Life on the seafloor in Queen Charlotte Sound, Tory Channel and adjacent Cook Strait

Life on the Seafloor

Prepared for Marlborough District Council

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Executive summary

NIWA was requested by the Marlborough District Council (MDC) to undertake an 11-day tow-video survey (MDC18 survey) to ground-truth and visually characterise habitats and communities across the HS51 survey area, building upon geo-referenced video surveys previously collected by NIWA (specifically video surveys from NIWA's MBIE-funded Bottlenecks programme (CB17 and BT17 surveys), and HS51's dropcam survey).

A total of 58 linear km's of seafloor video, with 6,251 seafloor characterisations from 358 video sites were collected during the four combined video surveys (MDC18, CB17, BT17 and HS51). Of this, the MDC18 survey collected 36.6 linear km's (63%) with 5,062 data points (81%) from 149 sites.

These data and observations ground-truthed a wide range of seafloor features and characterised their habitats and communities across the Queen Charlotte Sound (QCS), Tory Channel (TC) and Cook Strait regions, with many new and notable habitats, communities and species identified. This included new records of species within the Marlborough Sounds, new records of genera/families for New Zealand, as well as new records of size and colour-morphologies for known species. A summary of new and notable habitats, communities and species include:

Vibrant green ***Caulerpa* meadows** – a native green macroalgae – were found commonly on exposed high-current reefs in depths of 9-20 m at the entrances to QCS, TC and along the east coast of Cook Strait, with 15 new sites described (previously only one was purported). Meadows were composed of various mixes of two species (*C. brownii* and *C. flexilis*) that together and separately formed very lush high-density meadows on extensive reefs and rock walls.

Large areas with **patchy bryozoan reefs** – a coral-like organism that form concrete-like reefs – were discovered around the eastern and western channel entrances to QCS covering a delineated area of 9.58 km^{-2}. These patch reefs supported diverse and colourful sessile invertebrates including several species of reef-building bryozoans, sponges, ascidians, anemones, hydroids; and importantly appear to be a nursery ground for newly settling and juvenile blue cod. Patch reefs varied in size and vertical height (mostly ≤1 m high), interspersed by flat sandy muds and shell-debris, with horse mussels commonly found cemented within these reefs, and likely play an important role in bryozoan reefs establishing on these soft-sediment Banks. Importantly, these bryo-reef zones were visible in the HS51 bathymetry layers as dimpled surfaces (≤1 m) with 'high reflectance' (hard bottom) in the backscatter that enabled these areas to be delineated and measured.

Bryozoan reefs are also fragile (referred to as '*china shops*') that are easily broken and removed by mechanical fishing gear, such as dredges and trawls. There is some evidence based on historic catches and anecdotes from past fishers that these reefs used to occur more extensively across the "Duck Pond" (the large sediment bank or sill across the entrance of QCS) but are now mostly limited to the entrance ways into QCS. These habitats provide important and often critical structural habitat and refuge to a diversity of marine life and are known to act as nursery habitats for many commercial and recreationally important fish species, including blue cod. The consequences of habitat loss may have important consequences, including reduced recruitment of blue cod in this region.

Extensive fields of ***Galeolaria* mounds** covered the seafloor in what look like cities of skyscrapers from the air, and were recorded at 54 new sites mostly along the channel slopes within inner, mid and outer QCS down to a depth of 40 m. These are formed by the calcareous tubeworm, *Galeolaria hystrix* growing on top of each other and fusing to create large mounds (≤1-2 m high). Previously known only from 5 main locations around New Zealand, including Perano shoals in mid-QCS, these fragile habitats were now found on the sides of rocky ridges and often extended over broad areas of *Tucetona* shell-debris on the slopes adjacent to reefs.

Wide-spread **damage to *Galeolaria* mounds** across the Sounds was common, with damage recorded at 47 of the 54 sites. *Galeolaria* growing over reefs often had localised damage – with towers toppled or broken into rubble, likely caused by boat anchors. *Galeolaria* mounds out across the shell-debris slopes, often on exposed lower slopes, often had much more extensive damage, with towers demolished over 10-100's of metres with just small broken rubble remaining.

A new species of burrowing sea cucumber was discovered on very high-current deep slopes within the Sounds. This is a new taxonomic genera (and Family) not previously recorded in New Zealand waters. Specimens collected during the survey have been initially identified as *Thyone* spA. These animals bury their body in the sediment with their tentacles left exposed to filter plankton from the currents. Surprisingly, for a species not previously recorded, this species was extremely abundant (≤60 individuals per m^{-2}) especially at the QCS-TC junction near Dieffenbach Point, where they formed a distinct and significant habitat in depths of ~30-50 m.

NIWA's new ability to create **3-dimensional rotatable photographic mosaics** from the video footage of underwater habitats, was trialed for the first time on three Marlborough Sounds habitats. Mosaics of bryozoan reefs, *Galeolaria* towers, and the burrowing sea cucumbers show unprecedented imagery of how these seafloor communities appear in a landscape view, and provide an insightful and revolutionary way of imaging and studying these distinctive habitats.

The distribution and boundaries of several species of habitat-forming tubeworms were also documented, including those of the distinctive, but possibly highly invasive small **bluish-white fanworm *Bispira bispira* spA,** which now forms very dense zones in several previously known and new locations within the Sounds.

Live beds of robust dog cockles (*Tucetona laticostata*) were discovered at 25 sites within the Sounds, found buried on slopes with coarse sediments - often directly below rocky headlands - exposed to very strong currents, in depths ranging from 9-44 m. This species occurs around much of New Zealand's coast in depths to 100 m. However, this species appears to have an important role within the Sounds. After death, their large robust shells (≤12 cm diam), that can remain on the seafloor for thousands of years, accumulate on the seafloor down-slope providing hard structure for other sessile animals to grow on.

***Tucetona* shell debris fields** were a common feature on the mid slope of QCS (below the living beds), in depths of 15-30 m. These debris fields supported diverse encrusting and sessile invertebrate species (e.g., sponges, ascidians, hydroids) along with abundant motile invertebrates (e.g., brittlestars, starfish, sea cucumbers and urchins), and like bryozoan reefs, also supported notable numbers of newly settled and juvenile blue cod.

***Tucetona* sediment-covered debris-fields** further down slope in depth >30 m, were covered in a sediment-veneer, with silty depositional sediments increasing with depth. Here communities in depths of 30-50 m were characterised by the presence of brachiopods, solitary cup corals and red urchins – with twelve notable sites supporting fields of brachiopods. Brachiopods fields such as these are defined as a '*sensitive marine benthic habitat*' in MacDiarmid et al. (2013), while solitary cup corals belong to the order Scleractinia are protected under the Wildlife Act 1953. These deep slope sites were often within or adjacent to commercial-fished scallop areas, and as such many may have experienced disturbance and subsequent damage.

Similar *Tucetona*-made habitat zones were also present within the **high-current channels of Patten and Pickersgill Passages**. Here, live *Tucetona* beds were also present along the current-swept sediment banks (as previously reported), while very dense accumulations of *Tucetona* shell debris covered the seafloor within the channels creating a debris flow up to 250 m away from the channel. Beyond this, debris became more consolidated and partially buried by depositional sediments, with communities here more like those on the silt covered debris slopes across QCS.

***Amphiura*-dominated 'sediment plains'** were extensive mud habitats within the main channels and bays of QCS. These thick mud sediments were densely pocked with the rose-coloured brittlestars, *Amphiura correcta*, which lie buried beneath the sediment with only their pink arms extending out – making the sediment look like it is covered in pink hair-like follicles. These habitats also supported other taxa (e.g., mostly infaunal species, such as heart urchins).

The ***Amphiura*-zone** was strongly correlated with the HS51 backscatter reflectivity and sediment classification layers (Neil et al. 2018a,b), which depicted these areas as thick low reflectivity muds that comprised the most extensive habitat type mapped. However, Neil et al.'s '*sediment plain'* map-category also included the sandier muds on the Sill (i.e., the Duck Pond), which supported few to no *Amphiura*. Consequently, the 'sediment plain' category as it stands would greatly over-estimate the *Amphiura* zone. However, these 'sandier Sill sediments' are distinguishable from the *Amphiura*-dominated muds, by having >10% sand.

Kelp forests in Cook Strait were common along the east coast in depths mostly <15-17 m. These kelp forests were comprised of various mixes of species known to occur on the exposed east coast (e.g., *Lessonia variegata, Marginariella boryana* and *Landsburgia quercifolia*), as well as species also found within the Sounds (*Ecklonia radiata* and *Carpophyllum flexuosum*).

Kelp beds within the Sounds closely matched those depicted by Hay (1980a), with the addition of a newly discovered dense kelp forest of *E. radiata* off Waihi Point, near Cape Jackson. However, for previously known sites, marked compositional changes have occurred. While patchy kelp beds were still common along the shallow fringe in TC, with beds comprised of various assortments of giant kelp *Macrocystis pyrifera, E. radiata* and *C. flexuosum*, the exotic Japanese seaweed (or Wakame), *Undaria pinnatifida*, was now common within the kelp-zone at most sites. Within outer QCS, rocky reefs and rubble habitats around Motuara Is. and Motungarara Is. that once supported *M. pyrifera*, were now completely replaced by *U. pinnatifida* indicating wide-scale occurrence of *U. pinnatifida* though the Sounds, where it may be out-competing important native species.

Kina barrens (i.e., areas devoid of kelp with abundant kina) were common throughout most of the Sounds and was the most common reef community recorded on shallow rocky reefs. However, notably higher densities of kina (≤25-38 kina per m^{-2}) were recorded at three very high-current wave exposed locations: outer TC (≤35 per m^{-2}), off Waihi Point near Cape Jackson (≤38 per m^{-2}), and in Cook Strait south-east of Cape Koamaru (≤25 per m^{-2}). **Drift algae** commonly seen on the seabed at these sites, were covered in clusters of large-sized kina, and may be an important food source driving/supporting these high densities of kina in what are otherwise kelp-barren zones.

Drift-algal mats were common within the shallow bays off TC, with extensive areas of these soft-sediment bays (10-100's of m) covered in thick (est. <1 m high) dense mats, with the small beam trawls collecting extremely high volumes of living drift macroalgae (100 to >300 L). These drift-algal mats contained high numbers of small triplefins, newly settled leatherjackets and an assortment of other small fishes, as well as abundant small-sized infaunal bivalves and numerous nudibranchs (and their spaghetti-like eggs). While a significant drift-algal mat has previously been reported for Ngaruru Bay (Ecological Significant Marine Site (ESMS-5.11)) covering an estimated 41.9 ha, the current studies document 6 additional TC bays that also support extensive drift-algal mats, that based on the multiple time periods of these surveys are consistently present between years. This high-volume delivery of drift algae through TC is likely to be a significant driver of community structure within TC and its shallow bays.

Deep offshore reefs in Cook Strait (**Cook Rock, the Brothers, and Te Whētero)** were surveyed in depths of 60 to 132 m. Due to their exposure to high winds, high and changeable seas, and extremely high currents, these deep reefs had never been surveyed, and to do so was an intrepid endeavour. Reefs here were visually-stunning with steep pinnacles, ridges and rock walls, some 10-40 m high, that were densely packed with highly colourful sessile filter feeders with sponges, ascidians, vibrant yellow zooanthids, dense clusters of brachiopods, hydroids, hydroids trees, soft and hard bryozoans, along with many other species – leaving no rock space unclaimed. A suite of new species records, new size and colour morphs were discovered. Most notable were bleach-white *E. alata* sponges many the size of tractor tyres (new size and colour records for New Zealand), along with dense clusters of strange-looking barnacles attached to rock ledges by long furry stems – known as goose neck barnacles (new species record for Marlborough Sounds). These are notable discoveries for the Marlborough Sounds, but also important for New Zealand.

Deep high-relief reefs in the channel entrances to QCS and TC were surveyed in depths of 30-103 m. These reefs supported colorful sessile filter feeding communities that shared many similar species to those found on the deeper offshore reefs, including bleach-white sponges at the entrance to QCS, similar sponge garden species (both locations) and high diversity of species covering most available reef space.

Deep reefs within the Sounds, within inner bay or in the inner Sounds, were often covered in a veneer of sediment, with communities dominated by orange sea squirts and often high localised densities of solitary cup corals. Deep reefs off headlands exposed to higher currents (especially those around the QCS-TC junction) supported more striking sessile assemblages characterised by encrusting 'reef-building' bryozoans, ascidians, hydroids and rock anemones, and in some places, large clusters of white barnacles.

The deep reef off Dieffenbach Point extends 435 m offshore (under the path of the ferries) to depths of ~55-60 m. Steep jagged rock walls reaching vertical heights of 25 m in places, support some of the most striking communities seen within the Sounds. Here steep rock walls and ridge tops were densely packed with a rich assortment of sessile filter-feeding invertebrates including raised clusters of barnacles, rock anemones, bryozoans, ascidians, hydroids and large sponges (incl. bleach-white *E. alata* sponges - one of the few locations within the Sounds where these impressive sponges were found). The large crevices and overhangs also supported a variety of other fish species, including commercially and recreationally important species, but these included few large sized edible fishes. This deep reef is not included in any current ESS.

Factors shaping these deep reef communities. The relationship between communities of deep reefs inside the Sounds, to those at the entrance to the Sounds and further offshore on deeper reefs, identified a gradient offshore in community composition (and to some degree biodiversity), with predictable combinations of current strength, depth, vertical relief and spatial location important in predicting the structure of these communities.

TC channel slopes comprised three distinct 'habitat and community' types. **Soft sediment slopes** were found at the mouths of shallow TC bays where slope angle was <15° and max. slope-variance was <2°, characterised by low to dense biofilm, low to moderate densities of snake stars and cushion starfish, and occasional biogenic clumps. **Rubble and debris slopes** were often near bay-entrances with intermediate slope angles (10-25°) and max. slope variance of 2-4°, comprised of shell-debris, biogenic clumps, and/or low-lying rock and rubble that supported mostly small sessile invertebrates dominated by orange and/or green soft bryozoans, small mixed hydroids, biogenic clumps of relict and live 'reef-building bryozoans' along with colonial ascidians, and mostly moderate to high densities of snake stars and starfish.

Deep reef slopes within TC away from bay entrances, in depths >20 m with slope angles >30° supported diverse and colourful assortments of sessile invertebrate communities, including hard and soft bryozoans, erect and encrusting sponges, colonial, solitary and stalked ascidians, hydroids including hydroid trees, jewel anemones, deep encrusting coralline algae, brachiopods, along with rare occurrences of yellow zooanthids. These diverse slope communities have previously been described for several northern TC sites by Davison et al. (2011) and Davidson and Richards (2015), with these designated within ESMS-5.8. Here sites closest to TC-entrance with higher slope angles supported more notable communities, with the most notable record being several small clusters of gooseneck barnacles at a northern-channel site closest to TC-entrance. Several new deep slope communities were also identified on the southern side of TC, although deep slope communities were generally less common on this side of the channel due to shallower depths and gentler slopes.

Some signs of **mechanical damage to TC slope habitats** were also seen, including areas of biogenic-encrusted reefs that appeared to have been sheered clean, along with notable amount of rubble from completely demolished *Galeolaria* mounds at one slope sites, and similar *Galeolaria* rubble found in amongst accumulated shell debris in the main channel – indicating that more substantial *Galeolaria* mounds may previously also have occurred within TC.

Hard branching bryozoa (*Galeopsis porcellanicus*) that form pretty pink and often large sized florets (also considered a china-shop species), were found growing both on the cobble seafloor close to TC-entrance and on the bryozoan patch reefs at QCS-entrance. his species has also been reported from Allen Strait, French Pass and Stephens passage indicating a probable relationship with these very high current environments.

The seafloor within the **main channel of TC** varied from accumulated shell debris within inner to mid sections of the channel, to low-lying cobbles and rock near TC-entrance, and supported low total % cover of small filter-feeding invertebrates (e.g., small hydroids a few cm high) and encrusting species (e.g., sponges, ascidians and deep water coralline algae), although % cover appears to increase on the approach to TC-entrance.

Within inner to mid TC, **large linear wave-like features** visible in the HS51-bathymetry were ground-truthed at a few sites. These features were found to be rows of accumulated shell debris (≤0.5-0.75 m high and ~6 m across) separated by flat-sediment troughs, with a wave periodicity of ~6-8 m, equaling those seen in the bathymetry. These shell-mounds support a variety of encrusting and small invertebrate species and high numbers of starfish, along with moderate densities of parchment worms which may help bind these mounds together. Based on the HS51 bathymetry, these wave-like mounds cover large areas of the seafloor within inner to mid TC.

Deep rock/rubble slopes elsewhere in Cook Strait and at the entrance to QCS supported similar rubble communities to those seen in TC with slope angles <15° dominated by soft bryozoa and other small-sized taxa (incl. small hydroids and solitary cup corals). Slopes with slightly raised reef (few cm's) supported mostly orange soft bryozoans and, at some sites, notably high densities of cup corals (≤38 individuals per m^{-2}), while slopes with more gravel scree were dominated by mostly green soft bryozoa (a characteristic also seen in TC). At some sites these rock/rubble slopes may be reflective of altered and/or damaged habitats due to bottom fishing gear, such as kina and scallop dredges within the Sounds, and bottom trawling in Cook Strait.

Relict bryozoan reefs were common at the entrance to QCS – both on the outer slopes of the Duck Pond (or Sill) and in the deep channels on the eastern and western side of the entrance. These relict reefs were partially or heavily buried by down-slope sediments and varied in vertical height from a few cm' to <2 m. Although these low-lying relict reefs did not support a significant biological community the presence of such a large area of relict bryozoan reef along with still active growing reef is likely to have important implications to understanding the paleoecology and geology of this region.

Although **blue cod** were commonly recorded throughout the Sounds, large legal sized blue cod were rare, as too were other large-sized commercial fish or crayfish. The few locations where large fish were found were under the path of the ferries , or on deep reefs not previously charted – indicating a natural but very limited refuge from fishing pressure.

Human trash was recorded in over a third of all sites (36%), with the highest occurrences in inner-QCS (65% of inner-QCS sites). However, the amount of trash within sites was low (2.1% of all records, and 5.3% of inner-QCS records), reflecting low amounts of widely distributed trash. The types of trash varied from small items (mostly beer bottles, few soda cans, food-wrappers) and fishing gear (including lines, ropes and burley pots), to large discarded industrial items (e.g., 10 gallon drums, pipes, car tyres, and the back end of a tractor), with the latter most common within inner bays, often near homesteads. Macro-plastics however were rare (<6% of all trash). All trash items were recorded with a GPS position (± ~3 m error).

A wide variety of other significant and notable habitats, sites and species were also identified and are described in this report. These findings provide significant new insight into the types of habitats, species and communities present within the HS51 survey area, and unearths the value of physical attributes (from the HS51 data layers and maps) in predicting their distributions.

The findings presented in this report provide one of the most comprehensive stock-takes of marine habitats and associated communities within New Zealand, and provide significant new knowledge that will help form the foundation of future spatial management strategies and conservation endeavours.

These findings provide critical knowledge on the natural (or at least current) character of these diverse marine environments - an essential requirement needed for Marlborough District Council to fulfil its mandate in coastal planning and biodiversity and meet their obligations under the Resource Management Act 1991 and New Zealand's Coastal Policy Statement 2010. It also provides MDC with the distributions and current state of these habitats and communities (including those that have incurred considerable damage). This information will provide MDC with the necessary knowledge to help them meet their statutory obligations under the New Zealand Biodiversity Strategy 2000 to halt the decline of, and maintain and restore a full range of natural habitats and ecosystems.

1 Introduction

1.1 Background

Marlborough District Council, as with other regional councils in New Zealand, has specific management responsibilities over coastal waters and habitats which lie within New Zealand's territorial seas out to 12 nm offshore. In the face of increasing use of coastal resources, regional councils must recognise and provide for the matters of national importance listed in Section 6 of the Resource Management Act 1991 (RMA). In particular regional councils must provide for the preservation of natural character (which includes an ecological element) (Section 6a) and protection of indigenous vegetation and fauna (Section 6c). They also must give effect to the policies on natural character in the New Zealand Coastal Policy Statement 2010 (NZCPS). Additionally, regional councils need to take into consideration the New Zealand Biodiversity Strategy 2000 (NZBS) to halt the decline in New Zealand's indigenous biodiversity, maintain and restore a full range of remaining natural habitats and ecosystems to a healthy functioning state, enhance critically scarce habitats, and sustain the more modified ecosystems in production and urban environments; and do what else is necessary to protect a full range of natural marine habitats and ecosystems to effectively conserve marine biodiversity. These are statutory obligations, not just a commitment.

As part of this obligation, Marlborough District Council has been leading the way in procuring state of the art Multi-Beam Echo Sounder (MBES) surveys that provide 2 m resolution bathymetry (vertical relief), and backscatter (seafloor hardness) along with eight terrain attributes (MBES derived data layers that incl. seafloor slope, rugosity, benthic terrain models, and seafloor classifications) (examples in Figure 1). Together these high-resolution MBES data layers provided detailed maps of the physical structure of the seafloor across a 433 km^2 section of seafloor covering Queen Charlotte Sound (Tōtaranui), Tory Channel (Kura Te Au) and adjacent areas in Cook Strait (Hydrographic Survey No. 51 (HS51), described in Neil et al. 2018a,b).

Having documented the physical shape and structure of features on the seafloor across the survey area, the next step was to determine (or ground-truth) these features, by visually seeing what they looked like, and what types of habitats and biological communities were present within this management region. Previous studies, especially those examining Significant Ecological Marine Sites (ESMS) within the Sounds, have undertaken a variety of surveys to characterise mostly nearshore habitats (e.g., Davidson et al. 2011; 2017a; Davidson and Richards 2015; *citing the unpublished surveys of Duffy et al. 1989/90*). These reports described ESMS based on detailed target surveys at a few sites to more commonly brief site visits, with almost all of these limited to shallow snorkelling and SCUBA diving depths (< 20 m), with some limited drop camera surveys at some target sites (e.g., Davidson et al. 2017a). Other targeted surveys examining potential or existing farm sites have also provided valuable knowledge on the types of habitat and communities present within this region (e.g., Clark et al. 2011; Keeley and Taylor 2011; Morrisey et al. 2015; Brown et al. 2016a), but have been limited to localised shallow sites. The large spatial extent of the HS51 mapped region, covering a depth range of 0 down to 380 m, required large-scale systematic surveys to ground-truth features across the entire mapped area, and to ensure a full stock-take of habitats and communities was established, so that future management and conservation strategies adequately incorporate the entire marine environment.

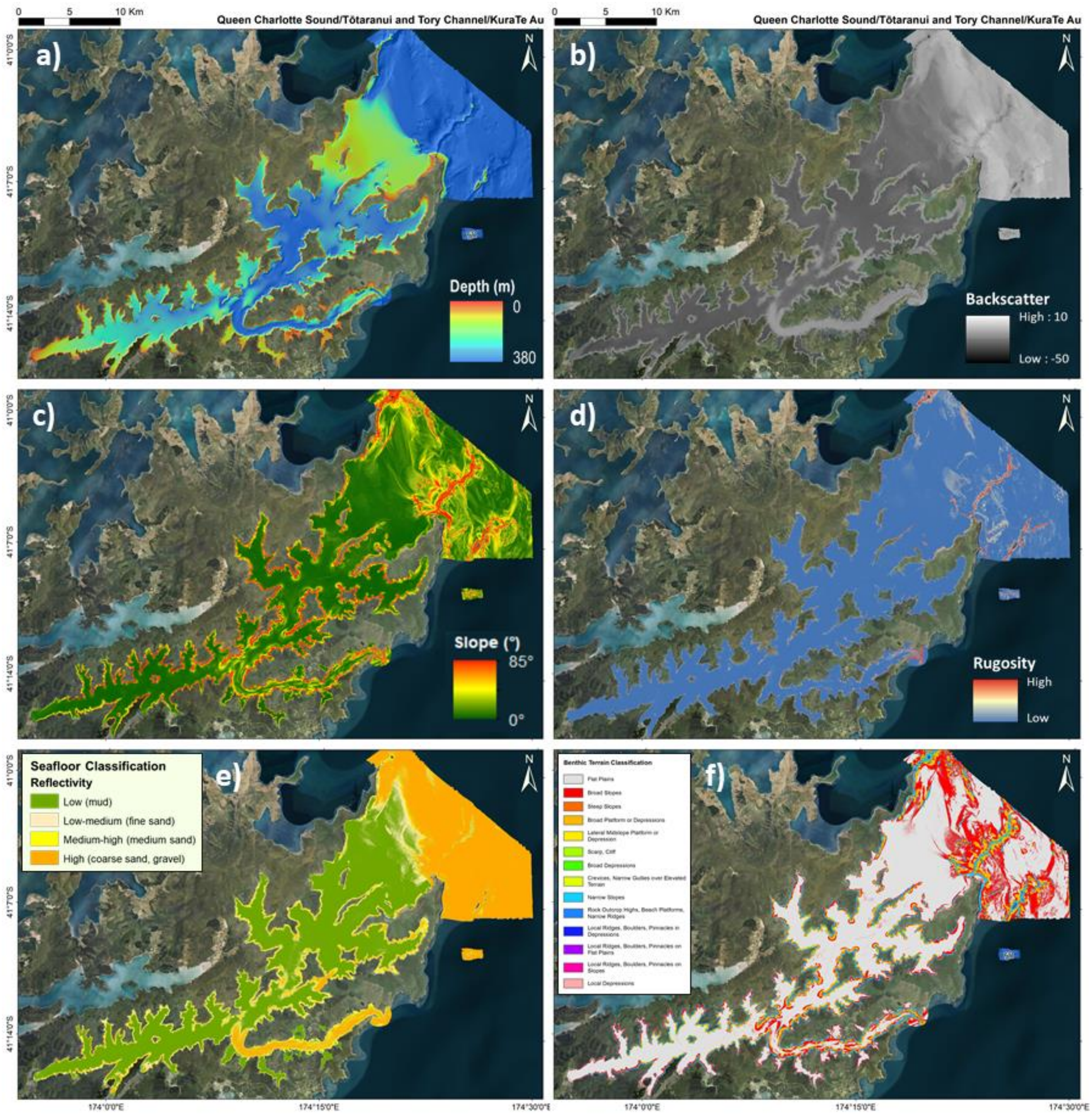

Figure 1: Examples of HS51 Multibeam data layers (2 m resolution, based on the combined EM2040 and Geoswath bathymetry) from Neil et al. (2018a), across the extent of the HS51 survey area. a) Bathymetry image (with sun-illuminated digital elevation model (DEM)); b) Backscatter; c) Slope terrain attribute; d) Rugosity of terrain attribute (increased seafloor rugosity are associated with rocky ridges and reefs); e) Seafloor classification map (based on supervised segmentation/classification of backscatter strength relative to sediment grain-size samples; f) Benthic terrain model (BTM) classifications (seafloor geomorphology) generated from bathymetric data.

1.2 Project focus

In March 2018, Dr Steve Urlich from MDC, discussed with NIWA the possibility for its brand new state-of-the art tow-video camera system (called CBedcam – a new fibre optic tow-video camera system that provides unprecedented footage of the seafloor in coastal environments) to ground-truth MDC's new high-resolution HS51 maps. Consequently, NIWA was requested to:

- Undertaken an 11-day broad-scale tow-video field survey (using CBedcam for depths <70 m and NIWA's more rugged Coastcam in deeper depths and very strong current environments) to ground-truth the newly acquired HS51 MBES maps and visually characterise habitats and communities, prioritising areas where "*new and potentially high quality or significant habitats and communities*" were likely to occur – based on the bathymetry and local environmental conditions, focusing on areas not previously surveyed by other studies.

- Provide good spatial coverage across the HS51 survey area to include as many different feature types as possible within the limited time frame. Two to three survey days were to be allocated to surveying high-relief and complex features newly mapped in Cook Strait (weather permitting).
- Build upon geo-referenced video surveys previously collected by NIWA within the HS51 survey area. Specifically tow-video footage collected during two video surveys in 2017 undertaken as part of NIWA's MBIE Endeavour-funded Bottlenecks programme (C01X1618), including : 1) A dedicated tow-video survey (CB17 survey n=43 sites), and 2) A small beam-trawl survey that included two attached GoPro video cameras (BT17 survey n=44 sites), and 3) A broad-scale drop-cam survey that was undertaken during the HS51 survey to describe seafloor sediments (n=132 sites).
- Preliminarily examine species-habitat-physical associations to determine if the HS51 MBES data layers can be used to predict species and/or habitat distributions and abundance over these large-scales.

2 Methods

2.1 Sampling overview

NIWA was commissioned to undertake an 11-day field survey (MDC18 survey) using tow-video to ground-truth and characterised newly mapped seabed features across the HS51 survey area. These new survey data were to build on three existing NIWA video surveys undertaken within the survey area. These included NIWA's 2017 MBIE tow-video (CB17 survey 43 sites) and beam trawl (BT17 survey, n=34 sites) surveys for those sites within the HS51 survey area; and drop camera video sites co-surveyed during the HS51 grab sampling surveys (n=132) (Figure 2 and Figure 3). For the current (MDC18) survey, a total of 150 sites (Figure 2) was allocated using a multi-step approach. To ensure a broad range of habitats, seafloor complexity and feature types were ground-truthed across the breadth of the survey area, sites were allocated to eight subregions: three within Queen Charlotte Sound (i.e., inner, mid and outer QCS), three within Tory Channel (i.e., inner, mid and outer TC) and two in Cook Strait (i.e., CStrait-QCS = those sites closest to QCS-entrance, and CStrait-TC = those sites in the immediate proximity to TC-entrance). The number of sites allocated to each sub-region reflected the locations of existing video-sites from the other three surveys, and the amount of information already available based on previous studies (e.g., Davidson et al. 2011, 2015, 2017; 2019; Davidson and Richards 2015; Clark et al. 2011; Keeley and Taylor 2011; Morrisey et al. 2015; Brown et al. 2016), which combined would provide the best achievable coverage and knowledge across the survey area (Figure 2).

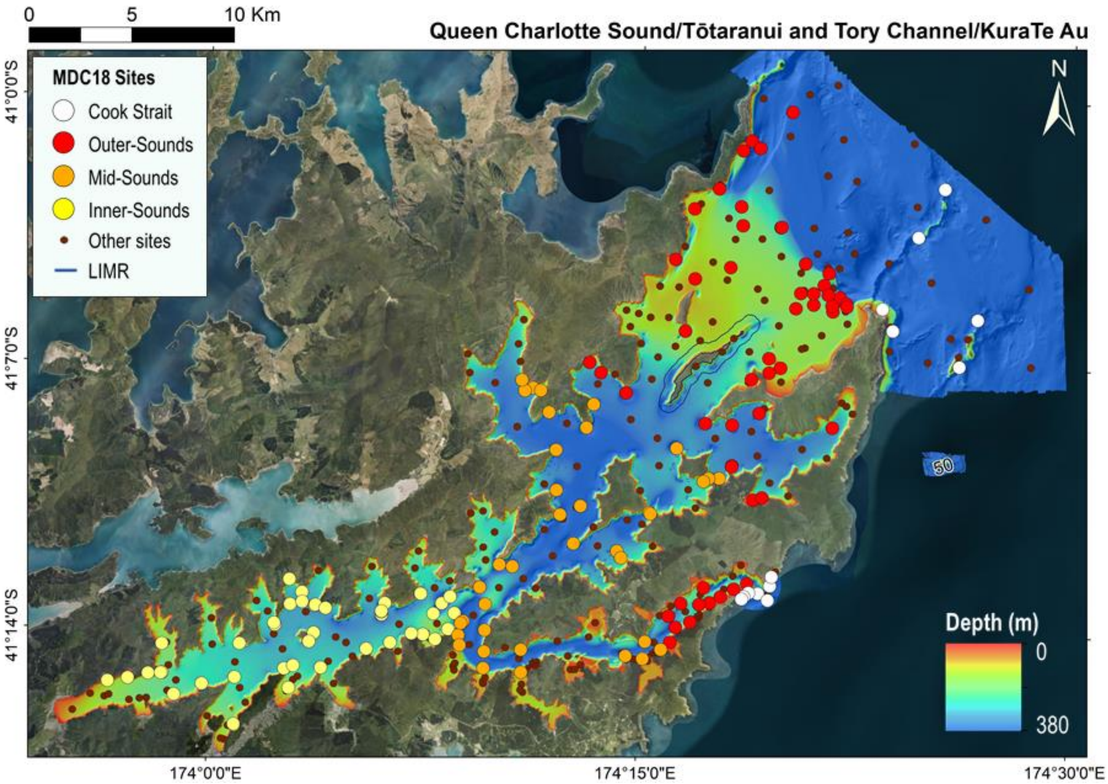

Figure 2: Location of the 150 'new-sampling' tow-video sites used to ground-truth the Multibeam HS51 seafloor maps. Sites are colour-coded by their location within the Sounds (inner, mid, outer) and Cook Strait. Burgundy circles represent existing video sites from previous NIWA surveys. LIMR= Long Island Marine Reserve boundary.

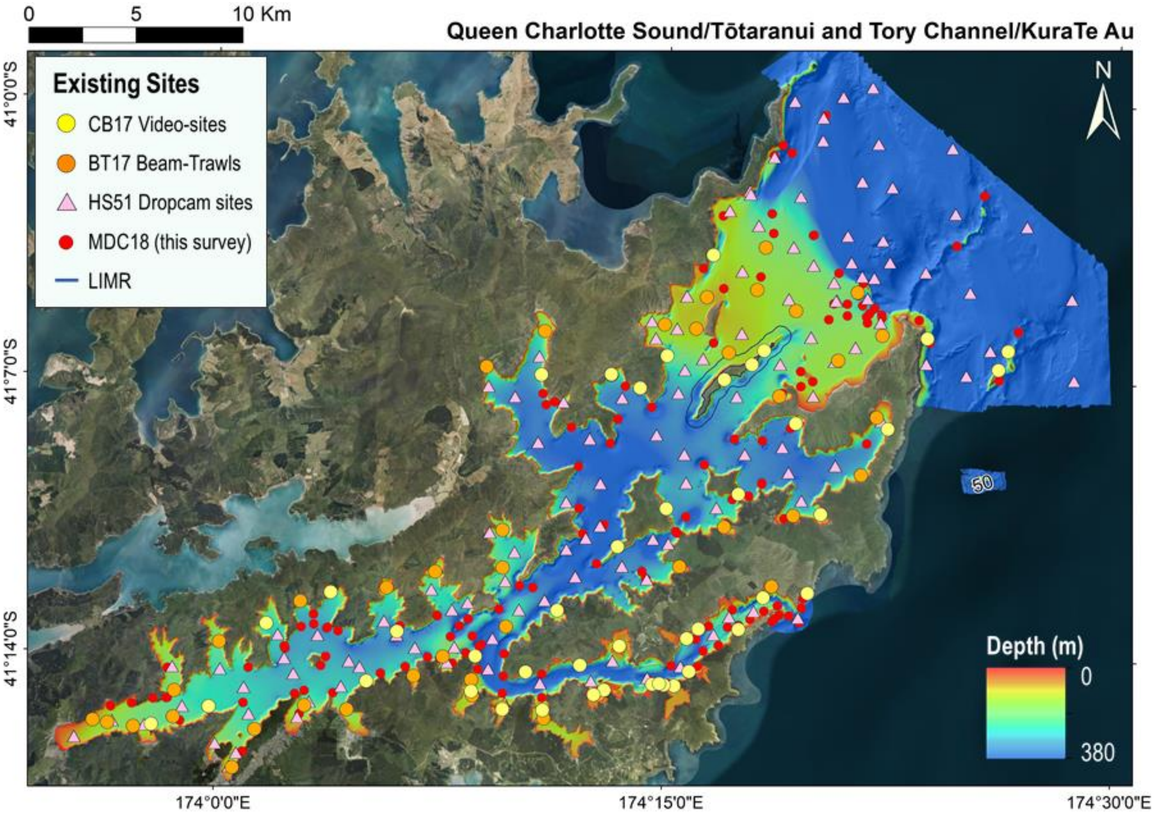

Figure 3: Location of existing NIWA seafloor imagery (non-red symbols) relative to the new sampling sites collected from this ground-truthing survey (red circles). Existing site information are from NIWA's MBIE Bottlenecks CBed-camera sites (seafloor characterisations, incl. GPS along transect) and GoPro Beam Trawl sites (some benthic information depending on water visibility, GPS at start and end of tows); and NIWA's HS51 multibeam mapping survey (presence-only of key features and taxa, single GPS waypoint).

Within each subregion to best "*ground-truth*" newly mapped features and characterise "*new and potentially significant habitats and communities*" the selection of priority-sites targeted newly-mapped areas that resolved complicated or unusual seafloor features based on the HS51 bathymetry, backscatter and the derived MBES data layers (e.g., slope angle, deviation of slope, rugosity, sediment characteristics, benthic terrain models, etc., as depicted in Figure 1), particularly where these features were located in high-energy and/or high-current environments where significant marine life might be expected, but where seafloor information had not already been collected (Figure 2 and in consultation with Steve Urlich from MDC). This included MDC's request for NIWA to survey as many Cook Strait sites within the HS51 survey area (including Cook Rock, the Brothers and the deep reef features outside TC-entrance) as could be sampled within 2-3 days of good weather (if available during the survey).

The survey design, including the allocation and stepped priority of sites, also included some flexibility (in consultation with MDC) to ensure that new areas found with significant or notable habitats could be adequately characterised (sites added or additional transects sampled across the same feature), while areas less significant or more homogenous than predicted could be down-graded in their survey priority (i.e., fewer transects sampled). During the planning phase, after consultation with MDC, sampling effort was reduced in two sub-regions: Outer region of mid-QCS to reflect concurrent video-surveys by the Sustainable Seas Tipping Points research[1], and in mid-TC to reflect existing video imagery and data following as suite of surveys assessing proposed and operational marine farm sites (e.g., Morrisey et al. 2015; Brown et al. 2016a,b) and potential Significant Sites surveys (e.g., Davidson et al. 2017a). The reduced sampling effort from these two sub-regions was reallocated to other subregions within the survey area to ensure maximum sampling effort could be achieved for MDC.

To ensure that the greatest range of habitats could be characterised at each site, including characterising and mapping habitat transition zones, video-transects between 200-400 m in length (depending on the terrain) were designed to run across the greatest change in seafloor depth (i.e., biotic zones often are strongly demarcated by depth), and/or seafloor complexity (e.g., rugosity, backscatter and benthic terrain categories). Final direction of surveyed transects, however, was conditional on weather, particularly wind and currents. At a few sites where significant biogenic habitats were found, two video-transect were run perpendicular to each other to map the habitat boundaries.

2.2 MDC18 survey

2.2.1 Tow-video survey

A total of 150 tow-video sites were surveyed between the 29th of September to the 9th of October 2018, using one of two towed-camera systems dependent on the depth and degree of current. Deep and very high current sites require a very robust and heavy tow-body system with extensive cable. To capture the best possible imagery across seafloor features and habitats in depths or cable lengths <~70 m, NIWA's revolutionary new fibre-optic **CBedcam** tow-video system was used (Figure 4). However, to survey much deeper Cook Strait sites and/or areas where high currents required cable pay-out >70 m (such as in the high current areas within QCS and TC entrances), NIWA's more rugged, larger and substantially heavier **Coastcam** tow-video system was used (Figure 5). Both towed camera systems were deployed from the stern of NIWA's RV *Ikatere* (a 14-m twin jet-powered catamaran) and towed at a speed-over-ground of 0.5-1.0 knots, at an altitude of ~1 m above the seafloor.

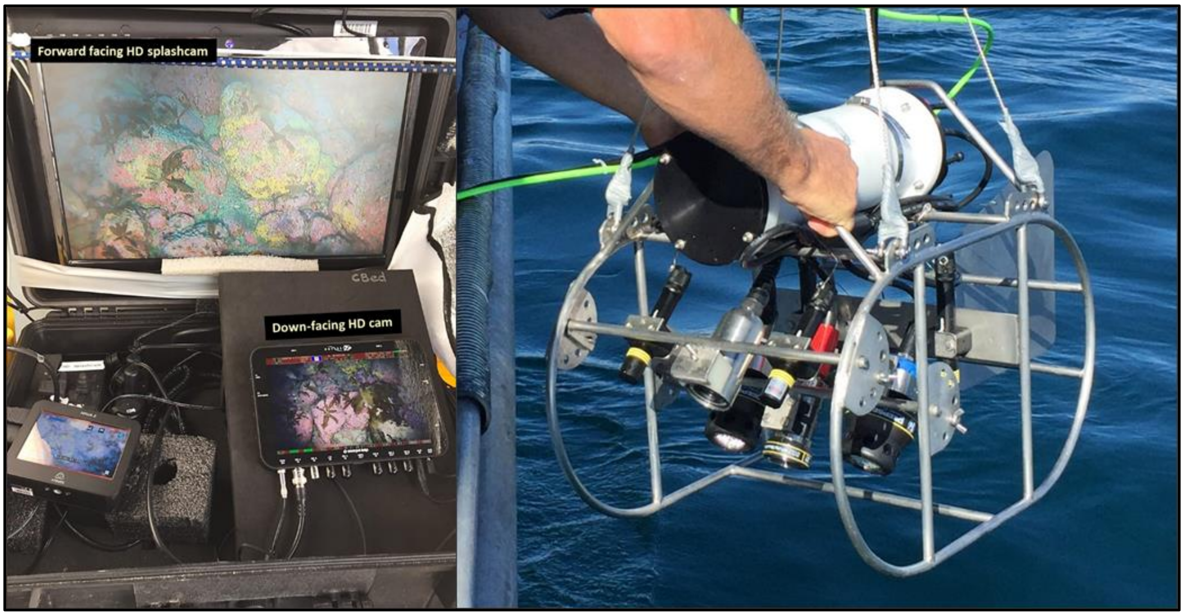

Figure 4: CBedcam towed-imaging system. NIWA's HD fibre-optic towed camera system. Topside monitors/recorders showing HD topside footage being recorded during a video-transect of the seafloor (left image). CBedcam being hand-deployed for the vessel (right image).

CBedcam is NIWA's small hand-deployable towed camera system (90 [L] x 43 [W] x 52 [H] cm) that is fitted with two high-definition (HD 1080p) video cameras: one facing forward at 45° for obstacle avoidance and to identify fish, the other facing downwards at 15° to discern small cryptic species, with both cameras used to characterise the benthos (designed and built by T. Anderson specifically for nearshore ground-truthing and biological characterisation surveys). CBedcam illuminates the seafloor using to two very powerful 9000 lumen SeaLites (Deep Sea Power and Lights [DSPL]), while paired lasers, set 20 cm apart, are projected onto the seafloor to provide a visual reference to size objects and organisms. A revolutionary Xtreme green fibre-optic cable provides surface-supplied power down to the tow-system, and enables real-time video footage from both high-definition (dual 1080 p) video cameras to be transmitted simultaneously up the fibre-optic cable to be viewed (and recorded in full resolution) on the dual topside monitor and recording screens. Video from CBedcam was recorded as MOV files to dual recording devices and later backed up to NIWA's archive drive. Real-time imagery of the seafloor enables the winch operators and skipper to alter the altitude and speed of the towed-body to avoid seafloor obstacles. High-resolution video imagery at the surface also enables the trained science-team to characterise seafloor habitats and biota along the transect in real-time. The ability to view two high-definition underwater cameras at the surface in real-time is a world first for underwater tow camera systems, and combined with powerful seafloor illumination from the 18000 lumens provides researchers with an unrivalled view of the seafloor habitats and their communities.

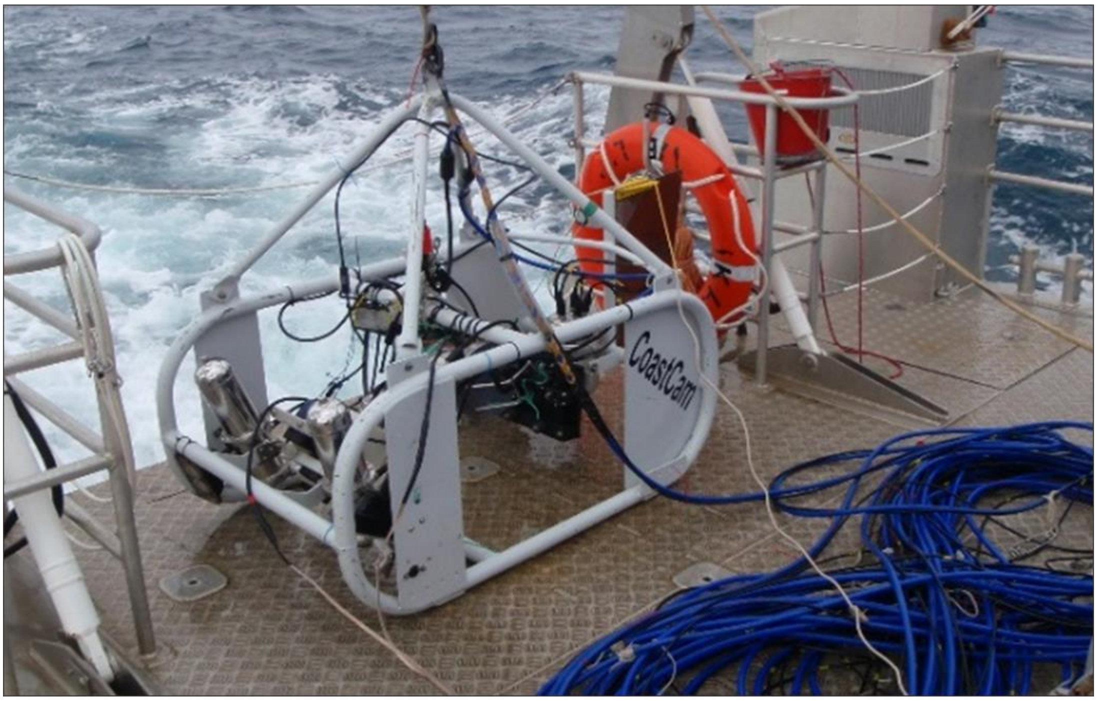

Figure 5: NIWA's Coastcam towed-imaging system ready for deployment on the deck of the RV *Ikatere*.

Coastcam: The solid tow frame of the Coastcam is considerably larger (1150 L x 740 W x 1060 H cm) and heavier (~50 kg), and provides more durable protection in deep (≤ 250 m) high-current environments such as those in Cook Strait and around the entrances to QCS and TC. Coastcam is fitted with a single forward-facing high-resolution video camera (AVC HD Hybrid Sony video-camera 1080p) and a single 3000 lumens LED light, along with scaling lasers set at 20 cm apart to enable sizes of features/organisms to be determined. The unit is powered by underwater batteries attached to the frame. The Coastcam systems has real-time video feed to the surface via a VDSL modem connection through the winch cable that enables reduced-resolution imagery to be seen by the winch operator, to view the seabed to avoid obstacles, and the science team to characterise the seabed in real-time; while full-resolution 1080p imagery was recorded as MTS files to a recording unit on the tow-frame, backed up initially on the vessel, and later to NIWA's archive drive.

At each site, video transects were generally run from deep to shallow water depths, where wind and currents allowed, to ensure video cameras (at the front of the tow-body) collected the best and closest imagery of the seafloor. Areas of very strong currents (e.g., entrance to QCS, Tory Channel and narrow passages between islands) were only attempted on or around slack tides. However, given the strong tidal currents present within much of the Sounds, the final locations and direction of transects reflected what was achievable by the skipper given the prevailing conditions.

Real-time seafloor characterisations

Seafloor habitats and biota were characterised in real-time using the 3-tiered characterisation scheme of Anderson et al. (2008) to provide semi-quantitative characterisations of substrata types, bedform structure/vertical relief, and macroflora and fauna. Real-time data were entered using the combinations of 'YoNav' GIS-navigation software with real-time data acquisition functions (© John Gann 2004) and a 142-key programmable keyboard (© Cherry 2008) (Figure 6).

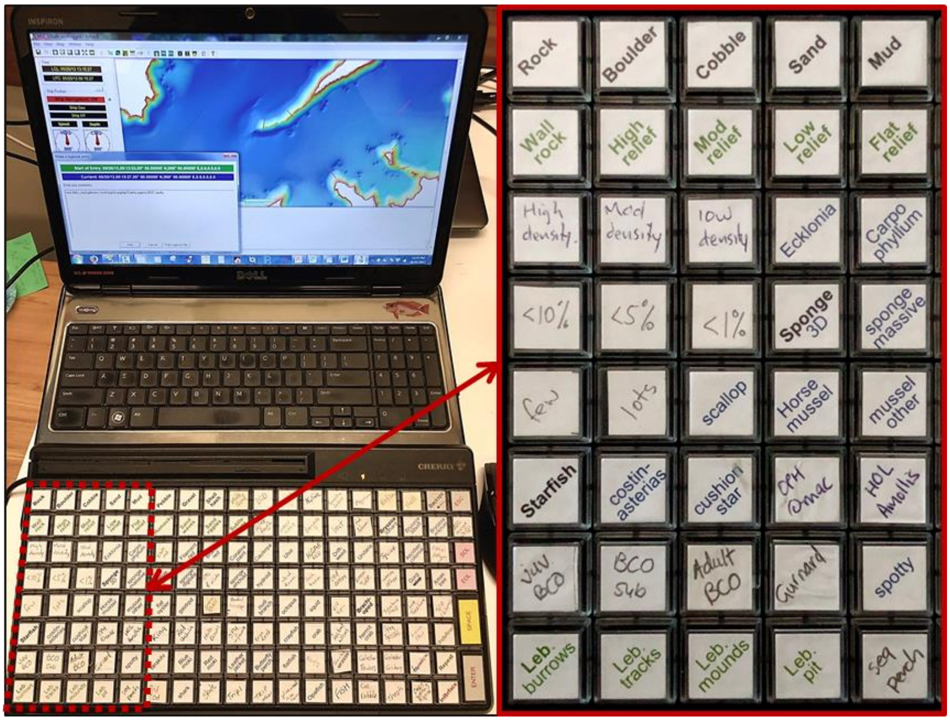

Figure 6: Real-time data-entry using YoNav and a programmable keypad. Left image: Topside laptop running YoNav navigation and data acquisition software (top), with attached programmable keypad (bottom). Right image: Zoomed-in section of the programmable keypad.

Habitats and the biota were categorized at ~30-sec intervals along each tow-video transect. For each data entry, the seafloor was evaluated by the scientific observer for a period of 15-seconds (i.e., 5 seconds prior to and 10 seconds following the GPS fix), and characterised using the 3-tiered characterisation scheme of Anderson et al. (2008): Substrata, bedform-relief, and biota.

Substratum type (i.e., rock, boulders (>25.5cm), cobbles (6.5-25.5 cm), gravel, sand (grains visible) and mud (no-grains visible)) was categorised by primary (>50%) and secondary (>20%) percent-cover following the protocol of Stein et al. (1992) and Yoklavich et al. (2000). For example, if the seafloor was comprised of >50% mud and >20% cobble the substratum composition was classified as 'mud-cobble', alternatively >70% mud was classified as 'mud-mud'. Bedform-relief was defined as either i) soft-sediment 'bedform' - such as hummocky (undulating mound formations), sediment ripples, or sediment waves, or ii) by the vertical 'relief' of consolidated sediments - where relief classes included: flat (0 m), low (<1 m), moderate (1-3 m), to high relief (>3 m), or rock walls (high-relief with >80° incline, following Anderson et al. 2007). Benthic communities were characterised by the occurrence of all flora and fauna seen on the seabed within the 15-time window. Key taxa were also semi-quantified using either rank % cover or rank count categories. Here, significant habitat-forming organisms (e.g., kelps, bryozoan-reefs, sponge gardens) and identifiable key species were entered followed by their rank percent cover categories (dense [≥51-70%], moderate [20-50%], low [11-20%], 6-10% [common], 2-5% [few], 1% [present], 0% [absent]). Conversely, key motile invertebrates (e.g., kina, snake stars, sea cucumbers) were recorded using rank count categories (very abundant (>20), abundant (10-20), common (4-10), few (2-3), present (1) or absent (0)). All other benthic macro-flora and macro-fauna seen within the 15 second window were recorded as presence/absence to various levels of taxonomic resolution depending on what was possible during the survey. This included for example: i) species-levels identifications (e.g., the giant surface-kelp (*M. pyrifera*), and paddle-weed (*Ecklonia radiata*); bivalves e.g., dog cockles (*T. laticostata*), scallops (*Pecten novaezelandiae*) and cockles (*Austrovenus stutchburyi*); fishes e.g., opalfish (*Hemerocoetes monopterygius*), red gurnard (*Chelidonichthys kumu*); ii) genera (e.g., the algae *Ulva* spp., *Adamsiella* spp.); species complexes (e.g., 'wireweed'-like tubeworms (*Chaetopterid, cf Spiochaetopterus*)); iii) morphotypes for example red algae (e.g., bladed, strappy, filamentous, encrusting) and sponges (e.g., massive, fan, digitate, cup or encrusting); iv) class (e.g., other bivalves, other gastropods and nudibranchs spp), and some key taxa separation of species by size class (e.g., blue cod (juvenile [<20 cm], sub-adult [20-30 cm], or adult [>30 cm]), and tarakihi (subadult [<20 cm] and adult [≥20 cm)).

Data entry using the pre-programmed keyboard took between 3-12 seconds and required a two-person team: one to observe the seabed and call out the observations, and keyboard data-enterer. Ships navigation (UTC date, time, latitude, longitude, speed over ground, heading) were automatically captured for each data entry 'record' along each transect to enable habitat and biota distributions along and between transects to be plotted in ArcGIS relative to mapped features. Ships navigation was also logged continuously (1-2 second fixes) to provide 1-sec navigational tracks.

Postprocessing QA/QC

Post-processing of video was undertaken for quality assurance and quality control (QA/QC) to check consistency of categories and percent cover estimates, and to determine or verify taxa identifications. These real-time data records are aimed at providing preliminary distributions and relative rank abundance for taxa across the survey area in terms of mapping species-habitat relationships. Detailed post-processing, however, would be required to formally determine counts and densities. However, video footage can be post-processed for detailed estimates, including digitised %cover and densities per area surveyed. For some taxa especially small cryptic species, species identifications were not consistently possible within and/or among sites (e.g., brachiopods), but where taxonomic identifications were possible (often based on video images sent to taxonomic specialists) these identifications are presented with these associated caveats.

2.2.2 Seafloor photographic mosaics – three test cases

Video footage collected using the high-definition CBedcam during the MDC18 surveys was used to create 3-dimensional photographic-mosaics of the seafloor, for three notable habitat and community types. Seafloor mosaics were created using a series of steps that included extracting individual frames (photographic images) from the video ensuring that the sequence of images had 80% overlap; these photos were then sequentially aligned and stitched together using a sequence of photogrammetric algorithms to form a single interconnected 3-dimensional image along the video-transect. This is similar in concept to a panoramic photo created by a now-common Smartphone. The mosaiced photos are then placed across a 3-dimensional mesh using Agisoft Structure from Motion (SfM) software, creating a landscape image of the seafloor depicting the height and shape of physical and biological features seen on the seafloor. This enables the resulting 3D mosaics to be rotated in space by the user, to examine the height and structure of seafloor features and their associated organisms. Seafloor features can then be measured horizontally and vertically to quantify the shape and height of seafloor structures. This approach can also be used to examine the landscape distribution of species relative to seafloor features. Each photographic image is aligned with the ships navigation along the transect, once this is done, the photo-mosaics can then be imported into ArcGIS and overlaid (or draped) over the HS51 bathymetry. In this report three examples are presented, with the combination of data layers used to examine the relationship between the fine-scale complexity of the seabed and the larger scale MBES data layers.

2.2.3 Dredge sampling/specimen identification

To provide taxonomic identifications for key taxa, specifically ones unable to be identified from the HD seafloor video imagery, we deployed one of two dredges to collect specimens at a few targeted sites. NIWA's small epibenthic Ottoman dredge was used in soft-sediment habitats, while the heavy more robust Agassiz dredge was used for harder substrata. Each dredge was deployed from the stern of the RV *Ikatere* and towed along the seafloor at ~2 knots for '*as short a distance as practical to collect the targeted specimen*' (between ~50-250 m). A total of four dredges (3 Agassiz and 1 Ottoman) were sampled at the four sites (Figure 7).

Dredge sites targeted three habitat types:

1) Specimens of the newly discovered burrowing holothurian were targeted on two lower slope sites (D03 and D04) in Tory channel near Point Dieffenbach. Both dredge sites were aligned with our previous video-transects (MDC18-Q171 and MDC18-Q140, respectively), where relatively dense fields of the burrowing holothurian had been recorded on the lower shell-debris slopes in a depth of 35-55 m. Initially, two Ottoman dredges were deployed, but both failed to reach the seafloor due to the strong Tory Channel currents. The heavier Agassiz dredge was then deployed and successfully reached the seafloor at both sites.

2) To target the habitat-forming *Acromegalomma* tubeworms - discovered in soft-sediment bays in Tory Channel during the MBIE bottlenecks BT17 and CB17 surveys - we deployed the Ottoman dredge in Onapua Bay in a water depth of 13 m. However, the soft-sediment Ottoman dredge filled quickly with thick black mud within several metres before being retrieved and failed to collect any tubeworms.

3) To identify the physical and biological composition of the shell-waved features[1] mapped using sidescan sonar during the MPI16401 surveys, but only characterised along the shallower edges of this feature (see Brown et al. 2016a), a final dredge site (D06) was successfully sampled directly offshore of Te Weka Bay.

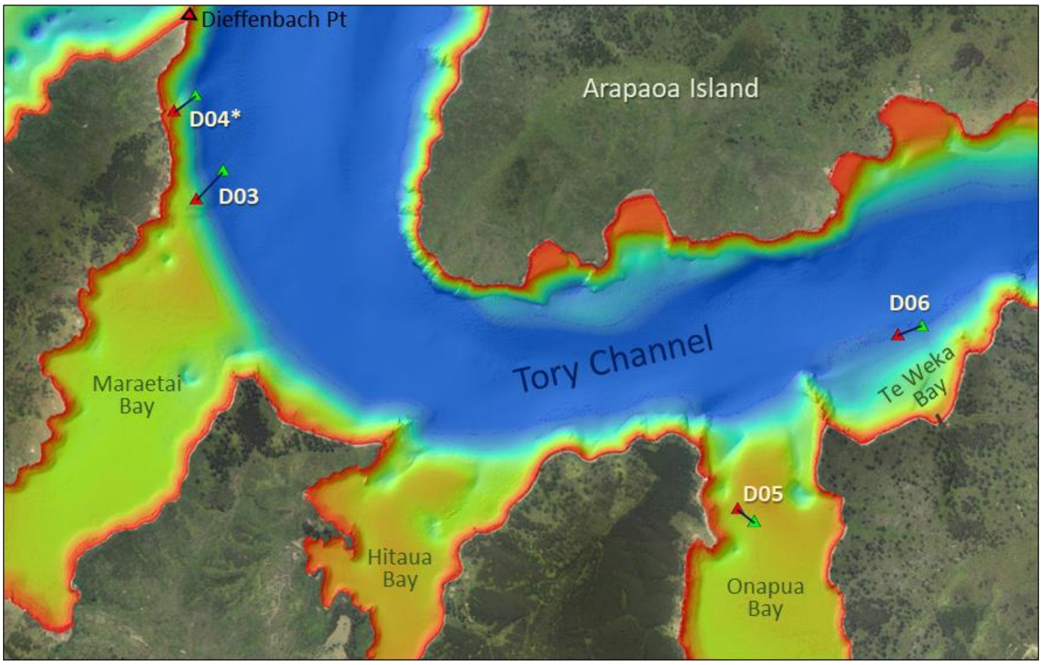

Figure 7: Location of the four targeted dredge sites in Tory Channel. Dredge sampling used an Agassiz dredge on hard substrata sites (D03, D04, D06) and an Ottoman dredge on soft-sediments (sites D05). Three of the four dredge sites targeted MDC18 camera sites (D03=camera site Q171, D04 = Camera site Q140, D05 = camera site Q196), while dredge site D06 sampled across a noted feature in the sidescan of the MPI16 Te Weka Bay site. D04* indicates that a new species records (burrowing holothurians) were collected from this site.

[1] Brown et al. (2016a) stated that "*This offshore bivalve rubble zone comprised semi-consolidated aggregations of whole shell rubble, shell hash that form distinct wave-like biogenic mounds on the seafloor, which were depicted as an extensive area in the sidescan imagery* (Figure 3-66 in Brown et al. 2016a)".

Figure 8: NIWA's small Agassiz epibenthic dredge and examples of specimens collected. a) Agassiz epibenthic dredge being deployed from the stern of the RV *Ikatere*; b-c) Example catch from the Tory channel slope site (Dredge site D04) showing a bivalve shell-debris dominated catch (common on the lower slopes in this area), along with sea cucumbers (*Australostichopus mollis*), large predatory starfish (e.g., 11-armed starfish (*Coscinasterias muricata*), kina (*Evechinus chloroticus*), and the newly discovered burrowing sea-cucumber (insert showing the branchial crown of a burrowing sea cucumber - identified as *Thyone* spA)).

2.3 MBIE Bottlenecks BT17 and CB17 surveys

As part of NIWA's MBIE Bottlenecks programme (C01X1618) looking at the nursery habitat of juvenile blue cod in the Marlborough Sounds (vs Snapper in the Hauraki Gulf), two large-scale surveys within depths of ~3-30 m were undertaken across the much broader region of the Marlborough Sounds from the boulder Bank in Nelson to Port Underwood on the east coast, from the 3 March to 18th May of 2017. Two survey methods were employed to identify and characterise blue cod nursery: A beam trawl (with GoPro video cameras attached) sampling trawlable ground and a subsequent high-resolution tow-video survey across more rugged untrawlable habitats. Of these, 44 beam trawl sites (*orange circles in* Figure 3) and 43 tow-video sites (*yellow circles in* Figure 3) were surveyed within the HS51 survey area (here referred to as the BT17 and CB17 surveys, respectively), and are presented here with respect to contributing to seabed habitat and community characterisations, and the ground-truthing of the newly mapped MBES features in this region.

2.3.1 BT17 Beam Trawl survey

BT17 beam trawl setup: The 44 trawlable sites (labelled sites in Appendix G; and GPS positions listed Table J-1) were all surveyed within the Sounds (in March-April 2017), using a single small 3-m wide by 6 m long trawl net (described in Hamer et al. 1998), with two GoPro-3 video cameras, placed in underwater housings, attached off centre of the 3-m wide spreader beam: one pointing forward to characterize seafloor habitats within the trawl area, the other facing the net to verify it was on the seafloor and fishing correctly. The beam trawl was deployed off the stern of the MV *Cappy* (a 34ft Aluminum launch) and towed for four minutes at a speed of 1.5-2 knots (average distance of ~300 m). A GPS position was recorded at the start and end of the tow.

Catch: Once back on board the vessel, the catch was sorted with fish identified and fork length measured (mm), and then released immediately back to the sea (except for blue cod smaller than 20 cm that were retained as part of the Bottlenecks programme). Bycatch was sorted into taxonomic groups and either counted (motile species) or measured by volume (sessile organism), photographed and returned to the sea. Numerous macroalgae specimens, including subsamples of all macroalgal species collected in Cook Strait, were pressed for permanent museum records (by either R. D'Archino or T.J. Anderson), with tissue subsamples preserved in gel crystals for future DNA analyses – following the guidance and protocols set out by NIWA's macroalgal specialists. Algal specimens were later identified by taxonomic specialist R. D'Archino and W. Nelson (NIWA Wellington). Several rare and unidentifiable fishes were also retained and submitted to Te Papa for identification by Andrew Stewart, while some rare bycatch taxa were retained and sent to taxonomic specialists. Bycatch data are only presented here in summary as support or to verify species seen in the video footage.

Seafloor characterisations: Video footage from each trawl was later post-processed (by T.J. Anderson) characterising the seafloor within the trawl patch by i) substratum types (as % cover of mud, sand and shell debris), ii) seabed relief/bedform (categorised as flat, rough, bioturbated or low-relief < 30 cm), and iii) the percent cover of habitat forming species (e.g., horse mussels, sponges, bryozoans, etc.), with each estimate representing the entire beam trawl (i.e., one single data point for the site). A qualitative value of seafloor visibility and image quality were also recorded. As GoPro video cameras rely solely on natural light and adequate water clarity to see the seafloor, the quality of this imagery was highly variable, with the seafloor at highly turbid sites (e.g., inner bays and much of the inner Sounds), often only discernible at the very start of the tow when the net was stationary. Consequently, while a general characterisation of the benthos was possible at all sites within the HS51 survey area, discerning the presence or absence of species was often impossible. However, all sites regardless of the visibility returned some catch that helped discern/confirm the type of seafloor present.

2.3.2 CB17 tow-video survey

The 43 tow-video sites were surveyed in ~3-30 m across the HS51 survey area (in April-May of 2017), and included 39 sites within the Sounds and four in Cook Strait - with two sites at the Brothers (labelled sites in Appendix F; see Table I-1 for GPS positions). Sites included a variety of habitat types that included likely biogenic, rubble and debris habitats on outer banks and along the outer edges of coastal reefs. This tow-video survey was the very first NIWA survey to trial the then brand new **CBedcam** (described above in Section 2.2.1). Here the CBedcam system was deployed using the same methods as described above, except that it was deployed from starboard side of the MV *Cappy*, a non-NIWA chartered vessel, owned and run by Seabird Charters Nelson.

Seafloor habitats, relief/bedform and biota were characterised in real-time using the methods and 3-tiered characterisation scheme of Anderson et al. (2008), with the seafloor characterised every ~30-seconds along each video-transect as described above (see Section 0 and 0). However, while substratum type and relief/bedform were recorded using the exact same method, biota were recorded in a two-step approach. Here, only significant habitat-forming taxa (e.g., kelps, bryozoan-reefs, horse mussels and sponge gardens) were recorded with rank percent cover (dense [≥51-70%], moderate [20-50%], low [11-20%], 6-10% [common], 2-5% [few], 1% [present], 0% [absent]), while all other macrofauna and macroflora were recorded as present/absent. A qualitative value of seafloor visibility and image quality were also recorded. Video footage was also post-processed for quality assurance and quality control (QA/QC) and corrected any inconsistency of categories, and to determine or verify taxa identifications.

2.4 HS51 dropcam survey

During NIWA's HS51 mapping survey for Marlborough District Council (Neil et al. 2018a,b), sediment samples of the seafloor were collected at 132 sites during the summer of 2016-17 (two 3-day trips: 5-7 December 2016 and 5-7 May 2017). To determine the seabed type and texture at each of the 132 sites, one of two drop-video systems, dependent on depth and current strength, were used to capture brief (≤~1-2 min) video imagery of the seabed, with a single ships-GPS position recorded to denote the position of the site (*pink triangles in* Figure 3; see Appendix E *for labelled site map*). At deep sites, both within the Sounds and in Cook Strait (n=77 sites), NIWA's heavy duty **Coastcam** system was deployed (see Figure 5; described above in Section 2.2.1), while in shallower depths within the Sounds (n=54 sites), NIWA's small hand-deployable **Dropcam** system was used (Figure 9).

Dropcam system: NIWA's Dropcam system is a small hand-deployable unit (85L x 24H x 24W cm), comprised of a high-definition video camera (Splashcam Deep-Blue HD-1080 p video camera), two basic dive lights (1500-lumen LED dive-lights, that provide some close-to-the-seabed illumination). The system has a real-time video-feed to the surface vessel via a 90-m coax cable, that transmits high-definition 1080p imagery of the seafloor to a small topside NINJA monitor/recording unit. The Dropcam system, like the BT17 GoPro cameras, relies heavily on natural light in clear water to view the seabed, and as a consequence video imagery was highly variable among sites, with some sites (particularly those in shallow depths or in the outer sounds) clearly able to discern biota on the seafloor, while little could be discerned from highly turbid sites (incl. many inner bay and inner Sound sites).

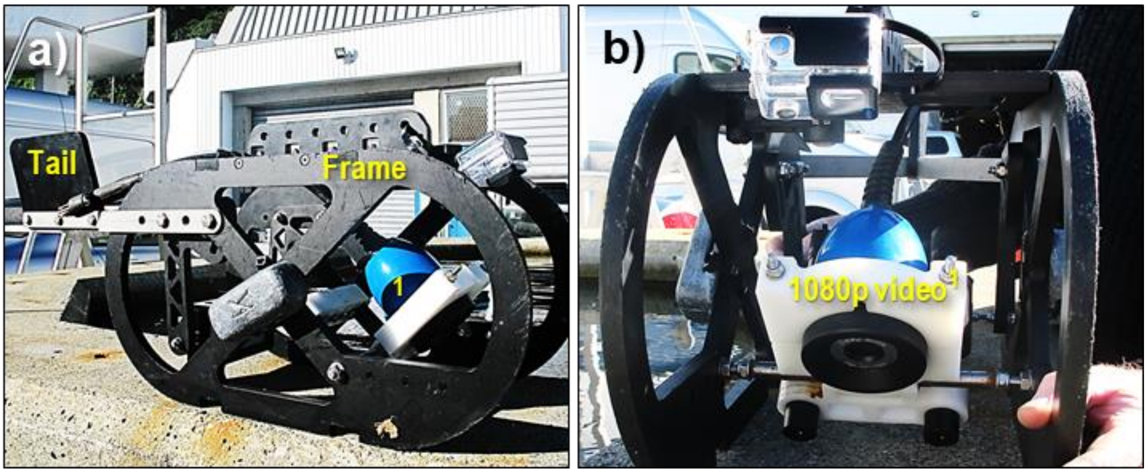

Figure 9: NIWA's small hand-deployable Dropcam system. NIWA's Deep blue 1080p Splashcam in protective frame from side view (a) and front view (b).

While data from this video survey was initially processed as descriptive presence data, these characterisations were largely incompatible to those of the other ground-truthing video surveys. To ensure comparability between the four camera-surveys, these very short video-clips were quickly re-processed with the programmable keypad using the 3-tiered classification scheme described above (Section 2.2.1). However, here the seafloor was characterised for the length of the short-video clip (~30 second) but represents a single data entry record.

2.5 Other existing video-imagery

In 2016, NIWA collected video-imagery as part of an impact assessment of three potential new salmon farm sites within Tory channel (MPI16401 surveys - Brown *et al.,* 2016a,b). The proposed farm sites and surrounding areas were small in size (circa 400 x 700 m), with the assessments requiring habitat and biological characterisations from a series of drop cameras (see Figure 10b-d), video sleds, and diver transects at each of the three sites: Tipi Bay (33 dropcams, 4 video-transects, 2 diver transects), Motukina Bay (38 dropcams, 3 video-transects, 2 diver transects), Te Weka Bay (37 dropcams, 4 video-transects, 2 diver transects). Video-transects and diver transects recorded start and end of line positions, but were not georeferenced along transects, and were not quantitatively processed - so are not included here, but full descriptive characterisations are provided in Brown *et al.,* 2016a. In contrast, dropcam sites were all georeferenced, with approx. 2 minutes of seafloor video collected for each site. Seafloor habitats and biota were later characterised from the video footage using the 3-tiered characterisation scheme of Anderson et al. (2008) as described above (Section 2.2.1) to provide semi-quantitative characterisations of primary and secondary substrata types (e.g., Figure 10b-d), bedform/relief, and biota – here recorded as simple presence/absence. As these data have been presented in Brown et al. (2016a), they are only presented here as supporting information for habitat and community characterisations for the TC chapters, where relevant.

While other video data may exist, these were not available to us, or did not have explicit GPS data to be included. However, description of seafloor habitats from published work are included where relevant.

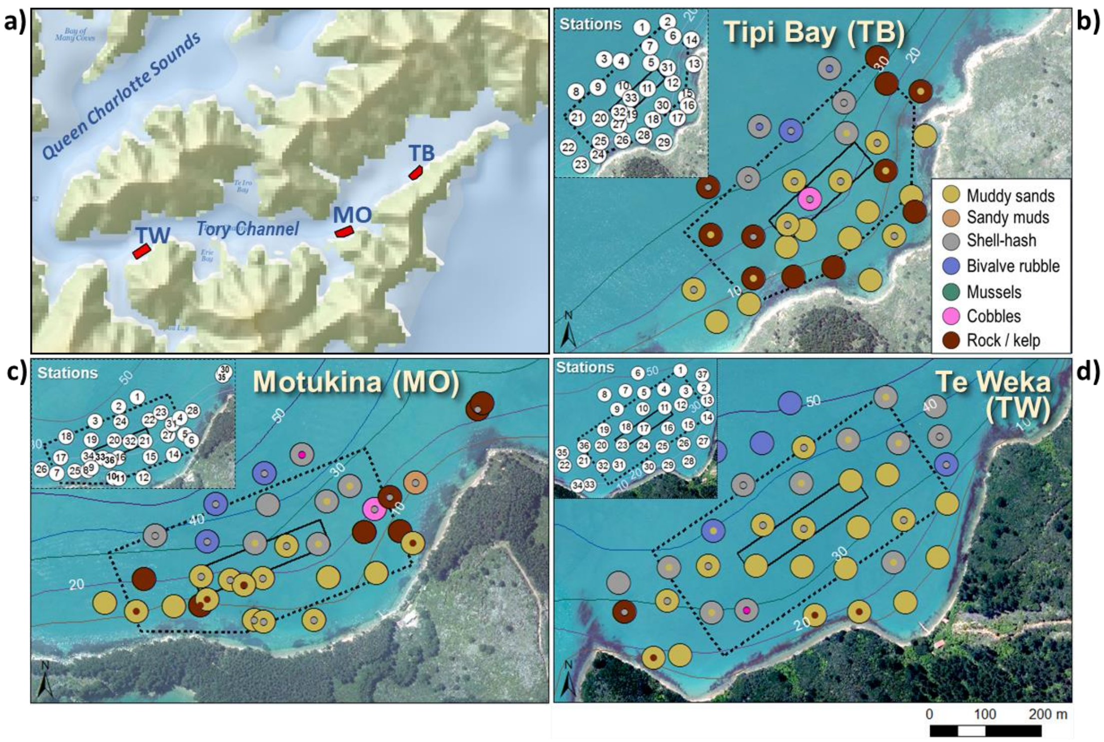

Figure 10: Location of MPI16401 dropcam sites in Tory Channel (based on Brown et al., 2016a). a) The location of potential salmon farm sites surveyed by NIWA in 2016 (depicted by the three red boxes). b-d) surveyed areas for the three potential farm sites at Tipi Bay (TB), Motukina (MO) and Te Weka Bay (TW). Inserts in the upper left of each image, depict the dropcam site numbers for that site; rectangle box = proposed farm cages; dotted lines = extent of farm infrastructure at each site; large and smaller inner coloured circles depict the primary and secondary habitat types (respectively). Legend in (a) depicts habitat types for all three sites.

2.6 Data processing and analysis

Data processing and preliminary analyses were undertaken using SAS 9.4 statistical software. Habitat categories were recorded as continuous numerical variables to represent the rank categories, where rank percent cover was recoded as 0, 1, 5, 10, 20, 50, 70% cover (following the protocol of Anderson and Yoklavich 2007), similar rank counts were recoded as 0, 1, 3, 10, 20. Mean percent cover of substratum types were then calculated for each site for the CB17 and MDC18 surveys. Frequency of occurrence of records within sites and for sites within subregions were then calculated for each taxa type. BT17 and HS51 surveys represent a single data point per site, while limited visibility at many sites limits spatial comparisons so no frequency of occurrence estimates are presented from these data.

All four video data sets, however, were exported and converted into shape files and plotted in ArcGIS Desktop 10.6, using the NZGD 2000 New Zealand Transverse Mercator projected coordinate system. As data from the four video surveys were somewhat disparate, data from each survey were kept as separate data layers ArcGIS. HS51 raster values for MBES data layers (e.g., bathymetry, backscatter, sediment classification, slope and rugosity) were then extracted for each video data point, for all four surveys and used to examine preliminary relationships important in predicting and describing habitat and species distributions. Video data categories were then systematically examined relative to HS51 multibeam echosounder (MBES) data layers, for each feature and community type. To examine the relationship between tow-video habitats and communities, depth and slope profiles were calculated in ArcGIS for target transects or across larger features in the vicinity of video-transects, where depth profiles were calculated from the digital elevation model (DEM) while slope angles (and in some cases slope deviation) were calculated from the 2m_slope layers.

Distribution maps were then plotted for relevant taxa. However due to the many difference in survey gear, methods used, and the types of data recorded (rank %cover or counts vs presence/absence) between these four datasets, some caveats in data integration, interpretation and use are required, as these differences have implications for data presentations and interpretation of results. To reduce any confusion, we have standardized our GIS-map presentations so that %rank data from the MDC18 survey are presented as bubble plots, while the other three datasets are presented as presence/absence (triangle symbols). Due to the four video surveys having disparate data types, calculating summary statistics was problematic. To resolve this, summary statistics are calculated from MDC18 survey data only (which represent 81% of the combined data points), unless otherwise stated. This dual data-presentation approach enables examination of the entire data distributions in the maps, while still examining relative abundances from the MDC18 survey.

Important caveats: There are several important caveats to interpreting these data. While these data are all extremely valuable and combined provide more coverage of the seafloor, imagery from the BT17 and HS51 surveys are variable in quality (esp. BT17-GoPro and the HS51-Splashcam) due to the reliance on natural light levels in often highly turbid water conditions. Where water quality is low, many taxa are difficult and sometimes impossible to detect, and these taxa were not well represented in the natural-light video surveys of BT17 and HS51-dropcam. For these surveys, any additional presence data is extremely valuable and as such all presence records from all surveys are presented. However, the inclusion of absence data for these taxa may mis-represent species true absence-distributions (i.e., showing them as absent when they are present but could not be seen/detected). Consequently, absence data from low visibility sites/surveys are not presented on those distribution maps. In contrast, the external lighting on Coastcam (1x 3000 lumen light) provide considerably better illumination of the seafloor at most sites, while the CBedcam provide six times more light (a total of 18000 lumens) in the MDC18 and CB17 surveys and provide significantly improved visibility in almost all water conditions, and greatly improved detection and identification of very small and/or cryptic taxa which are usually not consistently detectable by most tow-video systems.

To provide maximum densities seen for some key species, images representing high densities, were used to count the number of individuals within the image, standardized by the area of the image (measured using the 20 cm spaced lasers) and represented as densities per/m^{-2}. These, while these represent accurate estimates of maximum densities and are presented to provide an initial comparison among sites and subregions (and broadly to other studies), no measures of means densities (per habitat, zone or site) are provided, as this would require full post-processing of the video-footage, which was not within the scope of this project.

3 Results

3.1 Sites and data types

Data and information from four video surveys are presented here. Each of these four datasets provides supplementary coverage of the seafloor and valuable seafloor and benthic community characterisations. Importantly, however, each survey varies slightly in the amount and type of data collected, reflecting the varying aims of each survey. The MDC18 survey collected a total of 36.6 linear km's of seafloor video characterizing seafloor habitat and biological communities from 5062 data points from 149 sites. The combination of all four surveys collected an overall total of 58 linear km's of seafloor video, and 6,251 data points from 358 video sites (a breakdown of survey effort is provided in Table 3-1 and Table 3-2). The combined data from these surveys provides substantial new knowledge of seafloor presence, distribution and relative availability of habitats and their associated biological communities across the regions in depths of ~1-132 m, and provides a range of new taxonomic records for the broader Marlborough Sounds management region (including adjacent Cook Strait sites), as well as a new genera of burrowing sea cucumbers for New Zealand.

These data are intended to provide both broad (survey-wide) and fine (within-site) scale distributions of habitat and their associated biological communities across the survey region. We also examine distributional differences by sub-region (listed in Table 3-2 and colour coded on the maps in Appendices A-D), within three regions: Queen Charlotte Sounds (QCS), Tory Channel (TC) and Cook Strait (CStrait). In addition to providing seafloor characterisation and spatial distributions of taxa over the study region, we also present categorical/rank values for percentage (%) cover and counts for some taxa, these are based on real-time data entry, and while these data have been QA-QC'd, they are presented here only as a first real-time assessment in terms of relative distribution and abundance, and should not be relied on for precise estimates of taxa abundance, which would require detailed post-processing of the video.

For some small, cryptic or buried taxa, video quality - relative to water clarity, currents and other conditions that affect the speed and altitude of the towed-camera system - may be reflected in data records. For example, the presence of solitary cup corals in the data definitely denote where cup corals were, however, due to the inability to detect small individual cup corals in all conditions across different locations (within or between sites), makes it difficult to say definitively that they were absent at all other data locations or sites. Again, more detailed review/post-processing of the video (frame-by-frame) would be required to confirm true absences (i.e., where the seafloor could be adequately seen, but no cup corals were present), versus 'no data' records (i.e., where seafloor visibility was inadequate to detect small cryptic species). However, as very few solitary cup coral records were previously available within the Sounds, particularly over this spatial-scale, the inclusion of these presence-alone data is very significant.

Table 3-1: Summary measures of survey effort for the three tow-video surveys. HS51 is not included here, as only a single GPS waypoint was recorded for each site, so no tow-distance measure could be calculated.

Survey	Linear km's Surveyed	Mean (SE) Transect Length (m's)	Transect Length Range (m's)
MDC18	36.6	245.8 m ± 7.5 SE	37.8 – 642.5
CB17	9.1	209.4 m ±	42.9 - 653.1
BT17	12.3	293.0 m ± 14.2 SE	54.7†-479.4
Total	58 linear km	n/a	37.8 – 653.1

† beam trawl (BT17-Q58) filled with cockles, tow stopped and net hauled in.

Table 3-2: Overview of the sampling effort by sub-region for each of the four video surveys used in this report. Sites = Total sites sampled, Records = Total number 30-sec calls along each transect summed by subregion. QCS = Queen Charlotte Sounds; TC = Tory Channel; and CStrait = Cook Strait. MDC18 (tow-video / this survey); NIWA's 2017 MBIE surveys for tow-video (CB17) and beam trawl with GoPro's (BT17) sites within the survey area; and HS51 dropcam sites – and comprise the data and findings presented in this report.

Subregions	MDC18 Tow-video		MBIE-CB17 Tow-video		MBIE-BT17 GoPro/BTrawl		HS51 Dropcam		Totals	
	Sites	Records	Sites	Records	Sites	Records	Sites	Records	Sites	Records
QCS-inner	43	1261	6	133	12	12	29	29	**82**	**1427**
QCS-mid	25	736	5	139	8	8	27	27	**65**	**910**
QCS-outer[2]	43	1733	10	223	17	17	46	50	**114**	**2021**
QCS-CStrait	6	178	3	45	0	0	15	17	**24**	**240**
Tory-inner	10	279	5	131	4	4	4	4	**23**	**418**
Tory-mid[3]	4	319	9	204	2*	2*	7	7	**22**	**532**
Tory-outer	11	354	4	113	1	1	3	3	**19**	**471**
Tory-CStrait	7	202	1	29	0	0	1	1	**9**	**232**
Total	**149**	**5062**	**43**	**1017**	**44**	**44**	**132**	**138**	**358**	**6251**

* Beam trawl at one site (BT17-QC39) failed (bar broke and catch released), but video footage was fine.

Table 3-3: Summary depth statistics for each subregions, for those sampled during the combined video surveys relative to the actual depths available/present (derived from the HS51 bathymetry). Depth values are presented as mean ± Standard deviation (Std) (depth minimum-maximum) for HS51 bathymetry, while camera depths are presented as minimum-maximum depth.

Sub-regions	Area of each subregion (km^{-2})	HS51 Bathymetry (m)		Video Surveys
		Mean ± Std	Depth range (m)	Depth range (m)
QCS-inner	65	28.7 ± 12.1	0-68.0	3.2-54.2
QCS-mid	81	41.7 ± 14.9	0-82.6	2.4-78.6
QCS-outer	133	36.3 ± 24.7	0-180.4	4.1-100.3
QCS-CStrait	122	137.3 ± 53.8$^{\Delta}$	0-385.0$^{\Delta}$	12-132.0
Tory-inner	11	31.7 ± 22.1	0-69.2	1-64.6
Tory-mid	10	27.3 ± 19.9	0-70.8	10.5-62.5
Tory-outer	8	26.2 ± 15.7	0-70.9	3.8-51.6
Tory-CStrait	2	51.0 ± 26.8	0-126.3	7.4-111.9
Total	433 km^{-2}	64.3 ± 56.7	0-385.5	1-132.0

Δ Most of the adjacent Cook Strait area was in depths of <250 m, with a localised area around Walker Rock off Cape Jackson, extending down to 386 m. Cook Rock ranged in depth from 2.5 down to 227 m (mean of 118.9 m ± 44. 3 m).

[2] NB: As Sustainable Seas research was planning to undertake tow-video sampling to characterise the benthos within mid-QCS (as part of ecosystem-functioning programme), following consultation with MDC (Steve Urlich) our originally higher survey effort in this subregion was reduced and reallocated to other subregions within the survey area to ensure maximum sampling effort could be achieved for MDC.

[3] Similarly, to reflect the recent sampling effort undertaken within mid-Tory Channel in response to new farm allocations, sampling effort was reduced/reallocated to outer Tory Channel sites. In addition, attempts to survey the remaining planned mid-Tory sites were frequently impeded by extremely strong currents. Although, these sites were no worse than entrance sites, entrance sites had been given top priority to be undertaken during the very short slack tide phase, which due to time limitations left mid-Tory to do during running current. However, previous more-detailed research studies already exist for the Mid-Tory region (e.g. Morrisey et al. 2016).

3.2 Significant and notable habitats and species

3.2.1 *Caulerpa* beds/meadows

Background: Commercial paua divers previously reported extensive subtidal areas covered with bright green algae (cf. *Caulerpa* meadows) off Cape Jackson (Steve Urlich, pers. comm., MDC *unpublished records*), but due to the extremely exposed, high-current and often perilous environment of this site, the presence of *Caulerpa* meadows (or sea rimu or 'rimurimu' meadows) there had not been independently verified. A significant site has been delineated around this strong-current swept reef off Cape Jackson (Area 7.1) and defined as supporting current-swept communities (Davidson et al. 2011 based on '*pers. comm*.' information Table 8 p114). During the MDC18 survey, MDC requested NIWA attempt to run a video-transect in or around Cape Jackson if good weather conditions prevailed. During survey work in Cook Strait, a video-transect up the exposed rock ridge off Waihi Point at Cape Jackson was successfully surveyed. In addition to this site, we were also able to survey other highly exposed wave and current locations, incl. the NW side of White Rocks (an extremely exposed reef located in the channel entrance between QCS and Cook Strait) and a further eight rocky reefs sites along the exposed coastline of Cook Strait.

Ground-truthing surveys: *Caulerpa* spp. meadows were verified at the Waihi Point, Cape Jackson site (Table 3-4, Figure 11d, Figure 12-Insert A), along with 11 new sites records of *Caulerpa* spp. meadows within the survey area, and four new site records located just beyond the HS51 mapped survey area[4] - giving a total of 16 new site records for *Caulerpa* - all in extremely high-current and/or waved-exposed sites at either the entrances to QCS and TC or along the coastline of the Cook Strait (Table 3-4, Figure 11, Figure 12). At these sites, *Caulerpa* spp. distributions were restricted to highly exposed rocky reef areas in water depths of 3.8 m down to 26.8 m, although dense meadows were most common in depths of 10-20 m (mean depth 17.2 m ± 0.49 m SE). While small isolated patches of *Caulerpa* were recorded within the shallower kelp-forest zone, large meadows of *Caulerpa* occurred immediately below the kelp-zone, and at many of these sites, occurred as very extensive lush meadows growing across the tops of reefs and down near-vertical rock walls. The densest and most extensive meadows recorded during these surveys occurred at sites from Waihi Point at Cape Jackson and White Rocks -located on the inner-edge of the eastern channel entrance to QCS, down to two Cook Strait reefs either side of the entrance into TC.

At Waihi Point, Cape Jackson (Site MDC18-Q121), *C. flexilis* was recorded at the base of the reef growing in small (<30 cm diam.) patches on either low-lying or sediment-buried rock in ~12 m water depth, and then in very dense lush meadows (80-100% cover) up the near-vertical rock walls spanning depths of 10-4 m over this very high-relief ridge feature (Table 3-4, Figure 12-Insert A). On the upper reaches of these very steep rock walls, extensive and very dense kelp forests of *E. radiata* became dominant, but were interspersed in places with dense but relatively small isolated patches *C. flexilis* (e.g., Figure 11d). At the White Rocks site (Site MDC18-Q129), *Caulerpa* meadows were growing across the steep to near-vertical rock walls and ravine-like fractures in the reef, forming a very dense and expansive mono-specific meadow of *C. flexilis* within a depth zone of ~13-20 m - although *C. flexilis* were also found in low % cover in slightly deeper and shallower sections of this reef. Overall, *C. flexilis* was present along 50% of the transect (Table 3-4, Figure 12-Insert B). Within the higher density '*Caulerpa*-zone', a near contiguous meadow of lush *C. flexilis* was present covering >~75-100% of the reef (Figure 11a-c). Our video-transect traversed up the slope and then along and round a series of steep rock walls, spanning a meadow distance of 74 m that covered a

[4] *Caulerpa* meadows (cf. *brownii*) were also recorded at four additional Cook Strait sites, located beyond the extent of the HS51 maps, with two coastal sites north of TC (CB17 sites EC02 and EC22), and two south of TC (CB17 sites EC04 in Lucky Bay, EC05 in Glasgow Bay).

near continuous band of *C. flexilis*. This new footage shows *C. flexilis* to be the dominant-habitat former within this depth zone, and given the symmetrical relief structure around White Rock, would likely extend around large sections (at least the wave-exposed front and sides, if not all) of this large rock feature - within the 13-20 m depth-zone.

Further south, outside TC on an extensive reef platform just north of East Head, in Cook Strait (MDC18- Q153), *Caulerpa* spp. formed an extensive lush meadow across the tops and rock walls of a large reef platform in depths down to almost 20 m (e.g., Figure 11f), with the meadow spanning a linear distance of ~243 m – along the direction of our transect. Several good close-ups of this algal meadow identified two species of *Caulerpa* (*Caulerpa flexilis* and *Caulerpa brownii*), with *C. flexilis* present on the tops and shallower sections of the reef platforms (e.g., Figure 11f), while *C. brownii* was observed on rock walls and in deeper zones (e.g., Figure 11g). At one location, *C. flexilis* identified on the top of the reef, with what looked like *C. brownii* on the rock slope directly below, indicating that these species may co-occur within this meadow, albeit in possibly different sub-zones. At this site, *Caulerpa* (spp.) was present along 69% of this transect, in depths of 12.3-26.4 m (Table 3-4, Figure 12-Insert C).

Not all *Caulerpa* meadows were present as extensive and/or lush dense beds. For example, at a site south of TC entrance (MDC18-Q83 - cove south of West Head), a broken moderate to high-relief reef supported an extensive area of *Caulerpa* (Table 3-4, Figure 12-Insert C), but this meadow was characterised by variable-density patches of 10-100 % cover (mean density of 41.4 ± 79%) comprising at least two co-occurring species. *Caulerpa brownii* was present across most of the meadow along with *C. flexilis*. On the deeper sections of this reef, *Caulerpa* spp. dominated by *C. brownii* (characterised by its long single strands) was patchy and sporadic, while on shallower reefs, larger and denser patches were more common (e.g., Figure 11h). The low-density meadows also comprised small fleshy plants of what looked like *C. flexilis* amongst the *C. brownii* (but these two species could not be identified consistent across these meadows from the video-imagery alone). Over the entire transect, *Caulerpa* (spp.) was present along 60% of this transect, within the albeit patchy meadow measuring 142 m wide – along the direction of our transect (Table 3-4, Figure 12-Insert C).

During the MBIE BT17 beam trawl surveys, *Caulerpa* specimens (all *C. brownii*) were collected from three sites within the survey area[5] – all likely reflecting drift algae in sites located at some distance from where the once-attached plants grew. A small 20 ml fragment of *C. brownii* was collected from a soft-sediment site on the outer Banks of QCS (BT17-QC09, 26-28 m water depth) located ~ 500 m south of White Rocks. Additional fragments of *C. brownii* were collected from drift-algal mats in two bays within Tory Channel. This included a 12 ml fragment from Te Pangu Bay mid-Tory Channel (Site BT17-QC38), and 7 kg's of material from Okukari Bay (Site BT17-QC70). The two TC embayment sites were characterised by thick mats of drift algae covering large areas of the seafloor. The occurrence of *Caulerpa* in these algal mats indicates that accumulation of drift algae in these bays likely comes from algae transported from outer Tory Channel and possibly Cook Strait. GoPro video footage at these beam-trawled sites found no attached/growing *Caulerpa*.

[5] *Caulerpa brownii* was also collected (≤ 150 ml fragments) in three beam trawl catches undertaken beyond the mapped HS51 survey (outside the scope of this report): one site within an exposed sandy bay, near Bushy Point in Cook Strait (BT17 EC11) – that collected large amounts of drift algae and also included 1-ml of *Caulerpa geminata*, and from two beam trawl sites in Port Underwood (BT17 EC16 and EC26). As well as several sites around D'Urville Island.

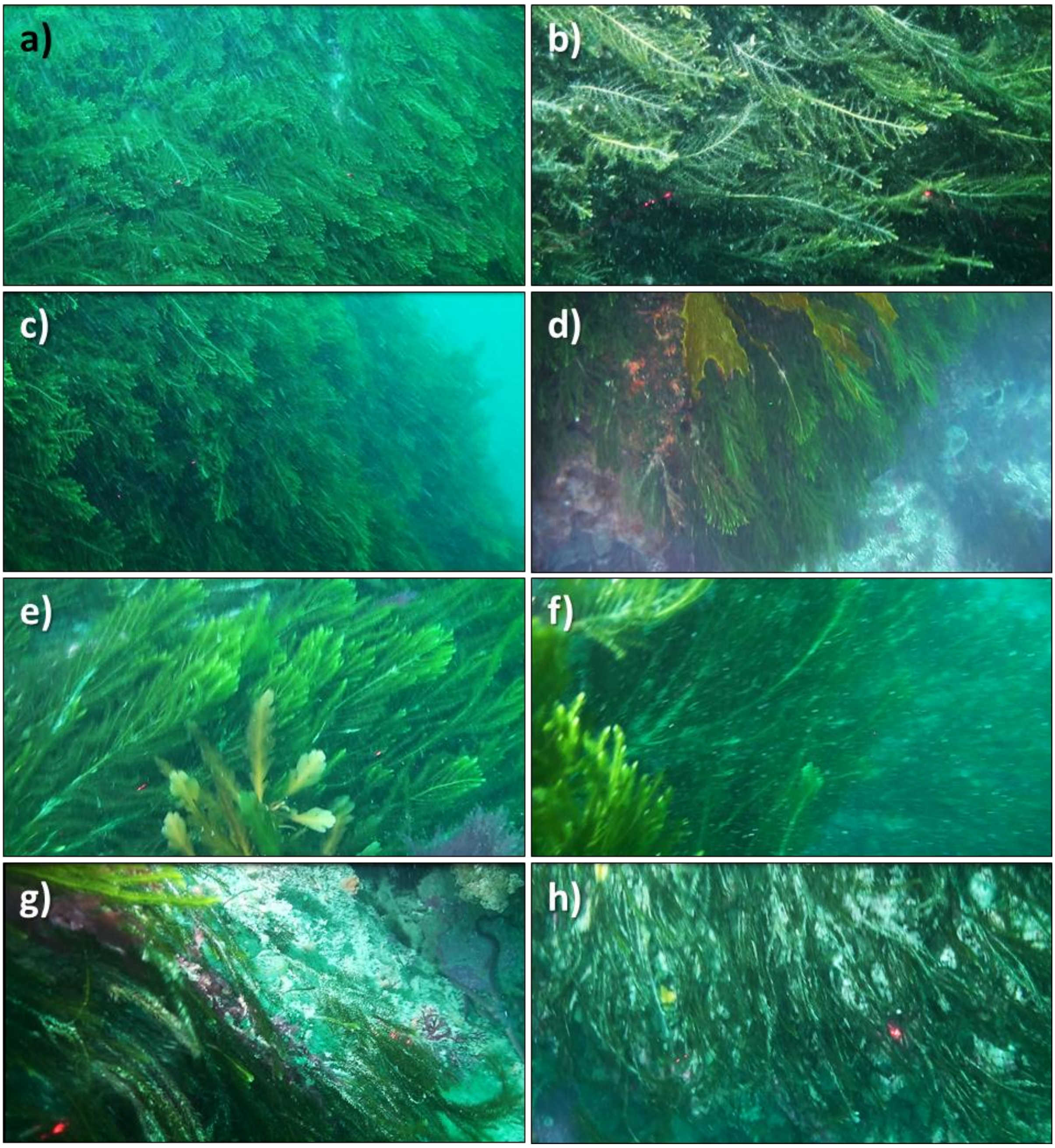

Figure 11: Examples of significant Caulerpa meadows from outer Sounds and Cook Strait sites. a-c) *C. flexilis* forming extensive meadows on the west side of White Rocks (entrance to QCS, Site MDC18-Q129), present as a zone of near continuous cover on the steep rock faces in depths of ~13-23 m; d) *C. flexilis* forming a dense zone on the rock face at Waihi Point, in depths of ~10-14 m (entrance to QCS/Cape Jackson, Site MDC18-Q121); e) *C. flexilis* (with kelp – *Landsburgia quercifolia*) on high-relief reefs in Cook Strait, south of Tory Channel entrance (Site MDC18-Q148); f-g) extensive meadows of *C. flexilis* (f)-shallower (~12-17 m) and *C. brownii* (g)-deeper (15-22 m) on Cook Strait reefs adjacent / north of Tory Channel (Site MDC18-Q153), where *C. flexilis* was mostly on the tops and upper-flanks of high-relief rock features, while *C. brownii* was more common in the deeper zones and on the lower flanks of these rock features (NB: *Caulerpa* was present in 68% of all data-records at this site); h) dense *C. brownii* on high-relief reefs in Cook Strait, adjacent / south of Tory Channel (Site MDC18-Q83).

A site on the outskirts of the mapped section of Cook Strait, north of TC (CB17-EC03) as well as several CB17 sites surveyed further north beyond the HS51 mapped region (e.g., CB17-EC20 and EC02), supported patchy cover of *C. brownii* on low-lying boulders and broken reef, that included small to very large areas of denuded rhyzomes, indicating areas of damage. Many sites where *Caulerpa* was present, had varying amounts of sediment-veneer over moderate to low-lying reefs. *Caulerpa* is known to colonise and grow in reefs that are at times heavily veneered in coarse sediments, but the presence of sediment covering these reefs and the occurrence of denuded sections of rhyzomes indicates that sediment scouring on these reefs during storms may be a frequent disturbance that can impact these communities.

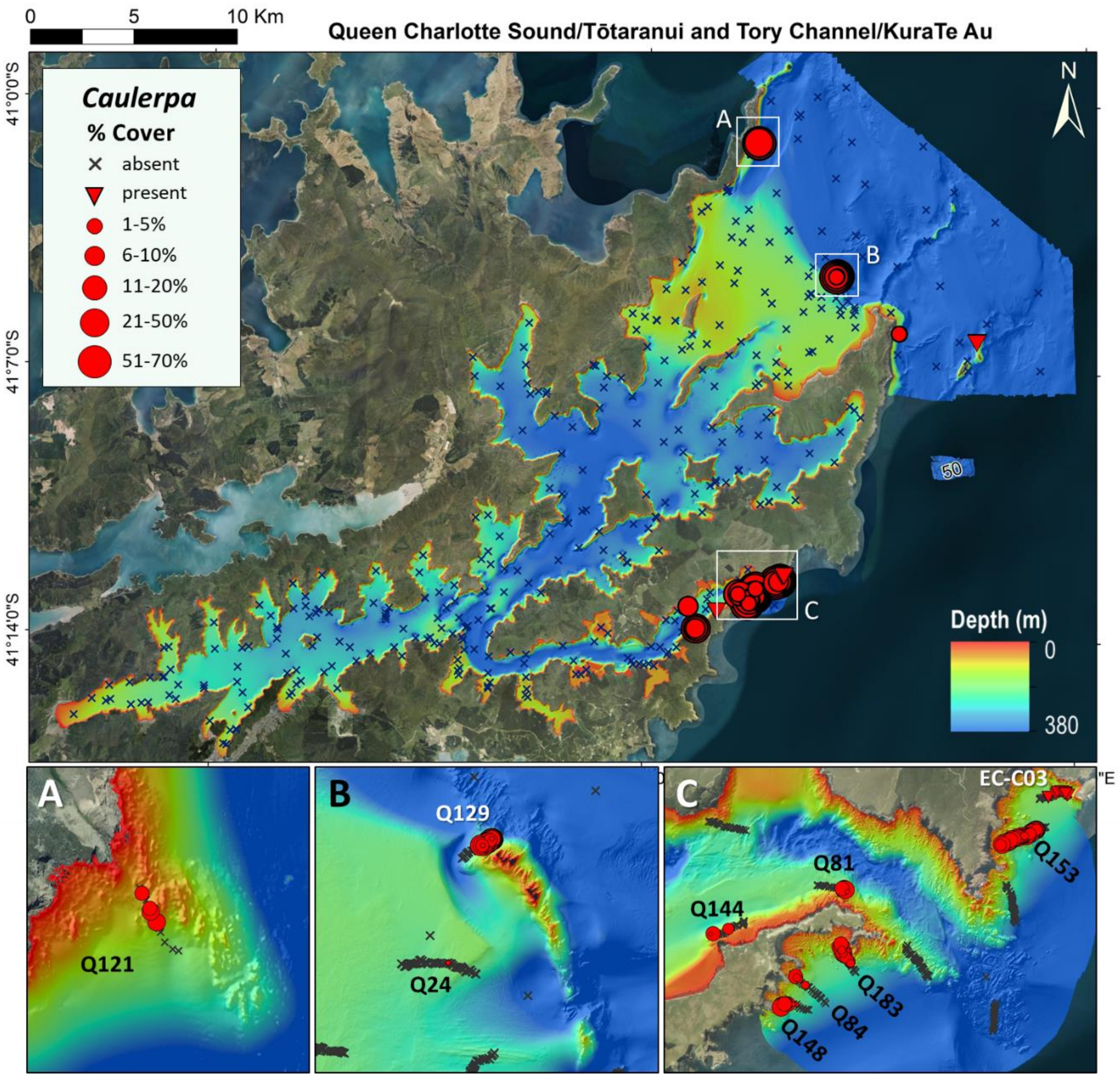

Figure 12: Distribution and relative abundance of *Caulerpa* beds (green macroalgae) in the outer reaches of the Marlborough Sounds and adjacent Cook Strait. Inserts A-C) provide added detail of significant *Caulerpa* sites from MDC18 (e.g., Q24-Q153) and CB17 (EC03) surveys.

Table 3-4: Summary statistics for *Caulerpa* meadows (percent cover and depth ranges of meadows) for the MDC18 survey. Queen Charlotte Sounds (QCS) and Tory Channel (TC). % of records = Number of records where *Caulerpa* was observed along the transect expressed as a percentage. Δ = Presence records (CB17 occurrence only). Identification of *Caulerpa* to species is difficult in video, but identification was determined from some imagery, but this may not represent species composition for the entire transect. To provide estimates of relative meadow densities at a site, mean percent cover estimates are presented for only the records that had *Caulerpa* and therefore represent the mean cover within the meadow, not across the entire transect.

Survey	Subregion	Site	Description	Species verified	% of records	Percent cover ▾		Depth (m)	
						Mean (±SE)	Range %	Mean (±SE)	Range (m)
MDC18	Outer QCS	Q121 *	Dense meadows on rock walls, Waihi Point, Cape Jackson.	*C. flexilis*	33%	75.0 (14.4)	50-100	7.2 (1.8)	4.1 - 11.7
MDC18	Outer QCS	Q129*	Dense meadows on rock walls west side of White Rocks.	*C. flexilis*	50%	80.0 (6.4)	1-100	17.8 (0.4)	13.8 - 22.7
MDC18	Cook Strait (TC)	Q153 *	Dense meadows on tops of high-relief rocks, East Head.	*C. flexilis* *C. brownii*	69%	70.8 (5.3)	10-100	19.2 (0.5)	12.3 - 26.4
MDC18	Cook Strait (TC)	Q148	Dense meadows on rock walls.	*C. flexilis* *C. brownii*	50%	56.7 (12.4)	5-100	18.0 (2.0)	7.4 - 26.8
MDC18	Cook Strait (TC)	Q83 *	Dense meadows on tops of high-relief rocks.	*Caulerpa spp.* *C. brownii*	60%	41.4 (7.9)	10-100	19.9 (1.5)	9.8 - 26.5
MDC18	Cook Strait (TC)	Q84	Few patches variable density.	*C. brownii*	18%	20.0 (10.0)	10-100	18.9 (2.1)	14.6 - 24.3
CB17	Cook Strait (TC)	EC03	Patchy cover, with some patches of denuded rhyzomes.	*C. flexilis* *C. brownii*	60%	Δ	Δ	*22.8 (2.1)*	*18.7-25.3*
CB17	Cook Strait-Brothers	EC15	few patches of ~10-20% cover.	*C. brownii (?)*	12%	Δ	Δ	*20.5 (0.7)*	*17.7-24.7*
MDC18	Outer TC	Q81	Dense on rock slope[1]. ≤ 100% cover, 40 m extent but patchy.	*C. flexilis*[1]	25%	70.2 (19.8)	1-100	13.0 (0.1)	12.9 - 13.2
MDC18	Outer TC	Q159	Few medium density patches.	*C. brownii*	14%	27.0 (6.4)	10-50	6.1 (0.9)	3.8 - 9.0
MDC18	Outer TC	Q157	Few small low-density patches.	*C. brownii*	.	Δ	5-20	.	.
MDC18	Outer TC	Q144	Few medium density patches in rock gulley's.	*C. brownii*	11%	25.3 (14.1)	1-50	14.1 (1.3)	11.4 - 15.6
CB17	Outer TC	C22	few patches of 10-15% cover.	*C. brownii*	24%	Δ	Δ	*10.1 (0.5)*	*7.9-11.1*
MDC18	Outer QCS	Q54	One small plant <1% cover.	*C. geminata*	.	Δ	Δ	.	.

▾ *Caulerpa* values from the MDC18 data were re-processed as true percent cover and are presented here.
* photos of these significant beds are provided in Figure 11.
? = identification was not verified.
[1] two small patches of what looked to be *C. brownii* lower on reef, but not able to be verified.

3.2.2 Bryozoan patch-reefs

Background: Some species of bryozoans can form significant coral-like thickets or reefs across often large areas of the seafloor, with 27 reef-forming species known within New Zealand waters (Wood et al. 2012; review by Anderson et al. 2019). Several of these species are known to occur within the broader Marlborough Sounds Region (Gordon et al. 2009). These include the encrusting 'reef-building' bryozoa also known as Tasman Bay coral, *Celleporaria agglutinans* that is known to form large reefs off Separation Point, with other branching-forms of reef-building bryozoa (e.g., *Cinctipora elegans*, *Galeopsis porcellanicus, Diaperoecia purpurascens,* and *Hornera robusta*), along with other rigid-erect species (e.g., *Cellaria tenuirostris* and *Cellaria immerse*) that can also contribute to reef-structure, albeit to a much lesser extent. *C. agglutinans* is an encrusting species that over time can form large cemented reef-like structures (or mounds) each up to 40 cm tall and 50 cm wide (Grange et al. 2003), while the branching forms of *G. porcellanicus* and *C. elegans* are known to build compact colonies that can form patchy km-scale thickets (Wood et al. 2012; Anderson et al. 2019). Both species are known to occur within the Marlborough Sounds, in areas with strong tidal currents (e.g., Allen Strait, French Pass and Stephens Passage, Davidson et al. 2011). Within the survey area *C. agglutinans* and *G. porcellanicus* have been recorded growing in patches on reef slopes within TC, and as part of biogenic-clumps in other zones within TC (e.g., Davidson et al. 2011; Morrisey et al. 2014; Brown et al. 2016a). Extensive areas characterised by patchy bryozoan reefs comprised of *C. agglutinans* and *C. elegans* have also been recorded offshore on large sediment banks in the Outer Sounds north of Pelorus Sounds, most notably around Rangitoto, Trios and Chetwode Islands (Davidson et al. 2010b; *T. Anderson pers. obs.*, NIWA-MBIE *unpublished data*) - growing on relict aggregated shell material and encrusting living horse mussels (*T. Anderson pers. obs.*). In contrast, only one site within the survey area has been purported (by past fishers) to have similar bryozoan reef structure: this spot is located on an outer sand bank in the western entrance to QCS, east of Cape Jackson. Based on this knowledge this site was designated as a significant area (ESMS-7.2 in Davidson et al. 2011 p115). To verify bryozoan reefs at this location, MDC requested NIWA run a video-transect within significant site 7.2, if weather conditions prevailed.

Ground-truthing surveys: Bryozoan patch-reefs were verified within the area defined as ESMS-7.2 (HS51-D09; HS51-D14). The seafloor at these sites was characterized by muddy sand with occasional patches of low-lying rubble and small patches of very low-lying bryozoan patch reef (<15 cm height). No significantly large or high patches of bryozoan reef were recorded, however these two Dropcam sites collected only very short-duration footage (<1-min). During the MDC survey an additional transect was run in this area, but strong currents pushed the vessel off-course and resulted in a transect being run just north of the ESMS-7.2 boundary on the outer slope along the 81 m depth contour (MDC18-Q120). This high-current slope was characterized by similar muddy sands with occasional patches of low-lying rubble, but negligible amounts of what may be relict bryozoan structure of very low vertical height (<10 cm). Instead this site was characterized by high occurrences, albeit in low densities, of large fleshy translucent-pink anemones, of the genera *Actinia* (see Section 3.7.4 for a description of this species).

In addition to surveying ESMS-7.2, numerous video-transects were run across the mid and outer sections of what Neil et al. (2018a) refer to as the Sill and is locally known as the "Duck Pond". The Duck Pond spans the entrance to QCS (~9 km across x 4-5 km wide)[6]. During the MDC surveys, 16

[6] Past fishers and long-time residents of the Sounds have indicated that the Duck Pond (defined as the area north of Long Island that stretches between the East and West entrance to QCS) was renowned for juvenile blue cod (NIWA *unpublished Local Ecological Knowledge*

new records of bryozoan reefs were discovered across the outer sections of this banks, with additional HS51 dropcam and BT17 beam trawl sites supporting these observations, and providing broader spatial context (Figure 14, Table 3-5). Bryozoan patch reefs (referred to as bryo-reefs hereafter) were present across the mid-outer regions of the Bank, over the Bank edges, and down the upper section of the outer slope (Figure 14), with highest densities and areal coverage around the eastern and western entrances to QCS (e.g., Figure 14-Insert A). Depths ranged from 13.2 m along the western edge of the Bank (Site MDC18-Q126) down to 67.6 m near the base of the eastern channel slope (MDC18-Q02), however, most of the bryo-reef biomass was recorded in 20-30 m depth (mean 26.4 m ± 0.30 m SE).

These higher biomass bryo-reef zones were characterized by thick muddy sands interspersed by clusters of bryozoan patch reefs of various sizes and heights (e.g., Figure 13), each composed of various amounts of relict and living bryozoa – dominated by the encrusting reef-building species *C. agglutinans* (Tasman Bay coral) (e.g., Figure 19a,b,d,e). Patches varied in size from as small as 20 cm in diam. to large interwoven clumps of patches that spanned 100's of metres, while their vertical heights varied, often within and between sites, from 20 cm up to ~1 m (e.g., Figure 13 and Figure 15). Bryo-reefs were interspersed with localised patches of shell-debris and bryozoan rubble, or small to large patches of muddy sand with burrows (e.g., Figure 15, Figure 16 and Figure 17). Depth profiles along cross-sections of reefs (e.g., Figure 17 MDC18-Q127), identified that in many areas the shell-debris fields occurred in raised sections around and between the reefs, while the thick muddy sediments lay in the deeper troughs between these raised features. Although reef-forming bryozoans have been recorded growing in numerous locations throughout the Sounds (e.g., on the slopes with Tory Channel), bryozoan reefs growing in soft-sediment habitats, have been limited to the Outer Sounds north of Pelorus Sounds, and have not been recorded elsewhere within the survey area – with the exception of the significant area 7.1 reported by past commercial fishers. Importantly the size and solid structure of these newly discovered QCS bryo-reefs revelled if not bettered those already described for the Outer Sounds areas of Rangitoto (incl. ESMS-2.5 and 2.6), Trios (incl. ESMS-2.10) and Chetwode Islands.

Like the bryo-reefs in the outer Pelorus Sounds, the newly- discovered ones in outer QCS supported diverse epibenthic assemblages, with higher and larger patches supporting more impressive faunas (e.g., Figure 13). For example, small reef patches with relict and living *C. agglutinans* supported a few associated species generally dominated by colonial ascidians, most commonly the yellow-mustard coloured cf *Cystodytes dellechiajei*, along with a few motile invertebrates, such as snake stars (*Ophiopsammus maculata*, referred to as 'snake stars' hereafter) and the common sea cucumber (*A. mollis*). Larger more prominent patches, however, supported more diverse faunas that included, sometime in large amounts other reef-building bryozoa (most commonly branching species, *C. elegans* and poss. *G. porcellanicus*), large erect sponges (e.g., *Iophon minor*), various colonial ascidians (most often cf *C. dellechiajei*), hydroids (including the fine-branching orange hydroid, *Halopteris campanula*), solitary sea squirts and at some sites the common white-striped rock anemone (*Anthothoe albocincta*, referred to as 'rock anemones' hereafter).

data). Local Ecological Knowledge data includes interviews with long-time residents and fishers and was collected as part of the larger MBIE Bottlenecks Programme (C01X1618).

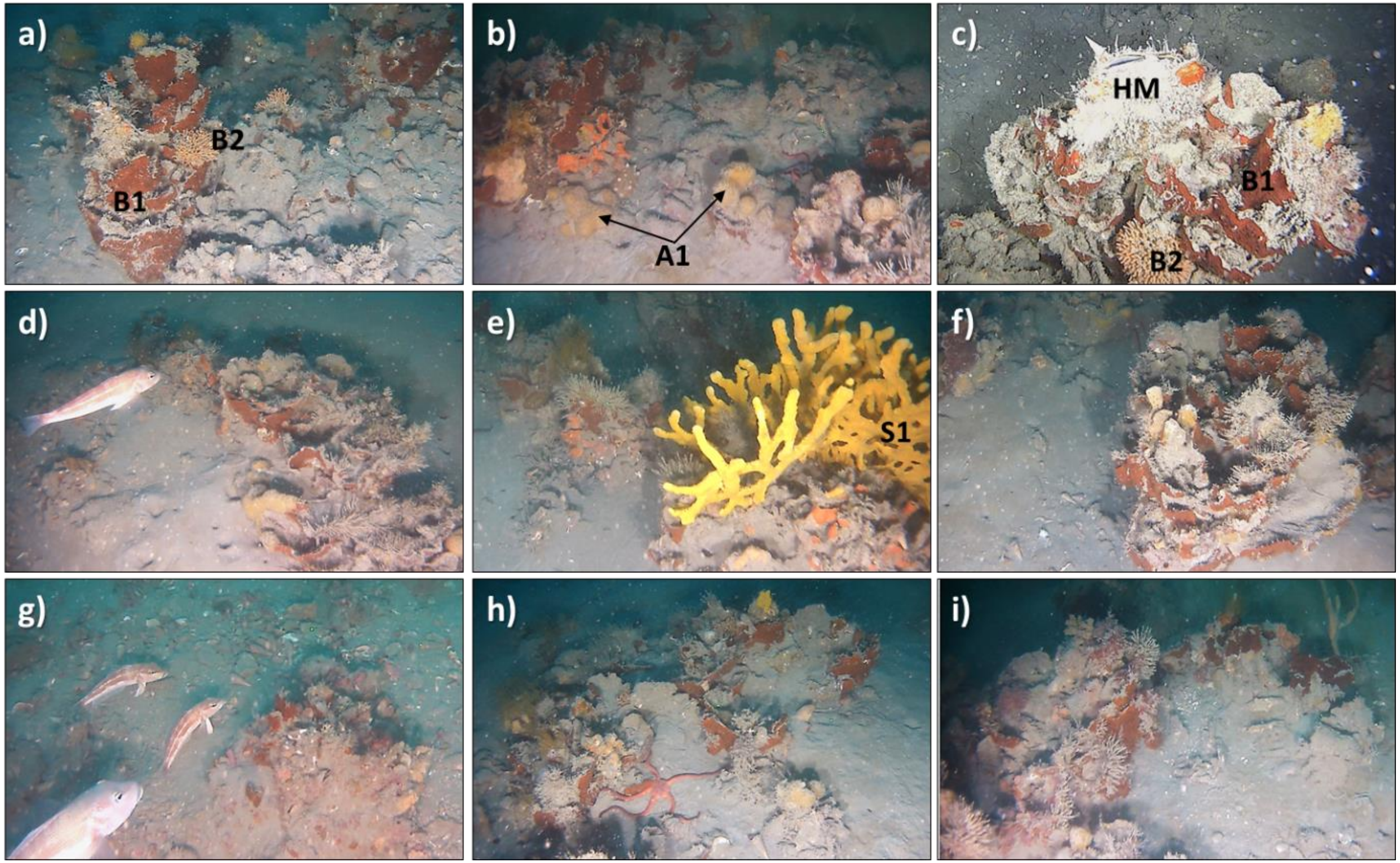

Figure 13: Examples of significant bryozoan patch reefs on the outer Banks at the entrance to Queen Charlotte Sounds – comprised of the reef building bryozoa (The Tasman Bay coral, *C. agglutinans*). a-b) bryo-reef comprised of the reef building bryozoa (B1=*C. agglutinans*) with small branching bryozoa (B2= *G. porcellanicus*) and colonial ascidians (A1=*C. dellechiajei*) (Site MDC18-Q57 and Q56, respectively); c) bryo-reef growing around a large horse mussel (HM), with branching bryozoa (poss. *C. elegans*) and colonial ascidians (*C. dellechiajei*) (Site MDC18-Q57); d) low-lying bryo-reef and sediment with subadult blue cod (Site MDC18-Q57); e) bryo-reef with large erect yellow sponge (S1=*Iophon minor*) (Site MDC18-Q57); f) tall bryo-reef patch with moderately abundant living *C. agglutinans* (Site MDC18-Q57); g) low-lying bryo-reef and shell-debris with 2 juvenile [~13-15 cm] and a subadult blue cod (Site MDC18-Q118); h) low-lying bryo-reef with *H. campanula*, colonial ascidians and snake stars (Site MDC18-Q57); 1) undulating bryo-reef with small hydroids and digitate sponge (Site MDC18-Q56).

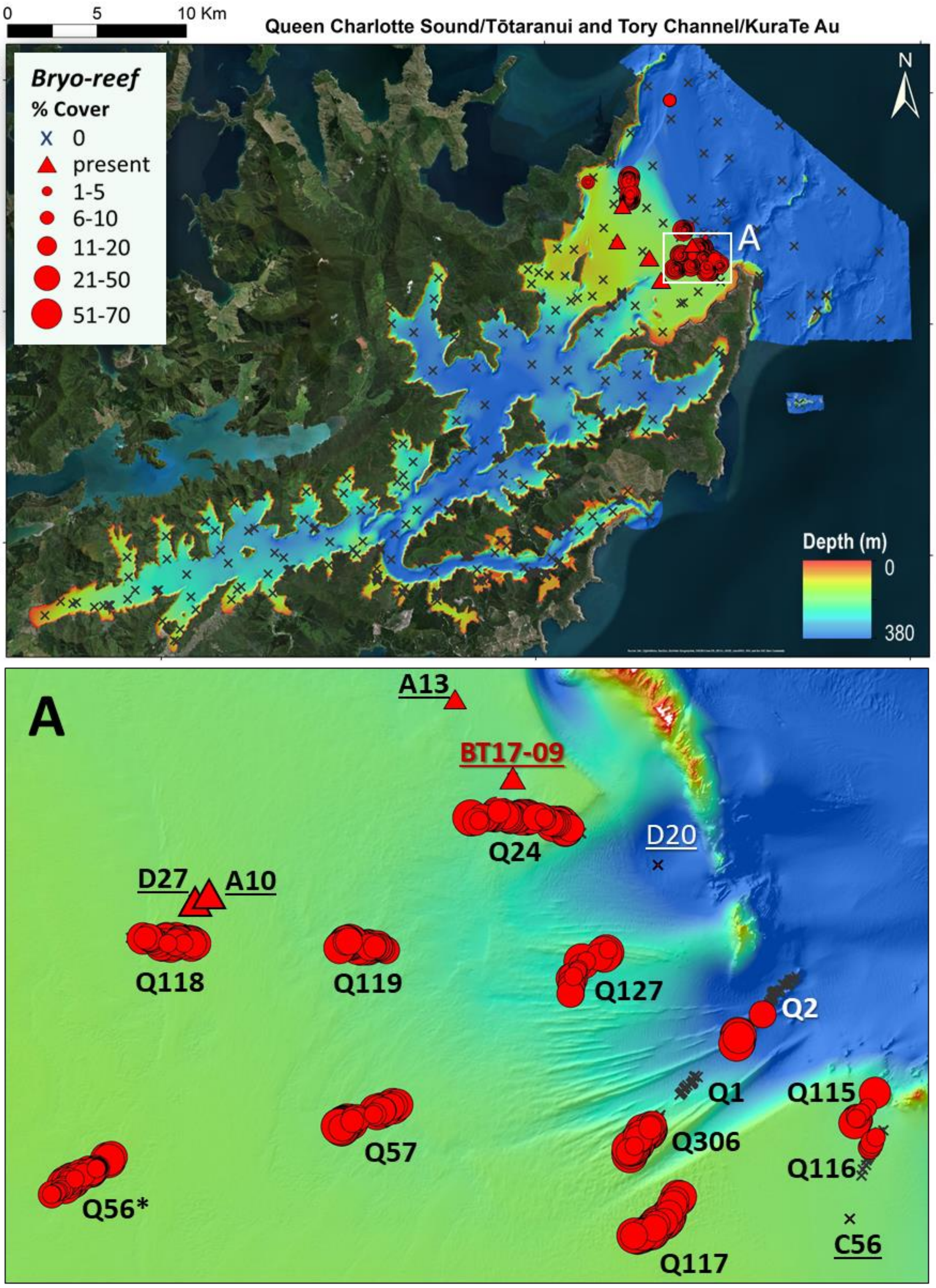

Figure 14: Distribution and relative %cover of bryozoan patch reefs from all surveys, across the outer edge of the Bank (known as the Duck Pond) on the eastern side of QCS entrance. Insert-A) zoomed-in section of the extensive bryozoan patch reef area along the upper slope and outer bank of QCS entrance, off Cape Koamaru. Raised and dimpled features in the HS51 bathymetry for this area depict a mixture of relict and living bryozoan reefs (~0.2-1 m in height). Where red triangles = presence; with sites labelled are from multiple surveys, orange site label= BT17 (Site BT17-09); underlined site labels = HS51 dropcam sites, where x = no bryo-reef recorded. Bubble plots = rank % cover for MDC18 sites (site label = no underline). Q56* indicates a photo-mosaic was created for this site (see Figure 15).

Table 3-5: Sites, locations and zones where bryozoan patch reefs were recorded, with the relative occurrence and associated depths (mean, SE and depth range) all survey sites, where bryozoan patch reefs were recorded. Queen Charlotte Sounds (QCS); location refers to east and west sides of the bank; zone= the location across the Duck Pond (mid-bank, outer bank, Edge of bank, Upper slope and lower (deep) slope); SA 7.2 denotes Significant area 7.2. Occur (%) = percent occurrence based on the number of records within a site where Bryozoan patch reefs were observed (calculated as percentage of total records at the site). Bold site numbers indicate bryozoan reefs of significant size and or structure, underlined site numbers indicate the presence of very large consolidated bryo-reefs; * bryozoan reefs with observed damaged.

Survey	Subregion	Location	Zone	Site	Occur (%)	Depth (m)	
						Mean (±SE)	Range (m)
MDC18	Outer QCS	East	Lower slope	Q02	9.4	51.4 (3.3)	46.6-67.6
MDC18	Outer QCS	East	Bank edge	Q23	73.9	36.0 (0.5)	31.8-41.8
MDC18	Outer QCS	East	Bank edge	Q24*	71.0	26.7 (0.3)	24.1-28.6
MDC18	Outer QCS	West	Outer bank	Q55	73.8	24.4 (0.1)	23.7-25.1
MDC18	Outer QCS	East	Mid-bank	Q56	71.2	21.4 (0.0)	21.1-21.7
MDC18	Outer QCS	East	Mid-bank	Q57	57.4	24.6 (0.0)	24.2-25.0
MDC18	Outer QCS	East	Outer bank	Q115	34.8	27.0 (0.6)	25.9-30.8
MDC18	Outer QCS	East	Outer bank	Q116	22.2	25.3 (0.1)	25.2-25.6
MDC18	Outer QCS	East	Outer bank	Q117	96.8	21.8 (0.0)	21.5-22.1
MDC18	Outer QCS	East	Mid-bank	Q118	69.8	22.2 (0.0)	21.9-22.6
MDC18	Outer QCS	East	Outer bank	Q119*	83.9	26.2 (0.1)	25.6-27.4
MDC18	Outer QCS	West	Outer bank	Q124*	22.9	32.3 (0.2)	30.9-33.5
MDC18	Outer QCS	West	Outer bank	Q126	11.1	13.3 (0.0)	13.2-13.4
MDC18	Outer QCS	East	Upper slope	Q127*	59.3	32.5 (0.4)	29.5-34.6
MDC18	Outer QCS	East	Lower slope	Q129	3.7	26.1 (1.0)	25.1-27.1
MDC18	Outer QCS	East	Upper slope	Q306	84.4	24.0 (0.3)	22.6-28.2
BT17	Outer QCS	East	Mid/outer	Q02	n/a	n/a	22.2
BT17	Outer QCS	East	Mid-bank	Q03	n/a	n/a	16.6
BT17	Outer QCS	East	Mid-bank	Q08	n/a	n/a	20.0
BT17	Outer QCS	West	Outer bank	Q09	n/a	n/a	27.14
HS51	Outer QCS	East	Mid-bank	A09a	n/a	n/a	24.0
HS51	Outer QCS	East	Mid/outer	A10	n/a	n/a	23.0
HS51	Outer QCS	East	Outer bank	A12	n/a	n/a	24.5
HS51	Outer QCS	West	Outer bank	A13	n/a	n/a	26.0
HS51	Outer QCS	West	Outer bank	C55	n/a	n/a	26.7
HS51	Outer QCS	West	ESMS-7.2	D14	n/a	n/a	79.0
HS51	Outer QCS	West	ESMS-7.2	D09	n/a	n/a	61.0
HS51	Outer QCS	East	Mid/outer	D27	n/a	n/a	23.0

Table 3-6: Preliminary geometric estimates of the bryo-reef zones. Bryo-reef zone = Area of significant bryozoan reefs, characterised by patchy bryzoan reefs interspersed by shell and bryozoan rubble and muddy sand with burrows. Estimates of area and perimeters of these polygons (Figure 21), are based on preliminary polygons delineating the outer area of these bryo-reefs zones.

Bryo-reef Zones	Area (km)	Perimeter (km)
Bryo-reef West	4.515	13.955
Bryo-reef East	5.032	28.347
Total	**9.547**	**42.302**

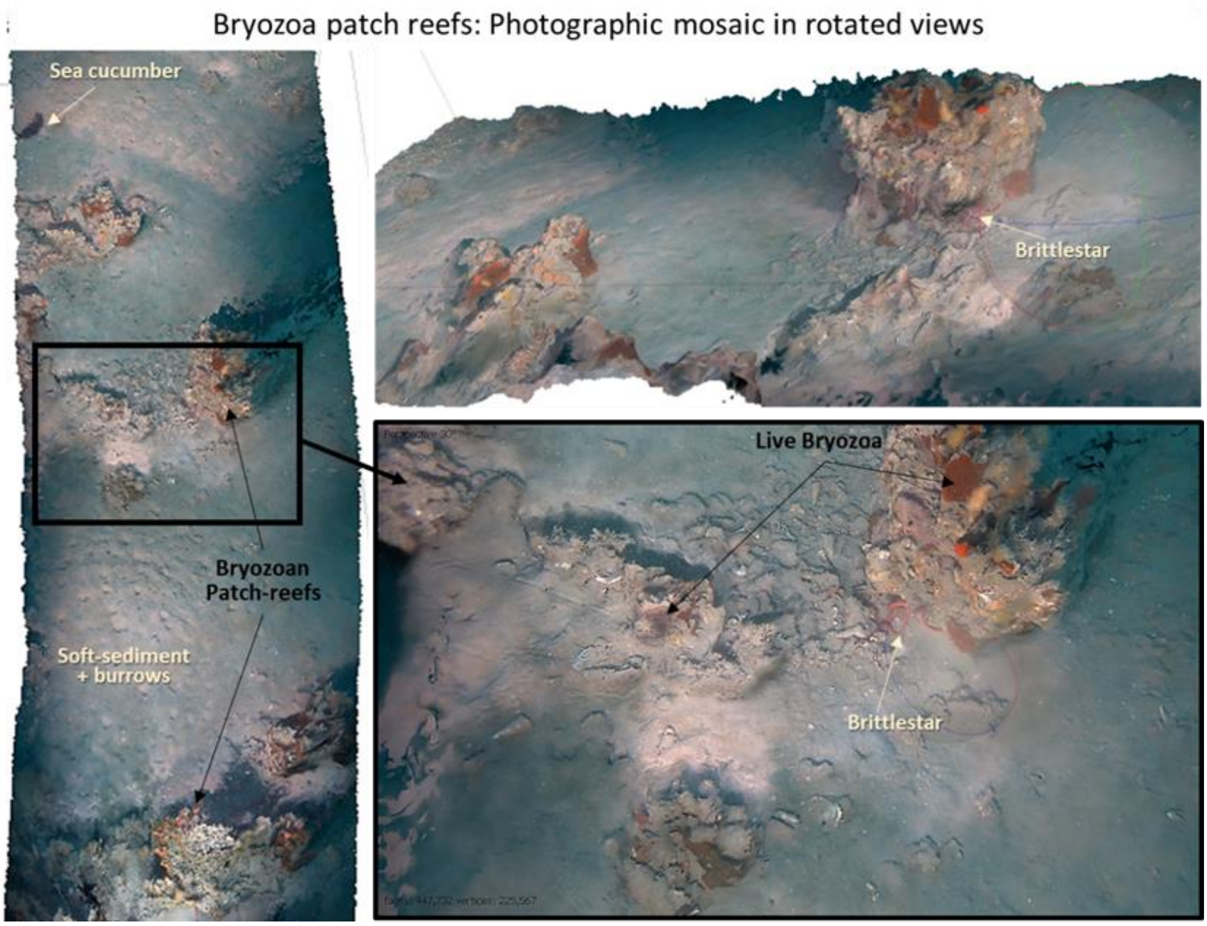

Figure 15: Example of 3-dimensional photo-mosaic imagery. Here showing bryozoan patch reefs on the outer Banks at the entrance to Queen Charlotte Sounds, presented in three rotated views (site MBIE-Q56). In these images the physical structure of the patches is comprised of relict and living bryozoan reef formed by the Tasman Bay Coral, *C. agglutinans*, which in turn provides hard structure for a plethora of encrusting and erect invertebrates, including branching bryozoa, sponges hydroids and ascidians, as well as motile invertebrates, such as snake stars and sea cucumbers (*A. mollis*), and small fish. Vertical height of patch reefs within the mosaic are measured at 33-52 cm. The location of this video-transect (Site MDC18-Q56), is shown in Figure 16.

Horse mussels were also commonly seen in low numbers, often in small clusters across the bryo-reef zone, with many seen cemented within medium to large sized bryozoan reefs (e.g., Figure 13c), while others were heavily encrusted with *C. agglutinans* and other epibenthic fauna. A range of motile species were also associated with more prominent patches, these included higher densities of snake stars, sea cucumbers (*A. mollis*), and more fish species. The most common fish seen in amongst the bryozoan patch reefs were blue cod (e.g., Figure 13d,g and Figure 16-Q56), mostly large juveniles (12-20 cm) and subadult sizes (20-30 cm), with some adults (>30 cm) and notable numbers of newly settled (<10 cm) blue cod. Other fish seen in these areas included leatherjackets (e.g., Figure 16-Q56), spotties, Yellow-and-black triplefins, seaperch (in deeper sites), with fish often seen hiding amongst or darting into the bryozoan structure for refuge. Biogenic habitats, especially the bryo-reefs in the Outer Sounds around Rangitoto, Trios and Chetwode Islands have recently been quantified as important nursery habitats for blue cod (Anderson et al. *in prep*.). The very large spatial extent of these newly discovered bryo-reef areas, also supported very small newly settled blue cod (<5 cm sized fish), indicating that these outer QCS reefs may provide an important nursery habitat for the blue cod population of Queen Charlotte Sounds.

Examination of the distribution and abundance of the bryo-reefs relative to the MBES data layers, identified a strong correlation with fine-scale bathymetric features (vertical heights of >0.2 –3.5 m), with associated high-backscatter (i.e., low-medium to medium-high reflectivity). Neill et al. (1918a) described these areas as "*small patches of an irregular backscatter separating middle Queen Charlotte Sounds from Cook Strait*" (Figure 3-10 of Neill et al. 1918a). Close examination of individuals transects across the MBES-feature boundaries into adjacent and extensive soft-sediment areas identified a near 1:1 match between bryo-reef occurrence and the raised high-backscatter sections of the transects, while the flat low reflectivity areas in the MBES were verified as muddy sands devoid of bryo-reef or any low-lying rubble (e.g., Figure 16-Q118). Similarly, where video transects traversed bryo-reefs that also traversed sediment gaps >2 m[7], a similar 1:1 match between bryo-reef occurrence and sediment gaps was depicted in the change from the raised bathymetric/high-backscatter zone into low reflective muds (e.g., Figure 16-Q56 and Q57).

However, not all areas were clearly matched. For example, the area between the east channel and Cape Koamaru was characterised by a large zone of relatively little to no vertical relief but with very high backscatter (e.g., Figure 16- area around Sites Q115 and Q116). While patches of bryo-reef were recorded within some sections of this zone (i.e., Sites Q115 and Q116), no boundaries delineating these bryo-reef sections were visible in the MBES layers. This may in part be due to isolated patches at scales <2 m not being able to be resolved within the MBES layers or the signal from larger patches is lost in the noise associated with the high-backscatter properties of this zone. Specifically, this large area of high-backscatter is likely due to the presence of large-sized shell-debris from the robust dog cockle, *T. laticostata,* which was seen accumulated on the seafloor in this area (e.g., MDC18 sites Q115 and Q116). Long-time fishers have noted the presence of a large robust dog cockle bed upslope in the region (NIWA-MBIE Local Ecological Knowledge surveys, NIWA, *unpublished data*[8]) – and while large amounts of *T. laticostata* shell debris verify its existence (and match the large area denoted by the long-time fishers in this area), we did not find the live *T. laticostata* bed. Although shells of this species can persist for millennia, their occurrence on the seafloor with little sediment burial suggests that the live *T. laticostata* bed is likely still active in this vicinity.

Given the correlation across defined boundaries from the raised bathymetry/high backscatter bryo-reef zones into the low reflectivity soft-sediments surrounding these reef, delineation of the bryo-reef zone using the new HS51 MBES layers should provide an excellent first step in delineating new-habitat zone. However, this would require a supervised approach to distinguish and exclude areas such as the *T. laticostata*-debris fields. As a preliminary step[9], we created two polygons delineating the western and eastern bryo-reef zones using the combined MBES data layers (Figure 21). This enabled us to calculate initial geometric estimate of these new habitat zones (Table 3-6), with an estimated area of 4.52 km^{-2} in the western zone and 5.03 km^{-2} in the eastern zone, with a combined total of 9.58 km^{-2}. Within the bryo-reef zone, bryozoa reefs were not homogeneous or contiguous, but rather were very patchily distributed, this included scales <2 m (as seen in Figure 15). However, as fine-scales (<2 m) cannot be resolved in the HS51 MBES data, quantifying the amount of actual hard bryo-reef structure within this newly discovered bryo-reef zone is not yet possible by this approach. Estimates of structural cover can, however, be calculated following detailed post-processing of the video-footage and using within-transect measures of habitat patchiness to interpolate across this habitat-zone. This would provide an initial estimate of habitat patchiness

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[7] MBES layers have a 2 m horizontal resolution. This means that they can only resolve features on the seafloor that are >2 m.
[8] Local Ecological Knowledge survey data includes interviews with long-time residents and fishers and was collected as part of the larger MBIE Bottlenecks Programme (C01X1618).
[9] Bryozoan mound polygons were revised in July 2020 as part of the Supplementary modelling project (MDC20301), with revised polygons and areal estimates present in the Supplementary Appendix 9.

within-zone, and an estimate of the amount of reef-structure available to the benthic organisms, such as juvenile blue cod, associated with these features. To calculate more precise estimates of structural cover within the bryo-reef zone, finer-resolution multibeam sonar that targets this discrete area would be required. Although sidescan sonar provides a cheaper alternative to multibeam and can map features like these well, towing a sidescan sonar in parallel overlapping transects in these extreme high-current locations would likely be impractical, if not impossible.

During the 2017 MBIE Bottlenecks surveys, six beam trawl sites were allocated across the 'Duck Pond' – a location identified to be a past nursery area for blue cod. Of the six sites, one sampled the outer edge of this Bank (Site BT17-QC09), while three sites sampled the central west-side of the Bank (QC02, QC03 and QC08), with the remaining two sites sampling the eastern side (BT17-QC10 and QC11). The majority of the seafloor seen in these areas was thick muddy sands (depicted in the HS51 seafloor classifications as low reflectivity sediments), with moderate-high levels of biofilm (diatoms covering the sediment surface), burrows (mostly ≤20 %), tracks, gastropods, and patches of red algae (≤20 %) (Figure 18).

However, at some sites, patches of reef building bryozoa (*C. agglutinans* or Tasman Bay coral) were seen in the video and/or collected in the beam trawl (Figure 18 and Figure 19). The site on the outer edge of the Bank (BT17-QC09[10]) traversed mostly muddy sands then passed over an extensive area of bryo-reef, but did not collect any bryozoans. However, at the two sites in the centre of the Bank on the western side, collected solid clumps of bryozoan reef (2kg at BT17-QC02, 5 kg at QC03), however, only very minute patches of bryozoan reef were seen on the seafloor during the trawl. Horse mussels were also recorded in these central mud-bank zones, but this was limited to only a few individuals per site. Horse mussel beds have also been recorded in Outer Queen Charlotte Sound, where they are regularly dredged (review by Handley 2018). Mapped horse mussel beds include north and offshore of Motuara Island (Significant site 7.4 - Davidson and Richards 2015; and Hay 1990b) and around the northern sections of Long Island (Haggitt 2017). Recreational and commercial dredging across the outer QCS and over the Duck Pond would break and remove both horse mussels and bryozoan reefs. For example, both horse mussels and 'hard coral' (referring to bryozoan structures) have been collected as bycatch during bottom fishing across the central banks of the Duck Pond (MPI data). It is unclear what impact bottom fishing has had on the distribution of the bryo-reef zone, but deeper edges of the Bank, which are harder to navigate safely during bottom fishing and are likely beyond the fishability of some gears, may act as a natural refuge for these structurally complex but relatively fragile habitats. However, the loss of these complex bryo-reefs from across the upper sections Bank would likely have major consequences for the associated biodiversity, and for the recruitment of juvenile blue cod.

[10] Site MDC18-Q24 was run close to this site to verify the composition of these reefs (as GoPro footage using natural lighting could not adequately determine the composition of these reefs) using the high-resolution bright lighting of the Cbedcam.

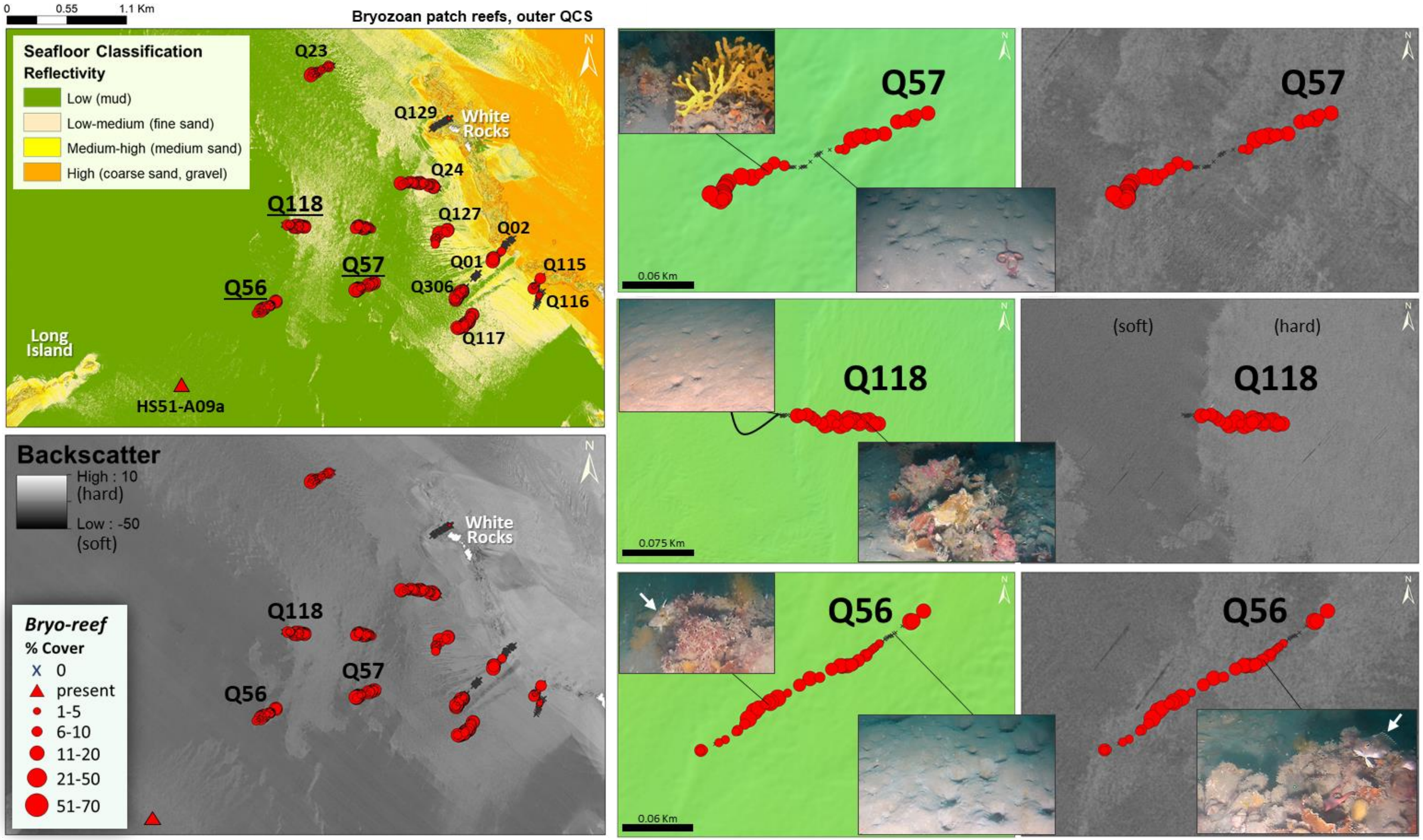


Figure 16: Bryozoan patch reef on the eastern side of QCS entrance, with zoomed-in examples of three MBC18 video transects (as labelled), showing the location of Bryozoan observations (red circles) relative to HS51 multibeam data of seafloor classification (top left), backscatter (bottom left and far right column), and bathymetry (central column). Examples of seafloor MDC18 video Images are provided to illustrate the habitat patch types seen along each transect. White arrows on insert images for Site Q56 denote associated fish: a leather jacket (left) and a sub-adult blue cod. (right).

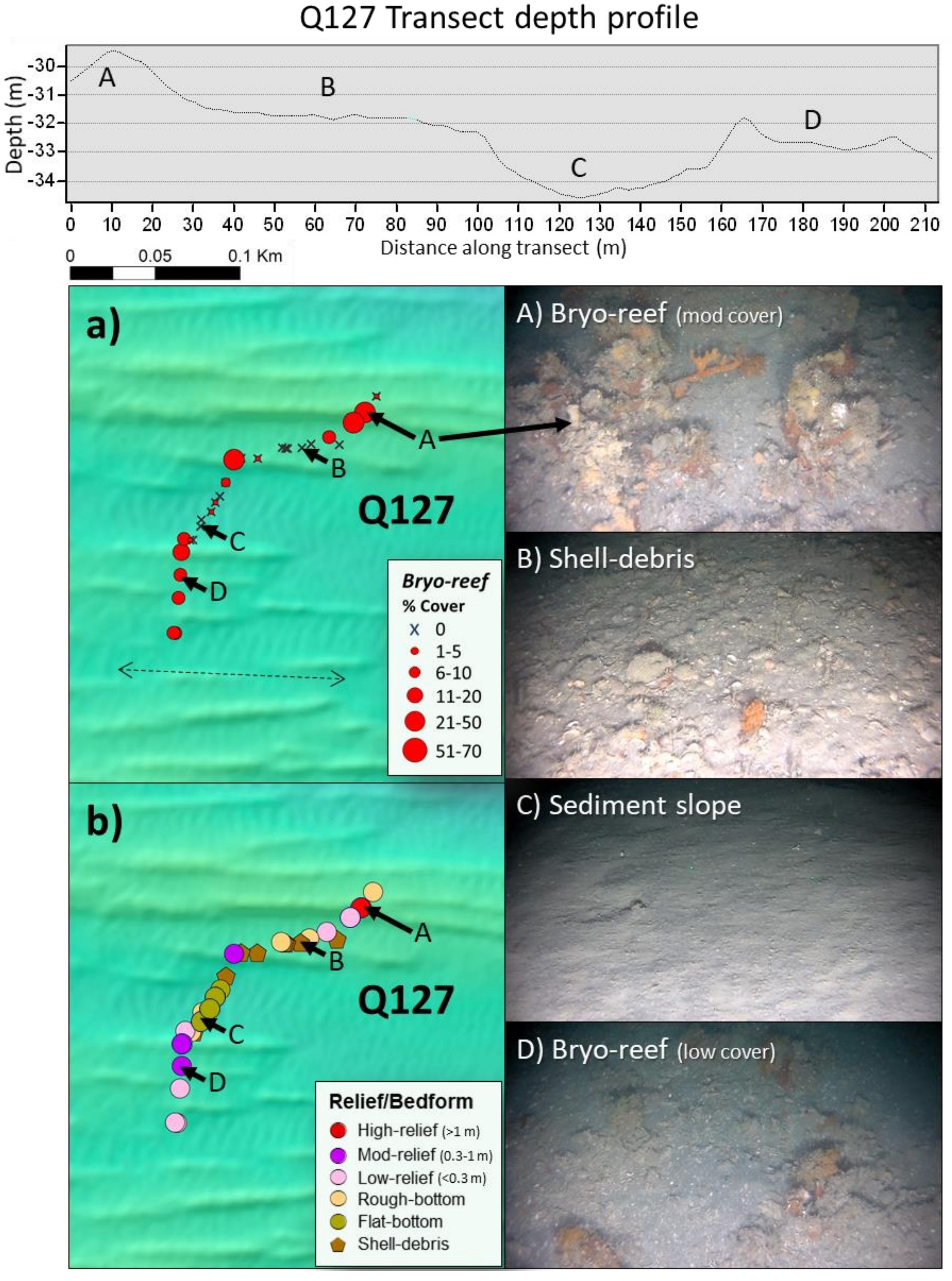


Figure 17: Example of a video transect (Q127) running across slope perpendicular to the raised linear features (aligning down slope) with their associated seafloor images. a) Percent cover of bryozoan reef (bryo-reef) along the transect; b) Relief and bedform class at same intervals; dotted arrow indicates the direction of slope left-direction going up slope. Images of the seafloor (and associated video footage) show these linear features are composed of patchy bryozoan reef, with a wide range of encrusting and erect invertebrates (dominated by encrusting and erect sponges, soft and hard bryozoans, and colonial ascidians), interspersed with shell-debris fields in raised areas, and flat sediments in the narrow troughs between these features.

