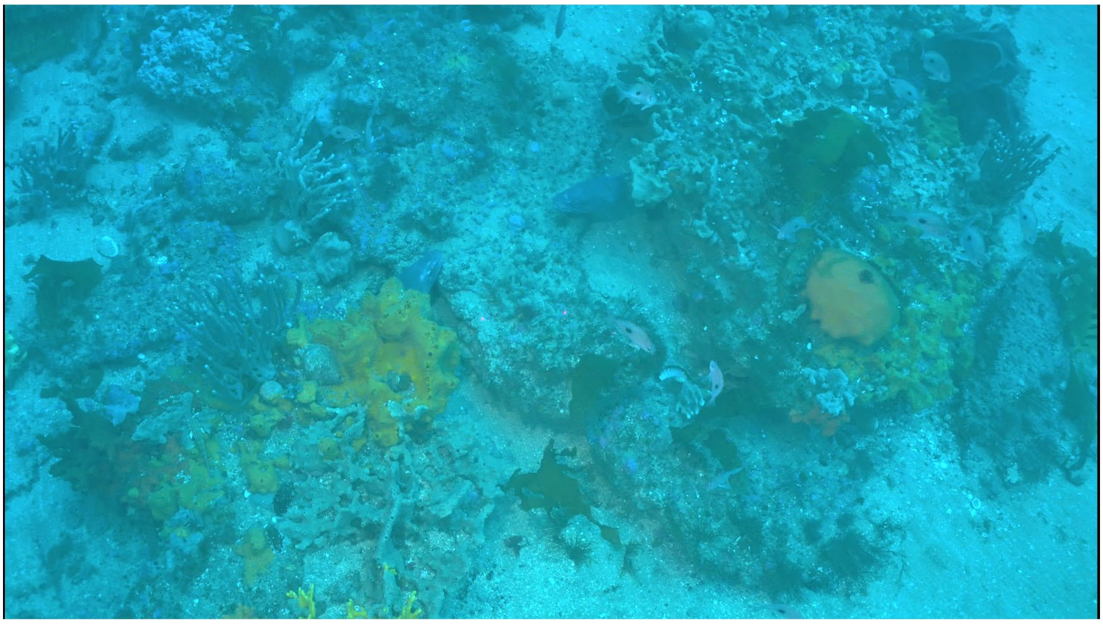
Offshore subtidal rocky reef habitats on Pātea Bank, South Taranaki

Prepared for Taranaki Regional Council

September 2022



Prepared by:
Mark Morrison, Kimberley Seaward, Charlotte Bodie, Brooke Madden, Oliver Evans, Penny Smale, Karen Pratt, Bruce Boyd, Joshua Richardson, Richard Guy, Thomas McElroy, Stephen Williams, Arne Pallentin, Kevin Mackay

For any information regarding this report please contact:

Mark Morrison
Senior Scientist
NIWA Auckland
+64-9-375 2063
mark.morrison@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Private Bag 99940
Viaduct Harbour
Auckland 1010

Phone +64 9 375 2050

NIWA CLIENT REPORT No: 2022229AK
Report date: September 2022
NIWA Project: ELF202202

Revision	Description	Date
Version 1.0		22 December 2022

Quality Assurance Statement		
J Beaumont	Reviewed by:	Jennifer Beaumont
	Formatting checked by:	Jess Moffat
J.P. Moores	Approved for release by:	Jonathan Moores Regional Manager Auckland

Contents

Tables

Figures

Executive summary

The Taranaki Regional Council engaged NIWA to undertake an analysis and classification of existing survey data on sub-tidal rocky reef habitat in the South Taranaki Bight. Presently, the coastal marine area of South Taranaki is poorly understood. There is a need to identify and characterise subtidal reef systems in the South Taranaki Bight to provide Council and the community with a good inventory of habitats and species present. This will in turn inform decision-making around both land and coastal management where activities may impact South Taranaki sub-tidal reefs.

A targeted selection of subtidal reefs of Pātea Bank, South Taranaki, were surveyed using a two phase approach.

In 2020, a multibeam sonar mapping route was created for the survey region, crossing over as many potential reef sites as possible. Likely reef sites were identified using local divers/fishers knowledge, DOCs (putative) reef polygon coverage, and the local chart. Time was also allowed for the mapping of patch reefs to either side of the survey route as practical. A route track of more than 250 km was achieved, mapping 61.5 km^2 of seafloor. Numerous reefs were revealed across the entire survey area, ranging from small knolls and patches, through to extensive linear ridges several kilometres long. Application of Benthic Terrain Modelling, which uses seafloor bathymetry to identify a range of topographic features, returned nine feature classes likely to be reefs. Collectively, these covered 9.3 % of the mapped area (corrected to remove some likely soft sediment bedforms in the deeper south-west of the survey region). Fault-lines were evident for several of the reefs.

In 2021, 14 of these reef features were sampled using a towed video camera system (NIWA's CoastCam), using the multibeam sonar maps to direct video transect placement. Those video transects were processed to provide detailed spatial estimates of reef geomorphologies, biogenic habitat covers, and invertebrate and fish species counts/abundances. A diverse landscape of reef and reef-associated species was found. Reef geologies included mudstone/papa rock and sandstone/limestone, with mudstone reefs having demonstrably lower biodiversity than sandstone reefs. Macroalgae dominated the habitat cover of most sandstone reefs, including narrow *Ecklonia radiata* (kelp) forests running for potentially kilometres along the reef ridgelines, and extensive meadows of the fleshy green algae *Caulerpa flexilis* covering step terrace reefs. Some of these *C. flexilis* meadows were closely associated with a low 'pillow ridge' reef form, aligned as long linear rows, and what appeared to be carbonate ridges (30 x 30 cm scale). These have not been seen elsewhere. Sponge-rich habitat clusters were present on the boundaries of some reefs, as patches in association with rock tells (limited rock just at or before sediment surface) and as a relatively large patchy sponge garden at the deepest site surveyed (30–33 metres). This deeper site also held high densities of juvenile blue cod, consistent with it providing important nursery habitat for this species. Several other smaller nursery habitat areas were discovered on the edges of some reefs.

In addition to macroalgae, 39 sponge species were identified as present across the reefs, as well as 30 fish species. Blue cod dominated the fish assemblage and were often abundant over habitat mosaics and at the reef/soft sediment boundaries. Other abundant fish species were scarlet wrasse, butterfly perch, leatherjacket, and tarakihi. Mobile invertebrates were uncommon, but kina were relatively abundant at two sites, where they formed urchin barrens. Valuable finer scale data and observations were available for one reef site through the local citizen science Project Reef team and were incorporated to provide additional insights into seafloor composition, blue cod dynamics (2016–2021), and local-scale fish occurrences over time using a novel in-situ camera.

These 14 Pātea Banks reef sites were compared to the wider subtidal reef information available for North and South Taranaki. North Taranaki reefs were found to differ in their composition, being volcanic boulder or bedrock based. The most northern Taranaki reef, Pariokariwa Reef, appeared to have a similar mudstone geology as some of the South Taranaki reefs, but was dominated by sponge garden assemblages not seen in South Taranaki. There appeared to be significant differences in the habitats and fish assemblages of North and South Taranaki, although these remain to be formally tested with suitable data.

This report demonstrates that subtidal reefs are in fact common on Pātea Bank, with many more awaiting discovery by multibeam sonar mapping. Associated with these reefs are extensive areas of biogenic habitat, dominated by macroalgae (notably *Ecklonia* forests, *Caulerpa* meadows, mixed macroalgal meadows, and soft bryozoan fields), as well as areas of sponge garden (areas of higher sponge cover more than 5 metres in width). The associated fish assemblages are abundant, dominated by blue cod, scarlet wrasse, butterfly perch, leatherjackets and tarakihi, with other fisheries species likely to be common (e.g., snapper, trevally, kingfish, and kahawai). The unusual distance of these reef systems from shore, occurring on a wide shallow continental shelf, makes them relatively unique in the New Zealand context, and may have protected them (in part) from land-based impacts seen elsewhere around New Zealand. They are worthy of careful management by the TRC, and other governance entities.

1 Introduction

The Taranaki Regional Council (TRC) has management responsibilities for the territorial sea area (out to 12 nautical miles; 22.22 kilometres) of the South Taranaki Bight, including Pātea Bank. This report provides a detailed quantitative narrative on recent 2020–2021 mapping and ecological survey work targeting subtidal rocky patch reefs on Pātea Bank. This new knowledge is put within the context of existing knowledge of other subtidal reef systems within TRC's management region (territorial sea). This new knowledge helps fill in major fundamental gaps around coastal habitats and associated ecological assemblages, which fall under TRCs management responsibilities.

1.1 General background

The South Taranaki Bight (STB) covers an extensive seafloor area (12,500 km^2) and is in part characterised by an extensive shallow continental shelf, extending to over 40 km offshore of the Taranaki coast. Its inner shoals cover around 1,700 km^2, including Pātea Bank and the area known as the "Rolling Rounds"; with a further 1,100 km^2 of shoals further offshore. At the national scale, it is unusual in holding extensive areas of relatively shallow water away from the coast proper, which has consequences for light climates at the seafloor. An estimated 612 km^2 (4.9 % of the STB) of its seafloor extent is estimated to receive sufficient light to support microalgae growth (Pinkerton 2014).

The coastline is well known to be erosion prone, with the main sources being sediment delivery to the coast from its catchments via rivers, and more directly, cliff falls of sediment as the cliffs retreat from sea-driven erosion. Suspended Sediment Concentrations (SSC) show a strong gradient from inshore to offshore. From the coastal edge to 10 km offshore, average SSC is 1.4 grams per cubic metre (m^3) of seawater (exceeds 3 g m^{-3} 27% of the time); this drops to 0.2–0.7 g m^{-3} at distances of 10 to 40 km from the coast (exceeds 3 g m^{-3} <5% of the time) (Pinkerton 2014).

The STB is influenced by upwellings of nutrient rich water occurring off Cape Farewell, with these water masses being transported north by currents to the STB region. Zooplankton densities have been measured as sometimes exceeding four times that of other New Zealand continental shelf regions, and 6.5 times more than for the North Taranaki Bight (DOC 2006).

Knowledge of the inshore STB's seafloor habitats and ecological assemblages is limited, due to its often rough sea climate, limited land access points, and relative remoteness from research agencies and institutions (DOC 2006). Fisheries research trawl surveys of the west coast of the North Island have avoided the general Pātea Banks area due to the presence of uncharted/unknown subtidal rocky reefs. Paradoxically, there has been a wider general perception that subtidal reefs are rare in the region, and combined with the remote access and weather issues, this region has been one of the least studied coastal regions of New Zealand. For example, the national scale shallow reef macroalgae and invertebrates survey by Shears et al. (2007) did not include any sites in South Taranaki, while the national scale assessment of reef fish distributions by Francis (2003) listed no reef-fish studies for this area. An exception to this was a short DOC-funded drop camera survey of the North and South Traps (two large reef complexes on the southern Pātea Bank) by ASR Ltd, which was later analysed in more detail by Bombosch (2008). Local retired commercial fishers were also interviewed in 2011/12 for their Local Ecological Knowledge (LEK) as part of an MPI-funded study, to help assess what biogenic habitats might be present in this region (and across 13 other regions around New Zealand) (Jones et al. 2016).

This data-poor situation was bought into sharp focus when a company (Trans-Tasman Resources (TTR Ltd.) applied for resource consent to mine large volumes of seafloor soft sediments for iron-sands. As part of this process, TTR Ltd. conducted a comprehensive suite of investigations into the STB environment, and modelling to predict the likely effects of the proposed mining operation. Included was extensive ecological sampling of the seafloor area around the proposed project area, focused on an area on/adjacent to the northern Pātea Bank area (Beaumont et al. 2015). That work sampled 145 sites in 2011, and fundamentally advanced our ecological knowledge of some of Pātea Bank's soft sediments areas. However, multibeam sonar seafloor mapping was not part of the ecological work, and sites were placed haphazardly. Just seven of the 145 sites were associated with rock/rocky reefs. A second smaller 2013 survey sampled a further 36 sites closer inshore and more broadly along the coast, of which five were rock-associated sites (independent of the 2011 sites) (Anderson et al. 2015).

Concern from the local community about the sand-mining proposal, and a desire to gain more knowledge on the reefs of the region, prompted the South Taranaki Underwater Club (STUC) to seek and gain funding for a marine project from the Ministry of Business, Innovation and Enterprise (MBIE)'s Curious Minds Fund in 2015 (one of the first funded by that fund). On the suggestion of one of the STUC members, a small reef observed by divers to support rich fish life and abundant reef cover was adopted as the project's focus, and unofficially came to be known as 'Project Reef'. The Project Reef citizen science group was created, with iwi partners (Ngā Rauru, Ngati Ruanui), and outreach initiatives to work with local high school students. The Taranaki Regional Council also provided support in the earlier years as the project's science partner. The Project Reef is around 3,000 m^2 in extent, and located 11 km offshore of Pātea, in 23 metres water depth. The Project Reef team has investigated the reef from 2016 to the present day; while the Taranaki Regional Council has listed the site in its 2021 interim Coastal Plan in Schedule 1 as having outstanding value, and in Schedule 2 as an area of Outstanding Natural Character (ONC)

The North Taranaki coast has received more focus on its subtidal reef systems, largely driven by the presence of the Sugarloaf Islands (Ngā Motu) complex and associated subtidal reefs immediately adjacent to New Plymouth. In December 1986, the Sugar Loaf Islands Marine Park was created using the Fisheries Act 1983, with the then Ministry of Agriculture and Fisheries (MAF) setting regulations to control recreational and commercial fishing within the Park. Protection was strengthened in 1991 with the passing of the Sugar Loaf Islands Marine Protected Area Act 1991, with the area's seabed, foreshore, waters, and islands being protected; and fisheries resources managed by the Ministry of Fisheries. Limited fishing was (and continues to be) allowed within the Sugar Loaf Islands Marine Protected Area (SLIMPA), except for the area around Waikaranga/Seal Rocks, which was totally protected (except for trolling for kingfish and kahawai). In 2008, the Tapuae Marine Reserve was established, encompassing 1,404 ha (14.04 km^2) of the Taranaki coast from the Tapuae Stream north of Ōakura, to Herekawe Stream, New Plymouth. It overlaps around one-third of the SLIMPA area, and protects all marine life, including pelagic fish.

Research work in the SLIMPA/Tapuae Marine Reserve area has included quantitative monitoring surveys of invertebrate, macroalgae, and fish assemblages from 2001–2003 (Millar et al. 2012, Miller et al. 2005, respectively); Baited Underwater Video (BUV) monitoring of fish assemblages (2011, 2013, 2015, DOC unpubl. data), side-scan sonar mapping in 2011 (DOC/UoW, undated), and multibeam sonar mapping in 2021 (DML 2021).

Slightly further north, the coastal Pariokariwa Reef and surrounding area was first broadly mapped in 1992 using a conventional echo-sounder at 1 km intervals along the shore (transects out to sea) to quantify seafloor bathymetry, with spot diving to validate seafloor types (Coffey & Williams 1992). In

1997, the reef was fully side-scan sonar mapped (DOC 1998). In 2006 the Parininihi Marine Reserve was created, covering 1800 ha (18 km^2), encompassing the Pariokariwa reef and extensive areas of adjacent silty sediment. In 2014, both Pariokariwa Reef, and the smaller separate Waikiekie Reef immediately to the north-east, were fully multibeam sonar mapped (Sturgess 2015).

The first ecological survey of Pariokariwa Reef was completed in 1995, with one day of diving survey focussed on its sponge assemblages (Battershill & Page 1996). In 2007, an invertebrate survey of these reefs (and the Sugarloaf Islands) was undertaken, but the sampling details, data, and draft report produced have not been able to be located (quoted as an 8-page draft report (Smith 2007) in Sturgess 2015). Also in 2007, attempts were made to survey the fish assemblages of Pariokariwa Reef and the adjacent smaller Waikiekie Reef (MetOceans Solutions 2007). Initially, a drop camera was deployed across both reefs, with sites selected by placing a grid over the 1997 side-scan map and retaining all those intercepts falling on reef as drop camera sites (117 and 20 sites respectively). These video observations were then used to select 30 fish count sites to be surveyed by divers. Only 10 of these sites were subsequently successfully surveyed (one day of diver fish counts), due to poor underwater visibility. The drop video data were never reported on, though the video files were later utilised by Sturgess (2015) to help direct sampling strategy. Sturgess (2015) collected limited additional drop camera video of Pariokariwa Reef, as well as new diver-collected data from the north-eastern side of the reef. DOC undertook Baited Underwater Video (BUV) monitoring of the reefs fish assemblages in 2011, 2013, and 2015 (DOC, unpubl. data).

1.2 New Pātea Banks survey knowledge and application

Outreach collaboration between NIWA's MBIE-funded 'Juvenile fish habitat bottlenecks' CO1X1618 research programme, and the Taranaki-based citizen science Project Reef group (see https://www.projectreefsouthtaranaki.org/, https://www.youtube.com/watch?v=QX_eAeyZgTE) led to two field sampling events in 2020 and 2021, to search for potential key juvenile blue cod habitats/nurseries on Pātea Bank. This field work targeted subtidal rocky reefs, using a combination of multibeam sonar mapping, high resolution towed video, and fish traps with attached Go-Pro cameras. Local ecological knowledge of fishers and divers was used to identify potential reef locations and drive the spatial design of the multibeam sonar survey in 2020. The subsequent seafloor maps were used to inform the placement of fourteen ground-truthing sites and associated ecological survey in 2021. Collectively, these methods revealed an extensive mosaic of individual reefs and associated rich ecological assemblages (fish, invertebrates, and macroalgae).

These rich ecological systems are of particular interest to TRC with respect to their management responsibilities for the coastal ecosystem in a region that has been poorly sampled. To help address this fundamental knowledge gap, an Envirolink project was secured by TRC to help complete analysis of video footage, integrate these and the other data components into a quantitative narrative on what exists on Pātea Bank's offshore subtidal rocky reefs; and compare these reef systems to others at the wider Taranaki scale. These new survey data (2020–21) are collectively presented and narrated through summary maps, plots, and tables. Formal statistical data analyses are beyond the scope of this report but future work is planned to undertake such analyses and progress their publication in the primary science literature. As these data and the methods that created them are reported here for the first time and not documented elsewhere, a detailed account is given of the field methodology, as well as the post-processing data extraction approaches used. Additional data created by the citizen science Project Reef group between 2016–2021 is also incorporated proving a valuable finer-scale detailed view of the Project Reef; set against the broader scale surrounding subtidal rocky reef systems.

2 Methods

2.1 Identification of potential subtidal reef sites

To maximise the number of patch reefs likely to be detected, a range of information sources were collated and spatially plotted. The Project Reef location was provided by the Project Reef team, and other South Taranaki Underwater Club members and local divers kindly provided in confidence several known/likely reef sites from their diving and fishing activities. Additionally, a GIS shapefile of small polygons likely to be rocky reef was available from the Department of Conservation (DOC). Working at the national scale, DOC had used old faring sheets to identify potential reef locations around New Zealand, in the 0 to 100 metres depth range. Abrupt shifts in bathymetry were used as a proxy for likely reef presence, and polygons created around these depth features. The positions of the seven rock-associated sites of Beaumont et al. (2015) were also included. Collectively, these geospatial data were plotted over the South Taranaki nautical chart, allowing the collective points/polygons likely to indicate reef/rock presence to be visually assessed against charted bathymetric features.

2.2 Multibeam sampling

The multibeam survey was conducted in August 2020, with approximately 30 hours of on-site vessel time (NIWA's RV Kaharoa, a 28 m research trawler) available for the multibeam survey. Using an anticipated 6 knot vessel speed, a network route was drawn across as many reef/rock targets as possible, while maximising the geographic (north/south) and depth (to 50 metres) spread of targets and allowing sufficient time to map out patch reefs when encountered. The route ran directly over sites represented as latitude/longitude points, and through the central mass of DOC putative reef polygons.

The effective swathe width of the multibeam sonar was 4x the water depth. When the vessel passed over a likely reef target (raised elevation, topographic features, backscatter change), it turned back and mapped the seafloor on either side of the transect to capture the full extent of the reef, where practical. Several interesting and unusual soft sediment bedform features encountered were also mapped in some of the deeper areas. Not all putative reef features encountered were able to be mapped, with the trade-off being completing the mapping route, versus mapping out as many reef targets as possible when detected.

2.3 Video imagery (NIWA's CoastCam)

In March 2021, NIWA's R.V. Ikatere (14 m) spent three days sampling a subset of the rocky reef locations revealed through the multibeam sonar mapping, working out of Whanganui each day. Using the multibeam sonar data (bathymetry and backscatter), twenty sites were selected for potential sampling. Site selection was based on achieving a good spatial spread from north to south, encompassing an on-shore/off-shore depth gradient, and encompassing a range of putative reef geo-morphologies, including long ridges, terraces, patches, and indeterminate mixes of rock and soft sediments. Each target site was assigned a unique letter as its identity, starting from A, and ordered from north to south. At each selected site, a single continuous towed video transect was carried out, passing over the different putative seafloor reef elements as shown in the multibeam sonar data. Turns within some transects were included to maximise capturing as much local reef variation as practical. Transect length (and associated survey times) varied from site to site depending on putative reef extent and complexity, with an average time target of 30 minutes; set as a pragmatic trade-off between the number of sites surveyed, versus collecting sufficient video footage within each site.

NIWA's 'CoastCam' towed video system was used for the sampling. This system has two high-resolution video cameras and one high-resolution still image camera. One of the videos faces forward at an angle to the seafloor (circa 35 degrees), and the second faces down to the seafloor. The stills camera also faces directly down to the seafloor and takes images at programmed intervals (here every 15 seconds). The stills cameras field of view is smaller than that of the video cameras. Lighting is used to illuminate the seafloor for both the video (continuous) and still cameras (flash). Two parallel scaling lasers (here 20 cm) were used as seafloor object/field of view distance measures. The CoastCam was flown at approximately 1.5 m altitude at a speed of approximately 0.6 knots. Altitude/height above the seabed was controlled using a remotely-controlled winch, with the winch operator using real-time video feeds to watch for changing water depth and water clarity/field-of-view, and to avoid seafloor obstacles.

The CoastCam system was designed to primarily quantify seafloor habitats, rather than fish. Fish must remain in front of the system as it approaches for the 35 degree camera to detect them and remain in the field of view as CoastCam passes over them for the downward facing cameras to detect them. Only the 35 degree camera footage was formally used for scoring both fish and the seafloor, so that as many fish were detected as possible with their associated seafloor habitat. More mobile fish species that may occur further off the seafloor (e.g., snapper, kahawai, kingfish) are known to be poorly detected with CoastCam, while more directly demersal species (e.g., blue cod, scarlet wrasse) are better quantified. To provide some background on whether larger mobile fish might be evading detection during this survey a forward-facing low-light camera was also attached to the CoastCam frame, without direct lighting or scaling lasers (as it was angled to the horizon). That footage has not been formally analysed but opportunistic viewing of some of the footage did not reveal additional fish individuals (aside from a specific instance at site V, which is discussed in that sites narrative).

The R.V. Ikatere's GPS was used to continuously record vessel position, and by extension, the location of the camera. It was not possible in this project to attach a tracking device on the actual camera system, to calculate the true camera position. Spatial error in the cameras plotted position includes GPS inherent error, distance from the GPS units' position on the vessel to the stern (6 metres) and the camera's cable layback from the vessel (which increases with water depth). Added caveats include the camera not always being directly behind the vessel, due to effects of currents, swells, and wind push on the camera/vessel; as well as during occasional vessel turns.

Days 1 and 2 completed pre-planned transect paths. On Day 3, sea conditions began to move towards being marginal for deploying the CoastCam. A three-metre and rising long swell restricted the safe directions in which CoastCam could be towed, with the tow direction having to run with the swell, to avoid putting excessive abrupt strains on the towing wire, winch drum, and camera unit. The planned gently zig-zagging transect paths to work along long reef ridges were not workable, as they sat at right-angles to the swell direction. Tows therefore were restricted to simple straight paths that ran with the swell and crossed these reef features across their narrowest extents.

It is important to remember that the three field survey days were exploratory and aimed to cover as much overall reef complexity and variation within the survey extent as possible, rather than investigate any individual reef in greater depth. The video transect placements were not random, in that they were placed to traverse as many habitat features as possible per transect; and there was no transect replication within any of the sites. The one exception was Site K (the 'Project Reef'), where it's small spatial extent (around 130 x 150 metres), and key focus for the Project Reef citizen science programme, attracted a placement of multiple parallel video transects nominally 10-metres apart, encompassing the full reef. The various seafloor %cover estimates presented in this report represent the transect footprint, rather than the full reefs. Nevertheless, they are likely to generally be a good first approximation of seafloor covers across the different reefs.

2.4 Baited fish traps

To provide additional data on the fish assemblages of the reefs, including species known to avoid towed cameras (e.g., snapper), a limited number of baited fish traps with attached Go-Pro cameras were deployed adjacent to a subset of the towed video sites. Umbrella traps, each with eight entrances, were baited with circa 300 grams of pilchards. Go-Pro cameras were mounted on a side pole extension, which positioned the camera one metre out from the trap, at 40 cm above the seafloor, and facing the trap. This provided a fixed field of view encompassing the trap (90 cm diameter) and a 90 cm strip to each side of the trap. Traps were left to fish for a minimum of one hour, before being retrieved. The caught fish were identified and measured down to the nearest mm fork/total length, and then released alive. The Go-Pro video was downloaded and stored on portable hard drives.

Originally the target was 4 replicates per trapping site (a subset of CoastCam transect sites), but time lost waiting for fuel in Whanganui Port reduced the time available to set traps (CoastCam transects being the key priority). More traps than expected were also lost to the reefs, along with their cameras and associated data (video/catch) for that set. That, and the subsequent camera pool reduction, further reduced the replication achieved.

2.5 Project Reef team methodology

2.5.1 Reef composition

The seafloor composition of the Project reef was assessed by SCUBA divers in 2017, 2018, and 2020 (Project Reef Citizen Science group). In 2017 (29 October–23 November), five 30-metre long transects were haphazardly deployed across the reef, starting from the survey vessel's anchor point due to safety reasons (the site is subject to often high currents and/or reduced underwater visibility). For each transect, a diver swam out a 30 metre measuring tape along a pre-determined random compass direction. A second diver, equipped with an underwater camera fixed to a 50x50 cm (0.25 m^2) sampling frame, followed along the tape, and took a seafloor photograph at one metre intervals. Collectively, this returned 30 images per transect, and 150 images overall.

In 2018 and 2020 the methodology changed to deploying a singled fixed transect, and the photograph sampling frame changed to 80 x 65 mm (0.52 m^2).

2.5.2 Blue cod population structure assessed by rod fishing

To assess blue cod population structure at the Project Reef over time, standardised rod and reel fishing was deployed from a small boat. The number of hours fished, and rods used, was recorded for each event. The fish catch was identified to species and measured for length (down to the nearest mm). All fish were returned alive to the sea.

2.5.3 Baited Underwater Video (BUV)

Three successful BUV deployments were made, using a downward facing camera over a baited burley pot set within a metal frame with scale bars (the same standardised system used by DOC). The BUV unit was deployed on the reef for 30 minutes, and then retrieved using the units attached surface float and dropline.

2.5.4 In-situ video camera monitoring

The Project Reef team developed an in-situ video camera system, able to be deployed for multiple weeks at a time. Equipped with lights for night operation, and a programable intervalometer, the camera was programmed to record 30 seconds of video, every 20 minutes. This system was deployed at a fixed location at the Project Reef, over eight discrete deployments between 2017 to 2020, with video footage recorded both during the day and at night.

2.6 Data processing

2.6.1 Multibeam sonar data

NIWA's standard approach to grooming and cleaning multi-beam sonar data sets were applied to the raw data to remove artefacts and errors (for instance, the removal of 'false' seafloor detections from features such as fish schools). This created final bathymetry and backscatter data-sets, with a 1-metre pixel resolution. The bathymetry data was then analysed using the Benthic Terrain Model (software), to cluster local-scale depth pixels into landscape-level bathymetric features such as ridges, slopes, depressions, and knolls. Such an approach is especially well suited to more rugged three-dimensional seafloors such as those of patch reefs; but is less informative for 'flat' bathymetries. Backscatter data were plotted as a visual backdrop in map plots to help with the assessment of the sampled reef sites. All the processed data outputs were loaded into ArcMap/ArcGIS Pro software for plotting and the production of maps.

The extent of each video-surveyed reef was estimated by manually drawing a polygon over the multi beam sonar bathymetry, tracking around the reef/s boundary. This was at the scale of the full reef, with a reef defined as a continuous elevated surface relative to the surrounding seafloor (as seen in the GIS ArcMap using sunlight illumination). Reef depth range was taken from the shallowest depth recorded in the multibeam sonar data (the top of the reef) to the lowest depth value associated with the reef boundary polygon (the reef-sediment boundary).

2.6.2 Towed video (CoastCam) processing

Geomorphologies

Biogenic habitat and geomorphology occurred as complicated spatial mosaics at different scales along the video. To address this, the video footage was divided into twenty second sequential intervals, and each treated as the base sampling unit. On average the video camera travelled 6.2 metres in distance in a twenty second period. Time was chosen as the unit of measure, as video time elapsed was able to be seen directly on the videos, was easy for the video analyst to keep track of and allowed each second that passed to be a good proxy for 5% of the video segment having been viewed. The alternative of using a fixed distance travelled as the base unit of measure was also considered (as a better statistical unit) but was found to be problematic for the video analysts (re, keeping track of when each individual segment started/stopped, and in calculating associated percent covers).

To estimate percent cover of the geomorphology classes, each 20 second video segment was viewed by the video analyst, and visually scored for the % cover of each class present. Class intervals of 5% were used, with rarer elements being classed in 1% bins up to 5%. This was considered to match the likely visual estimation accuracy achievable by the analyst. The combined percent cover was required to add to 100%. Each segment was viewed as many times as necessary to estimate the geomorphology covers present, with the estimates noted manually on paper. The start and end positions of each segment was determined using OFOP.

To generate a scoring scheme for reef and soft sediment geomorphologies, all video was initially viewed, and a broad classification scheme developed to categorise the features and bottom type's present. Broadly speaking, this was arranged in order of increasing 'object size', using the Wentworth particle approach for sediments, and rugosity and 'patchiness' for harder substrates. For example, soft sediment types ranged from sands through gravels to shells; while harder seafloor types ranged from cobbles, boulders, flat basement reef, gutters, and low reef, through to high relief reef. Rock type was divided into putatively mudstones (known regionally as Papa rock) and sandstones.

To help provide some potential future guidance (beyond this current report) on quantitively reducing the spatial offsets between the very spatially accurate multibeam seafloor maps and the less accurate towed video positions, when a significant vertical wall/terrace feature, or abrupt transition between reef and soft sediments was passed over squarely by the camera, a spatial position point record was made. These abrupt features are also well captured in the multibeam sonar seafloor maps, and a comparison between the two datasets (also including water depth as a proxy for camera cable length deployed) may allow for the camera's positional accuracy to be improved for future formal statistical analyses; through the application of new offset adjustments.

Biogenic habitat classes

The analysis of percent cover of biogenic habitat classes was handled in a similar fashion. Each habitat class was assigned a percent cover estimate, with class intervals of 1% up to 5%, 5% bins up to 10 % and then in intervals of 10%. These % cover classes were broader than those for geomorphology. Ten percent bins were thought to reflect the likely accuracy of visual cover estimates. There was no requirement for the biogenic classes to sum to 100%, as large extents and patches of seafloor did not have biogenic habitat cover. During analysis it was noted that small, new, *E. radiata* recruits (less than 10 cm in size, no stalk/stipe) could be reliably seen and counted, so a count of these per 20 interval was also included.

A range of habitat forming taxa were not amenable to being scored as individuals, including macroalgae and soft bryozoans, due to their close packed and often species mixed context, small size, variable resolution ability across and within the video footage, and tentative-only formal species identification by taxonomists. To allow for this, broader level classes were used, using general morphology and colour to create classes that could be consistently applied across the different situations encountered. These biogenic habitat classes were scored as percent cover. Bryozoans were recorded as either calcified (hard) or uncalcified (soft) species forms. Species able to be consistently scored as clearly monospecific covers (e.g., *E. radiata*, the two *Caulerpa* species) were identified to species.

To keep scoring classifications as consistent as possible with other New Zealand studies, the shallow-reef classification scheme of Shears et al (2004) was used as a base framework. Shears et al. validated a previously informal shallow rock reef habitat classification which was developed for north-eastern New Zealand but is broadly considered to hold for the North Island. Their summary table is reproduced here (Table 1). We note that this classification was developed for reef systems in shallower water (0 to 12 metres) than those encompassed in this Pātea Banks survey (12 to 38 metres; one shallow reef top to 9 metres). Several of Shears et al. (2004) habitat classes were not seen (e.g., *Carpophyllum*-dominated classes), along with new ones being encountered (e.g., soft bryozoan fields).

Table 1: Shears et al. (2004) shallow reef habitat classification [Note: "*Figures in the descriptions are indicative only. Habitats were determined by subjective assessment of dominant species*") (Source: table 1, Shears et al 2004).

Habitat	Typical depth range (m)	Description
Shallow Carpophyllum	<3	Dominated by high abundances (≥20 adult plants m^{-2}) of Carpophyllum maschalocarpum, Carpophyllum plumosum, and Carpophyllum angustifolium. Ecklonia radiata and the red algae Pterocladia lucida, Osmundaria colensoi, and Melanthalia abscissa also common. Sea urchin Evechinus chloroticus occurs at low numbers and generally occupies crevices.
Ecklonia forest	>5	Generally monospecific stands of mature Ecklonia form a complete canopy (≥4 adult plants m^{-2}), occasional C. flexuosum plants. Urchins at low numbers (<1 exposed urchins m^{-2}) and usually occupy crevices.
Carpophyllum flexuosum forest	3 to 12	C. flexuosum plants dominate (≥4 adult plants m^{-2}), on sheltered reefs plants are large and associated with high levels of sediment. On more exposed reefs plants are short and generally associated with Evechinus.
Mixed algae	2 to 10	Mixture of large brown algal species. No clear dominance of one particular species, usually only partial canopy (≥4 adult plants m^{-2}) and urchins may also occur at low numbers (<2 exposed urchins m^{-2}).
Red foliose algae	2 to 9	Substratum predominantly covered (>40 %) by red foliose algae such as P. lucida or O. colensoi. Low numbers of large brown algae (<4 adult plants m^{-2})
Turfing algae	3 to 12	Substratum predominantly covered by turfing algae (e.g., articulated corallines and other red turfing algae) (>30 % cover). Low numbers of large brown algae (<4 adult plants m^{-2}) and urchins may be common.
Caulerpa mats	2 to 12	Green algae, usually Caulerpa flexilis, form dense mats over the substratum (>40 %). Urchins and large brown algae rare.
Urchin barrens	3 to 9	Very low numbers of large brown algae present (2 exposed urchins m^{-2}), substratum typically devoid of macroalgae. Usually associated with grazing activity of Evechinus (>2 exposed urchins m^{-2}), which leaves the substratum relatively devoid of macroalgae. C. flexuosum and Sargassum sinclairii may occur
Cobbles		Reef comprises cobbles (c. <0.5 m diam.), unstable and subject to high levels of agitation from wave exposure. Crustose coralline algae are dominant along with a high cover of bare rock and sand. Large brown algae are generally absent
Encrusting invertebrates		Usually vertical walls, substratum predominantly covered by community of encrusting ascidians, sponges, hydroids, and bryozoans. Large brown algae rare.
Sponge flats	> 10	Sponges visually dominant, high cover of sediment. Usually occurs on the reef-sand interface. Low numbers of Ecklonia may be present (<4 adult plants m^{-2}).

The geomorphology and biogenic habitat class cover estimations were made by two independent video analysts respectively, as the two tasks could not be done simultaneously. This by default also prevented between-observer variability being present within each of the two groups estimations.

Individual species counts

The CoastCam's forward-facing camera was used for all video analysis. To create a master list of species present, the video files were initially viewed and multiple screen-grabs taken of all the different putative species present that could be reliably and consistently identified (broadly speaking, >4cm in size). Technical field issues with the still camera's focus and resolution limited use to largely just video being used for this process. Invertebrates including sponges, ascidians, sea-slugs (nudibranchs), hydroids, molluscs (bivalves, gastropods), echinoderms (urchins, starfish) and calcified bryozoans were identified to species where practical, while soft bryozoans were treated as a single Operational Taxonomic Unit (OTU) as distinguishing between species from video is problematic. Macroalgae included kelp species (e.g., *Ecklonia radiata*, *Carpophyllum maschalocarpum*) and a range of smaller species (e.g., *Caulerpa flexis*, *Caulerpa gemmata*, other green, red, and brown algae). Fish included all species seen (excluding triplefins). Selected invertebrate and macroalgae species imagery was distributed to a range of expert taxonomists, who identified these to species level where possible, or higher group levels if not. All species that were thought to be potentially identifiable from the video imagery were included in this process, including species already well known to the project team, to ensure a consistent approach. External expert opinion was sought for fish species that were well outside their normal national distribution (e.g., a porae), or relatively rare tropical stragglers (e.g., a red morwong). Triplefins were excluded due to their small size and highly variable detection rates using towed video. These identifications were used to generate a species scoring list for the video analysts to use, along with an informal visual species guide.

Each video file was loaded into the Ocean Seafloor Observation Protocol (OFOP) software, along with the matching GPS file recorded at the time of sampling. The GPS files were cleaned before input using a splining approach, which smooths out (removes) any spurious abrupt-short spatial deviations/jumps from the track-line that can occur when the GPS occasionally loses satellites and suffers spatial accuracy degradation. OFOP matches the timestamps of the video and the GPS files, to assign a spatial position to each observation scored by the video analyst. Using the pre-defined species master list loaded into OFOP, the video analysts scored each fish and invertebrate individual seen as a discrete point observation. Different video analysts scored the fish and invertebrates separately. This single scorer approach enabled each analyst to analyse all sites and thus removed inter-observer scoring variability (a form of processing error).

For invertebrates both individual and colonial species were present. An 'individual' was defined as either a single true individual (e.g., kina, sea-slugs, gastropods), or a colonial species that occurred as a discrete singular colony (e.g., finger and ball sponges, and hydroid trees) or as a discrete 'patch' that could be visually defined as a discrete object spatially distinct from other nearby patches (e.g., massive sponges such as *Ecionemia alata*, or patch formers such as *Crella incrustans* and Family Chondropsidae (*Psammoclema* sp. indet or *Chondrosia* sp. indet.) species 2. The video analyst used their best judgement to consistently score the number of patches/individuals present; colonies less than 5 cm in size were not scored.

Attraction of fish to the camera, and more specifically the lasers, was an issue for blue cod and to a lesser extent scarlet wrasse. A protocol was used to minimise the potential for overestimating fish abundance through fish being attracted into the field of view and following the lasers and being counted more than once in the video. Only fish entering the field of view from the upper half of the video field-of-view were counted; those appearing from the lower sides and the bottom of the field-of-view were ignored. Fish that were counted, and then continued to follow the lasers and remain in the field of view, were excluded from being re-counted. To provide more information on the size distributions of blue cod, individuals were assigned to length bins of <13 cm, 13–20, 21–30, and 30+ cm. The <13 cm length bin was further subdivided into juvenile blue cod still in their black and white coloration (recent recruits have a light white body and horizontal black stripes colouration), versus putatively older juveniles that had changed their coloration to 'brown phase'. The twelve cm break was selected after viewing several videos and looking for the length at which the 0+ and 1+ age juvenile blue cod cohorts were clearly separated in size (0+ refers to fish from 0 to 1 year in age, 1+ as fish from between 1 to 2 years old, and so on). Tarahiki and snapper were also assigned into the same length bins, but with a 10 cm rather than 12 cm length break.

At thirty second intervals a screen-grab was taken, and the fixed distance scaling lasers bottom intercepts used to estimate the field of view. Issues of being unable to discern the lasers in some of the footage became apparent, with 393 estimates successfully made. The average estimated width of view was 225 cm, and this average was used across all the video transects. Further improvements for future formal data analysis (beyond this report) are possible through estimating missing values using interpolation calculations from those successfully estimated and applying these within and between transects.

Towed video data integration

To combine the four data streams (fish, invertebrates, geomorphology, and habitat classes), the 20 second video intervals were treated as the basic sampling unit (hence referred to as a segment). Code written in Python and R was used to take the OFOP geomorphology text files and extract the start and end spatial coordinates of each sequential 20-second segment, and within each of these, manipulate and re-order the geomorphology classes and associated percent cover estimates to create a flat table matrix (text) file. In this file, each 20 second interval was recorded as a single data line, with geomorphology classes as variable types along the top of the table, and percent cover estimates as data in the actual table. The biogenic habitat classes and associated percent cover estimates were added to this flat table, using time stamp matching to add these data to their respective unique video segments.

The fish and invertebrate records, scored in OFOP as individual point records, were assigned to the respective 20-second video segments that they fell within, again using time-stamp matching to assign them correctly. These were added to the master flat table as summed counts per species/identity per video segment.

The spatial start and end positions of each segment were used to calculate the distance covered by each video segment. The mid-point of each segment was used to plot bubble maps for selected species. The final master flat table consisted of 1,886 20-second segments (some of lesser time, if at the end of a given video run), with each segment being represented as a single data line with all its associated spatial information.

Each 20-second video segment was assigned a unique sequential number (range 0–1,874) and those numbers used as a spatial position index for the percent cover and species counts plots and maps. Where used in an individual site section to highlight areas of particular interest along the video transects, they are given as an index range prefaced by the symbol #; to avoid clutter, the associated figure is not referenced.

Each site section also presents a range of seafloor images, with each image assigned a unique sequential number within that site section (e.g., Site A has 18 seafloor images, numbered 1 to 18). Within a given site's section, these are referred to without an associated figure number, to avoid clutter.

2.6.3 Fish traps with Go-pro cameras

Each Go-Pro video associated with a fish trap was viewed and scored for the maximum number of individuals able to be seen in one frame shot, for each of the fish species present. This metric, known as Nmax, is an estimate of the maximum density of fish present (by species), and avoids issues of double-counting individuals. Fish suitably aligned to the camera (e.g., not head/tail on/at a sharp oblique angle) were also estimated for length, using known distances between elements of the fish trap as a scale measure. It should be noted that the use of a single camera returns length estimates subject to greater measurement error than systems that use dual stereo cameras.

2.6.4 Project Reef team sample post-processing

Reef composition

The photo-quadrat images were loaded into the open license software PhotoQuad, and each image analysed for percentage cover, using 100 random point intercepts placed across the image. Each point intercept was assigned to one of the following seafloor classes

- Encrusting plants and animals – identified to phyla/taxa group
- Reef conglomerate – including bare rock and cobble mixes
- Biogenic habitat – mixed species cover of small algae, sponge, ascidians, bryozoans, and other encrusting organisms that could not be resolved to individual species at the level of resolution available
- Turfing algae – mixture of small species
- Shell hash – broken and intact dead shell cover
- Sand – excluding very light dustings on the reef surface
- Unknown – unidentifiable point intercepts, largely because of poor image quality and/or varying depth of field.
- Frame artefact – in the 2020 survey, a small part of the camera frame fell within the image field, obscuring the seafloor

Several individual images that were of too poor quality were excluded from analysis. All of the successfully processed images were treated as quadrats sampled along a transect, and the average of the quadrats along the transect presented as the base sampling unit. Error estimates were not calculated, as two of the three surveys contained only a single sampling unit (one transect).

Blue cod population structure assessed by rod fishing

Blue cod caught by line fishing, over measured time periods, were standardised to a Catch Per Unit Effort (CPUE) metric, expressed as fish caught per rod per hour fished. As each event was a single fishing trip, there was no replication, and error estimates were not able to be calculated.

Baited Underwater Video (BUV)

As with the Go-Pro trap cameras, each 30 minute video recorded was viewed, and Nmax for blue cod estimated. As one BUV deployment was made in each of the years sampled (two in 2020), there was no replication, and error estimates were not able to be calculated. Fish were not measured for lengths.

In-situ video camera monitoring

Formal counts/time present estimates of fish species from the in-situ camera deployments have not been made, but Project Team members viewed many of the 20-second video segments, and recorded narratives of what was seen.

3 Results

3.1 Multibeam sonar mapping

Around 30 hours of multibeam sonar mapping was achieved, over a route track of more than 250 km, and with an overall seafloor coverage of 61.5 km^2 (Figure 3-1) Numerous areas of rocky reef were encountered, and a number of these mapped out to a larger extent to each side of the initial transect. Large soft sediment bedforms were also observed in several areas, ranging from sand/gravel waves, through to large raised bedform features, which remain to be ground-truthed. All the locations identified through local fishing/diving knowledge held reefs. Many additional reef (complex local bathymetry) locations were identified, both adjacent to/around the local knowledge sites, and more broadly across the survey extent. The putative DOC rocky reef polygons were less often found to hold reefs, except for the South Trap, and the long raised NE/SW ridge features of the most south-eastern area.

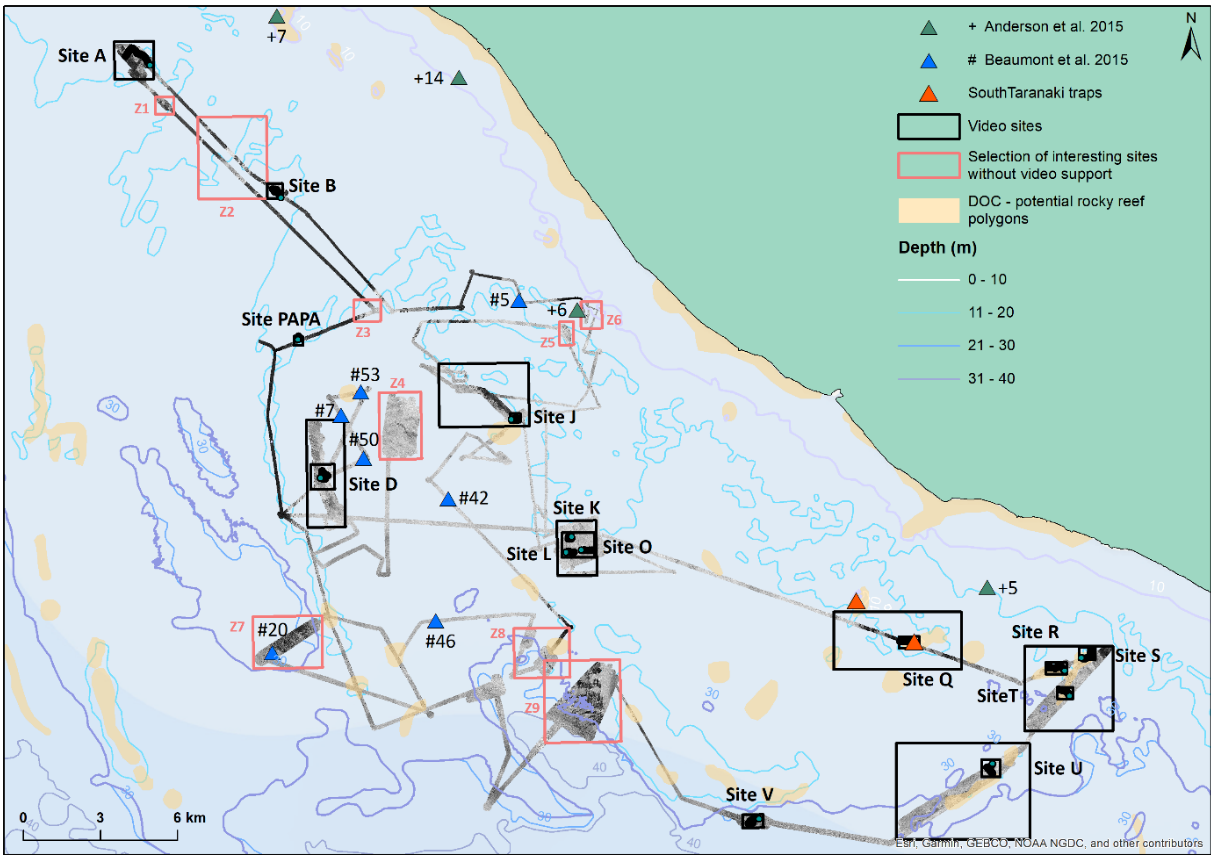


Figure 3-1: The multibeam sonar route (backscatter displayed) and the 14 site locations successfully sampled, and ground-truthed, using the towed camera system (CoastCam) are shown.

Target sites that were not able to be visited due to time constraints in the field are not shown. The black boxes show the sites sampled by video; where the reef sites fell within a larger reef complex, two scales are marked – one at finer scale focused on the video transect, and one at larger scale to illustrate the wider reef system. The pink boxes (Z series) indicate other particularly interesting sites, some reef focussed and some soft sediment, that were not able to be sampled with the CoastCam due to logistic constraints (see Appendix B for close-up images of backscatter and bathymetry). Many additional rock/reef features were also mapped but not marked up here. DOCs putative reef polygons are shown in yellow. Ten-metre depth contours are shown. Local knowledge sites are not shown to respect the information generously shared with us. To help protect the exact spatial coordinates of sites, latitude and longitude markers are not provided, the coastline is displayed at relatively low resolution, and geographic names are not included. Rock/reef sites encountered by Beaumont et al. (2015) and Anderson et al. (2015) are also shown.

Application of the Benthic Terrain Model (BTM) to the bathymetry data characterised the seafloor landscape into 14 feature classes (Figure 3-2), with flat plains being the dominant 'base background' within which the other 13 classes occurred. Of these 13 classes, eight were indicative of reefs for this region

- Steep slopes
- Scarp/cliff
- Rock outcrop highs, narrow ridges
- Local ridges/boulders/ pinnacles on slopes
- Local ridges/boulders/pinnacles on broad flats
- Local ridges/boulders/pinnacles in depressions
- Flat ridge tops

For finer spatial representation, multibeam data was split into six blocks for the calculations of percent putative reef (Table 2, Figure 3-2). These six spatial blocks are shown in greater resolution in Appendix A.

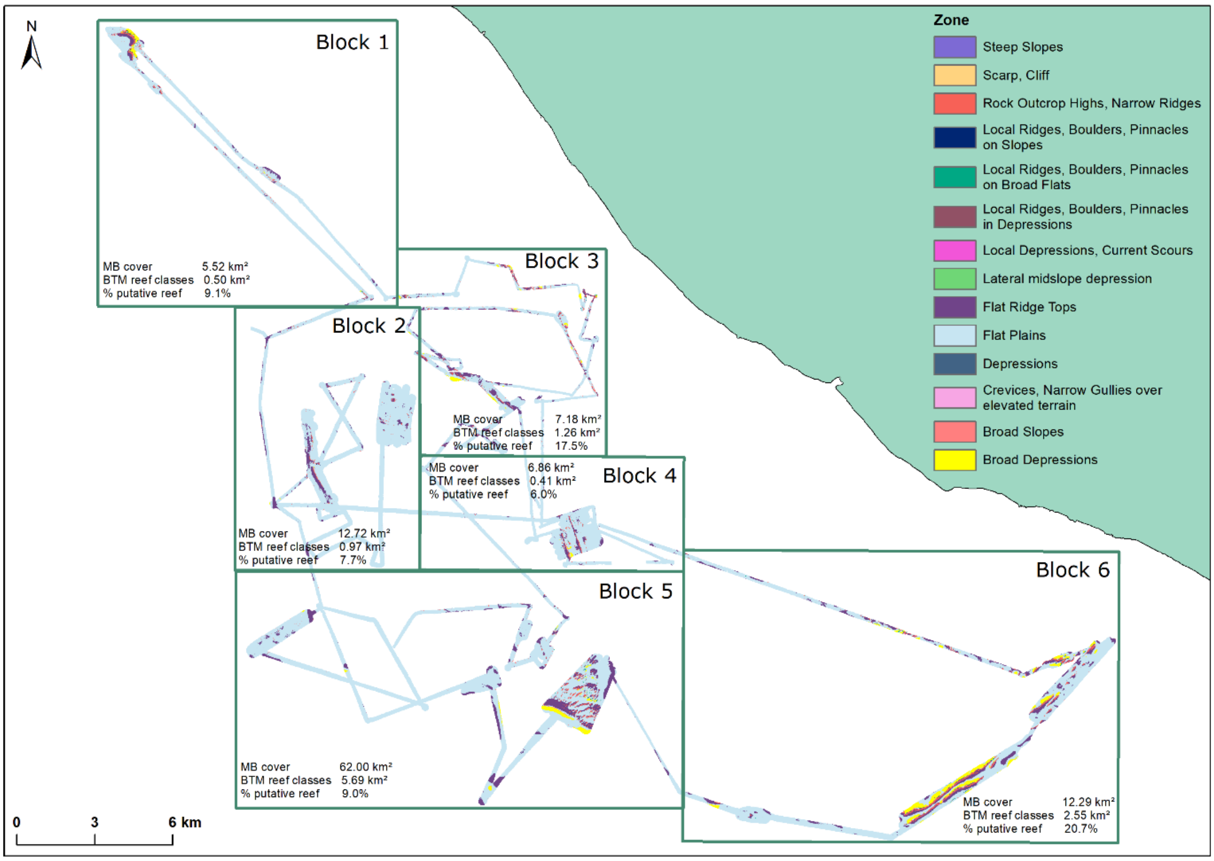


Figure 3-2: BTM classification of the multibeam bathymetric data, and conservative estimates of reef extent. Most of the possible reef categories shown in Block 5 are more likely to be large scale soft sediment features, although it is possible that reef components are present and contributing to the formation and presence of the soft sediment bedforms. Larger scale maps are given in Appendix A.

Table 2: Areal extent of seafloor mapped by multibeam sonar by sub-area; probable rock/reef extents and % contributions.

