina); benthic diatoms
CS1	CS	39° 58.714	175° 00.394	39° 58.685	175° 00.408	13.5 – 13.7	54	12	**Mudstone outcrop** (moderate relief mudstone adjacent to rippled sediments); benthic diatoms, red algae and a few small sponges.
CS2	CS	39° 59.141	175° 00.171	39° 59.137	175° 00.137	14.4	56	12	**Rippled sediments** (sinuous/catenary-shaped), burrows and benthic diatoms
CS3	CS	39° 59.549	174° 59.958	39° 59.560	175° 00.001	16.4 – 16.8	67	13	**Rippled sediments**, no visible biota
CS4	CS	39° 59.977	174° 59.746	39° 59.968	174° 59.783	19.0 – 19.8	54	12	**Rippled sediments** (catenary-shaped), coquina, no visible biota
CS5	CS	40° 00.449	174° 59.520	40° 00.440	174° 59.545	22.4 – 22.8	66	12	**Rippled sediments** (linear-sinuous shaped); shell hash; no visible biota
CS6	CS	40° 00.831	174° 59.294	40° 00.833	174° 59.332	21.6 – 22.0	70	11	**Rippled sediments** (linear-sinuous shaped); shell hash; no visible biota
CS7	CS	40° 01.250	174° 59.074	40° 01.262	174° 59.121	23.5 – 23.7	54	12	**Shell-hashed sediments** (flat/subtly rippled bedform); drift algae
CS8	CS	40° 01.689	174° 58.874	40° 01.696	174° 58.914	22.3 – 24.0	72	12	**Shell-hashed sediments** (linear-lunar shaped bedform); burrows, but no visible biota
CS9	CS	40° 02.100	174° 58.617	40° 02.118	174° 58.691	25.0 – 28.0	75	12	**Shell-hashed sediments** (flat/subtly rippled bedform); no visible biota
CS10	CS	40° 02.565	174° 58.456	40° 02.576	174° 58.548	30.0 – 30.8	198	12	**Shell-hashed sediments** (flat/subtly rippled bedform); gurnard and finger-sponge

Appendix B Sediment grab locations and surficial sediments

Area: S=Southern, N=Northern, C=Central, CS=Cross-shelf transect regions within the survey area. Sediment descriptions are based on the wet-sieve grain-size analyses and GRADISTAT sediment descriptions; mod. = moderately; v. = very.