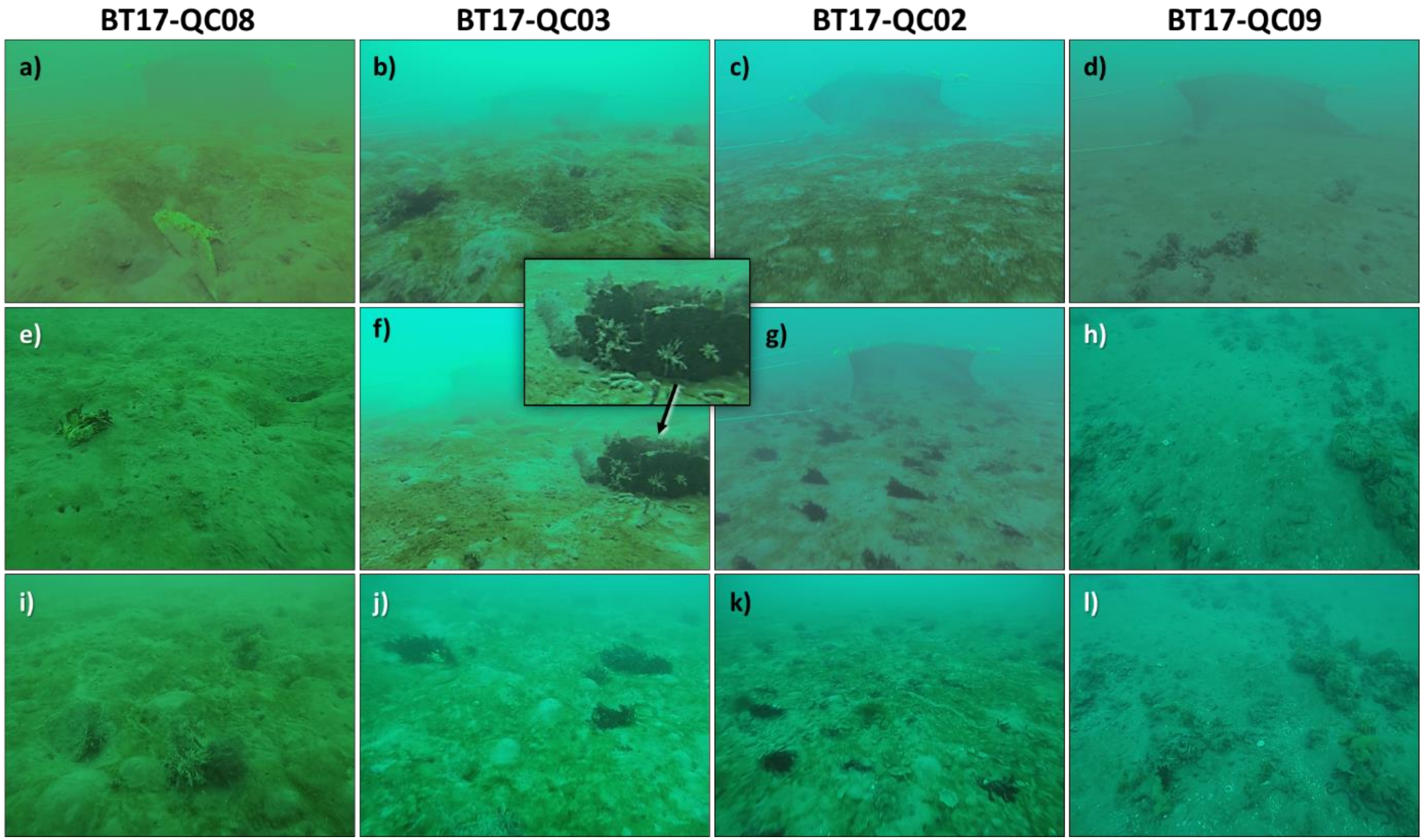


Figure 18: Seafloor imagery of four outer Bank sites near the entrance to QCS (*locally known by long time fishers as the 'Duck Pond'*) from MBIE BT17 GoPro/beam trawls (Sites QC08, QC02, QC03 and QC09). a,e,i) Mid Bank / Duck Pond site (BT17-QC08 - immediately north of Long Island) with characteristic biofilm covered silty sediments and occasional horse mussels and shell debris, with colonial ascidians; b,f,j) Mid Duck Pond site (BT17-QC03 - NE of Long Island) with characteristic biofilm covered silty sediments, occasional horse mussels and small isolated clumps of bryozoan reef (e.g., Insert - image-f); c,g,k) Outer Bank, eastern side (BT17-QC02) with characteristic biofilm covered silty sediments with sparse red algae, occasional horse mussels, shell-debris and small biogenic clumps; d,h,i) Outer Bank, western side (BT17-QC09) biofilm covered sediments, occasional horse mussels, then in final ¾ of tow shell-debris and patchy often linear stretches of bryo-reef (e.g., images h-i).

Figure 19: Examples of specimens collected from mid to outer Duck Pond sites, where some reef building bryozoa were either collected or seen in the GoPro footage of MBIE BT17 beam trawls (Sites BT17-QC02, QC03 and QC09). a,b,d,e) pieces of reef building bryozoa (*C. agglutinans*) [a-b QC02, and d-e QC03], along with examples of associated specimens of the bryozoan patch reefs (c-l) from the three sites: c) colonial ascidian sp. seen encrusting horse mussels and shell debris on the Bank [QC03], f) small fan-like bryozoa (poss. *Menipea vectifera*) [QC02]; g) branching bryozoa (*C. elegans*) (QC09]; h,k) Digitate sponge (*Dactylia varia*) [QC09];i) Bushy (soft) bryozoa (Catenicellidae) [QC09]; j) Turret-shells – commonly found in and around Bryo-reefs [here collected from QC03]; l) clump of red sponge, *Crella incrustans*, characteristic of Bryo-reefs at the Trios and Chetwode Islands [QC03].

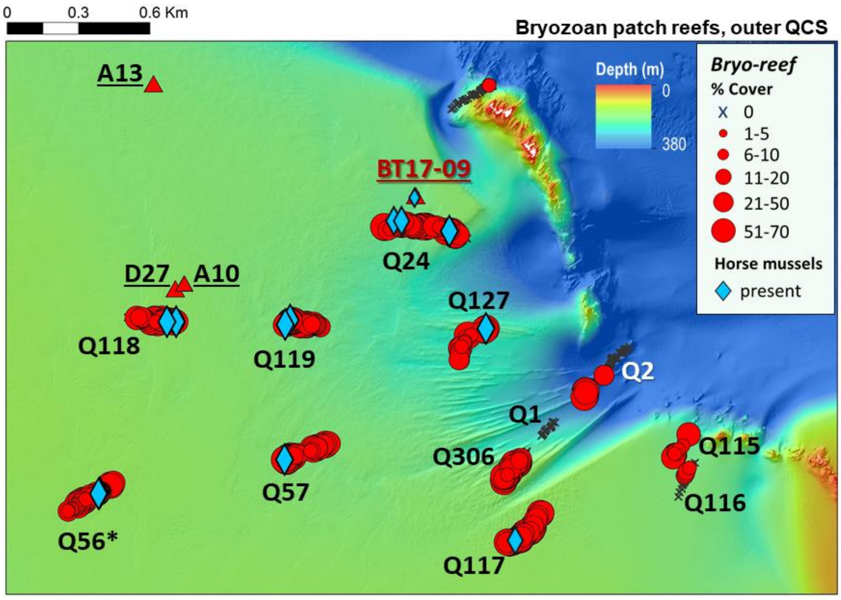


Figure 20: Presence of horse mussels within the bryozoan patch reefs. Horse mussels were often seen heavily fouled by reef building bryozoa (*C. agglutinans* or Tasman Bay coral), or completely cemented in place within the bryozoan-reef structure. Red triangles = bryozoan presence: orange site label= BT17 (Site BT17-09); underlined site labels = HS51 dropcam sites, where x = no bryo-reef recorded. Bubble plots = rank % cover for MDC18 sites (site label = no underline). Q56* indicates a photo-mosaic was created for this site (see Figure 15).

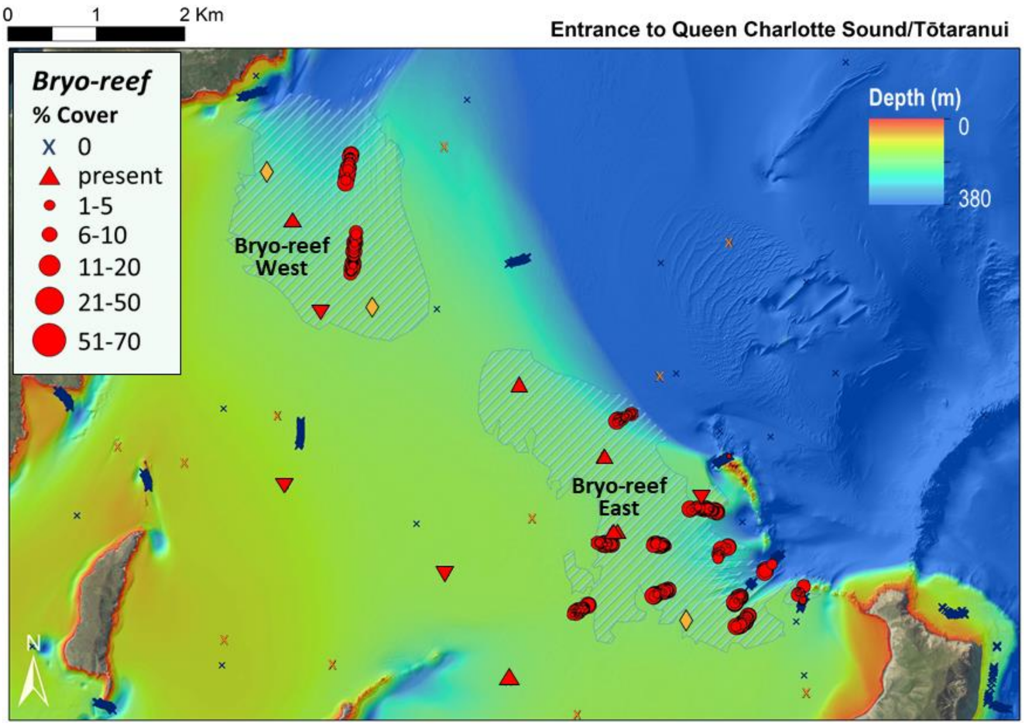


Figure 21: Location of the bryzoan patch reef (bryo-reef) zones located around the east and west entrances to QCS. Hashed zones and labels = areas of patchy bryozoan reefs, and depict large zones (4.9 km2 around the west entrance) and 5.0 km2 around the east entrance) that includes patchy bryo-reef, interspersed with shell-and bryozoan rubble, and thick muddy sand with burrows. Red triangles = presence; Bubble plots = rank % cover for MDC18 sites, x = no bryo-reef recorded. Orange-filled diamonds depict historic sites where live bryozoa were collected during the 1983 DSIR horse mussel dredge survey, orange-crosses depict no live bryozoa (data transcribed from DSIR Logbooks for Cruise No. 1153).

3.2.3 *Galeolaria hystrix* (calcareous tubeworm mounds)

Background: *Galeolaria hystrix* is a suspension feeding serpulid worm that lives in calcareous tubes, either as individuals or cemented together in colonies. In a very limited number of locations around New/ Zealand, such as Patterson Inlet, Stewart Island, Port Underwood, and Perano Shoal in Queen Charlotte Sounds, these worms aggregate and cement together to form complex three-dimensional mounds (or reef-like structures) that can become more than a metre high and several metres in diameter (see review by Anderson et al. 2019). *Galeolaria hystrix* mounds (referred to as *Galeolaria* mounds hereafter) can be as old as 50 years, taking 9 years to form, and are composed of thousands of tubes from successive generations settling on top of each other, with each generation living for ~12 years (Smith et al. 2005; Riedi 2012). The individual tubes and *Galeolaria* mounds however are highly vulnerable to physical disturbance or damage, with a single boat anchor able to smash these fragile habitats (Elliot 1995; Davidson and Richards 2015), while large areas would be susceptible to benthic fishing activities, such as dredging, and benthic trawling (Davidson and Richards 2015, review by Anderson et al. 2019).

Within the Marlborough Sounds, *G. hystrix* is known to occur widely throughout sheltered areas, mostly as solitary tubeworms or in small clumps growing on hard surfaces in hard and soft sediment habitats (Estcourt 1967; Davidson et al. 2010b, Davidson and Richards 2015; Davidson et al. 2017b). However, *Galeolaria* mounds were only recorded from three sites within the Marlborough Sounds, two sites in Port Underwood covering 0.9 ha (Whataroa Bay) and 3.4 ha (The Knobbies), and an extensive ~ 5.5 ha area along the upper slopes of Perano Shoal in Queen Charlotte Sounds (Davidson et al. 2010b, 2017b; Davidson and Richards 2015; Page 2017, *also see review of NZ's biogenic habitats in* Anderson et al. 2019). Davidson et al. (2015) defined Perano Shoal as an Ecologically Significant Site (ESMS-4.16) that was intolerant to most forms of benthic physical seafloor disturbance, including anchoring and all forms of dredging and trawling.

Ground-truthing surveys – Perano Shoal: Perano Shoal lies at the entrance to Blackwood Bay, in inner QCS. The Bank is ~517 m long x 267 m wide at its base, with the top of shoal occurring in depths of between 5 and 10 m (HS51 bathymetry), while the base of the Shoal meets the surrounding basin sediments in 42 m, with the exception of sink holes scattered around the base reaching localised depths of up to 56 m (Figure 23). In 2017, as part of the MBIE bottlenecks project to determine what habitat were important to juvenile blue cod, we ran a single tow-video transect upslope and across the *G. hystrix* mounds on the western side of Perano Shoal (CB17-C27, Figure 23a). No juvenile blue cod were recorded, but *Galeolaria* mounds were extensively recorded across the upper slopes at this site (Figure 22d). As part of the MDC18 surveys, three additional video transects were run across this feature extending from the deep slope habitats of one side of the Shoal and traversing up and over the top then down the opposing side of the Shoal (MDC18 sites Q101, Q102 and Q103, location of transects is shown in Figure 23 and Figure 24).

The four video-transects collected a combined 1.2 linear km's of video footage across Perano Shoal, across water depths of 5.7 m (top of Q101) down to 50.6 m (sink hole at the base of Q101). *Galeolaria hystrix* mounds were extensive and in near-pristine condition in most locations where they formed large contiguous fields across the upper slopes of the Shoal in water depths of 5.9 to 29.8 m (mean depths of 14.5 m ± 6.2 SE) (Figure 23a, Figure 22a-e, Figure 25a), although some areas of localised damage were also recorded (e.g., Figure 22f and Figure 22e). *Galeolaria* mounds were growing attached to the upper slopes on moderate-high relief rock (e.g., Figure 22a-c; Figure 25), while low-lying platform rock on the top of the shoals, which in places was covered in coarse sediments, had solitary or small clusters of *G. hystrix* but little to no mounds. *Galeolaria* mounds also extended well beyond the base of the reef, up to ~30-40 m (along the direction of the transects), out onto the surrounding sediment slopes (Figure 22g-h). Here, often large and extensive fields of *Galeolaria* mounds were growing attached to what appeared to be a consolidated shell base (Figure 22g-i). Many *Galeolaria* mounds within this zone, were seen to have live animals actively feeding in the currents, identified by their bright orange feeding-appendages which extend out from their cement-like tubes. Rank cover of *Galeolaria* mounds recorded during the 2015 drop camera survey (as provided to us by Rob Davidson and co-plotted in Figure 23), closely matched distributions seen in this survey. The Davidson and Richards (2015) boundary for the significant site 4.16, provides a good approximation of the *Galeolaria*-zone boundary. However, some fine tuning would be recommended based on the inclusion of these additional surveys. A photographic mosaic (or panoramic-image) along a 50 m stretch of the video-transect was created as one of three photographic-mosaic test areas, where a sub-section of this mosaic is presented in Figure 25. This provided a 3-dimensional landscape views of these complex *Galeolaria* reef-like formations (Figure 25), showing an extensive interconnected series of mounds ranging in height from ~32-57 cm, while some mounds beyond the mosaic reached heights >1 m in some places.

Other species were also present in the Perano Shoals *Galeolaria* mound fields (Table 3-7). These included *H. campanula* and rock anemones, found commonly on elevated sections of dense mounds, a variety of fish (e.g., leatherjackets, spotties, blue cod and triplefins) in amongst dense high-relief mounds, low densities of kina and *A. mollis*, and a few to moderately abundant scallops along with the occasional horse mussel in the sediment gaps between the mounds (Table 3-7). During transect Q102, which traversed over the long-axis of the reef (Figure 23a), a sizeable section of relative flat platform reef was present, partially infilled with sediment, here the exposed low-lying reef supported only low densities of small clumps and isolated *G. hystrix*, with markedly higher densities of *A. mollis* and kina.

Three additional habitat zones were characterised down the slopes of Perano Shoal. Live *T. laticostata* beds were recorded along the upper slopes of the Shoal in water depths of 14.1 to 25.5 m (mean depths of 19.66 m ± 1.67 SE) where there was an accumulation of coarse sands and gravels thick enough for this infaunal bivalve species to bury in (Figure 23j). At the surface, and accumulating on the slopes below these live *T. laticostata* beds, was *T. laticostata* shell-debris, that in places had accumulated in undulating shell-debris mounds down the flanks of the Shoal. In many places these shells were partially to heavily bound by relict and sometimes living *G. hystrix* sometimes with low densities of colonial and solitary ascidians. Further down slope, in depths >35 m, accumulated shell debris becomes more heavily inundated with depositional silty-muds, that have partially or near-completely buried these shells. As with other ridge and slopes habitats across QCS, similar species were associated with these shell-debris zones. For example, shells on the upper slopes were colonised, albeit in relatively low densities, by coralline algae (NGC), *H. campanula*, colonial and solitary ascidians, with scallops, and occasional horse mussels, along with a range of motile invertebrates (e.g., kina, *A. mollis,* and snake stars) (Table 3-7), while shells that were partially to heavily buried down slope, supported low densities of red urchins (*P. albocinctus*), horse mussels, snake stars and opalfish, along with occasional brachiopods and cup corals (Table 3-7). In addition to living biota, several items of trash were recorded across Perano Shoal (Appendix Table M-1), including bottles (tops and sides of the Shoal), along with a large piece of sacking (CB17-C27).

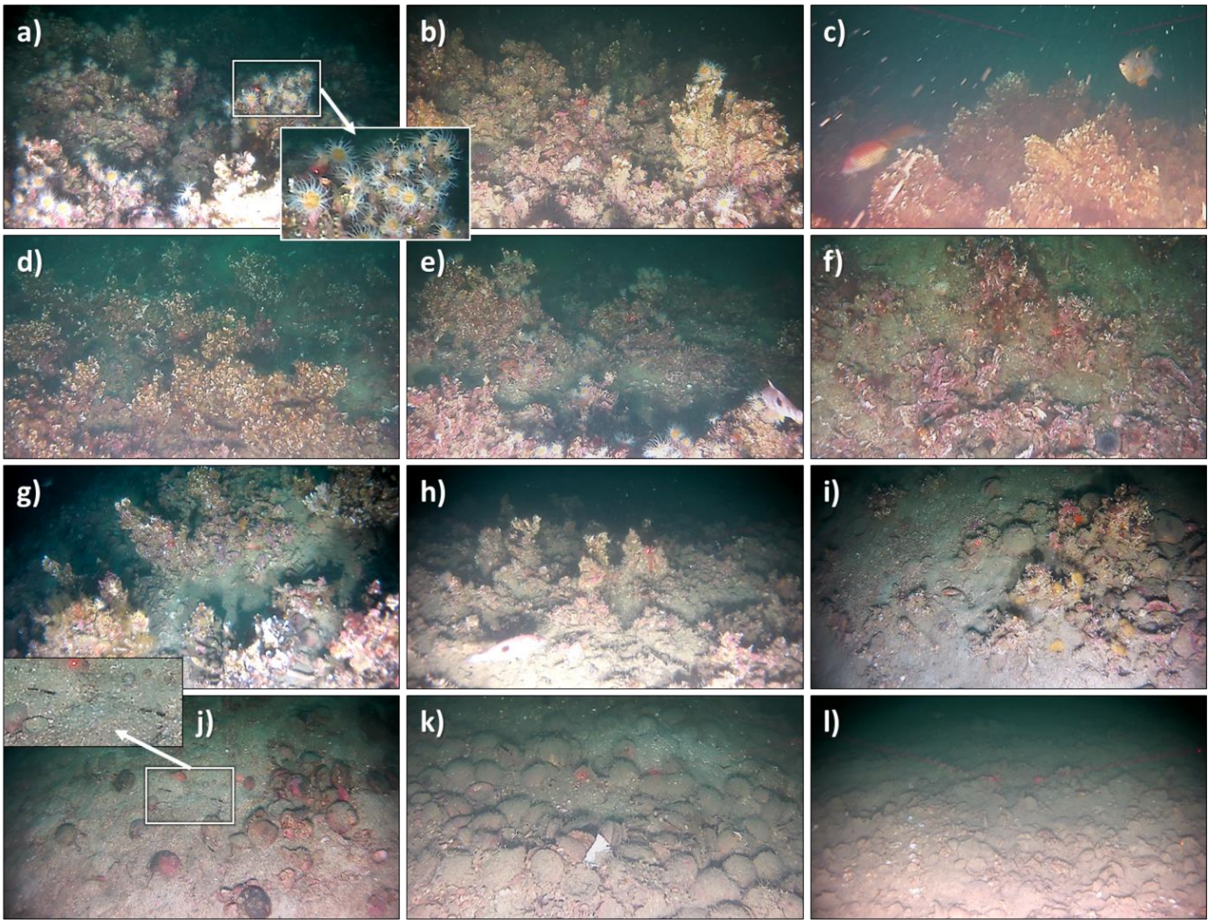


Figure 22: Examples of extensive *Galeolaria* mounds and *T. laticostata* zones found across Perano Shoal, within inner QCS collected from CB17 and MDC18 surveys. a-e) large contiguous *Galeolaria* mounds across the top and upper flanks of the Shoal; Orange tinge around the tops of many of these mounds (e.g., image-d) = large numbers of *Galeolaria* worms out feeding in the current (clearly identifiable in raw video footage); f) remains of broken *Galeolaria* mounds along with *Galeolaria* rubble and dead base (front of reef Q102 – depicted in Figure 24e). This section is from site Q103 at the reef edge and extends several meters along the transect where red algae was growing over the dead structure (not characteristic of live healthy mounds, which are generally clean of algae); g-i) extensive mounds to smaller patches of *Galeolaria* growing out over the soft sediment slopes, on top of the shell-debris that litters the seafloor; j) coarse sand and shell debris sediments with Live *T. laticostata* beds (2-dash marks of their siphons showing at the sediment surface; k) *T. laticostata* shell-debris accumulating down slope of the Live *T. laticostata* beds; shell-debris characteristic of the lower slopes of Perano Shoal, where shells are buried or are heavily burdened with silty/mud sediments. Inserts are zoomed up sections showing – rock anemones [a] and signs of live *T. laticostata* [j]; Other species seen = rock anemones [a,b,e], leatherjacket (*M. scaber*) and scarlet wrasse (*P. miles*) [c]; spotty [e,h]; and kina [b,d,f].

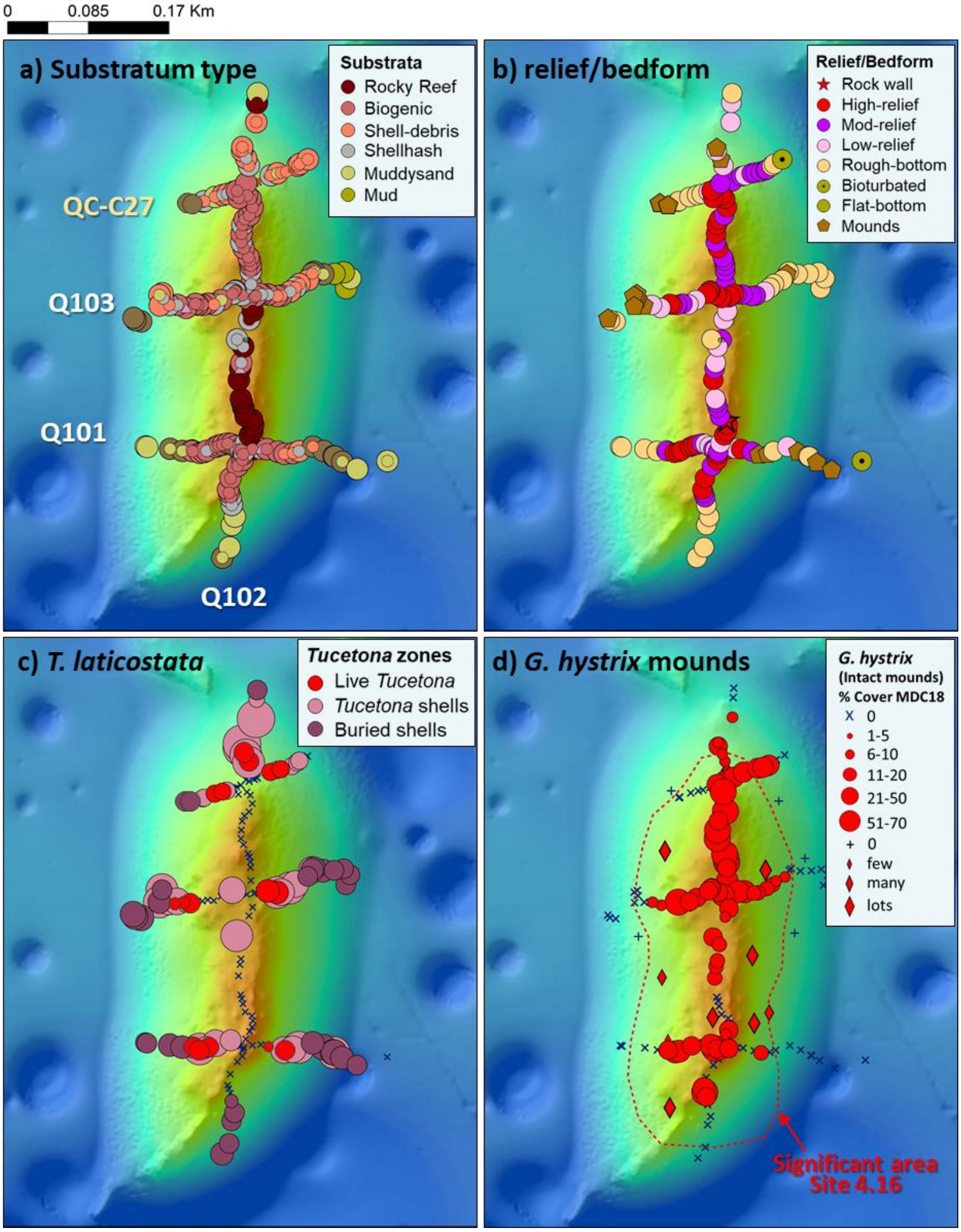


Figure 23: Habitat and biota characteristics across Perano Shoal, collected during the CB17 and MDC18 surveys. Transect labels are presented in graph [a], where MDC18 surveys =white site labels and CB17= yellow label; Seafloor characterisations represent ~30 sec intervals along towed video transects, where seafloor was visible: a) Primary and secondary substratum types, where primary substrata (≥ 50% cover) are depicted by the larger-outer circles, and secondary substrata (≥ 20% cover) are depicted by the smaller-central circles, here depicting rocky reef outcrops at the top of the Shoal surrounding by steep slopes covered in shell-debris; b) Relief/Bedform classifications; c) The distribution of *T. laticostata*, with live beds located below the reef, and its shell-debris accumulating down-slope, bubble size is the same as that depicted in graph [d]; d) Rank % cover of intact *Galeolaria hystrix* mounds on the upper slopes and across moderate to high relief sections of the reef. Additional data presented in graph [d] are from drop camera sites surveyed in 2015, where diamond size represent rank *G. hystrix* cover as per legend (data provided by Rob Davidson) – these along with shallower dive surveys were used to delineate the *Galeolaria*-zone (dotted red line depicting Significant area Site 4.16 as defined and described in Davidson et al. 2015).

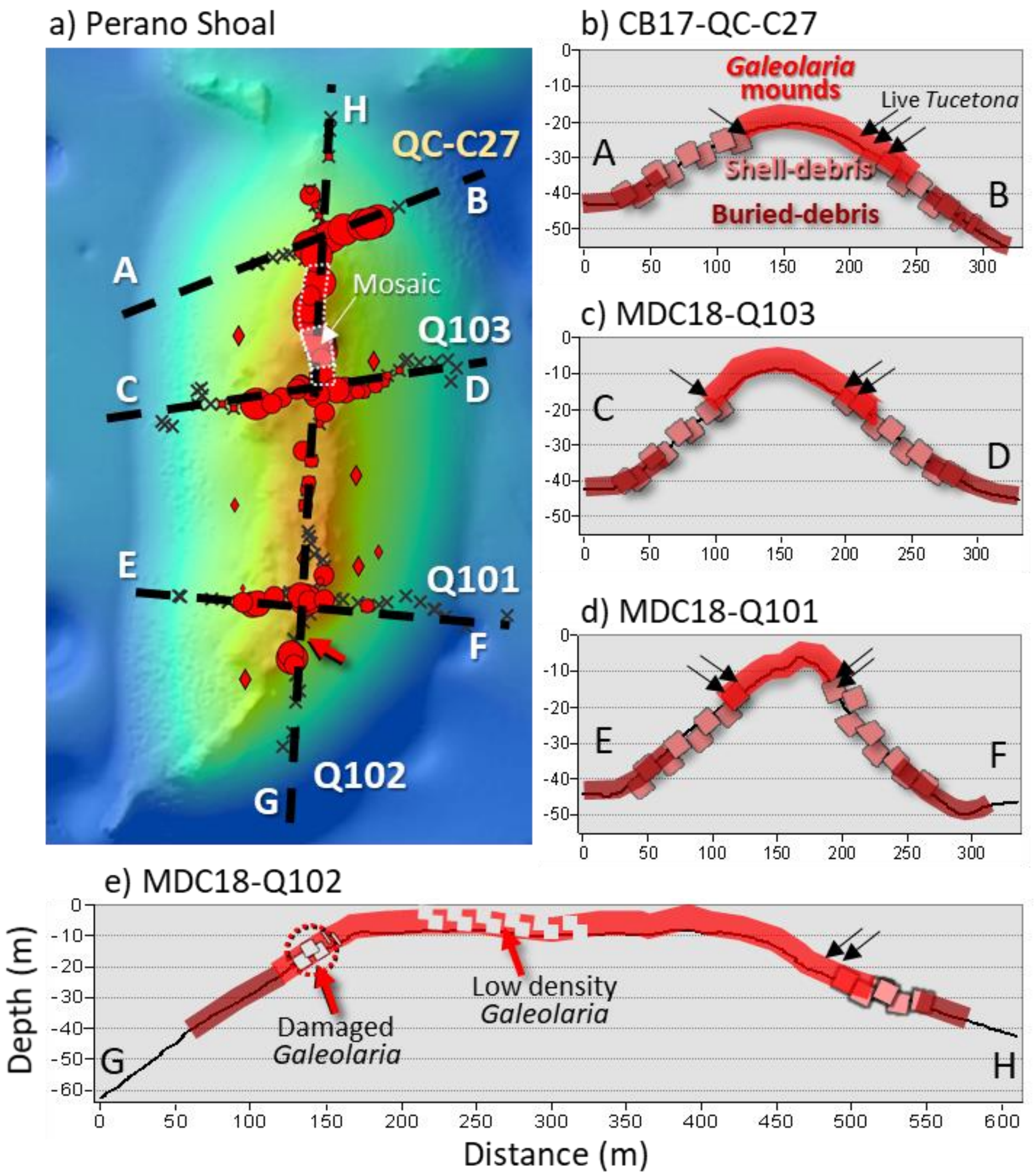


Figure 24: Depth profiles across Perano Shoal relative to the four video-transects – illustrating slope and the depth distributions (zones) of the four key habitats found across the Shoal: *Galeolaria* mounds, live *T. laticostata* beds, *T. laticostata* shell-debris, and buried debris relative to aspect and distance down slope.
a) Location map with the position of video-transects and their aligned depth profiles (black dotted lines, with white capital letters indicating the start and end locations relative to graphs, photographic mosaic was created for the section depicted by the white dotted rectangle, with the shaded area presented in Figure 25a. a-e); red bubbles = *Galeolaria* mound rank % cover (Legend as per Figure 23d); b-e) Depth profiles across Perano Shoal; x-axes = distance across the Shoal in metres; y-axes = HS51 bathymetry in metres. Depth profiles: b-d) are across the short-axis of the Bank; e) is along the longest axis of the Bank aligned with video-transect Q102. Habitats depth zones illustrated here represent actual data: Red bars = depths at which *Galeolaria* mound zone begins and ends on each side of the Shoal; black arrows = location of the live *T. laticostata* beds; Tan-dashed boxes = depth-zone across the upper slopes where *T. laticostata* shell-debris occurs; burgundy bar= the depth zone across the lower slopes where heavily sediment-burdened to buried shell-debris occurs. The damaged area (depicted by red arrow in profile [a] and [e]) = area where algal covered base material along with some broken *Galeolaria* mounds were recorded (e.g., Figure 22f).

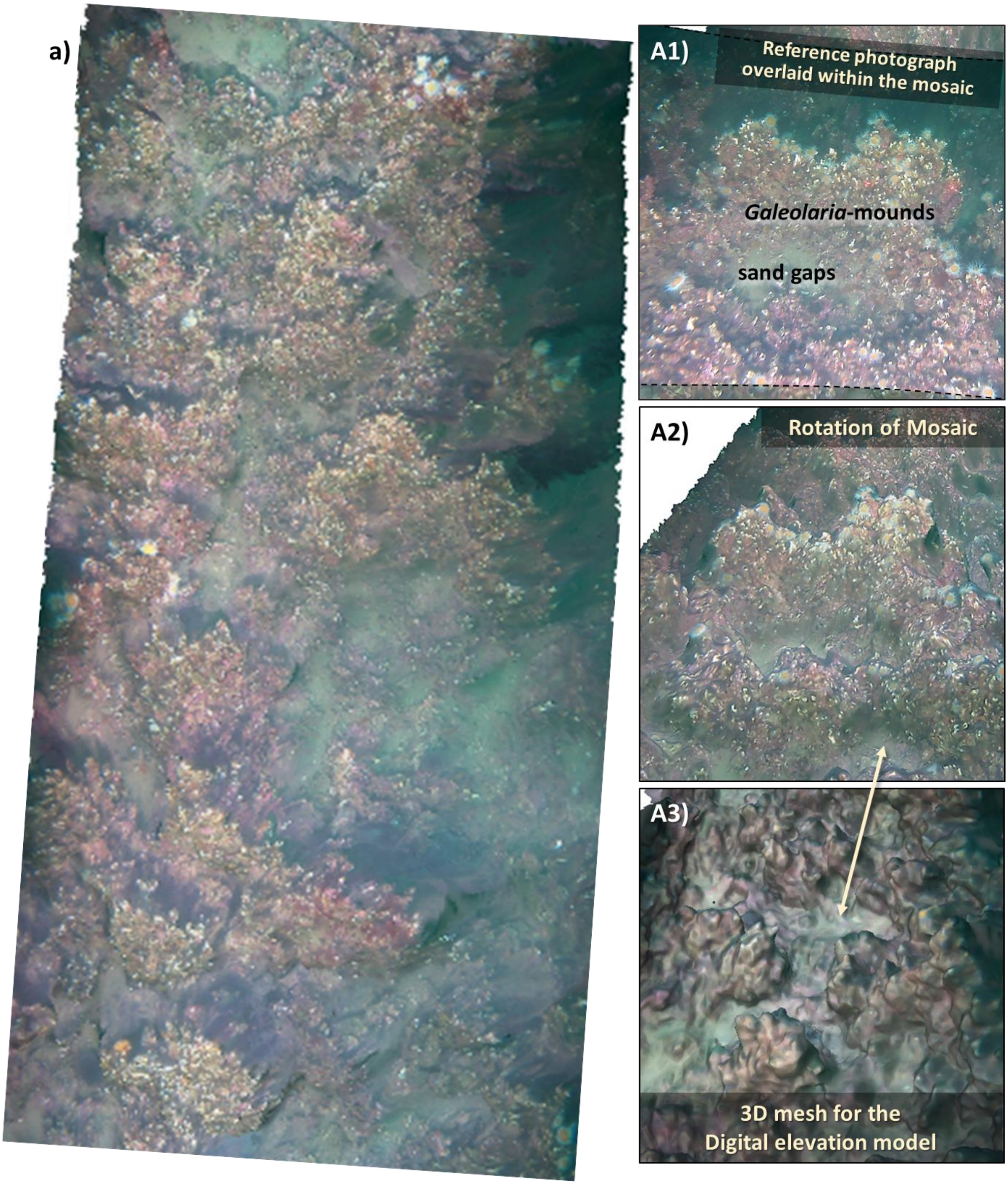


Figure 25: Example of 3-dimensional photographic mosaic showing a field of *Galeolaria* mounds across the top of Perano Shoals. A) Photo-mosaic showing a 3-dimensional landscape view of a dense field of *Galeolaria* mounds growing across the top of Perano Shoals (Site MDC18-Q102); Location of the mosaic is shown in Figure 24a – as white dotted/shaded rectangle. A1) Example of a reference photograph projected into the mosaic; A2) the 3D photo-mosaic for the area of the photograph as shown in A1; A3) Example of the 3D mesh used to create the Digital Terrain Model (DTM), which enable the rotation of the image and measurement of features in horizonal and vertical planes. Here mounds varied in height from 32-57 cm. Paired lasers projected into the field of view (image A1) are 20 cm apart.

Table 3-7: Perano Shoal: Habitat zones and associated taxa.

Habitat Zones	Taxa present
Reef - little to no *Galeolaria* (top of Shoal - low-lying reef)	Solitary or small clusters of *G. hystrix,* coralline algae (NGC) on rocks, Kina and *A. mollis* (in moderate-high densities), as well as sediment covered worm tubes (poss. buried *G. hystrix*) in more than one location.
***Galeolaria* mound fields** (moderate-high reef, edges and upper sediment slopes)	*Extensive G. hystrix* mounds growing on rock and out over biogenic-debris, with *H. campanula* and rock anemones (common on the tops of rock features and mounds), kina (sparse-low densities), scallops (≤few), *A. mollis*, *C. muricata*, yellow spikey-looking encrusting sponge (*D. oxeata*), coralline algae (NGC) on shells, triplefins, incl. the variable triplefin (*F. varium,* common), triplefins (*F. flavonigrum*), spotties, leatherjackets, scarlet wrasse, blue cod.
T. laticostata* shell-debris, and patchy *Galeolaria (upper-mid slope)	Live *T. laticostata* beds <25 m water depth, scallops (≥few), hydroids (e.g., *H. campanula*), colonial ascidians (*C. dellechiajei* and pink *Botyrlloides* spp.), *A. mollis*, cushion starfish (*P. regularis*, common; *Pentagonaster pulchellus,* occasional), solitary sea squirts, charcoal-grey *E. alata* sponges (occasional), sabellid fanworms, carpet shark, spotties.
Buried shell-debris and silty/muds (mid-deep slope)	Sparse densities of horse mussels, snake stars, *C. muricata*, *P. albocinctus,* indet. brachiopods, sediment anemones (few deeper), scallops (rare), carpet shark, sabellid fanworms, burrows, tracks, spotties, opalfish, flatfish, John dory (1 only).

Solitary *Galeolaria hystrix*: *G. hystrix* were found throughout much of QCS, with negligible numbers recorded in Tory Channel, and none recorded outside in Cook Strait. Three forms of *G. hystrix* (solitary, mounds and damaged) were recorded across the survey area. Solitary *G. hystrix*, are defined as solitary or small isolated clusters of tubes <1 m diam. attached to the benthos[11]), were widely distributed throughout QCS (51 sites) were they occurred in almost half of all QCS sites surveyed (46.36% of QCS sites, 4.42% of QCS within-site records), but were rare in TC (1 site), and absent in Cook Strait. Solitary *G. hystrix,* were found mostly attached to rock surfaces in water depths of 2.4 m down to 34.7 m, but were more common in shallow depths (mean 13.70 ± 0.56 m), albeit in mostly low densities (1-10% mean cover). Occurrence was highest within the inner QCS (65.1% of sites, and 5.4% of records), and decreased in the mid (48.0% of sites, 4.8% of records) to outer Sounds (25.6% of sites, 3.6% of records).

***Galeolaria* mounds - Newly discovered sites:** Although *Galeolaria* mounds (identified as *H. hystrix* tubes cemented together to form raised reef-like structures >1 m diam.) were previously thought to be limited to three locations in the Marlborough Sounds, the broad-scale MDC18 video survey discovered *Galeolaria* mounds at 54 sites with all but two sites (96.6%) recorded from within QCS (Figure 27a). Intact *Galeolaria* mounds were recorded in just over half of all QCS sites (51.8% of QCS records, 13.7% within-site records and 96.6% of all *Galeolaria* mounds) present in water depths spanning 2.4-39.1 m (mean 16.3 ± 0.27 m S.E.) (Figure 27a, Table 3-9), albeit it in varying amounts and spatial extents (e.g., Figure 26; Table 3-8; Figure 28c-d). However, like the solitary forms, intact mounds were rare in TC (two Inner TC sites, 0.32% of all TC records and 3.4% of all *Galeolaria* mounds) and absent in Cook Strait. Within QCS, sites with intact mounds were more common within the more sheltered areas of the inner and mid QCS (72.1% and 64.0% of sites, and 23.1% and 18% of within-site records, respectively), than in the outer QCS (23.3% of sites and 4.0% of records)[12] (Figure

[11] As defined in Anderson et al. 2019 Chapter 3.10

[12] NB: The aim of this survey was to ground-truthing seafloor features and identifying significant and notable habitats and benthic communities, resulting complex topography and high-current locations being targeted. Ridge and slope features were specifically targeted

27a). *Galeolaria* mounds contributed a significant amount of vertical structure (e.g., Figure 26) across two habitat zones. They were found in variable densities on both moderate to high relief rock outcrops (e.g., Figure 26h,I,j), and commonly extended some distance (1-100's m) out over adjacent sediment slopes, specifically where shell-debris was present (e.g., Figure 26a-g; Figure 28c-d). In these adjacent slope habitats, similar to Perano Shoals, they appeared to be attached either to underlying rock or to a consolidated shell-debris base (e.g., Figure 22i and Figure 26b-insert). Live *T. laticostata* beds, in mid to outer QCS, along with shell-debris from other infaunal bivalve (e.g., sunset shells, *Gari lineolate*), were often recorded at the base of many ridge/slope features, and as such may play an important role in generating shell-debris down-slope, which in turn may provide an important base material for *Galeolaria* to colonise and consolidate. Live scallops and scallop shells were also commonly recorded along the sediment slopes adjacent to and within the *Galeolaria* zones. More distant sediment slopes, and slopes areas without rocky-reef ridgelines (although less commonly sampled during these surveys), were characterised by little to no accumulated shell debris, and/or coarse to fine sediments, with little to no *Galeolaria* – in any form.

***Galeolaria* mounds – notable damage**: In addition to intact mounds, varying amounts of damaged *Galeolaria* mounds were also recorded (Figure 29; Figure 27b). Damaged *Galeolaria* areas, recorded as dead structure and rubble (DSR), were found at 47 sites (53 transects, 36.6% of all surveyed sites, and 5.41% of all data records) (Figure 27b; Table 3-9), in water depths spanning 2.78 m down to 39.86 m (mean 20.7 ± 0.37 m S.E.). Damaged mounds comprised 36% of all *Galeolaria* mound records, while at sites with *Galeolaria* mounds, within-site damage ranged from very little damage (min. 1.3% site) to expansive areas of dead *Galeolaria* structure and/or rubble (range 1.3-74%, e.g., Figure 29; Table 3-9), while mean within-site damage was 23.7 % ± 2.55. While the MDC18 real-time data identified extensive areas of damaged Galeolaria mounds, more detailed post-processing of the video footage would be required to quantify intact versus damaged % cover at these sites, while *in situ* diver-surveys (such as those undertaken across the *Galeolaria* mounds in Whataroa Bay, Page 2017) would be required to determine the percent cover of live mounds within the significant intact mound sites.

Four types of *Galeolaria* mound damage was identified, defined here as:

Toppled structure - Sections or whole mounds broken off at their base and lay detached on the seafloor (e.g., Figure 29i,j).

Dead-structure - Some physical height (>15 cm) still present but mounds appear dead and/or partially-completely covered in epiphytic fauna and flora, such as ascidians and filamentous red algae (e.g., Figure 29h).

Base-only - The base of the mounds (<~15 cm) remained attached to the seafloor, with tube structures visible, but no active (live) tubes could be detected (e.g., Figure 29f).

Detached rubble - Small pieces of mounds lying detached on the seafloor (e.g., Figure 29g).

and surveyed from deep to shallow, so Galeolaria mounds present across the interface will be more frequently sampled that random. We would recommend these data, and/or future data, be examine relative to habitat availability (not covered in the scope of this summary report).

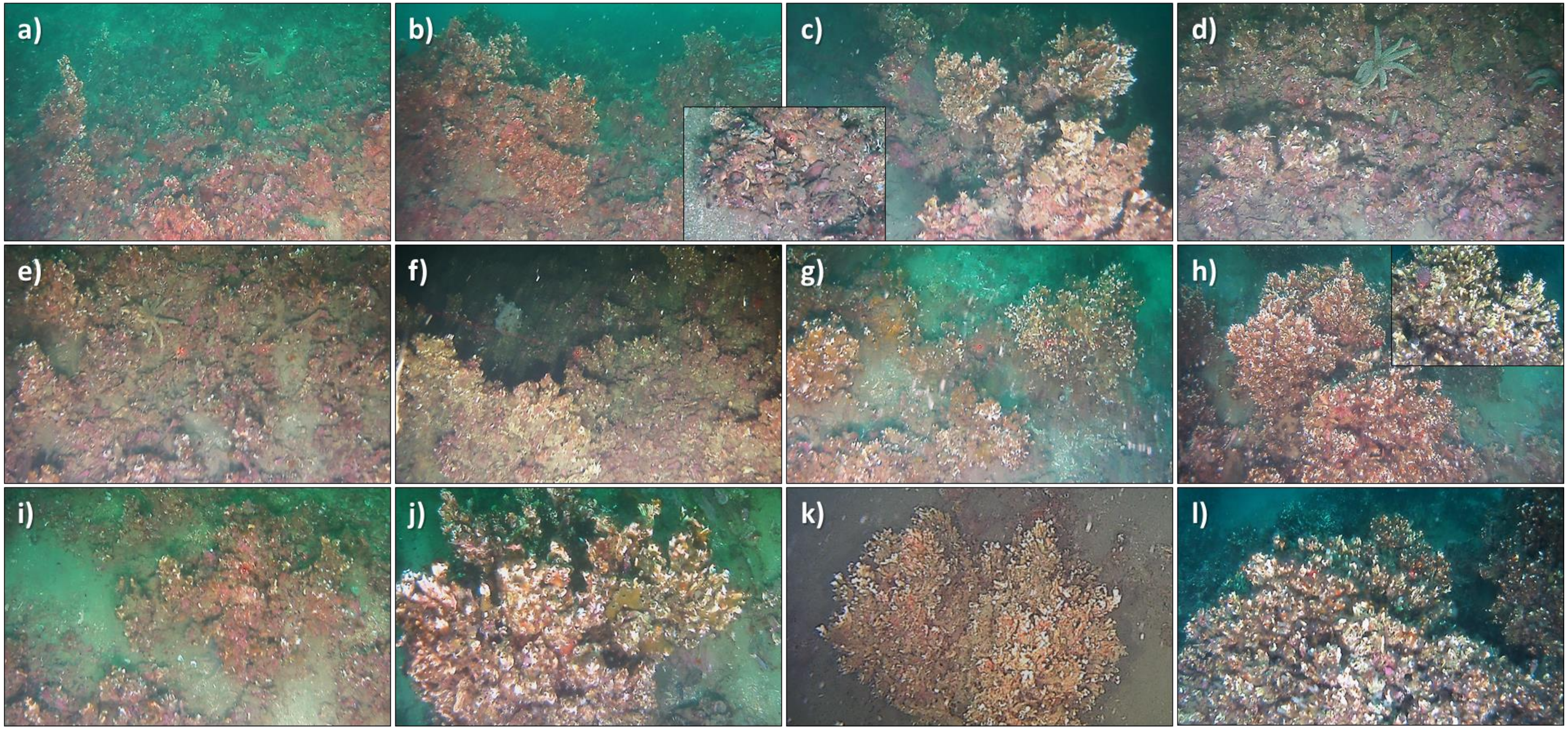


Figure 26: Examples of significant new sites with notable to extensive fields of *Galeolaria* mounds within QCS. a-c) Extensive field of *Galeolaria* mounds along the reef-slope interface at Pihaka Point, inner QCS – Insert: shell-debris in the conglomerate base material (Site MDC18-Q89, 13-15 m water depth); d-e) extensive field of *Galeolaria* mounds at Kumutoto Point, inner QCS (Site MDC18-Q106, 16.5 m); f) extensive zone of variable quality mounds either side ridgelines in Kaipapa Bay, inner QCS (Site MDC18-Q94, 23.9 m); g) *Galeolaria* mounds at the reef-slope interface at Edgecomb Point, Mid QCS (Site MDC18-Q36, 11.5 m); h) large tall mounds on moderate to high relief rocky ridgeline, Amerikiwhati Is., mid QCS – Insert: shows worms feeding-appendages out (orangey-red) (Site MDC18-Q33, 12 m); i) zone of variable quality mounds across the reef-slope interface, Double Cove, inner QCS (Site MDC18-Q91, 13 m); j) example of large mounds on subtidal reefs around All Ports Is. (Site MDC18-Q04, 12.5 m); k) Example of a large living mound within a poor-quality zone up the ridgeline of The Snout, Waikawa, inner QCS (Site MDC18-Q06, 22 m); l) Example of large mounds along rocky ledges at Whatapu, Resolution Bay, mid QCS (Site MDC18-Q44).

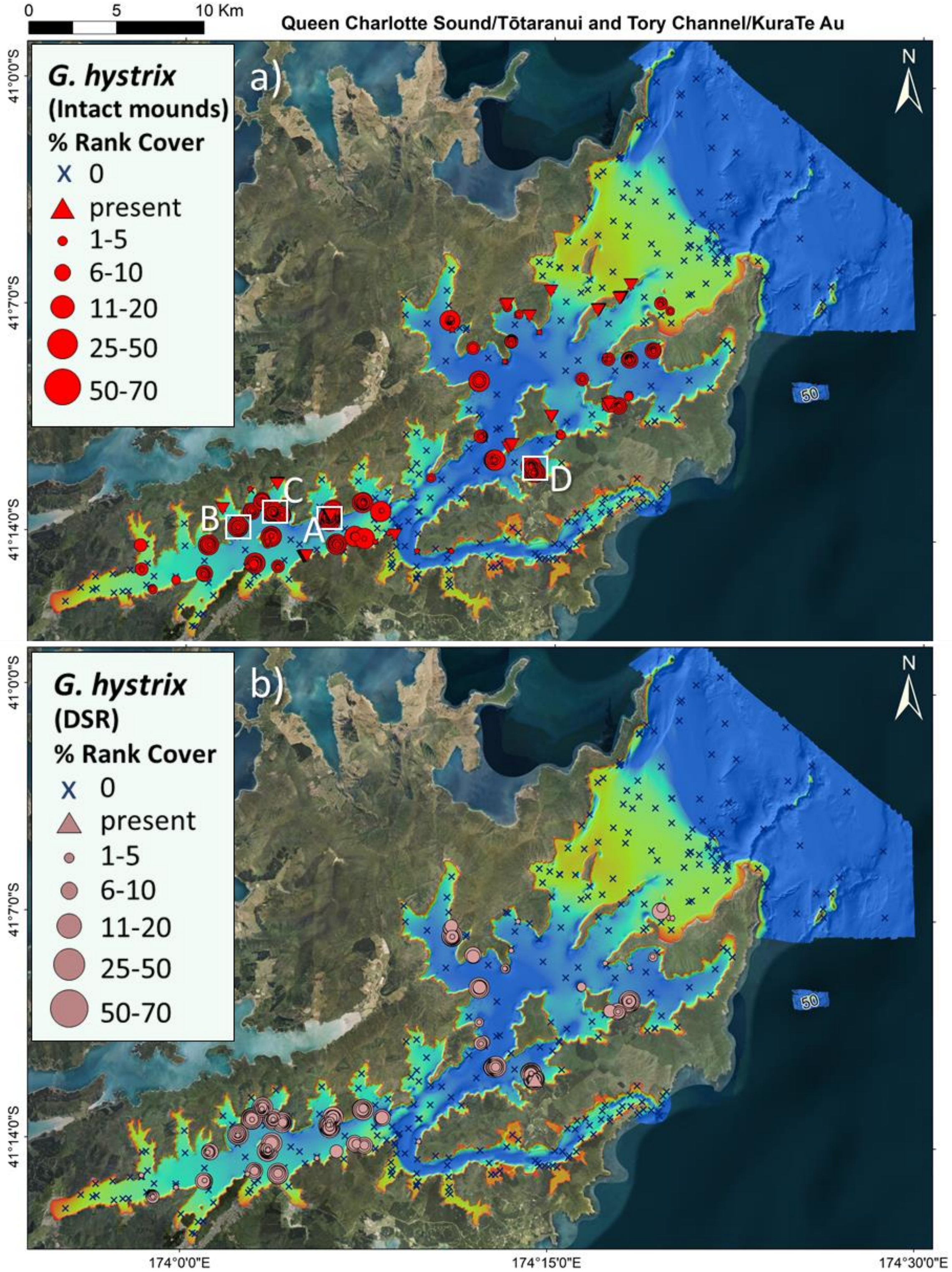


Figure 27: Distribution and relative abundance of *Galeolaria hystrix* mounds (a) and remnant dead structure and rubble (b) within QCS and TC. Intact mounds = Galeolaria mounds or mounds; DSR = dead structure and rubble. a) Structurally intact *Galeolaria hystrix* mounds (or mounds) growing on consolidated shell-debris and/or rocky reefs; b) DSR: Remnant dead *Galeolaria* structure (partially or fully intact but visibly dead colonies), and/or *Galeolaria* rubble (broken or detached debris within which tubes are visible). Bubble plot distributions of % Cover = rank % cover categories from the MDC18 and CB17 surveys. White boxes labelled A-D, are presented in zoomed in form in Figure 28.

Almost all reef-slope interfaces were characterised by a band (or zone) of *Galeolaria* comprising either narrow to very extensive areas of intact *Galeolaria* mounds (e.g., Pihaka and Kumutoto Points), and/or extensive areas of DSR (Figure 26; Figure 28; Figure 29; Table 3-8). This was a very unexpected result, and indicates that tall and extensive *Galeolaria* mounds were likely a dominant biogenic habitat in the past within QCS. They are still a prominent habitat, but our initial results indicated that there were more damaged mound areas than intact ones. It is unclear what damaged these mounds; however, the spatial patterns and varying scales of the damage may indicate likely impacts. For example, some sites had extensive areas of intact mounds with only very localised damage (e.g., Perano Shoals), where one or more mounds were toppled or a small area (<~3 m) of damage was recorded. This scale and type of damage likely reflects impacts from localised bottom-contact activities, such as damage caused by boat anchors (e.g., Perano Shoals - as described in Davidson et al. 2015). However, many sites had extensive damage, particularly on the adjacent slopes away from rock outcrops. Relative to intact *Galeolaria* mound, damaged zones (DSR-zones) were most prevalent along the deeper edges of *Galeolaria* fields, rather than along the shallower edges, indicating that physical damage due to storms was unlikely to be the cause of this damage. Some extensive areas were also comprised of mounds that were structurally intact but were mostly dead and covered in very fine-branching filamentous algae and invertebrates (e.g., sea squirt and colonial ascidians, etc., and marine-cobwebs; e.g., Site Q100 coastal site opposite Perano Shoals - Figure 29h), indicating that detrimental environmental conditions were likely present rather than physical impact, although physical damage (base-only structure and rubble) were also present at these sites too. Fine sediment deposits on reefs was also recorded at many sites, especially on the tops of shallow reefs or reefs on the upper slopes. These areas often had dead tubes visible under a thick sediment layer (e.g., Perano Shoals [Site Q102] and Edgecomb Point [MDC18-Q36] – Figure 29l). The most prevalent form of DSR however, was spatially extensive physical damage across what were once extensive and dense *Galeolaria* mound fields. These areas looked like something had mechanically mowed down large areas of mounds, indicating a far more extensive disturbance to the seafloor, possibly by bottom-fishing activities, such as from recreational scallop and/or commercial scallop dredges. Tall undamaged mounds in these areas were often limited to upper slope rocky reef areas. Extensive *Galeolaria* zones across these sediment slopes also commonly supported scallops, with at least one severely damaged *Galeolaria* mound site being very close to a known recreational scallop bed. Regardless of the causes, considerable biomass of *Galeolaria* has been removed. Further, more-detailed quantitative, post-processing of these data would be required to determine the specific ratios of the different types of damage incurred versus intact mounds, which in turn could be used to determine the amount of remaining biomass (intact mounds) versus that estimated loss of biomass over the DSR-zones.

At sites with extensive damage, moderate to high relief reefs appear to have provided natural refuge from mechanical disturbance/bottom-fishing activities. However, localised damage characterised by toppled mounds indicate that mounds on reefs are also incurring ongoing localised damage – likely from boat anchoring, as these moderate to high-relief reefs are also targeted by line-fishers (as indicated by lost fishing line over many of these reefs). Consequently, these very fragile, easily damaged mound-habitats have (and are) likely to be suffering ongoing damage from multiple activities. As *Galeolaria* mounds are known to take at least 9 years to establish and upwards of 50 years to build - reflecting multiple generations of worms building upon each other - recovery following these sorts of extensive physical disturbances will likely be in the order of decades, but only where suitable substratum remains available, and where no further physical disturbance occurs.

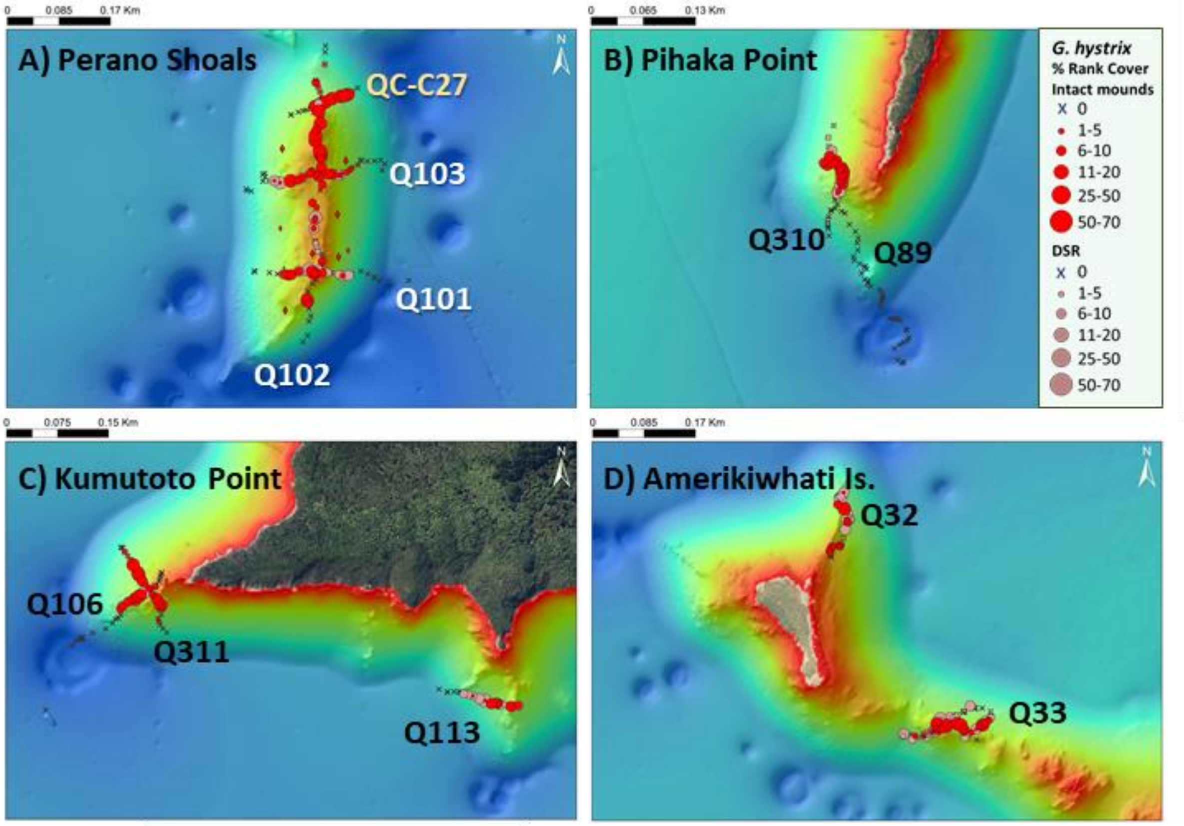


Figure 28: Zoomed-in site examples showing the distributions and relative abundances of intact *Galeolaria hystrix* mounds (red circles) and DSR = remnant dead structure and rubble (mauve circles) at significant *Galeolaria* mound sites. The location of the four sites are shown as white boxes labelled A-D in Figure 27. Bubble plot distributions of % Cover = rank % cover categories from CB17(C27-only) and MDC18 surveys (all other sites). A) Extensive mostly pristine *Galeolaria* mounds on the upper slopes of Perano Shoal, with some associated rubble in places (4 transects from 2 surveys: MDC18 Q101-Q103 and CB17-C27). B) A significant newly discovered area of intact *Galeolaria* mounds at Pihaka Point, with some DSR, particularly around its NW edge; C) A significant newly discovered area of mixed-quality *Galeolaria* mounds at Kumutoto Point, with some good quality mounds present, but also broken and toppled mounds visible; D) Extensive area of living intact mounds (tall interconnected live mounds) on moderate to high relief reef, with extensive areas of DSR (mixed base-only and extensive areas of detached rubble) on the slopes either side of these reefs - Amerikiwhati Is. mid QCS (Q33, and to a lesser extent Q32).

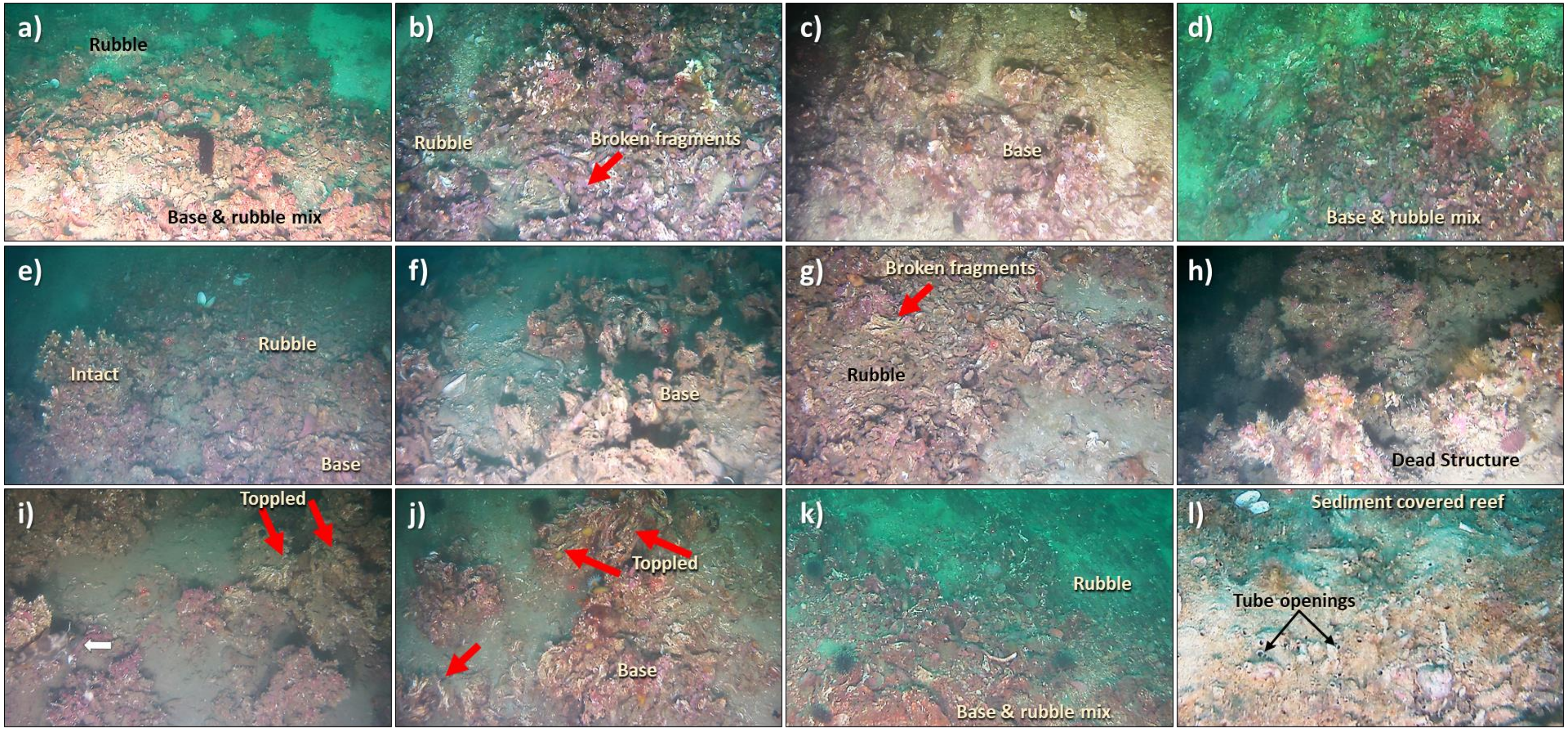


Figure 29: Examples of fields of *Galeolaria* mounds with notable to significant damage (dead structure and/or rubble) within QCS sites (MDC18 survey). DSR = dead structure and rubble comprised of *Galeolaria* mounds. a) Zone of DSR along outer edge of mound field at Pihaka Point - showing dead base and rubble (Inner QCS, Site MDC18-Q89); b-c) Extensive DSR-zone at Kumutoto Point - showing base and rubble, red arrow indicates broken fragments (Inner QCS,[b]=Q106, [c]=Q311); d) extensive DSR-zone of base-only structure and detached *Galeolaria* rubble at Kaipakirikiri Point (Inner QCS, Q108); e-f) extensive damage around the deep ridgeline at Karaka Point - showing a mixture of intact, base-only and detached *Galeolaria* rubble (Inner QCS, Q94); g) Severe DSR-zones on either side of the rocky ridgeline between Amerikiwhati Is. To Arapaoa Is. (mid-QCS, Q33); h) structurally intact, but dead mounds covered in epibenthos (inner QCS, Q100); i) significant DSR at Snout Point, Waikawa - with red arrows indicating large toppled mound, white arrow= leatherjacket (inner QCS, Q06); j) Example from an extensive DSR zone on the upper slope of Ngatakore Point - showing base-only structure and toppled mounds (red arrows)(Inner QCS, Q179); k) extensive DSR-zone on ridgeline-slope on southern side of Kaipakirikiri Bay (Inner QCS, Q107); l) reef top, with dense wormtubes (indet., poss. parchment worms) buried beneath a thick layer of fine sediment (Mid-QCS, Q36).

Table 3-8: Location and description of significant and/or notable *Galeolaria hystrix* sites within QCS, along with some examples of damaged and patchy sites. Summary data are from MDC18 data only. Green shading = sites with significant areas of intact Galeolaria mounds (GM); orange shading = site with significant intact mounds, but also evidence of notable damage (DSR=dead structure and/or rubble); red shading = sites with evidence of extensive damage. Extent of field: two values are provided: bold value in brackets depicts the linear distance of good quality intact mounds, while the underlined value denotes the total extent of the *Galeolaria* zone including relict/DSR and living mounds (Extent values here represent along-transect distance); values with both bold and underlined indicate an area with both intact and DSR mounds intermixed; All values depict distances along the video-transects, with the actual fields likely extending in other directions across the slope; however, values separated by 'x' depict linear lengths in more than one direction (e.g., for Perano Shoals the intact mound field extends 450 m north to south and 125 m east to west).

Sub-region	Location	Site/ Transects	Quality	Extent of field	Description
QSC Inner	Perano Shoal	C27 Q101 Q103 Q102	Mostly Pristine + some DSR	~450m NS x 125m EW	Extensive and mostly pristine areas of *G. hystrix* on the upper slopes of this Bank. Mounds are growing on consolidated shell debris (mid-upper slopes) and on the edges of the exposed reef at the top of the Bank. The upper parts of the rock feature have mostly solitary, or small clumps, of *G. hystrix*. Some toppled mounds, broken fragments and detached *Galeolaria* debris were also seen, mostly along the lower edges of these fields, but some localised DSR was also recorded within dense zones of intact mounds.
QSC Inner	Pihaka Point	Q89, Q310	Good* + some DSR	101.4 m (69.2 m)	Significant new *Galeolaria* site, comprising ~69.2 m of good quality - dense and relatively tall intact mounds along the upper slope (12.8-22.9 m), situated on the west side of the ridge. Large zone of DSR (28.8 m of dead-base and broken rubble) on the NW side of GM field, and 3-4 m on the SW side with a further 8 m of partial rubble intermixed with good mounds. * would need evaluating regarding % living.
QSC Inner	Kumutoto Point	Q106, Q311	Good* + DSR	120.26 x 61.23	Significant new *Galeolaria* site of variable quality. Patchy fields of *Galeolaria* growing on consolidated shell-debris at base of rock outcrops. These include good quality mounds, but also broken and toppled mounds visible (damage mostly along the high-relief ridge line, with some isolate rubble patches on the slopes). *would need evaluating regarding % living.
QSC Mid	Amerikiwhati Is.	Q33	Good + high DSR	146.8 (90.4)	Good sized tall interconnected live mounds mostly on rocks, but also extensive DSR on slopes either side of these reefs.
QSC Inner	Tauranga Bay	Q100	Mostly dead structure	130 m	Coastal site adjacent to Perano Shoal, extensive *Galeolaria* structure across the upper slope, but mostly dead structure with very fine-branching filamentous red algae and encrusting invertebrates (e.g., colonial ascidians and solitary sea squirts).

Sub-region	Location	Site/ Transects	Quality	Extent of field	Description
QSC Inner	Double Cover	Q91	Mixed	146 m	Variable quality. some intact mounds but also mixture of base-only and rubble. Rock slopes and ridge with larger sized mounds/clumps, while adjacent sediment slope primarily rubble with some structure and intact mounds albeit of low-height.
QSC Inner	The Snout, Waikawa	Q06		110.3 m	Some large tall mounds growing on rocks, with some damaged mounds in depths of 15-22m. several large mounds seen broken off and toppled over. Detached rubble also present.
QSC Mid	Amerikiwhati Is.	Q32	mostly damaged	104.6m	Some intact mounds on reef, but otherwise mostly DSR (dead structure and rubble).
QCS Mid	Edgecomb Point	Q36	Mostly damaged/Degraded	83 m	Extensive patches of DSR, mainly dead-base and detached rubble, with some nice live intact mounds in shallow slope/ridge interface zone. Then thick sediment- veneer on top of ridgeline (low/flat relief) with buried worm-tubes, biofilm and very fine filamentous red algae.
QSC Inner	Allports Is.	Q04, Q90	Good+DSR	90m (30m) 102m (<5m)	Good sized mounds/clumps on shallow reef, with DSR on slopes - mostly loose rubble and base-only.
QSC Inner	Kaipapa Bay	Q313	Variable quality	40.1 m	Variable quality. Extensive areas of *Galeolaria* structure over shell-debris slopes at the base of rock outcrops. Site characterised by mostly low-lying *Galeolaria* base structure <15 cm high, with some nice patches of *Galeolaria* mounds 20-30 cm high. No recent signs of damage.
QSC Inner	Allports Is.	Q04, Q90	Good+DSR	30 m 90 m, <5m 102 m	Good sized mounds/clumps on shallow reef, with DSR on slopes, mostly loose rubble and base.
QSC Inner	Kaipakirikiri Point	Q108	Poor	204 m	Some live mounds, but mostly extensive area of base-only and/or rubble.
QSC Inner	Kaipakirikiri Bay	Q107	Poor	77 m	Extensive area of DSR, with base-only structure, toppled mounds and associated rubble. Some horse mussels and scallops also present.
QSC Inner	Karaka Point	Q94	Poor/badly damaged	57.2 m	Mostly damaged with smashed up, toppled and detached rubble commonly seen, with some good (live & tall) intact *Galeolaria* mounds.
QSC Inner	Wedge Point, Picton	Q07	Poor/ damaged	48 m	Deep ridge, with dead/relict structure now partially covered in sea squirts and other invertebrates; some rubble and base-only also recorded between dead structure.
QCS Outer	East Bay-Sth	Q72, Q316	DSR (??)	Patchy DSR	Deep reef and rocky ridgeline, with considerable biogenic structure (but unclear if this is DSR). Midway along Q316 there are obvious toppled mounds lying on the ledges below

Sub-region	Location	Site/ Transects	Quality	Extent of field	Description
					(long ago broken based on their appearance), then an area of *Galeolaria* rubble down-slope– indicating that these reefs might once have been covered in *Galeolaria* mounds – which would account for the biogenic covering on the reefs – but this would need to be verified by divers (?). Reef with thick coating of sediment in places.
TC Outer	Nth of Te Rua Bay	Q185	DSR	10's of m's	Large patch of detached *Galeolaria* rubble mid-slope, some obvious broken/smashed *Galeolaria*. No living *Galeolaria* mounds seen.
QCS-mid	Sth Blumine Is.	Q319	DSR	260 m	Patches of live intact *Galeolaria* mounds of rocky reefs, but extensive DSR on the adjacent slopes.
QCS Outer	Arapside Ridge Pickersgill	Q73	Some good patches	35 m	Live *Galeolaria* mounds limited to rock in shallow (4-6 m depth), with ~20-50% cover in places, some toppled and broken mounds visible, along with some rubble at base of these rocks.
QCS Mid	Resolution Bay	Q44	good	83 m, but patchy	Some sizeable live *Galeolaria* mounds on series of rocky ledges, with ~20-50% cover in places. Lower section of ledges with thick coating of sediment.
QSC Inner	Double Cover	Q96	DSR bits	patchy	Few bits of *Galeolaria* rubble on sediment slope by reef.
QSC Inner	East Bay (little)	Q104	variable	patchy	Some live *Galeolaria* mounds on rock outcrops, low-relief ledges covered in sediment-veneer and buried worm-tubes. Some DSR including dead mounds covered in fine filamentous algae and cobwebs.
QSC Inner	Kahikatea	Q105	Some okay patches	patchy	Some sizeable live *Galeolaria* mounds on rock outcrops, low-relief ledges though covered in sediment-veneer with dense patches of parchment worms, fine filamentous red algae common on substratum and some GM.
QSC Inner	Kaireperepe Pt	Q09	DSR	patchy	Low-lying reef/ridge, with patchy DSR – mostly patchy dead base, and some sediment-veneer.

Table 3-9: MDC18 sites where *Galeolaria* mounds (GM) and/or damage *Galeolaria* (DSR=dead structure and rubble) were recorded, with relative occurrence and associated depths (mean, SE and depth range). Queen Charlotte Sounds (QCS) and Tory Channel (TC). Records (%) = Number of records (% of records at that site) where observed. Bold site numbers denote locally dense zones. Bold site numbers and values denote sites with proportionally high occurrence of *Galeolaria* mounds, while underlined ones indicate sites with proportionally high DSR. NB: These data are based on real-time data entry and while they provide an excellent first-level assessment, values should be used as preliminary/indicative estimates only, as quantitative post-processing would be required to document relative amounts of GM versus DSR.

Subregion	Site	Total Records	GM Occur %	GM Depth (m) Mean ± SE	GM Depth range (m)	DSR Occur %	DSR Depth (m) Mean ± SE	DSR Depth range (m)
QSC Inner	Q04	30	26.7	14.4 (2.9)	3.9-29.1	13.3	23.8 (2.3)	18.0-29.1
QSC Inner	Q05	18	11.1	13.3 (0.7)	12.6-14.0	5.6	12.6	n/a
QSC Inner	**<u>Q06</u>**	**22**	**63.6**	**17.5 (1.6)**	**7.2-26.3**	27.3	18.1 (1.1)	15.0-22.1
QSC Inner	Q07	44	22.7	27.2 (0.4)	25.7-28.9	20.5	28.8 (0.8)	26.7-32.8
QSC Inner	Q08	27	3.7	8.8	n/a	3.7	8.5	n/a
QSC Inner	Q09	31	19.4	16.7 (0.2)	15.8-17.0	29	17.6 (0.8)	15.4-21.5
QSC Mid	Q18	24	33.3	11.8 (3.9)	2.8-38.4	25	17.1 (7.0)	2.8-39.9
QSC Outer	Q20	25	12.0	9.9 (0.8)	9.0-11.5	4	9	n/a
QSC Outer	Q21	20	15.0	16.0 (1.1)	14.3-17.9	5	17.9	n/a
QSC Mid	**<u>Q32</u>**	**30**	**50.0**	**15.2 (1.6)**	**7.5-26.3**	<u>40</u>	<u>20.1 (1.1)</u>	<u>12.2-26.3</u>
QSC Mid	**<u>Q33</u>**	**67**	**52.2**	**16.3 (0.6)**	**11.1-23.4**	<u>50.7</u>	<u>19.3 (0.7)</u>	<u>12.9-25.8</u>
QSC Mid	Q36	31	19.4	12.0 (1.0)	8.4-15.7	19.4	13.5 (1.8)	8.9-21.7
QCS Mid	Q37	10	0	0.0	0.0	10	20.6 (0.5)	20.1-21.1
QSC Mid	Q39	21	14.3	16.5 (1.3)	14.0-18.4	14.3	23.7 (6.0)	17.0-35.8
QSC Mid	Q42	51	2.0	32	n/a	31.4	34.2 (0.9)	29.2-39.5
QSC Mid	**Q44**	**23**	**56.5**	**15.0 (1.1)**	**11.0-23.8**	4.3	26.5	n/a
QSC Mid	Q45	23	21.7	27.5 (1.6)	21.6-31.6	26.1	26.8 (1.3)	21.6-30.1
QSC Outer	Q47	26	3.8	22.4	n/a	1.5	19.9	n/a
QSC Outer	Q51	66	24.2	19.1 (1.7)	9.8-27.7	10	19.6 (0.4)	19.0-20.9
QSC Outer	Q52	40	10.0	12.7 (0.7)	10.8-13.8	5.8	17.0 (1.8)	13.7-20.0
QSC Outer	Q59	52	17.3	14.2 (1.0)	9.9-20.0	1.3	28.7	n/a
QSC Outer	Q67	75	24.0	16.3 (1.2)	9.1-28.7	3.4	20.7 (6.0)	14.7-26.7
QSC Outer	<u>Q68</u>	59	18.6	17.7 (1.7)	11.4-27.0	22.9	32.4 (0.7)	27.5-37.3
QSC Mid	Q73	29	31.0	8.1 (1.7)	2.4-17.4	20.7	21.8 (1.8)	15.2-26.6
QSC Mid	Q74	28	17.9	24.3 (0.4)	23.5-25.9	3.6	23.8	n/a
QSC Mid	Q76	20	20.0	12.4 (1.8)	9.2-17.2	10	26.7 (8.3)	18.5-35.0
QSC Inner	Q89	58	13.8	18.5 (1.7)	13.6-24.9	17.2	18.1 (1.4)	13.6-24.9
QSC Inner	<u>Q90</u>	44	13.6	22.7 (1.8)	17.8-27.4	<u>47.7</u>	<u>27.3 (0.9)</u>	<u>17.8-33.5</u>

Subregion	Site	Total Records	GM Occur %	GM Depth (m) Mean ± SE	GM Depth range (m)	DSR Occur %	DSR Depth (m) Mean ± SE	DSR Depth range (m)
QSC Inner	**Q91**	**20**	**45.0**	**13.5 (0.7)**	**10.1-17.2**	45	16.6 (1.4)	11.0-22.7
QSC Inner	Q92	43	9.3	10.8 (1.2)	8.0-12.8	4.7	12.7 (0.1)	12.6-12.8
QSC Inner	Q93	0	0	0	0	7.4	13.8 (1.3)	12.4-15.1
QSC Inner	Q94	31	32.3	15.2 (0.6)	11.1-17.4	38.7	15.7 (0.4)	13.6-18.9
QSC Inner	Q96	26	3.8	9.9	n/a			
QSC Inner	Q97	39	5.1	8.6 (3.4)	5.2-12.0	7.7	15.6 (3.5)	9.1-21.1
QSC Inner	Q98	26	3.8	14.1	n/a			
QSC Inner	Q99	23	13.0	7.5 (0.9)	6.3-9.3			
QSC Inner	**Q100**	**21**	**95.2**	**20.7 (0.4)**	**16.3-23.4**	57.1	21.0 (0.6)	16.3-23.4
QSC Inner	**Q101**	**31**	**48.4**	**13.1 (1.4)**	**6.0-24.4**	35.5	15.7 (2.1)	8.0-28.3
QSC Inner	**Q102**	**54**	**74.1**	**12.5 (1.0)**	**6.0-29.8**	29.6	14.3 (2.0)	6.3-29.8
QSC Inner	**Q103**	38	60.5	14.5 (1.0)	8.7-24.4	39.5	15.1 (1.6)	8.7-25.3
QSC Inner	Q104	27	22.2	13.0 (1.9)	7.0-17.7	14.8	17.6 (1.8)	14.6-22.6
QSC Inner	**Q105**	**25**	**48.0**	**13.1 (1.2)**	**9.1-21.4**	4	14.3	n/a
QSC Inner	**Q106**	**31**	**29.0**	**17.6 (1.9)**	**8.4-25.2**	29	17.6 (1.8)	8.4-25.2
QSC Inner	**Q107**	**32**	**40.6**	**16.1 (1.1)**	**9.8-23.4**	50	17.9 (1.5)	8.8-33.4
QSC Inner	**Q108**	**31**	**41.9**	**20.0 (1.4)**	**12.1-25.4**	74.2	19.5 (1.1)	11.8-27.4
QSC Outer	Q118	43	2.3	22.2	n/a			
TC Inner	Q165	23	8.7	33.0 (6.1)	26.9-39.1			
TC Inner	Q169	26	3.8	4.8	n/a			
Tory Inner	Q172	3.7				3.7	26.2	n/a
QSC Inner	Q173	37	8.1	21.1 (1.8)	18.9-24.6	16.2	21.9 (1.3)	18.9-25.1
QSC Mid	Q175	28	7.1	13.7 (3.1)	10.6-16.8			
QSC Mid	Q176	26	3.8	25.6	n/a			
QSC Inner	**Q178**	**21**	**42.9**	**17.5 (0.7)**	**13.8-20.7**	33.3	18.6 (1.0)	13.8-22.4
QSC Inner	Q179	23	26.1	13.0 (1.8)	8.9-20.8	30.4	14.5 (2.1)	8.9-23.2
QSC Inner	Q193	30	3.3	7.9	n/a			
QSC Inner	**Q310**	**22**	**40.9**	**15.4 (0.8)**	**12.7-19.6**	45.5	22.3 (2.2)	12.7-32.4
QSC Inner	**Q311**	**26**	**69.2**	**18.2 (1.4)**	**11.2-29.0**	11.5	19.7 (4.8)	12.7-29.0
QSC Inner	**Q313**	**18**	**50.0**	**23.6 (1.1)**	**19.1-29.0**	66.7	25.1 (1.2)	19.1-31.9
QSC Mid	**Q315**	**29**	**34.5**	**15.5 (1.8)**	**8.5-28.7**	20.7	20.2 (4.0)	8.5-31.8
QSC Outer	Q316	17	9.3	23.7 (0.8)	21.2-24.8	23.3	29.4 (0.7)	23.1-33.1
QSC Mid	Q318	34	11.8	13.4 (1.8)	8.1-16.2			
QSC Mid	Q319	51	25.5	18.0 (1.0)	14.0-23.1	31.4	18.3 (0.8)	13.9-23.3

3.2.4 Burrowing sea cucumbers (*Thyone* spA)

Background: Burrowing sea cucumbers are found in soft-sediment where they lie buried with just their tentacles and anterior-end exposed above the seafloor. Species of burrowing holothurians feed by filtering food from the water column, with some also collecting deposited organic material from the seafloor, by sweeping their tentacles over the surrounding sediment (Pearse 1908). Several species of burrowing holothurian (sea cucumbers), such as *Pentadactyla longidentis,* are known to occur commonly within the Marlborough Sounds (Knight and Grange 1991), but are not known to form dense beds on the seafloor. The MDC18 tow-video surveys targeted a wide range of habitats that include numerous deep (>30 m) slope environments. High-current locations and raised features were also frequently targeted to document potentially significant and notable habitats and species associated with these newly mapped features.

Ground-truthing surveys: Numerous small burrowing holothurians (or sea cucumbers) with red-brown tentacles exposed at the sediment surface were found, often locally abundant, in high-current sites in mid to outer QCS and TC, along with a few individuals on the high-current slopes at the entrance to QCS (Site MDC18-Q02), and a solitary individual seen on the deep shell-debris slope of Cook Strait, just south of TC entrance (Site MDC18-Q84) (Figure 30a-e; Figure 32; full site list provided in Table 3-10). These burrowing sea cucumbers were often found in high densities (≤60 indiv. per m^{-2}) on deep high-current slopes either in shell-debris sediments (e.g., Figure 30a-e, g) or to a lesser extent, in muddy sediments (Figure 30f,h), where they lay buried with just their tentacles and anterior-body exposed to the water column (e.g., Figure 30). No previous records of this species were made during the MBIE bottleneck surveys – likely due to shallower depths surveyed (3-30 m range) that also did not target these very high-current areas.

Video imagery of these burrowing sea cucumbers indicated that this species had 10-tentacles (e.g., Figure 30-Inserts), and therefore was not likely described for the Marlborough Sounds (N. Davey, Holothurian taxonomist, NIWA, *pers. comm*.) and were not *P. longidentis* (species having 20-tentacles of similar red-brown colouring). To get specimens for formal identification, targeted dredge sampling was undertaken at two sites characterised by high densities of burrowing sea cucumbers (MDC18 camera sites: Q171 and Q140, Figure 30a). While the first dredge was unsuccessful due to very strong currents, three specimens were successfully collected from site-Q140, but all three were damaged. Collected specimens had their anterior 'above-ground' feeding tentacles, calcareous-ring (holds the tentacles in place), and their 'introvert' (the long internal-neck that attaches the tentacles to the intestines) intact (Figure 33), but were all missing their posterior 'below-ground' body parts, including the external body wall with its tiny calcareous ossicles that are required for species-level identification. However, specimens were still able to be identified as belonging to genera *Thyone* (Family Phyllophoridae, subfamily Thyoninae) (N. Davey, *pers. comm.*), and are here after referred to as *Thyone* spA. Species in this genera have a complex calcareous ring with 10-tentacles (Thandar 2017), which they use to feed by extending their tentacles out in the water column and also wiping them over the surface of the adjacent seafloor to filter out food particles, then each tentacle is brought down one at a time into its mouth where food particles are removed and ingested. Although apparently common across the survey area (from this study), no other records of this genera, or even this family, have been recorded in New Zealand waters– possibly due to the difficulty in surveying or sampling in these deep (>30 m) and very high-current environments. However, due to its frequency and abundance in these environments, this species may be equally common in other regions of the Marlborough Sounds, and possibly New Zealand. If partial specimens have been collected in the past, there might also be unidentified or poss. misidentified specimens present in New Zealand museum collections.

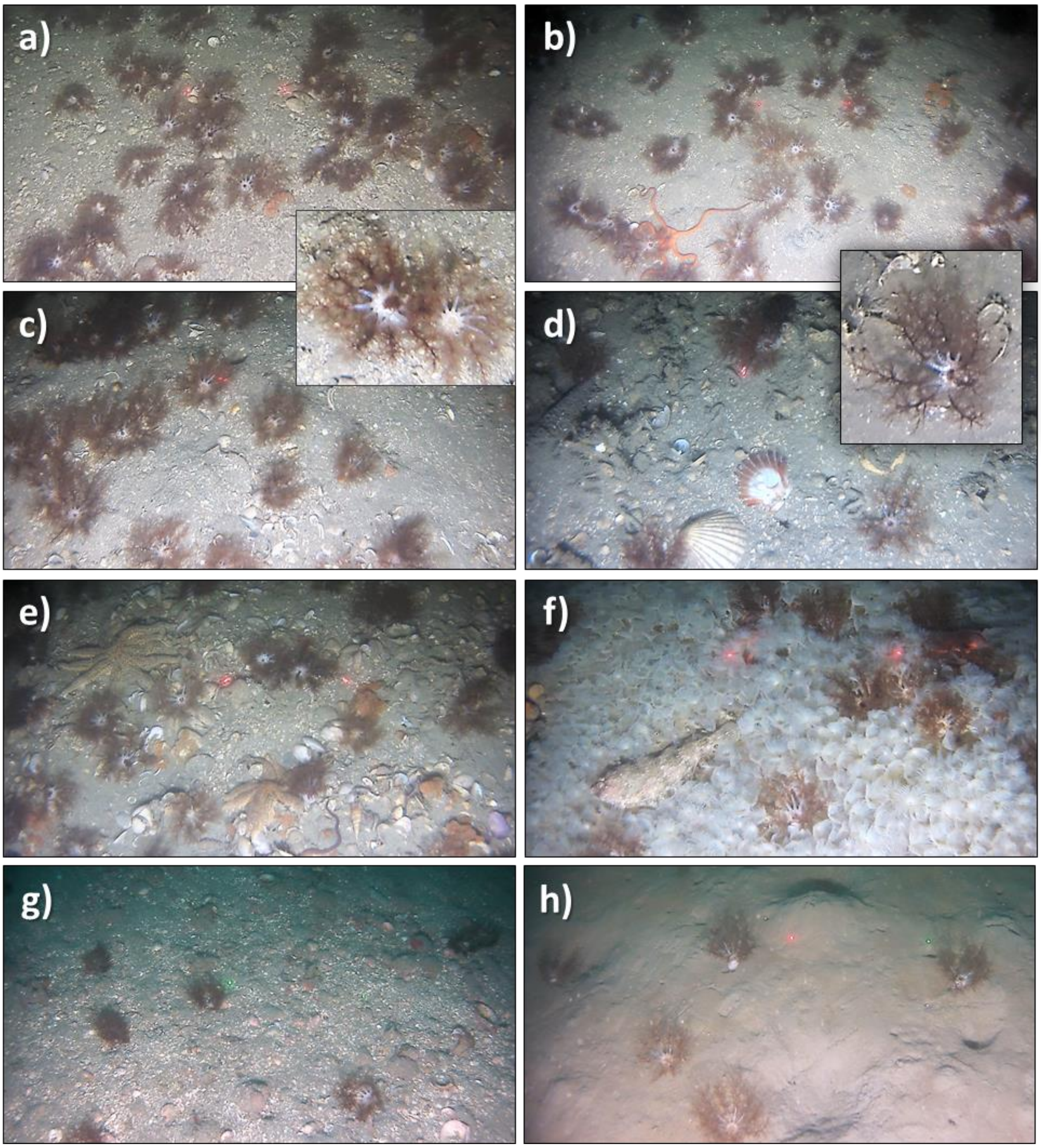


Figure 30: Examples of significant new species – Burrowing sea cucumbers (*Thyone* spA.) from high-current deep slope zones within the inner-mid Tory Channel and mid-outer QCS Sounds. a-e) Moderate to dense zone of *Thyone* spA. on the deep shell-gravel slopes off Dieffenbach Point and along the inner Tory channel (MDC18-Q140[13] (a-c), Q177 (d) and Q171 (e); f) *Thyone* spA[14]. and flatfish in amongst a dense field of the small white tubeworm, *Bispira bispira* spA. on 'The Pimple -' a small raised sediment feature at the entrance to Oyster Bay, mid-Tory Channel (MDC18-Q180, 30 m); g) moderate densities of *Thyone* spA in high-current area on the shell-debris bank adjacent to the eastern channel at the entrance to QCS, Cape Koamaru (MDC18-Q116, 24 m); h) sparse to moderate densities of burrowing holothurians on the sediment slopes of Motungarara Island, outer QCS (MDC18-Q52, 22 m). Inserts showing close-up of the above ground body parts (i.e., branchial crown/feeding tentacles. The rest of the body is buried under the sediment.

[13] Three specimens were collected from this site [D04 dredge site]) ~35-55 m depth

[14] Burrowing sea cucumbers at The Pimple had initially been thought to be *Pentadactyla longidentis* based on their red/brown colour (O'Callaghan et al. 2014), however Cbedcam video imagery clearly depicts the 10-tentacles of *Thyone* spA and not the 20-tentacles diagnostic of *P. longidentis*.

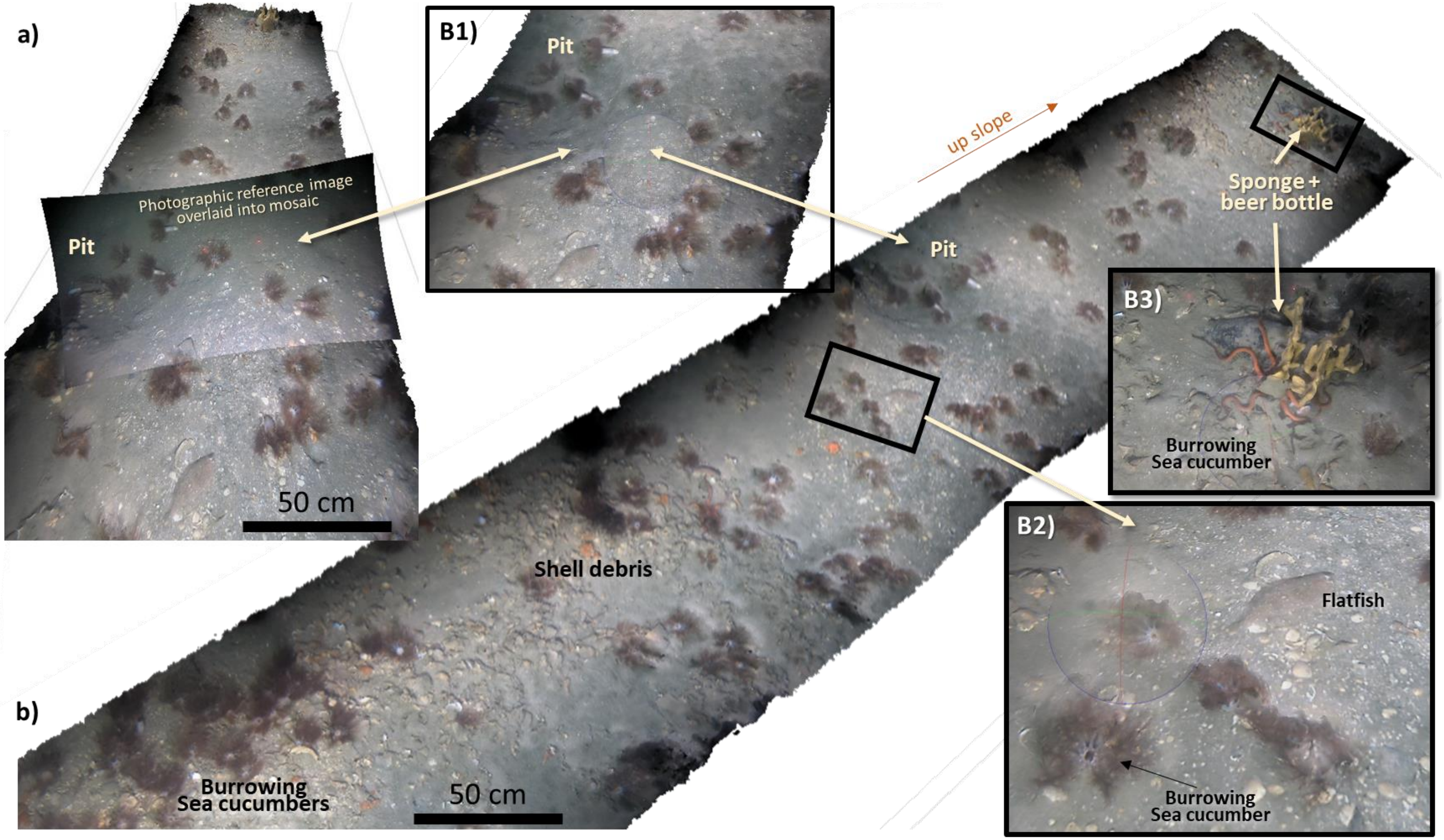


Figure 31: Example of 3-dimensional photo-mosaic showing moderate densities of the burrowing sea cucumber (*Thyone* spA) on a shell-debris slope in inner Tory Channel (Site MBIE-Q140, 35-45 m depth section) - presented in two rotated views. a) Rotated-view facing directly up slope, overlaid by the respective referenced photographic image – which in comparison with the rotated view in image [b] and zoomed in image [B1] shows an excellent quality-match with the final photographic mosaic, b) Longer section of the full mosaic providing a landscape view of the substrata (here patches of shell-debris interspersed with patches of muddy sand) in relation to the distribution of *Thyone* spA., which can be seen buried in amongst shell-debris and in patches of muddy sand, with some localised clustering. Inserts B1-B3, provide zoomed in examples of the mosaic: showing pits (measured at 47 cm diam.) [B1]; flatfish and close-up of burrowing sea cucumber [B2]; and a yellow sponge growing next to a beer bottle, with snake stars intertwined [B3].

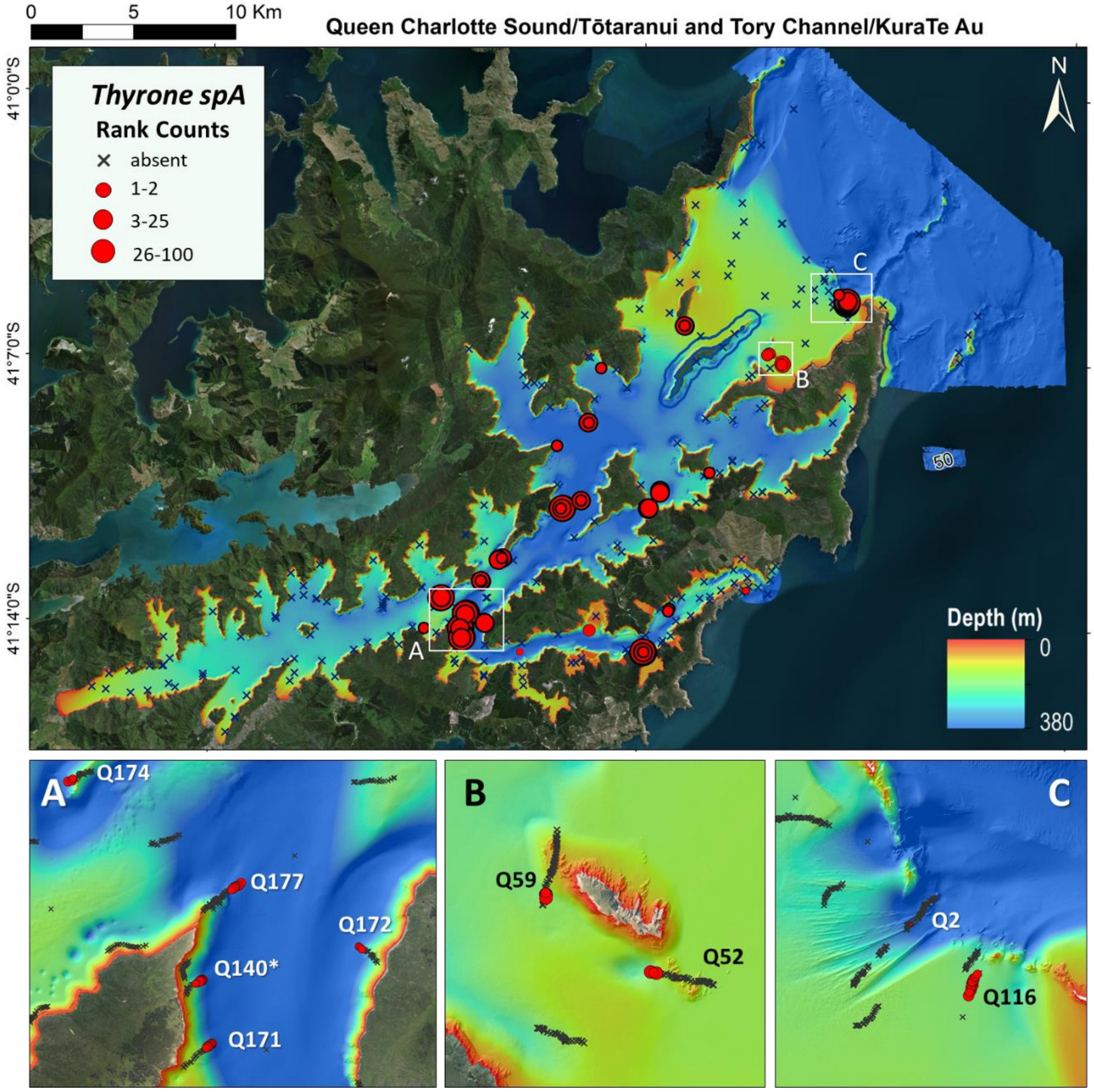


Figure 32: Distribution and relative abundance of burrowing sea cucumbers (*Thyone* spA) in high-current areas in depths of ~20-60 m within QCS and Tory Channel. Inserts A-C) show zoomed-in examples of *Thyone* from MDC18 sites, for inner Tory, and inner to outer QCS. Site Q140* indicates that *Thyone* specimens were collected by dredge at this site (MDC18-D04 dredge site). Counts = relative abundance ranks of absent (0), presence (1-2), few (3-25), abundant (26-~100 individuals) per ~30-sec call.

Thyone spA were recorded in 213 data calls from 26 sites in depths of 21-65 m (mean depth of 34.7 m ± 9.0 S.E.) (Table 3-10), and formed a distinct habitat zone on the lower slopes within high-current areas in the mid to outer Sounds, although the densest zones were between 35 and 55 m depth along the inner slopes of Tory Channel (Table 3-10; Figure 30a-e; Figure 32). The tentacles of most individuals were tan-brown (e.g., Figure 30), however, occasionally, 1-3 larger and darker coloured individuals were seen. It is unclear whether this represents variability in colour and size for this species or whether more than one species may be present. Only specimens of the first type were collected.

HS51 bathymetry, backscatter and derived data layers were then examined to determine which variables might be important in describing the distribution of this new species. Many of the slope habitats where *Thyone* were recorded were categorised by 'broad slopes' (HS51's Benthic Terrain Model category), but this was not a consistent predictor of their distributions across the regions, as some *Thyone* were found on steeper slopes (e.g., Q173), while others were found on low-angle slopes (e.g., Q52 and Q59). Sediment type was also not a good predictor, as *Thyone* were found in muddy sediments covered to varying degrees with shell-debris (e.g., Inner-TC sites: Sites Q140, Q171 and Q177a) as well as bare sediments composed of silty (Outer-QCS Sites Q59 and Q52) and thick (Oyster Bay, Mid-TC Site Q150) muds, while other sites with these sediment characteristics had no individuals present.

Table 3-10: Summary information for burrowing sea cucumbers (*Thyone* spA), with frequency of occurrence and associated depths (mean, SE and depth range) by sites. Queen Charlotte Sounds (QCS) and Tory Channel (TC). Total number of occurrence - left of brackets, and frequency of occurrence (%) at each site - within brackets. Underlined site numbers denote locally dense zones of *Thyone* spA.

Survey	Subregion	Site	Frequency of occurrence (%)	Depth (m)	
				Mean (±SE)	Range (m)
MDC18	Inner QCS	Q97	1 (3%)	34	n/a
MDC18	Inner QCS	Q139	2 (7%)	47.0 (4.5)	42.5 - 51.4
MDC18	Inner QCS	Q173	4 (11%)	32.7 (3.8)	26.9 - 43.5
MDC18	Inner TC	Q140*†	9 (29%)	41.8 (1.4)	34.5 - 46.3
MDC18	Inner TC	Q171*	9 (27%)	42.6 (1.2)	37.3 - 48.0
MDC18	Inner TC	Q172	4 (15%)	52.5 (1.3)	49.4 - 55.3
MDC18	Inner TC	Q177a*	8 (21%)	61.5 (0.6)	60.0 - 64.6
MDC18	Mid Tory	Q180^	106 (39%)	31.1 (0.0)	30.4 - 31.5
MDC18	Outer TC	Q186	9 (17%)	37.4 (0.3)	36.5 - 38.8
MDC18	Mid QCS	Q16	5 (16%)	38.3 (1.2)	35.0 - 42.0
MDC18	Mid QCS	Q18	6 (25%)	41.7 (4.3)	22.6 - 53.8
MDC18	Mid QCS	Q36	1 (3%)	21.4	n/a
MDC18	Mid QCS	Q45	3 (13%)	34.9 (1.7)	32.6 - 38.1
MDC18	Mid QCS	Q74	1 (4%)	21.3	n/a
MDC18	Mid QCS	Q175	5 (18%)	37.1 (2.4)	29.5 - 42.3
MDC18	Mid QCS	Q176	7 (27%)	41.9 (0.2)	41.3 - 42.6
MDC18	Mid QCS	Q202	3 (10%)	60.4 (0.1)	60.2 - 60.6
MDC18	Mid QCS	Q318	1 (3%)	40.1	n/a
MDC18	Outer QCS	Q02	1 (2%)	51	n/a
MDC18	Outer QCS	Q20	1 (4%)	23	n/a
MDC18	Outer QCS	Q43	4 (13%)	26.7 (0.7)	25.0 - 27.9
MDC18	Outer QCS	Q52	3 (8%)	23.6 (0.9)	21.9 - 25.1
MDC18	Outer QCS	Q59	4 (8%)	22.5 (0.1)	22.4 - 22.6
MDC18	Outer QCS	Q116*	14 (78%)	25.1 (0.1)	24.5 - 25.9
MDC18	CStrait-TC	Q84	1x indiv. at ~ 35 m	n/a	n/a
HS51	Mid QCS	C47	5x indiv. at 34 m	n/a	n/a

* see example photos of these significant *Thyone* zones in Figure 30.
† *Thyone* specimens collected at this site (MDC18-D04 dredge site).
^ *Thyone* were common at Site 180, however, the very high number of occurrences (Records) at this site does not reflect significantly higher abundances at this site, rather it occurred as a result of running video-lines repeatedly across the same feature ('The Pimple') and adjacent shell-debris habitats where *Thyone* spA were common.

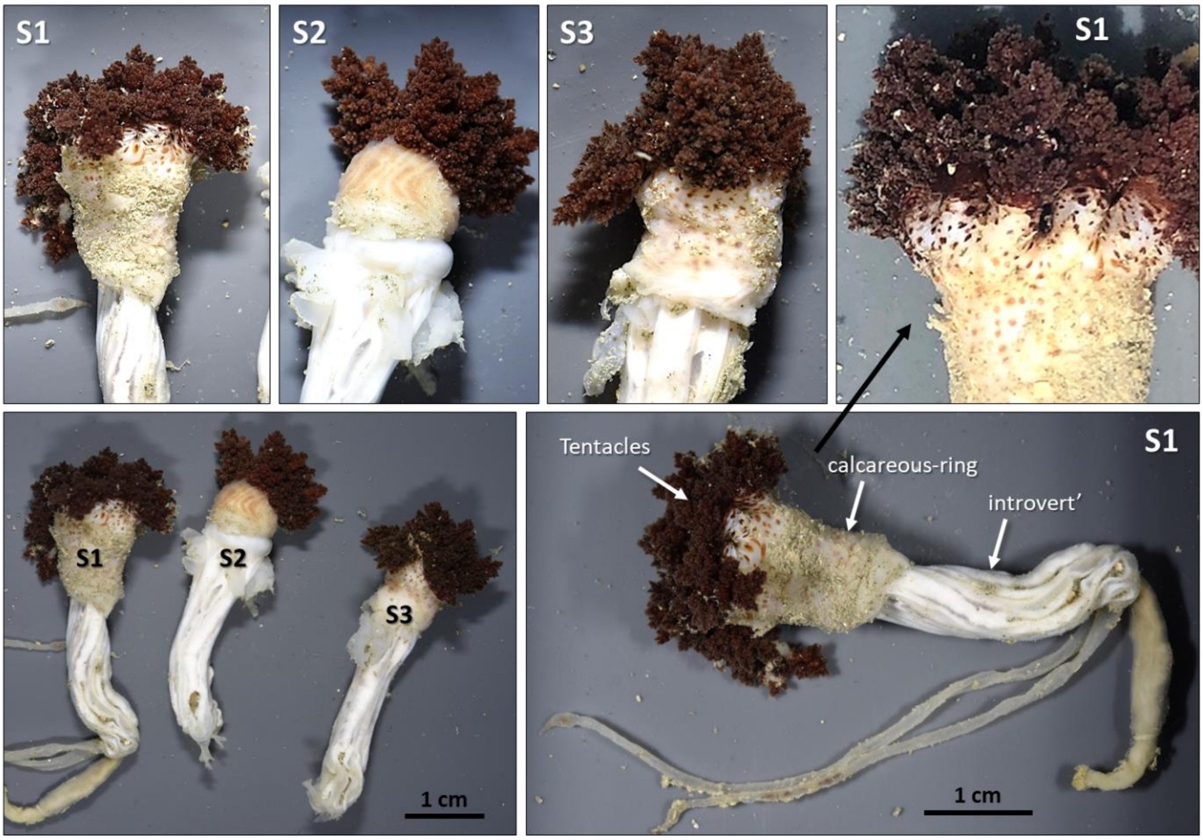


Figure 33: Burrowing sea cucumber specimens (*Thyone* spA), collected in NIWA's small epibenthic dredge, from a deep shell-gravel slope in inner Tory channel (MDC18- D04 dredge site/camera site Q140). Three partial-specimens (specimens S1-S3) were collected from this site, but all were missing their posterior (below-ground) body-parts. The above-ground body parts collected, included their feeding tentacles (brown flesh sections), calcareous-ring (that holds the tentacles in place), and their 'introvert' (the long internal-neck that attaches the tentacles to the intestines) - indicated in the bottom-right image.

Although there were quite distinct demarcations of *Thyone* spA distributions with depth, the depth of this demarcation varied between sites. For example, in the outer QCS around Motungarara Island, on the east side of Long Island, *Thyone* were present in depths of 21-25 m. In contrast, at the junction of TC and QCS, *Thyone* occurred in much greater depths (>35 m), but even in these closely adjacent sites, the minimum depth of the *Thyone*-zone varied (e.g., 34 to ≥46 m at Site Q140, 37m to ≥47 at Site Q171, and 60 to ≥ 65 m at Site Q177a). The broader depth range also varied with *Thyone* spA found in Pickersgill Passage in depths of 21 m, and off Dieffenbach Point in depths down to at least 65 m (off Dieffenbach Point). Both Pickersgill Passage and the slopes of Dieffenbach Point are very high-current areas indicating that current, rather than depth per se is likely to be important to this species. However, examination of *Thyone* occurrence relative to Hadfield et al.'s (2014) hydrodynamic model output (Figure 34) show that not all high current slopes within similar sediment characteristics had *Thyone*.

As *Thyone* spA live buried in sediments on slopes, correlation with backscatter – which can be a useful indicator of sediment thickness - may be an important correlate. No obvious relationships between *Thyone* distribution and backscatter strength were found. However, backscatter reflectance was high and noisy in the large-shell debris environments where *Thyone* occur (esp. at the junction between QCS and TC where the whole inner channel and junction had high reflectivity). While the presence of large-shell debris covering the sediment slopes along the Inner-TC would be expected to give off high reflectance, the presence of burrowing sea cucumbers in these habitats indicate that there is at least enough sediment on these slopes for *Thyone* to bury in.

Some burrowing cucumbers in the same Phyllophoridae Family, including species of the genera *Thyone* are known to occur in the sediments near rocks (Byrne and O'Hara 2017). To examine and compare *Thyone* depth distributions and their distance to reefs, depth profiles were generated in ArcGIS for six video transects where *Thyone* were present (Figure 35). This identified a clear relationship between sloping sediments directly below outcropping reefs/ridge lines. It is therefore likely that a combination of variables (depth, slope, near bed current-velocity and vicinity to reefs) are likely to be important in predicting the distribution of *Thyone* spA.

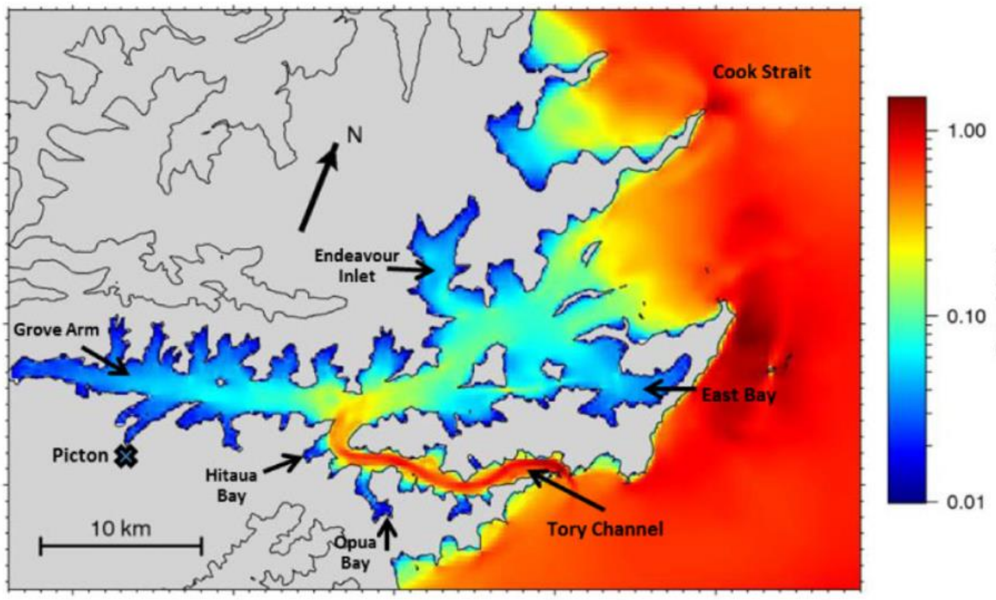


Figure 34: Mean surface current speed from the hydrodynamic model of QCS, TC and the adjacent Cook Strait (*from Figure 3-14 of Hadfield et al. 2014*), showing high current areas (reds and yellows) across the study region. Model mean current speed at 5 m depth, based on one year's hourly data from the 200 m model (described in Hadfield et al., 2014).

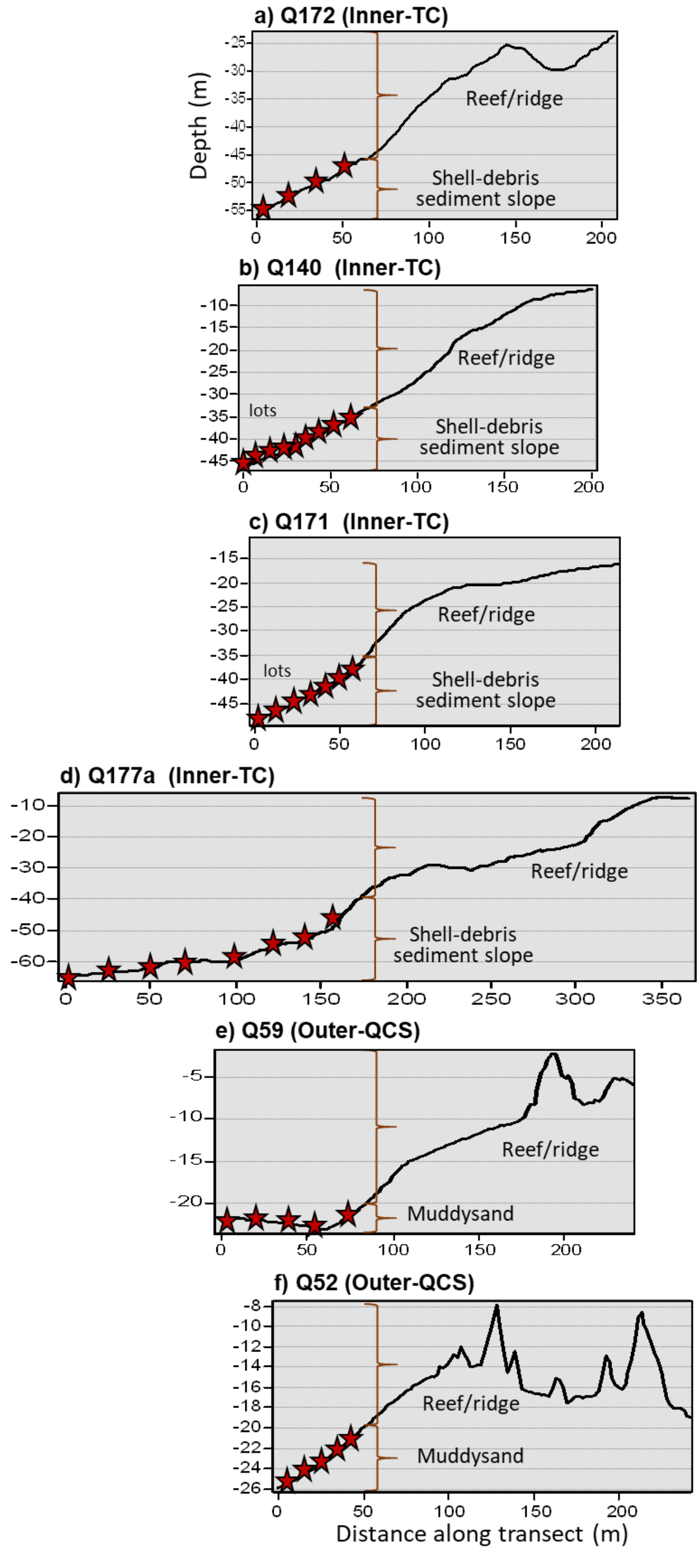


Figure 35: Depth profiles along six video-transects (MDC18 survey) –- showing the comparative depths, sediment types and distance from reefs of the burrowing sea cucumber *Thyone* spA (red stars). The six graphs are aligned by the location of the reef-sediment interface. Spacing of red stars depicts relative densities of *Thyone*; x-axis is distance travelled by each video-transect in an upslope direction; y-axis is HS51 bathymetry in metres. Brown brackets (centrally aligned) denote the depth-range of each habitat (shell-debris sediments, muddy sand or reef). a-f) show that regardless of depth and/or sediment type, the depth zone for *Thyone* started within a few metres of the reef base and continued deeper than surveyed.

3.2.5 Tubeworm fields (non-calcareous)

Background: Several species of tubeworms are known to occur within the Marlborough Sounds, however, the distribution and abundance across most areas are not well known. Parchment worms (likely invasive), unidentified Chaetopterid tubeworms and other soft unidentified tubeworms have been reported in specific locations within the Marlborough Sounds, as part of brief site descriptions within water depths <20 m (Davidson et al. 2010b; 2011; 2015; 2018). More detailed diver and drop camera surveys have also described and mapped localised distributions of some tubeworm species, including: *Owenia petersenae* (a sand-grain covered tubeworm belonging to the family Oweniidae) in 10-12 m off Gannet Point in Port Gore (Davidson et al. 2010b); and a small bluish-white tubeworm, identified as *Bispira bispira* spA (a bristleworm from the family Sabellidae) in 3-6 m within Bob's Bay in Picton (Davidson et al. 2011, covering an area of ~3.6 ha). The distribution and community descriptions of soft-sediments within Marlborough Sounds from a grab survey by Estcourt (1967) also reported on two species of infaunal mud worms (*Asychis theodori* and *A. trifilosus* from the family Maldanidae) collected in sheltered muddy-sediments within PS and QCS, where they co-occurred with heart urchins (*E. cordatum*) and Amphiurid brittlestars (*Amphiura rosea*-dominated sediments in Pelorus Sounds and *A. correcta*-dominated sediments in QCS – also see Section 3.3.5: *Amphiura*-dominated communities). More recently, two additional habitat-forming tubeworms (*Acromegalomma suspiciens*[15] and *Spiochaetopterus* spp.[16]) have been reported from the Marlborough Sounds from the CB17 and BT17 surveys (Anderson et al. 2019[17]), which are described here for the HS51 survey area in more detail. Additional distribution and rank abundance data for both species are also presented from the MDC18 survey, along with targeted transects across two *B. bispira spA* tubeworm beds. In this report three non-calcareous tubeworm species (*Acromegalomma suspiciens* and *Spiochaetopterus* spp., and *Bispira bispira* spA.) are present. Other tubeworms species were also recorded within the HS51 survey area, including parchment worms and sand-grained tubeworms (likely *Owenia* spp.), however, more detailed post-processing of the ground-truthing video footage would be required to determine their relative distributions and abundances.

Acromegalomma - tubeworm patches

Acromegalomma suspiciens is a large endemic sabellid tubeworm, with sponge-like tubes that grow to about 150 mm in length in tight-clusters 'or fanworm-bundles' (e.g., Figure 37) within silty soft-sediments from numerous sites across the broader Marlborough Sounds, including bays off Tory Channel, the Knobbies within inner Port Underwood, bays within the inner to mid Pelorus Sounds (esp. Nikau Bay) and within the inner sections of Croisilles Harbour (Anderson et al. 2019). The emergent tubes of this species extend above the soft sediment for approx. 10-50 cm, that in turn provide habitat surfaces and structural refuge for a wide range of associated species (e.g., Figure 38; Anderson et al. 2019).

[15] previously known as *Megalomma suspiciens*
[16] Preliminarily described as *Spiochaetopterus* spp (Geoff Read, pers. comm. to T. Anderson), but live specimens have been requested by Dr Read to verify the taxonomy of this species or species-group.
[17] Based on the preliminary findings from the broader-scale MBIE CB17 video surveys and BT17 beam trawl surveys (NIWA *unpublished data*)

Within the HS51 survey area, habitat-forming clusters of *A. suspiciens* were recorded from a total of nine sites from five locations within the survey area (Figure 36). This included a few small patches within Bottle Bay, within inner QCS (MDC18-Q320) and eight sites (3 beam trawl sites and 5 video sites) from four TC-bays (Maraetai, Hitaua, Onapua, Te Pangu Bays – details in: Table 3-11; Table 3-12; e.g., Figure 36; Figure 38). In contrast to the extensive sites in Pelorus Sound (e.g., 100 m long bed recorded in Nikau Bay, Pelorus Sound, Anderson et al. 2019), only small patches ~0.3-3 m diam. were recorded within QCS and TC (e.g., Figure 38). The seafloor in these areas was composed of silty muds with moderate to high levels of biofilm, some burrows and tracks, cushion stars (*P. regularis*) and accumulated patches of drift algae (mostly *Ulva* spp., strappy and filamentous red algae, and drift kelp) (see Table 3-13). Emergent tubeworm clusters stood 10-50 cm high relative to the surrounding seafloor, and often contained sediment patches within their structure (i.e., internal gaps) (e.g., Figure 38a,b,c,e), with many patches, regardless of size, having some level of drift algae present – partially trapped amongst their emergent tubes. All specimens collected had a robust sponge-like texture and were fused together in 'fanworm bundles' (e.g., Figure 37a,d), with numerous strands of *Spiochaetopterus*-like spp. (Geoff Read, *pers. comm*.) also collected intertwined together.

Table 3-11: *Acromegalomma suspiciens* recorded from video surveys (MDC18 and CB17 surveys), within the survey area. Table presents the number of records with *A. suspiciens*. The minimum-maximum depths (HS51 bathymetry) are presented for *A. suspiciens* per site.

Survey	Subregion	Location	Site	Depth range (m)	Records (%)	Patch size range (m)
CB17	TC-inner	Maraetai Bay	C50	15.8-16.4	7 (20.6%)	0.3-1.5 m
CB17	TC-inner	Hitaua Bay	C51	11.8-12.3	5 (29.4%)	0.2->1 m
CB17	TC-inner	Onapua Bay	C52	11.9-12.9	10 (33.3%)	0.3->1.5 m
CB17	TC-mid	Te Pangu Bay[18]	C24	24.5	1	0.3
MDC18	TC-inner	Onapua Bay	Q196	11.1-12.0	2 (5.4%)	~0.3-3 m *
MDC18	QCS-inner	Bottle Bay	Q320	17.0-17.8	2 (5.21%)	0.2-0.4 m

*Heavily fouled

Table 3-12: *Acromegalomma suspiciens* specimens collected in BT17 beam-trawls sites, within the survey area. Table presents the volume of specimens collected in litres per site. Tow-depth is based on ships depth at the start and the end of tows and is presented as minimum-maximum of those depths.

Survey	Subregion	Location	Site	Tow-depth (m)	Vol (L)
BT17	TC-inner	Maraetai Bay	QC35B	16.2-16.6	1.580
BT17	TC-inner	Hitaua Bay	QC36	11.4-15.4	1.500
BT17	TC-inner	Onapua Bay	QC37	13.6-14.5	60.00

[18] See photo in Figure 96.

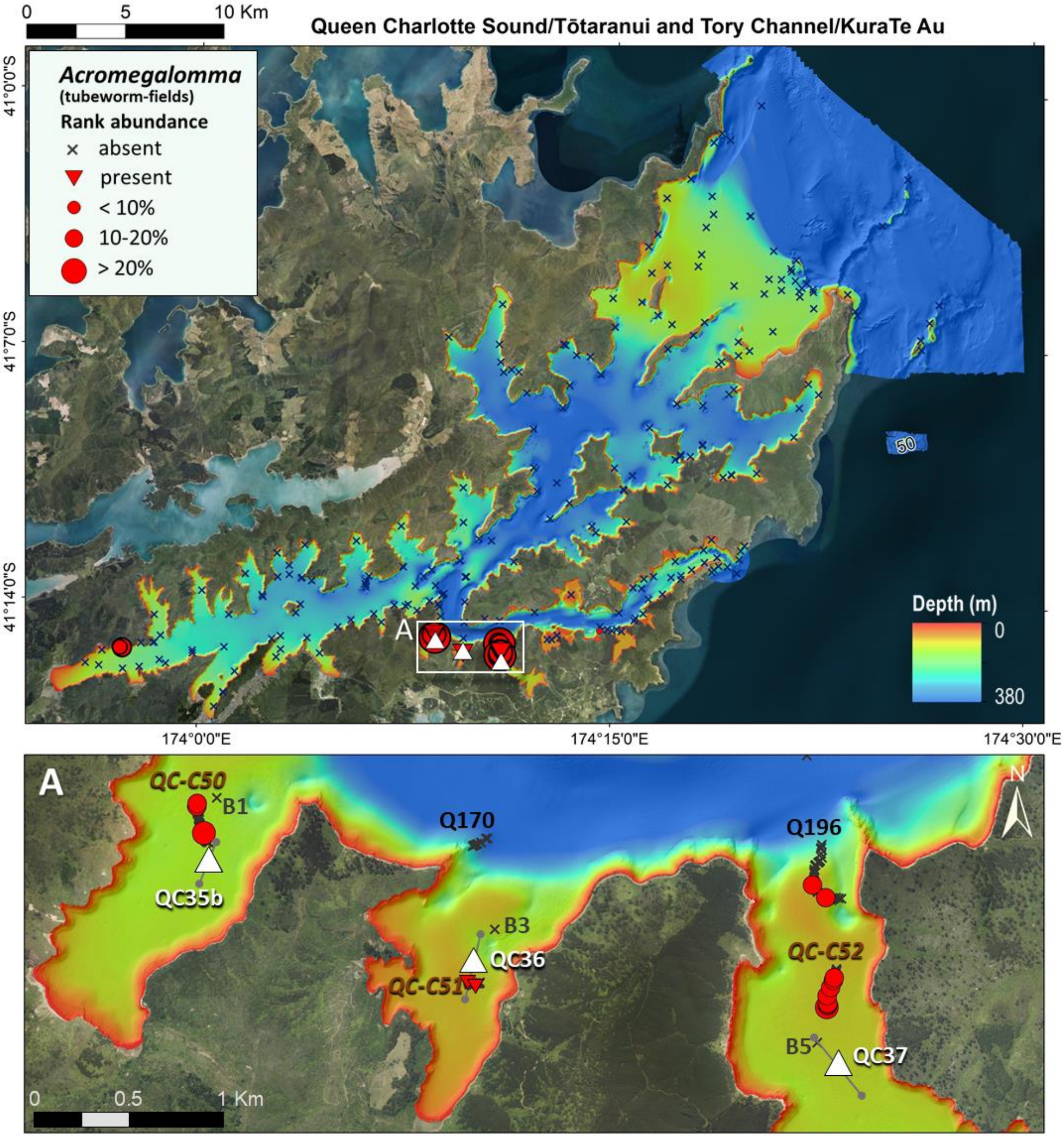


Figure 36: Distribution and rank % cover of *Acromegalomma suspiciens* tubeworm clusters within QCS and TC. Bubble plot distributions coloured red are % Cover (rank %cover categories) from the MDC18 and CB17 surveys[19]; triangles represent presence (red inverted = CB17, and white upright=BT17 collections). Plot A) show zoomed-in locations of *A. suspiciens* distributions from all four surveys, where black labels = MDC18 sites, Burgundy labels= CB17 sites, white labels=BT17 collections (NB: grey lines with grey circled ends depicts the length and direction of each beam trawl), and grey labels B1-5 = HS51 sites.

[19] At CB17-C50-52, *Acromegalomma* was recorded as 0 (absent), 1 (present), 20 (secondary habitat ≥20%), 50 (primary habitat ≥50%) within a single call.

Figure 37: Specimen collections of *Acromegalomma suspiciens* tubeworms from BT17 beam trawls within TC bays. Images show 'fanworm bundles' of *A suspiciens* collected within three adjacent bays: a-b) Hitaua Bay (site BT17-QC36, 1.5 L collected from ~12.3 m), with close-up showing the branchial crown out feeding [b]; c) large volumes (60 L) collected from Onapua Bay (site BT17-QC37, mean depth of ~13.8 m); d) Maraetai Bay (BT17-QC35B, 1.5L from ~16.6 m).

Although most patches weren't very large, *A. suspiciens* even in small patches provided substratum and structure for other species, including bright orange colonial ascidians (*unident. sp.,* Mike Page pers. comm.) growing conspicuously on the top sections of *A. suspiciens* tubes (Figure 37a,c,d; Figure 96i), other colonial ascidians species (e.g., Figure 37c - *C. dellechiajei*), as well as encrusting and erect sponges, small epiphytic bivalves, snake stars and starfish and often heavy loads of epiphytic red algae (Table 3-13; Figure 38). The 3D structure of these patches also provided refuge for a wide variety of motile invertebrates and fish, incl. numerous small-size fish, such as triplefins and spotties, seen darting for cover or hiding in amongst the tubes in these patches (e.g., Figure 38d; Table 3-13 for full species/taxa list).

The highest occurrence of *A. suspiciens* patches was recorded in Onapua Bay, in TC (Figure 36-A). *A. suspiciens* specimens were also collected in beam trawls from the three shallow bays in TC, in depths of 12.3-16.6 m. This included sizeable collections (60 L) in a beam trawl within Onapua Bay (BT17-QC37, ~13.8 m, Figure 37c), along with associated video footage showing a series of small-sized patches (~0.3-3 m diam.) each separated by distances of ~10-50 m along-transects. Sizeable catches (~1.5 L) were also recorded from Maraetai Bay (BT17-QC35B, in ~16.6 m) and Hitaua Bay (BT17-QC36, ~12.3 m) (Figure 37a and d, respectively).

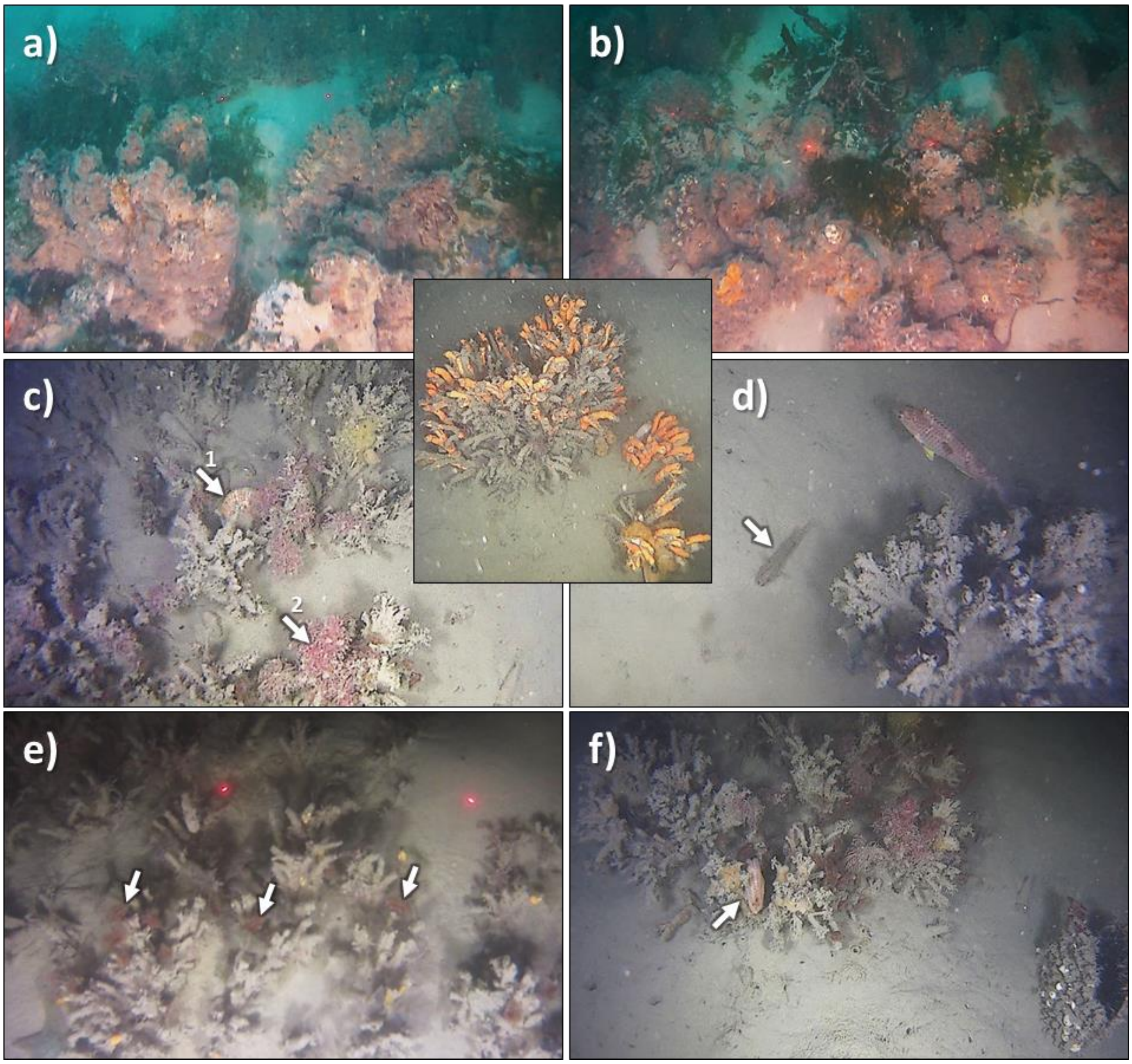


Figure 38: ***Acromegalomma suspiciens*** **tubeworm habitats in TC bays.** Fanworm bundles of *A suspiciens* growing in dense clumps (or clusters) within otherwise open flat soft-sediments within shallow bays: Example present are from: a-b) close to the edge of the bank in the entrance to Onapua Bay, Tory Channel (Site MDC18-Q196), with large clumps of drift algae (incl. *Ulva*, *Carpophyllum* and red-foliose macroalgae) trapped in amongst the emergent tubes of *A suspiciens* which here stand ~10-25 cm high; c,d,f) various sized patches in Maraetai Bay, TC (CB17-C50), with epiphytic clam, *T. zelandiae* [c^1, f], epiphytic filamentous red-algae [c^{-2}], Insert-image: showing the tops of *A suspiciens* emergent tubes covered in a dense colonial ascidian (sp. Mike Page *pers. comm*.); d) small clump (or cluster) of *A. suspiciens* in Maraetai Bay, Tory Channel, with spotty and small fish (*Grahamichthys* sp.) indicated by white arrow (CB17-C50); e) tubeworm cluster (arrows indicating actively feeding *A. suspiciens* – with their characteristically red-brown branchial crowns out feeding), Onapua Bay, TC (CB17-C52).

Table 3-13: Species collected in BT17 beam trawls, where *A. suspiciens* were also collected, as well as additional species only seen in video. Species occurrences are combined here for Maraetai Bay (BT17-QC35B), Hitaua Bay (QC36) and Onapua Bay (QC37), to provide an overview of *A. suspiciens* associated species.

Group	Species collected
Drift algae†	*Haraldiophyllum crispatum, M. pyrifera, Rhodymenia linearis, Schizoseris* spp, *Ulva* spp., *Undaria pinnatifida*. (combined volume of 10.5 litres).
Epibenthic species	Sea squirts (*M. squamiger* and *Cnemidocarpa bicornuta*); colonial ascidians (*C. dellechiajei, Leptoclinides novaezelandiae* and *D. listerianum*); Sponges (*Mycale (Carmia) hentscheli* and Poecilosclerid (*Tendania* sp.), incl. digitate forms *Callyspongia* spp., *Euryspongia* sp., and *Dactylia varia*); a brachiopod (*M. sanguinea*); epiphytic bivalves (*T. zelandiae*).
Motile invertebrates	Starfish (*P. regularis*†, *C. muricata*†); Sea cucumbers (*A. mollis*† and *Pentadactyla longidentis*^); Brittlestars (*Ophiomyxa brevirima,* snake stars†, *A. correcta*^); Nudibranch (*Archidoris wellingtoniensis*); Opistobranchs (*Pleurobranchia maculata*, *Philine orientalis*); a sea mouse (*Euphione squamosa*^); Crabs (Hermit crabs†, decorator crabs, spider crabs – *Halicarcinus* spp.); pygmy octopus (*Octopus warringa*).
Other tubeworms	Wireweed (entangled in-amongst *A. suspiciens* clusters; initial described as *Spiochaetopterus* spp., Geoff Read, *pers. comm*.) and mudworms (*Asychis* sp. - poss. *Asychis trifilosus* – identified from images by Geoff Read).
Infaunal species	Numerous small bivalve species -likely collected from the surrounding soft-sediments.
Fish	Triplefins (*F. varium, F. flavonigrum, F. capito*, *Grahamichthys* sp.); juvenile leather jackets (*M. scaber*), spotties, tarakihi.
Additional species seen only in video	Kina, hydroids, *A. insignis* (x1), horse mussels (few), small patches of reef-building bryozoa, subadult (x1) and adult blue cod (x1), epiphytic algae - filamentous and foliose red algae (common), *Octopus maorum* (x1).

† Taxa/species seen on adjacent soft sediments as well as amongst the tubeworm fields.
^ Known or likely sediment-associates or infauna species.

Straw-weed tubeworms (Chaetopterids: Spiochaetopterus spp.)

Previous described in Anderson et al. (2019) as a straw-weed Chaetopterid tubeworm (*Spiochaetopterus* spp)., these tubeworms have long and thin tubes that grow to about 200-400 mm and look like tangled straw when collected in the beam trawl (e.g., Figure 39) – and thus are here on referred to as straw-weed tubeworms. These tubeworms lay almost totally buried beneath the sediment surface, with the emergent tubes extending only 1-3 cm above the sediment (e.g., Figure 41; Anderson et al. 2019). Localized densities of *Spiochaetopterus* spp., can be extremely high, and where present can stabilise sediments forming raised mounds that cover small to extensive areas of the seafloor (Anderson et al. 2019). Although, the emergent tubes of this genera do not extend very high above the seafloor, their emergent tubes still provide substrata for other species, particularly epiphytic red algae, and when tubeworm beds are extensive, they are often heavily fouled by algal meadow species (Anderson et al. 2019).

Straw-weed chaetopterid tubeworm specimens were collected from seven BT17 beam trawl sites, across the inner, mid and outer QCS, and an embayment within inner TC (Table 3-14; Figure 40). Based on the video footage, these sites were comprised of flat muddy sediments with low numbers of burrows, and were in depths of 16.6-28.5 m (mean 24.7 m ± 1.59 SE), noting that BT17 sites only sampled in depths of 3-30 m. These straw-weed tubeworms were very distinctive having very long and thin light-brown tubes that closely resemble the appearance of the Otago wire-weed tubeworms (described in Jones et al. 2018a,b; review by Anderson et al. 2019), but unlike the hard-to-cut wire-like integrity of the Otago wire-weed tubes, straw-weed chaetopterid tubeworms within the Marlborough Sounds were easily cut. Straw-weed tubeworms collected from the BT17 sites have been initial described as *Spiochaetopterus* spp (Geoff Read, *pers. comm.* to T. Anderson), however, live specimens or specifically-preserved specimens[20], would be required to verify this, and determine whether more than one species is present (Geoff Read, *pers. comm.*). Species also collected from these sites included: red algae, horse mussels and sometimes other tubeworm species (e.g., *Acromegalomma* or mudworms, *Asychis* sp. (poss. *Asychis trifilosu*s)). The highest volume of straw-weed spiochaetopterids were collected from the entrance to Aratawa Bay, in the upper reaches of the Bay of Many Coves where 2.5 L were collected (Table 3-14), although higher volumes were collected in Port Underwood and Guards Bank[21] (T. Anderson *pers. obs.,* NIWA *unpublished data*).

Table 3-14: Chaetopterid specimens (likely *Spiochaetopterus* spp.) collected in BT17 beam-trawls sites, within the survey area. Table presents the volume of specimens collected in litres per site. Tow-depth is based on ships depth at the start and the end of tows and is presented as minimum-maximum of those depths.

Survey	Subregion	Location	Site	Tow-depth (m)	Vol (L)
BT17	TC-outer	Papatoia	QC13	21.9-22.6	0.100
BT17	TC-mid	Bay of Many Coves	QC28	26.6-29.0	2.500
BT17	TC-inner	Ruakaka Bay ^	QC32	24.7-26.1	0.350
BT17	TC-inner	Maraetai Bay *	QC35b	16.2-16.6	0.500
BT17	TC-inner	Blackwood Bay	QC43	27.0-30.0	0.060
BT17	TC-inner	Kahikatea Bay	QC44	21.8-25.2	0.060
BT17	TC-inner	Lochmara Bay	QC50	25.7-28.5	0.080

*Co-occurring entwined with *Acromegalomma suspiciens.*
^ Co-occurring with large volumes of mud worms (poss. *Asychis trifilosu*s).

Figure 39: Specimen collections of Chaetopterid tubeworms (likely *Spiochaetopterus* spp.) from the Marlborough Sounds (image from Anderson et al. 2019). This habitat is common throughout the Marlborough Sounds as mono-specific beds, and intertwined within *Acromegalomma suspiciens* patches or mud worms (*Asychis* spp.).

[20] using hypodermic needles to inject formalin down the lengths of the tube to ensure preservation within these tough but very long tubes.
[21] MBIE BT17 Large-scale surveys collected 17 L of *Spiochaetopterus* spp. from Site EC19 in Port Underwood, and 9.5 L from OS27 in the upper reaches of Guards Bank, with other sites within these areas also having *Spiochaetopterus* spp.