	Area mapped (m²)		
Block	All	Reef-associated classes	% likely reef
1	5,521,336	500,572	9.1%
2	12,719,137	973,833	7.7%
3	7,179,593	1,259,662	17.5%
4	6,859,173	411,216	6.0%
5	16,961,169	2,600,423	15.3%
6	12,285,293	2,547,834	20.7%
Total	61,525,701	8,293,539	13.5%
	Corrected for Block 5	5,693,116	9.3%

Across the six blocks, the seafloor extent mapped with multibeam sonar ranged from 5.52 to 16.96 km^2, with the percent reef estimates ranging from 6.0 to 20.7% (0.41 to 2.0 km^2), and an overall percent reef estimate of 13.5% (Table 2). A caveat to this estimate is that the raised bathymetry features of Block 5 were highly likely to be soft sediment bedform features (based on their repeated patterns, and orientations to each other), rather than reef; though some reef elements may also have been present in these structures (e.g., site #20, Figure , identified as 'low relief outcrop partially buried' by Beaumont et al. 2015) . No ground-truth video data was collected from Block 5. The backscatter data, while showing the Block 5 complex raised features to be highly reflective (often a characteristic of reefs), was not informative here. Visual examination of the backscatter data across the overall survey region showed that reefs were not consistently distinct from non-reef soft sediment habitats in their backscatter signal strength, with rock and coarse sand often having the same backscatter response. In some sub-areas, the coarse sand returns had a stronger acoustic return than rock seafloor.

Excluding the Block 5 percent reef estimate as being largely (but not completely) attributable to seafloor bedforms other than reefs, reduced the combined six block percent reef estimate to 9.3% of the surveyed area. This estimate is likely to be conservative, as the BTM classes were driven by bathymetric variations; flat rock/reef extents on a wider flat seafloor background were effectively 'invisible' to detection by BTM. There is evidence of this for some CoastCam sites, where flat rock-based seafloors as seen on the video transects did not always map onto BTM classes indicative of reefs.

The topographies of the reefs encountered are covered in more detail in later sections. Briefly, the presence of long narrow rock ridges, some extending for kilometres, was notable in Blocks 2, 3, 4, and 6 (Figure 3-2). Smaller scattered patch reefs and knolls were dominant in Block 1, along with the larger raised reef complex in the north (Four-Mile Reef). Numerous patch reefs were also present in the shallower north-eastern quadrant of Block 3, though these may have in part been components of larger ridge systems. This is hinted at by the linear orientations of these patch reefs, their boundaries extending outside of the narrow multibeam sonar transects (due to the shallow water depths), and the presence of such large ridge features in the south-west quadrat of the same block.

3.2 Towed camera data

Thirteen out of 20 potential target sites were successfully sampled using the CoastCam, covering as much of the multibeam sonar bathymetric and backscatter variation present as practical. One additional site was also added in the field, targeting a soft mudstone 'terrace' site discovered by local divers in 2021 (after the multibeam sonar survey). That site was assigned the name identifier 'Papa', in recognition of the soft mudstone nature of the reef. The site fell just north of part of the multibeam mapping route transect (Figure 3-1).

The video survey results section of this report is split into two parts. In the first section, the classes generated for the biogenic habitats and geomorphology are presented across the 14 sites sampled collectively, along with the fish and invertebrate data. In the second section, each site is looked at individually. Later in this report, these data and the new knowledge gained from them are set within the context of other previous work on Taranaki reefs

3.2.1 Geomorphology

The initial visual assessment of the fourteen transects revealed a series of complex seafloor geo-morphologies, often with many changes over short spatial differences, and the presence of habitat mosaics. Repeated viewing of the video transects resulted in a set of consistent visual geomorphology classes being created, that could be reliably used by the video analyst to estimate the percent cover contributions of those classes present in any given 20-second video segment.

Table 3 provides a summary of the geomorphology classes developed and used; Figure a selection of visual examples of the different rock-based geomorphology classes, and Table 4 the percent contributions of these and soft sediment classes at the site (video transect) scale.

Table 3: Rock-based geomorphology class descriptions (created for this project).

Rock habitat class	Description
Bare grey river stones	Round smooth light grey stones, that appear to be of a harder rock type, are not colonised by epifauna/flora, and are usually present in drifts and piles. They are strikingly similar in appearance to stones seen in some large, braided rivers; and may have had an origin as river-eroded stones.
Mixed irregular cobbles	Irregularly shaped cobbles, often flat and rectangular, of various sizes, often occurring embedded in a mix with soft sediments
Tell	Flat rock, or the slight bumps on otherwise flat rock, that is almost entirely covered with a soft sediment veneer, and just barely emerges as very small, exposed elements (< $1m^2$), or is shown to be present by the attachment of small clumps of hard-substrate sponge species, although the actual rock cannot be visually seen. The actual rock surface may be quite extensive, but most of it is covered by soft sediment veneer, making it unviable for attachment/use by reef-dwelling species. Sand/soft sediment movements may bury/expose these tells over time, as evidenced by varying covers of epifauna/flora, and situations where sessile fauna such as sponges are seen partially buried.
Bare raw rock	Recently exposed 'new' mudstone/papa rock surface, that is flush with or slightly depressed, relative to surrounding soft sediments. Likely to have been exposed by sediment scouring, and often seen adjacent to the base of reefs. Its newly exposed status is suggested by flat, smooth, and unblemished surfaces, devoid of animal burrows and other biological marks. Often also fractured as thin cracked slabs (cm's thick) in part, probably from wave/swell action.
Boulder	Discrete rocks, that may sit as discrete objects on rock surfaces, or be sitting in soft sediments. When in soft sediments, they are visually distinguished from patch reefs by having a clear rounded/square-edged appearance, and/or not possessing under-hangs or ledge-type elements.
Flat basement	Flat rock with little topographic variation at the local scale. This does not mean that the rock surfaces are necessarily flush with the surrounding seafloor. For instance, the stepped flat terraces seen at some sites were scored as flat basement, along with the short walls/scarps. Each terrace was at different depth than its neighbours, but all were higher than the surrounding seafloor. They are also not necessarily flat in the sense of being horizontal; sloping uniform rock surfaces were also included in this class. A visual quirk of using the CoastCam over bathymetrically varying seafloor was that the camera was constantly being adjusted using the remote-controlled winch to maintain a relatively constant height above the seafloor. These fine-scale continuous adjustments often removed the visual signals (in post-processing) that the seafloor was not horizontal, but rather sloping. This effect was 'invisible' to the video analyst working on the video imagery back in the office; where some rock surface appearing to be horizontal but were sloping. Combining video data with fine-scale multibeam derived variables such as slope and rugosity , addresses this issue in formal statistical analyses.
Low patch reef	Low relief small discrete raised patches of rock, surrounded by soft sediment. Generally, less than 5 metres in width, as seen along the video transect
Low broken rock	Low broken rock, that extends over distances of more than 5 metres, often as long expanses of reef. Included in this class are situations where low-relief rock outcrops are present within irregular cobble fields.

Rock habitat class	Description
High broken rock	Like low broken rock, but higher in height at the local scale of view (generally around 1 to 2 metres variation), with high local visual topographic variability including walls, channels, knobs, and outcrops at the multiple metres scale
Pillow ridges	Low 20–30 cm semi-parallel rows of 'pillowed' rock, alternating with shallow troughs at the sub-metre scale, that form local 'fields'. Always associated with *C. flexilis* cover.
Fallen slabs (mudstone only)	Large mudstone rock slabs, immediately adjacent to scarp faces, that appear to be produced by eroding and retreating scarp faces. Only found at site Papa
Rock fingers/gutters	Alternating narrow rock fingers and gutters, all aligned in the same compass direction. Only found at Site Q (South Trap). Some other sites held localised 'lattice' reef forms that might be a similar erosion process of the same rock type, but those small areas were hard to determine boundaries for and were included in the high broken rock class.

Across the survey region, twelve rock-based geological classes were visually identifiable in the soft sediment seafloor areas (Table 3, Table 4, Figure 3-3). Arranged in increasing average particle size order, they included light and dark coloured sands (the latter probably due to higher iron content), fine gravels, shell dominated sediments ranging from loose shell though to shell armoured bottom and drifts of dead whole dog cockle shells (deepest site V only). These soft sediment classes collectively surrounded the reefs, and often were present at the start and end of the transects (transects started and ended on soft sediment where practical), so that the reef-soft sediment boundaries were included in the video imagery. Soft sediment patches were also often interspersed amongst and between reef outcrops and ridges. The dark (iron) sands were geographically constrained to the northern half of the survey region (sites Papa to J, limited cover at K), while lighter coloured sands were more broadly distributed (sites Papa, K, Q, and U). Gravels were largely limited to the southern sites (sites T, U, V). Shell based soft sediments (excluding dog cockles) occurred in varying proportions across most sites (J being an exception), with small whole shells being a major contributor at sites D, K and L. Within some sites, transitions occurred between some of the soft sediment classes, ranging from relatively abrupt boundaries through to diffuse change gradients.

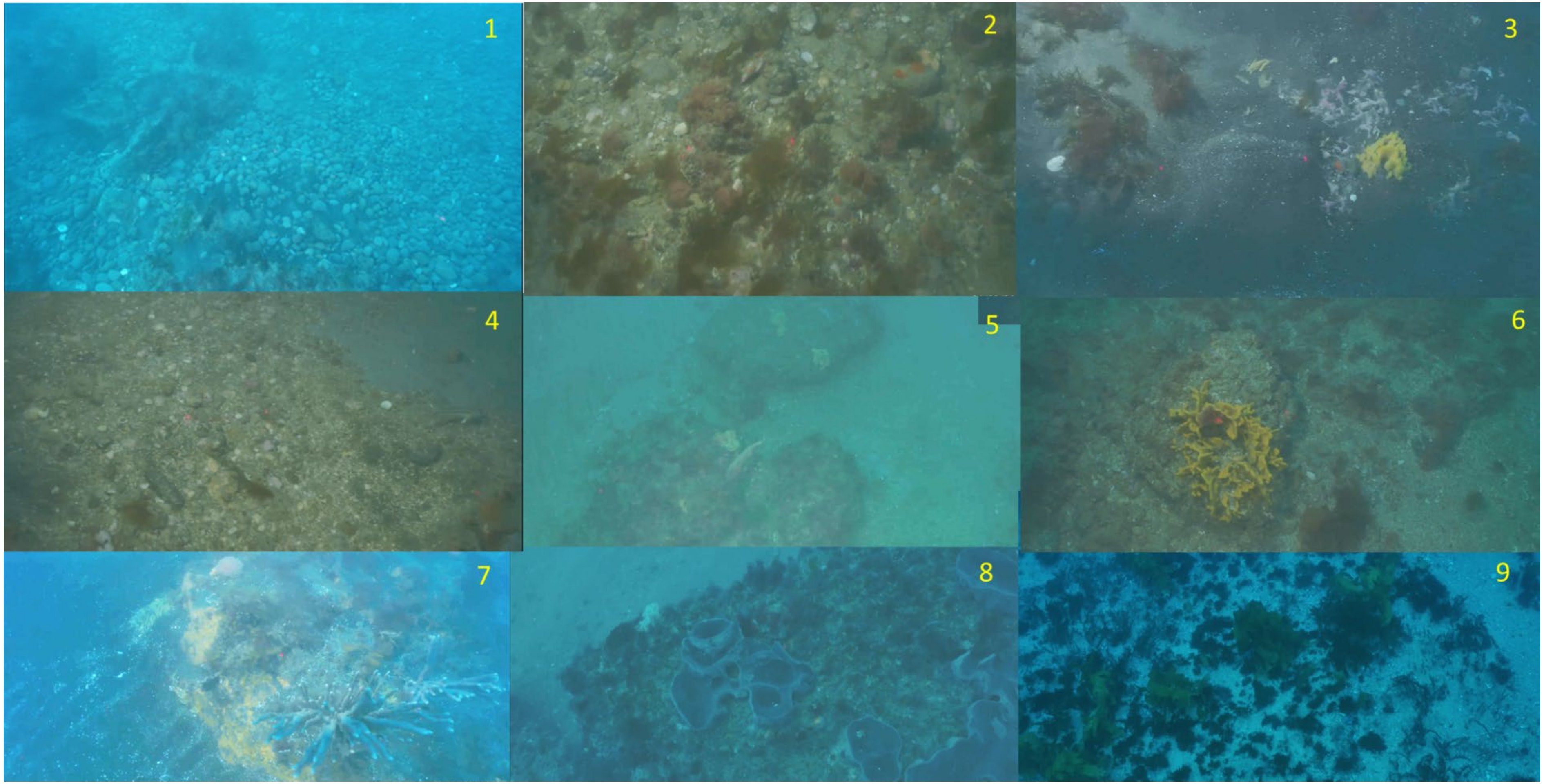


Figure 3-3: Geomorphology class examples 1) smooth grey stones; 2) irregular cobbles; 3) rock tells; 4) bare raw rock; 5) boulders on soft sediment; 6) boulder on flat basement; 7) low patch reef, 8) high patch reef (high slab); 9) flat basement.

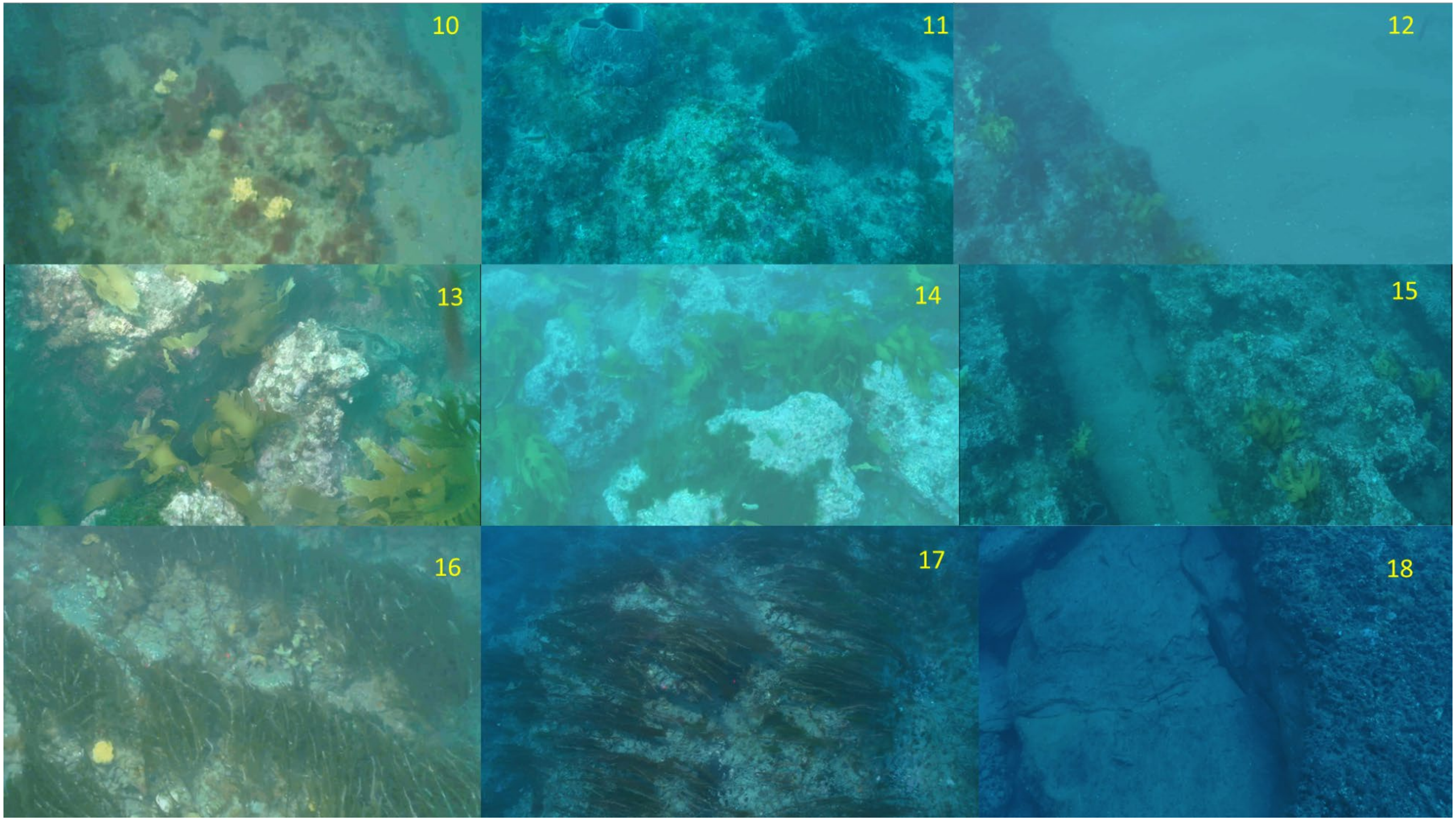


Figure 3-3: continued. Geomorphology class examples 10–11) low broken rock; 12–14) high broken rock (showing lattice form); 15) rock finger and gutter complex; 16–17) pillow ridge reef, 18) fallen slabs (site Papa only, mudstone/papa rock).

Table 4: Geomorphology classes and % contributions at the video transect/site. While not differentiated within the table, sites Papa and D were composed of a different rock type (mudstone, known as Papa) than the other sites, which were composed of harder sandstones/limestones (and site V appeared to be breccia rock). Their associated values are underlined, and their site name marked with a *, to draw attention to this difference. Each video segment within a given transect is given equal weight; individual segments have not been standardised to true area (distance covered, multiplied by the field of view).

	Site													
	A	B	Papa*	D*	J	K	L	O	Q	R	S	T	U	V
Soft sediment habitats														
Sand			31.7			6.6		<1	2.7				12.6	
Dark sand (iron)	23.2	21.1	48.5	37.0	53.4	4.2	-	-	-	-	-	-	-	-
Gravel	-	0.8	-	-	-	<1	-	-	<1	0.9	-	81.2	11.5	59.7
Shell/broken shell mix	2.9	1.8	-	14.6	0.3	9.4	3.6	0.9	-	-	-	-	-	-
Poorly sorted shell/sand	-	-	2.7	1.0	-	4.3	-	3.7	-	6.6	3.2	-	25.8	2.1
Small whole shell	<1	1.8	-	21.2	-	26.8	22.9	6.3	-	-	-	-	-	-
Coarse shell armour	-	-	<1	-	-	-	-	-	-	-	-	-	-	2.9
Large gravel/stones and shells	-	1.3	-	<1	-	4.4	<1	<1	4.7	3.1	<1	-	-	5.9
Dog cockles scattered	-	-	-	-	-	-	-	0.6	-	-	-	-	-	2.0
Dog cockle shell drift	-	-	-	-	-	-	-	-	-	-	-	-	-	7.4

Table 4: Continued.

														Site
Rock/reef habitats	A	B	Papa*	D*	J	K	L	O	Q	R	S	T	U	V
Rock habitats														
Bare grey river stones	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Mixed irregular cobbles	7.5	16.8	-	<1	36.8	35.8	64.4	84.9	-	<1	33.7	-	-	-
Tell	<1	0.9	*0.6*	1.1	1.5	0.8	0.9	-	2.1	0.6	<1	1.1	3.3	3.5
Bare raw rock	<1	-	*<1*	-	-	-	<1	<1	-	<1	2.3	-	-	-
Boulder	0.1	1.7	*1.3*	<1	<1	<1	-	-	-	1.9	1.4	<1	-	0.6
Low patch reef	0.7	0.9	*1.6*	0.6	2.0	3.0	0.8	1.2	3.3	5.7	9.7	2.9	16.1	3.9
Flat basement	7.8	47.3	*7.1*	18.6	1.2	0.6	-	-	2.3	8.2	11.1	13.8	-	11.3
Low broken rock	23.9	4.4	*1.8*	-	4.6	3.5	7.1	1.7	12.2	35.0	10.3	1.0	-	0.6
High broken rock	13.6	1.3	*< 1*	-	-	-	-	-	16.6	8.7	-	-	-	-
Rock fingers/gutters	-	-	-	-	-	-	-	-	55.7	-	-	-	-	-
Pillow ridge reef	16.5	-	-	-	-	-	-	-	-	28.5	27.0	-	-	-
Fallen slabs (mudstone only)	-	-	-	5.6	-	-	-	-	-	-	-	-	-	-
Video track distance (m)	1,683	852	323	1,078	313	1,258	348	470	653	823	669	483	640	757
Area sampled (m^2)	3,787	1,917	726	2,426	705	2,831	784	1,057	1,469	1,852	1,505	1,087	1,441	1,703

At several sites, small-scale ripples, and wave bedforms were associated with some of the soft-sediment seafloor types (and can be seen in various figures in this report); these were not quantified. Sand/shell wave bedforms were also quite noticeable in the multibeam sonar bathymetry at some areas, scales ranging from metres to tens of metres.

Harder seafloor substrates (rock-based) were present at all fourteen sites sampled. These included stones, cobbles, boulders, rock buried under fine veneers of soft sediment, low rock basement, and raised complex rock topographies. Table 3 provides a description of the rock-based geomorphology classes used to classify observed seabed features. Based on visual observation, at least two underlying rock types were present. A light brown mudstone (papa), which appeared very erosion-prone and 'crumbly' and often pitted with small holes/burrows, formed reefs at two neighbouring sites. Mudstone was dominant at the Papa site, present as broken rock piles and low terraces. At site D it formed a low terrace drop, structured as a sharp vertical scarp/s of 1–3 metres, that ran for several km in length. These scarp faces were often directly adjacent to large rock slabs, that could be a result of the scarp face eroding and retreating over time. It is possible that wave and current actions erode the base of the scarp at a differential rate, and as the base ceases to be able to support the rock weight/mass above it, the scarp calves off akin to glacier wall collapses, and ends up as large slab blocks at the scarp base. This topography was only seen at site Papa. It is possible that site Papa is an older reef site than D and shows the final stages of eroded mudstone scarps, with low boulder piles, and very low terraces.

The second rock type was classed as sandstone and was much more widespread throughout the survey. Without direct physical collection it was not possible to definitively identify all rock types observed, so for simplicity we refer to all reefs in this report (except the mudstone at Papa and D) as being sandstone. Sandstone was light coloured but appeared more 'robust' than the mudstone of sites Papa and D, was not burrowed, and formed both low and high-relief reefs. Some of the rocks seen may have been limestone. Additionally, site V appeared to be a rock type prone to forming large flat or slightly raised slabs, with bumps on the rock, suggesting some form of breccia (coarse rock fragments held together by cement or a fine-grained matrix).

Sandstone reefs occurred throughout the survey region in various topographic configurations. Two notable examples of variability in the reef topographies formed from this sandstone were extensive low 'pillow' reef fields; and alternating narrow rock finger and gutter complexes. The pillow reef feature was present at sites A, R, and S, and consisted of low 20–30 cm high parallel rows of 'pillowed' rock, alternating with shallow troughs, at the sub-metre scale. This topographic feature was always closely associated with dense and extensive green macroalgae (*Caulerpa flexis*) meadows, which grew on the rock pillows (but not in the shallow troughs). Small bryozoans and sponges were also co-associated. The nature of these fauna/flora associations and the appearance of the rock suggest a potential biological basis for these rows, through perhaps some form of carbonate production.

The narrow rock finger and gutter complexes consisted of alternating narrow rock fingers and gutters, all aligned in the same compass direction, with multiple alternations. This complex was clearly visible in the multibeam bathymetry, with the gutters/fingers being 1 to 2 metres deep/tall, with vertical walls, and relatively flat finger tops and gutter bottoms. This very visual topography was largely restricted to site Q (South Trap) where it contributed 56% cover. However, other reefs also hinted at the same rock type and process in parts, with short distance 'lattice' forms seen (Figure , images 13–14) on some reef tops. As they only occurred over short distances and had indeterminate boundaries, these were included in the high broken rock class.

At some sites, it was evident that soft sediment movement had uncovered small extents (cm – metres scale) of 'new' rock recently exposed to the water column (smooth, flat, unblemished). This rock was largely papa mudstone and seen just adjacent to the bottom edge of some reef sites, as small patches flush with or slightly depressed in depth, relative to the surrounding soft sediment. The rock was dark grey in colour and flat, and visually identical to that seen terrestrially in the Whanganui region when papa rock is found recently exposed and water saturated (Morrison, pers. obs.). A number of these patches showed recent erosion impacts, with the presence of thin fractured/cracked slabs (cm's thick) in situ, probably created by wave/swell action.

Irregularly shaped cobbles, of mixed sizes and densities, were a common seafloor element at seven sites, ranging from 7.5 to 84.9% cover. These could be the result of erosion of sandstone bedrock, with wave and storm action moving them to more sheltered areas where they accumulate.

Site A held a unique rock cobble class, in the form of smooth rounded light grey stones. These appeared visually very similar to the stones seen in braided river systems and were labelled as 'smooth bare grey stones' to distinguish them in this report. Largely devoid of attached fauna/flora, they occurred as small piles and accumulations within local mosaic landscapes of low rock and soft sediments. It is suggested that these stones are mobile and move around during rough sea conditions

3.2.2 Biogenic habitats

Initial assessment of the video imagery revealed a range of biogenic habitat forming species, which occurred at sufficient densities to form biogenic habitat covers. The biogenic classes used, modified from Shears et al. 2004 (see Table 1), are given in Table 5. Urchin (kina) barrens were present at sites Q and U but to keep geomorphology (innate objects) and the species counts / densities / biogenic habitats (living organisms) data series separate, these were not included within the biogenic habitat categories. Examples of the classes "*Ecklonia* forest", "red foliose algae", "turfing algae", "*Caulerpa* mats", "*encrusting invertebrates*", and "*sponge flats*" are given in Figure . New habitat classes not included in Shears et al. (2006) included soft bryozoan patches and fields, and green 'lawn' algae (Table 5, Figure 3-4).

Table 5: Biogenic habitat classes used and their descriptions Modified from Shears et al. 2004 (table 1) to better represent observed biogenic habitats.

Biogenic habitat class	Description
Wiry green filamentous algae	Green algae with a 'wiry' morphology appearance, Species unknown
Filamentous green algae	'Green' algae that is filamentous, but not visually 'wiry'. However, algal taxonomists think these are brown algae (despite their colouration).
Yellow-red blade algae	An algae with broad ribbon like blades, with a low number of individual blades. Usually associated with the reef/soft sediment boundary.
Green (brown) shrubby algae	A low dense shrubby algae that appears dark green in colouration but is probably a brown algae. Probably *Zonaria,* along with other brown algae such as *Cladostephus hirsutus, Microzonia*, and *Dictyota* species
Green 'lawn' algae	A very fine filamentous algae, that formed low flat mats, often in a form that strongly resembles Astro-turf lawn
Filamentous red algae	Red algae that is filamentous, very likely to include a range of different species

Biogenic habitat class	Description
Spikey red algae	Red algae that is 'spikey' in appearance, and sometimes seen in close association with sponges. Likely to include several species
Red foliose algae	Red algae that is foliose/feathery in appearance, and almost certainly includes several different species. Includes *Plocamium*.
Carpophyllum maschalocarpum	Solitary individuals, or two to three plants immediately adjacent to each other. Patch and forest scale aggregations (see *Ecklonia*) absent. Uncommon
Caulerpa geminata	Small patches of this matt forming algae, never a dominant biogenic habitat cover. Some limited patches may be misidentified *Halopteris* (a brown algae known as Sea Flax Weed)
Caulerpa flexilis	Large patches and continuous meadows, often the dominant biogenic habitat species when present
Ecklonia single plants	Single plants at low densities, that are spatially discrete from each other.
Ecklonia patches	Aggregated patches of multiple plants that form small discrete aggregations, but do not form semi-continuous/continuous cover across the video segment (and cannot occupy more than 50% of the video segment)
Ecklonia forest	Semi-continuous/continuous plant cover, across some/all the video segments. A defining feature is that some of the video frames must be fully occupied by plants, for a distance of at least 3 to 5 metres. Kelp forests in the context of these reefs appears to often occur as very narrow forests, 5 to 10 metres wide, on the top of reef ridges, which may extend for kilometres as a very narrow band.
Soft bryozoans	All soft (uncalcified) bryozoan species
Small anemones	*Anthothoe albocincta*, patches only (individuals not part of patches ignored)
Sponge, ascidian, other cover	The summed cover of sessile fauna, except for bryozoans.
Calcified bryozoans	Bryozoan species that have calcified frames, contributing species included *Diaperoecia purpurascens*, *Celleporina grandis*, and *Celleporaria agglutinans*

Multiple macro-algal species were present as sparse-to-dense patches and meadows, both as single and mixed species assemblages. Seven morphology/colour groups were created (Table 5) that lumped species into groups that could be reliably and consistently visually identified in the video footage, over the varying resolution conditions present across the videos. Two species was kept as a putatively single species classes: 'green lawn algae', as it was distinctive, and at times formed a significant cover; and 'yellow-red blade algae', which was present largely on rock surfaces at reef/soft sediment boundaries (a preferred juvenile blue cod zone) and was quite distinctive.

Shears et al. (2004)'s '*Caulerpa* mats' class was split into two separate single species classes; *Caulerpa geminata*, and *Caulerpa flexilis*. Their "*Carpophyllum flexuosum forest*" class was not seen in the survey, but solitary and two-to-three plant groupings were present. A class *Carpophyllum flexuosum* was created to keep this important habitat forming species visible in the data sets as a specific identity. "*Ecklonia radiata* forest" was present, and used as a class, although it was defined using percent cover and local spatial extent, rather than Shears et al.'s "*complete canopy (≥4 adult* *plants m^{-2})*" (Table 1 definition). Additional new classes of '*Ecklonia* single plants' and '*Ecklonia* patches' were created (Table 5), as *E. radiata* was often present at the reef sites in spatial configurations that were not forests (Figure 3-4).

Biogenic habitat forming faunal groups that occurred in sufficient densities to form biogenic habitats were combined into four classes. A soft bryozoan's class was created, inclusive of all soft bryozoan species (Family Catenicellidae), with several species likely to be present (D. Gordon, bryozoan taxonomist, pers. obs.). Calcified frame-building bryozoans were also present, and scored as a collective species class, although they were quite uncommon and did not reach densities/extents that provided significant seafloor cover. The small anemone *Anthothoe albocincta* occurred as both solitary individuals and as occasional visually obvious patches, depending on site. Too numerous to individually count, this species was enumerated as a biogenic habitat class cover when it was present as visually obvious clusters (solitary scattered individuals were ignored). All other sessile invertebrate biogenic habitat forming species (including hydroids) were collectively assessed together as the class 'Sponge, ascidian, other cover', equivalent to combining Shears et al.'s "*Encrusting invertebrates*" and "*Sponge flats*" classes. They were classed in this way to keep the geomorphology and biogenic habitat classes as separate entities.

Figure 3-4: Biogenic habitat class examples: 1) filamentous green (brown) algae; 2) dark shrubby algae; 3) yellow-red blade algae; 4) green 'lawn' algae; 5–6) filamentous red algae (image 5 is from the CoastCam still camera); 7) spikey red algae; 8–9) red foliose algae. See Table 5 for habitat descriptions.

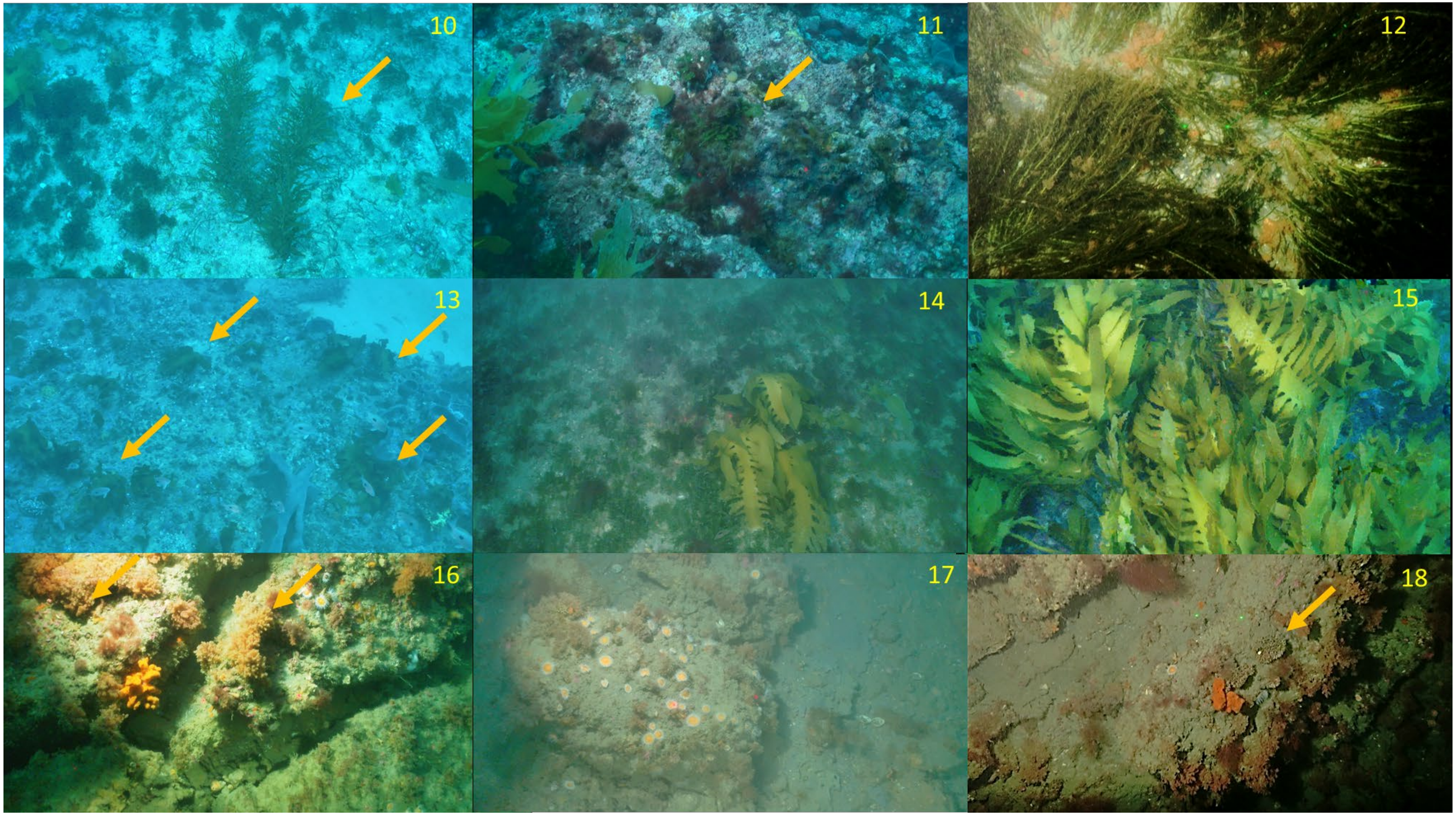


Figure 3-4: continued. Biogenic habitat class examples: 10) *Carpophyllum maschalocarpum*; 11) *Caulerpa geminata*; 12) *Caulerpa flexilis*; 13) *Ecklonia* single plants; 14) *Ecklonia* patch; 15) *Ecklonia* forest; 16) soft bryozoans; 17) Small anemone patch (*Anthothoe albocincta*); 18) calcified bryozoans. See Table 5 for habitat descriptions.

Table 6: Percent cover of each biogenic habitat class at each site. Reef containing sites only (see Table 5). Area of reef present (m^2) estimated as the summed area of all video segments containing one or more rock-based geomorphology classes. Percent cover estimates are of the whole video segment/transect including soft-sediment areas

Biogenic Habitat Class	Site													
	A	B	Papa	D	J	K	L	O	Q	R	S	T	U	V
Wiry green filamentous algae	-	-	-	-	-	0.54	-	11.38	-	-	-	-	0.01	-
Filamentous green algae	1.60	0.03	-	-	2.92	0.65	0.29	0.05	0.36	0.33	0.49	0.10	0.21	-
Green (brown) shrubby algae	0.07	-	-	0.02	2.58	1.24	2.96	-	0.07	0.25	0.07	0.20	5.87	0.01
Yellow blade algae	0.00	-	-	-	0.20	-	-	-	-	0.00	0.01	-	-	-
Green 'lawn' algae	-	-	-	-	0.02	-	-	-	9.02	0.51	0.16	0.92	0.01	-
Filamentous red algae	2.88	34.07	0.01	-	0.05	1.26	3.19	0.17	0.38	0.59	0.29	0.25	0.18	1.10
Spikey red algae	-	-	-	-	-	-	-	-	-	-	0.02	-	-	0.02
Red foliose algae	0.98	-	-	-	-	-	-	-	0.11	1.16	-	1.68	-	-
Caulerpa gemmata	0.18	0.01	-	-	0.11	0.18	0.70	0.36	0.85	0.23	0.19	1.35	0.01	-
Caulerpa flexilis	15.83	0.03	-	-	-	-	-	-	0.51	13.50	7.31	0.46	2.30	-
Ecklonia radiata all	1.44	0.01			0.02	4.96	4.21	1.43	10.03	10.73	0.95	0.72	11.11	1.00
Ecklonia (single plants)	*0.30*	-	-	-	*0.02*	*1.85*	*1.06*	*0.26*	*1.81*	*0.54*	*0.07*	*0.43*	*0.60*	*1.00*
Ecklonia patches	*0.54*	*0.01*	-	-	-	*2.37*	*1.60*	*0.15*	*1.30*	*0.74*	*0.81*	*0.29*	*2.93*	-
Ecklonia forest	*0.60*	-	-	-	-	*0.74*	*1.54*	*1.02*	*6.92*	*9.45*	*0.07*	-	*7.58*	-
Sponge, ascidian, other cover	0.41	2.94	0.01	2.20	0.79	2.55	3.81	4.56	0.66	0.59	0.42	0.49	0.52	5.57
Small anemones	0.01	0.02	-	-	0.01	-	-	0.02	0.03	-	0.05	0.04	-	-
Soft bryozoans	0.01	0.04	-	-	-	-	0.04	0.01	0.04	0.61	1.22	0.45	0.02	-
Calcified bryozoans	-	-	-	-	-	-	-	-	0.01	-	-	-	-	0.17
% Biogenic habitat	23.40	37.15	0.02	2.23	6.70	11.37	15.20	17.98	22.07	28.50	11.38	6.66	20.39	7.87
Reef area (m^2)	3,486	1,715	296	1,241	453	1,993	689	955	1,452	1,813	1,478	443	1,379	943

Soft sediments contributed an average 39% (range 8–83%) of the area of seafloor surveyed (Table 4). To focus specifically on rock-based habitats, all purely soft sediment video segments were excluded from calculations presented in Table 6, while all video segments that held one or more of the nine rock-based geomorphology classes were included. This retained virtually all observations of biogenic habitat except for some dog cockle shell drifts at site V (with occasional small sponges), and a coarse sediment flat at Site U supporting low density macroalgae cover. This filtering approach retained all video segments that were a mixture/mosaic of rock and soft-sediment classes, including those with rock tells and patch reefs that often had high biogenic habitat covers. Estimates of reef area (m^2) were calculated using the distance travelled for each video segment (measured using the start and end coordinates of each segment), multiplied by the average camera width of view (2.23 m); and summed at the transect scale.

Overall biogenic habitats covered 0.02 to 28.50% of video transects (Table 6). The two lowest values were for the mudstone sites Papa (0.02%) and D (2.23%). This low biogenic cover may be a consequence of the highly erodible nature of the rock and the low height profiles observed (except for the 3–4 m high scarp present at Site D) making much of the rock habitat susceptible to being covered/uncovered with soft sediments. Site Papa was largely bare, aside from the presence of occasional filamentous algae, some rock-boring sponges, and ascidians. Site D supported a low percent cover of sponges and ascidians, largely concentrated on the top of the scarp; on the narrow flat rock pavement present before the scarp drop, to where soft sediment started to overlay the rock surface. Of note, the mudstone/papa reef surfaces were often highly pocked and burrowed, suggesting that a substantial infaunal burrowing animal assemblage was present.

The highest biogenic cover (37.15%) was seen at Site B, where meadows of filamentous algae (34.07%) were associated with extensive irregular cobble fields. Sponges made a smaller contribution (2.94%), associated with small low rock outcrops (<0.5 m height, metres width) and several larger rock knolls (3–4 m height, 10s of metres in width).

Macroalgal biogenic habitats dominated the sandstone reefs of the survey region (all sites except Papa and D). Small macroalgal species (browns, reds, and greens) occurred as both discrete patches and as larger meadows, with different species mixtures and dominances. Average percent cover across the 11 sandstone reef sites (excluding site B) was 5.12% (range 1.13–11.60%). While these were scored as nine classes (both single species and group based), many species were likely to be contributing. In some instances where the towed camera dropped very close to/onto the seafloor, the very close camera lighting and higher image resolution revealed a range of macroalgae colourations and fine morphologies suggesting a multi-species mix – although the enhanced details were still largely insufficient to make definitive species identifications. Of note, the 'green lawn algae' class was a dominant biogenic habitat cover (9.02%) at site Q (South Trap)

Caulerpa flexilis, a fleshy green algae with a growth form of horizontal stolons with upward facing foliose shoots, was common at sites A (15.83%), R (13.50%), and S (7.31%) where it formed extensive mono-specific meadows. It was often closely associated with the pillow reef geomorphology class, with co-associations of low density small sponges and bryozoans, and coralline algae plates (counted as individuals, see following sections). It was also common on flat rock terraces, with a co-association of occasional very large solitary *Ecionemia alata* sponges within the meadows. On more broken raised reefs, *C. flexilis* occurred as patches, often mosaiced with *E. radiata* kelp patches, as well as smaller patches of a second *Caulerpa* species, *Caulerpa gemmata*. *C. gemmata* was present at all the sandstone reefs except for the deeper reef at site V. At the transect scale it contributed only a small percent cover (0.4%) but formed localised patches on some reefs that made a much higher contribution in small areas.

Ecklonia radiata was the only common large brown kelp, and occurred on all the reefs surveyed, with the exceptions of sites Papa and D where only a few unattached drift plants were observed. The occurrence of kelp ranged from occasional single plants, through small plant clusters/patches, to continuous kelp forest (though 90–100% canopy cover was only observed twice). Overall cover (all classes summed) at the site level ranged from 0.1% at site B (concentrated on a single high rock knoll) and 0.2% at site J (concentrated on a low very limited extent rocky outcrop); to 10–11% on the higher relief complex reefs of Q, R, S, and U. At these three latter sites, *Ecklonia* forest contributed most of the cover (7–9%), rather than patches and individual plants. These forests were generally associated with raised reef features, including the extensive finger and gutter reef areas of site Q (South Trap) and narrow reef ridges (S, R, U). The limited *Ecklonia* forest extents found at sites A, L, and O (1.43–4.43%) were also closely associated with reef ridge tops (with the video transects passing across these ridges). These narrow ridge features extended for kilometres at some camera-surveyed sites; with ridges also a dominant feature of many unsurveyed reef sites (as mapped by multibeam sonar). It is highly likely that long, very narrow *Ecklonia* forests extend right along these ridges, with some being more than 4 km long. *Ecklonia* forest was absent from sites J and V.

Ecklonia patches were more widespread and were often found associated with small topographic reef variations, such as small ledges/terrace edges, and raised outcrops (metres scale). They contributed an average 1.1.% cover (range 0.01–2.37%) across the sandstone reefs (absent at sites J and V). The *Ecklonia* single plant class was present at all the sandstone reef sites except for site B, with an average contribution of 0.79% (range 0.02–1.85%).

All the *E. radiata* seen appeared to be in very good condition, with unblemished and 'vibrant' canopies, with no browsing damage evident, and uniform plant sizes with little variation at local spatial scales. Plants were estimated to be at most 50 cm high (on average shorter), with short stipes. No elongated stipe morphologies, as sometimes seen on deeper reefs in other regions such as the Hauraki Gulf where light levels are thought to be limited, were seen (at the deepest site V, single *Ecklonia* plants covered 1% of the reef, at depths of around 31–32 metres). Local knowledge observations are that *Ecklonia* cover comes and goes on the reef systems, related to the frequency and intensity of larger storm events. This would explain the size uniformity and very healthy condition of the *Ecklonia* seen, assuming that these populations are composed almost entirely of younger individuals, representing only one or two large recruitment events. Small *Ecklonia* recruits (<10 cm height, single blade, no thalli visible) were common across several of the sites and were seen in greatest densities adjacent to adult plant patches/forest (see following section)

Large brown kelp algae (aside from *Ecklonia radiata*) were rare, and only present at one site in sufficient cover to constitute biogenic habitat. At site U, *Carpophyllum maschalocarpum* adult plants were present as scattered individuals and occasional groups of 2–3 plants, on coarse sand and shell flats adjacent to the main reef (these video segments had no rock present and did not contribute to Table 6). Scattered single plants, and occasionally 2–3 plant patches were also seen on the reef structure, where they contributed 0.14% cover (not included in Table 6).

Biogenic habitats created by invertebrates were far less common than macroalgal ones. The combined biogenic habitat class of sponges, ascidians, hydroids and other epifauna occurred across all the sites, though virtually absent (0.01%) from the Papa site. Cover was higher at mudstone site D (2.20%), with the main contribution coming from several sponge and ascidian species that formed low covers on the rock and appeared to be rock-boring. Across the sandstone sites, percent cover ranged from 0.41 to 5.57%. Sponges (numerous species) were by far the dominant contributors, and in some localised areas of the video transects, were dense and species-diverse enough to be regarded as sponge gardens (sites O, V). These sponge gardens were found on the edge of the reef proper and were associated with localised extents of low exposed rock (Site O), or rock tells and small patch reefs partially covered by soft sediments (Site V). This association was also evident at sites where rock tells/small rock patches, adjacent to the reef proper, were present as occasional small, low density scattered features (e.g., at sites A, Q)

The faunal biogenic habitat classes of 'soft bryozoans' and 'small anemones' often occurred together, along with red filamentous algae, in the deeper sub-areas of the sandstone reefs, on rock substates that appeared more sedimented, and in areas with higher turbidity (and lower light). These biogenic habitats had low percent cover; soft bryozoans averaged 0.15% (range 0.1–0.64%), and anemones 0.02% (range 0.01–0.04%). Soft bryozoans were absent as a biogenic habitat class from sites J, K, and V; and small anemones were absent as a biogenic habitat from sites K and V.

The biogenic habitat class 'calcified bryozoans' was largely absent from the surveyed reefs, with only occasional small individuals observed (which did not qualify as biogenic habitat cover given their tiny footprint). For example, calcified bryozoans had an average percent cover of 0.01% and 0.17% at sites Q and V respectively. They are retained here as a biogenic habitat class as a contrast to further offshore on Pātea Bank in deeper water depths (50–70 m), extensive calcified bryozoan fields are common, co-occurring with dog cockle beds/shell drifts (Beaumont et al. 2015).

3.2.3 Invertebrate abundance

In total, 62 taxa were able to be consistently and reliably identified in the video footage, encompassing 39 sponge, 3 ascidian, 1 hydroid (*Solanderia* sp. 'trees'), 2 calcified bryozoans, 3 gastropods (Cook's Turbans, saw shells, and a general gastropod class), 1 urchin (kina), 3 starfish, 1 crayfish (red rock lobster), 1 large scale-worm, 1 ophiuroid, and 3 anemone taxa (Table 7, Figure 3-5). One algal taxa was also included, that of small discrete pink-and-white coloured coralline plates. The sponge taxa morphologies included finger, mound, cup, ball ridge, and low spreading forms; with a size range extending from small cm-scale golf-ball sponges (4 species), through to large, massive colonies of the grey sponge *Ecionemia alata* (metres in diameter) (Figure 3-5). Of the 11,221 sponges counted, one species contributed 5,258 individuals (47% of all sponge counted). This species is yet to be formally described but has a current working name of "Family Chondropsidae (*Psammoclema* sp. indet or *Chondrosia* sp. indet.) species 2" (hence referred to as "Family Chondropsidae species 2") based on previous specimens collected by the Project Reef team, and passed on to M. Kelly, NIWA sponge taxonomist. It has a low spreading form, with low narrow ridges that hold lines of oscules (filtering hole structures used by the sponge for feeding and excretion). The dominant colour is various shades of grey, although yellow ones were also observed, and treated as likely colour morphs. *Crella incrustans*, which occurred in yellow/orange broken ridges form, was the next most common sponge species (1,216 records, 11%), followed by the grey cone sponge *Stelletta conulosa* (890 records, 8%). A further 16 species were present as 100 or more individuals (3,572 total records, 32%), and 20 species with less than 45 individuals (285 records, 3%).

Sponges occurred at all 14 sites but had the lowest abundance and species diversity at the soft mudstone Papa site (Table 7). Site D, also formed of mudstone, also had low species richness relative to the sandstone sites. The other 12 sites supported a higher diversity of sponge species, and in some subareas formed small sponge garden habitats (see biogenic habitats section above). Coralline algal plates occurred at 11 sites but with highest abundances at sites R and S, where they were often found in association with *Caulerpa flexilis* meadows. Ascidians were largely represented by a small bright orange solitary species (identity not confirmed), which occurred sporadically within the reef habitats present, often in the lee of small topographic rock variations (cm to metres scale). Hydroid trees (*Solanderia* sp.) were observed at 11 sites, as solitary colonies, and occasional small clusters. This was the only hydroid species large enough to be reliably seen and counted on the video footage but many other smaller species were likely present. Calcified bryozoans, of sufficient size to be reliably seen on video, were uncommon and limited to larger colony-forming species (*Galeopsis porcellanicus*, *Adeonellopsis macewindui, Cinctipora elegans*). Other species seen occasionally when the camera was particularly close to the seafloor included *Diaperoecia purpurascens*, *Celleporina grandis*, and *Celleporaria agglutinans*). *C*. *agglutinans* is an important biogenic reef former in some parts of New Zealand, where it grows as large, very heavy colonies composed of 'chimneys and plates', and has been shown to support very highly abundant and diverse invertebrate communities (e.g., Rangitoto Islands, east D'Urville Island, Morrison et al., unpubl. data), as well as supporting juvenile fish nurseries. However, on Pātea reefs it was only present as occasional, small, solitary colonies.

Eleven species of mobile invertebrates were recorded, as well as a general gastropod class that included larger gastropods unable to be identified to species due to image resolution/eroded shell forms (including probably some Cooks Turban/saw shell individuals). Kina (*Evechinus chloroticus*) was the only urchin species recorded, with 1111 individuals counted across 7 sites. This was a conservative count, as many would have been 'invisible' to the camera, e.g., when passing over the rock finger and gutter complexes of site Q (South Trap), where the gutter walls closest to the camera were not observed. The highest abundances of kina were recorded at site Q (890 inds.), followed by site U (149 inds.). Densities varied from occasional individuals to more than 5 per square metre, well above the minimum urchin density threshold of 2 exposed urchins m^{-2} on open rock used to define 'urchin barrens' (Shears et al. 2004).

Two large gastropod species were commonly observed and counted. High abundances of Cooks Turban (*Cookia sulcata*), a large herbivorous gastropod, were recorded at sites Q and R, where they were concentrated on the higher, more rugose reef areas. The saw-shell (*Astrea heliotropium*) was less common and occurred in low numbers across a wider range of reef geomorphologies. The large sea-slug/nudibranch, *Aphelodoris luctuosa,* occurred at low densities across most of the reef sites, with a strong co-association with the dominant grey ridge sponge Family Chondropsidae species 2, on which it feeds. It was also recorded where this sponge species was absent. Three species of starfish were observed and counted. Herbivorous cushion stars (Family Asterinidae) were rare and restricted to sites S and T, where a few individuals were seen on the coarser soft sediments adjacent to the reefs. Two predatory starfish species were observed, the reef star *Stichaster australis*, and the 11-armed starfish *Coscinasterias muricata*. These two species were hard to separate in video footage, and so were grouped. *S. australis* was restricted to rock habitats, while *C. muricata* was present over both rock and soft sediments. *S. australis* was most common at site Q., while *C. muricata* had a wider distribution across sites (M. Morrison, pers. obs.). Three rock lobsters were seen, sheltering under structure on the top of outcrops that were observable by the towed camera; the majority of day-time rock lobster habitat (under overhangs/ledges, in crevices) was not amenable to sampling with towed cameras. A single large-bodied scale-worm (perhaps *Euphione squamosa*) and a single snake star (*Ophiopsammus maculata*) were recorded.

Figure 3-5: Taxa examples, 14 most common sponge species, starfish, and hydroid tree. Note that images vary in scale: 1–4) Family Chondropsidae species 2 (grey and yellow colour morphs); 5–6) *Crella incrustans* (orange and yellow colour morphs); 7) *Stelletta conulosa*, 8) *Aaptos globosa* (right) and Unid. Sp., order Haplosclerida/Poecilosclerida (left); 9) *Raspailia topsenti* (left), *Tethya bergquistae* (right).

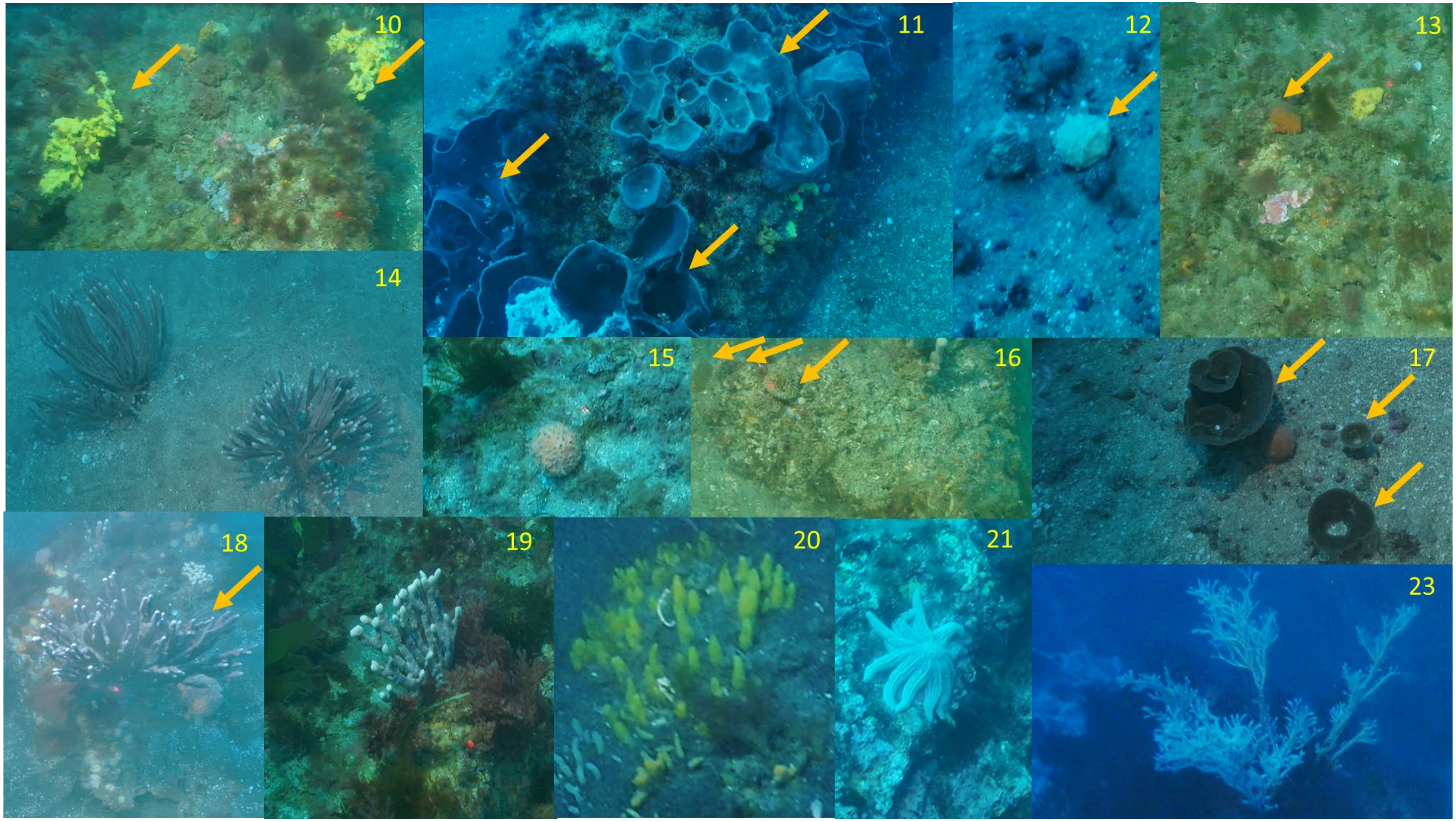


Figure 3-5a: continued. 10) *Darwinella oxeata*; 11) *Ecionemia alata* (grey colour variations); 12–13) *Tedania* sp. indet. (white and yellow colour morphs); 14) *Callyspongia ramosa* (*Callyspongia nuda*); 15) *Tethya bergquistae*; 16) *Cinctipora elegans* (calcified bryozoans); 17) *Cymbastela lamellata*; 18–19) *Dactylia varia*; 20) *Ciocalypta polymastia*; 21) *Stichaster australis* (starfish); 23) *Solanderia* sp. (hydroid tree).