Site	*Area*	*Latitude S*	*Longitude E*	*Depth (m)*	*Sediment Type*	*Textural Group*	*Grain Size Description*	*Mean (µm)*	*Sorting (µm)*	*Skewness (µm)*
1	S	40° 26.436	175° 10.926	28.0	Unimodal, poorly sorted	Muddy Sand	v. coarse silty fine sand	105	2.3	-0.6
3	S	40° 06.049	175° 06.937	19.0	Unimodal, mod. sorted	Sand	medium sand	348	1.7	0.0
4	N	39° 53.486	174° 46.646	16.0	Unimodal, mod. well sorted	Sand	fine sand	194	1.5	-0.3
5	N	39° 50.914	174° 34.824	22.0	Bimodal, mod. well sorted	Sand	fine sand	203	1.6	0.1
6	N	39° 44.949	174° 23.428	21.0	Bimodal, poorly sorted	Muddy Sand†	v. coarse silty v. fine sand	219	3.8	0.1
8	S	40° 22.359	175° 10.926	11.5	Unimodal, well sorted	Sand	fine sand	135	1.4	-0.2
9	S	40° 11.282	175° 10.979	15.5	Unimodal, well sorted	Sand	fine sand	133	1.3	-0.1
10	C	40° 02.533	175° 03.164	10.0	Bimodal, poorly sorted	Sand	fine sand	179	2.1	0.5
11	C	39° 53.046	174° 50.858	8.0	Too little sample retrieved.	-	-	-	-	-
14	N	39° 39.959	174° 20.177	14.0	Bimodal, poorly sorted	Sand	fine sandy coarse silt	24	3.8	0.1
15	S	40° 17.813	175° 12.745	5.5	Unimodal, well sorted	Sand	fine sand	142	1.3	-0.1
17	C	40° 00.240	175° 03.164	4.0	Unimodal, well sorted	Sand	fine sand	139	1.3	-0.1
18	C	39° 53.640	174° 50.376	2.5	Unimodal, well sorted	Sand	fine sand	152	1.3	-0.1
20	N	39° 48.438	174° 31.875	6.0	Unimodal, well sorted	Sand	fine sand	144	1.3	-0.1
23	C	39° 57.859	174° 58.516	12.5	Unimodal, well sorted	Sand	fine sand	162	1.4	-0.1
24	C	39° 58.364	175° 00.862	4.5	Unimodal, well sorted	Sand	fine sand	148	1.3	-0.1
25	C	39° 55.427	174° 57.055	5.0	Too little sample retrieved.	-	-	-	-	-
26	C	40° 00.378	175° 01.278	15.6	Unimodal, mod. well sorted	Sand	medium sand	252	1.6	-0.1
CS1	CS	39° 58.714	175° 00.394	13.5	Unimodal, poorly sorted,	Muddy Sand	v. coarse silty v. fine sand	113	2.7	-0.1
CS2	CS	39° 59.141	175° 00.171	14.4	Unimodal, mod. well sorted	Sand	v. fine sand	105	1.4	-0.2
CS3	CS	39° 59.549	174° 59.958	16.5	Unimodal, mod. well sorted	Sand	v. fine sand	119	1.5	0.0
CS4	CS	39° 59.977	174° 59.746	19.0	Bimodal, mod. sorted	Sand	fine sand	161	1.7	-0.4
CS5	CS	40° 00.449	174° 59.520	22.5	Unimodal, mod. sorted	Muddy Sand	v. coarse silty v. fine sand	107	1.7	-0.2
CS6	CS	40° 00.831	174° 59.294	21.6	Bimodal, poorly sorted	Sand	fine sand	301	2.0	0.4
CS7	CS	40° 01.250	174° 59.074	23.5	Unimodal, mod. well sorted	Sand†	fine sand	202	1.5	0.2
CS8	CS	40° 01.689	174° 58.874	22.3	Bimodal, mod. sorted	Sand†	fine sand	336	2.0	0.4
CS9	CS	40° 02.100	174° 58.617	25.0	Unimodal, mod. sorted	Sand†	medium sand	277	1.7	0.2

Site	*Area*	*Latitude S*	*Longitude E*	*Depth (m)*	*Sediment Type*	*Textural Group*	*Grain Size Description*	*Mean (µm)*	*Sorting (µm)*	*Skewness (µm)*
CS10	CS	40° 02.565	174° 58.456	30.0	Trimodal, poorly sorted	Sand†	fine sand	302	2.1	0.4

Appendix C Sediment composition based on dry sieve fractions

Proportions of gravel and sands (coarse, medium, fine, and very fine) for those sites with gravel or shell hash material (material coarser than >1.6 mm) in significant amounts to analyse. N= nearshore, CS=cross-shelf.

Site	*Area*	*Latitude S*	*Longitude E*	*Depth (m)*	**% Gravel (> 1.6mm)**	**% Coarse Sands (1.6 mm-500 μm)**	**% Med. Sands (250-500 μm)**	**% Fine Sands (125-250 μm)**	**% V. Fine Sands (63-125 μm)**
6	N	39° 44.949	174° 23.428	21.0	18.5%	8.5	18.0	50.4	3.5
CS8	CS	40° 01.689	174° 58.874	22.3	83.0	7.2	3.4	1.4	3.0

NB: Several additional sites (e.g. CS1, CS7, CS8, CS9 and CS10) contained visible shell or gravel fractions (≥1.6 mm), but did not contain either enough gravel or enough remaining sediment to be re-analysed using the laser sizer.

Appendix D Benthic dredge locations and sample descriptions

Az=Agassiz dredge used to sample rocky outcrops, Ok= Oklemann dredge used to sample soft-sediments.
* indicates taxa that were subsampled.