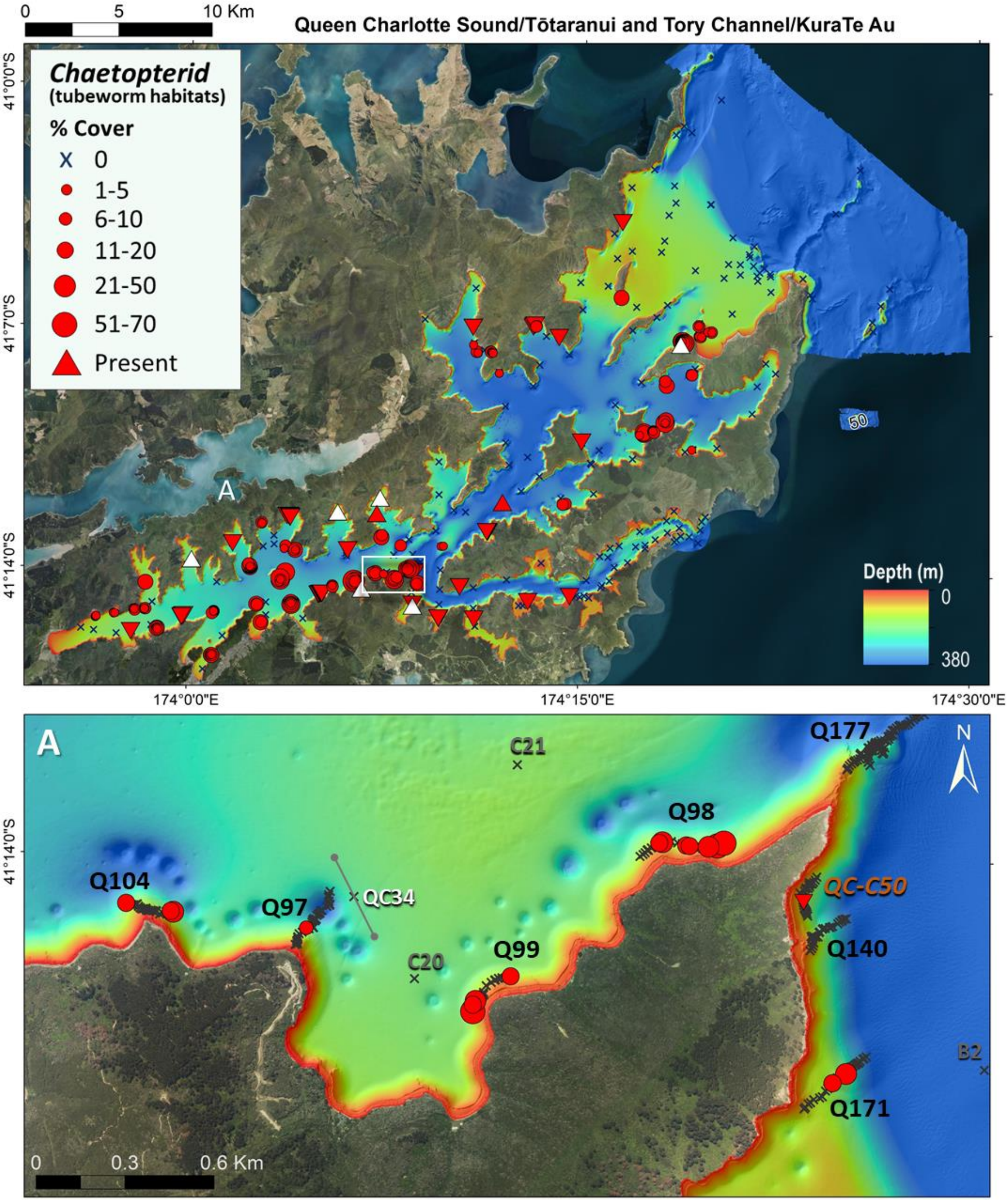


Figure 40: Distribution and rank % cover of Chaetopterid tubeworm beds (likely *Spiochaetopterus* spp.) within QCS and TC. Bubble plot distributions coloured red are rank %cover categories from the MDC18 survey[22]; triangles represent presence (red inverted = HS51, red inverted = CB17, and white upright=BT17 collections). Plot A) show zoomed-in locations of *Spiochaetopterus* spp. distributions from all four surveys, where black labels = MDC18 sites, orange labels= CB17 sites, white labels=BT17 collections (NB: grey lines with grey circled ends depicts the length and direction of each beam trawl), and grey labels = HS51 sites.

[22] At CB17-C50-52, *Acromegalomma* was recorded as 0 (absent), 1 (present), 20 (secondary habitat ≥20%), 50 (primary habitat ≥50%) within a single call.

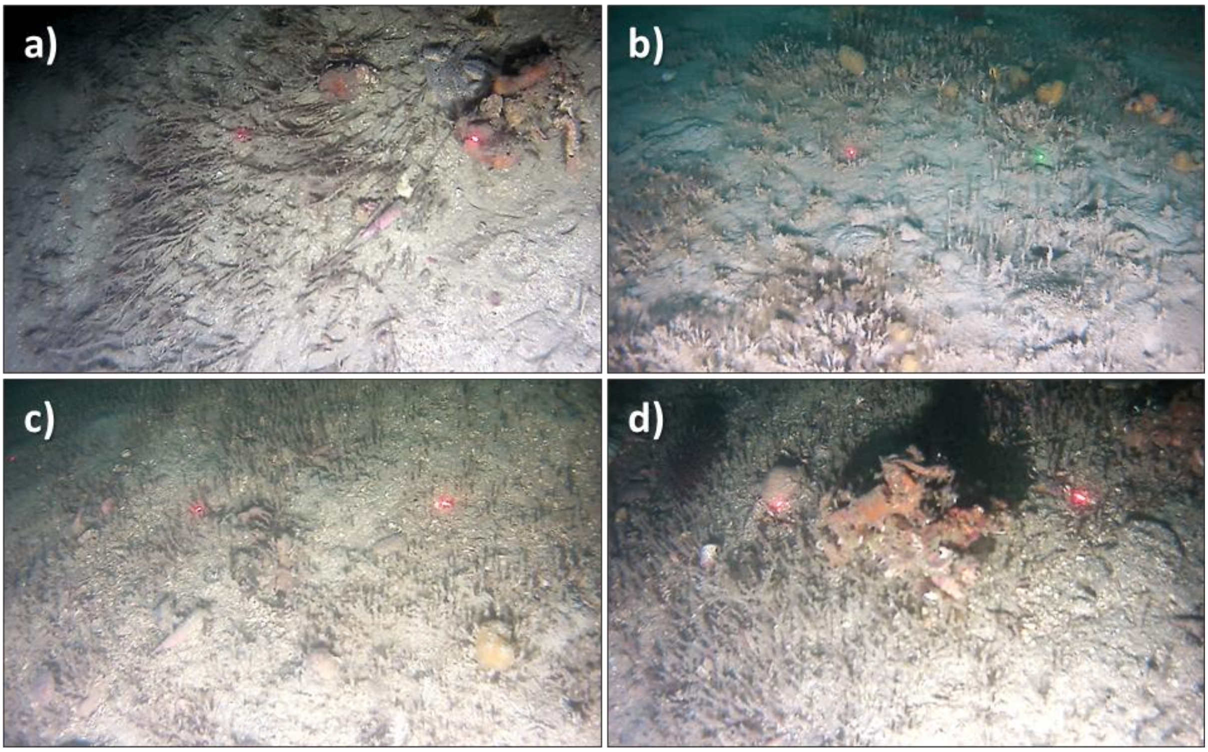


Figure 41: Examples of straw-weed habitat within QCS and TC from MDC18 and CB17 video surveys. Examples of straw-weed patches from: a) Tauranga Bay, Inner QCS (CB17-C28); b) Papatoia, Outer QCS (Site MDC18-Q190, 23 m); c-d) The Snout, Waikawa, Inner QCS (Site MDC18-Q94, ~18 and 19 m, respectively).

Straw-weed chaetopterids (likely *Spiochaetopterus* spp., referred to as Spiochaetopterids hereafter) form distinctive habitats (e.g., Figure 41) that are readily identified from video - although it is unclear from video or collections, how many species are present within the Sounds. Spiochaetopterids were recorded in 36.6% of all sites (excluding Cook Strait sites), and were found commonly throughout QCS and in soft-sediment bays within TC (Table 3-15; Figure 40), in depths of 9.6 to 50.2 m (MDC mean 25.6 ± 0.58). No Spiochaetopterids were recorded outside of the Sounds in Cook Strait, or in the main channel in TC. Inner-QCS had the highest percentage of Spiochaetopterid sites and records (63% and 13.4%, respectively), with notable % occurrences also recorded in mid-QCS, shallow bays within inner-TC and outer-QCS (40-26% of sites and 5.6-2.7% of records) (Table 3-15; Figure 40).

Spiochaetopterids were recorded in silty sediments in bays to sediment covered slopes (Figure 41). Although the emergent tubes of straw-weed Spiochaetopterids only extend above the sediment for a few cms, they can provide habitat for a wide range of flora (most red algal species) and fauna (5-armed starfish, holothurians, ophiuroids, and small fishes, such as triplefins and spotties) (e.g., Figure 41a-d). Rank % cover of Spiochaetopterids was highly variable both within and among sites, ranging from very small isolated patches to locally dense and more extensive beds (range 1-70% cover, where 70% = dense), albeit almost always with some degree of local patchiness. The most extensive Spiochaetopterid beds recorded were at Papatoia (bay east of Long Islands, MDC18-Q190), where 100% of calls along the 200 m video-transect had some Spiochaetopterids (1-50% cover per call, geometric mean of 23.1 % cover ± 1.0 SE), in depths of 23.1-23.7 m (e.g., Figure 41b). Given the consistent depth within this bay, it is likely that this bed may extends across a much larger area of this bay, although this would need to be verified. Variable density patches of Spiochaetopterids were common along the upper-slopes within inner QCS, particularly between depths of ~12-25 m (e.g.,

Figure 41a,c,d). For example, all sites surveyed between Whatamango Bay to a site close to Dieffenbach Point (encompassing a shoreline distance of 3.597 Km) supported some amount of Spiochaetopterids (Figure 40-A). In some of these sites large amount of red filamentous (almost flocculant) algae was also present growing on the emergent tubes. The invasive 'parchment worm', is also a Chaetopterid tubeworm, although generally this species (or group of species) have distinctive white parchment-paper-like colouring and appearance to their tubes. While these are generally distinctive, and were recorded separately where possible, it is likely that some overlap and/or misidentification of these mostly-buried Chaetopterids worms may exist. As such the findings presented here should be used as a preliminary guide to the distribution and abundance of Spiochaetopterids spp., with collections required to validate and document the species present.

Table 3-15: Summary details of Spiochaetopterid tubeworms recorded in video footage within QCS and TC (MDC18 and CB17 surveys). QCS=Queen Charlotte Sounds, TC= Tory Channel; CStrait=Cook Strait. Totals and percentage values are presented for sites and records inside the Sounds only. Spiochaet. = straw-weed Chaetopterids (likely *Spiochaetopterus* spp.); %Cover range values are from MDC18 Survey only.

Survey	Subregion	Sites with Spiochaet. (%)	Records with Spiochaet. (%)	% Cover range	Depth (m)	
					Mean (SE)	Range
MDC18	QCS-inner	63	13.4	1-70%	25.5 (0.9)	9.6-50.3
MDC18	QCS-mid	40	5.6	1-50%	30.9 (1.2)	14.8-43.9
MDC18	QCS-outer	26	3.7	1-50%	23.7 (0.6)	13.2-41.5
MDC18	TC-inner	40	2.7	10-25%	15.1 (1.3)	11.3-24.9
MDC18	TC-mid	0	0	0	0	0
MDC18	TC-outer	0	0	0	0	0
MDC18	**Totals**	**36.6 %**	**5.7 %**	**1-70 %**	**25.6 (0.58)**	**9.6 -50.2**

No Chaetopterid tubeworms were recorded from Cook Strait sites.

Bispira bispira spA. (bluish-white fanworm) beds

The polychaete bristleworm *Bispira bispira* spA, is a small Sabellid tubeworm with distinctive bluish-white feeding appendages (e.g., Figure 43). Over the last ~10 years, this species has been reported from four localised locations within Marlborough Sounds (Bob's Bay, Picton, on the northern shore of Waikawa Bay, in the entrance of Oyster Bay, and at Blow Hole Point in Pelorus Sounds) as well as one in Houhora Harbour (Davidson et al. 2011). Within Bob's Bay in Picton, *Bispira* are known to form a dense tubeworm bed in 3-6 m water depths within the bay, with the reported as an ecologically significant site within the Marlborough Sounds (Davidson et al. 2010b; 2011). NIWA in 2014, identified a *Bispira* bed on a small raised reef-like feature (referred to as 'The Pimple') within the entrance to Oyster Bay, within mid TC (O'Callaghan et al. 2014). Since then, other researchers have identified several smaller less dense patches within the same vicinity (Clark and Taylor 2016). At present, there does not appear to be any definitive information on whether this species is a cryptic native species not previously described, or whether this is an invasive species not yet documented. Other species in the *Bispira* genera have been likened to the invasive Mediterranean tubeworm, however, no genetic information is yet available to determine the origin or MPI-status of this species.

During the MDC18 survey, two *Bispira* tubeworms beds were surveyed using the high-resolution CBedcam tow-video system: one in Bob's Bay, Picton (Figure 42a) and the other on the Pimple in Oyster Bay, Tory Channel (Figure 42b). Video transects were run in multiple directions over both areas to determine the boundaries and extents of these tubeworm beds. Habitat characterisations were also aimed at determining the substratum type and community composition on the raised pimple-like feature in Oyster Bay, and across the tubeworm-bed in Bob's Bay that was previously mapped in 2015 (Davidson et al. 2015).

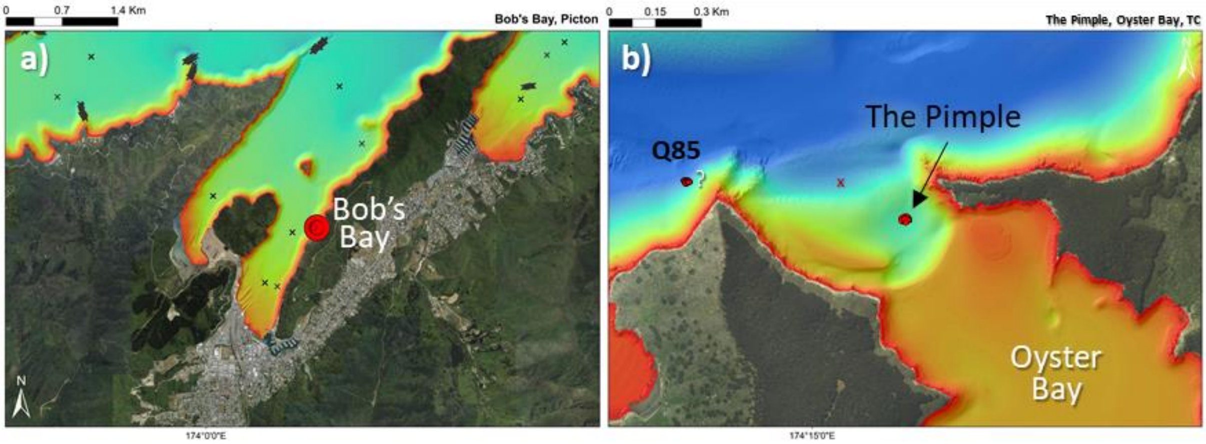


Figure 42: Locations of the two *B. bispira spA* tubeworm beds surveyed in Bob's Bay Picton (a) and inside the entrance to Oyster Bay in TC (b). The Pimple refers to the raised reef-like feature see in the HS51 Bathymetry – indicated by the arrow, comprised of soft mudstone that *Bispira* are densely covering; burgundy x = the approximate location where a 2nd Bispira cluster was recorded by Clark and Taylor 2016; Red bubbles denoted by Q85, indicates the location where a dense zone was recorded of small blue-white organisms (in keeping with *Bispira*, but that could not be clearly seen/verified from the Coastcam imagery).

Bob's Bay - *Bispira* bed: In Bob's Bay, *B. bispira spA* formed a dense fanworm-field across a ~58 x 48 m area (Figure 43a-d). The seafloor within the *Bispira*-zone was comprised of fine-silty muds (e.g., Figure 43a-b), while the adjacent seafloor was characterized by rough pebble/rubble debris, with varying levels of shell-debris (e.g., Figure 43e), with clear demarcations between these two habitats (Figure 44, Figure 45). The pebble-rubble zone continued to a depth of ~15.5 m, beyond which were silty muds with occasional burrowing sediment anemones (e.g., Figure 43e) extending down to at least 20 m. The occurrence and high-densities of *Bispira* tubeworms across the fine-silty mud zone (Figure 44) correlated well with Davidson et al.'s (2015) significant sites boundary-polygon (based on 2015-mapped distributions), indicating that the extent of the *Bispira*-zone had not changed noticeably through time – across the sections we surveyed. The MDC18 survey attempted to run one transect along-shore and the other perpendicular to shore. This second transect was blown slightly off course, but still managed to intersect the bed, with both transects intersecting the edge of the bed in six locations. Very high-densities (>70% to near 100% cover) of *Bispira* were recorded across bed within depths of 10.5 m on the western side to <4.5 m on the eastern side - where high densities of *Bispira* could be seen to continue into shallower water, but were beyond safe vessel navigation due to onshore winds.

The boundaries between the dense *Bispira* bed and the surrounding pebble/rubble fields was abrupt, with only low densities of *Bispira* occurring on the adjacent rubble within <1 m on the western, northern and southern boundaries (Figure 44). Only one observation of *Bispira* outside the boundary-polygon was recorded; located 22 m down slope from the western boundary in 15.4 m water depth (Figure 44). Here a few *Bispira* (~5-10 indiv.) were present within a very localized patch of muddy sediment within an otherwise expansive zone of pebble-sized rubble (e.g., Figure 43e).

Depth profiles taken along the two transects (Figure 45a-b) show that the dense *Bispira* bed is sitting on a subtly raised sediment feature along the upper slope of Bob's Bay (Figure 45a). Fine silty muds were observed across the entire extent of the bed, along with several horse mussels, indicating that there was at least enough soft sediment for adult horse mussels to bury.

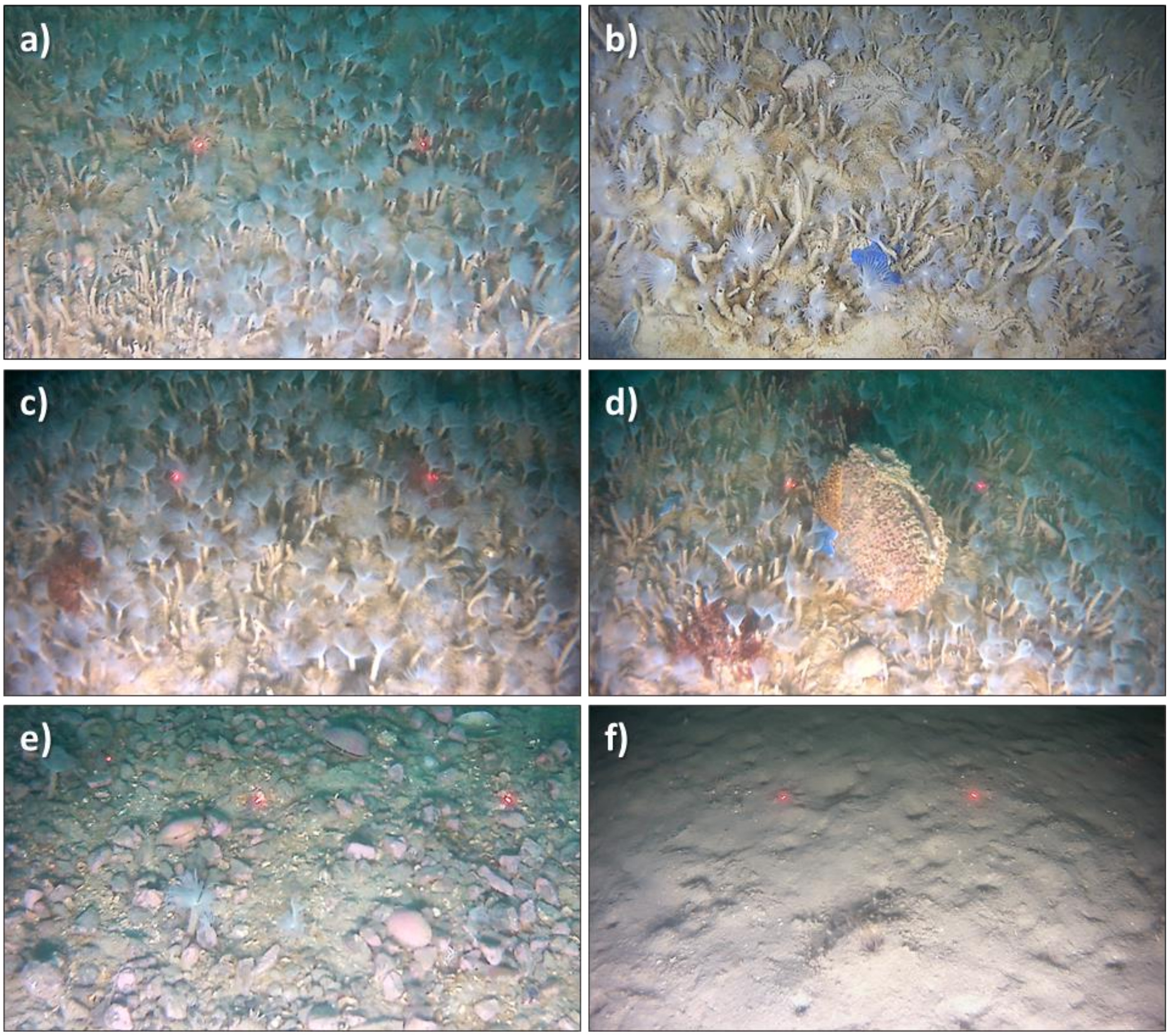


Figure 43: Examples of the dense field of the small blue-white tubeworms, *Bispira bispira* A, within Bob's Bay, Picton (MDC18 survey). a-d) *Bispira* bed in Bob's Bay Picton, Inner QCS (MDC18 Sites Q10 and Q11) in depth of 4.5-10.5 m, along with blue-coloured cushion star, *Meridiastra mortenseni* [b,d], horse mussel [d] and hermit crab [b]; e) Pebble rubble debris in depths of 10.5-15.5 m, 22 m from the main beds with a few isolated Bispira tubeworms; f) soft sediments in 15-20 m water depth, with few burrows and occasional burrowing sediment anemone.

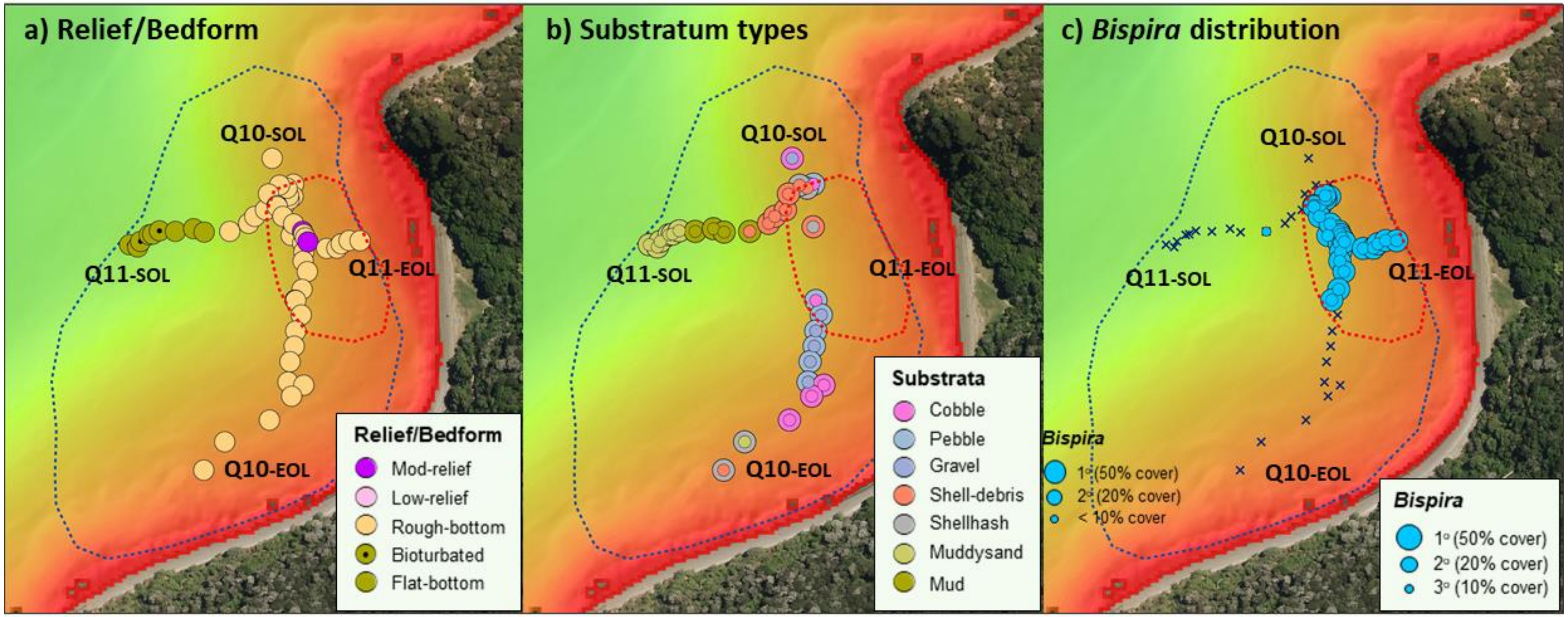


Figure 44: The distribution of substratum type, relief and bedform, and the occurrence and abundance of *Bispira* A. relative to the significant-site and previously mapped *Bispira* mound within Bob's Bay, Picton, (MDC18 surveys). Red dotted line = the 2015 distribution boundary of the *Bispira bispira* spA tubeworm mounds, mapped by Davidson et al. 2015; Blue dotted line = the preliminary 2011 boundary depicted prior to mapping this tubeworm mound. a-c) Show the location of two video transects from the MDC18 video-survey within Bob's Bay (MDC18 sites Q10 and Q11). SOL (Start of line) and EOL (End of line) are included to provide clarity on where the two transect start and finish. a) Seafloor relief and bedform type, based on video characterisations, along each transect; b-c) Seafloor substratum types - showing primary (larger circles) and secondary (smaller inner circles) substratum types: here substratum types have been split between graphs b and c showing abiotic substrata-only in b, and biogenic-habitats (here referring to *Bispira*) in graph c. Large blue circles depict rank %cover of x=0, 10%, 20%, 50% and 70% cover; where the large outer circle = primary habitat (≥ 50% cover), mid-sized inner blue circles = secondary habitat (≥ 20% cover), and where one inside the other denote = 70% cover of *Bispira bispira* spA.

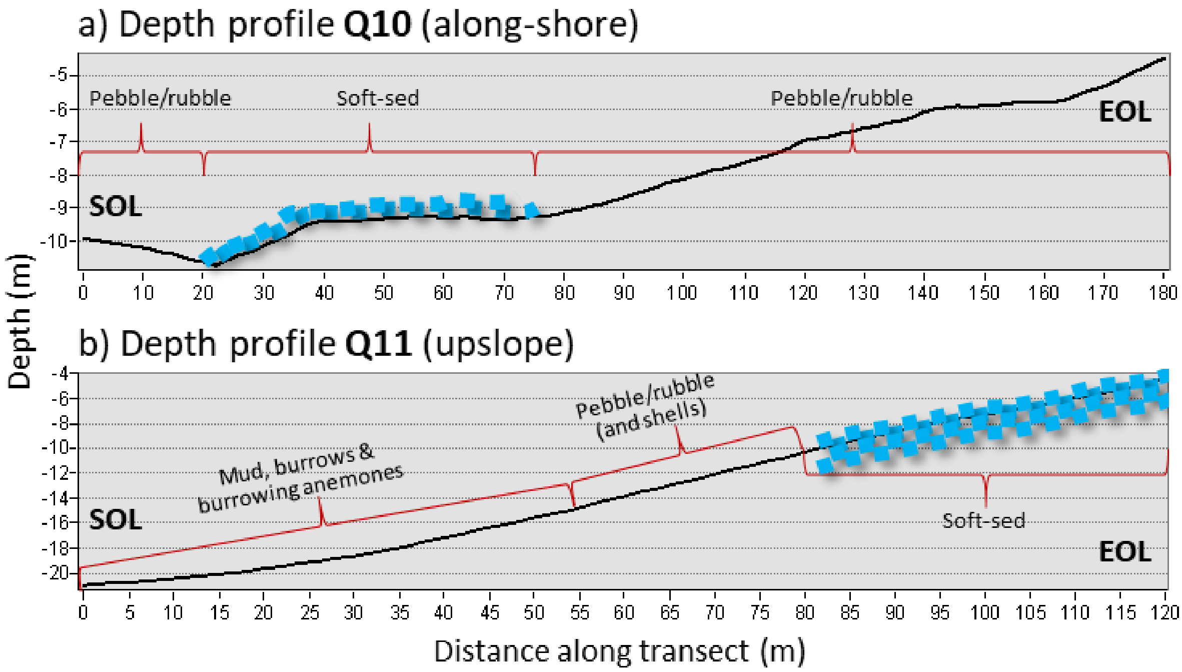


Figure 45: Depth profiles along two video-transects (MDC18 survey) -- showing the comparative depths, sediment types and position along the transect of the *B. bispira spA* fanworm bed (thick blue dashed lines). x-axis is distance travelled along each video-transect; y-axis is HS51 bathymetry in metres, The SOL (Start of Line) and EOL (End of line) position for each transect are shown in Figure 44). Brown brackets (centrally aligned) denote the depth-range of each habitat (mud, pebble/rubble, soft-sediments).

The Pimple - *Bispira* bed: 'The Pimple' describes a small raised feature that is 10 m in diameter with a height of 1 m above the surrounding seafloor, located within Oyster Bay, 160 m from the entrance to TC (Figure 42b; Figure 46). This feature had previously been side-scanned by NIWA in 2013, and a single camera drop identified an unusual fauna, including what appeared to be fields of tentacles (poss. anemones) and the tentacles of what was thought to be burrowing sea cucumbers (thought to be *Pentadactyla longidentis*), but poor visibility and high currents prohibited any further description. In order to ground-truth this raised pimple-like feature and identify and describe the community associated with this feature, we undertook a single towed camera across this feature (MDC18-Q180) that passed over feature in multiple directions. Based on the ground-truthing video observations, the Pimple appears to be the remains of a small pocket of heavily weathered mudstone that is elevated above the surrounding seafloor, due to it eroding more slowly than the surrounding sediments. Sediments surrounding the Pimple were characterised by low-relief cobbles and shell-debris the covered most of the seafloor. In contrast, the raised feature of the pimple was characterised by firm mud-like sediments, with sloping sides (MBES angles up to 20º, Figure 46). These sloping mud surfaces were densely covered (90-100%) with *Bispira bispira* spA tubeworms (e.g.'s in Figure 47, and referred to as '*Bispira'* hereafter). Other species recorded on the Pimple included low densities of burrowing sea cucumbers identified as *Thyone* spA, a few sparse horse mussels, a lemon sole, and snake stars (e.g.'s in Figure 47). Around the base of the Pimple, were several various sized biogenic clumps, with encrusting bryozoans, and an assortment of sessile invertebrates (e.g., sponges, sea squirts, small hydroids), as well as a few scarlet wrasses, and some drift kelp (*Cystophora*). On the eastern side of the Pimple, were thick clay-like like muds with rugose surfaces that had very few organisms, except for a few snake stars (e.g., Figure 47c). On the northern and western sides of the Pimple , the seafloor was characterised by extensive cobbles and shell debris (e.g., Figure 47a,g,j,k) that supported low to moderately high densities of burrowing sea cucumbers (*Thyone* spA, e.g., Figure 47j,k), abundant snake stars and cushion stars (*P. regularis*), along with green soft bryozoans (~0-10% cover, e.g., Figure 47j), moderately-large *Epiactis* anemones, and frequent occurrences of sub-adult blue cod (e.g., Figure 47g).

It is currently not known whether this *Bispira* species is a native or an introduced exotic. However, its dense very localised distributions and dense cover at new sites indicate that it may be an invasive species. Other studies within Oyster Bay have also recorded *Bispira* tubeworms in small clusters (Clark and Taylor 2016) at a site closer to the entrance of the Bay and only ~250 m NNW of the Pimple (‘x’ in Figure 42). While we could not verify *Bispira* from the video footage at Tio Pt in outer Te Punga Bay (MDC18-Q85), out-of-focus bluish-white clusters (indicative of *Bispira*) were present in discrete patches on the upper slope of this site (e.g., Figure 96s). This Tio Pt/Te Pangu site is right next to Oyster Bay and <800 m away from the Pimple, and only <600 m away from Clark and Taylor *Bispira* site. While the presence of *Bispira* at site Q85 would need to be verified, it does indicate that close monitoring of this species may be urgently required. Importantly, sabellid polychaetes, including the genera *Bispira*, can clone off juveniles enabling them to rapidly colonise localised areas once they arrive at a new location. This species has to date been treated as an undescribed native species (Davidson *et al*. 2011; O'Callaghan et al*.* 2014), however, given the discovery of high-density beds at multiple locations it would suggest that there is a pressing need to determine its MPI-status.

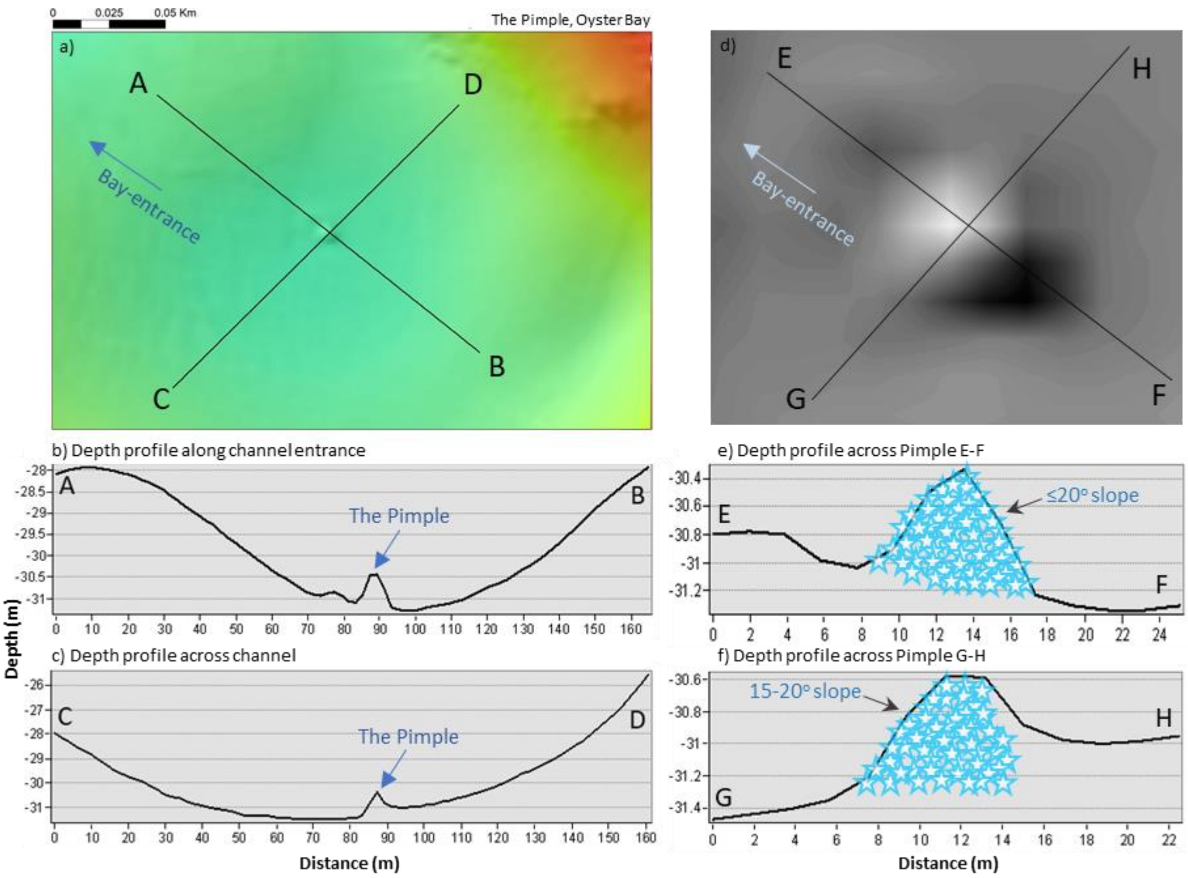


Figure 46: Depth profiles across the Pimple showing its bathymetric position within the channel (a-c), and the shape of the Pimple in zoomed-in view (d-f). b-c) show the Pimple is located in a 3-m deep furrow between the sill at the mouth of the channel [A] and the slope up into the shallow bay [B]; d) MBES-hillshaded relief of zoomed-in view of the Pimple showing the location of the two zoomed-in depth profiles: e-f) show the shape of the 10 m diam. by 1 m high feature (The Pimple) and the surrounding seafloor; Blue and white stars depict the occurrence of *Bispira* tubeworms over the feature.

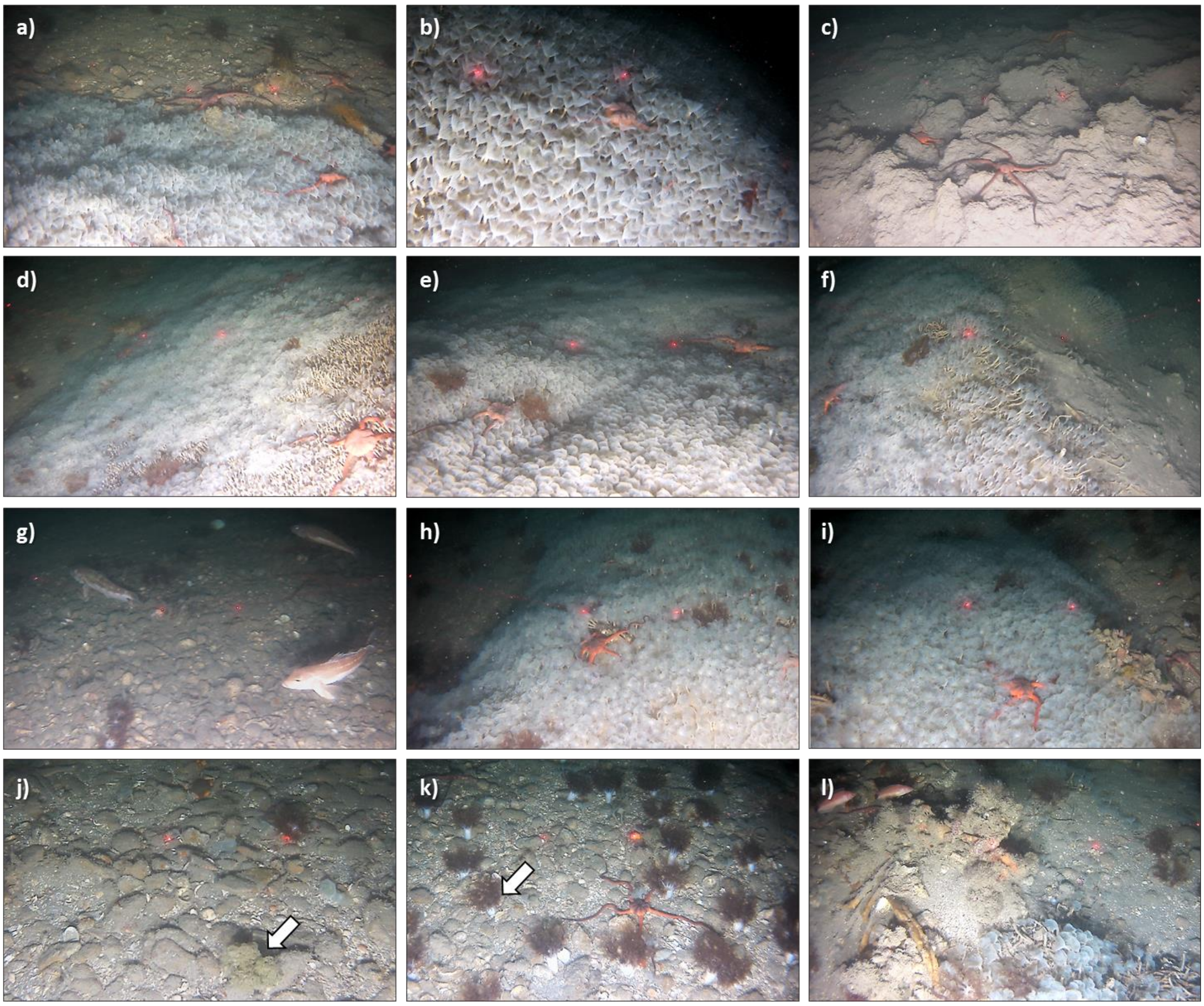


Figure 47: Representative images of the fields of small white tubeworms (*Bispira bispira* spA) densely covering the Pimple - a raised bathymetric feature in the entrance of Oyster Bay, TC. white arrow [j] indicates green soft bryozoa; white arrow [k] indicates one of the many burrowing holothurians *Thyone* spA) seen on and adjacent to the Pimple.

3.2.6 *Adamsiella* meadows

Background: *Adamsiella* is an endemic red alga that can form dense meadows in soft sediment environments, by attaching to small shell or cobble fragments, and is also known to occurs in amongst horse mussels, tube worm colonies, and on low-lying sediment-associated reefs (Davidson et al. 2011; Anderson et al. 2019). *Adamsiella* species are characterised by robust blades, that grow to a height of ~15-20 cm, with both species able to colonise and densely cover large areas of seafloor, with these meadows supporting elevated species diversity (Rainer 1981; Hare 1992). Two species of *Adamsiella* (A. *chauvinii* and *A. angustifolia*) commonly form meadows in New Zealand, with both known to occur in the Marlborough Sounds (Davidson et al. 2011; Anderson et al. 2019). Large beds of *Adamsiella* spp. meadows have been reported at several locations across the Sounds (e.g., Davidson et al. 2010b p17; Davidson et al. 2015 p32), where they are regarded as significant species for providing biogenic habitat for a variety of species, including bivalves, holothurians and fish (Davidson et al. 2011; Morrisey et al. 2018). Meadows within the Marlborough Sounds includes two large beds of *A. chauvinii*, one in depths of 15-23 m in Puriri Bay, East Bay (Significant AreESMS-4.1, ˜14.3ha area with 100% cover), the other is a large meadow growing near Houhou Point, Grove Arm, in inner QCS - described as having “some of the highest density red algae beds known in the Queen Charlotte Sound” Davidson et al. (2015, ESMS-4.4).

Ground-truthing surveys: *Adamsiella* was recorded from a total of four sites within the survey area (Figure 49)[23]. This included three beam trawl sites (BT17 survey: QC16, QC70 and QC20)[24], and two targeted tow-video transects run across the known *Adamsiella* meadow at Houhou Point (MDC18 Sites Q92 and Q322). The BT17 beam trawl surveys also collected *A. chauvinii* specimens from two sites within the survey area (Table 3-16; Figure 49-top image). A small fragment of *A. chauvinii* (10 ml) was collected from a red-algal meadow dominated by *Rhodymenia* in Big Bay, Endeavour inlet (outer QCS: Site BT17-QC16), while a notable amount of *A chauvinii* (10 L) was also collected from an extensive drift-algal mat in Okukari Inlet, near the entrance to TC (site BT17-QC70*, also see Section 3.4.8: Drift algae*) - indicating that *A. chauvinii* is likely growing nearby, although no *Adamsiella* was recorded in tow-video footage in TC, *Adamsiella* was recorded in Cook Strait south of TC beyond the survey area (CB17-C05 Lat. -41.3001057, Long. 174.2343655).

Table 3-16: *Adamsiella* specimens either collected during the BT17 Beam trawl survey, or seen during the CB17 and MDC18 surveys. BT17= MBIE Beam trawl survey 2017; MDC18 = this survey; no *Adamsiella* was recorded in the CB17 surveys. Voucher ID’s of *Adamsiella* specimens listed below are stored in the Macroalgal collection at NIWA, Wellington.

Survey	Subregion	Site	Location	Depth range (m)	Species	Vol (L)	Voucher ID
BT17	QCS-Outer	QC20	Otanerau Bay, East Bay	24-26	*A. angustifolia*	18	MS-183
BT17	QCS-Outer	QC16	Big Bay, Endeavour Inlet	17-27	*A. chauvinii*	0.01	MS-189
BT17	TC-Outer	QC70†	Okukari Inlet, TC	4-9	*A. chauvinii*	10	MS-204
MDC18	QCS-Outer	Q28	Otanerau Bay, East Bay	25	*Adamsiella sp.*	n/a	n/a
MDC18	QCS-Inner	Q92/Q322	Houhou Point	8.8-15.4	*A. chauvinii*	n/a	n/a

†GoPro video of the seafloor at this site shows an extensive accumulation of drift-weed on the seafloor.

[23] *Adamsiella* was also collected from three MBIE beam trawl sites in Port Underwood (Sites BT17-EC19 and EC26 comprising small fragments of *A. chauvinii* and EC27 comprising a small fragment of *A. angustifolia*) – these data are outside the scope of the current survey area so are discussed here further.

[24] All macroalgal specimens for the MBIE (BT17) beam trawl survey were collected and identified by Dr R. D’Archino (NIWA’s red algal taxonomy specialist), with *Adamsiella* voucher specimens (i.e., pressed algae and DNA subsamples) retained for each site (see Table 3-16).

Adamsiella angustifolia at Puriri Bay, East Bay.

The BT17 beam trawl surveys collected a notable amount of *A. angustifolia* (18 L) from a single site offshore of Puriri Bay, East Bay (BT17-QC20, 24-26 m depth) (Table 3-16; Figure 49-top image). This beam trawl site was characterised from GoPro footage and bycatch as a sparse to moderately dense horse mussel bed, with large volumes of red algae, dominated by *A. angustifolia*, along with high densities of sea cucumbers (*A. mollis*), heart urchins, red urchins, triplefins, and several newly settle blue cod (14-18 cm's size range). During the MDC18 surveys, a further two video transects were surveyed within Puriri Bay (Q27 and Q28). Site Q28 also supported a relatively extensive but very patchy low % cover zone of *Adamsiella* sp. with the seafloor at this site heavily dusted in fine depositional silt (e.g., Figure 48).

Adamsiella meadows have undergone a significant reduction in area based on surveys undertaken by Davidson et al. (2011 vs 2015), with characterisations from our surveys indicating further losses may have occurred since then, although more detailed site-specific comparisons between these studies would be required to verify this. Regardless, *Adamsiella* at site Q28 is unlikely to fare well under this amount of fine silt, indicating that further losses may occur. Previous descriptions of the red algal meadow within this bay were identified as *Adamsiella chauvinii* (Davidson et al. 2011 – Identified by R. D'Archino, *pers. comm.*). All specimens collected from the BT17-QC20 site were identified as *A. angustifolia* (by macroalgal specialist R. D'Archino, who was on the BT17 survey and the previous Davidson et al. 2010 survey), with specimens from the BT17 survey pressed and also retained for possible future molecular studies. Specific level identification was not possible from the video footage from BT17 or MDC18 sites within this bay due to visibility and the amount of silt covering the meadow. It is, therefore, unclear if *Adamsiella* at these sites refer to separate monospecific beds, or one or more meadows composed of both species (*A. angustifolia* and *A. chauvinii*).

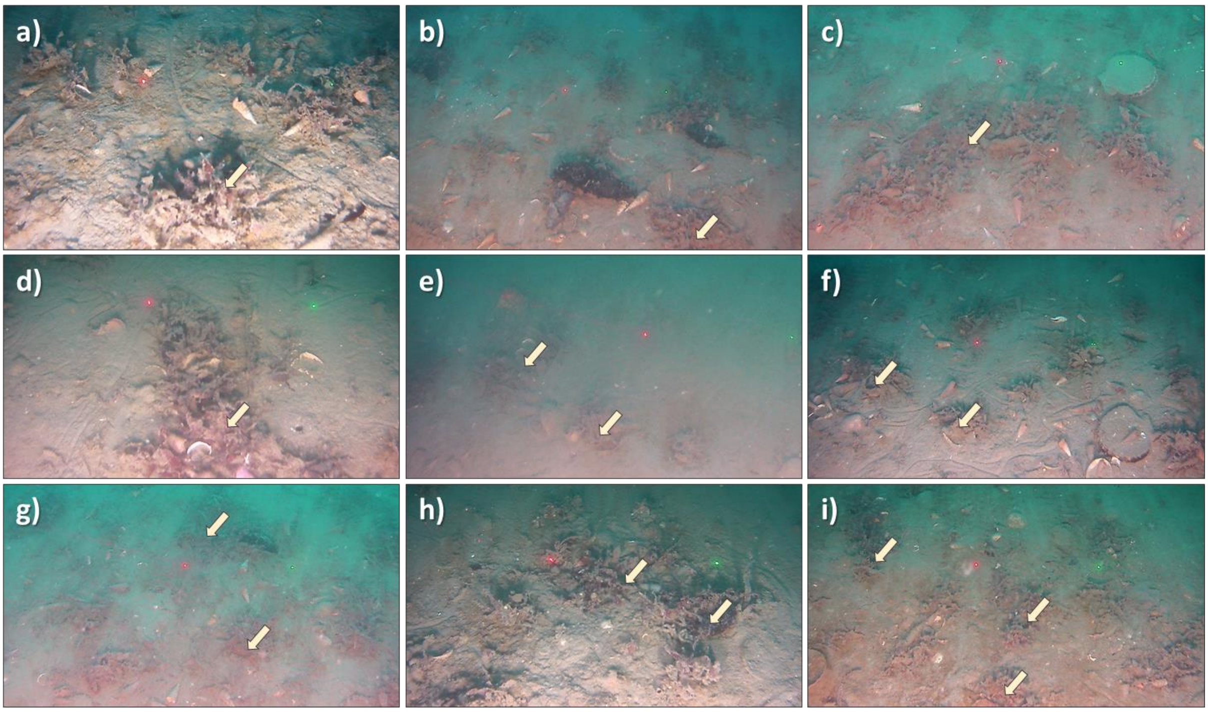


Figure 48: Patchy sparse to moderate % cover zone of red algae *Adamsiella* spp., heavily dusted in fine-depositional silts, from within Puriri/Otanerau Bays (MDC18-Q28). Arrow show examples of *Adamsiella* sp. patches. Other species include screwshells, common sea cucumbers (*A. mollis*) and scallops.

Adamsiella chauvinii meadow at Houhou Point.

To examine the spatial distribution and abundance of the *A. chauvinii* meadow at Houhou Point, relative to the newly HS51 bathymetry and MBES-derived data layers, we ran two bisecting towed video transects at this location (MDC18 Sites Q92 and Q322) (Figure 49A$^{1-4}$). We ran the first transect (Q92) as planned, perpendicular to shore from the seafloor plains up the slope and inshore across the *Adamsiella* meadow, the second transect (Q322), which was to be run across the sediment-groin parallel to the shore, to determine how far down the sides of the groin *Adamsiella* extended, could not be surveyed as planned due to prevailing winds and currents. However, this transect did successfully cross the outer section of the meadow down to 15.4 m where the meadow was becoming patchy and appeared to be becoming buried in muddier sediments (Figure 49A$^{1-4}$).

The *A. chauvinii* meadow at Houhou Point was growing out across an extensive sediment groin that has accumulated between the offshore reef and the shoreline (Figure 49A$^{1-2}$; e.g., Figure 50; Figure 51). The shoreward edge of the meadow began in 13 m below the cobble and shell debris zones, and continued up and across the entire sediment-groin to within a few metres of the offshore rocky-reef in 11.5 m (Figure 49A^{1}). The sediment across the groin was characterised by what looked like a base of fine to moderately coarse sand (e.g., Figure 50c,f,i), with varying amounts of small-sized shell debris (1-25% cover) and varying levels of finer depositional-sediments that covered and in-filled the meadow, especially closer to shore and further down the slopes (Figure 49A^{1}, e.g., Figure 50d, g). The meadow itself spans 95 m offshore by ≥45 m alongshore (Figure 51a,c), growing in depths of 8.8 m on top of the sediment groin near the offshore reef, down to at least 15.4 m down the groin-slope.

Within the meadow itself, *A. chauvinii* densities ranged from 10-100% cover, with most of the meadow supporting good densities (mean 69.3% cover ± 6.3 S.E). The thickest and most lush areas were seen across the top of the groin on the outer third of the meadow (e.g., Figure 50a,b,e and f), closest to the offshore rocky reef, while the deeper sections of the slope supported much patchier densities with increasing amounts of depositional sediments (e.g., Figure 50 d,f,g,i). For example, on the western slope (transect-Q322), mini-sediment ledges were seen in depths >12 m with notable amounts of sediment deposition partially burying the plants (e.g., Figure 50d,g), and what appeared to be decreasing amounts of *A. chauvinii* (depths >13.5 m) with increasingly muddier sediments as we neared the end of the transect in 15.4 m (e.g., Figure 50g).

It therefore unclear how far down the groin-slope the meadow extends and whether depth extents are consistent on all side of the meadow. Although we weren't unable to document the exact edge and maximum depth of the meadow on either side of the groin-slopes, Davidson et al. (2011) described this *A. chauvinii* meadow as occurring in water depths of 6-15 m with up to 100% cover in many places. This appears very consistent with our observations. To determine the areal extent of the meadow, we consequently used the maximum observed depth from the video observations of the four intersection points to extrapolate the edge of the meadow across the groin. This gives us a predicted meadow area of at least 3,263 m^{-2} (Figure 49A^{2} dotted red polygon = 'predicted meadow zone').

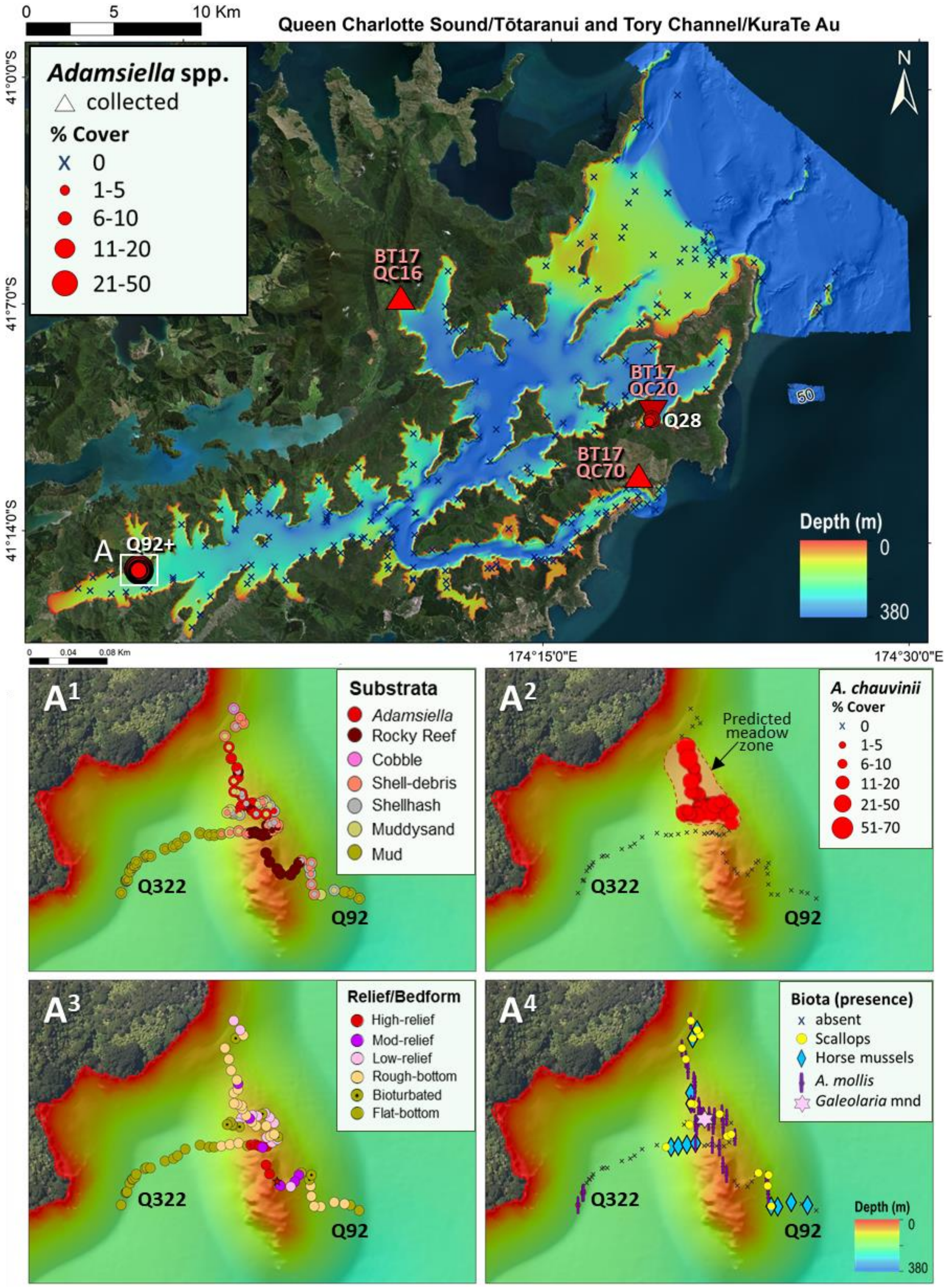


Figure 49: Distribution and relative abundance of *Adamsiella* spp. within the survey area. Triangles denote specimens collected in BT17 beam trawl survey (inverted burgundy triangle = *A. angustifolia* specimens; upright red triangles = *A. chauvinii* specimens; details provided in Table 3-16); Red bubbles in main graph = rank %cover of *Adamsiella* spp. (MDC18 video survey). Inserts A) zoomed-in section of the extensive *A. chauvinii* meadow at Houhou Point, inner QCS (MDC18 Sites Q92 and Q322); A^1) The primary and secondary substratum types at ~30 sec intervals along each transects. Larger-outer circles = primary substrata (≥ 50% cover), while smaller-central circles = secondary substrata (≥ 20% cover); A^2) The rank percent cover of *A. chauvinii*, depicting a relatively dense contiguous meadow across the sand groin between the reef and the foreshore; red-dotted/filled polygon = predicted meadow extent based on min/max observed depths; A^3) Relief and bedform structure across the feature; A^4) The presence of other common taxa.

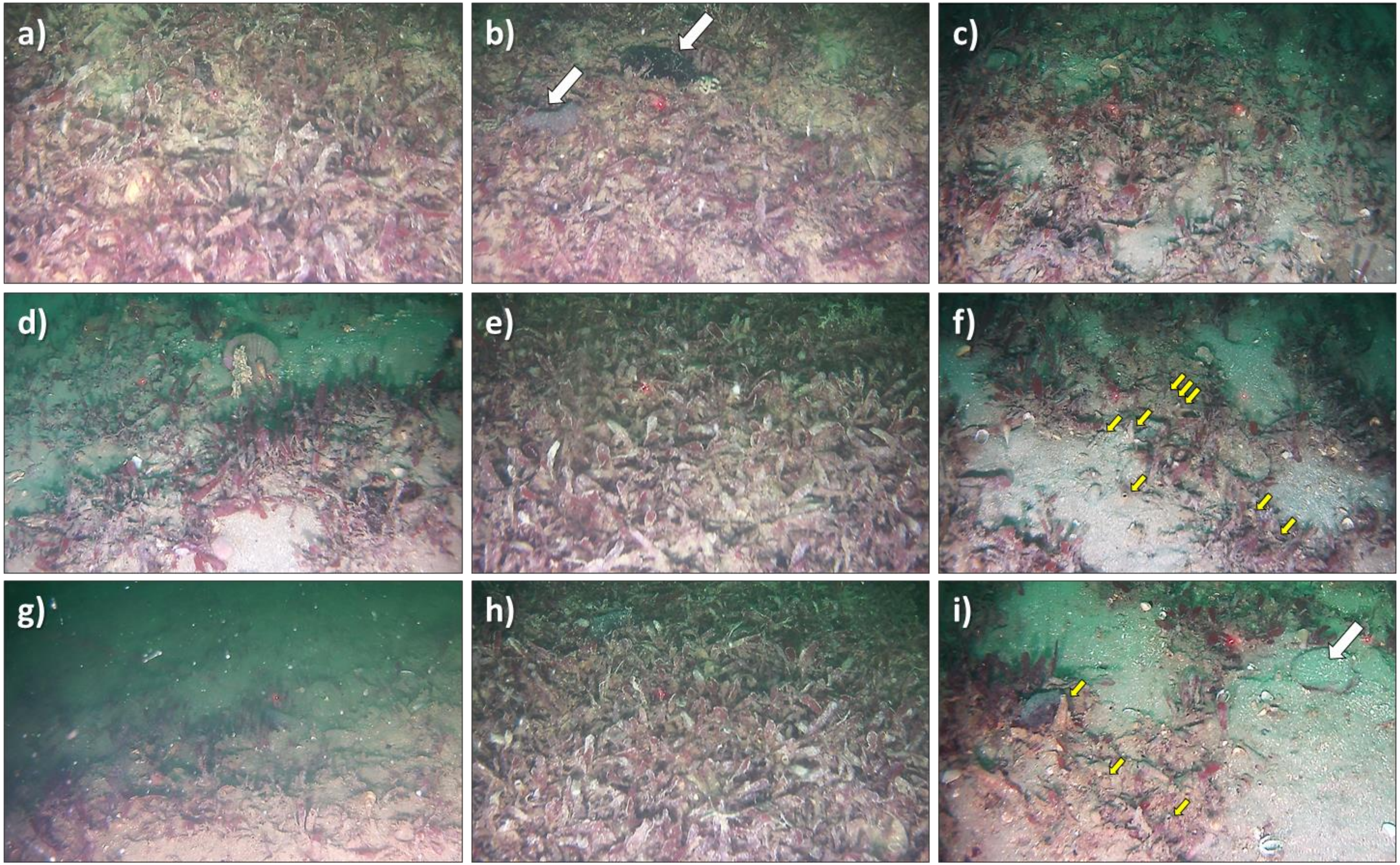


Figure 50: ***Adamsiella chauvinii* meadow across the sediment-groin at Houhou Point, Grove Arm, inner QCS (Sites MDC18-Q92 and Q322).** Left images = western side of the meadow; central images = central top section of the meadow; right images = eastern side of the meadow. Other animals seen in these images include *A. mollis* = white arrows in image-b; scallop = white arrow in image-I; and parchment tubeworms = yellow arrows in images f and i.

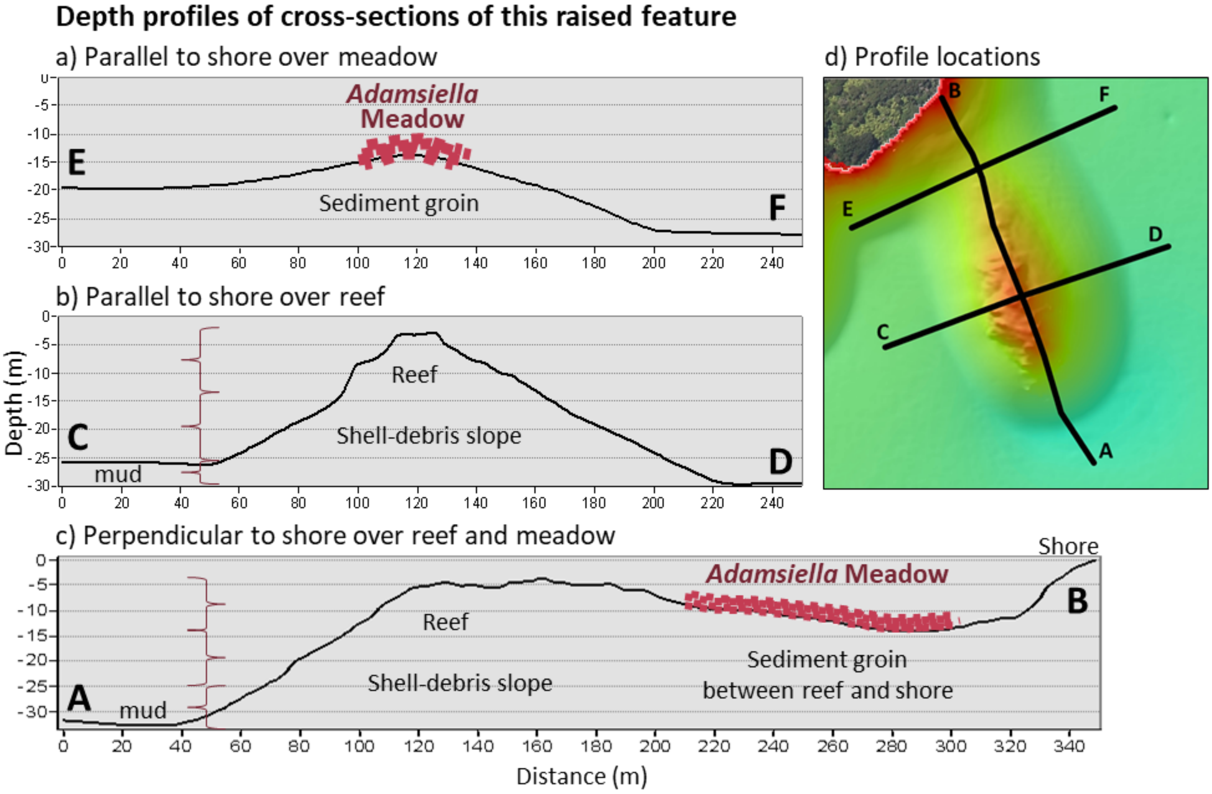


Figure 51: Depth profiles across the offshore reef and sediment groin, near Houhou Point, Grove Arm, Inner QCS, with illustrated location of the *Adamsiella chauvinii* meadow. a-b) Depth profiles running parallel to shore, a) across the sediment groin between the reef and the shore; b) over the reef itself; c) Depth profile running perpendicular to shore in an onshore direction. Depth profile positions are provided in adjacent map [d]. brown brackets indicate the depth range of habitat zones across the feature; mauve hashed bars depict the location the *A. chauvinii* meadow on the sand groin between the subtidal reef and the foreshore.

Species seen within this *A. chauvinii* meadow included scallops, *A. mollis* and a few horse mussel (Figure 49A[4]; e.g., Figure 50b,i). Spotties were also frequently seen along the transect, especially where rock outcrops were nearby. Parchment worms were also seen in various localised densities growing within the meadow (e.g., Figure 50f,i), especially in patchy *A. chauvinii* areas with depositional silts. Parchment worms (genus *Chaetopterus*) are small tubeworms with distinct white parchment-paper like tubes that were seen at numerous sites within the survey area – particularly in areas with extensive deposition of silty sediments on otherwise hard or shell-debris habitats. It is not presently known whether parchment tubeworms within the Sounds are native or exotic, and as such, it is unclear whether the presence of parchment tubeworms within this meadow is a sign of degraded environmental conditions due to sediment deposition, or whether these tubeworms are a pre-existing component of these meadows. However, given that parchment tubeworms are known to increase in local densities very rapidly in other locations around New Zealand, some form of monitoring of parchment worms across the Sounds, including significant sites such as this *A. chauvinii* meadow, would be advisable to identify both the temporal-changes in the distribution and abundance of these tubeworms, and any negative impacts on native communities.

3.2.7 Burrowing-anemones (*Cerianthus*)

Two forms of burrowing anemone (*Cerianthus* sp.) were recorded during the four video-surveys. One form, previously described in Davidson et al. (2011 p43), lives within a large erect tube that can stand at least 40 cm above the seafloor (e.g., Figure 52- left images), while most of the tube is below the sediment – and as such is referred to in Davidson et al. as 'burrowing anemone' (*Cerianthus* sp., referred to as *Cerianthus* sp1 hereafter). *Cerianthus* sp1 has been recorded from several locations within the Marlborough Sounds, within silty, shell and sandy sediments with low to moderate tidal flow, but are considered a significant species due to its rarity and low abundance (Davidson et al. 2011). This species has also been referred to as a tube-anemone (e.g., Clark et al. 2011).

A second type of burrowing anemone was also recorded in deeper silty sediments during the MDC18 survey (referred to as *Cerianthus* sp2 hereafter). This species lives within an almost totally buried tube where the tentacles of the anemone are near level with the sediment surface, or slightly raised surrounded by a small sediment mound (Figure 52- right images). *Cerianthus* sp2 was found in on deep thick-sediment slopes within the Sounds and across the seafloor plains (Figure 52- right images) co-occurring with *Amphiura correcta* (See Section 3.3.6 and Figure 77h).

Cerianthus sp1 *Cerianthus* sp2

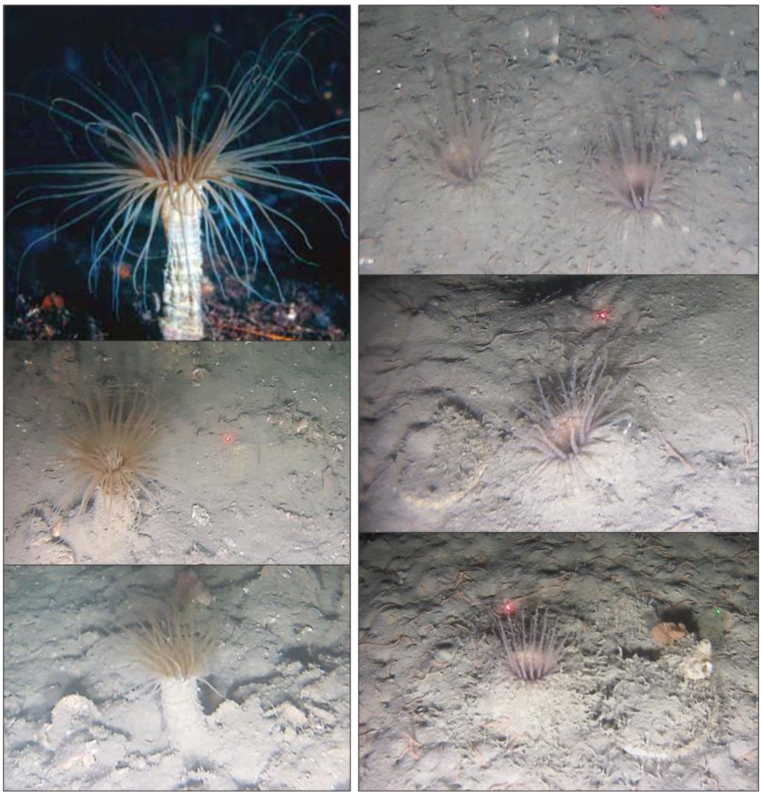


Figure 52: Examples of the two species of burrowing anemone (*Cerianthus*) recorded during the four video-surveys. Images on the left: *Cerianthus* sp1 illustrating the large erect tube that can stand up to at least 40 cm above the seafloor; (Top left image is from Davidson et al. 2011 - p43); Images on the right: *Cerianthus* sp2 illustrating the almost totally buried tube with the tentacles of this species near-level with the sediment surface (top right), or slightly raised surrounded by a small sediment mound (bottom right).

Burrowing/tube-anemones (Cerianthus sp1)

Burrowing/tube-anemones, *Cerianthus* sp1, were recorded in silty and shell debris habitats on the slopes within the Sounds in a mean depth of 32.0 ± 1.2 and depth range of 11.4-55.0 m (MDC18-survey:) at 26 sites (19.1% of all sites), but only 1.7% of records (excluding Cook Strait sites, Table 3-17; Figure 53), indicating sparse patchy distributions within these sites. Of the 79 records, between 1 and 3 tube-anemones (or anemone tubes) were recorded. Mid QCS had the highest percentage of *Cerianthus* sp1 sites (48%) and records (5.2%), followed by inner and outer QCS (16 % of sites) and records (0.7 and 1.8%), respectively (Table 3-17; Figure 53). Although no burrowing/tube anemones (*Cerianthus* sp1) were recorded within TC during these four video-surveys, *Cerianthus* sp1 have been recorded from TC during previous surveys, for example at 19 m in Ngamahau Bay (Clark et al. 2011) and Tio Point, Oyster Bay (Clark and Taylor 2016). No burrowing/tube anemones (*Cerianthus* sp1) were recorded in Cook Strait. The shallowest site supporting *Cerianthus* sp1 was at Edgecombe Point, at the entrance to Endeavour Inlet (MDC18-Q36), while the deepest site was at Bottle Rock at the entrance to Resolution Bay (MDC18-Q47), where *Cerianthus* sp1 were found on the shell debris slopes beneath these rock promontories. Sites with notable occurrences of *Cerianthus* sp1 were also found on shell and sediment debris slopes directly adjacent to deep reefs, for example, north of Patten Passage (MDC18-Q139), off deep reefs in Endeavour inlet (Q40 and Q39), and off Fitzgerald Bay (Sites Q72 and Q316), indicating that sediment and shell debris below rocky ridges may be important to this species.

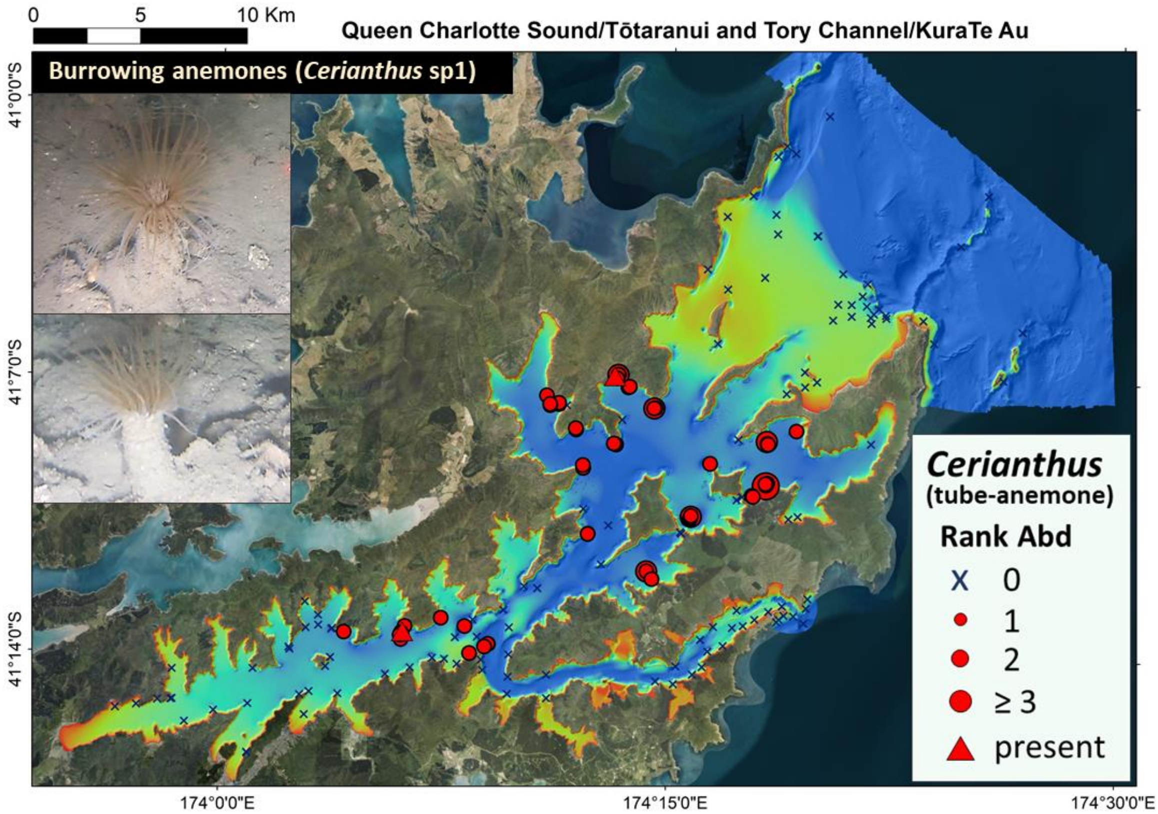


Figure 53: Distribution and rank abundance of burrowing/tube anemones (*Cerianthus* sp1), within the survey area. Bubble plot distributions coloured red are rank abundance per 15-sec call from the MDC18 survey; Red triangles represent presence from other video surveys (upright=HS51, inverted = CB17).

Table 3-17: Summary details of burrowing/tube anemones (*Cerianthus* sp1) recorded within QCS and TC (MDC18 survey only). QCS=Queen Charlotte Sounds, TC= Tory Channel. Totals and percentage values are presented for sites and records inside the Sounds only. Abd=abundance.

Survey	Subregion	Sites with *Cerianthus* sp1 (%)	Records with *Cerianthus* sp (%)	Abd. range per call	Depth (m)	
					Mean (SE)	Range
MDC18	QCS-inner	16.3	0.7	1-2	20.6 (1.8)	14.6-32.5
MDC18	QCS-mid	48.0	5.2	1-3	34.4 (1.6)	11.4-50.2
MDC18	QCS-outer	16.3	1.8	1-3	32.3 (1.7)	16.7-55.4
MDC18	TC-inner	0	0	0	n/a	n/a
MDC18	TC-mid	0	0	0	n/a	n/a
MDC18	TC-outer	0	0	0	n/a	n/a
MDC18	**Totals**	**19.1%**	**1.7%**	**1-3**	**32.0 (1.2)**	**11.4-55.0**

No burrowing anemones were recorded from Cook Strait sites.
** = 1 site only* (Dieffenbach Pt, MDC18-Q177).

Burrowing-anemone (Cerianthus sp2)

Burrowing-anemones, *Cerianthus* sp2, were recorded in silty sediments in depths of 24.6 down to 54.1 m (MDC18-survey: mean 40.5 ± 0.53) in 16.2% of all sites (excluding Cook Strait sites) (Table 3-18). Inner QCS had the highest percentage of *Cerianthus* sp2 sites (39.5%) and records (12.2%), followed by markedly few fewer sites and records in mid-QCS (16% sites, 1.4% records), while outer QCS had only a few specimens at 1 site (0.1 records) (Table 3-18;Figure 54). Outer QCS, however, also had two sites with burrows that were indicative of *Cerianthus* sp2, but actual anemones were not seen to verify their presence. Consequently, it is not known whether these burrows may have held *Cerianthus* sp2 individuals that were just not out feeding, or were simply similar-looking burrows made by other animals. No burrowing-anemones were recorded in Cook Strait, or within TC (Figure 54).

Table 3-18: Summary details of burrowing-anemones (*Cerianthus* sp2) recorded within QCS and TC (MDC18 survey only). QCS=Queen Charlotte Sounds, TC= Tory Channel. Totals and percentage values are presented for sites and records inside the Sounds only.

Survey	Subregion	Sites with *Cerianthus* sp2 (%)	Records with *Cerianthus* sp2 (%)	% Cover range	Depth (m)	
					Mean (SE)	Range
MDC18	QCS-inner	39.5	12.2	1->10	40.5 (0.6)	24.6-54.1
MDC18	QCS-mid	16.0	1.4	1-3	41.8 (1.0)	37.3-46.5
MDC18	QCS-outer	2.3	0.1	1-2	27.5 (.)	27.5-27.5
MDC18	TC-inner	0	0	0	n/a	n/a
MDC18	TC-mid	0	0	0	n/a	n/a
MDC18	TC-outer	0	0	0	n/a	n/a
MDC18	**Totals**	**16.2%**	**3.5%**	**1->10**	**40.5 (0.53)**	**24.6-54.1**

No burrowing anemones were recorded from Cook Strait sites.

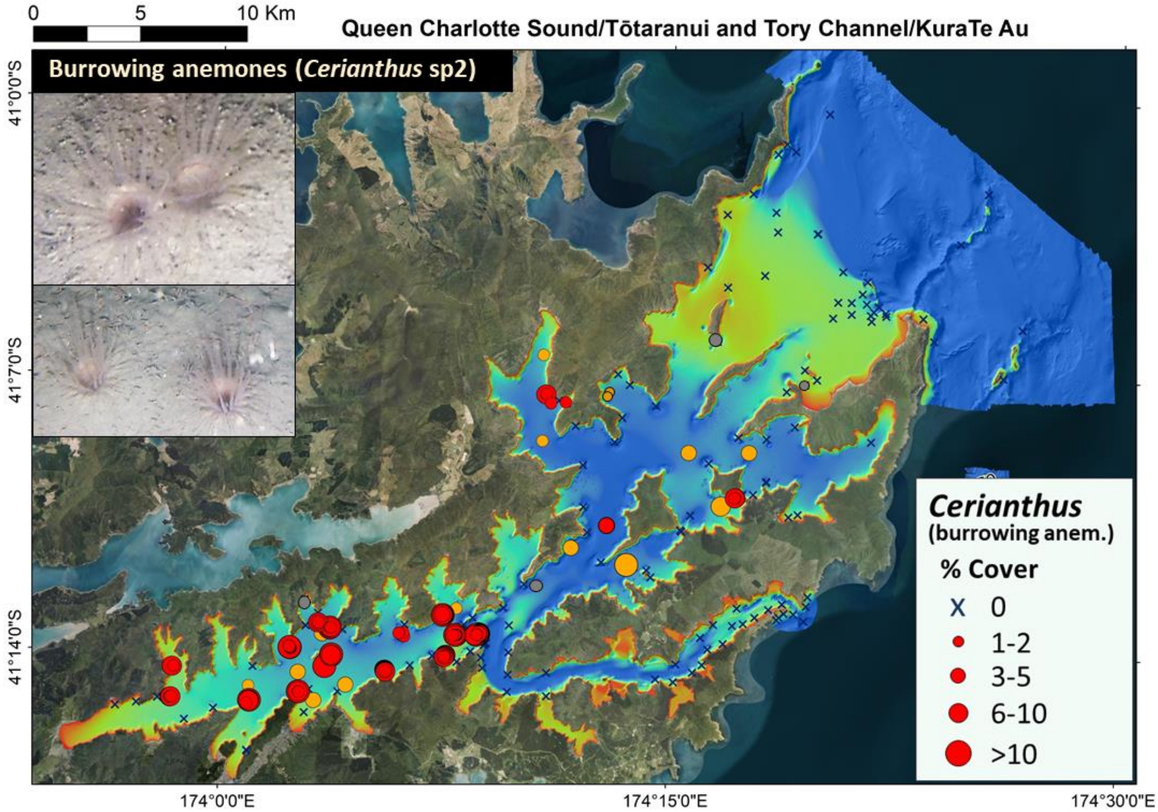


Figure 54: Distribution and rank abundance of burrowing anemones (*Cerianthus* sp2), within the survey area. Bubble plot distributions coloured red are rank abundance per 15-sec call from the MDC18 survey; Bubbles coloured orange = burrowing anemones counts (raw) from the HS51 drop-camera footage; grey circles = indicate possible, but unverified occurrence (i.e., anemone-like burrows, but no live anemones seen). burrowing anemones were not recorded in CB17 survey.

3.2.8 Brachiopod beds

Background: Brachiopods (commonly called lamp shells) are filter feeders belonging to an ancient Phylum that superficially look-like molluscan bivalves, but are comprised of two bilaterally symmetrical shells (Lee and Smith 2007, overview in MacDiarmid et al. 2013). There are 38 species from 26 genera within New Zealand waters, with 18 of these species' endemic to New Zealand (MacFarlan et al. 2009). Several species have been recorded from the Marlborough Sounds, with four common endemic species (*Magasella* [was *Terebratula*] *sanguinea; Calloria* [was *Waltonia*] *inconspicua; Neothyris lenticularis; and Liothyrella neozelanica*) recorded within the survey area (e.g., Davidson et al. 2011; 2015; McKnight and Grange 1991; Morrisey et al. 2015; Brown et al. 2016a). Brachiopods are found attached and/or free-living on a range of subtidal habitats from rock surfaces to soft sediments covered in varying amounts of shell debris (MacDiarmid et al. 2013). In some locations, brachiopods can form dense beds sometimes 2 or 3 layers deep and up to 1000 individuals per m^{-2} (Lee and Smith 2007), with brachiopod beds (defined as densities ≥1 per m^{-2}) classified as 'sensitive marine benthic habitats' (MacDiarmid et al. 2013). In some areas dead brachiopod shells can also contribute to habitat complexity and provide habitat for small animals (MacDiarmid et al. 2013).

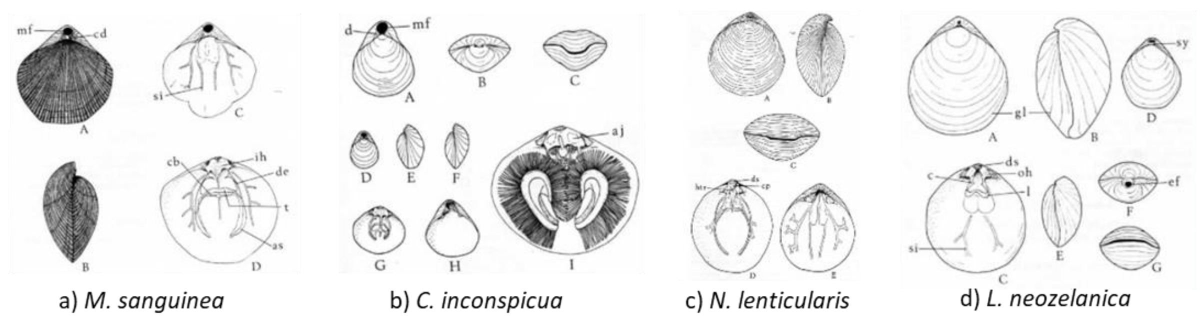


Figure 55: Diagnostic shell-morphologies of four common brachiopods (from Bowen 1968, with taxonomic names updated), recorded from the survey area. a) *Magasella sanguinea* (red-ribbed)*;* b) *Calloria inconspicua* (small smooth; known as witches toenail)*;* c) *Neothyris lenticularis* (large smooth lampshell)*;* d) *Liothyrella neozelanica* (white lampshell)*.* Sizes are not to scale (see Bowen 1968 for full taxonomic descriptions).

Ground-truthing surveys: Previously, tow-video imagery of the seafloor using standard resolution cameras made detecting and distinguishing small cryptic animals (≤ 5 cm in size), such as brachiopods, difficult and unreliable, except where present in aggregated beds (MacDiarmid et al. 2013)[25]. The incorporation of higher definition (≥1080p resolution) underwater imagery, such as used in the MDC18 and CB17 surveys, has greatly improved the ability to detect smaller cryptic species, however, some limitations to detecting and distinguishing small cryptic species are still present (e.g., water clarity, height off the seafloor, distinguishing living from dead specimens, etc.). Both the MDC18 and CB17 towed-camera surveys used the CBedcam two 1080p cameras system, enabling brachiopods to be relatively easy to detect during calls at most sites. The presence of brachiopods was recorded in real-time, and where possible the rank abundance of brachiopods (0, 1-2, 3-5, 5-10, >10) and the occurrence of notable brachiopod beds were also recorded. However, community characterisations were made in real-time, under variable environmental (and therefore image-quality conditions) so small sized animals like brachiopods can easily be missed in complex habitats, especially where large similar-sized shell debris co-occurs. Therefore, while the occurrences of brachiopods and beds of brachiopods, presented below, provide valuable, and often new, information, there are also some important limitations/caveats to these data. Specifically: i) The spatial distributions presented here provide valuable presence data, but should not be used to determine true-absence of brachiopods - as absence from video-calls may simply reflect the inability to detect them rather than their true-absence from a site/call; ii) While species level identification was possible in some close-up imagery, this was not consistent within or between sites, so we present generic level distributions with some species level information; iii) Distinguishing living versus dead specimens was difficult at some sites/calls, particularly when large amounts of similar-sized shell-debris was present (which was often the case in brachiopod zones or beds). However, brachiopod 'presence' at a site/call, was only made where 'living' brachiopods were identified. Because of the living vs dead detectability-issue, 'rank abundance' should be used cautiously and should be validated by detailed post-processing of the video-footage along with *in situ* sampling. Brachiopod specimens were also collected from some beam-trawl sites (BT17 survey within depths of 3-30 m) within the survey area – and thus provide some verification of brachiopod distributions and species-level identifications.

[25] Video-imagery from the low resolution and natural light cameras used in the BT17 and HS51 surveys were rarely able to detect or distinguish brachiopods, but in some limited situations provide additional presence-only data (n=3).

Brachiopods were recorded at almost a third of the MDC18 sites surveyed (29.5%), in depths of 8.6 down to 131.1 m (mean depth of 40.2 m ± 2.0 SE; Table 3-19). However, most sites had only a few brachiopod records (3.3% of all records), indicating that while brachiopods occurred in most locations, their occurrences within sites were very localised (Table 3-19; Figure 56). Mid-QCS and deep Cook Strait sites, had the highest percentage of brachiopod sites (64% and 50%) and records (7.7% and 9.6%), respectively, while Tory Channel supported the fewest[26] (<10% of sites and <0.6% of records) (Table 3-19). An additional 22 brachiopod records from 7 sites were recorded during the earlier CB17 video-survey (Figure 56), in water depths of 17-35 m (Mean depth 22.8 m ± 4.13 SE). Six brachiopod species were preliminarily distinguished from tow-video imagery. Three of these (*M. sanguinea*, *C. inconspicua* and *N. lenticularis*) were verified from collected specimens during the BT17 beam-trawl (i.e., depths <30 m; e.g., Figure 57a-i) and MDC18 dredge (D04 and D06) surveys. *M. sanguinea* is a small-medium sized (≤45 mm) red-ribbed brachiopod (Bowen 1968; Cooper and Lee 1993; also see Figure 55a; e.g., Figure 57b) that has been commonly recorded across the Marlborough Sounds (e.g., Davidson et al. 2011; 2015), and at some sites can form extensive brachiopods beds (e.g., Horse Shoe Bay, Brown et al. 2016a). *C. inconspicua* (or Witches Toe Nail) is a smaller sized (≤25 mm) smooth red brachiopod (Bowen 1968; Cooper and Lee 1993; also see Figure 55b; e.g., Figure 57b) - that has been reported from numerous locations within the survey area (e.g., McKnight and Grange 1991; Morissey et al. 2014; Brown et al. 2016a). *N. lenticularis* is the largest (at least 60 mm) brachiopod species found in New Zealand waters, with a smooth red shell that has the beak strongly curved towards the dorsal value (Bowen 1968; Jeff Robinson *pers. comm*.; Figure 55c; e.g., Figure 57a,d,g), and is known from numerous sites within the Marlborough Sounds, with notable beds within the survey area recorded in East Bay (e.g., ESS 4.25), Houhou point (ESS 4.4), and Grove arm (ESS 4.7 and 4.8) (Davidson et al. 2011; 2015). During the current surveys, no specimen collections were made deeper than 30 m, so the remaining three species that were only observed in tow-video footage in depths >30 m could not be taxonomically identified/verified. Although these species were able to be morphologically distinguished in some close-up imagery, species-level identifications were not able to be recorded consistently from video-footage across the Survey area, and, therefore are only presented as generic 'brachiopods' in summary distribution maps.

[26] Likely reflecting the reduced sampling effort in Mid-TC, and the reduced detectability of small taxa/ brachiopods due to high currents resulting in higher-altitudes and/or faster-speed along the transect.

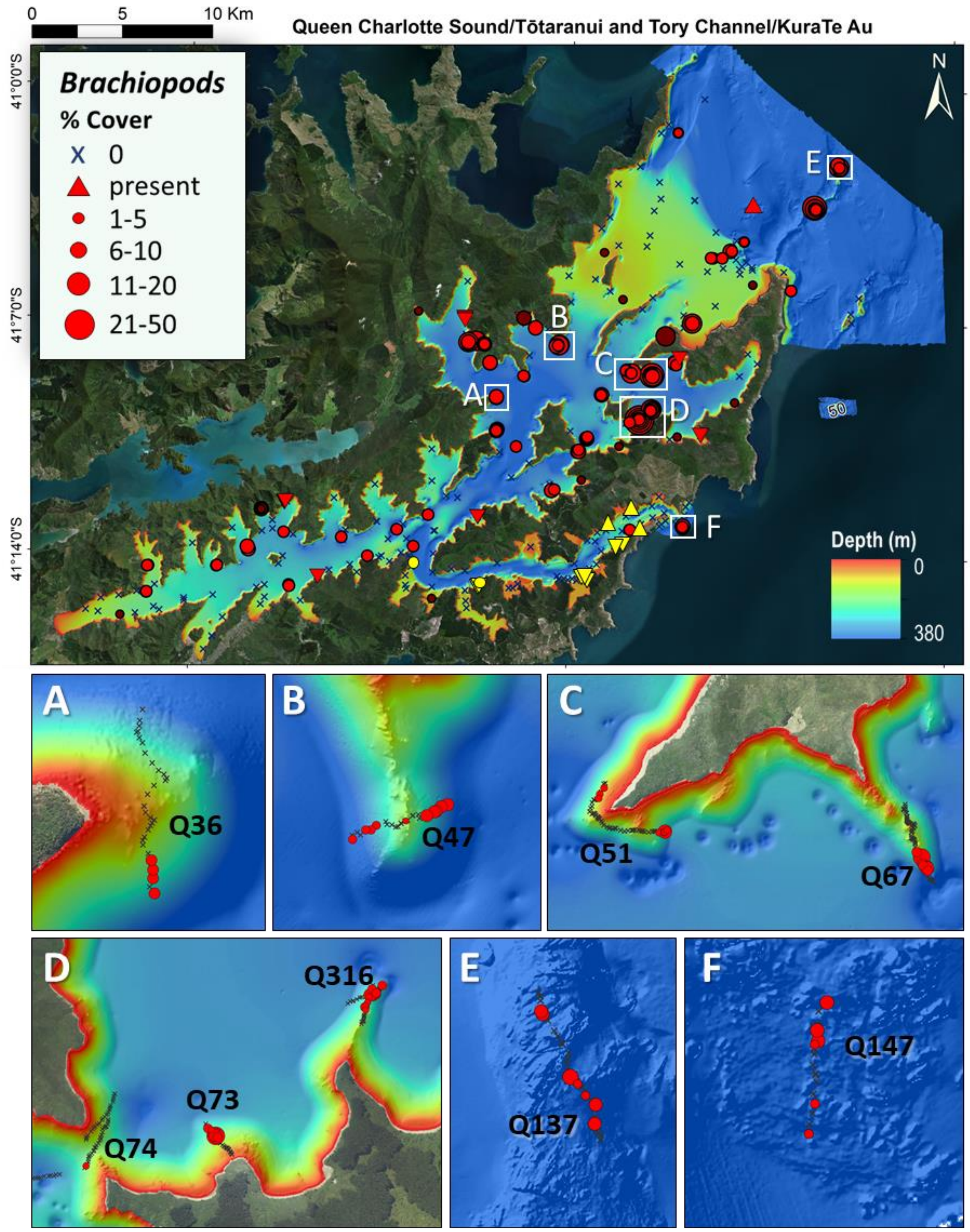


Figure 56: Distribution and relative abundance of brachiopods spp (mixed genera) within QCS, TC and Cook Strait. Bubble plot distributions coloured red are rank %cover per 15-sec call from the MDC18 survey; Bubbles coloured dark-burgundy = Brachiopods collected in the beam trawls (p/100 m^{-2}); Yellow bubbles = Brachiopod counts (raw) collected in the MDC18 dredges samples. Red triangles represent presence from other video surveys (upright=HS51, inverted = CB17), while yellow triangles represent collections from previous NIWA surveys (upright=Morrisey et al. 2015; inverted = Brown et al. 2016a). Plots A-F) show zoomed-in examples of brachiopod distributions and relative abundance from the MDC18 survey, with plots A-D) Mid to outer QCS sites; and (E-F) Deep reef sites in Cook Strait.

Table 3-19: Summary occurrences of brachiopods recorded in video footage by sub-region (MDC18-survey only[27]). QCS=Queen Charlotte Sounds, TC= Tory Channel; CStrait=Cook Strait.

Survey	Subregion	Sites with brachiopods (%)	Records with Brachiopods (%)	Depth (m)	
				Mean (SE)	Range
MDC18	QCS-CStrait	50	9.6	102.4 (5.3)	33.6-131
MDC18	QCS-inner	23	1.6	25.2 (1.4)	9.4-37.0
MDC18	QCS-mid	64	7.2	31.7 (1.2)	8.6-59.2
MDC18	QCS-outer	28	4.0	31.5 (0.9)	15.7-55.6
MDC18	TC-CStrait	14	3.0	95.4 (4.4)	80.2-112
MDC18	TC-inner	*10	0.4	32.9 (n/a)	32.9-32.9
MDC18	TC-mid	0	0	n/a	n/a
MDC18	TC-outer	9	0.6	32.8 (0.3)	32.5-33.1
MDC18	**Totals**	**29.5%**	**3.3%**	**40.2 (2.0)**	**8.6-131.1**

** = 1 site only*

Table 3-20: Brachiopod specimens collected in BT17 beam-trawls for sites within the survey area, and in MDC18 dredges. BT17 sampling was only undertaken in depths 3-30 m, while MDC18 dredge sites were targeting deep slope shell debris habitats. Table presents the number of individuals collected per species per site. Tow-depth is based on vessel-measured depth at the start and the end of tows and is presented as minimum-maximum of those depths. NB: the depth at which the brachiopods were collected is unlikely to represent the entire depth range, but rather some depth within that tow.

Survey	Subregion	Location	Site	Species	Tow-depth (m)	Count
BT17	QCS outer	Near Motuara Is.	QC04	*N. lenticularis*	12.6-13.0	4
BT17	QCS outer	West of Long Is.	QC06	*M. sanguinea*	15.8-17.4	4
BT17	QCS outer	Te Huahua Bay	QC10	*C. inconspicua*	21.4-22.6	1
BT17	QCS outer	Papatoia Bay	QC13	*M. sanguinea* *C. inconspicua*	21.9-22.6	4 5
BT17	QCS outer	Resolution Bay	QC14	*N. lenticularis* *M. sanguinea*	22.9-26.7	2 13
BT17	QCS outer	East Bay	QC19	*M. sanguinea* *N. lenticularis*	25.2-28.1	1 2
BT17	QCS outer	East Bay	QC20	*N. lenticularis*	25.1-25.8	3
BT17	QCS mid	Endeavour Inlet	QC16	*N. lenticularis* *M. sanguinea*	17.6-27.9	1 1
BT17	QCS mid	Wharehunga Bay	QC22	*M. sanguinea*	17.8-30.1	1
BT17	QCS mid	Te Ipapakereru Bay	QC25	*M. sanguinea*	14.6-30.9	5
BT17	QCS inner	Kaipakirikiri Bay	QC46	*N. lenticularis* *C. inconspicua*	15.3-23.2	1 1
BT17	QCS inner	Ngakuta Bay	QC55	*N. lenticularis*	21.5-22.9	1
BT17	TC inner	Hitaua Bay	QC36	*M. sanguinea*	11.4-15.4	1
MDC18-Dredge	TC inner	Slope Sth of Dieffenbach Pt	D04	*N. lenticularis*	~25-45 m	1
MDC18-Dredge	TC mid	Motukina Bay	D06	*M. sanguinea*	47-49 m	1

[27]HS51 imagery was mostly too short and/or not able to distinguish small cryptic taxa due to lower light.

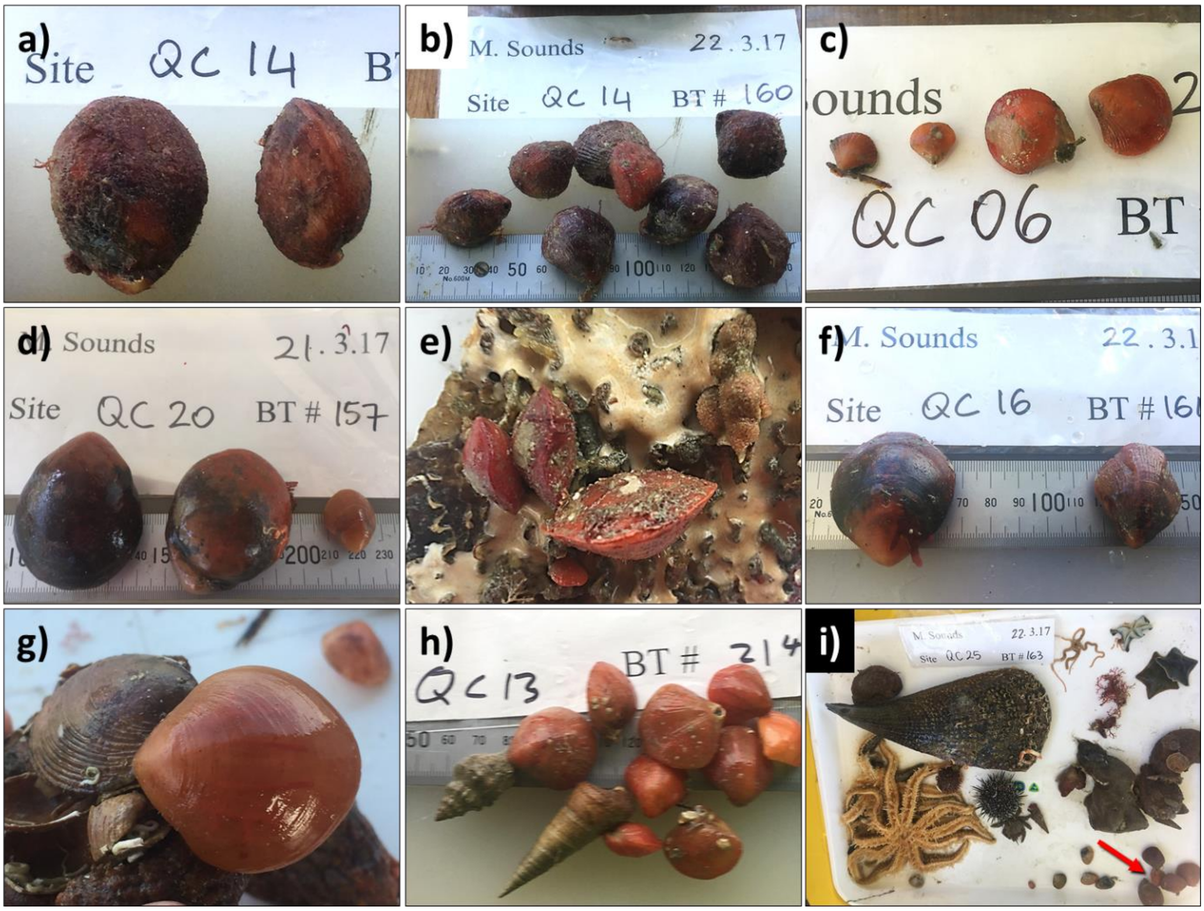


Figure 57: Examples of brachiopod (lampshell) specimens collected from mid to outer QCS sites in the MBIE BT17 beam trawl survey 2017. a) *N. lenticularis* inner Resolution Bay (BT17-QC14); b) *M. sanguinea* inner Resolution Bay (BT17-QC14); c) *M. sanguinea* from the commercial scallop bed west of Long Island (BT17-QC06); d) *N. lenticularis* Matiere Point, East Bay (BT17-QC20); e) *C. inconspicua* growing on a live horse mussel, near Motuara Is. (QC04); f) *N. lenticularis* [left-smooth] and *M. sanguinea* [right-ribbed] from inner Endeavour Inlet (BT17-QC16); g) *N. lenticularis* – up-close, growing on biogenic-sea squirt clump (East bay, QC19); h) *M. sanguinea* [ribbed] and *C. inconspicua* [smooth] Papatoia east of Long Island (BT17-QC13); i) red arrow indicated small brachiopods (*M. sanguinea*) collected from in amongst horse mussels, Te Ipapakereru Bay, Mid QCS (BT17-QC25).

Within the Marlborough Sounds, brachiopods were recorded in depth of 8.6 – 59.2 m (mean depth of 30.7 m ± 0.7 SE MDC18 survey), within all subregions of the Marlborough Sounds, with the exception of mid-QCS which had very few sites surveyed (All four surveys - Figure 56; MDC18 - Table 3-19). Brachiopods, however, are known to occur on both sides of the mid-TC based on earlier biologically-intensive studies, with two species of brachiopods (*M. sanguinea* and *C. inconspicua*) collected (e.g., Morissey et al. 2014; Brown et al. 2016a - yellow triangles in Figure 56). Within QCS, brachiopods (identified in MDC18 close-ups and BT17 collections as *M. sanguinea, C. inconspicua* and/or *N. lenticularis*) were most commonly recorded on the deep slope regions in depths >25 m, where shell-debris was heavily veneered in sediment (e.g., Figure 58), and were part of the characteristic taxa of deep slope habitats (also see: Section 3.3.4 - *QCS Deep slope communities*). The occurrence and densities of brachiopods in these deep slope habitats were highest in sites with ample shell debris, particularly below rocky promontories, such as in Resolution Bay, East Bay and Endeavour inlet (Table 3-20; Figure 56; Figure 58), possibly indicating areas of good current and therefore plankton food supply, but also the upper slope zones below these promontories support beds of live infaunal bivalves (e.g., see Section 3.3.1 – *Live T. laticostata beds*) that would ensure the continued supply of shell debris down slope. However, brachiopods were also found in shallow areas throughout the Sounds, including in horse mussel beds, where they were found both growing on the shells of live horse mussels, or on or amongst sediment-veneered shell debris (e.g., MDC18-Q139; BT17-QC20 and QC25 - Figure 57; Figure 58d,e,i).

Within the Cook Strait and at the entrances to the Sounds (depths >30 m), brachiopods were recorded in depths of 33.5-131 m (mean depths of 100.6 m ± 4.1 SE) at 50% of all sites and 9.6 % of records (Table 3-19, also see Table 3-49: *Cook Strait deep reef community* structure.). Although brachiopods were recorded over a variety of depths on these reefs (e.g., Figure 56E-F), they were mostly found in small/localized low-high density patches (e.g., Figure 59). Three additional brachiopod species were observed in depths >30 m (see Table 3-49). The most common brachiopod was a small light-coloured (whitish-cream) brachiopod (poss. *L. neozelanica* [28]), which was present in low to high density patches on three deep rocky reefs in Cook Strait (Cooks Rock - MDC18 Sites Q134, Q137; and the Brother - Q182), and on deep reefs at the entrance to QCS (>30 m) (e.g., Figure 59). A small pink unidentified brachiopod was also recorded on the same three deep reefs in Cook Strait, while a third darker-coloured (black-tinge, but also heavily encrusted) brachiopod (poss. *Notosaria nigricans*[29]) was recorded in lower numbers at three deep reef sites (MDC18 Sites Q134, Q137, Q147 - Table 3-49). Collections or high-resolution imagery would be required to taxonomically identify these deep-reef brachiopod species. However, these reefs are in extremely exposed, treacherous waters with extreme currents, and are very deep with very rugged topography making them extremely difficult and dangerous to collect specimens or get closer-up video-imagery from these sites. During the MDC18 surveys, NIWA's deep-water Coastcam was used for all Cook Strait sites, as it is extremely durable and was a great asset in collecting imagery from these hazardous high-current deep-reef systems. However, due to underwater (on-frame) battery limitations, only a single light could be used with a single forward-facing 1080p video camera. Coastcam's limited lighting, meant video-imagery was poorer than imagery acquired by the dual light and dual video-camera system of CBedcam (designed for shallow depths). However, due to the quality and success of the CBedcam, NIWA's Coastcam is being upgraded and fitted with a fibre-optic cable (similar to CBedcam), this means that power limitations would be removed allowing for dual lighting and video-cameras. Future deployments using this upgraded fibre-optic system, would greatly improve the illumination of the seafloor in these dark environments resulting in significantly better video-imagery, which would enable better taxonomic identification of these deep sessile fauna.

Twelve MDC18 sites were characterized as having conspicuous beds or fields of brachiopods that meet MacDiarmid et al. (2013) definition of 'sensitive marine benthic habitats' (Table 3-21). These brachiopod beds were mostly in depths of 30-48 m, with a few beds in depths as shallow as 25 m (e.g., Figure 56 A-D; Figure 58). Several of the most conspicuous beds were recorded on the deep slopes below rocky promontories in Resolution Bay (Figure 58a-b, ~38-45 m depth range), East Bay (Figure 58c-d, 32-46 m) and Endeavour inlet (Figure 58e-f, 31-39 m), while localized dense patches of brachiopods were also present on ledges and walls on deep reefs in the Cook Strait (e.g., Figure 59; Table 3-21).

[28] *L. neozelanica* is a small-medium sized (≤ 53 mm) white brachiopod with an elongate oval shell with prominent growth lines (Bowen, 1968), that occurs predominantly in depths >18 m down to 800 m and has been recorded from several sites in Cook Strait (Dawson 1971).
[29] *N. nigricans* is a distinctive black ribbed brachiopod small-medium size (≤ 20 mm) that occurs in water depths of up to 880 m (although it is more common in depths <200 m) and has been recorded at many locations in Cook Strait (Bowen 1968; Lee 1978).

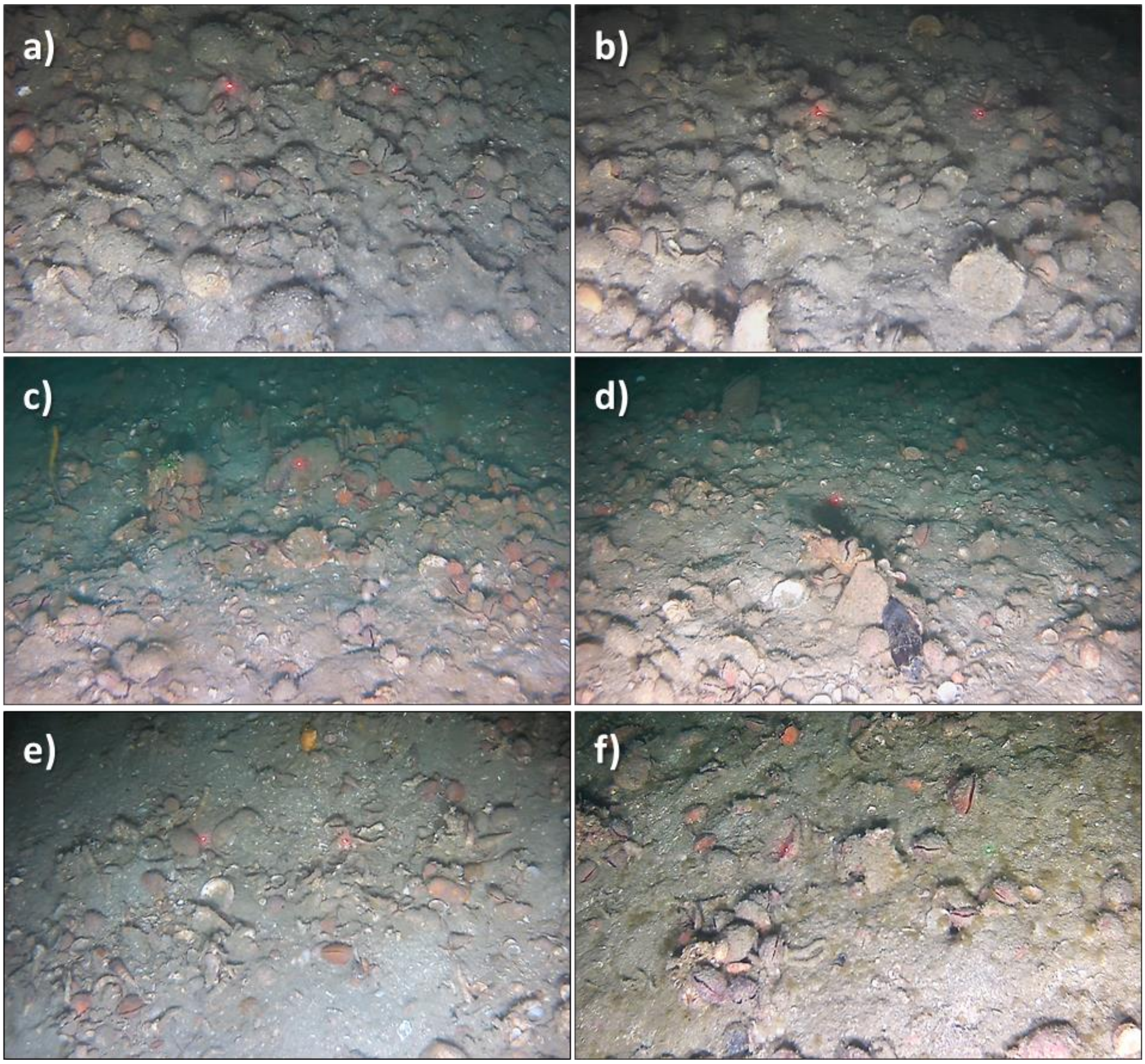


Figure 58: Examples of notable brachiopod beds on the deep slopes within mid-outer QCS (MDC18-survey, CBedcam Imagery). a-b) Dense fields of small brachiopods on deep sediment-buried shell-debris slope, in depths of ~32-46 m, off Bottle Rock, Outer Resolution Bay, Outer QCS (Site MDC18-Q47); c-d) Moderately dense fields of small brachiopods on deep sediment-buried shell-debris slope in Onario Point, outer East Bay, Outer QCS (MDC18-Q67); e) Sparse to moderately dense fields of small brachiopods on partially buried shell-debris slope, Edgecomb Point, outer Endeavour Inlet, Mid QCS (MDC18-Q36, 38 m); f) Moderately dense fields of what appear to be mostly smooth brachiopods on a buried shell-debris slope, with veneer of fine silt and biofilm - near Marine Head, Endeavour Inlet (MDC18-Q39, 31-33 m).

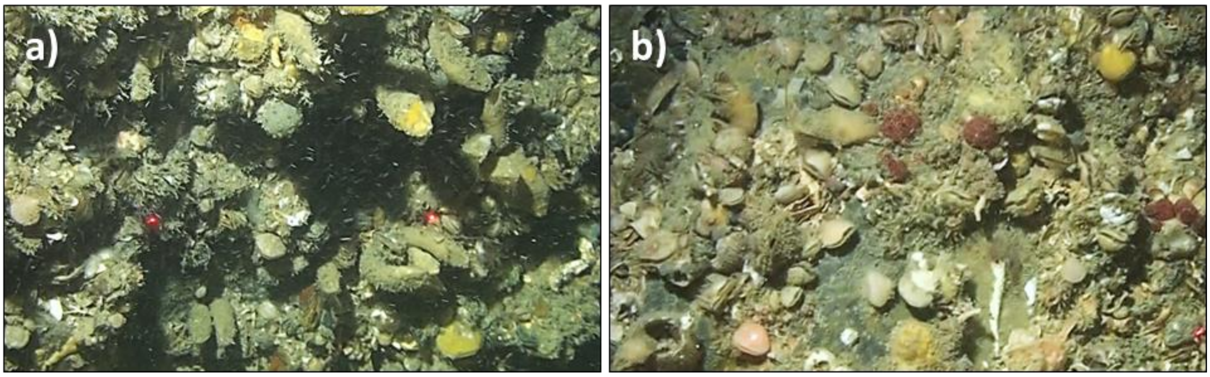


Figure 59: Examples of deep Cook Strait reefs with notable densities of brachiopods (MDC18-Coastcam Imagery). a) vertical rock wall on outer Cook Rock (~110 m) densely covered in sessile invertebrates dominated by small brachiopods and gooseneck barnacles (Site MDC18-Q137); b) Moderate densities of small brachiopods on deep reef ledge (~100 m) (Site MDC18-Q147).

Table 3-21: MDC18 sites with notable brachiopod beds. QCS=Queen Charlotte Sounds, TC= Tory Channel; CStrait=Cook Strait. Rank Abd = rank abundance, where values represent the range of real-time rank abundance categories (0, 1, 3, 5, 10, >10) as seen from real-time towed video. NB: Brachiopods are small and cryptic and are not well surveyed by tow-video so these estimate should be used cautiously, as they may not accurately represent *in situ* densities. Depth ranges represent the shallowest and deepest records for brachiopods per site, and may not represent the min and max depths of the bed itself.

Subregion	Location	Site	Records with Brachiopods (%)	Rank Abd Range	Depth (m)	
					Mean (SE)	Range
QCS-out	Resolution Bay	47	38.5	1-**10**	40.5 (2.8)	22.4-55.6
QCS-out	East Bay	51	12.1	1-**10**	29.0 (3.3)	16.6-38.0
QCS-out	East Bay	67	9.3	3-**>10**	35.8 (2.2)	26.1-42.8
QCS-out	East Bay	68	32.2	1-5	31.6 (0.7)	26.7-37.9
QCS-out	East Bay	72	25.0	3-**10**	33.1 (1.3)	29.9-40.6
QCS-out	East Bay	316	20.0	1-5	30.2 (0.6)	28.7-33.1
QCS-mid	Endeavour Inlet	36	4.0	3	31.4 (2.8)	25.1-38.6
QCS-mid	Endeavour Inlet	45	2.0	1	32.6 (5.5)	27.2-38.1
QCS-mid	Pickergill Passage	73	24.1	1-**>10**	26.0 (1.3)	22.7-32.1
QCS-mid	Blumine Is.	139	21.4	1-5	42.3 (1.1)	39.8-47.2
QCS-mid	Patten Passage	318	17.6	3-5	34.8 (0.8)	33.0-37.6
QCS-CStrait	Cook Rock (mid)	134	25.7	1-**>10**	99.6 (1.3)	93.4-104.5
QCS-CStrait	Cook Rock (out)	137	21.2	1-**10**	115.7 (6.1)	92.5-131.1
Tory-CStrait	Deep Reef	147	30.0	1-5	95.4 (4.4)	80.2-111.9

3.2.9 Scleractinian cup corals

Background: Scleractinian cup corals are 'true' or 'stony' hard corals belong to the order of Scleractinia (Phylum Cnidaria, Class Anthozoa), which are protected under the Wildlife Act 1953. However, unlike most other corals, cup corals do not have zooxanthellae (symbiotic single-celled algae) in their tissues, and therefore can inhabit deep waters. Within the Sounds two species of small solitary cup corals (*Monomyces* [was *Flabellum*] *rubrum* and *Flabellum knoxi*), both belonging to the family Flabellidae (Table 3-22; Figure 61), and one colonial species (*Culicia rubeola*) from the family Rhizangiidae (Davidson et al. 2011) have been recorded (Figure 60). *Monomyces rubrum* is small solitary cup coral, with salmon-coloured polyps, distinguished by a sturdy low-angled corallum (or cup), and is found in depths of <10 down to 200 m, while *Flabellum knoxi* is a similar size and colour, but can be distinguished from *M. rubrum*, by having a much wider corallum (>100°) (Squires and Keyes 1967). Squires and Keyes 1967, also describe *F. knoxi* over a much deeper depth range (400-500 m – with Cairns subsequently documenting depths of 201-1167 m), however, *F. knoxi* specimen is reported from the western entrance of QCS in only 81 m (C.127582; Table 3-22; Figure 61), indicating that this depth range, or the identification, may not be valid. *Culicia rubeola* is a distinctive colonial cup coral, with joined raised corallum that is found growing over hard substrata in water depths of ~1-20 m (Squires and Keyes 1967). Davidson et al. (2011) documents these small colonial cup corals as occurring at a number of rocky reef sites around the Marlborough Sounds.

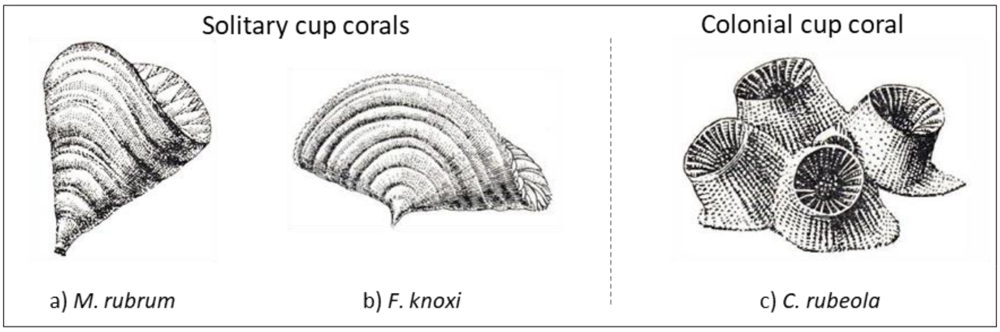


Figure 60: Morphologies of two species of solitary cup corals (*Monomyces rubrum* and *Flabellum knoxi*) and one colonial cup coral (*Culcia rubeola*) (from Squires and Keyes 1967 p19) that have been collected from the Marlborough Sounds Region. a) *M. rubrum* is small solitary cup coral distinguished by a sturdy upright corallum; b) *F. knoxi* has a markedly wider corallum (angle >100°); c) The colonial cup coral, *Culicia rubeola*. Sizes are not to scale. See Squires and Keyes 1967 for full taxonomic descriptions and national distributions.

Ground-truthing surveys: Like Brachiopods, cup corals are small cryptic animals that are often hard to detect using tow-video camera imagery. Surprisingly, numerous cup corals were detected during the MDC18 surveys. However, like brachiopods, occurrence data presented here should not be used to determine true absence of cup corals, but does provide valuable new information on these protected hard corals. Only a few cup corals were recorded during the CB17 surveys, in part due to the shallower depths sampled (3-30 m), but also the focus of the CB17 survey was on blue cod and their biogenic habitats, rather than small cryptic invertebrates. No cup corals were recorded from the HS51 and BT17 video footage, likely due to detection-limitations in the natural-light imagery. No solitary cup corals were collected at any beam trawl sites during the BT17 surveys (restricted to depths of 3-30 m), however surprisingly (given they grow on hard substrata) colonial coral polyps were collected at two sites, however, both specimens were growing on small objects (Sites QC50 on a horse mussel shell, and Sites QC16 on a large bottle - Figure 65a).

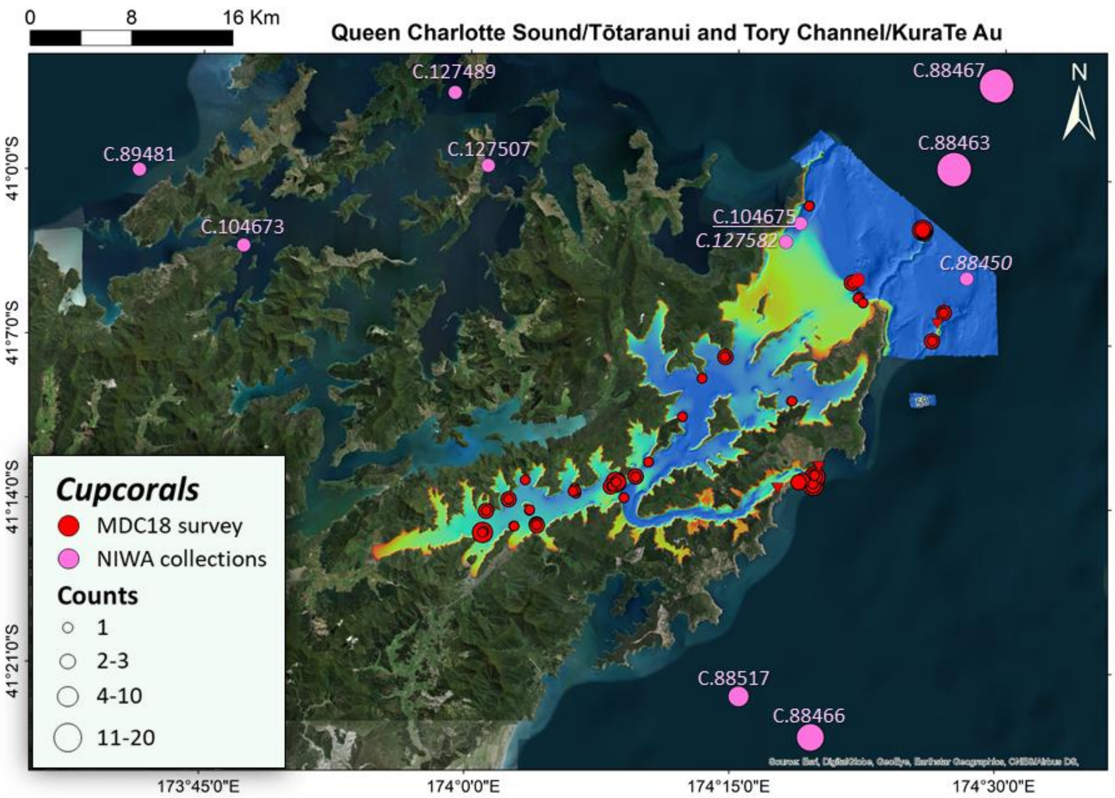


Figure 61: The distribution and relative abundance of Flabellidae cup corals from i) NIWA's taxonomic museum specimens (Specify database) for the broader Marlborough Sounds (pink circles), and ii) Rank abundance records from the MDC18 and CB17 video surveys. Pink labels (e.g., C.89481) depict NIWA catalogue numbers for each specimen lot (see Table 3-22), with species denoted by 'normal font' = *Monomyces rubrum,* 'underline' =*Flabellum knoxi*, and 'italics' = *Flabellum* spp.

Table 3-22: NIWA invertebrate collection of solitary cup coral (Phylum: Cnidaria, Class: Anthozoa, Order: Scleractinia, Family: Flabellidae) within or adjacent to the Marlborough Sounds (as of May 2019). QCS=Queen Charlotte Sounds, TC= Tory Channel; CStrait=Cook Strait; PS=Pelorus sounds; TB=Tasman Bay. Cat. No. = NIWA Catalogue number; Date col. = Date collected; Latitude and Longitude presented in decimal degrees; count= number of cup coral specimens collected at each site. Subscript numbers following the taxonomic 'Genera-Species' indicate the taxonomic specialist that identified the specimen(s), where [1]= Squires D.F. & Keyes I.W.; [2]= Cairns, S.D.; and [3]= Kitahara, M.V.

Subregions	Cat. No.	Date Col.	Latitude	Longitude	Genera-Species	Depth (m)	Count
QCS-CStrait	88450	11/09/1959	-41.0708	174.4667	*Monomyces rubrum*[1]	117	1
QCS-CStrait	88463	04/10/1958	-40.9933	174.4533	*Monomyces rubrum*[1]	146	11
TC-CStrait	88466	07/05/1958	-41.3983	174.3267	*Monomyces rubrum*[1]	106	4
QCS-CStrait	88467	11/09/1959	-40.9333	174.4917	*Monomyces rubrum*[1]	165	20
TC-CStrait	88517	08/06/1956	-41.3700	174.2583	*Monomyces rubrum*	86	2
TB	89481	05/10/1964	-41.0000	173.6900	*Monomyces rubrum*[2]	42	1
PS-mid	104673	14/12/1983	-41.0533	173.7883	*Flabellum spp.*	27	1
QCS-out	104675	07/12/1983	-41.0467	174.2967	*Flabellum spp.*	33	1
PS-out	127489	14/12/1983	-40.9433	173.9850	*Monomyces rubrum*[3]	29	1
PS-out	127507	14/11/1978	-40.9950	174.01669	*Monomyces rubrum*[3]	0	1
QCS-out	127582	07/12/1983	-41.0333	174.31000	*Flabellum Knoxi*[3]	81	1

Table 3-23: Summary details of cup corals recorded in video footage (MDC18-only[30]) by sub-region. QCS=Queen Charlotte Sounds, TC= Tory Channel; CStrait=Cook Strait. Site (%) and Records (%) = The percentage of 'sites' and 'recorded within sites' where solitary cup corals (*M. rubrum*) were present.

Subregion	Solitary cup coral Sites (%)	Solitary cup coral Records (%)	Depth (m)	
			Mean (SE)	Range
QCS-CStrait	50.0	9.6	89.7 (7.4)	36.4-131.2
QCS-inner	27.9	2.9	31.2 (1.1)	20.7-50.6
QCS-mid	16.0	1.1	37.4 (2.8)	20.1-45.0
QCS-outer	16.3	1.2	47.1 (5.1)	24.3-94.6
Tory-CStrait	57.1	9.4	51.5 (6.5)	27.7-112.0
Tory-inner	10.0	0.4	31.2 (.)	31.2-31.2
Tory-mid	0	0	N/A	N/A
Tory-outer	0	0	N/A	N/A
Totals	**20.8%**	**2.0%**	**48.5 (28.7)**	**20.1-131.2**

No specimens were collected during the Beam Trawl survey.

A total 44 solitary Flabellidae cup corals from 11 sites within the Marlborough Sounds region are listed in NIWA's SPECIFY invertebrate database (Table 3-22: NIWA-Specify/Invertebrate Collection, May 2019). Although specimen records occur across the broader Marlborough Sounds region (Figure 61), the majority of collected specimens (86%) are from the Cook Strait, either north of QCS or east of TC-entrance (Table 3-22; Figure 61). Most of these specimens were identified as *Monomyces rubrum* (93%)*,* with a single *Flabellum knoxi* specimen identified from the western entrance of QCS and two specimens identified only to genera (*Flabellum* spp.).

During the MDC18 video survey, a total of 102 records of solitary cup corals from 31 sites[31] were documented across a depth range of 20.1-131.2 m (mean 48.5 m ± 28.7 S.E.) (Appendix Table L-1). Although solitary cup corals were recorded from 20.8% of all sites, they were only present in 2% of records, indicating that cup corals occurrences within sites were very localised (Table 3-23) – albeit a likely underestimation due to detection-limitations of these small cryptic corals. Numerous small cryptic cup corals, however, were consistently observed from video at some sites (Figure 62; Figure 63), but this depended greatly on the tow-systems altitude, speed over ground and water visibility. Solitary cup corals in up-close video observations both within the Sounds and in Cook Strait were identified as *Monomyces rubrum* (e.g., Figure 62 and Figure 63) - having a salmon-pink colouration and a comparatively narrow vase-like corallum (as shown in Figure 60), however, collections would be required to confirm this.

The highest occurrences of solitary cup corals by subregion for this survey were recorded at sites within the Cook Strait (especially at the Brothers), both north of QCS (50% of sites and 9.6% or records at those sites) and east of TC (57.1 of sites and 9.4% of records), while the lowest occurrences were within TC (Table 3-23). Solitary cup corals recorded within the survey area were found in depths of 27.7 down to 131.2 m, either on rock-rubble slopes within the Sounds and in Cook Strait (variable densities ≤25-38 indiv. per m^{-2}), in high but very localised densities (≤44 indiv. per m^{-2}) on small low-lowing sediment-covered reefs within the Sounds (most notably Wedge point, Picton, Site MDC18-Q07 e.g., Figure 63d), or in mostly small localised clusters (≤3-10 per m^{-2}) on the sloping rock ledges of deep offshore reefs (i.e., Cook Rock, the Brothers, and Te Whētero). However,

[30] MBIE surveys rarely sampled in depths where cup corals occur, and HS51 imagery was mostly too short and/or not able to distinguish such small items due to lower light.
[31] Solitary cup corals are small cryptic corals that are not well detected in tow-video surveys. Consequently, tow-video records of solitary cup coral occurrences are likely to be underestimate their distribution and abundance, and should be used as a preliminary guide only.

while densities were often consistently high on rock-rubble slopes in Cook Strait (e.g., ≤~16-38 per m^{-2} at MDC18-Q80 and Q307), densities at inner Sounds sites were highly variable with most of the site characterised by much lower densities (i.e., ≤0.5-5 per m^{-2}), as were deep reefs in Cook Strait (i.e., ≤0.3-3 per m^{-2})[32] highlighting their very patchy distribution within these sites.

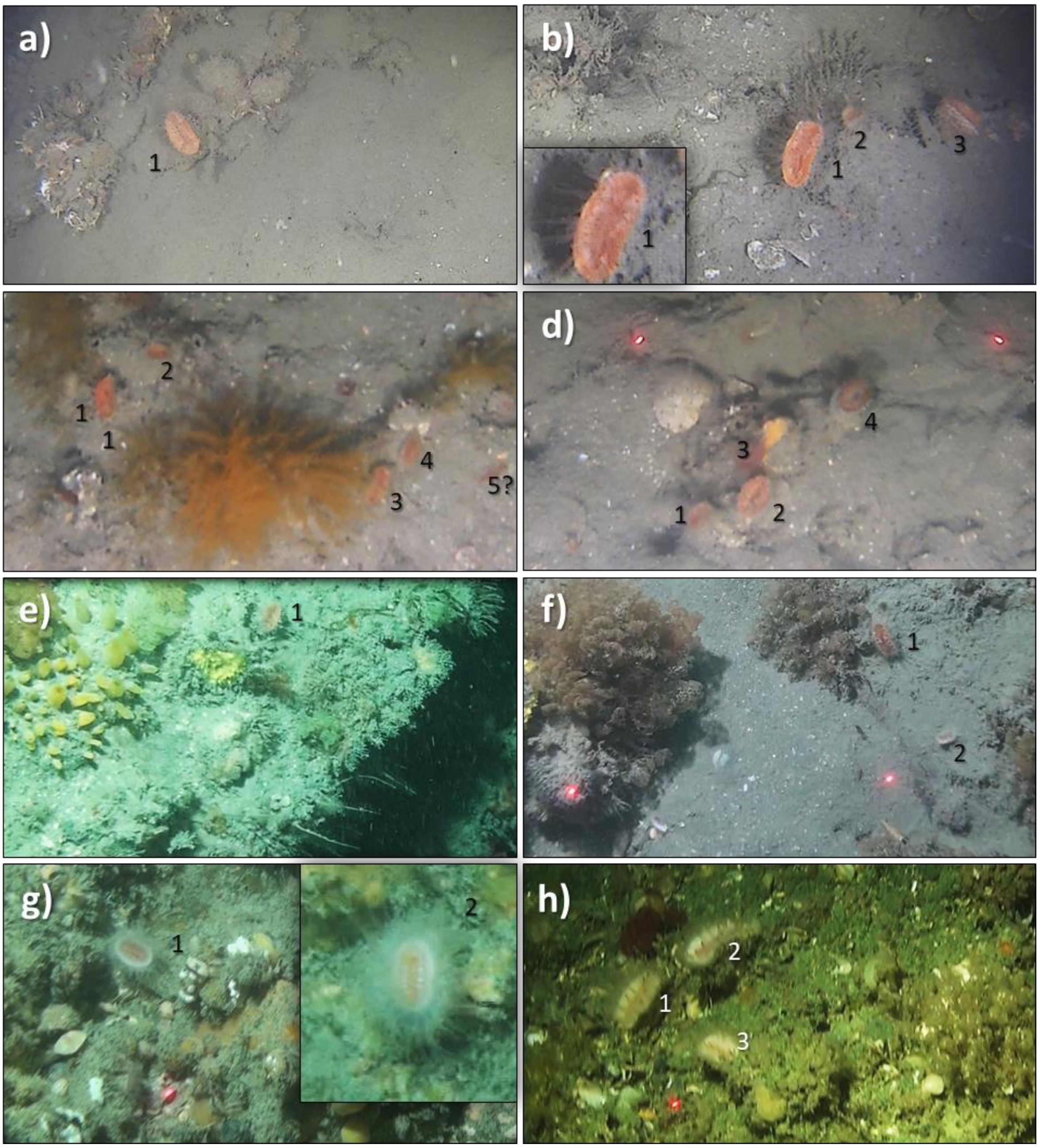


Figure 62: Examples of solitary cup corals found on the deep slopes within mid-outer QCS (a-d), and on deep reefs at the entrance to QCS (e-f) and in Cook Strait (g-h). a-d) cup corals growing on deep debris-field slopes on three sediment-covered ridges in Inner-QCS (a-b: Site MDC18-Q90 ~36 m, c: Site MDC18-Q174, ~35 m, Site MDC18-Q91, ~25 m); e-f) cup corals growing on sediment-veneered rock at the base of White Rock, at the entrance to QCS with yellow sponge (*Polymastia hirsuta* [e]) and orange soft bryozoa [f] (Site MDC18-Q129), ~34 m); g-h) Cup corals growing on rock at the base of large deep reefs beyond the entrance to TC (Sites MDC18-Q147, ~107 m) and north of The Brothers (Sites MDC18-Q182, ~95 m). Insert (g) shows close-up of a solitary cup coral with feeding polyps fully extended. Cup corals in these images look like *M. rubrum*, but collections would be required to confirm this.

[32] Although this is likely an underestimation in many areas of these very high-relief reefs where the seafloor could not always be seen.

Within QCS, solitary cup corals occurred within 10% of inner, and 16% of mid and outer QCS sites within depths of 20.1 down to 50.6 m, but were only present in 1.1-2.9% of all records (Table 3-23) – although again this may be an underestimation. Solitary cup corals within QCS, however, were predictably detected within the same habitat/depth zone – that being the deep slope habitats (>20 m) where shell-debris is heavily veneered by depositional sediments, and in turn was a key species characterising this habitat zone (also see Section 3.3.4 - *QCS Deep slope communities*). Solitary cup corals we also found at the entrance to QCS on sloping reef ledges in depths of 40-94.6 m, but these assemblages more resembled the deep reef systems in Cook Strait than those inside the Sounds. The most solitary cup corals seen was any site, was at the south-end of the Brother (MDC18-Q307), where approx. 2-14 cup corals were seen in almost every frame, growing on a cobble-rock slope in depths of 31-45 m that was also characterised by turfing and encrusting species (incl. deep corallines [NGC] and sponges) and soft bryozoans, with notable patches of hydroid trees, and a few Colonial cup corals were not systematically recorded during any of the four surveys, but were common on rock reefs in shallow waters (<~20 m) throughout QCS. However, it was often unclear whether polyps were relict or living, and would require closer inspection to determine this – and thus would be better surveyed by SCUBA divers.

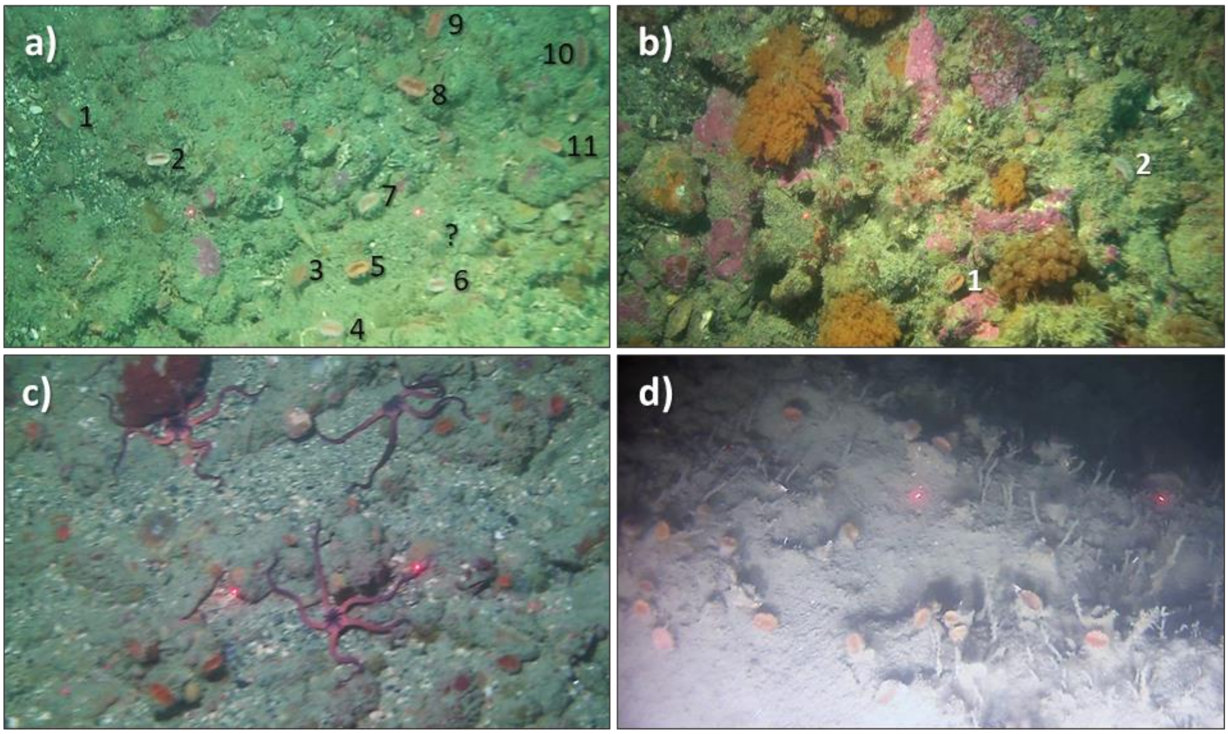


Figure 63: Examples of sites with notably high occurrences and/or densities of small solitary cup corals, within the HS51 survey area. Laser lights are 20 cm apart. a-b) Rock-rubble slope on the south-eastern side of the Brothers (MDC18-Q307); c) Rock-rubble slope off East Head, Cook Strait; d) Sediment covered low-lying deep reef of Wedge point, Picton (MDC18-Q07). Solitary cup corals identified from video were *Monomyces rubrum*.

Notable sites with both high occurrences and high densities of solitary cup corals included two sites in Cook Strait and one site off Wedge Point, in inner QCS: The highest densities (≤24 indiv. in a single video-image) and highest overall occurrence (>93% of rubble-zone records) were recorded in depths of ~30-50 m in Cook Strait, across an extensive rock-rubble slope adjacent to East Head at the entrance to TC (MDC18-Q80; e.g., Figure 63c; also see Section 3.6.6 on rubble slopes in Cook Strait). Similarly, the rock-rubble slope in depths of 35-45 m on the south-eastern side of the Brothers (Q307) also supported high localized densities and high occurrences of solitary cup corals (82% occurrence, and (≤14 indiv. per image e.g., Figure 63a, with most images having ≥2 solitary cup corals; e.g., Figure 63b). The third site off Wedge Point, in inner QCS solitary cup corals were locally dense on small low-lying rock outcrops that were heavily veneered with sediment (≤ 22 indiv. per image, e.g., Figure 63d).

3.2.10 Submerged trash

Background: Human use of the marine environment and urban presence adjacent to the coast can result in the trash being discarded within the marine environment or ending up there after being transported from coastal sources by rivers and runoff. Trash in the marine environment is attracting worldwide attention, as the prevalence and volume of trash increases. New Zealand is no exception, with trash visible along much of our coastline, and increasing volumes of trash being collected during beach surveys and clean-up events. However, little is known about the prevalence of marine trash in our coastal and offshore environments.

Ground-truthing surveys: In 2017, during NIWA's BT17 beam trawl surveys and the CB17 video surveys, the prevalence of trash seen and collected around the broader region of the Marlborough Sounds was documented for many sites (mostly within Pelorus Sounds and QCS), but as this was not the aim of these surveys, trash was not consistently recorded during these surveys. Presentations and discussions of these surveys with stakeholders (including MDC's Steve Urlich and Marine Futures members), information on the amount of trash within the Sounds was highlighted as an important issue. Consequently, during the MDC18 survey the presence of 'Trash' within and between sites was systematically recorded (*a full list of trash items with their GPS locations is presented in* Appendix Table M-1). Where time allowed, the type of trash seen was recorded during data entry or was written in our field logbook after the transect was finished. Three of the four surveys recorded trash (MDC18, CB17 and BT17), while only 1 item of trash was recorded during the HS51 surveys. HS51 drop-camera sites were not included in the data summaries of trash presented here, as the probability of detecting trash from the HS51 drop camera footage was very low due to the combination of: i) the very short time the seafloor was visible (a few seconds up to <1-3 min), ii) variable image quality at the seafloor in low-light or turbid conditions, and iii) most HS51 sites remained relatively stationary at a site (compared to the video-transecting surveys [MDC18, CB17 and BT17] that surveyed approx. ~200-300 m of seafloor at each site). Notably the one trash item (a car tyre) that was recorded the HS51 survey, was from site V08, during one of the few more extensive explorations over submerged wrecks.

A total of 144 items of trash in 69 sites were recorded during the combined surveys (MDC18 and CB17), equating to 36% of all MDC18 and CB17 towed-camera sites (Figure 64; Appendix Table M-1). Trash was seen in depths ranging from 2.3 to 91.2 m, although 81% of all trash was in depths <30 m. These sites had between 1-14 items of trash, although most sites only had 1 item of trash (a full list of trash items with their locations is presented in Appendix Table M-1). While 36% of all sites is a notable percentage, the total amount of trash covering the seafloor within sites was very low (2.1% of all data points) – identifying that small amounts of trash are littered across a third of all sites within the survey area (QCS, TC and Cook Strait). Discarded trash, however, was not evenly distributed throughout the Sounds, but rather decreased with distance out of the Sounds (Figure 64; Table 3-24). Inner QCS had the highest amounts of trash, with more than two thirds of sites (65% of all Inner QCS sites) having some form of trash (32 sites with 82 items of trash), along with the highest amounts of within-site trash (5.3 % of all records contained 'trash' in this zone). Mid QCS, Inner and Outer TC had the next highest amounts, with 50%, 40% and 33% of sites containing some trash (respectively), with intermediate levels of within-site trash (2.6%, 1.7% and 1.7% of all data points contained 'trash', respectively), while more distant sites in Cook Strait adjacent to TC, Outer QCS and Cook Strait adjacent to QCS having noticeably less trash (25%, 13% and 11% of sites, respectively and <1% within-site).

A wide range of discarded trash types were recorded (e.g., Figure 65; Table 3-24; Appendix Table M-1). All trash items seen (although only some were itemised) fell into one of three class types: i) small discarded items - dominated by glass beer bottles (most prevalent trash items seen), along with a few soda cans, plastic bottles, food-wrappers, as well as a glass jar, a broken bowl, and a plastic hook; ii) lost items of fishing gear that included fishing lines, ropes, a burley-pot and sacking material); and iii) large discarded industrial items (e.g., 10 gallon drums, iron wheels, scaffolding, metal pipes, cable-lines, car tyres, an oil-filter and large wheel-hubs). In addition to trash recorded in the video, seven items of small trash (e.g., bottle, food wrappers, cloth-rag) were also collected from six BT17 beam trawl sites, weighing a total of 3.5 kg[33].

The highest volumes of trash were seen near piers and/or commercial accommodation, where multiple and often large items of trash were seen (e.g., Resolution Bay and Endeavour Inlet - Figure 65 l,q,w and v,x,u respectively). In contrast, trash at more distant sites in the outer Sounds were composed mostly of snagged and lost fishing gear, such as cray-fishery pots and ropes (Site MDC18-Q147), anchor ropes and fishing lines, while in Cook Strait, fishing-gear was the only type of trash seen. The only exception to the pattern of decreasing trash with distance out of the Sounds was in Mid TC, which had less trash than would be expected by its spatial location (1% of sites and <1% of all records). However, while strong currents might transport light trash out of this region (as it does with drift seaweeds), the low occurrence of trash in this subregion may also reflect a combination of the comparatively low sampling effort (lowest of all subregions as outlined in the methods) and reduced detectability at these sites due to the occurrence of kelp canopies and reduced detectability associated with increased speed-over-ground during strong tidal flows[34]. If light weight trash is transported away from high current channel sites, then one might expect that this trash, like the drift-seaweed, would end up in amongst the drift algal mats that accumulate within the TC bays. However, no trash was collected in the six beam trawls within TC bays, even though large volumes of algae were collected.

Of the trash found, the highest volume were industrial items, reflecting their size, while the most abundant items recorded were glass beer bottles – often found on or directly adjacent to reefs suggesting that these items might have been discarded during fishing expeditions to these reefs. As bottles do not decompose, the discarded bottles recorded during these surveys may reflect the amalgamation of disposal over long time scales (decades). Macro-plastics in the marine environment is an increasing global concern, however, we estimate that only a small percent (<6%) of the trash recorded across the Sounds was composed of macro-plastics (e.g., plastic bottles, food-wrappers,

[33] All trash collected in the beam trawls was retained and disposed of to landfill.

[34] While mid-Tory does not have higher current speeds than outer channel sites (e.g. sites at the entrances of TC and QSC), these other high current sites were given priority (as previous more-focused research studies already existed for mid-TC). Consequently, those prioritized sites were sampled on the slack tides, which due to time-limitations unavoidably left mid-TC to be surveyed when strong currents were running. As a result of these often extremely high currents many mid-TC sites were unable to be successfully surveyed.

and a plastic hook).

Table 3-24: Summary details of the amounts of discarded trash recorded, by sub-region, during the MDC18 and CB17 surveys (combined). QCS=Queen Charlotte Sounds, TC= Tory Channel; CStrait=Cook Strait. Site (%) and Records (%) = The percentage of 'sites' and 'recorded within sites', where Trash was present.