Table 7: Summary of taxa identities and number of individuals recorded from CoastCam video footage at each site. Area of reef present estimated as the summed area of all video segments containing one or more rock-based geomorphology classes. Includes soft sediment where present in those video segments with rock elements. *, species sampled/photographed by Project Reef divers at site K (Project Reef), and identified by M. Kelly, sponge taxonomist, NIWA; but not seen in the CoastCam survey of site K. Additional species confirmed from the Project Reef are *Leucettusa lancifera*, *Stelletta columna*, and *Chalinulan* sp. (powder soft feathery bush)(Porifera, Haplosclerida, Chalinidae). Species occasionally seen by CoastCam when very close/on the seafloor included an anemone (white tentacles, purple body, Family Actiniidae), small white (*Cryptolaria* sp.) or golden (Sertulariidae) hydroids, the bryozoans *Diaperoecia purpurascens*, *Celleporina grandis*, and *Celleporaria agglutinans*, and the green top shell *Coelotrochus viridis*.

		Area of reef present (m^2)		3,486	1,715	296	1,241	453	1,993	689	955	1,452	1,813	1,505	443	1,379	943
																	Site
Taxa group	**Description**	**Taxonomic name**	**Total**	**A**	**B**	**Papa**	**D**	**J**	**K**	**L**	**O**	**Q**	**R**	**S**	**T**	**U**	**V**
Sponge	Low flowing encrusting	Family Chondropsidae (Psammoclema sp. indet or *Chondrosia* sp. indet.) species 2	5258	443	691	51	261	49	854	410	330	533	750	223	140	213	359
Sponge	Yellow broken ridge form	*Crella incrustans* (Carter, 1885)*	1216	116	229	3	14	40	229	203	258	49	19	18	9	45	24
Sponge	Grey cone	*Stelletta conulosa*	890	37	116	-	-	10	174	66	74	154	111	32	25	74	27
Sponge	Orange/grey multi-stalk	*Raspailia topsenti*/*Axinella* sp. indet.	397	156	22	-	18	13	13	3	2	28	60	70	14	4	7
Sponge	Yellow foamy low sponge	*Darwinella oxeata* Bergquist, 1961*	388	43	17	7	44	8	7	11	10	41	54	88	13	14	39
Sponge	Massive colonies	*Ecionemia alata* (Dendy, 1924)	366	21	81	-	-	6	25	10	8	141	39	15	8	12	6
Sponge	Pale pink ball	*Aaptos globosa**	308	6	55	-	-	25	162	24	7	-	11	22	20	-	1
Sponge	Orange/yellow/grey ball	*Tedania* sp. indet.?*	228	9	22	1	-	-	39	1	7	4	7	21	1	-	116
Sponge	Bright yellow combs	*Ciocalypta polymastia**	226	80	14	-	22	3	40	20	20	1	1	3	-	4	21
Sponge	Slender purple finger	*Callyspongia ramosa* (*Callyspongia nuda*)	204	-	6	-	-	-	6	2	21	-	8	6	4	26	125
Sponge	Pale orange/pink ball	*Tethya bergquistae**	188	44	28	1	-	6	29	1	1	2	47	25	6	-	4
Sponge	Bright yellow flanges	*Raspailia topsenti**	185	55	24	1	2	5	5	3	3	2	36	40	7	5	2
Sponge	Thick purple finger	*Dactylia varia*	183	23	14	-	8	2	12	-	25	-	14	23	13	-	51
Sponge	Yellow, rock-boring	Unid. Sp., order Haplosclerida/Poecilosclerida*	181	5	4	3	63	4	6	5	8	3	1	69	3	5	6
Sponge	Dark grey spiral cup	*Cymbastela lamellata*	179	1	-	-	-	-	-*	-	-	-	-	-	-	-	178
Sponge	Orange top, oblong dull	Unid. Sp., order Poecilosclerida*, encrusting	155	-	-	-	-	-	-	4	7	-	-	141	3	-	-
Sponge	Orange fluffy mound	*Stylissa* sp. indet.	150	6	-	-	-	-	2	2	-	-	101	18	11	3	7
Sponge	Grey/white smooth foamy	Family Irciniidae (*Psammocinia* sp. indet.)*	127	23	3	1	5	-	3	2	1	8	43	26	3	2	7

		Area of reef present (m^2)		3,486	1,715	296	1,241	453	1,993	689	955	1,452	1,813	1,505	443	1,379	943
																	Site
Taxa group	**Description**	**Taxonomic name**	**Total**	**A**	**B**	**Papa**	**D**	**J**	**K**	**L**	**O**	**Q**	**R**	**S**	**T**	**U**	**V**
Sponge	Dirty yellow encrusting	Family Halichondriidae, genus & sp. unid.*	107	-	-	-	-	-	-	-	-	4	102	1	-	-	-
Sponge	Reddish-pink/grey ball	*Aaptos rosacea*	45	-	-	-	-	-	-	-	-	-	-	39	5	-	1
Sponge	Grey branching finger	Order Axinellida genus and species indet.	35	-	4	-	1	-	-	-	1	-	5	11	2	-	11
Sponge	Bright yellow cone	*Stelletta crater* (Dendy, 1924)	33	1	15	-	-	-	9	1	3	-	2	1	-	1	-
Sponge	Pink-orange lumpy ball	*Tethya fastigata**	32	3	2	-	-	1	1	7	-	1	4	9	3	-	2
Sponge	Grey fuzzy football	*Polymastia* cf *massalis*	31	1	2	-	-	-	1	-	-	7	4	2	-	2	12
Sponge	White udon noodles	*Polymastia echinus**	19	3	-	-	11	1	-	1	-	-	3	-	1	-	-
Sponge	Grey-dirty tan ridge form	*Stryphnus ariena**	15	11	-	-	-	-	1	2	-	-	-	1	-	-	-
Sponge	Yellow foamy with holes	*Iophon minor**	14	1	5	-	-	-	4	-	1	3	-	-	-	-	-
Sponge	Yellow branching	Family Axinellidae genus and species indet.?*	13	-	-	-	-	-	-	-	-	-	9	3	1	-	-
Sponge	Low mound	*Biemna rufescens** (base colour, no maroon)	10	-	2	-	-	-	-	-	-	3	3	1	1	-	-
Sponge	Broken flange sphere	*Desmacidon mammilatum*	9	-	-	-	1	-	1	-	1	1	3	1	-	-	1
Sponge	Low mound	Family Chondropsidae (*Psammoclema* sp.*)	8	-	1	-	-	-	-	-	1	4	-	2	-	-	-
Sponge	Grey-white rough foamy	Family Irciniidae (*Psammocinia* sp. indet.), Family Chondropsidae (*Psammoclema* sp. indet or *Chondrosia* sp. indet.) species 1	7	1	4	-	-	1	-	-	-	2	-	-	-	-	-
Sponge	White pod cluster	Class Calcarea, possibly *Leucetta* sp. 2*	5	1	4	-	-	-	-	-	-	-	-	-	-	-	-
Sponge	Pink low ridges	*Haliclona venustina** or *Haliclona caminata**	3	-	-	-	-	-	-*	-	-	-	3	-	-	-	-
Sponge	Yellow half-buried tubers	Order Axinellidae genus & species indet.*	2	1	-	-	-	-	-	-	-	1	-	-	-	-	-
Sponge	Grey, white oblong	Family Dysideidae, possibly *Dysidea* sp. indet. (rough surface) of class Calcarea (*Leucetta* sp. 1).	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Sponge	Grey brain-like mound	*Polymastia* sp. indet.*	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Sponge	Dull round, algae epibionts	Family Halichondriidae genus & species unid.*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Sponge	Dull yellow smooth	*Iophon proximum**	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Coralline	Coralline algae plate		1297	142	27	-	1	7	67	75	118	7	258	537	41	24	-

		Area of reef present (m^2)		3,486	1,715	296	1,241	453	1,993	689	955	1,452	1,813	1,505	443	1,379	943
																	Site
Taxa group	**Description**	**Taxonomic name**	**Total**	**A**	**B**	**Papa**	**D**	**J**	**K**	**L**	**O**	**Q**	**R**	**S**	**T**	**U**	**V**
Ascidian?	Bright orange		839	180	93	6	21	9	46	16	17	8	141	230	53	13	15
Ascidian	Grey scraggly broken	*Didemnum* sp. indet.	89	2	2	9	57	-	4	1	-	-	1	10	1	-	2
Ascidian?	Ascidian?		4	-	-	-	-	-	-	-	-	-	-	1	3	-	-
Hydroid	White hydroid tree	*Solanderia* sp.	110	14	6	-	-	-	11	1	-	40	20	6	2	9	1
Bryozoan		*Galeopsis porcellanicus*	148	-	8	-	1	-	2	1	-	4	72	42	12	4	2
Bryozoan		*Adeonellopsis macewindui*	132	-	-	-	-	-	1	5	-	-	22	82	11	6	5
Uncertain	Encrusting, grey wax drip	(not a bryozoan)	20	-	-	-	-	-	-	-	-	2	15	2	-	-	1
Urchin	Kina	*Evechinus chloroticus*	1111	48	-	-	-	-	30	2	-	870	8	4	-	149	-
Gastropod	Cooks' turban	*Cookia sulcata*	226	-	-	-	4	-	9	3	-	159	39	3	-	7	2
Gastropod	General gastropod		51	1	2	4	2	-	2	1	-	4	5	-	-	7	23
Gastropod	Saw shell	*Astrea heliotropium*	42	-	-	-	-	-	1	1	1	7	14	1	1	15	1
Nudibranch	Sea slug	*Aphelodoris luctuosa* (Cheeseman, 1882)	117	1	4	4	19	-	-	-	-	8	58	12	8	1	2
Starfish	Reef/eleven-armed star	*Stichaster australis*/*Coscinasterias muricata*	52	-	-	-	-	-	1	1	1	30	3	2	11	3	-
Starfish	Cushion star	Family Asterinidae	11	-	-	-	-	2	-	-	-	-	-	9	2	-	-
Crayfish	Rock lobster	*Jasus edwardsii*	4	-	3	-	-	-	-	-	-	-	-	1	-	-	-
Worm	Scale worm	Polynoidae, perhaps *Euphione squamosa*	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Ophiuroid	Smooth armed snake star	*Ophiopsammus maculata*	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Hermit crab	Hermit crabs in gastropod		4	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Dead shell	Dead paua shell		4	-	-	-	-	-	-	-	-	1	1	2	-	-	-
Anemone	Small white and yellow	*Anthothoe albocincta (patches only)*	188	10	18	-	-	3	1	-	8	18	10	110	10	3	-
Anemone	Jewel anemones	*Corynactis australis (patches only)*	4	-	-	-	-		-*	-	-	2	-	1	-	1	-

3.2.4 Fish abundance

Twenty-six fish species were observed on the towed video transects (Table 8, Figure 3-6). Blue cod were the most abundant and were present at all 14 sites. Blue cod sizes ranged from 0+ juveniles (black and white colouration) through to large adults; with 0+ fish contributing 19% of blue cod counted. While blue cod were abundant, there did not appear to be a strong component of large (>45 cm) fish in the population/s. Site V had the highest number of 0+ fish, with 231 seen (59% of blue cod counted), strongly associated with sponge assemblages on rock tells and small patch reefs off the main reef (Figure 3-6), and dog cockle shell drifts. The 0+ juveniles counted at other reef sites were also concentrated on the reef/soft sediment interfaces. Larger, older blue cod were predominantly seen on and around the lower reef edges and were not common up on the reefs proper. The two mudstone reef sites (Papa, D) held relatively high numbers of blue cod, in strong contrast to the counts/covers of invertebrates and biogenic habitat covers on this reef type.

Butterfly perch were the next most common species, often occurring as small schools of adults in the water column (Figure 3-6), associated with abrupt bathymetric changes such as ridge tops, knolls, and terrace drops. Juveniles were also frequently seen, and at some sites in association with *C. flexilis* meadows and/or sponges (Figure 3-6). Site V had the highest butterfly perch count and was notable for a small area of reef that held a mixed schooling fish concentration of butterfly perch and tarakihi with a lower density background contribution from leatherjackets, goatfish, and blue moki (e.g., Figure 3-6).

Scarlet wrasse were ubiquitous across most of the 14 sites (aside from only a single individual being seen at Site J) and were present across most reef habitat types. Juveniles (<10 cm) were seen associated with *C. flexilis* meadows in small loose schools; as single individuals with some *Ecklonia* kelp locations; and at some sponge patch areas on/adjacent to reef edges. Leatherjackets were also seen often across all reefs except site Papa's bare mudstone low outcrops and boulder piles. Sites D, Q, and U held higher numbers, with leatherjackets being one of the species more commonly observed in association with *Ecklonia* forest and patches. Tarakihi were observed at five sites but were most common at Site V (65% of the 107 fish counted), where they occurred as several small schools. Two smaller juveniles (10–20 cm) were seen at the mudstone reef at site D.

Twenty further fish species had recorded abundances of 100 individuals or less, the most numerous being goatfish, sweep, red moki and spotty with abundances ranging from 11 to 54 fish. Spotties (the wrasse *Notolabrus celidotus*) were surprisingly uncommon (11 individuals), as a species that is regarded as ubiquitous on shallow reefs and other structured habitats around New Zealand. However, as true for most reef fish species in New Zealand, we have a rather poor understanding of most species depth range and how densities are distributed over that range. Those ranges are also likely to vary with factors such as water temperature. For instance, tarakihi are seldom (if at all) seen on shallow reefs in northeastern New Zealand by divers but become progressively more commonly seen on shallow reefs with increasing latitude. The depth range of this present survey (12–34 metres) may have been deeper than the main depth distribution of spotties in this region.

Small sharks and rays (elasmobranchs) were only occasionally seen; five carpet sharks, two rig, one stingray and one eagle ray. All were sitting inert on the seafloor, on or between rocky sea-floor. Two 'tropical straggler' species were seen. A magpie perch (*Cheilodactylus nigripes*) at Site K (the Project Reef), one of a resident pair often seen at the reef by Project Reef divers (both fish – the pair – were seen on Coast-Cams second video camera). A red morwong (*Cheilodactylus fucus*) was seen at Site S. One porae (*Nemadactylus douglasii*) was recorded. The STB is outside this species normal distribution along the north-eastern coast of New Zealand (warm temperate waters).

The remaining sixteen species had total counts ranging from 1 to 5 individuals. Snapper were only seen once (a single individual), which was expected as this species is seldom seen on day-time towed video).

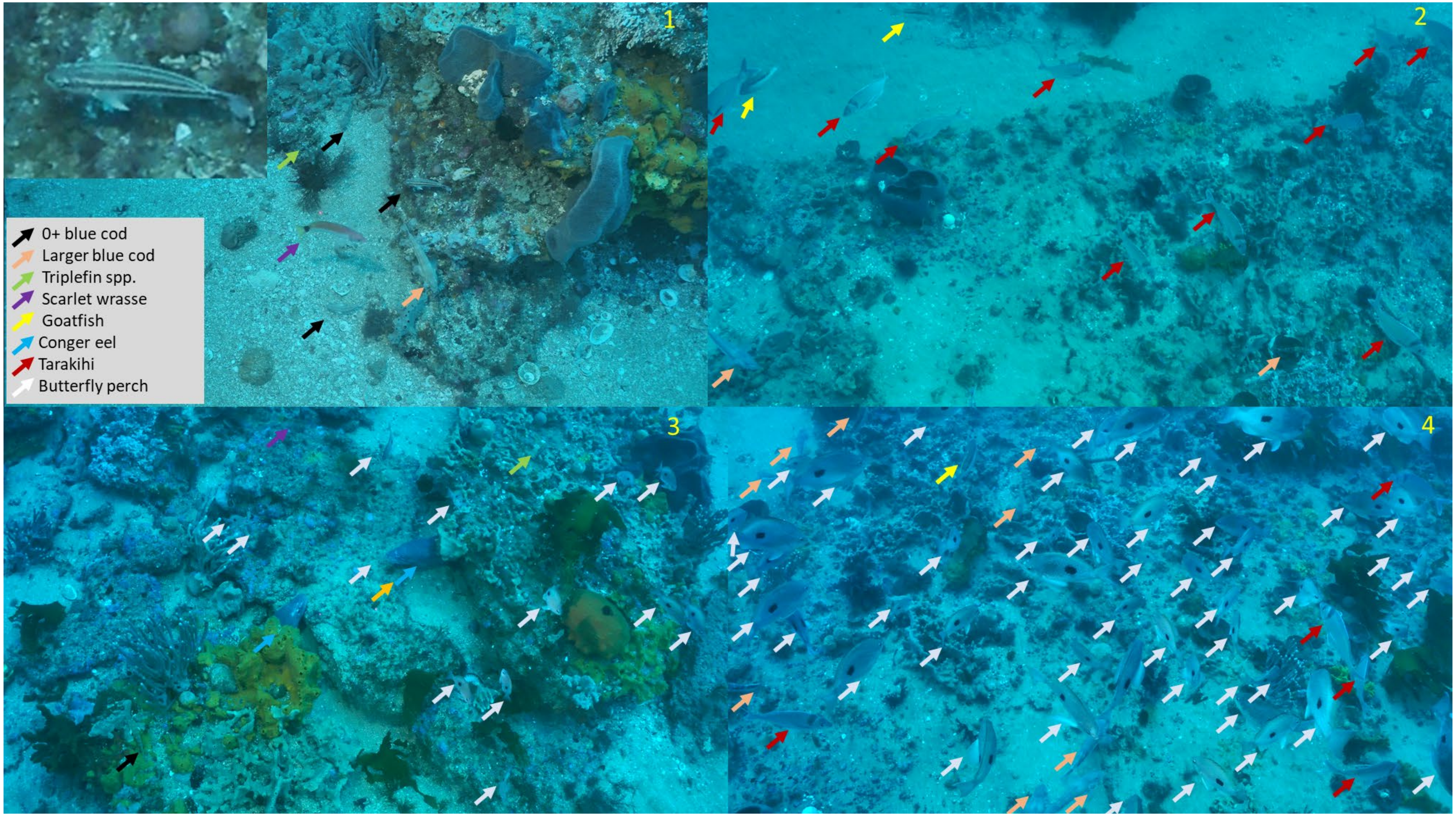


Figure 3-6: Fish examples from Site V, for reef #V1, 32 metres water depth Individual species are marked by coloured arrows: 1) soft sediment to reef boundary with sponge biogenic habitat, and 0+ juvenile blue cod (insert: close-up of 0+ black & white colouration), blue cod, triplefin, scarlet wrasse; 2) reef and soft sediment channel with sponge biogenic habitat, tarakihi school, goatfish, blue cod (an adult blue moki is out of shot); 3) reef/sand mosaic area with sponge and *E. radiata* biogenic habitat, 0+ blue cod, conger eels, scarlet wrasse, triplefin, and juvenile butterfly perch (school on moving video); 4) rock platform with sediment, sponge and *E. radiata* biogenic habitat, school of adult butterfly perch, tarakihi, goatfish, and tarakihi.

Table 8: Summary of fish counts recorded from CoastCam video footage. Note that triplefin species were difficult to see due to their small size and cryptic nature and so were excluded from formal counting. However, any incidental observations that were made have been included here.

	Area of reef present (m^2) >>	**(see Table 7) >>**	**1,715**	**296**	**3,486**	**1,241**	**453**	**1,993**	**689**	**955**	**1,452**	**1,813**	**1,505**	**443**	**1,379**	**943**
																Site
Species	**Taxonomic name**	**Total individuals**	**A**	**B**	**Papa**	**D**	**J**	**K**	**L**	**O**	**Q**	**R**	**S**	**T**	**U**	**V**
Blue cod all sizes	*Parapercis colias*	2200	98	73	146	218	16	115	105	76	53	44	45	30	256	391
Blue cod (0+ B&W)		*405*	*9*	*2*	*10*	*39*	*2*	*21*	8	*19*	*1*	-	-	-	*63*	*231*
Blue cod <12cm not B&W		*35*	-	*1*	-	-	-	-	-	*1*	-	-	*8*	*5*	*19*	*1*
Blue cod (13-20cm)		*615*	*54*	*36*	*75*	*82*	*1*	*39*	35	*28*	*13*	*21*	*25*	*18*	*99*	*89*
Blue cod (21-30cm)		*387*	*24*	*27*	*40*	*56*	*8*	*26*	34	*17*	*25*	*21*	*4*	*7*	*53*	*45*
Blue cod (>30cm)		*224*	*11*	*7*	*21*	*41*	*5*	*29*	28	*11*	*14*	*2*	*8*	-	*22*	*25*
Butterfly perch	*Caesioperca lepidoptera*	931	5	97	-	21	11	88	3	-	52	71	90	36	208	252
Scarlet wrasse	*Pseudolabrus miles*	744	137	57	13	37	1	33	13	8	103	89	88	37	120	21
Leatherjacket	*Meuschenia scaber*	228	23	4	-	50	2	18	5	1	46	13	15	4	50	5
Tarakihi all sizes	*Nemadactylus macropterus*	107	-	4	-	15	-	1	-	-	-	-	17	-	-	70
Tarakihi (10-20cm)		*2*	-	-	-	*2*	-	-	-	-	-	-	-	-	-	-
Tarakihi (21-30cm)		*25*	-	*3*	-	*13*	-	*1*	-	-	-	-	-	-	-	*8*
Tarakihi (>30cm)		*80*	-	*1*	-	-	-	-	-	-	-	-	*17*	-	-	*62*
Goatfish (Red mullet)	*Upeneichthys lineatus*	54	-	1	1	7	-	1	1	-	3	1	-	-	19	21
Sweep	*Scorpis lineolatus*	23	3	-	-	-	-	-	-	-	20	-	-	-	-	-
Red moki	*Cheilodactylus spectabilis*	11	-	-	-	1	-	-	-	-	3	1	5	-	1	-
Spotty	*Notolabrus celidotus*	11	2	-	-	3	2	-	-	-	-	2	2	-	-	-
Carpet shark	*Cephaloscyllium isabellum*	5	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Blue moki	*Latridopsis ciliaris*	4	-	1	-	-	-	-	-	-	-	-	-	-	-	3
Southern conger	*Conger verreauxi*	4	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Banded wrasse	*Notolabrus fucicola*	3	-	-	-	-	-	-	-	-	3	-	-	-	-	-

Species	Taxonomic name	Total individuals	A	B	Papa	D	J	K	L	O	Q	R	S	T	U	V
	Area of reef present (m^2) >>	**(see Table 7) >>**	**1,715**	**296**	**3,486**	**1,241**	**453**	**1,993**	**689**	**955**	**1,452**	**1,813**	**1,505**	**443**	**1,379**	**943**
																Site
Sea perch	*Helicolenus percoides*	3	1	-	-	-	-	-	-	-	-	-	1	-	1	-
Marble fish	*Aplodactylus arctidens*	2	1	-	-	-	-	-	-	-	1	-	-	-	-	-
Rig	*Mustelus lenticulatus*	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Common roughy	*Paratrachichthys trailli*	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Butterfish	*Odax pullus*	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Copper moki	*Latridopsis forsteri*	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Magpie perch	*Cheilodactylus nigripes*	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Snapper (21-30cm)	*Chrysophrys auratus*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Red morwong	*Cheilodactylus fucus*	1	-	-	-	-	-	-	-	-	-	-	*1*	-	-	-
Red banded perch	*Hypoplectrodes huntii.*	1														
Porae	*Nemadactylus douglasii*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	*1*
Porcupine fish	*Allomycterus pilatus*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	*1*
Stingray (only partially in view)		1														
Eagle ray	*Myliobatis tenuicaudatus*	1														
Triplefin species																
Banded triplefin	*Forsterygion malcolmi*	26	3	5	1	-	-	1	-	-	4	3	1	1	5	2
Oblique-swimming triplefin	*Forsterygion maryannae*	10	-	-	-	-	-	-	-	-	10	-	-	-	-	-
Yellow and black triplefin	*Forsterygion flavonigrum*	4	-	-	-	-	-	-	-	-	-	-	-	-	4	-

3.3 Fish species counts from the baited fish trap video

Thirteen successful baited fish traps deployments were made across six sites. Note that fish traps were several hundred meters away from the CoastCam transects conducted at these sites. Given the low within-site replication and large variability, the data are presented in narrative form only.

Trap catch was low (28 blue cod, 6 scarlet wrasse, and 4 carpet sharks) but camera observations were much more informative. Table 9 gives the Nmax counts for the species seen (16 fish species, and the crayfish *J. edwardsii*), with a summed Nmax (all species) of 278 individuals. Blue cod dominated, contributing 47% of the individuals, with an estimated average fish length of 24 cm (range 13–43 cm, n = 131); trap catch lengths averaged 23 cm (range 13–35 cm, n = 28). Blue cod were present at all six sites, and in all 13 replicates. Average Nmax was 10 fish (range 1–20, all 13 trap sets treated as replicates).

Snapper were the second most common species, contributing 11% of individuals, with an average fish length of 32 cm (range 19–48 cm, n = 31). No snapper were caught in the traps. Fish were present at 5 sites, and in 8 replicates. Average Nmax was 2.5 fish (range 0–14).

Scarlet wrasse were the third most common species, contributing 10% of individuals, with an average fish length of 25 cm (range 20–30 cm, n = 28); trap catch lengths averaged 19 cm (range 14–21 cm, all from one single Q site trap). Average Nmax was 2.2 fish (range 0–14).

Trevally were the fourth most common species, contributing 10% of individuals, with an average fish length of 26 cm (range 25–30 cm, n = 27). No trevally were caught in the traps. Average Nmax was 2.1 fish (range 0–10.).

All other species had less than 15 individuals scored (sum of Nmax values). Eleven tarakihi (size range 30–33 cm) were seen passing by in the background at two sites (coming from behind the trap and passing to one side several metres behind the trap). Trevally had a similar behaviour but passed much closer to the trap (Figure 3-7). Kingfish, barracouta, and trevally were all seen in the baited trap videos but were absent from the CoastCam videos. These are all mobile species that are less likely to be observed on the seafloor. As with snapper (only one individual seen by CoastCam), they are likely to be towed camera adverse in general.

Table 9: Species Nmax counts from baited video An asterisk (*) indicates fish species not seen on the towed video transects. Replicates at sites D and S are labelled sequentially.

	Site/replicate >>	A	D1	D2	D3	D4	L	O	Q1	Q2	S1	S2	S3	S4	Total
Species	Taxonomic name														
Blue cod	*Parapercis colias*	8	5	1	13	11	16	14	7	15	7	7	20	6	130
Snapper	*Chrysophrys auratus*	3			14	2	5			1	3	1		3	31
Scarlet wrasse	*Pseudolabrus miles*	1					2	1	16		1			7	28
Trevally*	*Pseudocaranx dentex*		10		9				7	1					27
Spotty	*Notolabrus celidotus*	2						1	10				1		14
Tarakihi	*N. macropterus*				4		7								11
Leatherjacket	*Meuschenia scaber*	2					2	1	1				1	2	9
Carpet shark	*C. isabellum*						1	1	1	2		1	1	1	8
Sweep	*Scorpis lineolatus*								7						7
Kingfish*	*Seriola lalandi*				2	2			2						6
Barracouta*	*Thyrsites atun*	1											1	1	3
Long-tailed ray*	*Dasyatis thetidis*		1										1		2
Red mullet	*Upeneichthys lineatus*						2								2
Crayfish	*Jasus edwardsii*						1								1
Blue moki	*Latridopsis ciliaris*					1								1	1
Porcupine fish	*Allomycterus pilatus*												1		1
Totals		17	16	1	42	16	36	18	46	19	11	9	26	21	278

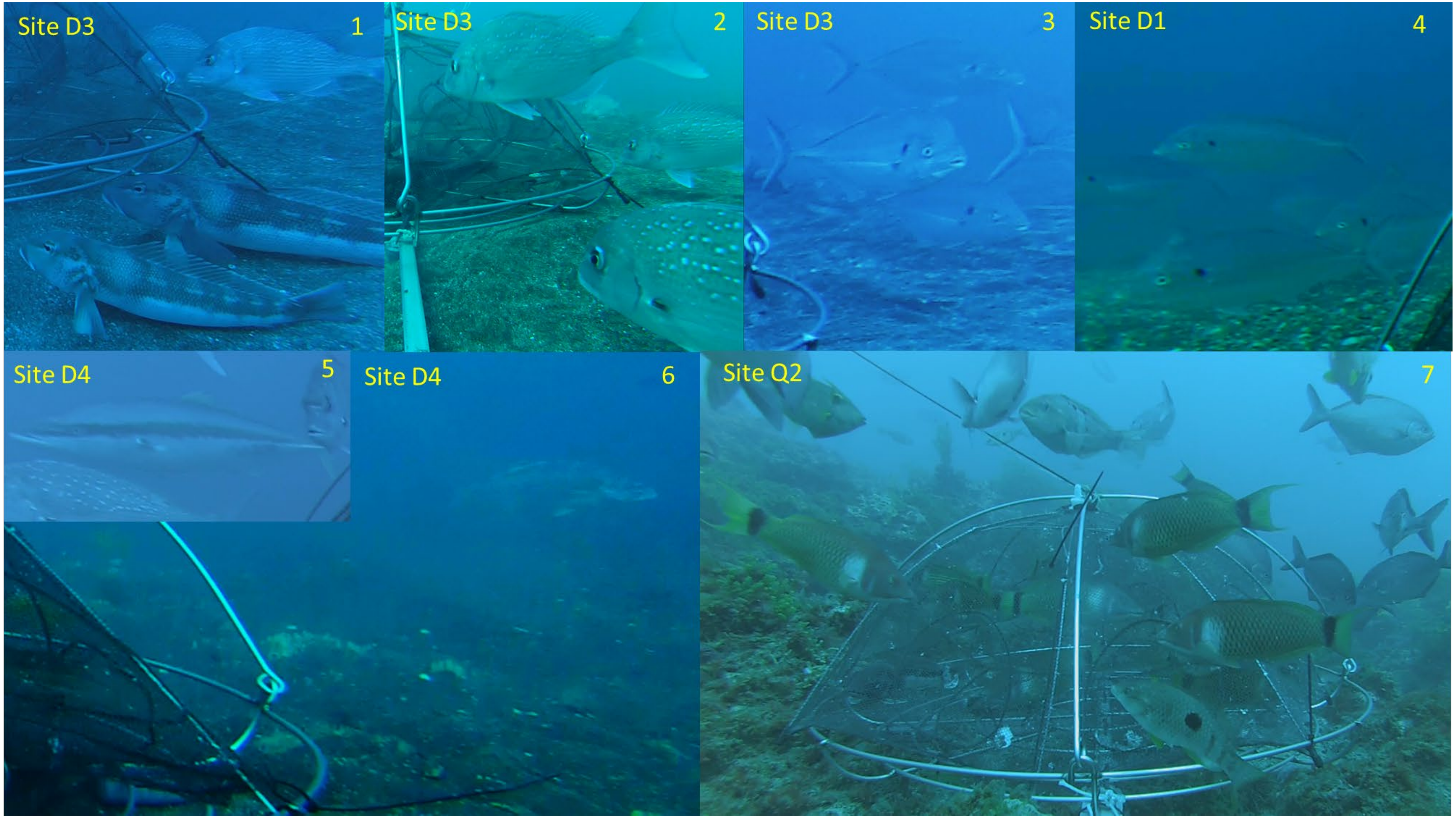


Figure 3-7: Fish species seen in baited fish trap video: 1) snapper and blue cod; 2) snapper; 3–4) trevally (part of wider dispersed schools of 10–20+ individuals); 5) kingfish (~70 cm), 6) blue moki (~60 cm); 7) scarlet wrasse, spotties, sweep, leatherjacket, and blue cod (in trap). Other species seen but not shown here are barracouta, short-tailed stingray, red mullet, porcupine fish, tarakihi, blue moki, and crayfish. Some imagery has been darkened to reduce 'washout' of fish against light background.

3.4 Project Reef (site K) diver-based photo quadrats (2017, 2018, 2020)

The results of the Project Reef diver-collected photo-quadrats, as percent cover, are given in Table 10. These still camera images were of higher resolution that the CoastCam video cameras. The 2017 survey was the most comprehensive, with 4 random transects; versus the 2018 and 2020 single fixed transects and so we have focused on the 2017 data.

Table 10: Seafloor %cover assessed by the Project Reef team. The classification scheme differs from that used for the CoastCam video transects. *, biogenic reef class was assigned to the most likely epifauna/epiflora classes in 2017, while in 2018 and 2020 it was left as a class.

Class	Sub-class	2017	2018	2020
Abiotic Material	Reef conglomerate	48.8	22.4	47.8
	Shell hash	9.0	7.4	11.1
	Sand	0.4	0.9	0.9
Encrusting Animals	Biogenic Reef	*	5.6	1.9
	Porifera	13.4	5.8	6.7
	Bryozoa	0.2	0.4	0.2
	Chordata	3.4	0.4	1.7
	Cnidaria	2.2	0.4	0.9
Mobile invertebrates	Mollusca	0.2	0.1	0.2
	Echinodermata	0.6	0.7	0.3
Macroalgae	Chlorophyta	3.6	2.4	4.4
	Rhodophyta	1.6	1.7	5.8
	Ochrophyta	6.6	6.3	7.1
Turfing Algae		9.8	43.5	9.1
Fish		0	0	0.2
Unknown		0.2	2.2	0.3
Sampling frame intrusion		0	0	1.5

Turfing algae had a percent cover of 9.8% of 2017 survey (43.5 % in 2018, 9.1% in 2020). This very low height, fine turf was not included as a class in the CoastCam video classification, as it was largely not able to be distinguished by the image scale and resolution used.

The Project Reef Citizen Science group (2017) informal report noted that while some small bryozoans, sponges, and various forms of macroalgae were known to be present (from finer-scale macrophotography taken outside the scope of this project), they were not distinguishable at the 0.25 m^2 image scale used here. *E. radiata* kelp plants were also noted to have obscured the seafloor beneath their blades, resulting in an underestimation of benthic cover on the seafloor proper.

Table 11 provides a detailed breakdown of taxon contributions (percent cover) of the seafloor from the 2017 photo quadrats to the finest practical taxa/species level. The higher resolution of images allowed the identification of three species not identified in the broader scale CoastCam video transect: the small gastropod *Buccinulum linea* (the lined whelk, endemic to New Zealand) the macroalgae *Polysiphonia* sp., and *Zonaria turneriana* (the latter could occasionally be identified to *Zonaria* sp. when the CoastCam system was unusually close to the seafloor).

Table 11: Taxa contributions (%cover) from the 2017 photo quadrats sampling the Project Reef.

Taxon group	Taxa/species	%cover	Sub-totals	All
Sponges	*Chondropsis* sp.	1.81%		
	Crella incrustans	1.36%		
	Unidentified sponges	1.22%		
	Ecionemia alata	0.61%		
	Stelletta conulosa	0.56%		
	Aaptos globosa	0.47%		
	Ciocalypta polymastia	0.22%		
	Tethya bergquistae	0.17%		
	Psammocinia perforodorsa	0.11%		
	Iophon minor	0.08%	6.61%	
Ascidians	*Didemnum* sp.	1.08%		
	Unidentified Ascidiacea	0.56%	1.64%	
Bryozoans	Unidentified Bryozoan	0.19%	0.19%	
Anemones	*Anthothoe albocincta*	0.86%	0.86%	
Mobile invertebrates	*Evechinus chloroticus*	0.31%		
	Unidentified mollusca	0.08%		
	Cookia sulcata	0.06%		
	Buccinulum linea	0.03%	0.47%	
Kelps/macroalgae	Unidentified turfing algae	9.72%		
	Ecklonia radiata	5.94%		
	Caulerpa geminata	4.06%		
	Polysiphonia sp.	3.00%		
	Coralline algae	2.08%		
	Unidentified Ochrophyta	0.86%		
	Unidentified Rhodophyta	0.75%		
	Unidentified Chlorophyta	0.19%		
	Zonaria turneriana	0.14%		
	Caulerpa flexilis	0.03%	26.78%	36.56%

The Project Reef team has also collected various video and still imagery of the reef (e.g., Figure 3-8). Their web page (https://www.projectreefsouthtaranaki.org/) has a range of high quality still and video imagery of the reef, together with their research on the reef, community engagement, and the history and activities of the group.

Figure 3-8: Project Reef imagery of the reef Top image), top raised edge of reef terrace with *Ecklonia* patches, soft bryozoans, *C. flexilis*, and various sponge species. Bottom image), the same reef , but taken about 3 metres further back, showing the terrace drop to soft sediment. The reef is formed from rock with a high fossil content, probably limestone.

3.5 Project Reef (site K) blue cod and fish assemblage

3.5.1 Baited Underwater Video (BUV)

Four single BUV drops were carried out on the Project Reef between November and March in 2017, 2018, 2019 and 2021. The respective Nmax numbers were 20, 30, 17, and 71. These numbers cannot be directly compared to the fish trap Nmax numbers due to the different methodological approach (e.g., vertical versus horizonal cameras, use of traps), but nevertheless have upper/higher values (Table 9). Other species were not counted, but included snapper, scarlet wrasse, tarakihi, and carpet shark; and three species not seen in either the CoastCam or fish trap videos: octopus, seven-gilled shark (*Notorynchus cepedianus*), and school shark (*Galeorhinus galeus*).

Two BUV drops were also made in 2020 but these were unable to be quantified (one too short, the other dragged in the current).

3.5.2 In-situ camera

Thirty-two species of fish were recorded in eight deployments of a fixed in-situ video camera were made, with the footage partially reviewed by the Project Reef team (Table 12). Seven of these species were not seen by any of the other sampling methods. These were southern bastard cod (*Pseudophycis barbata*), giant boarfish (*Paristiopterus labiosus*) (Figure 3-9), rock cod (a *Lotella* sp.), lantern fish (Family Myctophidae), slender roughy (*Optivus elongatus*), frostfish (*Lepidopus caudatus*), and piper (*Hyporhamphus ihi*). Other non-fish species recorded were shrimps, crayfish, octopus, a crab, a nudibranch, a sea cucumber, and a New Zealand fur seal (*Arctocephalus forsteri*). There was no obvious relationship between species richness and season (Table 12).

Across the four seasons (over four years), snapper were consistently present across all 8 deployments (two of which were in winter 2020). Blue moki, leatherjackets, scarlet wrasse and southern bastard cod were seen in 7 out of 8 deployments 8% (88%). Leatherjackets were seen in 73% of deployments; giant boarfish, butterfly perch, carpet sharks, common roughy, and oblique triplefins in 63% of deployments; and kingfish and trevally in 50% of deployments. Blue cod were only seen in 38% of deployments. Whether the fish seen were resident on the reef, or more transient seasonal or haphazard visitors, is unknown (though small-bodied species such as triplefins are likely to be resident at a fine scale).

Table 12: Species presence by season, from the Project Reef in-situ camera Number of 20-second video clips reviewed was 3,145. Fish species not seen by any of other methods marked with *.

	Month	Nov	Jan	Jan	Feb	Feb	Mar	June	July
	Year	17	20	18	19	20	17	20	20
	Season	Spr	Spr	Sum	Sum	Sum	Aut	Win	Win
	Fish species richness	15	16	8	20	11	11	17	21
% time	Species								
100%	Snapper	1	1	1	1	1	1	1	1
88%	Blue moki	1	1	1	1		1	1	1
	Leatherjackets	1	1	1	1	1	1		1
	Scarlet wrasse	1	1	1		1	1	1	1
	Southern bastard cod	1	1		1	1	1	1	1
75%	Goatfish	1	1		1	1		1	1

	Month	Nov	Jan	Jan	Feb	Feb	Mar	June	July
	Year	**17**	**20**	**18**	**19**	**20**	**17**	**20**	**20**
	Season	**Spr**	**Spr**	**Sum**	**Sum**	**Sum**	**Aut**	**Win**	**Win**
	Fish species richness	**15**	**16**	**8**	**20**	**11**	**11**	**17**	**21**
% time	**Species**								
63%	Giant boarfish	1			1	1		1	1
	Butterfly perch	1	1		1			1	1
	Carpet shark	1			1	1		1	1
	Common roughy	1	1		1		1	1	
	Oblique triplefin			1	1	1		1	1
	Tarakihi	1	1		1	1		1	
50%	Kingfish	1	1					1	1
	Trevally		1		1		1		1
38%	Black and yellow triplefin	1					1		1
	Blue cod		1			1			1
	Crayfish		1		1			1	
	Eagle ray			1	1	1			
	Rock cod			1	1			1	
	Sea perch	1						1	1
	Shrimps	1						1	1
25%	Conger eel				1		1		
	Copper moki		1					1	
	Eagle ray			1					1
	Lantern fish*						1	1	
	*Octopus**							1	1
	Slender roughy*				1				1
	Spotty	1							1
	Unidentified shark		1						1
13%	Banded triplefin		1						
	Crab				1				
	Frostfish*				1				
	Magpie perch								1
	New Zealand fur seal							1	
	Nudibranch			1					
	Piper*				1				
	Porcupine fish						1		
	Sea cucumber		1						
	Short-tailed ray				1				
	Sweep								1

Figure 3-9: The fixed field of view of the in-situ camera The camera is bolted to a heavy permanently fixed base. The site is in a small notch feature/indent in the Project Reef's southern side and faces south onto the adjacent low rock and coarse sediments, as well as the reef edge (right side). Shown are a small school of giant boarfish (five individuals) which in this video spent some time sitting up on the reef wall facing into the current. Later, this group swam from behind the central mooring rope to pass the camera at close range on the left side. Also present are two scarlet wrasse and a leatherjacket.

3.5.3 Research rod fishing

Eleven separate fishing events were completed on the Project Reef between 2016 and 2021. Two of these were on the same day, and another two separated by only five days; these two pairs were each combined, giving nine fishing events overall. A total of nine fishing events occurred between 2016 and 2021. Figure (top graph) shows the sizes of all blue cod measured (n = 391), plotted by event. Fish ranged in size from 155 to 550 mm. Fitting of a simple linear regression found a very small but significant positive relationship between time and size ($r^2 = 0.09$). Predicted average fish size rose from 293 mm in 2016, to 334 mm in 2021 (a 40 mm increase). Re-expressing the same data as the proportion of legal-sized fish (330+ mm) caught, plotted against time (Figure 10, second graph), also showed a significant positive relationship ($r^2 = 0.39$). The predicted legal size fish proportion increased from 25% to 62%.

There are several possible reasons for this observed increase in the size of blue cod over the five year period, for the blue cod sampled population (nominally fish 155 mm and larger). New recruitment to the sampled population (juvenile fish growing larger than 154 mm) over time may have been less than previous years, resulting in an aging fish population (and, therefore, on average larger fish). Natural variations in fish population abundance and size compositions over time are normal. Little is known about natural blue cod recruitment dynamics over time, but it is highly likely that year class strength varies naturally between years (some spawning years are much more successful than others). An alternative possibility is that the Project Reef was experiencing some level of fishing removals prior to being adopted by the local (human) community; and that with the creation of Project Reef, this fishing pressure ceased/reduced as a voluntary response, allowing more fish to grow to a larger size.

Standardisation of the blue cod catches to a Catch Per Unit Effort (CPUE) metric, expressed as fish caught per rod per hour fished, is plotted in Figure (bottom graph). Sampling effort averaged 6.26 rod hours fished per event (range 3.2–12.2). There was a small but significant downward trend in CPUE over the five-year period (r^2 = 0.09), with a predicted 30% decline. This finding favoured the lower recruitment hypothesis for explaining the increase in average fish size seen over the same period.

Other species were caught in numbers too low to support numerical investigation; a catch summary is given in Table 13.

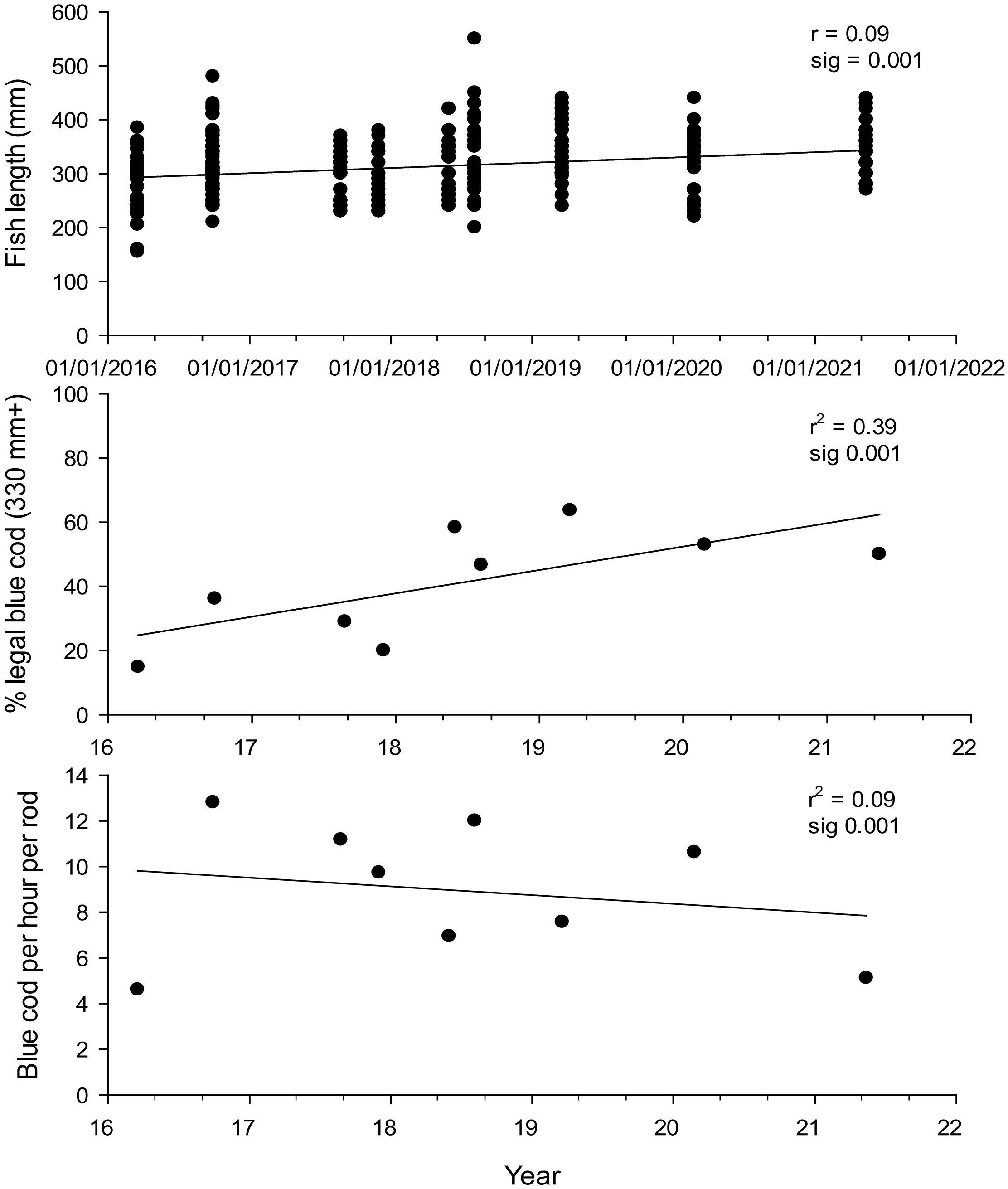


Figure 3-10: Fishing survey blue cod data from Project Reef top) fish lengths by event; middle) proportion of fish of legal size (300 mm and greater); bottom) CPUE, measured as fish per rod hour fished.

Table 13: Rod fishing catch summary of all fish species other than blue cod The maximum possible number of fishing events is nine. For snapper, 21 fish (57% of individuals sampled) were caught during one sampling event (1/06/2018).

Species	n	Av. Size	Range	No. of events
Snapper	37	37	27–79	5
Kahawai	8	64	50–56	3
Spikey dogfish	8	74	74–75	1
Scarlett wrasse	6	28	25–31	3
Trevally	4	49	46–54	1
Tarakihi	3	29	29–30	3
Sea perch	3	N/A	N/A	2
Carpet shark	2	100	-	1

3.6 Individual site descriptions (CoastCam)

This section describes each site in more detail.

As the various identity keys for graph plots take a lot of space, they are presented once below (Figure 3-11), to be referred to when viewing the figures below. In the graph plots for a site, all geomorphology and biogenic habitat covers are presented. As a broad overview of sponges, each video segment is plotted for its sponge count (sum of 'individuals' seen) and sponge richness (number of species present). Coralline algal plates, *E. radiata* recruits and hydroid trees are plotted as important / interesting species counts, summed by video segment. Mobile invertebrates are plotted for the five most common species/taxa, with kina represented by a red star symbol to help them stand out as a key habitat-structuring species. The five most abundant fish species are also plotted as summed counts per video segment, with blue cod and tarakihi further divided into size classes. 0+ juvenile blue cod are represented with stars, to help them stand out on the plots also.

For the maps in the individual sections that include the Benthic Terrain Model (BTM) classes, the BTM key is also not included on each individual map to save space. Figure provides the key to refer to, it is given as part of Appendix A. To avoid clutter, within an individual site section, seafloor images are referred to by number (1–32) without a corresponding Figure reference. Similarly, video segment numbers are referred to simply by their number, prefaced by a # to separate them from the seafloor image numbers.

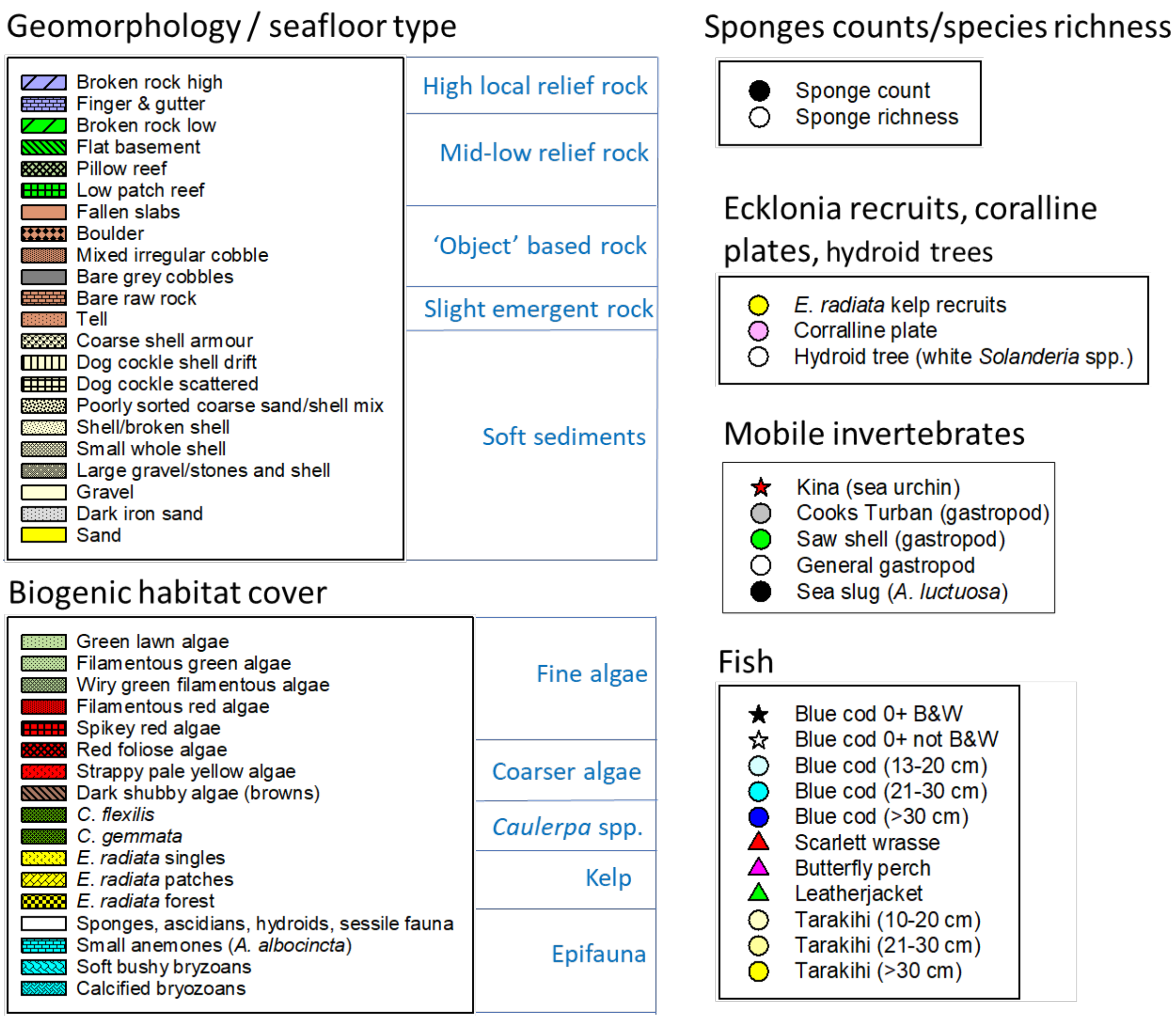


Figure 3-11: Master key for graphs in the individual sites section Geomorphology/seafloor type classes are ordered broadly by decreasing local topographic/height complexity and particle size. Biogenic cover is ordered for macroalgae by increasing form complexity/size, and for epifauna so that the general class of 'sponge, ascidians, hydroid' provide a clear visual break between epifauna and epiflora (macroalgae) classes where both are present. For the three plots of individual taxa abundance, most symbol colours were chosen to broadly match the organisms, with within-colour gradients used for blue cod and tarakihi to separate different size classes (lightest shade for smallest fish). Blue cod 0+ juveniles are shown as star symbols, to help likely blue cod nursery habitats/areas stand out clearly; kina are also shown as star symbols, given their potentially strong effect on structuring subtidal reef benthic assemblages.