Site	Gear	Start Latitude S	Start Longitude E	End Latitude S	End Longitude E	Depth range (m)	Distance (m)	Sample Description
1	Ok	40° 26.360	175° 11.030	40° 26.430	175° 10.990	28.8 – 29.1	147	Hermit crabs, gastropods
3	Ok	40° 06.020	175° 06.950	40° 06.000	175° 06.950	19.7 – 19.8	135	Shell fragments, bivalves, hermit crabs
5	Ok	39° 50.902	174° 34.762	39° 50.969	174° 34.793	20.8 – 21.1	153	Sponges, bryozoans*; amphipods, brittle stars, crab, hermit crabs, mixed algae
6	Az	39° 44.913	174° 23.488	39° 44.970	174° 23.430	18.6 – 19.4	194	Mixed algae; bryozoans, sponges*, starfish, gastropods, crustacean, polychaetes
9	Ok	40° 11.230	175° 11.010	40° 11.270	175° 10.950	15.6 - 17	117	Shell fragments; hermit crabs, bivalves, gastropods, amphipods, polychaetes
11	Ok	39° 53.067	174° 50.830	39° 53.114	174° 50.889	8.7 – 9.2	128	shell fragments, gastropods
13	Az	39° 46.511	174° 27.665	39° 46.673	174° 27.669	10 – 11.7	300	Fragments of algae; sponge, crab
14	Az	39° 39.920	174° 20.020	39° 39.975	174° 20.155	11.5 – 13.1	219	5 kg papa rock; red algae, bivalves, polychaetes and sipunculid worms
15	Ok	40° 17.770	175° 12.740	40° 17.840	175° 12.740	7.5	145	Sand dollars (4 retained, *61 discarded); hermit crabs, bivalves, gastropods, crab, shrimp, starfish
17	Ok	40° 00.200	175° 03.160	40° 00.270	175° 03.170	7.0	130	Bivalves, gastropods, crab, amphipods, sand dollars, polychaetes, sand dollars
19	Az	39° 52.497	174° 43.899	39° 52.568	174° 43.929	5.6 – 6.5	136	Mixed algae; shrimp, amphipods, gastropods, hermit crabs
21	Az	39° 42.566	174° 23.430	39° 42.533	174° 23.348	5 - 7	186	Mixed algae; various crustaceans
22	Ok	39° 56.440	174° 56.019	39° 56.429	174° 56.007	16.5 – 16.8	147	Hermit crabs, bivalves, polychaetes, algae
23	Ok	39° 57.830	174° 58.480	39° 57.900	174° 58.490	13.2 – 14.0	153	Black fetid mud; algae, hermit crabs, bivalves, gastropods, sand dollar (x1), shrimp
CS3	Ok	39° 59.530	174° 59.960	39° 59.600	174° 59.930	16.5	138	Shell fragments, salp
CS7	Ok	40° 01.203	174° 59.113	40° 01.278	174° 59.078	25.4 – 25.8	136	Gastropods, shrimp, amphipods, hermit crabs
CS10	Ok	40° 02.450	174° 58.460	40° 02.510	174° 58.430	32.1	120	Shell fragments, hermit crabs, amphipods, crab, polychaetes, bivalves, gastropods