Sub-region	Total trash	Sites with trash (%)	Records with trash (%)
QCS-inner	82	32 (65%)	5.3%
QCS-mid	22	15 (50%)	2.6%
Tory-inner	7	6 (40%)	1.7%
Tory-outer	8	5 (33%)	1.7%
Tory-CStrait	2	2 (25%)	0.9%
QCS-outer	17	7 (13%)	0.9%
QCS-CStrait	1	1 (11%)	0.4%
Tory-mid	3	1 (1%)	0.6%
Totals	**142**	-	**2.1%**

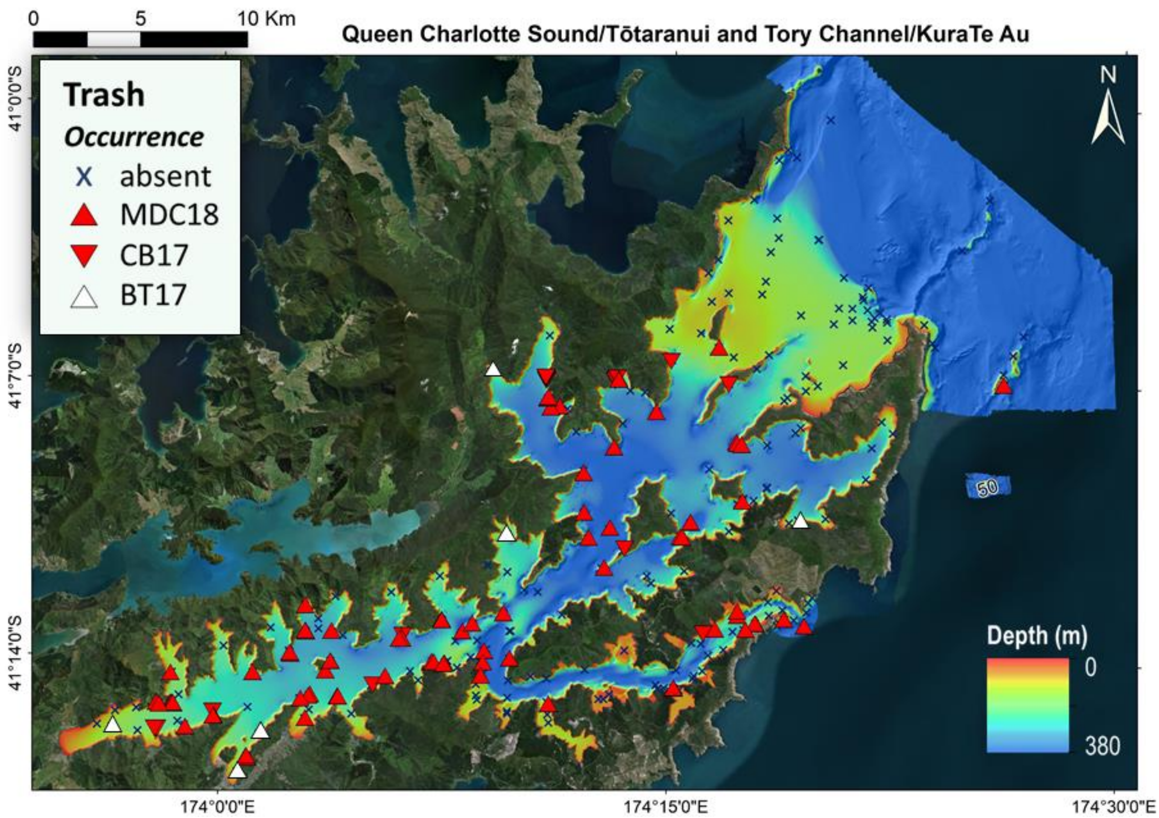


Figure 64: The location of discarded trash found within HS51-mapped survey area.

Figure 65: Examples of discarded and submerged trash areas found at a range of sites within QCS and TC, including small discarded items, fishing gear and industrial objects. a-d) items of trash collected in the beam trawls: a) Large bottle filled with berry-cider heavily encrusted with coral-polyps (BT17-QC16), b) cloth-rag (Site BT17-QC48), c-d) chip and muesli food-wrappers, respectively (BT17-QC60, BT17-QC57); e-x) items of trashed seem in video. e) Coralline-encrusted beer bottle along with j) Broken glass/beer bottle and p) Stack of car tyres all in a single site in Grove Arm, Inner QCS (CB17-C32) – this site also had numerous elephantfish egg-cases; f) Plastic hook next to burrowing anemone (*Cerianthus* spA) north of Green Bay, Inner-QCS (MDC18-Q93); g) Cable/line, south of Green Bay, inner-QCS (CB17-C28); h) Car tyre and r) Metal pot and beer bottle seen at two sites at The Snout, outer Waikawa, Inner QCS (MDC18-Q5 and Q6, respectively); i) Beer bottle, Kaireperepe Point, Inner-QCS (MDC18-Q9); k) Taut rope, off Ngamahau Bay (Mid-Tory CB17-C58); l,q,w) Wheel-hub, beer bottle, and rope, respectively, in a single site in Endeavour Inlet - near 'The Pines', Mid-QCS (CB17-C14); m) Beer bottle in the burrowing sea cucumber zone, near Dieffenbach Point, Inner-TC (MDC18-Q140); n) cloth sac, western end of Perano Shoal, Inner-QCS (CB17-C27); o) encrusted anchor rope on the reef at Kumutoto Point, Inner-QCS (Site MDC18-Q106); s) anchor[?]-rope inside the Long Island Marine Reserve, Outer-QCS (CB17-C05); t) Industrial frame/machinery covered in drift algae and dense cluster of Kina, Onapua Bay, inner TC (Site MDC18-Q196); u) coralline and invertebrate encrusted 10-gal drum, along with v) rope and x) metal frame/Tbar with ropes - from Resolution Bay, Outer-QCS (CB17-C62[v,x] and MDC-Q21[u]).

3.3 Queen Charlotte Sound (QCS) - Characteristic habitats and communities

3.3.1 Shallow reefs – upper slope (<30 m)

In this study, shallow reefs were prevalent along the shorelines of QCS, however, community structure varied from inner to outer Sounds (Table 3-25; Figure 66), likely reflecting a gradient of exposure and current-flow. Shallow reefs at the entrance to QCS, are in extremely high-current wave-exposed environments, where they supported dense macroalgae communities, dominated by kelps such as the extensive *E. radiata* forests seen at Waihi Pt, near Cape Jackson (e.g., Figure 66c), above an extensive zone of vibrant-green *Caulerpa* meadows – such as those seen at both White Rocks[35] and Waihi Pt (Figure 11a,b respectively). The extensive *E. radiata* forest seen off Waihi Point was in depths of 4.4-8.9 m, and extended to at least 32 m, and from the aerial view seen in the video footage appears to form an extensive dense forest at this site. It is unclear how extensive this forest is alongshore but based on the HS51 bathymetric layer identified >~4000 m^{-2} of reef available in this depth zone around this headland, indicating that this *E. radiata* forest might be quite extensive. The HS51 bathymetry also depicts similar reef structure out toward Cape Jackson within the same depth range, that might also support similar kelp forests. Comparison with the HS51 'detected-kelp' layer (Neil et al. 2018b) found that this layer failed to detect this extensive and very dense *E. radiata* forest. It did however predict mixed kelp (i.e., combinations of tall and short kelp) both 100 m north and south of this site, and on several reefs out towards and at Cape Jackson – but these were not able to be ground-truthed. Similar extensive high-density kelp forests also went undetected in the HS51 kelp layer from the Cook Strait coast adjacent to TC. Consequently, while kelp is likely to occur on exposed reefs in this outer-QCS region, kelp-detection success in the HS51 layer may be unreliable in these high-relief areas.

Once inside the entrance to QCS, the large rock outcrops and reefs around Motuara Island (MDC18-Q54) and Motungarara Island (MDC18-Q59) supported lush macroalgae communities, dominated by fleshy reds (e.g., Figure 66a) and patchy kelp beds comprised mostly of the exotic Japanese seaweed (or Wakame), *Undaria pinnatifida* (e.g., Figure 66b), although some small kina-barren zones were also present. At Motuara Island, for example, *U. pinnatifida* occurred in 72.7% of all records at this site, growing both on the reef and on low-lying rubble and shell debris present across the adjacent soft-sediment/rubble areas between and adjacent to these reef outcrops. Patches of *U. pinnatifida* were also observed on low-lying reefs in little Waikawa Bay (Q53), NW of Motuara Island. Kelp at most of these sites (e.g., Q53, Q54 and Q52) were accurately detected in the HS51 kelp layer, and while the kelp layer predicted patchy kelp along the northern side of Motungarara Island (which were not ground-truthed), the kelp layer failed to detect patches of *U. pinnatifida* on the SW end of this island, although most of these plants were small, making them extremely difficult to detect in the water column.

Throughout QCS, shoreline reefs were common, but the most extensive reefs were mostly around headlands of coves and bays. Reefs within QCS were mostly devoid of fleshy macroalgae (incl. kelps), typified by either kina-barrens (e.g., Figure 66e-g,i), or varying %cover of *Galeolaria hystrix (e.g.* Figure 66h). Kina-barrens were characterised by high %cover of coralline algae (NGC) with moderate to high densities of kina, and the absence of kelp and fleshy reds which the kina feed on. Kina were recorded throughout all regions of the Sounds, often in very high densities (see Figure 134 and Section 3.7.7: Kina distributions), with kina-barrens being the most common and widespread shallow reef-type within QCS in depth <20 m. The most notable densities of kina (~38 kina per m^{-2}) were

[35] Kelp forests were also seen in the shallow surface waters around White Rocks (as seen from the vessel), but were not surveyed within the video-transect (MDC18-QQ129) due to swell and proximity of the vessel to these rocks.

seen off Waihi Point near Cape Jackson on low to moderate relief reef in a depth range of ~16-18 m (MDC18-Q121; Figure 66f).

Shallow reefs covered in varying amounts of *G. hystrix* were also a common reef-type within QCS. These reefs were characterised by varying amounts of solitary *G. hystrix* (e.g., Figure 66g) and/or large clumps to substantial mounds of *Galeolaria* (e.g., Figure 66g,h, respectively) growing on the tops and sides of moderate to high-relief rocky reefs - especially those around exposed promontories (e.g., Clark and Papakura Point, MDC18 Sites Q51 and Q57, respectively) along with rock anemones - likely indicating high-current environments. Other species recorded on mid and outer shallow reefs included paua (*Haliotis iris*) and windowpane oysters (*Placuna placenta*) mostly on the sides of barrens rocks (e.g., both species in Figure 66f), patches of coral polyps across reef tops (e.g., Figure 66e,g), while reefs around promontories where *Galeolaria* mounds were present often supported an assortments of other sessile and motile invertebrates (Table 3-25 for full species list). A few patches of kelp were recorded on shallow rocky reefs along the edges of Pickersgill and Pattern passage, however most video-transects were terminated in these shallow depth, so very little footage was collected of these zones. The only notable kelp-bed seen in the mid-outer QCS during these surveys, was around the emergent reef on the north-eastern side of Amerikiwhati Is. (immediately inshore of transect Q32), where a dense surface bed could be seen at the surface from the vessel, however only a small amount of flapjack kelp (*C. flexuosum*) was recorded at the end of that video transect. Mixed (tall and short) kelp was also detected in the HS51 kelp-layer at this location, with four detected data points, indicating that kelp may be present within a ~41 x 122 m zone around the northern end of this island, with additional 'low' kelp data points also detected on the western side of the Island – although these would need ground-truthing.

Shallow reefs within inner QCS were mostly dominated by moderate to high densities of sea squirts (*Microcosmus squamiger*) (e.g., Figure 66j,k, but see Table 3-25 for full species list). These reefs often had a veneer of depositional sediments that combined with the high densities of sea squirts may be indicative of degraded habitats. The only kelp recorded in inner QCS during these surveys was on the shallow reef offshore of Houhou Point, which supported some straggly-looking flapjack kelp (*C. flexuosum*) that was heavily laden with epiphytic algae, and a few sizeable *Galeolaria* clumps. The most common fishes seen on shallow reefs were blue cod, spottys and triplefins. Large-sized fish, including blue cod (>30 cm), were generally uncommon, although a notable school of subadult tarakihi were also recorded at the base of the reef at Motungarara Island (MDC18-Q59), while hordes of blue cod were seen at Whatapu, Resolution Bay (MDC18-Q44) and Onario Point, outer East Bay (MDC18-Q67), but most of these fish were 20-30 cm in size.

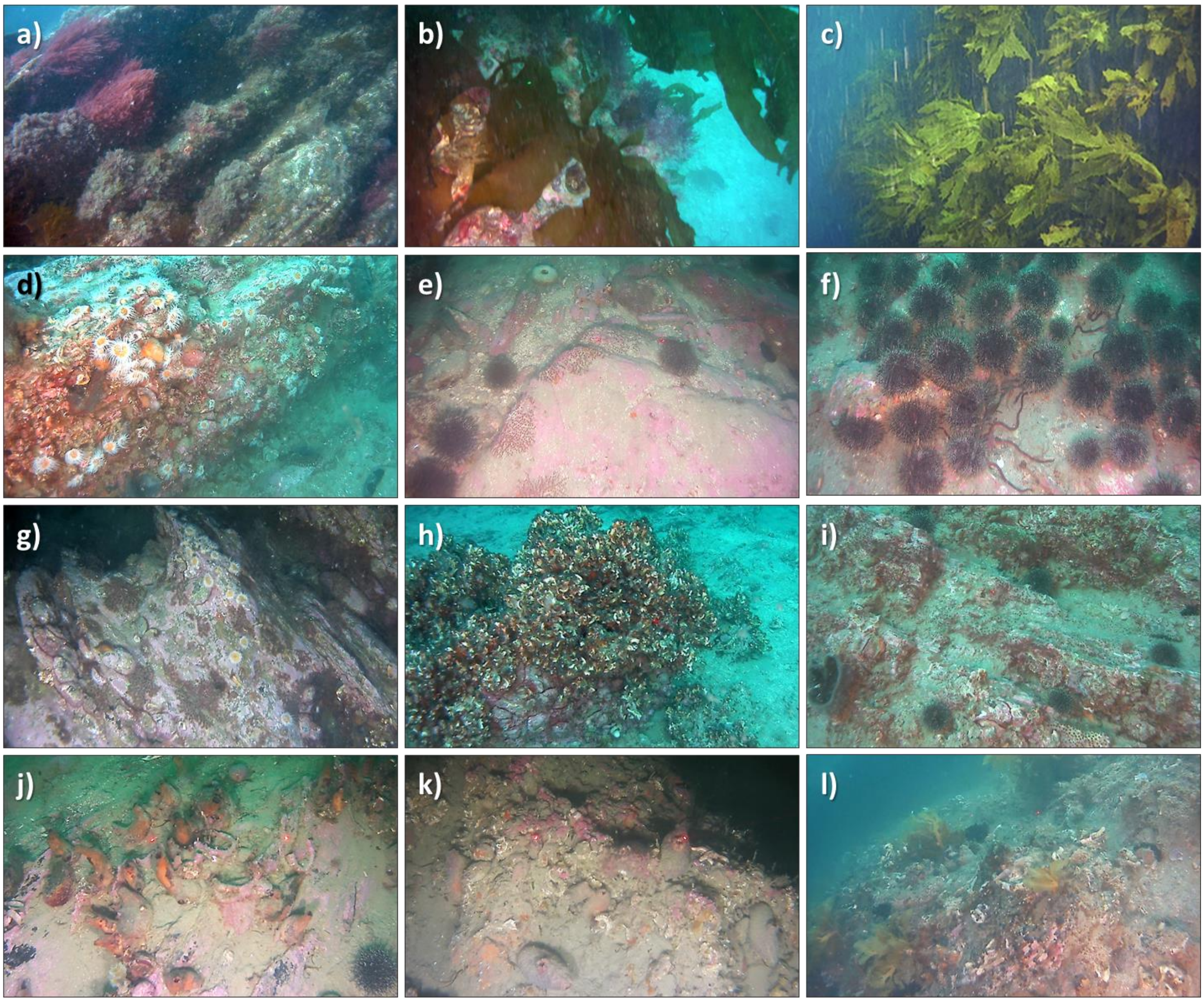


Figure 66: Representative images of shallow reefs (<20 m) and their associated biological communities within QCS. Images are from MDC18 survey unless otherwise stated. a) Mixed red algae reef, Motungarara Island, Outer QCS (Q59); b) *U. pinnatifida* canopy, reef north of Motuara Is., Outer QCS (Q54); c) dense *E. radiata* forest, Waihi Pt, near Cape Jackson, Outer QCS (MDC18-Q121); d) rock anemones, coralline algae, sea squirts and small *E. alata* sponges, Clark Point, outer East Bay, Outer QCS (MDC18-Q51); e) Kina-barrens and coralline algae, with coral polyps and light sediment veneer, LIMR (CB17-C04); f) rock barrens with coralline algae, paua and windowpane oysters (*P. placenta*), Pickersgill Island, Mid QCS (MDC18-Q76); urchin barrens with coralline algae and small clumps of *G. hystrix*, Edgecomb Point, Mid-QCS (MDC18-Q36); h) Large clumps of *G. hystrix* growing on the tops of reef/ridge, with paua at base in Anatohia Bay, outer East Bay, (MDC18-Q51); i) Kina-barrens with coralline algae and solitary *G. hystrix*, Onario Point, outer East Bay (MDC18-Q67); j) low-lying reef, with sea squirts and coralline algae, Onahau Bay, Inner QCS (MDC18-Q96); k) sediment-veneered reef with sea squirts, coralline algae and epiphytic bivalves, Kaireperepe Pt ,Inner QCS (MDC18-Q09); l) *Sargassum* basal plants, with solitary *G. hystrix*, coralline and filamentous red algae, Kumutoto Point, Inner QCS (MDC18-Q106).

Table 3-25: Characteristic features of shallow reef habitats (<20 m) in QCS. Sites refer to MDC18 unless otherwise stated.

QCS Shallow Reefs	Characteristic features and significant/notable taxa
Substrata	Rock outcrops low-high relief. Outer QCS and reefs off promontories were generally of higher relief than shoreline reefs within bays. The majority of shallow reefs within outer to inner QCS had some level of sediment veneer, with Inner QCS reefs generally having the thickest veneer of fine sediments.
Benthic community	**QCS-entrance/Outer QCS**: kelp forests mostly *E. radiata* (dominant, Q121), with dense *C. flexilis* meadows (dominant, Q121, Q129), *Asparagopsis*, coralline algae (common), *Halopteris* (common) drift-kelp (with abundant kina). Macroalgal-dominated reefs (Q54, Q59): dominated by fleshy red algae and *U. pinnatifida* (common-abundant), encrusting coralline algae (common), *G. hystrix* (few-common), jewel anemones, colonial cup corals (*Culicia rubeola*), *E. alata* sponges (occasional). Algal species identified from site Q54 incl. *Codium fragile*, *Schizoseris*, *U. pinnatifida, Scinaia*, Kallymenieceae (undescribed sp.), *Caulerpa geminata* (<1%, Q59), *Asparagopsis* (also at Q59), *Sarcodia*, *Crassiphycus proliferus*, *Ulva* spp. **Outer/Mid-QCS**: Kina-barrens: encrusting coralline algae (NGC, dominant), kina (moderate to high densities), rock anemones (few-abundant), colonial cup corals (*C. rubeola,* common), windowpane oysters (*P. placenta*, occasional-few), epiphytic bivalves on some reefs (occasional). *Galeolaria*-dominated reefs: Solitary and/or series of large clumps and/or mounds of *Galeolaria hystrix,* often with rock anemones*,* filamentous red algae. **Inner QCS**: Sea-squirt-dominated reefs: sea squirts (*M. squamiger*, dominant) esp. common in inner QCS; *C. flexuosum* (e.g., Houhou Pt), encrusting coralline algae (common), filamentous reds (common), encrusting orange sponge (occasional-few), *screwshells* (*Maoricolpus roseus,* Houhou Pt).
Motile invertebrates	Kina barrens (common at most sites, e.g., Q52, Q59; densities highest in kina-barrens at Waihi Pt, Q121), sea cucumbers (*A. mollis*, common-abundant), and snake stars (common in mid-outer QCS, but mostly absent in inner QCS), paua in the shallows (mid-outer QCS), cushion star (*P. regularis,* few), *C. muricata* (few).
Fish	Variable triplefin (few-common), adult and sub-adult blue cod (few-hordes [Q44, Q67]), spotties (common-abundant), tarakihi (e.g., Q54, Q59, Q67, Q68), mimic blenny (QCS-entrance, Q121), blue-eyed triplefin (*Notoclinops segmentatus*, Q59 x1).

3.3.2 Live *Tucetona laticostata* beds – upper slope:

Background: The Robust dog-cockle (*Tucetona laticostata*[36]) are large heavy shelled bivalves that live buried in the sediments on the continental shelf and sloping coastal sediments around New Zealand, in areas with high current, commonly within depths of ~25-75 m (review by Anderson et al. 2019), but may occur to 100 m (Cook 2010). Once they die their shells can remain on the seafloor for thousands of years (Gillespie and Nelson 1998; Beu 2004), and over time accumulate down slope from the living beds (See Sections 3.3.3 and 3.3.4). *T. laticostata* are known to occur from a variety of locations throughout the great Marlborough Sounds, but their local distributions are not well known.

[36] Previously known as *Glycymeris laticostata.*

Ground-truthing surveys: During the Ground-truthing surveys, 26 live *T. laticostata* beds (here on referred to as live *Tucetona* beds) were found in coarse sand-gravel sediments in depths of 9.5 and 33.8[37] m. These habitat zones were found on strongly sloping banks within high current environments, most commonly at the base or immediately down-slope from prominent rocky ridges. These habitats are comprised moderate amounts of *Tucetona* shell debris, both in amongst and downslope from the live bed. The most exposed site where live *Tucetona* beds were recorded, was at Cape Jackson across a depth range of ~ 17-23 m, where moderate densities of live *Tucetona* were buried in very coarse sands with gravel and shell-debris, that lay directly below the base of the exposed coastline reef.

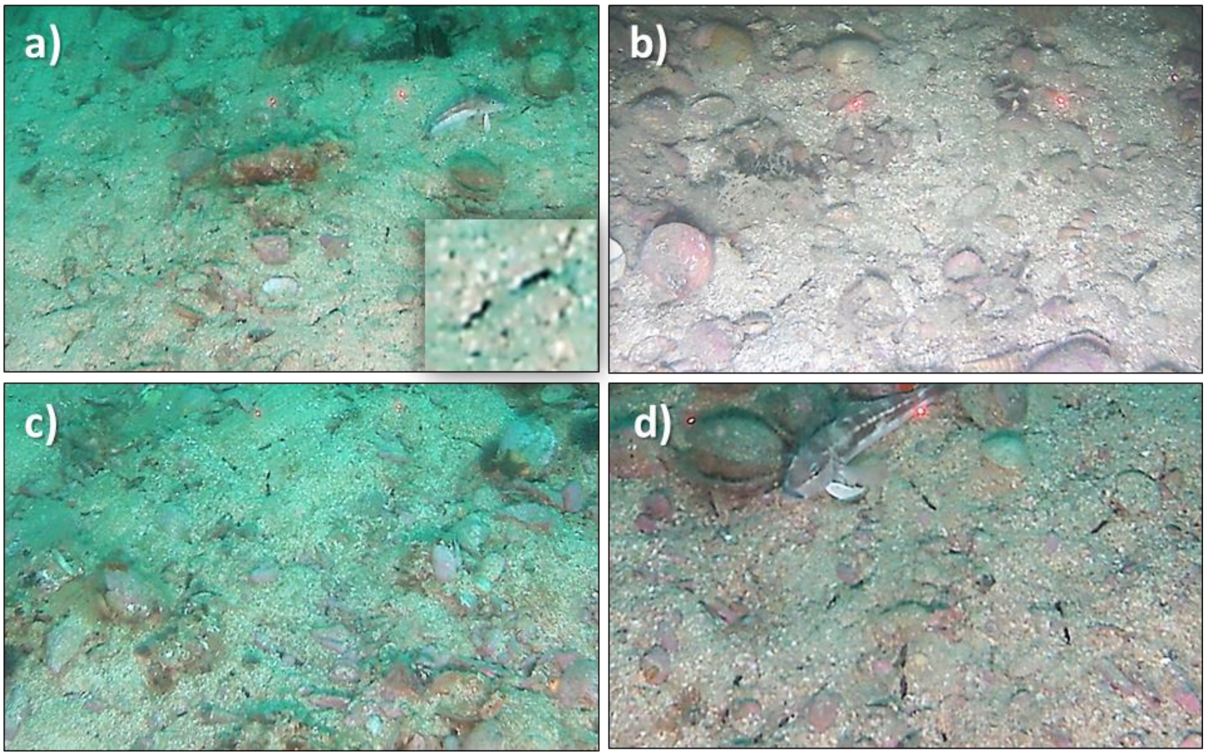


Figure 67: Examples of live robust-cockle beds, formed by *T. laticostata*, in current-swept sediment slopes in mid to outer QCS. a-d) Relict (dead) *Tucetona* shell with moderate to relatively dense populations of living *T. laticostata* (*Tucetona* beds) within the sediments - identified by the many two-dashed holes at the sediment surface (Insert shows zoomed-up example of the two siphons), indicative of the inhalant and exhalent siphons of *e* a-b) Whatapu, Resolution Bay, mid QCS (MDC18-Q44) and c-d) Longfellow Bay, mid QCS (MDC18-Q37), large juvenile blue cod (~18-19cm) [a]; Sub-adult blue cod ~22-23 cm [d].

[37] Live *Tucetona* were also recorded on a sediment bank in TC (MDC18-Q186 in depths of 36.3-42.8 m.

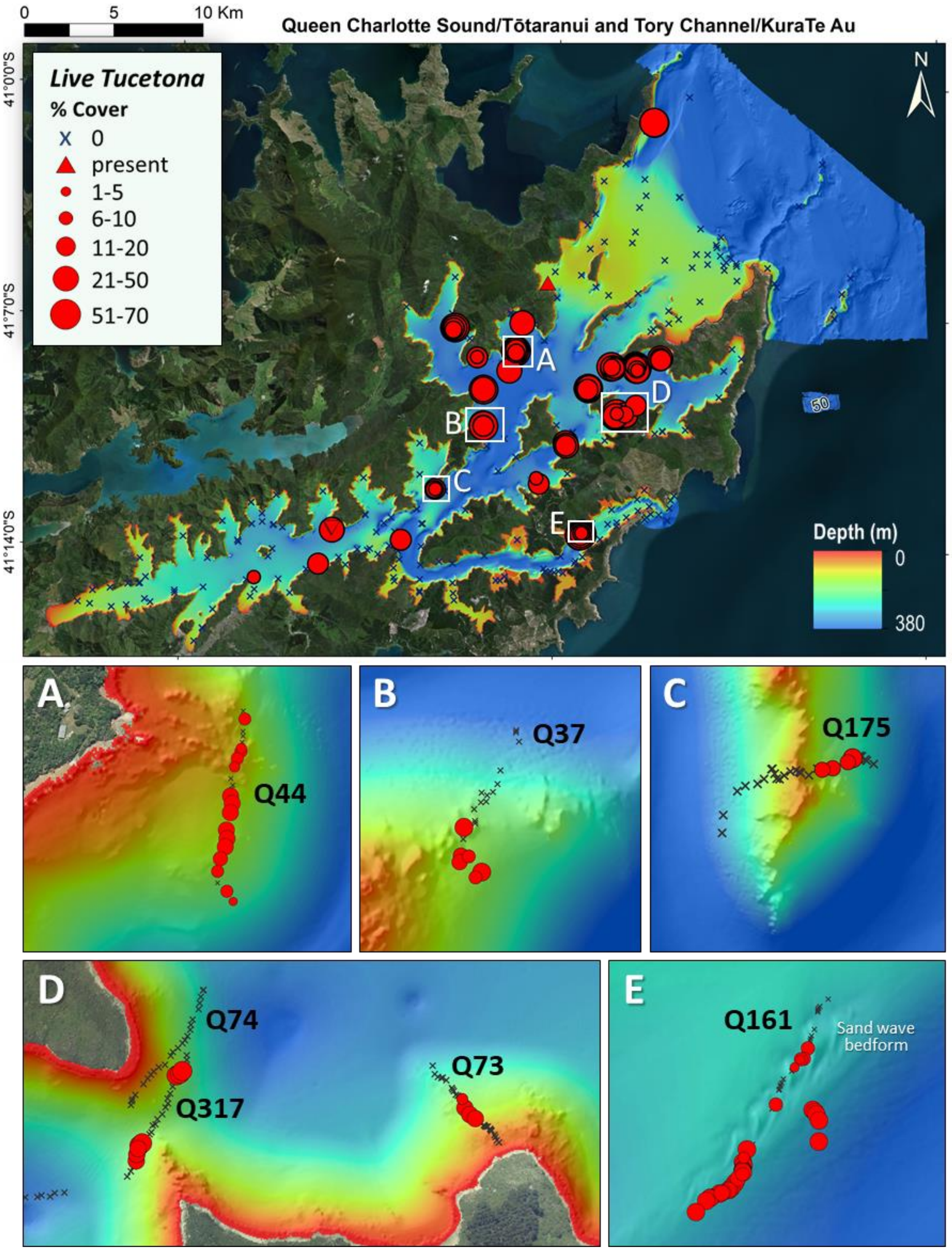


Figure 68: Distribution and relative abundance of live *Tucetona* beds (the Robust-dog cockle *T. laticostata*) buried in sediment areas exposed to strong-currents within depths of ~9-43 m within QCS and TC. Bubble plot distributions represent the MDC18 survey, while triangles representing presence are from other surveys (upright=HS51, inverted = CB17 surveys). No live *T. laticostata* were collected in the BT17 beam trawls within QCS or TC[38]. A) Whatapu, Resolution Bay, Mid-QCS (MDC18-Q44); B) Longfellow Bay, mid-QCS (MDC18-Q37); C) Snake Point, Bay of Many Coves, Mid-QCS (MDC18-Q175); D) Pickergill Passage, Mid-QCS (MDC18 Sites Q74, Q73 and Q317); E) Sand Bank off Ngamhau Bay, Mid-TC (MDC18-Q161 - *detailed in TC-Section 3.4.9*).

[38] Not surprising given this is species is fully buried beneath the sediments.

Table 3-26: Frequency of occurrence of live beds of *T. laticostata* (robust dog cockle) recorded in MDC18 video footage[39] by sub-region. QCS=Queen Charlotte Sounds, TC= Tory Channel; CStrait=Cook Strait. Live *Tucetona = Live T. laticostata* beds; Site (%) = Frequency of live *Tucetona* beds occurrence within subregions (site %) and within sites (Records (%) = The percentage of 'sites' and 'recorded within sites' where live *T. laticostata* were present.

Subregion	Live *Tucetona* % of sites	Live *Tucetona* % of records	Depth (m)	
			Mean (SE)	Range (m)
QCS-CStrait	0	0	N/A	N/A
QCS-inner	7.0	0.3	14.5 (0.8)	12.4-16.3
QCS-mid	56.0	9.4	20.4 (0.7)	9.5-32.7
QCS-outer	14.0	2.3	23.5 (0.9)	12.1-33.8
Tory-CStrait	0	0	N/A	N/A
Tory-inner	10.0	0.7	26.0 (0.3)	25.8-26.3
Tory-mid	0	0	N/A	N/A
Tory-outer	9.1	9.3	38.4 (0.2)	36.4-42.8
HS51 survey area	**16.8%**	**2.9%**	**25.2(8.7)**	**9.5-42.8**

* Extensive areas of *Tucetona* shell debris were recorded at Q113 on the upper slopes east of Cape Koamaru, but no live *Tucetona* beds were identified, but are likely to occur higher up on the slope above its shell debris.

Table 3-27: Characteristic features of live *Tucetona* beds on the upper slopes of high current sites in QCS. .

Tucetona-debris fields	Characteristic features and significant/notable taxa
Substrata	Sediment comprising coarse sands, with gravels and relict shells present on the surface (levels of shell debris retained over the beds depends on degree of slope), mostly in depths of ~9-34 m.
Benthic community	Live *Tucetona* – identified by two-dash siphons at sediment surface. Coralline algae (NGC) on relict shells, but shell debris relatively clean (reflecting scouring by coarse sediments in these high current environments), some hydroids and solitary-*Galeolaria* may be present.
Motile invertebrates	Snake stars (common),
Fish	Blue cod (common), including juvenile blue cod at some sites, where shell debris is present.

3.3.3 Shell-debris fields (encrusting invertebrates)

Background: Dead shell from species such as *T. laticostata* that live up on slopes in high current areas, are known to have their relict shells accumulate down-slope over time (Anderson et al. 2019). The thick robust nature of *Tucetona* shells are resistant to erosions, with relict shells carbon dated to at least 9,170 ± 210 years BP – (Gillespie and Nelson 1998) and 35,800 ± 2250 years (Beu 2004). Consequently, the ongoing accumulations of these shells can result in extensive shell-debris fields that can provide substantial hard substrata to other organisms, in otherwise 2-dimensional soft-sediments (Anderson et al. 2019). *Tucetona* shell-debris fields are known to become colonised and consolidated by other matrix-forming species, such as reef-building bryozoans, encrusting and erect sponges, as well as colonial and solitary ascidians (e.g., Dewas and O'Shea 2012; Beaumont et al. 2015). A variety of shell-debris areas that underly other biogenic habitats, such as bryozoa reefs have also been documented in some locations (e.g., Patea Shoal and Whanganui shelf: Beaumont et

[39] BT17 did not collected any live *T. laticostata*, but this is not surprising given this species lies buried beneath the surface of the sediment; Live *T. laticostata* beds were also recorded at one site during the CB17 survey, found on the upper sediment slope with some *Tucetona* shell debris at Perano Shoal (CB17-C27).

al. 2015 and Gillespie and Nelson 1996), but due to the widespread occurrence of *T. laticostata* around the New Zealand coastline, consolidated *Tucetona*-debris habitats are expected to be more widespread than presently known.

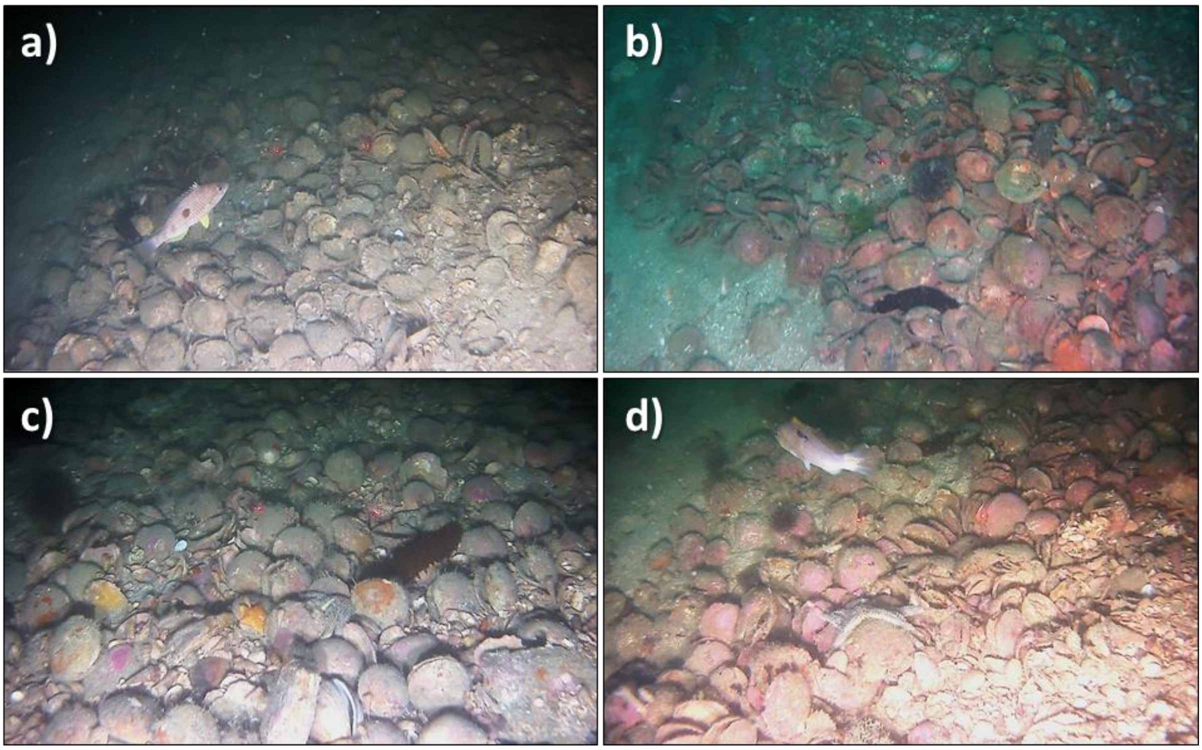


Figure 69: Examples of shell-debris fields and slopes, dominated by large robust cockle shells (*T. laticostata*), that accumulate in mounds throughout much of QCS and TC. Shell-debris fields from: a) Scott Point, Endeavour Inlet, mid-QCS (MDC18-Q45); b) Onario Point, outer East Bay, outer QCS (MDC18-Q67), c) northern slope off Allports Island, inner-QCS (MDC18-Q04); d) Longfellow Bay, mid-QCS (MDC18-Q37). Photos show that these large robust shells become encrusted over time with coralline algae, encrusting sponges, and become habitat for a wide range of small invertebrates, such as crabs, as well as more mobile species such as holothurians, kina, starfish and fishes.

The current surveys found *Tucetona* shell-debris to be extremely widespread throughout the survey area, especially within QCS on slope-habitats adjacent to or below rocky ridgelines exposed to strong-currents. While many live *Tucetona* beds were recorded, either near, or on the slopes above the *Tucetona* shell-debris fields, the live beds responsible for the debris were not always determined, especially where transects ran along shore. For example, a large *Tucetona* debris field was present in Cook Strait on the east coast approx. 500 m south-east of Cape Koamaru (MDC18-Q113), where it occurred in dense piles both below and in amongst low-relief patch reefs located ~250 m from shore. Sediment banks away from ridges were sampled less frequently within the survey area, however at the few sites that were sampled little to no shell debris was observed, instead the seafloor on these slopes were characterised by patches of straw-weed Chaetopterids supporting various amounts of red algae (e.g., see Figure 41).

In areas down-slope of reefs, where *Tucetona* shell debris builds up in mounds above the sediment, shells were colonised by a diverse array of sessile species, dominated by coralline algae (NGC), encrusting sponges, colonial ascidians, sea squirts, brachiopods and cup corals (in deeper slope areas) and epiphytic bivalves, solitary *Galeolaria* and occasionally small amounts of reef-forming bryozoa that contribute to collectively bind and stabilise these shell mounds. These shell-debris fields also supported high densities of mobile invertebrates, incl. snake stars, *A. mollis,* starfish (esp. *P. regularis* and *C. muricata* - although *C. muricata* numbers were more abundant near the live *Tucetona* beds), kina, *P. albocinctus*, as well as small invertebrates, such as crabs (Table 3-28). Shell-debris mounds within the outer half of QCS (i.e., mid to outer QCS) were also one of three important nursery habitats for blue cod, with juvenile blue cod recorded in low densities in these shell-debris habitats.

Table 3-28: Characteristic features of mid-slope shell-debris fields in QCS.

***Tucetona*-debris fields**	**Characteristic features and significant/notable taxa**
Substrata	Mid-slope sediment where the robust shells of dead *T. laticostata* accumulate down slope from live *Tucetona* beds, associated with high-current ridgelines in ~15-30 m. High backscatter reflectivity.
Benthic community	Coralline algae (NGC) and encrusting invertebrates (e.g., encrusting sponges, colonial and solitary ascidians) grow on the shells, along with small red bladed algae (e.g., *Galene* spp.). Where shell debris is consolidated by encrusting organisms, erect species occur (e.g., charcoal-grey *E. alata* sponges*,* digitate sponges *Dactylia varia* and *Euryspongia* sp., and hydroids incl. the *H. campanula* and horse mussels (few).
Motile invertebrates	snake stars, *A. mollis*, *P. regularis, C. muricata*, kina and *P. albocinctus* are common, numerous hermit crabs and crabs. scallops (few/lots at some locations).
Fish	Spotties, triplefins, blue cod, incl. juvenile blue cod (nursery habitat).

3.3.4 Deep buried-debris slope (cup corals and/or brachiopods)

Shell-debris fields in the mid- and deeper slope zones reflect a gradient of decreasing amounts of exposed shell debris and with greater quantities of depositional muds, creating a heavily veneered rubble-slope zone, with the rubble here composed of mostly buried *Tucetona* shell debris. The buried-rubble zone supported a notably different community to that of the mostly sediment-free shell-debris zone higher up the slope. Here, very few to almost no encrusting organisms were present, and those that were, were restricted to the few shells that weren't covered or buried by sediment. This was in marked comparison with the often heavily encrusted shell-debris fields further up the slope. Instead, the benthic community in this deeper zone was characterised by the presence of cup corals, brachiopods (of varying densities), small hydroids (although large hydroids were also present at some sites), *P. albocinctus* (common in low numbers), along with occasional horse mussels, scallops and spotties (Table 3-29; Figure 70).

Shell debris slopes with and without depositional sediments had intermediate backscatter reflectivity compared to the distinctively lower backscatter reflectivity that characterised the thick-sediment plains and deeper thick-sediment covered slopes found inundated with *Amphiura* (e.g., see next sections Figure 80; Figure 81), indicating that the backscatter signals appear to accurately delineate the lower edge of these buried-rubble slopes. In contrast, backscatter signals showed little to no differentiation between the shell-debris fields (further up the slope) and the buried-debris zone, as would be expected given that seafloor in both areas are covered by large amounts of shell. Further evaluation of the ground-truthing data with combination of slope angle, backscatter and distance from reef may provide improve the ability in detecting and delineating the boundary between these two shell habitat zones – which would be extremely valuable in determining the areas occupied by these habitats and the very different communities.

Table 3-29: Characteristic features of deep buried-debris slopes in QCS. .

Muddy slopes with buried-debris	Characteristic features and significant/notable taxa
Substrata	Sediment slopes with shell-debris buried in silt/muddy sand, in depth mostly of ~30-50 m. Shell-debris fields become more heavily burdened with depositional silty sediments deeper down the slope – here shells are moderate to heavily veneered in sediment. Low/medium backscatter reflectivity.
Benthic community	**Characteristic species**: Solitary cup corals (cf *M. rubrum*), brachiopod beds (of varying densities) and hydroids (incl. hydroid trees (*Solandaria* sp. at some sites). Other species also recorded: colonial ascidians (*C. dellechiajei*), horse mussels and sabellid fanworms (few to many), occasional sediment-tolerant yellow sponge (*Polymastia hirsuta*), large tube anemones (sp1), burrowing anemone (sp2) mostly deeper down slope indicative of thicker sediments. At some locations, moderate-dense burrowing sea cucumbers (*Thyone* spA – see Section 3.2.3 for details). Occasional small patches of encrusting species (<2-15%) restricted to exposed shell debris.
Motile invertebrates	Characterised by the regular presence of *P. albocinctus* in low numbers, along with mostly low densities of snake stars, *A. mollis*, *P. regularis, C. muricata*, with rare occurrences of kina. Scallops (few/lots at some locations).
Fish	Opalfish (few), spotties, carpet sharks and dog sharks (occasional), red gurnard and john dory (rare).

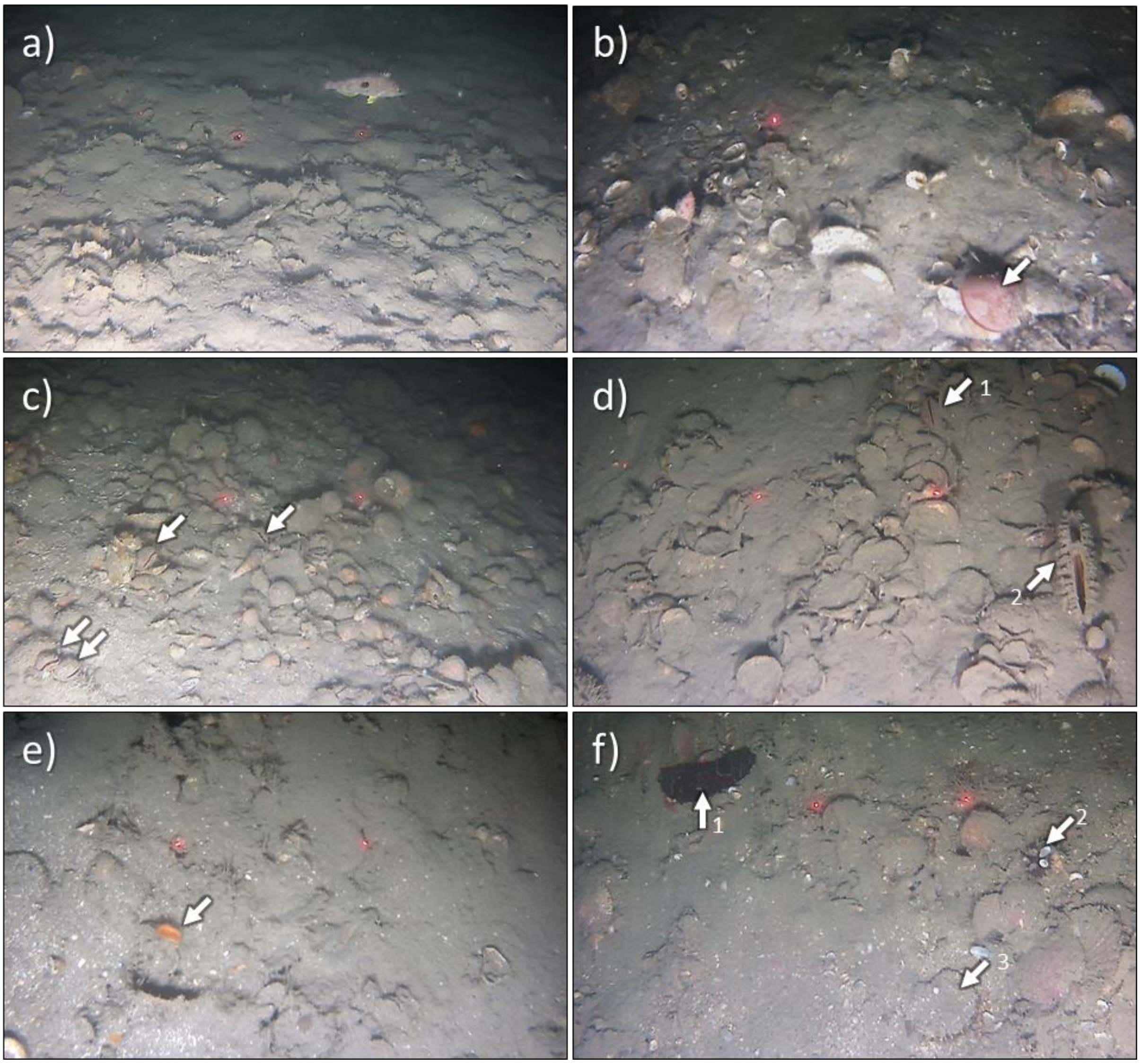


Figure 70: Examples of characteristic deep slope habitat with shell-debris heavily veneered/buried in depositional sediment. Buried shell-debris fields from: a) Inner-transect at Perano Shoal, inner QCS (Site MDC18-Q103); b) Anatohia Bay in East Bay, Outer QCS (MDC18-Q68), c) off Bottle Rock, Outer QCS (MDC18-Q47); d) Iwirua Point, inner QCS (MDC18-Q08); e) West head, mid QCS (MDC18-Q173); f) Outer-transect at Perano Shoal, inner QCS (MDC18-Q102). Photos show that shell debris down-slope in deeper zones become heavily veneered to almost completely buried in depositional silty sediments, associated species (depicted by white arrows) included spotty [a], brachiopods [b,c,d^{1}], horse mussels [d^{-2}], cup corals [e], *A. mollis* [f^{1}], *P. albocinctus* [f^{-2}] and scallops [f^{3}].

3.3.5 Deep rock outcrops (>30 m)

Multibeam bathymetry mapped a range of deep reef features within the survey area, with the highest relief features recorded in Cook Strait (Neil et al. 2018a), and are examined separately (see Section: 3.5.1 – Deep offshore reefs). The next most notable deep reefs were at the entrances to TC and QCS, with considerably fewer deep reefs occurring within the Sounds, and fewer with notable levels of vertical relief. During the MDC18 surveys, several deep reef features within QCS and across the QCS-entrance were targeted to characterise the physical and biological composition of these deep reef habitats.

Deep Reefs within QCS

Based on the bathymetry and rugosity layers in Neil et al. (2018a), numerous rocky ridges extend 10's to 100's of metres off headlands around the many marginal bays and inlets within QCS. However, few occur in depths >30 m and less to 50 m (e.g., Blumine Island, Neil et al. 2018a). As part of the MDC18 surveys, several of these deep reef features (>30 m) were targeted, while many video-transects also targeted nearshore rocky ridges that traversed much of the slope at these sites. In this section, sites along both sides of the QCS-TC junction are included and presented together here as these sites shared similar assemblages, but those in TC are also discussed in the TC chapter below.

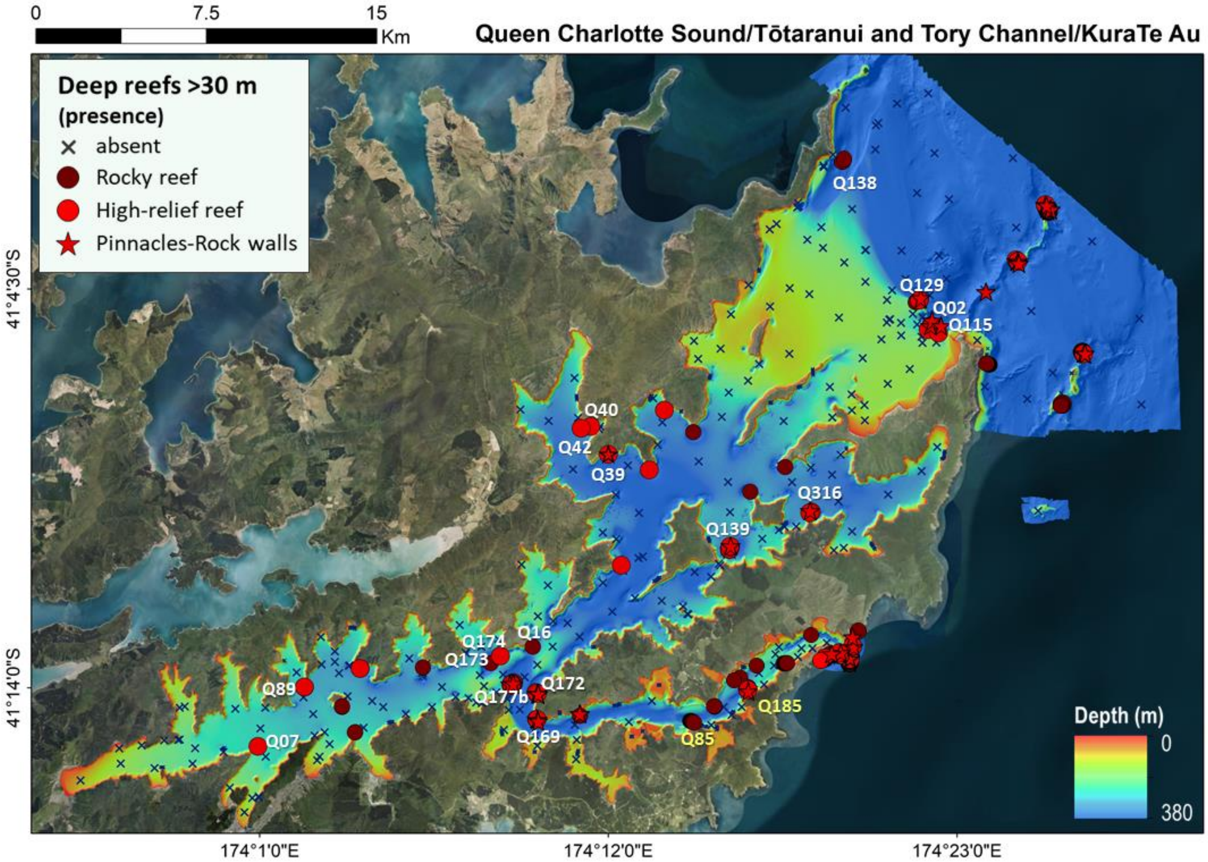


Figure 71: Location of deep rocky reefs within the HS51 survey area (depths >30 m), based on video observations.

Deep rock outcrops (>30 m) were recorded at a range of sites from inner to outer QCS (Figure 71). Rock outcrops varied in their size and vertical relief (Table 3-31; Appendix Table N-1), but were all part of more extensive rocky ridges off coastal headlands (Figure 31), with some extending up to 400 and 800 m away from the shoreline (e.g., Dieffenbach Point and Pattern Reef, respectively; Table 3-31). Rock outcrops in depth >30 m, were dominated by sessile invertebrate communities, although species composition differed depending on the vertical relief and location relative to current strength and exposure and the amount of sediment-veneer covering these reefs (although these are also strongly correlated).

Inner QCS: Within Inner-QCS, rock outcrops were recorded at eight sites (Appendix Table N-1). Most observations at these sites represented very small isolated outcrops less than a few metres in size (represented by ≤3 records). Rock outcrops within the sheltered waters of the inner sounds were generally of low to moderate relief, covered in various amounts of depositional sediments, and supported benthic communities dominated by solitary sea squirts, with mixed encrusting species (occasional *E. alata* sponges on more elevated sections of outcrop) along with a few sediment-tolerant yellow sponges (*P. hirsuta*). The two largest and most notable deep outcrops were at Pihaka Point (Q89, Q310) and at the Snout, Picton (Q07). The deep outcrop at Pihaka Point occurs within 107-165 m offshore, in depths of 31-43 m. This feature measures ~62 m downslope and ~34 m across-slope, with highest section of the outcrop standing 8 m high (Table 3-31). This deep reef supported several large grey *E. alata* sponges (e.g., Figure 72a) and a variety of small sessile invertebrates, including small hydroids, solitary cup corals (≤ 5 per image), indeterminant small brachiopods, and sea squirts, along with seaperch and a dwarf Scorpionfish (Table 3-30), as well as an elephant fish on the adjacent lower slope. The boundary of ESMS-4.14 at Pihaka Point does not include this deep reef, with the shallowest edge of the reef lying 3 m beyond the outer edge of ESMS-4.14. The extension of the ESMS-4.14 boundary to include this deep reef feature may be worthy of discussion. At the Snout, an extensive, but relatively narrow ridgeline extends 774 m offshore, with the last 318 m occurring in depths of 30-35 m. This deep section of the ridge is less than 19 m wide, with highest section of the outcrop standing ≤4 m high (Table 3-31). Outcrops seen here were heavily laden with sediment, and supported a relatively indistinctive benthic community, except for notably high localised densities of solitary cup corals. The rubble slopes along the flanks of this deep reef also supported regular occurrences of solitary cup corals, albeit in much lower densities. In contrast, the few small low-lying outcrops seen supported some of the highest localised densities recorded within the survey, and were the highest seen within Inner QCS (see Section: 0 - cup corals).As with Pihaka, the deep reef at the Snout does not lie within the nearby ESMS-4.9 which is limited to reefs <30 m.

QCS-TC junction sites: Deep reefs around the high current channels at the QCS-TC junction supported much richer sessile communities that covered most of, if not all the reefs surface, with localised or little sediment-veneer. Here communities were characterised by a wide assortment of species including dense clusters of reef-encrusting barnacles (extensive structure covering the reefs), notable bleach-white *E. alata* sponges (e.g., Q169, Q172 and Q177b), along with a rich assortment of sessile invertebrates including encrusting ‘reef-building’ bryozoans, ascidians, hydroids and rock anemones (e.g., Figure 12d-h, see Table 3-30).

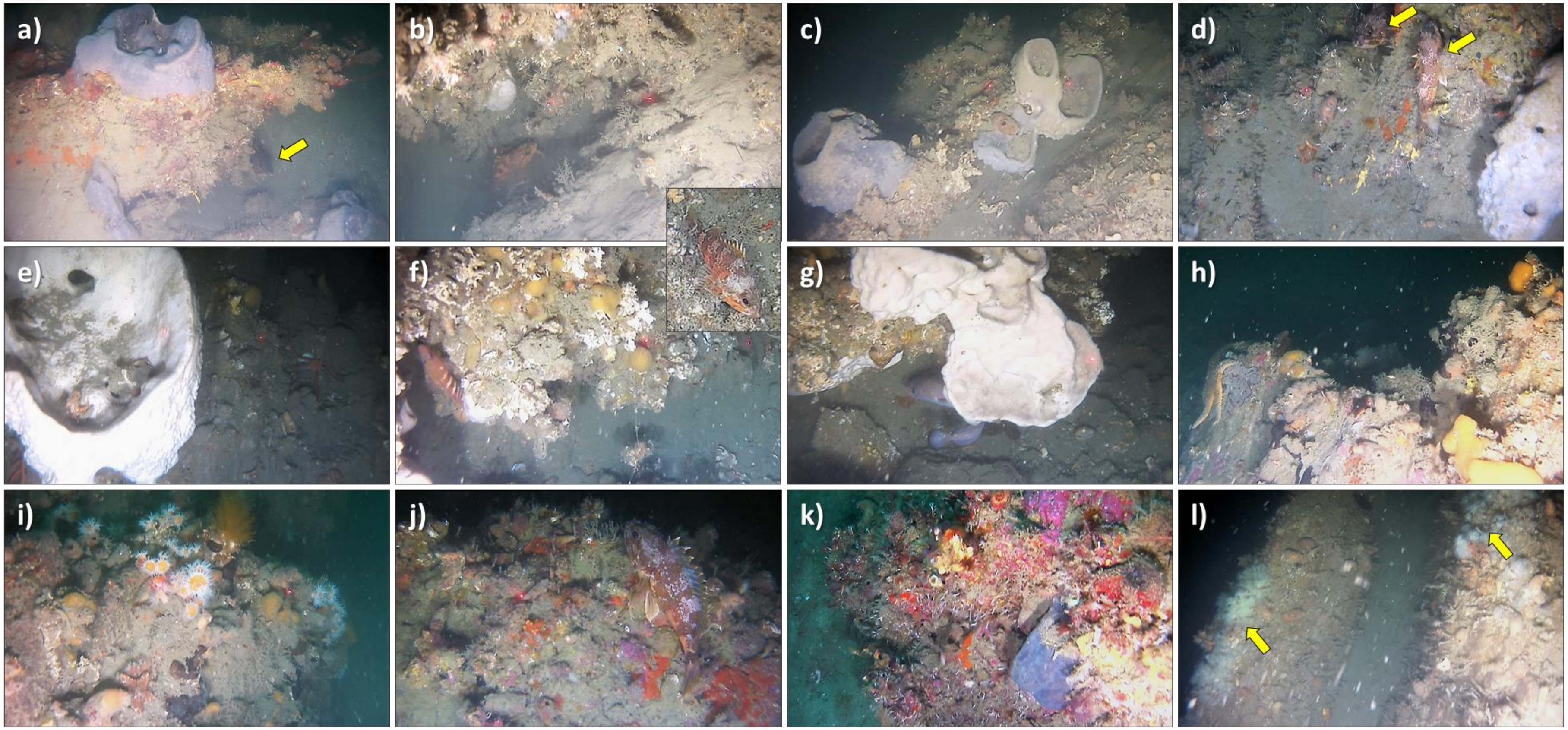


Figure 72: Examples of deep reef communities within inner, mid and outer QCS. a-d) Deep rocky reefs within inner QCS, with: a) *E. alata* sponges and sea perch (yellow arrow), Wedge Point, Picton, 31 m (Q07); b-c) Deep rock outcrops and ledges off Pihaka Point (Inner QCS, Q89), with sea perch in deep crevice [b] and large *grey E. alata* sponges with sea squirts and small encrusting invertebrates, 37 m (c); d) Deep ridgeline with large blue-grey sponge and seaperch (yellow arrows) in Tawa Bay, Endeavour Inlet, 32 m (Q40); e-i) Deep rocky reefs at or near the junction of QCS-TC**:** e-f) Extensive deep reef off Dieffenbach Point, with large bleach-white *E. alata* sponges [e], banded wrasse in crevice and small sessile invertebrates dominated by epiphytic bivalves and white barnacles densely encrusting the reef [f] in ~40-45 m (Q315, Q177b); Deep reef off Ruaomoko Point, with large bleach-white *E. alata* sponge with rockcod beneath it, ~41-43 m (Q169); h-i) Bio-encrusted deep rocky ridgeline off West Head, Ruakaka Bay (adjacent to QCS-TC junction), with sea squirts, small encrusting invertebrates and starfish, ~31-33 m (MDC18-Q173, Q174); j-l) Deep ridgeline reefs in mid/outer QCS: j) Deep ridgeline, southern headland to East Bay, with seaperch, 31 m (Q316); k) Deep ridgeline with colourful sessile invertebrates, near Marine Head, outer Endeavour Inlet, 35 m (MDC19-Q39); l) Deep ridgeline pinnacles with sea squirts, patches of jewel anemones (yellow arrows), NE of Pattern Passage, in 40 m mid QCS (Q139).

The most impressive reef was the extensive high-relief reef feature off Dieffenbach Point that reaches a vertical height of 25 m in deep section and supported the most striking communities seen on deep reefs within the Sounds (e.g., Figure 12f-g), including dense raised clusters of barnacles and rock anemones on the tops of the rock pinnacles. This reef is described in detail in the Tory Channel Chapter (Section 3.4.4; with more images in Figure 90). Similar communities were also recorded at sites Q169 and Q172, although the vertical height at these sites were still notably high (6-7 m vertical height) and also supprted striking large bleach-white *E. alata* sponges, with large fishes occasional seen under overhangs (e.g., Figure 12g), these features and species assortments were less than those seen at Dieffenbach Point, including notably fewer barnacles clusters and rock anemones. Sites across the channel at West Head (at the outer headland of Ruakaka Bay), and Bull Head (the outer headland of Bay of Many Coves) also exposed to the extremely strong currents of the QCS-TC junction, were also characterised by diverse and colourful sessile invertebrate communities similar to those of the east/TC-entrance side of the junction, although again these sites supported lower vertical structures (2-7 m vertical height) and fewer barnacles and *E. alata* sponges (e.g., Figure 12h-i).

Mid-Outer QCS: Rock outcrops were recorded at 11 mid-QCS sites and 5 outer-QCS, in survey depths ranging from 30-51 m (Appendix Table N-1). However, at these sites most observations represented the very edge of shallower rocky ridges (represented by ≤3 records). Deep ridgelines located on exposed headlands, such as those at the entrances to Endeavour Inlet, Resolution Bay and East Bay, and adjacent to Pattern Passage appeared to support intermediate levels of diversity with reefs supporting moderately-dense cover of mixed sea squirt and encrusting sessile invertebrates, with some grey coloured *E. alata* sponges on higher relief sections of reefs, but also had moderate to high amounts of sediment-veneer on most of the lower-lying sections of reef (e.g., Figure 12j-l). However, unlike the reefs at the QCS-TC junction, no bleach-white *E. alata* sponges or reef-encrusting barnacles were recorded. Some mixed amounts of *Galeolaria* were also recorded, but was not a dominant component of these deep reefs. The most notable reef structure in this region was a deep narrow (19-44 m wide) ridgeline reef that extends 807 m offshore of Arapaoa Island (almost twice as far as Dieffenbach Point, but <1/3 of its width). This deep reef comprised steep side pinnacles (≤4.5 m tall), parallel series of ridges (e.g., Figure 12l), and narrow pillars (20 cm diam.) standing vertically with anchor rope snagged across them. These series of high-moderate relief outcrops supported notable numbers of large sized fish, that included sea perch, rockcod and adult blue cod, with rock surfaces covered in a mixture of sea squirts, and mostly small encrusting invertebrate that also included a few patches of jewel anemones (yellow arrows in Figure 12l). The flanks and gullys adjacent to these rock outcrops were characterised by rubbly sediment with a few shells, and supported notable numbers of tube anemone (*Cerianthus* sp1) and regular occurrences of giant lampshells in mostly low numbers.

A slight anomaly was seen at a deep on the headland on the NE side of Fitzgerald Bay at the entrance to East Bay (NE headland sites MDC18-Q72 and Q312). The deep reef off this headland along with the coarse sediment shell-debris habitats that flank this ridge were all heavily dusted in a homogenous layer of very fine silt that looked out of place on this otherwise exposed ridgeline (e.g., Figure 73d,f-l). This site also had some delicate filter feeders but only in low densities mostly on the very tops reefs (e.g., Figure 73f i), along with sections of both intact *Galeolaria* mounds and areas of rubble, all similarly covered in this very fine (almost noxious) looking silt, where some of the smothered species were dead (very few *Galeolaria* tubes were living), while other species appeared to be in poor condition (hydroids). In many places the silt layer was also covered in biofilm. A site surveyed on the SW headland of Fitzgerald Bay (MDC18-Q73 <2 km away), also had the very same heavy dusting of fine silts covering the seafloor, that was also covering coarser-underlying sediments where live *Tucetona* were present, indicating that this is not a normal composite of these habitat (as *live Tucetona* have a strong association with coarse sediments and are not found in sediment comprised of fine silts), but rather reflects a more recent and rather large-scale deposition event.

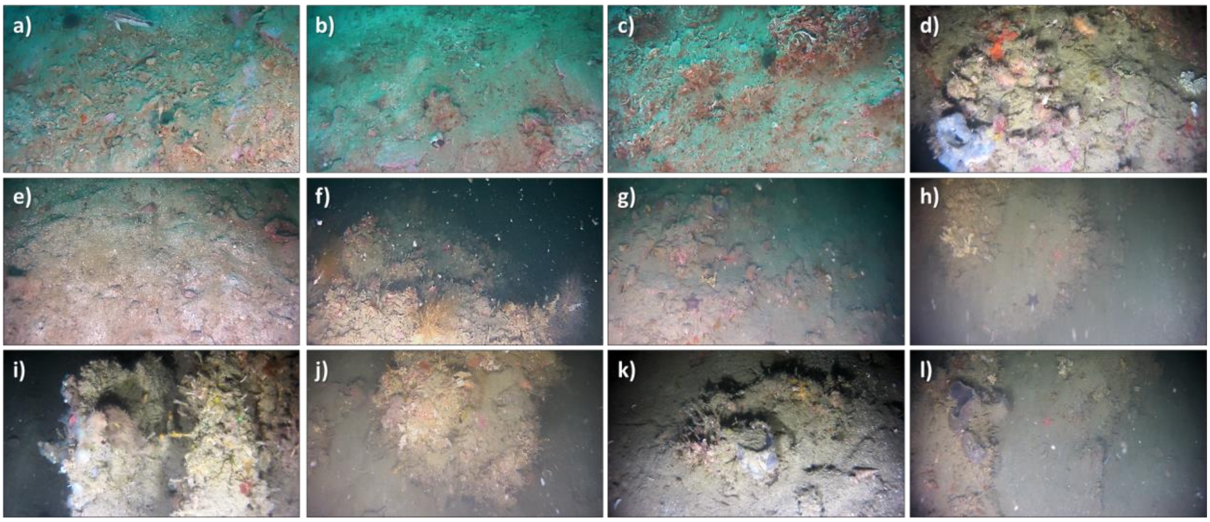


Figure 73: Examples of various habitats seen at the NE and SW headlands of Fitzgerald Bay, all covered in a thick homogeneous dusting of very fine silt that looked somewhat out of place on this otherwise exposed ridgeline. a-c,e) SW headlands of Fitzgerald Bay (site Q73); d,f-l) NE headlands of Fitzgerald Bay (sites Q72 and Q312). a-c) parchment tubeworm mats covered in silt; e) Live *Tucetona beds* that are characteristically found in coarse sediments all veneered in a dusting of fine depositional silt – the latter not a normal habitat for this species; d, f-l) all reefs except the very tallest one were all heavily dusted with depositional silt, smothering lower sections of reef and heavily dusting others e.g., sponges [k].

Outer QCS: Due to the shallow sediment sill (described in Neil et al. 2018a,b) that lies across the entrance of QCS, most of the seafloor in this region is in depths <30 m, so deep outcrops are rare. Although Long Island Marine Reserve (LIMR) supports a notable rim of nearshore reefs, very little reef extends to depths >30 m, and if it does these small outcrops mostly lie outside of the LIMR boundary. The only exception is a narrow line of outcrops (292m long by 12m wide, with a vertical height of ≤2.5 m) that lie within LIMR boundary in depths of 33 m, at 655-893 m north-east of Kokomohua Island. Three CB17 transects were surveyed within the LIMR, but these covered habitats in depths <30 m.

Deep reefs were well depicted in the HS51 bathymetry and rugosity layers, however seafloor classifications of secondary features that predicted rock outcrops, varied in the prediction success of these deep habitats. Large outcrops were generally well predicted in this layer, but often included rough shell debris mounds flanking these reefs as rock (e.g., outer section of the deep reef off Dieffenbach Point). Others mirrored the shape and size well, but again included rubble areas that were not reef (e.g., Pihaka point), while some small outcrops were absent in the rock outcrops layer (e.g., Q40). Consequently, while this layer provides a great first guide to where reefs occur, it needs to be used in conjunction with the underlying bathymetry and rugosity layers to depict the location and extents of deep outcrops. Fine tuning of this rock outcrop layer or delineating the boundaries of deep reefs individually is now required determine the areal estimates and relative availability of these rarer habitats throughout the Sounds.

Table 3-30: Characteristic features of deep reef habitats (>30 m) within inner and mid QCS. Underline sites = inner QCS sites, ^=mid QCS sites; *= outer QCS sites; #=QCS-TC junction.

Deep Reefs (within QCS)	Characteristic features and significant/notable taxa
Substrata	Moderate to high relief rock outcrops, some with biogenic-reef structure from reef-building bryozoa and other taxa incl. sea squirts, epiphytic bivalves and brachiopods. Sediment veneer present on most deep reefs: heavy (Q39^, Q40^), moderate (Q07, Q89) to low (Q139^, Q177b^, Q169).
Benthic community	High sediment sites characterised by sea squirts, cup corals and small encrusting invertebrates. Low sediment sites characterised by encrusted biogenic reef with diverse and colourful sessile invertebrates. **Sessile invertebrates:** Sea squirts (*M. squamiger*, common at Q07, Q89, Q310, Q40^, Q39^ abundant at Q139^, Q40^), grey *E. alata* sponges (few Q07, Q310, Q139^), Solitary cup corals (few Q39^, common at Q89, Q310, Q40^, abundant at Q07), large smooth red brachiopods (likely *N. lenticularis*, Q139^), indet. brachiopods (few at Q316*, Q72*common at Q89), Small hydroids (common Q07, Q89, Q310), mixed hydroids (Q139^), yellow sponges (*Polymastia hirsuta*, occasional at Q89, few at Q07, Q40^, common/patchy Q139^), large blue-grey dumpling sponge (Q40^), rock anemones (<15% cover at Q139), Jewel anemones (<2% Q07, Q89), small sparsely spaced tubeworms (Q40^, abundant at Q39^, Q139^), encrusting yellow orange sponge (<10% Q40^, Q39^), yellow spikey sponge (*D. oxeata*, <2%, Q72*), Sabellid fanworms (occasional, Q139^, Q177b). **Other notable species incl**. Jewel anemones ((<2% Q07, Q16^, Q89, Q40^, <15% Q139^), tube anemones (*Cerianthus* sp1, edges amongst reefs (e.g., Q139^, Q40^, Q39^), burrowing sea cucumbers (*Thyone* spA, few Q139^). **Species found only at QCS-TC Junction sites**: white barnacles, bleach-white *E. alata* sponges (but also present at site in QCS-entrance).
Motile invertebrates	Snake stars (few Q07, Q139^), Cushion star (*P. regularis* few Q07, Q40^), *A. insignis* (Q39^), biscuit cushion star (rare, Q40^, Q39^, often common), the apricot starfish, *Sclerasterias mollis* (rare, Q40^), *C. muricata* (Q40^, Q139^), Kina (rare, Q40^), *A. mollis* (common, Q139^), crayfish (extremely rare/ ecological extinct), large predatory gastropods sp. (few, Q139^).
Fish	Sea perch (occasional at Q07, Q16^, Q89, Q310, Q39^, Q72*, common at Q40^, abundant at Q139^, Q316*), red-banded perch (Q07, Q89, Q177b), Dwarf Scorpionfish (Q310, Q313), blue cod (few Q139^, Q177b, hordes at Q72*), juv. blue cod (2x 9-12 cm, Q39^, Q316*), elephantfish (soft-sediment near reef Q310), Rockcod (few at Q177b, Q169, Q139^), schools of roughy (in ravines and under hangs, Q177b, Q169), schools of butterfly-perch (high-relief sections, Q177, Q139^), Yellow-and-black triplefins (occasional Q139^, common Q177b, Q316*), John Dory (only at Q177a/b).opalfish (on sediment within reefs, Q40^), spotty (Q39^, Q139^) Large adult sized fish (Q139^, Q177b, Q169).
other	Anchor? Rope (Q139), beer bottle (Q139), broken plate (Q39), rope (Q39^) Fine silty sediment cover (on everything at Q72/Q316*, thick layer at Q39^, Q40^, Q42^).

Table 3-31: Summary descriptions of deep reefs surveyed within QCS. Measurements are based on HS51 MBES mapped layers using a combination of bathymetry with hillshaded relief and rugosity to determine the location and boundaries of these deep rocky outcrops.

Subregion	Site	Entire feature		Outcrop in >30m		Max. depth of feature	Is it within an ESS
		Max. length	Max. width	Max. vertical height	Max. length (Max. width)		
QCS-Inner	Q07	774 m	79 m	≤4 m	318 m (19 m)	≤34 m	No
QCS-Inner	Q89-310	170 m	116 m	**≤8 m**	62 m (34 m)	≤43 m	No
QCS-Inner	Q106	144 m	90 m	≤2 m	24 m (36 m)	≤36 m	No
QCS-TC junct.	Q177b	435 m	170	**≤14 m**	**162 m (132 m)**	≤56 m (poss. ≤61 m)	No[40]
QCS-TC junct.	Q172	200 m	144 m	≤3-**7.5 m**	90 m (~≥89 m)	≤50 m	ESMS-5.4 (2015)[41]
QCS-TC junct.	Q169*	105 m	*Continuous-TC*	**≤6.5 m**	30-43 m (contin.)	≤54 m	ESMS-5.4
QCS-TC junct.	Q173-174	1,157 m	170 m	<3-**7 m**	Contin. (<6-134 m)[42]	≤53 m (poss. ≤61 m)	No
QCS-mid	Q16	304 m	78 m	≤2-4 m	99 m (59 m)	≤46 m	No
QCS-mid	Q139	807 m	19-44 m	<3-4.5 m	**459 m** (44 m)	≤49 m	No
QCS-mid	Q39	140 m	54 m	≤3.5 m	19 m x (16 m)	≤35 m	No
QCS-mid	Q42	246 m	130 m	≤4.5 m	79 m (56 m)	≤47 m	No
QCS-mid	Q40	Isolated	18 x 16	≤2-3m	18 m (16 m)	≤41 m	No
QCS-out	Q316/Q72	393 m	18-98 m	**≤8 m**	172 m (98 m)	≤48 m	No

[40] Surprisingly none of the deep reef off Dieffenbach Point lies within an ESS, ESMS-5.1 does not include any of this extensive highly diverse deep reef system. Although likely to be a natural refuge to some degree given it lies underneath the ferry path.
[41] Based on the recommend revised boundary for ESMS-5.4 then yes, but it is outside the original 2011 boundary.
[42] Extremely long rocky ridgeline but mostly <30 m, with only a narrow strip at the lower edge of this ridge in depths >30 m.

Deep rock outcrops within QCS-entrance

At the entrance to QCS, several deep reef features occur in water depths of 31-110 m (Area D in Neil et al. 2018a). During the MDC18 surveys four of these deep reef features were surveyed (Figure 71; Table 3-33; Figure 75; Figure 76). On the eastern side of the entrance to QCS, three deep reef sites were surveyed (Sites Q02, Q115 and Q129, Figure 71): one at the top of the slope (Q115) in depths of 30-39 m; one at the base of the steep sloping channel in 68-90 m (Q02); and the third was a section of deep sloping reef of the much-more extensive sections of deeper reef (down to 101 m) that lie below White Rocks (although only depths down to 43.9 m were surveyed).

QCS-entrance - eastern channel: Outcrops at the top of the slope (Q115) were relatively small in comparison to other reefs in the entrance with vertical relief ≤6 m (Table 3-33; Figure 75d). These outcrops were characterised by a thick covering of biogenic structure formed by relict bryozoan reef along with actively growing bryozoa (*C. agglutinans*) along with an assortment of other encrusting taxa. These outcropping reefs supported very diverse and dense cover (≤100% cover) of small sessile invertebrates (e.g., Figure 74b), including colonial ascidians, small sponges, sea squirts, jewel anemones, clusters of brachiopods (indet species) and small hydroids, along with occasional orange soft bryozoans and a variety of small indeterminant turfing species – possible smaller hydroids. At the tops of these often-steep features were notably large grey *E. alata* sponges (e.g., Figure 74a,c, >50 cm diam.). Low-lying areas between these outcrops and the main channel slope adjacent to these outcrops were composed of biogenic rubble and shell debris, with snake stars, green soft bryozoa (≤ 30% cover), small hydroids, various starfish and a few Sabellid fanworms - all of which are also characteristic of other rubble-slopes across the survey area (see subsequent chapters).

The large outcrops along the lower sections and base of this slope (Q02) measure 162 x 74 m in size, with vertical relief up to 10 m (Table 3-33; Figure 75c). The reefs were composed of undulating reef structure with vertical walls and steep ridgelines that created a complex reef-scape. These outcrops appeared to be comprised of mostly biogenic-reef structure, or at least so heavily encrusted with biogenic structure to not see any bedrock. These reefs supported high diversity and very dense cover (≤100% cover), that included impressively large bleach-white *E. alata* sponges (e.g., Figure 74e-h), along with a wide range of other small and large taxa. For example, the base and lower sections of these reefs were heavily encrusted with mixed sessile invertebrates, dominated by dense clusters of brachiopods (~50 indiv. in a single image), along with sea squirts, colonial ascidians, and abundant snake stars. The sides and sloping sections supported fewer brachiopods and more encrusting sponges, colonial ascidians, notable numbers of very large hydroid tree, along with a few solitary cup corals; while the reef tops and ridgelines supported very large sponges (>50 diam.) of various morphologies, including large-sized cream-brown sponges (*P. cf massalis*) along with lines of large bleach-white *E. alata* sponges. Low-lying areas between and around these outcrops were filled with coarse shellhash and gravels with some small shells (incl. a few *Panopea* shells), through which several sessile invertebrates (<15% cover) were growing indicating hard substratum beneath. These included orange soft bryozoa, hydroid trees and strappy sponges. In a few sections between these ridgelines up slope, the seafloor flattened out and was comprised of a shelly-rubble slope, characterised by snake stars and green soft bryozoa (<15 % cover), also with occasional hydroid trees. Q02 was the most notable reef surveyed in the entrance to QCS, and along with Dieffenbach reef, were the two most notable reefs surveyed within the Sounds.

Most reef structure seen on the slopes around the east entrance were composed of biogenic reefs, likely created by the reef-building bryozoa (*C. agglutinans*), along with contributions from other encrusting and clumping taxa, with various sized patches of living *C. agglutinans* also common. The large size and vertical relief offered by these reefs indicate that bryozoan reefs in this region are likely to have been a historic building block associated with the slope and sill sections of the Duck Pond, and in turn provide substrata for a wealth of sessile and motile invertebrates and fishes.

On the outer exposed side of White Rocks, rock walls in 30-44 m depth comprised relatively flat rock slope with increasing steepness as we ran up slope. At 44 m depth the angle of the slope was ~20^0, with the rock surface covered in a veneer of sediment and supported a range of small sessile invertebrates characterised by orange soft bryozoans, solitary cup corals (≤8 indiv. per image), encrusting sponges, along with the sediment tolerant sponge (*P. hirsuta*) (e.g., Figure 74j,k). Sections of reef-slope were infilled with coarse gravelly sediments, and in places looked like a scree slope – here green soft bryozoans were common with some solitary cup corals (≤1-3 indiv. per image). Small low-relief ledges on the rock wall were encrusted with relict bryozoan-reef with various sized patches of living *C. agglutinans* also present. Further up the slope the angle steadily increased to 60^o, here the rock wall supported a variety of sponge garden species including cream-brown sponges (*P. cf massalis*), pink ball sponge (*Aaptos* sp.), and moderate to large yellow cup sponge (*S. crater*, e.g., Figure 74l), along with several orange strappy sponges (*P. sinclairii*) and grey chimney sponges (*P. beresfordae*). These rock walls also had a thin but noticeable veneer of fine sediments. These sponge garden species were also common on deep reefs in the entrance to TC (see Section: 3.6.5, but markedly less than the gentler slopes down deeper.

Although these three deep eastern-channel reefs varied in their spatial extent and vertical relief (Table 3-33; Figure 75), where relief was high they supported diverse communities characterised by sessile filter feeders with a rich assortment of small encrusting species and a either a range of sponge garden species and/or large sized sponges (e.g., Figure 74a-i), with many taxa similarities to those found out on the offshore deep reefs (as described in Section 3.5.1).

QCS-entrance - western channel: On the other side of the entrance to QCS, in the western channel, a large low-lying feature is present on the channel floor in depths of 94-100 m, directly offshore of Waihi Point, near Cape Jackson (Site Q138, Figure 71; Figure 76a,c). This feature is ~1,641 x 715 m in size, with a maximum vertical height of only ≤2-4 m (as measured across the depth profiles), and is located approx. two-thirds of the way down the channel slope (e.g., Figure 76a,d; Table 3-33). The slope here is <$10\text{-}20^o$, but increases to an angle of ~44^o on the lower slope directly below this feature before returning to a slope of <10^o.

The video-transect across this feature (MDC18-Q139), found this deep reef to be composed entirely of relict bryozoan-reef, with convoluted reef structure mostly raised only a few cm's above the surrounding seafloor (max. observed height of ≤~30 cm). Based on the HS51 rugosity map of this reef (Figure 76b) in combination with the ground-truthing video observations, this low-lying bryo-reef is heavily inundated with coarse and fine sediment that looked to be flowing down-slope filling in any low-lying areas. The amount of exposed bryo-reef was highly variable along the transect, quickly changing from slightly raised, to patchy bryo-reef partially-covered and infilled with sand and some shell debris, into sloping seafloor covered completely in muddy sands that extend a few metres up to 10's of metres across the feature. Sections of raised reef supported mostly low % cover of sessile invertebrates (≤2-30% cover) of mostly encrusting or small invertebrates (e.g., Figure 74m-n), characterised by live hard encrusting bryozoans (*C. agglutinans*, ≤5-20% cover), along with a few other species including colonial ascidians, hydroids (<3% cover, including *H. campanula*), along with a few occurrences of erect species, such as digitate and strappy sponges (e.g., Figure 74o), smooth red brachiopods, and an occasional tube anemone or hydroid trees. The highest sections of reef (still less than 20-30 cm in height) supported the highest % cover (i.e., ≤30% cover), although these areas were small and few (e.g., Figure 74m-n,q). Lower-lying sections of the reef were in-filled or covered in a thick veneer of sediment (≤70% cover), with some shell debris, comprised of a range of species, including screw shells, *Talochlamys* shells, and various sized bivalve shells (e.g., Figure 74p), along with numerous saw shells (*Astrea heliotropium*). Sections of reef heavily veneered in sediment were characterised by snake stars and *A. mollis*, while rubble and shell debris slopes were characterised by patchy % cover of green soft bryozoans (≤5-30% cover) (e.g., Figure 74-p[10]). Several sea perch were also recorded across the feature.

These video-observations marry well with the rugosity maps that depict semi-linear sections of rugose seafloor surrounded by patches of low rugosity that range in size from 7-35 m in the vicinity of this transect (equally those seen in the video), but also include some low-rugosity patches up to 50 and 100 m in size in other areas of this feature. While many of these low rugosity patches were muddy sands with some gravels, other low to intermediate rugosity patches were comprised of mixtures of sediment and partially-buried rubble and shell-debris, similar to those seen along the mid to upper slopes of the eastern channel (as described in Section 3.2.2 – Bryozoan patch-reefs).

In contrast to the rugosity layer, which accurately depicted areas of relict bryozoan reef versus inundated areas of sediment and debris slopes, this deep-reef feature was not depicted at all in the second order ‘Rocky outcrop’ classification layer. Consequently, the rocky outcrop layer would be of little use in calculating the area of this reef. However, calculating the area of this relict bryozoan reef (i.e., emergent relict-reef) should be well estimated by calculating the total area of high rugosity (red areas in Figure 76b). Although his low-lying reef does not support a significant biological community the present of such a large area of relict bryozoan reef along with still active growing reef is likely to have important implications to understanding the paleoecology and geology of this region.

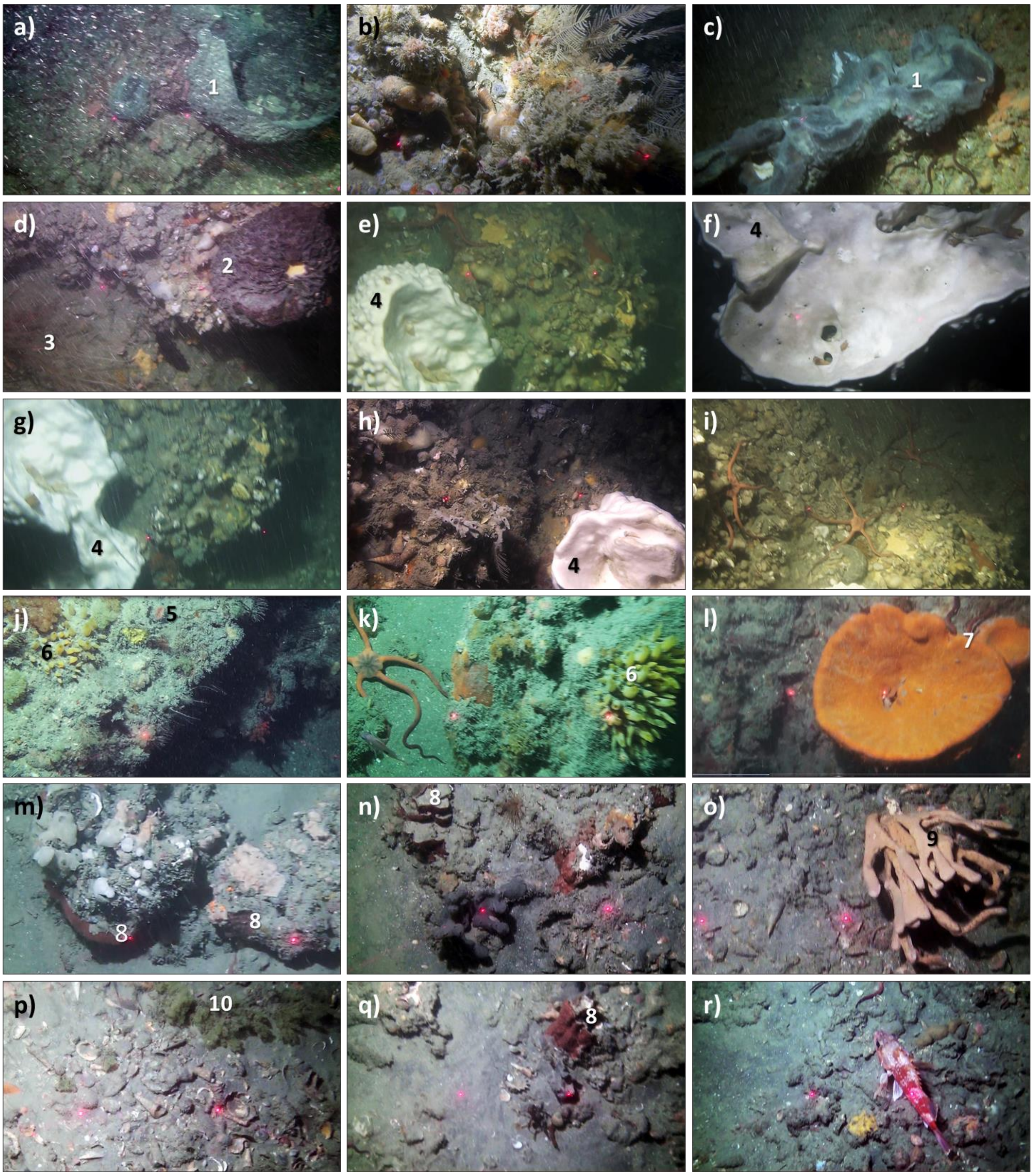


Figure 74: Examples of deep reef communities within the entrance to QCS. a-c) Deep patchy reefs ≤4 m high, along the outer edge of the Duck Pond near Cape Koamaru (Q115, 28-33 m water depth); d-i) Deep high-relief reefs (≤10 high) on the outer slope of the eastern channel, near Cape Koamaru (Q02, 68-84 m); j-l) Deep reef community on reef slope around White Rocks (Q129, 19-36 m); m-r) Low-lying relict bryozoan reef on the outer slope of the western channel adjacent to Waihi Point, near Cape Jackson (Q138, 89-100 m). [1]Grey *E. alata*; [2]Large purple sponge; [3]Hydroid tree; [4]Large bleach-white *E. alata* sponges; [5]Solitary cup corals; [6]Sediment-tolerant yellow sponge (*P. hirsuta*); [7]Orange cup sponge (*S. crater*); [8]reef-building bryozoa (*C. agglutinans*); [9]Orange strappy sponge; [10]Green soft-bryozoa on shell rubble slope; seaperch [r].

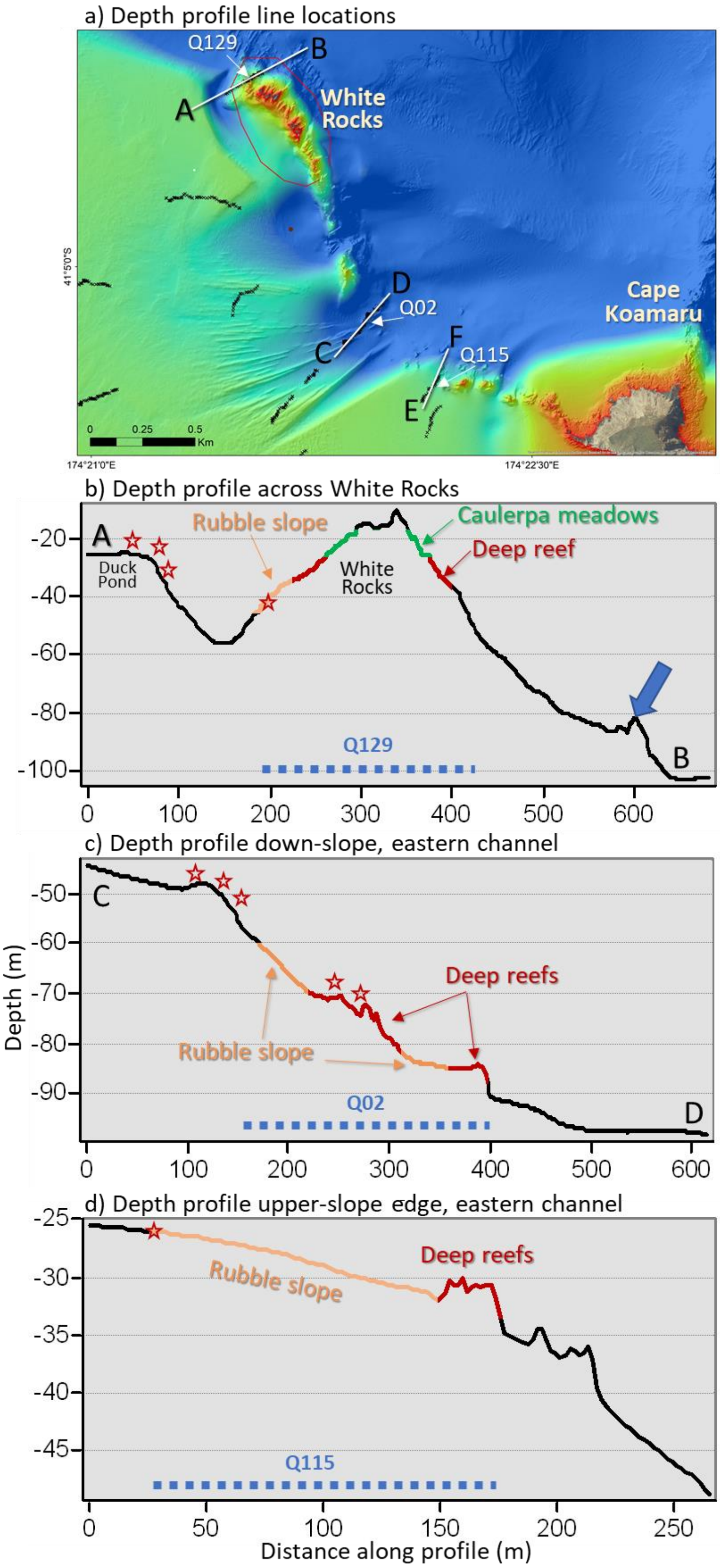


Figure 75: Depth profiles and illustrated habitat types across three deep reefs in the eastern channel entrance to QCS (a). a) The location of the three depth profiles showing their and proximity to video transects at these sites (white lines); b) Depth profile across the western side of White Rocks intersecting part of video-transect MDC18-Q129; c) Depth profile down-slope through site MDC18-Q02; b) Depth profile across the top of the Bank through site MDC18-Q115. Burgundy stars = outcrops composed almost entirely of relict bryozoan-reef, although larger outcrops were also encrusted with relict bryozoan-reef structure.

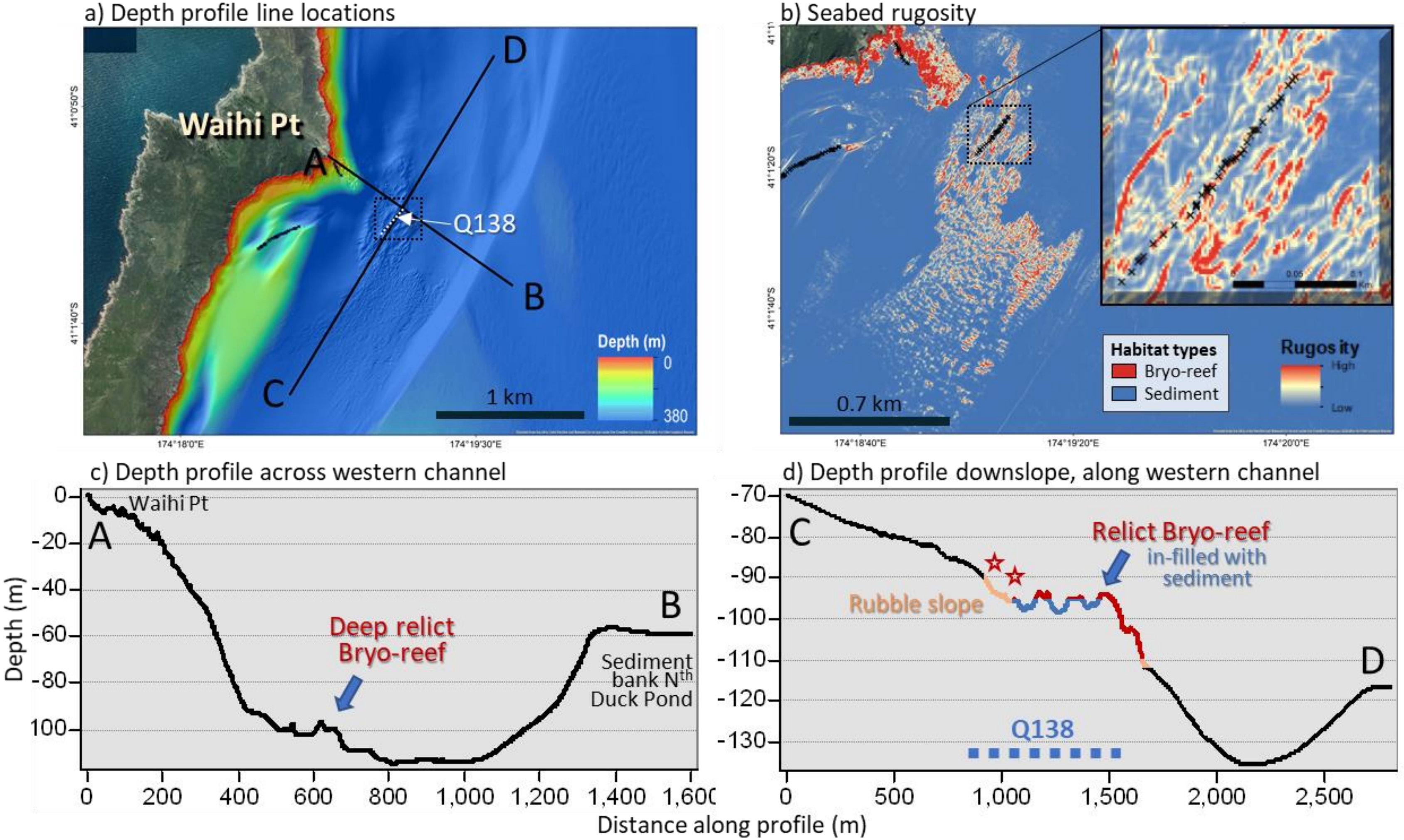


Figure 76: Depth profiles and illustrated habitat types across the deep relict bryo-reef located in the western channel entrance to QCS (a). a) HS51 bathymetric map showing the location of the two depth profiles (black lines A-D) and their proximity to video-transect MDC18-Q138; black dotted box= zoomed-in section shown in Figure b-insert; b) HS51 Seafloor rugosity layer with zoomed-in section (black dotted line) shown in Insert. c) Depth profile A-B across the channel through site MDC18-Q138 off Waihi Point; d) Depth profile C-D down-slope through site MDC18-Q138, depicting low-lying relict bryozoan reef in filled and/or partly buried by slope-sediments (based on video-observations). Burgundy stars depict patchy bryo-reef structure at sediment level in other low-lying rubble slopes.

Table 3-32: Characteristic features of deep reefs in the entrance to QCS.

Deep Reefs (QCS-entrance)	Characteristic features and significant/notable taxa
Substrata	Deep rock outcrops within the high-current channels on the eastern (e.g., Q02, Q115, Q138) and western (Q138) sides of QCS-entrance. Outcrops often heavily covered in biogenic-reef structure (from reef-building bryozoa), with some outcrops comprised completely of bryozoan reef (e.g., sections of channel slope at Q02 and Q115, and the entire reef structure at Q138). Sediment covering the reef in some sections at some sites (deeper ledges at Q129, low relief sections of Q02, most of Q138).
Benthic community	Deep reefs characterised by sessile invertebrates, with high relief with notably high % cover (60-100%) that may incl. large sponges (50-80 cm diam.), sponge garden species and large hydroid trees (e.g., Q02). **Sponges**: yellow cup sponge (*Stelletta crater*, Q02, Q129), large grey *E. alata* sponges (Q115, Q129), also large bleach-white *E. alata* sponges (common at Q02), cream-brown sponges (*P. cf massalis*, occasional at Q129), orange strappy sponges (*P. sinclairii*, few Q02, Q129, Q138), pink ball sponges (*Aaptos* sp., Q129), green spheres (*Latrunculia* sp. Q115), yellow spikey sponge (*D. oxeata*, base of reef Q129), cream chimney sponge (*topsenti*-like, Q129), grey chimneys (poss. *P. beresfordae* Q129), misc. small sponges (common at Q129), grey sponge sp2 (Q115, Q129, Q138), massive purple sponge (50 cm diam. Q02), massive dimpled tan sponge (50 cm diam. Q02), yellow sponges (*P. hirsuta,* few at base of reef at Q02, Q129), encrusting red sponge (poss. *Crella incrustans*, Q129). **Other sessile invertebrates**: Encrusting reef-building bryozoans (*C. agglutinans*, Q02, Q115, Q129, Q138), orange soft bryozoa on reef (Q02, Q115, Q129), green soft bryozoans on gravelly-rubble slopes (e.g., Q02, Q115, Q138), solitary cup corals (base of reefs, common, Q02, Q129), Jewel anemone (Q115), black brachiopods (likely *N. nigricans* in clusters at Q02, Q129), indet. brachiopods (dense clusters at Q02, Q115), *P. pachydermatina (*occasional, Q02, Q115), mixed hydroids (common at Q02, Q115, Q129), including hydroid trees (common at Q02, Q138) and *H. campanula* (Q02, Q115, Q138), jewel anemones (Q115), misc. colonial ascidians (common, Q02, Q115, Q129), colonial ascidian (*C. dellechiajei*, <5% Q02), purple colonial ascidians (*Botyrlloides* spp. Q02), misc. sea squirts (common, Q02, Q115), Sabellid fanworm (few Q02, Q129, Q138), Tube anemones (occasional, Q02, Q138), Large purple-bodied anemone (Q129), light-pink anemones (*Actinia* spA, 1x Q138); **Macroalgae:** *C. flexilis* (<2%, Q129), Drift algae (occasional, Q02), deep encrusting coralline algae (<5% Q129).
Motile invertebrates	Snake stars (occasional all sites), kina (occasional, deep-Q129), *A. mollis* (Q02, Q115, Q129), *C. muricata* (Q02), sawshells (Q02, abundant at Q138), biscuit cushion star (Q115, Q129), cushion star.
Fish	Butterfly perch (Q129), sea perch (Q02, Q129, Q138), black-and-yellow triplefins (Q115, Q129), scarlet wrasse (occasional, Q129), skate egg case (few, Q138).
other	Shell debris included *T. laticostata* shells (Q115[43]).

[43] A dog cockle bed has been reported by past-fishers to occur somewhere above this site. While the dog cockle bed wasn't found during our transects in this area, the occurrence of dog cockle shells at this site is indicative of live bed in shallow water somewhere on the upper zone of this channel above site Q115.

Table 3-33: Summary descriptions of deep reefs surveyed in the entrance to QCS. Measurements are based on HS51 MBES mapped layers using a combination of bathymetry with hillshaded relief to determine the location of these features, along with rugosity to determine the edges of these rocky outcrops.

Subregion	Site	Rock outcrop Max. length	Rock outcrop Max. width	Depth range of feature	Max vertical relief in depth >30 m	Surveyed depths Mean (+SE)	Surveyed depths Min-max	Inside an ESS
QCS-entrance	Q02	162 m	74 m	68-89 m	≤6-10 m	72.8 (1.1)	67.6-84.5	No
QCS-entrance	Q115[44]	69 m	35 m	30-39 m	≤2-6 m	32.1 (0.7)	31.0-33.4	No
QCS-entrance	Q129	1,400	470 m	0-101 m	≤12-25 m	35.2 (1.0)	31.0-43.9	Yes, part of deep reef in ESMS-7.8
QCS-entrance	Q138	1,641	715 m	93[45]-109 m	≤2-3 m[46]	95.8 (0.3)	94.0-100.3m	No

[44] One of several deep rock features down the slope, part of the larger basement reef that makes up the headland off Cape Koamaru, but occur as a series of clustered outcrops surround by an otherwise sediment rubble slope (based on transects down the slope in other locations. Measurement presented in this table are for a single cluster of outcrops, of which we surveyed the upper section.

[45] The upper slope section of this deep outcrop reflects a less defined outcropping surrounded by a flatter rubble slope. This zone occurs in depths of 77-93 m.

[46] Possibly up to 6 over 50 m in places but this likely includes slope too.

3.3.6 Seafloor plains (*Amphiura*-dominated communities)

Background: QCS Sounds are geological defined as 'drowned valleys' that are sediment deposition environments (Davidson et al. 2011). Neil et al. (2018a) characterised these drowned depositional valleys from the HS51 multibeam maps as seafloor plains that are "generally featureless with bioturbated fine-grained mud, low backscatter reflectivity, rugosity, and slope". They also defined an extensive relatively flat seafloor plain of fine muds that dominate the central channels and large bays within the inner and mid Queen Charlotte Sound, and an extensive sill area composed of sandier muds in the outer sounds spanning the entrance of QCS. Soft sediment benthic communities within Marlborough sounds are known to support characteristic assemblages, that vary based on depth, sediment composition and hydrology (Estcourt 1967; Davidson et al. 2015). Muddy sediments within the Marlborough Sounds support taxa that are known to be widespread and common in both Queen Charlotte and Pelorus Sounds, dominated by heart urchins and brittlestars along with small infaunal bivalves and polychaete worms (e.g., Estcourt 1967; McKnight and Grange 1991).

Ground-truthing surveys: Considerable sampling effort already existed within the 'seafloor plains' zone from the previous three surveys, especially during the HS51 which included drop-camera video footage along with sediment grabs for >50 sites within the central channels and large bays within the inner and mid Queen Charlotte Sound, and >20 sites in outer QCS (incl. >15 sites on across the sill). While this information provided excellent information of sediment types and grain-size composition, video-imagery was very brief. To compliment this information, additional sampling effort was allocated to these areas during the MDC18 survey (i.e., providing video-transect scale information) to describe the biological community structure in these seafloor zones. Our findings identified that community structure was distinctly different between the muddy seafloor plains (within inner and mid QCS) and the sandier mud sediments on the sill (Outer QCS).

The bottom of the drowned valleys across QCS were classified as seafloor plains by Neil et al. (2018a) with low and low-medium reflectivity muds. These areas were the largest areal habitat mapped, which, based on seafloor backscatter classes, accounted for 58.1% of the seafloor area mapped. Seafloor plains within the inner and mid QCS supported a distinct *Amphiurid*-dominated community, characterized by relatively flat muddy sediments, low to moderate numbers of small to medium sized burrows and the presence – often in very high densities – of the rose-coloured brittlestar, *A. correcta* - which when emergent look like a sea of pink arms extending out of the sediment (e.g., Figure 77), and was consistently recorded across the extensive plains within inner and mid QCS) (Figure 78), in water depths of 17-63 m (Mean depth 42.1 m ±0.8 SE). *Amphiura correcta* (Koehler 1907; *Amphiura norae* of Estcourt 1967) is a small pink-coloured and very fragile brittlestar (disc <1 cm in diam.) with long thin arms (that easily fall to pieces during collection) (Figure 79a-f). These little brittlestars lie beneath the muddy sediment of the seafloor – often thousands per 100 m^{-2} – and extend their arms up through the mud ~2-4 cm into the water current to feed (e.g., Figure 77). *Amphiura*-dominated Seafloor plains were restricted to the inner and mid QCS, although a few specimens were also collected in localised silty mud habitats in outer QCS (e.g., BT17-QC10 in 22 m water depth) and in silty muds within a TC embayment (BT17-QC37 in 14 m), indicating the sediment composition rather than depth is important to *A. correcta*. McKnight et al. (1969) and McKnight and Grange (1991) also found extensive distributions of *Amphiura* spp. in homogenous mud zones over broad depth ranges (15-100 m).

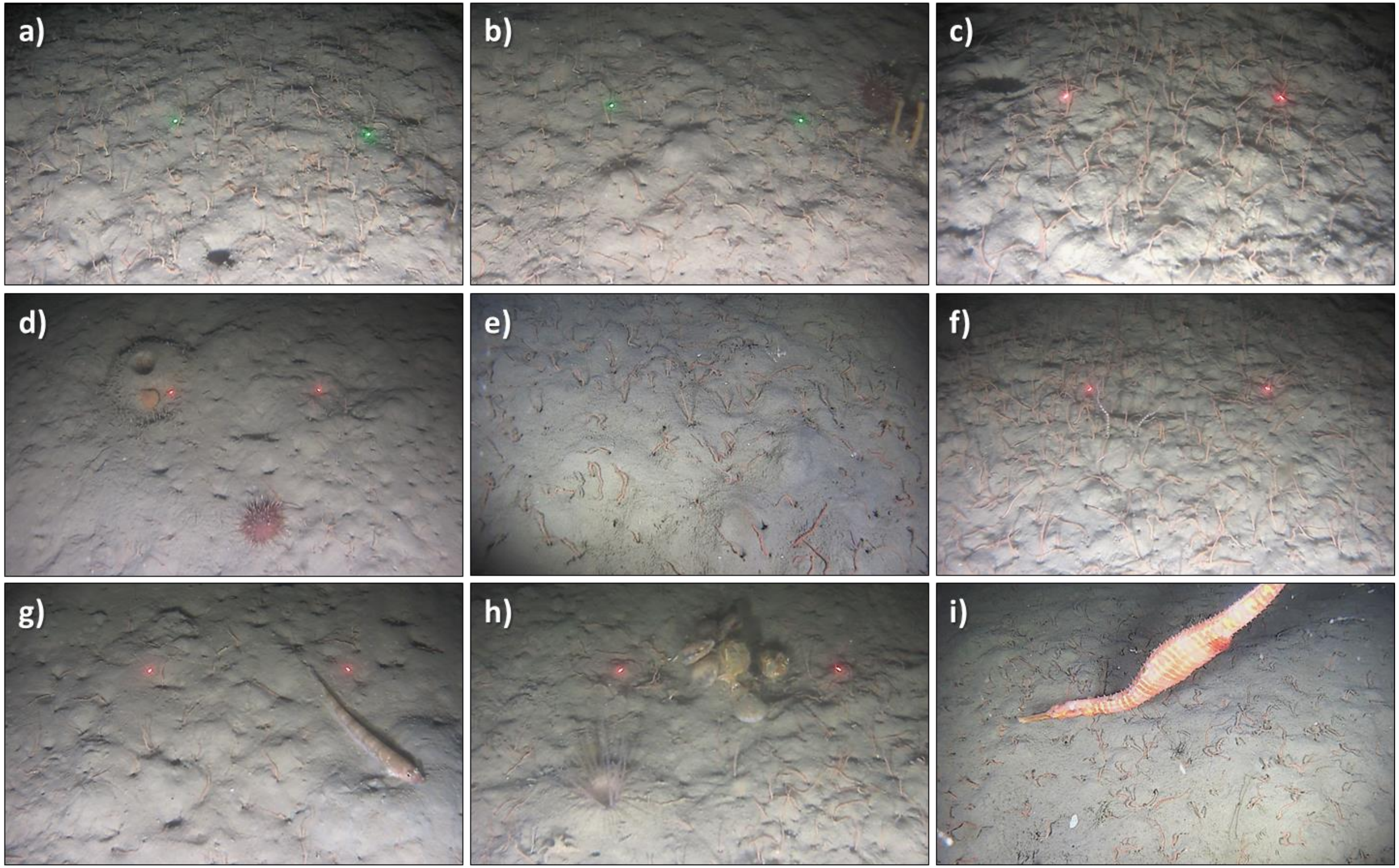


Figure 77: Examples of deep-basin muddy sediments with characteristic *Amphiura correcta* (the rose-coloured brittlestar) dominated communities within QCS. Images show buried *A. correcta* with their long pink arms extending up through the mud ~2-4 cm into the water current, from MDC18 survey. a) dense zone of *A. correcta* in depths of ~50 m (Mid-QCS site Q14); b,d,g) dense to sparse fields of *A. correcta* in depths of 30-46 m (Inner QCS, Site Q13); c,e,f,h,i) dense to moderate dense zones of *A. correcta* in depths of 59-62 m (Mid-QCS, Site Q202). Associated species seen here are *P. albocinctus* [b,e]; an opalfish [g]; the burrowing tube anemone, burrowing anemone *Cerianthus* spA, [d,h]; epiphytic fan shells, *Talochlamys zelandiae* [d,h]; and the sea dragon, *Solegnathus spinosissmus* [i].

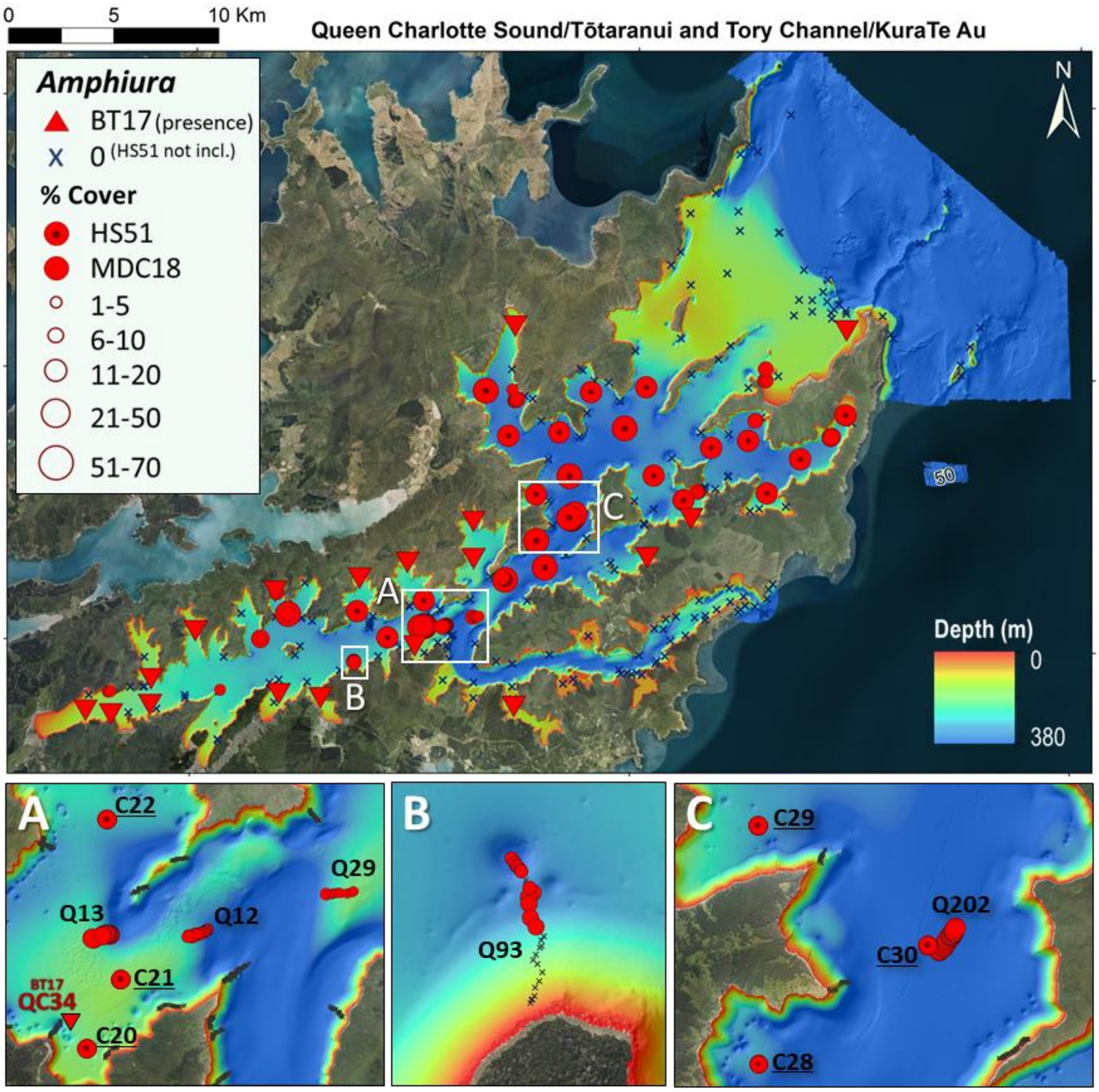


Figure 78: Distribution and rank % cover of *Amphiura* in the *Amphiura*-dominated seafloor plains within QCS and TC, based on all surveys. Bubble plots are presented for MDC18 and HS51 (No *Amphiura* were recorded in the CB17 survey[47]); Inverted triangles = presence of *A. correcta* in BT17 beam trawl catches (burgundy site label)[48]. Absence records are only presented for MDC18 and CB17 sites[49]. Insert A) Junction between QCS and TC showing moderate to dense *A. correcta* beds within the Seafloor plains; B) Site Q93 identifying the transition zone between deeper seafloor plains with *A. correcta* (here depths of 38-49 m) and slope habitats (here <38 m) off the southern point of Kahikatea Bay, Inner QCS (Site MDC18-Q93); C) Example sites with dense fields of *A. correcta* within mid QCS, with the highest densities recorded along most of video transect at site Q202 in 59-62 m water depth, west of Blumine Is. (with equivalent estimates recorded at the nearby site HS51-C30 in 59 m, with similar high densities recorded over much of the mid-QCS Sediment plain zone[-27].

[47] CB17 video transects targeted juvenile blue cod habitats in depth <30 m, and therefore did not sample expansive soft-sediment areas.
[48] Density of *A. correcta* collected in Beam trawls have been standardized by area sampled, however as this species buries in surficial sediments that are not well sampled by beam trawling, presence-only values are presented here.
[49] Reduced visibility in HS51 dropcam footage, especially in more turbid waters within the inner Sounds often inhibited detection of very small brittlestar arm, consequently we do not present HS51 absences ('x') here as presence vs absence could not be determined at these sites.

Amphiura correcta was by far the most abundant species seen in this habitat zone, however, other epibenthos were also observed on the seafloor in these sites. (e.g., Figure 79; Table 3-34). These included sparse densities of the red urchin, *Pseudochinus albocinctus* (e.g., Figure 77b,d), regular occurrences in low densities of the burrowing anemone, *Cerianthus* spA (e.g., Figure 77d,h; although more common on or near the lower slopes of the QCS), occasional occurrences of sessile invertebrates such as small digitate sponges (e.g., Figure 77b), and localised clusters at some sites of the epiphytic fan shell, *Talochlamys zelandiae* at some sites (common at site MDC18-Q202, west of Blumine Is. Figure 77d). Benthic fishes were also seen in low numbers, with species such as opalfish (e.g., Figure 77g), spotties and flatfish seen occasionally, while other species were rare (e.g., sea dragon in Figure 77i).

Amphiura-dominated communities were also collected from 16 Beam trawl sites that sampled the seafloor plains (BT17 survey; Table 3-34). Other species collected from these sites included heart urchins, *Echinocardium cordatum* (often in very high volumes e.g., Figure 79g,h), mudworms, *Asychis* spp. (that live in thick tubes made of mud, also often in very high volumes that clogged up the trawl net[50] Figure 79i), often high numbers of small infaunal bivalves, dominated by strawberry cockles (*Pratulum pulchellum*), along with other small bivalves (e.g., *Ennucula strangei, Neilo australis, Notocallista mutlistriata*); variable numbers of scallops (e.g., Figure 79j,l), as well as a broad range of taxa in low numbers (e.g., opalfish, flatfishes, *P. albocinctus*, *T. zelandiae*, 5-armed starfish, brachiopods, *P. regularis* and various mobile gastropods (e.g., spiny murex, *Poirieria zelandica*, *Amalda* spp. and the knobbled whelk, *Austrofusus glans* Figure 79l). Many of these species have previously been documented in association with *Amphiurid*-dominated assemblages around New Zealand (McKnight et al. 1969) and within the Marlborough Sounds (Estcourt 1967; McKnight and Grange (1991).

In contrast, to the homogeneous and contiguous silty muds across the inner and mid QCS, the outer Sill (the large sediment Bank feature across the entrance to QCS) was characterised by sandier muds, (HS51 sediment grain size plots in Figure 3-11 of Neil et al. 2018a). These sandier muds were characterised by the absence of *A. correcta*. Sill sediments were all characterised by varying amounts of biofilm and medium-sized burrows, but community structure otherwise varied spatially across the Sill. Inner Sill sites were characterised by live scallops, scallop and horse mussel shell debris – with shell debris at some sites supporting a range of encrusting and erect epibenthic species, such as small digitate sponges, and colonial and solitary ascidians (e.g., HS51-A5). The middle of the Sill was characterised by seafloor plains with patchy low-moderate density red algae (e.g., *Stenogramma interrupta, Sarcodia montagneana, Schizoseris* sp., *Sporochnus* sp., *Cladhymenia oblongifoli* sp., *Plocamium* sp. and *Rhodophyllis* sp. - species known to grow on muddy sands), while outer Sill sites were characterised by various amounts of patchy bryozoan reef (as described in 3.2.2 Bryozoan patch-reefs). Other species common at these sites included screwshells, hermit crabs, large epibenthic gastropods (whose trails were seen across the seafloor), *A. mollis* (common) and starfish (mostly *C. muricata* and *P. regularis*). Species characteristic of the *Amphiurid-dominated* plains, such as heart urchins, strawberry cockles, and *N. multistriata*, were collected at a few Sill sites, but mostly in low to negligible numbers.

[50] The mud-tubes of these mudworms often disintegrate during the process of collection.

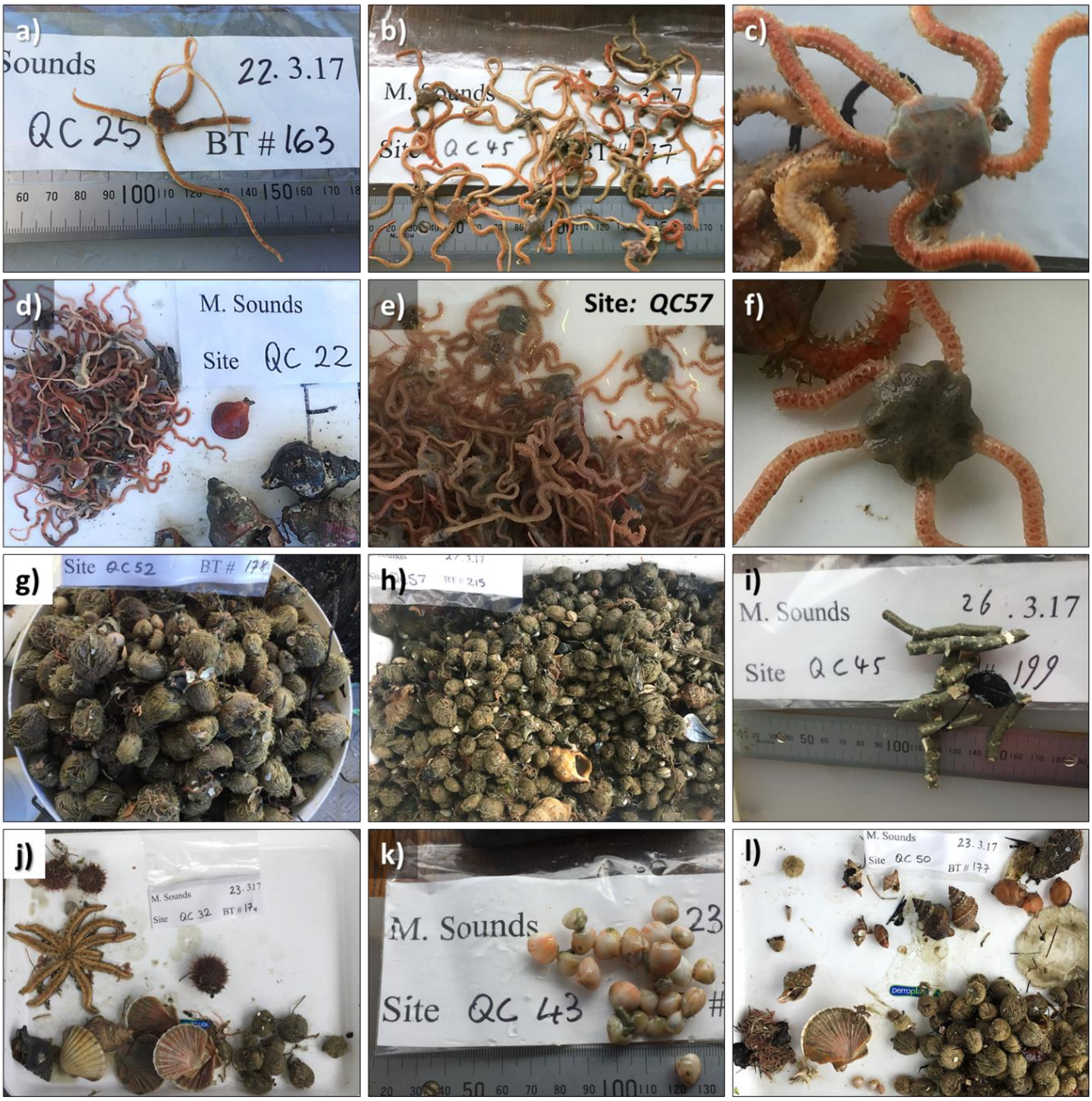


Figure 79: Examples of specimens collected from *A. correcta* (the rose-coloured brittlestar) dominated muddy basin sites QCS during the BT17 Beam trawl survey. a-f) Examples of *A. correcta* specimens collected from*:* a) Te Ipapakereru Bay, Mid-QCS (BT17-QC25); b-c) Whatamango Bay, Inner QCS (BT17-QC45); d) Wharehunga Bay, Mid-QCS (BT17-QC22); e-f) Grove Bay, Inner QCS (BT17-QC57); g-l) Examples of other species found in this habitat: g-h) Large volumes of heart urchins, *Echinocardium cordatum*, from Grove Bay, Inner QCS (BT17-QC52 and Q57, respectively); i) Subsample of mudworms specimens (poss. *Asychis trifilosus*) from Whatamango Bay, Inner QCS (BT17-QC45); j-l) Part of catch including j) *P. albocinctus*, scallops, heart urchins and the starfish, *C. muricata* specimens from Ruakaka Bay, Inner QCS (BT17-QC32); k) Subsample of strawberry cockles, *Purpurocardia purpurata*, from Blackwood Bay, Inner QCS (BT17-QC43); l) Heart urchins, scallop, gastropods *Amalda mucronata* and the knobbled whelk, *A. glans*, from Lochmara Bay, Inner QCS (BT17-QC50).

Table 3-34: Characteristic features and taxa of the *Amphiurid*-dominated seafloor plains in inner and mid QCS. Significant species are depicted by green text. Although sea dragons would be a significant species only one individual was recorded in this habitat.

Seafloor plains	Characteristic features and significant/notable taxa
Substrata	Thick silty muds, negligible relief, low backscatter reflectivity, low to moderate numbers of small to medium sized burrows, low-moderate biofilm.
Video-surveys: epibenthic community	**Epibenthos:** dominated by the sub-surface rose-coloured brittlestars (*Amphiura correcta*), sparse but regular occurrence of burrowing anemone (*Cerianthus* spA). At some sites localised clusters of small epiphytic clam (*Talochlamys zelandiae* - locally dense at Site Q212), horse mussels (occasional-rare). **Motile invertebrates:** *P. albocinctus* (*Pseudochinus albocinctus*), *P. regularis* (few), *C. muricata* (rare). **Fish:** Opalfish (common), spotties and flatfish (occasional), sea dragon (*Solegnathus spinosissmus* - 1 recorded in this habitat at site Q212).
BT17-Beam trawl infaunal and epifauna species collected in the Beam trawls	Surficial sediments dominated by infaunal brittlestars (*A. correcta*), heart urchins (*Echinocardium cordatum*), mudworms, *Asychis* sp. (poss. *Asychis trifilosus*), scallops (*Pecten novaezelandiae* - common) and horse mussels (occasional); along with small infaunal bivalves dominated by strawberry cockles (*Pratulum pulchellum*), along with *Ennucula strangei, Neilo australis, Notocallista multistriata*); motile gastropods dominated by spikey gastropod (*Poirieria zelandica*), *Amalda* spp. and the knobbled whelk (*Austrofusus glans*), and assorted crabs (most commonly hermit crabs). Other species collected in lower numbers, *P. albocinctus*, wireweed (Chaetopterid tubeworms few at some sites), *P. regularis*, *C. muricata, A. mollis,* occasional small biogenic clumps of solitary sea squirts (*Cnemidocarpa bicornuta, Ascidiella aspersa, Asterocarpa humilis* and *M. squamiger*) and/or *T. zelandiae.* 4 sites contained a few brachiopods. **Fish:** catches were characterised by spotties, opalfish, triplefins (mostly *Fosterygion capito*), gudgeon (*Grahamichthys*) and flatfishes (mostly witch (*Arnoglossus scapha*), along with some lemon sole (*Pelotretis flavilatus*), speckled sole (*Peltorhamphus latus*) and sand flounder (*Rhomosolea plebeian*)).

The observed distribution maps based on the combined video and beam trawl surveys provide extremely valuable information on the extensive distribution of *A. correcta* across the seafloor plains within inner and mid QCS. However, several caveats to interpreting these data are required.
i) At almost all MDC18 sites sampled within seafloor plains, at least some *A. correcta* arms were observed. However, as *A. correcta* lay buried in the sediment and are only visible when their arms are extended above the surface sediments, visual estimates of their densities are based on seeing their arms, which may vary relative to various environmental cues, such as time of day, tidal/current strength. Consequently, while the MDC18 data provide an excellent characterization of '*Amphiura*-dominated' habitat, comparing presence and relative densities between sites should be used as preliminary estimates only. ii) Due to limited camera lighting on the HS51 drop-camera system, while many sites were seen to support low to high densities of *A. correcta*, quantification, or even detection, of *A. correcta* was not always possible at many sites, especially those in deeper low-light conditions, where the water was also turbid (esp. inner QCS). Consequently, we have removed absences ('X') from the distribution maps for the HS51 sites for this species as we could simply not determine their presence or absence at these sites. iii) Beam trawls are not designed to effectively

and consistent sample infaunal species. However, MBIE BT17 beam trawls did regularly, albeit rather haphazardly, collect some surficial infaunal species (i.e., those living just beneath the sediment surface – such as *A. correcta* and heart urchins, *E. cordatum*). However, while catches of these species, and any co-occurring taxa, provide extremely valuable community information, these data are unlikely to provide accurate between-site presence/absence or density comparisons. To quantify the infaunal community across these seafloor plains a sampling programme using a box core or grab would be required. We would recommend including sites across the Sill to describe the infaunal community and verify the absence of *A. correcta* from this Sill-zone.

Correlation with HS51 Multibeam layers: Examination of the *Amphiurid*-dominated habitats with the multibeam data layers, provide valuable insight into the distribution and habitat requirements of this community. *A. correcta* were found in silty muddy sediments mostly restricted to the inner and mid QCS sub-regions within depths of 17-65 m. In the HS51 maps, seafloor plains were classified based on seafloor backscatter classes in conjunction with sediment grain-size samples, Neil et al. (2018a). These low and low-medium reflectivity sediments dominated by muds extend from inner QCS all the way out across the outer Sill at the entrance to QCS - covering 212.35 and 37.75 km^{-2} of the seafloor within the survey area, respectively, and together accounting for the largest areal habitat mapped (58.1% of the area mapped). However, while *A. correcta* dominated the inner and mid plain regions, they were rarely seen or collected from the outer Sill region, indicating that HS51 seafloor classifications were not a 1:1 match with the *Amphiurid*-dominated habitat zone. There was also no clear demarcation between these two zones (the inner and mid-QCS vs the out Sill) in the bathymetry, backscatter or seafloor classification layers. However, the transition from *Amphiurid*-dominated sediments to those mostly devoid of *Amphiura* correlates with a transition from silty muds (~>90% silt) within the inner and mid QCS, to muds with higher proportions of sand (>10-70% sand) over the Sill (HS51 sediment grain size plots in Figure 3-11 of Neil et al. 2018a), with a change in sediment types occurring slightly north of the southern end of Long Island. To determine the total area of the *Amphiurid*-dominated habitats (i.e., subset of the seafloor plains restricted to the inner and mid QCS), a map layer separating the seafloor plains on the Sill (i.e., sandier muds) from those of the inner and mid QCS (~>90% silt) using a finer separation of sediment types (i.e., silty muds versus sandier-muds) would be required. Video footage of the seafloor collected perpendicular to Long Island by DOC (details in Haggitt 2017) may, depending on video quality, provide additional information to better define this northern boundary of the *Amphiura*-dominated habitat zone.

Transitional zones between seafloor plains and the shallower slope habitats within the inner and mid QCS were also examined against the multibeam map layers. The boundaries between the seafloor plains depicted in the HS51 seafloor classification map and the adjacent slope habitats provide a broad-scale demarcation of this community, but at fine scales along transects (i.e., those that sampled across the seafloor plains up onto slope habitats), classification boundaries did not strictly match the observed transition between community types. The backscatter layer, however, provided a much better match with *Amphiurid*-community transitions at these finer-scales (Figure 80). Evaluation of the backscatter maps in these locations show that high-densities of *A. correcta* continue up the base of these slopes where thick silty muds are present (low-intermediate backscatter returns), but as soon as these muddy sediments thin out or give way to rough shell-debris bottom or rocky outcrops (respectively higher backscatter returns) then rapid transitions into other habitat and community types occur (Figure 80 and Figure 81).

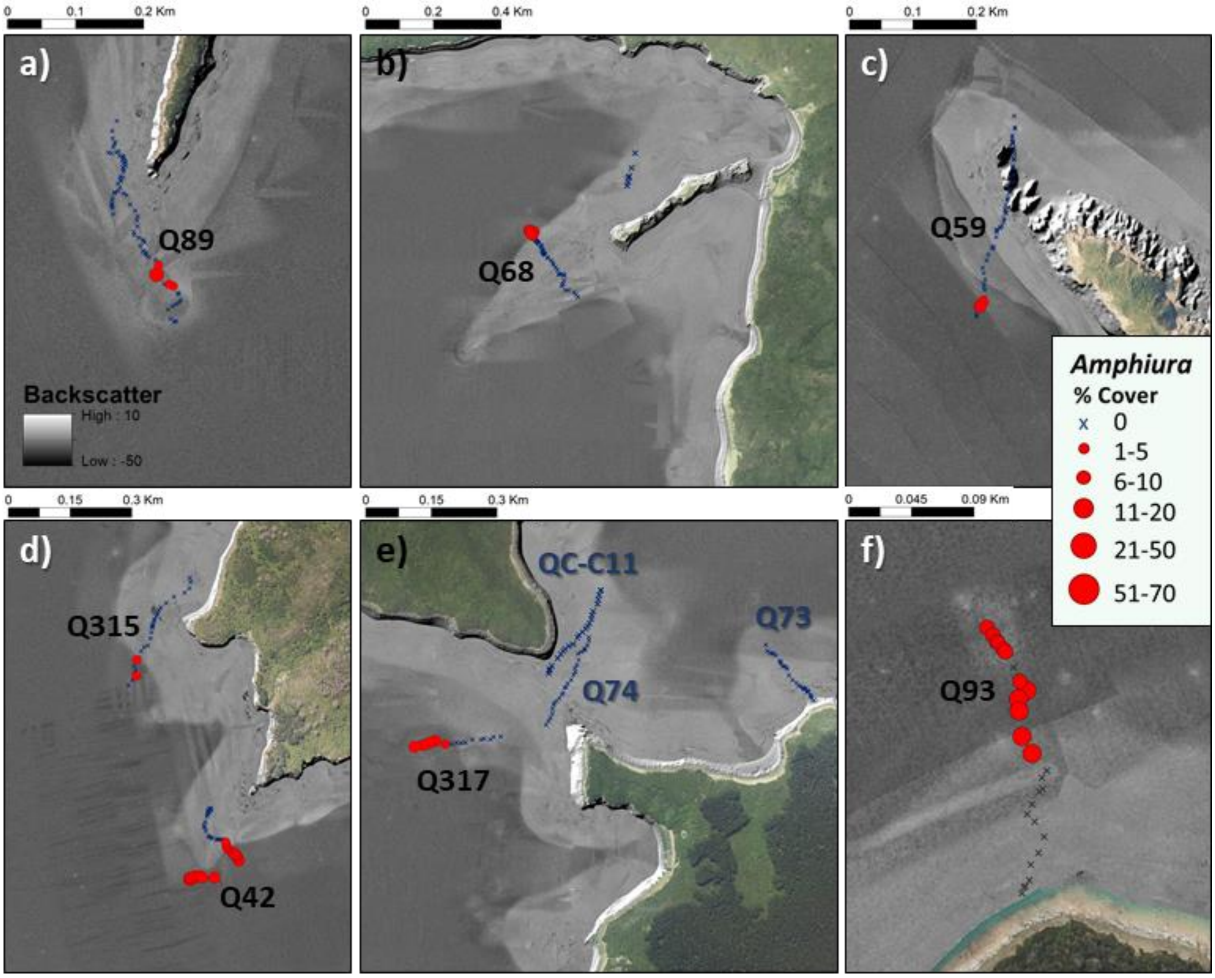


Figure 80: Examples of sites depicting within-transect distributions of *A. correcta* relative to seafloor reflectivity (Backscatter). Underlying grey layer depicts backscatter intensity as defined by the legend in graph-a – here dark areas depict low reflectivity muds while light grey areas depict coarser more reflective habitats (e.g., sediment with shell debris); red bubbles depict rank % cover estimates of *A. correcta*. graphs a-f) show *A. correcta* distributions relative to the boundary between low reflectivity mud within the Seafloor plains, where this species is common, and high reflectivity habitats of sediment slopes and channel habitats, where *A. correcta* are absent. Graphs a-f) show the distributions of *A. correcta* in silty muds: a) At the base of the slope, in 44-49 m, at Pihaka Point inner QCS, but absent on the slope and in the pockmark-hole adjacent to the slope (MDC18-Q89); b) At base of the slope in 49 m in Anatohia Bay, East Bay, Outer QCS (MDC18-Q68); c) At 20-22 m adjacent to Motungarara Is., outer QCS (MDC18 Q59); d) At base of slope in 39-41 m (Q315) and 40-50 m (Q315) Near Tawa Bay in Endeavour Inlet, outer QCS (MDC18 sites); e) In the seafloor plains, incl. small pockmark-holes, in depths of 43-46 m 300 m south of Pickersgill Passage, and just beyond the accumulation of *T. laticostata* shell-debris (with associated high-reflectivity) that has accumulated on the seafloor within and either side of Pickersgill passage (MDC18-Q317); f) In 39-50 m water depth at the base of slope , incl. pockmark-hole (46-50 m) at the base of the slope, and slightly up the mud slope (where intermediate reflectivity depicts an intermediate sediment thickness) northern end of Green Bay, Inner QCS (MDC18-Q93).

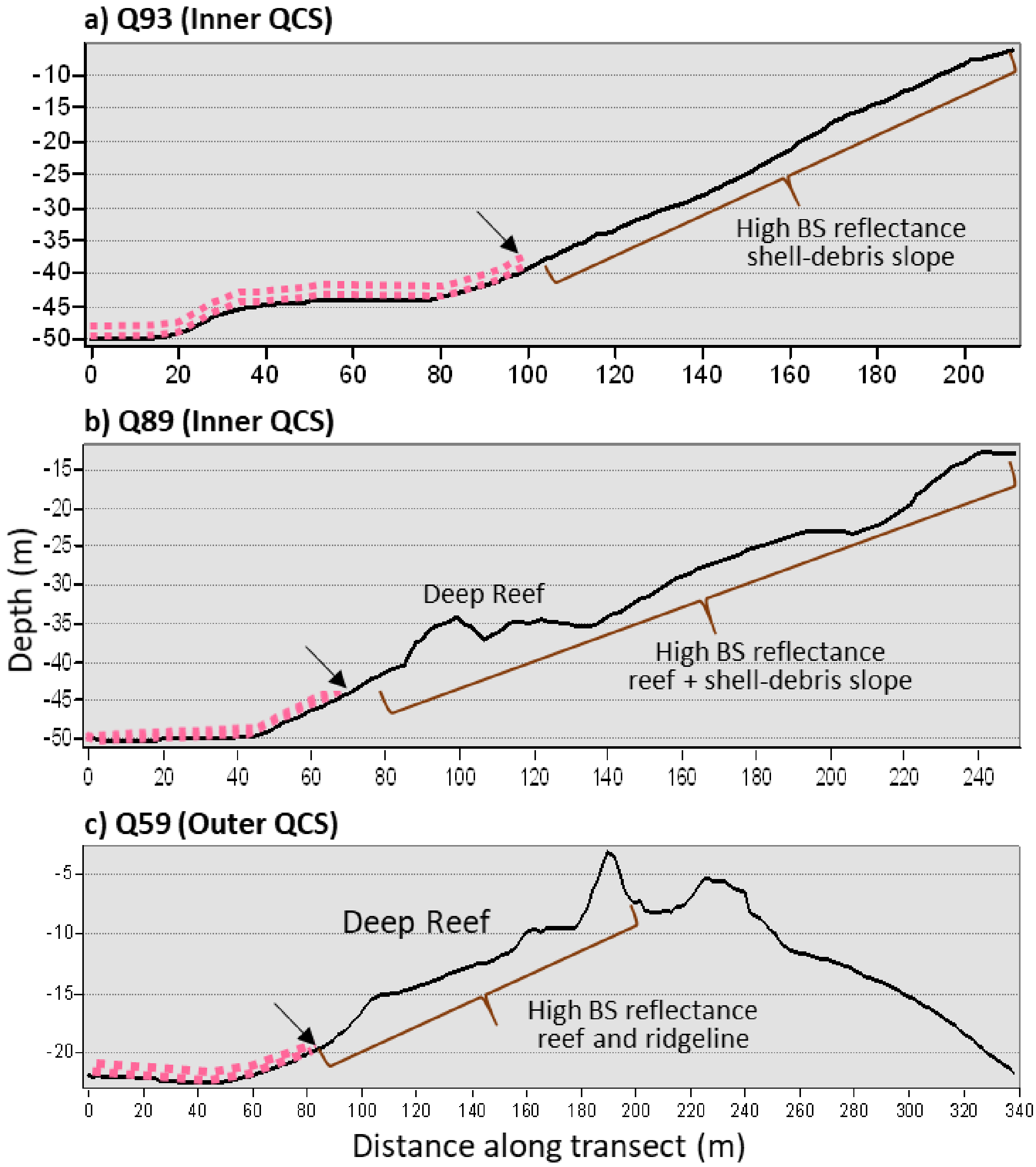


Figure 81: Depth profiles along three video-transects (MDC18 survey) - showing the comparative depths, and location relative to slope habitats of *Amphiura*-dominated communities (pink dashes). x-axis is distance travelled along each video-transect in an upslope direction; y-axis is HS51-derived bathymetry in metres. Brown brackets denote the zone of high-backscatter (BS reflectance) as seen in Figure 80f,a,c respectively). Graphs a-c) show that *A. correcta* occur in relative high densities right up to the edge of high backscatter zones.

3.3.7 Patten and Pickersgill Passages

Previous video observations in Allen Strait (Guards Pass), a narrow (~266 m-wide) high-current channel in outer Pelorus Sounds, identified diverse sessile invertebrate communities that included an abundance of hard branching bryozoa (*G. porcellanicus*) growing along the rocky slopes and cobble channel (Davidson et al. 2011; Anderson *pers. obs.*; NIWA CB17 *unpublished data*). Similar communities have also been recorded in other extremely high current areas incl. French Pass and Stephens Strait (Davidson et al. 2011 p64). Based on these findings, MDC requested that video-transects be run, where possible, within two high-current passages located in mid-QCS. These two passage are a similar width to Allen Strait, with Patten Passage being 241 m-wide between Blumine Island and Arapaoa Island, and a ~238 m-wide channel between Pickersgill Island and Arapaoa Island (her referred to as Pickersgill Passage. Davidson et al. (2011 p98) recommend an area around Patten Passage as a significant site (ESMS-4.18) based on a brief visit describing rocks with filter feeding invertebrates (incl. jewel anemones and *Galeolaria* mounds, along with dense beds of live *T. laticostata,* covered with intact and broken shells to 25 m). As part of the MDC18 and CB17 surveys we successful surveyed five video transects, two within each channel and an additional transect down-current from Pickersgill Passage to determine how far channel-associated communities extend from the entrance, and to determine the type of seafloor beneath an area were marine mammals are often seen.

Both Patten and Pickersgill passages had similar habitat zones and community structure, but these were very different from those seen in Allen Strait. Patten and Pickersgill Passages were characterised by live *Tucetona* beds of low to moderate densities within gravelly sands along the upper banks (~12-26 m) on both sides of these channels (Figure 83a,b; e.g., Figure 82a-c). The upper banks around the live beds were also littered with various amounts of relatively clean *T. laticostata* shells with many still articulated (valves still attached) (e.g., Figure 82a,c), as previous described by Davidson et al. (2011). Below these sediment banks the channel bottom was densely covered by a thick accumulation of *Tucetona* shell debris (≤100% cover; e.g., Figure 82d-f), with shell debris extending ≥290 m south of the entrance down to depths of 42.5 m at Patten Passage, and 200 m south of the entrance to depths of 43 m at Pickersgill Passage (although shell-debris was also recorded in 3-m deep depressions/seep holes here in 46 m). However, the characteristics of the debris field changed with distance away from the passage (for both sites). Once beyond the main entrance thicker mounds of debris were present, and with distance away from the channel shell-debris became more embedded in sediment and increasingly fouled by fine-branching hydroids (≤50%), occasional sponges (≤2%) and brachiopods (e.g., Figure 82g-h; see Table 3-35 for full species list). Adult blue cod were common in and around the reefs, and on the shell-debris fields, however, sub-adult blue cod were more common across the debris fields (e.g., Figure 82g), including several small blue cod (14-19 cm sizes) and , along with a few spottys. Occasional burrowing sea cucumbers (*Thyone* spA) were also seen in shell-debris sediments within the high-current channel, while motile invertebrates were common across the debris fields, with the *C. muricata* the most commonly seen (see Table 3-35). All the habitat and communities type described for Patten Passage, fall within the boundary for ESMS-4.18.

Transects through and across Pickersgill and Patten Passages identified that the shell-debris fields extended >100 and 200, respectively from these channel entrances. To determine how much further the shell-debris fields extended and to determine the type of seafloor beneath the area where mammals are often seen, we ran an additional transect starting ~180 m south-east of the channel at Pickersgill Passage and running in a south-east direction for 200. The seafloor here was a consistent depth of 43 m, but as we moved further away from the passage the seafloor slowly transitioned (30-50 m) from one initially composed of sediment-veneered shell debris (with regular occurrence of *P. albocinctus*) into contiguous muds with moderate densities of *A. correcta*, along with regular occurrences of burrowing anemones (*Cerianthus* sp2) – similar to those characterising similar seafloor plains habitats throughout QCS. The *Amphiura* zone occurred 250 m Southeast of Pickersgill Passage. Nothing else appeared unique about this habitat in respect to marine mammals.