3.6.1 Site A

Depth range. 13.9–24.8 metres **Reef size**: 425,000 m^2

Form. Low ridge/escarpment, composed of two main reef features. Discrete.

The larger northern part formed a low arcing bluff, extending 1,650 m along its axis (Figure 3-12). Cross-sectionally, the northern reef emerged from sand (18.4 m) on its south/west side, ramped up to a flat ridge top (shallowest area 13–14m), before dropping away more steeply and in more broken form on the north-east side, down to flat seafloor (22.9 m). The smaller southern reef, about 500 m along its axis, was similar in structure with an east-west orientation, but with less pronounced bathymetry, going from sand (19.4 m) to the reef top (18.5 m), then dropping away to the east (24.8 m).

BTM Divisions (east to west video transect): Flat Plains (sand) → Flat Ridge Tops → Rock Outcrops High/Narrow Ridges → Flat Ridge Tops → Broad slopes → Depressions → Broad Depressions (with some patches of Local Ridges, Boulders, Pinnacles in Depressions/on Broad Flats/on Slopes) (Figure 12).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-12 to Figure 3-14)

Geology: The reef was composed of a rock type that appeared hard but amenable to erosion (4,12), assumed to be sandstone with an additional component of smooth small grey stone drifts on the upper flanks of the ridge reef feature (4,9,10,12). On the deepest eastern side where the reef reached flat seafloor, small tell exposures of a flat grey basement rock (likely mudstone/papa rock) also appeared (17). Several clear geological NE/SW fault lines were present in the multibeam sonar data; but cannot be seen in the figures here, due to their small scale on the page.

On its southern side, the reef first appeared as small tells/rock patches surrounded by dark sand (1–2), then reef increased in cover going up the ridge flank as a mix of low broken rock, high patch reefs, and dark sand. Drifts of smooth, grey stone cobbles (4,10,12) were also apparent. These stones were intermixed with bedrock outcrops, occurring as patches and drifts, with the stones likely to be mobile during storm events. On the ridge top, high broken rock dominated (#725–762, #840–850), and the upper flanks/sides (#762–825) were composed of low broken rock, irregular mixed cobbles, and grey stone cobbles (9,11,12). Dropping away down-slope to the east, the transect crossed over alternating dominances of low broken rock and dark sand (#850–930), along with lesser contributions of mixed irregular cobbles and tells.

The reefs overall height was seven to nine metres, with local topography variability at metres scale. The exception was a limited area of larger rectangular reef blocks (6) (1–2 m high, 5–6 m long, 3–4 m wide) seen near the top of the ridge, surrounded by coarse sediment.

Biogenic habitats: On its west side, the reef emerged from a flat plain of dark sand (1) as small tells/patch reefs dominated by sponges, red filamentous, and yellow-bladed algae (2). As the reef increased in cover, patches of *C. flexilis* appeared (3), increasing to become the dominant reef cover (7,9,11). The very mosaiced nature of the reef (rock, cobbles, stones, soft sediments) limited *C. flexilis* to numerous patches (15–20% cover), rather than continuous dense meadows as seen on other reefs. Its dominance reduced in the eastern deeper area beyond the ridge top, where it forms a mixed biogenic habitat dominated by red filamentous algae (15–18), as well as patches of the green algae *C. geminata*.

E. radiata (kelp) occurred as intermittent single plants and small patches (7,13,16) across the transect, with kelp forest limited to the reef ridge-top, where it formed a dominant narrow habitat band (8) (10–15 metre wide). The transect passed over this narrow kelp forest band twice (separated by 450 m), strongly suggesting the existence of a long narrow kelp forest extending along the top of the ridge (750+ m). This forest may have been wider in the central area, where the flat ridge top widened to 50 m. Overall *E. radiata* cover was 1.44% (forest 0.60%). *Ecklonia* recruits were most abundant on the upper reef, near higher adult plant covers; as well as toward the transect end (#900+) (Figure 3-12).

Main invertebrate species: Sponges were the most common sessile invertebrates, with an overall low percent cover contribution across the video transect of 0.41% (Table 6). The dominant taxa were Family Chondropsidae sp 2, *Raspailia topsenti*/*Axinella* sp. indet., *Crella incrustans*, *Ciocalypta polymastia*, and *Tethya bergquistae*, as well as an unidentified bright orange ascidian. Sponge richness and abundance were highest on the tells/reef patches (2) at the transect start (<#700), as well as on the eastern side (>#850) as the reef dropped in depth as an alternating dominance mix of rock and soft sediments (15–18). Kina were present across the upper part of the reef, but in low numbers (48 counted) and never seen in groups of more than two to three. Other mobile invertebrates were rare (1 gastropod, 1 sea-slug) (Table 7).

Main fish species: Scarlet wrasse were the dominant species seen and were present across the reef. Blue cod were also common, with fish sizes dominated by larger juveniles and adults. Few 0+ juveniles were counted. Blue cod distribution was largely associated with reef/sediment boundaries, rather than on the reef proper. Leatherjackets were in lower numbers across the transect, while butterfly perch were uncommon (5 seen) compared to most other sites with similar sandstone rock types.

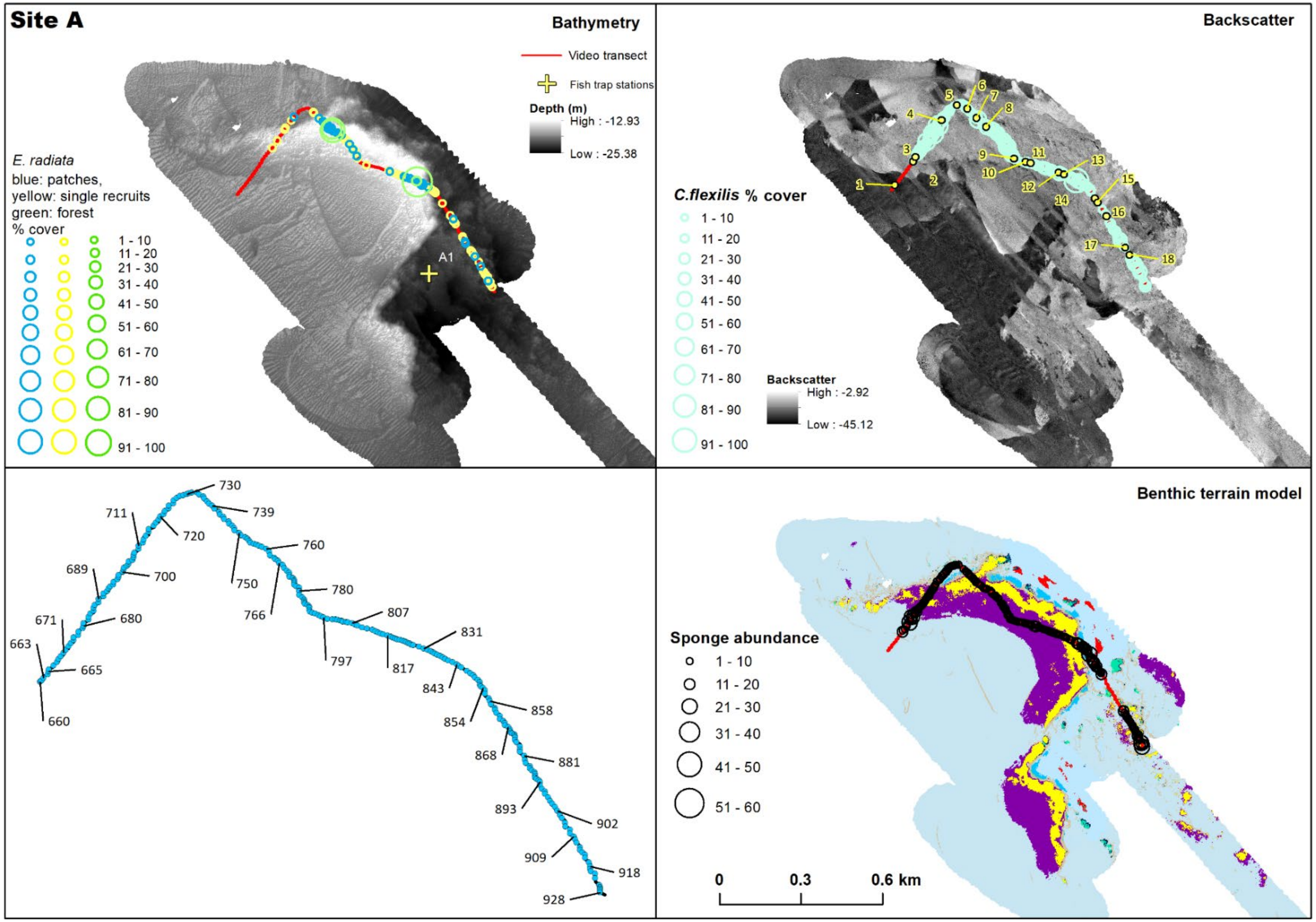


Figure 3-12: Maps of site A Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; bottom left) towed video transect with video segment sequential numbers; bottom right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

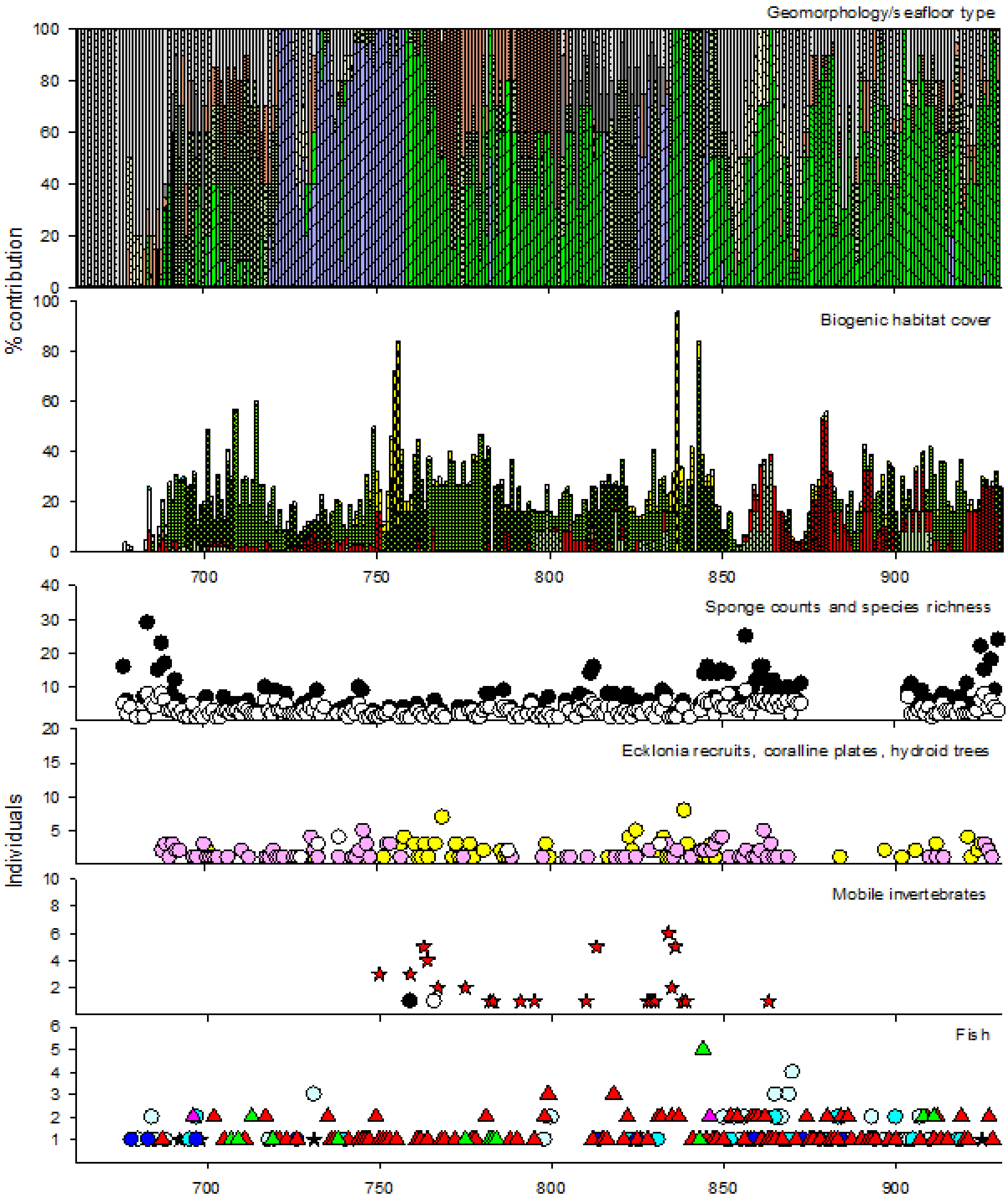


Figure 3-13: Site A CoastCam data. geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); Ecklonia recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. The data gap for sponge cover and richness (#825–900) is due to poor water visibility limiting resolution of sponge taxa. Class keys are given in Figure . The x axis plots the sequential spatial position index of the 20-second video segments, shown in map form in Figure 3-12.

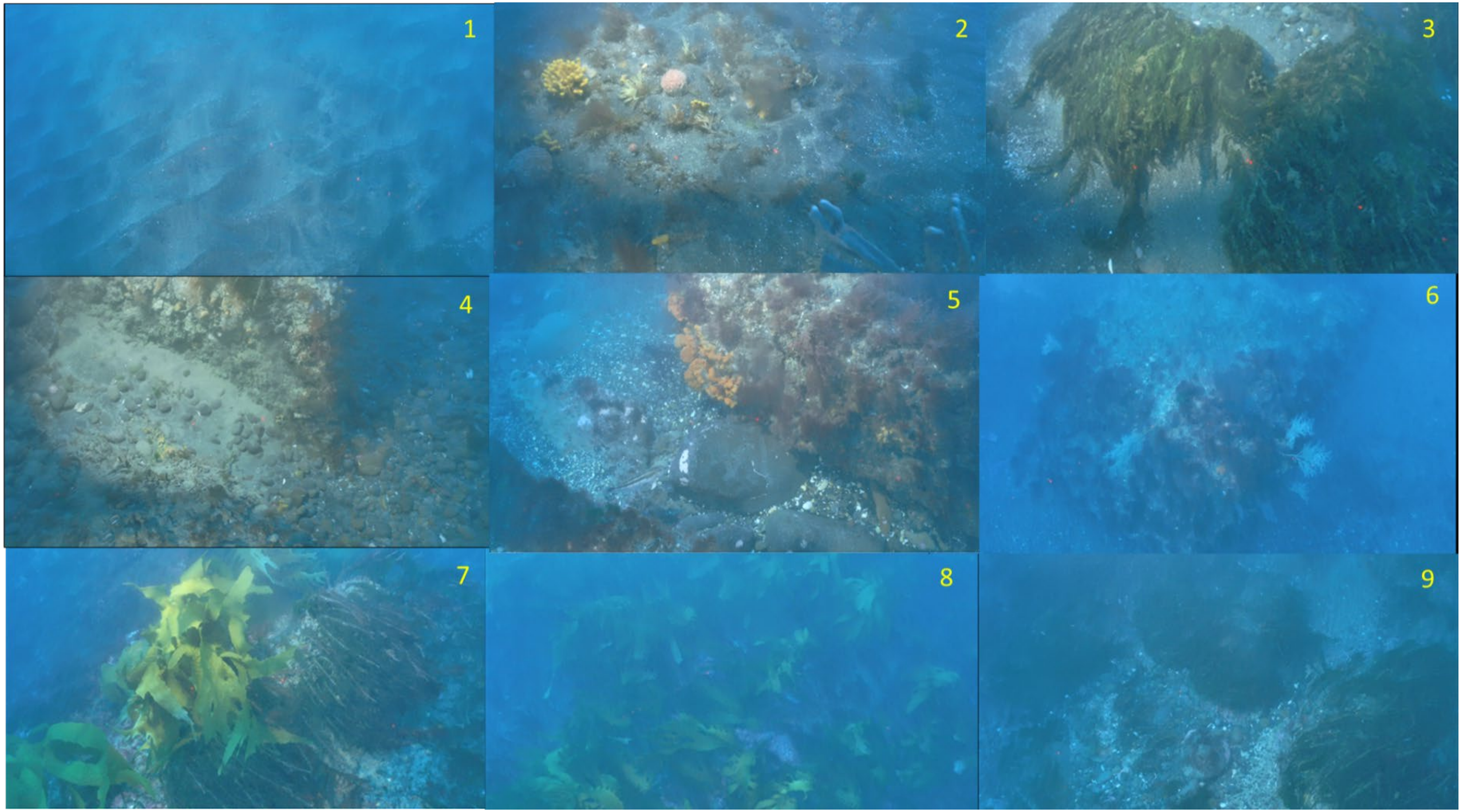


Figure 3-14: Site A seafloor images image numbers are plotted spatially in Figure 3-12 over multibeam sonar back scatter: 1) bare dark sand; 2) tells with sponges including; *R. topsenti*/*Axinella* sp. indet.; 3) *A. globosa*, *C. ramosa*) *C. flexilis* patches; 4) reef flanked by smooth grey cobbles; 5) small blue cod and sponge *C. incrustans* in mixed habitat (the small boulders may be a different rock type); 6) large rectangular reef block, with white hydroid trees (*Solanderia* sp.); 7) *Ecklonia* patch; 8) *Ecklonia* forest; 9) mixed reef and smooth grey cobbles habitat (the small boulders may be a different rock type).

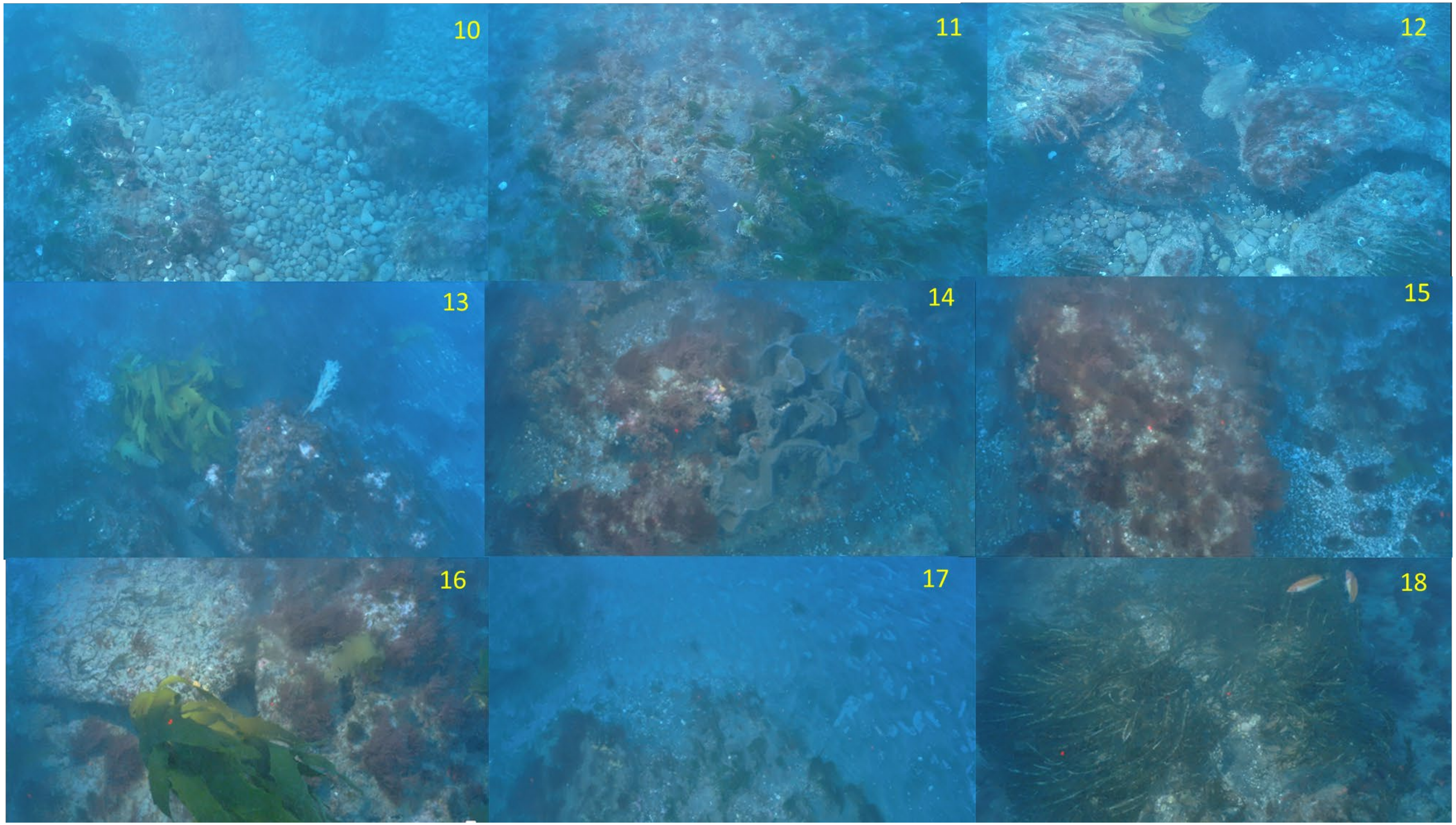


Figure 3-14: continued 10) smooth grey cobbles field; 11) flat basement reef with *C. flexilis*, off-white 'strings' are dead stolons); 12) mixed rock, smooth grey cobbles, dark sand; 13) low relied reef with *Ecklonia* patch and hydroid tree; 14) low relief reef with foliose red algae and the large grey sponge *E. alata*; 15–18); low relief reef, sediments, and bare rock class (17, thought to be mudstone/Papa rock); (18, two scarlet wrasse associated with *C. flexilis*).

3.6.2 Site B

Depth range. 21.2–25.9 metres **Reef size**: 211,957 m^2 (within overall MBES polygon)

Form. Extensive low mixed reef, cobble, and coarse sediment field, with several small rocky knolls and outcrops; adjacent to flat sand plain to the west. Figure shows the broader multibeam sonar block, which was used to calculate the area of reef.

This area was composed of a field/mosaic of low irregular basement rock, irregular cobbles, boulders, and coarse soft sediments. Occasional higher rocky knolls (3–4 metres height) were present within the field. This reef field was bordered by a flat sand plain, which also occurred occasionally inside the reef field. Additional low rocky knolls may be present within the flat sand plains, as indicated by multibeam sonar data. The dominant rock type was visually assessed as sandstone.

BTM Divisions (east to west video transect): Flat Plains (sand) → Broad slopes (sand/reef boundary) → Flat plains (low mixed reef) → Broad slopes (reef/sand/reef boundaries) → Local ridges Boulders, Pinnacles on Slopes (part of reef knoll) → Rock outcrops Highs/Narrow Ridges (reef knoll) → Broad slopes (reef/sand/reef boundaries) → Flat plains (mixed reef field) → Broad slopes → Scarp/cliff (side wall of reef knoll) → Rock outcrops Highs, narrow ridges (side of rocky knoll) → alternating Broad slopes and Flat plains → Broad depressions → alternating Broad slopes and Flat plains → some Rock Outcrop Highs, Narrow Ridges and Flat Ridge Tops towards end of transect (Figure 3-16).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-16 to Figure 3-18)

Geology: On the west side (start of video transect), a flat sand plain made an abrupt change into the reef field, associated with a bathymetry drop of 0.5–1 metres (1). This boundary drop was clearly visible in both the bathymetry and backscatter data and identified by BTM analysis as a very narrow ‘broad slopes’ feature delineating this boundary (Figure , 3-16). This BTM feature class ran as a largely continuous line north-west/south-east across the mapped block and was also visually obvious in the bathymetry and backscatter maps (Figure , 3-16). Smaller short segments of this feature class were also present both in the flat sediment plains and the rock field, suggesting smaller scale sand/reef patches in the extensive reef or sand dominated areas, respectively (Figure , 3-16). Most of the reef field transect was composed of a mosaic of flat basement reef (47.3%), mixed irregular cobbles (16.8%), low broken rock (4.4%), boulders (1.7%), and high broken rock (knolls). Several discrete rocky knolls were targeted by the transect (#950, 5–6; #982 and #1019, 10–12), which were defined by steep vertical slopes several metres high, which for the largest knoll were classed as cliff/scarp by the BTM analysis. Towards the end of the transect, further rock outcrops were identified by BTM, although they were just missed by the towed video/ not readily apparent in video footage.

Biogenic habitats: The bare sand plain habitat was devoid of fish, epifauna, and epifauna; this absence was consistent each time the transect passed over open sand habitat (Figure 3-16, 3-17). The mixed reef field was dominated by red filamentous algae (2–4,7,9,17), which covered 34% of the seafloor overall, (ranging up to >60% cover, depending on substrate). Within this dominant overall biogenic habitat were small patches of sponges, usually associated with small outcrops of basement reef (2,3,15), as well as occurring as solitary sponge individuals (16,17) (2.9% sponge cover overall).

The rocky knolls were in contrast dominated by relatively high sponge cover (5,6,10,11), especially of the grey sponges *E. alata* and *S. conulosa*, through the percent cover of red filamentous algae was also high. Several crayfish (*J. edwardsii*) were also seen sheltering under sponges on one of the rocky knolls (5, 6)

Main invertebrate species: The dominant taxa were the sponges Family Chondropsidae species 2, *R. topsenti*/*Axinella* sp. indet., *C. incrustans*, *S. conulosa, E. alata* and *A. globosa*, as well as an unidentified bright orange ascidian species. Overall percent cover of sponges and other encrusting invertebrates across the reef transect was 2.94%.

Sponge richness and abundance were highest on the tells/reef patches (2) at the transect start (<#700), as well as on the eastern side (>#850) as the reef dropped in depth as an alternating dominance mix of rock and soft sediments (15–18). Sponge richness was relatively constant through the reef field, with higher abundances often associated with the rock knolls and some low reef outcrops. Kina were not seen; other mobile invertebrates were limited to several general gastropod and sea slug individuals (Table 7, Figure 3-17).

Main fish species: Butterfly perch was the dominant species present (Table 8), largely as small school/s associated with the largest rocky knoll (10,11). Sub-adult and adult blue cod were the next most common species, but 0+ juveniles were rare (two counted). Scarlett wrasses were also common and distributed across the reef field (Figure 3-17). Other fish species were uncommon and included the only copper moki (*Latridopsis forsteri*) seen during the survey.

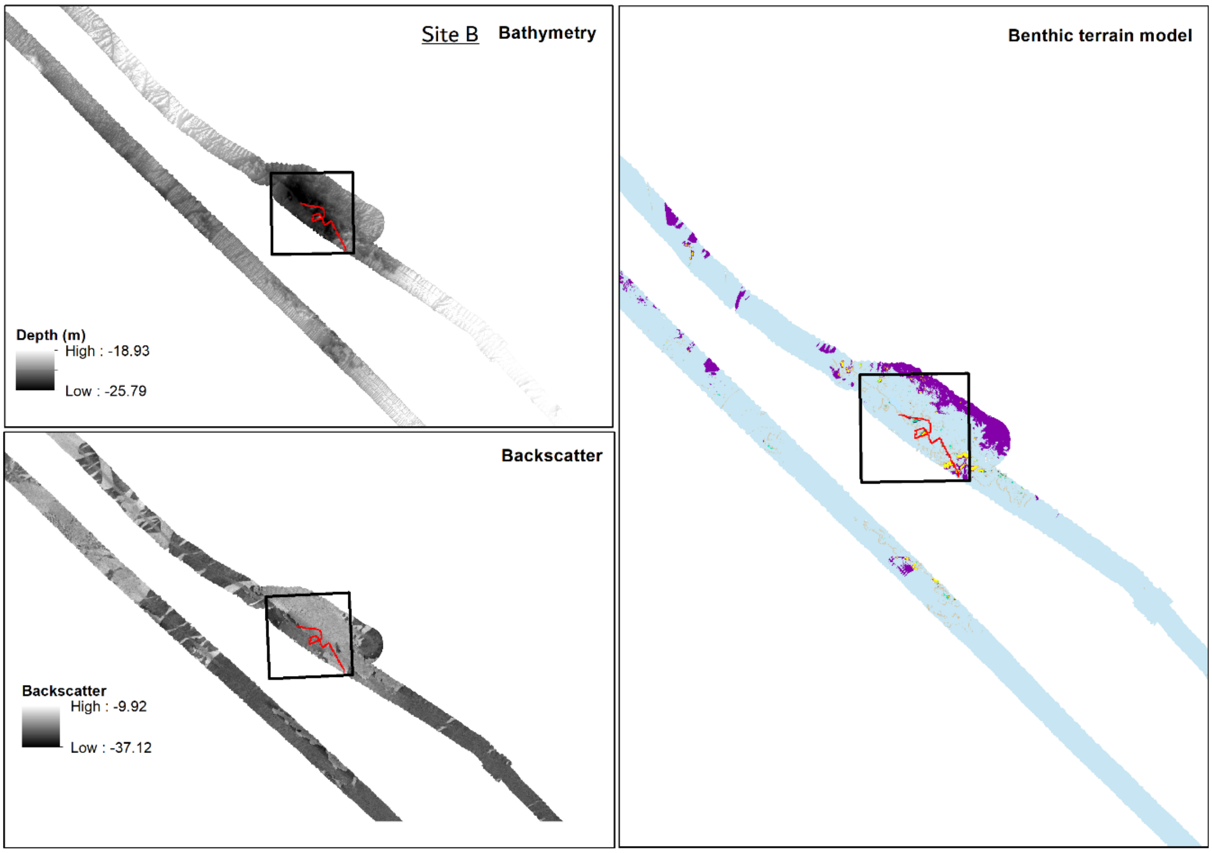


Figure 3-15: Broader extent maps of larger seafloor area mapped around site B upper left) multibeam sonar bathymetry; bottom left) multibeam sonar backscatter; right) BTM model classes.

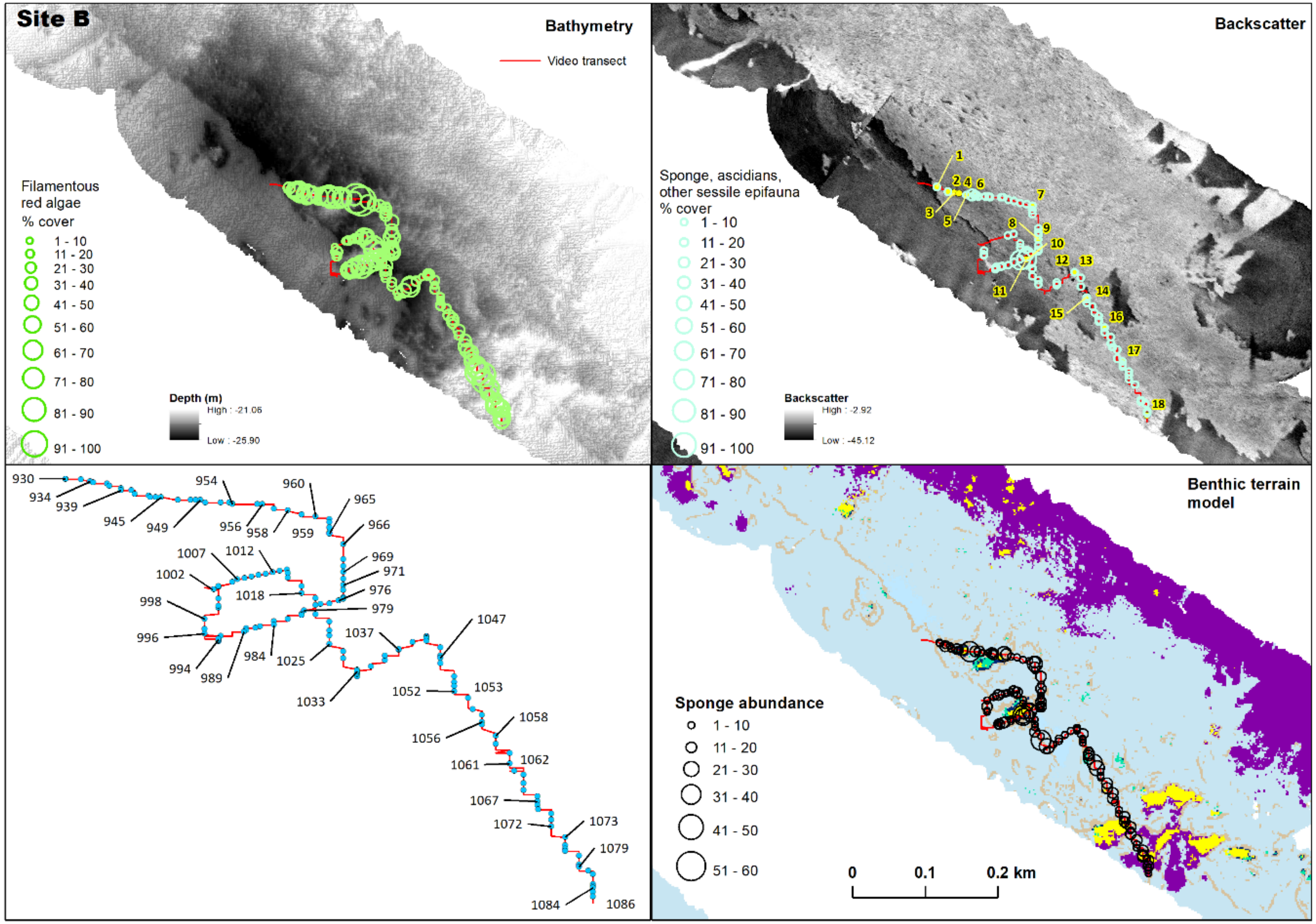


Figure 3-16: Maps of site B. Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment). Note that the reef knoll features are obscured by the bubble plots; refer to Figure 3-15).

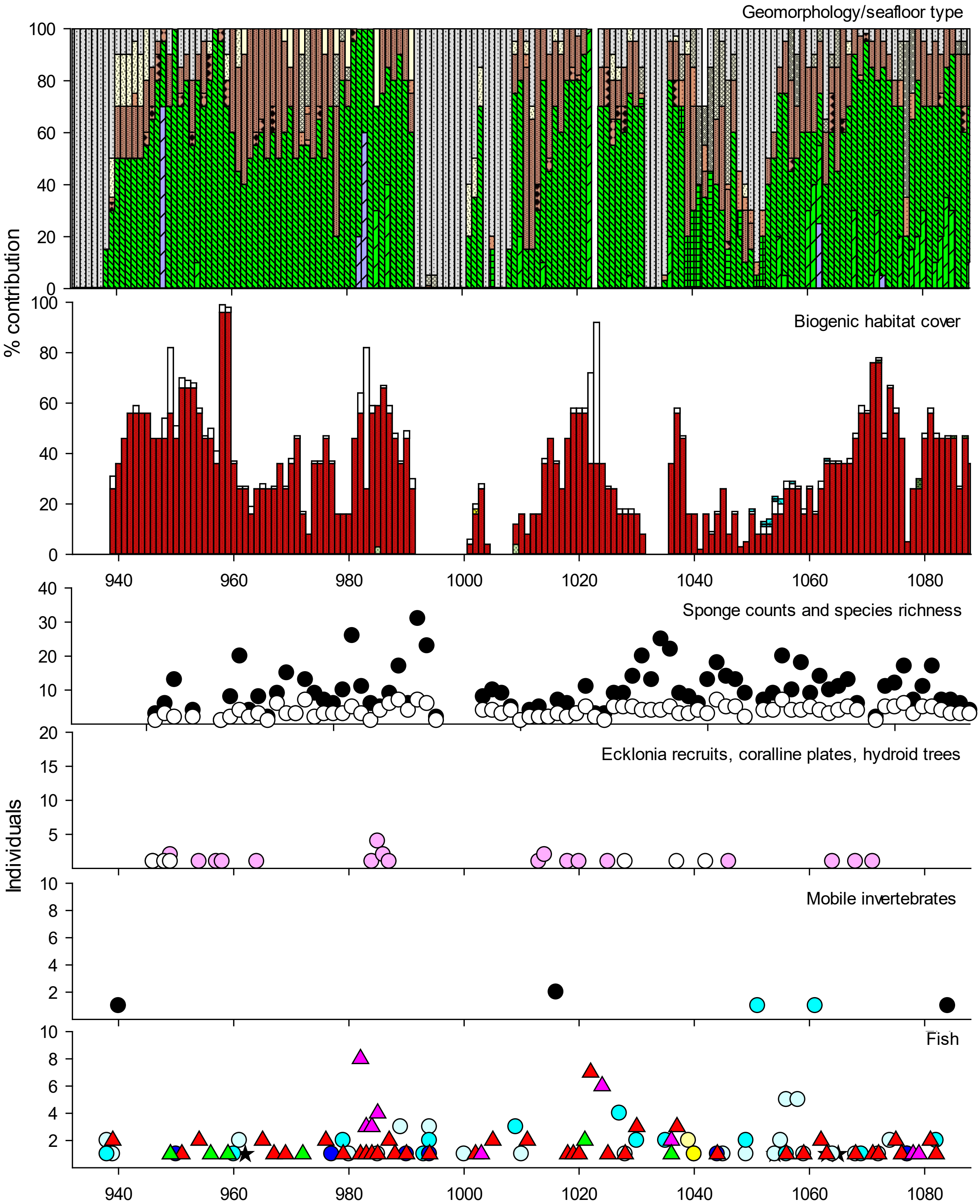


Figure 3-17: Site B CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish.Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-16

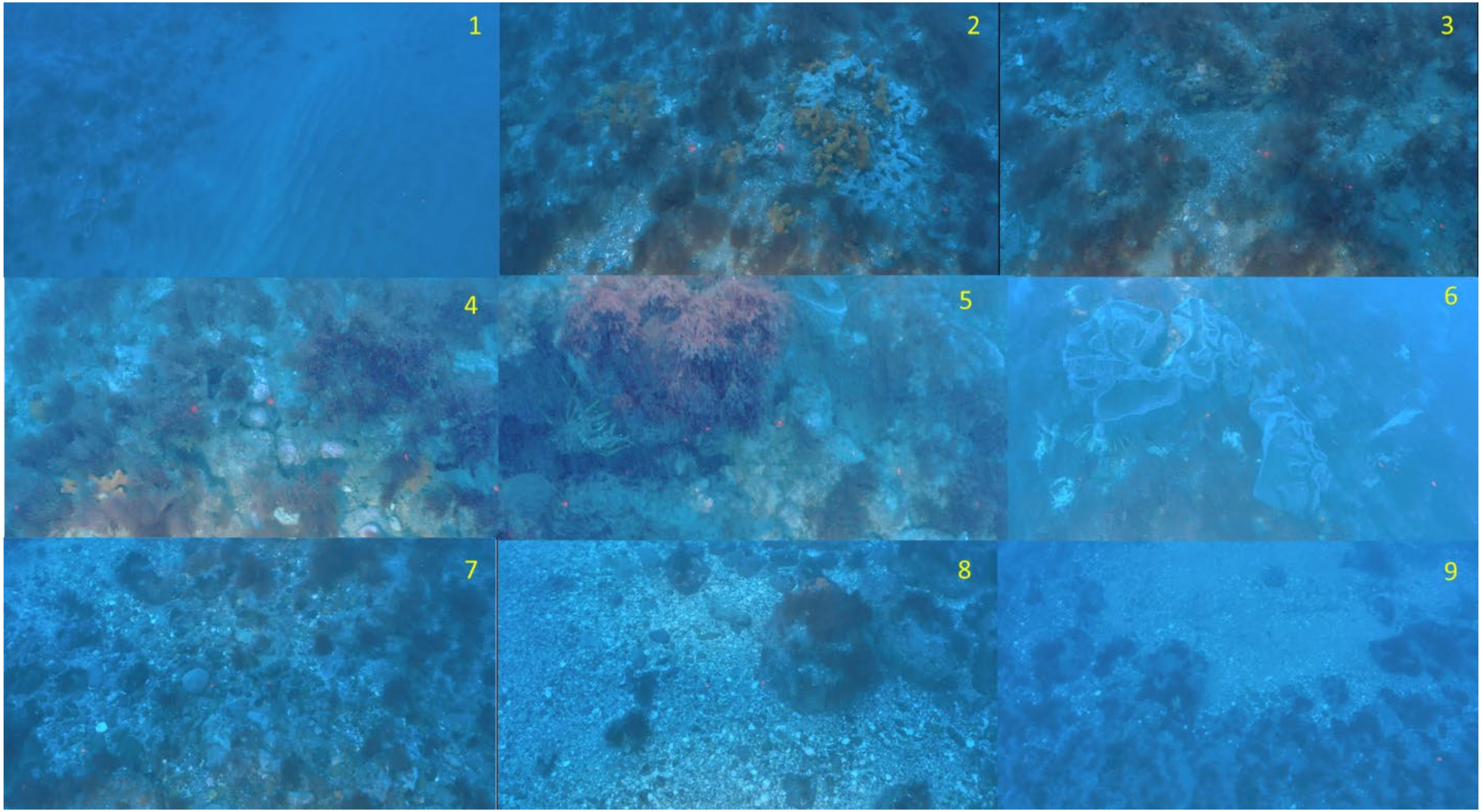


Figure 3-18: Site B seafloor images image numbers are plotted spatially in Figure 3-16 over multibeam sonar back scatter: 1) flat sand plain/reef field boundary; 2–4) low rock field, with sponges Family Chondropsidae species 2 (grey), and *C. incrustans* (orange); 5) crayfish associated with small reef knoll; 6) crayfish and grey sponge *E. alata* on small knoll; 7–9) reef field mixed substrates.

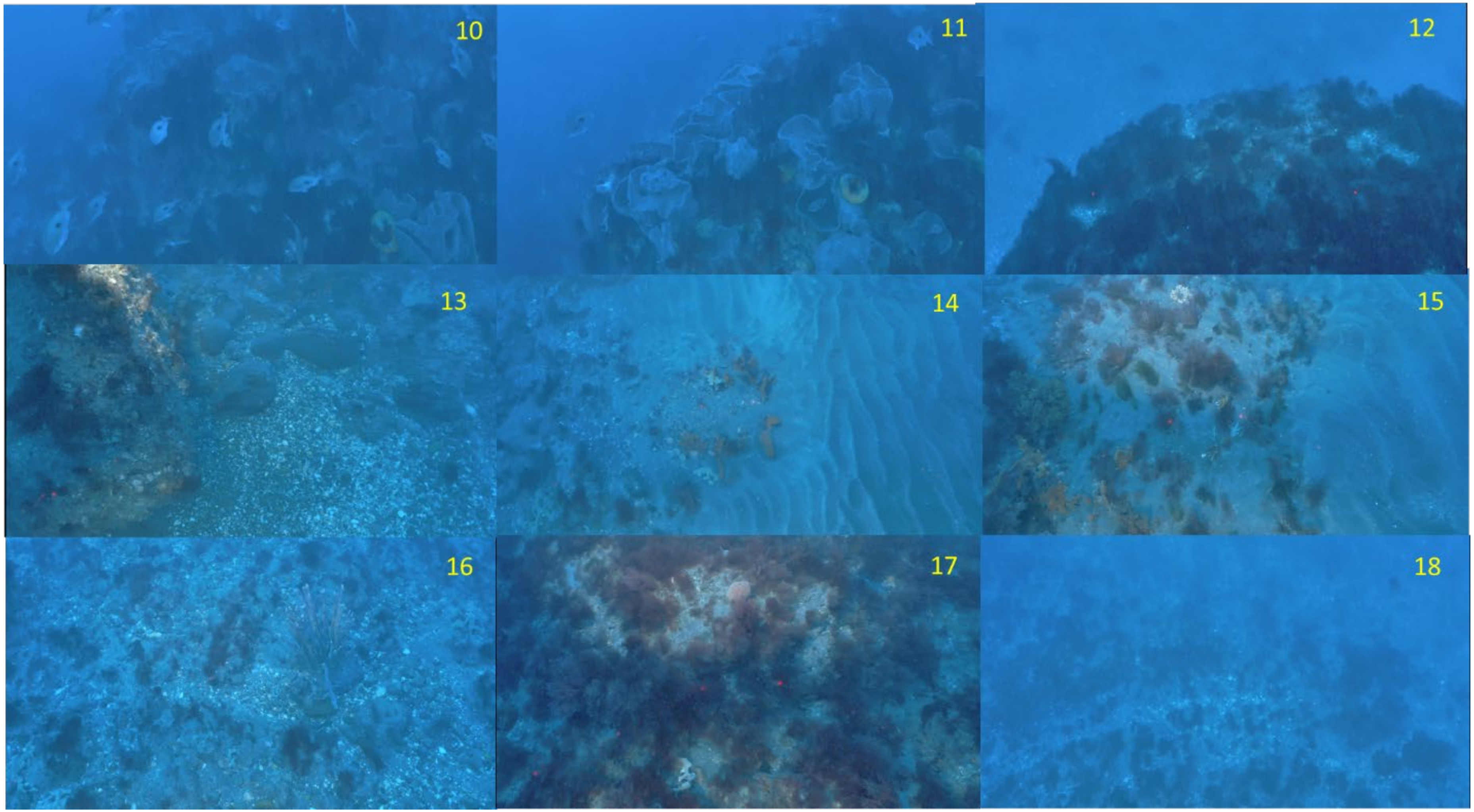


Figure 3-18: continued 10–11) butterfly perch sponges on the edges of the largest reef knoll); 12) drop-off of smaller rock knoll, 13) boulder patch (note the rock type may not be sandstone), 14–15) sand/reef boundaries, within the wider reef field; 16–18) reef field general views.

3.6.3 Site Papa

Depth range. 21.7–23.5 metres **Reef size**: Site mostly falls outside MBES mapped area

Form. Sparse patches of papa mudstone forming broken slabs/boulder piles and low basement outcrops, surrounded by flat sand plain. Some patches of flat grey tell partially covered by sand.

This unplanned site was added to cover a new reef and rock type (mudstone/Papa rock) discovered by local divers just prior to the survey. The site fell just north of one of the multibeam sonar lines, and has no underlying multibeam data, apart from the end where it extended into the mapped area. The looping nature of the transect was a result of trying to follow the reef features as they were encountered – which appeared to be very patchy and non-continuous.

This area was composed of an overall background of dark sand plain (1,6,7), with occasional low piles of broken boulders/slabs (4,5), low emerging basement terraces (3,8,9), occasional boulders (7), and tells (1) partially covered by sand. These reef features occurred both on their own, and in association with each other (2,3).

BTM Divisions (north–south along video transect): Most of the transect fell outside the BTM coverage. Towards the end of the transect where data were available, the pattern was: Broad depressions (sand) → Flat Ridge Top (flat basement rock) (Figure 3-19).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-19 to Figure 3-21)

Geology: Overall, this site was dominated by flat dark sand plain, within which sat scattered reef extents of broken boulders/slabs, low terrace, and occasional boulders. The rock type appeared to be papa mudstone, which was very bio-eroded (pitted surfaces with many tunnels/holes present). Low terraces (estimated 10–40 cm high) emerged at some spots, flanked by sands on either side (3,8), as well as standing clear as low outcrops (2,9). Piles of broken rock boulders were also seen (4,5), which are interpreted as low terraces breaking away under their own weight after being exposed by swell action over time (see site D for a much clearer example, where they form massive slabs). The occasional bare raw rock patches observed (1) were identical to those seen at site A, 12.5 kilometres to the north-west.

Biogenic habitats: The bare sand plain habitat was devoid of visually-obvious fish, epifauna, and epiflora. The papa rock was largely devoid of associated biogenic habitat-forming fauna and flora, aside from a few small patches of red filamentous algae and encrusting sponge/ascidian species (each contributing 0.01% cover) (Table 6). *E. radiata* and *Caulerpa* species were completely absent. The numerous burrows and holes evident in the rock suggest a richer reef infauna, probably including rock boring bivalves such as piddocks (Family Pholadidae), but the video resolution was not able to resolve any potential contributing species.

Main invertebrate species: The dominant taxa was the low encrusting sponge Family Chondropsidae species 2., which was present on some of the low terrace and boulder features (7,9) (Table 7, Figure 3-21). The few other sponge species occasionally present were also largely low encrusting/rock boring forms. The unidentified bright orange ascidian, and the low straggly ascidian *Didemnum* sp. indet., were also present in low numbers. Mobile marine invertebrates were rare, with four individual sea-slugs (*A*. *luctuosa*) and four gastropods seen (Table 7,Figure 3-21).

Main fish species: Blue cod were relatively common in association with the low reef features, with fish of all sizes present including some 0+ juveniles (Table 8, Figure 3-20). Scarlet wrasse were also present in low numbers (13 seen), along with a solitary goatfish.

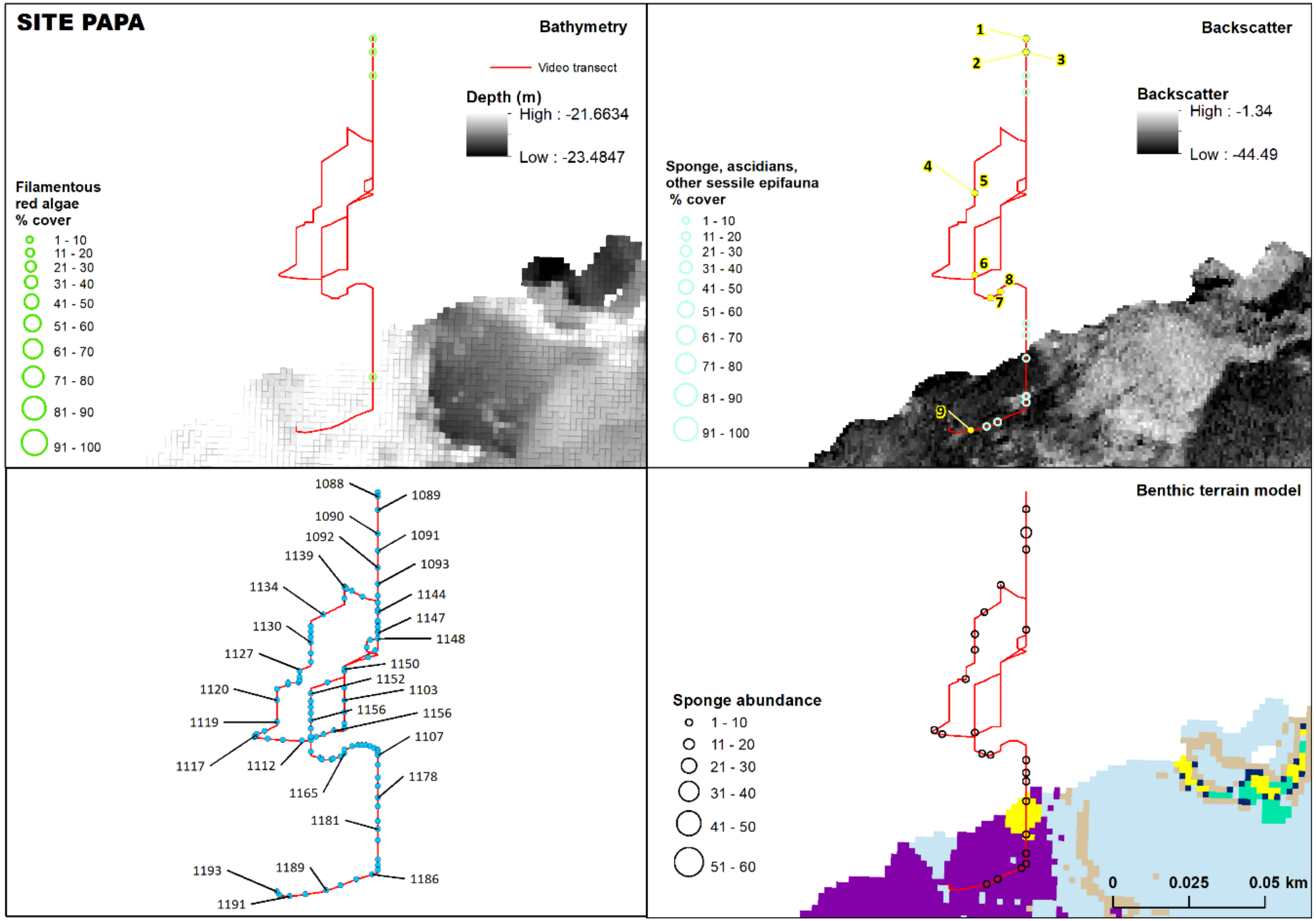


Figure 3-19: Maps of site Papa Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers (absent); top right) multibeam beam backscatter and 'Sponge, ascidians, other sessile epifauna' %covers (*C. flexilis* absent); lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

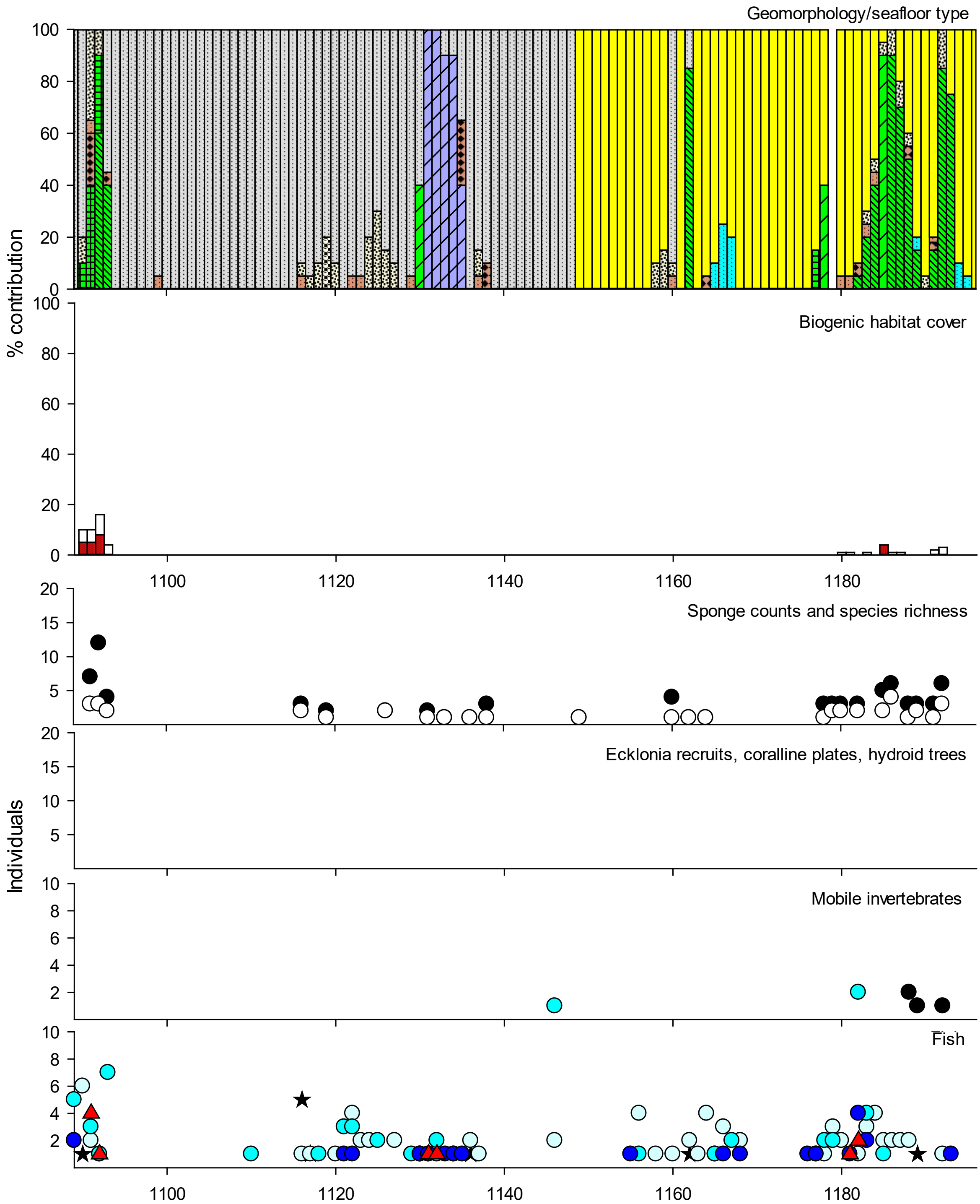


Figure 3-20: Site Papa CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish.Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-19.