Appendix E Macrobenthic species list

List of all species/OTU's collected in the benthic dredges and/or identified from video observations from nearshore (Sites 1-26) and cross-shelf (CS1-CS10) sites within the STB. Sites where species were collected are listed relative to habitat type (Rocky outcrops vs. Soft-sediments); n= total number of specimens collected across the entire survey, with the exception of macroalgae, which were only recorded as p=present; v=species identified from video footage only. Sites within brackets = species identified at these sites only from video footage; † = species with 5-10 individuals collected from this site; ‡ = species with 11-15 individuals collected from this site; **bold** = species with ≥ 20 individuals collected from this site; Blue text = genera classified within the Department of Conservation's (DoC) Threatened and At Risk species under naturally uncommon. However, it is unclear which species within these genera are referred in DoC's list. nd = species 'not defined'. 'Broader Region' depicts species that have previously been recorded from the broader Taranaki region: 'PS[1]' = species listed and 'Common-PS[1]' = species common from the region on or around Patea Shoals (Beaumont et al., 2013); 'NTC[2]' = species recorded in the North Taranaki Coast (Hayward et al., 1999); 'STB[3]' = species listed for the South Taranaki Bight region in the Ocean Biogeographic Information System (OBIS) database (see MacDiarmid et al., 2013: Table 6.2); 'BR[4]' = predicted occurrence based on fish-environment models (MacDiarmid et al., 2013); 'BR[5]' = target species of fisheries undertaken within the STB region.

Type	Subtype	Species/OTU	Functional Group	n	Rocky outcrops	Soft sediments	Broader Region
Macroalgae	Brown algae	*Halopteris novaezelandiae*	photosynthetic	p	Sites 13, 21	Sites 19, 23	PS[1]
Macroalgae	Brown algae	*Sporochnus moorei*	photosynthetic	p	Site 21	Sites 19, 23	PS[1]
Macroalgae	Brown algae	*Ecklonia radiata*	photosynthetic	v	(Site 7*)		PS[1]
Macroalgae	Green algae	*Caulerpa brownii*	photosynthetic	p	Site 5	-	
Macroalgae	Green algae	*Caulerpa flexilis*	photosynthetic	p	Sites 13, 21	Sites 19, 23	PS[1]
Macroalgae	Red algae	*Acrosorium ciliolatum*	photosynthetic	p	Sites 13, 14, 21	Sites 19, 23	
Macroalgae	Red algae	*Anotrichium crinitum*	photosynthetic	p	Site 21	Site19, 22	PS[1]
Macroalgae	Red algae	*Aphanocladia delicatula*	photosynthetic	p	Site 5, 13, 14	Sites 19, 23	PS[1]
Macroalgae	Red algae	*Ceramium* sp1	photosynthetic	p	Sites 13, 14, 21	Site 23	*C.* sp PS[1]
Macroalgae	Red algae	*Ceramium* sp2	photosynthetic	p	Site 21	-	*C.* sp PS[1]
Macroalgae	Red algae	*Dasyclonium incisum*	photosynthetic	p	-	Site19	
Macroalgae	Red algae	*Heterosiphonia squarrosa*	photosynthetic	p	-	Site23	PS[1]
Macroalgae	Red algae	*Hymenena* sp	photosynthetic	p	-	Site19	PS[1]
Macroalgae	Red algae	non geniculate coralline	photosynthetic	p	Site 5		PS[1]
Macroalgae	Red algae	*Plocamium angustum*	photosynthetic	p	Site 6	Site 23	
Macroalgae	Red algae	*Plocamium cirrhosum*	photosynthetic	p	Site 21	Site23	PS[1]
Macroalgae	Red algae	*Rhodymenia* sp	photosynthetic	p	Site 5, 14, 21	Site 23	PS[1]