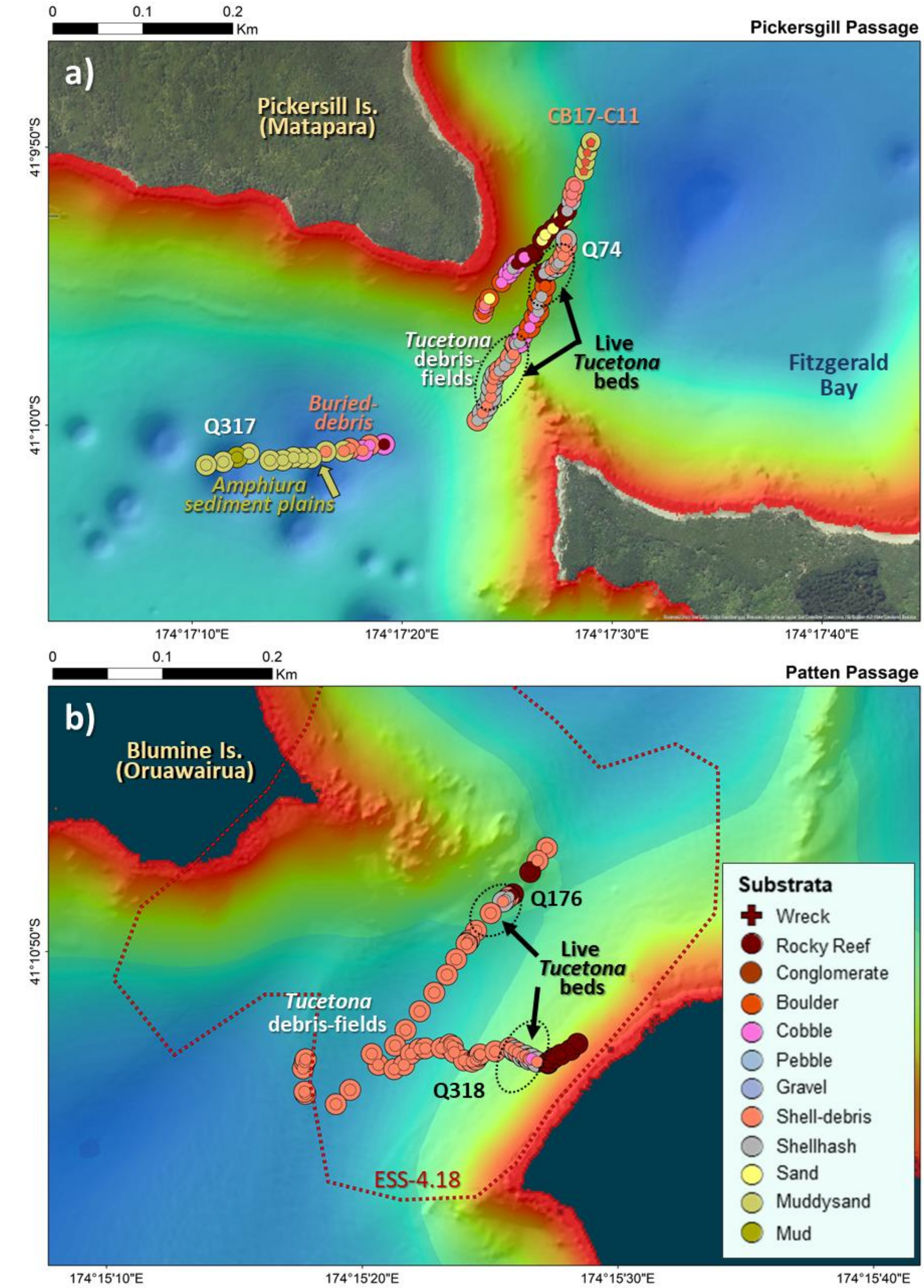


Figure 82: Seafloor substratum types within and adjacent to (a) Pickersgill Passage and (b) Pattern Passage (mid-QCS). Depicting the location of live *Tucetona* beds(black dotted circles) in the gravelly sediment banks on the slopes of these channels, and dense accumulation of *Tucetona* shell-debris across these channel floor, with a debris-field extending well beyond these channels (~200-250 m); Larger outer circles = primary substrata (≥ 50% cover); smaller central circles = secondary substrata (≥ 20% cover), where substrata records represent ~30 sec intervals along each tow-video transects where seafloor was visible. Red dotted-line in Figure-b depicts the location of the proposed ESMS-4.18.

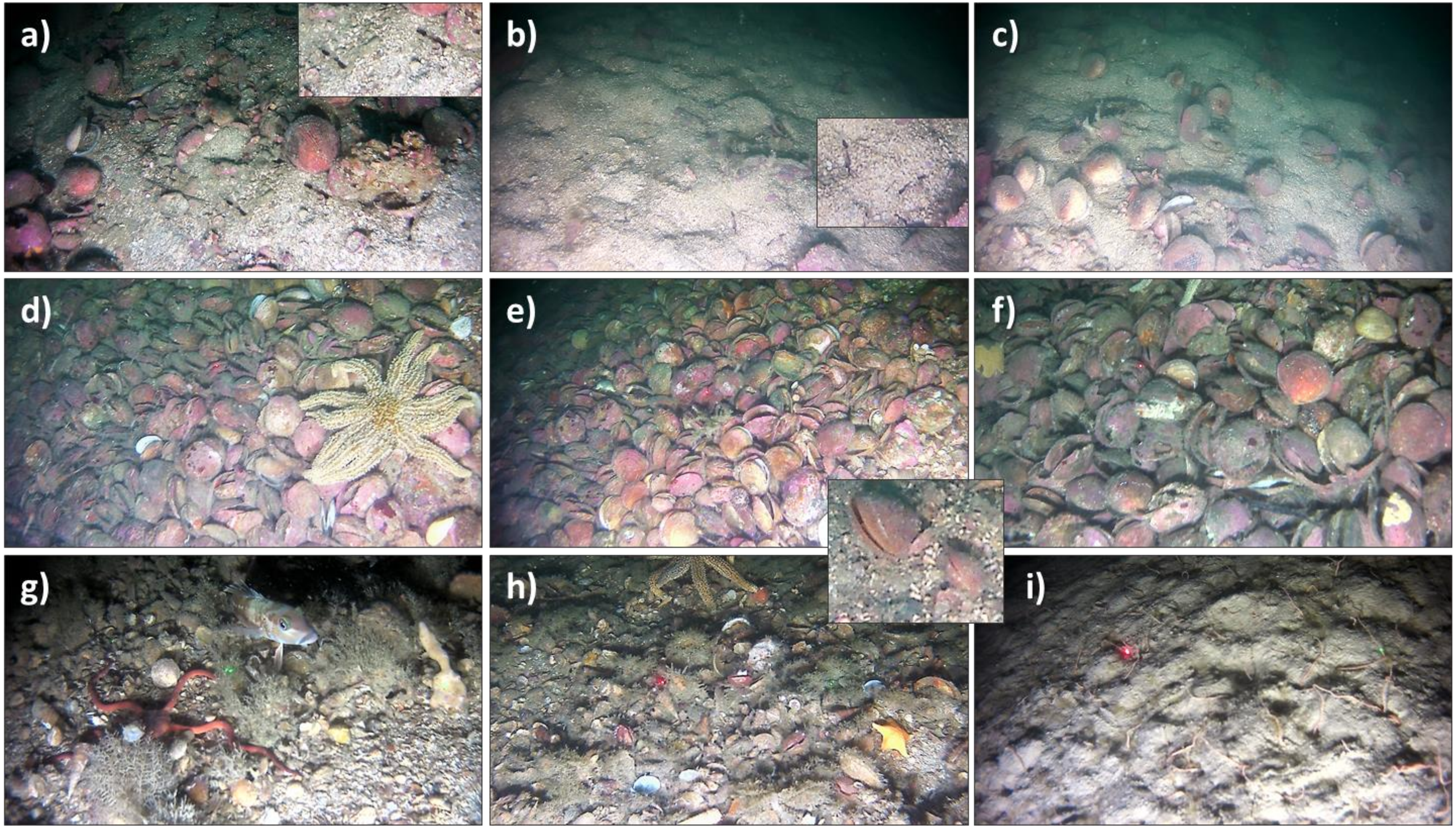


Figure 83: Example images of representative habitats within Pattern and Pickersgill Passages, mid-QCS. a-c) Live *Tucetona* beds in gravelly sands on channel banks (Inserts of 2-dash siphons of buried *Tucetona*);d-f) Examples of the dense *Tucetona* shell-debris fields accumulated within the channels, with *C. muricata* [d]; g-h) Further away from the channel, debris becomes more embedded in the sediment and more heavily fouled by bushy hydroids [g], with small sponges [g] and increasing occurrences of brachiopods [h, insert], with blue cod common [g]; i) further away (>~250 m) buried debris transitions into *Amphiura*-dominated sediment plains.

Although these channel habitats were distinctly different from those seen in Allen Strait, these *T. laticostata*-live and accumulating shell-debris habitats were similar to those found within the channel between the Rangitoto Islands (Tinui and Puangiangi) on the eastern side of D'Urville Island (NIWA CB17 unpublished data). Examination of the similarities and differences between these different types of high-current passages and straits may provide useful insight into the processes driving these community patterns.

Table 3-35: Characteristic features of shell-debris fields within the channels of both Patten and Pickersgill Passages in mid QCS This table represents habitats and species seen within five towed video transects, two in Patten Passage (MDC18-Q176 and Q318) and three in and adjacent to Pickersgill Passage (MDC18-Q74, Q317, CB17-C11).

***Tucetona*-debris fields**	**Characteristic features and significant/notable taxa**
Substrata	Sediment comprising coarse sands, with gravels and relict shells present on the surface, thick layers of *Tucetona* shell debris deposited across the channel in depths of (~23-42 m).
Benthic community	**Reef, boulders and cobbles:** present along shoreline, with encrusting coralline algae (abundant), rock anemones (≤35%), window-pane oysters, patches of live *Galeolaria* clumps, *Epiactis* sp. (few, Q318). **Live-*Tucetona* beds***:* identified by two-dash siphons at sediment surface. Coralline algae (NGC) on relict shells, but shell debris relatively clean, small patchy areas of wire-weed like tubeworms (Q74-only), small scallops (few, Q74). ***Tucetona* shell-debris fields**: mixed hydroids, (incl. *H. campanula*, ≤6%), and patches of moderately dense fine-branching hydroids (≤50%); erect sponges (<2%), incl. digitate sponges (*Callyspongia* sp.) and small *E. alata* sponges; small red brachiopods (Q318) and smooth red brachiopods (Q74); burrowing sea cucumbers (*Thyone* spA, few Q176), sabellid fanworms (few), horse mussels (occasional, e.g., Q318), sea squirts (occasional), yellow spikey sponge (*D. oxeata,* rare, Q318), hard branching bryozoa (poss. *G. porcellanicus* <0.01% - two tiny cm-sized colonies). **Deeper buried shell-debris** (Q317): *P. albocinctus* (few), hydroids (<5%) ***Amphiura*-sediment plains:** low-moderate densities of *A. correcta* (~250 m from channel, Q317).
Motile invertebrates	Snake stars (occasional), *C. muricata* (common), *P. regularis* (few), *A. mollis* (few) and kina (rare-few), biscuit cushion stars (few).
Fish	Subadult and adult blue cod (both common), juvenile bluecod (occasional, CB17-C11, 14-19 cm size-range), spotty (occasional).
Other	Patch of *Galeolaria*-DSR (toppled and broken rubble) along the lower edge of the nearshore reef (Q74), as well as mixed up in the *Tucetona* shell-debris fields (notable amounts <30% of debris in some patches Q74).

3.4 Tory Channel (TC) – Characteristic habitats and communities

Background: Tory Channel is a narrow (~0.6-1.5 km wide) and deep (42-67 m) high-current, nutrient-rich environment (≤7 knots through TC entrance, 1-3 knots through the rest of the channel) that is known to support significant marine communities (e.g., Davidson et al. 2011; 2015; 2018; Davidson and Richards 2015; Neil et al. 2018). The high resolution HS51 multibeam maps (Neil et al. 2018a) revealed steep high-reflectivity slopes and high rugosity reefs along the sides of TC, particularly around rocky headlands near and within the entrance to Cook Strait, as well as rocky reef promontories adjacent to the larger bays, while the scoured seafloor within the centre of the main channel is characterised by highly reflective sediments, dominated by coarse gravelly sands and cobbles. In contrast, the eight shallow bays branching off TC were defined by low reflectivity muds comprising silt and clay. Previous biological studies have also characterised the ecology of Tory Channel (e.g., Davidson et al. 2011; 2015; 2018; ; Davidson and Richards 2015; Clark et al. 2011; Keeley and Taylor 2011; Morrisey et al. 2015; Brown et al. 2016), with several distinct ecological community types documented, and Ecological Significant Marine Sites delineated (see Figure 84; Davidson et al. 2011; Davidson and Richards 2015; Davidson et al. 2017a; 2019).

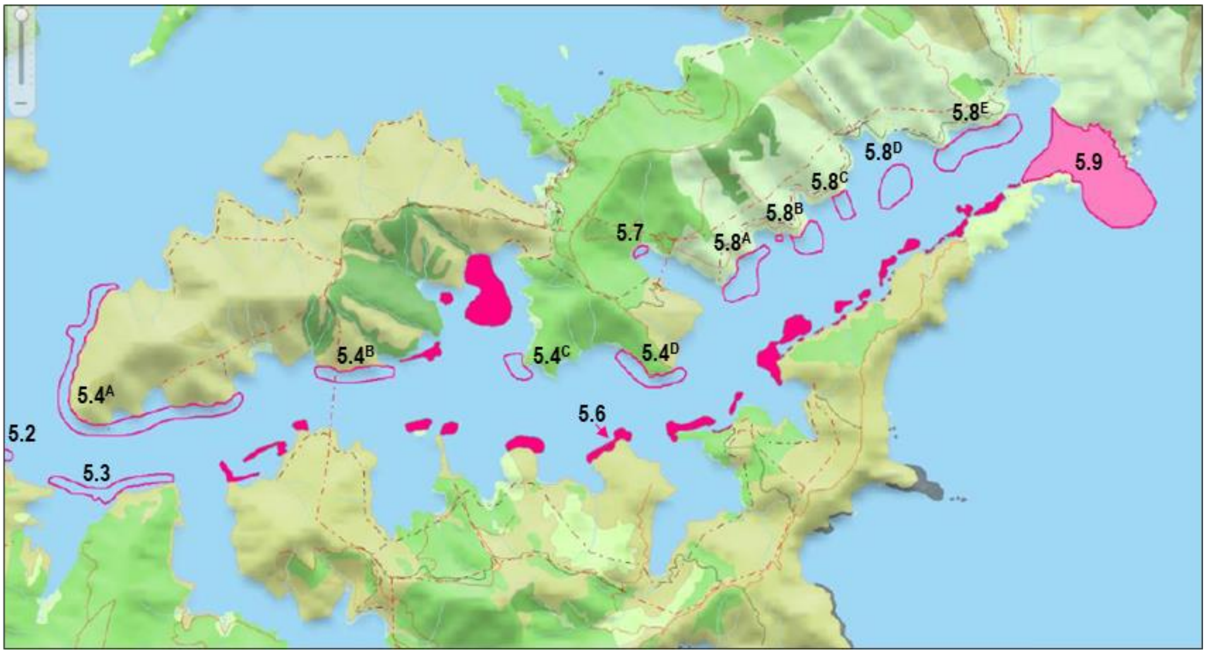


Figure 84: Location of known Ecologically Significant Sites (ESS 5.2-5.9), within Tory Channel (From Davidson et al. 2019). ESMS-5.2 = Biogenic clumps, Tikimaeroero Point (with encrusting reef-forming bryozoans, *C. agglutinans*); ESMS-5.3 = Biogenic clumps, Hitaua Bay (with bryozoan mounds, hydroids, sponges and ascidians); ESS 5.4[A-D] = Biogenic reefs and clumps, TC-west; ESMS-5.6 = Rocky reefs, Te Pangu Bay (with filter feeding species including hydroids, sponges and ascidians); ESMS-5.7 = cockle bed, Deep Bay; ESMS-5.8[A-E] = Rocky and biogenic reefs, TC-north-east (dense hydroids incl. hydroid trees, *Solandaria* sp., bushy bryozoans, sponges, zooanthids, macroalgae and ascidians); ESMS-5.9 = dense high-current encrusting species, TC-entrance (with bryozoans, hydroids, zooanthids and sponges). ESS community types are from Davidson et al. 2011; 2015; 2019. Filled-polygons show the recommended survey location from Rayes and Davidson (2016) that were subsequently surveyed 545 drop camera stations and 10 tow-video transects (Davidson et al. 2017a).

Ground-truthing surveys: In planning-discussions with MDC (Steve Urlich), the MDC18 program was asked to ground-truth newly mapped features, giving priority to those areas not previously surveyed that, based on the HS51 bathymetry, were likely to have significant habitats and communities, with highest priority given to i) 'high current sites near the entrance of TC' and ii) 'unique seafloor features identified in the HS51 maps' not yet ground-truthed during the HS51 dropcam survey, and iii) 'steep slope high rugosity habitats on both sides of the outer TC', that would complement those already documented in the significant habitats reviews (i.e., Davidson et al. 2015). During the MDC18 surveys we attempted to run towed-camera transects up slope from 'the main channel up the slope to the nearshore' to characterise the different depth-related habitat zones. However, high-priority sites at or near the entrance to TC in combination with traversing up-slope perpendicular to the current was extremely difficult and treacherous to survey, and therefore could only be attempted during or as close to slack tide as possible (very narrow time window), and even then these sites were still incredibly difficult to survey. However, the combined surveys successfully characterised 12 new outer TC sites (11 MDC18 and 1 CB17 sites). New sites were also successfully surveyed within mid (n=7: 4 MDC18 and 3 CB17 sites) and inner (n=13 sites: 10 MDC18 and 3 CB17) TC, and within the shallower TC bays (n=11 sites: 8 CB17, 3 HS51). HS51 drop cameras collected a series of drop-camera stations from inner to outer TC (n=9) to characterise the main channel, while BT17 beam trawls (with video footage) were successfully undertaken at six soft-sediment sites within five TC bays (see Appendices A-G).

Overview of findings: A range of biologically important habitats were present along the sloping sides of Tory Channel, with distinct habitat zones defined from shallow kelp-dominated zones down to deep biogenic reefs, and channel cobble fields (described below). However, the occurrence and extent of each habitat-zone varied by depth, substratum type, and slope steepness; while within a habitat zone, species composition varied relative to the distance from the TC-entrances. Slope communities described below for mid to outer TC provide very comparable information to those already collected by other studies (Clark et al. 2011; Keeley and Taylor 2011; Morrisey et al. 2015; Brown et al. 2016). In contrast, sites located in or near the TC entrance to Cook Strait, reflected a transitional-assemblage that reflected a mix of species from mid-inner TC as well as species more characteristic of the wave-exposed communities found on the coastal reefs in Cook Strait (see Section 3.6).

3.4.1 Shallow kelp-zone

Kelp beds were common on shallow rocky reefs along both sides of TC, although this habitat was generally patchy and reflected the availability of rock reefs. This semi-contiguous or patchy band of kelp was comprised of mixed species of *Macrocystis pyrifera, E. radiata* and *C. flexuosum* algae, along with varying amounts of the exotic Japanese seaweed or Wakame (*Undaria pinnatifida*) (Table 3-36; Figure 85a,b; Table O-1), with *U. pinnatifida* found in often high localized densities. A range of subtidal surveys undertaken along TC have documented similar mixed-species kelp beds with *M. pyrifera, E. radiata* and *C. flexuosum* macroalgae (e.g., Morrisey et al. 2015; Brown et al. 2016; Dunmore 2019), indicating these are general patterns within the shallow subtidal rock reef zone, where the relative proportions of *U. pinnatifida* increasing over time (Schiel et al. 2012; Desmond et al. 2019). While species composition was relative consistent along the length of Tory Channel, composition changed at sites near TC entrance, with a transitional kelp assemblage recorded. Sites within the entrance of TC, were characterized by *E. radiata* with increasing occurrences of *Lessonia variegata* and *Marginariella* sp. and the absence of *Macrocystis*.

Table 3-36: Characteristic features of shallow reef kelp beds within TC.

TC shallow kelp zone	Characteristic features and significant/notable taxa
Substrata	Combination of contiguous and patchy rock outcrops of low to moderate relief, interspersed by sandy sediments and/or low-lying rock with varying levels of sediment veneer.
Benthic community Kelp beds	Kelp beds present and often the dominant cover, with mixed species of *M. pyrifera* (e.g., C18), *E. radiata* (e.g., C20), and *C. flexuosum* (kelp species intermingled), along with *U. pinnatifida* (almost all sites, e.g., Q140, Q144, Q159, Q165, Q185, CB17-C18 although none was recorded at Q81). Epiphytic filamentous red algae (mostly *Asparagopsis armata*) also common mostly on *C. flexuosum.*
Benthic community Subcanopy species	Understory fleshy macroalgae similar composition to the mixed macroalgal zone (see below). Some site, esp. those closer to TC entrance with small charcoal-grey *E. alata* sponges, solitary sea tulips (*P. pachydermatina* e.g., C20) and patches of *C. brownii* (e.g., CB17-C122 and MDC18-Q157) and *C. flexilis* (MDC18-Q81).
Motile invertebrates	Kina common, often large-sized and locally dense. Snake stars, common.
Fish	Banded wrasse, scarlet wrasse (e.g., C20), various triplefins (e.g., *F. varium*), some butterfly perch on outer edge of kelp beds.

Dense beds of surface kelps (i.e., *Macrocystis*) are known to occur along the very shallow fringe of TC, as they can be seen at the water's surface. Satellite imagery from 2010 and 2013 was used to map / predict the distribution of surface kelps within TC (DOC *Unpublished data*). Observed kelp distribution (this study) were overlaid on the predicted kelp distributions within TC (DOC layers - provided to T. Anderson). However, 95% of our kelp observations occurred further offshore and in deeper water, so could not be used to verify (or ground-truth) the 'predicted distributions' along these fringing shoreline reefs - due to both the difficulty in running tow-video through dense surface kelp and the proximity to near-shore submerged rocks. However, our data were able to verify that the predicted distribution (based on 2010-2013 maps) do not accurately depict the outer edge of the current kelp-beds, which extend further offshore.

The comparison of 'observed' kelp distributions (this study) with HS51 multibeam layers, identified that at most sites' kelp beds were limited to the nearshore rocky reefs within 50 m of the shoreline in depths <20 m. Only at a few locations did kelp beds extend further from the shore. These sites reflected areas where shallow rocky reefs extended further out into the channel, such as at Dieffenbach Point, where dense mixed kelp beds were recorded 160 m from the shore, in depths of 7-10 m (Site Q177b). The HS51 'detected-kelp' layer at Dieffenbach Point plots mixed kelp in the nearshore and tall kelp along the top of the ridgeline at Dieffenbach extending out 170 m offshore. Based on the 'observed' ground-truthing video at this site we would predict that mixed kelp with some *M. pyrifera* occurs along this entire ridgeline, likely with some amount of *U. pinnatifida*.

The amount of kelp present in the shallow subtidal appeared to be habitat-limited, with kelp bed size often reflecting the underlying size of the patch reefs they were growing on, which at many sites were often small and interspersed by areas of soft sediment or low-lying-rocks with sediment veneer. Many sites had small patches of kelp that consisted of 1-3 long strands of *M. pyrifera* and *Carpophyllum* (commonly seen with long epiphytic *Asparagopsis armata* growing on them), attached to very small rock outcrops. A large number of kelp sites supported relatively high proportions of *U. pinnatifida* (Table O-1), identifying that *U. pinnatifida* is now well established along much of the shoreline within TC. *U. pinnatifida* has also been recorded on reefs at Te Pangu and Clay Point in mid-TC (Dunmore 2019).

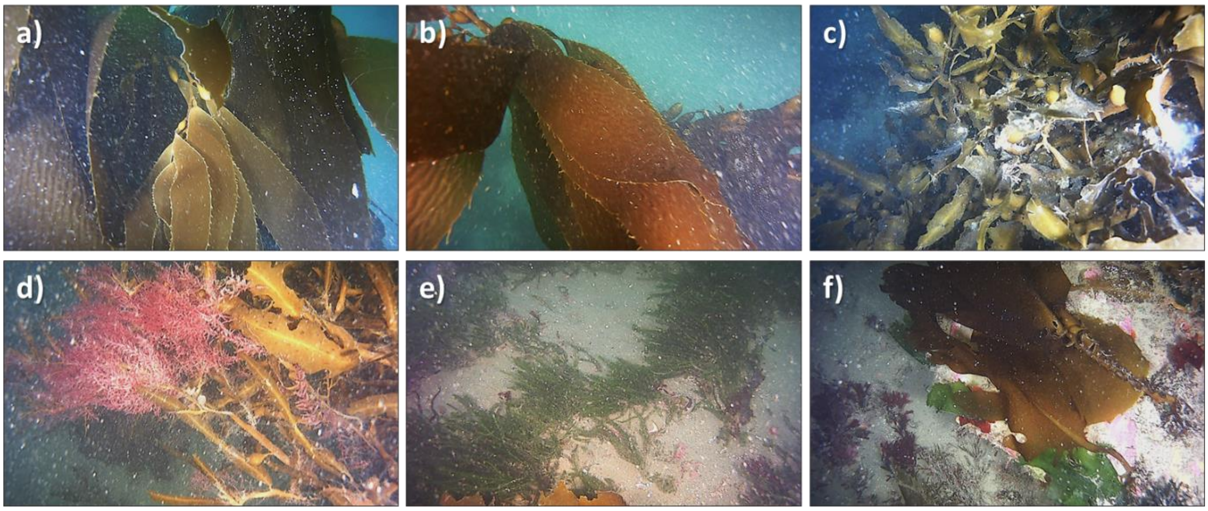


Figure 85: Examples of shallow kelp zone in TC. a-b) Giant/surface Kelp (*M. pyrifera*) growing on shallow outcrops of rock, Tipi Bay north (CB17-C22); c) *C. flexuosum*, interspersed amongst *M. pyrifera* (CB17-C-C22); d) *C. flexuosum* with notable amounts of epiphytic red filamentous algae (*Asparagopsis armata*), entrance to Deep Bay, outer-TC (CB17-C19); e) *Caulerpa* poss. *brownii* growing on sediment-covered rock, Tipi Bay north (CB17-C22); f) Example of the invasive Asian seaweed, *U. pinnatifida,* growing on upper rock slope, Wiriwaka Pt, mid-TC (CB17-C18).

Beneath these kelp beds, subcanopy species were characterized by fleshy macroalgae composed of mixtures of red, brown and green macroalgal species - dominated by red filamentous algae (e.g., *Asparagopsis armata*), robust strappy and bladed red algae, green algae (e.g., *Codium fragile* and *Ulva* spp, and mixed bushy brown algae (e.g., *Carpomitra costata, Halopteris* sp., *Spatoglossum*). These species were also observed in the adjacent low-lying reef habitats devoid of kelp, and in the mixed macroalgal zone in slightly deeper depths (see below). Understory species were mostly macroalgae within TC, however the presence of numerous small-sized charcoal grey *E. alata* sponges along with solitary sea tulips (*Pyura pachydermatina*) beneath the kelp were more frequent at sites closer to TC entrance (e.g., CB17-C20, 1600 m from TC entrance), with their increased presence down much of the slope at these near-entrance sites. Motile species included kina and snake stars, along with several species of fish (Table 3-36).

Comparisons between the HS51 'detected-kelp' layer and 'observed-kelp' from the tow-video and drop camera surveys (incl. those for Te Weka, Motukina and Tipi Bay from Brown et al. 2016a), found very close correlations at many nearshore rocky reef sites along the main TC channel (e.g., Q177a, Q156, Q157, Q159). These were mainly rocky headlands and fringing reef along the main channel where kelp is known to occur (Davidson et al. 2011; 2015; 2017a). However, the detect-kelp map layers often showed kelp in the vicinity of a site it often was not present within the transect site per se, indicating that fine-scale kelp occurrence was not well detected in the MBES maps. One reason for this could be that MBES water column records might reflect, to some degree, the different amounts of *M. pyrifera* in these kelp patches. However, this appears less likely as at some sites 'detected-kelp' represented kelp beds that had little to no *M. pyrifera*, such as those sites out near the entrance to TC (e.g., Q81, Q144). At some rocky reef sites (e.g., Q144) 'detected-kelp' also included zones of drift algae, identifying that not all detected kelp-records accurately depict attached growing kelp. This disparity was more apparent within shallow bays of TC. Here, often high numbers of 'kelp-detected' data points occurred out over soft-sediment within the middle of many of these Bays (*e.g., dotted white circles in* Figure 86), identifying that these detected-kelp data points are either spurious records, or more likely, reflect the presence of drift-algae mats that are now known to accumulate within these shallow bays (*as presented in* Section 3.4.8). The discrepancies between growing kelp and accumulated mixed macroalgae may to some degree reflect the two-data sources used in creating the HS51 'detected-kelp' layer, which integrated data from the MBES-water column (depicting vertical kelp profiles in the water column), and aerial imagery (Neil et al. 2018b), that can be used to delineate algal from darker-shaded areas seen in shallow water - although it is unclear from the HS51 GIS kelp-layer itself which data points come from which detection method. Currently, the HS51 kelp layer provides potentially-useful predictions of where kelp beds are in terms of rocky reef sites along the edges of the main channel, but given a suite of other issues, this layer should be used very cautiously. We recommend that if these layers are to be employed further that the MBES and aerial detected-kelp layers be evaluated separately to determine their relative validity, and examined to determine if drift algae can be predictively distinguished from growing kelp beds. All kelp-bed records out over soft-sediment should be removed from the 'detected kelp' layer and be included in a separate layer of 'likely-drift'.

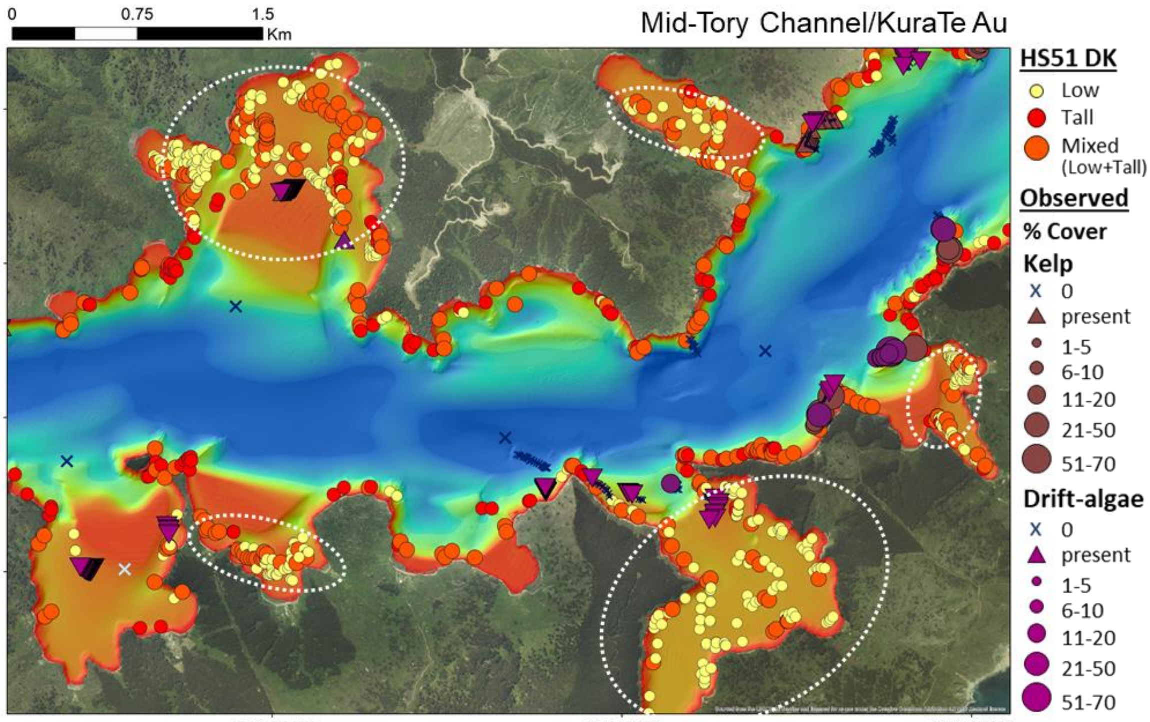


Figure 86: Mid-TC locations of 'detected-kelp' (DK) from the HS51 kelp layer (yellow-red-orange circles) versus those of observed kelp (brown symbols) and drift algae (purple symbols) from ground-truthing video observations. The HS51 detected-kelp layer integrated MBES water column detection (images of kelp seen in the water column) and aerial imagery dark areas on the seabed that were predicted to be areas of kelp. White dotted circles identify areas where records of 'detected-kelp' occur out over soft-sediments, and are either spurious data points or, more likely, depict varying amounts of drift algae in these shallow bays.

3.4.2 Mixed macroalgal assemblage (upper slope):

Mixed macroalgal assemblages commonly occurred along the upper reef slope (Table 3-37; Figure 87), both as subcanopy within the shallow kelp zone, but also extended down slope beyond the kelp. This zone was characterised by mixtures of red, green and brown fleshy macroalgae, with % cover dominated by red algal species (Table 3-37), although some sites (e.g., Q156) also had high amounts of *Halopteris*. Like the shallow kelp zone, species composition and abundance of the macroalgal-zone also varied relative to the distance from TC entrance. At most inner and mid TC sites (up to about Ngamahau Bay), the mixed macroalgal zone was characterised by red filamentous algae (e.g., *Asparagopsis armata*), strappy reds (*Crassiphycus proliferus* and *S. montagneana*) along with the green algae, *C. fragile*, occasionally *Ulva* spp, and mixed bushy brown algae (e.g., *C. costata, Halopteris* sp, *Spatoglossum*), along with mixed motile invertebrates dominated by Snake stars (see Table 3-37 for full species list), with these species being consistently present from Dieffenbach point through to Ngamahau Bay. At some sites, small blades (<30 cm in length) of *U. pinnatifida* were prolific[51] while at other sites some soft bryozoa and small hydroids were recorded (Table 3-37).

In contrast, sites closer to TC-entrance east of Ngamahau Bay (i.e., within 1.5 km of TC-entrance) supported denser macroalgae communities, due to higher percent cover of fleshy red algae, and a change in species composition to more 'exposed' species more similar to those more commonly found in Cook Strait (e.g., green algae: *C. brownii* and *C. flexilis*, and the red bladed alga: *Euptilota formosissima*) (Table 3-37). Community composition and species occurrences also varied by distance to the TC-entrance. For example, *E. formosissima* became a dominant macroalgal species on upper reef slopes within ~2 km of TC-entrance (e.g., CB17-C20), but was also present on shallow coastal reefs in Cook Strait (see Section 3.6), and has previously been reported from the Brothers (Davidson et al. 2011 p117). *C. brownii* occurred within ~4 km of TC-entrance (e.g., MDC18-Q159 and Q157), while *C. flexilis* was only identified from one TC sites within <1 km of TC-entrance (e.g., MDC18-Q81). Both species of *Caulerpa* were only recorded in small patches, with patches becoming larger and more lush at sites closer to Cook Strait, while the largest and lushest meadows were recorded on the wave-exposed coastal reefs in Cook Strait (e.g., Figure 85c,d; also see section 3.2.1 - *Caulerpa* meadow; Figure 12c). Macroalgal zones closer to TC-entrance, also had more filter feeding invertebrates with increasing numbers of charcoal grey *E. alata* sponges, *P. pachydermatina*, jewel anemones, and large hydroids, along with more motile invertebrates dominated by Snake stars and much larger-sized kina - that were often seen in clusters pinning drift kelp to the seafloor – although densities were much higher deeper down the slope (see Section 3.4.3 – Kina barrens).

[51] Identification of *Undaria* was verified (from video-only, along with other macroalgae) by Roberta D'Archino.

Table 3-37: Characteristic features of mixed red-algae habitats on the upper slopes of TC. Sites prefixed with Q=MDC18 survey; sites prefixed with C=CB17 survey.

Mixed-red algal zone	Characteristic features and significant/notable taxa
Substrata	Low to moderate relief rock - contiguous and/or patchy - outcrops, with sandy sediments between outcrops.
Benthic community A) Macroalgae[52]	Red algae dominant cover, with strappy, bladed, and filamentous (fine- and coarse-branching) growth forms present. Taxa preliminarily identified incl. **Red algae**: *Crassiphycus proliferus* (common, C19, Q157, Q165), *S. montagneana* (common, C19, C22, Q157, Q165), *Asparagopsis armata* (C22, Q165, 177b), *Rhodophyllis* (C19, Q157, Q165), *Sarcothalia livida* (few-common, Q156); *Rhodymenia* (Q165), Kallymeniaceae 'Pugetia Sounds' *undescribed sp.* (Q165), *Spatoglossum chapmanii* (Q165), *Euptilota formosissima* (Q156, common at 'exposed TC-entrance' C20). *Hymenena* (iridescent red, common, Q156, Q165, C19), *Rhodophyllis* (C19, Q165), erect branching genticulate coralline algae (e.g., C20, Q144, Q81). **Green algae:** *C. fragile* (common, Q157, Q156, 177b), *Codium gracile* (occasional, Q157), *Ulva* spp. (occasional, C19, Q157, 177b), *Caulerpa* spp. (common at 'exposed TC-entrance sites), incl. *C. brownii* (C22, Q144, Q157, Q81), *C. flexilis* (Q81). **Brown algae**: *C. costata* (common, C19, Q156, Q157), *Halopteris* (occasional-common, Q156, Q157, C20), *Zonaria* (Q156), *U. pinnatifida* (common at most sites, e.g., C18, Q165, Q177b).
Benthic community B) Sessile Invertebrates	Stalked sea tulip (*P. pachydermatina*), orange soft bryozoans and small-sized charcoal grey *E. alata* sponges present at sites near TC entrance [C20], yellow encrusting sponge (*D. oxeata*, occasional small patches, e.g., C20, Q159), grey-white hydroids (Q146), rock anemones (occasional clusters - e.g., Q146, Q165), *H. campanula* (occasional, Q165, Q169, Q172).
Motile invertebrates	Snake star (dominant), cushion stars (*P. regularis,* common; *P. pulchellus*, x1 Q156), *C. muricata* (few), kina (few-common), *A. mollis* (occasional, e.g., Q165), *Octopus maorum* (hanging on to kelp fast, CB17-C19), purple nudibranch (*Jason mirabilis*, Q146 x1).
Fish	Triplefins, incl. *F. varium* (occasional, Q146) and the common triplefin (*F. lapillum*, Q156 x1), spottys (*N. celidotus*, few), blue cod (abundant at Q146), Scarlet wrasse (Q146), schools of Kahawai, mimic blenny (few at CB17-C20).
BT17 Beam trawl Macroalgae collected in drift mats within TC	*Ulva* spp., *Anotrichium crinitum, Crassiphycus proliferus, S. montagneana, C. brownii, Cystophora, Sargassum sinclarii, Gigartina atropurpurea, Sarcothalia livida, Agarophyton chilense, Haraldiophyllum crispatum, Rhodophyllis* (see Table 3-44 for site and volumes specifics).

[52] Macroalgal taxa described here are based on video identifications verified by Roberta D'Archino, however, amounts were sometimes difficult to determine as species can often be difficult to identify in imagery both within and between TC sites.

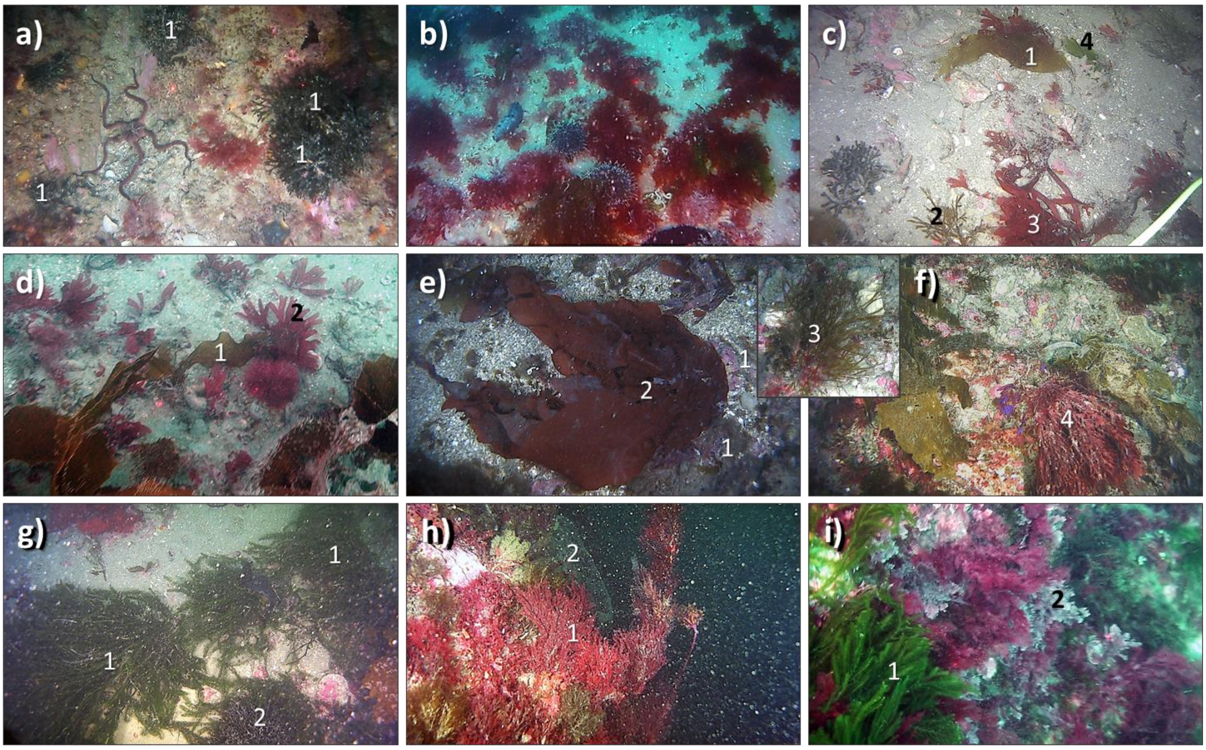


Figure 87: Examples images of the macroalgal zone in TC. a) mixed macroalgae (incl. 1 = *C. fragile*), Dieffenbach Pt, inner TC (MDC18-Q177b); b) macroalgae dominated by filamentous reds, with kina and *A. mollis,* inner QC (MDC18-Q140); c) macroalgae (incl. 1=*U. pinnatifida*; 2=*C. costata* sp.*,* 3=*Sarcodia*, 4= *Ulva*), Wiriwaka Pt, mid-TC (CB17-C18); d) macroalgae (incl. 1=*U. pinnatifida,* 2=*Sarcodia*), Tipi Bay south, outer TC (MDC18-Q159); e-f) mixed algae (1=coralline algae and 2=*Gigartina,* 3= *C. costata,* 4= *E. formosissima*) off Te Awaiti Bay, outer TC (MDC18-Q156); g)' exposed' mixed algae (1= *C. brownii*), Tipi Bay north, outer TC (CB17-C22); h) 'exposed' red algae (1= *E. formosissima*, 2= *E. alata* sponge) east of Fisherman's Bay, outer TC (CB17-C20); i) mixed algal zone (1=*C. flexilis* ,2= branching geniculate coralline alga), TC-entrance, near West Head (MDC18-Q81).

These patterns in community structure with distance from TC-entrance also correlated with similar changes in the shallow kelp communities, with two transitional zones identified. The first beginning just north of Ngamahau Bay, with the replacement of *C. fragile* and *Ulva* with *C. brownii* and increasing occurrences of the stalked sea tulip, *P. pachydermatina*, while the second begins north of Thoms Bay extending through the TC entrance (a distance of <2 km), characterised by increased abundance and higher species richness of both kelps and fleshy macroalgae, reflecting the co-occurrence of both outer Sounds species and the onset of Cook Strait species (e.g., *E. formosissima*, *C. flexilis*, as well as *L. variegata, Marginariella* and *Landsburgia*) (Table 3-36 and Table 3-37). Collection of macroalgae from these sites would be required to detail the change in species composition across this high-current to wave-exposed gradient.

3.4.3 Kina barrens

Kina (*Evechinus chloroticus*) were common on the slopes within TC, with numbers highest and test-sizes generally much larger in outer TC (see Section 3.7.7: Kina distributions). Kina barrens were also observed in mid-upper slope depths along both sides of inner, mid and outer TC, with more extensive kina-barrens seen close to the entrance to TC (e.g., MDC18-Q144 and Q81). Kina-barrens were generally found on low to moderate relief rock outcrops below the nearshore macroalgal zone, characterised by low amounts or the absence of kelps and fleshy macroalgae, the dominance of coralline algae (NGC) covering rock surfaces, and moderate to high densities of kina (Table 3-38; e.g., Figure 88). Many species of sea urchins, including kina (*E. chloroticus*), can when in high densities, graze kelps and macroalgae resulting in the removal of kelp and macroalgae from often extensive areas of reefs, with continued grazing maintain these barrens (Filbee-dexter and Scheibling 2014; Udy et al. 2019). Kina barrens were most prevalent in depths of 15-30 m. Sites with the most notable number of kina included sites near TC-entrance (MDC18-Q81) and near Te Uira-Karapa Pt (Q161), but see Section 3.7.7 - Figure 134 for the mapped distributions of Kina across the survey area.

Table 3-38: Characteristic features of kina-barren habitats on the mid to upper slopes of TC. Sites refer to MDC18 survey.

TC kina barrens	Characteristic features and significant/notable taxa
Substrata	Low to moderate relief reefs with contiguous or patchy rock outcrop; The seafloor commonly veneered with fine and coarse sediments in many places. Notable kina barrens incl. sites Q81, Q144, Q156, Q157, Q161, Q305, CB17-C18, CB17-C24.
Benthic community	Coralline algae (NGC) dominant algae covering rock surfaces, low amounts or the absence of flesh macroalgae or kelps. Some other sessile invertebrates occasionally present, incl. encrusting sponges and colonial ascidians (e.g., *Botyrlloides* spp., Q156), and encrusting bryozoa (*C. agglutinans*, patchy some sites, common at Q146).
Motile invertebrates	Kina most dominant mobile invertebrate - often large-sized and locally dense (often in tight clusters, esp. around drift weed), snake star (few-common), cushion stars (*P. regularis,* few-common), *C. muricata* (occasional, Q146), *A. mollis (*occasional, Q146), wandering anemone (Q146 x1).
Fish	Blue cod (few), scarlet wrasse (occasional), sea perch (occasional), butterfly perch (occasional schools), *F. varium* (occasional e.g., Q146).
Other	Drift algae with kina (e.g., Q157, Q81, Q161, notable amounts at Q144).

Although kina were present on slopes throughout inner, mid and outer TC, exceptional high localized densities (~20-35 kina per m-^{2}) were recorded at some sites (e.g., near Wiriwaka Pt, CB17-C18 - Figure 85g), particularly those sites closest to TC-entrance (e.g., MDC18-Q81 and Q144, CB17-C22: Figure 88a-i), with high densities of large sized kina also recorded at Te Uira-Karapa Pt (MDC18-Q161). Within TC kina-barrens, very little attached/growing macroalgae was seen. However, kina in these zones were regularly seen in dense clusters on top of drift kelp (e.g., Figure 85g; Figure 88a-b), indicating that drift algae is likely to be an important food source for kina in these barren-zones.

Kina within TC were noticeably larger than those seen in QCS, with the highest density sites near the entrance of TC also having some of the largest-sized kina (approx. 130-155 mm) seen during the survey[53]. Kina collected in dredges sampled along the inner south side of TC (MDC18-D03, D04 and D06: see Figure 7; Figure 8c) reached sizes of up to 158 mm, while higher densities of very large sized kina (>130 mm) were most frequently seen east of Ngamahau Bay, towards TC-entrance (see Section 3.7.7). No kina barrens were recorded at the shallow Dieffenbach point site, even though there was extensive reef habitat with abundant kelps (MDC18-Q177b). Snake stars were present/common, while some fish, mostly a few blue cod, were also recorded (see Table 3-38 for full species list).

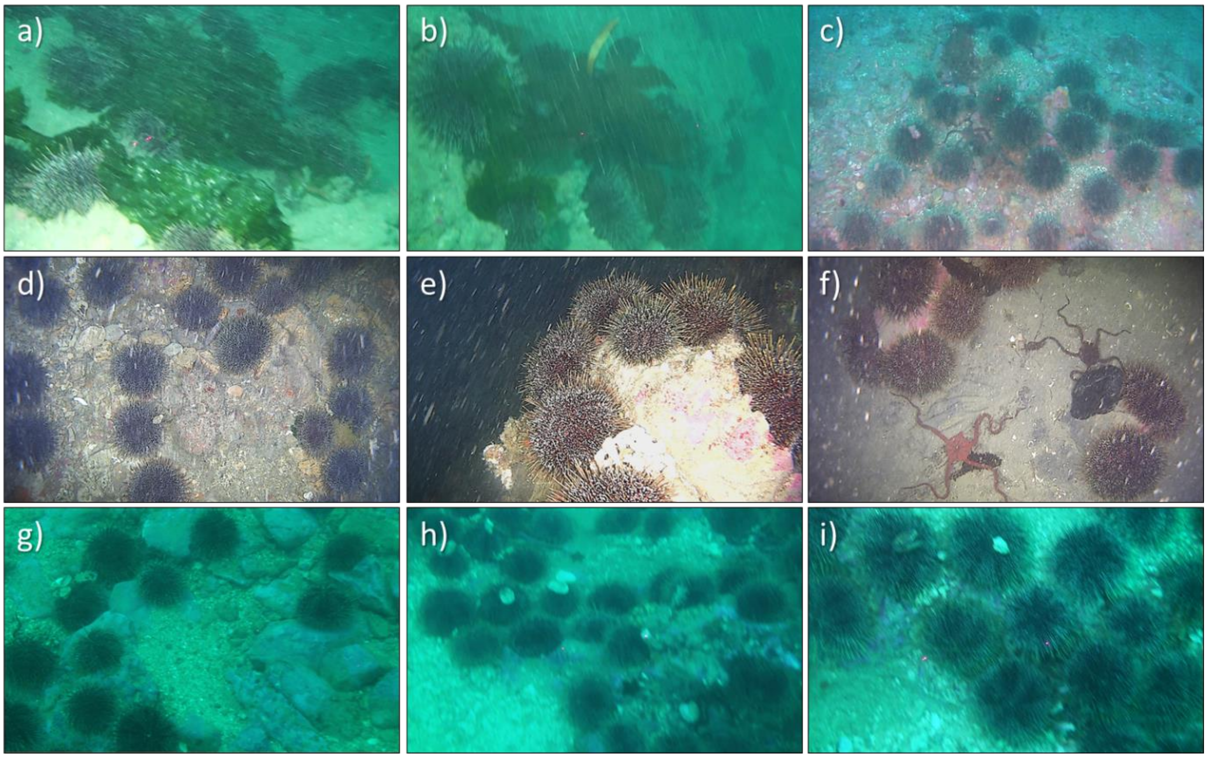


Figure 88: Examples of Kina densities and sites approaching TC entrance. a-b) Kina clusters on drift macroalgae south of Ngamahau Bay (MDC18-Q157); c) Kina cluster on rock, south of Thoms Bay (MDC18-Q146); d-e) Kina zone off Fishermans bay (MDC18-Q156); f) clusters of kina on very small rock outcrops, Tipi Bay (CB17-C22); g-i) An extensive and dense kina-zone within the entrance to TC (MDC18-Q81). Lasers are 20 cm apart, to provide reference for kina size (g, I show zoomed-in images).

[53] The only other site with high densities equivalent to outer TC sites, were at Waihi Point, Cape Jackson (Site MDC18-Q121) and in Cook Strait near Cape Koamaru. Kina at these site were also seen clustered over drift macroalgae, upon which they feed.

3.4.4 Dieffenbach Point (extensive reef feature)

The most significant deep reef observed during all four surveys within QCS or TC, was the extensive reef off Dieffenbach Point, at the junction between QCS and TC (Figure 89, Figure 90). Dieffenbach Point is defined as an Ecologically Significant Sites (ESS site 5.1) (*'based on a brief visit'*, Davidson et al. 2011). During the MDC18 survey, three tow-video transects were undertaken over this reef system (MDC18 Sites Q177a, Q177b, Q314) to characterise the deep and shallow sections of this large high-current reef system (Figure 90). This reef extends 435 m out from the shoreline[54] with a maximum reef slope of 60° (depth and slope profiles along-transect Q177a) and slope variance of 14°. The top of the high relief pinnacles that characterise this deep reef are ≤ 10 m wide, while the base of the reef is ≤~170 m wide (Figure 89a,b), reaching depths of 51-56 m (Figure 89a,b), below these depths the flanks of this reef are heavily laden with a matrix of shell-debris and sediment, with a slope angle of ≤~17°.

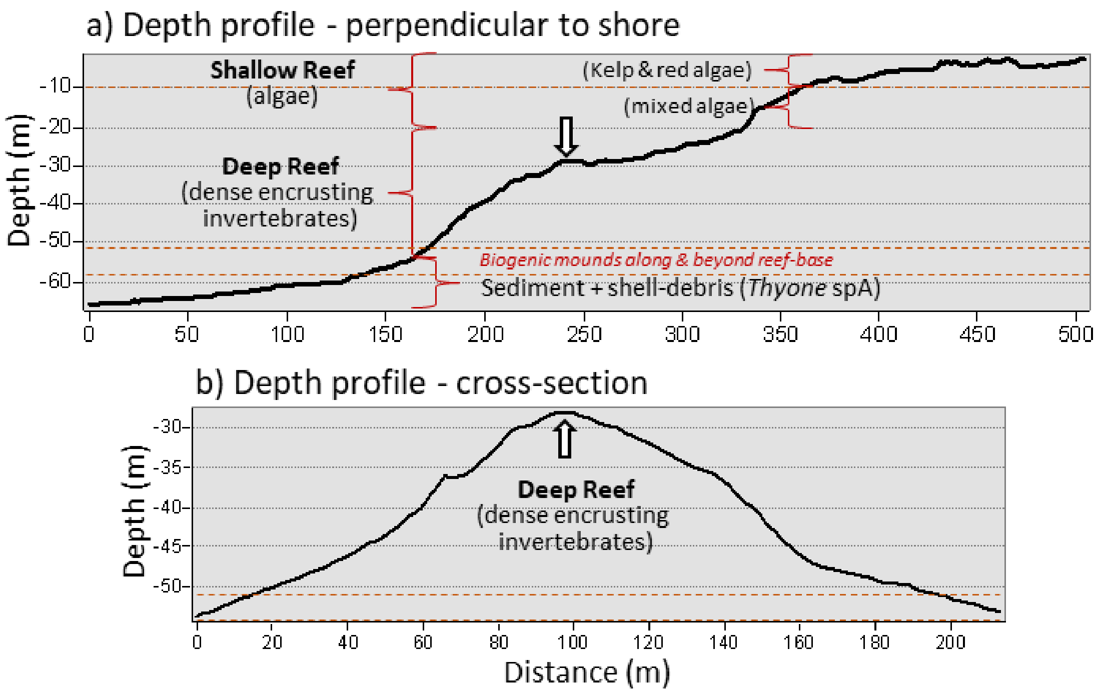


Figure 89: Depth profile of the deep reef system of Dieffenbach Point, at the QCS-TC Junction. The depth profile of this deep reef, a) running perpendicular to the shore down the ridgeline to 66 m; and b) across the reef at the point indicated by the white arrow.

Perpendicular to Dieffenbach Point, a shallow-section of the reef (i.e., <10 m) extended 164 m offshore – and as such is one of the few if not only reefs that extend this far away from the shore in this depth (Figure 89a). Shallow reefs surveyed (Q177b) supported dense patches of kelp – dominated by the giant kelp (*M. pyrifera*) and flapjack kelp (*C. flexuosum*), along with notable densities of the invasive kelp *U. pinnatifida.* Beneath this patchy multi-species kelp bed (e.g., Figure 90c), was a subcanopy of mixed red algal species (Figure 90a-b). Beyond the kelp-zone (~10-16 m depth) the reef supported a mix of red and green fleshy macroalgal species, characterised by encrusting corallines (NGC), a variety of mixed red algae (similar to those found beneath the kelp), and the fleshy green algae, *C. fragile* (commonly known as dead man's fingers) (e.g., Figure 90b). Shallow reef sessile invertebrates included low-density patches (<10% cover) of small rock

[54] Q177a began 464 m off the point Of Dieffenbach Point in 65 m water depth and ran up and along the ridge line finishing 130 m from the shoreline in 7.4 m.

anemones, encrusting sponges (0-10% cover), along with motile invertebrates characterised by low densities of kina, few to abundant snake stars and a few starfish (*C. muricata* and *P. regularis*). A variety of fish species were seen on the shallow section of the reef. These included leatherjackets, banded wrasse (both visible in Figure 90c), numerous spottys, several scarlet wrasse, a few triplefins (*F. flavonigrum*), a few adult blue cod and a male butterfish.

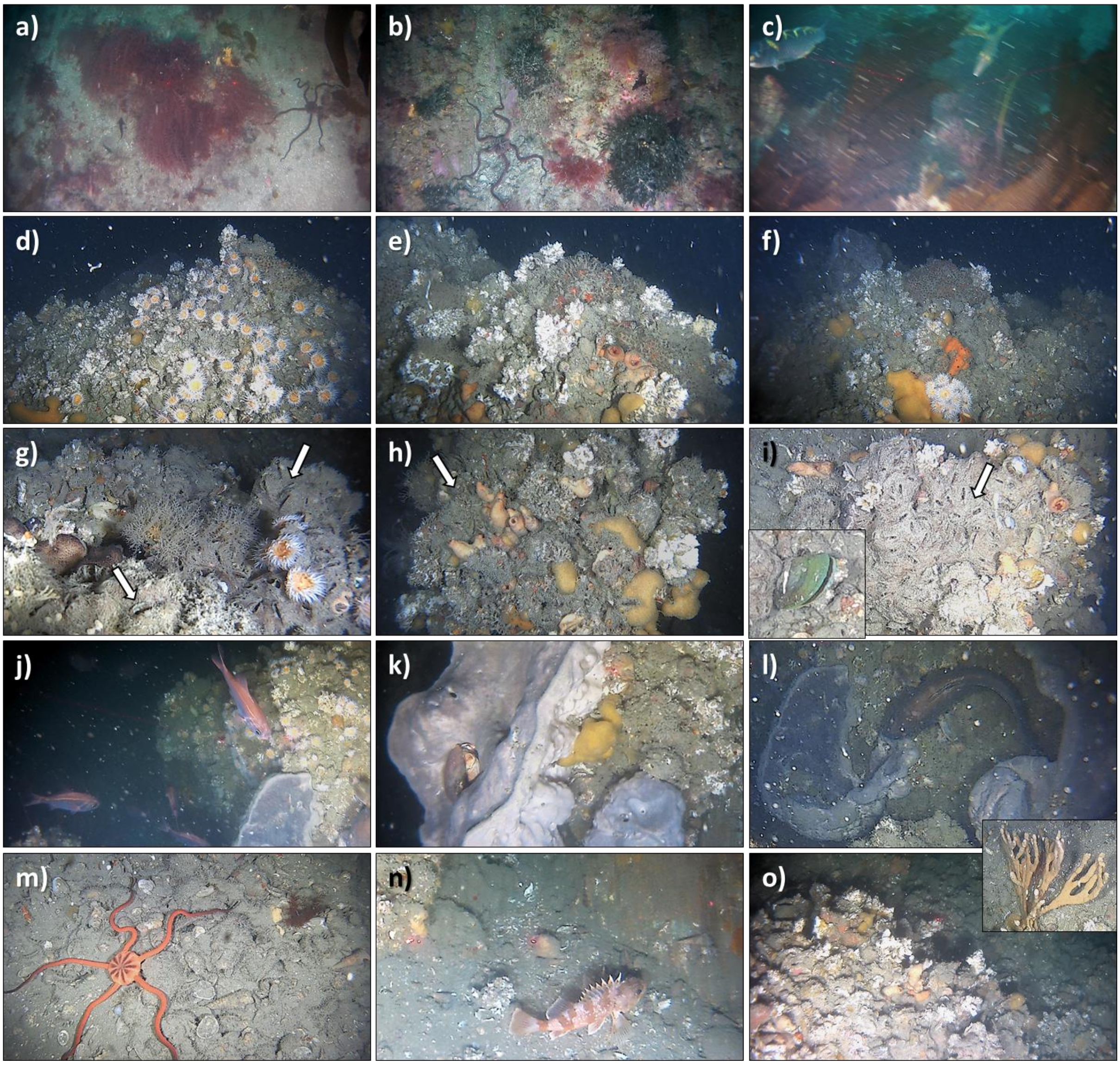


Figure 90: Significant and pristine reef off Dieffenbach Point, at the junction of QCS and TC, with examples of the types of habitat zones in 7-66 m. a-b) Mixed red dominated the shallow zone in ~7-10 m water depth; c) Kelp forest in ~7 m dominated by giant kelp (*M. pyrifera*), with mixed red algae and a banded wrasse and leatherjacket; d-f) Upper ridges of the deep reefs with dense filter feeding invertebrates, dominated by barnacles (white clustered patches), rock anemones, sea squirts and sponges; g-j) Mid-slope zone dominated by large clumps of epiphytic bivalves (indicated by white arrows), solitary sea squirts, and colonial ascidians. Insert shows one of several green-lipped mussels seen in this zone. j-l) High-relief fractured rock walls, in 30-45 m, providing refuge to a variety of fishes dominated by schools of roughy, occasional rockcod [l], while ridgelines supported massive sponges (*E. alata*) and rock anemones [j]; m-o) Three habitat types seen at the base of this extensive deep reef: m)Shell debris slopes partially buried in sediment in depths of ~60-66 m, with snake stars and a burrowing sea cucumber (*Thyone* spA); n) Reef-sediment interface at ~56 m with characteristic seaperch; o) Biogenic mounds of low to moderate relief comprised of semi-cemented shell debris by moderate density invertebrates –Insert of strappy sponge (poss. *Iophon minor*).

Deeper down the reef, macroalgae communities quickly gave way to rich invertebrate communities on high-relief deep-reefs across depths of ~16 down to 50 m. This extensive deep reefs was characterised by extremely steep and jagged rock walls, ledges and fissures, with notable amounts of conglomerate/biogenic covering (cement-like crust over the reef surface, likely a mix of relict biological material from encrusting bryozoans, epiphytic bivalves, barnacles, and other species found growing in clumps across these reefs). Rock walls and ledges were densely covered by invertebrate communities, where white barnacles densely covered ridgelines, zones of small rock anemones covered upper rock walls, dense patches of jewel anemones occurred on the mid-sections of the rock faces, with both charcoal-grey and large-sized bleach-white *E. alata* sponges projecting out from exposed rock ledges. Other taxa included brachiopods, dense patches of epiphytic bivalves, solitary sea squirts and colonial ascidians, hydroids, large digitate sponges, large red-purple rock anemones, cup corals (mostly deep), a few individual green-lipped mussels, and some hard encrusting and erect bryozoans. Many of these species are likely to contribute to the biogenic structure covering these reefs, particularly the encrusting bryozoa. Motile invertebrates were characterised by mostly snake stars, *A. mollis* and cushion starfish (*P. regularis* and *P. pulchellus*). The extreme vertical relief and complex reef configuration of this feature provided large crevices and overhangs giving refuge to various fishes (e.g., Figure 90j-l). Although this reef was not teaming with fish, as seen in other regions (e.g., Stephens Passage, and the Jags), it did support notably more fish and more fish species than all other reefs within the survey area, although few were of large sizes (>35 cm) – something rarely seen across most of the Sounds. Fish recorded on the reef included numerous seaperch in the deeper zones, schools of butterfly-perch, scarlet and banded wrasses. Several species, including banded perch, rockcod, and schools of roughy were seen in the ravines and under-hangs; while other sections of the reef supported adult blue cod, a few leatherjackets and an abundance of small black-and-yellow triplefins (commonly seen on mid to deeper sections of this reef). One of the very few John Dory recorded during these surveys was recorded at the edge of this reef (Site MDC18-Q177b). This reef is subjected to extremely high currents, with the deeper sections of the reef lying under the shipping-lane and ferry route, making fishing or diving this reef perilous. Based on the fish fauna and the relatively pristine benthic communities recorded on this reef compared to all other sites surveyed, this has likely acted to some degree to provide a natural refuge from fishing pressures. Nonetheless, several fishing lines were seen snagged on various sections of this reef, identifying that fishing activities do occur across this reef. Notably, hāpuka were once a common catch in Tory Channel, particularly in deep water off Dieffenbach Point, but are now rarely seen inside the Sounds (Davidson et al. 2011 p102). No hāpuka were observed at Dieffenbach Point during these surveys, or any other location within the survey area.

Beyond the base of the reef (approx. ~45-55 m), three habitat types were identified. Around the base of the reef, in 45-55 m depth, were large undulating mounds of small shell debris loosely bound in sediment, that appeared to overlay and possibly mirror the underlying reef terrain. This undulating shell-debris zone supported sparse % cover of sessile (e.g., few fan worms and sea squirts) and motile (e.g., snake stars) invertebrates. In some locations, however, mostly around or near the base of the reef, more elevated mounds (low to moderate relief) were recorded, composed in part of shell debris that appeared to be more tightly bound into a conglomerate/biogenic reef structure. These biogenic mounds were covered in moderate densities of sessile invertebrates, dominated by solitary sea squirts, brachiopods, dense patches of epiphytic bivalves and colonial ascidians (e.g., *C. dellechiajei*) – all of which are capable of binding loose material to form biogenic structures. Motile species, such as *P. albocinctus*, were also commonly seen on these mounds. Beyond both the reef and the adjacent undulating shell and biogenic zone (>55 m), the benthos became a more levelled sediment slope that was covered in coarse shell-debris. This zone supported a variety of motile invertebrates dominated by echinoderms, including burrowing cucumbers (*Thyone* spA), large and small starfishes (*C. muricata* and *P. regularis,* respectively), snake stars, *A. mollis*; along with moderate numbers of seaperch, a few sabellid fanworms and the occasional scallop.

3.4.5 Deep reef-slopes (sessile invertebrates)

Tory Channel is a drowned valley, where the narrow channel and strong tidal currents scour the seafloor that over geological time has resulted in steep sided channel walls (Neil et al. 2018; Figure 91). The main channel varies in width from >1.4 km near the QCS-TC junction, to less than 0.8 kms at the TC-entrance, with channel walls steeply sloping down to a slightly rounded or flat channel bottom (e.g., Figure 91). Past surveys have described and delimited several significant ecological habitats within TC (see Figure 84) including areas of deep reef-slope that support rich sessile invertebrate communities (e.g., ESMS-5.8, Davidson et al. 2011; 2019). During the towed video surveys, we characterised a total of 20 deep reef-slope sites (14 MDC18 and 6 CB17 sites) that provide additional information on these deep reef-slope communities within TC (Appendices D and F). However, these deep-slope habitats were incredibly difficult to survey due to the extremely strong tidal currents, which only briefly slacken and act to prohibit transects running perpendicular to the alongshore current. Consequently, to ensure vessel manoeuvrability along the transect and to avoid the towed-camera being swept away with the current, video-transects were often run on a reduced angle (see Figure 92 for transect locations and angles to shore).

The channel walls of TC are characterised by steep slopes along the main channel (Figure 91 and Figure 92-bottom row), with the amount of hard substrata dependent on the proximity to the shallow TC bays (Figure 92-top row), with three types of slope habitats identified, specifically: i) flat soft-sediments above shell debris slopes in front of TC-bays, ii) low-relief rubble and coarse sediment slopes near TC-bays (i and ii described in Section 3.4.6), and complex rocky and biogenic reefs on the steeper slopes away from bays (described here).

Channel slopes away from bays were characterised by steep slopes (31-58^{o}, max. range[55]), and slope-variation (i.e., 4-16^{o} Std dev. of slope) with the highest slopes and slope deviation measured in the TC-entrance. Ground-truthing video, identified these deep reef-slopes as having moderate to high relief with various combinations of rocky reef and biogenic-reef structure that support diverse and colourful filter-feeding communities – similar to those previously described in ESMS-5.8 by Davidson et al. (2011; 2019). Biogenic-reef structure was characterised by a convoluted cement-like crust over the reef surface, and was seen at most deep-slope sites in varying amounts, from small patches (e.g., Ngaionui Pt, Q165) to large amounts of convoluted reef structure (e.g., either end of Ngamahau Bay e.g., Q157 and CB17-C19 and south of Te Rua Bay e.g., CB17-C23; Figure 94c,d,g). This relict (no longer living) reef structure also contained sections of live reef-building bryozoa (*C. agglutinans*), indicating that this crust-like structure reflects a mixture of living and relict bryozoa reef, also bound together in some places by sea squirts and brachiopods (e.g., Figure 94d,g,i).

These deep reefs and slope walls, especially those on steep slopes subjected to very strong currents, supported a diverse and colourful array of species, including: reef-building bryozoan (*C. agglutinans*), other hard bryozoa, incl. foliose and fine-branching species (e.g., *C. elegans,* outer TC sites only), soft orange and green bryozoans, erect and encrusting sponges, colonial, solitary and stalked ascidians, hydroids, including hydroid trees, jewel anemones, deep encrusting coralline algae and brachiopods

[55] Based on maximum MBES slope values associated with depth profile cross sections depicted in Figure 91 (A-R profiles).

(e.g., Figure 94), along with rare occurrences of cup corals and goose-barnacles (later occurring only at CB17-C20 near TC-entrance) (e.g., Figure 94; see Table 3-39 for species list).

Hard bryozoan dominated by *C. agglutinans* were recorded on channel slopes from inner to outer TC, generally in small patches (e.g., Figure 94a,d,g) on most reef-slopes, particularly those in the outer sections of TC (e.g., Figure 95a-brown bubbles), with %cover ranging from ~1% up to ~35% (e.g., Wiriwaka PT, CB17-C18). Soft bryozoans, comprised of green and orange[56] coloured varieties were prevalent on most deep reef-slopes across outer TC, east of Te Pangu (e.g., Figure 94a,b,i,j,k), but were mostly absent at inner or mid TC sites west of Te Pangu[57] (Figure 95a -green bubbles). Orange forms of soft bryozoa were most common on steep sloping reefs (e.g., Figure 94a,b,i,j,k), while green forms appeared more characteristic of less-steep rubble slopes, although both species were seen across a broad depth range. Mixed species of hydroids were also a characteristic feature of most deep-reef slopes and included a variety of small fern-like and fan morphologies occurring at most TC sites, along with larger hydroid trees (*Solanderia* sp.) more commonly seen at outer TC sites (Figure 95b; e.g., Figure 94c,e,f). While hydroid trees were recorded at a number of TC-sites, densities and tree-size were highest on the northern side of outer TC, most notably at sites north and south of Ngamahau Bay (Q157 and C19, respectively; e.g., Figure 94c,e,f). Large erect sponges, dominated by charcoal-grey *E. alata* sponges, were also a characteristic feature of most deep-reef slopes (Figure 95c; Figure 94h,l). Interestingly, although bleach-white sponges were found on the deep-reefs at Dieffenbach and Ruaomoko Points, either side of the QCS-TC junction (see Section: 3.3.5 and 3.4.4), and in Cook Strait (see Section: 3.5), no bleach-white *E. alata* were recorded within the main channel of TC, even at the very high-current TC-entrance sites (Figure 127), although one single whiteish-grey sponge was seen at the deepest slope site at Q185 (just north of Te Rua Bay – indicating that this colour-morph may be related to deeper depths rather than current strength, alone. Site Q185 was a notable site in that it was one of only three sites (along with Q177b at Dieffenbach Point and the deep reef off Te Pangu Bay) that supported deep reef-slopes in depth down to or over 50 m, and supported notably numbers of hydroid trees in depths of ~40-51 m. Site Q185A is part of a larger series of deep rocky ridges that occur across a 700 m wide section of deep slope. The deep reef off Te Pangu Bay (Q85), although a much smaller feature (~90 x 92 m in size, ≤6 m vertical relief) was characterised by biogenic structure that supported abundant sea perch and dense patches of hydroids in depths of 44-62.5 m. This is one of the few deep channel reefs present within TC. Neither of these sites (Q185 and Q85) are currently described as an Ecological Significant Marine Sites. Some signs of mechanical damage to TC slope habitats were also seen, this included biogenic-encrusted reefs sheered clean, and one site (Q185) with notable amount of *Galeolaria* rubble. *Galeolaria* rubble was also seen within the main channel in TC – indicating localised damage or more likely the transport of damage *Galeolaria* from nearby slopes. While *Galeolaria* was recorded at many sites, most areas were limited to localised biogenic clumps. However, the presence of notable amounts of Galeolaria at these sites indicates that at least in a few locations that *Galeolaria* mounds were once present, and may have once been more common.

As a preliminary approach to determine the degree to which slope and depth were important in this deep reef-slope zone, we overlaid and interrogated the towed video characterisations (substrata, relief, and community structure) with HS51-MBES GIS layers, and plotted HS51 depth, slope and slope-variance (std dev.) profiles for the 20 reef-slope transects. This preliminary approach identified that the richest reef-slope communities were in depths of >20 m, where slope angle was >30^{o} (max. slope range of 30-53^{o}[58]), and slope variance was >4^{o} (with a max. std dev. of 16). This well-

[56] Also included a colour-range of mustard yellow and cream coloured soft bryozoa
[57] Although this may reflect the lower number of deep reef-slope sites surveyed west of Te Pangu.
[58] Values here represent slope profiles calculated along the towed video transects.

represented the most significant deep-slope communities, recorded at steeply sloping sites: off Ruaomoko Point, inner TC (Q169); along the extensive reef feature that projects out into TC between Te Awaiti Bay and Jacksons Bay (Q156); on the promontories north and south of Ngamahau Bay (CB17-C19 and Q157, respectively); and on the extensive reef slope and ridges off the headland between Fisherman's Bay and Okukari Bay (CB17-C20). In contrast, deep slope sites with reduced slope angles (<20°) comprised rocky ledges heavily covered in coarse sediments (e.g., Q165) with communities characterised more by colonial ascidians, green hydroids, and higher occurrences of motile invertebrates (e.g., *P. regularis, C. muricata* and *A. mollis*).

As with the shallower zones, at these sites, community composition of deep reef-slopes also varied with proximity to TC entrance, with sites near the entrance supporting the addition of fine-branching bryozoa (*C. elegans,* C20 only), notably higher numbers of stalked ascidians (*P. pachydermatina*, which are common in Cook Strait), the presence of more charcoal-grey *E. alata* over a broader depth range (from deep slopes up into the kelp zone), along with the presence of small clusters of what looked like goose-barnacles at the base of the reef-slope and on the cobble-rocks in the main channel (C20 only, not previously recorded within the Sounds).

Very little invertebrate slope community was seen on the southern side of TC from Thoms Bay north (e.g., Q81, Q144, Q146), however, this was likely due to the shallow depths surveyed at this site (<18-26 m), where deeper depths were prohibited due to the difficulty with currents. These southern outer-TC sites were either comprised of rock-rubble and gravelly sediment characterised by extensive kina-barrens across most of the mid-slope, with some of the highest kina densities recorded during the entire survey (e.g., Q81), or comprised a low-lying rock and cobble seafloor in depths of 15-25 m with low slope (<5° max. angle) (e.g., Q146), similar in composition to that of the channel floor further offshore in depths of 28-29 m (e.g., cross channel profile through Q146) – indicating that slope communities in these areas would be unlikely. The cobble field offshore of Q146, however, was notable for having schools of subadult (<20 cm) tarakihi. At the outer site closest to TC-entrance (Q81), a few slope species were seen at the deeper of this video-transect. These included a few *E. alata* sponges, yellow and orange encrusting sponges (<5% cover), orange soft bryozoans, and some deep encrusting corallines (<3% cover), indicating that deeper reef-slopes at sites closer to the entrance may support more slope-community species.

Location of depth profiles

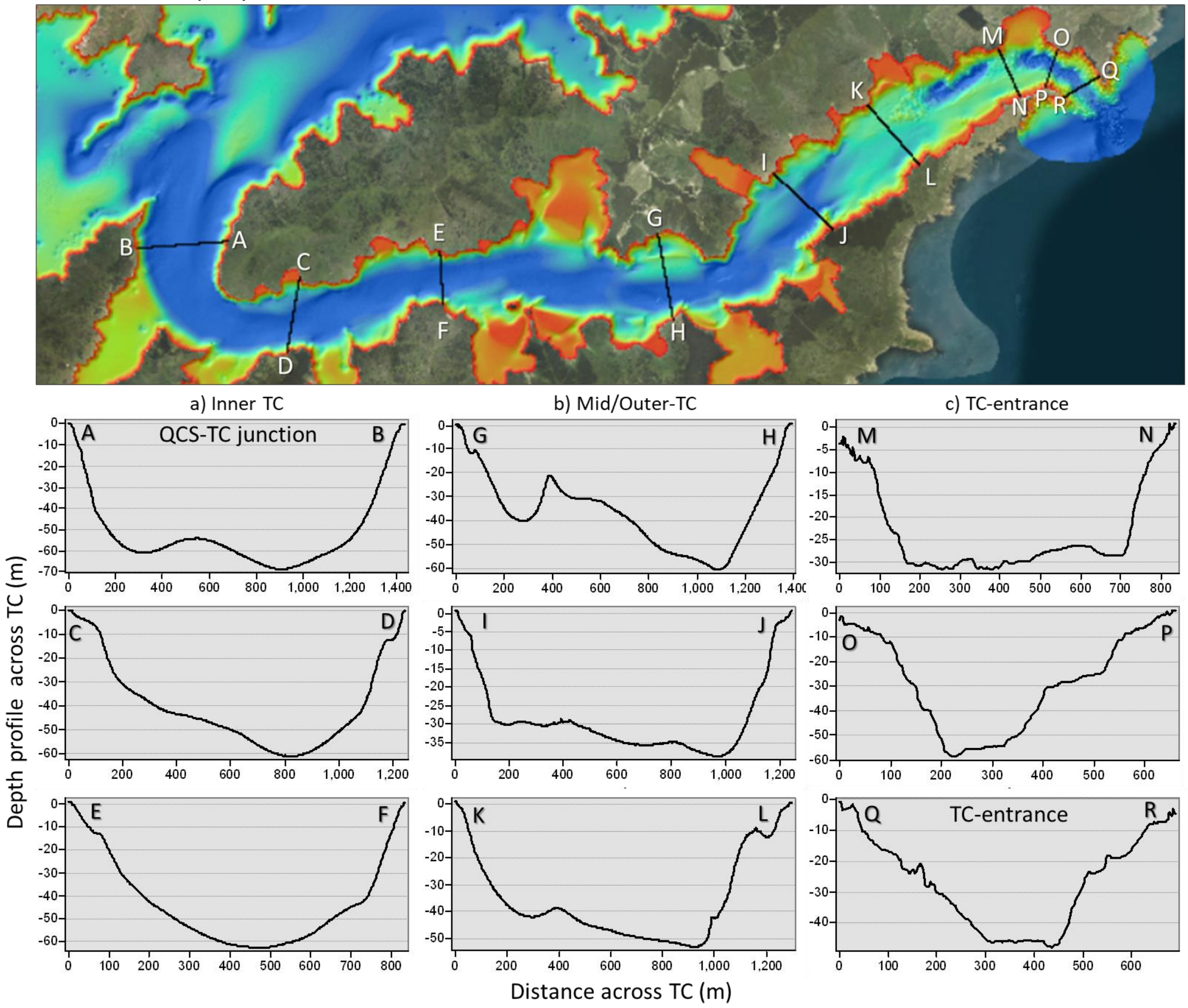


Figure 91: Depth profiles across Tory Channel, showing the shape of the channel and the angle of the channel walls. Letters denote the location and direction of each depth profile along and across the TC.

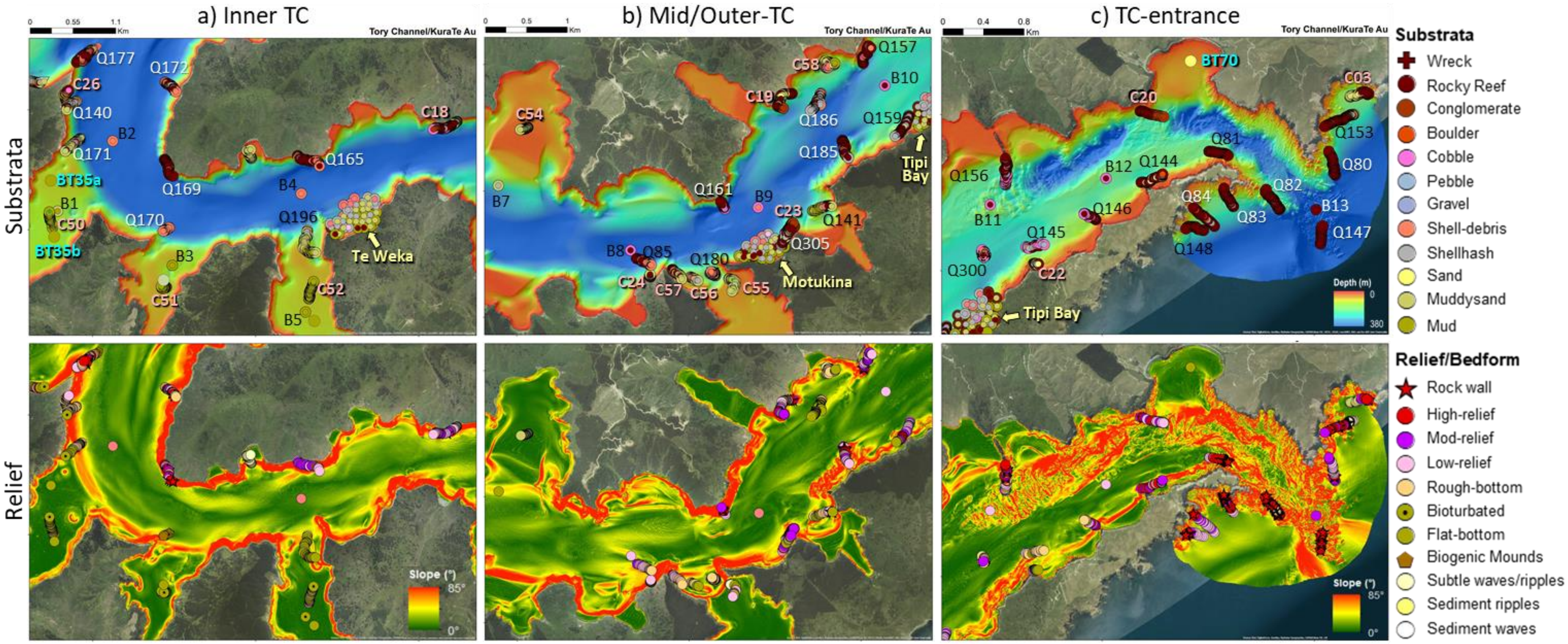


Figure 92: Multibeam bathymetry (top row), MBES-derived slope (bottom row) and towed video sites depicting substrata types and relief within inner, mid and outer TC (all surveys). Top row site labels depict MDC18-sites (Q#), CB17 sites (C#-orange text), HS51 sites (B1-13) and BT17 sites (BT#-blue text). Arrow labelled Te Weka, Motukina and Tipi Bay (top row only) depict substrata from clusters of sites within three TC Bays surveyed by Brown et al. (2016a).

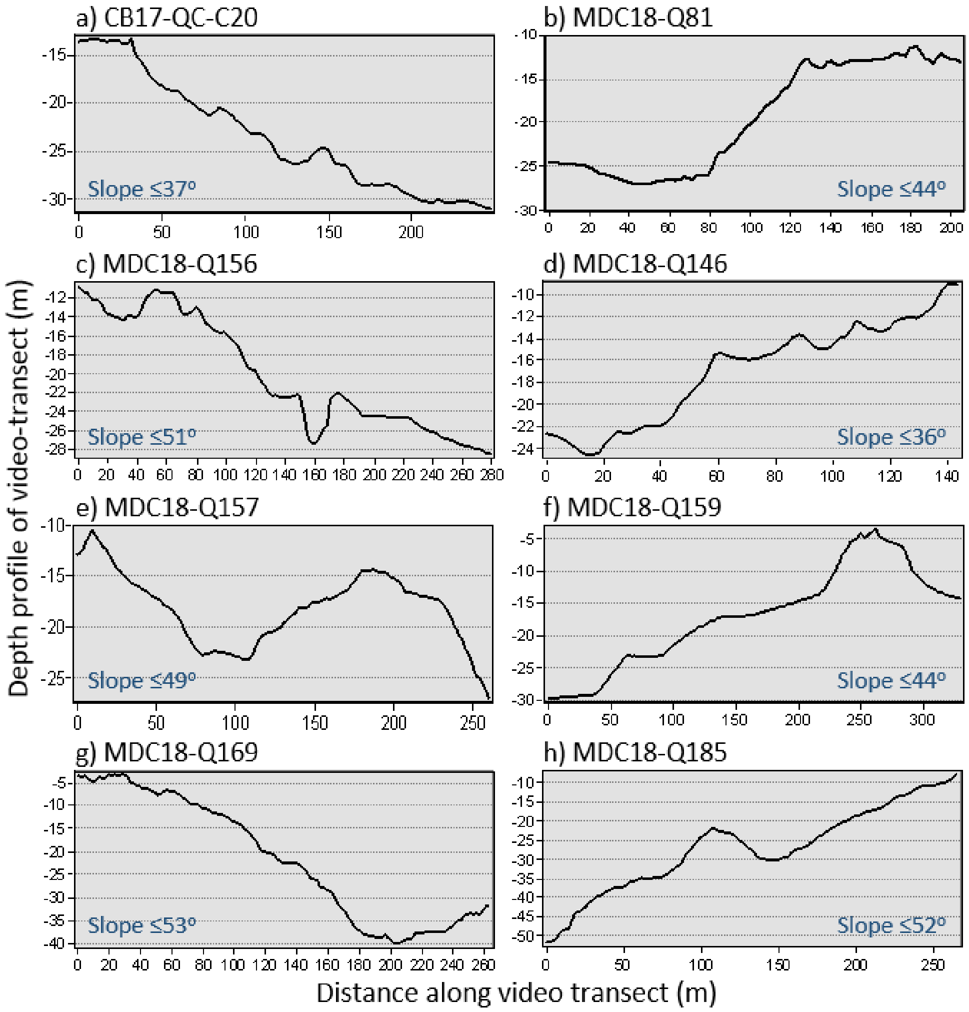


Figure 93: Examples of depth profiles along video transects surveyed on the northern (left) and southern (right) sides of TC. See Figure 92 for site/transect locations. MBES-derived slope values were calculated along transects, with values for maximum slope presented here for each transect. However, slope angles may underestimate the true angle of the slope wall, as video transect generally surveyed up slope at a reduced angle (i.e., not perpendicular to shore) to lessen issues with surveying in strong currents. See Figure 91 for actual slope of the channel in each area.

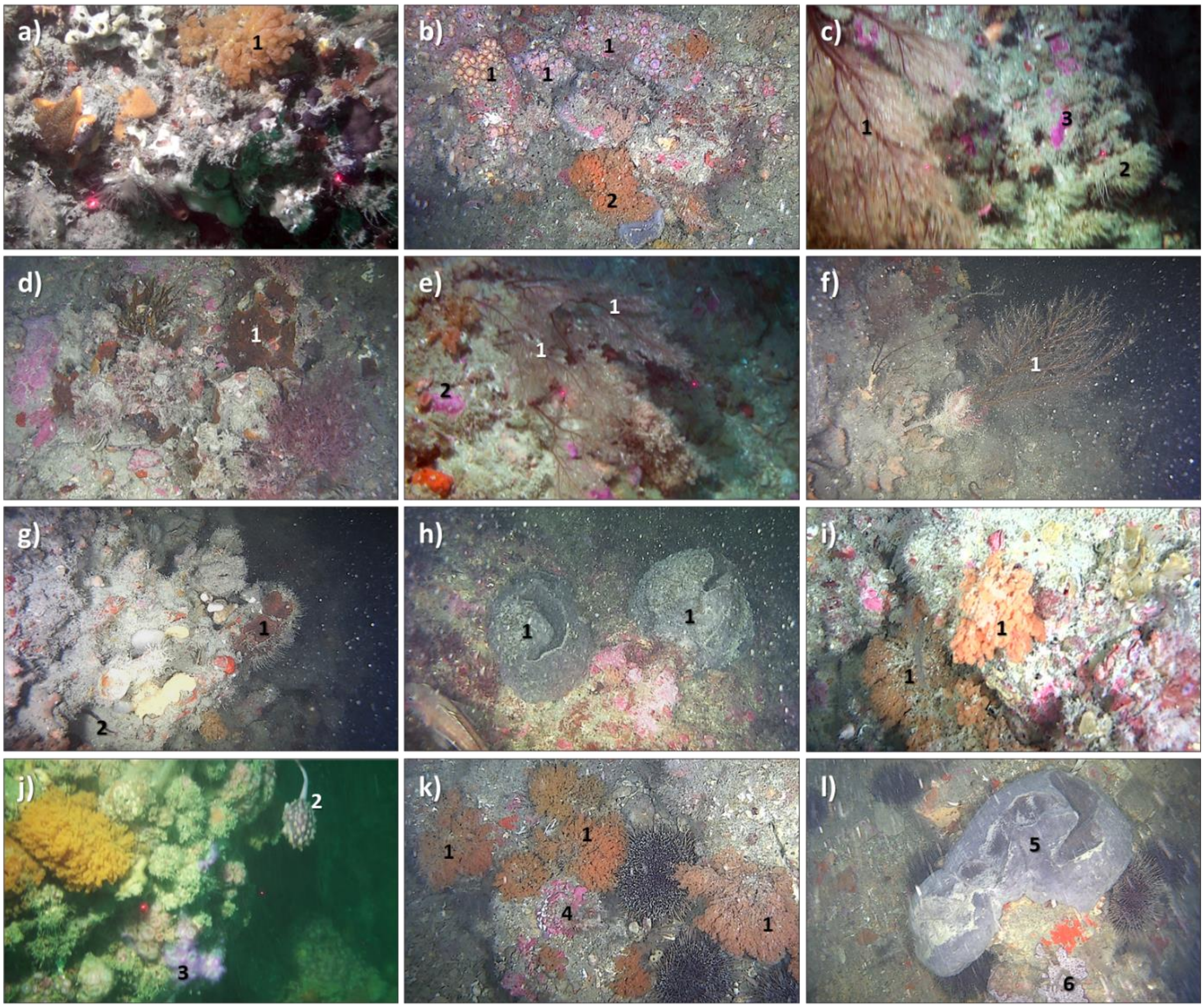


Figure 94: Examples images of the rich invertebrate assemblages on the deep reef slopes in TC. a) mixed invertebrates (1= orange soft bryozoa), north of Te Rua Bay (Q185); b) sessile invertebrates [1=jewel anemones, 2= orange soft bryozoa], off Te Awaiti Bay (Q156), c) biogenic reef with [1= large hydroid tree, 2= small dense hydroids, deep encrusting coralline algae, north of Ngamahau Bay (Q157); d) biogenic reef [1=reef-building bryozoa, *C. agglutinans*], south of Te Rua Bay (CB17-C23); e) biogenic reef slope (with 1= cluster of large hydroid trees 2=deep encrusting coralline algae north of Ngamahau Bay (Q157); f) biogenic reef slope [1= hydroid trees], south of Ngamahau Bay (CB17-C19); g) biogenic reef comprised of [1= reef-building bryozoa, *C. agglutinans*, 2= large brachiopod] south of Ngamahau Bay (CB17-C19); h) reef slope with [1= *charcoal-grey E. alata* sponges, 2= blue cod], east of Fisherman's Bay, outer TC (CB17-C20); i-l) biogenic reef slope at [1= orange soft bryozoa, 2= Stalked 'tulip' ascidian (*P. pachydermatina*), 3= jewel anemones, 4= deep encrusting coralline algae, 5= *charcoal-grey E. alata* sponges, 6= colonial ascidian (*Botyrlloides* spp.)] off Te Awaiti Bay (Q156).

Table 3-39: Characteristic features of deep slope habitats in TC.

TC Deep slope	Characteristic features and significant/notable taxa
Substrata	Moderate to steep sloping rock and/or biogenic reef (most commonly seen as a thick biogenic crust coating the reef - at least partially composed of reef-building bryozoa (*C. agglutinans*), with some biogenic clumps of sea squirts and brachiopods); Reef is veneered with dusting of sediment in many places; and with coarse gravelly sediments (e.g., Q185), with some high-relief or sloping wall features (e.g., Q156, Q157, Q185).
Benthic community	**Rich assemblage of encrusting and sessile invertebrates**: Live sections of reef-building bryozoa (*C. agglutinans*, patchy all slopes, e.g., C23), large charcoal grey *E. alata* sponges (occasional, often large Q185, Q156, C20)[59], encrusting yellow and orange sponges (occasional-common, e.g., Q81, Q156); yellow and orange erect chimney sponges (few, Q157, Q159, C20), fine-branching bryozoa (*C. elegans,* occasional,- outer TC sites only e.g., CB17-C20, Q145); foliose Bryozoa (few, C20), orange[60] soft bryozoa (common, e.g., Q157, Q156); green soft bryozoa[61] (occasional, e.g., Q185, Q156, abundant at Q157); deep coralline algae (small patches, common, e.g., C23, Q157, C20), colonials ascidians (spp. common), pink colonial ascidian (*Botyrlloides* spp., occasional-few, e.g., Q169, Q185, Q156, Q157), colonial ascidian (*C. dellechiajei*), occasional C18, although common at Q169), *P. pachydermatina* (occasional, Q156, Q157, frequent C20), small white stalked tulips (small clusters, Q169, Q172), small sea squirt (indet., occasional Q185); rock anemones (e.g., Q185, Q156), jewel anemones (patchy common, e.g., Q169, Q185, Q156, Q157, Q172); various hydroids (common, e.g., Q157), hydroid trees (*Solandaria* sp., occasion, but common and large in some places, e.g., Q157, Q185, C19), small red brachiopods (likely *M. sanguinea*, occasional clusters, Q156), large-ish brachiopods (occasional, e.g., C19, Q157), solitary cup coral (*M. rubrum*, Q157-1 seen), drift algae (occasional/patchy, e.g., Q81, Q157), Goose-barnacle (indet. rare C20), epiphytic bivalves (occasional, but common at Q172, Q165, Q177), white barnacles (occasional, but common at Q169, Q172, Q177 only).
Motile invertebrates	Snake stars (common), cushion stars (*P. regularis,* common; *P. pulchellus*, occasional- Q185, C20), *C. muricata* (occasional, e.g., Q169), Kina (common, but patchily distributed - often large-sized and locally dense often in tight clusters, esp. around drift weed e.g., MDC18-Q156), but less dense than kina-barrens, gastropod (topshell, Q169).
Fish	Blue cod (occasional-frequent, e.g., C20), schools of butterfly perch (common, e.g., Q156, Q157, C20); sea perch (occasional, Q169, Q57, C20), school of Kawahai (C20 x 1 school), leatherjacket (Q156, x1), triplefins (*F. flavonigrum*, frequent-common, Q156, Q185), scarlet wrasse (occasional, e.g., Q156, Q157, Q165, few C20), tarakihi (e.g., Q146), red-banded perch (occasional, Q165, Q169, Q185), oblique swimming triplefin (few, C20). Deep reefs also supported roughy (occasional, Q169), crayfish (rare/ ecologically extinct), rockcod (rare, Q169, Q177); leatherjacket (Q172 x1).
Other	Notable patch of broken *Galeolaria* rubble mid-slope at Q185, but no living *Galeolaria* seen.

[59] Q185 had a single *E. alata* sponge that was whitish grey.
[60] Also mixed with yellow and mustard coloured soft bryozoa (e.g. Q156)
[61] More characteristic of rubbly and/or less steep sections of reef.

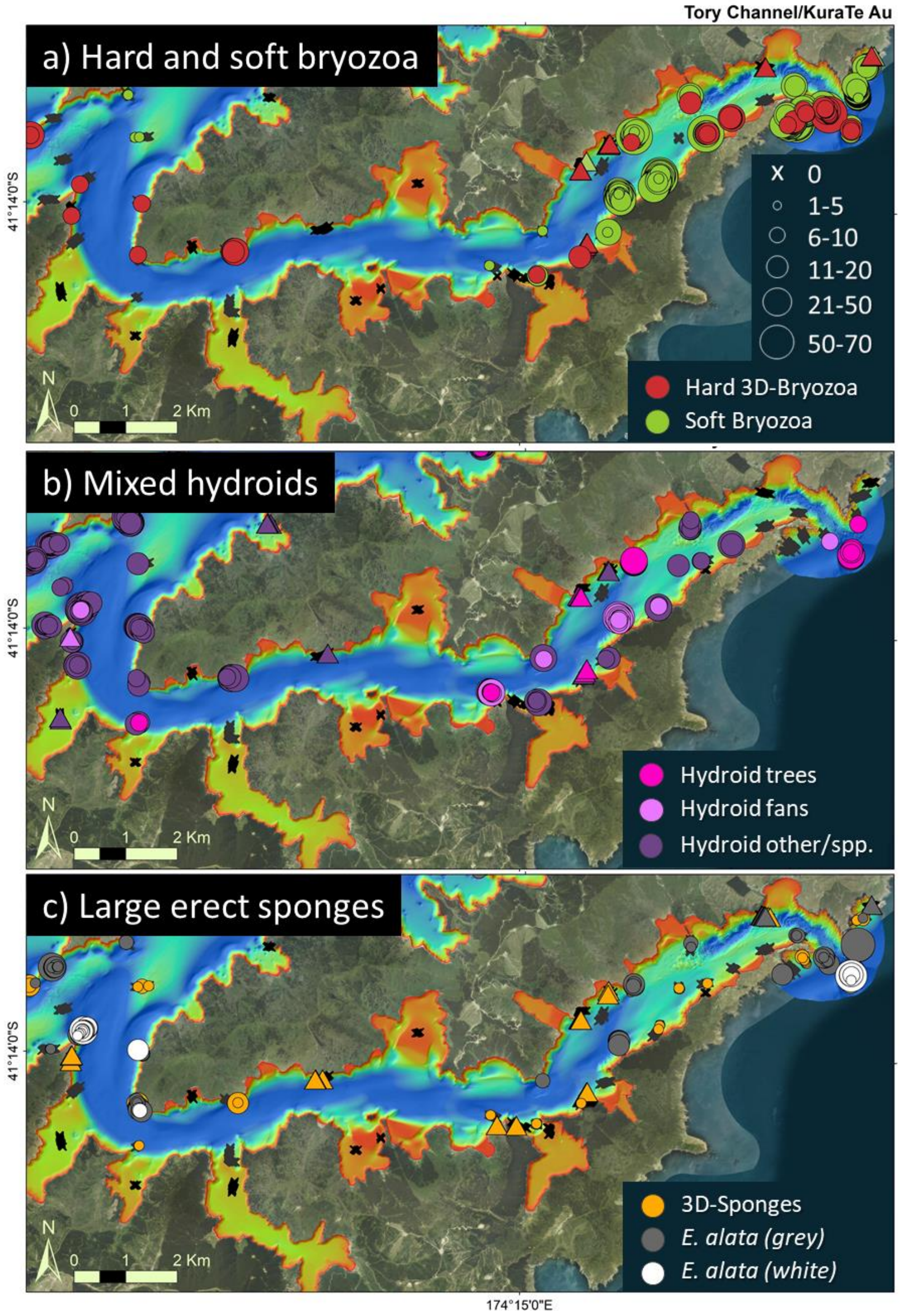


Figure 95: Distribution and relative %cover of sessile invertebrates within TC. a) hard and soft bryozoans, b) Three hydroids growth forms (trees, fern-like, and other); c) Erect (3D) sponges, incl. the grey and white colour morphologies of *E. alata* sponges. Coloured circles = distribution of each taxa type from the MDC18 survey, where bubble size represents %cover (legend in figure-a); coloured upright-triangles represent presence of each taxa type from CB17 survey. No BT17 beam trawls were undertaken in TC.

3.4.6 Rubble and sediment slopes

Channel slopes in, around and near TC bays were notably less steep (<25° angle and <4° slope-variance [Std dev. of the slope]) with lower relief than the deep reef-slopes described above (see Section 3.4.4), characterised by various combinations of soft-sediments, shell-debris, biogenic clumps, and at some sites low-lying rubble (Table 3-40; Table 3-41). The proximity to TC bays and the angle of the slope, and slope-variance were important factors associated with the types of habitat and communities present on these slopes. Those sites within or at the mouth of TC bays where slope angle was <15°, and max. slope-variance was <2° were generally characterised by soft sediment slopes (e.g., Figure 96a-f; Figure 97a-b; Table 3-40), with some sites having zones of shell debris either on the deeper slopes, or where deeper channel or gulley's were present (Figure 97c-d). Slopes with intermediate angles (i.e., 10-25° and max. slope variance of 2-4°), were generally in close proximity to TC bays, either around the headlands or adjacent to bays (e.g., Table 3-40[62]), and were characterised by mixtures of shell-debris (often in high quantities especially down slope), biogenic clumps, and low-lying rubble (e.g., Figure 96a-f).

Soft-sediment sites and zones were characterised by low to dense biofilm, low-moderate densities of snake stars and cushion starfish (*P. regularis*), and at some sites occasional biogenic clumps (<2% cover) or *Acromegalomma* fanworm-clusters (Figure 96a-e; see Table 3-41 for full species list). Fish at these sites were mostly low occurrences of flatfish and the occasional spotty, but also included rare occurrence of red gurnard, blue cod and a spiny dogfish (Table 3-41; e.g., Figure 96c). Sediment composition in or at the mouth of these bays appeared to vary by TC subregions (based on video-footage: e.g.'s Figure 96d,b,e): with bays in outer TC characterised by sandier sediments (e.g., BT17-QC70 in Okukari Bay, CB17-C58 in Ngamahau Bay, and coarse gravelly-sands from grab samples in Tipi Bay - Brown et al. 2016a), compared to the mud-dominated sites within inner TC bays (verified by grab samples at B1, B3 and B5 – Neil et al. 2018a), while both muddy and sandy sites and zones were recorded in mid TC bays (e.g., Oyster Bay: Sites CB17-C55 and C56, respectively).

In contrast, rubble and debris slopes in proximity to TC-bays, were characterised by a wide range of generally small sessile invertebrates (e.g., green soft bryozoans, mixed hydroids and colonial ascidians), accompanied by often high densities of motile invertebrates (e.g., snake stars, *C. muricata*, *A. mollis*, and an assortment of other starfish) (e.g., Figure 96; see Table 3-41 for full species list). A variety of fish was recorded in these habitats, including blue cod (mostly subadults), subadult tarakihi, spotties and sea perch in deeper sections, but these were mostly in low numbers (Table 3-41). Some debris sites also supported high densities of burrowing sea cucumbers (*Thyone* spA - e.g., Figure 96g,l,q-r) as described in detail in Section 3.2.3), while a few shallow sites supported locally dense cluster of small bluish-white *Bispira* tubeworms (described in detail in Section 3.2.5). Debris and rubble fields often included varying amounts of biogenic clumps comprised of aggregated biological material held together by encrusting bryozoans (*C. agglutinans*), colonial ascidians and solitary sea squirts, and provided hard surfaces for other sessile invertebrates, such as encrusting and erect sponges and hydroids (e.g., Figure 96; see Table 3-41 for full species list). Sites with higher amounts of low-lying rubble were characterised by similar assemblages, but often supported more hydroids, including hydroid trees at some sites (e.g., Q85 - e.g., Figure 96o), along with more biogenic-clumps supporting more taxa (Table 3-41). The most notable debris/rubble slope was at Tio Point, on the east side of Te Pangu Bay (Q85). The reef-slope at this site was of low angle and low relief (≤20° slope and ≤3.6° slope-variance) comprised of rock and biogenic rubble with coarse shell hash and gravels. Large sea perch were recorded on the deep reef and deeper

[62] 90% of the transect was represented by slopes lower than this MAX[1] value, but a few short sections of the transect may have steeper slopes max[2] as documented in Table 3-40.

slope-zone, along with notably high densities of snake stars, and frequent occurrences of large hydroid trees (see Table 3-41), as well as locally-dense clusters of small bluish-white ground-covering organism, on the upper section of the transect, of what might be the small bluish-white *Bispira* tubeworms (described in detail in Section 3.2.5). This deep TC-channel reef lies ~310 m offshore from Tio Pt in a NW-direction and ~460 m NE of Te Pangu Salmon Farm (Lat. -41.243, Long. 174.242). A few notably large hydroid trees were also seen at the entrances to Erie Bay and Ngaruru Bay (HS51 Sites B6 and B7, respectively) on sediment slopes with only a small amount of debris and rubble (e.g., Figure 96f). Of the sediment and rubble slope sites presented here, only CB17-C24 lay within an existing ES Site (here ESMS-5.4), however similar habitats with biogenic clumps are delineated in other locations (e.g., ESMS-5.2 and 5.3).

In 2016, Brown et al. (20016a) described habitats and communities off Te Weka, Motukina and Tipi Bays – with drop-camera seafloor characterisations presented in Figure 92a-c (top row). The inner sections of these bays were mostly silty sediments with biofilm, with increasing shell debris occurring down the slopes, and dense mounds of shell-debris occurring in depths of 35-45 m. These sites also comprised low-relief substrata and biogenic clumps (particularly around headland areas either end of these bays). Here, biogenic clumps were also comprised of encrusting bryozoans (including *C. agglutinans*) and ascidians, along with various sponges, hydroids, macroalgae and associated invertebrates including polychaetes (Brown et al. (20016a). These findings correlate well with the soft-sediment, shell debris and biogenic rubble zones described here, and reported by others nearby (e.g., Clark and Taylor 2011; Morrisey et al. 2014).

During the surveys at Te Weka Bay, sidescan footage also identified a series of wave-like formations offshore in depths of ~35-45 m (*Figure 3-66 in* Brown et al. 2016a p108), with video-sled observations identifying these as '*biogenic aggregations forming wave-like mounds comprising a matrix of shell rubble*' that supported hydroids, sponges, ascidians, bivalves, macroalgae, tubeworms, and motile invertebrates dominated by snake stars. Brown et al. (2016a) remarked that biogenic habitat had not been widely described within the greater Marlborough Sounds bioregion. Since then, however, the broader scale MBIE-CB17 surveys found biogenic shell-debris fields to be a common habitat in both PS and QCS, particularly down-slope of rocky reefs (T. Anderson *pers. obs.*; NIWA *unpublished data*). The MDC18 survey, along with the CB17 sites within the survey area – as presented in this report – now document the widespread occurrence of shell debris habitats within QCS (see Section: 3.3.3). However, the shell-debris fields within QCS were not observed in the HS51-bathymetry of MBES-derived slope layers. In contrast to this, the wave-like shell-debris fields mapped by Brown et al. (2016a) that were clearly visible in the HS51 bathymetry, and the MBES-derived slope layers (Neil et al. 2018, GIS layers) as linear wave-like features (measuring ~6-8 m from peak to peak, with the slightly elevated waves 10's of cm high measuring ~ 5 m across). These wave-features were seen commonly across the lower slopes, in depths of ~36-50 m, mostly around embayment headlands and channel slopes exposed to the main currents running through TC[63]. To determine if the wave-like formations depicted in the HS51-bathymetry, were like those described by Brown et al. (2016a), we surveyed two deep slope transects (Q170 and Q171) targeting these features, with transect Q170 successfully running perpendicular to the mapped wave-features. Transect Q170 began in 48 m off the western headlands of Hitaua Bay, and immediately traversed up slope (≤14° slope, ≤4.25° slope-variance - see depth and slope profiles for this transect in Figure 97b), over a series of wave-shaped shell-debris mounds (est. 20-40 cm in height comprised of mostly *Gari*, and strawberry cockle-like shells, with some *T. laticostata* shells), that were tightly bound in a

[63] Interestingly the google-earth basemap in the HS51-GIS, shows small waves across the water's surface in TC that measure 6-8 m from peak to peak.

matrix of sediment and shell-hash, interspersed by troughs of what looked like hard sand with coarse shell hash (e.g., Figure 96k,p; Figure 97b). These mounds supported high densities of motile invertebrates – dominated by snake stars and starfish (incl. *C. muricata*, cushion stars, and other starfish species); mostly low % cover of sessile invertebrates (3-15% cover) – dominated by small bushy hydroids, colonial and solitary ascidians; and a few spotties. Parchment worms were also visible within the mound matrix, where they likely help to bind and stabilise the debris-matrix. Sand troughs had notably less epibenthos, bar a few snake stars and cushion stars and the occasional opalfish. Video transect Q171, located West of Maraetai Bay, began in 48 m water depth on the shallower edge of the mapped wave-like formations (≤15^o slope, ≤4.95^o slope-variance - see depth and slope profiles for this transect in Figure 97a). However, the linear waves at this site ran perpendicular to shore – the same direction the video-transect ran – and as a consequence video observations did not cross multiple waves as we did at Site Q170, but rather (based on the GIS map of our video calls) recorded mounded shell debris along a single wave, and as such did not verify debris-waves at this site. The similarly raised thick shell-debris mounds, however, did support a similar community structure to that seen at Site Q170. Both video sites Q170 and Q171 were located close to the Ecological Significant Marine Sites ESMS-5.3 and 5.2, respectively, however, the extensive wave-debris features seen in deeper depths at these sites do not lie within either EE Site. However, some of the wave-debris features visible in the HS51-maps on the northern side of inner TC region do lie within ESMS-5.4A[64]. Davidson et al. (2017a), while running sidescan-sonar alongshore near the western headland to Te Rua Bay, mapped a nice section of these wave-like features describing them as '*unusual ridges and dimpling*' (*see plate 8 in* Davidson et al. 2017a p35). Brown et al. (2016a) also mapped this area as part of their 'Motukina' site using sidescan along with video-sleds, drop cameras and sediment grab sampling, documenting extensive shell-debris mounds offshore in 35-50 m (Figure 92b-top image, yellow arrow indicating 'Motukina' with filled circles depicting substrata types).

Based on the GPS positions of video-calls, these debris-mounds were ~6-8 m apart, pairing with those seen in the HS51-bathymetry. This tight correlation between the HS51-bathymetry and the video-findings presented here, along with those from Brown et al. (2016a), provides a valuable means of extrapolating and delineating these wave-debris habitats across the inner and mid TC. Clark and Taylor (2011) roughly delineated an extensive shell hash habitat in depths of 35-65 m offshore of the proposed Ruaomoko farm site near the QCS-TC junction. Examination of the HS51 bathymetry at this location found a similar series of wave-like formations within their shell-hash zone, further supporting this approach. Wave-formations were also visible in the HS51-bathymetry across large sections of the main channel within inner TC, including across the seafloor where HS51 drop camera sites B2 and B4 were surveyed. Although coarse shell debris was present at both sites, no wave formations were seen. However, the short duration (<1-min) of these camera drops would not be conducive to detecting the 8-10 m wave-features within this region. Therefore, longer video transects would be required within the main channel to verify the presence of debris-waves at these locations.

[64] Video-transect Q170 was terminated early due to excessively strong currents that were dragging the towed-camera away from the vessel.

Table 3-40: Characteristics of rubble and sediment slopes in, at or near TC bays. Sites are sorted by increasing average max. slope. Prox.=proximity 1=inside the channel to the bay, 2= at the entrance to the bay, 3= in close proximity to the bay (either at the headland or on the slopes adjacent to the bay). MBES-slope = slope profile along each transect, MAX[1] = maximum slope representing all or most of the transect (≥90% of transect), while MAX[2] (red text) is the true maximum angle, but this angle only occurred briefly <10% of slope); Slope type = soft-sediment, rubble =rubble and shell-debris; mixed= both sediment and shell-debris co-occurring, zones= soft-sediment zone and shell-debris zones within the transect.

Subregion	Survey	Site	Location	Prox.	MBES-Slope MAX[1] [MAX[2]]	slope type	Taxa types
Inner TC	MDC18	Q170	West of Hitaua Bay	3	<14°	debris	Shell-debris in wave-like features.
Mid TC	MDC18	Q180	Oyster Bay	1	<10° [TP-20°]	debris	Shell-debris with biogenic clumps and Pimple.
Inner TC	HS51	B6	Erie Bay	3	<12°	mixed	Soft sediments with some shells & debris.
Inner TC	HS51	B7	Ngaruru Bay	2	<12°	mixed	Soft sediments with some shells & debris
Mid TC	CB17	C56	Oyster Bay	1	<14°	debris	Shell-debris slope.
Inner TC	MDC18	Q196	Onapua Bay	1	<15°	mixed	Shell debris deep, soft-sediment shallow.
Inner TC	MDC18	Q171	West of Maraetai Bay	3	<15° [32°]	zones	Shell debris deep, soft-sediment shallow.
Inner TC	CB17	C17	Konini Bay	1	<15° [32°]	soft	Silty sediments.
Mid TC	MDC18	Q85	Tio Pt, Te Pangu Bay	2-3	<20°	rubble	Biogenic rubble coarse sand and shells.
Outer TC	MDC18	Q141	Te Rua Bay-nth	2	<20°	zones	Soft-sediment with biofilm; then shell-debris.
Outer TC	CB17	C58	Ngamahau Bay	1	<20° [27°]	zones	sandy-sediment slope with shell-debris mid.
Mid TC	MDC18	Q305	Motukina Bay	3	<22°	mixed	Muddy sand, rubble and shell-debris.
Mid TC	CB17	C24^	Te Pangu Bay	1	<24°	mixed	Muddy sands and rubble.
Mid TC	CB17	C23	Te Rua Bay-sth	3	<26°	rubble	Biogenic clumps, rubble and shell debris.

^ CB17-C24 lies within ESE-5.6.

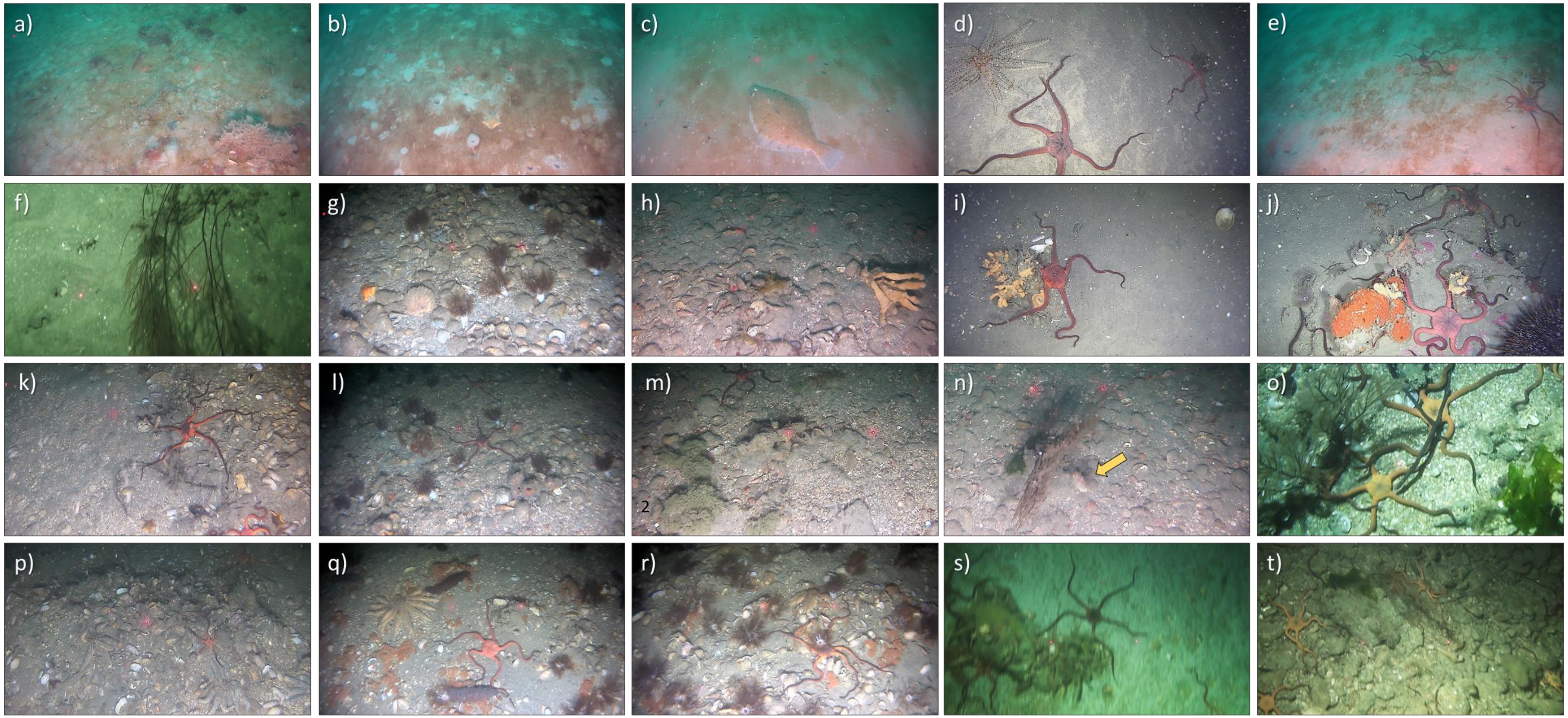


Figure 96: Examples of rubble and sediment slopes near or at the entrances of TC bays. Sites are from MDC18 survey unless otherwise stated. **a-f) Sediment slopes with:** a) hydroids & biofilm, west of Maraetai Bay (Q171); b-c) dense biofilm, inside entrance to Onapua (Q196); d) with snake stars and *C. muricata* at Ngamahau Bay (CB17-C58); e) biofilm and snake stars, northern point of Te Rua Bay (Q141); f) hydroid trees, western slope off Erie Bay (HS51-B6). **f-t) Rubble and shell-debris slopes with:** g,l) with burrowing sea cucumbers (*Thyone* spA), along with cushion stars [g] and snake stars, encrusting bryozoa and sea squirts [l], inside the entrance to Oyster Bay (Q180); h,m,n) hydroids and digitate sponge [h], green soft bryozoa and snake stars [m], hydroid tree with juv leatherjacket (yellow arrow) [n], northern point off Te Rua Bay (Q141); i-j) *Acromegalomma* clumps with snake star [i] and mixed invertebrates [j], Te Pangu Bay (CB17-C24); k,p) waved-like shell debris mounds with snake stars and starfish, west of Hitaua Bay (Q170); o,s,t) hydroid trees and snake stars [o], bluish-white patches of what might be *Bispira* and snake stars [s], hydroid trees and snakestars [t], off Tio Pt, off Te Pangu Bay (Q85); q,r) orange colonial ascidians, burrowing sea cucumbers (*Thyone* spA), and motile invertebrates, west of Maraetai Bay (Q171).

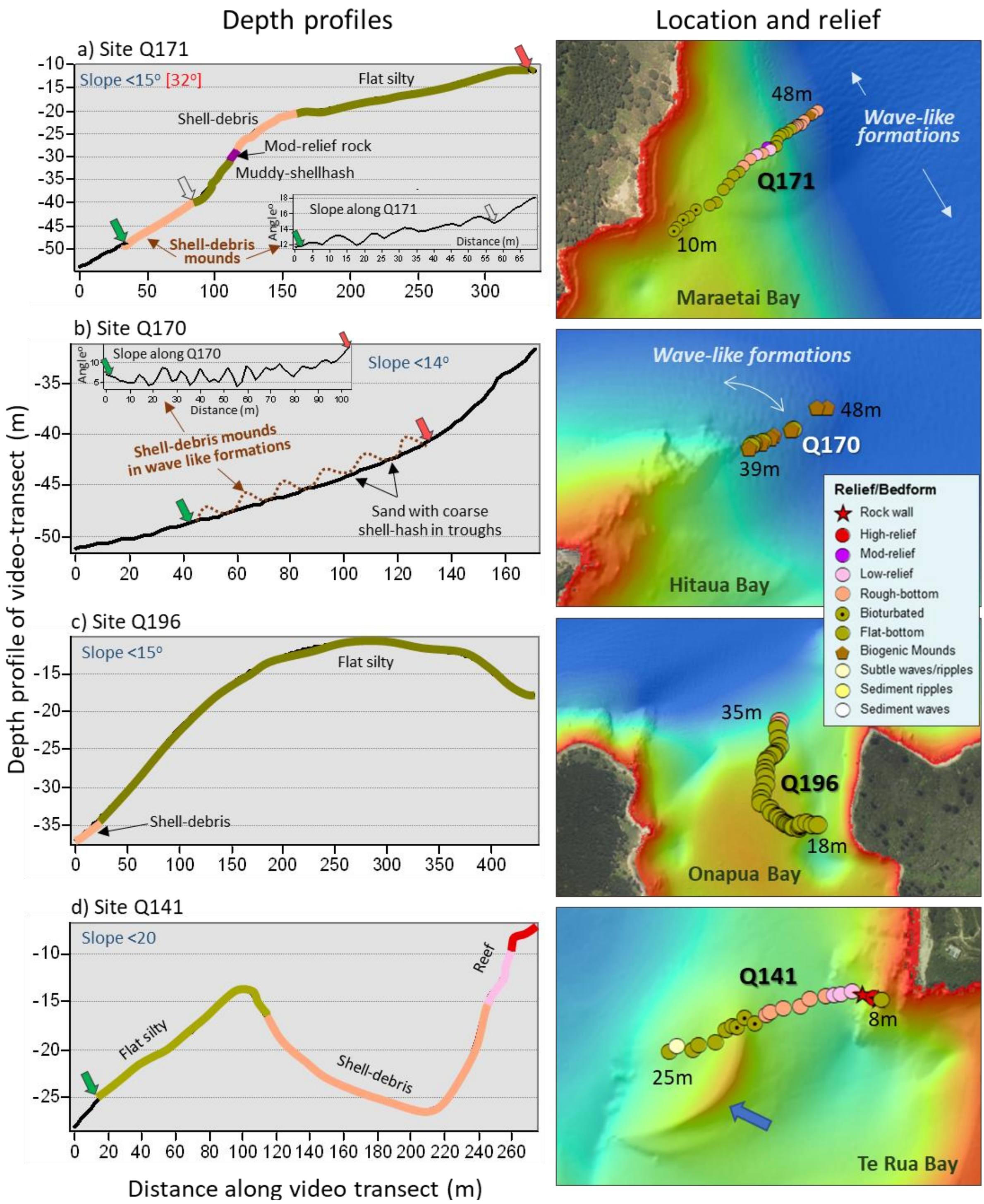


Figure 97: Depth profiles (left) and video-relief classifications (right) along four transect characterising channel slope at the mouth of TC-bays. Depth profiles (left) of transects at the entrance to TC-bays: a) Maraetai, b) Hitaua, c) Onapua and d) Te Rua Bay. Depth profiles are colour-coded by video-relief with descriptions of sequential seafloor habitat zones; green arrows=start of transect, red arrows=end of transects along slope profiles, grey arrow = depicts corresponding location between depth and slope profiles. HS51-bathymetry images (right) depict the location of each video transect and the relief types along each transects; blue arrow (bottom-right) indicates raised sediment bar at the entrance of Te Rua Bay. MBES-derived slope values (MAX^1 and MAX^2)[65] calculated along transects are presented here for MAX^1=blue text; MAX^2 = values are presented in red if >than MAX^1.

[65] MAX^1 = average maximum angle representative of 90% of transect, MAX^2 = absolute maximum slope.

Table 3-41: Characteristic features of Rubble and sediment slopes at or adjacent to TC bays.

TC rubble-slopes	Characteristic features and significant/notable taxa
Sites	Near bays: Erie Bay (HS51-B6, slope <12°), west of Hitaua Bay (Q170, <10°), west of Maraetai Bay (Q171, mostly <15°, but lower slope briefly up to 32°), Tio Pt, off Te Pangu Bay (Q85, <20°), Motukina Bay (Q305, <22°), southern end of Te Rua Bay (CB17-C23, <26°). At or in bay entrance: Lower slope in front of Ngaruru Bay (HS51-B7, slope <12°), inside entrance to Onapua (Q196, <15°), inside the entrance to Oyster Bay (Q180, mostly <10° but Pimple 15-20°), northern point of Te Rua Bay (Q141, <20°), Ngaruru Bay (CB17-C17, mostly <15° but briefly <32°), sediment slopes at Ngamahau Bay (CB17-C58, mostly <20°, but briefly up to 27°), Te Pangu Bay (CB17-C24, <24°), inside slope south side of Oyster Bay (CB17-C56, <14°).
Substrata	Sediment-slopes: Slopes comprised of mostly soft silty sediments (although coarser-grained muddy sands at C55, C58), with varying levels of biofilm; Some shell-debris esp. on lower slopes or in gulley's and channels, with small-medium sized biogenic clumps at some sites. Upper slopes and sediment sills at the mouth of bays characterised by fine-silty sediments. Rubble slopes: Sediment slopes with sandy-muds to coarse shell-hash, varying amounts of shell-debris (5-80% cover), low-relief rubble (0-50%) and rock (<5%) outcrops and biogenic clumps (0-10%), moderate biofilm covering some rubble sites (e.g., Q305).
Benthic community	Sediment-slopes and sills: burrows, biofilm (low-dense), *Acromegalomma* patches on sills only (occasional, e.g., Q196, C17, C24 x1), green algae (*Ulva* spp., occasional <2%, e.g., Q141, but abundant at C58), red-bladed algae (<15%, C58), Horse mussel (rare, Q171, Q180, C58, C23), orange encrusting ascidian (on *Acromegalomma* C24). Rubble slopes: small fern-shaped hydroids (common, Q180, C23), small-medium sized fan hydroids (frequent-common at some sites e.g., Q85), hydroid trees (occasional at Q141, notably large at B6), green soft bryozoan (rare-common at Q180, Q141), encrusting orange sponge (occasional-frequent, Q180), solitary sea squirts (*M. squamiger*, few <2%, e.g., Q141, C24), green algae (*Ulva* spp. 0-25%, e.g., B7, Q196, C55), red algae (indet. 0-15% cover, e.g., B6, Q305), mixed red bladed algae (common Q305, C55), *U. pinnatifida* (rare, Q171, but common at Q305), Rock anemones (rare, Q171, C23), Parchment worms (occasional, Q170, Q196), mod-large *Epiactis* anemone (Q180 x1); encrusting coralline algae (0-15%, Q305, C23, C55), orange-hair hydroid (<3% e.g., Q171, Q180, Q305, C23), yellow spikey sponge (*D. oxeata*, rare, e.g., Q305), solitary sabellid fanworms (occasional, Q141, C23, C24). **Biogenic clumps** (occasional-frequent <15%, e.g., Q171, Q196, Q180, Q141, C23, notable amounts at C23), beer bottle (e.g., Q180)), with encrusting bryozoans (*C.* agglutinans, occasional, Q171, Q180), colonial ascidians (e.g., *C. dellechiajei*, 0-20%, e.g., Q305, C23), solitary sea squirts (*M. squamiger*, few B7), *Crella incrustans* (<1%, Q196, C24), digitate sponge (*Callyspongia* spp., occasional/<2%, Q171, Q196, Q180, Q141), cream chimney sponge (poss. *Chondropsis topsenti*, <2% C58, but notable ones ~6% cover at C23), straw-weed tubeworms (*Spiochaetopterus* spp., only at Q171), orange-hair hydroid (inner-mid TC only, e.g., Q171, Q180), epiphytic bivalves, (*Talochlamys,* few, Q180).

TC rubble-slopes	Characteristic features and significant/notable taxa
Motile invertebrates	**The Pimple:** *Bispira bispira* spA (dense patches, Oyster Bay Q180, poss. Q85[66]), burrowing sea cucumbers (*Thyone* Sp A, sparse-dominant e.g., Q171, Q180). Sediment-slopes: Snake stars (common e.g., Q141, abundant at C58), cushion stars (*Mediaster/P. regularis* spp., few-common e.g., B7, Q180, C17), *C. muricata* (occasional, e.g., B7), *A. mollis (*occasional, B7), *S. mollis (*rare), scallops (few C58), *C. muricata* (C58). Rubble slopes: Snake stars (common, but abundant at Q85, C24), cushion star (*Mediaster/P. regularis* spp., few, e.g., Q180; *P. pulchellus*, rare, Q85, Q180, C23), *C. muricata* (occasional-few e.g., Q305, C55, but abundant at Q170, Q171), *S. mollis (*occasional Q141, Q196, few at Q85), *A. mollis (*occasional, Q180, Q305), gastropods (*Maoricolpus roseus*, few e.g., B6, lost at Q85), *A. insignis* (occasional, Q171), *A. mollis (*occasional, B7, Q171), kina (few, Q171, Q196, Q305, some dense clusters at C23). hermit crabs (Q171, Q141), scallops (occasional, Q171, C23), screwshells (*M. roseus*, occasional-common, Q171, Q141), wandering anemone (rare, Q170), *Octopus maorum* (rare, Q196), sawshell gastropod (rare, Q180, Q305).
Fish	Sediment-slopes: Spotties (occasional, Q196), sand flounder (Q196 x1), lemon sole (Q180 x2,), flatfish (indet., few, e.g., Q141, C17), NZ sole (*P. nova*, Q171 x1), red gurnard (C17 x1), juv. blue cod (on shell-debris, Q141 x1), spiny dogfish (C58). Rubble slopes: blue cod (occasional-frequent, e.g., Q180, Q305, Q141, C23), juv. blue cod (C23), school of juv. Tarakihi (C23, C57), Sea perch (occasional, Q171), spotties (occasional, Q170, Q171, Q141), juv. leatherjacket (Q141 x1[67]), opalfish (rare, Q170), Scarlett wrasse (rare-few associated with biogenic clumps, Q180).
Debris	Shell debris incl. sunset shells (*Gari lineolata* Q171, Q170), *Tucetona* shell debris (Q85, Q180, Q141), Scallop shells (Q141), *Panopea* shells (Q85); small cockle-like shells (Q141); green-lipped mussel shells (few-lots, only at C55), *Dosina*-like shell (C24), rubbish: beer bottle (e.g., Q180) fishing line (C58).

3.4.7 Central channel – cobble bottom

The seafloor within the central channel has been documented as having high to very high reflectivity – indicative of a hard seafloor, with channel sediments comprised of cobbles, gravels, shells and coarse sands (Neil et al. 2018a p41). The series of HS51 drop cameras, along with the few MDC18 tow-video sites, identified that the seafloor in the main channel was relatively flat with varying combinations of cobbles, shell-debris, pebbles and gravels (Table 3-42; Figure 98).

From the footage available it appears that there is a gradient in seafloor composition from inner to outer TC, with more shell-debris and gravels dominated sediments within inner TC sites (e.g., Figure 98a-c) to higher amounts of larger and more heavily fouled cobbles at outer TC sites (e.g., Figure 98g-i). *Tucetona* shell debris was also present at some sites (e.g., HS51 Sites B10 and B12, MDC18-Q300), particularly central channel sites near the living *Tucetona* bed recorded offshore of Ngamahau Bay (MDC18-Q186; see section 3.4.9). There was also some variability in substratum types within a site. For example, video footage of the seafloor around the TC-wreck (MDC18-Q300) documented extensive cobble fields (with some gravels and little shell debris) to the west of the wreck, while sediments accumulating against the wreck on the eastern side were coarse sands dominated by *Tucetona*-shell debris. The biological communities within the central channel were characterised by low % cover (<20%) of encrusting and small sessile filter feeders (<few cm’s high),

[66] Series of large blue-white patches, that look very much like *Bispira*, but Coastcam imagery not good enough here to verify.
[67] Juvenile leatherjacket ~5 cm in size hiding in amongst one large but solitary hydroid tree.

such as small hydroids, a few fanworms, encrusting sponges Table 3-42; Figure 98. Motile species were characterised by low to moderate densities of snake stars and occasional starfishes (Table 3-42; Figure 98). Biota on the channel floor also varied with proximity to the TC-entrance, although this was not as marked as other habitat zones. Here % cover of encrusting species such as sponges increased from <5% at inner TC sites up to 5-15% in outer TC sites. Deep coralline algae were only recorded on cobbles east of Oyster Bay, with more patches seen at outer TC sites. These patterns indicate a more scoured seafloor, exposing more stable substrata nearer the TC-entrance, while inner TC is less scoured with thin deposits of shells and gravelly sediments.

Table 3-42: Characteristic features of the seafloor across the central channel, TC.

TTC: Central channel	Characteristic features and significant/notable taxa
Substrata	Low-relief coarse substrata, characterised by cobbles, pebbles, shell debris, gravels and coarse sand, with inner TC comprised of more shell-debris, a mixture of cobbles and shell-debris and mid TC sites, while outer TC comprised mostly cobbles and some low-lying rock (e.g., bottom of CB17-C20). *Tucetona* shell debris was also present at some sites (e.g., HS51-B10, HS51-B12, MDC18-Q300).
Benthic community	Characterised by low cover of small filter feeders (<20% cover of short vertical height species), dominated by small hydroids. Other species seen incl. Sabellid fanworms (few-common), encrusting sponges (<1% cover), colonial ascidians (<1%), horse mussel (<1%, HS51-B4 only), digitate sponge (*Callyspongia* spp, <5%, e.g.,HS51-B4), deep coralline algae (<3%, e.g., HS51-B8, B9), *Talychlamys* sp. (HS51-B9 only-common), solitary anemone[68] (large purplish, x1, HS51-B10), erect sponge unident. (HS51-B12), Goose barnacles (6 small clusters on cobble-rock channel bottom at CB17-C20 only).
Motile invertebrates	Snake star (common-lots), cushion star (*Mediaster/P. regularis* spp., few), *A. insignis* (occasional-few), Apricot sea star (rare), sea star (*A. scabra*, occasional, e.g., C20); *C. muricata* (occasional), *A. mollis (*occasional), sawshells (occasional), wandering anemone (*P. tuberculosa,* HS51-B9 x1, CB17-C20 x1).
Fish	Blue cod (subadult and juvenile sizes), sea perch (occasional, C20).

[68] Large anemone on cobbles, with purplish centre white tentacles.

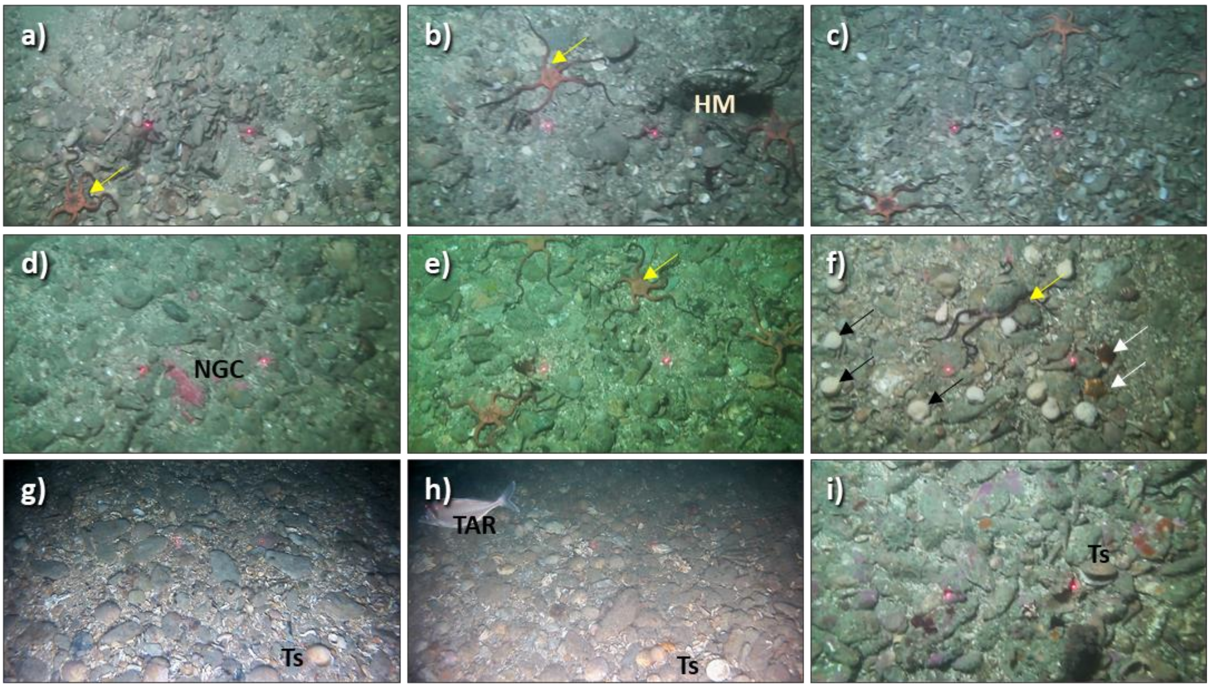


Figure 98: Representative images of the seafloor within the main central channel, TC. a-c) Inner TC sites with seafloor of shells, gravel, pebbles and cobbles (HS51-B2 [a], HS51-B4 [b,c]; d-f) Mid TC sites with cobbles, gravels, and shell debris (HS51-B8 [d,e] and HS51-B9 [f]; g-i) Outer TC sites dominated by cobbles with gravels and shells (MDC18-Q300 TC-wreck [g-h] and HS51-B12]. HM= Horse mussel; TAR=Tarakihi (near TC-wreck); Ts= *Tucetona* shell-debris; Yellow arrow = examples of snake star; black arrows = epiphytic bivalves (*Talochlamys zelandiae*); white arrows = cushion star (*P. regularis*).

3.4.8 Drift-algal mats within shallow TC bays

Background: Tory Channel consists of eight large bays, as well as several smaller bay, each of which is considerably shallower than the main channel (Neil et al. 2018a). Four of the bays (Onepua, Hitaua, Maraetai and Ngaruru Bays) are in depths <20 m, while the other bays (e.g., Deep, Oyster, Erie, Okukari Bay, Te Rua and Kawhia Bays) are all in depths <10 m. A shallow (1-3 m) sediment bar lies at the mouth of three of these bay (Deep, Erie, and Kawhia Bays[69]). Sediment samples collected from three large TC-bays during the HS51 mapping surveys (Neil et al. 2018a,b) found sandy muds, with high amounts of silt (83.4% in Maraetai [B1], Hitaua [61.5%], Onepua Bays [78%]), with drop cameras at these sites showing flat, generally featureless, bioturbated seafloor (Neil et al. 2018a). Previous studies have, however, indicated that high volumes of drift macroalgae can accumulate over soft substratum in these shallow bays. Davidson et al. (2017a) described two sites within the larger Ngaruru Bay (on the northern side of inner TC), estimating drift macroalgae to cover approx. 41.9 ha at these sites (combined). Davidson et al. (2017a) recommended that these sites be considered as Ecological Significant Marine Sites, but indicated that additional survey work was required to determine if these ephemeral beds were a permanent/frequently replenished feature of these sites.

Ground-truthing surveys: In 2017, during the BT17 surveys, seven beam trawls were undertaken within six of the TC bays: Maraetai (BT17-QC35A,B), Hitaua (BT17-QC36), Onepua (BT17-QC37), Oyster (BT17-Q39x) and Okukari Bays (BT17-QC70). To compliment the beam trawl catches and

[69] Kawhia Bay is the eastern bay that adjoins Ngaruru Bay, but the larger embayment area is also commonly referred to as Ngaruru Bay.

natural light video, an addition eight tow-video transects (7x CB17 and 1x MDC18 surveys) within TC bays were surveyed using NIWA's CBedcam.

Outer bay sites: Sites surveyed near the mouth of these bays were characterised by silty bioturbated sediments, with moderate to high biofilm (e.g., Maraetai Bay-Q35A and B; Hitaua-QC36), and few-frequent occurrences of small to medium sized patches of *Acromegalomma* tubeworm beds (e.g., Erie, Oyster and Okukari Bays: Table 3-45; Table 3-43; details presented in Section 3.2.5 - *Acromegalomma*). Beam trawls in these areas collected a mixture of tubeworm species dominated by *A. suspiciens*, with the straw-weed Spiochaetopterids, along with a range of habitat-associated taxa, incl. solitary ascidians (*M. squamiger* and *Cnemidocarpa bicornuta*), colonial ascidians (incl. *C. dellechiajei*, *Leptoclinides novaezelandiae*, *Diplosoma listerianum*) and various sponges, crabs and other taxa (see Section 3.2.5 for full description), as well as mudworms (*Asychis* sp. - poss. *Asychis trifilosus*) (see Table 3-43 and Table 3-44).

Inner bay sites: Beam trawls and video-transects undertaken further inside these bays (<10 m) identified silty mud (e.g., most bays) or sandy (only Okukari Bay) sediments, with dense patches of drift algae (Table 3-45; Table 3-43; e.g., Figure 99a-b,d,g-i). Within Erie, Oyster and Okukari Bays, these drift macroalgal areas (or 'mats') were very dense (80-100% cover) and thick (at least ¼-½ m high) and were spatially extensive, spanning most if not all of the transects at these sites (i.e., at least 96-250 m in length[70]) based on video footage (e.g., Erie, Oyster and Okukari Bays), while extremely large volumes of drift-algae were collected in the beam trawls from these three inner bays (200-300 L) (see Table 3-44 for full species list and volumes collected). At one failed beam-trawl site within Oyster Bay the volume of drift algae, dominated by *Ulva*, was so massive that the weight caused by the drag on the net broke the 3-m wide galvanized bar - that keeps the bar open - in half (see Table 3-44).

Beam trawls in these inner bays collected a total of at least 30 macroalgae species/taxa, with 26 of these taxa collected from a single trawl site in Okukari Bay (BT17-QC70) outer-TC (see Table 3-43 and Table 3-44 for full list and volumes). Drift algae at these sites were composed of a wide range of green, red and brown macroalgal species, dominated by the green algae *Ulva* spp. (sea lettuce, e.g., Figure 99b,d) and the red filamentous alga, *Anotrichium crinitum*, along with lower volumes of red bladed macroalgae (incl. *Haraldiophyllum crispatum* and *Schizoseris spp.*), kelps (e.g., *Macrocystis* and *U. pinnatifida*) and green macroalgae (*C. brownii*, Figure 99c) (see Table 3-43 and Table 3-44 for full list and volumes). While many of these species occur commonly throughout TC, the occurrence of some species only found at the entrance of TC and Cook Strait, such as *Caulerpa*, and the red-bladed algae, *Laingia hookeri*, identifies that accumulation of drift algae likely comes from algae transported from outer TC and Cook Strait, and indicates that TC may act as a conveyor belt that regularly delivers large amounts of detached/drift algae to these bays (Figure 100) – as predicted by Davidson et al. (2017), that then accumulates within several of these large shallow bays, not just Ngaruru Bay. The high-volume delivery of drift algae through TC is likely to be a significant driver of community structure within TC and its bays, both indirectly for infauna living within the sediments beneath and adjacent to the drift algal mats, through the breakdown of nutrients and detrital material within these bays, but also as a direct food source, for motile grazers such as kina. Transport of drift algae along the main channel is likely to be an important food-source (and explanatory variable) for the often extremely high densities of kina over much deeper depth than can be explained by growing kelp/macroalgae. Trophic food web studies along TC that also include

[70] Max. length to end of the transect/tow.

outer and inner sections of these bays, would help determine the relative roles and importance of drift algae in maintaining this local ecosystem.

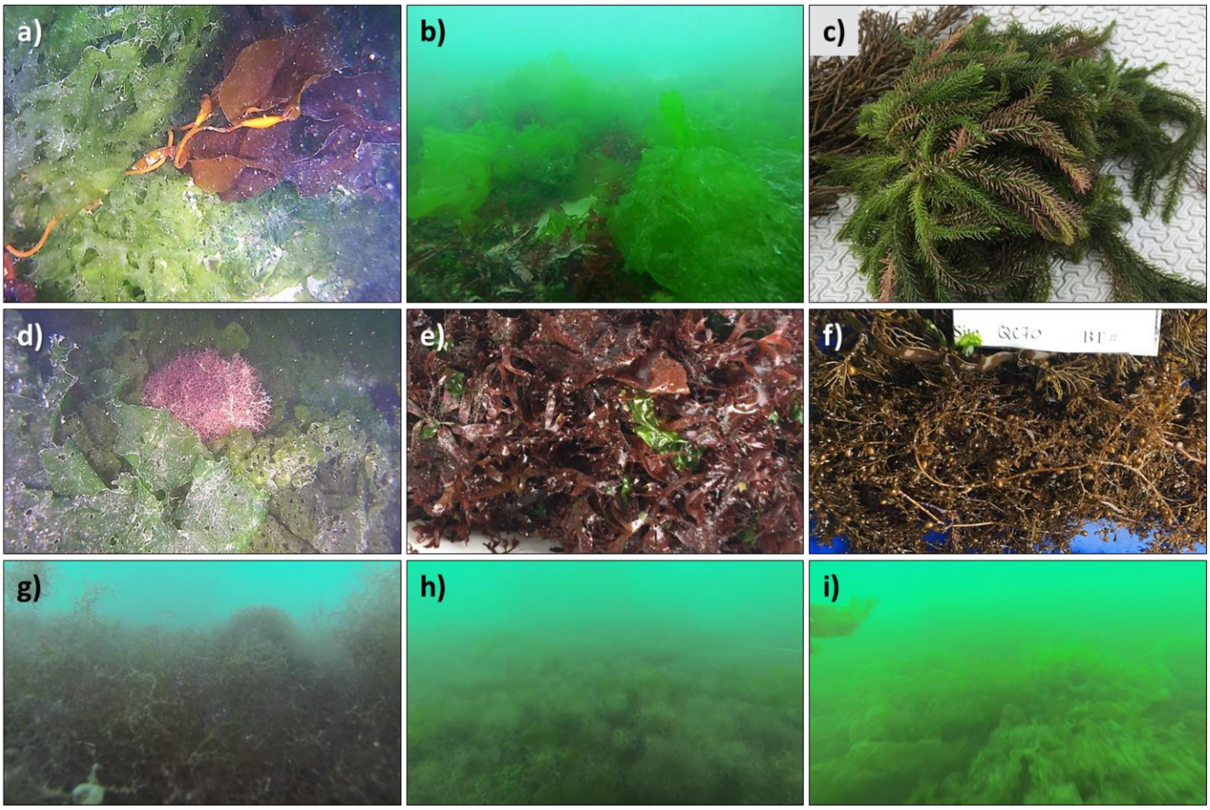


Figure 99: Examples of extensive and thick algal mats from sheltered bays along Tory Channel. a,d) Dense algal mat on soft sediment in Ngaruru Bay, Mid-TC (nth side) (CB17-C54); b) Extensive and dense algal mat in 4-9 m on fine sand, dominated by *Ulva* spp. within Okukari Bay, near the entrance to TC (GoPro footage, Site BT17-QC70); c,e,f) Examples of algal specimens collected at BT17-QC70, including *Caulerpa* [c], mixed reds [e], and *Carphophyllum* [f]; g-h) Dense algal mat with mixtures of red algae and *Ulva* in 4 m depth within Erie Bay, Mid-TC (GoPro footage, BT17-QC38); i) Dense algal mat in Oyster Bay Mid-TC, dominated by *Ulva* (, Site BT17-QC39x, from GoPro footage, Bar-broke no catch retained).