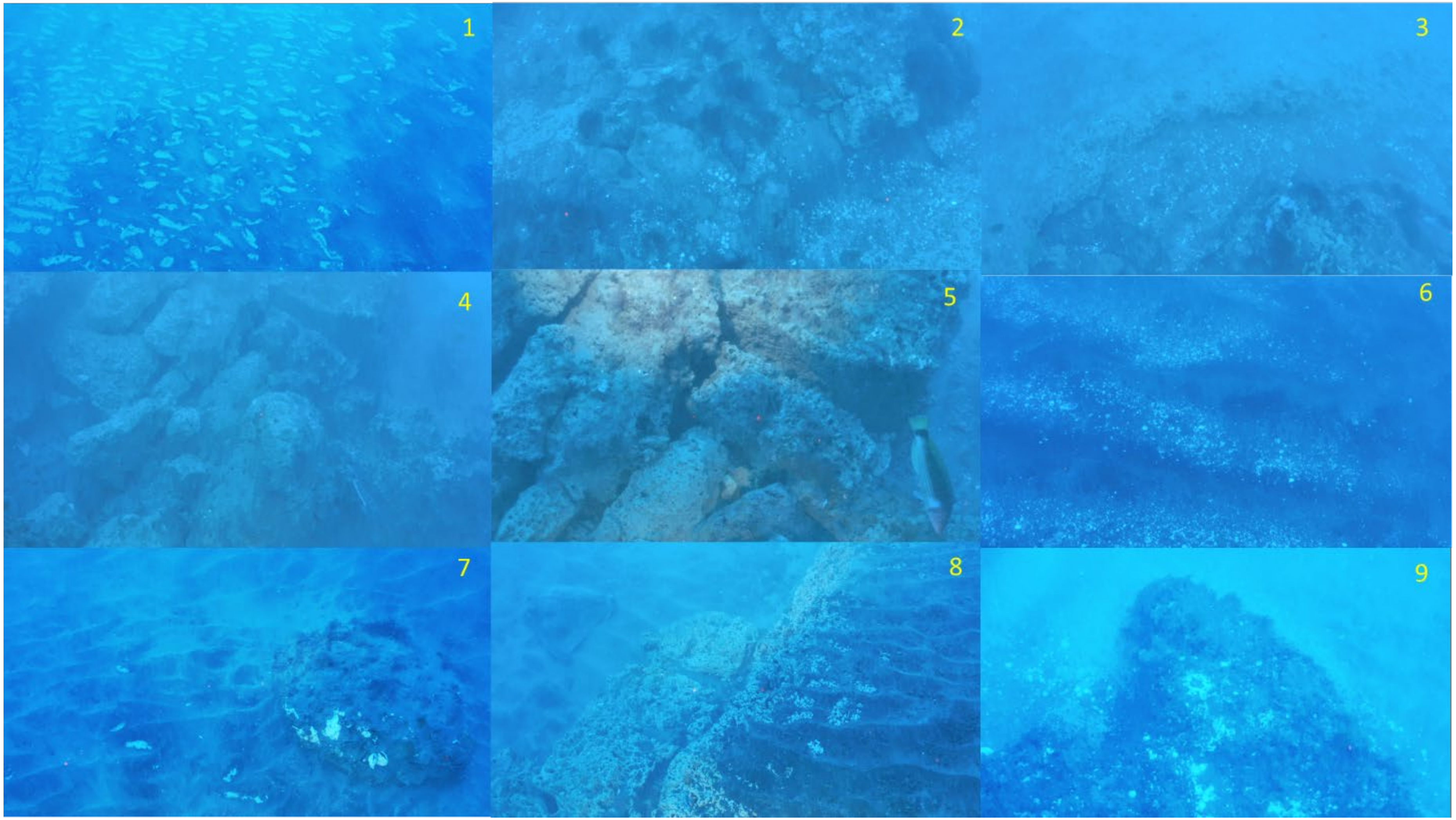


Figure 3-21: Site Papa seafloor images image numbers are plotted spatially in Figure 3-19 over multibeam sonar back scatter: 1) bare mudstone/Papa rock overlain with dark sands; 2) low outcrop; 3) low terrace (left) and boulder (right); 4–5) boulder piles with blue cod (4) and scarlet wrasse (5); 6) dark sand; 7) boulder with the ascidian *Didemnum* sp. Indet.; 8–9) low terraces (with an eagle ray in 8).

3.6.4 Site D

Depth range. 22.3–28 metres

Reef size: 399,750 m^2 within overall MBES polygon (excludes additional western structure/s)

Form. A long, largely continuous north-south reef terrace drop (scarp), running 3.45 km along its main axis (Figure 3-22). Includes several lesser terraces in some sections, a small eastern extension in the middle, and several incised 'bays' at its southern end. The main terrace wall ranged from 2 to 3 metres high, often with large broken sandstone slabs at the wall base. The terrace rock flats were narrow, and surrounded/overlain by soft sediments (sand, shell).

This area was composed of a rock type that looked soft, heavily bio-eroded, and which was visually identified as mudstone/Papa rock. It may be the same rock type as at Site Papa but appears to be less eroded. One possibility is that the rock has been exposed to the water column for a lesser time than site Papa.

BTM Divisions (north south along video transect): Set within a background of Flat Plains (sand, shell), the terrace drop was classified as Broad slopes for much of its length, along with components of Local Ridges, Boulders, Pinnacles on slopes, and Scarp/Cliff. The terrace proper was classed as Rock Outcrop Highs, Narrow Ridges, flanked by Flat Ridge Tops. In some sections, only the Flat Plains → Flat Ridge Tops transition was present. Some very limited areas of Broad Depressions occurred adjacent to the Broad Slopes component of the terrace wall (Figure , Figure 3-23).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-23 to Figure 3-25)

Geology: The video transect traversed both sides of the eastern reef extension mid-way down the overall terrace feature (Figure 3-23). Starting on a mixed sand and shell rippled seafloor (1), the reef first appeared as a series of low terraces surrounded by soft sediments (2,3) with low and wide stepped platforms apparent at some sections (4,5). Occasional fine scale structure was embedded in the rock, which might be indicative of fossils/or some past differential erosion process (5). The rock surfaces appeared quite bio-eroded and 'knobbled' in general. The terrace drop itself was first encountered as an undercut low wall (8) at the very narrow end of the eastern terrace extension. The transect then passed over a narrow (at this location) terrace top, then fell away to soft sediment again less than 10 metres on (9). The transect then followed along the terrace edge, revealing a vertical wall drop, flanked by large broken rock slabs (9–12). A number of these slabs appeared to be recently exposed, with smooth clear surfaces (10–12); as opposed to others that were pitted with bio-erosion and supported sponges (10–11). We suggest that this represents an actively eroding wall feature, where the wall is slowly undercut by swell and soft sediment erosion, and the low strength mudstone then collapses to form large heavy slabs. The overall terrace feature could be slowly eroding over time.

Further low terrace/step platforms re-appeared (13,14) later in the transect, as well as very occasional small patches of 'assembled' cobbles (15), possibly sourced from elsewhere through storm transport. The transect then moved onto bare dark sands (16) and shell gravel seafloor, with occasional very limited tells of darker rock. At the very end of the transect, the main terrace wall was again encountered (18).

Biogenic habitats: The bare sand/shell plain habitat was devoid of visually-obvious fish and invertebrate species, and this absence was consistent each time the transect crossed into bare sand habitat (Figure 3-23, Figure 3-24). The exception to this was the presence of small patches of green-lipped mussels (*Perna canaliculus*) (17), associated with some of the rock tells (<1 m^2 in size) seen in the second half of the transect, away from the terraces. These were very difficult to visually quantify from video, and so were not scored as biogenic habitat. However, these mussel beds were observed with close inspection of screen-grabs taken from video. Several small patches were also seen on the terrace reef itself (lower left, image 6, 'invisible' at the image scale shown), although the video resolution allowed for a putative species assignment only.

The terrace itself held a variable, low cover assemblage of sponges and other sessile species, most with low or rock-boring morphologies and covered 2.2% of the reef area (Tables 6, 7). Attached *E. radiata* was absent but a few drift plants were observed around the sandstone slabs. A few green/brown shrubby algae were seen (Figure 3-23) suggesting light levels were sufficient for macroalgal growth. The numerous burrows and holes evident in the rock suggested a possibly richer reef infauna, but the video resolution was not able to resolve any potential contributing species.

Main invertebrate species: The dominant taxa was the low encrusting sponge Family Chondropsidae species 2, followed by a yellow, rock-boring unidentified sponge species (order Haplosclerida/Poecilosclerida), the yellow foamy low sponge *D. oxeata*, the bright yellow *C. polymastia*, and the orange/grey multi-stalked sponge *R. topsenti*/*Axinella* sp. indet. (Table 7). The low straggly/broken-form ascidian *Didemnum* sp. indet. was also frequently observed (uncommon at other reef sites). Sponge and ascidians covered 2.23% of the (rock-associated) 20-second video segments. Mobile marine invertebrates were uncommon, except for the sea slug *A*. *luctuosa*, with 19 individuals counted, often in association with the sponge Family Chondropsidae species 2., on which they graze, and lay egg masses (there is a sea-slug cluster in the upper left of image 6). Four Cooks Turban (*C*. *sulcata*) and two other gastropods were also seen (one of which may have been a *Maurea* sp., also associated with a sponge) (Table 7). Kina were not observed.

Main fish species: Fish life was concentrated along the terrace wall and over and around the large sandstone slabs (Figure 3-24). Blue cod were relatively common around the reef features, with all size/age classes present, including 0+ juveniles (18% of the 218 individuals counted, Table 8). Leatherjackets (including juveniles), scarlet wrasse and butterfly perch were also present. Tarakihi were also seen, including the two smallest individuals seen across the survey (10–20 cm length). One common roughy (*Paratrachichthys trailli*) was counted. This is a nocturnally foraging zooplanktivore species and more fish may have been sheltering under the terrace wall and sandstone slabs (and possibility also other species such as slender roughy, which have been observed at the Project Reef (site K)).

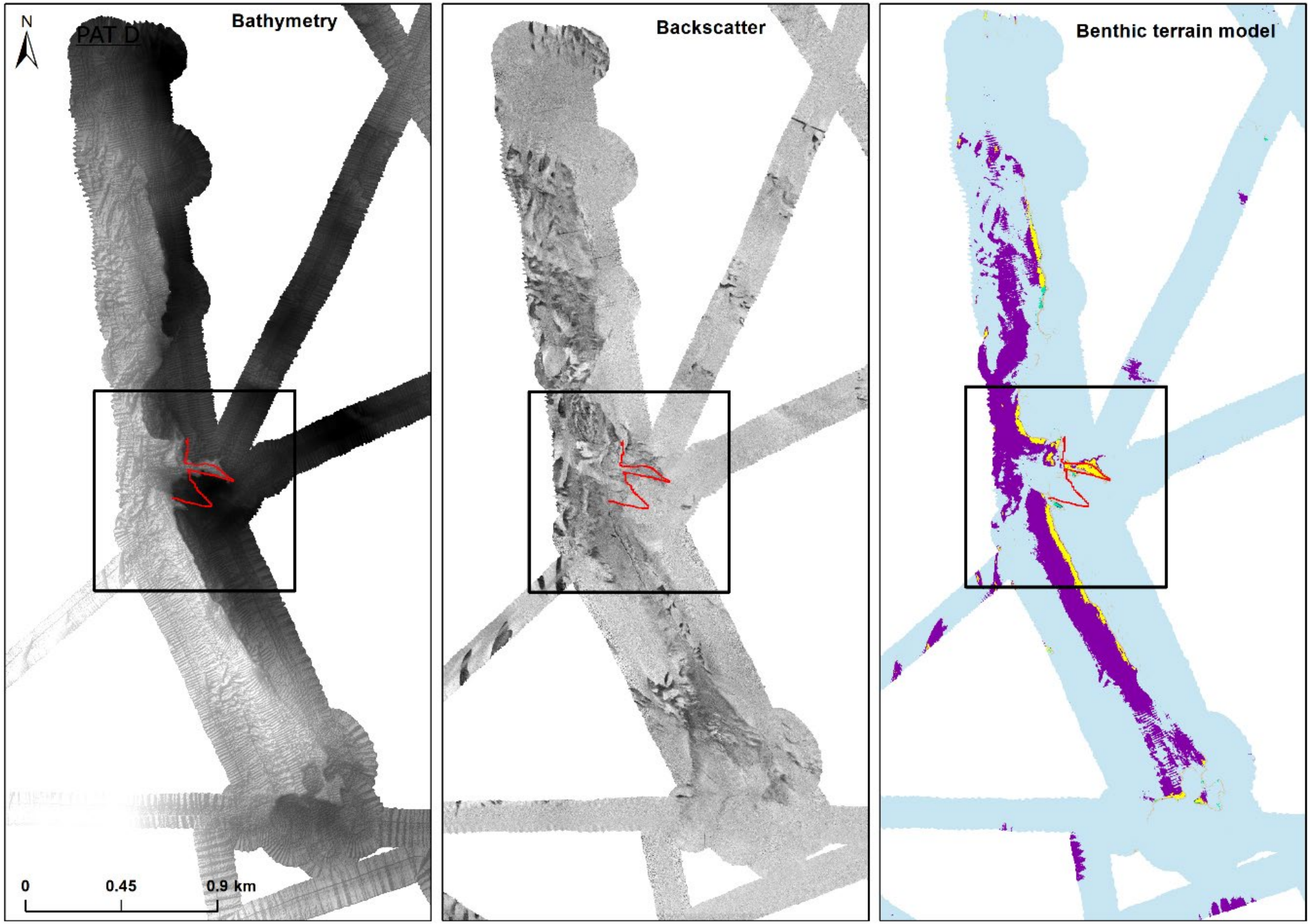


Figure 3-22: Broader extent maps of larger seafloor area mapped (a 3.5 km long terrace) around site D.

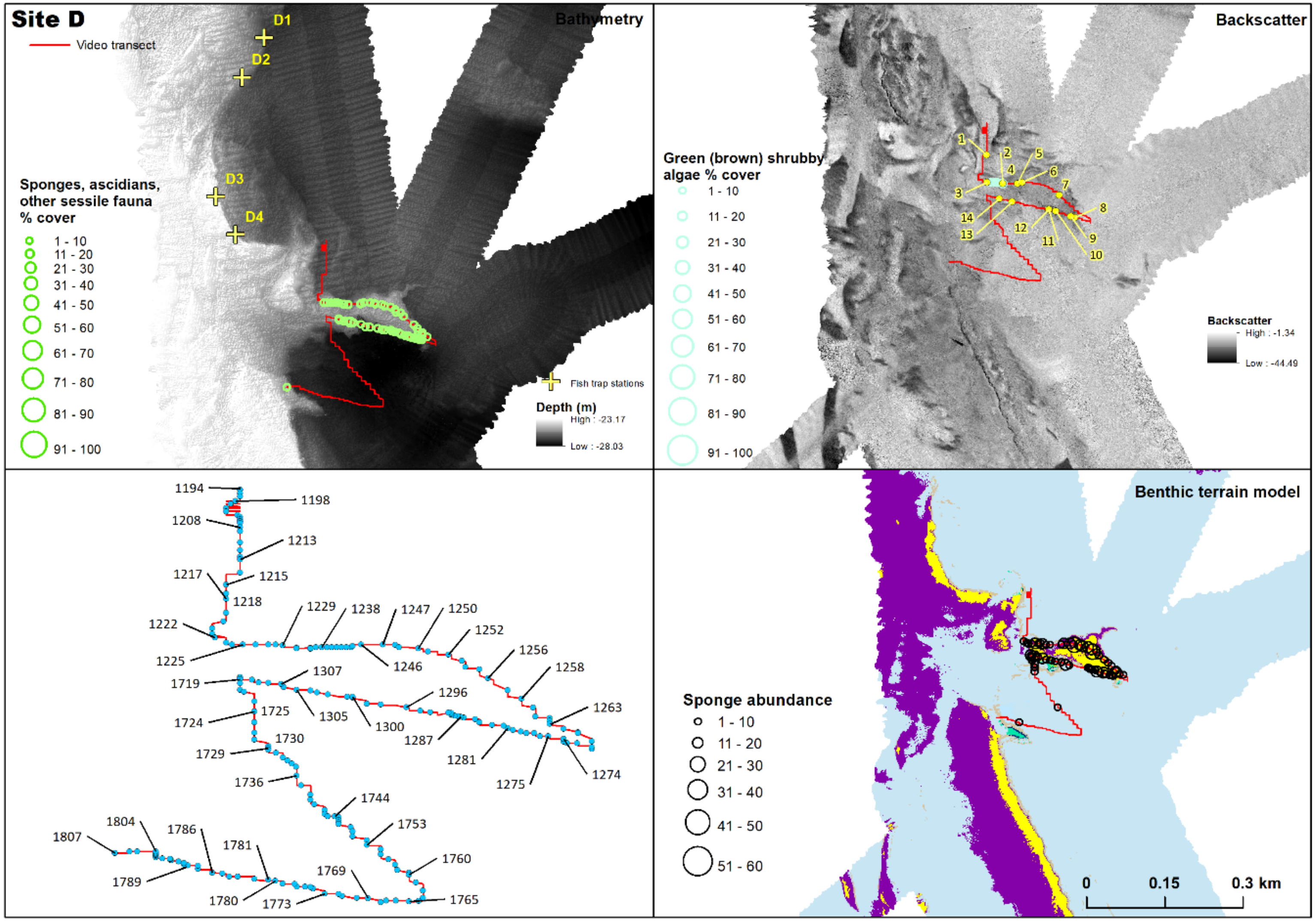


Figure 3-23: Maps of site D Top left) multibeam sonar bathymetry and sponge %cover (*E. radiata* kelp completely absent); top right) multibeam beam backscatter and brown shrubby algae cover (*C. flexilis* completely absent) %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

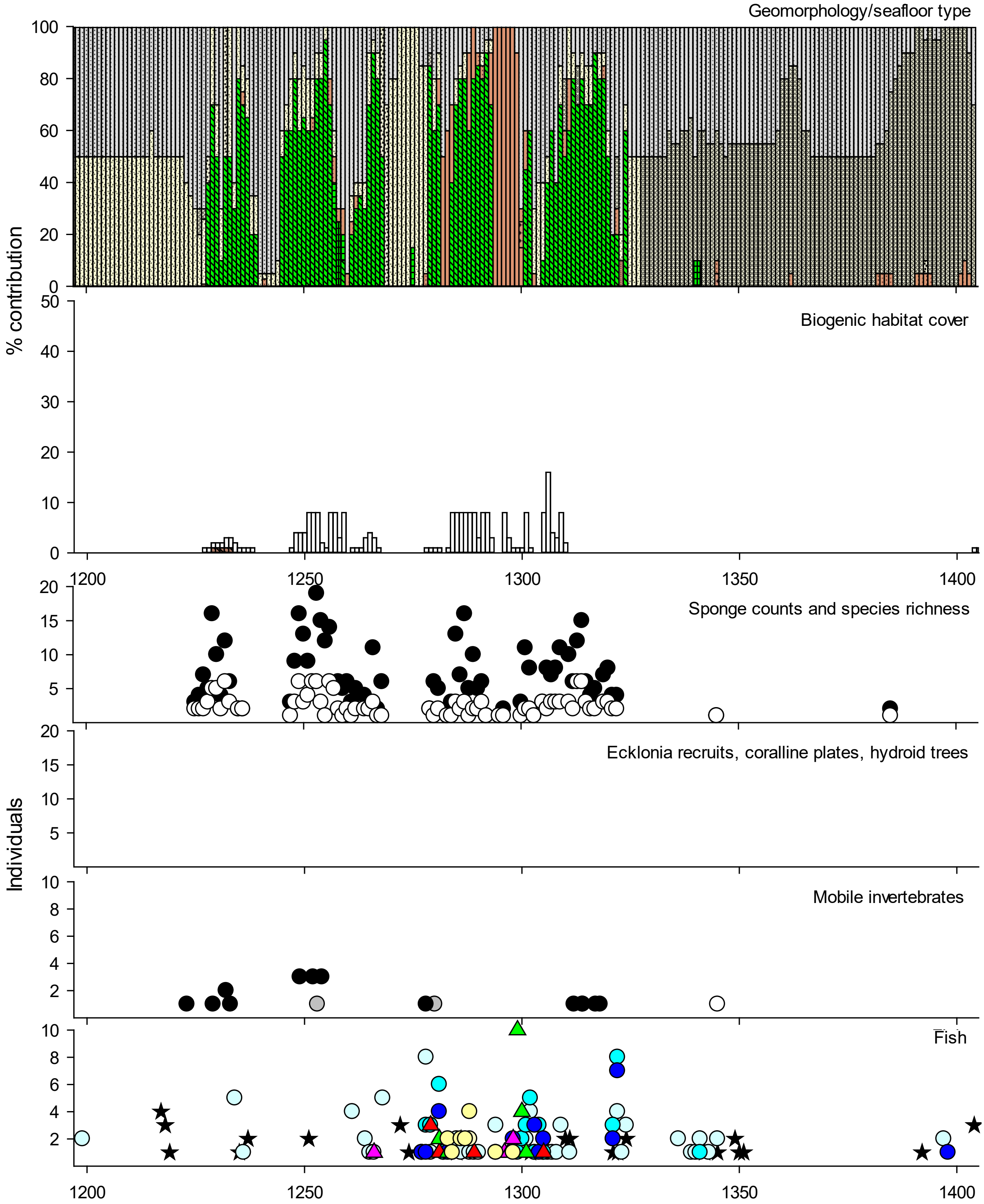


Figure 3-24: Site D CoastCam data: geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-23.

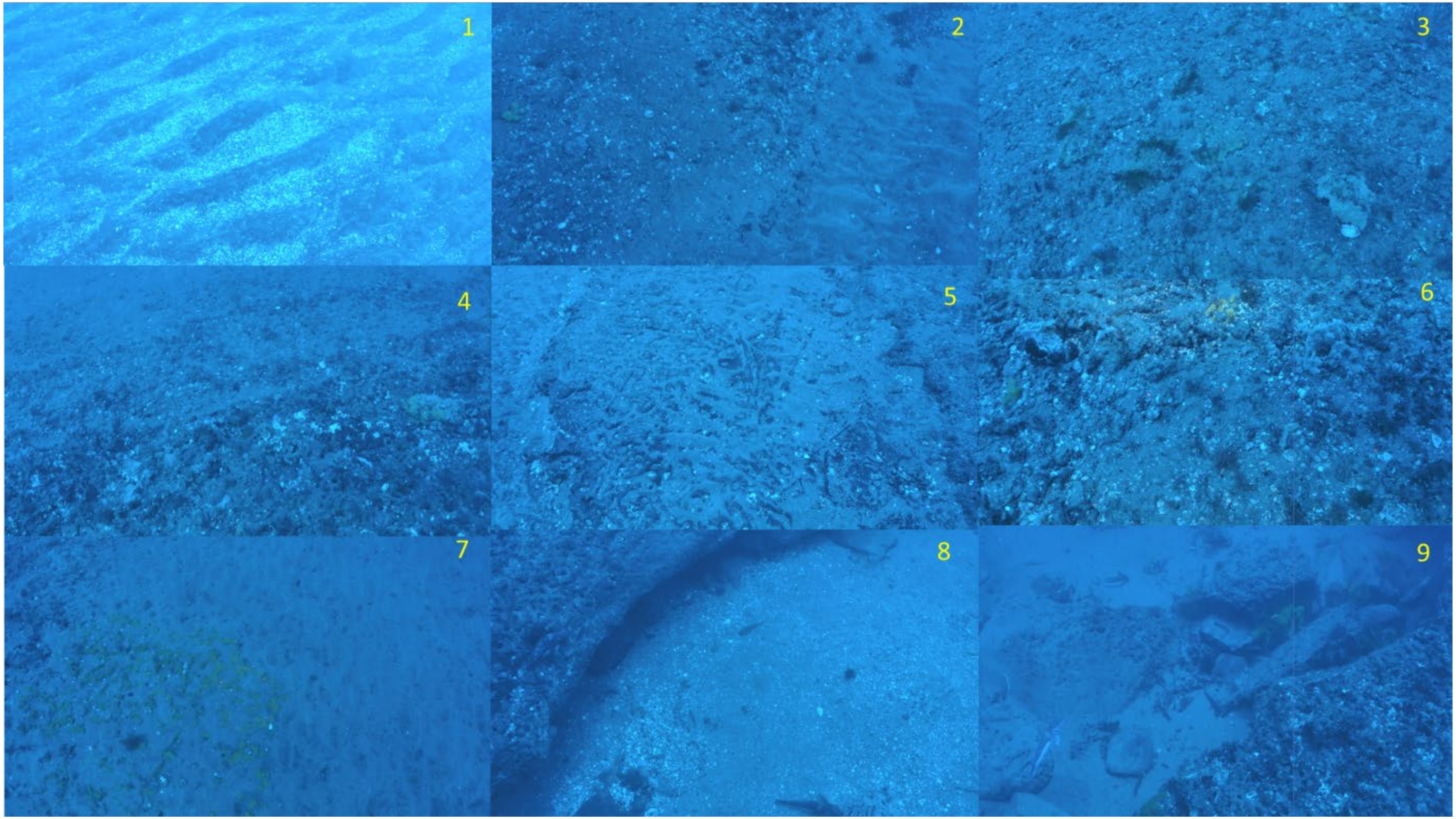


Figure 3-25: Site D seafloor images image numbers are plotted spatially in Figure 3-23 over multibeam sonar back scatter: 1) bare sediments; 2–3) low flat terrace; 4) multiple low stepped terraces dropping away from the camera; 5) terrace rock with embedded linear stick-like features (slightly embossed); 6) terrace rock; 7) terrace rock overlain with sediment; 8) low terrace drop at end of eastern extension; 9) looking down from the terrace onto large rock slabs adjacent to main terrace drop, and blue cod.

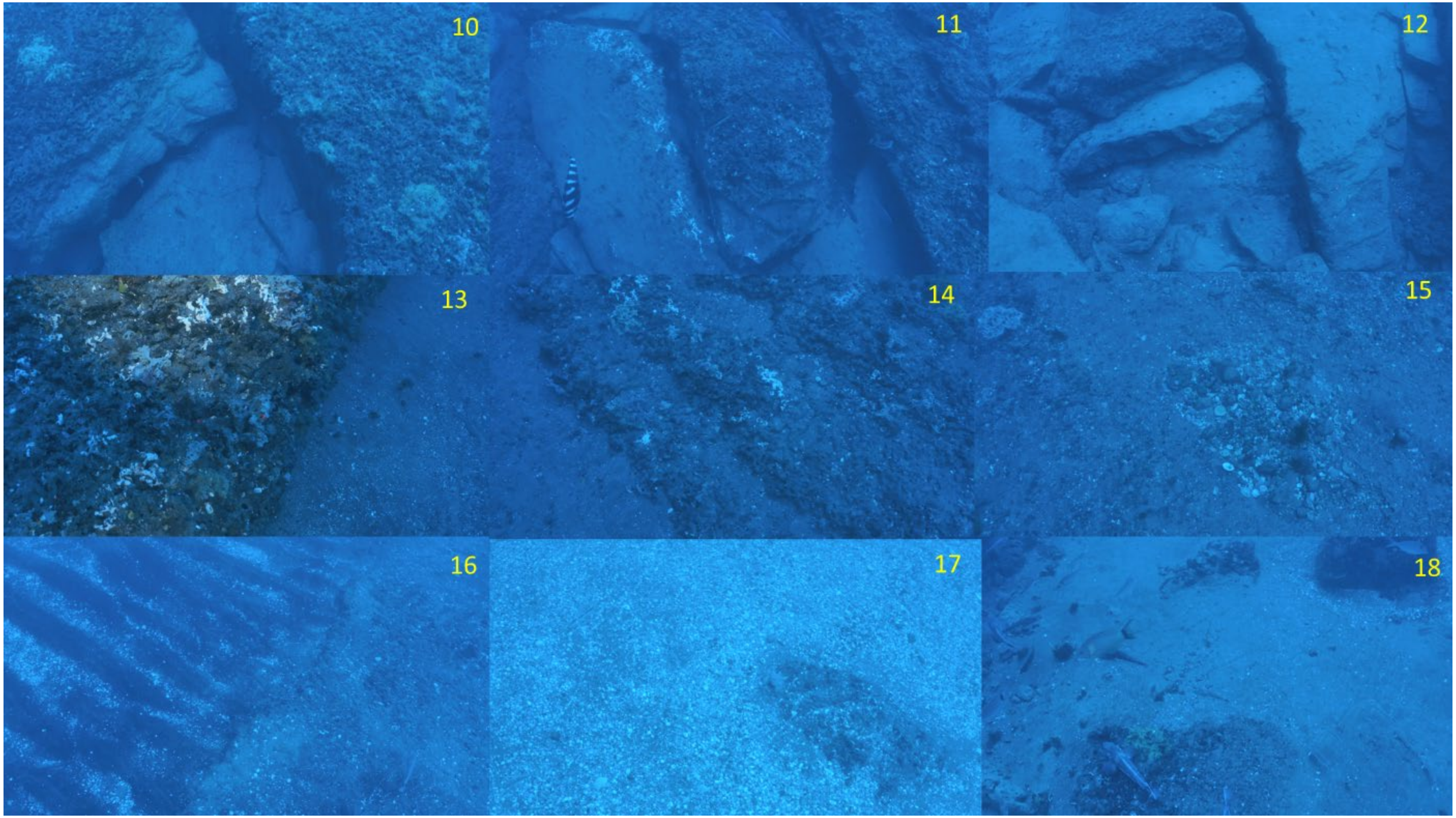


Figure 3-25: Continued 10–12) large rock slabs adjacent to terrace scarp (right side of image for 10–11; just off right of image for 12), and red moki (11); 13–14) higher cover epifauna areas on rock terrace/s; 15) cobble pocket; 16) dark sand; 17) small rock tell with attached, green-lipped mussel patches; 18) end of transect just adjacent to main terrace (just out of shot to left) with blue cod, scarlet wrasse, and tarakihi.

3.6.5 Site J

Depth range. 18.4–24.1 metres **Reef size**: 38,990 m^2

Form. Low broken ridge composed of low broken rock and irregular mixed cobbles. Part of much larger ridge reef complex that extends for 2.3 km (possibly even 4.6 km) (Figure 3-26).

This site crossed a small, low broken ridge feature, that extended for around 500 metres in a north-west/south-east orientation. It is part of a larger ridge feature, with a horizontal shear displacement of 80 metres between Site J and an adjacent larger ridge area to the north-west, strongly suggesting a geological fault. The two areas combined created a low ridge that is about 2.3 km long. Further exposed ridges occurred in the same orientation to the north-west; these may be separate ridge features, or part of the same overall feature (overall distance of 4.6 km) (Figure , Figure 3-27).

BTM Divisions (west to east along video transect): Flat Ridge Tops (sand) → Flat Plains → Broad slopes (1 pixel wide) → Rock Outcrop Highs, Narrow Ridges → Flat Ridge Tops → Broad slopes (1 pixel) → Flat Plains (Figure 3-27).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-27 to Figure 3-29)

Geology. The reef was composed of a rock type that appeared hard but amenable to erosion (3,4), that was assumed to be the same sandstone as site A. Other rock types may also be present (8). The ridge feature itself was narrow and broken, with a limited low broken rock contribution, overlain/dominated by a cover of irregular mixed cobbles (2–5) (Table 4, Figure 3-27). To the west, the broken rock was replaced by a mosaic of dark sand and irregular mixed cobbles dominated (6–8), with occasional low patch reef (9) and tells (not mudstone/Papa rock). Some flat basement reef was present at the end of the transect. To the east, the reef ridge was replaced by dark sand seafloor (1)

Biogenic habitats: On the east side of the ridge feature (<#1841), the bare sand/shell plain habitat was visually devoid of fish, epifauna, and epiflora. At the sand/reef ridge boundary, there was a narrow zone (about 9 m width) of relatively high cover (15.5%) of sponges, ascidians, and other sessile species (segment #1841, part of segment #1842). On the rest of the reef, this biogenic habitat class covered just 0.79% (Table 6, Figure 3-28) and was replaced with a mixed biogenic habitat of green (brown) shrubby macroalgae, green filamentous algae, and *C. geminata* patches (respectively 2.58, 2.92, and 0.11% cover). This biogenic habitat mix was associated with the ridge proper (~15% local cover) and was replaced with green filamentous algae cover once the ridge ended (#1851) and the substrate changed to a mixture of irregular cobbles and dark sand seafloor. This three-class biogenic habitat mix appeared again (in lesser cover) to the west, where low patch reef and irregular cobbles dominated. Yellow blade algae (0.20% cover) and filamentous red algae (0.05% cover) were also occasionally present.

E. radiata (kelp) occurred only as intermittent single plants (0.02% cover) and was limited to two 20-second video segments just west of the ridge proper (Figure 3-27).

Main invertebrate species: Sponges were the most common sessile invertebrates, dominated by Family Chondropsidae species 2, *C. incrustans, A. globosa, S. conulosa,* and *R. topsenti/Axinella* sp. indet. Ascidians were uncommon, with nine unidentified bright orange ascidians counted (Table 7). Mobile invertebrates were largely absent, with just two cushion stars observed. No kina were seen.

Main fish species: Blue cod and butterfly perch were both present, with 10 to 20 individuals recorded (Table 8), with the butterfly perch as an aggregation on the top of the reef ridge (Figure 3-28). A few leatherjacket, scarlet wrasse and a spotty were the only other fish counted.

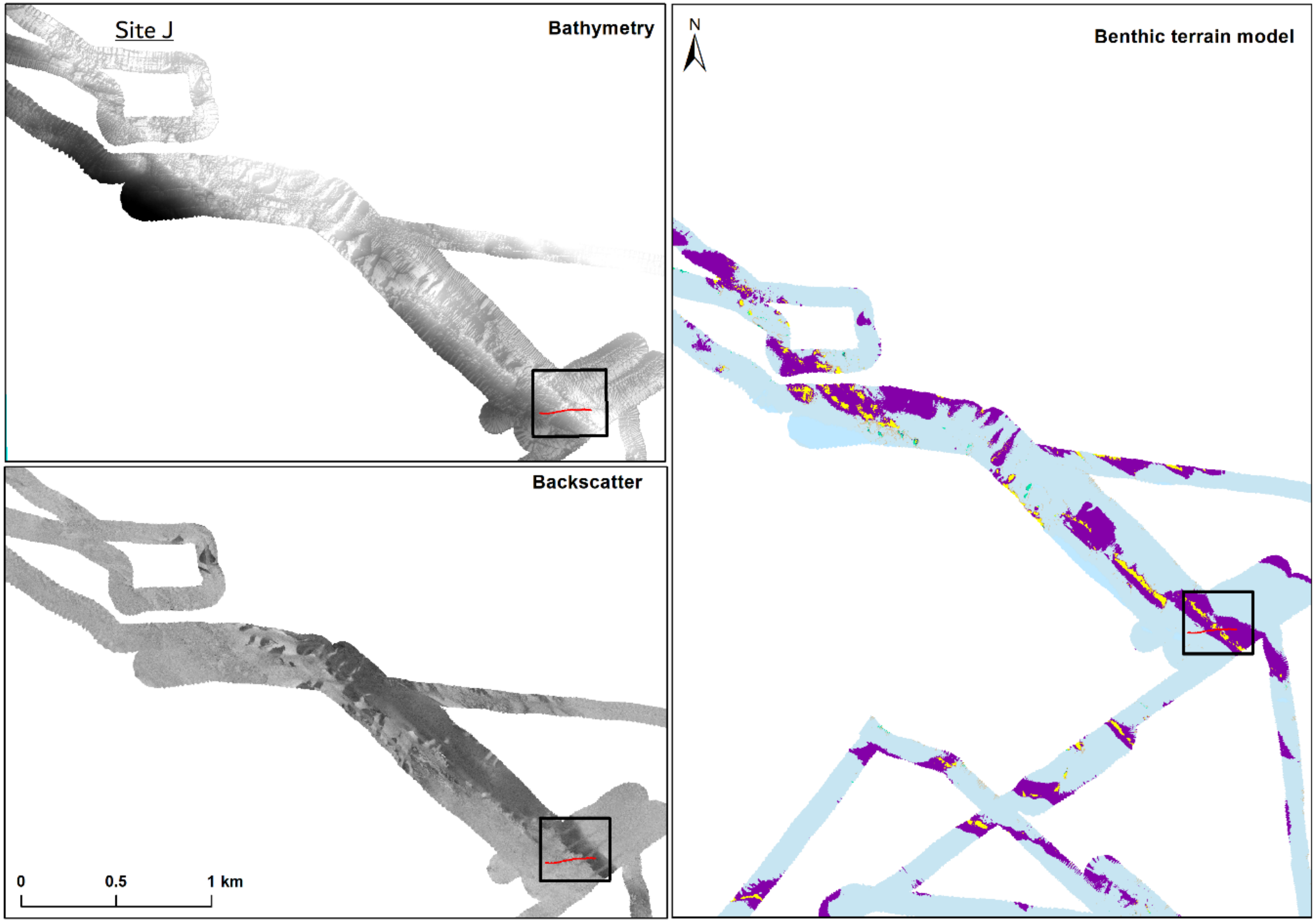


Figure 3-26: Broader extent maps of larger seafloor area mapped (a series of reef ridges) around site J.

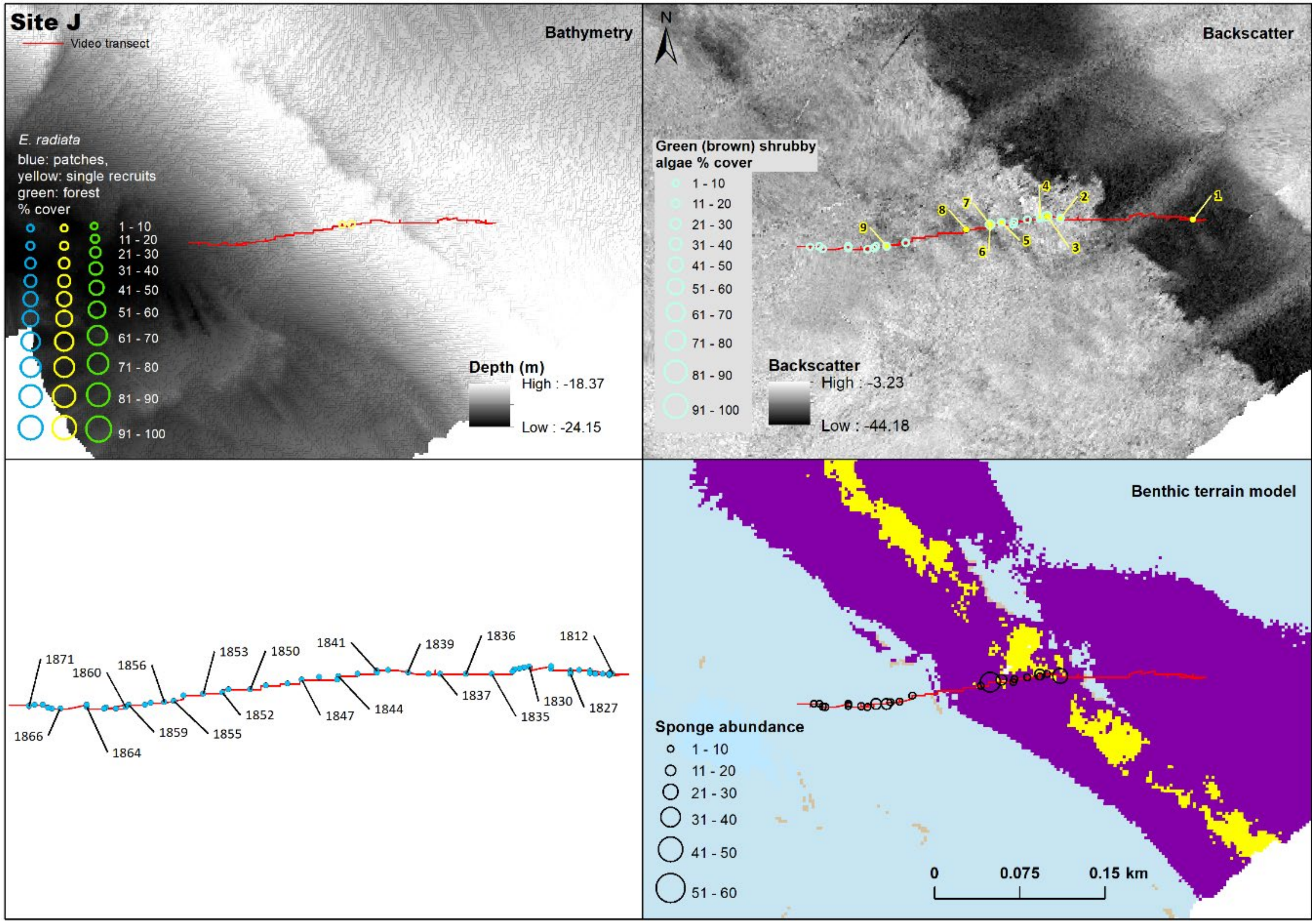


Figure 3-27: Maps of site J. Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers); top right) multibeam beam backscatter and green (brown) shrubby algae %cover (*C. flexilis* was absent); lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

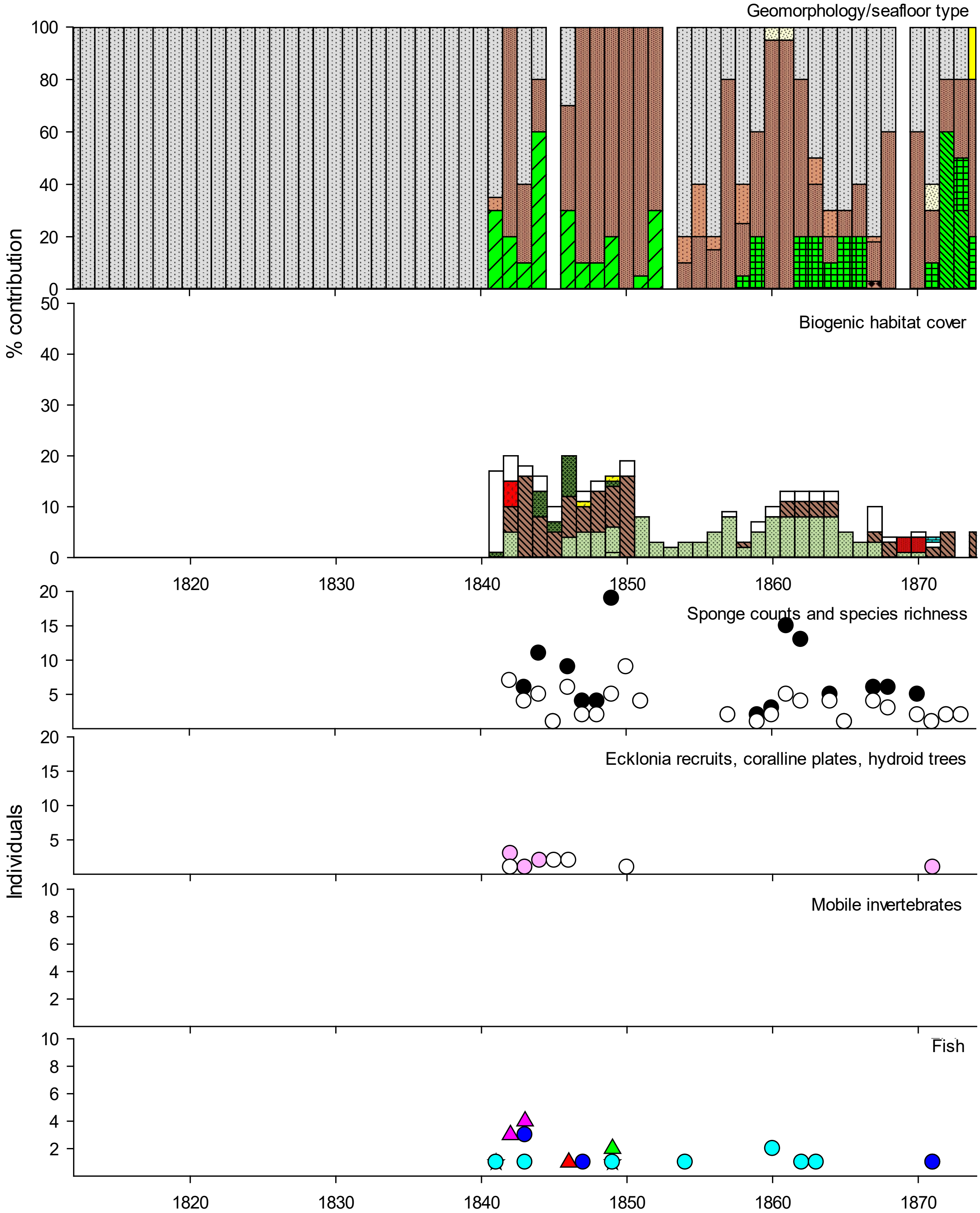


Figure 3-28: Site J CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-27.

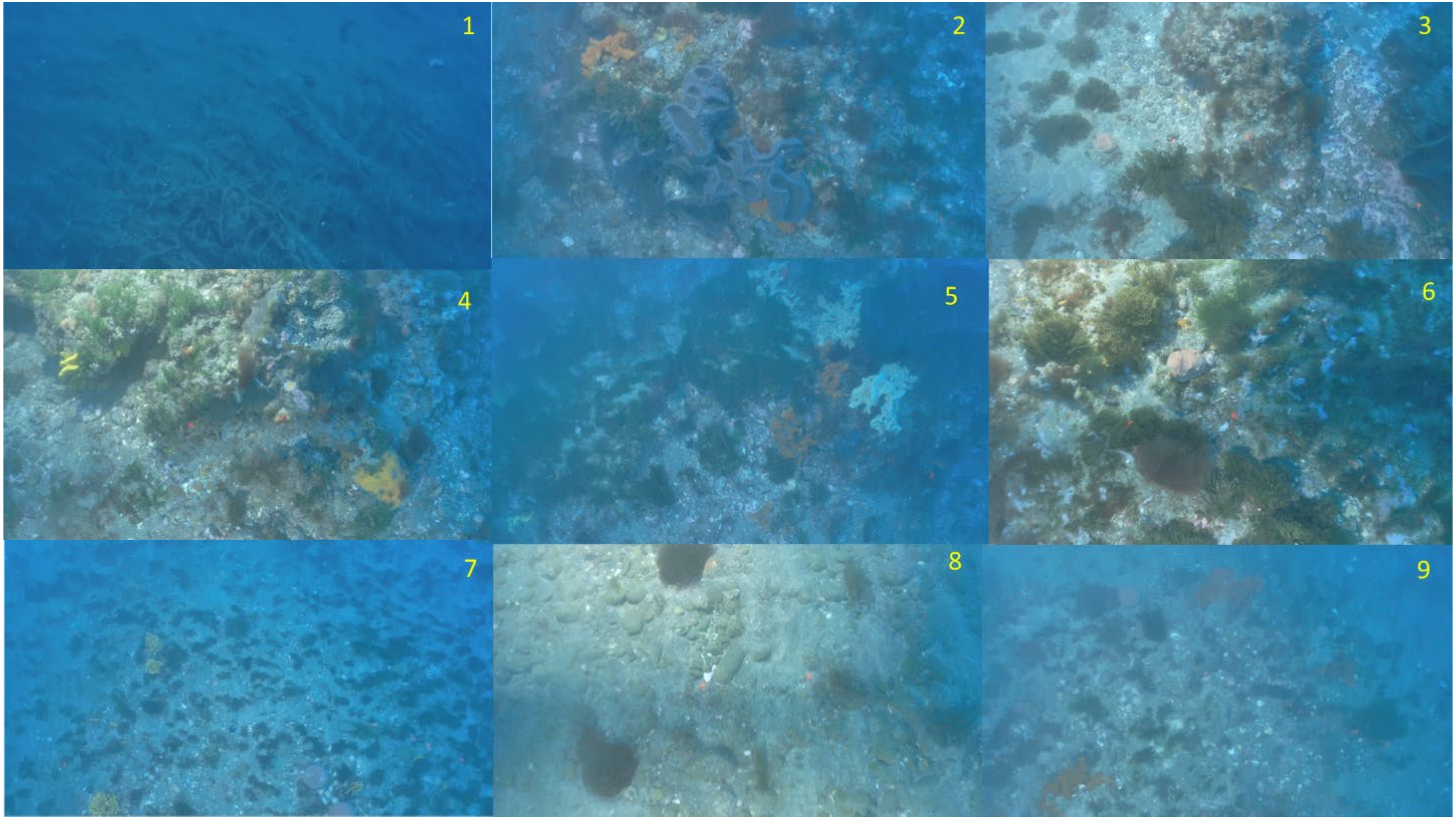


Figure 3-29: Site J seafloor images image numbers are plotted spatially in Figure 3-27 over multibeam sonar back scatter: 1) dark sand; 2) start of low ridge with higher sponge cover including grey *E. alata*; 3–5) low ridge seafloor; 7–9) mixed substrate seafloor to the west of the ridge feature.

3.6.6 Site K (Project Reef)

Depth range. 19.9–22.6 metres **Reef size**: 2,933 m^2

Form. Low mixed reef stack composed of low terrace rock, irregular mixed cobbles, and coarser soft sediments.

This is the Project Reef, monitored and observed by the citizen science Project Reef team since 2015. Numerous project dives have shown the raised terrace components (0.7–1.5 metres high) to be made of a hard fossil-abundant rock type, along with mixed irregular cobble patches, and various mixtures of whole shell, broken shell, and coarser soft sediment types. It sits within a much larger reef complex of long narrow ridges up to 1.9 km long but does not appear well aligned with those either in aspect or morphology (Figure 3-30). The Project Reef stands out quite clearly as a discrete bathymetric feature.

BTM Divisions (multiple east-west passes with video transect): Flat Plains → Broad slopes (1-3 pixels wide) → Rock Outcrop Highs, Narrow Ridges (the reef itself) → Broad slopes (1-3 pixels wide) → Flat Plains. Some reef edge pixels classed as Flat Ridge Tops / Steep Slopes / Local Ridges, Boulders, Pinnacles on Slopes (Figure 3-31).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-31 to Figure 3-33)

Geology. The reef terrace is known to be composed of a hard, fossil-rich rock (Figure 3-8), that forms the terrace features (8,10,16). The towed video transect passed over the reef itself seven times in an east-west orientation, with a nominal 9 metre transect spacing (Figure 3-31). Rough sea surface conditions at the time of sampling made the actual spacing more variable. The reef feature was classed as a mixture of low and high patch reef, and low broken rock (5–7,9,11–12, 14–15, 17–18), along with mixed irregular cobbles (2,4), which also extended beyond the reef. Various coarser grained soft sediment classes with variable shell contributions were also present around the reef (1,3,4,13), as well as sand.