Type	Subtype	Species/OTU	Functional Group	n	Rocky outcrops	Soft sediments	Broader Region
Macroalgae	Red algae	*Stenogramma interruptum*	photosynthetic	p	Site 14		PS[1]
Bryozoans	Bryozoans	*Aetea australis*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Beania discodermiae*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Beania plurispinosa*	suspension	3	Site 5		PS[1]
Bryozoans	Bryozoans	*Bicrisia edwardsiana*	suspension	3	Site 5, 6		Common-PS[1]
Bryozoans	Bryozoans	*Bugulopsis monotrypa*	suspension	4	Site 5, 6		PS[1]
Bryozoans	Bryozoans	*Caberea zelandica*	suspension	4	Site 5		PS[1]
Bryozoans	Bryozoans	*Catenicella* spA	suspension	6	Site 5, 6		
Bryozoans	Bryozoans	*Celleporina sinuata*	suspension	4	Site 5, 6		PS[1]
Bryozoans	Bryozoans	*Chaperiopsis spiculata*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Costaticella bicuspis*	suspension	4	Site 5, 6		Common-PS[1]
Bryozoans	Bryozoans	*Dimetopia cornuta*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Disporella pristis*	suspension	5	Site 5[†]		
Bryozoans	Bryozoans	*Emma triangula*	suspension	2	Site 5		
Bryozoans	Bryozoans	*Figularia carinata*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Galeopsis polyporus*	suspension	2	Site 5		PS[1]
Bryozoans	Bryozoans	*Orthoscuticella innominata*	suspension	5	Site 5, 6		PS[1]
Bryozoans	Bryozoans	*Parasmittina delicatula*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Pterocella scutella*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Pterocella vesiculosa*	suspension	9	Site 5, 6[†]		PS[1]
Bryozoans	Bryozoans	*Rhynchozoon paa*	suspension	5	Site 5[†]		PS[1]
Bryozoans	Bryozoans	*Scalicella crystallina*	suspension	3	Site 5, 6		Common-PS[1]
Bryozoans	Bryozoans	*Scruparia ambigua*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Smittina torques*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	*Stephanollona scintillans*	suspension	1	Site 5		PS[1]
Bryozoans	Bryozoans	Tubulipora Sp A	suspension	2	Site 5		
Bryozoans	Bryozoans	Tubulipora Sp B	suspension	1	Site 5		
Bryozoans	Bryozoans	Tubulipora Sp C	suspension	2	Site 5		

Type	Subtype	Species/OTU	Functional Group	n	Rocky outcrops	Soft sediments	Broader Region
Sponges	Sponges	*Aaptos globosum*	suspension	1	Site 5	Site 23	
Sponges	Sponges	*Callyspongia cf ramosa*	suspension	1	Site 6, (7*)		NTC[2]
Sponges	Sponges	*Haliclona* (*Adocia*) *venustina*	suspension	3	Site 6, (5, 7*)		*H.* Sp PS[1]
Sponges	Sponges	*Hymedesmia cf microstrongyla*	suspension	v	(Site 5, 6, 7*)		
Sponges	Sponges	*Leucettusa lancifera*	suspension	v	(Site 7*)		
Sponges	Sponges	*Halichondria sp.*	suspension	v	(Site 6*)		*H.* Sp PS[1]
Sponges	Sponges	*Iophon proximum*	suspension	5	Site 6, 13 (5*, 7*)		PS[1]
Crustaceans	Amphipods	*Atylus* sp	deposit/scavenger	2	Site 5		
Crustaceans	Amphipods	*Aoridae*	unknown	1		Site 7	
Crustaceans	Amphipods	*Caprellidae*	deposit/scavenger	1		Site 7	
Crustaceans	Amphipods	*Pardaliscidae*	unknown	6		Site 9, 19	
Crustaceans	Amphipods	*Synopiidae*	deposit/scavenger	1		Site 19	
Crustaceans	Amphipods	*Paradexaminidae cf houtete*	deposit/scavenger	4	Site 5, 6		
Crustaceans	Crabs	*Brachyura* spA	predator/scavenger	1		Site 17	
Crustaceans	Crabs	*Halicarcinus* sp	predator/scavenger	2	Site 6		*H.*. Sp PS[1]
Crustaceans	Crabs	*Hymenosoma depressum*	predator/scavenger	1		Site 9	
Crustaceans	Crabs	*Nectocarcinus antarcticus*	predator/scavenger	1		Site 9	PS[1]; STB[3]
Crustaceans	Crabs	*Nepinnotheres atrinicola*	predator/scavenger	1		Site 9	
Crustaceans	Crabs	*Notomithrax peronii*	predator/scavenger	2	Site 5, 13		PS[1]
Crustaceans	Crabs	*Ovalipes cathurus*	predator/scavenger	2		Site 15	PS[1]
Crustaceans	Hermit Crabs	*Areopaguristes setosus*	predator/scavenger	25		Site 3[†], 9, 22, 23[‡], CS7, CS10	Common-PS[1]
Crustaceans	Hermit Crabs	*Diacanthurus spinulimanus*	predator/scavenger	1		CCS10	PS[1]
Crustaceans	Hermit Crabs	*Lophopagurus cookii*	predator/scavenger	4		Site 1, 15, 19, CS7	STB[3]
Crustaceans	Mysids	*Tenagomysis* spA	predator/scavenger	2		Site 17	
Crustaceans	Shrimps	*Philocheras australis*	suspension	9	Site 21	Site 15, 17, 19, 23	
Crustaceans	Shrimps	*Philocheras pilosoides*	suspension	1		CS7	
Echinoderms	Echinoids	*Fellaster zelandiae*	deposit	68		**Site 15**, 17, 23	