Table 3-43: Description of drift algae collected during the MBIE BT17 beam trawl survey or observed/recorded during the CB17 and MDC18 surveys, within Tory Channel (TC). *=length of transect, algal mat may extend much further beyond start and/or finish of transect/tow.

Site	TC embayment	Description of seafloor (video) and catch (BT17 beam trawl)
QC35A	Maraetai Bay Inner-TC, 13 m	Video: Muddy sand with dense biofilm, small patches of *Acromegalomma suspiciens* tubeworms. Catch: <1 L of drift-algae collected. 12 small fish, along with abundant cushion starfish (*P. regularis*).
QC35B	Maraetai Bay Inner-TC, 16.4 m	Video: Muddy sand with dense biofilm, small patches of *Acromegalomma* tubeworms. Catch: No algae collected. 25 fish, 1.5 L of *Acromegalomma* [with assoc. straw-weed tubeworms (0.5L) and colonial ascidians], mudworms (≥1 L), hermit crabs (lots), cushion starfish (*P. regularis,* ~70 indiv./4 L).
QC36	Hitaua Bay Inner-TC, 13-15 m	Video: Muddy sand with sparse biofilm, sparse drift algae (<1-20% cover), few patches of tubeworms. Catch: 10 L of drift algae mostly *Haraldiophyllum* (5 L) and *Ulva* (3 L). *U. pinnatifida*[71] (1 L). Also 145 small fish, incl. spotties (lots), opalfish, triplefins, witch, speckled sole, tarakihi (x2: 18-20 cm); along with and abundance of *Theora* bivalves and hermit crabs; 1.5 L of *Acromegalomma* [with associated colonial ascidians and sponges].
QC37	Onepua Bay Inner QCS, 14.5 m	Video: zero visibility. Catch: <1 L of drift-algae collected, but 60 L of *Acromegalomma* tubeworms and 2 L of mudworms; along with 206 fish, incl. tarakihi (x2: 11-13 cm), witch, speckled sole, triplefins, spotties (lots); along with abundance of small bivalves (esp. *Theora* and strawberry cockles) and *Halicarcinus* crabs.
QC38	Erie Bay, Mid-TC, 4 m	Video: Muddy sand with 100% cover of dense drift algae. Catch: est ≥200 L - Net full (overfull) of drift algae. Net upended as too heavy, but still had **≥100 L** of drift algae. Algal subsamples kept for DNA and pressed Cat. No. MS212-216 (Roberta D'Archino, NIWA). Drift was dominated by 50 L of *Ulva*, 40 L of the red algae, *Anotrichium crinitum.* Also 46 small fish, incl. triplefins (lots), clingfish (few, sp4=poss. *D. puniceus*). ***Drift-algal mat= ≥˜96 m long*.***
QC39x	Oyster Bay, Mid-TC, 10-7 m,	Video: Muddy sand with low biofilm, burrows and 80% cover of dense drift algae (mostly *Ulva*). Catch: est >300 L - The entire net was completely full and over-flowing with drift algae, *Ulva* covering the bridle ropes and spreader bar. The weight/drag from the drift algae in the net was so great it snapped the spreader bar. Contents were discarded. ***Drift-algal mat= ≥˜240 m long*.***
QC70	Okukari Bay, Outer-TC, 4-9 m	Video: White sand, 100% cover of dense drift algae (mostly *Ulva*). Catch: 242 L - Massive haul of drift algae. Algal subsamples kept for DNA and pressed Cat. No. MS194-207 (Roberta D'Archino, NIWA). A total of 26 algal species, dominated by *Ulva* (100 L) and reds (40 L), with *Crassiphycus proliferus* (10 L), *Adamsiella chauvinii* (10 L), *S. montagneana* (10 L), *M. pyrifera* (9 L), *C. brownii* (7 L), *U. pinnatifida* (500 ml) also collected & disposed of. Also 222 fish, incl. triplefins (heaps, mixed species), juv. leatherjackets (lots), spotties (few), clinids (few), clingfish (sp4-few), opalfish (few), other fish (incl a sea horse and a red gurnard); plus kina (lots, 1.9-12 cm), nudibranchs (16 x *Aplysia,* & spaghetti-like egg-strings attached to the drift algae)). ***Drift-algal mat= ≥˜238 m long*.***

[71] Retained for disposal on land following MPI guidelines.

Table 3-44: Drift macroalgae taxa collected in BT17 Beam trawl sites (per 100 m-^{2}) within TC bays. Beam Trawl sites sampled trawlable-soft-sediment bottoms within the large bays off TC. Values = volume of macroalgae collected, standardised by area-trawled and presented as volumes in ml per/100 m. Bold values depict sites and taxa >100 ml.

		Inner TC				Mid-TC	Outer-TC
Groups	**Macroalgal Species**	**Maraetai**		**Hitaua**	**Onepua**	**Erie**	**Okukari**
		QC35A	**QC35B**	**QC36**	**QC37**	**QC38**	**QC70**
Reds	***Adamsiella chauvinii***						**2,796**
	Agarophyton chilense					**277**	14
	Anotrichium crinitum					**27,659**	
	Aphanocladia delicatula						3
	Ceramium spp.						14
	Crassiphycus proliferus						**2,796**
	Crustose Coralline Algae (CCA)						28
	Galene spp.						6
	Gigartina atropurpurea						**839**
	Gigartina spp.						3
	Haraldiophyllum crispatum	**105**		**948**	42	10	
	Hymenena spp.					10	14
	L. hookeri					10	
	Pterocladia spp.						3
	Rhodophyllis spp.						42
	***Rhodymenia* spp.**	7.9		**190**	3.4		
	S. montagneana						**2,796**
	Sarcothalia livida						**280**
	Schizoseris spp.			<1		10	6
Greens	***C. brownii***						**1,957**
	Caulerpa spp.					8	
	***Ulva* spp.**			**569**	3.4	**34,573**	**27,963**
Browns	***C. flexuosum***						**140**
	Colpomenia spp.					14	6
	Cystophora						**1,957**
	Halopteris spp.						3
	M. pyrifera						**2,517**
	Sargassum sinclarii						**839**
	U. pinnatifida	53		**190**			**140**
	Zonaria spp.						8
Macroalgal Groups (combined)		**QC35A**	**QC35B**	**QC36**	**QC37**	**QC38**	**QC70**
Green macroalgae				569	3	34,582	29,920
Red macroalgae		113		1,138	45	27,977	9,636
Brown macroalgae		53		190		14	5,609

Table 3-45: Characteristic features of Drift algal mats in TC bays.

Cook Strait Deep Reefs	Characteristic features and significant/notable taxa
Substrata	Soft-sediment silty muds (almost all sites), but sandy (Okukari Bay).
Benthic community	Patchy to very extensive areas of accumulated drift macroalgae in inner sheltered bays (particularly in Erie, Oyster, and Okukari Bas). Drift-algae dominated by various mixtures of *Ulva* spp. and the red filamentous alga, *Anotrichium crinitum*, along with strappy/bladed reds and smaller proportions of kelps and *Caulerpa*.
Motile invertebrates	*A. mollis,* snake stars, starfish (*P. regularis* and *C. muricata*), kina (clusters on drift weed, but also solitary on bare mud), scallops (few, 12-100 mm).
Fish	Spotties (lots), high densities of triplefins (e.g., *F. varium*, mixed spp), juvenile leatherjackets (*M. Scaber*, common-lots at BT17-QC70), sea horse (*Hippocampus abdominalis*, BT17-QC70), clinids (weedfish, QC70 incl. *Ericentrus rubrus, Notoclinus compressus*) and clingfish (sp4 - poss. *Diplocrepis puniceus*), Graham's gudgeon (*Grahamichthys radiata,* BT17-QC37), Dwarf Scorpionfish (*Scorpaena papillosa*, QC70).

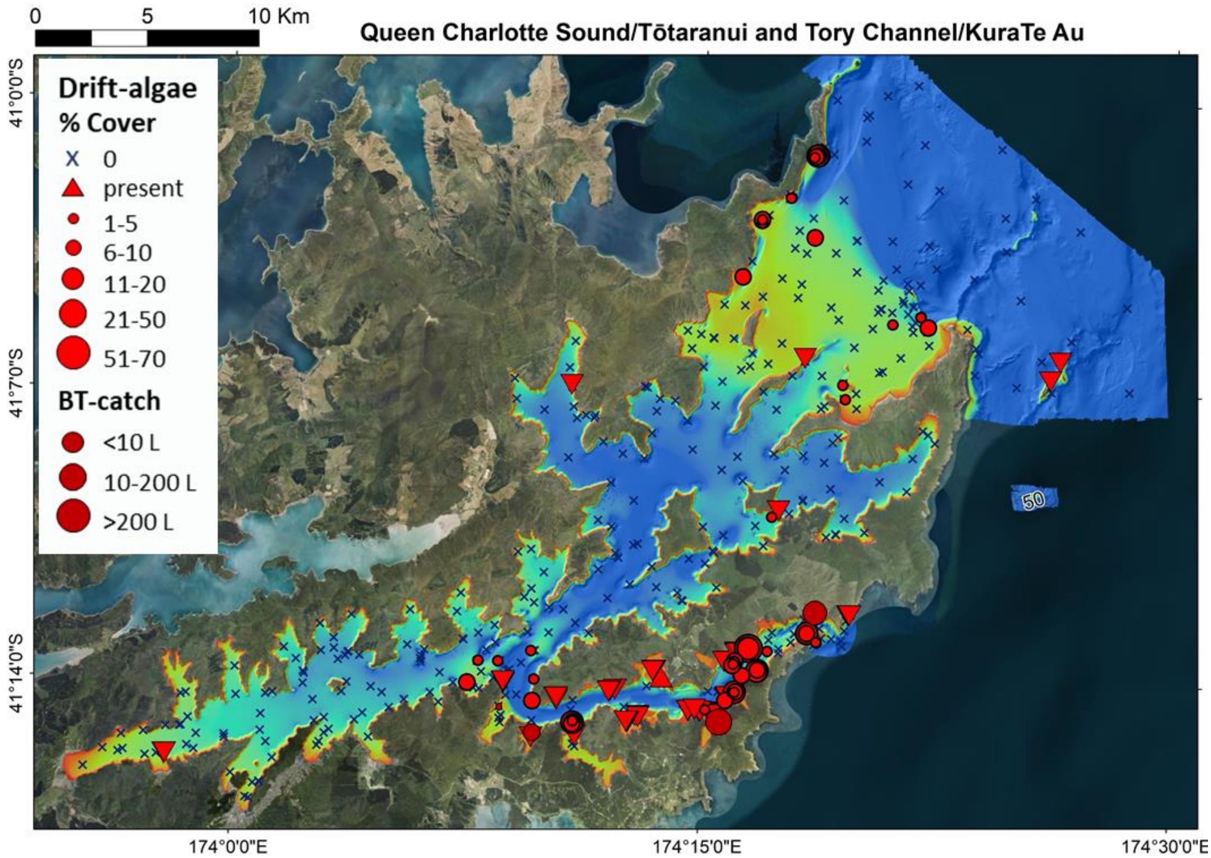


Figure 100: Distribution and rank percent cover of drift algae within QCS, TC and Cook Strait Red bubbles = % rank cover estimates from the MDC18 survey; Burgundy bubbles = volume (L) of drift algae collected in BT17 beam trawls (>1 L collected); triangles = presence for the CB17 survey (inverted triangles) and HS51 surveys (upright triangles).

3.4.9 Sediment bank - live *Tucetona* bed, off Ngamahau Bay

During the HS51 multibeam survey, a large sediment bank was mapped approx. 330 m off the southern end of Ngamahau Bay, in mid-TC (Figure 101a-b). The Bank starts in ~50 m water depth in TC rising to ~32 m on the top of the bank, then dropping bank down to 35-37 m on the shoreward side of the bank. The top of this feature is long and narrow (~245 m x 54 m wide), and had 7-8 raised crescent-shaped features each ~20-30 m apart, with the peak of each crescent rising 0.5 to 2 m above the surrounding seafloor (Figure 101a; Figure 103a). These raised crescents initially appeared to be wave-like features, but derived multibeam layers also depicted these raised crescents as having high rugosity (Figure 101b). To ground-truth this unusual feature, a single video transect (MDC18-Q186) was surveyed running up the northern-side of the bank and along the top of the bank intersecting as many of the raised crescent-shaped features as possible (Figure 101c-d).

Table 3-46: Characteristic features of the raised-feature off Ngamahau Bay, TC (MDC18-Q186).

TC Sediment Bank with *Tucetona* beds	Characteristic features and significant/notable taxa
Substrata	Raised sediment bank, with raised crescent-shaped sand waves on the top of the bank. Bank sediments appear (from video) to be coarse well sorted sands on the peaks, and large shell-debris and rubble in the troughs.
Benthic community	<u>Sand waves:</u> Live *Tucetona* beds in the sediments on the top and upper slopes of the bank (moderate-dense bed); burrowing sea cucumber (*Thyone* spA, few); drift-*Macrocystis*[72]. <u>Troughs</u>: Sabellid fanworms (lots); drift-*Macrocystis* (few pieces); attached algae (<5% total cover, incl. red bladed and red branching algae, *Ulva*), epiphytic bivalves (*Talochlmays*, x1), blue mussel (x1); red fan sponge (*Crella incrustans* <1% Figure 102i); green soft bryozoa (<1%).
Motile invertebrates	<u>Sand waves:</u> Snake stars (few-common). <u>Troughs:</u> High densities of *Snake stars* seen on the slopes and sand wave troughs on the banks; cushion star (*P. regularis,* few), hermit crabs (few), 6-armed starfish (x1), *C. muricata* (few), scallop (few), gastropods (few).
Fish	<u>Troughs:</u> Opalfish (*H. monopterygius*, x1); subadult blue cod.
Shell-debris (Troughs)	*T. laticostata,* scallops, blue mussels, green-lipped mussel, mixed of small-valved bivalves.

The top of the bank was characterised by sand waves with peaks composed of well sorted coarse sands, with troughs full of shell-debris and coarse rubble (Table 3-46; Figure 102), with the often dense shell debris likely the cause of the high rugosity values in Figure 101b. The top of the Bank supported an extensive live *Tucetona* bed in depths of 36.3-42.8 m (Figure 101d), with moderate densities of *T. laticostata* found mostly within the well sorted sand peaks, along with low abundances of snake stars and the occasional burrowing sea cucumber (*Thyone* spA) (Table 3-46; e.g., Figure 102a-d; Figure 101d). Conversely, the shell-debris filled troughs between these large sand wave features, supported an abundance of snake stars and Sabellid fanworms along with an assortment of other motile and sessile species (Table 3-46; e.g., Figure 102f-i).

[72] Towed Coastcam got caught up in a large drift-*Macrocystis* plant, but got untangled shortly after and continued with transect.

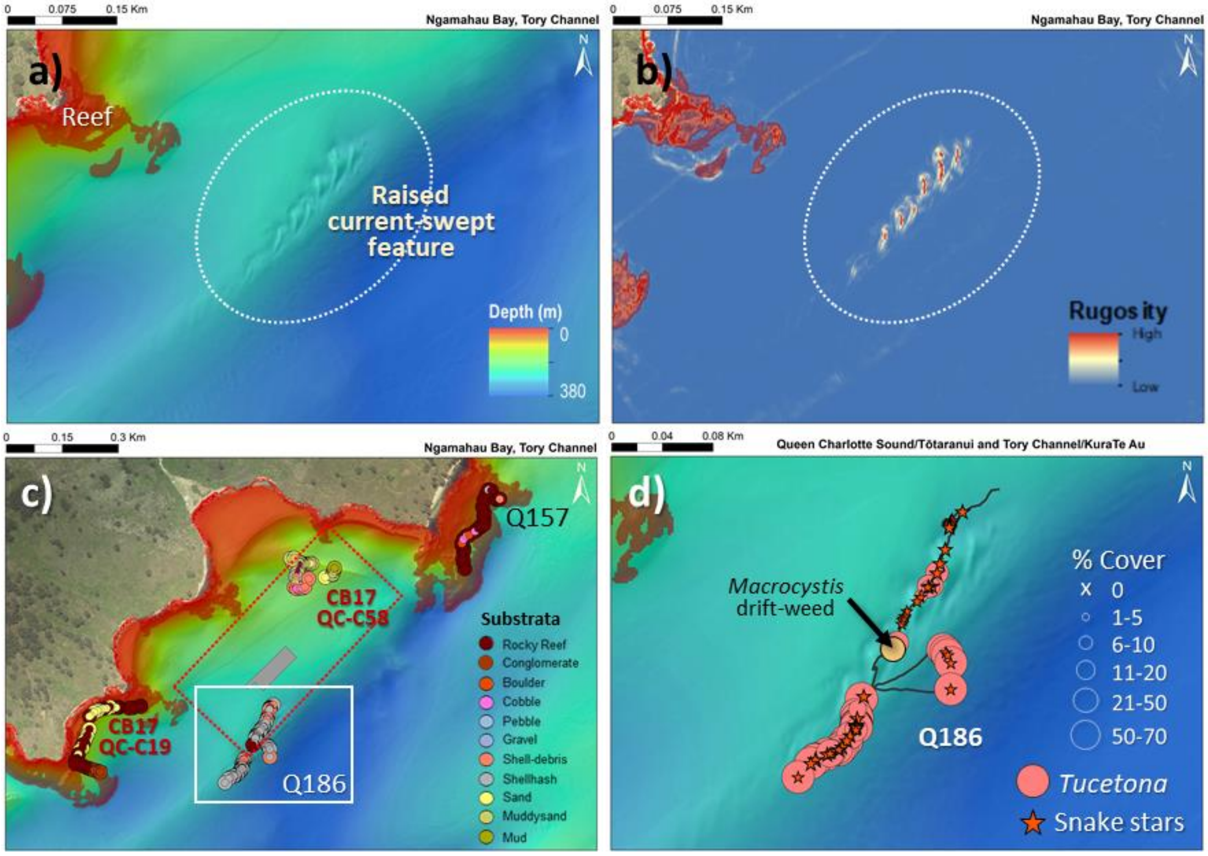


Figure 101: Sediment Bank - raised current-swept feature 330 m offshore from Ngamahau Bay, TC. a) HS51 bathymetry (2m-horizontal resolution) showing 7-8 raised crescent-shaped features that peak at an altitude of 0.5-1.5 m every 20-60 m; b) MBES-derived rugosity showing high rugosity across the peaks of the bank; c) Location of video-transects run within Ngamahau Bay (CB17 sites C58 and C19, and MDC sites Q157 and Q186), with substratum types for primary (larger circles) and secondary (smaller inner circles) substratum categories plotted along each transect. White box = zoomed up area shown in graph-d; Red-dotted lines = boundary of the NZ King Salmon Ngamahau farm; grey-filled box [c] depicts the location of the farm-cages[73]; d) %cover of live *T. laticostata* along the top of the bank (Transect MDC18-186); red stars = snake star occurrence.

[73] Farm cage polygon based on ESRI's Spot imagery, 2019.

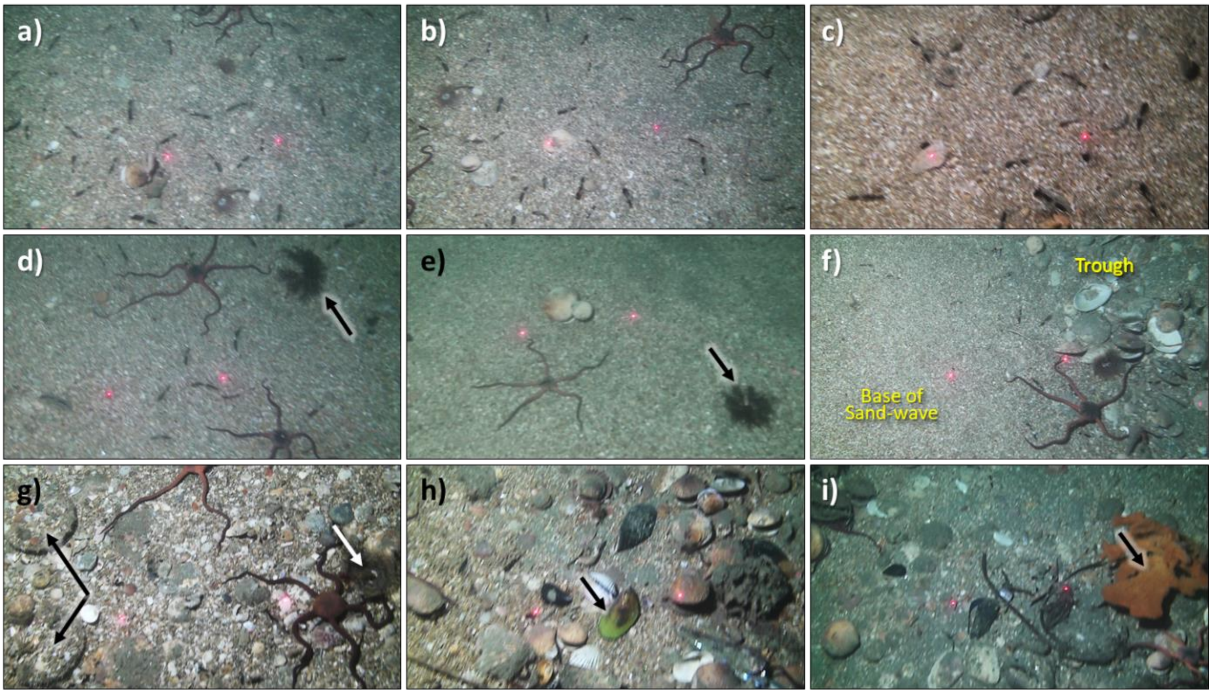


Figure 102: Representative images from the top of the sediment bank with live *Tucetona bed*, offshore of Ngamahau Bay, TC. a-d) Dense *T. laticostata* (double-dashed marks on the sediment) in the coarse sand-wave sediments, with snake stars and a few burrowing sea cucumbers (arrows in d-e); e) small patch of coarse sediment devoid of *T. laticostata*; f) interface been sand peak and trough; g-i) troughs filled with shell-debris, with snake stars, Sabellid fanworm (white arrow); assorted shell debris (e.g., *T. laticostata* and green-lipped scallop shells), with orange fan sponge, *Crella incrustans* [black arrow in i].

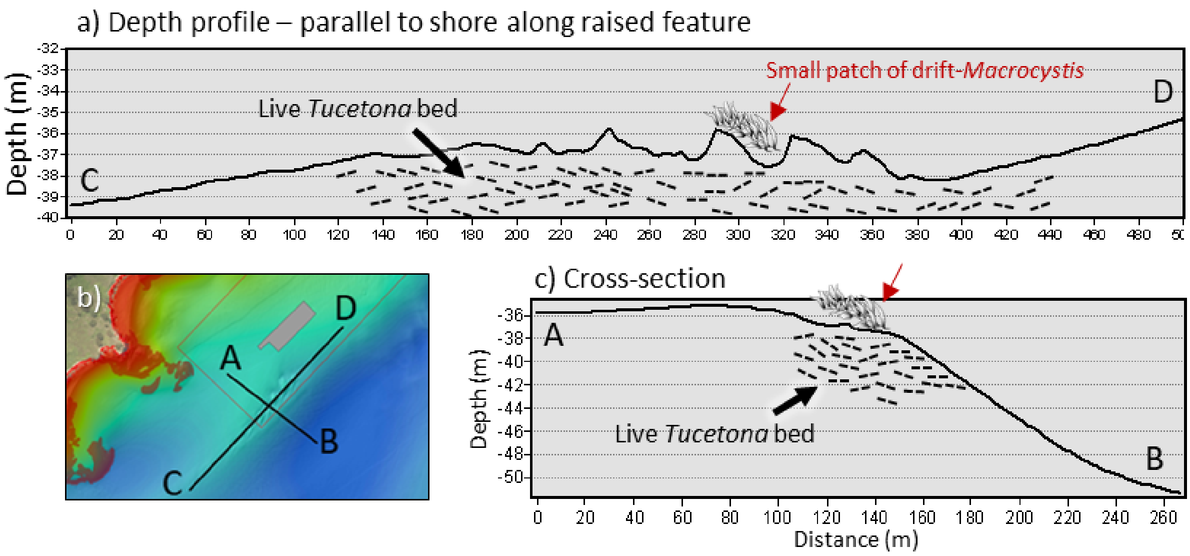


Figure 103: Depth profile along and across the sediment bank off Ngamahau Bay, TC. a) Depth profile C to D along the top of the bank; b) Position of the two depth profiles; c) Depth profile A to B across the bank. Profiles show that the top of the bank is ~245 long x 54 m wide and consists of 7-8 slightly-elevated crescent-shaped features, with peaks rising 0.5-1.5 m above the surrounding bank, every 20-30 m. Upper sediment banks were characterised by moderately dense live *Tucetona* beds (illustrated as 2-dash lines).

3.4.10 Submerged Wreck (outer TC)

HS51 survey provided maps and descriptions (based on acoustic information and video footage) on 10 submerged wrecks within the survey area (Neil et al. 2018). During the MDC18 survey, we video surveyed a small wreck (25-m long x <5 m wide) located in 35 m water depth on the seafloor in the main channel in outer TC - approx. 3 km from TC-entrance (MDC18-Q300; Lat. -41.221, Lon. 174.285; Figure 104). This wreck was an old steamship named the "John Anderson". It was used as a wharf at the Perano whaling station at Tipi Bay in Tory Channel, until it floated away one night and sunk off Thoms Bay in Tory Channel (Captain L. Grogan, Marlborough Harbour Master, *pers. comm.* to NIWA's K. MacKay). This submerged wreck is visible in the HS51 bathymetry as a small (25 x 5 m) low-lying (1-1.5 m high) feature on the seafloor, positioned perpendicular to the current and shoreline (Figure 104). This small (25 x 5 m) wreck is surround by a moat, that measures 17 m on the SW side, 14 m on the NE side, and <5 m at either end of the wreck (Figure 104). The moat surrounding the wreck was characterised by scoured loose sands, with some shell hash and small shells, and at least one large mound of accumulated shell debris mounded up against the vessel, which also included *Galeolaria* rubble. Inside the structure of the wreck, the seafloor beneath the metal frames comprised shelly-sands, like those seen in the moat. Beyond the moat, away from the wreck, the sea bed was characterised by an extensive bed of cobbles with varying amounts of pebbles, gravels, and small shells - characteristic of the main channel in this outer TC region (*see Section: 3.4.7 – Central channel*). This cobble bottom habitat supported 1-20% cover of small sessile invertebrates - mostly small hydroids and some encrusting sponges attached to cobbles.

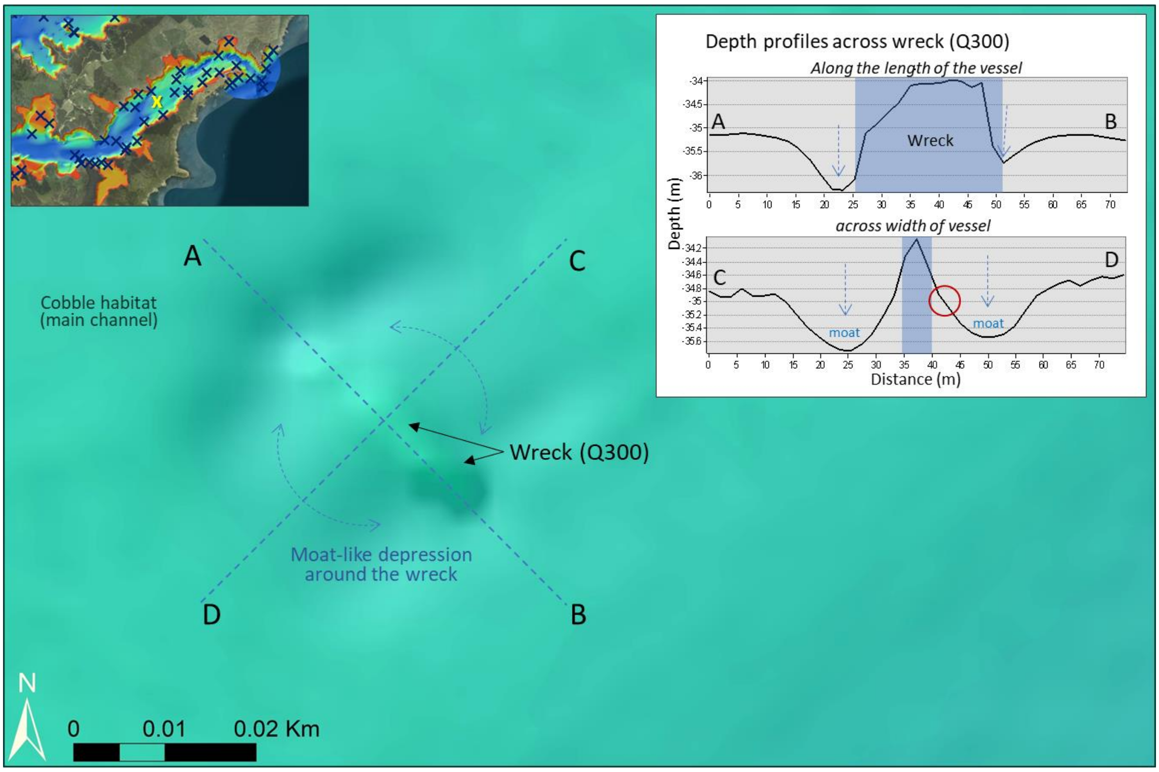


Figure 104: HS51 bathymetry of the submerged wreck, in outer TC (MDC18-Q300). Top-left insert: Yellow cross marks the location of the wreck within the main-channel in outer TC. Top-right insert: The depth profiles across the seafloor and wreck (wreck - indicated by blue blocking) along the length of the vessel perpendicular to shore [A-B], and across the width of the vessel parallel to shore in the direction of the current [C-D]. Dotted blue arrows denote the location of the moat -like depression around the wreck; red circle depicting the banking of coarse sediment and shell-debris up-against the side of the wreck.

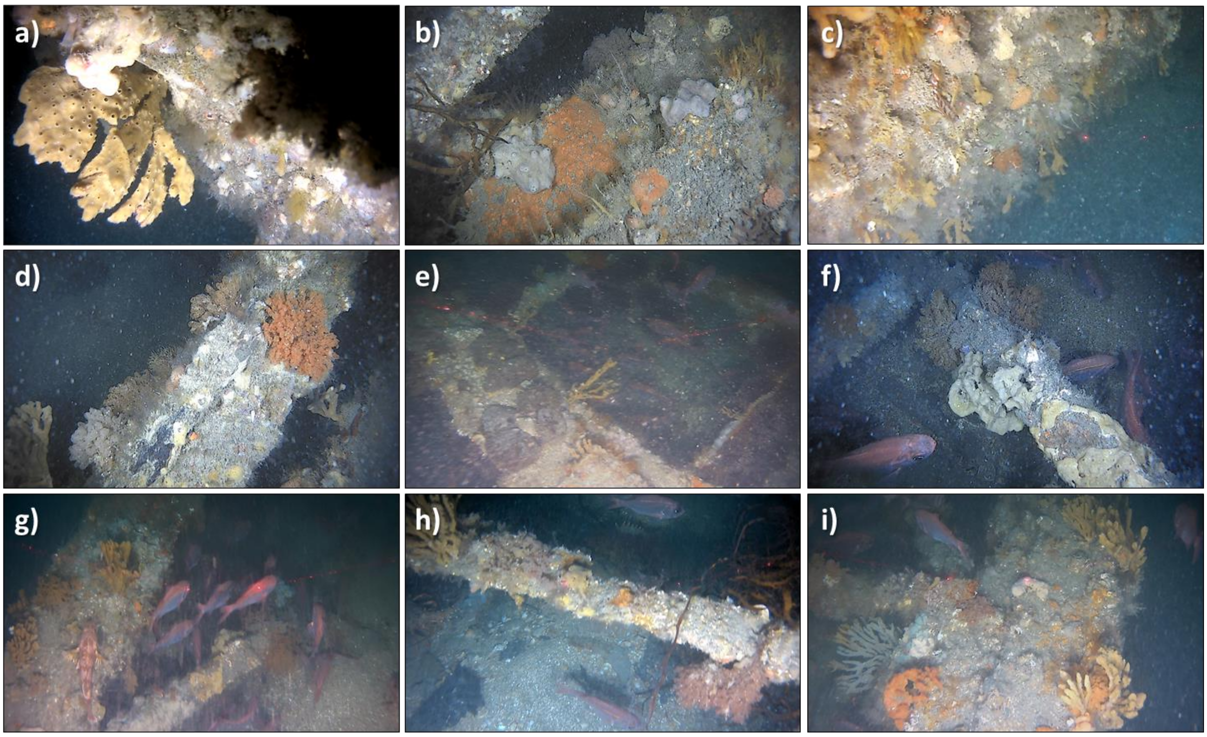


Figure 105: Representative images of the submerged wreck in outer TC (MDC18-Q300).showing portside (a,d,e), centre (b,e,h) and starboard (c,f,i) locations on the wrecks.

The metal structures of the wreck were relatively intact and supported a moderate to late staged successional community of sessile filter-feeders, comprising a colourful assortment of encrusting and large erect sponges, orange, cream and mustard coloured soft bryozoans (Family Catenicellidae), colonial ascidians, small fern-like hydroids, jewel anemones, along with drift kelp entangled in the structural beams of the wreck (e.g., photos in Figure 105). Remarkably, this small-sized wreck supported hordes of smaller non-commercial species, such as schools of roughy hiding within the centre of the vessel (Figure 105e-h), along with a mix of commercially and recreationally important fishery species, including blue cod, tarakihi and blue moki – although most of the latter were of small sizes, found swimming within the moat along the sides of the wreck (e.g., Figure 105a). Other fish included Yellow-and-black triplefins and a large conger eel.

3.5 Cook Strait – Offshore deep reef communities

3.5.1 Deep reefs (>60 m)

Background: Multibeam bathymetry mapped several significant deep reefs in Cook Strait (Neil et al. 2018), that are subjected to large southerly swells, strong tidal currents and cold nutrient-rich waters (Davidson et al. 2011). These were documented as having the largest depth range of any reefs mapped within the survey area, with some having emergent reefs (above the sea surface, e.g., Cook Rock and The Brother's), extending down to 380 m. These deep reef features comprised a mix of extensive steep-sided rock ridges, isolated shoaling reefs, and a series of deep rocky ridges, each exhibiting complex micro-topography or roughness (Neil et al. 2018; Figure 106).

Deep reefs in Cook Strait, included:

i) **Cook Rock** – an extensive (~7.5 km long x <1.1 km wide) deep reef system extending north of QCS from Cape Koamaru, with emergent offshore reefs extending down to depths of ~176 m (ESMS-7.10; Figure 106a).

ii) **Walker Rock** - a deep reef system approx. 1.3 x >3 km, north of Cape Jackson (ESMS-7.1), ranging in depths from the emergent reef known as Walters rock down to ~365 m.

iii) **The Brothers** – an deep Y-shaped reef feature (~1.8 wide x ~6.1 km long) running north-south that includes the emergent islands known as north and south Brothers (ESMS-7.11-7.12) extending down to depths of ~250 m north-east of the islands (Figure 106b).

iv) **Awash Rock** –located 10.7 km north-east of TC entrance (Davidson et al. 2011, ESMS-7.13), comprises an isolated series of deep reefs spanning approx. 1.5 x 0.8 km, in depths of 3.5 m below the sea surface (thus its name) down to depths of ~101 m on its eastern side.

v) An unnamed deep 'tongue-shaped' reef (~0.5 km wide by ~0.7 long) protruding out from the entrance (or mouth) of TC, in depths ranging from ~45 m at TC-entrance down to 126 m at its eastern edge (Figure 106c; partly included within ESMS-5.9); with this reef here on referred to as **Te Whētero** reef (meaning 'the protruding tongue').

Prior to this report little was known of the biology of these deep reef systems (but see Davidson et al. 2011). Cook Strait has always supported the main fishery for hāpuka (groper, *Polyprion oxygeneios*) in New Zealand (Fisheries New Zealand 2019), with catches known from most of these newly-mapped deep reefs (e.g., Walker Rock, Cook Rock, The Brothers and Awash Rock), and fishers known to target deep rock faces in depths of 26-300 m around these features (Johnston 1983; Beentjes and Francis 1999). In 1989-1990, shallow exploratory diver surveys were undertaken across the Marlborough Sounds, including sites out on Walker Rock (dive site 120, 0-18 m), Cook Rock (dive site unknown), The Brothers (dive site 16, 0-12 m) and Awash Rock (dive site 15, 0-24 m) (Duffy et al. *unpublished data*, but summary descriptions in Davidson et al. 2011; 2015). These brief exploratory dives found waved-exposed kelps, *Caulerpa* species and mixed fleshy sub-canopy macroalgae in depths of 0-10.5 m, while deeper reefs (>10.5-<20 m), supported diverse filter-feeding communities, characterised by "bushy bryozoans, sponges and hydroids" (*see Appendix 2 in* Davidson et al. 2015). Davidson et al. (2011 p117, citing Duffy et al. *unpublished report*) described deeper reef zones[74] at Cook Rock and The Brothers (referred to as 'offshore rock stacks') as having a high diversity where

[74] No depth range provided.

virtually all surfaces were covered with encrusting and filter-feeding organisms, including sponges, zooanthids, hydroids, ascidians, bryozoans and cup corals.

On the Wellington side of Cook Strait, deep reefs in the form of hard substrata on canyon walls, have also been reported to support similar diverse filter-feeding communities, also characterised by sponges, ascidians, hydrozoans, bryozoans, brachiopods and scleractinian corals (MacDiarmid et al. 2012; Lamarche et al. 2012), with these habitats and species identified as poorly represented in existing protected marine areas (MacDiarmid et al. 2012).

Ground-truthing surveys: During the planning of the MDC18 survey, in discussion with MDC (Steve Urlich), NIWA was asked to allocate up to three days for ground-truthing Cook Strait features – as identified in the new HS51 maps - with at least one day prioritised, weather dependent, to characterise the habitats and biological communities of deep Cook Strait reefs. HS51 surveys had already collected some limited information at two deep-reef sites albeit from very brief[75] tow-video footage (<1-min of seafloor footage, using NIWA's Coastcam)- one at ~91 m on the southern section of Cook Rock (HS51-D26), the other at 60 m on Te Whētero (HS51-D13). Although deep Cook Strait reefs were identified as high priority sites, these jagged and steep features out in extremely wave-exposed high-current areas, made these reefs extremely treacherous to survey - even in calm weather on slack tides. While we got several days of calm weather in Cook Strait, we were still extremely limited by tidal flow and currents relative to ground swell, with several deep reef sites abandoned due to excessively strong currents and/or standing waves. Nonetheless, using NIWA's rugged deep Coastcam system, we were able to successfully survey four additional deep reef sites (Table 3-47; Figure 106): two sites on the mid and outer sections of the very exposed Cook Rock feature (MDC18-Q134 and Q137, respectively; Figure 106a); a third site 'at the top end' (north) of the Brothers (MDC18-Q182; Figure 106b); and a fourth site extending across approx. one-third of Te Whētero (MDC18-Q147; Figure 106c). Further sites at Cook Rock and Awash Rock had also been planned during the earlier CB17 video survey, using the smaller lightweight CBedcam, however these sites were unable to be surveyed even on calm apparent-flat days, due to conditions deemed too dangerous (particularly strong currents against opposing swell).

The six deep reef sites (four MDC18 and two HS51 sites) in Cook Strait (Table 3-47; Figure 106), surveyed depths spanning 80-132 m, while the mapped features themselves ranged in depths from emergent Islands (Cook Rock and The Brothers) down to ~175 m (Cook Rock; but see Table 3-47 for depth ranges at each site). All three reef-systems comprised extremely high-relief reefs, comprised of rock walls, ridgelines, ledges, and steep ravine with vertical heights of ≤10-40 m and slope angles ≤58-78^{o} [76](Table 3-48). Specifically, the deep reefs at the three Cook Rock sites (HS51-D26, MDC18 Q134 and Q137) ranged in depths of 90-132 m, with all three sites characterised by steep pinnacles, vertical rock walls and steep ridgelines, while in the lower sections between these ridges were sloping ledges and brief rock gullys often infilled with brachiopod and goose barnacle shell debris (Figure 106a). At the Brothers, the single transect began in 95 m water depth near the edge of the reef in a low relief gravel and cobble field with shell debris[77], then over a gravel-scoured reef, quickly traversing up and over a series of steep ridges and pinnacles (Figure 106b). Te Whētero traverse up slope from 112 to 80 m over very high-relief steep ridges with some flat reef tops interspersed by narrow gullys infilled with pebbles, cave-like recesses and sloping ledges (Figure 106c).

[75] From variably quality to slightly out of focus footage, using NIWA's deep Coastcam towed-camera system.
[76] These maximum range values for vertical height and slope angle, are based on video-transects only (i.e. dropcam sites are not included here, as they did not traverse more than a few metres).
[77] Shell debris included relict valves from the wavy fanshell (*Mesopeplum convexum*) and occasional brachiopod and *Panopea* shells.

Table 3-47: Summary depth information of deep reefs surveyed (n=6). Depths surveyed along each video-transect were extracted from the HS51 multibeam bathymetry layer in ArcGIS, while the depth ranges for each feature in the area adjacent to the video transects were extracted from depth profiles. Max. vertical relief based on HS51 bathymetry depth profiles both 'along the transect' = value left of the brackets, and 'across the feature in the vicinity of the site' = value within brackets.

Survey	Site	Deep-reef feature	Depth range (m) surveyed	Depth range (m) of feature near site †	Max. vertical relief	Max slope angle (°)
HS51	D26	Cook Rock (south)	90.7	75-169	≤3 m (15 m)	22° (65°)
MDC18	Q134	Cook Rock (mid)	92-104.5	72-157	≤10 m (40 m)	67° (67°)
MDC18	Q137	Cook Rock (north)	80-132	80-175	≤40 m (40 m)	78° (78°)
MDC18	Q182	Brothers-deep (north)	87-96	88-125	≤10 m (15 m)	60° (72°)
()MDC18	Q147	Te Whētero (east)	80-112	58-122	≤ 6 m (15 m)	58° (71°)
HS51	B13	Te Whētero (east)	60	58-122	≤2 m (12 m)	30° (61°)

† depth range of deep reef, in the area where the video-transect was undertaken (i.e., possible depth range that could have been sampled at that specific location).

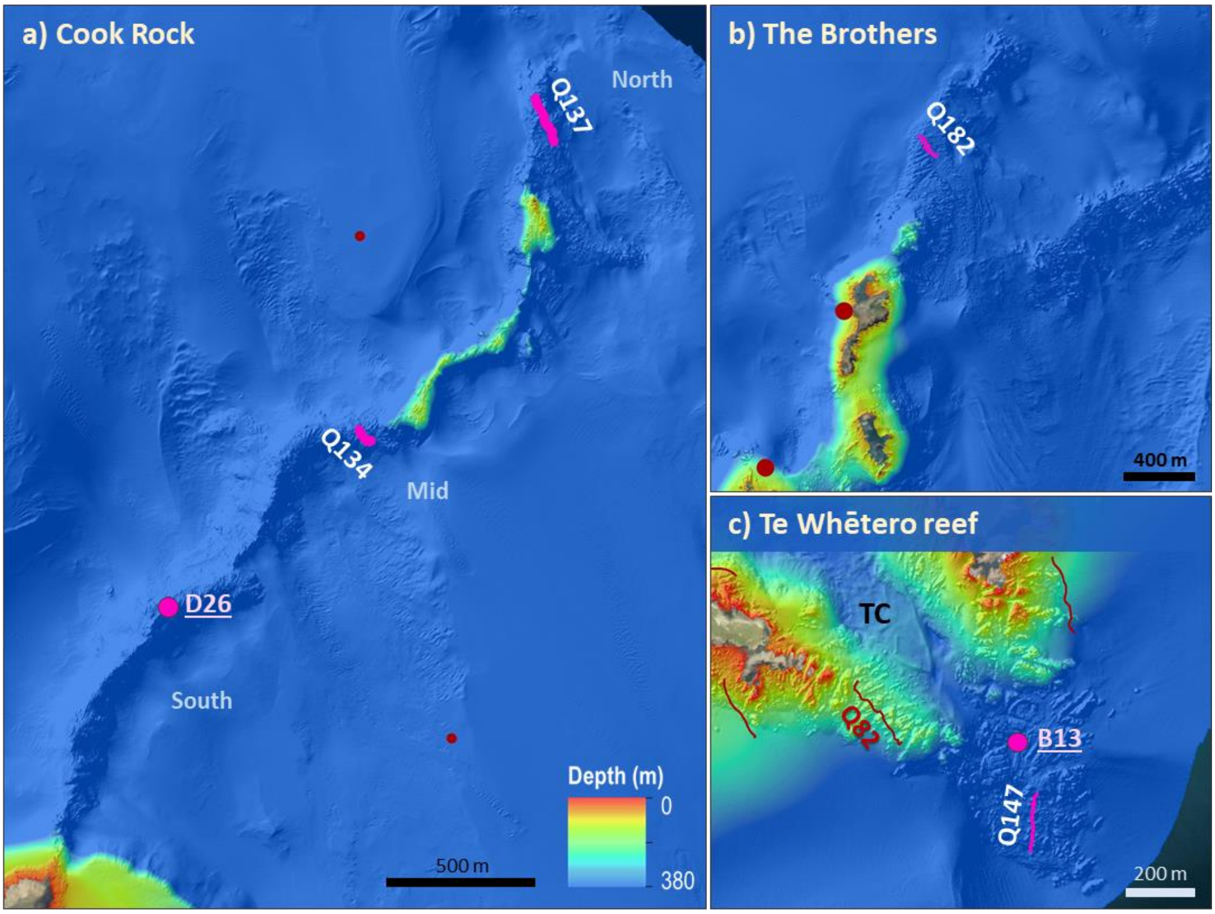


Figure 106: Map of tow-video sites on the deep-reefs in Cook Strait. Pink lines depict the four MDC18 tow-video transects/sites, while pink filled circles depict the two HS51 drop camera sites. a) The location and relative lengths of the three video sites surveyed across Cook Rock- south (HS51-D26), mid (MDC18-Q134) and north (MDC18-Q137) sections of this extensive deep-reef system that extends north of QCS off Cape Koamaru; b) The single tow-video transect surveyed over the deep-reef north of The Brothers (MDC18-Q182); c) Two video sites surveyed over the Te Whētero reef (HS51-B13 and MDC18-Q147) that extends out from the entrance of TC=Tory Channel, along with Site Q82 which was more similar to deep Cook Strait reefs.

All six sites shared very similar community structures, where virtually all rock surfaces were covered by a diverse, densely-packed and colourful assortment of encrusting and sessile filter-feeding organisms, characterised by a various mixtures of diverse sponges (incl. bleach-white *E. alata* sponges the size of tractor tyres), bright yellow zooanthids (*Parazoanthus* sp.), dense patches of goose barnacles (cf *Calantica villosa*), hydroids, ascidians, jewel anemones, soft bryozoans, clusters of epiphytic bivalves, brachiopods and cup corals (Table 3-49 and Table 3-48; e.g., Figure 107 and Figure 108).

Some species and abundance differences among reefs were also documented (Table 3-49). Species absences at HS51 sites, however, may simply reflect the very brief duration and/or the limited video quality at these two sites, so only differences between MDC18 sites are detailed here (but see Table 3-49 for full taxa comparison). The most obvious differences were the high number of goose barnacles on rock walls, ridgelines and ledges out on Cook Rock (e.g., images in Figure 108a,b,g,e), and to a lesser extent at The Brothers, while only a few very small clusters were seen on Te Whētero (MDC18-Q147 - Table 3-49; Figure 109). In addition, a single site, just inside TC entrance (CB17-C20), appeared to have a small isolated cluster of approx. seven goose barnacles (based on a single less than perfect image, and thus would require verification from other sources). Inversely, Te Whētero (Q147) had notably more large yellow cup sponge, *Stellata crater* (Porifera, Tetractinellida, Ancorinidae) (e.g., Figure 107f,j and Figure 108d), which were a key species characterising the sponge gardens seen on the upper slopes and reef tops at Te Whētero (Table 3-49). These sponge gardens at Te Whētero (Q147) also supported a colourful assortment of sponge species and morphologies (e.g., Figure 107 and Figure 108) that included: the cream-brown sponges (*Polymastia cf massalis*), orange and red strappy sponges (*P. sinclairii* and *Crella cf incrustans*), pink ball sponges (*Aaptos* sp.), grey chimneys (poss. *Psammocinia beresfordae*), green spheres (*Latrunculia* sp.) and orange bushy (poss *Axinella* sp.) erect sponges along with pink spikey-looking encrusting sponge (*Darwinella gardineri*), yellow papillate sponges (*Polymastia cf crocea* and poss. *P. hirsuta*). While many of these sponge species were seen on the other deep reefs, most were less prolific (Table 3-49), and may reflect the rarity of flat reef tops and ledges at the sites sampled at Cook Rock and the Brothers. The occurrence of hydroid trees were recorded at most deep reef sites, however, highest the most notable occurrences were at the Brothers, where several dense areas were recorded (Q182 - e.g., Figure 108p). Interestingly, notable numbers and large-sized hydroid trees were also recorded on the shallower reef (<30 m) at The Brothers (CB17-C16), approx. 1-km south of the deep Q182 reef.

Table 3-48: Characteristic features of offshore deep reefs in Cook Strait. .

Cook Strait: Offshore deep reefs	Characteristic features and significant/notable taxa
Substrata	Extremely high-relief reefs, with rock walls, ridgelines, ledges, and steep ravines. Some shell debris, incl. brachiopod debris, in low lying sections of these reefs. Strong currents. (Cook Rock, The Brothers and Te Whētero) occur in depths of up to 380 m (video surveyed depths of 79-132 m).
Benthic community	~100% invertebrate cover over reef surfaces. Impressive fauna, dominated by diverse and densely packed filter feeders incl., vibrant yellow zooanthid colonies (*Parazoanthus* cf *P. elongatus*); dense clusters of goose barnacles (likely *Calantica villosa*), brachiopods (walls and deep ledges), clusters of epiphytic bivalves, cup corals (base of walls), jewel anemones (walls), colonial ascidians, soft-bryozoans, hydroids, and hydroid trees, large solitary-white Sabellid fan worms (base of walls). Rich sponge assemblages with diverse morphologies, incl. *S. crater*, *P. cf massalis*, *P. sinclairii, C. cf incrustans*, pink-*Aaptos* sp., *cf P. beresfordae*, *Latrunculia* sp., poss. *Axinella* sp., *D. gardineri*, *P. cf crocea* and cf. *P. hirsuta*.
Motile invertebrates	*Snake stars* (common).
Fish	Yellow-and-black triplefins, seaperch, red-banded perch, grouper (Q134), scarlet wrasse.

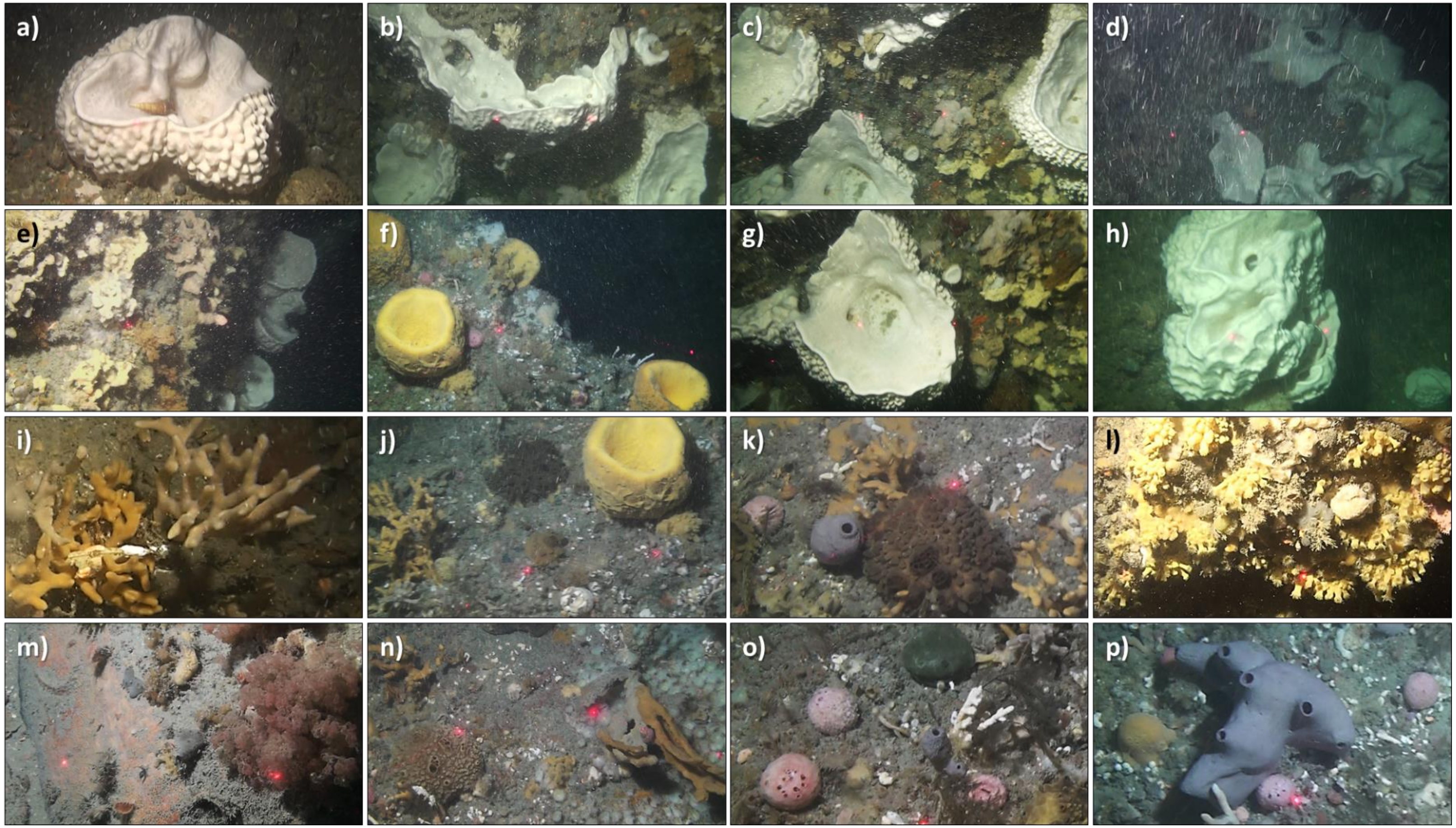


Figure 107: Representative images of biological communities on deep Cook Strait reefs (80-130 m) - part I. Scale: lasers are 20 cm apart. a-d) Large bleach-white *Ecionemia alata* sponges characteristic of rock walls and ridgelines (some >1.5 m in diam.), Cook Rock, Sites Q134 [a-b] and Q137 [c-d]); e) Rock wall densely encrusted with sponges, soft bryozoans, hydroids, jewel anemones, with *E. alata* on ridge line (Site Q137); f) Mixed sponges, incl. yellow cup sponges (*S. crater*) and hydroids (Site Q147); g-h) bleach-white *E. alata* (Sites 147-Tory [g], Q182 – The Brothers [h]); i) Strappy sponges (*P. sinclairii*) (Site Q137); j,k) reef top sponge garden, with brown (*P. cf massalis*), yellow cup (*S. crater*) and grey chimney (*P. beresfordae*) sponges (Site Q147); l) Bright yellow zooanthids, with hydroids and brachiopods (Site Q137); m) Encrusting sponge and soft bryozoan (poss. *Orthoscuticella* sp.); n) Mixed sponges, incl. brown (*P. cf massalis*) and digitate (*P. sinclairii*) sponges and jewel anemones (Site Q147); o) reef top sponge garden, with pink ball (*Aaptos* sp.), green sphere (*Latrunculia* sp.), grey chimney (*P. beresfordae*) sponges and black hydroids (Site Q147); p) Mixed sponges, incl. grey chimney (*P. beresfordae*)and pink ball (*Aaptos* sp.) sponges (Site Q147).

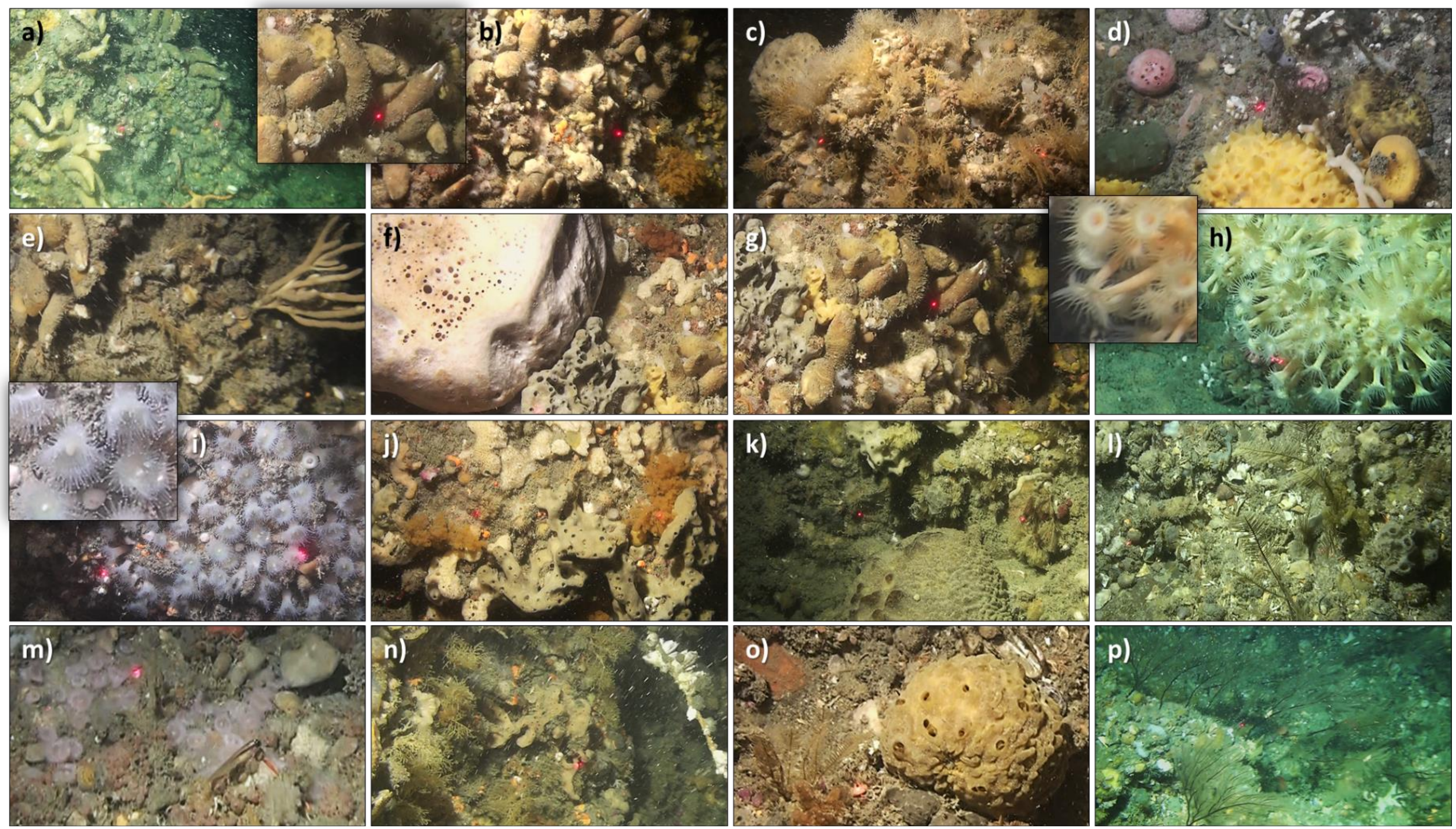


Figure 108: Representative images of biological communities on deep Cook Strait reefs (80-130 m) - part II. a-b) Clusters of goose barnacles (likely *C. villosa*) on ridge line (Q134) and rock wall (Q137), respectively (insert = close up, Q137); c) Dense invertebrates (mix of sponges, hydroids, jewel anemones and brachiopods) (Q134); d) Sponge garden on top of reef ledge, incl. pink ball (*Aaptos* sp.), yellow papillate (*Polymastia* cf *crocea*), green sphere (*Latrunculia* sp.) sponges (Site Q147); e) Dense invertebrates with goose barnacles, strappy sponge (*P. sinclairii*), hydroids and many brachiopods (indet. spp. Q134); f-g) Mixed sponges, soft bryozoans, and goose barnacles (Site Q134); h) Colony of Zooanthids (*cf P. elongatus* [insert = closeup of polyps] (Site 147); i) Jewel anemones cover rock wall (insert = close up of polyps) (Site 147); j-k) Dense invertebrates, with encrusting sponges and soft bryozoans (poss. *Orthoscuticella* sp.) and sponges (incl. *P.* cf *massalis*) and unident. hydroids (Site 134); l) Fern-like hydroids (Site Q134); m) Jewel anemones and triplefins (*F. flavonigrum*) (Site Q134); n) Sponges, hydroids and *P. pachydermatina* with epiphytic barnacles (Site Q134); o) Fern-like hydroids and sponge (*P.* cf *massalis*) (Q134); p) Dense hydroid trees (Site 182).

Community structure also varied in relation to meso-scale habitat features. For example, cup corals were found on the low sections and base ledges of deep reefs (e.g., Figure 62g-h), along with often dense clusters of brachiopods (e.g., Figure 59), the red bubble ascidian (*Hypsistozoa* sp.), and fern-shaped hydroids (mixed spp. - e.g., Figure 108l,n,o) and some hydroid trees (e.g., Figure 108p). In a few locations on Cooks Rock a few large solitary white Sabellid fanworms (~half a meter tall, with large white brachial crown) were also recorded, but have not yet been identified. Above these areas, the lower ridges supported often large dense clusters of goose barnacles (esp. at Cook Rock), mixed sponges (Figure 108j), soft orange-coloured Catenicellidae bryozoans (poss. *Orthoscuticella* sp.), bright yellow zooanthids, brachiopods in some places, and dense patches of epiphytic bivalves (mostly at Cook Rock, Q137). The upper sections of steep ridges were characterised by the often extremely large bleach-white *E. alata* sponges (e.g., Figure 107a-h) especially along the ridgelines with some the size of tractor tyres, dense clusters of goose barnacles (esp. at Cook Rock) along with large volumes of cream and mustard coloured reef-covering sponges (poss. *Xestospongia*) mixed in with abundant soft orange-coloured Catenicellidae bryozoans (e.g., Figure 108j). Dense and often extensive patches of jewel anemones, in a range of colours (incl. white, translucent-pink, to pinkish-orange) were also frequently seen on steep sloping ledges, with the largest patches seen at Te Whētero reef (Q147) just below the sponge garden zone (e.g., Figure 108i), although, jewel anemones were also recorded on the tops of reefs in the sponge garden zone, but only in much lower densities (e.g., Figure 107n). Motile invertebrates were rather depauperate, characterised by low densities of the snake star (*O. maculata*), mostly recorded on the low sections and base ledges of these deep reefs, rare occurrences of other starfish (e.g., *P. regularis* at inner Cook Rock -HS51-D26), an octopus (Q147), and a variety of gastropods (see Table 3-49 for full list). Fish were also relatively rare, with triplefins (*F. flavonigrum*, e.g., Figure 108m), sea perch and red-banded perch the most commonly seen fish (see Table 3-49 for full list). Roughy were also recorded in deep gullys and crevices at several Cook Strait sites (Table 3-49). A large (estimated length ≤ 80 cm) grouper was also observed swimming out of a deep crevice at north Cook Rock (Q134), but was too quick to be identified (although it had distinct tail botches on its body and tail - T. Anderson and M. Francis *pers. obs.*). Fish hiding in crevices and caves on these deep reefs would be greatly underestimated from these video data, due to the difficulty (and our reluctance) in getting close enough to see into caves and crevices without getting irretrievably snagged.

New records for the region: Many of the species on these reefs are likely to be new records for Marlborough Sounds, with many possibly new to Cook Strait and New Zealand. Very few specimen records exist for these types of deep reef habitats in Cook Strait (Sadie Mills *pers. comm.*). Goose-barnacles, identified from video-images as likely *C. villosa* by Andrew Hosie (Barnacle specialist at Western Australian Museum), appear to be new records for the Marlborough Sounds region. These goose barnacles were recorded from all three deep reef systems (Cook Rock, The Brothers and Te Whētero) and five out of the six video-sites (Table 3-49; Figure 109) in depths of 90.7 m down to 130.5 m (mean depth 107.8 ± 2.3 m SE). One TC site, inside the entrance to TC (CB17-C20, also within ESMS-5.8), appeared to have six small clusters of goose barnacles on the high-current cobble-rock bottom in the main channel - could not be fully verified from the video-imagery.

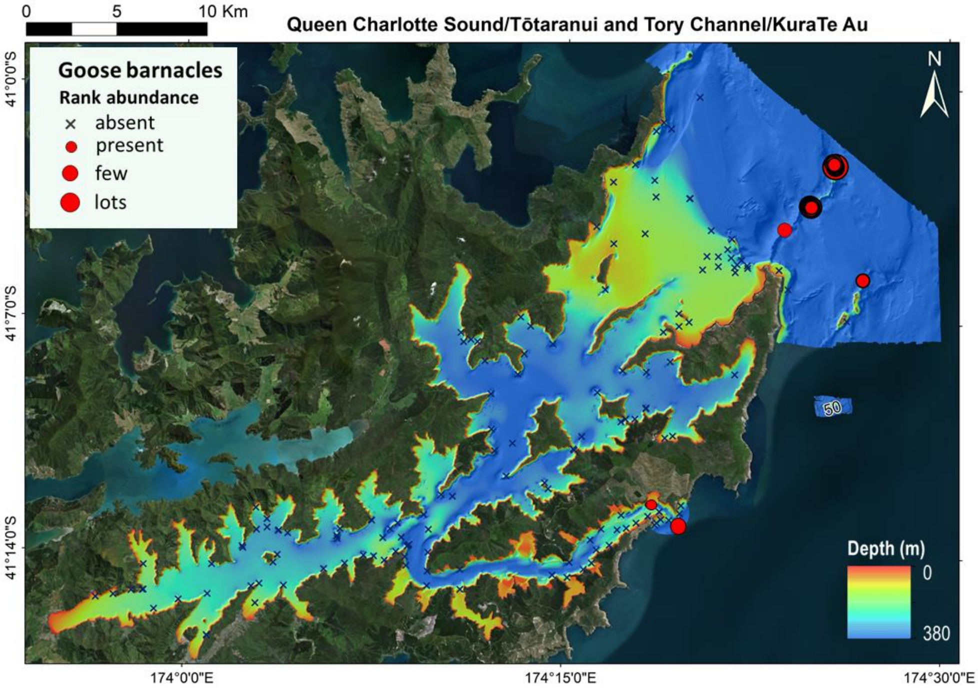


Figure 109: Distribution and rank abundance of goose barnacles (cf *C. villosa*) on the deep reefs in Cook Strait. Bubbles are % rank abundance estimates for the MDC18 survey**.**

Although zooanthids have been generically reported from Cook Rock in Cook Strait and from White Rocks, at the entrance to QCS (Davidson et al. 2011 p116-117 – based on Duffy et al. *unpublished 1989-90 data*), no specifics have been published. During the MDC survey zooanthids were a common and characteristic feature of these deep reef systems, occurring at all five sites surveyed: Cook Rock (Q134 and Q137), The Brothers (Q182) and Te Whētero (Q147). Zoonathids at these sites were recorded in depths of 80.0-118.5 m (mean depth 98.8 ± 2.68 m SE), with maximum %cover ranging from ≤5-40% cover, found mostly on high current rock ridges. Zoonathids were identified from video images as *Parazoanthus*, possibly *P. elongatus* (Frederic Sinniger, *pers. comm*.), however, collected specimens would be required to verify this. A search of NIWA's SPECIFY database identified that no zooanthid specimens have been collected for the Marlborough Sounds and Cook Strait regions (Sadie Mills *pers. comm*.).

Ecionemia alata (Porifera, Tetractinellida, Ancorinidae) is a common New Zealand sponge species known to grow up to 1 m in diam. and although variable in colour generally ranges from shark-grey to charcoal grey in colour (Kelly 2015). Both the bleach-white colour morph[78] and the extreme sizes of this species on the deep reefs in Cook Strait provide new records for this species (M. Kelly *pers. comm.*). Although the colouration of *E. alata* is variable, this bleach-white colour morph is a new record for this species (M. Kelly *pers. comm.*), while the exceptionally large *E. alata* sponges (≥1.5 m in diam.) from these sites provide new max. size records for New Zealand (M. Kelly *pers. comm.*). The extraordinarily large sizes and bleach-white colouration of *E. alata* sponges along with the sheer number of these sponges on some deep reefs (especially out on Cook Rock, Sites Q134 and Q137) was very impressive, and contributes to the uniqueness of these deep reef systems.

[78] Also recorded at some sites within the Sounds (see Section 3.7.1 and Figure 127).

Table 3-49: Cook Strait deep reef community structure. Presence and relative abundance of taxa recorded on Cook Strait deep reefs. ✓ = presence, ✓✓=common, ✓✓✓=dominant feature of the community. (value)= counts or % cover per transect for some taxa are provided. Symbols depict habitat-association of taxa: * Accumulated debris at base of walls, gulley's and ridgelines; ^ Base of walls and lower ledges; + Mid-upper wall zones; ✦ Gravel-shell-cobble-bottom at base of reef at the Brothers

Species/taxa	Cook Rock South (HS51-D26)	Cook Rock Mid (Q134)	Cook Rock North (Q137)	The Brothers North (Q182)	Te Whētero East of TC (Q147)	Te Whētero East of TC (HS51-B13)[79]
Sessile invertebrates						
Zooanthid colonies (*Parazoanthus*, poss. *P. elongatus*)	^	✓	✓✓✓+	✓✓✓^	✓✓✓	
Goose barnacles (cf *C. villosa*)	✓✓✓	✓✓✓	✓✓✓^	✓✓	✓	
Cup corals (Flabellidae, *M. rubrum*)			✓✓✓^+	✓✓✓^	✓✓✓	
Brachiopoda spp.		✓✓✓	✓✓✓^	✓✓✓	✓✓✓	
White brachiopod (poss. *L. neozelanica*)		✓✓✓	✓✓✓^+	✓✓		
Small pink brachiopod (indet.)		✓✓✓	✓✓✓	✓		
Brachiopod/black tinge (poss. *Notosaria nigricans*)		✓	✓✓+^		✓	
Epiphytic bivalves (indet. spp).			✓			
Jewel anemones (mixed colourations)	✓✓✓	✓✓	✓✓+	✓✓✓	✓✓✓	
Colonial ascidians (spp.)	✓	✓✓	✓✓+	✓✓^	✓	✓✓
Colonial ascidian - pink (*Botyrlloides* undescribed sp.).				✓✦	✓	
Red bubble ascidian (*Hypsistozoa* sp.)		✓✓	✓✓	✓✓^		
Stalked ascidian/sea tulip (*P. pachydermatina*) NB: with *Balanus*-like barnacles attached to the stalks		✓ (x1)	✓ (x2)	✓ (x4)		
Soft (Catenicellidae) bryozoans - orange/pink (poss. *Orthoscuticella* sp.)	✓✓	✓✓✓	✓✓+	✓✓✦	✓✓	
Soft-bryozoans - cream-grey (unident. spp)		✓✓✓		✓✓+^		
Hydroids (mixed spp)		✓✓✓	✓✓✓+^	✓✓✓✦^+	✓✓✓	✓✓
Hydroid trees (tall or tree-like hydroids)		✓		✓✓✓✦^+	✓ ✓✓	
Yellow branching hydroids (Family Sertulariidae)		✓✓	✓✓+^	✓✓		
Tan-coloured turf (indet. taxa)		✓	✓	✓✓		
Bryozoa – hard branching (poss. *Hornera robusta*)		✓(<1%)	✓(<1%)+	✓ (<1%) +^	✓	
Solitary anemone – large cream-coloured (sp-deep1)		✓	✓✓^		✓^	

[79] HS51 B13 comprised 18 seconds of video, most of which was not in focus, and while it was discernable that this assemblage was dominated by encrusting species (sponges, ascidians) and small turfing taxa (unidentified turf and hydroids) - further identification of specific taxa was difficult or not possible.

Species/taxa	Cook Rock South (HS51-D26)	Cook Rock Mid (Q134)	Cook Rock North (Q137)	The Brothers North (Q182)	Te Whētero East of TC (Q147)	Te Whētero East of TC (HS51-B13)[79]
Tube anemones			✓✓			
Large solitary-white Sabellid fan worms (indet.)		✓ (x3)	✓ (x9)^			
Fanworms				✓✦		
Sponges identified						
Sponges - 3D / erect (combined spp.)	✓	✓✓✓	✓✓+		✓✓	✓
Large bleach-white sponges (*E. alata*)	✓	✓✓✓	✓✓✓+	✓✓✓+	✓✓✓	
Yellow cups (*S. crater*)		✓✓		✓✓	✓✓✓	
Cream-brown sponges (*P.* cf *massalis*)		✓✓	✓✓	✓	✓✓✓	
Large cream sponge (Ancorinidae, poss. *Stellata*)			✓	✓		
Orange strappy sponges (*P. sinclairii*)		✓	✓	✓	✓✓✓	
Red strappy sponges (*C.* cf *incrustans*)					✓	
Pink ball sponges (*Aaptos* sp. indet.)		✓	✓+	✓✓	✓✓	
Grey chimneys (cf *P. beresfordae*)					✓✓	
Green spheres (*Latrunculia* sp.),		✓✓		✓✓	✓✓✓	
Grey-green encrusting (cf *Raspailia arbuscula*)		✓✓	✓✓	✓✓	✓	
Callyspongia (sp indet.)				✓^+	✓	
Orange bush (poss. *Axinella* sp.)				✓	✓✓	
Yellow papillate sponge (*P.* cf *crocea*)			✓✓^	✓	✓✓✓	
Yellow papillate sponges (*cf Polymastia hirsuta*)			✓✓^	✓	✓✓✓	
Sponges – encrusting (combined spp)	✓	✓✓✓	✓✓✓+	✓✓	✓✓✓	✓✓✓
Pink encrusting sponge (indet.)			✓	✓✓	✓✓	
Encrusting-small chimney sponges of variable colouration (cream, yellow and grey) (poss. *Xestospongia*).		✓✓	✓✓	✓	✓	
Pink spikey-encrusting sponge (*D. gardineri*)			✓✓+	✓	✓	
Yellow spikey-encrusting sponge (*D. oxeata*)					✓	
Motile invertebrates (+ counts per transect)						
Common snake brittlestar (*O. maculata*)	✓✓	✓	✓✓	✓✓✦^		
Common cushion star (*P. regularis*)	✓					
Large 7-arm star (poss. *A. scabra*)				✓ (x2)		

Species/taxa	Cook Rock South (HS51-D26)	Cook Rock Mid (Q134)	Cook Rock North (Q137)	The Brothers North (Q182)	Te Whētero East of TC (Q147)	Te Whētero East of TC (HS51-B13)[79]
6-armed starfish	✓					
Topshell (*Maurea*-like)		✓✓	✓ (x1)			
Whelk (*Buccinulum*-like)		✓ (x1)	✓ (x2)			
Sawshell (*A. heliotropium*)			✓ (x1)	✓^ (x3)		
Octopus (medium sized, unident.)					✓	
Fishes (counts per transect)						
Yellow-and-black triplefins (*F. flavonigrum*)		1				
Very large grouper (sp. indet.)		1				
Seaperch (*H. percoides*)		1	6	9 ✦^	4	
Roughy			2-4		25	
Red-banded perch (*H. huntii*)		1	2	1	5	
Scarlett wrasse (*P. miles*)		1				
Rockcod (*L. rhacina*)			✓?		✓ 1	
Conger eel (*C. verreauxi*)		1				
Other/shell debris						
Bare space	0	<1%	<1%	<1%		
Shell debris (brachiopods)		✓*	✓✓*			
Shell debris (goose barnacle plates)		✓✓*	✓✓*			
Wavy fan shell (*Mesopeplum convexum*) debris				✓✦		

3.6 Cook Strait – Characteristic habitats and communities

Background: Beyond the entrances to QCS and TC, the east coast of Marlborough Sounds along with the offshore reefs and Islands (e.g., Awash Rock and The Bothers) support rugged and steep coastlines with complex subtidal reefs that jointly reflect the exposed and harsh conditions of the Cook Strait. There is limited access to these parts and relatively limited recreational activity occurs in Cook Strait. The subtidal environments along this coastline, particularly in or near the TC-entrance, are subjected to some of the strongest currents found in New Zealand waters, that in turn make them extremely difficult and dangerous to study. Consequently, marine communities from this region are poorly known (Davidson et al. 2011). Marine flora and fauna specimens, especially for the nearshore marine environment, are woefully under-represented in the national museum collections (Te Papa, NIWA and the Australia's Virtual Herbarium searches, May 2019) – where specimen records mostly refer to a few large kelp species (see D'Archino et al. 2019). In 2018, upon the release of the HS51 bathymetric maps (Neil et al. 2018a,b) new and complex reef and bathymetry features were identified and described in the Cook Strait region (Neil et al. 2018a), shaped by accelerated tidal flows through Cook Strait (Heath 1978, Heath 1982;), particularly enhanced tidal flows, turbulence and constrictions around headlands (e.g., Vennell 1994), and through the entrance to Tory Channel (mean speed of 1.2 ms^{-1}, Hadfield et al. 2014).

Ground-truthing surveys: Of the 2-3 days prioritised to ground-truthing bathymetric features out in the Cook Strait, within limited weather opportunities sites, site selection was based on three priorities: 1) To ground-truth deep high-relief offshore reefs (as presented above); 2) To ground-truth complex bathymetric reef features along the coast in three areas – those adjacent to Tory Channel, after which, 3) reef and raised features off Cape Koamaru and at the Brothers were undertaken to complement those already collected during the CB17 and HS17 surveys (incl Awash Rock). Although we had near perfect weather conditions, excessively strong currents made surveying some sites impossible. Several of our planned sites at the Brothers and Awash rock, along with three sites to ground-truth complex seafloor features between Cape Koamaru and the Brothers were abandoned due to excessively strong currents[80], while at sites that could be surveyed, transect direction and position were often altered to meet on-site current conditions. Regardless, some impressive Cook Strait sites were surveyed(Figure 110; Figure 111), with a wide range of seafloor features ground-truthed and there benthic habitats and communities characterised.

In this section we present the finding from 22 video-sites surveyed within the Cook Strait region from the four combined surveys (Figure 111) - in addition to the six offshore deep reef video sites (presented separately in: Section 3.5.1). This included fifteen sites within the HS51 mapped survey area: seven adjacent to TC-entrance; four off Cape Koamaru, three around the Brothers, 1 short drop camera at Awash Rock (HS51 survey); along with an additional seven sites surveyed along the east coast from Cape Koamaru down to Robertson Point (the headland north of Port Underwood) (Figure 110; Figure 111).

[80] For example, the current conditions at two sites (a deep reef at the NW tip of the Brothers and the other a bathymetry ribbon-like feature between Cape Koamaru and The Brothers) were so strong that the first had a large and very powerful whirlpool water feature above it that prohibited safe vessel passage across it never mind running a video transect anywhere near it, while the other had an isolated series of current-forced standing-waves along the length of the feature a likely indication of the intense water movement and benthic forces that likely shape this complex raised sediment feature.

The additional seven east coast sites included five rocky reef video sites (CB17 survey) and two beam trawl sites (BT17 survey, trawlable-ground in two bays) (Figure 110). Although these sites are not within the HS51 study region (and therefore not addressed here in detail) they are presented in terms of supporting information on zonation patterns, and taxonomic species seen within these zones, but especially the more definitive identifications of specimens collected in the beam-trawls. As part of the MBIE bottlenecks programme, specimens of all flora collected in Cook Strait (most collected as drift algae from BT11) were pressed for permanent museum records (e.g., Figure 115).

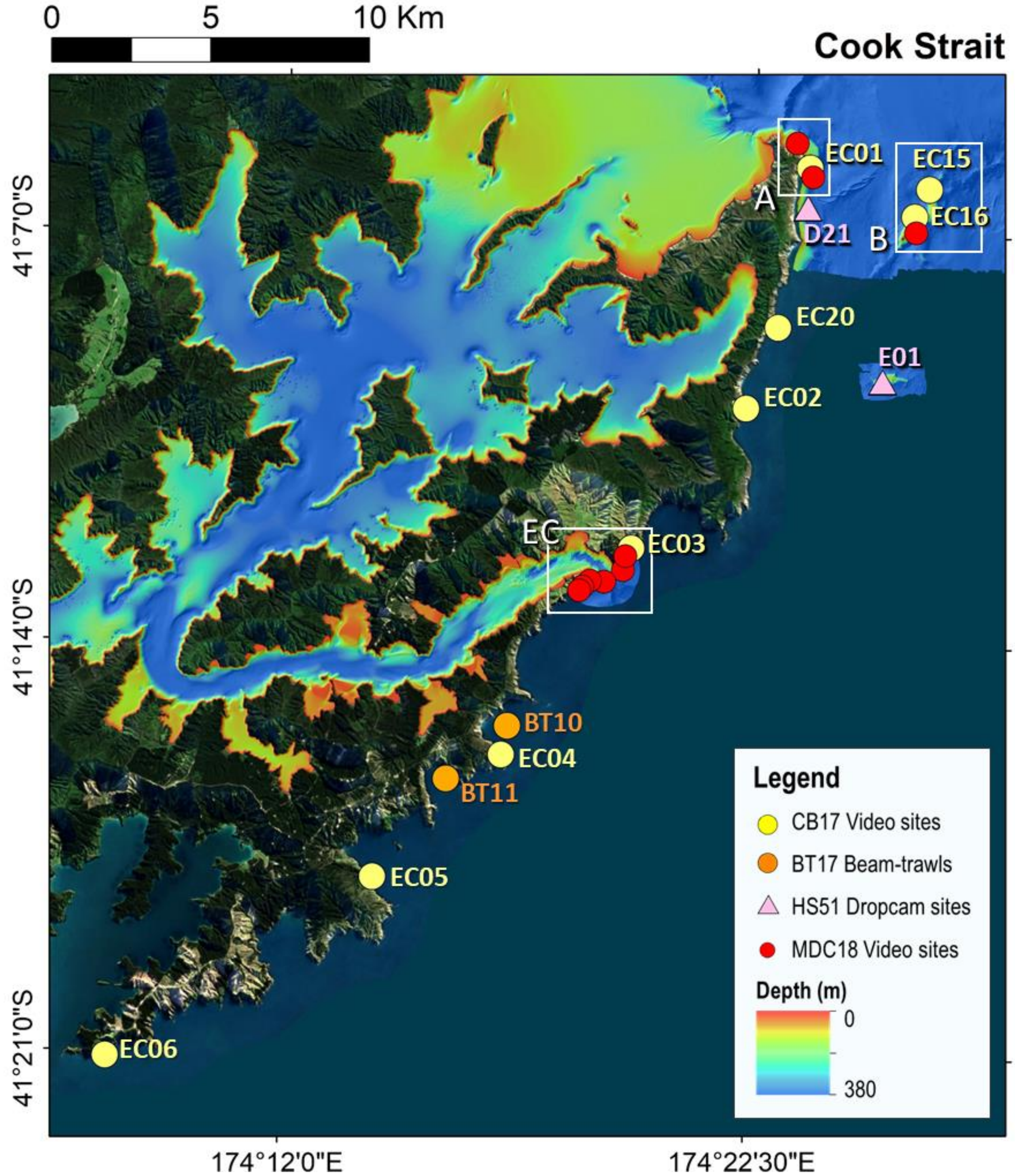


Figure 110: Location of Cook Strait coastal and island sites (n=23) for all four surveys. White Boxes A-C depict sites within the HS51 survey area, and are presented in zoomed-in scale with site labels in Figure 111.

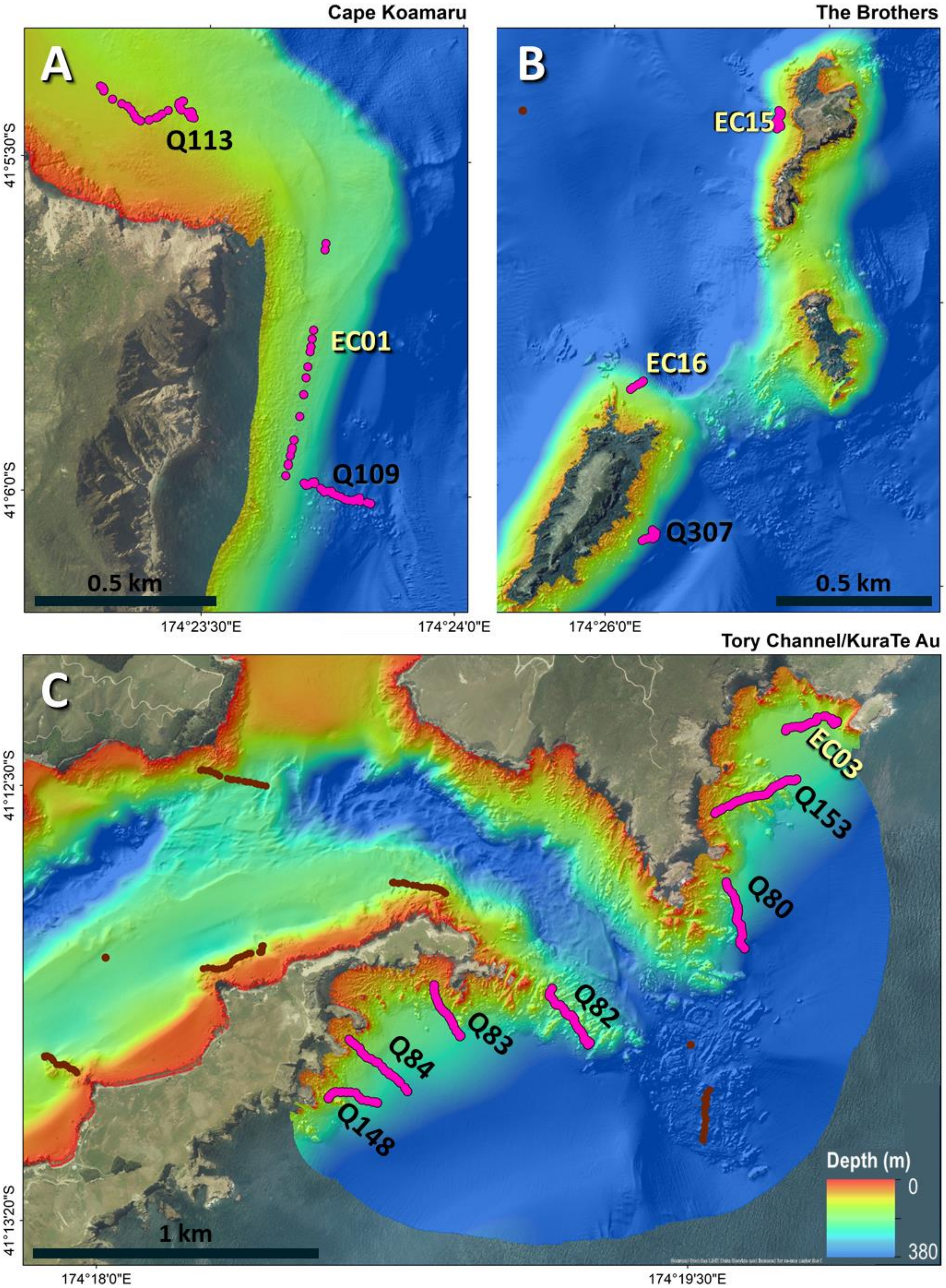


Figure 111: Location of Cook Strait coastal and island tow-video sites from the CB17 and MDC18 surveys. Video-transects for this area are highlighted in pink. Black labels = MDC18 sites; Yellow labels = CB17 sites. The locations of the additional 2 drop camera sites from the HS51 survey are presented in Figure 110.

To characterise the subtidal rocky reefs and deeper slopes adjacent to TC-entrance, tow-video transect were run perpendicular to the shore (where possible), starting offshore (>200 m from the shore in depths of >30 m), running up slope to as shallower a depth as could be safely surveyed. This included three sites north of East Head, one in the mouth of TC-entrance, and three south of West Head (Figure 111). Although we got a very calm 3-day weather window during the survey, an unexpected impediment to running video-transects in this area was the notably high number of cray pots densely lining the high-relief reefs. The greatest impediment to surveying sites in Cook Strait was around the entrance to TC on the pinnacle reefs off East and West Heads, and at the headland around Cape Koamaru. As a result, no inshore reef sites could be surveyed directly off Cape Koamaru, while planned transect-lines on nearshore reefs around TC-entrance, particularly East Head, had to be diverted to avoid entanglement. This resulted in transects Q80 and Q82 not being able to traverse up across the reefs as planned, with transect Q82 not being able to reach the kelp-zone, and Q80 almost missing the reef entirely. While two other transect-lines were also slightly diverted to avoid cray pots, the remaining transects all managed to successfully traverse the reef up into the kelp zone.

The nine Cook Strait transects undertaken during the CB17 survey were conducted during a single good weather day in Cook Strait (Table 3-50). These transect were undertaken using the CBedcam in depths <30 m (Figure 112; Figure 113), with transect direction and distance offshore determined largely by the skipper based on local site conditions. Similarly, MDC18 transects Q113 off Cape Koamaru and Q307, were not on the planned sites, but were altered locations based on strong prevailing currents.

Table 3-50: Summary details of the CB17 video transect undertaken in the Cook Strait on the 15 May 2017. Sites in blue text are located within the HS51 mapped survey area, while those in black are beyond the mapped zone. Area: EC-Nth = East Coast north of TC-entrance; EC-Sth = East Coast south of TC-entrance, BR= The Brothers. Latitude and Longitude are presented as decimal degree for sol; Depths are in metres measured from the vessel and are presented for sol = start of line, and eol = end of line; underlined depths are the shallowest.

Survey	Site	Area	Location	Latitude	Longitude	Depth (sol)	Depth (eol)
CB17	EC01	EC-Nth	Cape Oamaru	-41.09735	174.39486	<u>18.0</u>	25.6
CB17	EC15	BR	Brothers Islands- NW	-41.10303	174.43975	<u>11.0</u>	20.0
CB17	EC16	BR	Brothers Islands- SW	-41.11089	174.43445	<u>20.0</u>	32.0
CB17	EC20	EC-Nth	exposed East Coast	-41.14279	174.38377	<u>14.0</u>	16.0
CB17	EC02	EC-Nth	Hum Point	-41.16584	174.37228	20.0	<u>17.7</u>
CB17	EC03	EC-Nth	Outside Tory channel	-41.20597	174.32999	24.0	<u>18.6</u>
CB17	EC04	EC-Sth	sth of Lucky Bay	-41.26507	174.28211	20.8	<u>17.0</u>
CB17	EC05	EC-Sth	Glasgow Bay	-41.30011	174.23437	19.0	<u>12.0</u>
CB17	EC06	EC-Sth	Robertson Point	-41.35171	174.13475	13.0	<u>8.5</u>

Overview of results: Twenty two video-sites were surveyed within the Cook Strait in four main regions, surveying depths ranging from 6.1-58.3 m, with slopes varying from gentle slopes (<20^o slope angles) to extremely steep side deep reefs (50-70^o angles) (Figure 112; Figure 113).

Cook Strait areas successfully surveyed, included:

i) **Coastal sites adjacent to TC-entrance** (n=7) – Transect run perpendicular to the shore across large nearshore reefs and deeper habitat zones (Figure 111C; Figure 112).

ii) **South-east of Cape Koamaru** (n=4) One CB17 video-site was surveyed along shore, targeting potential reef habitats; along with two MDC18 sites, one targeting a narrow ridgeline feature down the slope, and a second up on the shelf near Cape Koamaru (Figure 111A; Figure 113-left-side graphs). A fourth brief (<1-min) drop camera site was also surveyed beyond the slope in 60 m.

iii) **The Brothers and Awash Rock** (n=4) At the Brothers, two nearshore CB17 video-sites surveyed coastal and island sites, possibly important to blue cod, in depths <~30 m; with a third MDC18 deep slope site, surveyed off the south east side of the Brothers (Figure 111B; Figure 113-right-side graphs). In addition, a single short-duration (<1-min) drop camera was surveyed at Awash Rock in 20 m depth.

iv) **East coast sites from Cape Koamaru down to Robertson Point** (n=7 beyond the HS51 mapped survey area, plus 2 sites - EC01 and EC03 -addressed above) Towed video surveys were undertaken at seven CB17 sites interspersed down the east coast, along with two videoed beam trawl BT17 sites, surveyed 5 and 7 km south of TC-entrance (e.g., Figure 110).

v) **Offshore deep reefs** (n=5) *Presented separately in Section 3.5.1.*

Strong community zonation was recorded at Cook Strait coastal and offshore Island sites, where substratum type, depth, angle of slope and the degree of habitat rugosity were found to be important factors predicting habitat structure and community composition. Six dominant and characteristic habitats, and their associated communities are presented here, broadly classed as:

1) **Kelp-zone** on rocky reefs in depths <15-17 m.
2) ***Caulerpa* meadows** in depths of 15-20 m often over expansive reefs.
3) **Mixed macroalgae** on reef below the *Caulerpa*-zone.
4) **Kina barrens** rare, except for Cape Koamaru.
5) **Deep reefs** with high-relief and steep slopes (30-70^o), with moderate to high % cover of diverse and colourful sessile invertebrates.
6) **Rock-rubble slopes** with gentle slopes (mostly <12-20^o), with low-moderate % cover of small-sized sessile invertebrates.

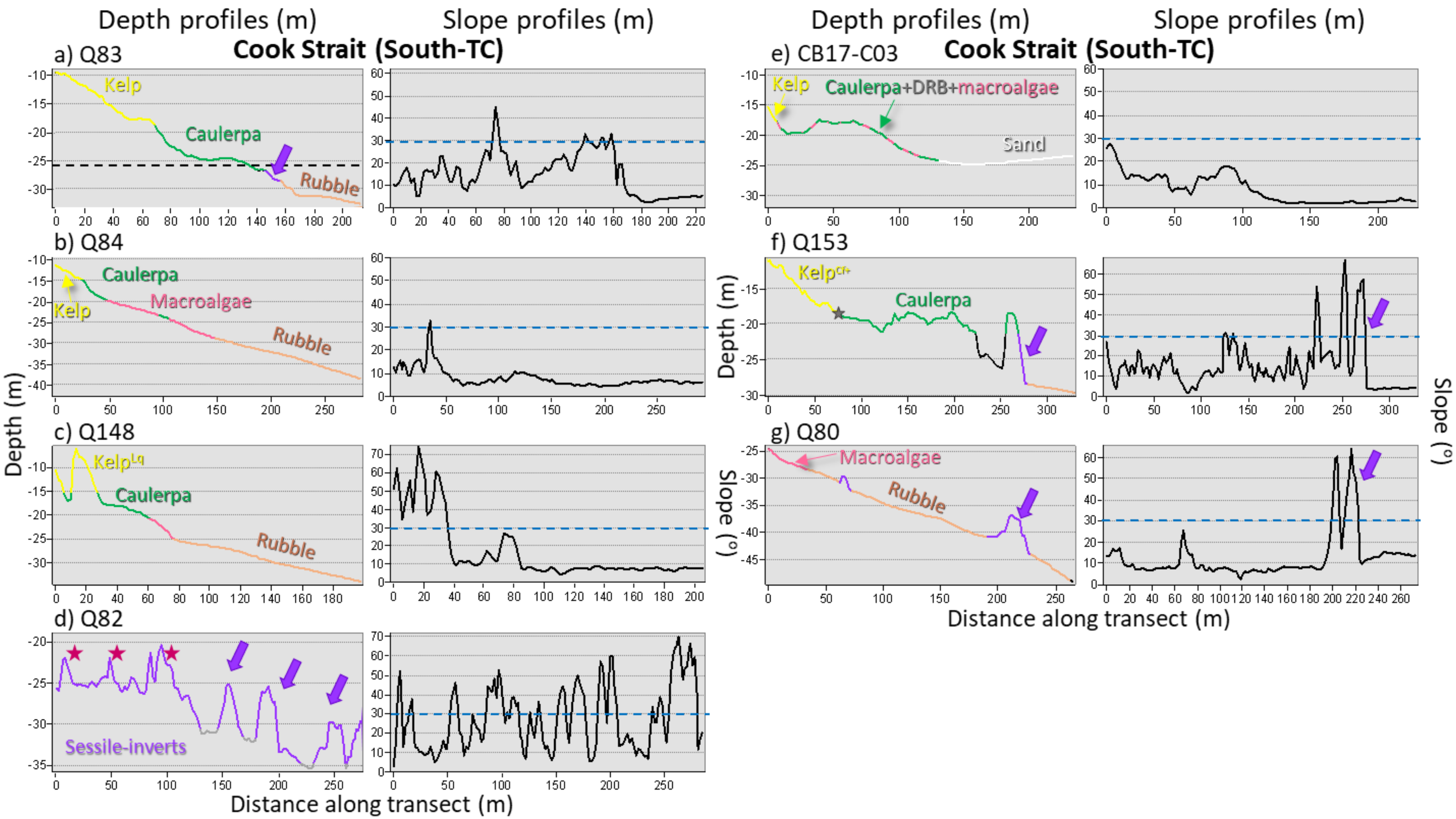


Figure 112: Illustration of habitat zones (depicted by coloured-lines and labels) for each video-transect along the depth profile, with paired slope profiles – for Cook Strait sites adjacent to TC-entrance. Yellow=kelp-zone; green=*Caulerpa*-zone, mauve=macroalgal and kina-barren zones, Tan/brown=low angle slopes with rock-rubble-gravel, purple = diverse sessile invertebrates on deep high-relief reefs. Burgundy stars represent the occurrence of red macroalgal species; grey stars=location of kina barrens; DRB = denuded *Caulerpa* rhyzome base.

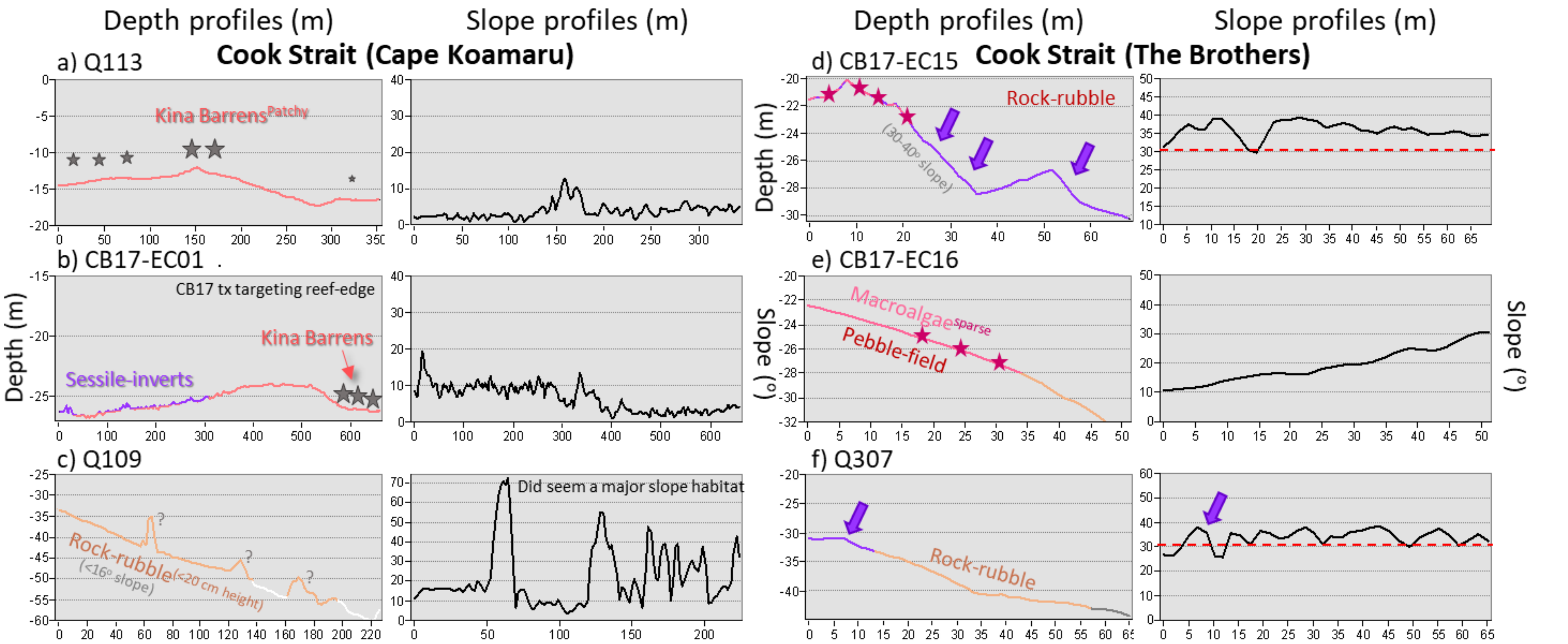


Figure 113: Illustration of habitat zones (depicted by coloured-lines and labels) for each video-transect along the depth profile, with paired slope profiles – for Cook Strait sites south-east of Cape Koamaru (left graphs), and the Brothers (right-graphs). Yellow=kelp-zone; green=*Caulerpa*-zone, mauve=macroalgal and kina-barren zones, Tan/brown=low angle slopes with rock-rubble-gravel, purple = diverse sessile invertebrates on deep high-relief reefs. Burgundy stars represent the occurrence of red macroalgal species; grey stars=location of kina barrens; DRB = denuded *Caulerpa* rhyzome base.

3.6.1 Kelp-forests

The kelp zone in Cook Strait was characterized by mixed large habitat-forming kelps, dominated by both laminarian (*Lessonia variegata*, *Ecklonia radiata*,) and fucoid (*Marginariella* spp., *Carpophyllum flexuosum* and *Landsburgia quercifolia*) species (e.g., Figure 114), that formed dense and often expansive kelp forests. Video transects run perpendicular to shore in the vicinity of TC-entrance (Figure 111c; Figure 112), recorded moderate to high-relief rocky reefs supporting moderate to dense kelp forests in depths <15-17 m that extended offshore to a distance of between 58-163 m (measured as the outer limit of the kelp bed to the shoreline at each video-transect site), although patchy kelp or individual kelp plants were sometimes seen down to 19 m (e.g., Q153).

Coastline reefs adjacent to TC-entrance, supported healthy and often dense kelp communities, although most video-transects had to be terminated soon after entering the kelp zone due to swell and proximity to emergent reefs, however the lower edge of these kelp zone were clearly demarcated, with the kelp beds themselves comprised of variety of mixed and monospecific beds (e.g., Figure 112; Figure 114). For example, sites MDC18-Q84 and Q153 supported forests comprised mostly of *C. flexuosum* with patches of *E. radiata* and *L. variegata*. Site MDC18-Q83 supported a more mixed assemblage of *E. radiata, C. flexuosum, L. variegata* and *L. quercifolia*, while site Q148 supported a dense mono-specific forest of *L. quercifolia*. Although these kelp species often co-occurred at sites, some spatial difference relative to depth across the reefs was recorded.

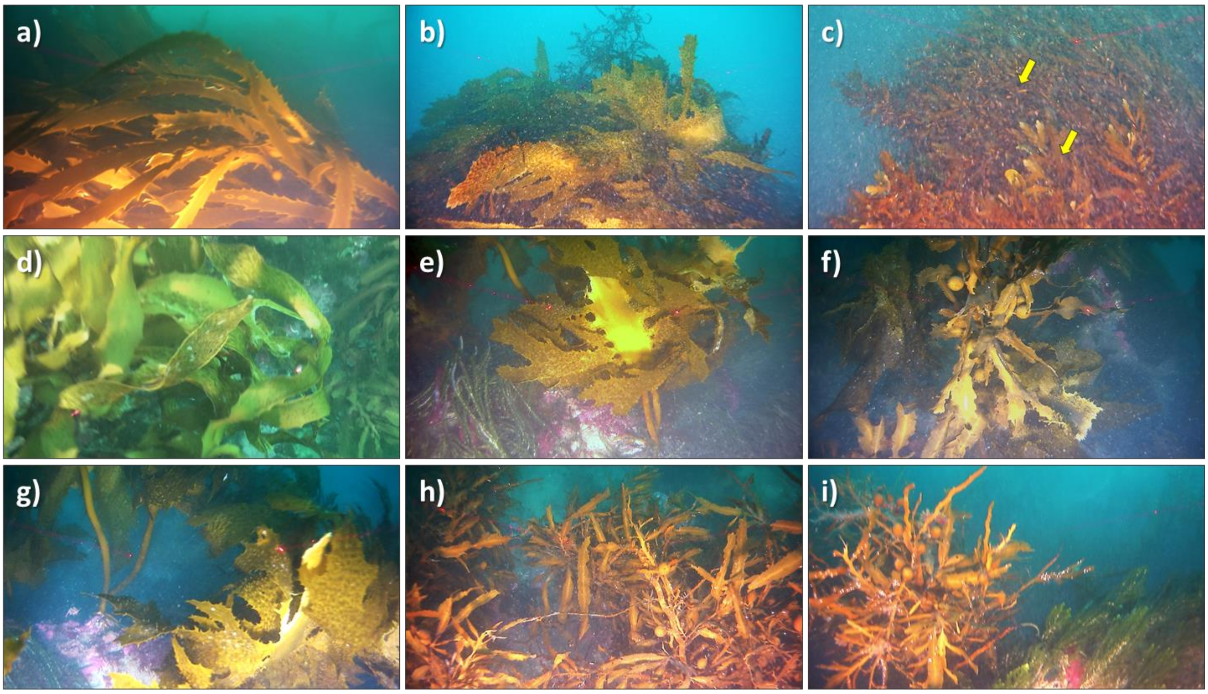


Figure 114: Examples of large habitat-forming kelps along the east coast of Cook Strait. a) *Marginariella urvilleana* (Site EC06); b) *Ecklonia radiata* with *Carpophyllum flexuosum*, and *Lessonia variegata* (Site EC02); c) *L. quercifolia*-dominated forest (yellow arrows, Site EC02); d) *L. variegata*; with *C. flexuosum;* e) *E. radiata* with *C. brownii* (EC05); f) *C. flexuosum* (EC05); g) *E. radiata* with *C. brownii* (EC05); h) *C. flexuosum*-dominated forest (EC04); i) *C. flexuosum* with *C. flexilis* (EC04).

Figure 115: Examples of some macroalgae collected from (BT17 Sites EC10 and EC11). a) *Marginariella boryana* (insert depicting characteristic oval bladders); b) *Lessonia variegata*; c) Pressed specimens ([1-2]*Halopteris;* [3]*C. brownii;* [4] *L. variegata;* [5]*Caulerpa geminata;* [6] *E. formosissima;* [7]*Pterocladia lucida*; [8]*Rhodymenia wilsonii*;[9]*Gymnogongrus furcatus*; [10]*Plocamium* (based on small fragment); [11]Fragment of red blade; [12]*Zonaria*; [13]*Rhodophyllis*; d) *E. radiata*; e) *Zonaria* sp.; g-h) Anemone indet. I) Bluntnose clinid (*Cologrammus flavescens*) belonging to the family Clinidae (or weedfish) is a very rare species -with only 15 specimens ever collected (Andrew Stewart, *pers. comm.*). This single specimen was only collected at this site amongst drift algae along with 4 juvenile leatherjackets (*M. scaber*-not shown here).

Depth zonation was most pronounced at offshore reef sites between Cape Koamaru and Robertson Point. Here, video transects run along the east coast between 100-350 m offshore found the seafloor to be characterised by a rolling landscape of steep pinnacles and well-rounded high-relief rocks (massive boulder-like features) interspersed by narrow gullys of cobbles or coarse sand (CB17 Sites EC20, EC02, EC 04 and EC06)[81]. At these sites, the very tops of high-relief rocks and pinnacles were dominated by dense patches of *Marginariella* (e.g., Figure 114a), with rock walls directly beneath supporting a dense zone of *L. variegata* (e.g., Figure 114d), with often patchy to dense *C. flexuosum* and/or *E. radiata* directly beneath (Figure 114e-i). The deeper sections of these rocky reefs were covered in often extensive and lush vertically meadows of *C. brownii* (see Section 3.2.1 - *Caulerpa*-zone), while the base of these rocks and rock walls were covered in dense invertebrate communities dominated by soft orange-cream coloured bryozoans and sponge gardens (see Section 3.6.6; Figure 123). These findings indicate that kelp beds are not limited to only shoreline reefs in

[81] These reefs were characterised very rounded high relief rocks several metres wide often with steep slopes and rock walls interspersed with sand or cobbles. As many of these transects are beyond the HS51 multibeam maps (CB17-CB02-CB06, CB20), no depth and slope profiles are available for these sites.

this region, but instead may occur further offshore over much larger spatial extents, albeit limited to the shallow sections of offshore rolling reefs.

Although video-transects along the east coast varied in the depths they surveyed (e.g., Table 3-50; Figure 112; Figure 113), those that traversed reefs <17 m, all supported healthy and dense kelp zones, and while not all species were seen at all sites, these large habitat-forming species are known to be a common feature of subtidally reefs on these open wave-exposed coastlines (*review by* D'Archino et al. 2018). Except for the extensive *E. radiata* forest seen near Cape Jackson, this high-current wave-exposed coast supported the best kelp forest communities recorded during all four surveys.

In direct contrast to the video ground-truthing surveys, the HS51 water column and aerial survey data detected no kelp on the shallow rocky reefs in Cook Strait adjacent to TC-entrance. It is unclear why the best kelp forests in the region did not get detected. Possibly high relief reefs in this area may inhibited kelp detection in the water column. The only kelp detected in this region was a single mixed kelp record from 44 m water depth along the outer edge of Te Whētero. Although *E. radiata* has been recorded on rocky habitats to depth of 90 m, no deep-water kelp of any species was observed on this or any other deep reef in this region, indicating that this is likely to be spurious 'detected-kelp' record. It might, however, represent a lost cray pot with a sub-surface rope, as a lost craypot-rope was encountered on this reef, where it was observed to stem from the reef high up into the water column. These significant 'kelp' detection-errors, however, indicate that while water column detection has a lot to offer, its use in detecting 'kelp' requires extensive ground-truthing and appears to be very limited in reef areas with high relief.

Table 3-51: Characteristic features of kelp forests, along the east coast in Cook Strait. CS=Cook Strait; EC# = CB17 sites, Q# = MDC18 sites.

CS: Kelp-forest zone	Characteristic features and significant/notable taxa
Substrata	Moderate to high relief rock reefs in depths <15-17 m.
Benthic community	**Characteristic species (Kelp zone):** *E. radiata* (common, mostly patchy - EC02, EC03, EC04, EC05, EC06, EC15, Q83 with some dense areas - Q83), *C. flexuosum* (common at most sites: patchy – EC02, Q83, EC05, Q83, to dominant - EC02, EC04, EC05, Q153), *L. quercifolia* (common: patchy - EC05, Q148 to dominant and/or monospecific forests, EC02), *L. variegata* (common, either in mixed forests - Q83, or as dense zone below *Marginariella* on rolling rock bathymetry - EC06), *Marginariella* spp. (dense on very tops of rolling rocks, most abundant though at EC06). **Subcanopy:** dominated by encrusting coralline algae (common, all sites), and mixed reds of indet. Taxa (but see species collected in beam trawl listed below). orange and yellow encrusting sponges (<10%, Q153).
BT17 Beam trawl Macroalgae collected in drift mats within Cook Strait (Sites EC11)	**Kelps:** *Marginariella boryana* (1.6 L), *E. radiata* (1.1 L), *L. variegata* (700 ml). **Red algae:** *H. crispatum* (10 L), *E. formosissima* (15 ml), *G. furcatus* (10 ml), *P. lucida* (15 ml), *Rhodophyllis* (10 ml). **Brown algae (sub-canopy)**: *Halopteris* (3 L), *Zonaria* (200 ml). **Green algae**: *Ulva* spp. (1 L), *C. brownii* (100 ml), *Caulerpa geminata* (30 ml). Photos of catch in Figure 115.
Fish	Marblefish (occasional, e.g., EC02, Q153), Scarlet wrasse (common), Oblique swimming triplefin (e.g., EC04), blue cod (few).

Over the broader region from Cape Koamaru to Robertson Point, *E. radiata* was recorded in depths from 4.5 to 16 m - where it occurred in dense patches across most reefs and was also present as isolated patches within the *Caulerpa*-zone. *Landsburgia* was recorded in dense monospecific forests at only a few sites (e.g., inshore at Q148, and offshore on shallower rocks and pinnacles at CB02), while at other sites it was present within multispecies forests (e.g., EC05), and/or as a few isolated plants within the deeper *E. radiata* forest, while at other sites it also occurred as isolated plants within the *Caulerpa* meadows (e.g., Q153). Although dense kelps cover and therefore obscure the seafloor beneath, some subcanopy taxa within the kelp zone (i.e., those species living under the canopy of the kelps) were observed. These were generally represented by a mix of fleshy red macroalgae, with low to moderately dense cover of encrusting coralline algae (NGC), with many of these growth forms also seen in the macroalgal zone too. However, several species of fleshy macroalgae were collected in a beam trawl over drift algae on a sandy site south of TC (Site EC11, See Table 3-51; specimen photos in Figure 115), with some species, such as *Halopteris* seen commonly within the deeper mixed macroalgal zone at some video sites, with other species collected also identified from video at some sites (e.g., *Pterocladia*, *Rhodophyllis* – but see Section 3.6.3). Kina were the most common mobile invertebrate present in low to moderate densities, with densities highest along the outer edge or in deeper rock gullys within this zone (but see Section 3.6.4 - Kina-barrens).

3.6.2 *Caulerpa* meadows

Immediately below the kelp-zone, a dense zone of *Caulerpa* spp. was present at most sites in depths <20 m, with *Caulerpa* spp. recorded in depths of 7.4 to 26.8 m (mean depth 19.2 m ± 0.54 m SE) (Figure 112). *Caulerpa* often formed extensive meadows on the tops of reefs and down rock walls in this depth zone (see Section 3.2.1 for a more detailed presentation of *Caulerpa* meadows across the entire survey area). The most notable *Caulerpa* meadow was at site MDC18-Q153, where it extended ~243 m away from the shoreline across an extensive reef, with the nearshore edge of the meadow starting in~12.3 m and ending at the outer edge of the reef in 19.3 m, although *C. brownii* meadows were also recorded down the steep sides of rock ridges, within the reef matrix, to depths of ~26 m (Figure 112f; bottom left graph in Figure 117b; but also, incl. e.g., Figure 11f-h). In contrast, although three *Caulerpa* species were identified at the Brothers (≤1-12% cover), no *Caulerpa* meadows were seen at either the Brothers or Awash rock – however depths <20 m where *Caulerpa* meadows might occur, were not surveyed at these sites.

Within Cook Strait *Caulerpa* densities varied within and between sites, but mostly commonly occurred as ~30-100% cover within the *Caulerpa*-zone. Although identification of *Caulerpa* meadows in the video was easy, determining species-level identifications was much harder, as the frond morphology – that distinguishes species - was often not visible when the fronds were moving in the swell. However, identification of species in some areas was possible and indicated that shallower depths were generally characterized by *C. flexilis* , with *C. brownii* present in deeper zones (see Table 3-4 for details per site and Section 3.2.1). Extensive flat-topped reefs, such as the one at Q153, were covered in several cm’s of sediment, with very few other sessile or motile species recorded in this zone. However, where rock was exposed and *Caulerpa* densities were high, only low amounts (2-10%) of co-occurring species were seen that included coralline algae (NGC) and fleshy red algae, with rare occurrences of kina and *A. mollis* (see Table 3-52 for full species list). Several species of large kelps (e.g., *E. radiata, C. flexuosum* and *Landsburgia*) were also recorded within the *Caulerpa* zone, but these were generally limited to a few solitary or small clusters of plants (e.g., Figure 11e), while sparse densities of stalked sea tulips were also present on most high-relief/vertical rock walls in both the kelp and *Caulerpa* depth-zones. At other sites (e.g., EC02, EC03 and EC04), large numbers of denuded *Caulerpa* rhyzomes were visible across the reef with only a few blades left attached. In these areas, notably higher quantities of co-occurring flora were recorded, dominated by a mix of fleshy and bladed red algae and the brown algae, *C. costata* and *Halopteris*.

Over the broader region from Cape Koamaru to Robertson Point[82], *Caulerpa* was the most dominant macroalgae seen within the rolling landscape of high-relief well-rounded rocks (Figure 116b-c, Figure 11f-h). Within this zone it formed an often dense and lush cover across most mid-depth rocks including steep and vertical walls (Figure 116a-c). However, at many sites notable numbers of denuded rhyzomes were also seen (Figure 116f-i), as well as sediment within the rhyzome matrix of both denuded (Figure 116) and healthy plants (e.g., Q83, Q153; Figure 116d) – indicating that the high relief reefs adjacent to TC-entrance and the rolling rocky-reef landscapes down the east coast are exposed to significant sediment scouring and periods of burial. *Caulerpa* is known to occur on reefs where sediment burial and scour occur and is one of the few species able to tolerate such conditions. However, the extensive loss of blades, especially across some lower-lying rocks indicates that these areas are likely to undergo substantial disturbance due to sediment scour and re-occurring burial, but as rhyzomes can re-grow blades these may reflect boom and bust cycles in growth, with deeper zones closer the seafloor likely incurring more frequent disturbance. Where denuded rhyzomes were common, notably more fleshy-red macroalgae and/or sessile invertebrates, such as orange soft bryozoans were seen (see Table 3-52 for full taxa list).

Table 3-52: Characteristic features of *Caulerpa* meadows, along the east coast in Cook Strait. CS=Cook Strait; EC# = CB17 sites, Q# = MDC18 sites.

CS: *Caulerpa*-zone	Characteristic features and significant/notable taxa
Substrata	Flat top reefs and tops of rock walls, often with thick veneers of fine sand covering the rock (e.g., EC02, Q153).
Benthic community	**Characteristic species (*Caulerpa* meadows):** Dominated by moderate to dense cover of *Caulerpa* spp. either *C. brownii* (patchy to dense lush meadows e.g., EC02, Q83, Q84, Q153), and/ or *C. flexilis* (patchy – EC04, to dense lush meadows - EC02, Q83, Q84 Q153). Denuded *Caulerpa* rhyzomes at many sites, e.g., EC02, EC03, EC04); and rocks thickly covered with sand in amongst rhyzomes (most notable across the extensive reef top at Q153). **Other species:** Encrusting coralline algae (common <3-15% - Q153, Q83), Encrusting yellow or orange sponge (<2% - Q153, Q83), Solitary cup corals (rare patch, Q153), *C. costata* (rare patches, Q153), *P. pachydermatina (*occasional, Q153, Q83), large kelp species: incl. *E. radiata* (occasional, Q83, Q153), *C. flexuosum* (occasional, Q153), *L. quercifolia* (occasional, Q153, Q148), *L. variegata* (occasional, Q83), Yellow zooanthids (small patch at Q83), Soft cream bryozoans (small patch at Q83), Red filamentous algae (indet. <2% at Q83), Mixed fleshy algae (patches <15% at Q83), pink ball sponges (*Aaptos* sp. rare Q83 x1), yellow papillate (*Polymastia* cf *crocea,* rare Q83 x1).
Motile invertebrates	Kina (few local clusters mostly in gullys, Q153), sea cucumber (*A. mollis*, frequent, Q153), snake star (rare Q153, Q83).
Fish	Scarlet wrasse (rare, Q153, few at Q83), Marblefish (e.g., Q153), Oblique swimming triplefin (few, Q153), Butterfly perch (Q83), Banded wrasse (Q148).
Other	Rope line (Q83).

[82] including those sites beyond the mapped area.

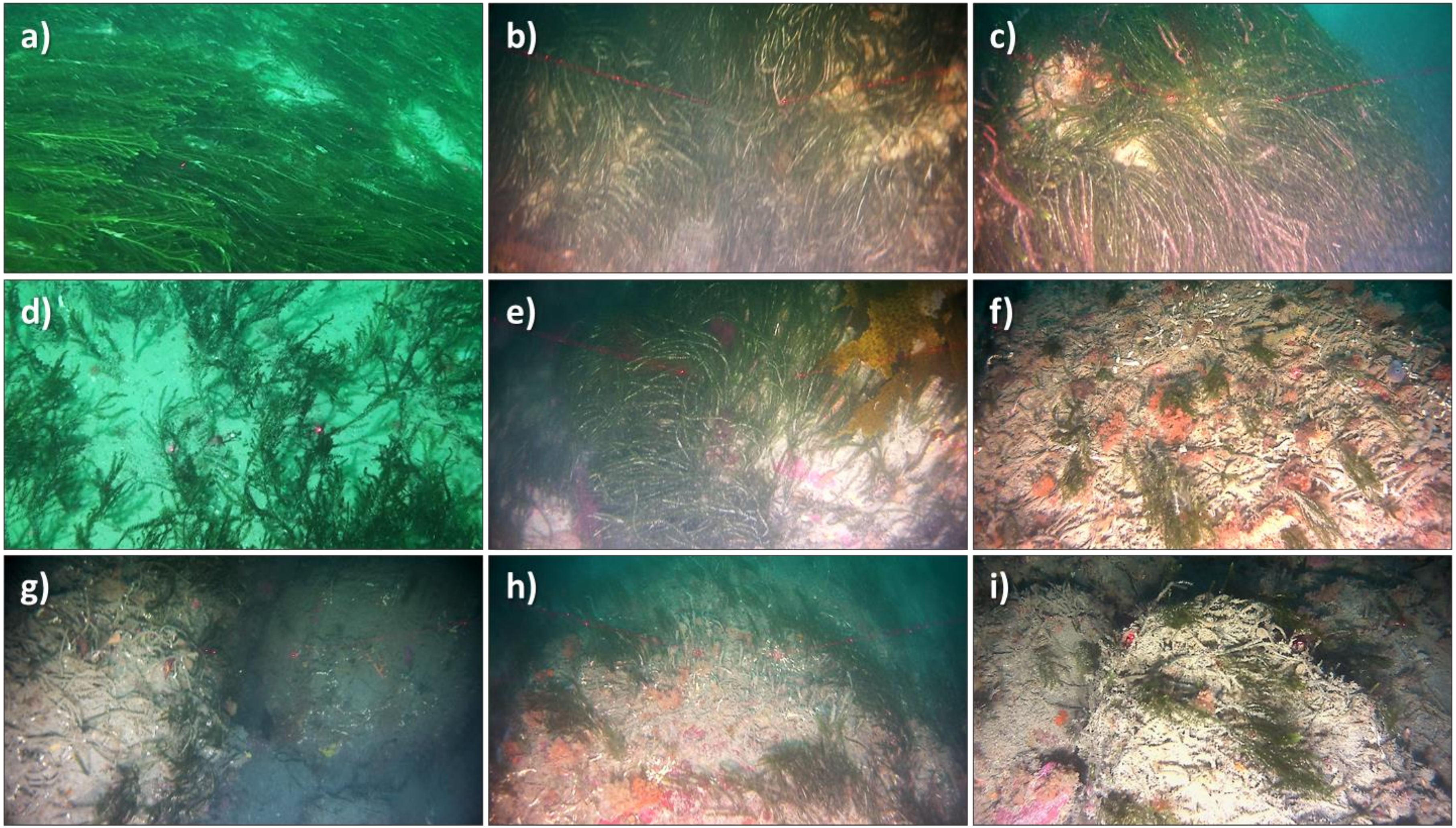


Figure 116: Examples of *Caulerpa* spp. meadows along the east coast of Cook Strait. a-c) examples of lush *Caulerpa* meadows, d-e, g) examples of sediment covering the reef and/or rhyzomes; f-i) examples of denuded rhyzomes and sediment within the rhyzome matrix of denuded and healthy plants.

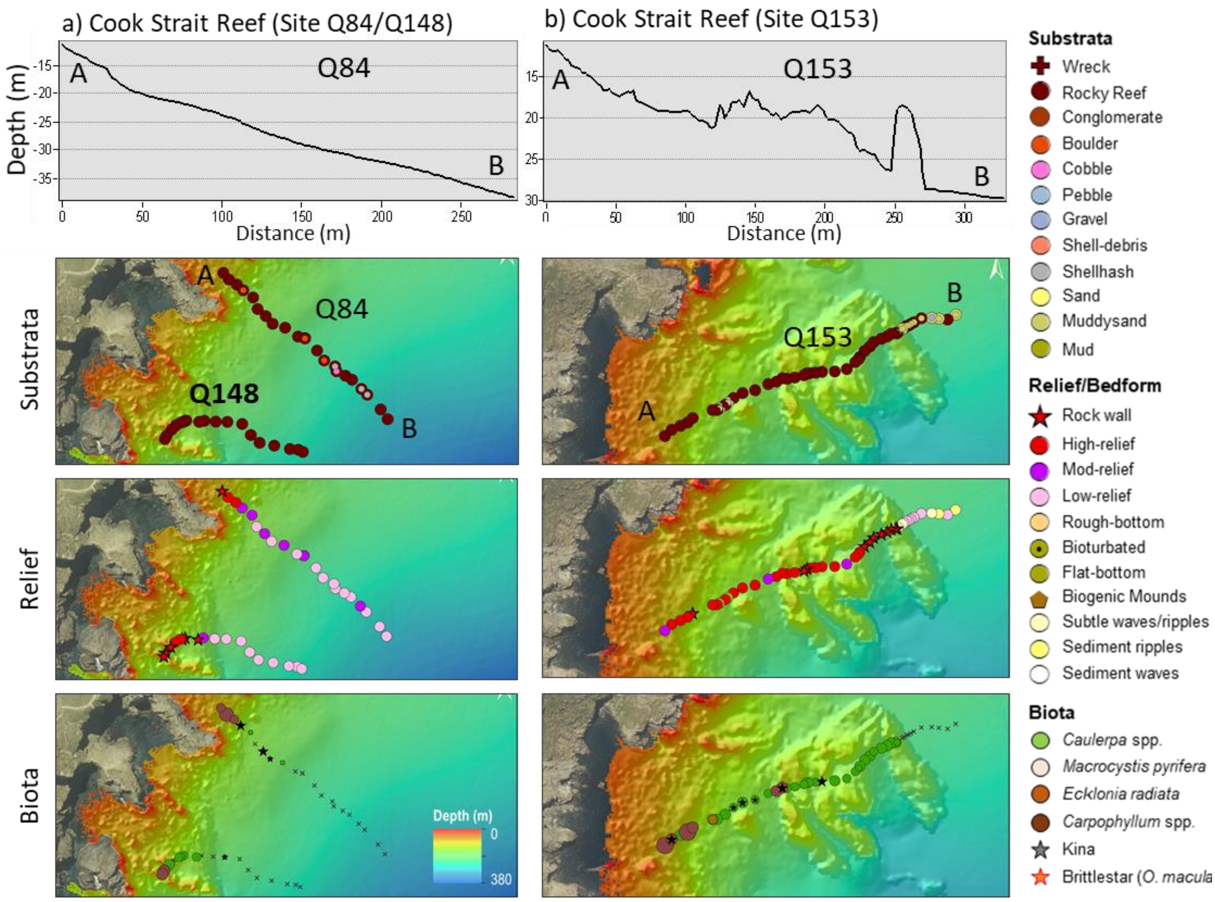


Figure 117: Example of reef depth profiles, substrata composition, relief and mixed kelp communities for three video transects in Outer TC and adjacent Cook Strait. A and B on the top two rows of graphs indicate the start and end of depth profile. a) Cook Strait reef, north of East Head (Site MDC18-Q153); b) Reef on southern side of TC entrance, near West Head (Site MDC18-Q153); c) Cook Strait reef south of West Head (Site MDC18-Q84 and Q148).

3.6.3 Mixed-macroalgal assemblage

Macroalgae were present on a range of rocky reef outcrops and reef slopes (e.g., Figure 118; Table 3-53) commonly dominated by branching brown algae (e.g., mostly *Halopteris* spp. and *C. costata*) along with a range of mixed red algal species including thin bladed and strappy red algal growth forms (e.g., *Rhodophyllis*, *Hymenenae*, *E. formosissima, P. lucida*), with some filamentous reds at some sites (e.g., EC04), and patchy occurrences of the green algae *C. brownii, C. flexilis and C. geminata* (<1% cover at only a few sites), and some case present as denuded rhyzomes (see Table 3-53). The mixed macroalgal zone was common in depths of 15-20 m, in low to moderate % cover (≤50%, often ≤20-30% cover; e.g., Figure 118) with some species also likely to occur beneath the kelp-canopy in shallower depths, and other low-light tolerant species may occur deeper (depths seen to 24 m on Q82). Fleshy mixed macroalgae were most commonly recorded beneath and along the lower edge of the *Caulerpa*-zone – most notably on the rolling rocks down the eastern coast (e.g., CB20 down to CB06, 15-20 m); as well as on the upper reef slopes at the Brothers (EC15, 15-20 m) and Awash Rock (dropcam at HS51-E01, ~20 m); across some low-lying broken reefs on the coastal reefs adjacent to TC-entrance (e.g., Q83, Q148, EC03); and on the shallower sections of high relief rocks at the entrance to Tory channel (Q82). Many of the red macroalgae were not taxonomically identifiable from video at most sites and would require further studies to verify species and to accurately document species distributions. Some macroalgal zones also supported a suite of sessile invertebrates that included soft- orange-coloured bryozoans, encrusting yellow and orange sponges and an assortment of other small sessile fauna. Notable areas with both macroalgae and sessile invertebrates were recorded at the Brothers and Awash Rock (EC16 and HS51-E01), on the lower base of rolling rocks along the south coasts (e.g., Figure 118h; especially at EC04 and EC20). A single short-duration (<1 min) drop camera that was surveyed in 20 m at Awash rock (e.g., Figure 118k), recorded encrusting coralline algae (20-50% cover), bladed-coarse branching red alga (poss. *Euptilota formosissima* ≤ 20% cover) and fleshy brown algae (poss. *Halopteris*); along with yellow and orange encrusting sponges, orange soft bryozoa, mixed hydroids, cream-orange zooanthids, and a few large *grey E. alata* sponges. On the upper reef slope at the brothers (Figure 113e, slope angle of ~30-40^0) in surveyed depths of >20 m, the macroalgal zone was present down to ~23 m, with variable low to moderate cover (≤50% combined macroalgal cover), characterised by fleshy brown macroalgae (≤ 30% cover, with mostly *Halopteris*, and some *C. costata*), a variety of fleshy to fine-bladed red algae - mostly undetermined species (≤ 20% combined cover; incl poss. *E. formosissima*, *Hymenene* spp. and *Rhodophyllis*), as well as occasional green algae (incl. *C. fragile* [occasional], C*. brownii* [<20% cover], *C. flexilis* [<1%] and *C. geminata* [<1% cover]) and a few *E. radiata* kelp plants, all growing along-side a suite of diverse and colourful sessile invertebrates. Many of these sessile invertebrates were also seen at 20 m on Awash rock, including yellow and orange encrusting sponges, orange soft bryozoa, mixed hydroids, *grey E. alata* sponges, with the additional occurrence at the Brothers of small patches of encrusting bryozoa (*C. agglutinans*, ≤1-5% cover) and tube anemones (which also were present across the deeper invertebrate slope).

Although many macroalgae could not be taxonomically determined a few notable species were recorded. These included *L. hookeri*, due to its very distinctive veined blades (e.g., Figure 118i) was characteristic, albeit in low % cover (<3-5% cover), of two low-relief sites: one adjacent to TC-entrance (EC03) where it was growing along the edge of the reef on broken rock interspersed with sands, and at another site on the pebble-covered sloping shelf at the Brothers (EC16). A bed of *Adamsiella* sp. was also recorded over a notable area of cobbles and pebbles covered in sands on the southern side of Glasgow Bay, 12 km south of TC-entrance (CB17-EC05, located inshore of Lat. -41.30011, Lon. 174.23437; see map Figure 110; Table 3-50). This video-transect began in sand and quickly traversed over the sand-covered pebble field with increasing % cover of *Adamsiella* sp. (≤30-70% cover), before crossing up over the nearshore-reef covered in kelp.

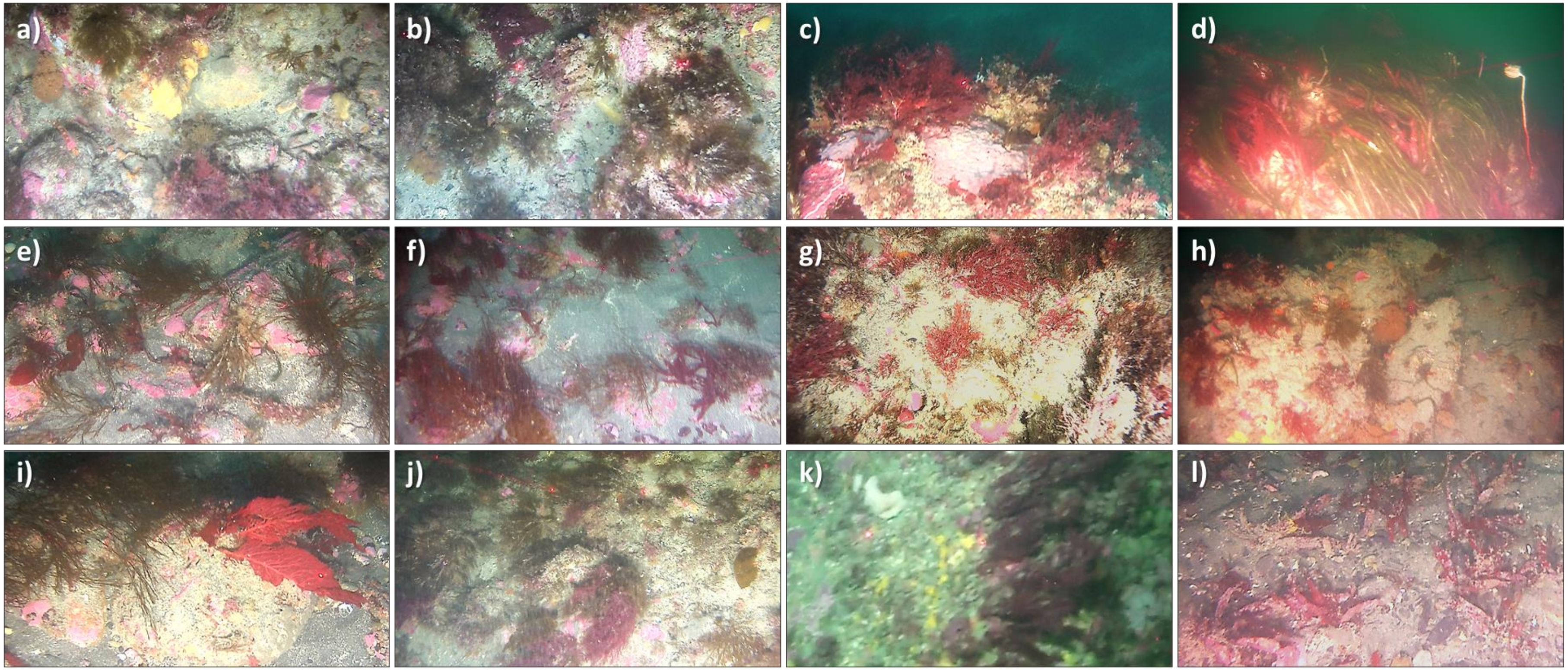


Figure 118: Examples of mixed macroalgae zone in Cook Strait. a-b) NE slope off the brothers (EC15); c-d) Rolling high-relief rock features along the east coast (sites CB04 and CB06, south of TC); e-f) low-lying rock and sand along reef edge directly north of TC (CB03), with *C. costata* and *Halopteris* and bladed and strappy red algae (poss. *Galene* [e] and poss. *Sarcodia* [f]); g) Mixed flesh macroalgae with *Halopteris* and bladed reds (poss. *Euptilota formosissima*, EC20); h) Mixed flesh macroalgae with *Halopteris* and bladed and filamentous reds (EC04); i) distinctive red bladed alga, *L. hookeri* and *C. costata* on low-lying rock at reef edge (EC03); j) reef with *C. costata* and *Halopteris* and fine bladed red algae (EC15); K) exposed reef at 20 m, Awash Rock (HS51-E01); l) *Adamsiella* sp. meadow growing over a large pebble and sediment zone (CB05, south of TC).

Table 3-53: Characteristic features of mixed macroalgal assemblage in Cook Strait. CS=Cook Strait; EC# = CB17 sites, Q# = MDC18 sites.

CS: Macroalgal zone	Characteristic features and significant/notable taxa
Substrata	Rock reefs, reef slopes and broken rock interspersed with sand, mostly in depths of 13-20 m, but some fleshy macroalgae seen to depths of 26 m.
Benthic community	**Characteristic species (macroalgal zone):** mixed macroalgal species, dominated by fine branching brown algae, encrusting coralline algae (common, all sites), along with a variety of fine branching bladed and strappy red algal growth forms, with some patches of *Caulerpa* and other branching green algae. **Brown algae:** *Halopteris* (common at most sites), *C. costata* (occasional (e.g., EC02) to common – most sites e.g., EC03, EC15, CB16, EC20, EC04), few isolated kelp plants incl. *E. radiata* (e.g., EC15) and *L. quercifolia* (Q83). **Red algae:** Encrusting coralline algae (common at all sites, 5-70% cover), most reds undetermined from video footage, but included: *L. hookeri* (EC03, EC05 and EC16), strappy red (looked-like *Sarcodia*, few at EC03, EC05), several fine bladed growth forms (e.g., EC20), strappy/bladed reds (poss. *Rhodophyllis,* EC13), iridescent reds (poss. *Hymenenae,* common), *Pterocladia* (verified at EC16), broad bladed reds (poss. *Callophyllis,* EC03), Strappy reds with veins (poss. *Schizoseris*, EC05, EC20; and poss. *Euptilota formosissima* at HS51-E01; EC15 and several coastal sites, e.g., EC05), *Asparagopsis* (EC05), *Adamsiella* sp. (only at EC05, but present as a notably-size moderately-dense meadow). **Green algae:** *Codium fragilis* (e.g., occasional at EC15, frequent at EC02), *Caulerpa* spp. (1-30% cover in macroalgal zone including, *C. brownii and C. flexilis* (e.g., <2% EC15), *C. geminata* (e.g., <1% EC15), *Codium fragilis* (occasional, EC02, EC15).
Sessile Invertebrates	Diverse suite of sessile invertebrates. Most commonly cream-orange colour soft bryozoa (≤20% cover), orange and yellow encrusting sponges (<10%, Q153), *grey E. alata* sponges at some sites (e.g., EC15), but more diverse communities mostly on sloping reefs (e.g., EC15 an HS51-E01 – species listed in text above).
Motile invertebrates[83]	Kina (sparse-low densities most sites, e.g., Q84, Q148) and *A. mollis* (rare only at Q83 and Q153, but few at Q84), various starfish (e.g., 7-armed starfish, cushions stars spp., incl. *C. muricata* e.g., few at Q84, EC15).
Fish	Scarlet wrasse (common), Marblefish (occasional, e.g., EC02, Q153), Oblique swimming triplefin (e.g., EC04), blue cod (occasional, but several at EC15), various triplefins (e.g., black-and-yellow and common triplefins at EC15).
BT17 Beam trawl Macroalgae collected in Cook Strait (Sites EC11)	**Red macroalgae:** *H. crispatum* (10 L), *E. formosissima* (15 ml), *G. furcatus* (10 ml), *P. lucida* (15 ml), *Rhodophyllis* (10 ml). **Brown macroalgae (non-kelp)**: *Halopteris* (3 L), *Zonaria* (200 ml). **Green macroalgae**: *Ulva* spp. (1 L), *C. brownii* (100 ml), *Caulerpa geminata* (30 ml).

[83] Snake stars notably absent from this habitat-zone in Cook Strait.

3.6.4 Kina barrens

Although kina were present at most sites, densities were mostly low, and notably less than those seen at the inside entrance to TC (see Section 3.4.3 – Kina barrens in TC). Some sites in Cook Strait supported kina in small localized clusters, mostly along the outer edge of the kelp-zone (e.g., EC04 and Q153 - Figure 119d,e respectively, also see profile in Figure 112f); and while the rocks in these areas were covered only in encrusting corallines (indicative of kina-barrens), these zones were very narrow, with kina-densities comparative low. On exposed coastal reefs with higher-relief, kina occurred across the mid to upper sections of these reefs in mostly low numbers, with higher numbers seen in gullys within the kelp-zone. Kina were also recorded on deeper rock and rubble sites but only sporadically. In contrast, however, two Cook Strait sites south-east of Cape Koamaru (Sites CB17-EC01 and MDC18-Q113) supported notably higher densities of kina across a low-relief cobble and rock seafloor, with the end of transect EC01 supporting very high densities rivaling those seen within TC (≤~25 kina per m^{-2}: Figure 119a-c; Figure 120, 1a-c). Site MDC18-Q113, which was ~650 m northwest from site EC01, also supported notable densities of kina, with low-lying rock surfaces (Figure 120, 1a-c) dominated by encrusting coralline algae devoid of fleshy macroalgae, with patchy reefs interspersed with coarse sands and accumulated *Tucetona* shell debris. However, kina densities at this sites were markedly lower (≤16 kina per m^{-2}, e.g., Figure 119f).

Both sites were located ~150 to 300 m offshore, within 0.6 km and 1.2 km south-east of Cape Koamaru. Although no rocky reef was delineated this far offshore in the HS51 reef layer, and there was only a very week rugosity signal, the hillshaded-relief layer shows an extensive rough area across this zone that matches well with the video characterisations, indicating that these low lying patchy reefs appear to extend an estimate 0.5 km offshore and ≥~1.5 km alongshore. Although this habitat may be prevalent, it is unclear how extensive the kina-barren zone may be, even within these sites there was considerable patchiness in kina occurrence and densities, indicating that densities of kina may be quite variable across this low-lying cobble-rock zone.

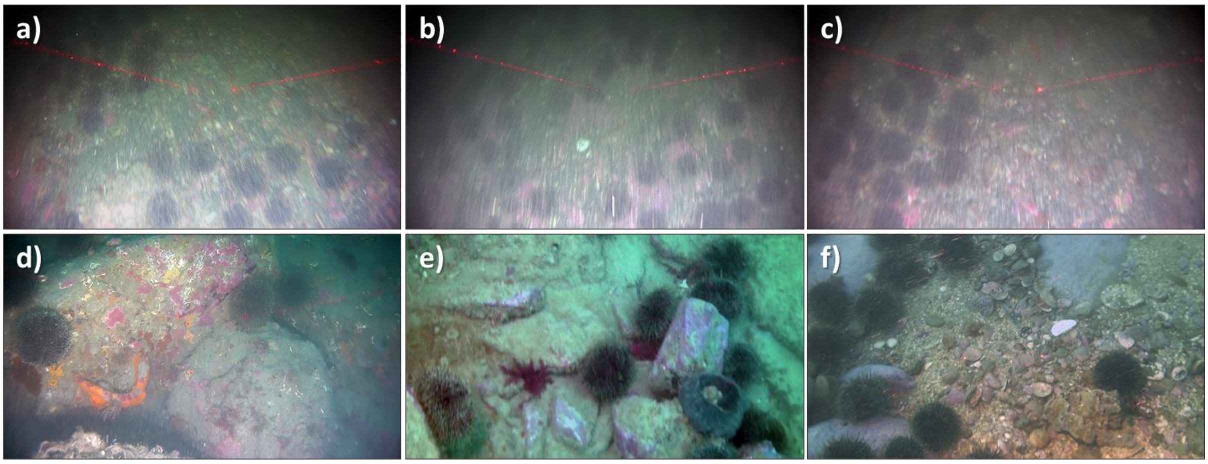


Figure 119: Examples of kina barrens in Cook Strait. a-c) High densities of kina across low-relief rock and cobbles, 1.2 km south-east of Cape Koamaru in 14-16 m depth; d) High localized densities of kina on and around large round-rock terrain, at Lucky Point, 6.5 km south of TC-entrance (CB17-C04); e) Localized clusters of kina within a narrow zone between the shallower kelp forest and deeper *Caulerpa* meadows at MDC18-Q153 (0.7 km north-east of TC-entrance, 17-19 m depth); f) Dense clusters of kina on low-lying rocks, 0.5 km south-east of Cape Koamaru in 13-16 m depth.

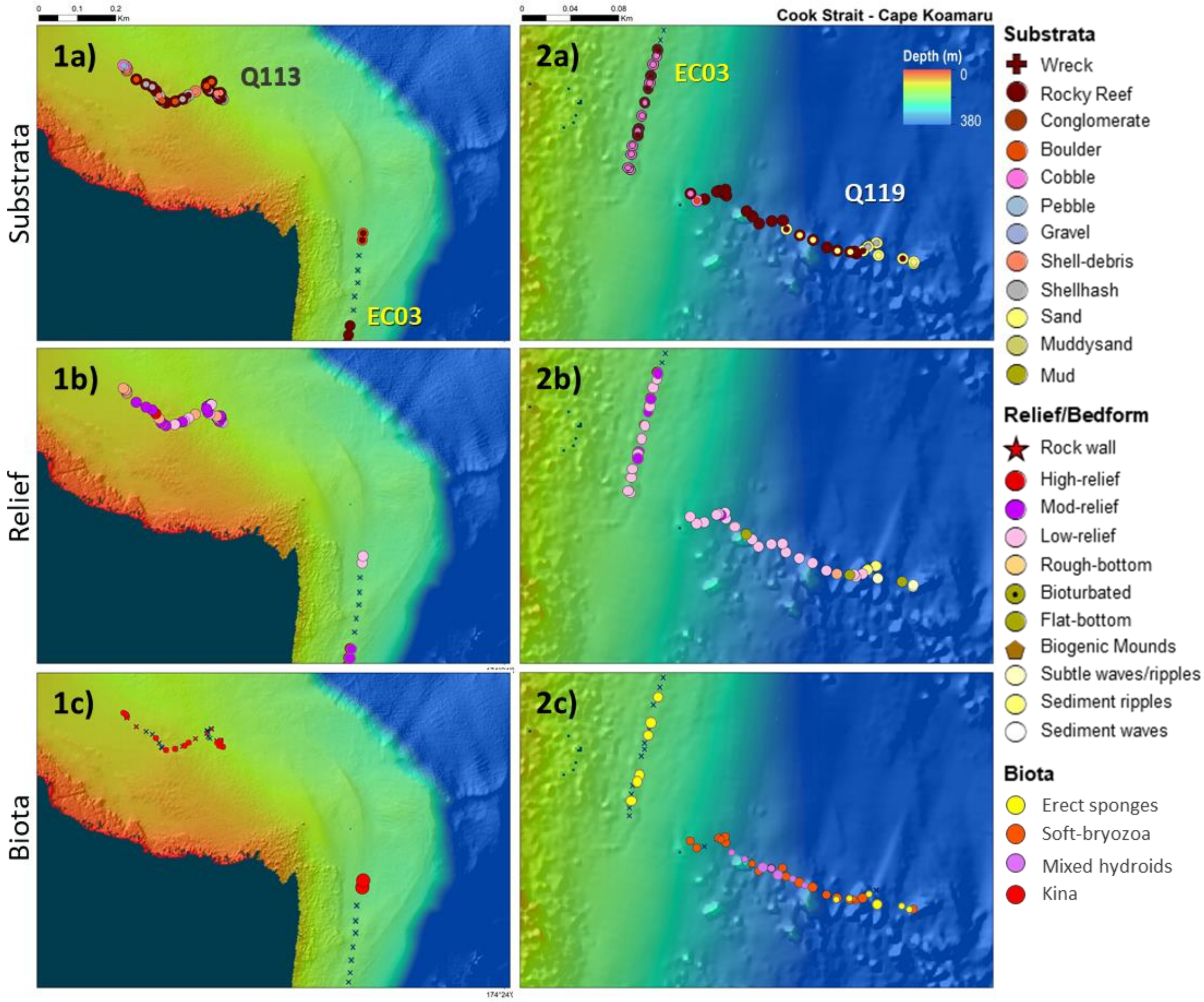


Figure 120: Substrata composition (a), benthic relief (b) and occurrence of key (c) taxa along three video transects surveyed south-east of Cape Koamaru, Cook Strait. Graphs 1a-c) show the location and benthic characteristics along transects MDC18-Q113 and the northern end of CB17-EC03; 1c) depicts kina (*E. chloroticus*) distributions within kina barrens (red bubbles). Graphs 2a-c) show the location and benthic characteristics along transects MDC18-Q119 and the southern end of CB17-EC03; 2c) Depicts the distribution of erect sponges (yellow bubbles), mixed hydroids (purple bubbles), and Orange soft bryozoa (orange bubbles).