Biogenic habitats: The reef held a mix of biogenic habitat classes, with the most common being *E. radiata* (4.7% cover), composed of single plants (5, 6, 11), patches (15,17), and one small 'forest' on the south-east edge of the reef. Sponge, ascidian, and other sessile fauna contributed 2.55% cover (6,9,12,18), along with filamentous red algae (1.3%) and green (brown) shrubby algae (11,18) (1.2%)(Table 6). *E. radiata* kelp cover was generally associated with high patch reef geomorphology, where it spanned several video segments at a time. Higher sponge and other sessile fauna cover also aligned with this reef type, but not where *E. radiata* dominated (this was not an artefact of kelp canopy obscurement). Filamentous red and green algae were patchily distributed, while green (brown) shrubby algae occurred in patches on the northern half of the reef, as well as off-reef to the east, where further rock habitat was present.

Main invertebrate species: Sponges were the most common sessile invertebrates, dominated by Family Chondropsidae species 2, *C. incrustans*, *S. conulosa*, and *A. globosa* (Table 7). Mobile marine invertebrates were uncommon, with kina the most often observed species (30 individuals), followed by Cooks Turban gastropods (9) (Table 7, Figure 3-32). The Project Reef benthic assemblage photo quadrats (2017) found a similar sponge species assemblage and dominance order (noting that finer-scale Project Reef work was done using point-based grid scoring of still camera imagery)(Table 11).

Main fish species: Blue cod were the dominant species, with 115 records, of which 21 were 0+ juveniles (Table 8, Figure 3-32) found on the reef edges (irregular cobbles). All size classes were relatively common. Butterfly perch were the second most observed species (88 individuals), followed by scarlet wrasse and leatherjackets. Five other species were seen as singletons only; tarakihi, goatfish, butterfish, and a magpie perch. The butterfish was the only one seen during the CoastCam survey, while the magpie perch was one of a resident pair often seen by Project Reef divers (the pair seen together on the second downward facing CoastCam camera).

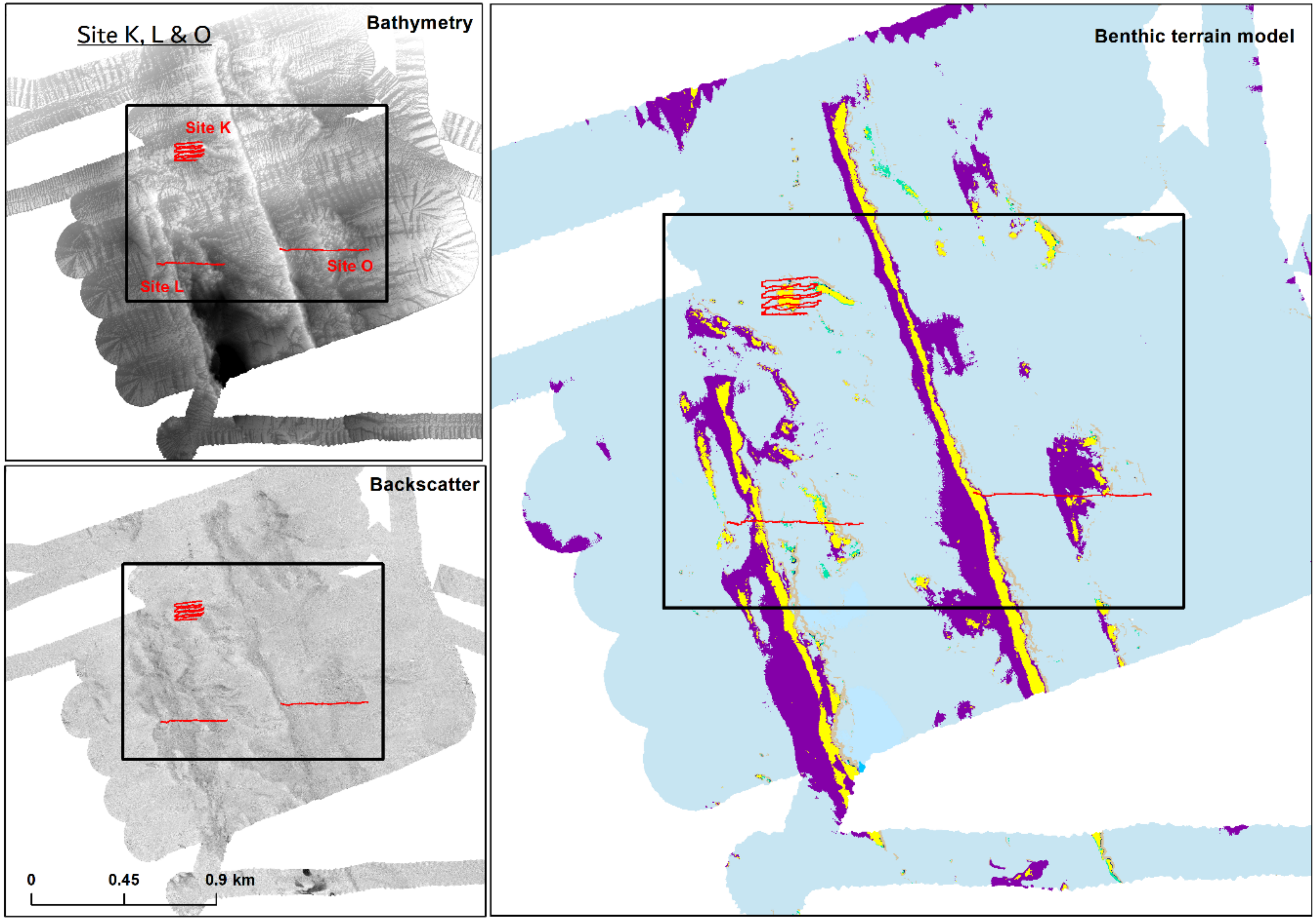


Figure 3-30: Broader extent maps of larger seafloor area mapped (a series of reef ridges) around sites K, L, and O.

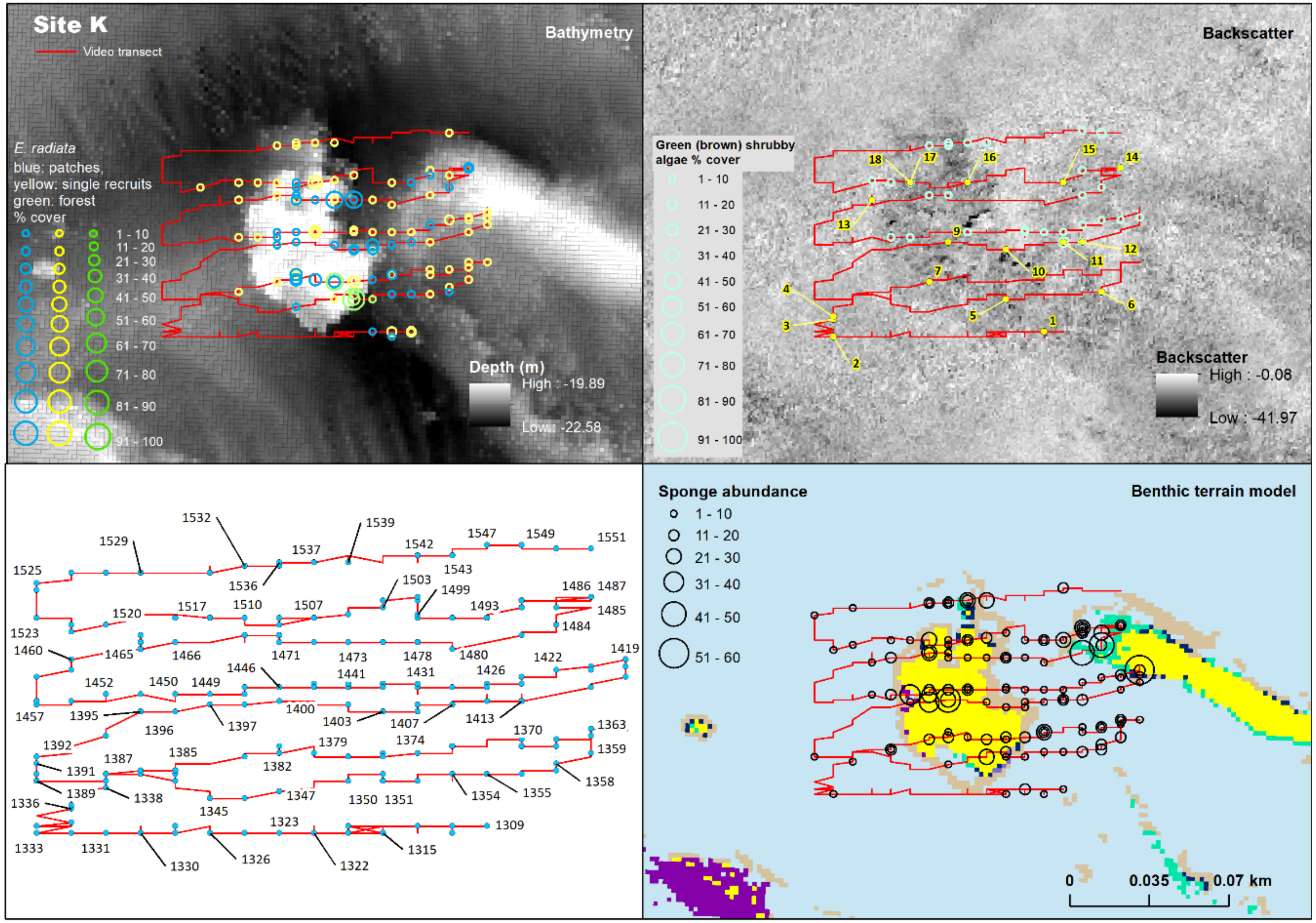


Figure 3-31: Maps of site K Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and green (brown) shrubby algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment). Image 10 marks the position of the Project Reef in-situ camera block. Images 5, 7–10, 16, 17, and 18 fall on the Project Reef; the other images are off-reef.

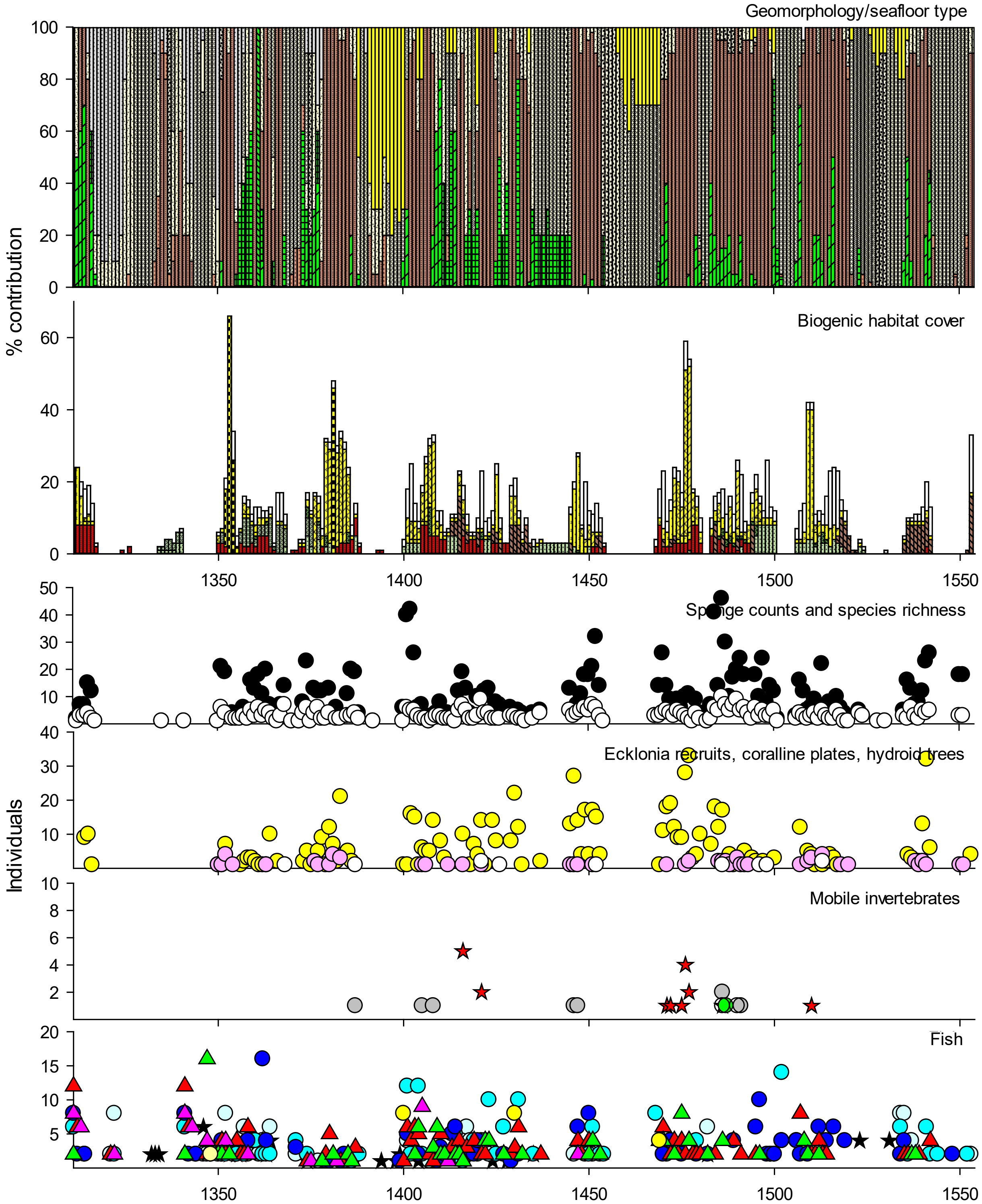


Figure 3-32: Site K CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-31.

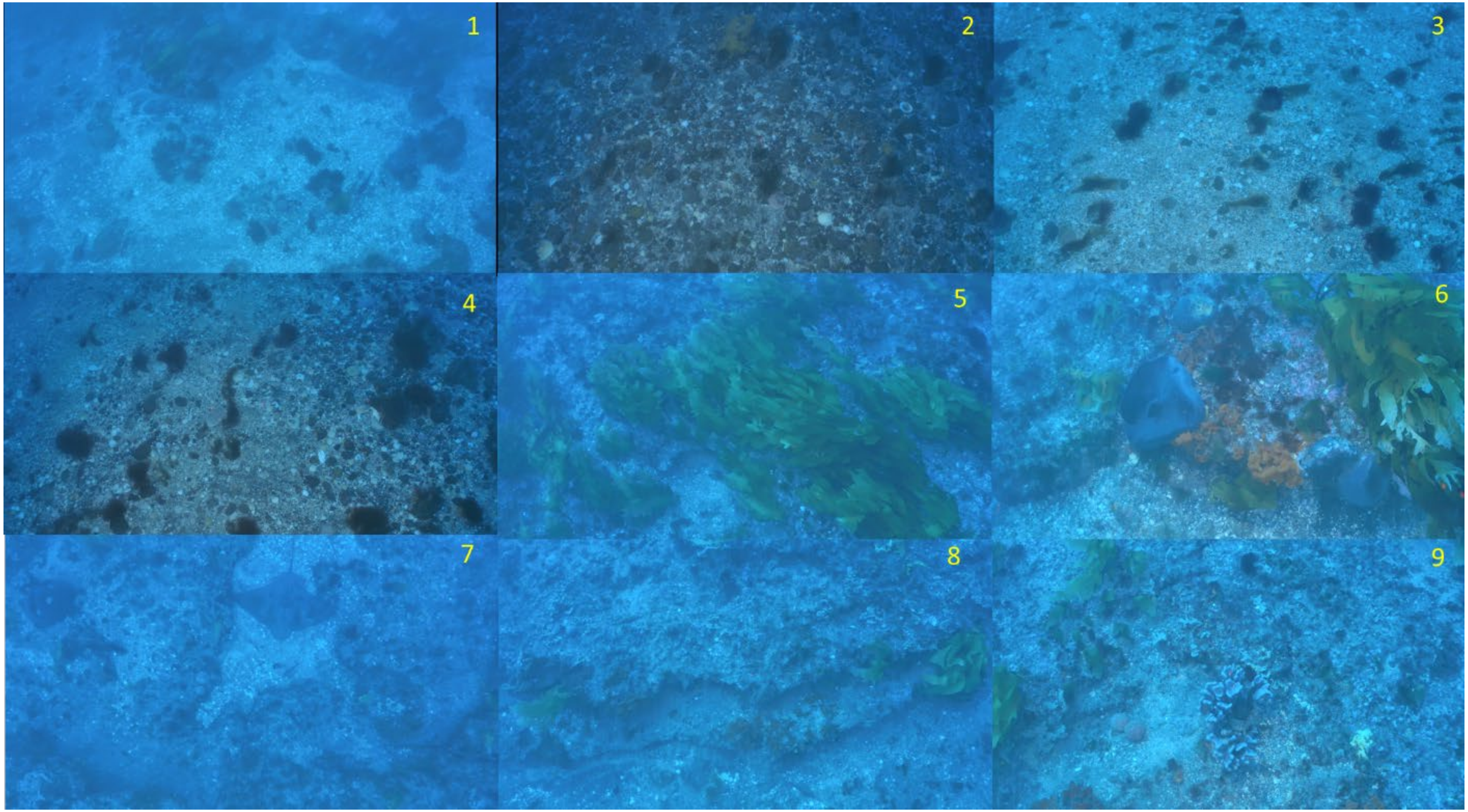


Figure 3-33: Site K seafloor images image numbers are plotted spatially in Figure 3-31 over multibeam sonar back scatter: 1–4) mixed soft sediment and small stones seafloor substrates off-reef; 5) *Ecklonia* patch on reef; 6) low small rock outcrop east of the reef, with a sponge cluster; 7) reef edge with resting eagle ray; 8) reef edge, with *Ecklonia* individuals and patch; 9) reef with the uncommon 'broken flange sponge' *Desmacidon mammilatum* (nine seen across the overall survey).

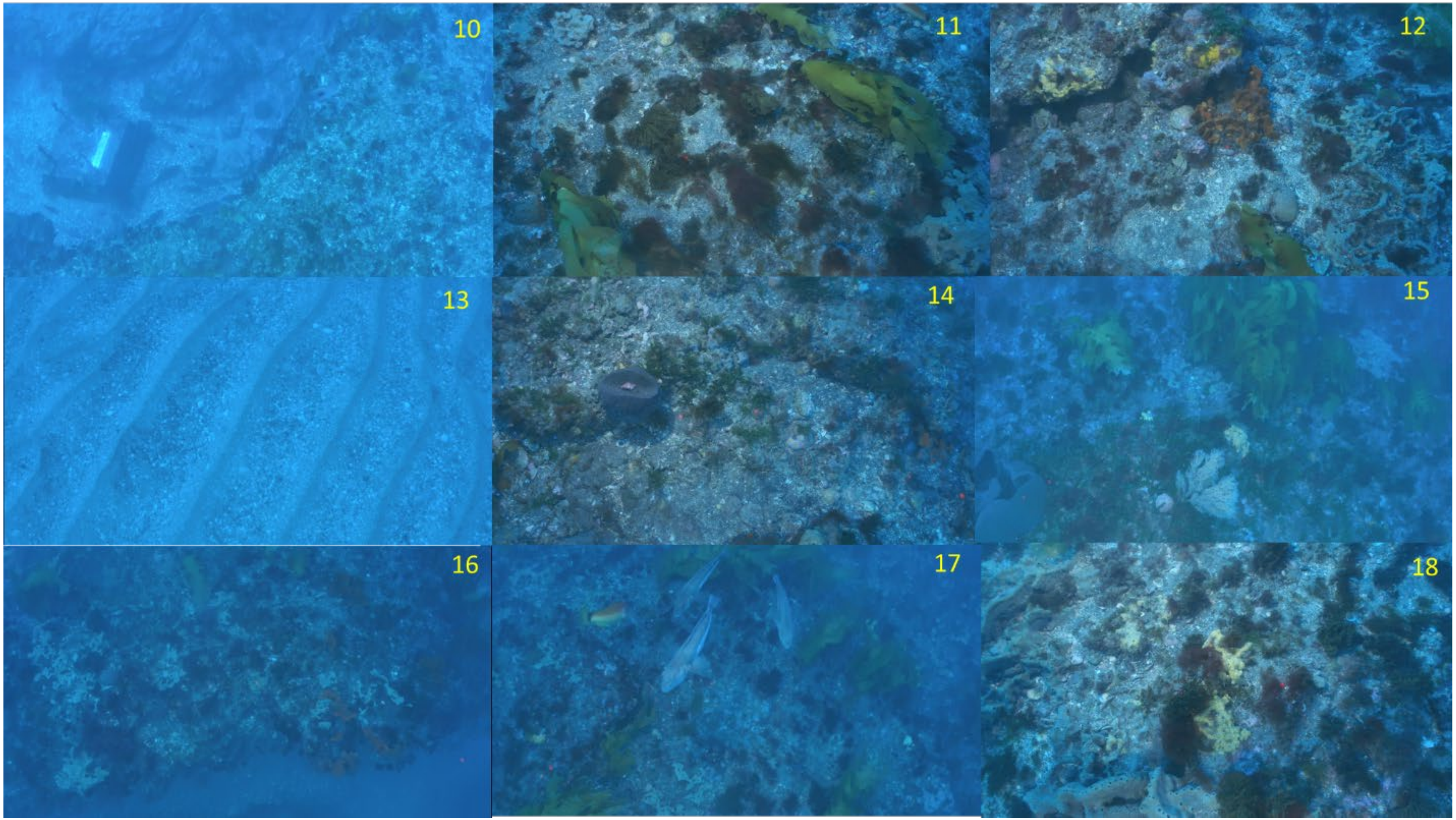


Figure 3-33: Continued. 10) the Project Reef in-situ camera site (in-situ camera not present); 11) green (brown) shrubby algae (off-reef); 12) small rock outcrop with sponges (off-reef); 13) soft sediments west of Project Reef; 14–15) small rock patch east of the Project reef, with sponges (unidentified gastropod sitting in sponge *S. conulosa* 'cone' in 14, and *Ecklonia* singles/patch in 15); 16) Project Reef north-east edge drop; 17) Project Reef blue cod and scarlet wrasse; 18) sponges, green (brown) shrubby and red algae on the Project Reef.

3.6.7 Site L

Depth range. 20.05–25.9 metres **Reef size**: 301,673 m^2 (full ridge feature)

Form. Long ridge feature approximately 1.17 km long, with flanking secondary shorter ‘scalloped’ ridges and reef depressions to the west and east (Figure 3-30).

The north-south ridge averaged around 300–330 m wide along most of its length, tapering to around 100 m width towards its southern end, and ending as a low 30 m wide ridge grading down into soft sediments. There were similar large ridge reef complexes to the east.

The video transect cut across the main ridge feature, and a secondary ridge to the east.

BTM Divisions (east to west along video transect): Flat Plains → Broad slopes → Rock Outcrops High/Narrow Ridges → Flat Ridge Tops → Flat Plains → Broad Slopes → Flat Ridge Tops → Rock Outcrops High/Narrow Ridges → Flat Ridge Tops → Flat Plains → Flat Ridge Tops → Flat plains (Figure 3-34).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-34 to Figure 3-36)

Geology. Most of the reef/rock extent was composed of mixed, irregular, cobbles (64.4%) (1–3), with low broken rock (7.1%) largely confined to the top of the ridge features (4,6,9,14). Various shell dominated soft sediments were present between the two ridge features, and on either end of the transect (2,11,18) (Table 4, Figure 3-34).

At the start of the video transect, on the eastern side of the reef, the seafloor was composed of irregular mixed cobbles and broken/mixed shell cover, which graded into 100% irregular mixed cobble (Figure 3-35). The secondary reef feature appeared as low broken rock (#1573–1582) covering up to 50% of the seafloor, along with irregular mixed cobbles. Cobbles again dominated as the transect moved off the ridge, were replaced by small-whole-shell soft sediment for a short distance (#1590–1597), before reappearing as the dominant seafloor cover (#1599 on). The main ridge feature had several short segments of low broken rock (#1612–1615) but was much less obvious than for the secondary ridge. Irregular broken cobbles extended right across the main ridge feature, until the bathymetry dropped down slightly to a depression in the west, with 100% seafloor cover of small-whole-shell soft sediment (#1621 on).

Biogenic habitats: On the eastern half of the transect, including to each side of the secondary ridge, biogenic habitat cover was largely dominated by green (brown) shrubby algae growing on cobbles, with occasional small contributions of sponge-ascidians-other-epifauna (Figure 3-35). Associated with the secondary ridge proper, and the main ridge (broken low rock) was a biogenic habitat class dominated by filamentous red algae, sponge-ascidians-other-epifauna, and some limited *C. geminata* and green lawn algae. This pattern was more ‘diffuse’ for the main ridge feature, where these classes extended more widely over the cobble as well as the rock seafloor (Figure 3-35).

E. radiata (kelp) occurred as small patches (4,6,9,14) across both ridge features and their flanks, although it had greater cover/extent on the main ridge, where it was also present as a narrow band (15) of kelp forest (6–10 metres wide) on the ridge-line proper (#1617–1618) (Figure 3-34). The distribution of *Ecklonia* forest, only on top of the reef ridge, was consistent with other reef ridge sites. It seems likely that this narrow *Ecklonia* forest ran right along the top of the 1.17 km ridge line (Figure 3-30). *Ecklonia* recruits appeared to be spatially associated with the presence of kelp patches and forest (Figure 3-35).

Main invertebrate species: Sponges were the most common sessile invertebrates, with a 3.8% cover contribution (Table 6). The dominant taxa were Family Chondropsidae sp 2, *C. incrustans*, *S. conulosa*, *A. globosa*, and *C. polymastia* (Table 7). Sponge richness and abundance were highest on and around the two ridge features, although there were clear negative associations with the narrow *Ecklonia* forest (as seen at other sites, not explainable as an artefact of kelp obscuring the seafloor) (Figure 3-35). Only two kina were observed (Figure 3-35). Other mobile invertebrates were rare (1 Cooks Turban gastropod, 1 starfish) (Table 7).

Main fish species: Blue cod were the dominant species seen and were present across the reef, with a few 0+ juveniles present (Table 8, Figure 3-35). Other species were less common, and included low numbers of butterfly perch, leatherjackets, and scarlet wrasse.

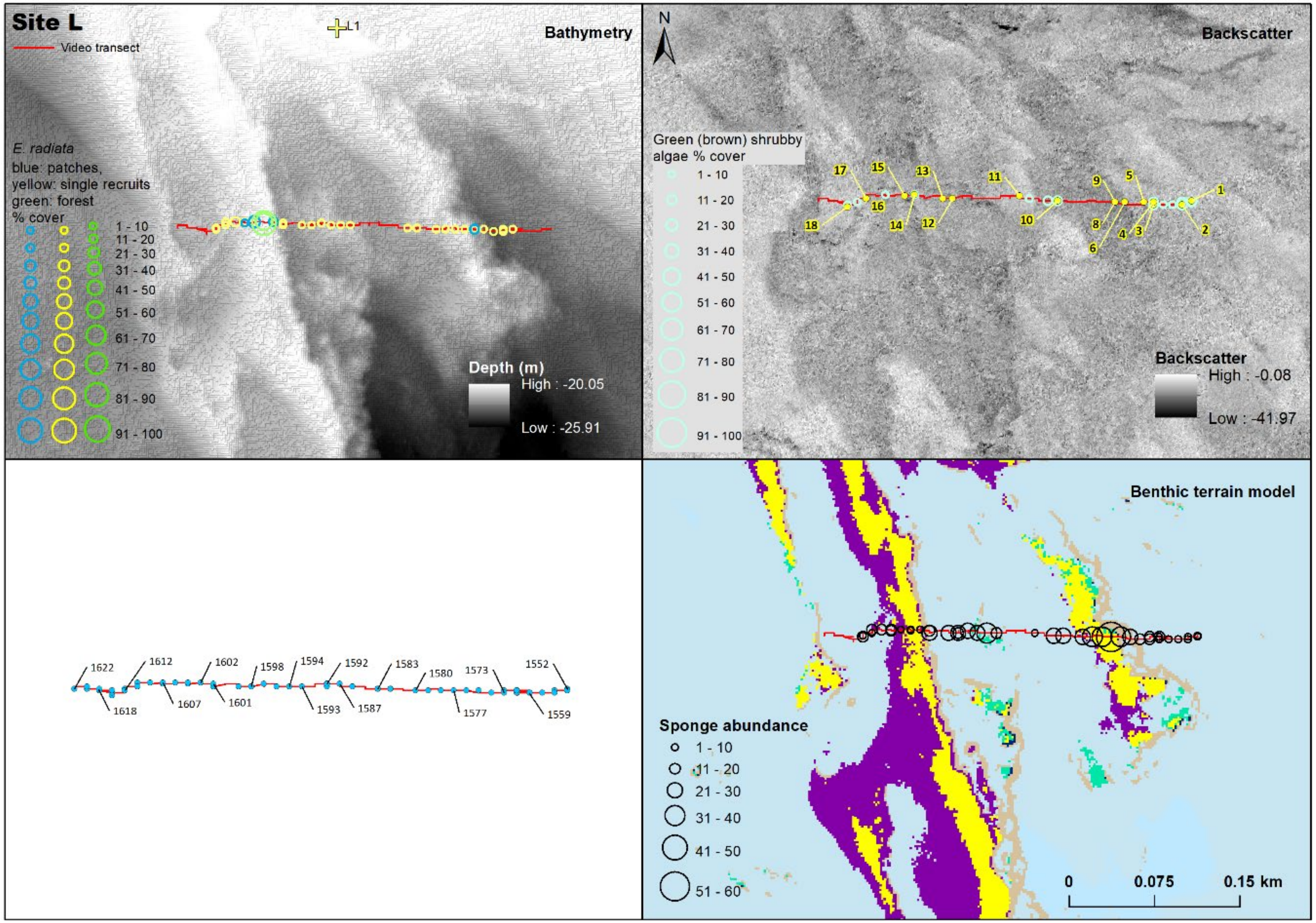


Figure 3-34: Maps of site L Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

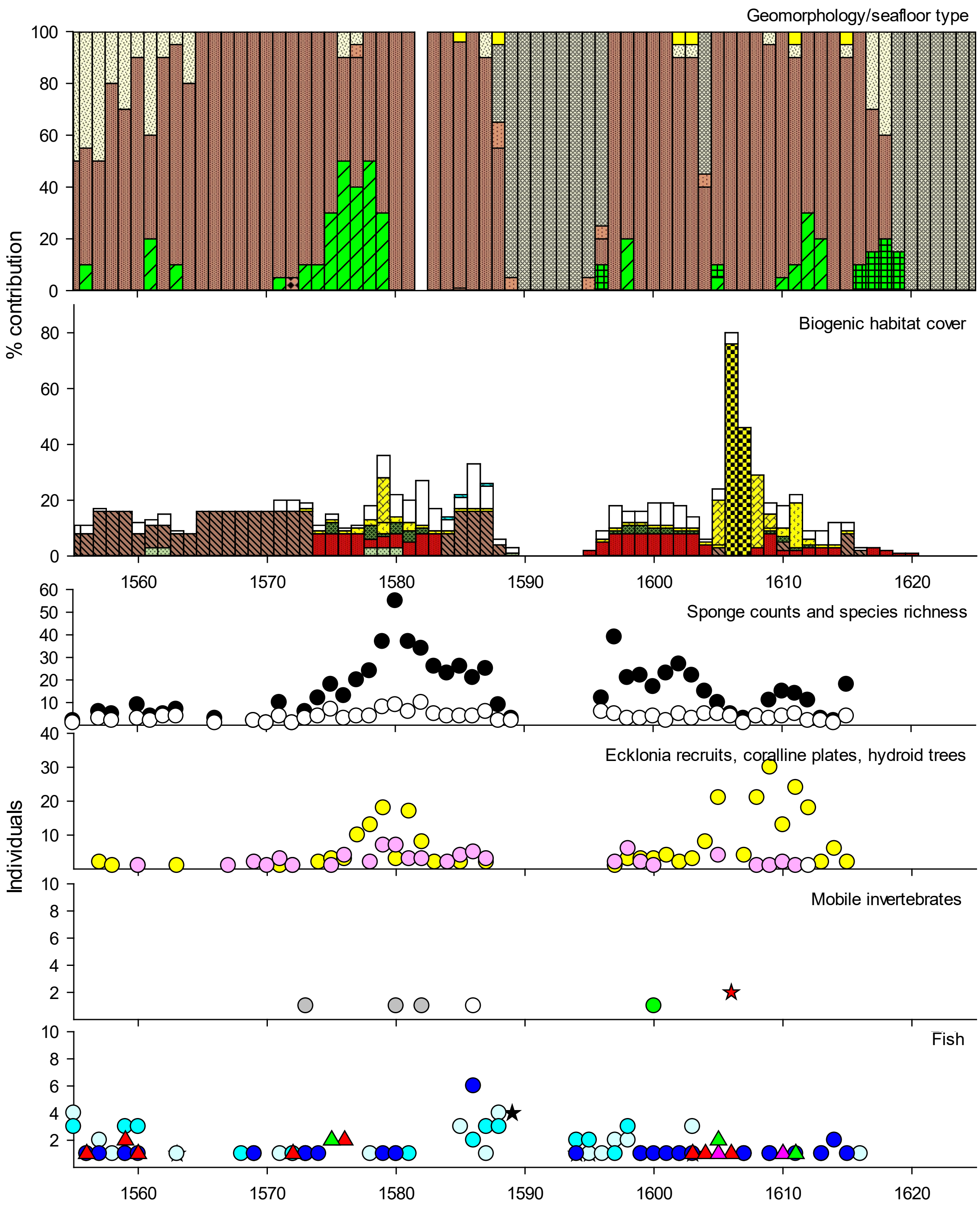


Figure 3-35: Site L CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, shown in map form in Figure 3-34.

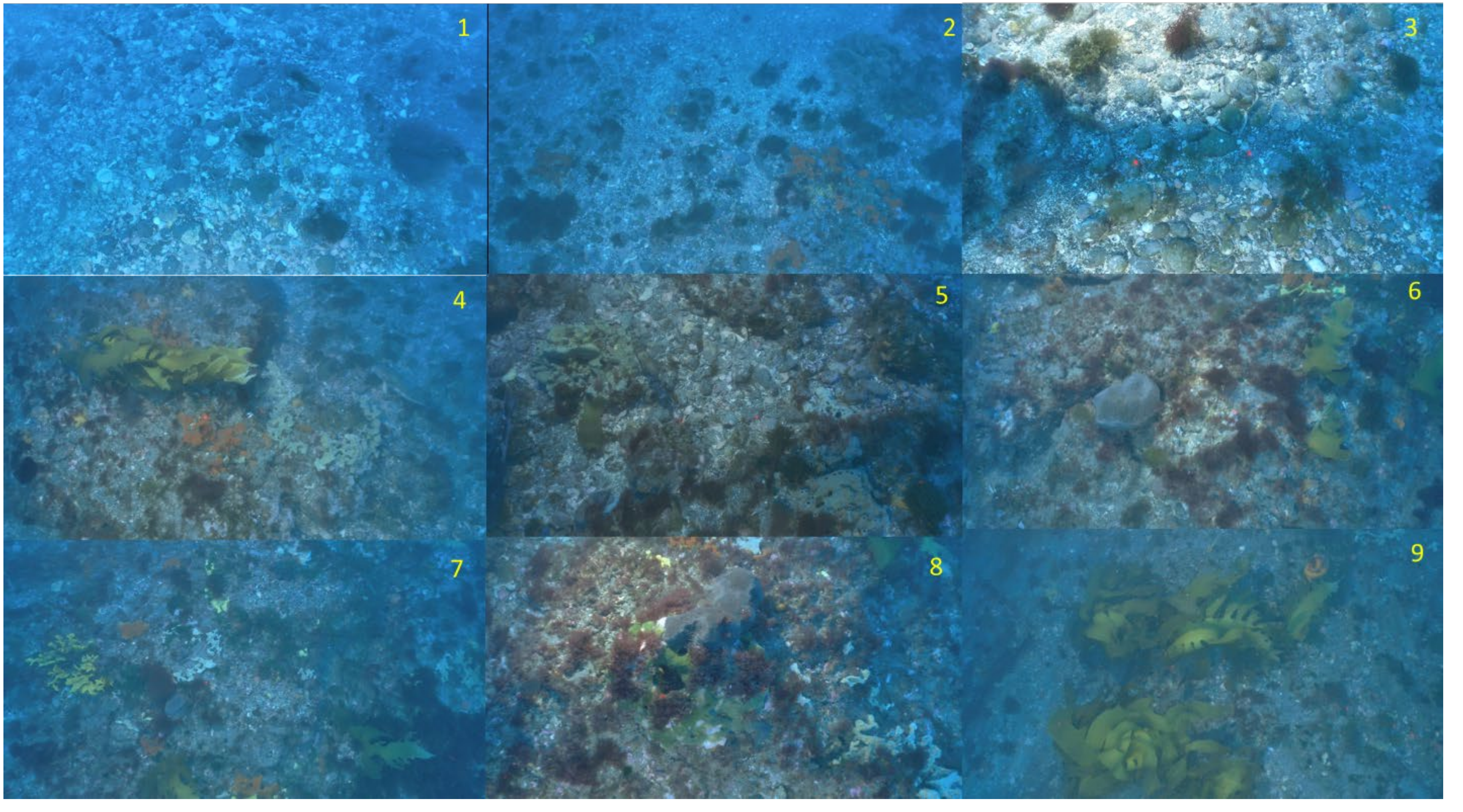


Figure 3-36: Site L seafloor images image numbers are plotted spatially in Figure 3-34 over multibeam sonar back scatter: 1–3) irregular cobbles field; 4–9) secondary ridge seafloor mixed rock substrates, and biogenic habitat covers of *Ecklonia* singles and patches, green (brown) shrubby algae, red algae, and sponge species.

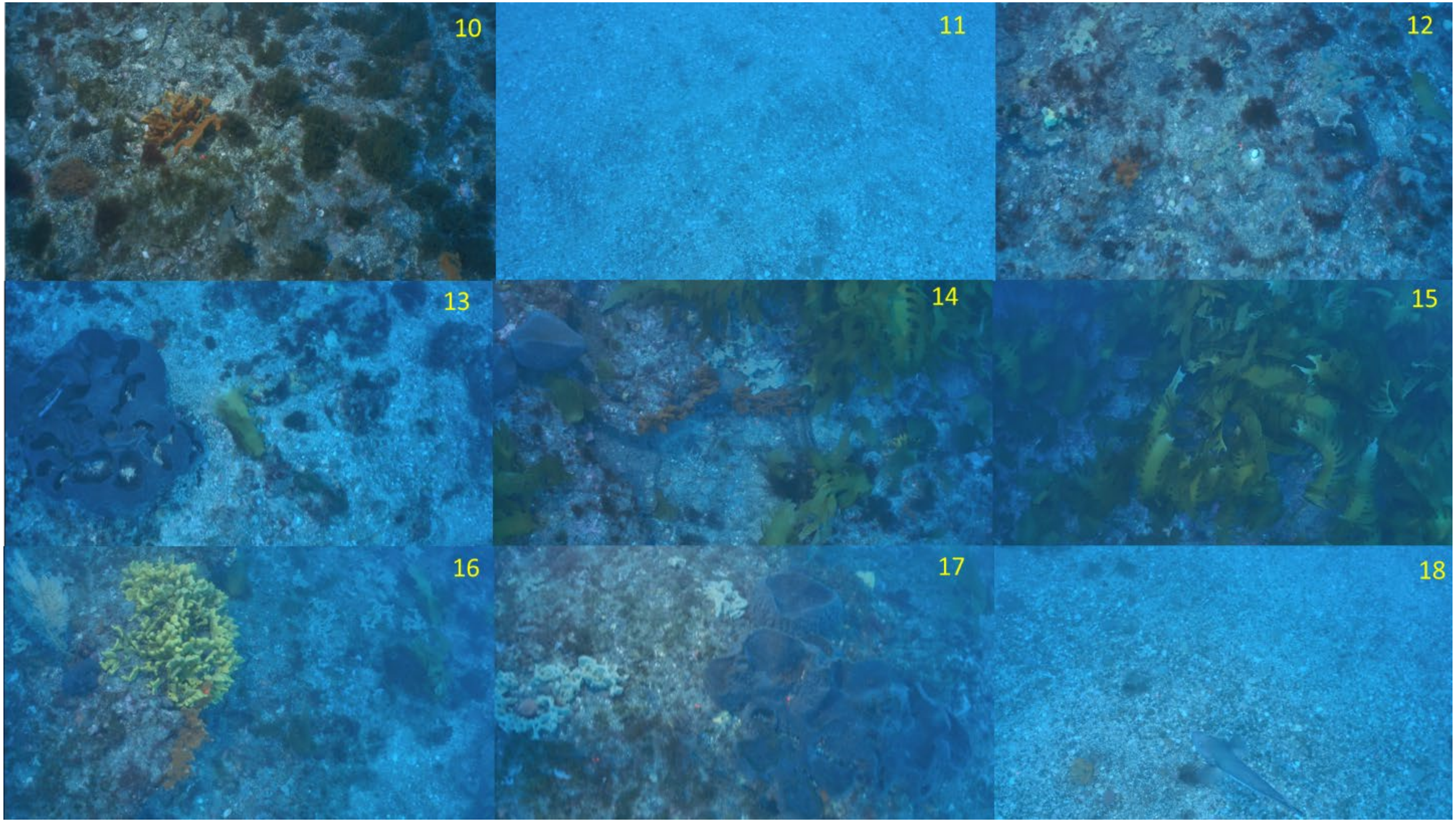


Figure 3-36: Continued 10) secondary ridge seafloor; 11) soft sediment seafloor; 12–17) main reef ridge seafloor, including grey sponge *E. alata* and blue cod (13), grey sponge *S. conulosa* (14), *Ecklonia* patches (14) and forest (15), yellow sponge *Crella incrustans* (16), grey sponge Family Chondropsidae species 2; (17) blue cod on reef edge; 18) gravel seafloor with blue cod.

3.6.8 Site O

Depth range. 19.6–25.4 metres **Reef size**: 109,994 (main ridge) + 66,698 m^2 (east reef)

Form. A ridge feature greater than 1.61 km long (southern end not mapped), with a second more broken and less starkly defined parallel ridge feature to the east (Figure 3-30). This east side reef started from the same north origin point as the larger ridge, ran out obliquely for 500 m south before disappearing, then re-merged from a soft sediment seafloor 500 m further south as a third ridge of broken reef (> 600 m long, southern end not mapped). This last ridge section had a large oblong reef extension extending to the east. A similar oblong reef feature was also present north-west of the main long ridge feature (slightly further south that the one on the east side).

These reef features were part of the wider complicated reef complex that also included sites K and L.

BTM Divisions (cross section along east to west transect): Flat Plains → Rock Outcrops High/Narrow Ridges → Flat Ridge Tops → Flat Plains → Broad Slopes → Flat Ridge Tops → Rock Outcrops High/Narrow Ridges (Figure 3-37).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-37 to Figure 3-39)

Geology. Most of the reef/rock extent was composed of mixed irregular cobbles (64.4%)(1–3), with very limited low broken rock (1.7%) largely confined to the top of the ridge features (4,6,9,14) (Table 4). Various shell dominated soft sediments were present between the two ridge features, and on either end of the transect (2,11,18) (Figure 3-38).

To the east, the seafloor was composed of broken/mixed shell cover (1), with occasional flat boulders (2) which graded into 100% irregular mixed cobbles (3). The secondary reef feature appeared briefly as low broken rock (4) (#1639–1642) covering up to 50% of the seafloor, along with irregular mixed cobbles. Most of the reef was irregular cobbles dominated with very occasional small rock patches (5). Moving off the reef feature, irregular cobbles continued to be dominant for the rest of the transect, to its western end. The main ridge feature had a few segments where low broken rock again appeared, but the ridge was covered by irregular cobbles (6,7). Soft sediments were present at the very western end of the transect (9) (Figure 3-38).

Biogenic habitats: On the eastern half of the transect, including to each side of the secondary ridge, biogenic habitat cover was largely dominated by wiry green filamentous algae growing on cobbles (3,4,6), with occasional small contributions of sponge-ascidians-other-epifauna (5,6) (Figure 3-38)

E. radiata forest was present as a narrow band on the western end of the transect (Figure 3-37, 3-38) associated with the top of the reef ridge feature. As with other ridge sites, this suggested a long narrow kelp forest extended along the >1.61 km long ridge top

Main invertebrate species: Sponges were the most common sessile invertebrates, but with a low percent cover (3.8%) cover contribution across the video transect (Table 6). The dominant taxa were Family Chondropsidae sp 2, *C. incrustans*, *S. conulosa, Dactylia varia*, *Callyspongia ramosa*, and *C. polymastia* (Table 7). Sponge richness was relatively constant, while sponge abundance was variable with no obvious seafloor-associated changes. Mobile invertebrates were rare, with one saw-shell (*A. heliotropium*) and one starfish (*Stichaster australis*/*Coscinasterias muricata*) being observed (Table 7).

Main fish species: Blue cod were the dominant (and largely only) fish species seen, distributed across the transect, with 0+ juveniles contributing 25% of the 79 individuals seen (Table 8, Figure 3-38). A few scarlet wrasse were counted, as well as one leatherjacket. Butterfly perch were conspicuously absent.

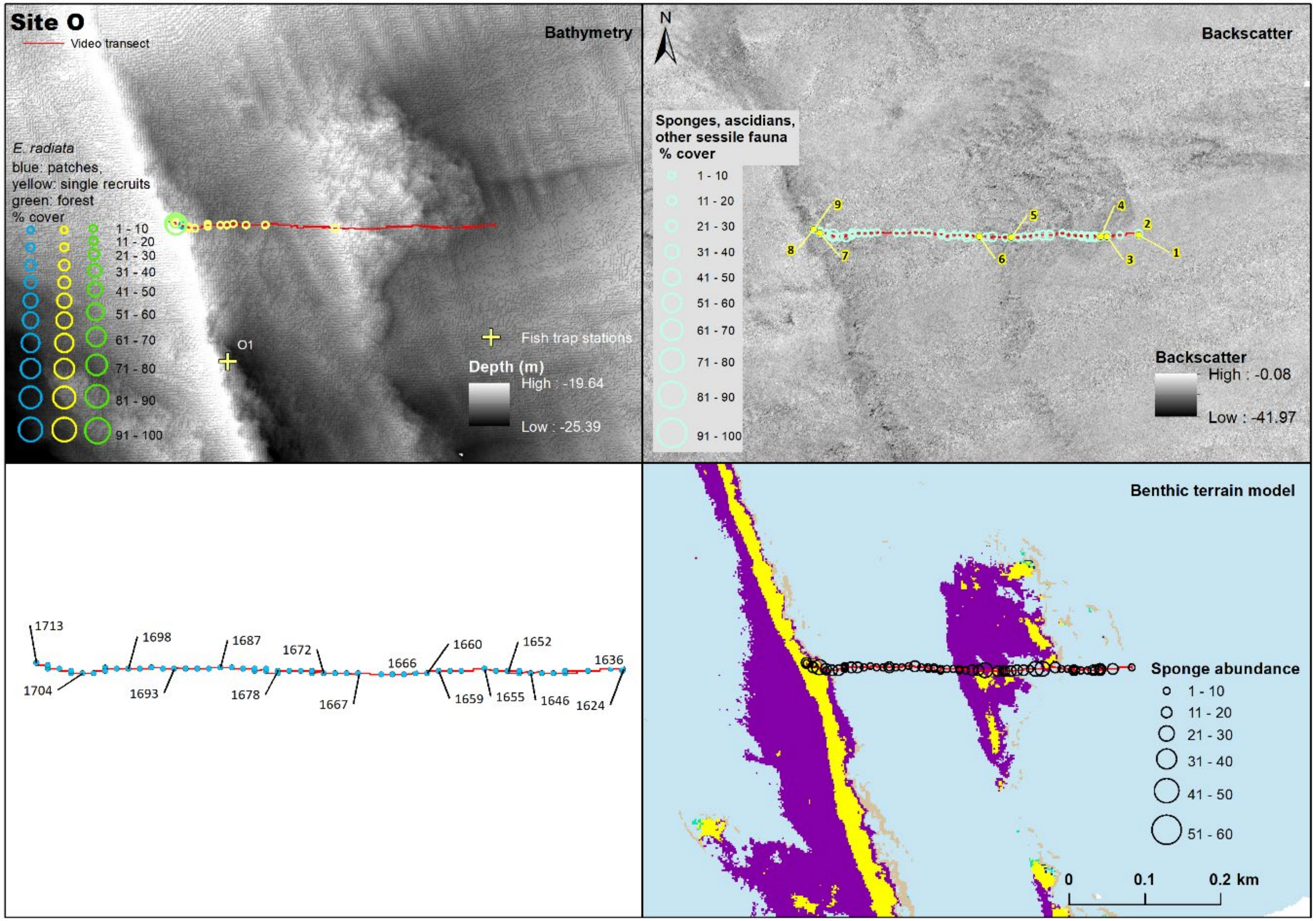


Figure 3-37: Maps of site O Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

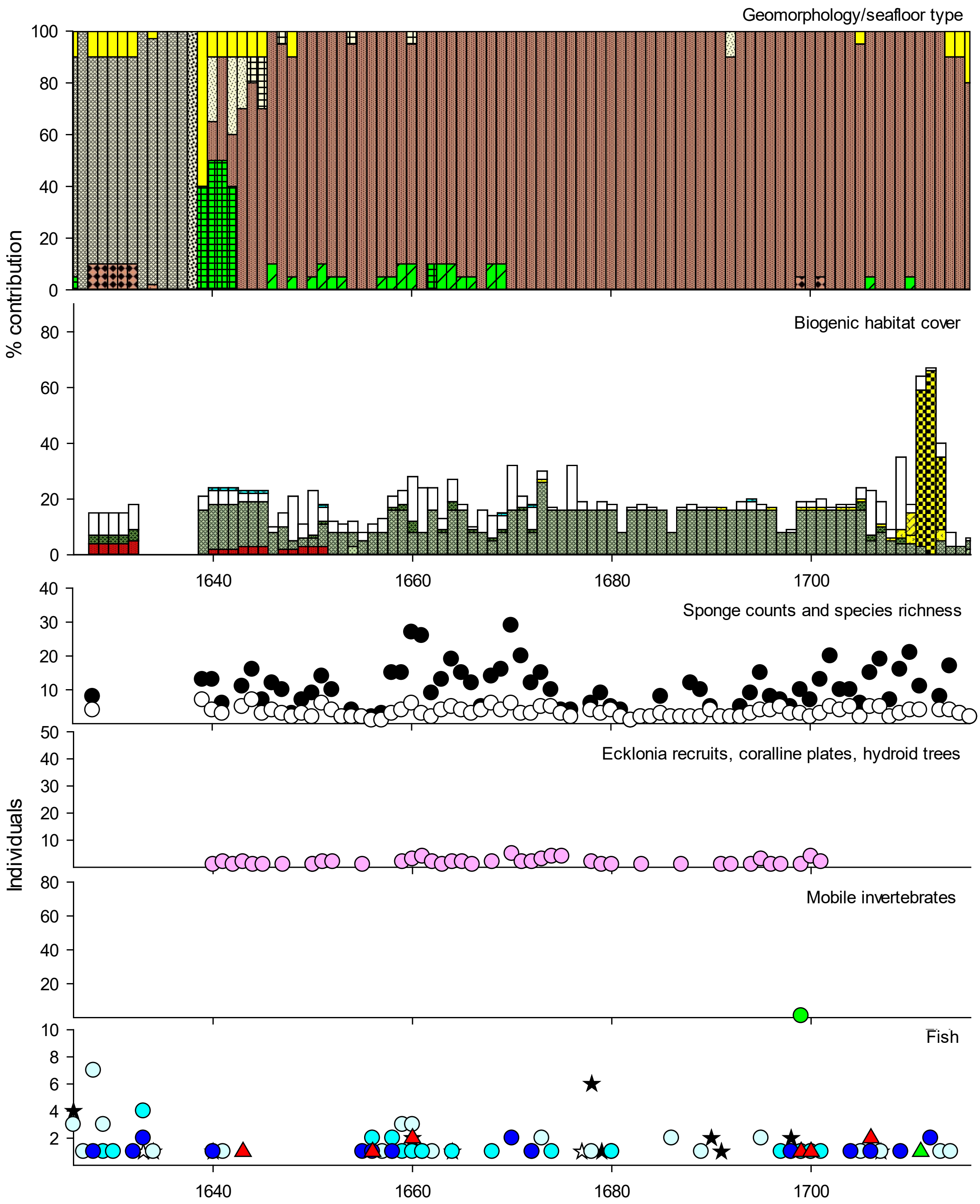


Figure 3-38: Site O CoastCam data Geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-37.