Type	Subtype	Species/OTU	Functional Group	n	Rocky outcrops	Soft sediments	Broader Region
Echinoderms	Ophiuroids	*Amphipholis squamata*	deposit/scavenger	1	Site 6		PS[1]
Echinoderms	Ophiuroids	*Amphiura magellanica*	deposit/scavenger	2	Site 6		PS[1]
Echinoderms	Asteroids	*Patiriealla mortensoni*	predator/scavenger		Site 6	Site 15	
Molluscs	Bivalves	*Barnea similis* (Rock-borer)	Suspension	1	Site 14		PS[1] NTC[2]
Molluscs	Bivalves	*Corbula zelandica*	suspension	1		Site CS10	Common-PS[1], NTC[2]
Molluscs	Bivalves	*Dosinia anus*	suspension	6		Site 9, 15, 23	
Molluscs	Bivalves	*Gari convexa*	suspension	1		Site 3	
Molluscs	Bivalves	*Mactra cf ordinaria*	suspension	11		Site 15, 17, 19, 22	PS[1] NTC[2]
Molluscs	Bivalves	*Nucula nitidula*	suspension	9		Site 9, 19, 23†	PS[1] NTC[2]
Molluscs	Gastropods	*Amalda australis*	predator/scavenger	19		Site 9, 15‡, 19, 23†	Common-PS[1]
Molluscs	Gastropods	*Antisolarium egenum*	grazer	2		Site 17, CS7	PS[1]
Molluscs	Gastropods	*Austrofusus glans*	predator	1		Site 23	PS[1]
Molluscs	Gastropods	*Calliostoma cf punctulata*	predator	1	Site 6		PS[1] NTC[2]
Molluscs	Gastropods	*Coelotrochus tiaratus*	grazer	1	Site 5		PS[1]
Molluscs	Gastropods	*Cominella adspersa*	predator	2	Site 5		PS[1] NTC[2]
Molluscs	Gastropods	*Pupa affinis*	predator	1		Site CS10	
Molluscs	Gastropods	*Tanea zelandica*	predator	1		Site 9	PS[1] NTC[2]
Fishes	Blue cod	*Parapercis colias*	predator	v	(Sites 5)		BR[4]
Fishes	Red gurnard	*Chelidonichthys kumu*	predator	v		(CS5, CS10)	BR[5]
worms	Polychaetes	Euchone nd	suspension	7		Site 9, 17, CS10†	
worms	Polychaetes	*Glycinde trifida*	predator/scavenger	3		Site 9, 22	PS[1]
worms	Polychaetes	Nereidid nd	predator/scavenger	1	Site 14		
worms	Polychaetes	Oenonid nd	predator	2		Site 9, 15	
worms	Polychaetes	*Paraprionospio cf pinnata*	deposit/suspension	1		Site 23	
worms	Polychaetes	*Platynereis australis*	predator/scavenger	1	Site 14		PS[1]
worms	Polychaetes	Polynoid nd	predator/scavenger	1	Site 5		
worms	Polychaetes	Sabellids nd	suspension	1	Site 6		
worms	Polychaetes	Terebellids nd	deposit	1	Site 6		

Type	Subtype	Species/OTU	Functional Group	n	Rocky outcrops	Soft sediments	Broader Region
worms	Sipunculan	Sipunculans nd	suspension	1	Site 14		