3.6.5 Deep reef (sessile invertebrates)

Like the deep-reef slopes inside TC, similar sessile-invertebrate dominated communities were found on deeper (>20 m) sections of steep (>30-70° slope angle) reefs in Cook Strait (Figure 116). Although, these reefs supported many similar species, including *grey E. alata* sponges, orange soft bryozoans, stalked ascidians and deep encrusting coralline algae, deep reefs in Cook Strait differed by supporting more zooanthids and jewel anemones along with a variety of sponge garden species (see Table 3-54), many of which were also found on the deeper offshore reefs in Cook Strait (see Section 3.5.1). Sponge garden species here included *P. cf massalis*, *Polymastia* cf *crocea*, *Aaptos* sp., *P. sinclairii*, *S. crater*, and cf *P. beresfordae* sponges (see Table 3-54 for full taxa list). However, unlike the deeper offshore reefs, no massive white-coloured *E. alata* sponges were observed nor any goose barnacles. Although deep reefs in this region appeared to support very high sessile invertebrate diversity, with moderately dense to dense cover across the reefs, with both diversity and cover much higher than those seen on the deep-reef slopes within TC, diversity and coverage appeared to be somewhat less than that seen on the much deeper Cook Strait reefs (esp. Cook Rock) indicating a gradient in diversity between these three regions that likely reflects a combinations of depth and location.

Deep high-relief reefs were prevalent off East and West Heads along the outer entrance to TC (e.g., MDC18 sites Q80, Q82, respectively), with reef profiles identifying pinnacle feature with steep near-vertical walls towering 10-15 m high in some locations. Off West Head, an extensive reef feature spans a width of ~192 m wide and extends ~465 offshore to a depth of ~60 m where it connects to Te Whētero. To characterise this reef we ran a 265 m long video transect (Q82) from near the lower southern edge of the reef in 38 m up the reef slope towards the shoreline of West Head, ending in 23m water depth ~ 90 m from shore (see Figure 111c; Figure 116d). This site was characterised by a series of 5-10 m high steeply sloping to vertical reef walls and pinnacles (Figure 116d) separated by narrow gullys covered in small smooth-rounded pebbles. The upper slopes and tops of these reefs supported the richest sessile communities recorded from this coastal region. At the shallower end of the transect in depths <26 m increasing amounts of fleshy bladed red algae (5-40% cover) was seen amongst the sessile filter-feeders. This looked to be *E. formosissima,* but is leaf morphology could not be verified from the video footage. The opposing side of TC-entrance, East Head also has an equally extensive reef that spans a width of ~380 m and extends ~369 m offshore, where it also connects to Te Whētero. While we had planned to run a transect straight up the middle of this reef, instead, due to cray pot sets, the 258 m long transect (Q80) only briefly skirted the eastern edge of this reef (Figure 111c). However, the high-relief section of reef we did traverse, albeit briefly, supported similarly diverse sessile filter feeders characterised by the same sponge garden species as those seen off West Head (see Table 3-54), indicating that the extensive deep reefs off East Head would be predicted to support similar and extensive deep-reef communities with depth >25 m where reef slope was >30^{o} – which based on the HS51 maps is most of this deep reef feature. Site Q82 and almost all the deep reef feature off West Head lies within ESMS-5.9. Although Site Q80 was outside ESMS-5.9, the majority of this large reef feature off East Head also lies within ESMS-5.9.

Deep reefs beyond TC-entrance were not common (at least within this mapped area adjacent to TC-entrance). While many of the shallow nearshore reefs had high vertical relief (upon which kelp-forests flourished), reefs further offshore in depths >25m were much rarer (Figure 116). However, two sites (Q83 and Q153; Figure 116a,f respectively) had very brief sections of high relief reef in water depths >25 m where max. slopes were greater than the requisite 30^{o}. Predictably these sites also supported similar sessile-invertebrate species to those seen at East and West Heads, albeit over a very minimal distance (<3-10 m). This deep reef zone was recorded along the outer reef-edge at both sites and was limited to the steep but brief outer slope of these reef, where the shallower reef tops (<20 m water depth) and were densely covered in *Caulerpa* meadows.

Fish fauna on these deep reefs were relatively depauperate, characterised by a few schools of butterfly perch, red banded perch, scarlet wrasse and black and yellow triplefins, along with a few sea perch, dwarf Scorpionfish , blue cod, and marblefish (Table 3-54). Very few crayfish were recorded in Cook Strait, but are likely under-represented in our video-characterisations of Cook Strait reefs due to the inability of the tow-video to venture down into the many deep ravines and crevices present on these high-relief rocky reefs, without getting snagged. However, this areas appears to be targeted by the cray-fishery, as is evident by the high number of crayfish-pots set on these reefs (*pers. obs.*).

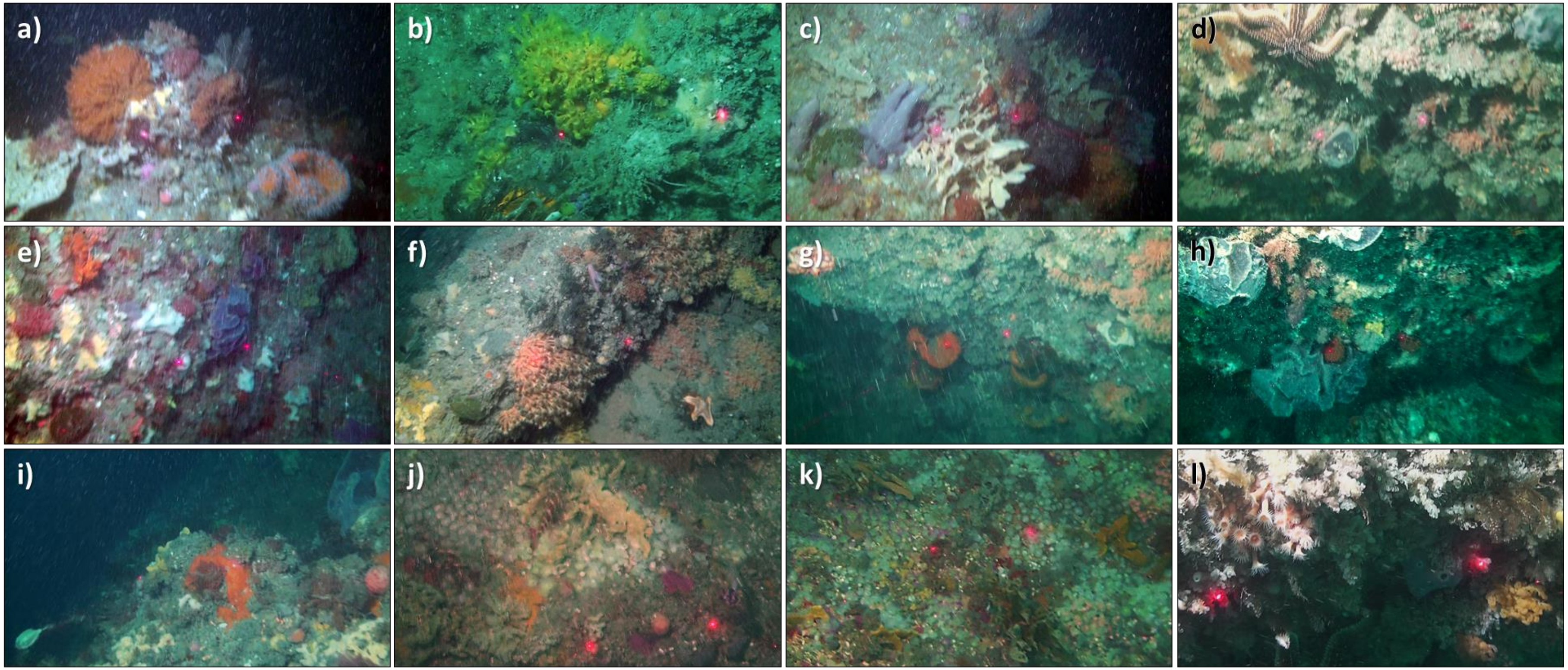


Figure 121: Examples of the deep high-relief reefs supporting rich and colourful sessile invertebrate communities off East and West Head, at the entrance to TC. a-c) Deep reef off the south-east edge of East Head (MDC18-Q80), with examples of diverse sponge garden species: incl. orange cup sponges (*S. crater* [a]), along with yellow zooanthids [b] hydroids and orange soft bryozoa [a], and diverse colourful sponges [c]; d-l) Extensive deep reef off West Head (MDC18-Q82), with steep walls covered in diverse invertebrates, including colourful arrays of sponges [e], yellow and pinky-orange zooanthids [f-g,l], jewel anemones [j,k], *E. alata* sponges [f,g], *P. pachydermatina* [i]; fern-like hydroids and cream coloured soft bryozoa [l], along with sponge garden species (e.g., *S. crater* [g,i] and *Aaptos* sp. [i,j) that are also present on deeper offshore reefs.

Table 3-54: Characteristic features of deep nearshore reefs, along the east coast and at the Brothers and Awash Rock, in Cook Strait. CS=Cook Strait; *indicates that deep reefs habitats only occurred in some small section of these sites. EC# = CB17 sites, Q# = MDC18 sites.

CS: Deep reefs	Characteristic features and significant/notable taxa
Substrata	Moderate to high relief reef in depths ≥20 m, with rock walls and reef tops common, vertical pinnacles at some sites (e.g., Q82), with max. slope angles 30-70°. Deep reefs were present at sites Q80, Q82*, Q83*, Q153*, Q307*, HS51-E01*, EC01*, EC04*. Pebbles and/or shell debris in gullys (Q82). Some deep reefs (>20 m) were also recorded at some rolling rocks sites along the exposed east coast (e.g., EC01*see Figure 123, EC20*, EC04*, EC06*).
Benthic community	**Characteristic species (Deep reefs):** Community characterised by diverse and colourful sessile invertebrates, with characteristic yellow and pinky-orange coloured zooanthids (few at Q80, abundant at Q82) along with jewel anemones (abundant large patches at Q82) and diverse sponge garden species with varied growth morphologies. **Sponges:** *P. cf massalis* (few at Q80, Q83, *Q307, frequent at Q82), *P.* cf *crocea* (few at Q82, Q83), pink *Aaptos* sp. (few at Q80, Q83, common at Q82, EC01, EC04), orange ball sponges (*Aaptos* sp2, few at Q83), *P. sinclairii* (few at Q80, Q83, Q153, common at Q82), *S. crater* (few at Q80, Q83 common at Q82), grey-*E. alata* (frequent at Q82, E01), misc. erect sponges (few at Q83, common at Q80, Q82, EC01, EC20), cf *P. beresfordae* (occasional, Q80, Q82, Q83), cream sponge with short-chimneys (*topsenti*-like[84], Q83), white chimney sponge (poss. *Leucettusa tubulosa*, Q82), cream and yellow raised-encrusting sponges (few at Q80, Q83, common, Q82), grey encrusting sponge spA (few, Q82), *Axinella*-type sponge (Q82 1 only). **Other taxa:** soft cream-orange-brown bryozoan (common, e.g., Q80, Q82, Q83), fern-like hydroids (common, Q80, Q82), *P. pachydermatina* (occasional Q80, Q83, frequent-abundant <30 m at Q82), hydroid trees (few at Q82), solitary cup corals (occasional clusters at Q82, Q80), brachiopods (indet., few, Q82), encrusting 'reef-building' bryozoa (*C. agglutinans*), coarse-branching bladed red macroalgae (likely *Euptilota formosissima,* <20-30% cover at Q82 in 21-24 m, and Awash Rock HS51-E01 in 20 m, EC06[?]), deep encrusting coralline (<2% Q82).
Motile invertebrates	Snake stars (common), *A. mollis (*occasional, Q80), kina (few at Q82), biscuit cushion star (few at Q82, Q83), 7-arm starfish (Q82), crayfish (very rare), cushion stars (*P. regularis,* few), *C. muricata* (occasional), Kina (rare), sawshells (few, Q80).
Fish	Schools of Butterfly fish (few at Q80, common at Q82), Red banded perch (occasional Q83, common-abundant at Q82), Scarlet wrasse (frequent at Q82, Q83), Sea perch (rare at Q80, few at Q82), dwarf Scorpionfish (Q80, few at Q82 in pebble gullys), Black-and-yellow triplefin (few at Q82, Q80), Blue cod (occasional, Q82), Marble fish (Q82 x1).
Other	Fishing line (Q80).

[84] Colour and morphology are like *Chondropsis topsenti*, but taxonomic identity has not yet been determined.

Other notable/significant communities: Two other notable communities were recorded during the Cook Strait surveys, both diverse invertebrate communities on moderate slope and relief reefs. The first was surveyed on the north-eastern slope at the Brothers and supported a diverse mix of sessile invertebrates (e.g., Figure 122c-i), with notable numbers of large hydroid trees and frequent occurrences of tube anemones (e.g., Figure 122e,f,h,i), that also included a mixed macroalgal zone in depths <22 m (Figure 122a-b), with a mixed macroalgal-invertebrate assemblages across a transitional zone in depths of ~23-26 m (Figure 122c,d,j). The second reef type was a series of rounded rocks along the exposed east coast in depths >23 m where rocks were moderate to densely covered in sessile invertebrates (e.g., EC01, EC20, EC04), with some rolling rocks off EC01 densely covered (>80% cover) in diverse moderately large erect sponges (e.g., moderate relief sections mid-way along video transect EC01; Figure 123).

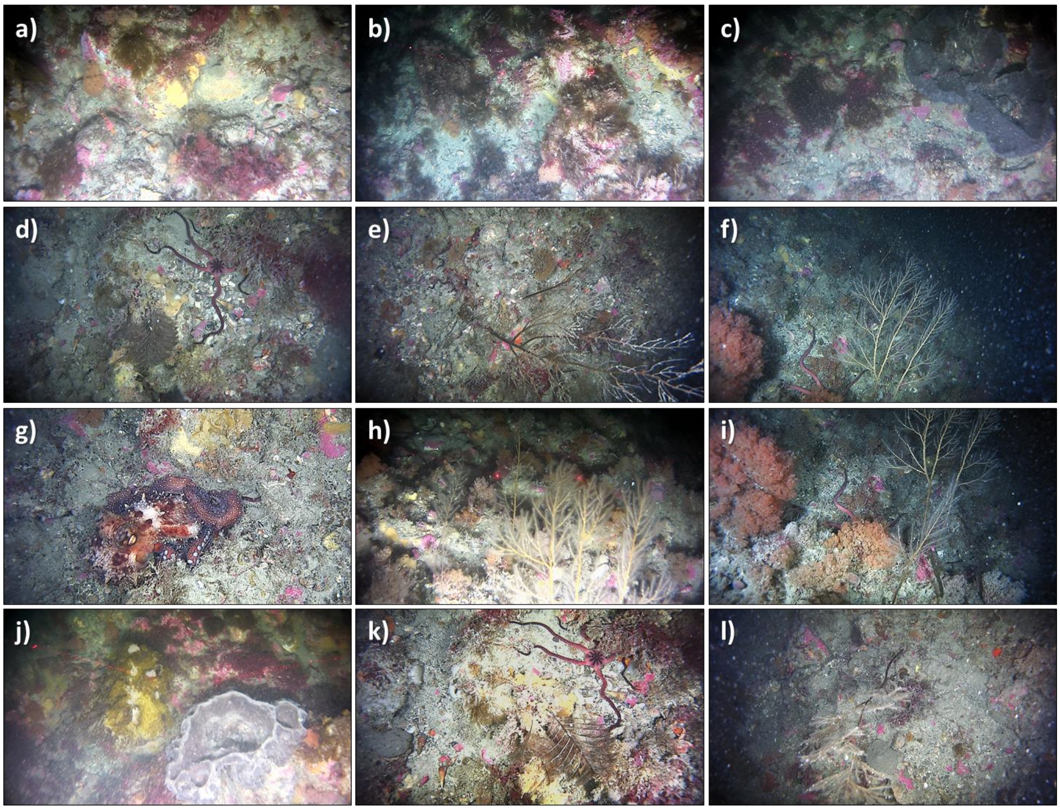


Figure 122: Examples of habitat and mixed algal-invertebrate community on the north-east slope at the Brothers (CB17-C16, 18-31 m water depth). a-c) Slope community dominated by fleshy macroalgae(e.g., *Halopteris* brown algae and mixed reds) in depths of ~18-20 m; d-i) Slope community dominated by sessile invertebrates (incl. notable occurrences of hydroid trees) in depths 20-30 m. *Macroctopus maorum* [g].

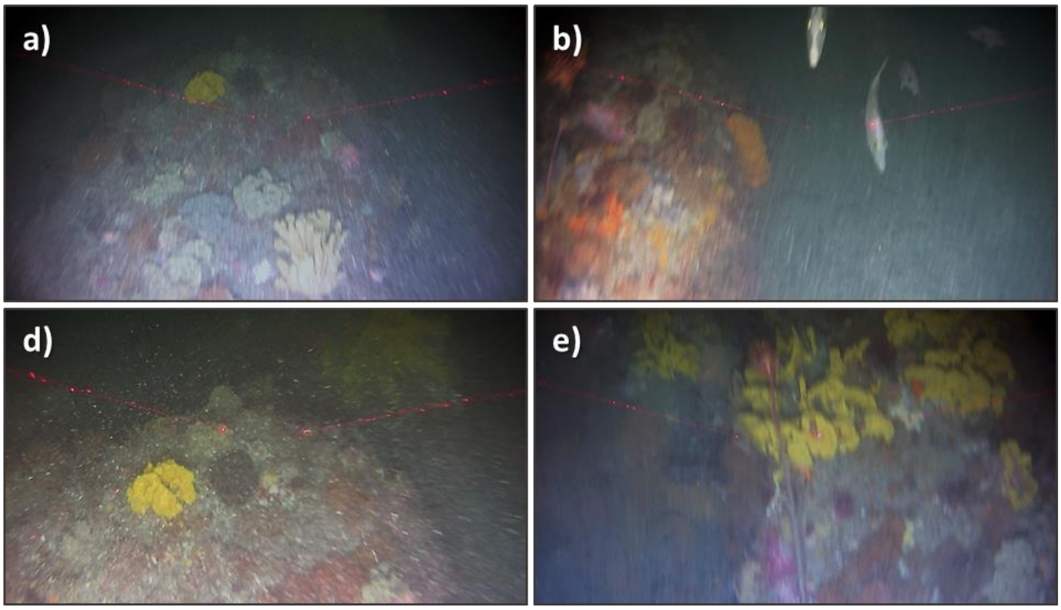


Figure 123: Examples of notable amounts of sponge garden species at CB17-EC01 - on the rolling rocks along the east coast of Tory Channel. Rolling rocks with sponge gardens were most notable midway along the video transect at this site (specifically: between Latitude -41.096823, Longitude 174.395022, depth 25.1 m and Latitude -41.095907, Longitude 174.395193, depth 24.1 m).

3.6.6 Rubble slopes (with or without coarse sediment)

Offshore of most coastal sites in the vicinity of TC-entrance, the outer reef edge of high-relief reefs – that are distinct in the bathymetric and slope maps - occurred within 100-300 m from the shore in depths >25-35 m, beyond which the maps depict a relatively featureless coarse grained seafloor sloping away from shore at a relatively gentle angle (<8-12^{o} max. slope angle) (Figure 124, see Figure 112). These gently sloping habitats comprised low-lying bedrock (near-ground level mostly <5-10 cm vertical relief) with various amounts of unconsolidated rubble (cobbles, pebbles, and biogenic rubble) that was partially covered with gravelly sediments. Reef structure was a combination of rounded bedrock with various amounts of relict biogenic crust over the reef surface. These rubble slopes supported low to moderate %cover of small-sized sessile invertebrates (e.g., Figure 125), characterised by various assortments of bushy soft bryozoa (orange and green colour forms), small-sized hydroids, with high occurrence, and at some sites high abundances, of solitary cup corals (*M. rubrum*, e.g., Figure 125k), along with regular occurrence of small patches (<5-15% cover) of darker-coloured encrusting coralline algae (e.g., Figure 125b,e) - indicative of lower-light tolerant corallines in depths >30 m (Nelson et al. 2014), along with a variety of other small sessile invertebrates (Figure 125; Table 3-55).

Two additional slope habitats were also surveyed, one out near Cape Koamaru (Q109) and another along the south-eastern side of the Brothers (Q307) (Figure 113c,f, respectively). These slopes also supported low-lying rock-rubble slopes, although Q307 was steeper sloping, with more consolidated rock and considerably less loose sediments (Figure 126), while Q109 was heavily veneered in gravelly sands on the upper slope (e.g., Figure 126g-i) and mostly buried beneath thick coarse sands down slope (e.g., Figure 126j-l). The biological communities present on low-lying rock and rubble slopes at Q307 were very similar to the rubble slopes adjacent to TC, in that they were characterised by similar high occurrence of soft orange and cream coloured bryozoa, various small hydroids and high occurrences (along with notably higher abundances) of solitary cup corals (e.g., Figure 126; Table 3-

55). As the video transect surveyed at MDC18-Q109 targeted a unique ridgeline feature, the findings of this transect are addressed separately in more detail below.

Some differences within and among sites within the rubble-slopes were also observed. For example, while orange and green colour forms of soft bryozoa were found at the same sites, it appeared that sections of slope with more gravels and unconsolidated rubble and less exposed hard substrata were dominated by abundant green-coloured soft bryozoa (e.g., Figure 125c-d), while sections of slope with more exposed rock and less gravel were characterised more by orange-coloured soft bryozoa – similar to the patterns seen on the rubble slopes inside TC. Similarly, while solitary cup corals were a characteristic feature of semi-consolidated rubble slopes, they were generally rare in areas with high amounts of gravel scree. Conversely, steeper rubble slopes surveyed on the south-eastern side of the Brothers and adjacent to East Head (e.g., Q307 and Q80) both supported notably higher occurrences and densities of solitary cup coral (e.g., Figure 125k, with ≤25 and 38 per m^{-2}, respectively) than all other sites– including those seen on deep offshore reefs (≤3-8 per m^{-2}). Sections of seafloor within sites with slightly steeper gradients or slightly raised bedrock (30 cm vertical relief) supported higher %cover of orange soft bryozoa along with higher amounts of encrusting 'reef-building' bryozoans, while rarer sections of higher-relief (>0.5 m vertical elevation) at a few sites (e.g., Q307 and Q80) supported other species more characteristic of deep high-relief reefs (e.g., zooanthids, *P. pachydermatina* and sponge garden species: *P. crocea, P. massalis*, *Aptos* sp., grey chimney sponges, and an assortment of other sponges), indicating predictable relationships between assemblage type and combinations of substratum type, slope and vertical-relief. While there was a clear demarcation between the deeper rubble slopes and shallower higher-relief reefs (e.g., Q80), at other site this was a very gradual change (e.g., Q84). Site Q80 also supported numerous tube anemones and several hydroids trees.

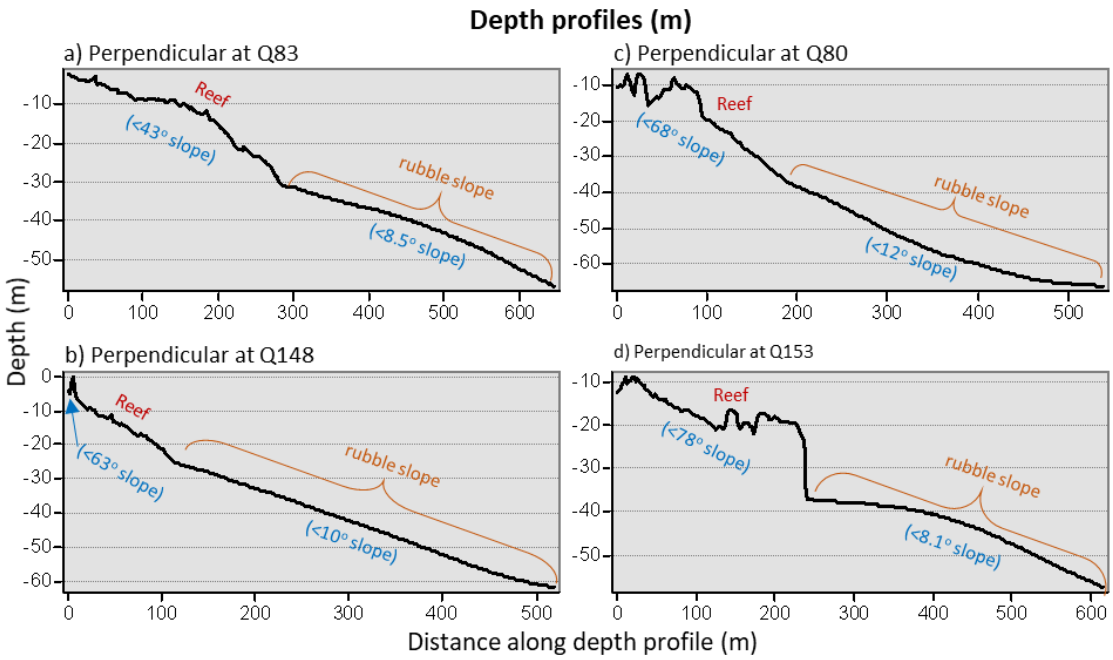


Figure 124: Examples of depth profiles and seafloor habitat types running perpendicular to shore on the east coast, adjacent to TC-entrance, in Cook Strait. Here two depth-profiles were run on either side of TC-entrance, perpendicular to the shore out to >0.5 km offshore. This was done to represent the full profile of the of these coastal sites (in comparison to those above that only represent the depth profiles along each video-transect). Profiles were aligned alongshore to run-through video transect sites to most-closely represent the results from the video survey. a-b) Depth profiles south of TC-entrance, c-d) Depth profiles north of TC-entrance. MBES-derived slope values were calculated along the same profile, with values for maximum slope presented here for each habitat zone.

Cook Strait sites adjacent to TC-entrance - rock-rubble slopes

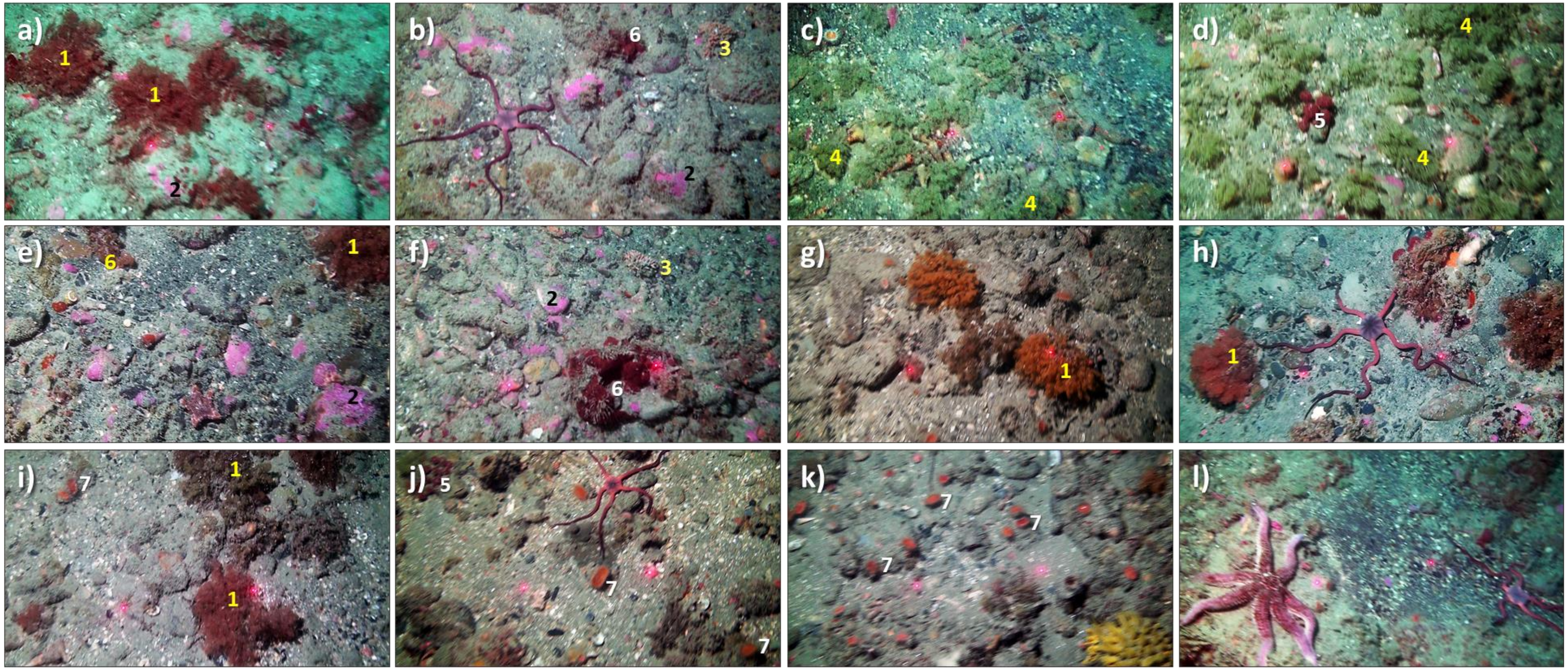
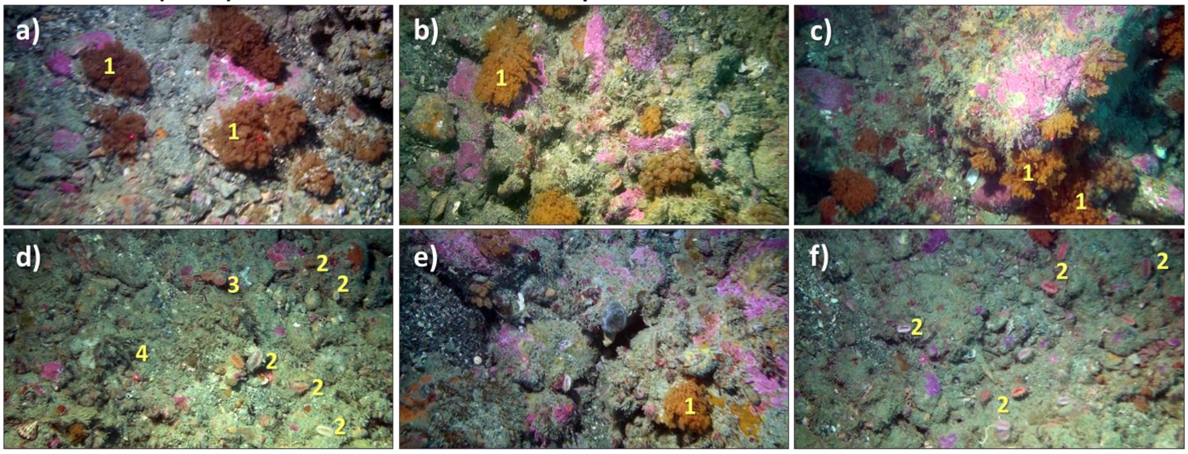


Figure 125: Examples of rock-rubble slopes in Cook Strait, adjacent to TC-entrance (depths >25 m). a-b) Rock-rubble slope with characteristic soft orange and brown coloured bryozoans [1] and deep encrusting corallines [2] (Q84, depths 30-40 m), c-d) Rubble slope with gravel-scree, characterised by high densities of the green soft bryozoa [4] and red bubble ascidian [5] (Q84); e-f) Rock-rubble slope with characteristic deep encrusting corallines, and small patches of reef-building bryozoa (*C. agglutinans* [6], and *C. elegans* [3]) (Q148); g-k) Rock-rubble slope with orange soft bryozoan, snake stars and solitary cup corals (*M. rubrum* [7]) (Q80); l) 7-armed starfish (*A. scabra*) and snake star (Q83).

The Brothers (Q307) - southeastern rock-rubble slope



South-east of Cape Koamaru (Q109) – partially buried rock slope

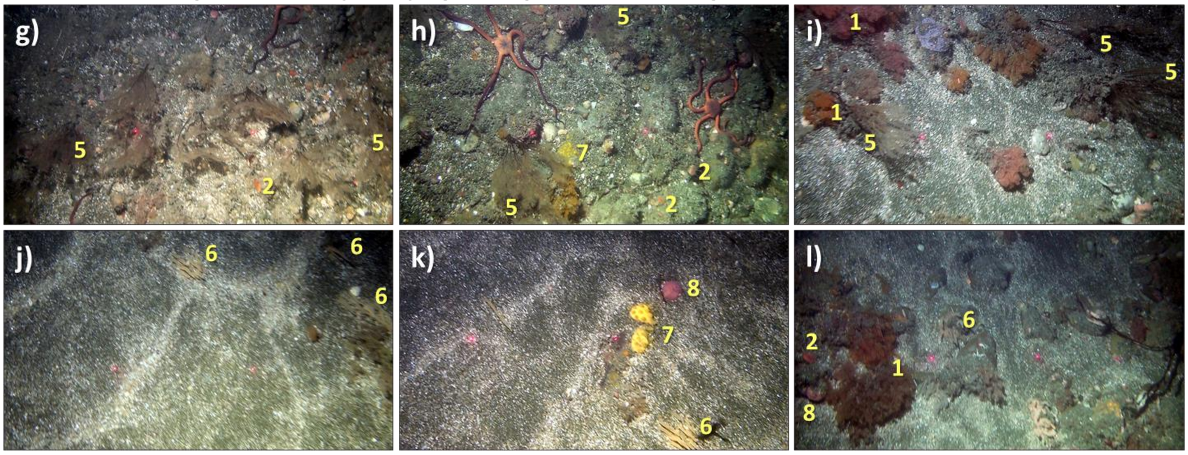


Figure 126: Representative images from two additional rock-rubble slopes in Cook Strait: one along the south-eastern side of the Brothers (Q307a-f); the other along a partially buried ridgeline south-east of Cape Koamaru (Q109g-l). a-f) Q307: Slope comprised of low-lying rock-rubble, albeit steeper than most sites near TC, with more consolidated rock and considerably less loose sediments; g-l) Q109: Slope heavily veneered in gravelly sands on the upper slope (g-h) and mostly buried beneath thick coarse sands down slope (j-l). Taxa identified in photos are: [1]orange soft bryozoa; [2]solitary cup corals (*M. rubrum*); [3]small red brachiopod sp2 (often seen in small clusters); [4]small fern-like hydroid; [5]field of hydroid fans; [6]yellow buried sponge (*P.* cf *hirsuta*); [7]partially buried yellow papillate sponge (*P.* cf *crocea*); [8]pink ball sponge (*Aaptos* sp.).

Table 3-55: Characteristic features of rock-rubble slopes, in Cook Strait. CS=Cook Strait; *Denotes sites where small sections of higher relief reefs were present within or adjacent to the rock-rubble zone. ^= buried species indicative of higher relief reefs. EC# = CB17 sites, Q# = MDC18 sites.

CS: Rock-rubble slopes	Characteristic features and significant/notable taxa
Substrata	**Coastal sites near TC-entrance:** gently slope (<8-12° angle) with low-lying rubble reef (Sites Q80*, Q83*, Q84, Q148), with some small-localised low-moderate relief outcrops, and/or thick veneer of coarse gravelly sediment. Rippled sand with pebbles and low-lying rubble (Site Q153*). **The Brothers (Q307*)** steeper mid-lower slope (<38°) with low-relief rock-rubble, deep slope with pebbles and cobbles. **Cape Koamaru (Q109)** mid-upper slope with low-lying rock-rubble veneered in coarse gravelly sands, lower slope mostly buried under coarse sands.
Benthic community	**Characteristic taxa (rock-rubble slopes):** Small sessile invertebrates, characterised by orange soft bryozoan (common-abundant, all sites), green soft bryozoan (common at Q80, Q83, Q148, abundant ≤60% at Q84), solitary cup corals (*M. rubrum*, few-common at Q84, Q109, Q83, abundant at Q80 and Q307), deep coralline algae (<5-15%, most sites), Mixed hydroids (common at Q148, Q307, notable fields at Q109). **Algae:** Mixed fleshy red macroalgae (indet. spp. depths <26-33 m Q83, Q84, Q148, Q307), incl. fine-branching reds (indet., shallow depths <25 m, Q148) and thin-bladed reds (poss. *Galene*, <1% Q83, Q84). **Other species** incl. small patches of reef-building bryozoa (*C. agglutinans*, <5-15%, e.g., Q80, Q84, Q148, Q307), fine-branching bryozoa (*C. elegans,* occasional <2% at Q84, Q148, Q307), foliose bryozoa (<1%, Q83, Q84), hydroid trees (notable at Q80), the colonial ascidian, *Hypsistozoa* sp. (few at Q80, frequent at Q84, Q148, Q307), brachiopods (indet. spp. few most sites), small red brachiopods (indet. sp. small clusters at Q307), rock anemones (rare, Q153, Q84), jewel anemones (<2% Q83*), large red sediment anemone (Q153 x1), tube anemones (common at Q80, sabellid fanworms (few at Q80), burrowing sea cucumber (*Thyone* spA, Q84 x1, Q109 x2?), *P. pachydermatina* (few at Q109^). Sponges on raised section of reefs: yellow papillate (*Polymastia* cf *crocea,* few, Q80, Q83), Yellow spikey sponge (*D. oxeata*, <2% Q148), encrusting yellow and orange sponges (<2-5%, Q80*, Q148*, Q307*), cream-brown sponges (*P. cf massalis*, occasional Q307*), grey chimneys (*cf P. beresfordae* occasional Q307*). Buried sponges (Q109^): buried yellow sponge (poss. *Polymastia hirsuta,* common), yellow papillate (*Polymastia* cf *crocea*), pink ball sponge (*Aaptos* sp.), other mixed sponge garden species (indet. few-frequent mostly deeper).
Motile invertebrates	Snake stars (common all sites), various starfish: incl. *C. muricata* (occasional, e.g., Q109), 7-arm starfish (*A. scabra*, occasional most sites, e.g., Q80, Q83, Q84, Q148), *S. mollis* (Q84 x1), cushion stars (incl. *P. regularis,* occasional Q83, few at Q84, Q148), poss. *Meridiastra mortenseni* (Q83), *Diplodontias miliaris* (Q80), biscuit cushion star (Q148), Kina (rare, Q84), *A. mollis* (few at Q80, Q83, Q84), sawshells (few, Q80, Q307), topshell (Q307), Aplysia sea slug (Q307 x1).
Fish	Black-and-yellow triplefin (common, Q80, Q82), dwarf Scorpionfish (rare, Q83), sea perch (Q83, Q109), scarlet wrasse (rare, Q84), blue cod (few Q109). Near base of reefs: Blue cod (few Q80, Q148, Q153) adult tarakihi (Q80 x1).
Other	Rope? (Q148), fishing line (Q307).

Cape Koamaru – rubble slope: HS51 bathymetry, slope and derived rugosity revealed a seam of narrow rock outcrop down the sediment slope in Cook Strait, ~ 2 km south-east of Cape Koamaru (MDC18-Q109 - Figure 111a, Figure 113c). This feature extended down slope where it connected to western end of what Neil et al. (2018a) describe as a 'large paired (intertwined) linear sediment-wave" feature (Figure 3-19 in Neil et al. 2018a) that crosses the seafloor between the east coast out towards the Brothers (visible between the white boxes a and b in Figure 110). To ground-truth this ridgeline reef feature we ran a video-transect up-slope from 58 to 33 m water depth. From the HS51 maps, the sediment slope has an angle of <20°. Within the maps this ridgeline rocky reef feature measured approx. 300 m down-slope and 62-145 m across-slope, with vertical relief of up to 0.5-7 m above the seafloor (Figure 111a, Figure 113c). However, at the start of the transect in 58 m depth the observed seafloor at this site was characterised by subtly rippled coarse sands on the lower slope (e.g., Figure 126j-l), with the rest of the transect up-slope being low relief rocks (<2-20 cm observed vertical elevation) comprised of rock-rubble with some gravelly sands (Figure 120-2a,b). No high-relief reefs were observed along the transect, and only one record of moderate relief was recorded on the upper slope. Instead most of the seafloor lay only a few cm above the surrounding seafloor, with much of the reef appearing to be mostly buried, or heavily veneered in coarse gravelly sediments (Figure 126g-i).

At the start of the transect, soft cream and orange coloured bryozoans appeared to be growing out of the sands, with subsequent soft bryozoans up slope seen growing on rocks that were nearly completely buried in coarse sands (e.g., Figure 126i,l). Several species of reef sponges were also observed buried by sand moving down the slope, or were partially inundated by gravelly sediments. These included frequent occurrences of yellow sponge (poss. *Polymastia hirsuta* – common in sediment scoured habitats) with their siphons exposed (Figure 126j-l[6]), along with several reef sponges partially buried by sands, incl. the yellow papillate (*Polymastia* cf *crocea*, e.g., Figure 126[7]) and a healthy looking pink ball sponge (*Aaptos* sp., e.g., Figure 126[8]), and even partially buried snake stars – indicating ongoing sediment movement and burial across this very low-lying outcrop. Further up slope, low-lying rubble was near level with the sediment, with signs of a strong down-slope current that was moving sediment down-slope across the reef, and was seen bending and shaking soft-bryozoans and hydroids. The biological community present on this low-lying rock-rubble slope, was also similar to those seen on the rubble slopes adjacent to TC, characterised here by similar high occurrence of soft orange and cream coloured bryozoa, hydroids and frequent occurrences of solitary cup corals (e.g., Figure 126g,h,l[2]), but had markedly higher densities of hydroids across the mid and upper slopes (e.g., Figure 126g), along with higher occurrence of sponge-garden species, albeit with many of these buried beneath down-slope moving sediments.

On the maps, this outcropping ridgeline is spatially patchy with some areas within the feature being low to the ground while large peaks stand 7 m height. So potentially we could have missed some of these raised features, but given our planned transect-line across multiple raised peaks it was unlikely that we would miss them all. However, the GPS position of our surveyed video-track is based on the vessels position. In high current conditions the tow-video system can be dragged some distance from the vessels incurring a layback error that could place us away from some of these features. Given the notable amount of sediment burial at this site including the observations of normally high relief sponges recorded mostly buried in sands indicates that significant amounts of reef-burial have recently occurred. However, it is unclear how much sediment burial may have occurred here.

3.7 Other notable findings

During the MDC18 survey, rank abundance estimates were recorded for most taxa. These are preliminary estimates, that would require more detailed verification from post-processing counts, but presently provide a preliminary estimate (to be used as a rough, but not exact guide) of the distribution and relative abundance of these taxa across the Sounds.

3.7.1 *Ecionemia alata* sponge distributions.

Ecionemia alata (Family Ancorinidae, synonymous with *Ancorina alata*) is a massive sponge that is very common on rocky reefs around New Zealand, from the intertidal down depths of 200 m. It has been recorded to reach up to 1 m in diameter and typically a shark to charcoal grey colour (Kelly and Herr 2015). *E. alata* is a common sponge found on rocky reefs across the Marlborough Sounds (Davidson et al. 2011). In this study *E. alata* was recorded in all subregions of the survey area (Figure 127), in depths of 2.8 down to 130.3 m, occurring in 44.2% of sites surveyed (50% of sites with some rock) and 4.74% of all records (13.3% of records with some rock) – indicating that *E. alata* is geographically widespread across the survey area, but is sparse or patchy within sites. *E. alata* were also recorded in non-reef locations (13% sites, and 1.2% of records), growing on biogenic habitat, such as bryozoan reefs, areas of stabilised large-shell-debris, *Galeolaria*-mounds, and Remnant dead *Galeolaria* structure. Most of the data presented here for *E. alata* are from the MDC18-survey, as the other three video surveys only recorded sponges by morphologies (3D-erect, digitate, ball, encrusting). However, some limited 'presence-only' information is presented for some sites (grey triangles in Figure 127) - based on additional field notes and/or post-survey video observations for some sites. No *E. alata* sponges were collected within the survey area during the BT17 survey, as these beam-trawls targeted trawlable non-reef areas.

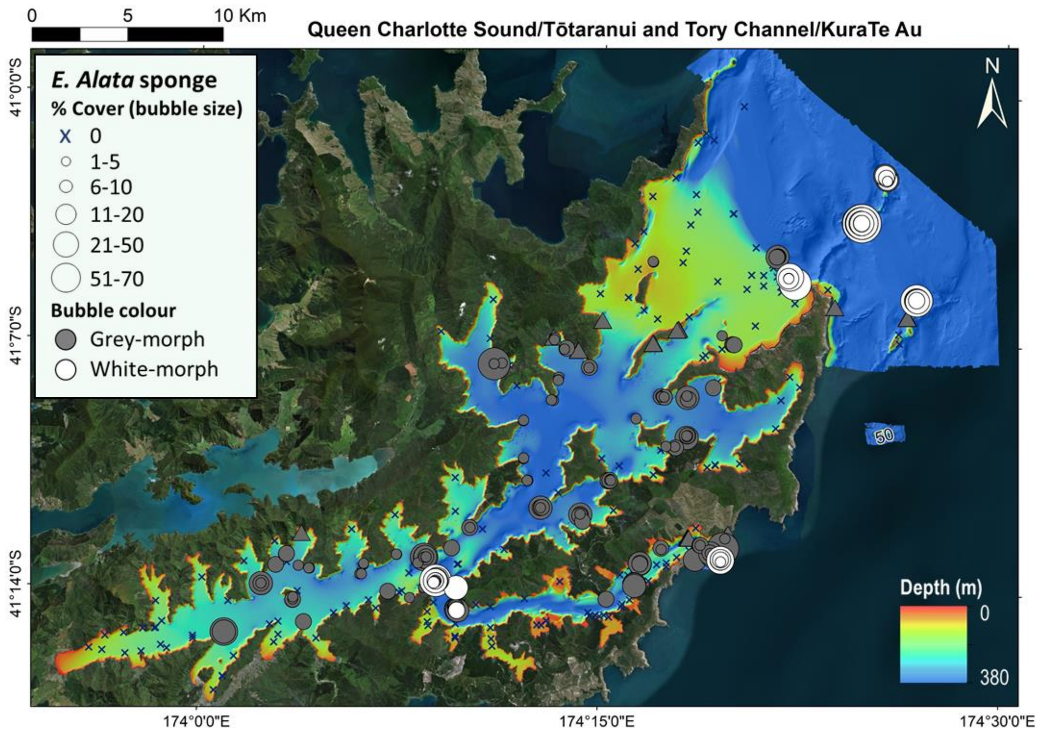


Figure 127: Distribution and rank percent cover of the common massive sponge (*E. alata*), on hard-substratum within QCS, TC and Cook Strait, showing the distribution of the two colour morphs (charcoal-grey vs bleach-white). Bubbles are % rank cover estimates from the MDC18 survey, triangles represent presence (based on field notes or post-survey video observations) for the CB17 survey (upright triangles) and HS51 surveys (inverted triangles).

Two very different colour morphs were record for *E. alata* across the survey area. This included the typical shark to charcoal grey colouring found on reefs and biogenic habitats within the Sounds, and a new bleach-white colour morph found on the deep-reefs in Cook Strait (Q134, Q137, Q182, Q149), as well as a few isolated location within the Sounds on White Rock at the entrance to QCS and off Dieffenbach Point and adjacent deep-reef sites at the junction between QCS and TC (Figure 127). This bleach-white colour morph has not been recorded previously, and is a new record for this species (M. Kelly *pers. comm*. to T. Anderson). Colour-morphs of this species varied by depth, with the grey-morph present in depths of 2.8 – 44.5 m (Mean of 24.5 m ± 0.7 SE), while the white-morph occurred in depths of 33.3 – 130.3 m (Mean of 87.7 m ± 3.5 SE). At most sites either grey or white morphs were present, however at a few sites at the QCS-TC junction (Q177, 169 and Q172) and at the entrance to QCS (QC02) both morphs were present, with some individual sponges presenting an intermediate colouration. There was also a difference in sponge size ranges between the two morphs. Grey morphs were generally small to medium sized (~20-80 cm size range) and well within the maximum size described for this species (i.e., <1 m in diam.), however, the white-morphs were notably larger, with many deep rock walls lined with moderately-large to massive-sized sponges (e.g., Figure 107b,d). with many exceeding the maximum size range known for this species (size range of 0.5 m to >1 m in diam.), including one very large elongate individual measuring ~1.5 m long.

3.7.2 Seagrass beds (TC/QCS)

No observations of subtidal seagrass were recorded during the four combined surveys, indicating that seagrass in TC, or QCS, is unlikely to be present, or at least common, beyond the very shallow nearshore, where small discrete patches are already known to occur within shallow bays along the southern shoreline of outer TC (*e.g. Figure 10 of* Davidson et al. 2017a; Tipi Bay, Brown et al. 2016a). Further surveys to determine the presence of seagrass in very shallow nearshore zones, would be more appropriately assessed by using an 'underwater viewing box' (or bathyscope e.g., Stevens and Robertson 2014) or small hand-deployed drop camera systems. The former approach is a common and very cost-effective method used to rapidly surveying/ground-truthing potential seagrass areas in shallow areas where deploying a larger tow-video system is neither practical or safe (review by Short and Coles 2001).

3.7.3 Hydroid fan fields (outer slope of duck pond, QCS)

Two sites (MDC18-Coastcam-Q22, 35-40 m depth, and MDC19-CBedcam-QC22B) surveyed on the outer slope of the Duck Pond in the central region of QCS-entrance, found moderately-dense fields of hydroid fans (each fan within ~10-30 cm wide and ~10-15 cm high), all aligned with the fans perpendicular to the current, growing on a low relief rubble (sediment-level). This slope was very steep and composed of what looks like buried shell debris and rubble (poss. buried relict bryozoan material), heavily veneered in sediments - resulting in a flat but rough sediment texture. The slope also had patches of what looked like burrows as well as very low-lying partially-exposed debris and some small raised patches of relict bryozoan-reef (<10 cm high, 0-5% cover), covered in mixed invertebrates (e.g., encrusting and erect sponges (incl. *C. incrustans*), colonial ascidians, rock anemones <1%, solitary cup coral x1). Other species recorded at this site include snake stars (common), orange soft bryozoans (0-3% cover), a few scallops (occasional) and horse mussels (occasional), sabellid fanworms (occasional), and what looked like sparse densities of possibly small infaunal tubeworms.

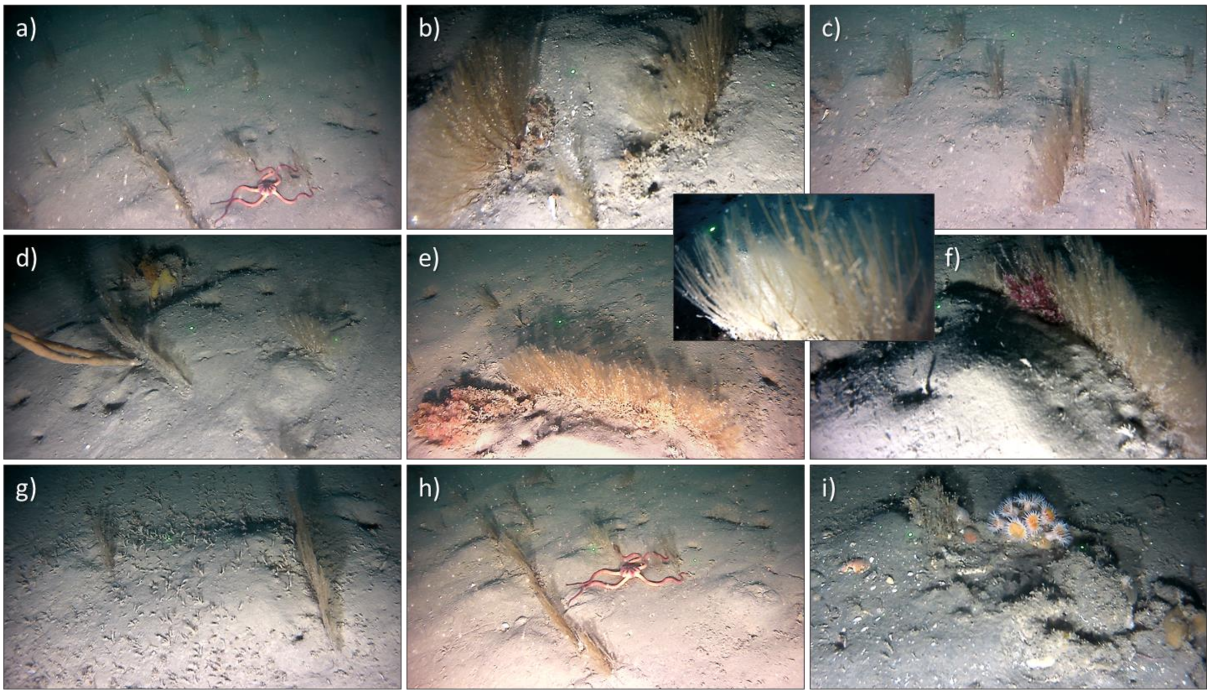


Figure 128: Field of hydroid fans on the outer slope of the Duck Pond in the centre of the entrance to QCS. a-i) Sediment slope showing low to moderately dense field of hydroid fans all aligned perpendicular to the current (MDC18-Q22B); g) shows close-up of what look-like the emergent tubes of infaunal tubeworms – seen commonly throughout this site/zone. Depths sampled were 40-32 m upslope.

3.7.4 Anemone fields (outer entrance to QCS)

Sediment slopes at or beyond the entrance to QCS, supported low densities of large fleshy translucent-pink anemones, of the genera *Actinia*, referred to here as *Actinia* spA (Figure 128). Sites with *Actinia* spA included several on the outer sediment slopes near Cape Jackson (e.g., MDC18-Q120), in and around the deep relict bryozoan reefs that lie in the western channel (MDC18-Q139), as well as sites further out in deeper habitats in the Cook Strait. The extremely high-current sediment slopes at the entrance to QCS (e.g., MDC18-Q120, 81 m depth) were characterized by high occurrences, albeit in low densities (mostly 1-3, but up to 5 *Actinia* spA per data call), of *Actinia* spA, with few other taxa seen. Other deeper Cook Strait sites where *Actinia* spA also occurred albeit in much lower numbers (~1-8 per transect), were characterized by soft or shell-debris covered sediments. This anemone appears similar in colour and shape to the one described for Paterson Inlet, in Stewart Island (Cook 2010 p164), but closer imagery along with collections of this species would be required to determine which species of *Actinia* this is.

This species was also seen at three other sites in this sub-region, 150 m up the slope at site HS51-D14 site (northern edge of Significant site 7.2 – 1 individual seen), 1.5 km down slope in depths of 150 m at HS51-D12 (2x indiv. recorded), and 3 km down slope in 171 m water depth at HS51-D13, where 8 individual *Actinia* spA were recorded. A single *Actinia* spA was also recorded amongst the deep (mostly relict) bryozoan reef in the western entrance to QCS (Site Q138), while another single *Actinia* spA was found in a cobble field covered in a veneer of sediment (HS51-D06). It is difficult to compare densities between the short HS51 dropcam sites and the much longer MDC18 video-transect stations, however the MDC18-Q120 site supported a frequent/notable presence of this species.

This anemone also appears identical in colour and shape to those recorded in video footage from a similar high-current deep sediment slope environment off Cape Lambert – specifically Site-C22 in a depth of ~90 m mid-way between Chetwode Island and McManaway Rocks (as per Figure 10 of Elvines et al. 2019), indicating that this anemone may occur more widely across the outer sound slopes of the Marlborough Sounds.

No other large anemones like this species were seen on the more-gravelly deep sediment slopes along the eastern coast of Cook Strait Coast, or any other locations across the survey area during any of the four surveys. Therefore, observations may represent a new species record for the Marlborough Sounds, and possibly a new species - one indicative of high-current deep sediment-slope habitats within the Marlborough Sounds. Anemones are notoriously difficult to taxonomically identify without a specimen to dissect. Consequently, *Actinia* spA is used here until a future specimen can be collected for taxonomic identification.

Figure 129: *Actinia* spA from two sites at the entrance to QCS. Site Q138 (left image) and site Q120 (right two images).

3.7.5 'Hairy-looking' red brittlestar (*Clarkcoma bollonsi*)

In a depth of 150 m in Cook Strait off Cape Jackson, video observations at a single HS51 video site (Site D10, Latitude -40.99280 and Longitude 174.36230) identified high densities of the 'hairy-looking' red brittlestar (most likely *Clarkcoma bollonsi*) on a low-relief habitat of rock, cobble and soft-sediment (Figure 131a-b), where it was co-occurring with much lower densities of the snake brittlestar, *O. maculata*. The hairy-looking red brittlestar, *C. bollonsi*, is an endemic ophiuroid found in depths down to 370 m from the Three Kings down to Stewart Island (Mills et al. 217). No specimens were collected from this very deep Site HS51-D10 site, however, a total of 5 similar-looking specimens of *O. antipodum* (e.g., Figure 131c-e) were collected in much shallower depths from three beam trawl sites within the survey areas (BT17 survey, Sites QC03, QC20 and QC29). *C. bollonsi* and *O. antipodum* are very similar in colour, morphology and habitat association, and require microscopic examination[85] to distinguish them (S. Mills, *pers. comm.*). The generally darker reddy-brown to dark burgundy (sometimes almost black) coloured *O. antipodum* (e.g., Figure 131) is also an endemic ophiuroid, that occurs from northland to the Stewart Island (Mills et al. 2017), but has only been reported to depths of 105 m and is generally found much shallower than this. Consequently, the deeper depths of Site D10 (150 m), makes it very unlikely to be *O. antipodum* and much more condiment that it is *C. bollonsi* which occurs down to depths of at least 350 m (within New Zealand, and down to 650 m in Australian waters) (Mills et al. 217).

[85] *Ophiopteris antipodum* is similar to *Clarkcoma bollonsi*, but has shortened arm spines (like scales) sitting on the base of each spine.

Figure 130: Notable site with high densities of the 'hairy-looking' red brittlestar (most likely *Clarkcoma bollonsi*), in 150 m off Cape Jackson, in the Cook Strait (HS51-Survey, Site D10).

Figure 131: Examples of *Ophiopteris antipodum* specimens collected from locations within the Marlborough Sounds. a) Two specimens collected within the survey area - from the Duck Pond, north of Motuara Island (BT17-QC03, 16-17m); b-c) A single specimen from outer Waitui Bay (BT17-OS29, 21-23 m: -40^{o} 58.924 S, 174^{o} 1.86) - showing dorsal [b] and ventral [c] views.

3.7.6 Cobble seafloor – west of the Brothers

The seafloor in deep sections of Cook Strait east of Cook Rock were surveyed at six brief (<1 min) dropcam sites during the HS51 surveys (locations shown in Figure 132). These sites were all characterised by low-relief beds of cobbles (Figure 133), with varying amounts of pebbles, gravels and at the most northern site a veneer of sediment over a cobble base (Figure 133f). These cobble habitats all supported low % cover of mostly encrusting species, such as sponges and poss. ascidians (e.g., Figure 133), with a few hydroid fans, epiphytic bivalves (*Talochlamys*), a single *Actinia* spA at site D06, and at site D04 the regular occurrence of delicate frame-building bryozoans, many of which were broken. Low densities of motile invertebrates were also common, and included a few snake stars (D01), a 7-armed starfish (D01), *A. mollis* (e.g., D04), saw shell gastropods and large whelks (e.g., D05). These offshore seafloor habitats are open ground to bottom fishing, with both the coastal and deep water trawl fishery operating over these areas, with an extensive fishing-footprint over the seabed in this area (Baird et al. 2015; Tuck et al. 2017; Baird and Wood 2018).

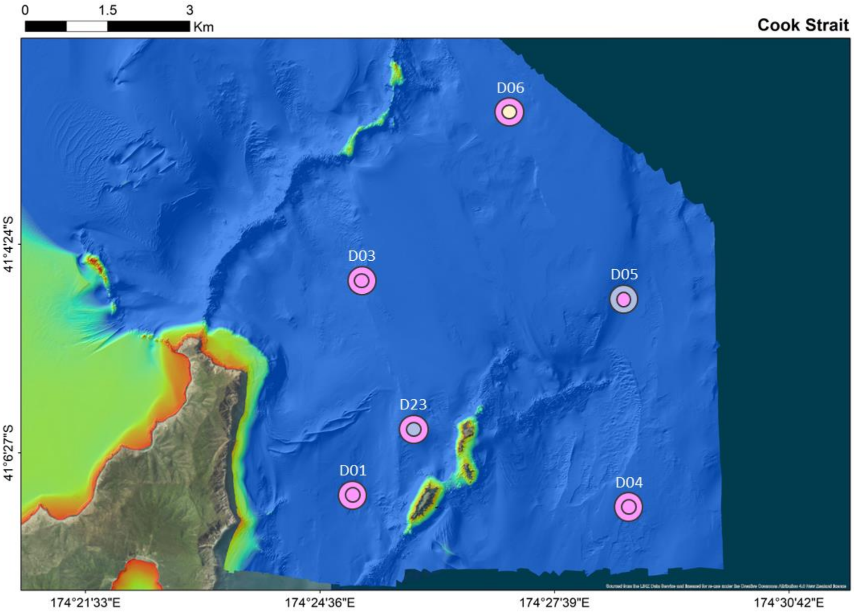


Figure 132: Cobble-seafloor sites in Cook Strait from the HS51 survey. Seafloor habitat types are presented for primary (larger circles) and secondary (smaller inner circles) substratum categories, where pink=cobbles, purple grey=pebbles, and light yellow=sediment (i.e., Site D06 here a sediment veneer over a hard cobble bottom).

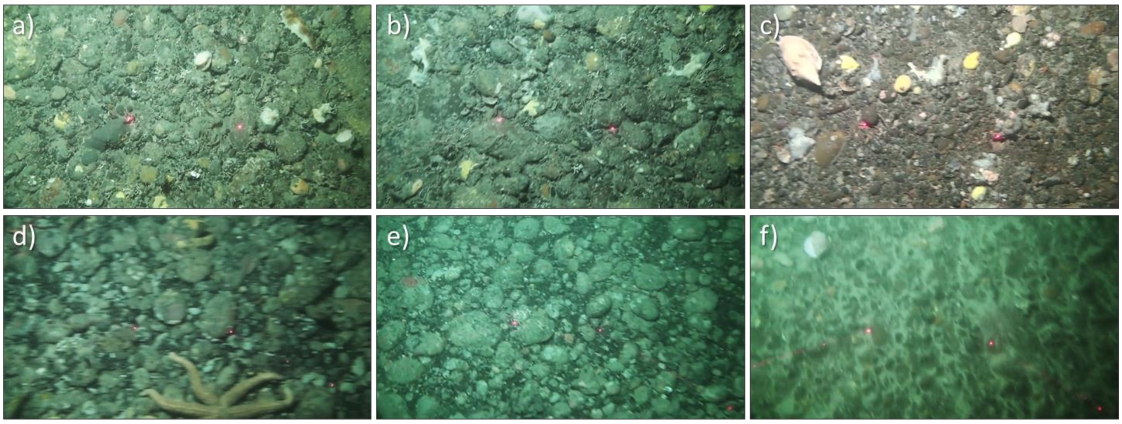


Figure 133: Cobble habitats across the seafloor in Cook Strait, east of Cook Rock from 6 HS51 dropcam sites. Photos are from HS51 sites: a-b) East of the Brothers (D04); c) NE of the Brothers (D05); d) west of south Brothers (D01); e) west of north Brothers (D23); f) East of Cook Rock (D06).

3.7.7 Kina distributions

The sea urchin, *Evechinus chloroticus* (or kina), is the most common sea urchin species in New Zealand, occurring on sheltered to moderately-exposed shallow rocky reefs from Three Kings Islands in the far north to the Snares Islands in the far south, including Chatham Islands (Barker 2013). Within the survey area, kina were broadly distributed across the Sounds occurring in 68.5% of all sites surveyed (Figure 134) and 14.6% of all records. Kina were recorded in depths of 2.6 m down to 60.1 m (mean depths of 17.23 ± 0.29 SE), although 83% of all kina were found in depths <20 m, with only 2% recorded in depths >35 m (Figure 135). Kina depth distributions varied between regions, with kina occurring over a much broader depth range within TC than in QCS or Cook Strait (Figure 135). In TC, 35% of kina were found in depths >20 m, compared only 2% in QCS and 0% in Cook Strait, while almost 10% of kina in TC were found in depths >40 m - albeit in in very low densities <~0.25

kina per m^{-2-} (e.g., off Te Pangu Bay Q85, 44-60.1 m). The deepest kina within the survey area, were recorded on the deep debris slopes off Dieffenbach Point (Q177a, 58 m) and off Hitaua Bay (Q170, 60 m), and on the deep channel reef and rubble slopes off Te Pangu Bay Q85, 60.1). However, deeper rocky reefs were not limited in QCS, but unlike TC, QCS reefs in depths >20 m were generally covered in *Galeolaria* mounds (or damaged *Galeolaria* rubble). However, sparse numbers of kina were recorded in these habitats too, notably higher densities were seen in damaged-*Galeolaria* habitats than in intact ones, possibly reflecting higher secondary algal growth in damaged area - indicating a likely increase in food supply for kina in these damaged habitats.

Kina were present within a broad range of habitat types, and while most commonly seen on rocky reefs, they were also recorded on biogenic habitats, shell-debris fields and on bare soft-sediments (e.g., BT17-QC10 and MDC-Q196). Most kina seen on soft-sediment were at sites where drift algae was also recorded. Kina barrens were common on reefs within mid to outer QCS where kina were in moderate densities (≤11 kina per m^{-2} incl. LIMR), but kina were also found in much higher densities (≤25-28 kina per m^{-2}) at three very high-current locations: at the entrance to QCS off Waihi Point (e.g., Figure 66f), along the inside entrance within 3-4 km of TC-entrance (e.g., Figure 88), and in Cook Strait on low-lying reefs within 2 km of Cape Koamaru (e.g., Figure 119). The maximum size of kina at these high density sites was also notably larger (mostly ~10-15 cm) than those seen within QCS (mostly ≤10 cm) based on video imagery and some collections (e.g., Table 3-56).

Table 3-56: Minimum and maximum size range of Kina collected in BT17 beam trawls and MDC18 dredge samples.

Survey	Subregion	Site	Count	Min. size (mm)	Max. size (mm)
BT17	QCS Outer	QC10*	16	38	87
BT17	QCS Outer	QC13	1	36	36
BT17	QCS Outer	QC21	2	72	76
BT17	QCS Outer	QC19	1	61	61
BT17	QCS Outer	QC20	1	46	46
BT17	QCS Mid	QC25	1	49	49
BT17	QCS Inner	QC60	1	32	32
BT17	TC Outer	QC70†	16	19	**122**
MDC18	TC Inner	D01	8	65	**110**
MDC18	TC Inner	D03	4	70	**123**
MDC18	TC Inner	D04	2	104	**150**

* Large cluster of kina out on soft-sediment, on the Duck Pond, eastern-side of QCS entrance.
† Kina collected in the drift algae mats within Okukari Bay, Outer TC.

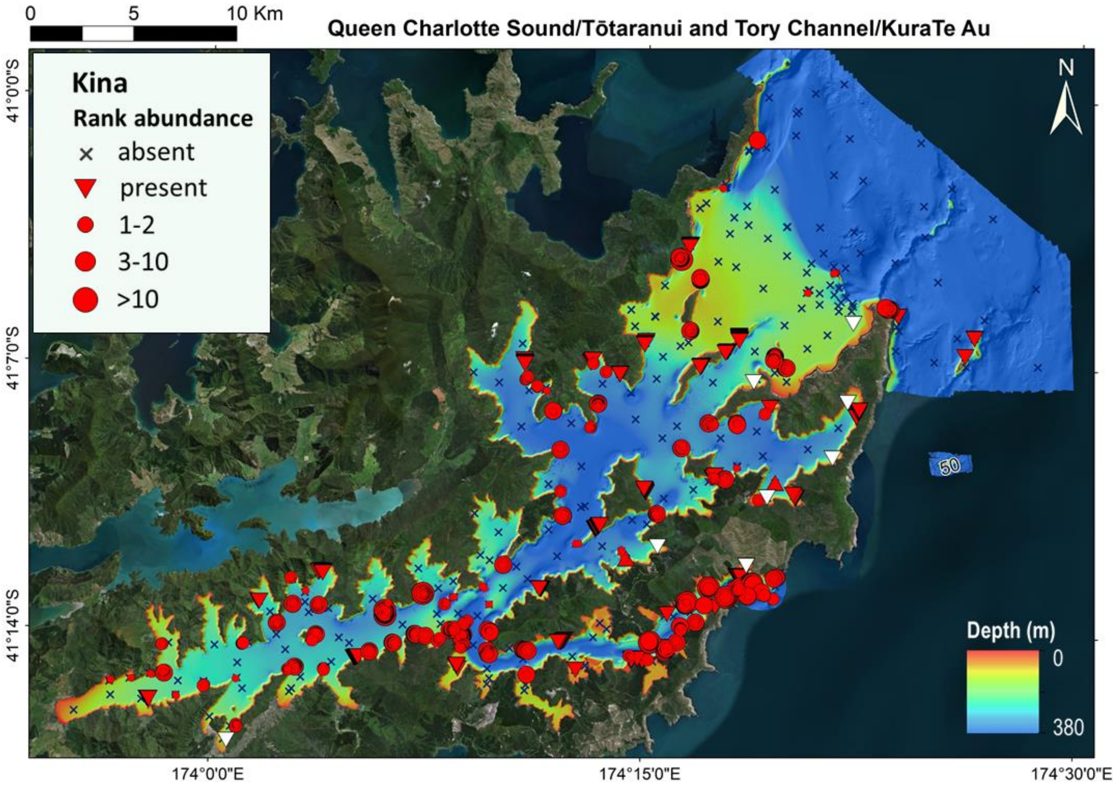


Figure 134: Distribution and rank abundance of Kina (*E. chloroticus*) within the survey area. Bubbles are % rank abundance estimates for the MDC18 survey; white inverted rectangles = BT17 beam trawl collection (presence); inverted red triangle = presence at CB17 sites, upright red triangle = presence at HS51 sites.

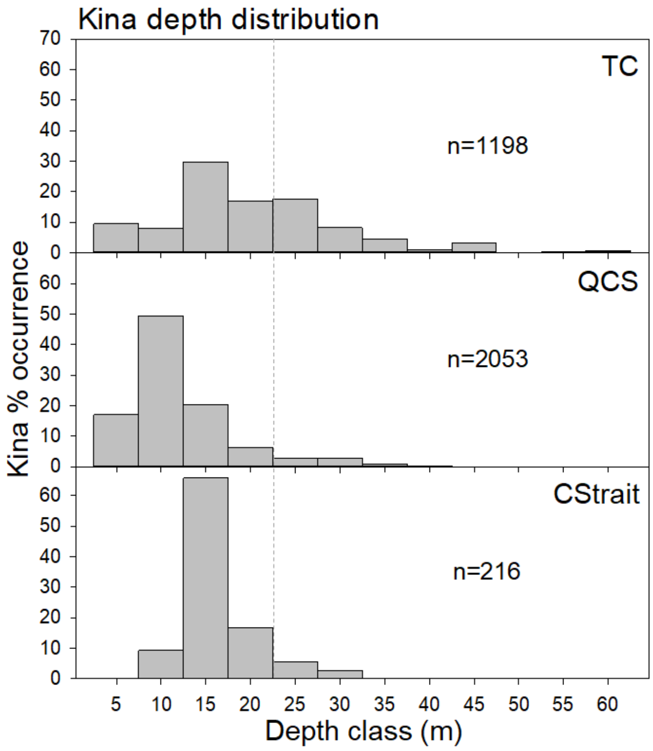


Figure 135: Depth distribution of kina by region, for the MDC18 survey. TC=Tory Channel, QCS=Queen Charlotte Sound; CStrait= Cook Strait. n= the rank number of kina recorded per region.

3.7.8 Cockle beds (Inner QCS)

Three cockle (*Austrovenus stutchburyi*) beds were recorded during the Ground-truthing surveys, one during the BT17 beam trawl survey (BT17-QC58), the second identified from video footage during the MDC18 survey (MDC18-Q197), and the third recorded from a short drop camera (HS51-C01), with all three occurring within Arms Grove, inner QCS. While it is not known how extensive these beds are alongshore or offshore these three locations around the sides of Grove arm indicate that while cockles are already known to form extensive beds at the head of Okiwa bay (Davidson et al. 2011), they also appear to be a significant and potentially extensive subtidal habitat too.

1) NW side of Grove arm: A dense cockle bed (30 cockles per m^{-2}) was recorded from a single beam trawl (BT17-QC58) on the northern side of Grove arm, ~200 m out from the shore on the northern side of the bay. At this sites, the beam trawl was terminated after only 54 m due to excessive weight that was due to the small net filling up quickly with 20 litres of cockles (Figure 136c). This transect started at -41.26263 latitude x 173.93273 longitude, and finished at -41.2629 latitude x 173.932183 longitude. Based on a random subset of cockles (n=192), the average cockle size in this bed was 34 mm ± 6.75 SD (range 9-58 mm). It is not known how extensive this bed is, however, the video-transect undertaken 900 m away over in Umungata Bay (MDC18-Q197) also supported a cockle bed (see below).

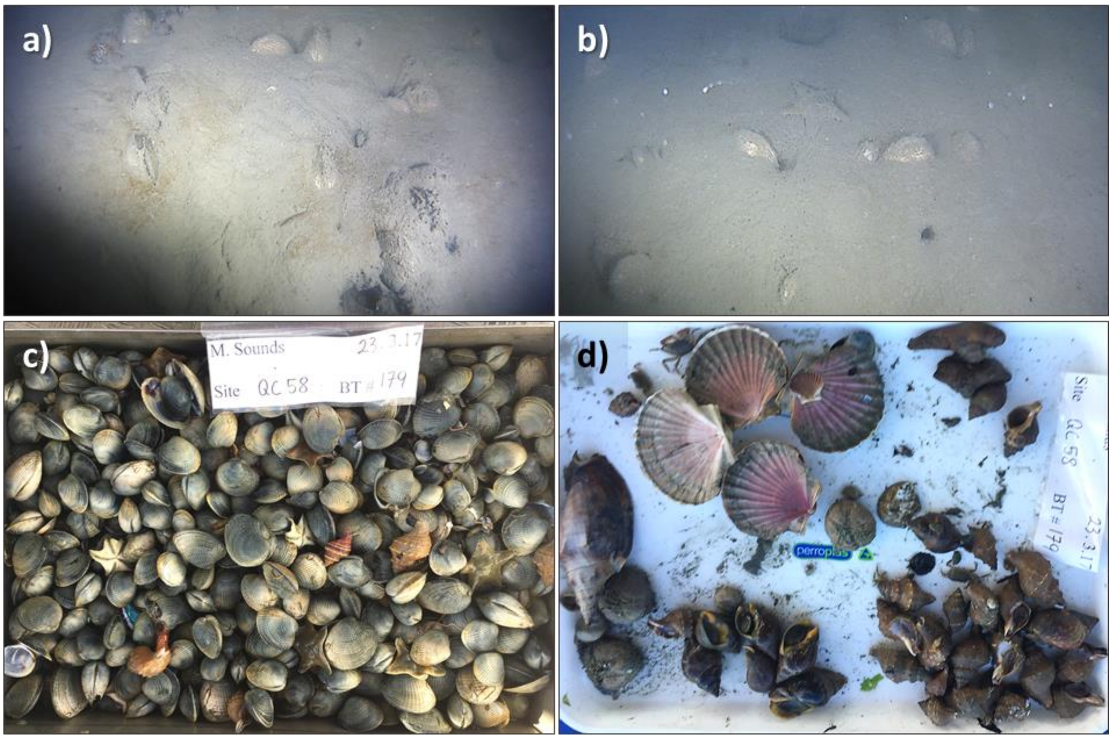


Figure 136: Cockle beds in Grove Arm, inner QCS (MDC18 and BT17 surveys). a-b) extensive cockle bed (density ~10-25 %) in Umungata Bay, Grove arm; c) Example of some of the 20 L of cockles collected during a ~54 m-long beam trawl on the northern side of Grove arm (BT17-QC58), ~200 m out from the shore; d) other species collected along with the 20 L of cockles (BT17-QC58).

2) Umungata Bay, Grove arm: Video observations at this site (MDC18-Q197) identified an extensive cockle bed (≥70 m, and may extent further beyond the deeper section of this transect) in muddy sediments at 11 m depths (Figure 136a-b). Video observations cannot determine infaunal densities, but visible surface density of ~10-25 % were recorded, however

this is unlikely to represent true infauna densities which would require other methods of sampling (such as grabs, or dredges). Given the proximity between this and the beam trawl sites it is likely that cockle beds may occur extensively around the large sheltered bay.

3) Okiwa Bay, Grove arm: A brief duration drop camera in 10.6 m at this site (HS51-C01) observed several patches of cockles, with images of this bed of similar observed densities to those seen at MDC18-Q197 (e.g., Figure 136a-b).

3.7.9 Sea cucumber, *Australostichopus mollis*

The common sea cucumber, *A. mollis*, was extremely prevalent across the survey area (Figure 137), occurring in 78% of all sites, and 17.2% of records (MDC18 survey), found mostly on the sediment slopes and rocky reefs, throughout the Sounds in depths of 2-107.6 m (mean 22.5 ± 0.49 m). Occurrence of *A. mollis* was highest in mid and inner QCS, where it occurred in >90% of these sites and >20% of those records (Figure 137). *A. mollis* were also prevalent on slopes and rocky reefs in Cook Strait sites adjacent to TC-entrance (71% of those sites, 5.9% of records), including the deep reef directly outside of TC (Site MDC18-Q147), but appear to be absent on the deep reefs in Cook Rock and around the Brothers.

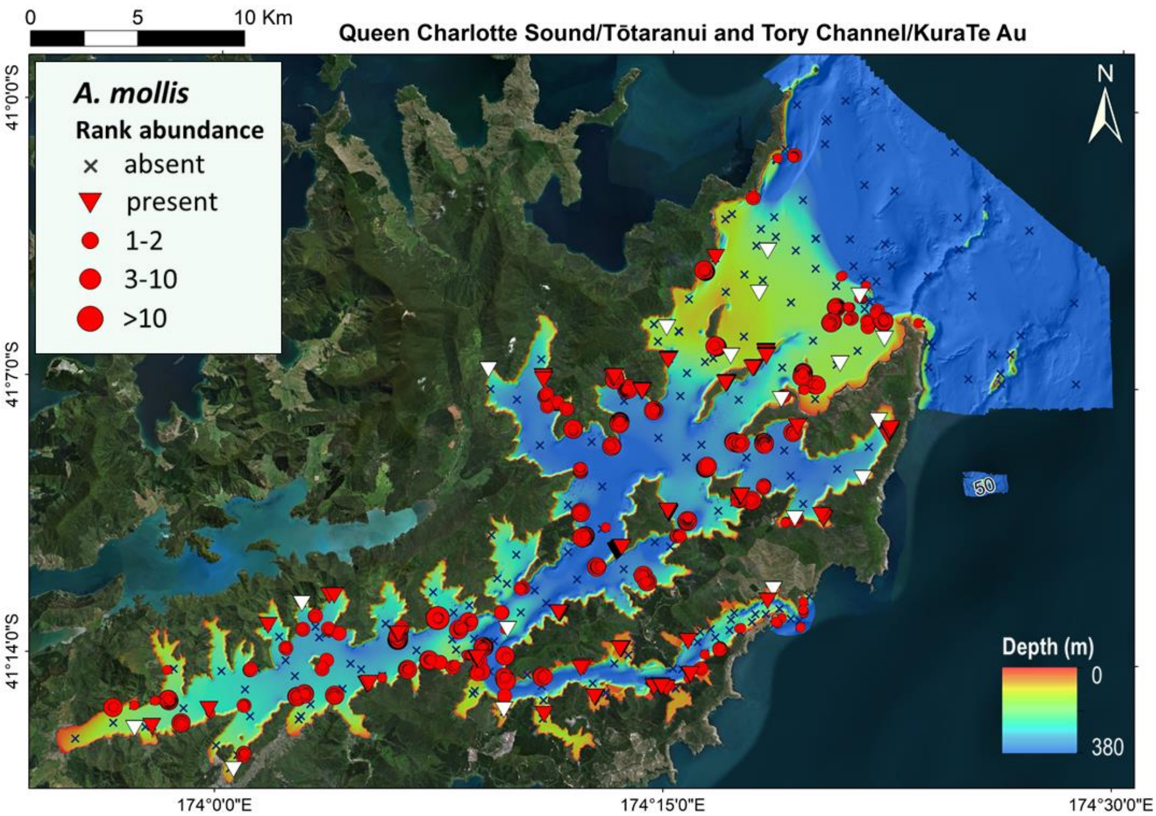


Figure 137: Distribution and rank abundance of the common sea cucumber, *A. mollis*, within survey area. Bubbles are rank abundance estimates from the MDC18 survey; white inverted rectangles = BT17 beam trawl sites where *A. mollis* were collected (presence); inverted red triangle = occurrence (presence) recorded along CB17 video-transects.

3.7.10 Snake star distributions

The snake star or 'Patakaroa' (*Ophiopsammus maculata*)*,* is a large endemic orange-coloured brittlestar (Class Ophiuroidea) that is known to occur in a wide range of habitats throughout the Sounds (Davidson et al. 2011). This species is an active carnivore and scavenger, with some detrital surface-feeding also reported (O'Hara and Byrne 2017). Like the common sea cucumber, snake stars were extremely prevalent (68.5% of all sites), occurring in 68.5% of all sites and 22.4% of all records within the MDC18 survey (Figure 138), in depths of 2.8-130.3 m (mean 35.0 ± 0.61 m) - with the deepest record from MDC18-Q134 out on the central section of Cook Rock. Occurrence and rank abundance of *Snake stars* was highest in high-current zones (Figure 138), particularly in TC (>90% of sites, 24-45% of records) on shell-debris and rubble habitats, and in a range of habitats in Cook Strait (83-85% of sites, 25-32% of records). Conversely, this species was mostly absent from inner-most section of inner QCS, with no snake stars seen inward of Wedge Point, Picton (Figure 138), suggesting that this species has an aversion to low-current environments. However, occurrence was very high in inner QCS sites in the very high-current sites adjacent to the QCS-TC junction.

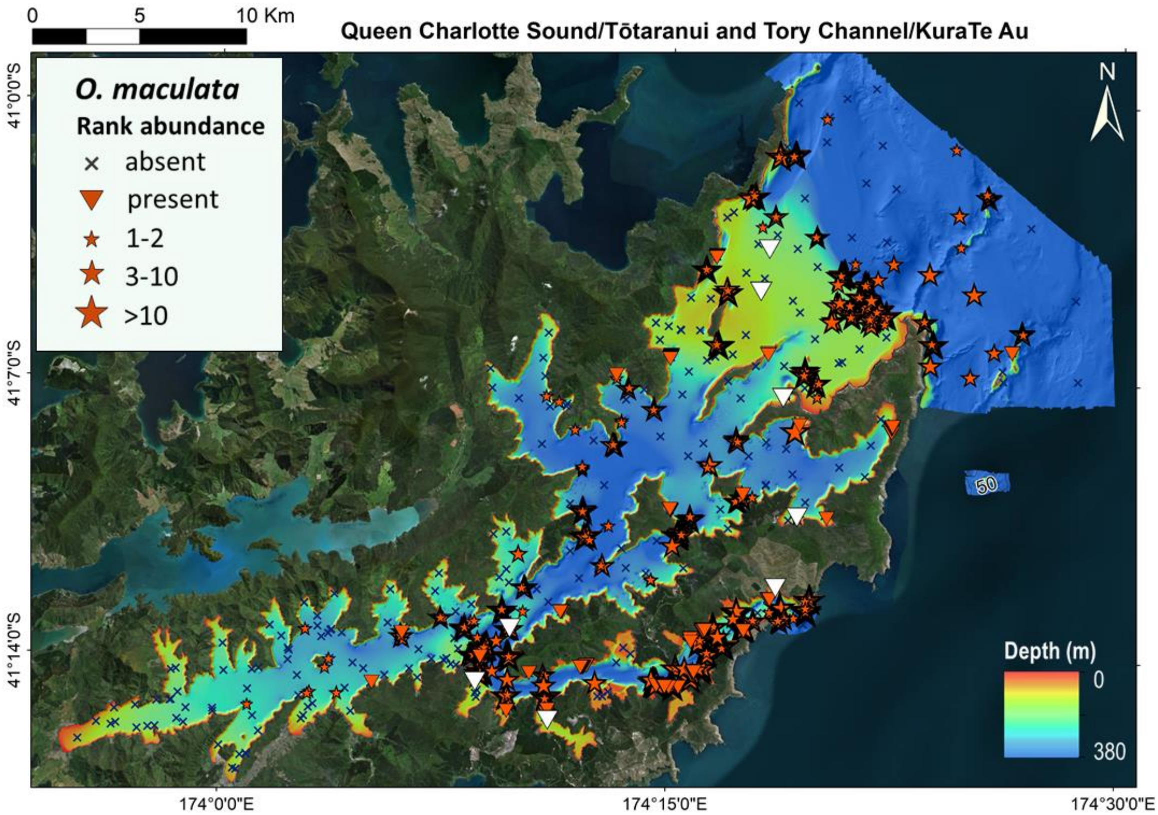


Figure 138: Distribution and rank abundance of the large ophiuroid or snake star (*O. maculata*), within the survey area. Bubbles are % rank cover estimates; white inverted rectangles = BT17 beam trawl specimen collections (presence); inverted red triangle = presence at CB17 sites.

3.7.11 Eleven-arm starfish distribution

The 11-arm starfish, *C. muricata,* is a large predatory starfish that occurs commonly within the Sounds, where it was recorded in depths of 2.3-81.5 m (mean 23.6 ± 0.52 SE). This species was recorded throughout QCS and TC, as well as in Cook Strait – both adjacent to the QCS and TC entrances, and at the Brothers (CB17 survey). Notably high densities of this species were recorded on the wave-like features of shell debris lining the deep slopes of inner TC (e.g., MDC Sites Q170, Q171 – see Section: 3.4.6).

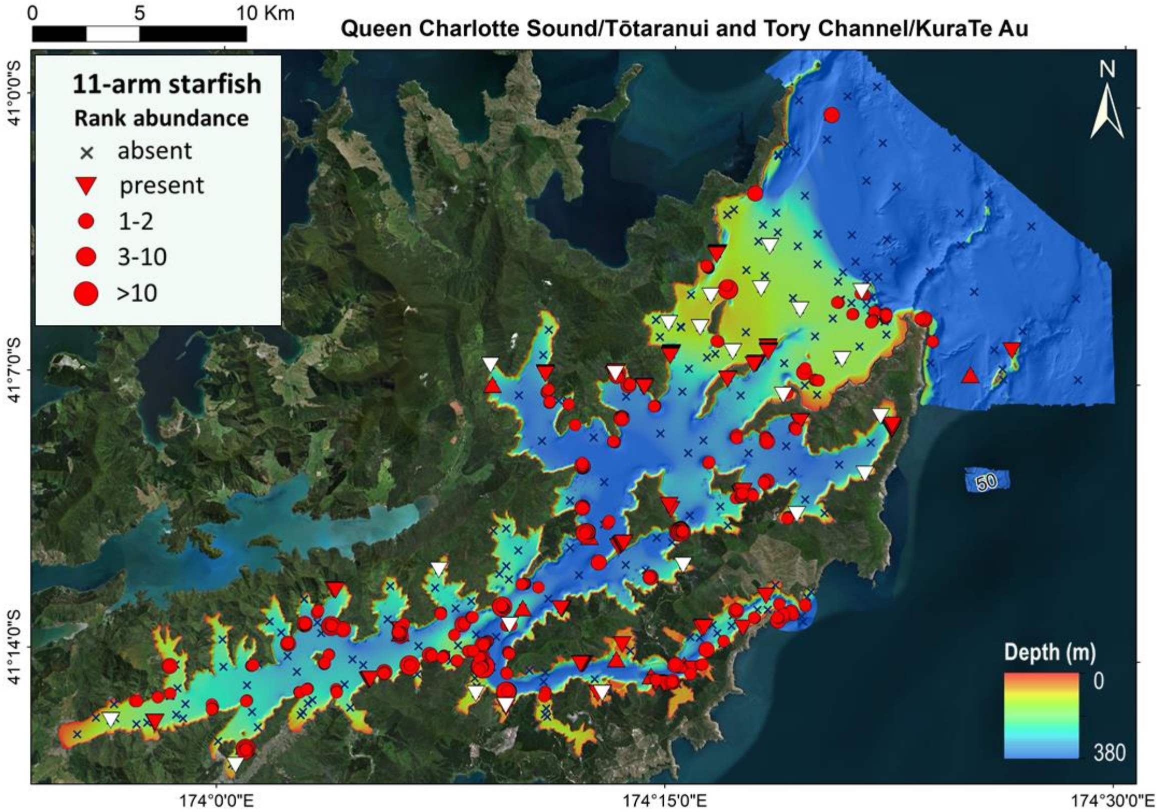


Figure 139: Distribution and rank abundance of the *C. muricata* (*C. muricata*) within the survey area. Bubbles are rank abundance estimates for the MDC18 survey; white inverted rectangles = BT17 beam trawl specimen collections (presence); inverted red triangle = presence at CB17 sites, upright red triangles = HS51 survey.

4 Discussion

4.1 Overview

Prior to these ground-truthing surveys, scientific information on benthic habitats and their communities within the HS51 survey area came from surveys in depths of <6-20 m (described in Davidson et al. 2011; 2015). These surveys were based on mostly 'brief visits' (using snorkelling or SCUBA) to intensive small-scale studies at a few sites (descriptive overviews in Davidson et al. 2011; 2015; 2017a); along with site-species farm surveys (e.g., Clark et al. 2011; Morrisey et al. 2015; Brown et al. 2016a); and a few historical grab and dredge surveys that surveyed deeper sites mostly within the muddy sediments (Dell 1951; Estcourt 1967; McKnight and Grange 1991) – which based on the findings of this report we now know most of these sites lie within the mapped '*Amphiura*-dominated sediment plains'. Those earlier studies provide the backbone of the ESMS planning and zoning, but little was known about habitats and communities in very high-current areas or in depths >6-20 m (but see Davidson et al. 2011). High-resolution multibeam maps, presented and described in Neil et al. (2018a,b), provided unprecedented detail of a complex seafloor, across depths of 0-320 m, with a wide variety of bottom features where no previous information was available on what these habitats were or their associated biological communities looked like.

To ground-truth these newly acquired maps and characterise habitats and communities across the HS51 survey area - particularly previously unknown and potentially high quality or biologically significant communities, Marlborough District Council (MDC) commissioned NIWA to undertake an 11-day tow-video survey (MDC18 survey), building upon geo-referenced video surveys previously collected by NIWA (i.e., CB17, BT17 and HS51 surveys). Over the 11-day survey, 36.6 of those linear km's was collected with 5,062 data points (81%) from a 149 sites. This combined with the three previous NIWA video surveys provided a total of 58 linear km's of seafloor video, with 6,251 seafloor characterisations from 358 video sites. This comprehensive coverage meant that a diverse range of seabed features were ground-truthed and characterised, including seafloor slopes, rocky reefs, ridges and deep outcrops, along with banks, bays and sediment plains across an extensive range of depths and locations, with their associated benthic communities. This level of detail is extremely rare around New Zealand's coast (review by Anderson et al. 2019) and where present is limited mostly to small and shallow coastal locations (e.g., Cape Rodney-Okakari Point Marine Reserve). These findings provide significant new insight into the types of habitats, species and communities present within the HS51 survey area, including new and 'notable'[86] habitats, sites and species, and unearths the value of physical attributes (HS51 MBES data layers and maps) in predicting their distributions. These findings provide critical knowledge on the natural and/or current character of these diverse marine environments.

4.2 Seafloor habitats and communities

Caulerpa meadows

Caulerpa meadows (or beds) were found commonly on exposed high-current reefs in depths of ~9-20 m at the entrances to QCS, TC and along the east coast of Cook Strait, with 15 new sites identified. These meadows were composed of various mixes of two species (*C. brownii* and *C. flexilis*) that together and separately formed very lush high-density meadows on extensive reefs and rock walls. *Caulerpa* meadows are known to occur throughout New Zealand, with national data depicting numerous meadows around the top of North Island, such as the Bay of Islands (*Figure 3-18 in*

[86] meaning '*significant*', but '*notable'* is used throughout this report to avoid confusion with Ecological *Significant* Marine Sites (ESMS)

Anderson et al. 2019, also see Morrison et al. 2014), and are also known from the Poor Knights (Andrew and Francis 2003), with extensive *Caulerpa* meadows found growing on vertical and steep sloping rock walls in Stewart Island (Wendy Nelson, *pers. comm*.).

Prior to the MDC18 surveys '*rocks covered in a bright green algae'* were purported by past fishers to occur out around Cape Jackson (S. Urlich, *pers. comm.*), while *C. brownii* was reported as a '*small scale habitat former in association with other macroalgae on rock walls in the outer region and entrances to the Sounds'* (*cited as Davidson pers. comm. in* Morrison et al. 2014 p37). During the ground-truthing surveys, extensive and lush *Caulerpa* meadows were verified out at Waihi Point near Cape Jackson confirming the reports by fishers that this species forms an extensive zone in depths between ~10-20 m along these exposed rocky reefs. Lush and extensive *Caulerpa* meadows were also documented at similar depths on the near vertical rock walls at White Rocks, and at an additional 14 sites covering reefs within 1-4 km inside TC-entrance (*C. flexilis and C. brownii*, respectively) to almost all sites along the entire Cook Strait east coast from south of Cape Koamaru down to Robertson Point off Port Underwood, identifying that this habitat-forming species is extremely prevalent on very wave exposed shallow (~10-20 m) rocky reefs. Nine native *Caulerpa* species are known to occur in New Zealand waters, although four are limited to subtropical Islands, and a fifth species, *Caulerpa fastigiata*, is only infrequent recorded). The four remaining species are known from mainland New Zealand, with three recorded within the survey region, although while *C. brownii* and *C. flexilis* were both abundant, *C. geminata* (small grape like form) was only found in <2% cover at a few locations (e.g., the Brothers, Motuara and Motungarara Islands). Two of the fifteen new sites with *Caulerpa* meadow currently lie within ESMS polygons. The very lush *C. flexilis* meadows on the rock walls at White Rocks (MDC18-Q129) lies within ESMS-7.8 and the dense patches of *C. flexilis* within the entrance to TC (MDC18-Q81) lies within ESMS-5.9. No *C. brownii* meadows presently lie within any ESMS, with most dense meadows occurring on the coastal reefs in Cook Strait.

Bryozoan patch-reefs

Patchy bryozoan reefs were discovered within two large areas around the eastern and western channels of QCS-entrance on the outer banks of the Duck Pond, which covered a combined area of 9.58 km^{-2}. The patch-reefs at the entrances to QCS were comprised of both relict and living bryozoans that varied in size and height (1-100's of linear metres by ≤1.5 m high). These patchy reefs support diverse and colourful sessile filter-feeding communities (e.g., sponges, ascidians, anemones, hydroids) and were important structural habitats for newly settled and juvenile blue cod. Where bryozoans form habitat they are known to contribute significantly to the complexity of a locality (MacDiarmid et al. 2013). At least 27 species of frame-building bryozoans are known to create robust reef structures that provide important hard substrata for diverse sessile invertebrate communities (Grange eta l. 2003; Wood et al. 2012, Anderson et al. 2019) that are also important habitats for recreational and commercial fish species (Morrison et al. 2014), including nursery habitat for juvenile blue cod (Morrison et al. 2014; Anderson et al. 2019, NIWA *unpublished data*). Bryozoan reefs are known to cover extensive areas of the seafloor at several locations around New Zealand, most notably off the Otago Shelf, Foveaux Strait, and off Separation Point in Tasman Bay (*see review by* Anderson et al. 2019) that have historically been targeted by commercial fisheries (reviews in Wood et al. 2012, Morrison et al. 2014; but see Michael et al. 2007).

Within the broader Marlborough Sounds, bryozoan patch reefs were previously known to form important biogenic-habitats on sediment Banks around Rangitoto, Trios and Chetwode Islands - north of Pelorus Sounds (Davidson et al. 2010b; 2011; Anderson et al. 2019). No similar areas were known within QCS, except for a purported site (by past fishers) east of Cape Jackson (*designated as ESMS-7.2 in* Davidson et al. 2011 p115). NIWA's combined surveys have now documented extensive areas of bryo-reef that importantly, were delineated using a combination of HS51 bathymetry and backscatter map layers. Extensive areas of bryozoan reef have also been delineated using sidescan and multibeam imagery off Separation point and depict similar fields of patch-reefs interspersed by soft-sediments (Grange et al. 2003; *see example imagery in Figure 3-31 in* Anderson et al. 2019) that support similar diverse faunas. However, while larger and taller consolidated bryo-reefs supported very diverse faunas (no current protection or ESS assignment), unconsolidated rubble patches or consolidated patches with little to no vertical-relief supported comparatively depauperate faunas (including those seen in ESMS-7.2). These new findings highlight the need to reassess the current location and size of ESMS-7.2. The discovery of bryozoan patch-reefs at the eastern and western entrances provide important fragile and vulnerable habitats that currently are not included in any management plan or ESS. Both the coastal and deep water trawl fishery operate mostly in deep water north of QCS-entrance, however the trawl footprint of effort in this areas (from Baird et al. 2015; Baird and Wood 2018) identify a few bottom trawls have been undertaken across the existing bryozoan patch reefs, indicating that bryozoan patch reefs in the entrances to QCS have already suffered some level of historic damage.

Horse mussels were frequently found cemented within the bryozoan patch reefs in QCS. Bryozoan patch reefs growing on the soft-sediment banks at Rangitoto, Trios and Chetwode Islands were also regularly seen with relict horse mussels within their matrix (e.g., Figure 140a), while live horse mussels were commonly heavily encrusted with branching and encrusting bryozoans (e.g., Figure 140b). Horse mussels were also collected from bryozoan patch reefs at Separation Point (Grange et al. 2003). Bryozoa need hard substrata to settle on, but as there is little other stable hard substratum present across these extensive soft-sediment banks the presence of horse mussels, and especially beds of horse mussels, are likely to play an important role in providing the initial hard substratum for bryozoans to become established. Horse mussels are known to settle in clusters (Hay 1990b), which may help facilitate the epiphytic growth of reef-building bryozoan to extend between adjacent horse mussels (e.g., Figure 140b). The scales of patchiness in horse mussel distributions are also likely to be mirrored in the patchiness of the resulting bryozoan reefs (e.g., Figure 140a), until, that is, reefs fill-in and become more contiguous.

Bryozoan reefs are fragile (sometimes referred to as '*china shops'*) and easily broken and removed by bottom-contact fishing gear, such as benthic/scallop-dredges and bottom-trawls (Cryer et al. 2000). Although few baseline and/or monitoring surveys exist to determine how bryozoan thickets have changed through time, some information exists to suggest that bryozoan reefs exposed to bottom fishing activity have undergone physical removal and damage possibly over extensive areas - kms of seafloor (e.g., Otago shelf, Separation Point and South Taranaki Bight) (reviews by: Wood et al. 2012, Morrison et al. 2014; Anderson et al. 2019). Within QCS, there is some evidence, based both on historic catches and anecdotes from past fishers, that horse mussels and bryozoan patch reefs may once have been more extensive across the mid and inner sections of the Duck Pond (e.g., Area B in Figure 141a), and that bryozoan reefs may have once occurred at a few high-current slope and bank locations such as the historic scallop grounds adjacent to QCS-TC Junction (e.g., Area A in Figure 141a). The seafloor in these areas - at the time of these studies – supported only negligible amounts of bryozoan ('coral'), but many showed some signs of more extensive habitats (i.e., regular occurrence of small amounts of biogenic rubble and/or a few larger clumps). However, the occurrence of bottom trawling (e.g., for blue cod pre-1990's Handley 2016) that has occurred over the Duck Pond, and/or decades of scallop dredging in both locations (e.g., Figure 141a vs b) would not enable these types of fragile habitats and communities to persist in those areas.

Recovery of bryozoan patch reefs within the Sounds, however, are likely to be in the order of decades reflecting the slow growth rates of frame-building species (Batson and Probert 2000). However, in areas where reef structure have been removed and where horse mussels have also been removed, or are in low numbers, then recovery of these areas will be hindered.

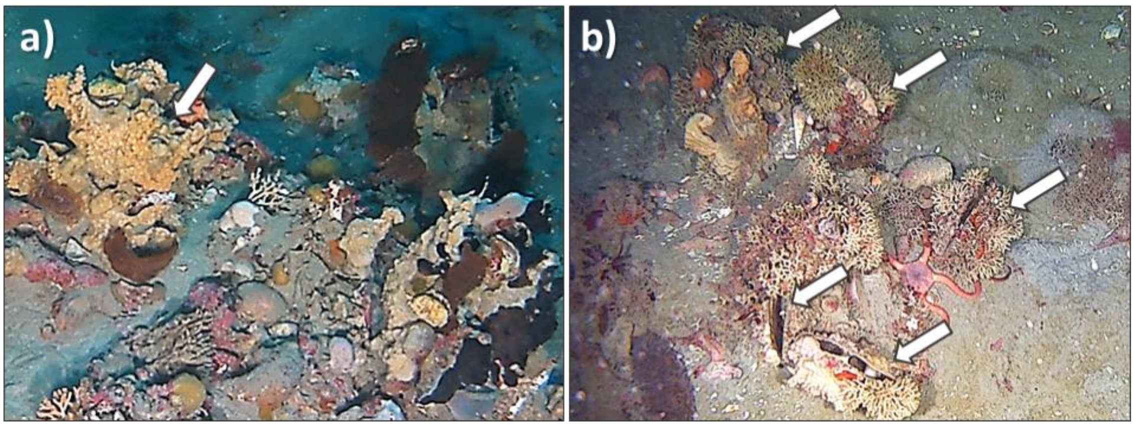


Figure 140: Examples of patchy bryozoan reefs with horse mussels heavily fouled by reef-building bryozoan species (*images g and h from Figure 3-25 of* Anderson et al. 2019). a) low-lying bryozoan reef and rubble on the sediment banks around Rangitoto Island, eastern-side of D'Urville Island; b) Horse mussel bed west of Chetwode Islands, Marlborough Sounds, with live mussels heavily encrusted with branching bryozoans. White arrow = location of horse mussels.

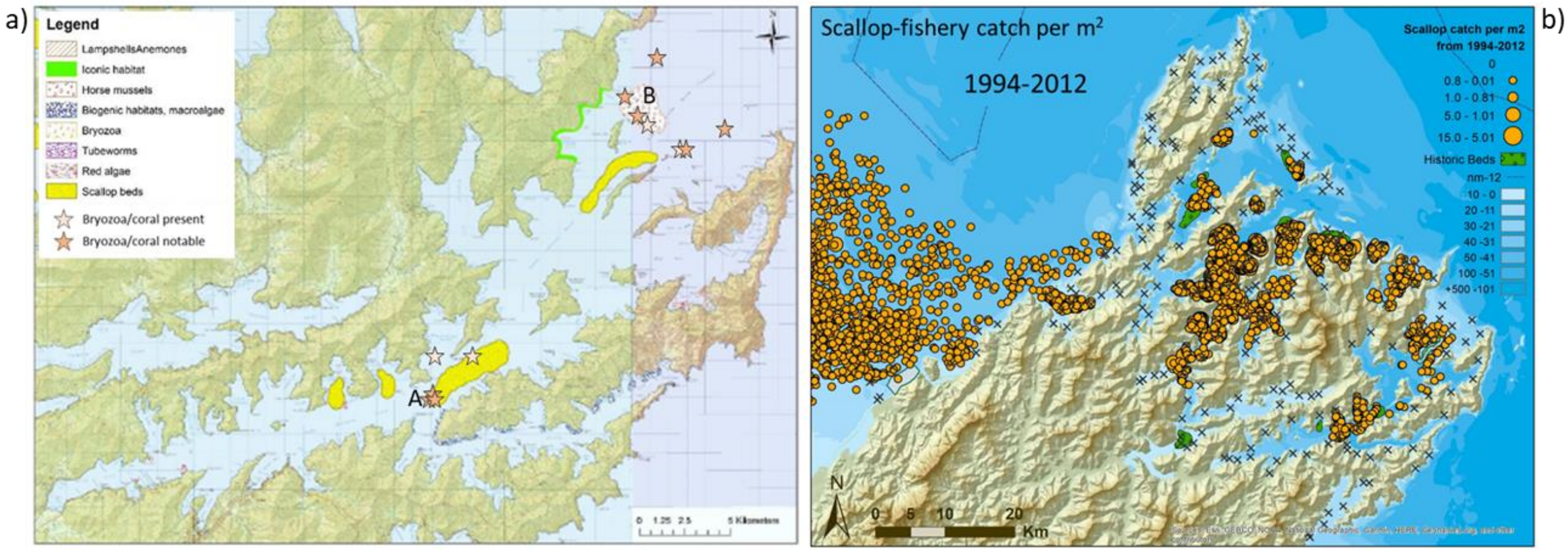


Figure 141: Map of biogenic habitats with approx. locations of bryozoa or 'coral' bycatch (a) and scallop fishery surveys showing catch per m^{-2} (b) relative these QCS locations. a) *Original image from Figure 5-2 of* Handley 2016, where stars depict the approx. locations of where bryozoa or 'coral' have been collected as bycatch[87]; b) small orange circles = densities of scallops caught in research dredge surveys in Marlborough Sounds from 1994–2012 (Data source: MPI and CSEC). Green underlying polygons = historical scallop beds (Handley 2016 "*citing drawn by SBull unpublished*"). x = Dredge stations where no scallops were collected.

[87] *Based on unpublished historic surveys, incl. DSIR surveys 1983 (NIWA unpublished data [e.g. McKnight and Grange 1991]), bycatch distribution maps presented in Figure 3-27 in Anderson et al. 2019*).

Galeolaria mounds

Fields of *Galeolaria hystrix* mounds were recorded at 54 new sites mostly along the channel slopes below rocky ridgelines within inner, mid and outer QCS down to a depth of 40 m, whereas only one location at Perano shoals in mid-QCS was previously known to occur within the survey area. *Galeolaria hystrix* is an endemic serpulid that can create "temperate carbonate reefs, the counterpart of tropical coral reefs", albeit more fragile (Riedi and Smith 2015). During the MDC18 surveys several notable sites were identified that contained extensive fields of intact mounds. However, large-scale damage was also widespread, with 47 of the 54 new sites containing some level of damage, ranging from localised small-scale damage mostly on reefs (few m's in size; 1-10% of the seafloor at a site) to extensive large-scale damage across (100's of m's ≤75% of the seafloor at any one site).

Small scale damage included mounds toppled or broken into rubble, likely caused by small-scale physical damage, such as those made by anchors. Due to the very fragile nature of these mounds, anchors from even small recreational boats can topple and smash these fragile towers (Elliot 1995; Davidson and Richards 2015), as a consequence of both anchor chains dragging and winding across them and especially anchors dragging across them during anchor setting and retrieval. The term 'china shops' has been used for fragile species such as *G. hystrix* to provide a mental comparison of literally dragging a boat anchor through a china shop to understand the likely damage of such a simple task as anchoring one's boat while fishing. While damage takes seconds, recovery, due to very slow growth rates, takes many decades (Riedi and Smith 2015). Boat anchors are known to cause similar scale damage within coral reefs (e.g., Davis 1977; Jaap 2000), seagrass meadows (e.g., Walker et al. 1989), rhodolith beds (e.g., Stellar et al. 2003; *also see illustrated example Plate 18 of* Davidson and Freeman 2013) and has previously been identified as a known threat to *Galeolaria* mounds at Perano Shoals (Davidson and Richards 2015), with many coastal management agencies around the world, including the Great Barrier Reef, now instituting localised no-anchoring zones above fragile habitats (e.g., Beeden et al. 2014; GBRMPA 2019).

The most prevalent and spatially extensive form of damage (10-100's of m's of *Galeolaria* rubble) was seen mostly on the lower slopes, where *Galeolaria* fields extend out across the sediment and shell-debris slopes that flank rocky ridges. Here extensive areas looked like something mechanical had mowed them down. In contrast, the shallower rocky reef zones at the same sites were left intact, indicating that physical damage due to storms - that would be expected to effect shallower areas more prolifically than deeper ones - was unlikely to be the cause of this damage. It also identified that this scale and degree of damage was limited to non-rocky reef habitats. Bottom fishing activities such as bottom trawling and dredging can cause extensive damage across large areas of seafloor where rock is absent (review by Thrush and Dayton 2002). For example, in a study comparing scallop dredged, previously-undredged, and areas closed to scallop dredging, Hall-Spencer and Moore (2000) documented a >70% reduction in fragile habitats dominated by rhodoliths (or maerl), illustrating the dramatic impacts scallop dredging can have on fragile seafloor habitats.

Galeolaria mound fields growing out over non-reef habitats are extremely vulnerable to physical disturbance from mechanical bottom fishing gear. The presence of moderate numbers of scallops within these areas and their locations near known recreational and commercial scallop beds increases their likelihood of damage. Several severely damaged sites were in very close vicinity to known scallop beds. As *Galeolaria* mounds are known to take at least 9 years to establish and upwards of 50 years to build (Smith et al. 2005; Riedi 2012), recovery of these areas will be in the order of many decades, but only where suitable substratum (e.g., *Tucetona* shell-debris) remains available, and where no further physical disturbance occurs. Removal of bottom-fishing gear from within *Galeolaria* zones would be required to protect existing intact *Galeolaria* mounds and enable their recovery within areas already damaged.

The loss of large areas of habitat-forming *Galeolaria* biomass is, however, likely to have (and have had) important consequences. Loss of the 3-dimensional structure that *Galeolaria* mounds afford may lead to a loss of other species. *Galeolaria* mounds provide habitat structure to an assortment of species that include widely occurring species such as rock anemones and hydroids, as well as species less common e.g., "Christmas tree" worms (*Spirobranchus latiscapus*), tube anemones (*Cerianthus* sp1) and the only living example of *Protulophila* hydroid (Davidson et al. 2015), along with notable numbers of fish – where extensive areas of intact-mounds are present. High biomass of filter-feeding polychaetes, like beds of bivalves, can play an enormous role in ecosystem services related to water quality within coastal environments by decreasing water turbidity/increasing light penetration, recycling nutrients and reducing eutrophication (e.g., Davies et al. 1989; review by Bruschetti 2019). The extensive *Galeolaria* areas, based on both intact and damaged biomass, indicate that *Galeolaria* towers once lined the deep slopes within the Sounds, and would likely have had an enormous contribution in maintaining water quality within the Sounds. Loss of these habitats may therefore have contributed to the significant decline in water quality from those described in the mid to late 1800's as the clear blue waters of the Sounds (Handley 2016 p11). Perano Shoals is still one of the best example of extensive *Galeolaria* mounds with multi-directional ground-truthing video transects identifying that most (~90%) of the mound fields at this location lie within the proposed ESMS-4.16 boundary. However, the other 53 sites do not lie within any ESMS sites, identifying that ESMS planning areas do not include a representative amount of these fragile and extremely vulnerable biogenic habitats. The current ESMS sites and boundaries represent mostly nearshore shallow depth habitats. As the majority of *Galeolaria* mound fields occur in depths > 15-20 m and occur offshore of rocky ridges, even where ESMS zones exist at the same locations they rarely if ever extend across these deeper offshore habitats. Consideration should be given to including additional *Galeolaria* mound fields within ESMS planning areas. This could be done in part by extending some ESMS sites (e.g., ESMS-4.14 at Pihaka Point).

Burrowing sea cucumbers

A novel discovery during these surveys was a new genera (and Family) of burrowing sea cucumber not previously recorded in New Zealand, preliminarily identified from 4 partial-specimens as *Thyone* spA (Family Phyllophoridae). Surprisingly – for a species that had never been reported before – this species was extremely abundant on deep high-current slopes, occurring at 26 sites within the Sounds in densities of up to 60 individuals per m^{-2}, while a few rare individuals were also recorded from deep rubble/debris slopes in Cook Strait. Although *Thyone* species can retract beneath the surface mostly for a few minutes for protection against negative stimuli, most animals remain at the surface to feed and respire (Pearse, 1908) indicating that distributions and densities presented here reflect most of the surveyed-population. Although this species was most abundant along the deep slopes within TC, especially near the QCS-TC junction, in depths of ~30-50 m, the correlation of this species with depth, current strength and slope angle, appears to be strongly contingent on their proximity to rocky reefs. This means that future habitat suitability models will need to include HS51 bathymetry and slope layers along with measures of reef proximity and near-bed current strength to adequately predict their distributions both within the HS51 survey area and to predict their likely occurrence in other locations across the broader Marlborough Sounds.

Other species of this genera are known to occur buried in both high current environments and in sediments near rocky reefs (Byrne and O'Hara 2017), although it is unclear what factors are driving these relationships. Current strength is known to stimulate feeding in some species (e.g., *Thyone fusus* review by Hunter-Rowe et al. 1977), and would be expected to be an import factor associated with feeding in *Thyone* spA. Other species within this family are known to attach and anchor themselves to underlying rock (Thandar 2017), but for *Thyone* spA the sediment appeared too thick (at some sites) for this to be likely. An interesting behavioural feature that might be important to explaining their distributions is that for some species (e.g., *Thyone briareus* based on detailed laboratory observations) branched sticky tentacles can be used not only to capture plankton from the water current, they can also use them to sweep and capture food off the benthos (Pearse 1908), selectively ejecting non-food particles from their mouths. Although arm-sweeping behaviours over the sediment were not identified during the tow-video surveys, similar tentacle morphology suggests this behaviour might also be possible in *Thyone* spA. Reef-associated organic matter and microbial organisms that rain down and accumulate at the base of reefs can be important for a range of phyllophorid species (review by Lopez and Levinton 1987), although, while depositional sediments were present in these habitats, it is unclear how much of this organic material would be deposited by the proximal reefs given these are such high current environments. It is clear however from the broader characterisations of sediment slopes below rocky ridges throughout the Sounds that these habitats often have higher near-bed currents than those without reefs, making the former more beneficial to benthic suspension feeding species, such as *Thyone* spA.

This species is an exciting discovery, with an interesting distribution that will require more detailed studies to determine its feeding behaviours and the importance of reef proximity, while full intact species will be essential to describing the taxonomy of this species. This would also allow taxonomic comparisons with known species, particularly those from neighbouring Australia (e.g., O'Loughlin et al. 2012) to determine if *Thyone* spA is synonymous with an already described Australia species or is a new species only known presently from the Marlborough Sounds.

Presently only very low numbers of *Thyone* spA at two sites (MDC-Q172 and MDC-Q176) lie within ESS planning areas (ESMS-5.4 2015-extended boundary and ESMS-4.18, respectively), all other sites lie outside ESS planning areas. One of the highest density zones of *Thyone* spA occurred on the southern slopes of TC near the QCS-TC junction (MDC18-Q140). At present the outer offshore boundary of ESMS-5.1 lies just SW of the shallowest edge of this newly discovered species and unique habitat-zone. Altering the boundary of ESMS-5.1 to extend it ~70 m NE of its current position encompassing depths to at least 50 m would help ensure this species is included within the ESS planning areas.

Seafloor mosaics – three test cases

On land, major photo-grammatic advancements have been within the movie industry (e.g., Lord of the Rings) whereby myriads of photos are taken of a 3-dimensional object, person or animals and stitched together using advanced algorithms to create life-like digital creatures on our movie screens. This same technology is also now used on smart phones to marry individual photos together to form 2-dimension panoramic images. As underwater imagery also advances with ever improving resolution and image quality, so too are the applications for photo-geometric approaches for joining underwater imagery together. NIWA's new ability to create 3-dimensional rotatable photographic mosaics from the video footage of underwater habitats, was trialed for the first time in the southern hemisphere on three Marlborough Sounds habitats. This innovative approach used imagery from NIWA's new fibre-optic high-resolution dual camera system (CBedcam) also the first of its kind in the southern hemisphere. Here individual photographs from bryozoan reefs, *Galeolaria* towers, and the burrowing sea cucumbers were married together in 3-dimensions along test sections of seafloor, and provide some of the very first landscape-scale imagery of these impressive biogenic habitats. These exciting new photographic mosaics provide an unprecedented view of the seafloor, as these mosaics can be rotated in 3-dimensional space to examine and quantify the shape and height of seafloor structures, and can be used to examine the distribution of species relative to these features. The integration of fine-scale video imagery (cm's to 100' of m's) with the large regional-scale HS51 maps, provides unique insight into how habitat structure is used by the associated benthic marine organisms. It also provides an exciting and revolutionary way for managers, stakeholders and the public to see the 3-dimensional complexity of undersea habitats in their local environments and why they're worthy or in need of protection. As imagery is georeferenced, these three dimensions maps can be used to measure attributes such as areal cover, habitat patchiness, vertical height and the amount of habitat-edge (feature all known to be important to habitat-associated species), and where repeated in time can map and measure area of damage and/or recover of these habitats. This new capability will be extremely valuable for coastal management.

Tubeworm fields

The distribution and abundance of four tube worm habitats are presented in this report. These include the calcareous (hard-tubed) tubeworm mounds created by *Galeolaria hystrix* (discussed above), and three non-calcareous (soft tubed) tubeworm habitats created by three different types of habitat forming species (the endemic tubeworms *Acromegalomma suspiciens* and *Spiochaetopterus* spp., and the exotic bristleworm *Bispira bispira* spA.). These three types of non-calcareous tubeworms are all able to form dense fields on the seafloor, with both *A. suspiciens* and *Spiochaetopterus* spp. forming biogenic habitats that increase epibenthic diversity in soft-sediment areas, (review by Anderson et al. 2019). The distribution and abundance of the two native tubeworm species, *A. suspiciens* and *Spiochaetopterus* spp., were both very patchy within the HS51 survey area, and although both species were often collected together, their overall distributions varied with *A. suspiciens* occurring mostly within silty-mud bays along TC, while *Spiochaetopterus* spp. occurred across a broad range of sediment types, and were a characteristic habitat-forming species on sediment slopes between headlands, and across some outer QCS bays. NIWA's MBIE Bottleneck surveys (incl. BT17 and CB17) were the very first records of habitat-forming clusters of *A. suspiciens*, which prior to these surveys was only known from a few individual tubes described from specimens collected near French Pass. (review by Anderson et al. 2019; G. Read *pers. comm.* to T. Anderson). These studies identified that this a large endemic sabellid tubeworm, can form fused tubeworm clusters that extend 10-50 cm above the seabed providing refuge and structure for a diverse variety of species (Anderson et al. 2019 p138-140). This species was also recorded from numerous silty soft-sediment sites across the broader Marlborough Sounds, including the Knobbies within inner Port Underwood, bays within the inner to mid Pelorus Sounds (esp. Nikau Bay) and within the inner sections of Croisilles Harbour, and can form extensive fields in some silty-mud bays, most notably within Nikau Bay (Anderson et al. 2019).

Straw-weed Spiochaetopterids (i.e., comprised of one or more Spiochaetopterid species) were common within the survey area, but their abundance was mostly patchy, with only a few extensive fields recorded within QCS (e.g., Papatoia, a bay east of Long Island). NIWA's MBIE Bottleneck surveys (incl. BT17 and CB17) undertaken across the broader Marlborough Sounds provided the first evidence of the occurrence and broad-scale distribution of straw-weed habitats, which were described and initially referred to as 'wireweed-like' tubeworms in Anderson et al. (2019), due to their close visual resemblance to an already known habitat-forming tubeworm that forms extensive fields in sediments on the Otago shelf - locally known as wireweed by local fishers due to it being extremely tough and hard to cut (Morrison et al. 2014; Jones et al. 2016; 2018). Straw-weed *Spiochaetopterus* spp. are described in more detail for the HS51 survey areas in this report, based on MDC18, CB17 and BT17 surveys. Straw-weed tubeworms create long thin tubes (that look a little like straw), which like wireweed, lie mostly beneath the sediment with their tubes extending only 1-3 cm above the sediment. The short emergent tubes of straw-weed provide habitat for a range of epibiont species, that include often moderate-dense cover of red algal meadow species (Anderson et al. 2019; and this study). Wireweed off Otago is also known to support a range of epibiont species, commonly dominated by encrusting and erect sponges (Morrison et al. 2014; Jones et al. 2016; 2018), it is unclear however, whether the different types of epibonts that occur on these two species reflects the structural differences of their tubes or simply reflect the distribution/occurrence of the available epibiont communities. Straw-weed fields occur in a range of soft-sediment types across the Marlborough Sounds, with the densest beds occurring in Port Gore, and Port Underwood (*see Figure 3-57 in* Anderson et al. 2019).

The polychaete bristleworm *Bispira bispira* spA, is a small Sabellid tubeworm with distinctive bluish-white feeding appendages. When it was first identified growing in Bob's Bay in Picton, subsamples of specimens provided to NIWA (to Dr Geoff Read) were examined using molecular techniques in an attempt to find a match with any known species overseas, however no molecular matches were at that time found, and morphological comparisons with a similar species in Australia, found they did not share similar physical markings (Geoff Read, *pers. comm.* to T. Anderson). Without a direct overseas species match it is very difficult to state definitely that the Bob's Bay *Bispira* species was a newly arrived exotic species or simply a cryptic native that had simply gone unnoticed prior to its discovery ~two decades ago. However, since that time, *Bispira bispira* spA has established dense mounds at multiple locations within the broader Marlborough Sounds, that now include several locations within the HS51 survey area including Waikawa Bay, and more recently several localised beds within Oyster Bay, and possibly now in TC. Over the last few years this species has also densely colonised new areas under wharves in Wellington Harbour, Whangarei Harbour, Mount Manganui, and Houhora Harbour (Davidson et al. 2015). Its recent spread associated with vessel harbours and bays operating marine farms, along with its very dense colonisation of new areas (through clonal budding) are highly indicative of an invasive species. It seems unlikely (and unwise) based on its rapid colonisation of new vessel-populated areas that this in a cryptic native, but rather should now be considered an exotic pest (Geoff Read, *pers. comm.* to T. Anderson). Given other species in the *Bispira* genera have been likened to the invasive Mediterranean tubeworm, formal and detailed genetic studies should be undertaken as soon as possible to help identify its overseas origin, and, examine steps to reduce its spread to new areas within and beyond the Sounds.

Kelp beds

The most notable kelp zones within the survey area were recorded on coastal reefs in Cook Strait, comprised of various mixes of species known to grow on exposed coastlines in this region of New Zealand (Shears and Babcock 2007; Schiel and Hickford 2001; D'Archino et al. 2019). Within the Sounds, patchy kelp beds were common in shallow water along the main channel of TC, particularly around rocky headlands, and reflected the availability of patchy reef in these areas. In contrast, very few kelp beds were recorded within QCS, which were instead characterised by extensive kina barrens. The exception to this was the dense and likely extensive *Ecklonia radiata* kelp forest off Waihi Point, near Cape Jackson.

During the HS51 surveys, acoustic returns were also used to map structure in the water column, and was combined with nearshore aerial imagery (<~5 m) to detect and map additional mid-water features. This method was used to map the in-water structure of marine farms including their ropes and anchor lines (Neil et al. 2018b). It was also used to indicate kelp growing in the water column. The ability to map the water column during seafloor acoustic surveys, is obviously an insightful new technological advancement, where ongoing improvements in resolution and accuracy will likely occur quickly now that this method is available, and already had great success for mapping in-water structure of the marine farms. However, ground-truthing of the purported kelp layer found a variety of major inconsistencies and issues. Although numerous kelp zones were correctly detected, accuracy appeared to be contingent on seafloor relief, method used to detect the kelp (i.e., MBES vs aerial imagery), and the type of macroalgae (tall *Macrocystis* vs other kelps and the presence of drift algae). Kelp on high relief reefs were not well detected during acoustic surveys. Although high relief reefs in Cook Strait, opposite TC-entrance, supported some of the best 'observed' kelp beds, no kelp at all was detected acoustically on these reefs. Similarly, although kelp was detected on various reefs along the promontory towards Cape Jackson, the observed dense and extensive *E. radiata* forest off Waihi Point was not detected, although kelp was detected ~300 north and south (although these have not been verified). The biggest error in kelp-bed detection, however, lay in the fact that attached growing kelp and drift macroalgae were indiscriminately detected. Detected kelp along TC often included areas with varying amounts of drift algae. Large numbers of records of detected kelp were also reported out over soft sediments within TC bays, where kelp beds do not grow, but where drift kelp is known to accumulate. These erroneous kelp records are likely a reflection of kelp-detected from aerial imagery rather than water column acoustic imagery, and indicates the need to separate the data-layers from these two kelp-detection methods. Remote sensing methods, such as aerial or LandSat imagery, is extremely useful in mapping the distribution and density of marine plants, but requires extensive ground-truthing to accurately distinguish between seagrass, drift-algae and growing macroalgae both among and within patches (review by Duffy et al. 2019). However, this problem may also provide a promising method for determining the presence, areal extent and temporal occurrence (where aerial imagery is available from multiple years) of drift macroalgae within these bays. Because of these multiple issues, these 'detected-kelp' maps should be used very cautiously with the above detection errors in mind.

Shallow reefs in Cook Strait (<15-17 m) supported kelp forests characterised by a waved-exposed kelp assemblage, comprising dense stands of mixed species including *Marginariella*, *Lessonia, Landsburgia*, *C. flexuosum* and *Ecklonia radiata*. *Marginariella*, *Lessonia and Landsburgia* were also observed within the entrance to TC. These species are all known to occur along the exposed east coast of the South Island, including several location on the east coast in Cook Strait and out around Cape Jackson (D'Archino et al. 2019[88]), which include data records from sites surveyed by Shears and Babcock 2007 and from the Duffy unpublished Marlborough Sounds Surveys undertaken in 1989-90. A site map and methods-overview from the Duffy et al. (*unpublished 1989-90 surveys* provided by R. Davidson to T. Anderson) show that 330 sites were surveyed in depth <6-20 m across the larger Marlborough Sounds Region. In terms of exposed Cook Strait areas that survey included six east coast Cook Strait sites (from fishing Bay south of TC-entrance, to ~6 km north of TC-entrance), one site at Walker Rock, and two sites in Outer QCS around Kempe Point (outer-QCS, 5 km from Cape Jackson). While some preliminary descriptions are provided in Davidson et al. (2011 e.g., kelp

[88] D'Archino et al. 2019 includes survey records obtained from data provided by Nick Shears (University of Auckland) and Clinton Duffy (Department of Conservation). The Duffy survey data included dive records around mainland New Zealand and the Three Kings Islands collected between 1980 and 2006, and includes the unpublished Marlborough Sounds Surveys undertaken in 1989-90 – as referred to by Davidson et al. (2011; 2015).

descriptions on p114-115), no site-specific fine-scale information has been published. Davidson describes kelp at Walker Rock out by Cape Jackson, as having a narrow band of narrow flapjack (*Carpophyllum maschalocarpum*) along the low tide mark, while east of Walker rock, paddle weed (*E. radiata*) covers the reef in depths of 3-12 m. As no specific site or distance away from Walker rock is specified it is unclear whether this description refers to the dive sites at Kempe Point, or elsewhere. Regardless, it appears based on Davidsons description, the HS51 detected-kelp records (used cautiously here) and our characterisations of Waihi Point that *E. radiata* forests may be common across reefs between Kempe Point and Cape Jackson. None of the exposed kelp forests we described from Cook Strait or at Waihi Point, are currently included within the current ESMS planning areas, although reefs beyond Cape Jackson around Walker Rock are within ESMS 7.1, but it's currently unclear what subtidal kelps (beyond the shallow fringe of *C. maschalocarpum*), if any, occur there.

Kelps within the Sounds comprised mostly patchy kelp-zones comprised of mixes of the giant surface kelp, *Macrocystis pyrifera*, along with *C. flexuosum and Ecklonia radiata*, and one invasive kelp - the exotic Japanese seaweed, *Undaria pinnatifida*. Shallow fringing kelps were not well sampled in TC or QCS during the tow-video surveys due to the dangers of emergent reefs and the difficulty in towing through dense surface kelp. As a consequence, our video-transects only rarely overlapped with DOCs predicted surface-kelp polygons (DOC *unpublished maps based on satellite imagery*; review by D'Archino et al. 2019 and map layers provided by DOC to T. Anderson). Consequently, these very nearshore kelp-zones could not be ground-truthed. Our video transect observations, however, were able to identify that the kelp zone at most sites in TC extended into deeper water often well beyond the DOC mapped kelp-zones. Although these sites generally included a mix of kelp species, subsurface and patchy surface kelp (*M. pyrifera*) was also present. The exotic kelp *U. pinnatifida* (Wakame) was common at most TC sites particularly those within the inner to mid TC, in often very high proportions relative to other kelp species.

The distribution of kelp seen during the combined ground-truthing video-surveys (this study) closely matched the geographic kelp distributions published in Hay (1990a). However, the composition of kelp differed, with the greatest difference being the presence and relative proportions of the exotic kelp *U. pinnatifida* (Wakame), and the absence of *M. pyrifera* at some sites. These differences in community composition were most pronounced around Motuara and Motungarara Islands, where previously Hay (1980a) had described moderately dense *M. pyrifera* plants growing both on the reefs and attached to horse mussel beds in the adjacent sediment zones. During our ground-truthing surveys, *M. pyrifera* was negligible or absent. Instead *U. pinnatifida* has now become prolific following its appearance in the Sounds in 1991 (Forrest et al. 2000; also see Russell et al. 2008), and on the reefs north of Motuara Island (a site previously surveyed by Hay 1990a,b), *U. pinnatifida* is was abundant in more than two-thirds of all records at this site where it is found growing in the same location previously described for *M. pyrifera* (i.e., both on the reef and growing on large shells on the adjacent sediments - where once horse mussel beds were common but now individual horse mussels were rarely seen). However, these kelp species are known to vary seasonally, indicating that detailed temporal surveys across a broad depth range would be required to confirm that this pattern reflects a true compositional shift, and not seasonal shifts. Quantitative temporal surveys may also help elucidate the duration of the adult plant phase within the Marlborough Sounds, as while both *M. pyrifera* and *U. pinnatifida* are strongly seasonal in the south, both species are now also known to persist throughout the year around the Wellington coast (W. Nelson *pers. comm.*, and T. Anderson *pers. obs.*).

Undaria pinnatifida is known to co-occur with other seaweeds, and is often an inferior competitor with endemic kelps in natural stable environments, but in areas subjected to kelp loss due to storm damage or moderate grazing pressure from kina, *U. pinnatifida* can competitively exclude native seaweeds (incl. *M. pyrifera, E. radiata*, and *C. flexuosum*) once it becomes established (review by Stuart 2004). Consequently, the loss of native kelps through a variety of mechanisms from small scale disturbance, such as storm damage, small to moderately large scale loss as a result of kina grazing, or large scale range contractions due to warming sea temperatures (e.g., loss of *M. pyrifera* in SE Tasmania - Johnson et al. 2011), are all likely to favour *U. pinnatifida* (Stuart 2004). Thompson and Schiel (2012) examined recruitment and establishment of *U. pinnatifida* into native canopy of *C. maschalocarpum* by experimentally clearing native kelp from gap sizes of 5 cm^{-2} up to 50 cm^{-2}. Their study found that *U. pinnatifida* recruited almost exclusively to coralline turf in cleared gaps of all sizes, but while small gaps were recovered by their native canopies that then precluded further recruitment of *U. pinnatifida*, large gaps of coralline turf supported vastly higher recruitment of *U. pinnatifida*, with coralline turf also retaining the microscopic stages of *U. pinnatifida* during its die back in summer helping to facilitate the regrowth of *U. pinnatifida* in following seasons.

Both Motuara and Motungarara Islands, along with nearby coastal areas (e.g., little Waikawa Bay) have undergone native kelp loss following increased kina densities (as purported by Udy et al. 2019), and was (at the time of our study) characterised by low to moderately dense cover of *U. pinnatifida*. While a diverse range of understory macroalgae is known to occur beneath native kelp canopies (Shears and Babcock 2007; and as described in this report), *U. pinnatifida* beds are also known to exclude subcanopy species resulting in a loss of macrofloral and macrofaunal diversity (review by Stuart 2004; Irigoyen et al. 2011). While many subcanopy species are still present across these reefs, increasing biomass of *U. pinnatifida* may possibly have ongoing negative consequences. Monitoring these sites, along with representative kelp-sites in TC and kina barren sites in inner to mid QCS is highly recommended. The loss of native kelp forests due to kina grazing and the increasing prevalence of kina barrens across inner-outer QCS, may also actively promote the increasing prevalence of this exotic kelp.

Kina barrens

Kina were extremely prevalent on shallow rocky reefs throughout the Sounds, with kina also recorded on rocky reefs in Cook Strait. Kina barrens (i.e., rocky reef areas devoid of kelp with abundant kina) were common throughout most of the Sounds, and notably, were the most common community-type recorded on shallow rocky reefs within QCS. However, notably higher densities of kina (≤25-38 kina per m^{-2}) were recorded at the entrances to QCS (off Waihi Point near Cape Jackson) and TC (north of Deep Bay), and in Cook Strait near Cape Koamaru. Although mean densities of kina around New Zealand (incl. Marlborough Sounds) are commonly <10 per m^{-2} (Schiel 1982; Choat & Schiel 1982; Davidson et al. 2010a), similar high maximum densities of kina have been recorded around much of New Zealand, where densities are known to reach ≤30 kina per m^{-2} in Fiordland (Wing et al. 2001); 35 per m^{-2} at Waterfall Reef, near the Leigh Marine Laboratory (Schiel 1982); ≤36.9 kina per m^{-2} within TC (Davidson et al. 2010a); >40 per m^{-2} at the Poor Knight Islands (Choat & Schiel 1982); and <50 per m^{-2} (1 quadrat at Wakatu Point, Kaikoura: Dix 1970). These high kina densities were recorded on shallow rocky reefs in depths <20 m. While high densities of kina at Waihi Point and Cape Koamaru were in depths <20 m, TC supported high densities of a much broader depth range, with 35% of all TC kina found in depths of 30 to 60 m, including locally dense clusters of large-sized kina. Although kina are known to occur down to 60 m (Barker 2007), most of the population generally occurs in much shallower depths (<15-20 m Barker 2007). Kina are known to graze on a variety of fucoid and laminarian kelps, particularly *E. radiata*. They are also known to feed on drift kelps where available (Harrold and Reed 1985), but may also actively feed on attached plants where drift algae is absent (Schiel 1982; Foster and Schiel 1988), and in areas where there is little kelp, they can reduce their metabolism and may switch to a diet that includes invertebrates and other algae (Ayling 1978; Wing et al. 2001). Wing et al. (2001) described large scale spatial differences in diet, condition and kina densities between inner and outer sites in Fiordland. That study found that kina had significantly more food in their guts at the entrance to the fiords, where laminarian kelp dominated by *Ecklonia radiata* is found, than at sites within the inner fiords where nutrition is thought to be limited to only red and filamentous green macroalgae (Wing et al. 2001). Similar patterns were found across the HS51 survey area, where densities and test size were notably higher and larger at and near the entrances to QCS and TC, and where the kelp-zone was also dominated by *E. radiata*. However, in TC the depth distribution of kelps (i.e., ≤15-17 m) alone did not explain the broad depth distribution of kina within TC (10-60 m depth range). However, drift kelp was commonly seen on the seabed at high density kina sites near the entrances to QCS and along the length and depth range of TC, where dense clusters of notably large-sized kina (120-150 mm test sizes) found on any available drift kelp, indicating that drift kelp is likely to be an important food source supporting or driving these high-density kina zones, and is most likely the only food source available in depths >20 m.

In contrast to TC, kina in QCS were found in depths <32 m, with drift algae rare or absent. Due to the lack of kelp beds in this region, growing or drift kelp are unlikely to be a dominant food source for kina in inner and mid QCS. The majority of shallow rocky reefs (<~20 m depth) in QCS were characterised as kina barrens, although, kina test sizes were notably smaller and densities markedly less (≤~11 kina per m^{-2}) than those at TC and QCS entrances. Harrold and Reed (1985) identified similar disparate communities where kina-barrens (similar to inner and mid QCS) had little drift algae, sea urchins were poorly nourished, occupied open, unprotected microhabitats, and actively grazed the substratum, while in kelp-dominated area, drift algae was abundant and was fed on by kina that were well nourished. Rocky reefs > 20 m within QCS were often covered in *Galeolaria* mounds (or damaged rubble), which mostly supported low densities of kina, although notably higher densities were recorded in dead or rubbled *Galeolaria* habitats where secondary red filamentous algal growth dominated - indicating a response to a new food supply for kina in these disturbed habitats.

Sea urchins can have a dramatic role in the appearance of rocky reefs. Although many interacting factors and trophic levels are involved in shaping the benthic communities we see, some processes and species-relationships can have dramatic effects on benthic communities. Sea urchins through their role as a dominant grazer of kelp, can actively mow down kelp beds like mini lawn mowers, leaving behind a very different looking community – one characterised by coralline encrusted rocks devoid of kelp (e.g., Schiel and Foster 1986; Andrew 1988; Tegner and Dayton 2000) that are often referred to as paradigm shifts or alternative stable states (Filbee-Dexter and Scheibling 2014). A common theory frequently examined is that fishing-down the numbers of large predators within area (e.g., large fish and crayfish, and predatory mammals such as otters in the northern hemisphere) to a level where they are 'ecologically extinct'(i.e. no longer able to fulfil their ecological function) can lead to increased kina densities that result in increased occurrence of kina barrens where once lush kelp-forests stood (Mann and Breen 1972; Estes et al. 1978; Dayton et al. 1998; Estes and Duggin 1995). Large predators, such as large adult blue cod, lobsters and other large carnivorous fishes are known to prey on adult sized kina (Andrews and MacDiarmid 1999; Tegner and Dayton 2000), with several studies (e.g., Cole and Keuskamp 1998; Udy 2019), identifying significantly fewer large predators outside marine reserves that correlate with less kelp and higher occurrences of barrens. A recent survey by Udy et al. (2019) examining the impact of fishing on urchin densities in QCS and Fiordland, recorded mean densities of ~9 kina ± ~1.5 SE per m^{-2} in fished areas (i.e., Motuara, Motungarara Islands and little Waikawa Bay) and ~6 kina ± ~1.5 SE per m^{-2} within marine reserves (i.e., LIMR) (*values approximated from Figure 4 in* Udy et al. 2019). These values are comparable to those we observed in kina barrens across QCS. Udy et al. (2019) found kina densities and frequency of occurrence were both significantly lower in marine reserves where predatory fish were more frequently recorded, than in unprotected areas where predatory fishes were less common. They also found that the amount of kelp present inside reserves was higher than outside in fished areas.

Impacts of kina fisheries:

Customary and commercial fisheries for kina operate within TC, QCS and Cook Strait (Area SUR7A), which within TC, includes free diving collections in depths of mostly 10-25 m (target depths of 10-15 m) and dredging down to 60 m, with dredging also occurring around Motuara Island in QCS (Miller and Abrahams 2011). However, under permit regulation 27A, there appears to be no apparent limitations as to where dredging is undertaken with TC, and as reporting is not mandatory, there is little to no reported information on catches or the location of these fishing activities (Miller and Abrahams, 2011; MPI *pers. comm.* to T. Anderson). Customary fishers interview by Miller and Abrahams (2011) stated that Te Tau Ihu/TC is a highly productive area for kina, with customary catch estimated at 20 tonnes per year, with an average days harvest for customary occasions collecting 350-1000 kina (10-20 sacks of 35-50 kina), and that even though kina has been fished here for over 35 years large aggregations can still be found. While hand-gathering is unlikely to negatively impact the seafloor, dredging for scallops or kina can have dramatic impacts on the benthos, particularly fragile habitat-forming species (e.g., Spencer and Moore 2000; review by Thrush and Dayton 2002). Most high-quality invertebrate assemblages seen in TC during the ground-truthing surveys were on slopes too steep for dredging. However, the gentler slopes within TC that could be dredged were characterised by high volumes of rubble reef habitats. It is unclear, however, whether these are natural rubble habitats that support rubble-associated communities dominated by early stage successional species, or whether these slopes may once have supported more fragile, longer-lived and later-successional stage species, such as those found on the steeper slopes. Although rubble habitats with similar communities were found in many high-current gentle slope communities that might indicate naturally occurring communities, some evidence of physical damage to fragile taxa was recorded on these gentler slopes, such as *Galeolaria* mounds reduced to rubble and the accumulation of *Galeolaria* rubble at several main channel sites – indicating that damage – likely mechanical – has already occurred it is just unclear to what degree and over what scales this has occurred.

During the ground-truthing surveys, kina barrens were common across QCS, and numbers of large predators were rarely seen. However, the highest density kina areas were generally adjacent or near extensive kelp forests, and in areas fished by humans. While these relationships are all likely to be important, this study provides a very large-scale site intensive survey that will hopefully help to provide a large spatial framework to view existing studies and examine the relative contributions of these factors.

Drift algae

Drift algae is an ephemeral habitat, accumulating in low energy sink areas, such as embayments, following storms that detach growing macroalgae that are then transported by currents over the seafloor. Where replenishment is frequent and biomass within the algal mat is high, algal accumulation and the cycle of nutrient-breakdown can be an important drivers of community structure in the receiving environment (Norkko et al. 2000; review by Engelsen et al. 2010). Large areas of dense drift algae on otherwise bare soft-sediments, provide considerable habitat structure and refuge for a myriad of motile fauna, such as small fishes, crabs, nudibranchs and other invertebrates (e.g., Hull 1987; Langtry and Jacoby 1996; Norkko et al. 2000), including settling larvae of various fish species (e.g., Kingsford 1992; Langtry and Jacoby 1996). However, ephemeral habitats such as drift algae may also function as ecological traps, where fish and invertebrates settle into habitats that do not persist, resulting in their mortality (Hale and Swearer 2016). During the combined ground-truthing surveys, abundant and diverse communities of small invertebrates were seen and collected from drift algal mats within TC bays, along with abundant nudibranchs at some sites and high numbers of a variety of small-sized fishes, including numerous newly settled leatherjackets, which are known to settle into pelagic drift-weed prior to it coming to rest on the seafloor (Kingsford 1992).

Within the Marlborough Sounds, storm dynamics are likely to increase the amount of detached kelp and macroalgae available, with higher intensity and frequency of detachment on the adjacent coastline in Cook Strait, while the strong tidal currents within TC would facilitate transport along the main channel and into these bays. Given the frequency of severe weather in Cook Strait and the strong persistent tidal currents in Tory Channel, one would expect the supply and transport of detached algae into these shallow bays to be relatively high and consistent – based on the observed frequency of drift algae within TC and sheer volume of accumulated material within these bays.

While we observed large areal extents and biomass of drift algae within and between bays, rates of persistence and replenishment are currently unknown, but will have important ecological consequences to both the animals that settle or move into these ephemeral habitats, and for the communities living in the sediments beneath. For example, where dense macroalgal mats are retained or continually reoccur, the sediments beneath can increase in silt content and organic matter as the macroalgae break down over time – equivalent to composting one's garden. Where sediments remain well oxygenated, this provision of additional organic matter can result in increased epifaunal densities and diversity (Rainer 1981; Soulsby et al. 1982), which may surpass other more permanent habitats, such as seagrass meadows (Holmquist 1984; Norkko et al. 2000). Conversely, dense macroalgal mats that are persistent in areas with low water movement, can result in hypoxic and anoxic conditions (Engelsen et al. 2010), leading to increased stress on the infaunal assemblage (Norkko et al. 2000), and if persistent can result in marked changes to the infaunal community (Cummins et al. 2004; Bona 2006; Green et al. 2014) often characterised by higher abundances of a fewer anoxic-tolerant species (Norkko and Bonsdorff 1996; Engelsen et al. 2010). From the limited number of beam trawls undertaken within several of these bays, the surficial infauna collected reflected diverse assemblages, generally dominated by small bivalve, while the macroalgae collected was detached, but still living with no signs of decomposing material – indicating well oxygenated algal mats. However, more detailed temporal and spatial studies would be required to evaluate the long-term persistence and benthic consequences of these mats.