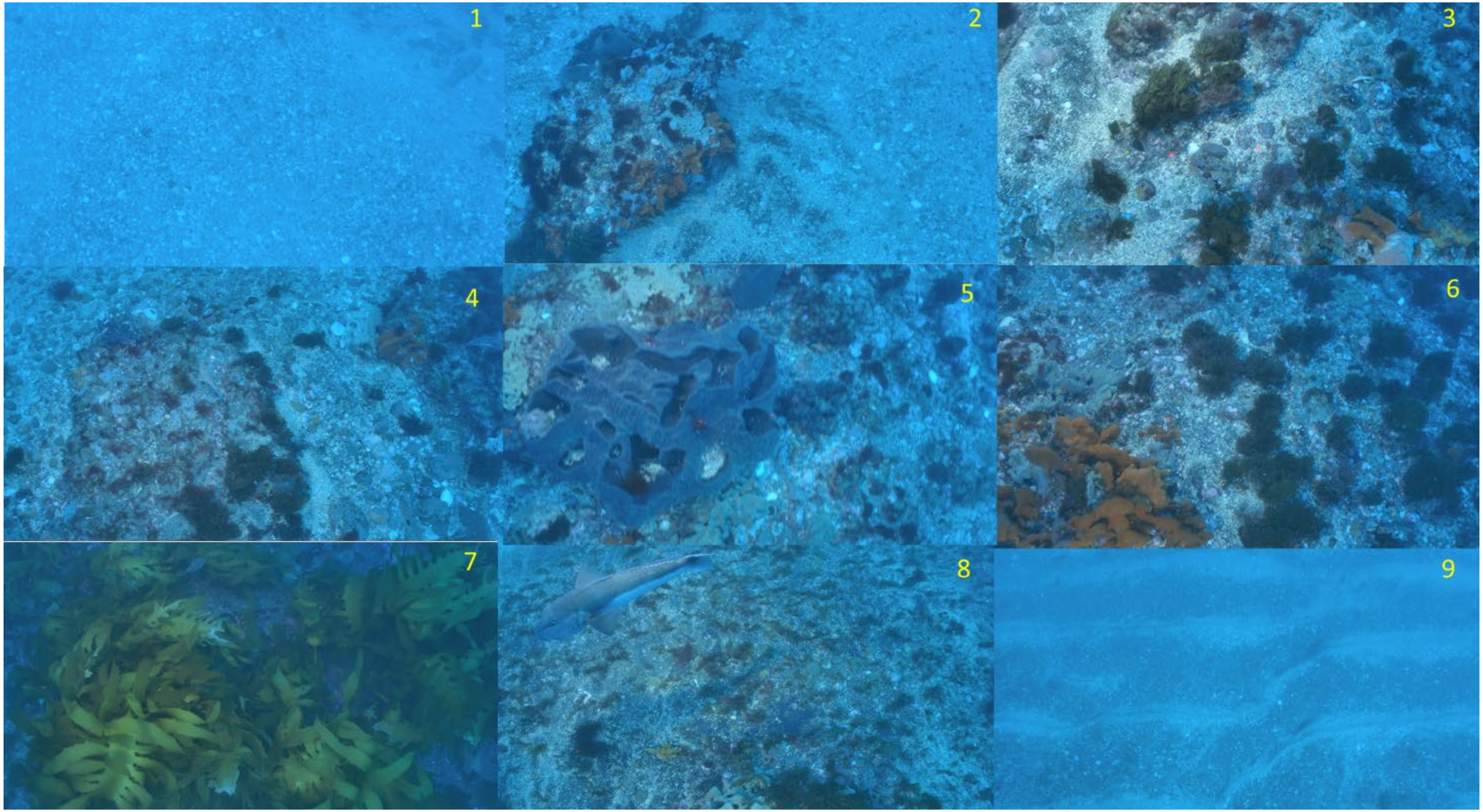


Figure 3-39: Site O seafloor images image numbers are plotted spatially in Figure 3-37 over multibeam sonar back scatter: 1) soft sediment seafloor; 2) boulder on soft sediment; 3) irregular cobble field; 4) low reef; 5–6) sponges *E. alata* and *C. incrustans*; 7) narrow *Ecklonia* forest; 8) blue cod; 9) soft sediments western end of transect.

3.6.9 Site Q (South Trap)

Depth range. 9.9–24.6 metres **Reef size**: 85,794 m^2 (MBES polygon extent only)

Form. Cross-section of a larger reef complex feature (South Trap), with long ridge and slope-platform features, composed of finer-scale finger-and-gutter reef morphologies, and more irregular rock. All features orientated north-east/south-west.

The reef was immediately flanked to the east and west by soft sediments.

A wider range of reef and other unknown seafloor features were present more broadly to the east and west (Figure 3-40), including the North Trap (see Figure 3-1), whose southern edge was just passed over by the multibeam sonar transect (see later Traps report section).

BTM Divisions (cross section along west to east transect): Broad Depression → Depressions → Lateral Mid-slope Depression → Steep Slopes → Flat Ridge Tops → Rock Outcrop Highs, Narrow Ridges → Flat Ridge Tops → Crevices, Narrow Gullies over elevated terrain → Lateral Mid-slope Depressions → Local Depressions, Current Scours → Lateral Mid-slope Depressions → Flat Ridge Tops → Rock Outcrop Highs, Narrow Ridges → Rock Outcrop Highs, Narrow Ridges/Flat Ridge Tops (Figure 3-41).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-41 to Figure 3-43)

Geology: Most of the 600 metre long video transect traversed reef habitat (93%), dominated by rock finger-and-gutter complexes (56%), with low broken rock (12%); and lesser contributions of low patch reef (3%), flat basement (2%) and tells (2%) (Table 4, Figure 3-42). Cobble habitat was absent. Soft sediments were present on the east side as gravel and stones interspersed with low patch reefs, and as sand patches towards the middle of the transect.

Biogenic habitats: On the west side, the transect started on soft sediments composed of large gravel/stones and shells (1), followed by low oblong patch reefs (2–4, 50% seafloor cover), orientated east-west on their longest axes (2). These patch reefs were in slab block form, with sharp right-angle edges, and elevated to around 0.5–1 m above the surrounding soft sediment. The initially patch reefs were dominated by large sponge cover (predominantly *E. alata*), which was quickly replaced by variable macro-algae contributions of filamentous green algae, green (brown) shrubby algae, and *C. flexilis* (5,6). This variable biogenic cover continued as the reef proper sloped up as a mixture of rock slab outcrops/stacks and flatter rock ledges (7,8) and associated low walls (8,9). Just before the ridge crest 'green lawn' algae biogenic habitat cover appeared as a dominant cover as well as scattered *E. radiata* plants (9). The reef from this point on was dominated by finger-and-gutter complexes, along with some short spans of broken rock, rock tells, and sand (10–18). Green lawn algae, and a lesser *E. radiata* contribution, covered up to 40–50% of the reef surface, before *E. radiata* forest became the dominant cover (10–15). In the latter part of the reef transect, the rock surface become more broken and less structured, and the *E. radiata* forest disappeared (16–18), with kina increasing in abundance. A lower cover of green lawn algae and filamentous red algae persisted.

Main invertebrate species: Sponges were the most common sessile invertebrates, with an overall low 0.7% cover contribution across the video transect (Table 6). The dominant taxa were Family Chondropsidae species 2, *S. conulosa*, *E. alata*, and *Darwinella oxeata* (Table 7). Sponge species richness abundance was negatively correlated with *Ecklonia* forest cover on the two ridge features (Figure 3-41). White hydroid trees (*Solanderia* sp.) were relatively common (40 individuals, 36% of animals surveyed). Kina were common (870, 78%), and appeared negatively correlated with *Ecklonia forest* (Table 7, Figure 3-42). Cooks Turban (herbivorous gastropods) were also relatively common (159, 70%), as were the starfish *Stichaster australis*/*Coscinasterias muricata* (30, 57%) (note virtually all *S. australis* seen in the survey were from this site, M. Morrison pers. obs.).

Main fish species: Scarlet wrasse dominated the fish assemblage and were recorded across the reef system (Table 8, Figure 3-42). Butterfly perch were present as small schools, usually associated with walls and drop-off features. Blue cod occurred in low numbers around the reef edges and broken rock. Sweep were also largely restrained to this site, with 20 of the 23 sweep (87%) seen (the other three from site A). This pattern was also seen in the baited traps video, where sweep were only seen at site Q1 (Nmax 7, Table 9, Figure 3-7). Banded wrasse were only seen at this site (3 individuals), as well as one of two marble fish seen across the survey (Table 8).

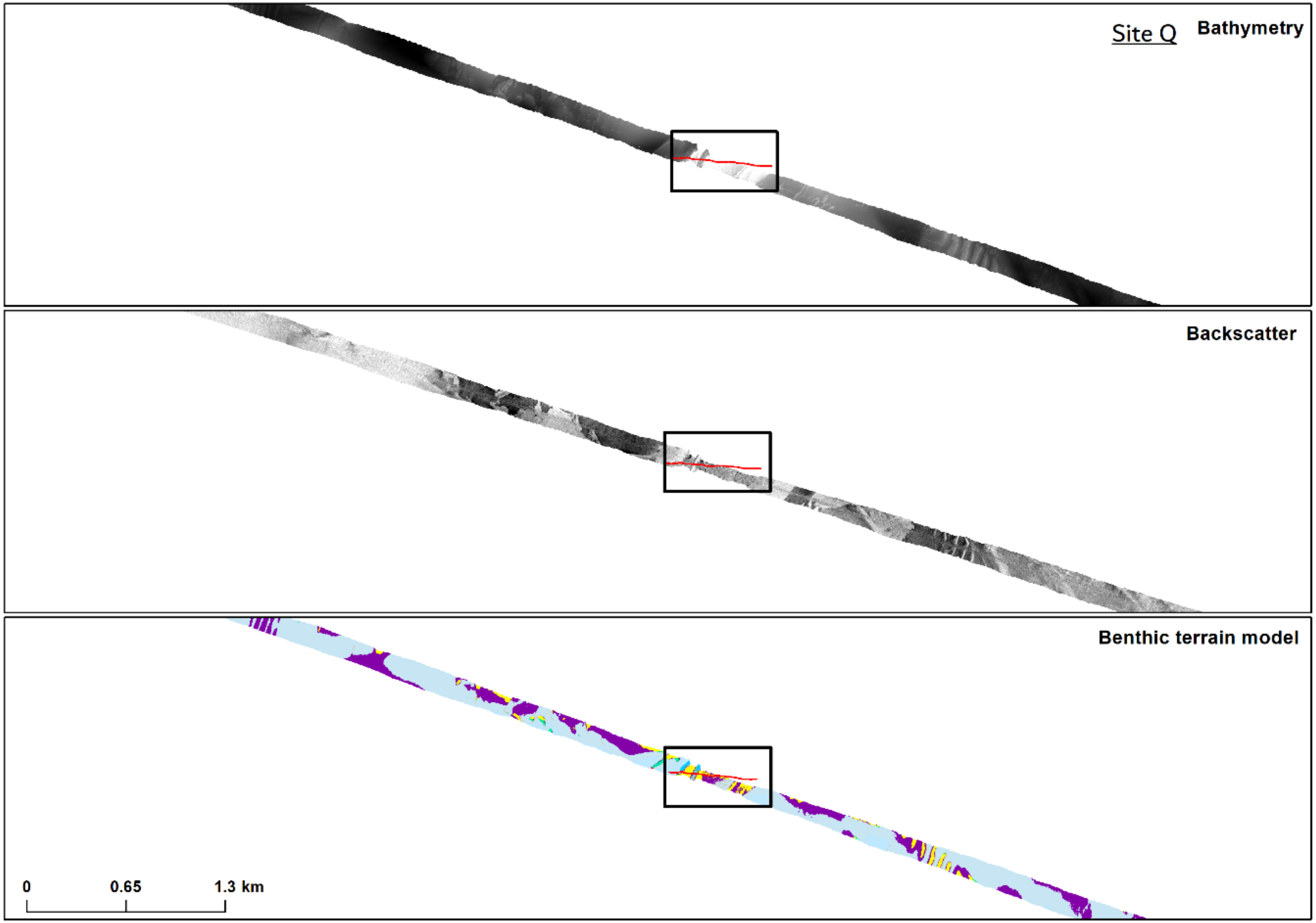


Figure 3-40: Broader extent maps of larger seafloor area mapped (reefs and other unknown features) around site Q (South Trap).

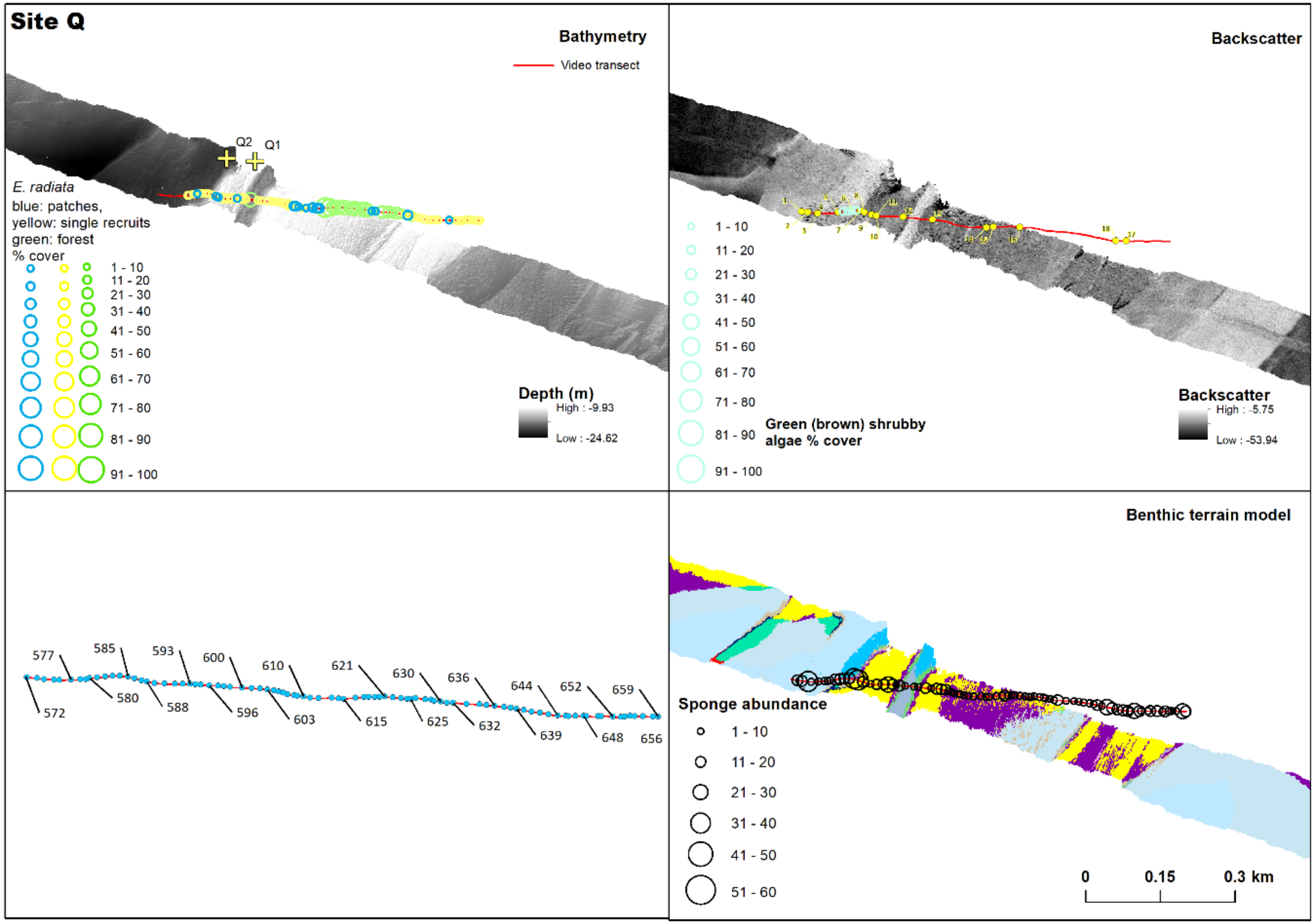


Figure 3-41: Maps of site Q Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment). Two fish traps deployments are also shown (Q1, Q2, see Table 9).

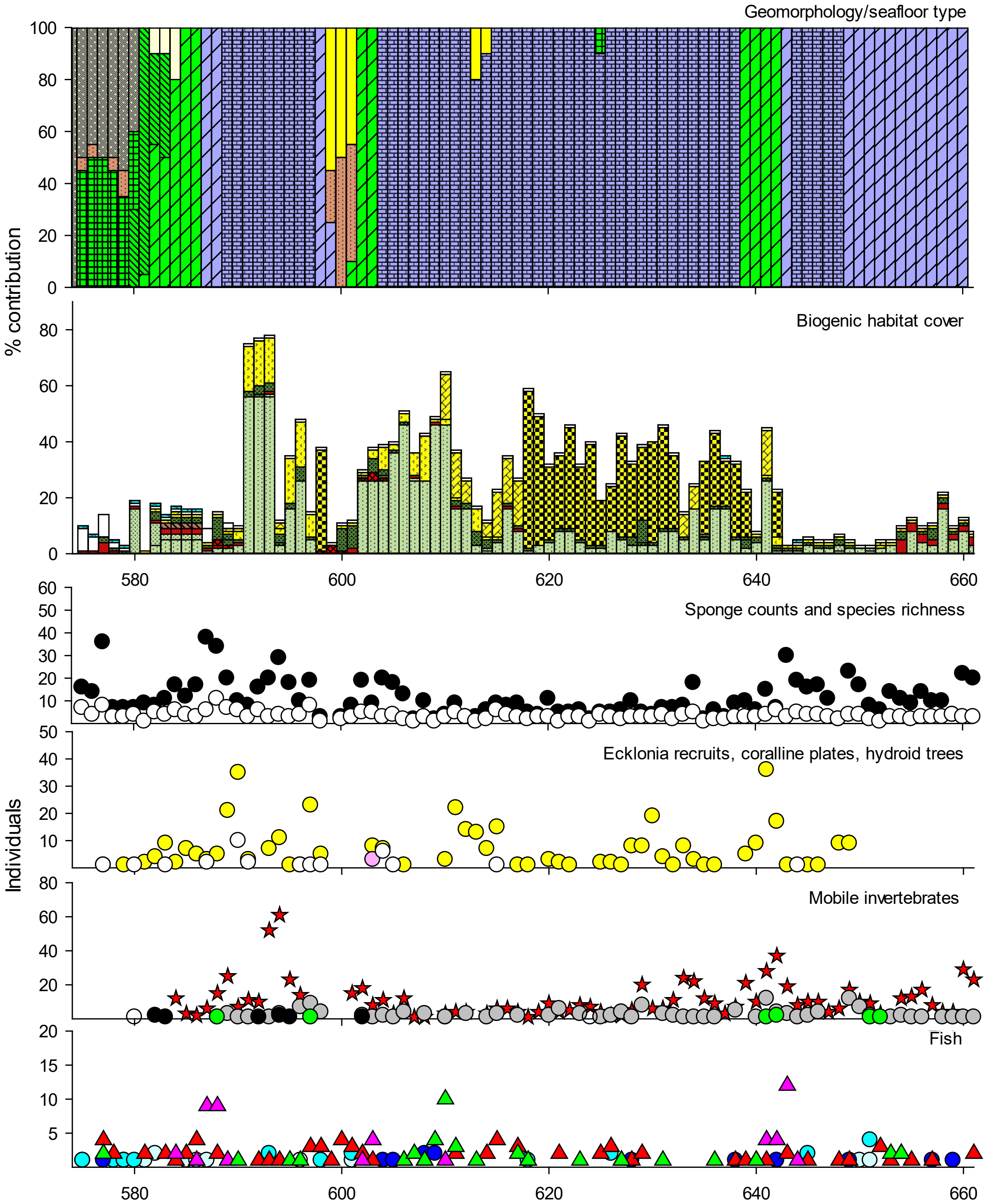


Figure 3-42: Site Q CoastCam data Geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-41.

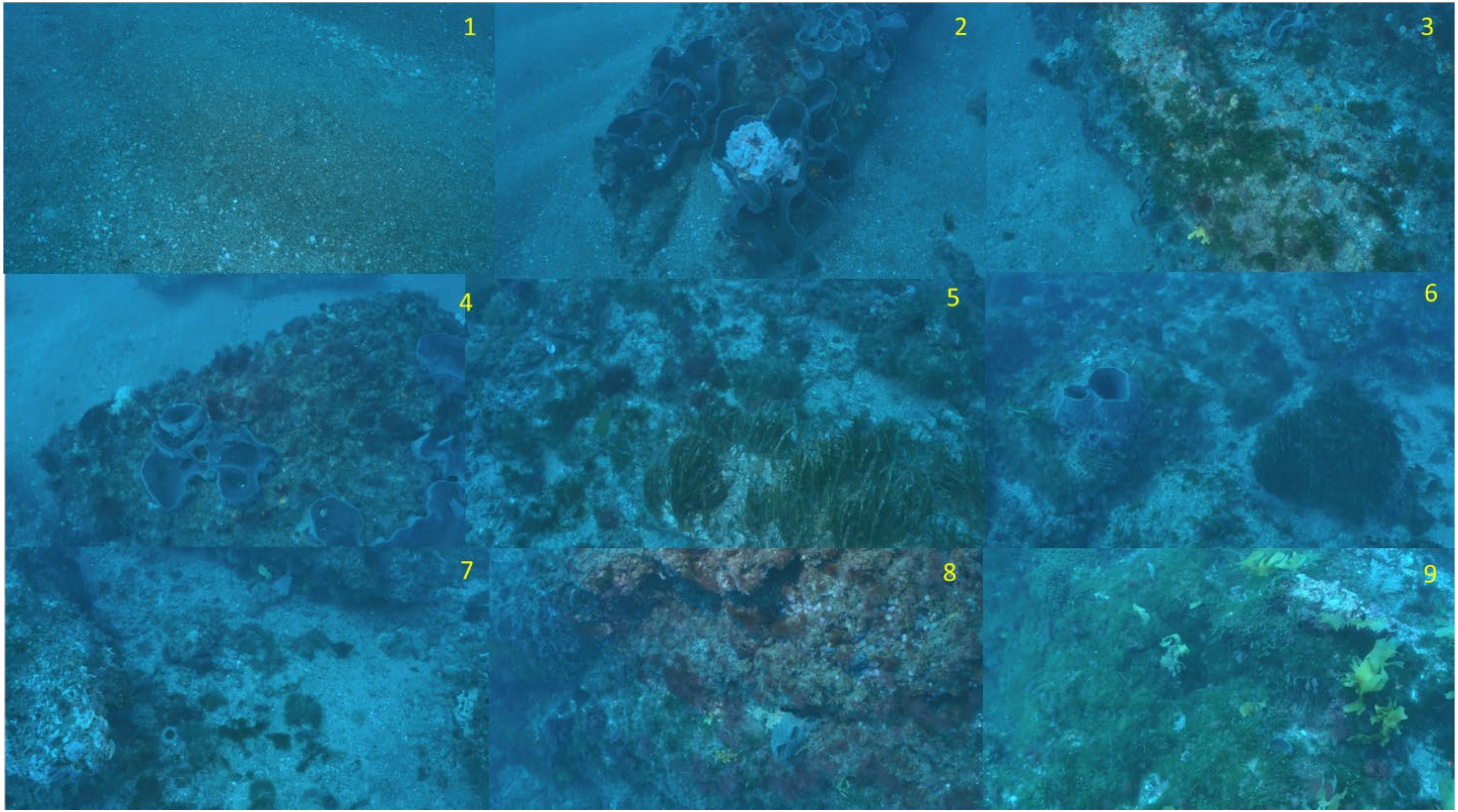


Figure 3-43: Site Q seafloor images image numbers are plotted spatially in Figure 3-41 over multibeam sonar back scatter: 1) soft sediment seafloor; 2–4) oblong reef blocks with grey sponge *E. alata* and white-grey sponge Family Irciniidae species 2; 5) *C. flexilis*; 6) grey cone sponge *S. conulosa*, and *C. flexilis* patch); 7) reef and soft sediment, large anemone (Family Actiniidae); 8–9) low walls, part of the rising reef, with red algae, green lawn algae, and *Ecklonia* individuals appearing prior to the start of *Ecklonia* forest from the ridge top on).

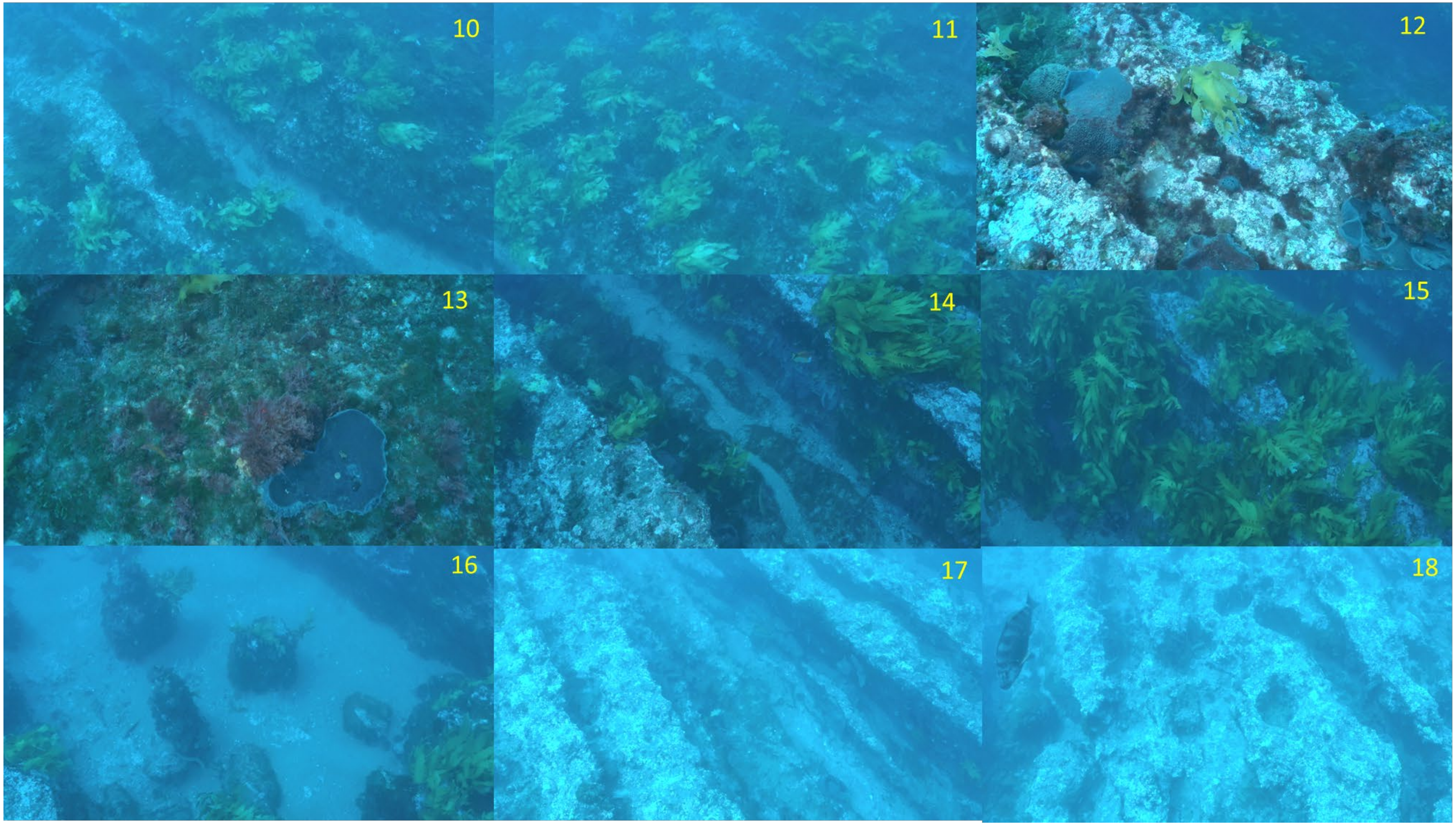


Figure 3-43 Continued 10–11) *Ecklonia* forest and green lawn algae in association with finger-and-gutter reef, (12) a small rock spine with the grey fuzzy football sponge *Polymastia* cf *massalis* (left), grey sponge *S. conulosa* (immediately adjacent), Cook Turban gastropod (far left centre) and grey sponge *E. alata* (right), and 'white coralline paint/crust'; 13) foliose red and green lawn algae; 14–15) finger-and-gutter reef examples; 16) eroded reef stubs; 17) bare finger-and-gutter reef; 18) eroded reef pot-hole form.

3.6.10 Site R

Depth range. 16.6–26.4 metres **Reef size**: 136,726 m^2

Form. A large, multi-faulted reef tilted up on its north side, with putatively 5 fault-line features creating lateral displacement of 60 to 130 metres for several blocks. Four low ridges were present on the north side of the tilted block, along with a large, rounded rock feature on the east side

Part of a larger area of reef features, with a discrete series of ridges and large rock outcrops, which included sites S, T, and U (Figure 3-44).

BTM Divisions (cross section along west to east transect): Steep Slopes → Rock Outcrop Highs, Narrow Ridges → Steep Slopes → Rock Outcrop Highs, Narrow Ridges → Steep Slopes → Broad Slopes → Flat Plains → Broad Depression → Depressions → Broad Depression → Broad Slope → Rock Outcrop Highs, Narrow Ridges → Steep Slope → Rock Outcrop Highs, Narrow Ridges → Steep Slopes → Flat Plains → Broad Slopes → Steep Slopes → Rock Outcrop Highs, Narrow Ridges → Steep Slopes (Figure 3-45).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-45 to Figure 3-47)

Geology. Most of the 820 metre long video transect traversed sandstone reef habitat, meandering along two ridge features in the western half, and then cutting obliquely over two further ridge features in the eastern half (Figure 3-45). Poorly sorted coarse sand and shell, and large gravel and stones and shell, contributed to soft sediment habitats on the flat plains either side of the eastern ridges. The ridges proper were composed of low and high broken rock, as well as pillow ridge rock. Some small patches of flat exposed rock tells were present adjacent to the base of the reef, that appeared to be mudstone/Papa rock (18, 20).

Biogenic habitats: Starting on the west side, the transect began a ridge of broken low rock supporting *E. radiata* kelp forest (1–3) with 20–60% cover, followed by broken rock and pillow ridge reef dominated by *C. flexilis* meadows (4–10) (Figure 3-46). The transect moved onto a second ridge, with broken low rock and associated *E. radiata* kelp forest (around 40% cover) (11–12). The second half of the transect cut obliquely across a third ridge with a narrow band of *E. radiata* forest on the ridge top, with soft sediments and flat basement and boulder seafloor flanking each side of the ridge supporting a low cover of red filamentous algae and bushy bryozoans (13–19) . On the far eastern side, the transect passed over a large rock feature, with a narrow band of *E. radiata* patches (20% cover) (22) present on the top of the feature, followed by mixed red algae and *C. flexilis* meadow cover (60%) on the eastern downward slope (23–26), grading into C. flexilis meadows on pillow reef (27).

Main invertebrate species: Sponges were the most common sessile invertebrates, with an overall low 0.6% cover contribution across the video transect (Table 6). The dominant taxa were Family Chondropsidae species 2, *S. conulosa*, Family Halichondriidae (genus & sp. unid.), *Stylissa* sp. indet., and *R. topsenti*/*Axinella* sp. indet. (Table 7). Most of the orange fluffy mound sponge *Stylissa* sp. indet. seen across the survey were counted at this site (101 individuals, 67% of all counted in the survey) (with the adjacent S and T sites contributing a further 19%). The reddish-pink/grey ball sponge, *Aaptos rosacea,* was also largely represented by this site (39 individuals, 87% of all counted). Sponge richness and abundance were negatively correlated with *E. radiata* cover on the ridge features. Calcified bryozoans, rare in the survey, were most abundant at this site (*Galeopsis porcellanicus* 48% of individuals, *Adeonellopsis macewindui* 22% of individuals); with the adjacent S and T sites contributing a further 16% and 63% (Table 7). These were associated with the *C. flexilis* meadows on pillow reef.

Mobile invertebrates occurred in low numbers across the reef, dominated by the sea slug *A*. *luctuosa*, and the gastropods *C*. *sulcata* and *A*. *heliotropium*. Only eight kina were counted. One solitary smooth snake-star, *O*. *maculata,* was also observed, the only individual seen during the survey.

Main fish species: Scarlet wrasse and butterfly perch dominated the fish assemblage, with scarlet wrasse observed across the reef, while butterfly perch occurred as small schools, often associated with abrupt bathymetry changes (Table 8, Figure 3-46). No 0+ juvenile blue cod were seen, with most of the sub-adult and adult blue cod clustered along the reef/ soft sediment interface.

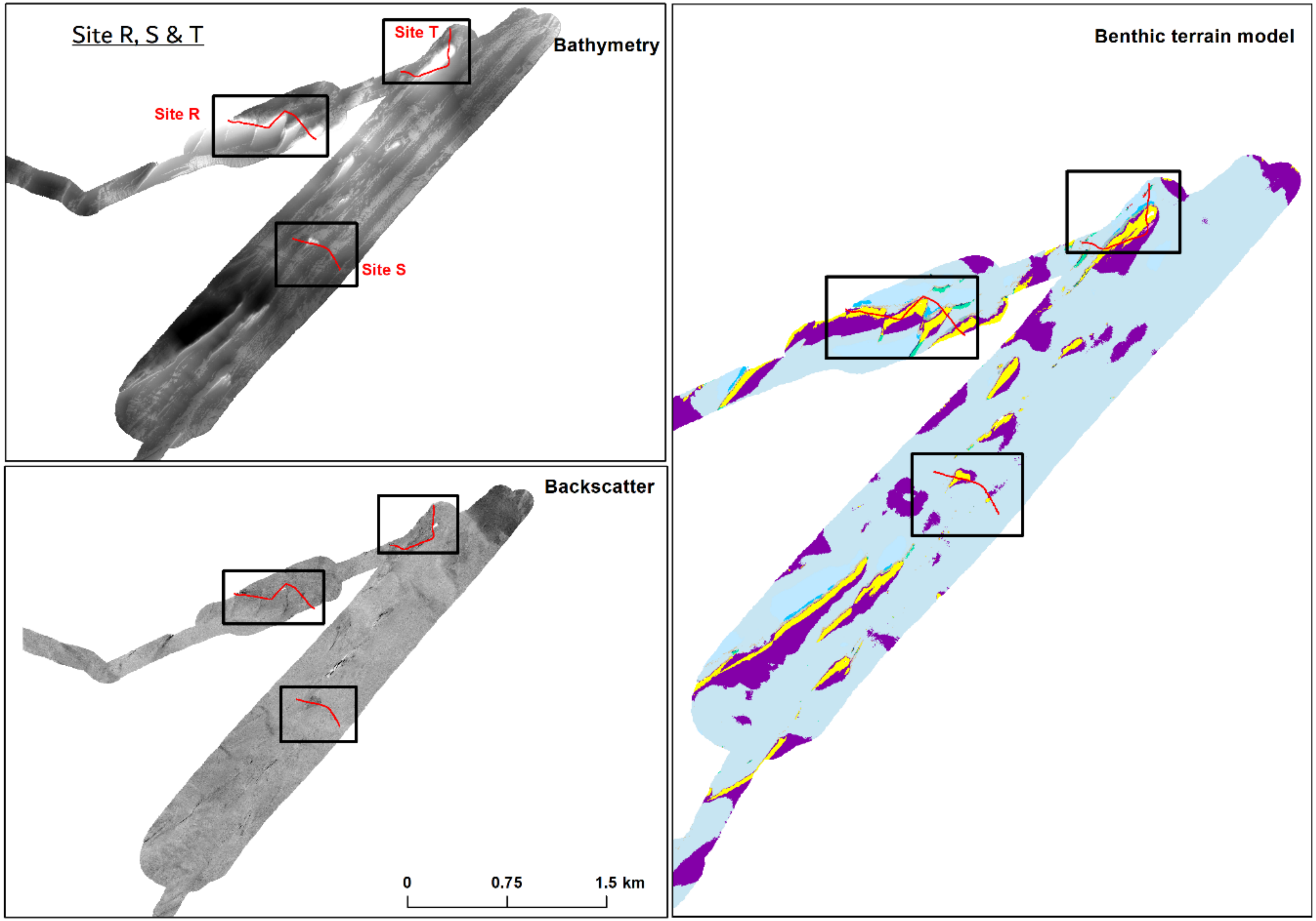


Figure 3-44: Broader extent maps of larger seafloor area mapped. (reef and other unknown features) around sites R, S and T.

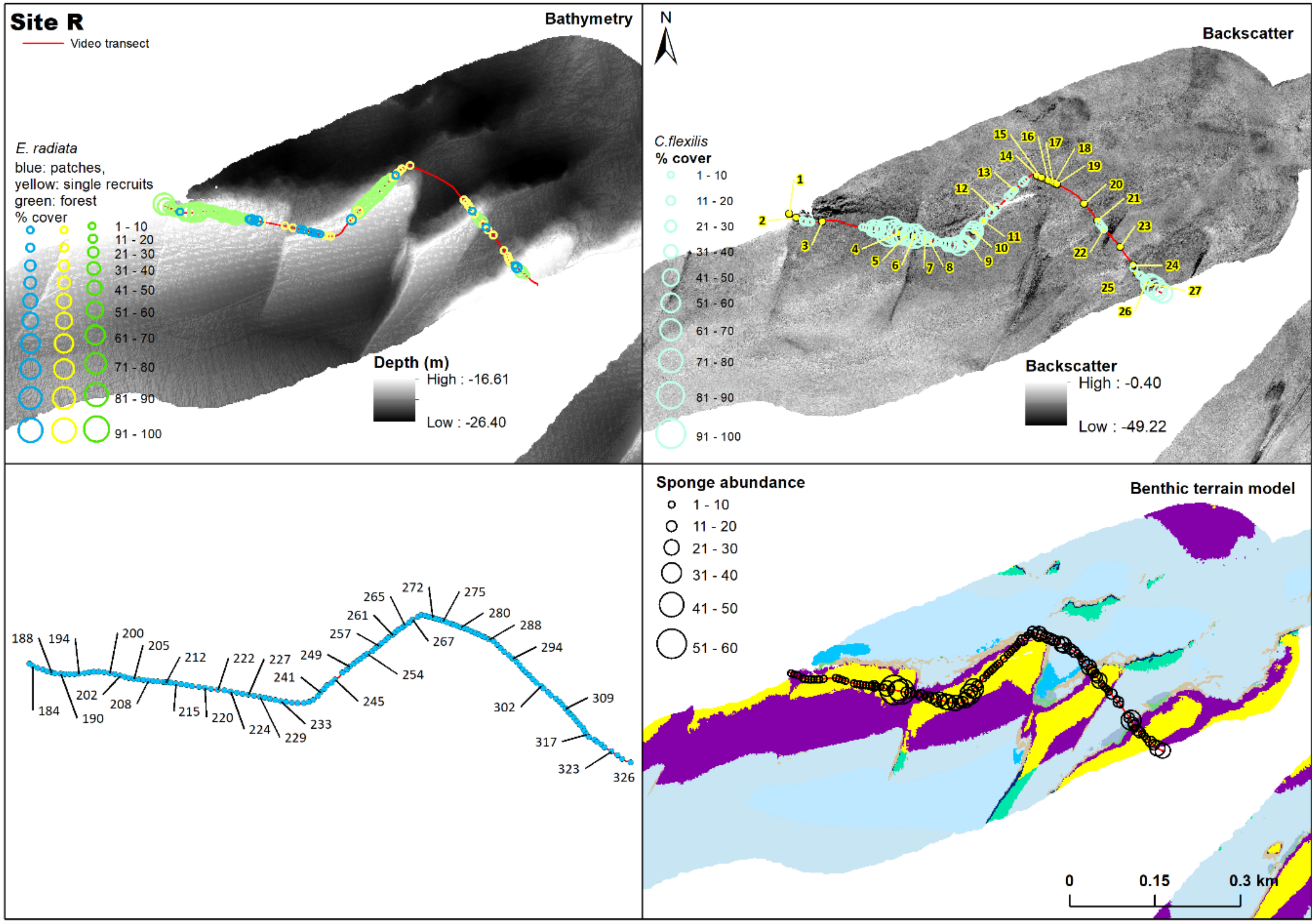


Figure 3-45: Maps of site R Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

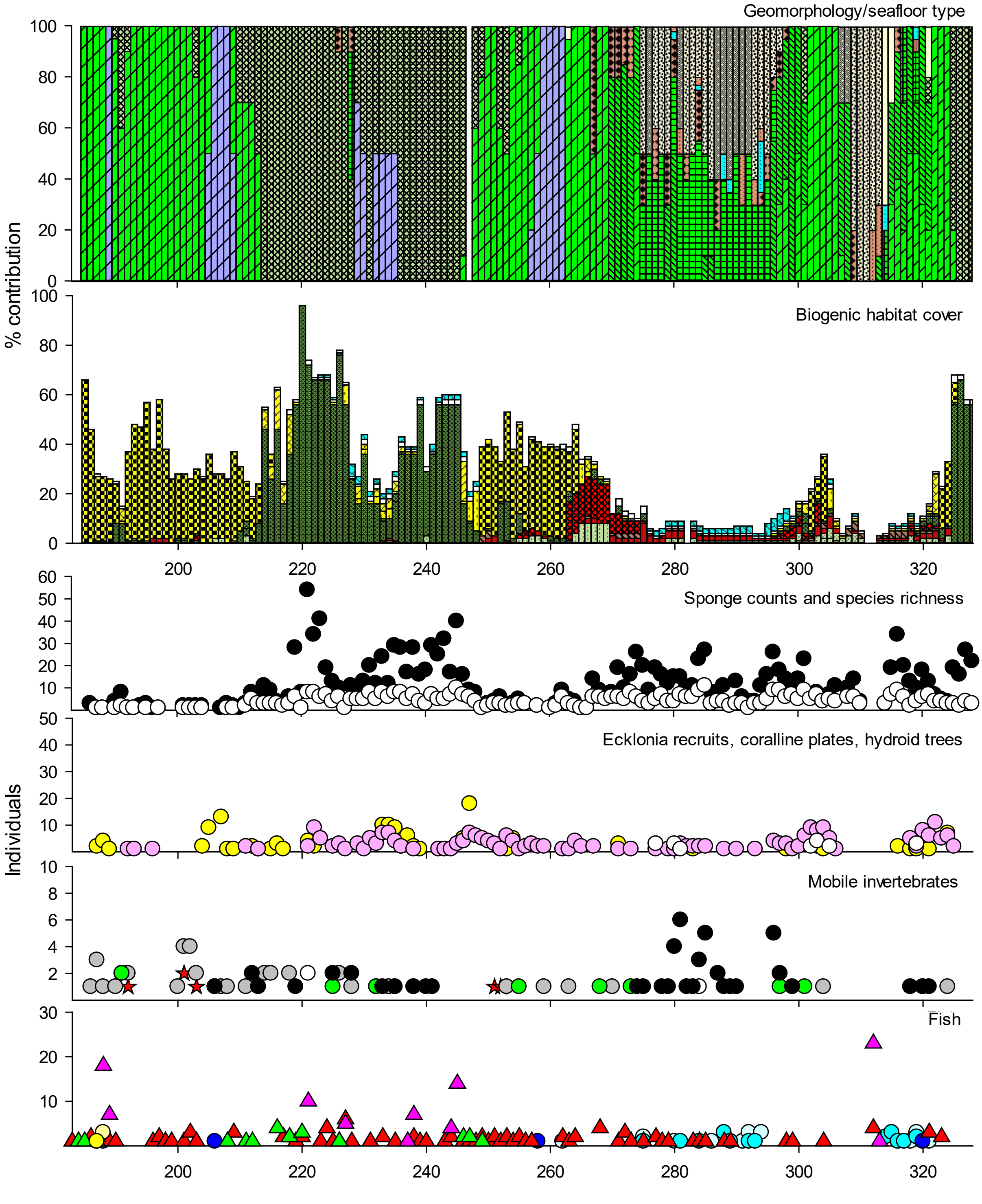


Figure 3-46: Site R CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-45.

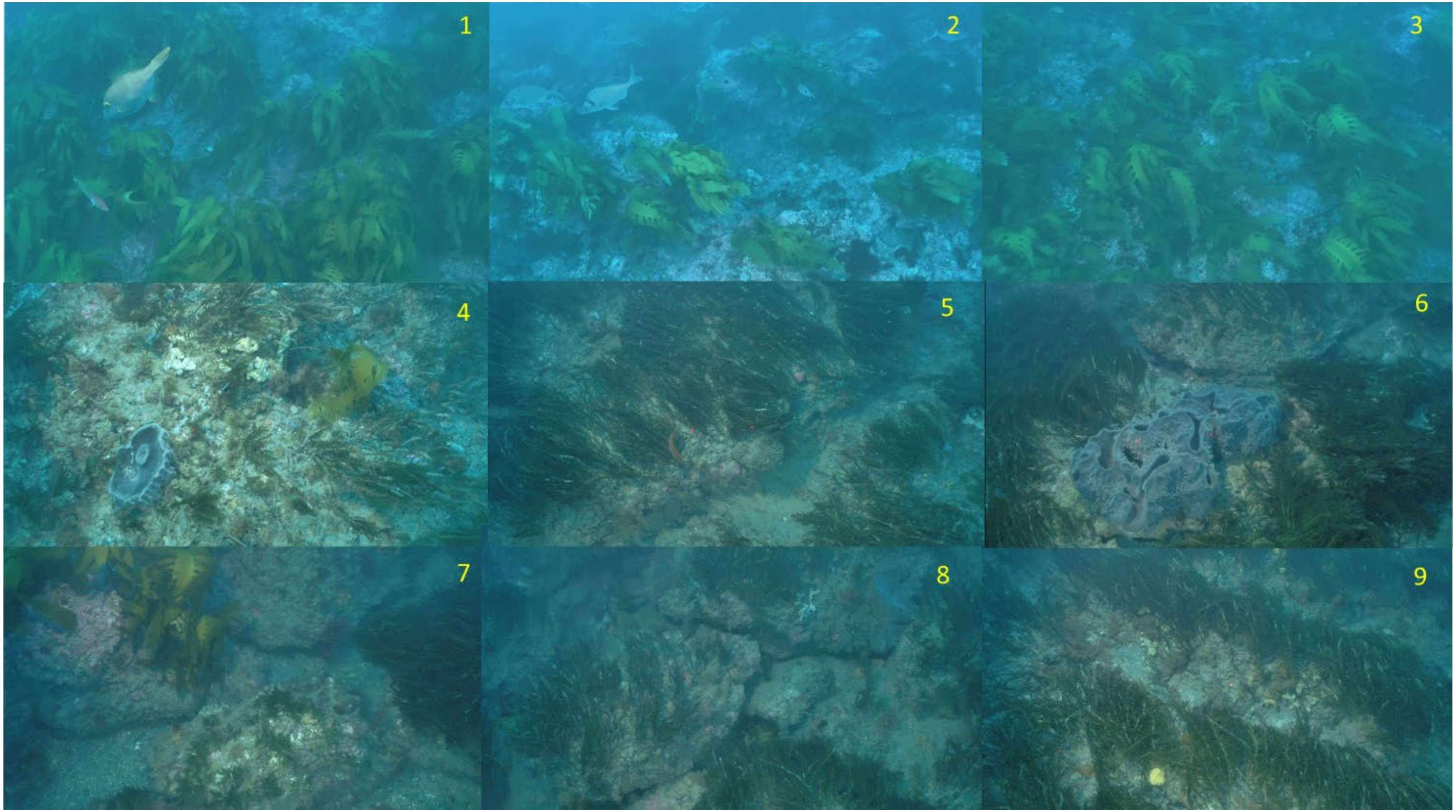


Figure 3-47: Site R seafloor images image numbers are plotted spatially in Figure 3-45 over multibeam sonar back scatter: 1–3) *Ecklonia* forest and patches on the ridge top (scarlet wrasse, leatherjacket and tarakihi present) (lattice reef form seen in 2); 4–9) various forms of 'pillow reef' and/or boulders, dominated by *C. flexis*, and occasional *S. conulosa* and *E. alata* sponges. Image 9 shows the often aligned tows of *C. flexis*, with co-association of small sponges and bryozoans.

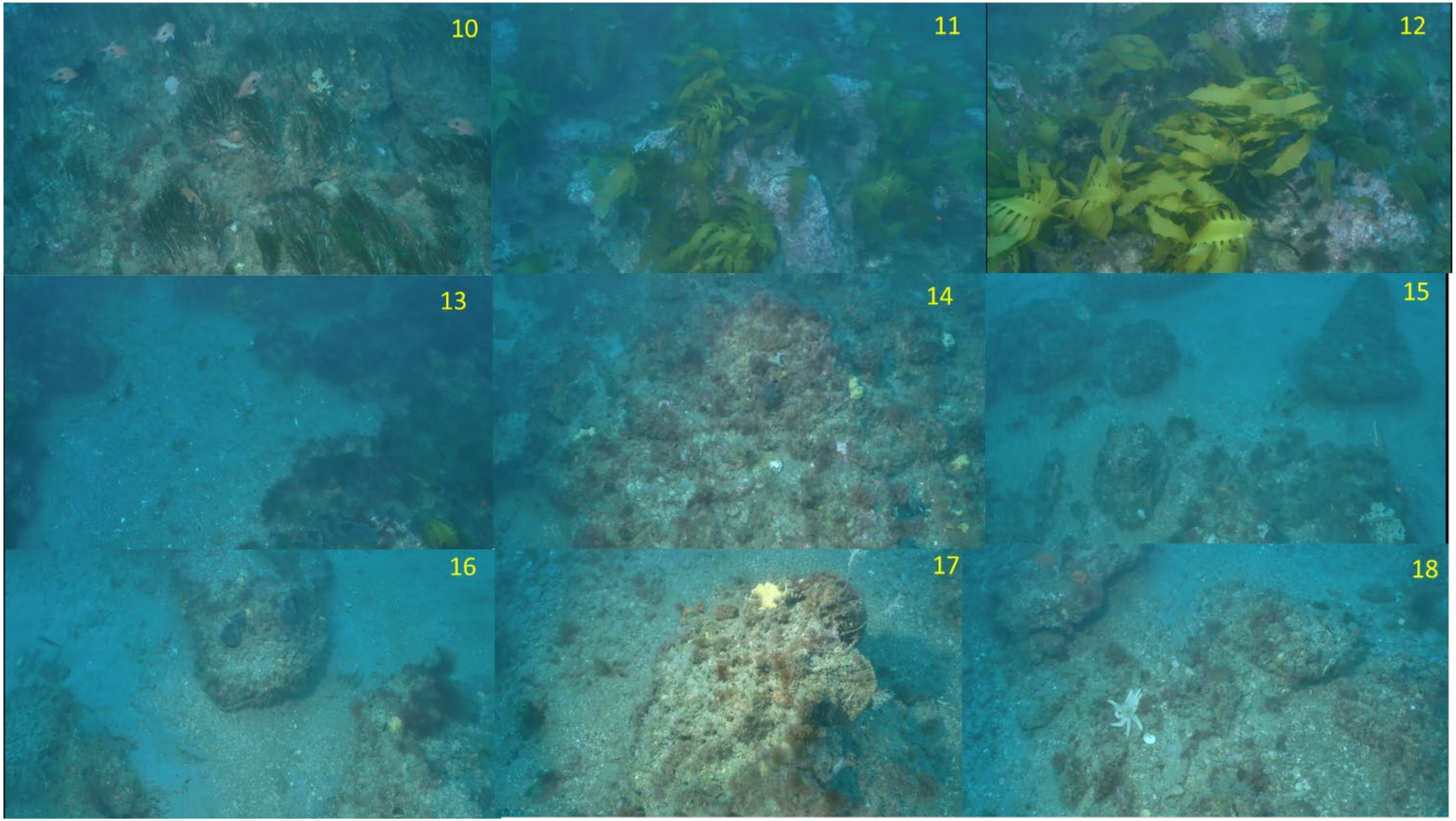


Figure 3-47: Continued 10) *C. flexilis* on pillow reef with small sponge and bryozoans association, with school of juvenile butterfly perch; 11-12) *Ecklonia* patches/forest (lattice reef form in 11); 13–18) flat basement rock and boulders with soft bryozoans and red algae, and the starfish *C. muricata* (18), sitting on small patches of mudstone/Papa rock (smoother flat grey rock).

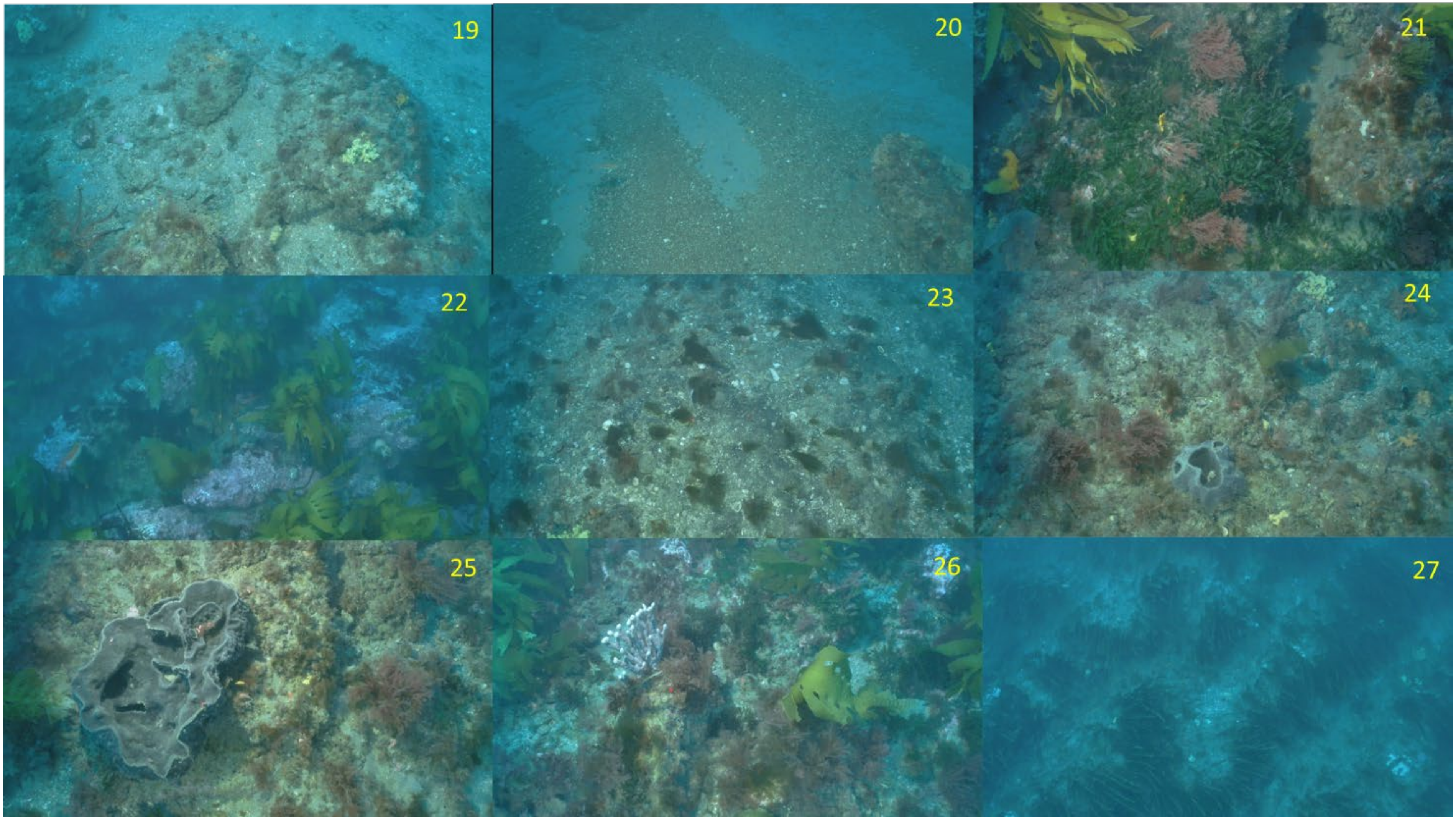


Figure 3-47: Continued 19) flat basement rock and boulders with soft bryozoans and red algae; 20) small patch of mudstone/Papa rock overlain by soft sediment drifts; 21) broken rock with *C. flexilis*, red algae, and *Ecklonia* singles; 22) *Ecklonia* patches (lattice reef form); 23–26) mixed biogenic habitats; 27) *C. flexilis* regular rows on pillow reef.