Tucetona habitat zones

Beds of live robust dog cockles (*Tucetona laticostata*) were discovered at 26 sites within the Sounds, found buried on slopes with coarse sediments exposed to very strong currents in depths ranging from 9-44 m. *Tucetona laticostata* is known to occur around much of New Zealand's coast in depths down to 100 m (*McKnight 1969 data plotted in Figure 6.1 in* Rowden et al. 2012; *Figure 3-47 in* Anderson et al. 2019), although depth distributions in any location appears to reflect the presence of coarse sediments exposed to high current flow. In the Hauraki Gulf, for example, live *Tucetona* beds occur in coarse gravelly sediments in depths of 5-15 m at the Noises (Dewas and O'Shea 2012), while in the South Taranaki Bight live beds occur in coarse sediments on high-current slopes in depths of 25–55 m (Beaumont et al. 2015), and on the eastern side of D'Urville Island, live beds and their shell-debris line the gravelly sediments within the high-current channel between Rangitoto Islands, Tinui and Puangiangi, in ~22 m water depth (T. Anderson *pers. obs.*, NIWA *unpublished data*). While beds of live bivalves are known to have a crucial role in ecosystem functioning (MacDiarmid et al. 2013), the shells of this species also play an important and often crucial role long after the animal dies, whereby the large robust shells (≤12 cm diam) of *T. laticostata* accumulate on the seafloor either down-current or down-slope of the live bed where they can remain over thousands of years, providing hard structure for other sessile animals to grow on (review by Anderson et al. 2019). In this study, three important habitat-forming *Tucetona* zones were consistently documented within inner, mid and outer QCS. A zone of live *Tucetona*, below which shell-debris fields were heavily encrusted by early-stage colonizers (dominated by encrusting invertebrates and algae) and abundant motile invertebrates, while shells further down slope shells were covered in silty sediments and supported brachiopods, red urchins and solitary cup corals. Beaumont et al. (2015) also recorded three *Tucetona* zones down the high-current slopes off the South Taranaki Bight, where live *Tucetona* beds lay above a shell-debris zone dominated by encrusting species, below which was older more weathered shell debris heavily encrusted with fragile frame-building bryozoans and diverse array of later-stage colonisers (e.g., encrusting and erect sponges, foliose bryozoans, colonial and solitary ascidians, brachiopods and epiphytic bivalves) that collectively bind and stabilise the shell-debris. Unlike STB, frame-building bryozoans were not commonly seen on *Tucetona* debris in QCS, however, *Tucetona* shell-debris fields abutting rocky ridges was found to provide critical habitat for *Galeolaria hystrix* to settle and grow on, that over many decades became complex landscapes of tower-like mounds. Although *Tucetona* had been recorded at Perano Shoals – the only QCS site known to have *Galeolaria* mounds prior to the MDC18 surveys – its role in providing habitat for *Galeolaria* beyond its rocky reef distribution had not been documented. Importantly, areas away from headland rocky ridges, supported very different benthic assemblages with no live *Tucetona* and very little hard surface for any epibonts to grow on, except epiphytic algae and colonial ascidians growing on the occasional rock or shell, or emergent patches of wireweed-like tubeworms. Loss of these *Tucetona* zones would therefore be expected to result in significant loss in habitat structure and epibenthic diversity.

Amphiura-dominated sediment plains

The drowned valley floor of QCS has, over geological times, been filled in with depositional sediments that now form extensive sediment plains across the seafloor in the main channels and bays. Neil et al. (2018a,b) used supervised classification of the backscatter that delineated thick seafloor sediments, describing these 'sediment plains' as thick mud sediments. The ground-truthing video surveys, however, identified two distinct habitat-community types. One with thick silty muds and very little sand, occurring from Grove Arm out to the southern end of Long Island that were dominated by often very high densities of the delicate rose-coloured brittlestar, *Amphiura (Amphiura) correcta*. The other occurred in sediment north of Long Island (including the Duck Pond) and comprised higher proportions of sand with very few to no *A. correcta*. Consequently, the 'sediment plain' category as it stands would greatly over-estimate the area covered by the *Amphiura*-zone, and would require it be split from the 'sandier sediments on the sill' (i.e., north of Long Island).

Various *Amphiura* species have long been known to dominant communities within thick muddy sediments around New Zealand (e.g., McKnight 1969), and have also been described within the Marlborough Sounds (Estcourt 1967; McKnight and Grange 1991; Davidson et al. 2011). Estcourt (1967) in a grab survey sampling 58 sites across Pelorus Sound (PS) and QCS, described two *Amphiura*-dominated communities within the Marlborough Sounds, one in PS dominated by *Amphiura rosea* and the other in QCS dominated by *A. correcta* (known then as *A. norae*), where related species had complimentary distributions correlated with depth and sediment composition. Davidson et al. (2011 p55) also described muddy sediments offshore dominated by *A. rosea* (along with heart urchins, turret shells and bivalves: *Dosinia*, *Neilo australis, Nucula* spp.) from in Area 1 Croisilles Harbour to Greville Harbour) – although it is unclear where exactly this species was found.

McKnight and Grange (1991) described benthic communities from a DSIR dredge survey in 1983 that sampled 97 sites across PS, the Outer Sounds, and QCS. *Amphiura*-dominated communities occurred in 74% of sites, along with the heart urchin (*Echinocardium cordatum*) and a suit of other infauna species. Field logbooks associated with the 1983 DSIR dredge survey recorded dominant species, including *A. correcta* as present, low, moderate and dense (NIWA *unpublished Logbook records*). During early ground-truth planning we plotted these distributions in ArcGIS. Comparisons of rank abundance for *A. correcta* from our combined ground-truthing surveys with those from the 1983 DSIR dredge surveys, show very similar distribution and abundance of this species within QCS, with highest densities found through mid-region of QCS (Figure 142), with no noticeable change in *A. correcta* across these sediment plains in 35 years.

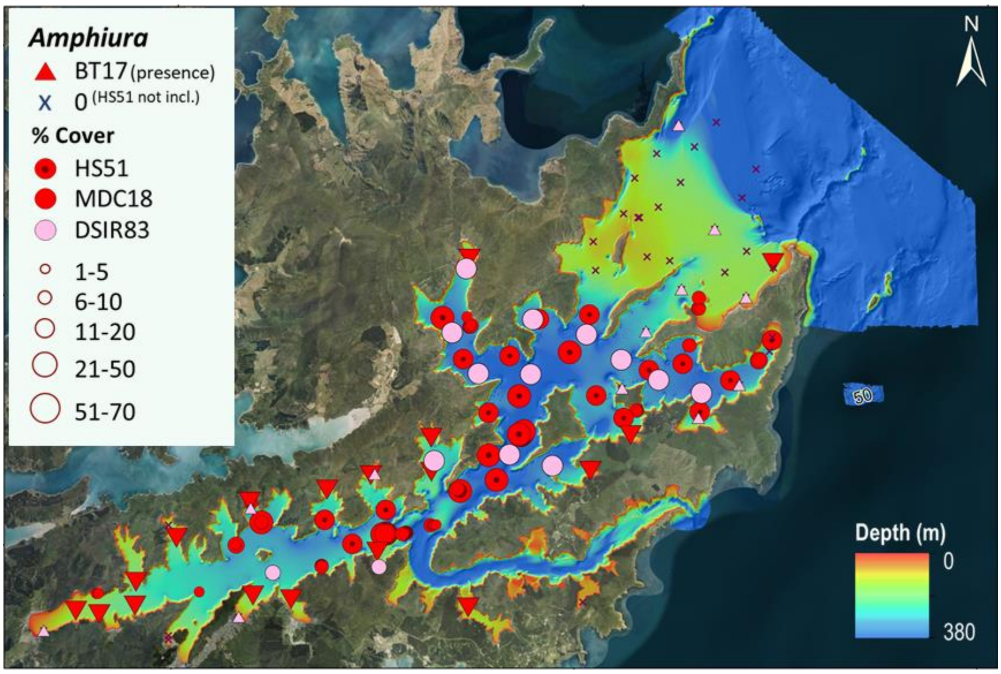


Figure 142: Distribution and rank abundance of the pink brittle star *A. correcta* between 1983 (pink symbols) and 2018 (red symbols). Pink triangles = present, while size of pink circles denote low, moderate and dense *A. correcta* from the DSIR 1983 dredge survey (site details in McKnight and Grange 1991).

Offshore deep reef communities (> 60 m)

High-relief deep reef features mapped during the HS51 surveys were described during the ground-truthing surveys. Cook Rock, the Brothers, and Te Whētero were surveyed in depths of 60 to 132 m. Some shallow reefs have been surveyed at Cook Rock, the Brothers, Walters Reef and Awash Rock previously but only to <20 m with brief descriptions provided in Davidson et al. (2011 - *citing Duffy et al's unpublished survey*). The deep sections of these reefs had not been observed before, likely due to the distance offshore and their exposure to high winds, high and changeable seas, and very high-current conditions that make these reefs extremely difficult to survey.

These offshore deep reefs were between 6 and 21 km apart, but all three reefs (six surveyed sites) were visually-stunning with extremely steep pinnacles, ridges and rock walls that included 10-40 m vertical height changes and maximum slope angles of ≤58-78^{o}. These high-relief reefs were densely packed with highly colourful and pristine communities of sessile filter-feeders. We discovered impressive sponge gardens with never before seen bleach-white *E. alata* sponges, some the size of tractor tyres, growing on the tops and side of steep ridge lines and rock walls, along with dense clusters of goose neck barnacles – these are strange-looking barnacles that attach themselves to the reef by long furry stems (that look like gooses necks), and that were both new records for Marlborough Sounds. Every inch of space on these deep reefs was packed with impressive invertebrates that included a vast array of shapes and sizes of sponges, ascidians, vibrant yellow zooanthids, dense clusters of brachiopods, hydroids, hydroids trees, soft and hard bryozoans, along with many other species. All three reefs are significant discoveries for Marlborough Sounds, but also important for New Zealand.

These deep reefs supported very similar assemblages (albeit with some differences), indicating that deep reefs around Awash Rock and Walkers Rock would likely support similar benthic communities – contingent on having similar 10-40 vertical height changes and ≤58-78^{o} maximum slope angles. The largest and most impressive numbers of bleach-white sponges were seen on the mid-section of Cook Rock (MDC18-Q134) immediately SE of ESMS-7.10, while the most impressive clusters of goose-barnacles were seen at the northern end of Cook Rock a complex section of reef NNE of ESMS-7.10. The current boundaries of ESMS-7.10 encompass a unique section of shallow and emergent reefs on Cook Rock that occur across the outer third of this very extensive ~8.1 km long reef system, and, while the current boundary does include deeper sections of seafloor around these shallow and emergent reefs, they do not currently include the same rugged high-relief features as those recorded beyond its boundaries. When the ESMS planning areas were assigned (Davidson et al. 2010) there was no information on the rugosity or vertical relief of these deep reefs and no information on what these deep reef communities looked like. The majority of deep reefs (i.e., >60 m) that lie within the current ESMS-7.10 boundaries can now be measured and have slope angles ≤~12-30^{o} that are unlikely to represent the same communities that we describe from the deep reefs beyond its boundaries that have measured slope angles of ≤70-80^{o}. To ensure these remarkable deep high-relief reef systems are included in the ESMS planning, we would recommend extending the boundary of ESMS-7.10, 300 m SW and 500 m NE to include these much more rugged high-relief deep-reefs that are representative of the much larger Cook Rock reef system.

A similar issue is present at ESMS-7.12 (encompassing the Brothers) and ESMS-7.13 (encompassing the almost-emergent reefs around Awash Rock), in that these ESMS boundaries were planned prior to the availability of the HS51 maps, and while these planning areas adequately capture shallow reefs systems, they do not adequately represent the much high-relief deep reef systems that support the stunning deep-reef communities that we describe here. We would recommend that minor adjustments to these boundaries be made using the hill-shaded bathymetry to ensure representative deep reefs are included. For example, extending the ESMS-7.13 boundary a further 300 m west; and ESMS-7.12 boundaries 300 m north and 250 m south would ensure representative offshore deep reefs are included in these planning areas.

At the mouth of TC, Te Whētero (the previously unnamed reef that protrudes out of TC like a tongue – thus our recommended name for it) supported proportionally more sponge garden species and jewel anemones, but unlike the other reefs no goose-barnacles were seen on this reef (2 sites). Two-thirds of this reef, including extensive sponge gardens and jewel anemones, lies within the ESMS-5.9 planning area, which extends out over the shallow to mid depth sections of this significant deep reef. Deeper sections of this reef (the very tip of the tongue) that lie beyond the ESMS boundary supported more brachiopods and solitary cup corals, but these would be expected to occur along the deeper sides of this reef too which do lie within the current ESMS boundary.

Although these high-relief deep reefs support pristine invertebrate communities, they are unlikely to reflect pristine fish communities – given the long and extensive fishing history targeting these reefs for hāpuka (Johnston 1983; Beentjes and Francis 1999). During our surveys, very few large fish and no hāpuka were seen, even though large fish are known to have occurred in these depths on these reefs. While it is likely that some fish were hiding in gullies and ravines that we could not see into, many of these ravines and gullies were visible. Hāpuka are known to occur to depths of 300 m in this region, so we may have not sampled deep enough. However, given the numbers of fish caught on these reefs in the past, one would expect to see at least some fish. For example, Beentjes and Francis (1999) undertook a tagging study between 1979 and 1984 to look at movement patterns of hāpuka at three regions around NZ with 13 sites in Cook Strait that included Cook Rock, the Brothers and Awash Rock (along with Marlborough Rock, Port Gore Reef, Lambert Head, White Rocks Bank, Cape Campbell and Jacksons Head). That study tagged and released 599 hāpuka caught by line fishing in depths of 60-200 m (mean depth caught of 125.8 m ± 2.6 SE). Although we recorded few to no commercial-sized fish, it is unclear from our survey of only six sites if this reflects a general trend in the numbers of large fish on these deep reefs or their avoidance of the towed imaging systems. However, slow declines in hāpuka fishery catches within Cook Strait were recorded historically (between 1949 to 1986), along with other key regions (Fisheries New Zealand 2019). Beentjes and Francis (1999) found that the hāpuka they tagged off the south-east of the South Island moved north past Kaikoura into southern Cook Strait within 1-year of tagging, at around the age of maturity - suggesting that Cook Strait was likely a spawning ground. If Cook Strait is a key spawning area, and these were once important hāpuka reefs, then the decline of hāpuka on these reefs would likely have important, possibly dire, consequences to the broader population. Protection of these high-relief deep reefs may provide an important step in the recovery of hāpuka to the region.

Reefs at QCS and TC entrances

Deep reefs at the entrances to QCS and TC varied in their degree of relief and composition. Those with high relief supported a mixture of species, including those found inside the Sounds, such as hydroid trees alongside others found on offshore deep reefs, such as sponge garden species and occasional large bleach-white *E. alata* sponges (very deep QCS-entrance only), although not all offshore species were present (e.g., goose barnacles were absent). Deep reefs at the entrance to the Sounds, like those further offshore, were packed with a myriad of species, although diversity and biomass appeared to be less that those offshore. Entrance sites at QCS also comprised relict bryozoan reefs of varying relief. Those with very low relief on the lower slopes were partially buried and supported only very low % cover of biota more similar to communities on rock-rubble slopes, while more complex bryozoan reefs supported mixtures of live reef-building bryozoans, along with colourful assortments of sessile invertebrates (sponges, ascidians, hydroids, etc.).

The occurrences of extensive relict bryozoan reefs on the channel slopes and deep channel entrances, along with still active growing reefs is likely to have important implications for understanding the paleoecology and geology of this region Bryozoan reefs, once established, grow on top of themselves (self-generating like coral reefs) often for long geological time periods, leaving a fossil footprint, beneath modern day sediments, of where they once grew. A vibrocore survey - that takes small but deep cores that are drilled down into the seafloor - at sites across the Duck Pond along with sub-bottom profiles, would help document where these reefs once grew, including how far they once extended across the Duck Pond, whether they were similarly patchy or perhaps more contiguous than they are now (as indicated by some of the backscatter imagery). Samples from these cores could also be dated to determine the timescales of when reefs were present and where reef loss occurred. For example, James et al. (2000) undertook a vibrocore study within the Great Australian Bight, where they discovered complex bryozoan mound habitats both directly below modern sediments and in deeper facies, identifying that bryozoan reefs had once formed large living reefs in these areas. Similarly, Woodroof et al. (2010) used vibrocore studies in combination with high resolution multibeam sonar surveys to discover and map relict coral reefs in deeper waters around Lord Howe Island, and were able to document past growth rates relative to changing paleo-environments. Vibrocore studies can shed considerable light on bryozoan growth rates through time along with the extent and time scales where habitat loss occurred - where this fossil footprint remains (like DNA studies can now identify long ago crimes). That information would provide MDC with unique knowledge on how much bryozoan reef has been historically and recently lost, especially in areas known to have been open to destructive bottom fishing gear, and where recovery of lost bryozoan reefs, in combination with essential settlement surfaces such as horse mussel beds, may be required or feasible.

Rocky reef within the Sounds

Shallow rocky reefs within the Sounds included a variety of fringing rocky, boulder and cobble reefs, along with more complex rocky ridges at the headlands of most bays. In contrast, deep reefs >30 m were almost always extensions of headland rocky ridges. All headland rocky ridges within QCS are flanked by depositional sediments and shell debris, with most ridges completely buried by sediment in depths ≥30 m. The rocky ridges in deeper water were simply the ones that extended the furthest offshore. Shallow and deep reef communities varied by subregion, reflecting a gradient in current strength and sedimentation. Models of hydrodynamic current strength across the HS51 survey area (e.g., Figure 143a-b; Hadfield et al. 2014) correlate well with the broad-scale patterns in the amount of sediment seen on the seabed and the types of communities recorded across the survey. Low relief reefs in low current areas, particularly those in depths >30 m, were generally covered by often thick depositional silt, and supported low density communities dominated by a few sediment tolerant species (e.g., the sea squirt, *M. squamiger*, solitary cup corals and the yellow papillate sponge, *Polymastia hirsute*), while other less tolerant species were likely stressed or threatened. Within the Sounds, deposited sediment on the seafloor is a natural facet of a depositional environment, however, the rate of sedimentation and changes in these rates are likely to be important in the persistence and composition of benthic communities (review by Airoldi 2003; Schwarz et al. 2006). In depositional environments (such as those within inner bays), suspended fine sediments in the water column (i.e., that make the water look turbid) settle out and rain down on the seabed through time, accumulating and smothering the flora and fauna living there, leading to communities dominated by sediment tolerant species (Airoldi 2003; Hendrick et al. 2016). Episodic sedimentation events following heavy rains or severe storms can dramatically increase suspended sediment loads (e.g., ≤560 ppm in the Bay of Many Coves - O'Loughlin 1980) that can lead to catastrophic smothering of sessile assemblages resulting in a loss of sediment intolerant species and a decline in biodiversity (e.g., Battershill 1993; Airoldi 2003; Hendrick et al. 2016). In contrast, high-current erosional environments (such as those around the junction of QCS-TC) can keep fine sediments suspended and have benthic currents that are able to resuspend fine sediments washing them away downstream (e.g., Figure 143a-b; Hadfield et al. 2014). Rocky reefs off headlands exposed to higher currents (especially those around the QCS-TC junction) comprised comparatively little to no silt veneer and supported diverse and healthy filter-feeding assemblages that include encrusting 'reef-building' bryozoans, ascidians, hydroids and rock anemones, and in some places, large clusters of white barnacles, most of which are likely to be sensitive to fine depositional silts that can clog their filtering appendages (reviews by Airoldi 2003; Schwarz et al. 2006; Hendrick et al. 2016).

An exception to this pattern, however, were three video transects for two locations either side of Fitzgerald Bay at the entrance to East Bay (NE headland sites Q72/Q316 and SW headlands site Q73; sites depicted by yellow stars in Figure 144) near Pickersgill Passage. These sites are exposed to moderate surface currents based on the hydrodynamic models of Hadfield et al. (2014) and moderate benthic currents Hadfield (2015) that resuspend fine sediments washing them away downstream (Figure 143a-b). Yet, even though bottom stress exceeds 0.1 Pascal, the seafloor at these sites were heavy dusted in very fine depositional silt that indiscriminately covered the seafloor on this otherwise exposed ridgeline (*seafloor images in Figure 73 of results*).

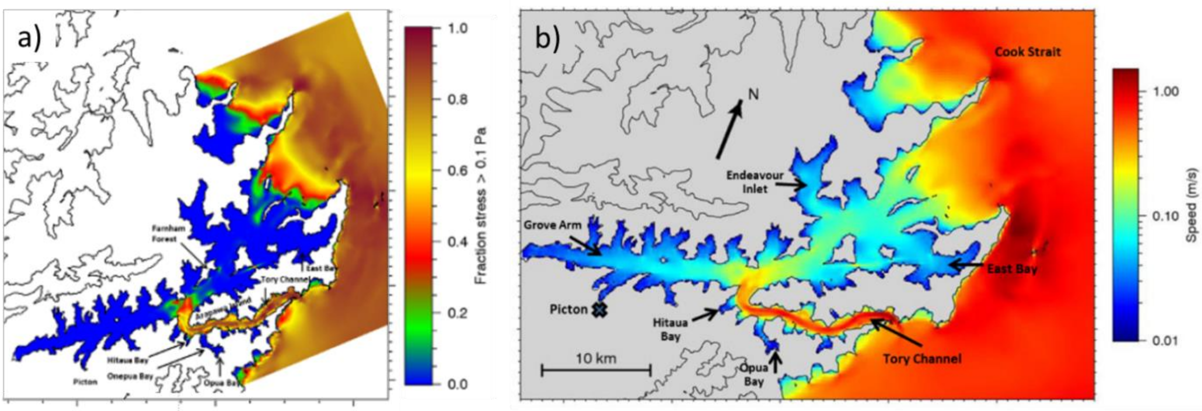


Figure 143: Hydrodynamic model of bottom stress resuspension potential (a) and surface current speed (b) for QCS, TC and the adjacent Cook Strait (NIWA hydrodynamic model from Hadfield 2015 and Hadfield et al. 2014, respectively). a) Bottom stress resuspension potential for fine-sediments showing the fraction of time the modelled bottom stress exceeds 0.1 Pascal (Pa) (*from Figure 1-1* in Hadfield 2015), based on existing hydrodynamic models (Hadfield et al. 2014); b) Model mean current speed at 5 m depth, based on one year's hourly data from the 200 m model (*from Figure 3-14* in Hadfield et al. 2014).

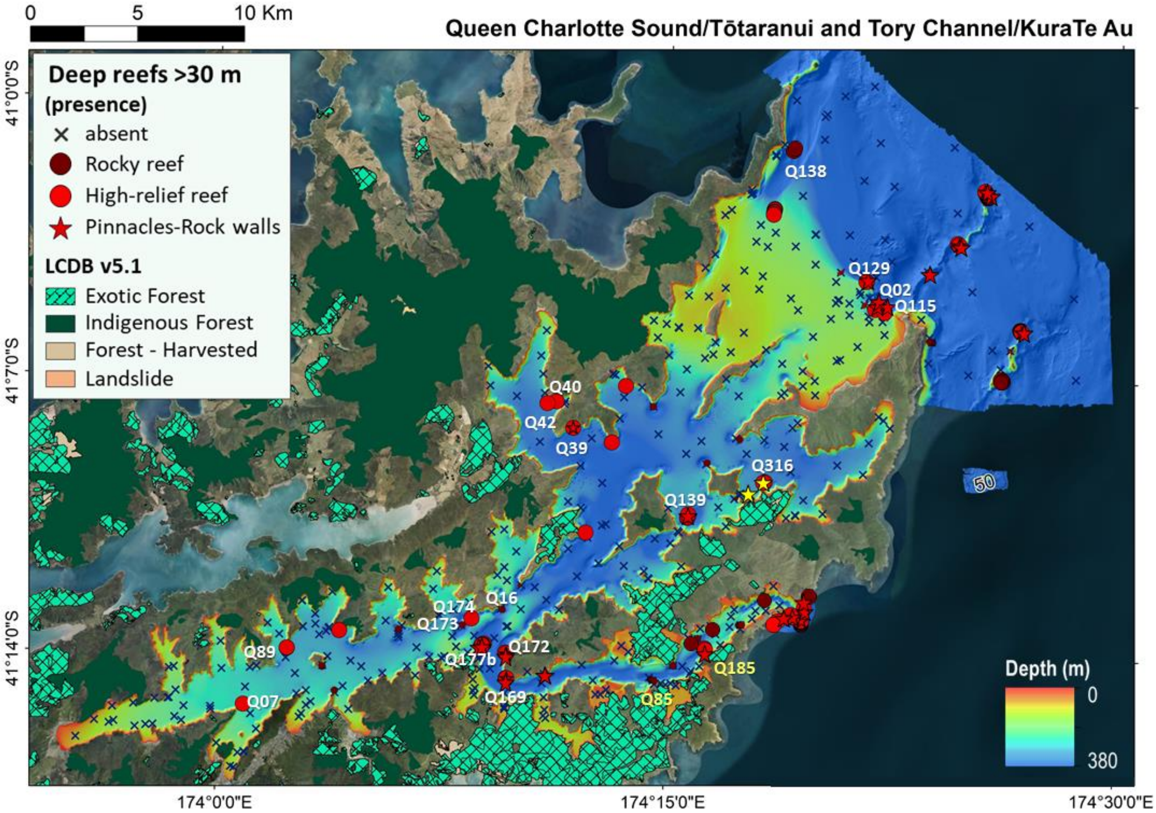


Figure 144: Location of exotic and indigenous forests relative to deep rock reefs (>30 m) within the HS51 survey area. Exotic and indigenous forest areas are plotted from the GIS Landcare database (LCDB) version 5.1. Yellow stars depict the location of the two anomalous video transect sites (MDC18-Q316/Q72 and Q73) where the seafloor was heavily dusted in fine depositional silt.

This heavy dusting of fine silt covered not only the deep reefs at site Q316, but also the shell-debris flanks at all three sites, and the coarse-sediments with live *Tucetona* beds at site Q73, where these very fine silts looked out of place, and partially-covered most sessile animals including sponges, hydroids, *Galeolaria* mounds, and live *Tucetona*. Some of the more heavily smothered species were dead (e.g., very few *Galeolaria* tubes were living), while other species appeared to be in poor condition (e.g., hydroids). Live *Tucetona* have a strong association with coarse sediments and are not found in finer sediments (McKnight 1969), identifying that this fine-silt veneer is not a normal feature of these habitat, but rather reflects a more recent and rather large-scale deposition event. Sites on the other side of East Bay did not have this very dusting of fine-silt, nor did other headlands in strong current areas. However, the seabed and patchy *Adamsiella* beds on the opposite side of the headland within Puriri/Otanerau Bays (MDC18-Q28 and Q27), was also heavily dusted in fine-depositional silts. Based on the New Zealand Land Cover Database (LCDB version 5.1 Dec 2019), the sites in Fitzgerald Bay and Puriri/Otanerau Bays are directly below a large block of exotic forest that includes harvested areas on relatively steep sloping hills (Figure 145a-b).

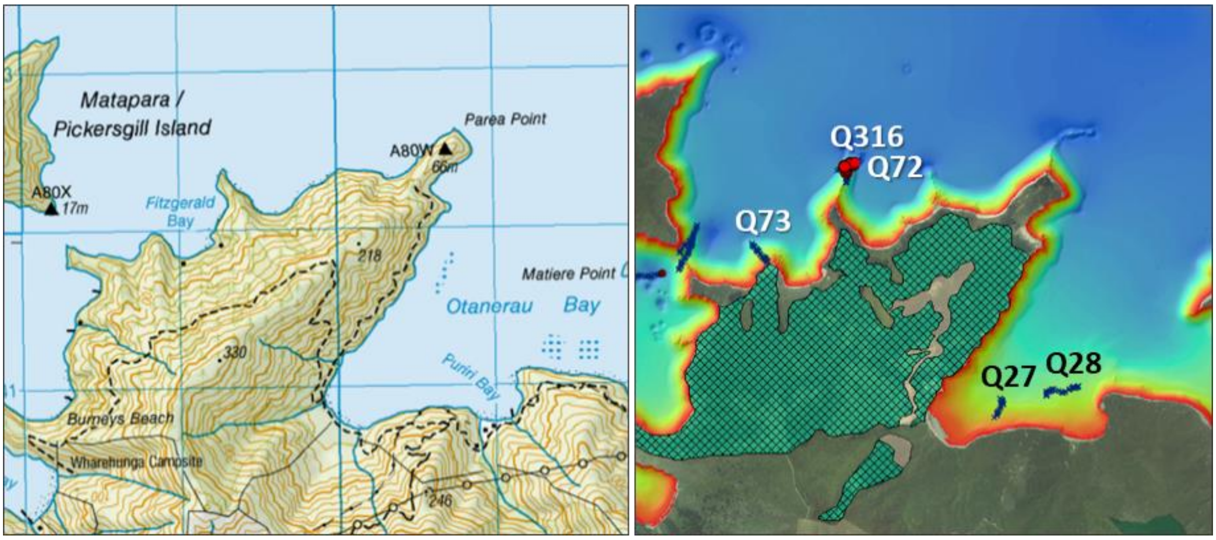


Figure 145: Location of exotic forests relative to surveyed video sites within the HS51 survey area. Left-image = New Zealand topographic map showing elevation/slope of the land between Fitzgerald Bay and Puriri Bay with Otanerau Bay/East Bay; Right-image = zoomed in view of Figure 144 showing the exotic forest block and harvested areas (green hatched and cream areas, respectively*, see Figure 144 for details*). Numbered sites are where the seafloor was heavily dusted in fine depositional silt. Red bubbles indicate the location of the deep reef at sites Q316 and Q72.

The delivery of terrigenous suspended sediments can become extremely elevated in marine areas adjacent to deforested land (review by Urlich 2015). For example, O'Loughlin (1979 *cited in* Urlich 2015) recorded sediment loads of up to 13,000 ppm in harvested areas within the Marlborough Sounds compared to 30 ppm in non-harvested areas, while Johnson et al. (1981) found that the seabed below harvested areas was smothered in sediment, while the seabed remained healthy and diverse below unharvested forests (*comparative photos in* Figure A1a in Urlich 2015), but these studies were all within the upper reaches of low-current bays. These studies also found that terrestrially-derived suspended sediments from these events were deposited on the seafloor within a short distance from the shore/point source (i.e., <50 m in O'Loughlin 1980; to ~>200 m in review by Urlich 2015). The sites at Fitzgerald Bay, however, were on headlands exposed to moderate to high currents (Figure 143b), which would be expected to wash away such fine sediments, and were located much further offshore ~ 130-300 m and ~867 m apart. While the SE headland at Fitzgerald Bay was blanketed evenly with respect to distance offshore, at the NE site the heaviest dusting was further away from shore while the shallow raised reef had less or little silt. Consequently, while a moderate-scale depositional event has occurred it is unclear how these silts have dispersed offshore and/or alongshore before settling to the seafloor. It may be that higher currents have swept the suspended sediments further afield before they settled out. Fahey and Coker (1992) estimated 200 tonnes of fine terrigenous sediments were entering Marlborough Sounds bays annually, where multiple point sources across the Sounds would likely be impacting much large regions (review by Urlich 2015). Correlation between seafloor health and land-use practices are beyond the scope of this study, but definitely warrant further investigation. Future studies examining the rates of deposition over rocky reefs, particularly deep rocky ridges in depths of 30-50 m, across these three subregions would be an important step in determining the differential rates of burial over reefs at different depths, and how location relative to currents influences these patterns.

Deep reefs were well depicted in the HS51 bathymetry and rugosity layers, however seafloor classifications of secondary features that predicted rock outcrops, varied in the prediction success of these deep habitats. Large outcrops were generally well predicted in the 'rock outcrops' layer, however the actual size and shape of reefs were not always accurate and/or precise, and often included non-rocky areas (such as the rough shell debris mounds that flanked these reefs, e.g., outer section of the deep reef off Dieffenbach Point), while in other areas the 'rock outcrops' layer failed to detect some outcrops in their entirety (e.g., small outcrop at Q40, but this also includes the extensive low relief reef at Q138). Consequently, while this layer provides a great first guide to where reefs occur, this layer needs to be used cautiously, and only in conjunction with the underlying bathymetry and rugosity layers. Fine tuning of this rock outcrop layer or delineating the boundaries of individual deep reefs would be required to accurately determine the areal estimates and relative availability of rock outcrops.

Deep rocky outcrops, like most other habitats discovered in water depth >20 m, are not well represented within the current suite of ESMS planning areas. This simply reflects that absence of studies in these depths, as well as the difficulty in surveying these deeper ecosystems, and knowing where these reefs were before they were revealed in the HS51 maps. The most notable deep reef communities within the Sounds occurred at the QCS-TC Junction which has high near bed currents (as depicted in Figure 143a). The extensive deep reef off Dieffenbach Point, was by far the most notable, supporting spectacular pinnacles and ridge lines densely packed with a diverse assortment of sessile filter-feeding invertebrates that were present in near pristine condition, including large bleach-white sponges and extensive areas covered by dense clusters of white barnacles (seen nowhere else in such high densities). The high relief rock features at this site also provide considerable crevices and overhangs, which in the past likely supported large fishes that today are rarely seen. Although these reefs have experienced fishing pressure with large hāpuka no longer caught off these reefs, this extensive reef system would provide high-quality refuge to help large commercially targeted fish and crayfish repopulate. We would therefore recommend that the extensive rocky ridge off Dieffenbach point be assessed as either an extension to ESMS 5.1 or as an additional ESMS both for its nearshore kelp community and for its exceptional deep reef community.

TC-deep slopes

Depth, slope angle, and exposure were all important predictors of deep reef slopes in TC. Deep rock slopes in TC (i.e., depths of 20-50 m) that had slope angles >30^{o} supported diverse and notable communities characterised by a plethora of a sessile invertebrates that include hard and soft bryozoans, anemones, sponges, ascidians and hydroids – all of which have been previously described by Davidson et al. (2011; 2015) and delineated within ESMS-5.8. These diverse deep reef slope communities were more commonly seen on the northern side of TC, with more notable communities seen on steeper sloping reefs and reefs east of Deep Bay toward TC-entrance. However, two new sites on the southern side of TC were also described (MDC18-Q185 and Q159), but these do not currently lie within any ESS planning area. Given there is a change in community composition with distance from TC-entrance, that includes two notable transitions the first within 1 km of the entrance and the second 4 km from the entrance, it is recommended that management strategies and ESMS planning areas adequately represent these patterns. The proposed series of ESMS-5.4, -5.8 and -5.9 planning areas appear to adequately encompass changes in the deep invertebrate slopes, although these are all on the northern side of TC. However, current planning areas are unlikely to capture the nearshore macroalgae changes, particularly *C. brownii*, which appears to be more prevalent on the southern side of the channel where currently no ESMS are planned.

Rock/rubble slopes

Slope angle was an important predictor of community types across the HS51 survey area. Rock/rubble slopes supporting low to moderate cover of small sessile invertebrate of mostly early-colonising taxa, such as soft bryozoans, hydroids, and biogenic clumps, have previously been reported at numerous sites within TC (e.g., Clark et al. 2011; Davidson et al. 2011; 2017a; Morrisey et al. 2015; Brown et al. 2016a). During the ground-truthing surveys, rock/rubble slopes all had maximum slope angles between 10-20^{o} (max. range 10-28^{o}). Importantly, slopes with similar angles (along with other MBES variables, incl. bathymetry, and rugosity), even between different locations (e.g., Cook Strait-TC and QCS-entrance slopes), supported similar types of communities characterised by early successional species. Rock/rubble slope communities at all locations were characterised by low to moderate % cover of mostly small-sized sessile invertebrates, such as bushy and fern hydroids, green soft bryozoan's and high numbers of motile invertebrates, such as snake stars and starfish. There was also some indication that shifts in dominance from orange to green soft bryozoans reflected a shift from slightly raised rock/rubble to a prevalence of gravel scree, respectively. However, this would require more detailed post-processing of these data to examine this relationship more formally. Although orange soft bryozoans were one of the most numerically dominant species in rock/rubble slopes, this taxa also occurs on low and high relief reefs composed of rock and/or biogenic material in high-current areas, and therefore (by itself) would likely be a very poor predictor of rubble slope habitats. Hopefully a series of specimens of the orange (incl. mustard, cream and yellowish varieties) versus the green soft bryozoan forms can be collected from a variety of habitats and locations within the HS51 survey area for detailed taxonomic identification to help clarify whether the orange form is a single species with generalist properties, or represents multiple species with differing habitat associations.

In Cook Strait, expansive rock/rubble slopes (described in this report) are open-ground to bottom fishing targeting a range of species including warehou, moki, red cod, flatfish and tarakihi as part of the coastal trawl fishery over the last decade that include the slopes along the east coast of Cook Strait, including those on either side of TC-entrance (Baird et al. 2015; Tuck et al. 2017; Baird and Wood 2018). Trawling over the seabed in these habitats may be an important factor explaining why the seabed community had low % cover of mostly very small, soft-bodied and early stage colonisers, with larger erect fragile and late stage colonisers rarely if ever observed, and why although high amounts of relict bryozoan rubble was observed, live 'reef-building' bryozoa (including fine-branching species) were only recorded in very low amounts. Bottom trawling would likely break and sheer-off growing bryozoa, also explaining the notable amounts of biogenic rubble on the seafloor at most sites. Although solitary cup corals were present at almost all Cook Strait slope sites, densities were mostly low at open-ground/trawlable sites. In contrast, sites naturally protected from trawling, (i.e., areas in between or next to untrawlable high-relief reefs), supported some of the highest densities of solitary cup corals recorded during these surveys (i.e., MDC18-Q80 off East Head, and Q307 SE side of the Brothers). While many factors are likely to be important in determining the distribution and abundance of solitary cup corals, it appears that while some solitary cup corals can persist in bottom trawled areas, densities may be significantly impacted. Notable numbers of hydroid trees – a fragile species that is extremely vulnerable to trawling - were also recorded at the untrawlable Q80 site, but were extremely rare at other sites. The frequent occurrence of very small (< few cm's in height and width) colonies of branching (*C. elegans*) and foliose (indet. sp) bryozoans at sites within trawled areas, also suggests that before trawling, some very high-current slope habitats may have once supported more structurally complex bryozoan colonies, similar to those observed in untrawlable areas off D'Urville Island where high % cover of large ~>10 cm high colonies of *C. elegans* and other frame-building bryozoans have been recorded along with other later successional stage species (Davidson et al. 2010; 2011; T. Anderson *pers. obs.* NIWA *unpublished data*). While it is difficult to know what benthic communities looked like on the slope habitats prior to trawling, we do known that frame-building bryozoans, particularly foliose and fine-branching species, such as *C. elegans*, are highly vulnerable to benthic disturbance from bottom fishing activities, and would be unable to attain such heights and benthic % cover in the face of trawling (review by Anderson et al. 2019), while more complex community structure could not persist (review by Thrush and Dayton 2002).

Submerged trash

Human-derived trash (or rubbish) was recorded in 36% of all sites, with trash most prevalent (65%) within inner QCS. Although found in many sites, the amount of trash at each site was low (<6%) consisting mostly of small items like beer bottles and cans, along with lost fishing line and gear, and the occasional large industrial items. Microplastics were rare. The human-derived trash seen within the Sounds is likely to reflect many decades of disposal. Unlike urban areas where large amounts of rubbish, dominated by plastics, are delivered to the marine environment by waterways (Valois et al. 2019), the locations of human-derived rubbish within the survey area appears to be the effect of small scale but widely dispersed disposal from vessels. This included beer bottles and cans discarded at headland reefs where fishing line was also recorded, while industrial sized trash was in bays near or along vessel routes to homesteads or farms. Most trash seen on the seabed were inert (e.g., glass bottles) or non-hazardous, with only a few industrial items (e.g., 10 gallon drums) that might contain potential pollutants (e.g., oil), although the condition of these items indicates that they have been on the seabed for some time. All trash items were recorded with a GPS position (± ~3 m error) where 81% of trash items were in diving (≤30 m) depths. Volunteer community organisations like 'Ghost Fishing New Zealand' target areas to remove rubbish. However, the wide scale dispersal of these small items makes retrieval difficult, while targeted removal of large items would require lifting equipment.

During the survey, real-time records were entered under the data entry key 'trash' but were not able to document trash-type in real time. Some items were recorded in the data book and these have been populated into the dataset, but the majority of items require itemisation. We would recommend post-processing of the video footage to fully document the types of trash present within the Sounds.

4.3 Relationships with physical data layers

Although the scope of this report did not include full-scale formal analyses, numerous correlations between the physical HS51 maps and data layers and seafloor habitats and communities were identified. For example, HS51 backscatter intensity was important in determining the channel boundaries of the *Amphiura*-dominated sediment plains and the location and extent of the newly discovered bryozoan patch reefs. Derived MBES layers were also very important predictors of some habitats. For example, HS51 slope angle and slope deviation, that can now be measured for any locations within the Sounds, can be used to predict the type of rock, rock/rubble or sediment communities present based on the angle of these slopes. Although the derived 'rock outcrop' layer, that delineates rock features throughout the Sounds, was found to adequately depict many rock features, many rock outcrops, particularly those in deep water were often not detected in this layer. This means that this data layer in its current form cannot be used to accurately estimate the areal extent of rock habitats, and should be used cautiously. However, rugosity alone or in combinations with other HS51 layers (e.g., bathymetry, backscatter and other derived data layers) was able to be used to accurately detect and delineated deep reefs features across the HS51 survey area. HS51 bathymetry and slope, for example, can be used in Cook Strait to determine the presence and availability of high-relief features (i.e., >10-40 m vertical relief) known to support dense and diverse sessile communities, such as those described for Cook Rock, the Brother and Te Whētero**.** This approach was used in this report to establish that the current ESMS-7.10 does not include these high relief deep reef habitats and therefore is unlikely to protect these impressive high-relief associated communities. For other species, a variety of physical variables were required to predict their distribution. For example, the new discovered burrowing sea cucumber was correlated with depth and slope angle, contingent on reefs (detected in the bathymetry and rugosity layers) being nearby. The distribution of many species was also correlated with current strength and exposure, where proxies of these (e.g., distance from entrance, proximity to QCS-TC junctions) in combination with HS51 MBES variables, were useful predictors of community structure. This was particularly importance in predicting community changes near TC-entrance, and deep reef communities relative to the occurrence of depositional silts. Sequences of habitat-species contingencies were also identified, but these were also sequential predictable using MBES data layers in combination with predicted current strength. For example, *Tucetona* shell debris habitats were strongly zoned by depth, but their occurrence was contingent on the presence of live *Tucetona* beds up slope, where the occurrence of live *Tucetona* beds was in turn contingent on the presence of coarse sediments below high-current rocky promontories. Future habitat-suitability models using a combination of bathymetry, backscatter and 'mean current speed' (from Hadfield et al. 2014 hydrodynamic model outputs) would help predictable delineation of these habitats.

While most HS51 data layers were useful either alone or in various combinations, some layers (e.g., the derived Benthic Terrain Model (BTM) categories and Aspect) were not useful predictors of habitat and/or community structure. Aspect (e.g., the direction a reef or slope faced east, west, etc.,) did not provide any predictive insight into community structure within the survey area. 'Aspect' has been found to be an important predictor in some ecosystems particularly in areas exposed to a prevailing swell (e.g., exposed vs leeward side of islands and reefs, e.g., Hill et al. 2014). While gradients in current and wave exposure were key drivers of habitats and communities within the HS51 survey area, exposure was not strongly linked to aspect. For example, habitats and communities on either side of TC would have inverse values of aspect, but identical exposure to the current. Similarly, although exposure on the east coast is directional, no leeward protection is provided. The exception to this, might be present around The Brothers, but this would require more intensive surveys to quantify this, and the general exposure of these islands may find that all sides are very exposed. Benthic Terrain Model categories provided excellent knowledge on the types of geomorphic features present within the survey area, but the same category types often occurred across large depth and/or exposure gradients, and as species in this ecosystem (and generally) respond strongly to depth and exposure, the BTM categories did not reflect habitat types or their communities. For example, rocks in shallow depths in the inner sounds were in the same category as rocks offshore in deep water, but their communities were extremely different. Given the predictive generality of slope communities with slope angle, we would have expected that slope categories in the BTM layer, might have been a good predictors of slope communities. However, the upper and lower bounds of the BTM categories did not reflect the slope angle ranges that distinguished these different communities. However, the ground-truthing data does identify that a revised 'habitat map' that uses the HS51 data layers to delineate 'community-relevant' categories is achievable and if created would be an extremely useful management tool. We believe this would be a very important next important step, along with formal data analyses that fully integrate these data to create habitat-suitability maps for key species and broad-scale habitat maps for the entire HS51 region.

4.4 Comparison with ESMS planning areas

Prior to the ground-truthing surveys presented in this report, most of the information available on seafloor habitats and communities within the survey area came from nearshore snorkelling and diving surveys in depths of <6-20 m (descriptive overviews in e.g., Davidson et al. 2011; 2015; 2017a), along with a few historical grab and dredge surveys (Dell 1951; Estcourt 1967; McKnight and Grange 1991) and site-species farm surveys (e.g., Clark et al. 2011; Morrisey et al. 2015; Brown et al. 2016a). These studies have provided the scientific knowledge for the Ecological Significant Marine Sites (ESMS) planning areas, as presented in Topic 6: Indigenous Biodiversity Planning, in volume 1 of the proposed Marlborough Environment Plan (2019). The ESMS planning zones have been clearly described in Davidson et al. (2011; 2015). Although a range of overlaps exist, the ESMS areas were generally not targeted during our combined surveys, except where ground-truthing relative to the HS51 maps was required. Overall, the findings of the ground-truthing surveys matched those already described (e.g., Davidson et al. 2011; 2015) and either confirmed or provided additional supporting information on the boundaries and distribution of key habitats, species and communities within these ESMS areas. Minor updates included the likely change in status of *Bispira bispira* spA from a ‘possible cryptic native’ to a ‘probable exotic pest’, based on its spread around and beyond the Sounds; along with additional information suggesting further apparent degradation of the *Adamsiella* meadow at ESMS-4.23. The ESMS planning zones are well described (e.g., Davidson et al. 2010; 2011; 2015), however, the majority of the underlying scientific survey information and site-specific detail referred to in these descriptions remain unpublished (e.g., Davidson et al. 2011; 2015 cite the unpublished survey data: *Duffy et al., unpublished 1989/1990 survey*, along with pers. comms. based on other unpublished data e.g., *Hay et al., unpublished DSIR horse mussel surveys*). While this does not infer any issues with the current ESMS zones, it does cause issue with any attempts to compare findings, or infer change through time.

The findings in this report identified and described a wide range of ‘notable’ (here meaning significant) habitats and communities with many previously known. These include a variety of unique, biogenic, highly diverse and vulnerable communities, over much deeper depths and much further offshore than previously surveyed. Importantly, almost all notable habitats and communities in depths ≥20 m are not represented in the current ESMS planning. This is to be expected given little was known about these deeper habitats and communities prior to the ground-truthing surveys. To ensure that ESMS are representative of all depths, we would highly recommend that ‘notable’ habitats and communities discovered in deeper water (as presented in this report) be assessed for inclusion in ESMS planning either as extensions to existing sites, if and where feasible, or as sites in their own right. Whether this is part of first round or subsequent second round ESMS designations, we believe this would be essential in providing a fully representative ESMS plan. As part of this, it would be recommended that ‘notable’ habitats and communities for ESMS assessment include: the newly discovered bryzoan patch reefs at the entrance to QCS; notable *Galeolaria* mounds (including reef and slope zones over a representative depth range); the newly discovered burrowing sea cucumber *Thyone* spA (such as MDC18-Q140); representative offshore deep reefs that support the dense and highly diverse filter feeding communities (incl. goose barnacles, sponge garden species, and giant bleach-white sponges); and notable deep reef communities within the Sounds - the most notable being the extensive rocky ridge off Dieffenbach Point. Given that many of the biogenic-habitats (e.g., bryozoan patch reefs and *Galeolaria* mounds) providing essential structure critical for other species are highly vulnerable 'china-shop' species that have already undergone notable damage, we feel that some urgency is required to protect these habitats and communities for future generations.

4.5 Conclusion

These surveys provide substantial new knowledge on the presence, distribution and relative availability of a diverse range of shallow to deep habitats (range 1-132 m) and their associated biological communities within the HS51 survey area. New habitats and communities were discovered and new-levels of detail on habitats and communities already known are provided. These include highly-diverse and visually-stunning communities on deep reefs in the Cook Strait that had never before been seen, dramatic landscapes of fragile tubeworm towers growing out across the shell-debris slopes across the Sounds, to extensive sediment plains that instead of being featureless soft-sediment areas as one might expect, were instead inhabited by millions of pink brittlestar arms emerging out through the mud. New discoveries included new taxonomic records for the Marlborough Sounds and adjacent Cook Strait, as well as an entire new genera/family of burrowing sea cucumbers for New Zealand, now known to form dense zones along high-current deep slopes.

The distribution, abundance and natural character of important biogenic habitats (e.g., bryozoan patch reefs, *Galeolaria* mounds, tubeworm mounds, kelp forests and algal meadows) are also documented and described in this report, many also new discoveries (e.g., bryozoan patch reefs at the entrance to QCS). These biogenic habitats provide structure and refuge for a diverse range of sessile invertebrates and fishes, with some (e.g., bryozoan mounds) acting as important nurseries for blue cod. Other species (e.g., *Tucetona* and horse mussels) were also identified to be important underlying drivers of community structure within the Sounds, by providing critical shell substrata for other habitat-forming species to settle and grow on., where losses of these species will likely have extensive follow-on effects to community structure over very large scales.

Physical variables derived from the HS51 multibeam survey (especially depth, slope angle, slope variance, backscatter and rugosity) along with geographic variables (distance to entrance, distance to promontories, as proxies for current-strength and exposure), in various combinations, were important predictors of benthic habitats and communities. While this report provides significant new information regarding habitat and community types and the variables important in predicting their distribution, the next important step will be to formally integrate these data to create habitat-suitability maps for key species and broad-scale habitat maps for the entire HS51 region.

In combination, these video surveys provide a treasure trove of new knowledge that we believe will be the foundation of future spatial management strategies and conservation endeavours.

The findings presented in this report, provide one of the most comprehensive stock-takes of marine habitats and associated communities within New Zealand. They provide MDC with the critical knowledge on the natural (current) character, vulnerability, and relative availability of the diverse habitats and communities that occur within the HS51 survey areas. It also provides timely new information on the representativeness of habitats, species and communities with MDC's ESMS planning. This information will provide MDC with the necessary knowledge to help them fulfil their mandate in coastal planning and biodiversity and meet their statutory obligations under the New Zealand Biodiversity Strategy 2000 to halt the decline of, and maintain and restore a full range of natural habitats and ecosystems.

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6 Glossary of abbreviations and terms

Term	Definition
Benthic	Associated with the seafloor.
Biodiversity	The variability among living organisms from all sources; this includes diversity within species, between species and of ecosystems.
Biofilm	Here referring to benthic diatom covering the surface of the sediment, or other habitats.
Biogenic	“*Produced or brought about by living organisms”* The Oxford English Dictionary (2018).
Biogenic habitat	Physical habitat created by living organisms, such as coral reefs, oyster beds, tubeworm reefs, kelp beds, seagrass beds.
Colonial	Animals that live as a part of one physically connected colony, such as corals, bryozoans and some tubeworms and tunicates.
DEM	Digital Elevation Model. A three-dimensional grid representation of the shape of the earth (seafloor or land) surface.
Depositional environment	An environment where the forces responsible for sediment deposition are greater than erosional forces.
Depositional sediments	The build-up of sediments deposited on the seafloor over a period of time. Source of dispositional sediment can include fine sediment from the water column and sediment movement down slope, such as landslides.
DOC	Department of Conservation (New Zealand).
Dredging	Towing a device over the seafloor primarily for the collection of shellfish.
Ecosystem	An interacting system of living and non-living parts.
Emergent (habitat/structure)	Above ground structure that is higher than neighbouring habitats.
Endemic	Species only known to occur at one location or area of defined extent, such as a country or sea area.
Epifauna	Animals living on the surface of the seafloor.
ESMS	Ecologically Significant Marine Sites as defined in MDC 2019. Previously referred to as Ecologically Significant Sites [ESS] as defined in Davidson et al. 2011 and 2015.
Flora	Plants.
GIS	Geographic Information System. Computer software for the handling of spatial data, and advanced data manipulations and analysis.
Goose barnacle	A stalked barnacle (order Pedunculata). These barnacles have a long, fleshy stalk, and are filter-feeding crustaceans that live attached to hard surfaces.
Habitat	The environment where an individual, species or group of species live that can be repeatedly found in nature.
HS51	LINZ Project HYD-2016/17-01 (HS51) Hydrographic Survey of Queen Charlotte Sound / Tōtaranui and Tory Channel / Kura Te Au.

Indet.	'Indeterminant' referring to taxa that could not be identified to species from the video imagery.
Infauna	Animals living in sediments.
LIMR	Long island marine reserve.
MDC	Marlborough District Council.
Monospecific	Consisting of only one species.
MPI	Ministry of Primary Industry.
Paleoecology	A branch of ecology that is concerned with the characteristics of ancient environments and with their relationships to ancient plants and animals.
Polygon	An area fully encompassed by a series of connected lines. In this review depicting (or predicting) an area where a habitat occurs within.
Relict	Of biological original, but no longer living (e.g., The remaining tubes, shells or hard structures of animals now dead).
Sessile	Fixed in one position, immobile. Includes animals attached to the substratum or living in permanent tubes (e.g., Tubeworms).
Subcanopy	Those species living under the canopy of the kelps.
Substratum (singular) Substrata (plural)	In biology, it refers to a substance or surface that an organism grows on, lives in, on or above and is supported by (e.g., rock, cobbles, mud and sand).
Subtidal	The benthic ocean environment below low tide that is always covered by water.
Zones	Here referring to different spatial areas where characteristic fauna and flora are found, such as intertidal zones of barnacles, then mussels, then kelp on a foreshore.
Zooanthid	Are colony-forming soft corals (order Zoanthidea) and can be very colourful.

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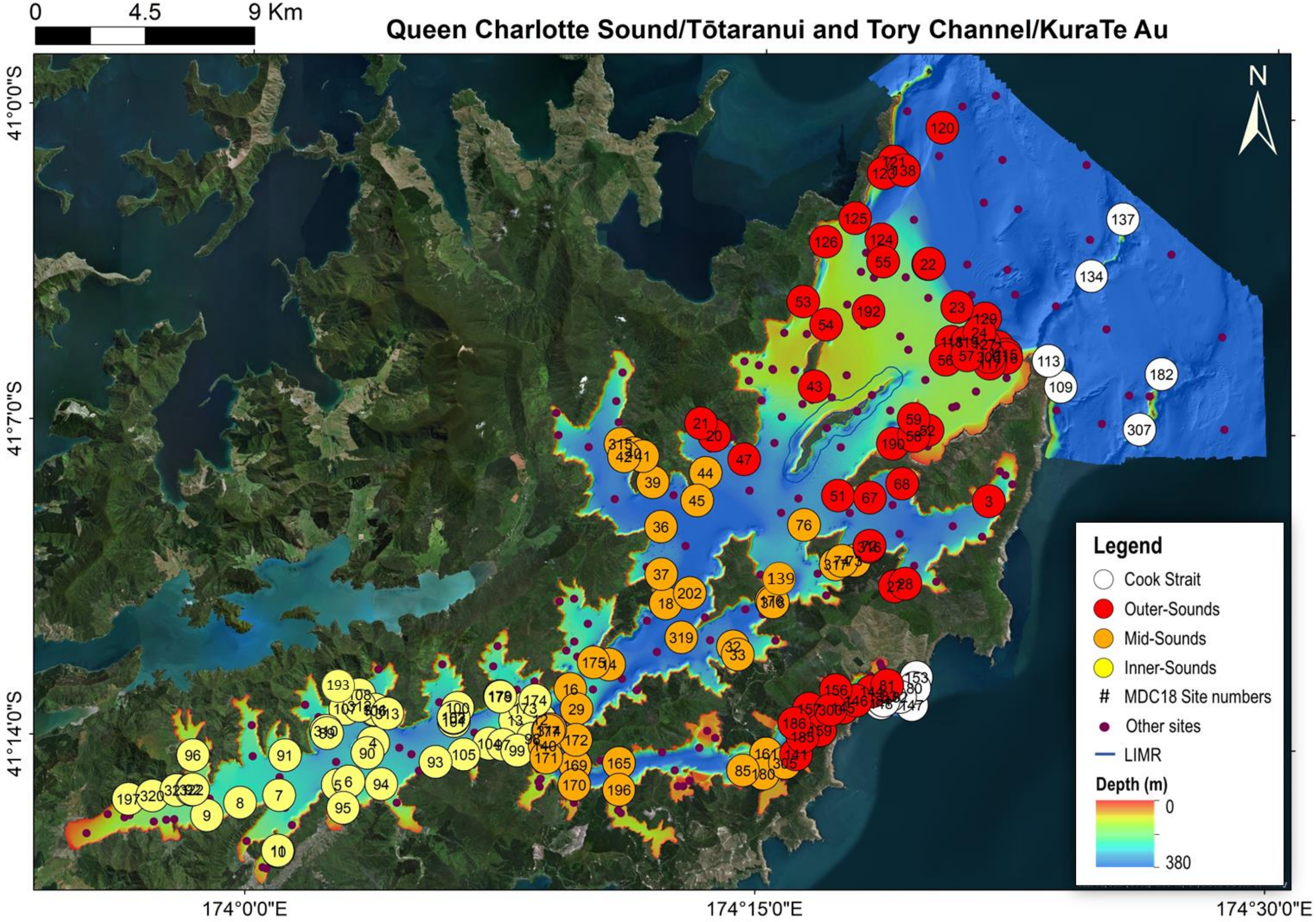
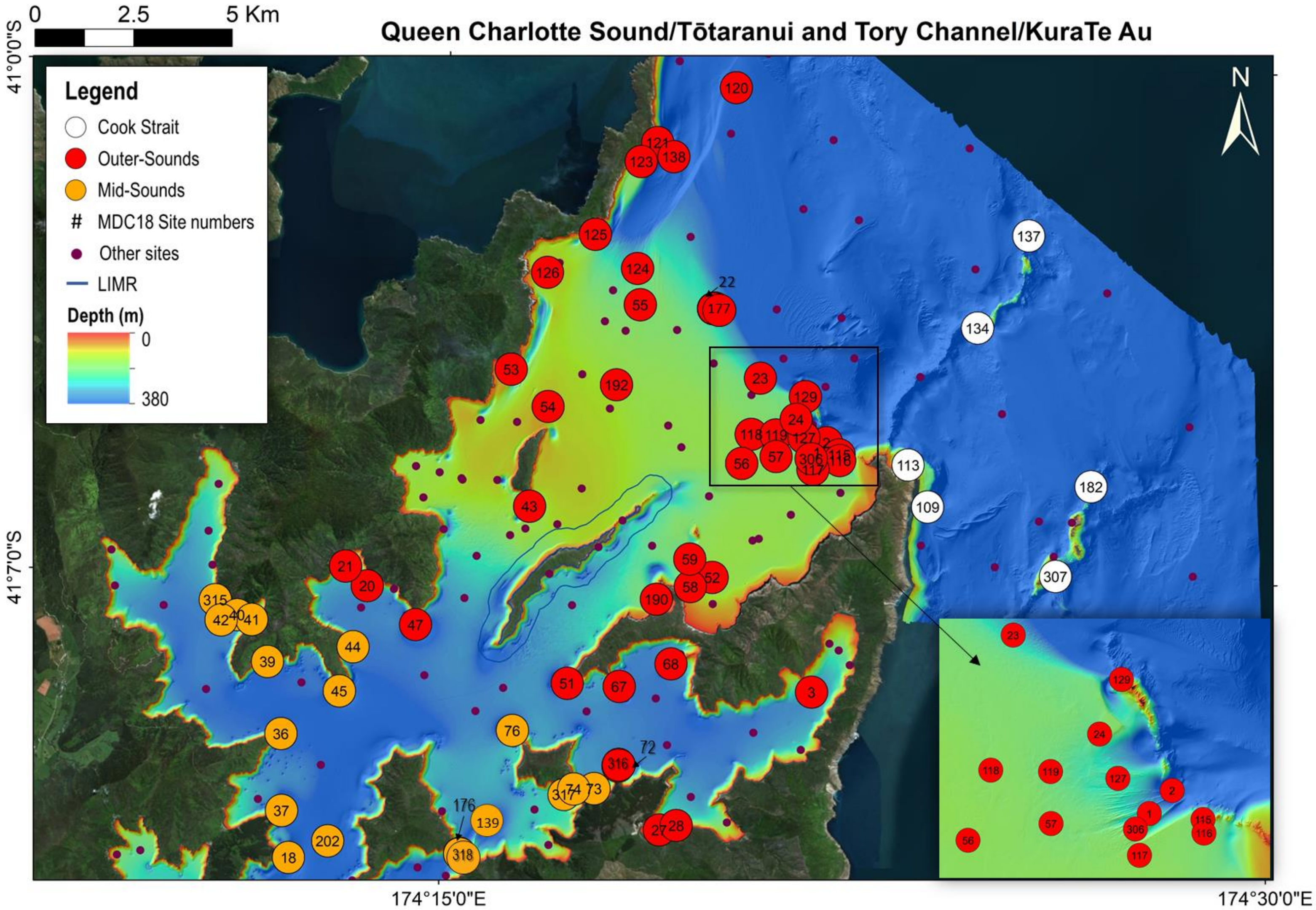
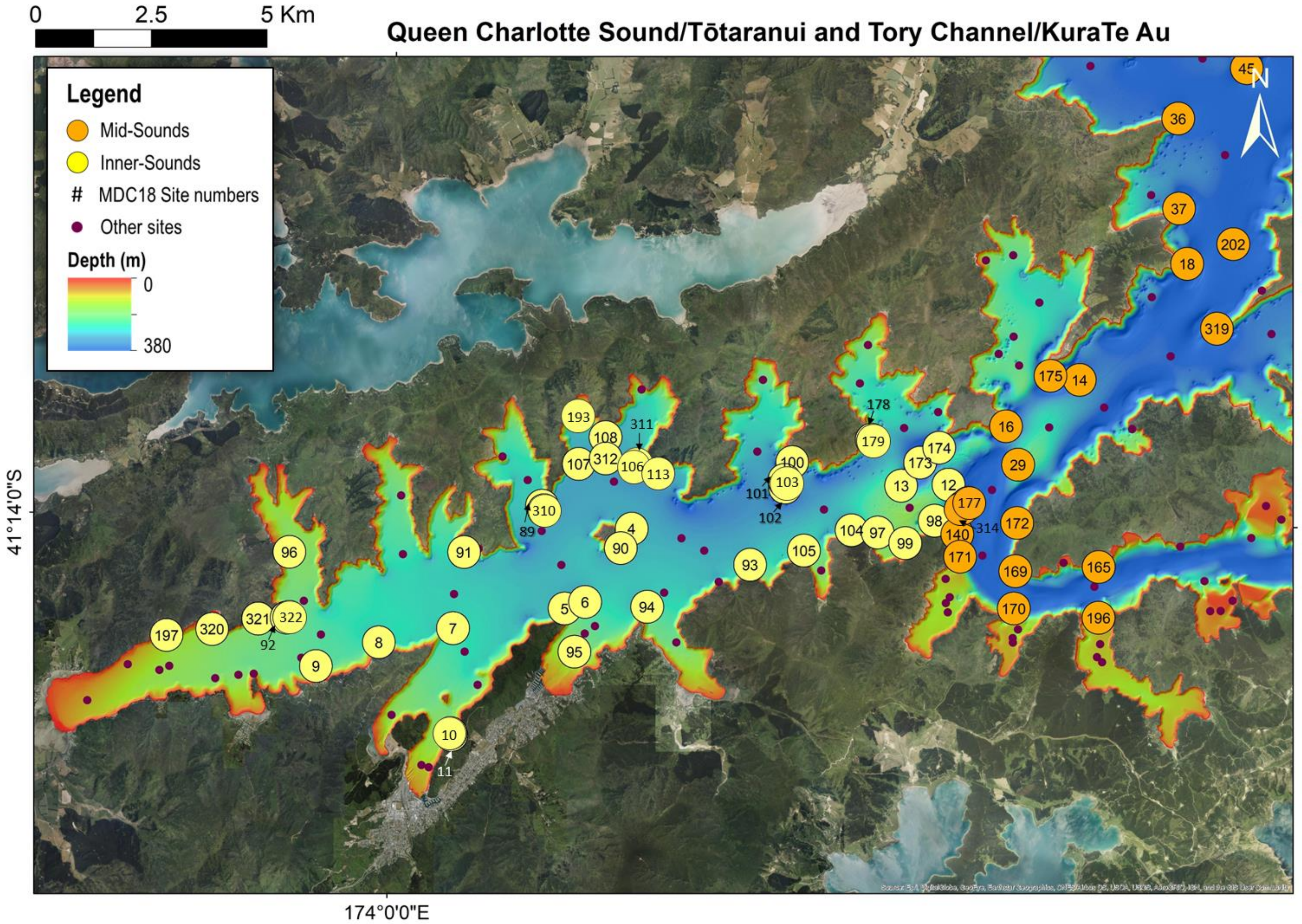
Appendix A Map of MDC18 site locations (*see zoomed-in maps in Appendices B-D*).



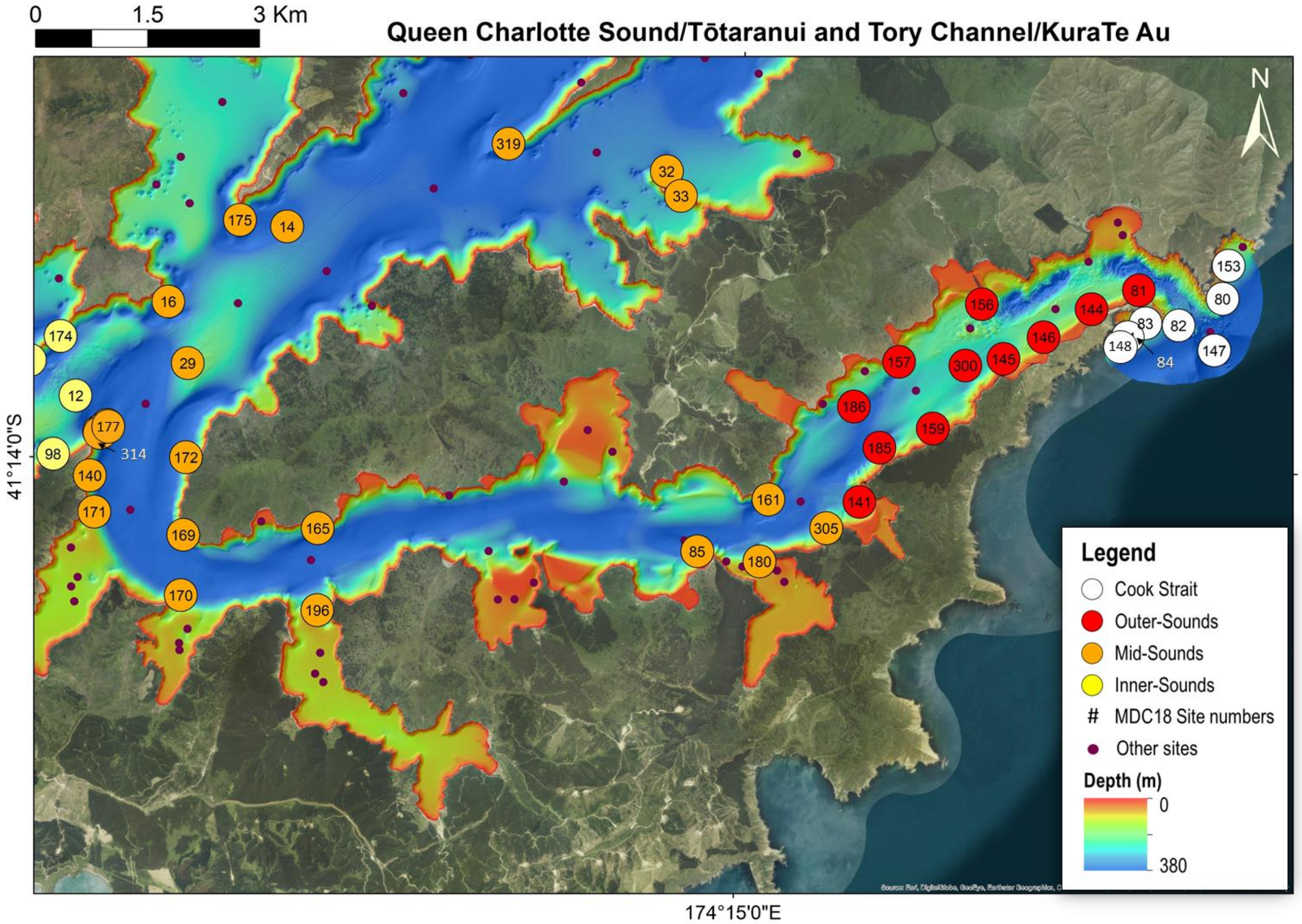
Appendix B Zoomed-in map of MDC18 site locations - Outer QCS and Cook Strait.



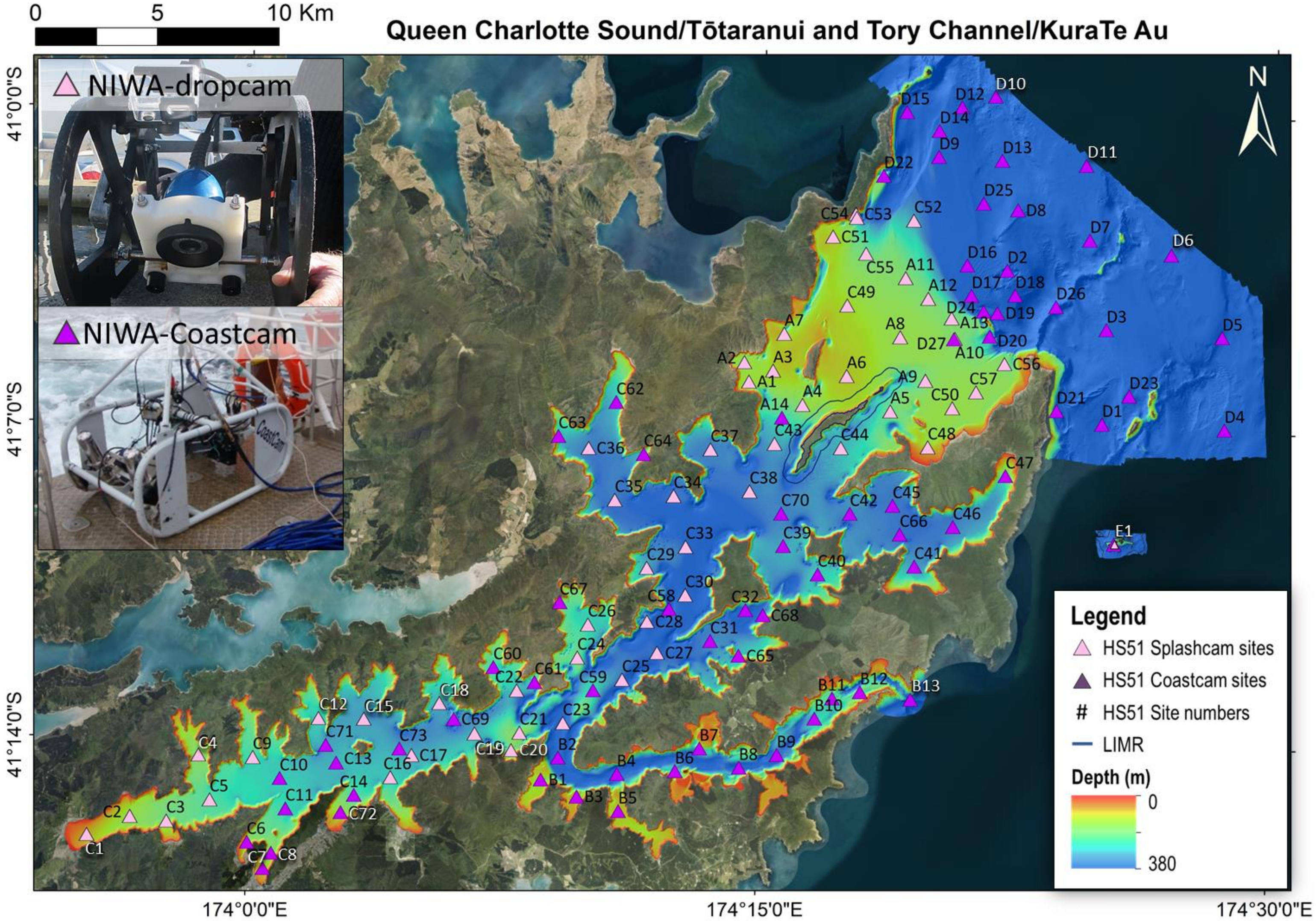
Appendix C Zoomed-in map of MDC18 site locations - Inner and mid QCS.



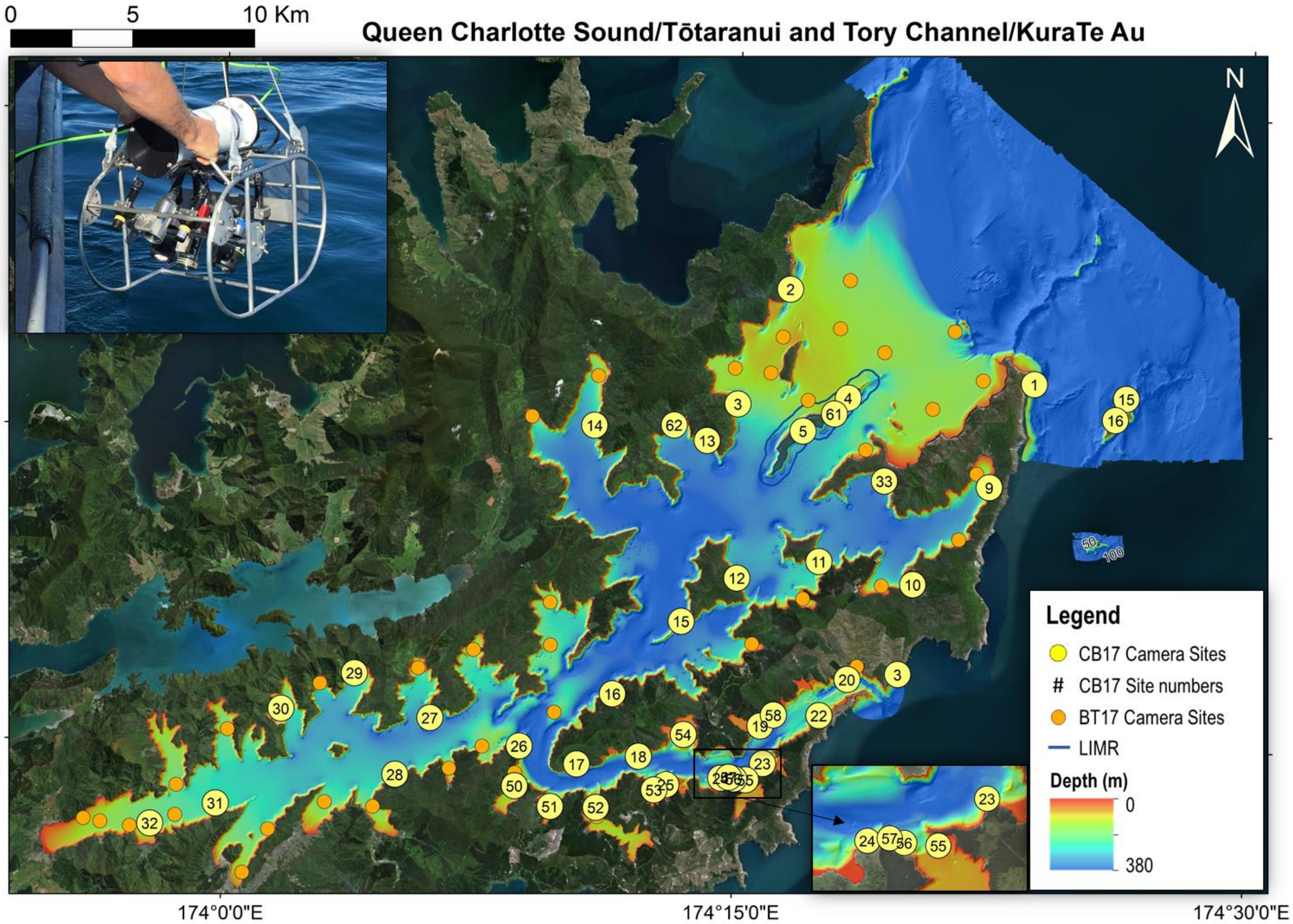
Appendix D Zoomed-in map of MDC18 site locations - TC.



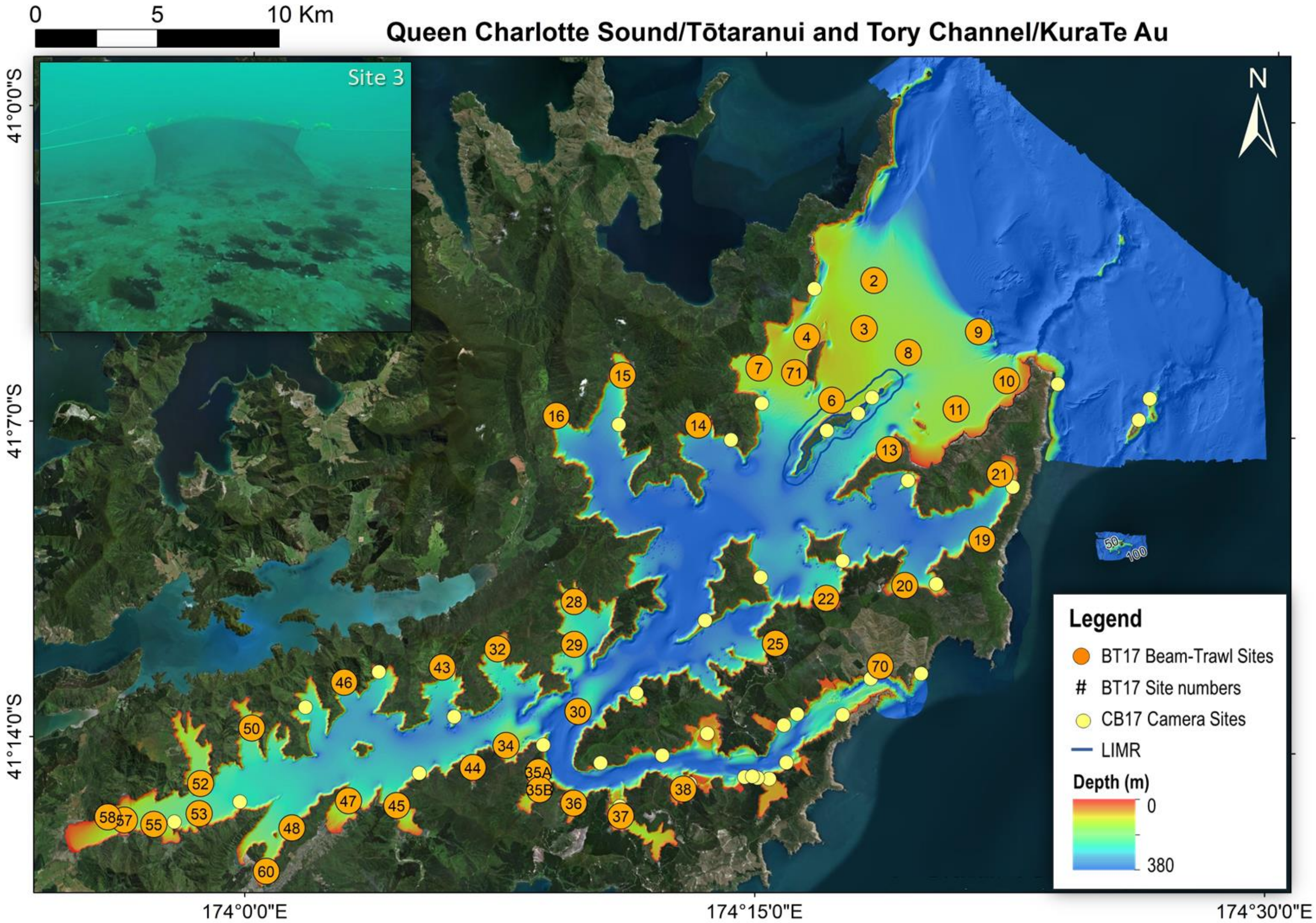
Appendix E Map of HS51 Drop-camera site locations.



Appendix F Map of MBIE-CB17 Tow-video (CBedcam) site locations.



Appendix G Map of MBIE-BT17 Beam trawl (with GoPro-video) site locations.



Appendix H Site locations and summary depths for the MDC18 video survey.

Table H-1: Site locations and summary depths for the MDC18 survey. QCS=Queen Charlotte Sounds; TC=Tory Channel; CStrait=Cook Strait; Site locations are expressed here as the mean Latitude and Longitude position, along each towed-transects, in decimal degrees (dd); Records=Ncall or Number of data calls along each transect within a site; Depth values along transect lines are extracted HS51 bathymetry values presented here as mean (minimum-maximum) depth.

Survey	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Records	Depth (m)
MDC18	Q01	QCS	QCS-outer	-41.08786	174.36241	16	39 (36-42)
MDC18	Q02	QCS	QCS-outer	-41.08561	174.36535	64	68 (47-85)
MDC18	Q03	QCS	QCS-outer	-41.14260	174.36197	15	42 (42-42)
MDC18	Q04	QCS	QCS-inner	-41.23520	174.06197	30	31 (4-45)
MDC18	Q05	QCS	QCS-inner	-41.25095	174.04495	18	24 (11-39)
MDC18	Q06	QCS	QCS-inner	-41.24960	174.05029	22	16 (6-30)
MDC18	Q07	QCS	QCS-inner	-41.25515	174.01626	44	30 (26-35)
MDC18	Q08	QCS	QCS-inner	-41.25824	173.99715	27	16 (7-30)
MDC18	Q09	QCS	QCS-inner	-41.26270	173.98092	31	22 (15-30)
MDC18	Q10	QCS	QCS-inner	-41.27580	174.01620	21	8 (5-15)
MDC18	Q11	QCS	QCS-inner	-41.27550	174.01609	35	12 (4-21)
MDC18	Q12	QCS	QCS-inner	-41.22590	174.14373	27	43 (36-49)
MDC18	Q13	QCS	QCS-inner	-41.22615	174.13154	25	38 (30-46)
MDC18	Q14	QCS	QCS-mid	-41.20510	174.17712	15	53 (48-55)
MDC18	Q16	QCS	QCS-mid	-41.21443	174.15831	31	35 (23-45)
MDC18	Q18	QCS	QCS-mid	-41.18205	174.20449	24	25 (3-54)
MDC18	Q20	QCS	QCS-outer	-41.11990	174.22709	25	18 (9-32)
MDC18	Q21	QCS	QCS-outer	-41.11535	174.22049	20	23 (14-28)
MDC18	Q22	QCS	QCS-outer	-41.05539	174.33055	36	36 (34-39)
MDC18	Q22b	QCS	QCS-outer	-41.05532	174.33092	20	37 (35-39)
MDC18	Q23	QCS	QCS-outer	-41.07120	174.34481	46	37 (32-43)
MDC18	Q24	QCS	QCS-outer	-41.08033	174.35580	62	27 (24-31)
MDC18	Q27	QCS	QCS-outer	-41.17459	174.31651	21	17 (11-21)
MDC18	Q28	QCS	QCS-outer	-41.17365	174.32168	36	22 (20-24)
MDC18	Q29	QCS	QCS-mid	-41.22181	174.16149	24	32 (26-40)
MDC18	Q32	QCS	QCS-mid	-41.19775	174.23774	30	17 (8-26)
MDC18	Q33	QCS	QCS-mid	-41.20079	174.24011	67	19 (11-26)
MDC18	Q36	QCS	QCS-mid	-41.15402	174.20166	31	24 (8-46)
MDC18	Q37	QCS	QCS-mid	-41.17149	174.20213	20	28 (19-48)
MDC18	Q39	QCS	QCS-mid	-41.13739	174.19726	21	21 (5-39)
MDC18	Q40	QCS	QCS-mid	-41.12698	174.18784	30	33 (13-42)
MDC18	Q41	QCS	QCS-mid	-41.12797	174.19225	29	30 (8-38)
MDC18	Q42	QCS	QCS-mid	-41.12806	174.18300	51	40 (29-51)

Survey	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Records	Depth (m)
MDC18	Q43	QCS	QCS-outer	-41.10117	174.27584	31	23 (7-39)
MDC18	Q44	QCS	QCS-mid	-41.13375	174.22312	23	16 (11-30)
MDC18	Q45	QCS	QCS-mid	-41.14398	174.21926	23	32 (22-48)
MDC18	Q47	QCS	QCS-outer	-41.12862	174.24196	26	35 (20-56)
MDC18	Q51	QCS	QCS-outer	-41.14184	174.28747	66	20 (8-38)
MDC18	Q52	QCS	QCS-outer	-41.11682	174.33132	40	17 (9-25)
MDC18	Q53	QCS	QCS-outer	-41.06988	174.26964	55	10 (4-15)
MDC18	Q54	QCS	QCS-outer	-41.07838	174.28111	25	11 (9-13)
MDC18	Q55	QCS	QCS-outer	-41.05479	174.30833	61	24 (24-25)
MDC18	Q56	QCS	QCS-outer	-41.09062	174.33989	52	21 (21-22)
MDC18	Q57	QCS	QCS-outer	-41.08899	174.35004	61	25 (24-25)
MDC18	Q58	QCS	QCS-outer	-41.11898	174.32468	38	21 (16-25)
MDC18	Q59	QCS	QCS-outer	-41.11273	174.32457	52	14 (4-23)
MDC18	Q67	QCS	QCS-outer	-41.14180	174.30366	75	24 (9-54)
MDC18	Q68	QCS	QCS-outer	-41.13660	174.31915	59	32 (11-45)
MDC18	Q72	QCS	QCS-outer	-41.15986	174.30402	28	36 (27-43)
MDC18	Q73	QCS	QCS-mid	-41.16556	174.29655	29	18 (2-36)
MDC18	Q74	QCS	QCS-mid	-41.16566	174.29046	28	23 (18-27)
MDC18	Q76	QCS	QCS-mid	-41.15255	174.27155	20	22 (9-51)
MDC18	Q80	CStrait	TC-CStrait	-41.21230	174.32691	30	37 (25-49)
MDC18	Q81	TC	TC-outer	-41.21140	174.31359	20	19 (13-27)
MDC18	Q82	CStrait	TC-CStrait	-41.21546	174.31998	41	28 (21-35)
MDC18	Q83	CStrait	TC-CStrait	-41.21535	174.31453	23	23 (10-33)
MDC18	Q84	CStrait	TC-CStrait	-41.21702	174.31179	22	26 (11-38)
MDC18	Q85	TC	TC-mid	-41.24366	174.24346	19	54 (44-62)
MDC18	Q89	QCS	QCS-inner	-41.23197	174.03935	58	35 (14-50)
MDC18	Q90	QCS	QCS-inner	-41.23913	174.05933	44	29 (18-40)
MDC18	Q91	QCS	QCS-inner	-41.24024	174.01890	20	17 (10-27)
MDC18	Q92	QCS	QCS-inner	-41.25322	173.97400	43	13 (5-29)
MDC18	Q93	QCS	QCS-inner	-41.24204	174.09278	27	33 (6-50)
MDC18	Q94	QCS	QCS-inner	-41.25045	174.06640	31	22 (11-32)
MDC18	Q95	QCS	QCS-inner	-41.25931	174.04774	10	21 (19-22)
MDC18	Q96	QCS	QCS-inner	-41.24052	173.97391	26	20 (9-24)
MDC18	Q97	QCS	QCS-inner	-41.23533	174.12561	39	33 (3-51)
MDC18	Q98	QCS	QCS-inner	-41.23293	174.14034	26	16 (10-22)
MDC18	Q99	QCS	QCS-inner	-41.23743	174.13251	23	12 (6-15)
MDC18	Q100	QCS	QCS-inner	-41.22192	174.10330	21	21 (16-23)
MDC18	Q101	QCS	QCS-inner	-41.22684	174.10132	31	23 (6-51)
MDC18	Q102	QCS	QCS-inner	-41.22570	174.10136	54	14 (6-36)

Survey	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Records	Depth (m)
MDC18	Q103	QCS	QCS-inner	-41.22538	174.10129	38	21 (9-37)
MDC18	Q104	QCS	QCS-inner	-41.23503	174.11879	27	16 (6-31)
MDC18	Q105	QCS	QCS-inner	-41.23907	174.10650	25	12 (9-21)
MDC18	Q106	QCS	QCS-inner	-41.22315	174.06262	31	25 (7-54)
MDC18	Q107	QCS	QCS-inner	-41.22276	174.04827	32	20 (9-37)
MDC18	Q108	QCS	QCS-inner	-41.21761	174.05499	31	22 (12-34)
MDC18	Q109	CStrait	QCS-CStrait	-41.10005	174.39617	31	48 (34-60)
MDC18	Q113	CStrait	QCS-CStrait	-41.09051	174.39046	38	15 (12-18)
MDC18	Q115	QCS	QCS-outer	-41.08832	174.36914	23	29 (26-33)
MDC18	Q116	QCS	QCS-outer	-41.08960	174.36924	18	25 (25-26)
MDC18	Q117	QCS	QCS-outer	-41.09193	174.36120	31	22 (22-22)
MDC18	Q118	QCS	QCS-outer	-41.08399	174.34252	43	22 (22-23)
MDC18	Q119	QCS	QCS-outer	-41.08406	174.34971	31	26 (26-27)
MDC18	Q120	QCS	QCS-outer	-41.00486	174.33637	18	81 (81-82)
MDC18	Q121	QCS	QCS-outer	-41.01763	174.31286	12	13 (4-24)
MDC18	Q123	QCS	QCS-outer	-41.02203	174.30787	64	34 (28-38)
MDC18	Q124	QCS	QCS-outer	-41.04669	174.30732	109	32 (31-34)
MDC18	Q125	QCS	QCS-outer	-41.03888	174.29428	46	31 (20-47)
MDC18	Q126	QCS	QCS-outer	-41.04759	174.28025	36	13 (13-14)
MDC18	Q127	QCS	QCS-outer	-41.08451	174.35822	27	33 (30-35)
MDC18	Q129	QCS	QCS-outer	-41.07509	174.35881	54	24 (14-44)
MDC18	Q134	CStrait	QCS-CStrait	-41.05895	174.41038	35	100 (92-154)
MDC18	Q137	CStrait	QCS-CStrait	-41.03778	174.42530	33	114 (80-131)
MDC18	Q138	QCS	QCS-outer	-41.02072	174.31790	41	96 (94-150)
MDC18	Q139	QCS	QCS-mid	-41.21115	174.04845	28	44 (39-52)
MDC18	Q139	QCS	QCS-mid	-41.17532	174.26131	1	43 (43-43)
MDC18	Q140	TC	TC-inner	-41.23560	174.14594	31	24 (6-46)
MDC18	Q141	TC	TC-outer	-41.23738	174.26917	23	20 (8-26)
MDC18	Q144	TC	TC-outer	-41.21367	174.30603	28	14 (8-20)
MDC18	Q145	TC	TC-outer	-41.21984	174.29207	21	32 (30-34)
MDC18	Q146	TC	TC-outer	-41.21724	174.29842	16	18 (8-26)
MDC18	Q147	CStrait	TC-CStrait	-41.21843	174.32565	20	97 (80-112)
MDC18	Q148	CStrait	TC-CStrait	-41.21805	174.31038	18	23 (7-34)
MDC18	Q153	CStrait	TC-CStrait	-41.20829	174.32794	48	21 (12-30)
MDC18	Q156	TC	TC-outer	-41.21324	174.28839	39	20 (11-28)
MDC18	Q157	TC	TC-outer	-41.22047	174.27540	27	19 (11-27)
MDC18	Q159	TC	TC-outer	-41.22852	174.28085	35	17 (4-30)
MDC18	Q161	TC	TC-mid	-41.23728	174.25471	9	30 (11-54)
MDC18	Q165	TC	TC-inner	-41.24157	174.18268	23	20 (-1-49)

Survey	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Records	Depth (m)
MDC18	Q169	TC	TC-inner	-41.24237	174.16123	26	17 (-0-43)
MDC18	Q170	TC	TC-inner	-41.24988	174.16080	13	43 (40-48)
MDC18	Q171	TC	TC-inner	-41.23974	174.14711	33	28 (11-48)
MDC18	Q172	TC	TC-inner	-41.23307	174.16151	27	37 (24-55)
MDC18	Q173	QCS	QCS-inner	-41.22157	174.13625	37	25 (19-43)
MDC18	Q174	QCS	QCS-inner	-41.21870	174.14111	24	25 (21-40)
MDC18	Q175	QCS	QCS-mid	-41.20437	174.16954	28	24 (6-42)
MDC18	Q176	QCS	QCS-mid	-41.18064	174.25647	26	35 (26-43)
MDC18	Q177a	TC	TC-inner	-41.22942	174.14881	39	45 (23-65)
MDC18	Q177b	TC	TC-inner	-41.23019	174.14753	22	20 (8-31)
MDC18	Q178	QCS	QCS-inner	-41.21727	174.12374	21	19 (13-33)
MDC18	Q179	QCS	QCS-inner	-41.21755	174.12406	23	29 (8-53)
MDC18	Q180	TC	TC-mid	-41.24479	174.25344	273	31 (30-31)
MDC18	Q182	CStrait	QCS-CStrait	-41.09472	174.44531	27	96 (89-154)
MDC18	Q185	TC	TC-outer	-41.23076	174.27232	38	30 (9-52)
MDC18	Q186	TC	TC-outer	-41.22588	174.26828	54	38 (36-43)
MDC18	Q190	QCS	QCS-outer	-41.12206	174.31471	33	23 (23-24)
MDC18	Q192	QCS	QCS-outer	-41.07316	174.30154	55	18 (18-18)
MDC18	Q193	QCS	QCS-inner	-41.21180	174.04766	30	19 (6-26)
MDC18	Q196	TC	TC-inner	-41.25183	174.18270	37	16 (11-33)
MDC18	Q197	QCS	QCS-inner	-41.25702	173.94242	29	8 (4-11)
MDC18	Q202	QCS	QCS-mid	-41.17823	174.21623	29	61 (59-63)
MDC18	Q300	TC	TC-outer	-41.22080	174.28595	53	35 (34-36)
MDC18	Q305	TC	TC-mid	-41.24058	174.26408	18	15 (13-17)
MDC18	Q306	QCS	QCS-outer	-41.08934	174.36057	32	25 (23-31)
MDC18	Q307	CStrait	QCS-CStrait	-41.11537	174.43510	14	39 (31-45)
MDC18	Q310	QCS	QCS-inner	-41.23097	174.03884	22	23 (13-35)
MDC18	Q311	QCS	QCS-inner	-41.22301	174.06300	26	21 (11-32)
MDC18	Q312	QCS	QCS-inner	-41.22160	174.05514	9	41 (41-41)
MDC18	Q313	QCS	QCS-inner	-41.22436	174.06876	18	28 (19-38)
MDC18	Q314	QCS	TC-inner	-41.22991	174.14810	28	30 (26-36)
MDC18	Q315	QCS	QCS-mid	-41.12343	174.18121	29	23 (8-42)
MDC18	Q316	QCS	QCS-outer	-41.16022	174.30372	30	28 (21-39)
MDC18	Q317	QCS	QCS-mid	-41.16696	174.28752	15	45 (43-47)
MDC18	Q318	QCS	QCS-mid	-41.18135	174.25687	34	27 (8-40)
MDC18	Q319	QCS	QCS-mid	-41.19476	174.21233	51	20 (14-24)
MDC18	Q320	QCS	QCS-inner	-41.25569	173.95402	38	16 (10-18)
MDC18	Q321	QCS	QCS-inner	-41.25352	173.96608	21	17 (7-20)
MDC18	Q322	QCS	QCS-inner	-41.25332	173.97357	46	17 (8-25)

Appendix I Site locations and summary depths for the CB17 video survey.

Table I-1: Site locations and summary depths for the CB17 survey. QCS=Queen Charlotte Sounds; TC=Tory Channel; CStrait=Cook Strait; Site locations are expressed here as the mean Latitude and Longitude position, along each towed-transects, in decimal degrees (dd); Records=Ncall or Number of data calls along each transect within a site; Depth values along transect lines are extracted HS51 bathymetry values presented here as mean (minimum-maximum) depth.

Survey	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Records	Depth (m)
CB17	EC01	CStrait	QCS-CStrait	-41.09806	174.39478	19	26 (24-27)
CB17	EC03	CStrait	TC-CStrait	-41.20596	174.33003	29	22 (15-25)
CB17	EC15	CStrait	QCS-CStrait	-41.10300	174.43975	19	24 (18-32)
CB17	EC16	CStrait	QCS-CStrait	-41.11086	174.43452	7	28 (23-33)
CB17	C02	QCS	QCS-outer	-41.06418	174.27500	17	12 (10-13)
CB17	C03	QCS	QCS-outer	-41.10684	174.25006	18	18 (14-23)
CB17	C04	QCS	QCS-outer	-41.10408	174.30401	31	20 (8-36)
CB17	C05	QCS	QCS-outer	-41.11654	174.28204	32	9 (3-17)
CB17	C09	QCS	QCS-outer	-41.13643	174.37351	34	14 (9-20)
CB17	C10	QCS	QCS-outer	-41.17265	174.33681	20	20 (16-23)
CB17	C11	QCS	QCS-mid	-41.16466	174.29074	24	21 (7-37)
CB17	C12	QCS	QCS-mid	-41.17116	174.25076	24	27 (9-37)
CB17	C13	QCS	QCS-outer	-41.12055	174.23526	14	19 (11-25)
CB17	C14	QCS	QCS-mid	-41.11545	174.18034	20	22 (19-24)
CB17	C15	QCS	QCS-mid	-41.18741	174.22391	45	7 (4-14)
CB17	C16	QCS	QCS-mid	-41.21459	174.19072	26	22 (17-29)
CB17	C17	TC	TC-inner	-41.24070	174.17362	22	6 (3-19)
CB17	C18	TC	TC-mid	-41.23755	174.20384	38	17 (9-30)
CB17	C19	TC	TC-outer	-41.22569	174.26314	37	13 (5-30)
CB17	C20	TC	TC-outer	-41.20806	174.30538	21	23 (13-31)
CB17	C22	TC	TC-outer	-41.22151	174.29186	22	9 (7-11)
CB17	C23	TC	TC-mid	-41.23954	174.26461	24	19 (15-25)
CB17	C24	TC	TC-mid	-41.24517	174.24430	22	22 (18-24)
CB17	C25	TC	TC-mid	-41.24781	174.21744	18	7 (5-8)
CB17	C26	TC	TC-inner	-41.23426	174.14545	28	15 (10-19)

Survey	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Records	Depth (m)
CB17	C27	QCS	QCS-inner	-41.22427	174.10157	20	23 (17-33)
CB17	C28	QCS	QCS-inner	-41.24533	174.08483	32	17 (10-21)
CB17	C29	QCS	QCS-inner	-41.20803	174.06439	37	16 (8-23)
CB17	C30	QCS	QCS-inner	-41.22146	174.02863	14	20 (14-24)
CB17	C31	QCS	QCS-inner	-41.25671	173.99708	16	30 (22-38)
CB17	C32	QCS	QCS-inner	-41.26437	173.96506	14	12 (10-16)
CB17	C33	QCS	QCS-outer	-41.13460	174.32213	6	33 (29-38)
CB17	C50	TC	TC-inner	-41.24902	174.14332	34	16 (16-17)
CB17	C51	TC	TC-inner	-41.25649	174.16089	17	12 (11-13)
CB17	C52	TC	TC-inner	-41.25658	174.18331	30	12 (12-13)
CB17	C53	TC	TC-mid	-41.24986	174.21169	25	6 (5-6)
CB17	C54	TC	TC-mid	-41.22925	174.22575	25	3 (3-3)
CB17	C55	TC	TC-mid	-41.24567	174.25642	24	5 (3-7)
CB17	C56	TC	TC-mid	-41.24538	174.25060	11	15 (14-16)
CB17	C57	TC	TC-mid	-41.24481	174.24810	17	15 (12-17)
CB17	C58	TC	TC-outer	-41.22158	174.26963	33	19 (13-24)
CB17	C61	QCS	QCS-outer	-41.11004	174.29728	14	13 (8-21)
CB17	C62	QCS	QCS-outer	-41.11498	174.21918	37	18 (8-23)

Appendix J Site locations and summary depths for the BT17 beam-trawl survey.

Table J-1: Site locations and summary depths for the BT17 beam-trawl survey. QCS=Queen Charlotte Sounds; TC=Tory Channel; CStrait=Cook Strait; Site locations are expressed here as the mean Latitude and Longitude position in decimal degrees (dd, based on single start and end locations); SOL = Start of beam trawl depth; EOL depth = End of beam trawl depth as measured from the vessel depth sounder.

Survey	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	SOL depth (m)	EOL depth (m)
BT17	QC02	QCS	QCS-outer	-41.06077	174.30411	21.4	22.6
BT17	QC03	QCS	QCS-outer	-41.07862	174.29969	17.2	16.2
BT17	QC04	QCS	QCS-outer	-41.08196	174.27173	13.0	12.6
BT17	QC06	QCS	QCS-outer	-41.10525	174.28433	17.4	15.8
BT17	QC07	QCS	QCS-outer	-41.09374	174.24856	17.8	18.4
BT17	QC08	QCS	QCS-outer	-41.08721	174.32142	19.8	19.5
BT17	QC09	QCS	QCS-outer	-41.07913	174.35557	25.2	28.6
BT17	QC10	QCS	QCS-outer	-41.09708	174.36972	22.6	21.4
BT17	QC11	QCS	QCS-outer	-41.10786	174.34526	19.8	19.5
BT17	QC13	QCS	QCS-outer	-41.12323	174.31282	22.6	21.9
BT17	QC14	QCS	QCS-outer	-41.11517	174.21926	26.7	22.9
BT17	QC15	QCS	QCS-outer	-41.09711	174.18185	23.4	29.9
BT17	QC16	QCS	QCS-outer	-41.11239	174.14974	17.6	27.9
BT17	QC19	QCS	QCS-outer	-41.15594	174.35894	25.2	28.1
BT17	QC20	QCS	QCS-outer	-41.17335	174.32141	25.8	25.1
BT17	QC21	QCS	QCS-outer	-41.13158	174.36712	14.5	27.7
BT17	QC22	QCS	QCS-mid	-41.17855	174.28307	17.8	30.1
BT17	QC25	QCS	QCS-mid	-41.19552	174.25849	14.6	30.9
BT17	QC28	QCS	QCS-mid	-41.18104	174.15962	26.6	29.0
BT17	QC29	QCS	QCS-mid	-41.19690	174.16002	29.5	30.0
BT17	QC30	QCS	QCS-mid	-41.22168	174.16227	28.8	31.0
BT17	QC32	QCS	QCS-mid	-41.19893	174.12247	24.7	26.1
BT17	QC34	QCS	QCS-inner	-41.23458	174.12724	25.8	37.8
BT17	QC35A	TC	TC-inner	-41.24426	174.14328	13.4	13.0
BT17	QC35B	TC	TC-inner	-41.25075	174.14393	16.2	16.6

Survey	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	SOL depth (m)	EOL depth (m)
BT17	QC36	TC	TC-inner	-41.25562	174.16078	11.4	15.4
BT17	QC37	TC	TC-inner	-41.26011	174.18395	14.5	13.6
BT17	QC38	TC	TC-mid	-41.24979	174.21433	4.2	3.9
BT17	QC43	QCS	QCS-inner	-41.20594	174.09554	27.0	30.0
BT17	QC44	QCS	QCS-inner	-41.24292	174.11113	21.8	25.2
BT17	QC45	QCS	QCS-inner	-41.25729	174.07401	29.0	25.7
BT17	QC46	QCS	QCS-inner	-41.21196	174.04754	15.3	23.2
BT17	QC47	QCS	QCS-inner	-41.25579	174.05034	29.6	24.7
BT17	QC48	QCS	QCS-inner	-41.26603	174.02284	29.2	26.8
BT17	QC50	QCS	QCS-inner	-41.22932	174.00256	25.7	28.5
BT17	QC52	QCS	QCS-inner	-41.25005	173.97778	26.6	27.7
BT17	QC53	QCS	QCS-inner	-41.26115	173.97726	29.9	28.8
BT17	QC55	QCS	QCS-inner	-41.26531	173.95511	21.5	22.9
BT17	QC57	QCS	QCS-inner	-41.26384	173.94065	18.6	18.6
BT17	QC58	QCS	QCS-inner	-41.26277	173.93246	11.3	11.0
BT17	QC60	QCS	QCS-inner	-41.28220	174.01046	13.4	15.8
BT17	QC70	TC	TC-outer	-41.20324	174.30995	4.5	9.2
BT17	QC71	QCS	QCS-outer	-41.09531	174.26599	14.2	13.9

Appendix K Site locations and summary depths for the HS51 dropcam survey.

Table K-1: Site locations and summary depths for the HS51 video survey. QCS=Queen Charlotte Sounds; TC=Tory Channel; CStrait=Cook Strait; Site locations are expressed here as the mean Latitude and Longitude position in decimal degrees (dd, based on single start and end locations); SOL = Start of beam trawl depth; EOL depth = End of beam trawl depth as measured from the vessel depth sounder.

Survey	Camera type	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Depth (m)
BT17	Dropcam	A01	QCS	QCS-outer	-41.09952	174.24374	17.6
BT17	Dropcam	A02	QCS	QCS-outer	-41.09238	174.24141	18.9
BT17	Dropcam	A03	QCS	QCS-outer	-41.09533	174.25548	16.0
BT17	Dropcam	A04	QCS	QCS-outer	-41.10786	174.27008	21.5
BT17	Dropcam	A05	QCS	QCS-outer	-41.10983	174.31305	27.5
BT17	Dropcam	A06	QCS	QCS-outer	-41.09696	174.29151	14.0
BT17	Dropcam	A07	QCS	QCS-outer	-41.08167	174.26064	17.2
BT17	Dropcam	A08	QCS	QCS-outer	-41.08228	174.31734	19.5
BT17	Coastcam	A09a	QCS	QCS-outer	-41.09829	174.33001	24.0
BT17	Dropcam	A09b	QCS	QCS-outer	-41.09829	174.33001	24.0
BT17	Dropcam	A10	QCS	QCS-outer	-41.08264	174.34412	22.8
BT17	Dropcam	A11	QCS	QCS-outer	-41.06043	174.31963	23.9
BT17	Dropcam	A12	QCS	QCS-outer	-41.06794	174.33084	24.2
BT17	Dropcam	A13	QCS	QCS-outer	-41.07504	174.34235	24.6
BT17	Coastcam	A14	QCS	QCS-outer	-41.11270	174.26010	33.0
BT17	Coastcam	B01	TC	TC-inner	-41.24780	174.14440	16.1
BT17	Coastcam	B02	TC	TC-inner	-41.23960	174.15270	64.5
BT17	Coastcam	B03	TC	TC-inner	-41.25390	174.16210	14.0
BT17	Coastcam	B04	TC	TC-inner	-41.24540	174.18170	59.4
BT17	Coastcam	B05	TC	TC-inner	-41.25910	174.18260	13.5
BT17	Coastcam	B06	TC	TC-mid	-41.24400	174.21010	31.8
BT17	Coastcam	B07	TC	TC-mid	-41.23550	174.22200	32.8
BT17	Coastcam	B08	TC	TC-mid	-41.24240	174.24140	66.1
BT17	Coastcam	B09	TC	TC-mid	-41.23750	174.25990	49.0
BT17	Coastcam	B10	TC	TC-outer	-41.22390	174.27810	36.7

Survey	Camera type	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Depth (m)
BT17	Coastcam	B11	TC	TC-outer	-41.21629	174.28660	25.5
BT17	Coastcam	B12	TC	TC-outer	-41.21380	174.30020	27.4
BT17	Coastcam	B13	CStrait	TC-CStrait	-41.21630	174.32500	68.6
BT17	Coastcam	C01	QCS	QCS-inner	-41.26989	173.92214	10.6
BT17	Dropcam	C01	QCS	QCS-inner	-41.26989	173.92214	10.6
BT17	Coastcam	C02	QCS	QCS-inner	-41.26301	173.94319	19.2
BT17	Dropcam	C02	QCS	QCS-inner	-41.26301	173.94319	19.2
BT17	Dropcam	C03	QCS	QCS-inner	-41.26461	173.96108	23.2
BT17	Dropcam	C04	QCS	QCS-inner	-41.24003	173.97657	22.4
BT17	Dropcam	C05	QCS	QCS-inner	-41.25659	173.98225	30.7
BT17	Coastcam	C06	QCS	QCS-inner	-41.27210	174.00070	20.8
BT17	Coastcam	C07	QCS	QCS-inner	-41.28180	174.00860	15.5
BT17	Coastcam	C08	QCS	QCS-inner	-41.27610	174.01260	21.4
BT17	Dropcam	C09	QCS	QCS-inner	-41.24077	174.00318	32.3
BT17	Coastcam	C10	QCS	QCS-inner	-41.24840	174.01650	35.1
BT17	Coastcam	C11	QCS	QCS-inner	-41.25960	174.01940	33.2
BT17	Dropcam	C12	QCS	QCS-inner	-41.22604	174.03517	35.0
BT17	Coastcam	C13	QCS	QCS-inner	-41.24250	174.04410	38.2
BT17	Coastcam	C14	QCS	QCS-inner	-41.25433	174.05294	30.1
BT17	Dropcam	C15	QCS	QCS-inner	-41.22614	174.05741	41.3
BT17	Dropcam	C16	QCS	QCS-inner	-41.24763	174.07068	35.3
BT17	Dropcam	C17	QCS	QCS-inner	-41.23935	174.08093	39.6
BT17	Dropcam	C18	QCS	QCS-inner	-41.21995	174.09426	38.7
BT17	Dropcam	C19	QCS	QCS-inner	-41.23105	174.11168	39.0
BT17	Dropcam	C20	QCS	QCS-inner	-41.23704	174.12972	24.6
BT17	Dropcam	C21	QCS	QCS-inner	-41.23051	174.13375	22.2
BT17	Dropcam	C22	QCS	QCS-inner	-41.21496	174.13206	37.3
BT17	Dropcam	C23	QCS	QCS-mid	-41.22679	174.15493	64.9
BT17	Dropcam	C24	QCS	QCS-mid	-41.20249	174.16154	28.5
BT17	Dropcam	C25	QCS	QCS-mid	-41.21047	174.18359	49.9

Survey	Camera type	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Depth (m)
BT17	Dropcam	C26	QCS	QCS-mid	-41.19022	174.16653	34.2
BT17	Dropcam	C27	QCS	QCS-mid	-41.20032	174.20054	49.9
BT17	Dropcam	C28	QCS	QCS-mid	-41.18885	174.19546	41.7
BT17	Dropcam	C29	QCS	QCS-mid	-41.16898	174.19499	40.9
BT17	Dropcam	C30	QCS	QCS-mid	-41.17886	174.21396	58.2
BT17	Coastcam	C31	QCS	QCS-mid	-41.19570	174.22650	44.7
BT17	Coastcam	C32	QCS	QCS-mid	-41.18410	174.24360	52.9
BT17	Dropcam	C33	QCS	QCS-mid	-41.16097	174.21389	50.4
BT17	Dropcam	C34	QCS	QCS-mid	-41.14222	174.20768	47.9
BT17	Dropcam	C35	QCS	QCS-mid	-41.14399	174.17888	46.8
BT17	Dropcam	C36	QCS	QCS-mid	-41.12492	174.16575	45.8
BT17	Dropcam	C37	QCS	QCS-mid	-41.12488	174.22542	45.5
BT17	Dropcam	C38	QCS	QCS-mid	-41.14018	174.24482	46.4
BT17	Coastcam	C39	QCS	QCS-mid	-41.16020	174.26160	40.5
BT17	Coastcam	C40	QCS	QCS-mid	-41.17050	174.27870	35.3
BT17	Coastcam	C41	QCS	QCS-outer	-41.16710	174.32590	41.3
BT17	Coastcam	C42	QCS	QCS-outer	-41.14790	174.29400	44.3
BT17	Dropcam	C43	QCS	QCS-outer	-41.12240	174.25660	40.2
BT17	Dropcam	C44	QCS	QCS-outer	-41.12366	174.28911	38.5
BT17	Coastcam	C45	QCS	QCS-outer	-41.14470	174.31490	46.9
BT17	Coastcam	C46	QCS	QCS-outer	-41.15220	174.34450	45.7
BT17	Coastcam	C47	QCS	QCS-outer	-41.13310	174.36990	28.3
BT17	Dropcam	C48	QCS	QCS-outer	-41.12291	174.33166	12.9
BT17	Dropcam	C49	QCS	QCS-outer	-41.07088	174.29121	16.2
BT17	Dropcam	C50	QCS	QCS-outer	-41.10829	174.34337	19.2
BT17	Dropcam	C51	QCS	QCS-outer	-41.04548	174.28387	15.0
BT17	Dropcam	C52	QCS	QCS-outer	-41.03912	174.32327	41.8
BT17	Dropcam	C53	QCS	QCS-outer	-41.03700	174.29491	13.5
BT17	Dropcam	C54	QCS	QCS-outer	-41.03835	174.29530	39.8
BT17	Dropcam	C55	QCS	QCS-outer	-41.05159	174.30009	26.7

Survey	Camera type	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Depth (m)
BT17	Dropcam	C56	QCS	QCS-outer	-41.09163	174.36855	24.2
BT17	Dropcam	C57	QCS	QCS-outer	-41.10228	174.35481	19.9
BT17	Coastcam	C58	QCS	QCS-mid	-41.18410	174.20610	78.6
BT17	Coastcam	C59	QCS	QCS-mid	-41.21450	174.16950	32.9
BT17	Coastcam	C60	QCS	QCS-inner	-41.20640	174.12050	32.0
BT17	Coastcam	C61	QCS	QCS-inner	-41.21180	174.14080	33.9
BT17	Coastcam	C62	QCS	QCS-mid	-41.10780	174.17900	35.8
BT17	Coastcam	C63	QCS	QCS-mid	-41.12060	174.15090	30.7
BT17	Coastcam	C64	QCS	QCS-mid	-41.12690	174.19280	36.0
BT17	Coastcam	C65	QCS	QCS-mid	-41.20100	174.24050	13.5
BT17	Coastcam	C66	QCS	QCS-outer	-41.15530	174.31850	47.8
BT17	Coastcam	C67	QCS	QCS-mid	-41.18210	174.15260	20.2
BT17	Coastcam	C68	QCS	QCS-mid	-41.18590	174.25220	42.1
BT17	Coastcam	C69	QCS	QCS-inner	-41.22580	174.10140	9.2
BT17	Coastcam	C70	QCS	QCS-mid	-41.14820	174.26040	44.8
BT17	Coastcam	C71	QCS	QCS-inner	-41.23590	174.03890	39.8
BT17	Coastcam	C72	QCS	QCS-inner	-41.26080	174.04650	18.5
BT17	Coastcam	C73	QCS	QCS-inner	-41.23700	174.07500	40.5
BT17	Coastcam	D01	CStrait	QCS-CStrait	-41.11350	174.41670	143.3
BT17	Coastcam	D02	CStrait	QCS-CStrait	-41.05710	174.36920	51.0
BT17	Coastcam	D03	CStrait	QCS-CStrait	-41.07850	174.41810	118.4
BT17	Coastcam	D04	CStrait	QCS-CStrait	-41.11490	174.47660	174.1
BT17	Coastcam	D05	CStrait	QCS-CStrait	-41.08080	174.47480	169.9
BT17	Coastcam	D06	CStrait	QCS-CStrait	-41.05050	174.44930	123.5
BT17	Coastcam	D07	CStrait	QCS-CStrait	-41.04550	174.40940	82.7
BT17	Coastcam	D08	CStrait	QCS-CStrait	-41.03470	174.37400	82.9
BT17	Coastcam	D09	QCS	QCS-outer	-41.01540	174.33500	58.6
BT17	Coastcam	D10	CStrait	QCS-CStrait	-40.99280	174.36230	242.9
BT17	Coastcam	D11	CStrait	QCS-CStrait	-41.01790	174.40710	119.9
BT17	Coastcam	D12	CStrait	QCS-CStrait	-40.99700	174.34600	148.7

Survey	Camera type	Site	Region	Subregion	Latitude (dd)	Longitude (dd)	Depth (m)
BT17	Coastcam	D13	CStrait	QCS-CStrait	-41.01650	174.36600	176.4
BT17	Coastcam	D14	QCS	QCS-outer	-41.00580	174.33510	77.8
BT17	Coastcam	D15	QCS	QCS-outer	-40.99900	174.31920	95.6
BT17	Coastcam	D16	QCS	QCS-outer	-41.05540	174.34960	59.8
BT17	Coastcam	D17	QCS	QCS-outer	-41.06660	174.35190	71.8
BT17	Coastcam	D18	CStrait	QCS-CStrait	-41.06630	174.37330	85.7
BT17	Coastcam	D19	QCS	QCS-outer	-41.07290	174.36470	110.1
BT17	Coastcam	D20	QCS	QCS-outer	-41.08160	174.36110	56.9
BT17	Coastcam	D21	CStrait	QCS-CStrait	-41.10880	174.39430	57.6
BT17	Coastcam	D22	QCS	QCS-outer	-41.02270	174.30820	37.6
BT17	Coastcam	D23	CStrait	QCS-CStrait	-41.10290	174.42980	72.9
BT17	Coastcam	D24	QCS	QCS-outer	-41.07240	174.35790	88.4
BT17	Coastcam	D25	CStrait	QCS-CStrait	-41.03240	174.35720	113.6
BT17	Coastcam	D26	CStrait	QCS-CStrait	-41.07030	174.39330	91.7
BT17	Coastcam	D27	QCS	QCS-outer	-41.08280	174.34360	22.6
BT17	Coastcam	E01	CStrait	QCS-CStrait	-41.15780	174.42337	20.3

Appendix L Summary statistics for solitary cup corals

Table L-1: Summary statistics for solitary cup corals (counts and depth ranges) for the MDC18 survey. QCS=Queen Charlotte Sounds; TC=Tory Channel; CStrait=Cook Strait; rank-abd= Rank-abundance: as present (1), few (2-5), common (5-10), notable >10.

Area	Site	Total records	Cup corals rank-abd range	Depth (m)	
				Mean (±SE)	Range
QCS-outer	Q02	3	1	77.7 (6.8)	64.2-84.6
QCS-inner	Q05	2	1	26.0 (3.4)	22.6-29.4
QCS-inner	Q07	7	>10	31.0 (0.8)	27.8-33.7
QCS-mid	Q16	4	1-5	42.5 (1.2)	39.6-45
QCS-mid	Q37	1	1	20.1	n/a
QCS-mid	Q45	1	1	38.1	n/a
QCS-outer	Q47	5	1-5	44.5 (3.7)	30.7-52.1
QCS-outer	Q72	1	1	39.4	n/a
TC-CStrait	Q80	11	1->10	40.2 (1.3)	36-47.8
TC-CStrait	Q83	2	2-5	32.2 (0.3)	31.9-32.6
TC-CStrait	Q84	2	2-5	28.6 (0.9)	27.7-29.6
QCS-inner	Q89	7	1-5	35.4 (0.2)	34.7-36
QCS-inner	Q90	2	1	32.1 (4.3)	27.8-36.4
QCS-inner	Q91	3	1-5	22.7 (1.1)	20.7-24.6
QCS-inner	Q94	4	1-5	29.3 (1.7)	25.5-32.5
QCS-inner	Q101	1	1	50.6	n/a
QCS-inner	Q102	1	1	35.3	n/a
QCS-inner	Q103	3	1	36.1 (0.7)	35-37.4
QCS-inner	Q108	1	1	32.2	n/a
QCS-outer	Q116	1	1	25.9	n/a
QCS-outer	Q129	8	1-5	30.9 (1.7)	24.3-35.9
QCS-CStrait	Q137	10	5-10	106.1 (5.4)	79.9-131
QCS-outer	Q138	2	1	94.5 (0.2)	94.3-94.6
TC-CStrait	Q147	4	10	103.9 (4.6)	90.8-112
QCS-inner	Q173	4	1-5	29.9 (3.0)	21.1-33.6
QCS-inner	Q174	4	10	26.6 (4.5)	21.6-40.1
QCS-mid	Q175	2	1	35.6 (1.0)	34.6-36.6
TC-inner	Q177b	1	1	31.2	n/a
QCS-CStrait	Q182	3	1-5	98.9 (2.2)	94.6-152
QCS-CStrait	Q307	14	1->10	41.9 (1.9)	36.4-44.6
QCS-outer	Q316	1	1	33.1	n/a

Appendix M Records of submerged trash within the survey area.

Table M-1: Records of submerged trash within QCS and TC. QCS=Queen Charlotte Sounds; TC=Tory Channel; Depth Mean (min-max). DD=decimal degrees. Depth is extracted from HS51 bathymetry for all data records along each transect/site. For MDC18 and CB17 the latitude and longitude represent the data point (15 sec interval) within which trash was recorded ± ≤3 m (GPS accuracy/layback error). HS51 bathy= HS 51 bathymetry were extract for each data point (CB17 and MDC18 surveys). For BT17 (Beam Trawl sites) a single mid-way latitude and longitude position between the start and end points of the tow, along with mean HS51-bathy values, are presented (values underlined). All trash collected in the beam trawls was retained and disposed of to landfill.

Item	Survey	Site	Latitude (dd)	Longitude (dd)	Depth (m)	Trash type	Count
1	MDC18	Q04	-41.23527	174.06214	34.1	trash	1
2	MDC18	Q04	-41.23522	174.06199	32.1	trash	1
3	MDC18	Q05	-41.25111	174.04539	16	trash-bottle	1
4	MDC18	Q05	-41.25111	174.04539	16	trash-can	1
5	MDC18	Q05	-41.25111	174.04554	15.1	trash-bottle	1
6	MDC18	Q05	-41.2512	174.04592	11.3	trash	3
7	MDC18	Q06	-41.24927	174.0508	26.3	trash	1
8	MDC18	Q06	-41.2499	174.04984	7.2	trash-bottle	1
9	MDC18	Q08	-41.25845	173.99722	8.8	trash-jar	1
10	MDC18	Q08	-41.25867	173.99715	7.1	trash	1
11	MDC18	Q08	-41.25869	173.99711	7.1	trash	1
12	MDC18	Q08	-41.25871	173.99708	7	trash	1
13	MDC18	Q08	-41.25873	173.99699	7.3	trash	1
14	MDC18	Q08	-41.25873	173.99698	7.3	trash	1
15	MDC18	Q08	-41.25875	173.99696	7.3	trash	1
16	MDC18	Q08	-41.25878	173.99689	7.5	trash	1
17	MDC18	Q08	-41.25877	173.99689	7.5	trash	1
18	MDC18	Q09	-41.26346	173.9814	15.8	trash	1
19	MDC18	Q10	-41.27617	174.01616	7.3	trash	1
20	MDC18	Q10	-41.27618	174.01626	6.6	trash	1
21	MDC18	Q10	-41.27634	174.01606	6.2	trash	1
22	MDC18	Q102	-41.22527	174.10144	10.9	trash	1
23	MDC18	Q102	-41.2248	174.10131	8.5	trash	1

Item	Survey	Site	Latitude (dd)	Longitude (dd)	Depth (m)	Trash type	Count
24	MDC18	Q102	-41.22471	174.10132	9.2	trash	1
25	MDC18	Q103	-41.22538	174.10177	16.3	trash	1
26	MDC18	Q103	-41.22549	174.1003	28.7	trash-bottle	1
27	MDC18	Q104	-41.23496	174.11858	11.2	trash	1
28	MDC18	Q104	-41.23515	174.11956	16.8	trash	1
29	MDC18	Q106	-41.22294	174.0631	8.4	trash-bottle	1
30	MDC18	Q106	-41.22294	174.0631	8.4	trash-fishingline	1
31	MDC18	Q107	-41.22293	174.04829	20.5	trash-pipe	1
32	MDC18	Q107	-41.22248	174.04798	12.1	trash	1
33	MDC18	Q107	-41.22248	174.04778	8.8	trash	1
34	MDC18	Q11	-41.2755	174.01548	19	trash	1
35	MDC18	Q11	-41.2755	174.01565	17.3	trash	1
36	MDC18	Q139	-41.17505	174.26154	39.3	trash-rope	1
37	MDC18	Q139	-41.17494	174.26163	39.8	trash-bottle	1
38	MDC18	Q139	-41.21193	174.04776	21.8	trash	1
39	MDC18	Q140	-41.23507	174.14699	45.3	trash	1
40	MDC18	Q145	-41.21978	174.29303	30.5	trash-bottle	1
41	MDC18	Q146	-41.21736	174.29876	13.8	trash	1
42	MDC18	Q146	-41.21724	174.2982	17.5	trash	1
43	MDC18	Q147	-41.218	174.32569	91.2	trash-ropecraypot	1
44	MDC18	Q156	-41.21398	174.28847	24.6	trash	1
45	MDC18	Q156	-41.21218	174.28831	11.2	trash	1
46	MDC18	Q157	-41.21982	174.27596	25.2	trash	1
47	MDC18	Q16	-41.21423	174.15814	33	trash	1
48	MDC18	Q169	-41.24181	174.16082	2.3	trash	1
49	MDC18	Q169	-41.24181	174.16082	2.3	trash-fishingline	1
50	MDC18	Q171	-41.24056	174.14585	14.7	trash	1
51	MDC18	Q172	-41.23327	174.1618	28.4	trash-rope	1
52	MDC18	Q173	-41.22204	174.13542	32.1	trash	1
53	MDC18	Q174	-41.21875	174.14079	24.6	trash	1

Item	Survey	Site	Latitude (dd)	Longitude (dd)	Depth (m)	Trash type	Count
54	MDC18	Q176	-41.18116	174.25598	38.5	trash-bottle	1
55	MDC18	Q177b	-41.23019	174.14753	21.4	trash-fishingline	1
56	MDC18	Q178	-41.2172	174.12371	12.7	trash-bottle	1
57	MDC18	Q178	-41.21722	174.12372	12.7	trash	1
58	MDC18	Q178	-41.21727	174.12374	13.8	trash-bottle	1
59	MDC18	Q178	-41.21751	174.12376	19.3	trash	1
60	MDC18	Q18	-41.18197	174.20503	39.9	trash	1
61	MDC18	Q180	-41.24496	174.2536	31.3	trash	1
62	MDC18	Q180	-41.24495	174.25359	31.4	trash	1
63	MDC18	Q180	-41.24473	174.25332	31	trash	1
64	MDC18	Q196	-41.2522	174.18384	17.1	trash	1
65	MDC18	Q202	-41.17764	174.21689	62.2	trash	1
66	MDC18	Q21	-41.11491	174.22073	25.4	trash-ironwheel	1
67	MDC18	Q21	-41.11531	174.22051	28	trash-10gal-drum	1
68	MDC18	Q307	-41.11543	174.43479	32	trash-fishingline	1
69	MDC18	Q311	-41.22248	174.06255	29	trash	1
70	MDC18	Q315	-41.12355	174.1812	19.3	trash	1
71	MDC18	Q315	-41.12343	174.18121	16.8	trash	1
72	MDC18	Q315	-41.1229	174.18161	13	trash	1
73	MDC18	Q318	-41.18132	174.25695	26.8	trash-burleypot	1
74	MDC18	Q319	-41.19451	174.21386	19.5	trash	1
75	MDC18	Q321	-41.25329	173.96511	18.5	trash	1
76	MDC18	Q321	-41.25401	173.96671	10.9	trash	1
77	MDC18	Q322	-41.25342	173.97292	24.9	trash-wheelhub	1
78	MDC18	Q322	-41.25332	173.97355	14.9	trash	1
79	MDC18	Q322	-41.25324	173.97414	11.4	trash	1
80	MDC18	Q36	-41.15476	174.20173	32.4	trash	1
81	MDC18	Q37	-41.17138	174.20225	30	trash-bottle	1
82	MDC18	Q40	-41.12682	174.18787	38	trash	1
83	MDC18	Q42	-41.12738	174.18299	28.7	trash	1

Item	Survey	Site	Latitude (dd)	Longitude (dd)	Depth (m)	Trash type	Count
84	MDC18	Q43	-41.1012	174.27619	18.8	trash	1
85	MDC18	Q45	-41.1438	174.21855	39.1	trash	1
86	MDC18	Q47	-41.12866	174.24175	30.7	trash-bottle	1
87	MDC18	Q51	-41.14086	174.28661	25.1	trash	1
88	MDC18	Q51	-41.14159	174.28712	10.6	trash-can	1
89	MDC18	Q51	-41.142	174.28943	14.9	trash	1
90	MDC18	Q74	-41.16579	174.29032	22.1	trash	1
91	MDC18	Q83	-41.21531	174.31447	24.7	trash-rope	1
92	MDC18	Q89	-41.23244	174.03976	49.8	trash	1
93	MDC18	Q89	-41.23185	174.03935	35	trash-rope	1
94	MDC18	Q89	-41.23183	174.03927	35.7	trash-rope	1
95	MDC18	Q90	-41.23922	174.05932	27	trash	1
96	MDC18	Q91	-41.24024	174.01879	18.4	trash	1
97	MDC18	Q92	-41.25387	173.97467	17.7	trash	1
98	MDC18	Q92	-41.25359	173.9744	11.8	trash-bottle	1
99	MDC18	Q93	-41.24129	174.09259	48.5	trash-plastic	1
100	MDC18	Q94	-41.24985	174.06615	27.5	trash	1
101	MDC18	Q94	-41.25014	174.06642	26.9	trash-can	1
102	MDC18	Q95	-41.25928	174.04825	21.9	trash	1
103	MDC18	Q96	-41.24076	173.97298	10.8	trash-bottle	1
104	MDC18	Q97	-41.23553	174.1256	33.5	trash	1
105	MDC18	Q97	-41.23557	174.12545	30.4	trash	1
106	MDC18	Q97	-41.23594	174.12496	9.1	trash	1
107	CB17	C03	-41.10733	174.24977	15.9	trash	1
108	CB17	C05	-41.11674	174.28187	13.8	trash-rope	1
109	CB17	C14	-41.11469	174.18012	22.6	trash-bottle	1
110	CB17	C14	-41.11489	174.18018	22.1	trash-bottle	1
111	CB17	C14	-41.11518	174.18025	23.3	trash-rope	1
112	CB17	C14	-41.11579	174.18039	20.5	trash-wheelhub	1
113	CB17	C14	-41.11612	174.18043	19.9	trash-bottle	1

Item	Survey	Site	Latitude (dd)	Longitude (dd)	Depth (m)	Trash type	Count
114	CB17	C15	-41.18651	174.22508	5.1	trash-bottle	1
115	CB17	C15	-41.18651	174.22517	4.4	trash-cartyre	1
116	CB17	C27	-41.22409	174.10213	33.2	trash-sac	1
117	CB17	C28	-41.24516	174.08588	17.6	trash-cableline	1
118	CB17	C31	-41.25694	173.99667	23.8	trash	1
119	CB17	C32	-41.2643	173.96428	15.3	trash-bottle	1
120	CB17	C32	-41.26438	173.9646	11.6	trash-glass	1
121	CB17	C32	-41.26438	173.96465	11	trash-bottle	1
122	CB17	C32	-41.26437	173.96474	10.8	trash-bottle	1
123	CB17	C32	-41.26444	173.96539	10.6	trash-cartyre	1
124	CB17	C32	-41.26438	173.96561	12.6	trash-bottle	1
125	CB17	C32	-41.26433	173.96575	14.7	trash-bottle	1
126	CB17	C58	-41.22177	174.2695	21.3	trash	1
127	CB17	C58	-41.22187	174.26949	22.6	trash-rope	1
128	CB17	C62	-41.1159	174.21867	22	trash-unk	1
129	CB17	C62	-41.11547	174.21885	19.8	trash-pipe	1
130	CB17	C62	-41.11547	174.21885	19.8	trash-rope	1
131	CB17	C62	-41.11471	174.21938	16	trash	1
132	CB17	C62	-41.11471	174.21938	16	trash-pipe	1
133	CB17	C62	-41.1146	174.2199	17.5	trash	1
134	CB17	C62	-41.1146	174.2199	17.5	trash-rope	1
135	CB17	C62	-41.1146	174.2199	17.5	trash	1
136	TB17	QC16	-41.11239	174.14974	23.5	trash-plasticbottle	1
137	TB17	QC20	-41.17335	174.32141	24.3	trash-paper	1
138	TB17	QC28	-41.18103	174.15962	28.5	trash-bottle	1
139	TB17	QC48	-41.26603	174.02284	28	trash-foodwrapper	2
140	TB17	QC57	-41.26384	173.94065	18.7	trash-foodwrapper	1
141	TB17	QC60	-41.2822	174.01046	14.3	trash-clothrag	1

Appendix N Summary depth information for deep reef sites (≥30 m).

Table N-1: Summary depth information for deep reef sites (≥30 m) within the survey area (MDC18 survey). Data were extracted for all recorded where depth was ≥30 m and rock was >0; mean + S.E., and minimum and maximum depth values were then calculated on the extracted data for each site.

Subregion	Sites with some deep reef	Records in depth >30m	Mean depth (+SE, m)	Depth (m) min-max
QCS-in	Q07	4	30.2 (<0.1)	30.2-32.3
QCS-in	Q102	1	33.6 (n/a)	n/a
QCS-in	Q173	2	32.4 (0.4)	32.0-32.8
QCS-in	Q174	2	32.2 (1.5)	30.7-33.6
QCS-in	Q313	3	34.4 (1.1)	32.8-36.4
QCS-in	Q89	5	35.5 (0.4)	34.7-37.0
QCS-in	Q90	6	32.0 (0.5)	30.2-33.5
QCS-in	Q94	4	31.5 (0.5)	30.0-32.5
QCS-mid	Q139	21	43.1 (0.8)	38.8-51.1
QCS-mid	Q16	7	39.8 (1.9)	32.5-45.0
QCS-mid	Q175	3	39.1 (3.2)	32.8-42.3
QCS-mid	Q18	2	34.6 (1.6)	33.0-36.3
QCS-mid	Q317	1	43.4 (n/a)	n/a
QCS-mid	Q39	1	33.6 (n/a)	n/a
QCS-mid	Q40	9	39.5 (0.5)	36.3-41.1
QCS-mid	Q42	11	32.2 (0.3)	30.5-33.5
QCS-mid	Q45	2	30.3 (0.2)	30.1-30.5
QCS-mid	Q73	1	30.9 (n/a)	n/a
QCS-mid	Q76	2	35.9 (3.1)	32.7-39.0
QCS-out	Q20	2	31.0 (0.9)	30.1-31.9
QCS-out	Q316	4	30.6 (0.2)	30.2-31.1
QCS-out	Q47	2	32.1 (1.3)	30.7-33.4
QCS-out	Q51	4	33.6 (1.6)	30.8-36.5
QCS-out	Q72	8	34.8 (0.9)	32.4-39.4
QCS-entrance	Q02	17	72.8 (1.1)	67.6-84.5

Subregion	Sites with some deep reef	Records in depth >30m	Mean depth (+SE, m)	Depth (m) min-max
QCS-entrance	Q115	3	32.1 (0.7)	31.0-33.4
QCS-entrance	Q120	1	81.6 (n/a)	n/a
QCS-entrance	Q125	3	37.2 (3.4)	30.4-41.4
QCS-entrance	Q129	12	35.2 (1.0)	31.0-43.9
QCS-entrance	Q24	1	30.6 (n/a)	n/a
QCS-Cstrait	Q109	23	45.9 (1.5)	33.6-59.7
QCS-Cstrait	Q134	35	99.6 (0.6)	92.1-104
QCS-Cstrait	Q137	33	113.5 (2.7)	79.9-131
QCS-Cstrait	Q182	25	96.2 (0.7)	89.4-104
QCS-Cstrait	Q307	14	38.8 (1.3)	31.1-44.6
Tory-in	Q169	7	35.9 (1.8)	30.3-43.3
Tory-in	Q171	1	33.7 (n/a)	n/a
Tory-in	Q172	15	40.4 (1.7)	30.4-49.4
Tory-in	Q177	16	37.6 (2.3)	30.3-55.9
Tory-in	Q314	10	32.6 (0.5)	31.4-35.6
Tory-mid	Q161	3	37.6 (4.6)	31.3-46.5
Tory-mid	Q180	13	31.1 (0.1)	30.7-31.5
Tory-mid	Q85	17	55.3 (1.7)	44.4-62.5
Tory-out	Q145	13	32.7 (0.1)	31.7-33.6
Tory-out	Q185	17	38.8 (1.5)	30.1-51.6
Tory-out	Q186	6	37.9 (0.2)	37.0-38.3
Tory-Cstrait	Q147	20	97.0 (1.8)	80.2-112
Tory-Cstrait	Q148	4	32.7 (0.6)	31.2-33.8
Tory-Cstrait	Q80	25	39.1 (0.9)	31.3-48.7
Tory-Cstrait	Q82	16	32.1 (0.4)	30.2-34.8
Tory-Cstrait	Q83	4	32.1 (0.3)	31.4-32.6
Tory-Cstrait	Q84	9	33.8 (0.9)	30.5-38.4

Appendix O Location and description of significant and/or notable kelp sites within QCS and TC, along with the presence of the exotic Japanese seaweed, *U. pinnatifida*.

Table O-1: Location and description of significant and/or notable kelp sites within QCS and TC, along with the presence of the exotic Asian Kelp, *U. pinnatifida*. Summaries from BT17, CB17 and MDC18 surveys, undertaken in March-April 20017, April-May 2017 and September-October 2018, respectively. % cover are based on qualitative estimates of video-footage[89]. Green shading = sites with significant areas of intact native kelp forests; orange shading = intermediate condition; red shading = sites with presence of notable amounts of *U. pinnatifida,* but may also have native kelps as well. %cover = post-processing qualitative assessment of kelp cover: two % cover values may be provided the first in black text= total kelp cover, the second red text = %cover of the exotic *U. pinnatifida*. Where dense kelp forests are recorded, an extent value is also provided (black text value followed by the word 'extent') – these values depict distances along the video-transects, with the kelp forest likely extending in other directions alongshore – unless otherwise stated. (?) = preliminary identification of taxa/species based on best assessment of video image, but this identification could not be verified; ≤ = up to (i.e., denotes the maximum % cover seen); tx=transect.

Sub-region	Site	Location	Habitat type	Max. % cover	Description
QCS Outer	Q121	Waihi Pt	Wave-exposed rocky reef	≤100% cover ≥ 32 m extent extensive	*E. radiata* forest – dense and extensive, in depths of 4.4-8.9 m, NB: transect up slope (so 32 m = vertical band height), but *E. radiata* forest appears to be extensive alongshore too based on wide angle view.
TC Outer	Q144	(South-side TC) Sth Thoms Bay	High-current kelp-zone	≤~65% cover 214 m extent, patchy	Extensive moderately-dense mixed kelp bed, in depths of 8.8-15.2 m, dominated by *E. radiata* with *C. flexuosum* (few), *Macrocystis* (x1) plants, and an abundance of *U. pinnatifida* plants (mostly small blades x~45 and medium-sized plants x~11). Subcanopy of mixed red algae (mostly bushy forms) and large patches of *Caulerpa*.
TC Outer	Q156	(North-side TC) off Te Awaiti Bay	High-current kelp-zone	≤30-50% cover 71 m extent, patchy	Mixed kelp bed dominated by *E. radiata,* with few wispy *Macrocystis* on high-relief shallow reefs, but also few (<~10) small-medium sized *U. pinnatifida* (?) plants. Subcanopy of mixed algae (incl. *Gigartina atropurpurea, C. costata, C. fragile*).
TC Outer	Q81	(South-side TC) entrance to TC	Rocky reef slope	≤30% cover 80 m extent patchy	Mix kelp bed with *E. radiata*, along with patches of *L. variegata* and *Marginariella* (i.e., transitional TC-CStrait kelp assemblage), poss. *Landsburgia* (?). Understory mixed reds, incl. turfing NGC. Lush sections of *C. flexilis*. Few (≤3) small un-identified new recruit plants (poss. *U. pinnatifida*).
TC Outer	CB17 C22	(South-side TC) Nth of Tipi Bay	Soft-sediment and patchy rock outcrops	≤~30% cover 26 m extent, but patchy	Nice healthy-looking mixed kelp bed with long tall *Macrocystis* and very tall and bush *C. flexuosum* plants (26 m extent, but patchy). Understory mixed reds and small patch of *Caulerpa* sp.

[89] We would recommend formal post-processing of the ground-truthing video imagery to be able to determine quantitative % cover for all kelp species within the kelp zone.

Sub-region	Site	Location	Habitat type	Max. % cover	Description
QCS Mid	Q32	Amerikiwhati Is.	Shallow reef	Negligible in tx, But kelp-zone seen from boat	~2x small basal plants of *C. flexuosum* in tx. NB: "Lots of *Carphophyllum* visible in front of boat around emergent reef."
TC Outer	Q146	(south side TC) sth Thoms Bay	Rock, cobble, & coarse sediments	≤1% cover *U. pinnatifida* (?)	12 x small recruit blades at 8.3 m, poss. *U. pinnatifida* (?). hard to tell. No other kelp.
TC Outer	Q157	reef north of Ngamahau Bay (north-side TC)	Conglomerate upper slope	≤~15%cover *U. pinnatifida*	Conglomerate outcrop on upper slope with mixed kelp (low density) dominated by *E. radiata*, with ≤~3 small-medium sized *U. pinnatifida* plants.
TC Outer	CB17 C20	(North-side TC)	High-relief reef	≤~30% cover ≤1% *U. pinnatifida* (?)	Mixed kelp bed, dominated by *E. radiata*, with some long and tall *Macrocystis* and a few medium-sized *U. pinnatifida* (?). Diverse mixed algal subcanopy (incl. *E. formosissima*). NB: Identification difficult from video as often too high up (avoiding entanglement in surface kelp).
TC Mid	CB17-C18	North side West of Wiriwaka Point (north-side TC)	Soft-sediment with cobbles and shells	≤20% cover ≤5% *U. pinnatifida*	Coarse grained sediment with mixed kelp growing on the few shells and cobbles, and small rock outcrops present in depths of 8-13 m. Long strands of 1-3 *Macrocystis* plants (7 plants in total counted), plus long strands of *C. flexuosum*, with few *Carpophyllum* or *Sargassum* plants (hard to Identify), and quite a lot of small and rather large *U. pinnatifida* plants in amongst the *Macrocystis*. *U. pinnatifida* mostly small plants (≥ 9 recruit blades, plus 3 medium-large plants).
QCS Outer	Q54 and BT17-QC04	Reef 500 m north of Motuara Is.	Reef + adjacent soft-sediment with cobbles and shells	≤35% cover mostly ≤35% *U. pinnatifida*	Large numbers of small to medium sized *U. pinnatifida* young plants growing near base of reef on shell/cobble rubble, with more established medium-large *U. pinnatifida* plants on the reef – relatively continuous cover along transect. Native kelp limited to few strands of *Carpophyllum* spp. The BT17 beam trawl survey (site BT17-QC04) collected ~1 litre of *U. pinnatifida* from a soft-sediment site ~850 m west of this MDC18-Q54 site.
TC Outer	Q141	Across North entrance of Te Rua Bay (south-side TC)	Sediment + debris with patchy reef	Patchy, ≤25% cover mostly ≤20% *U. pinnatifida*	Top of reef with small patches of *E. radiata* 1-4 plants per small patch reef, then a small rock patch with couple of long *C. flexuosum* and *Macrocystis* plants. However up slope and around other kelps were several small to medium sized *U. pinnatifida* plants.
Tory Mid	Q305	South entrance of Te Rua Bay (south-side TC)	Sediment and low-lying patchy reef	≤20% cover most ≤20% *U. pinnatifida*	2x large Macrocystis plants up slope, an abundance of small to medium sized *U. pinnatifida* all the way up the slope (>10 medium sized, >20 small recruit plants); 1 small patch of *E. radiata* at top of slope on rocky ridge.

Sub-region	Site	Location	Habitat type	Max. % cover	Description
QCS Outer	Q59	Motungarara Is	reef	≤5-10% *U. pinnatifida*	Reef characterised by mixed red algal cover with several *U. pinnatifida* plants of small to med-large sizes (~4-7 m depth).
QCS Outer	Q52	Motungarara Is	reef	≤5% *U. pinnatifida*	Reef characterised by mixed red algal cover with 1 single small (recruit blade) *U. pinnatifida* plant (~15 m depth).
QCS Outer	Q53	Little Waikawa Bay	reef	≤15% *U. pinnatifida*	Low-lying coralline encrusted reef, with patches of sea urchins, and low density patches of small to moderate sized *U. pinnatifida* plants (most ~4-6 m depth, + 13 m).
TC Inner	Q177b	Dieffenbach Pt	Large reef	≤80% cover ≤30% *U. pinnatifida*	Shallow reef (7 m) bed of mixed kelp, dominated by *Macrocystis*, with few *Carpophyllum* or *Sargassum* plants (hard to Identify), and quite a lot of small and rather large *U. pinnatifida* plants in amongst the *Macrocystis*.
TC Outer	Q185	north of Te Rua Bay(Sth side TC)	Ridge slope	≤55% *U. pinnatifida*	Lots of small recruit blades and small to medium sized *U. pinnatifida* plants.
TC Outer	Q159	Sth of Tipi Bay (South side TC)	Conglomerate upper slope	≤70% cover ≤50% *U. pinnatifida*	Mixed kelp forest on top of reef mostly *U. pinnatifida* with patches of *E. radiata* and few *C. flexuosum*
TC Outer	CB17 C19	reef south of Ngamahau Bay (north-side TC)	Sediment slope with patchy reef	≤~50% cover ≤~25% *U. pinnatifida*	Top of slope comprising patch reefs and sand: Small rock outcrops with mixed kelp dominated by *E. radiata*, but also numerous *U. pinnatifida* plants, and patches of long *Macrocystis* and *C. flexuosum* plants.
TC Inner	Q165	North side (TC) opposite Takatea Pt	top of slope consolidated rubble	≤5% *U. pinnatifida*	Few single *E. radiata* and *C. flexuosum* plants (≤1%) plus, multiple *U. pinnatifida* plants identified, but also an abundance of small recruit blades unidentified but look like poss. *U. pinnatifida* (≤ 20 plants).
QCS Mid	Q175	Snake Point, Bay of Many Coves	Shallow reef	≤5% *U. pinnatifida*	~27 small *U. pinnatifida* plants (several definite ID's).
QCS Inner	Q98	Site midway between east bay (little) and Dieffenbach Pt	top of slope consolidated rubble	≤2% *U. pinnatifida*	Several small recruit blades of *U. pinnatifida* plants identified, (≤ 6 small recruit plants).
QCS Inner	Q92 Q322	Reef nth of Houhou pt	Shallow reef	≤15% cover	Few tall *C. flexuosum* along with several small plants <~10.
QCS Mid	Q318	Patten Passage	Shallow reef	negligible	~3x small basal plants of *C. flexuosum* (?)
QCS Inner	Q106	KumutotoPt	Shallow reef	negligible	<~10 small basal plants of *C. flexuosum* (?)

NB: *U. pinnatifida* was also recorded on western side of the Duck Pond, off Kaikanohi headland (1 long plant, Site CB17-C02.