3.6.11 Site S

Depth range. 12.7–26.3 metres **Reef size**: 29,393 m^2

Form. A large oblong rock orientated north-east/south-west, approximately 359 metres long by 85 metres wide. The reef rises from around 22–24 metres, to 12.7 m depth, although a small patch of the shallowest northern reef area was not mapped by multibeam. The reef was composed of long terraces/platforms running along its longest axis, that were slightly tilted.

Part of a larger area of reef features, with a discrete series of ridges and large rock outcrops, which included sites S, T, and U (Figure 3-44).

BTM Divisions (north to south along video transect): Broad Depression → Local Ridge, Boulders, Pinnacles on Slope → Lateral mid-slope depression → Flat plains → Broad depressions → Depressions → Steep Slopes → Broad slopes → Flat Ridge Tops → Rock Outcrops Highs, Narrow Ridges → Flat Ridge Tops → Crevice, Narrow Gullies over Elevated Terrain → Flat Ridge Tops & Rock Outcrop Highs, Narrow Ridges → Scarp, Cliff → Flat Plains → Local Ridges, Boulders, Pinnacles on Broad Flats (Figure 3-48).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-48 to Figure 3-50)

Geology. Approximately 400 metres of the 670 metre long video transect traversed the block reef habitat proper, with additional boulders and rock tells also present outside of the reef block (transect start in the north (1–4), and some patch reefs to the south-west (32,33,36)). The reef itself was composed of stepped terraces, with broken rock on the reef top/ridge. The terraces were separated by vertical drops of 1 to 2 metres (8,15,18,21,23,24,26,28–30), some of which could be seen as 'creases' on the multibeam sonar bathymetry (Figure 3-48)

Biogenic habitats: The video transect started to the north of the reef block, on a seafloor of poorly sorted coarse sand and shell, with some low, bare, rock (mudstone/Papa rock) showing through the soft sediments. Soft bryozoans were the dominant biogenic habitat cover (2,3,4) (around 20%), with an association of the small yellow and white anemone *Anthothoe albocincta* (Table 6, Figure 3-49). The northern edge of the reef block was a field of broken slabs/boulders with many small crevices, with associated biogenic habitat cover of *C. flexis* and red foliose algae (5–7). Flat step terraces followed (8), rising to a reef top of broken rock (12), more flat step terraces on the eastern side (15), followed by irregular broken cobbles with soft bryozoan cover (16–17). These terraces were dominated by *C. flexis* meadow (8–10, 13), with *E. radiata* kelp patches also present (9,12,14). The video transect turned in a wide arc over the off-reef broken cobble field, which supported a low cover of soft bryozoans (17), before passing over the main reef block again going west. Stepped terraces (18,19) rose to the reef top (20) then dropped down the western side as terraces (21–31) to soft sediments and some patch reefs (31–36). *C. flexilis* meadow was the dominant biogenic habitat cover on the terraces (50–100% cover). *E. radiata* was limited to a narrow zone on the reef top, where it occurred as kelp forest (one segment wide) and adjacent patches (20). Sponge cover was low, but a notable feature was the presence of occasional large *E. alata* individuals within the *C. flexilis* meadows (25).

Main invertebrate species: Sponges were the most common sessile invertebrates, with an overall low 0.59% cover contribution across the video transect (Table 6). The dominant sponge taxa were Family Chondropsidae species 2, *S. conulosa*, Family Halichondriidae, genus & sp. unid., *Stylissa* sp. indet. and *R. topsenti/Axinella* sp. indet. (Table 7). Sponge richness and abundance were consistent through-out the first half of the video transect, but noticeably declined on the second half of the transect (Figure 3-49). As with adjacent sites R and T, the calcified bryozoans *G. porcellanicus* and *A. macewindui* were present in association with *C. flexilis* meadow on pillow ridge reef, (*A. macewindui* 82 individuals, 62% of individuals counted in the survey, Table 7). Mobile invertebrates were uncommon, with low numbers of the sea slug *A. luctuosa*, cushion stars (off reef), kina, and the gastropod *C. sulcata* (Table 7, Figure 3-49).

Main fish species: Butterfly perch and scarlet wrasse dominated the fish assemblage (Table 8), with scarlet wrasse observed across the reef system, while butterfly perch occurred as adults often associated with abrupt bathymetry changes (15), and as juveniles over the *C. flexilis* meadows (Figure 3-49). Blue cod were relatively uncommon and occurred on the reef edges, as well as having an association with *Axinella* sp. and other finger sponges on soft sediments (35).

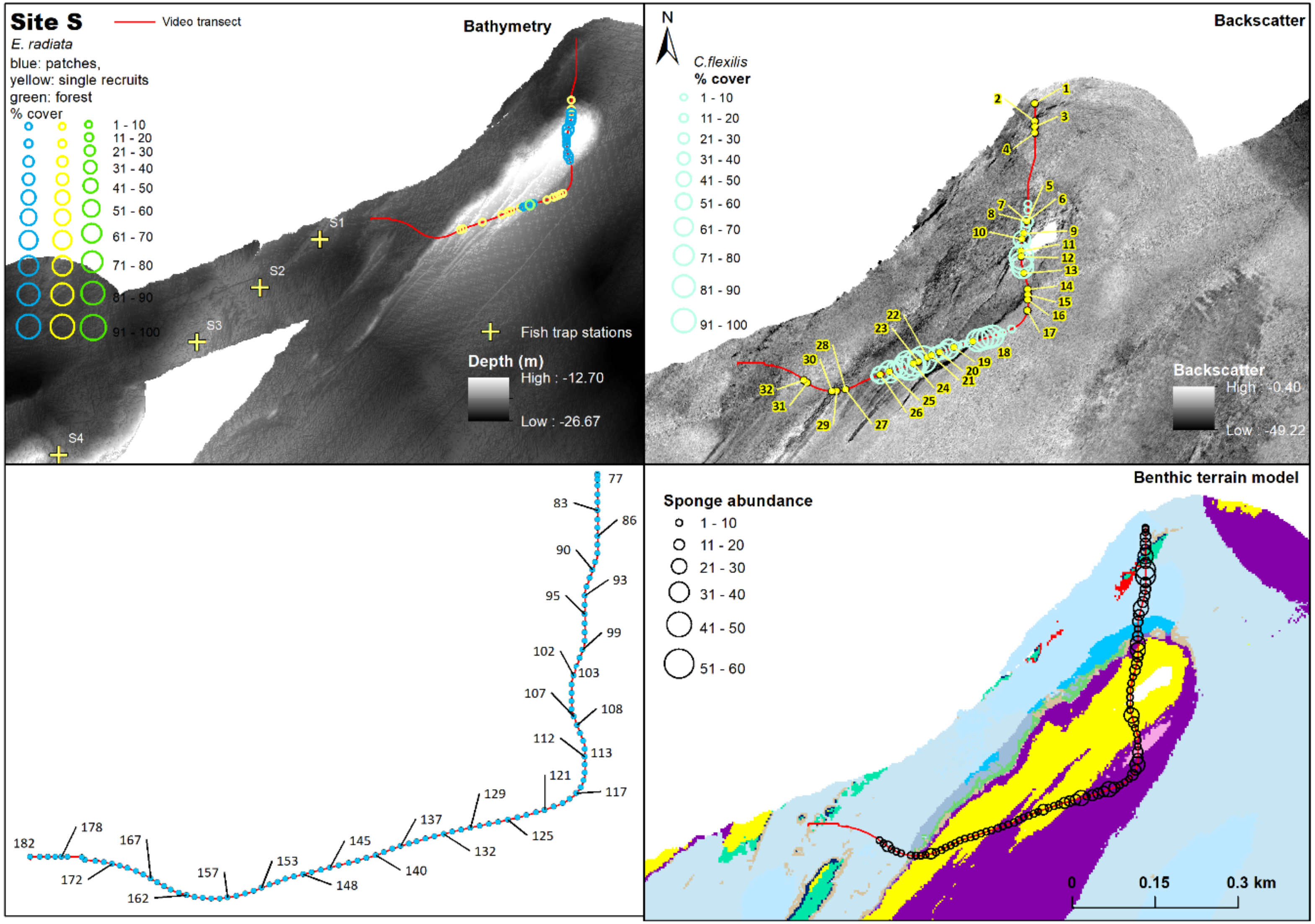


Figure 3-48: Maps of site S Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment). Note that the grey scale colour ramp used to best illustrate the sites depth range 'washes out' some shallower reef complexity.

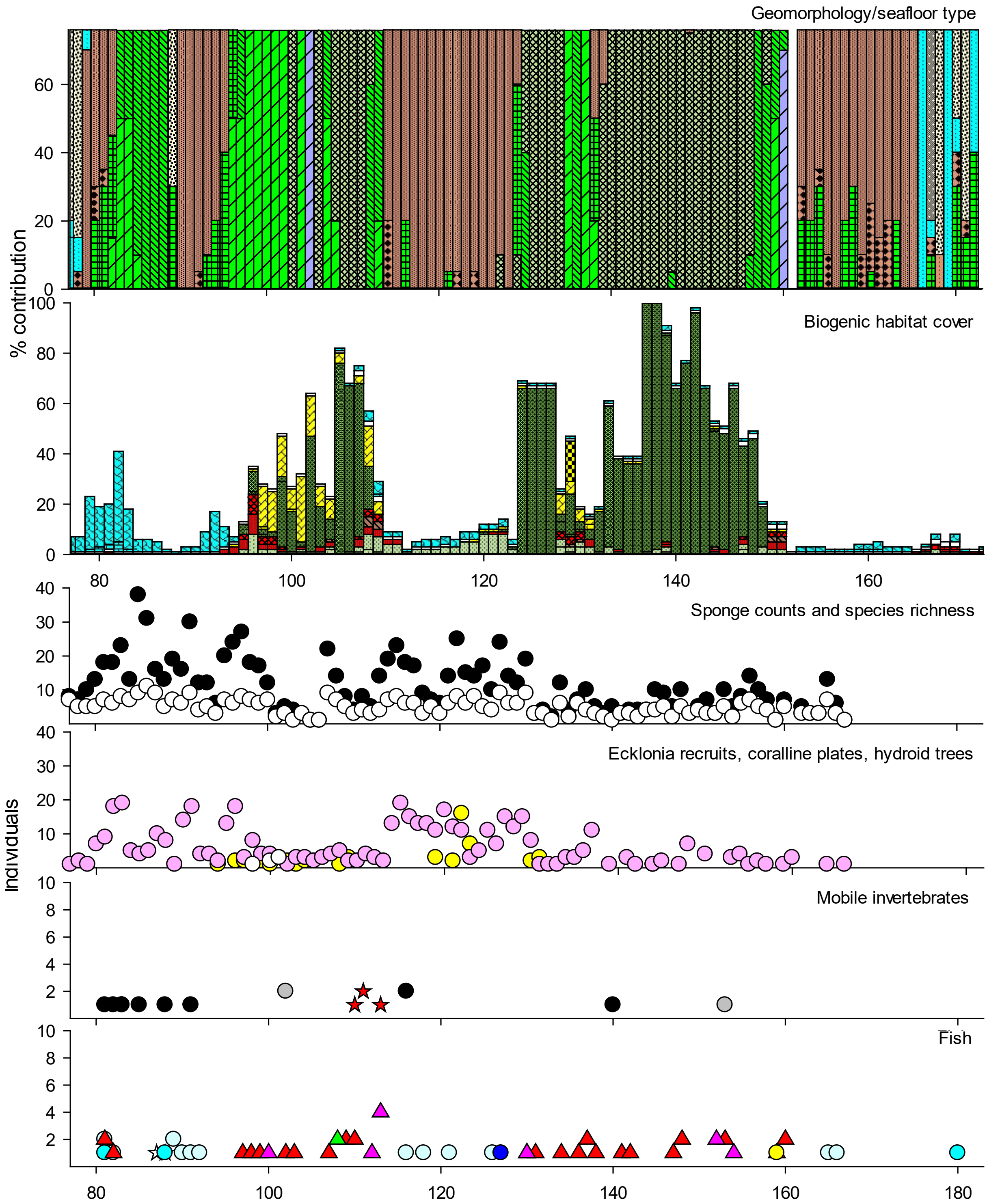


Figure 3-49: Site S CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); invertebrates, and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-48.

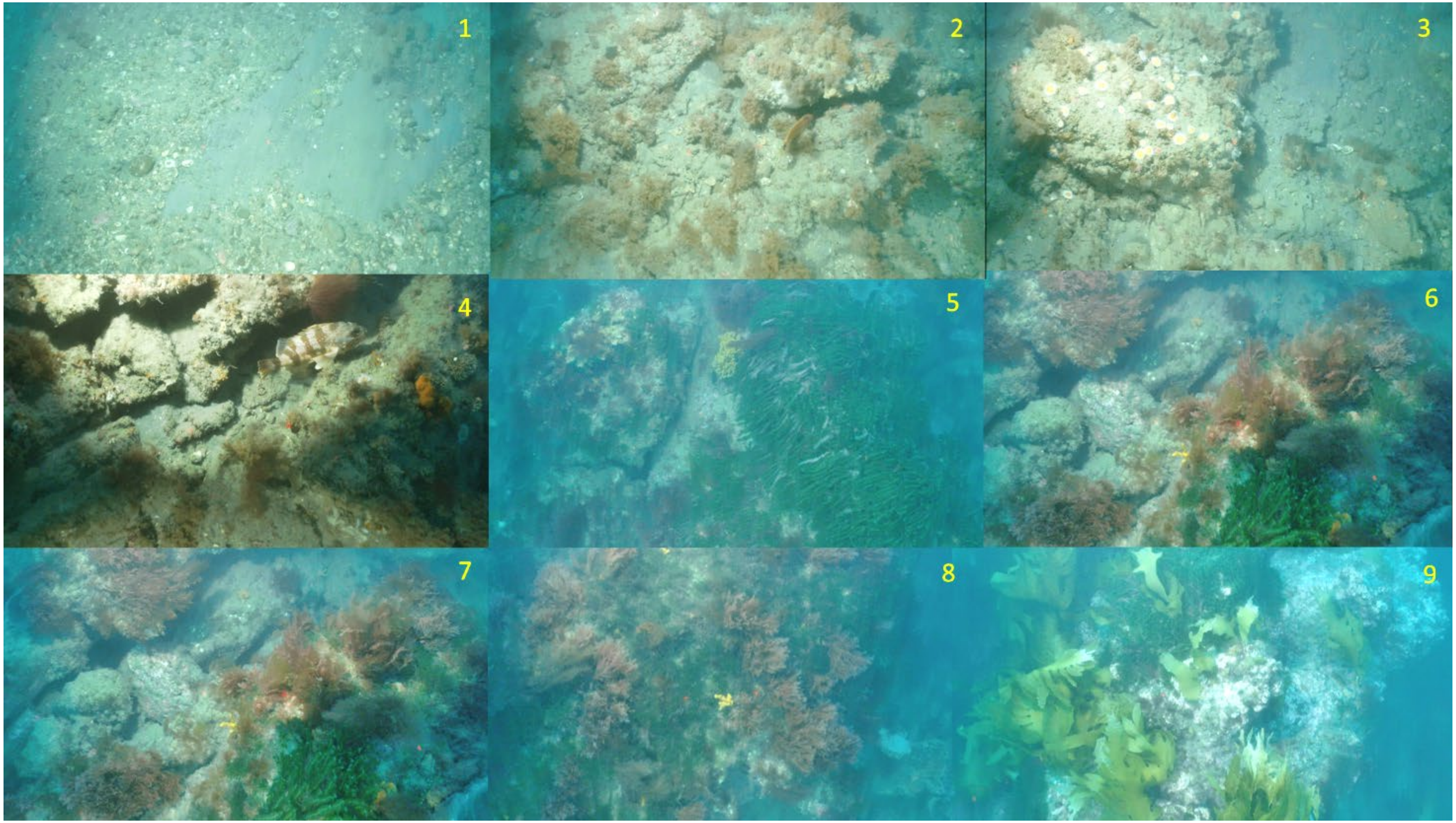


Figure 3-50: Site S seafloor images image numbers are plotted spatially in Figure 3-48 over multibeam sonar back scatter: 1) bare rock tell (mudstone/Papa rock) overlain with soft sediments; 2–4) low reef and boulders (not part of main reef), with soft bryozoans and anemone (*Anthothoe albocincta*) associations and one of two sea perch seen across the survey; 5–7) low broken rock with *C. flexilis* and red algae); 8) step terrace and drop); 9) reef top area with *Ecklonia* forest.

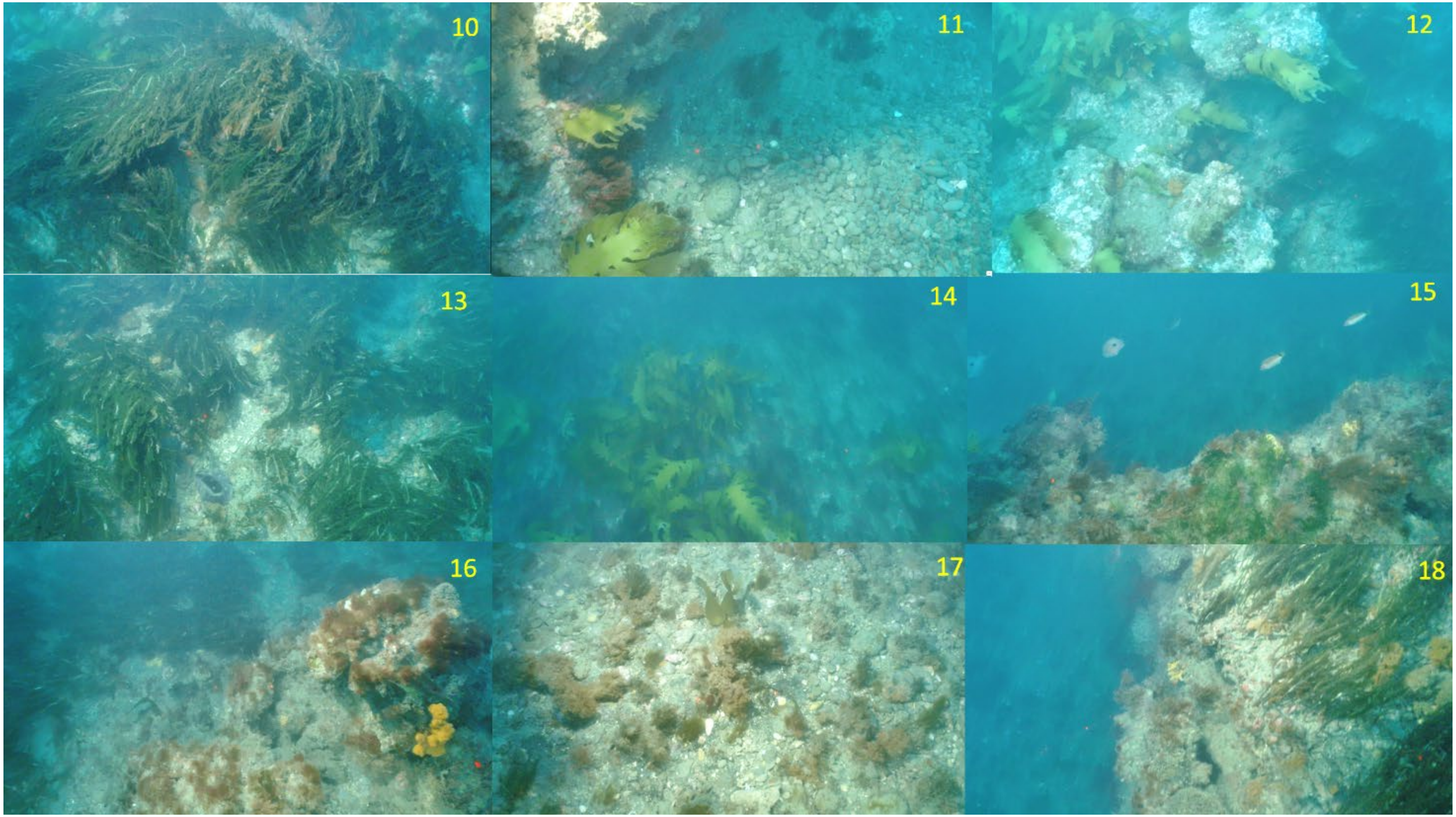


Figure 3-50: Continued. 10–12) reef top area with *C. flexilis* and *Ecklonia*; 13–15) terraces and drops; 16–17) off-reef low rock and irregular cobbles with soft bryozoans (to east of reef); 18) terrace and drop.

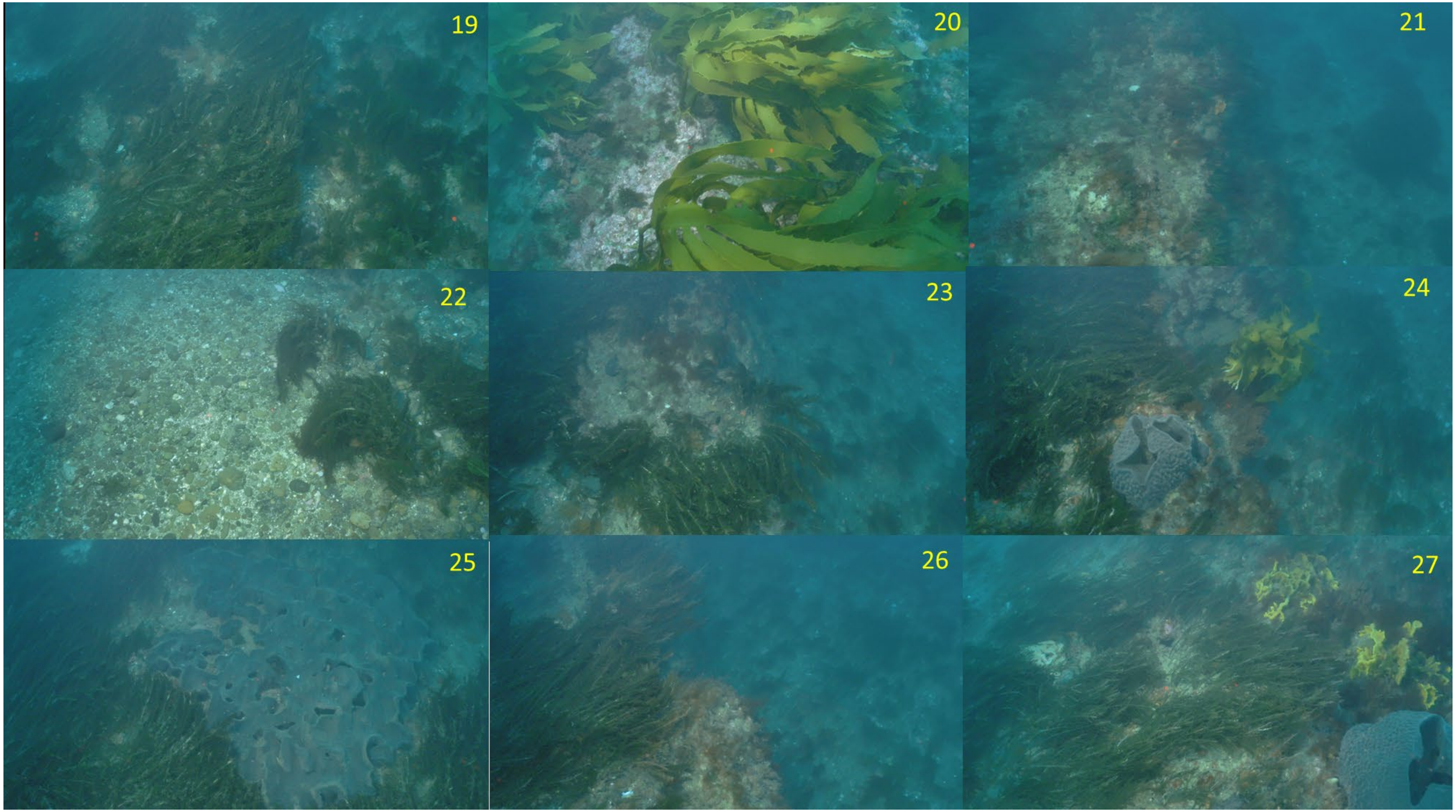


Figure 3-50: Continued 19) terrace with *C. flexilis*; 20) reef top with *Ecklonia*; 21–27) reef terraces and drops, with a large *E. alata* sponge associated with *C. flexilis* meadow (25).

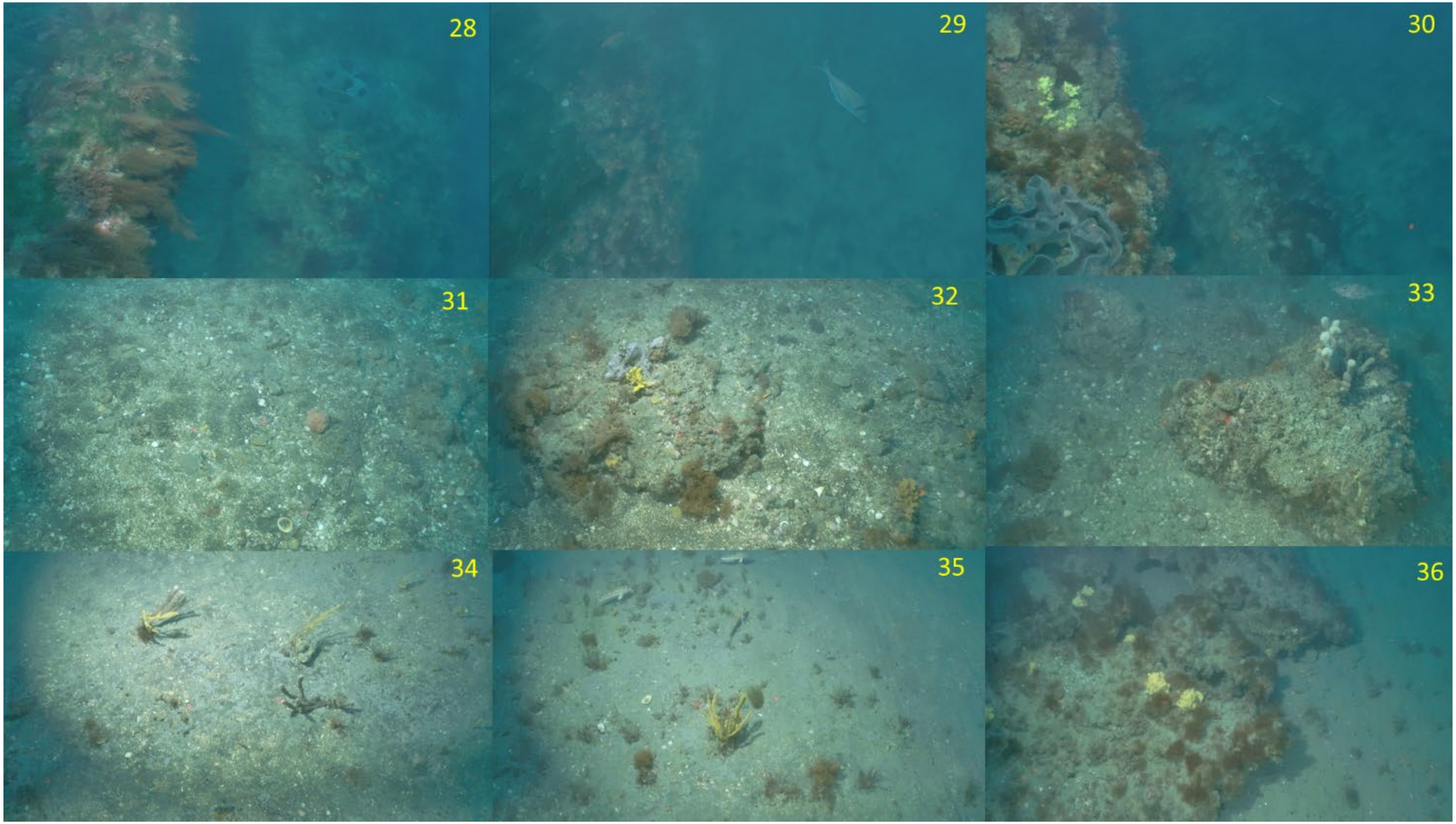


Figure 3-50: Continued 28–30) reef terraces and drops; 31) soft sediments; 32–33) boulders with associated soft bryozoans and sponges; 34–35) soft sediment veneer on flat rock surface, with yellow finger sponges *Axinella* sp. (possibly *Axinella australiensis*), grey sponge *Dactylia varia*, and blue cod; 36) low reef with soft bryozoans and sponges.

3.6.12 Site T

Depth range. 18.7–28.7 metres **Reef size**: 7,101 m^2

Form. A large triangular rock, composed of five terraces with intervening bathymetry drops, orientated west-east. The reef rose from soft sediments at 24–25 metres depth, to the shallowest depth of 18.7 m (6–7 m reef height). Dimensions along the longest two axes were 126 x 95 metres. On the west side, the reef was initially in the form of large, discrete, raised rock slabs surrounded by soft sediments; before becoming continuous reef.

A separate area of low broken rock was present 120 metres to the south-east.

Part of a larger area of reef features, with a discrete series of ridges and large rock outcrops, which included sites S, T, and U (Figure 3-40).

BTM Divisions (west to east along video transect): Flat Plains → Local Depressions, Current Scours → Broad Slopes → Flat Ridge Tops → Rock Outcrop Highs, Narrow Ridges → Flat Ridge Tops → Flat Plains → Flat Ridge Tops → Flat Plains (Figure 3-51).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-51 to Figure 3-53)

Geology. The video transect traversed the reef for 95 metres, crossing a series of flat terraces, separated by abrupt bathymetry changes (Figure 3-51). On the western side the reef first appeared as small tells (2), then discrete large, raised rock slabs (3) surrounded by soft sediment, then full continuous reef terraces (4–12), ending on soft sediments on its eastern side (13). A separate area of low broken rock patches were also present to the east (15,17).

Biogenic Habitats: The video transect started to the west of the reef block, on a gravel seafloor (1,2) with no visually-apparent epifauna present (Figure 3-52) followed by small rock tells off the main reef, which supported sponge patches (2). Large, raised rock slabs then appeared, with some sponge cover (3), followed by the reef proper. Composed of terraces, the reef had a variable mixed cover of *C. flexilis* and *C. gemmata*, red foliose algae, filamentous green algae, and bushy bryozoans (4–14). *E. radiata* single kelp plants and patches were present (5,7) but relatively uncommon and occurred largely on the upper shallower reef area. Moving east, the reef gave way to gravel seafloor again (14–18), with an area of low patch reef 120 metres to the east supporting a low biogenic habitat cover of filamentous red algae, bushy bryozoans, and sponges (15).

Main invertebrate species: Sponges and bushy bryozoans were the most common sessile invertebrates, with overall low cover of 0.49% and 0.45% respectively (Table 6). The dominant sponge taxa were the Family Chondropsidae species 2, with lesser numbers of *S. conulosa*, the pink ball sponge *Aaptos globosa*, *R. topsenti*/*Axinella* sp. indet., and the low yellow foamy *D. oxeata* (Table 7). Sponge richness and abundance were relatively consistent across the reef feature, with lower values on the low broken rock and gravel patch mosaic to the east (Figure 3-52).

Mobile invertebrates were uncommon, with low numbers of the starfish *Coscinasterias muricata* and cushion stars on the soft sediments to the east of the main reef feature, and the sea-slug *A. luctuosa* on the reefs (Table 7, Figure 3-52). One saw shell *A. heliotropium* was seen, while no kina were observed.

Main fish species: Butterfly perch, scarlet wrasse, and blue cod dominated the fish assemblage, with leatherjackets being the only other species seen (Table 8). All the butterfly perch occurred as one diffuse school, spread across two contiguous video segments over the main reef (Figure 3-52). Scarlet wrasse occurred as individuals spread across the main reef, while blue cod were found on the reef/soft sediment boundary, and in association with the low broken rock/gravel mosaic to the east.

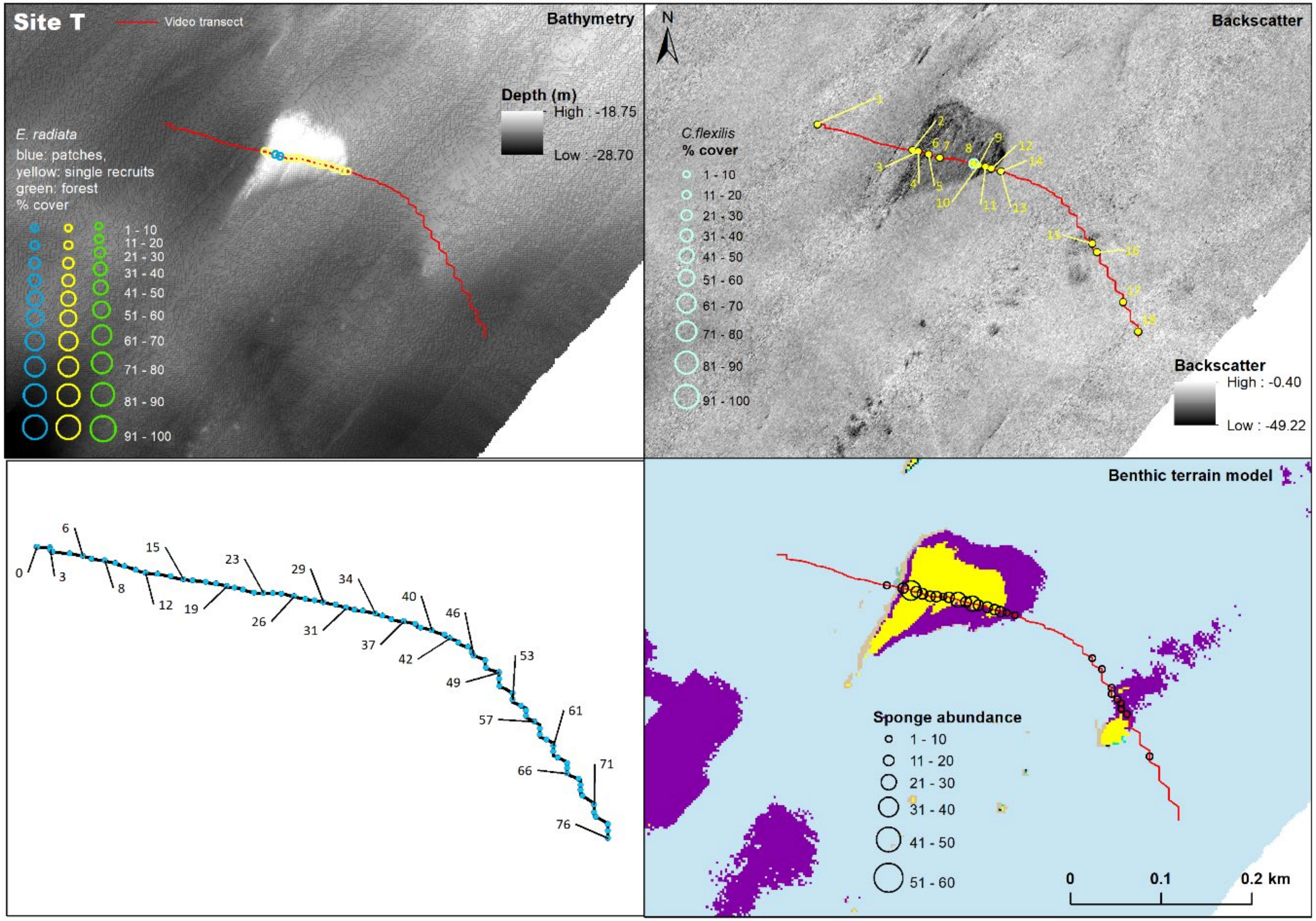


Figure 3-51: Maps of site T Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

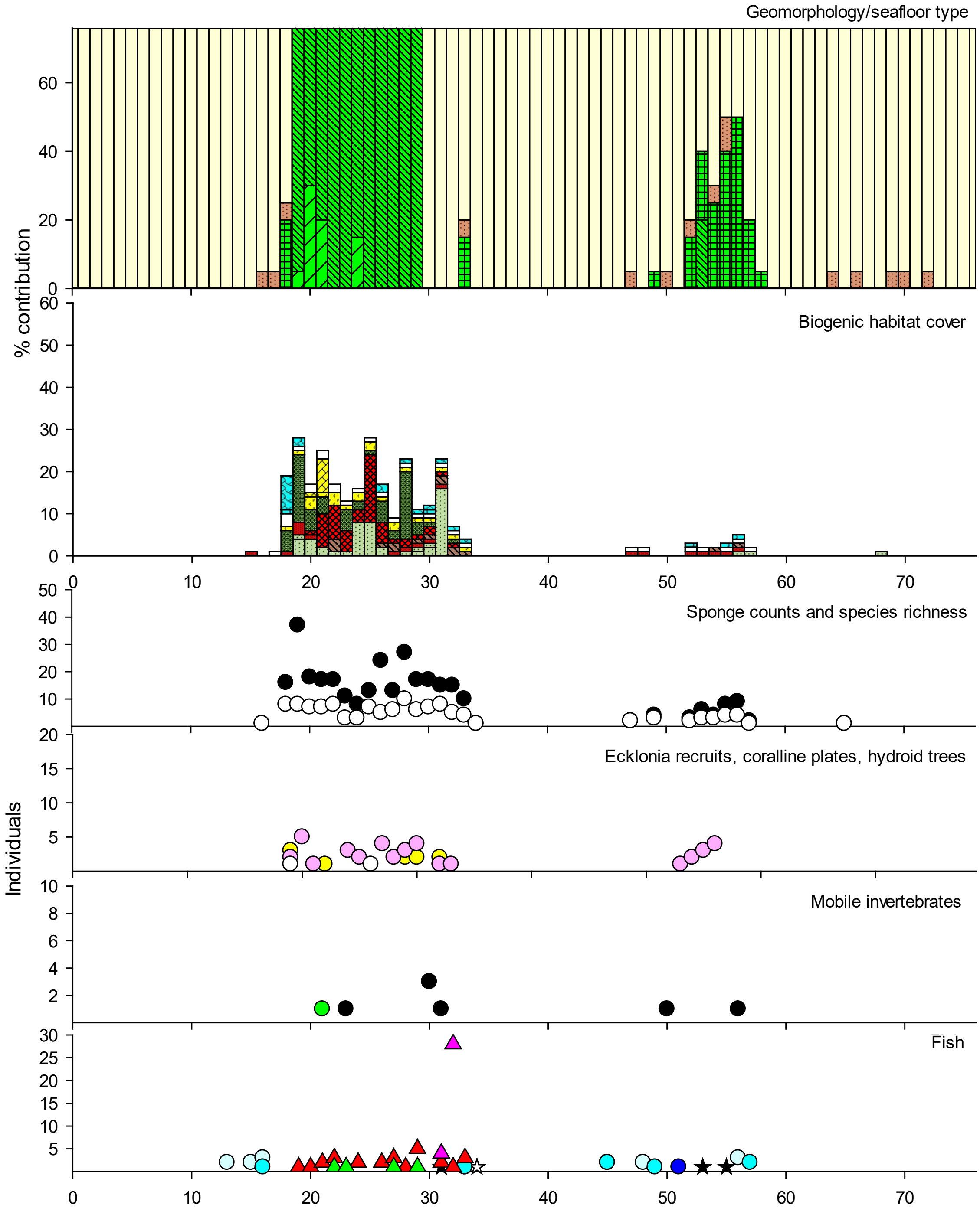


Figure 3-52: Site T CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-51.

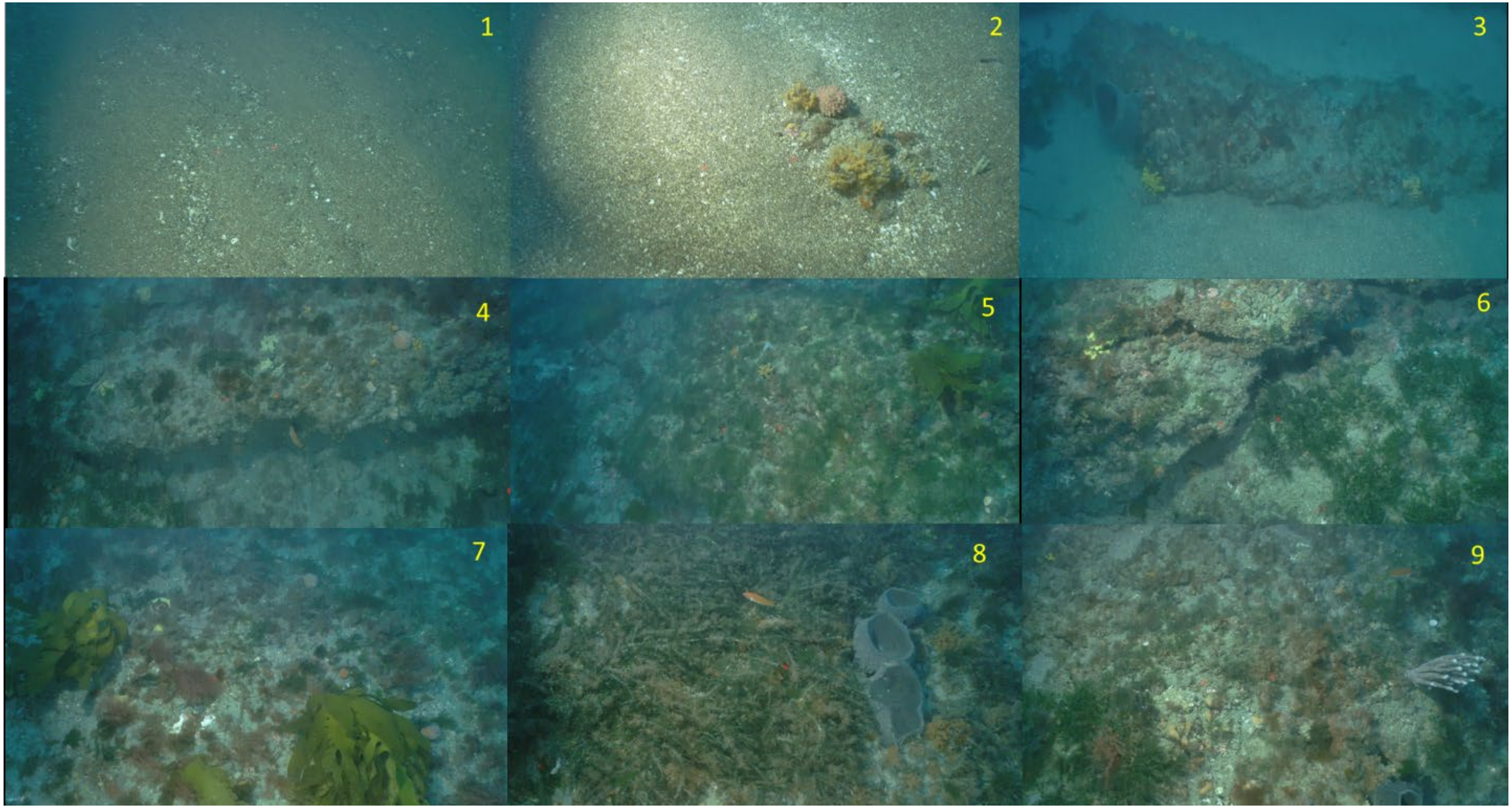


Figure 3-53: Site T seafloor images image numbers are plotted spatially in Figure 3-51 over multibeam sonar back scatter: 1) soft sediments; 2) reef tell with sponge cluster; 3) patch reef with sponges; 4–9) stepped terraces with *C. flexilis*, red algae, *Ecklonia* and sponges

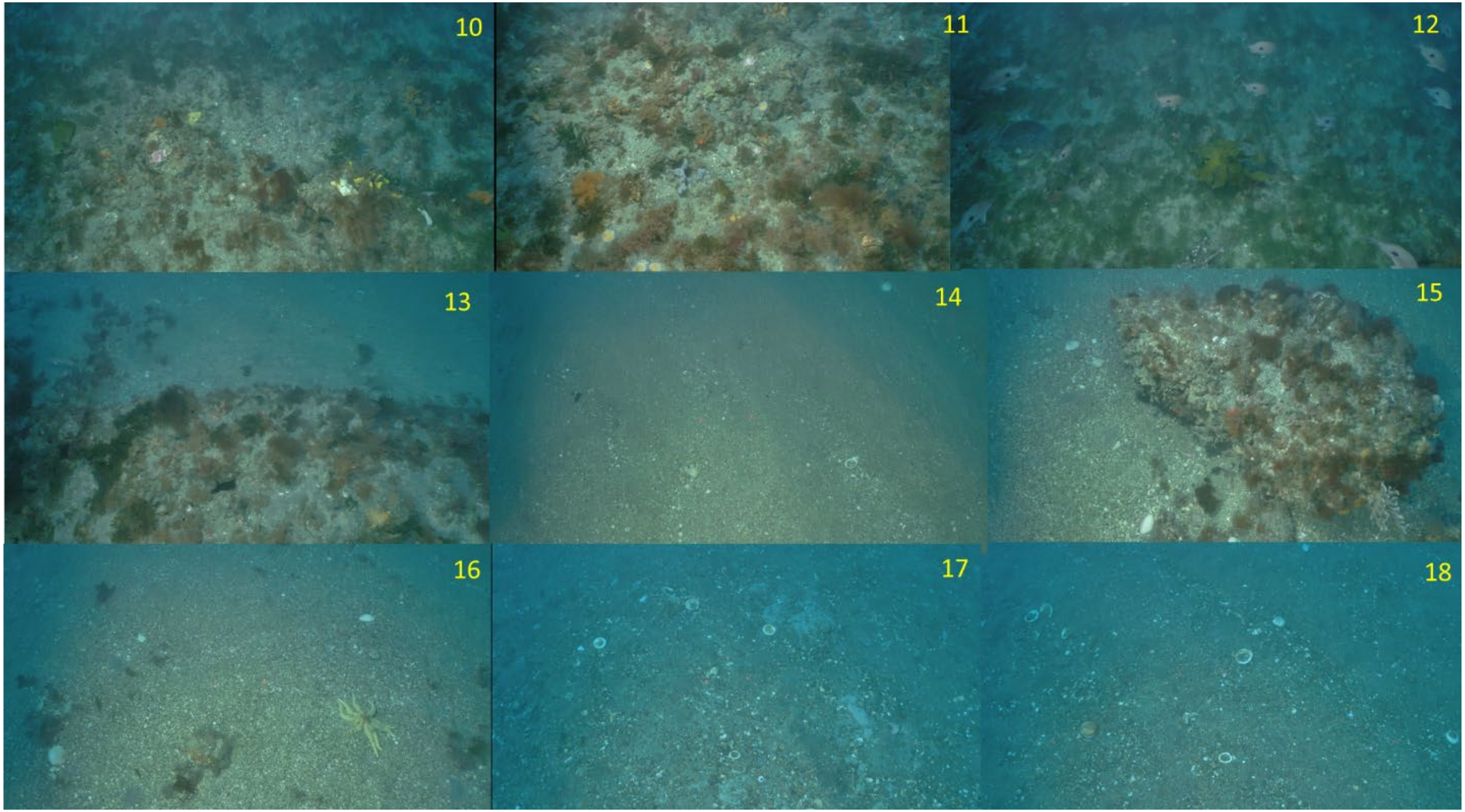


Figure 3-53: Continued 10–13) stepped terraces with *C. flexilis*, red algae, *Ecklonia* and sponges, and part of a school of butterfly perch (12); 14) bare sediment; 15) boulder with soft bryozoans; 16) starfish *C. muricata*; 17-18) tells (probably mudstone/Papa rock but are slightly bumpy), and soft sediments.

3.6.13 Site U

Depth range: 16.9–29.2 metres

Reef size: Reef U#1, 22,695 m^2, Reef U#2 part of a much larger complex (10x longer), difficult to estimate boundaries

Form. The video transect crossed two reefs/reef complexes. These were part of a much larger surrounding series of extensive ridge reef (Figure 3-54).

Reef U#1 was a large 580 metre-long elongated rock feature, orientated north-east/south-west. Tapered at its two ends, it spanned 50 metres at its widest point. It rose from around 23 metres depth, up to 16.9 metres (i.e., 6 metres in height).

Reef U#2 was part of a much more extensive reef complex, that ran parallel to Reef U#1, around 70 metres to the west (Figure 3-55). The most northern extent of U#2 started parallel to the most northern extent of Reef U#1 and ran parallel to Reef U#1, but then it continued south-west as a ridge feature for around 4.5 kilometres (Figure 3-54). A further reef ridge complex (not video surveyed) started 450 metres south-west of Reef U#1, and then ran parallel to the Reef U#2 ridge complex, for 3.6 kilometres (Figure 3-54).

BTM Divisions (east to west along video transect): Flat Plains → Flat Ridge Tops → Crevices, Narrow Gullies over elevated terrain → Rock Outcrops High, Narrow Ridges → Flat Ridge Tops → Narrow Gullies over elevated terrain → Lateral Mid-slope Depression → Local Depression, Current Scours → Flat Plains → Flat Ridge Tops → Rock Outcrop Highs, Narrow Ridges → Lateral Mid-slope Depression → Steep Slopes → Broad Depression → Broad Slopes → Local Ridges, Boulders, Pinnacles on Slopes → Flat Plains → Broad Slopes → Local Ridges, Boulders, Pinnacles on Slopes → Rock Outcrops High, Narrow Ridges (Figure 3-55).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-55 to Figure 3-57)

Geology. Reef U#1 had an initial sharp reef boundary edge (4), followed by upward sloping rock flats that rose to the reef top (5–7), where the reef was fractured by several large crevices/cracks (8,9) (Figure 3-55). The reef then sloped down to the west, as a series of large broken slabs (9,10) before grading into soft sediment flats (11,12).

Reef U#2 began as pebble/cobble seafloor, and then as low flat rock (15,16). This rock then dropped down a slope (17,18), where it merged into coarse sand seafloor (19). The video transect then swung around to the east, and re-crossed Reef U#2, traversing initially small patches of reef surrounded by sand (20), and then continuous low broken reef (21–27).

Biogenic habitats: The soft sediment flats at the start of the transect were composed of poorly sorted coarse and shell (Figure 3-56). Unlike most other sites, these soft sediments supported a low but widespread cover of macro-algae, including individual green (brown) shrubby macroalgae, *E. radiata* singles, and some *Carpophyllum maschalocarpum* kelp. Several (five) recessed (alive) scallops were also observed, the only live scallops seen in the survey; although very occasionally, recently dead shells had been seen elsewhere on reef edges (possibly a result of octopus predation), and out on soft sediment plains. Reef U#1 appeared as an abrupt boundary of rising solid reef, with an associated school of large adult butterfly perch (4), and spotties. A narrow band of very healthy (dense, fronds without damage, good colouration) *E. radiata* kelp forest extended from the reef edge up the reef for about 15 metres. This forest gave way to bare rock with turf and occasional sponges, along with kina at sufficient densities (>1–2 m^2) to be called 'urchin barrens' (6,7). At the reef crest, several large fractures/cracks were evident (8,9), and a small patch of (putatively) jewel anemones present (8). The reef then sloped down as a series of large rock slabs, with variable patch cover of *E. radiata*, to soft sandy sediments. After a short distance, a pebbly seafloor appeared, which had a variable biogenic habitat cover of green (brown) shrubby macroalgae (10–50% cover), along with lesser contributions of *E. radiata* individuals and *C. flexilis*.

Reef U#2 began as flat rock with *E. radiata* patches and single plants cover (15, 16), followed by the reef sloping down (17,18) to coarse sediment flat (19). These coarse soft sediment flats held numbers of the finger sponge *Callyspongia ramosa*, at the highest densities seen during the survey. The video transect then turned east to return to Reef U#2, where small rock patches were surrounded by soft sediments (20) with *C. maschalocarpum* (singles, some groups of 2–3 plants) kelp plants being a notable occurrence. Full low reef cover then appeared, with an initial relatively high cover of sponges at the edge of the reef (21,22), which was quickly replaced by variable *E. radiata* cover (individuals, patches, forest), as well as green (brown) shrubby macroalgae and *C. flexilis* (23–27). Occasional sponge patches on raised rock were also apparent (27).

Ecklonia forest was the dominant biogenic habitat, with a percent cover of 11.11% (equivalent to sites Q and R, 10.03–10.73%). *Ecklonia* forest covered 7.58% of the rock-based habitats, with Ecklonia patches of 2.93% cover, and singleton plants covering 0.60 of the reef. The kelp distribution on the two reefs differed from the other reef sites. For Reef U#1, *Ecklonia* formed a narrow forest on the east side of the reef, which started flush with the soft sediment boundary, and extended up the reef slope for around 15 metres (#350–352) before being replaced by 'kina barrens'. This forest may extend north and south along the reef side to form a narrow eastern side kelp forest up to 580 metres long (Figure 3-54). Beyond the urchin barrens and past the reef ridge, *Ecklonia* forest re-appeared (#371–372) in association with a roughly 45 degree reef slope, forming a second narrow forest band, that also may extend along the reef side to form a second narrow western side kelp forest up to 580 metres long. *Ecklonia* was largely absent from the reef ridge top.

Reef U#2 had no elevated ridge feature, but rather was a narrow rocky reef slope that dropped around three to five metres, separating two soft sediment flats. The video transect first crossed this slope square-on to reveal an associated narrow *Ecklonia* forest, moved onto soft sediments, and then turned back to run along the U#2 reef slope feature, where *Ecklonia* forest continued to be present. This suggests that a long narrow *Ecklonia* forest could be associated with the 4.5 kilometre long Reef U#2 (Figure 3-54); and with the 3.5 kilometre long reef feature east of it (not video surveyed).

Main invertebrate species: Sponges were the most common sessile invertebrates, with overall low cover of 0.52% (Table 6). The dominant sponge taxa were Family Chondropsidae sp 2, with lesser numbers of the grey cone *S. conulosa*, yellow-broken ridge *C. incrustans*, and the finger sponge *C. ramosa* (Table 7). Sponge richness and abundance values were relatively consistent across the reef features, with some higher abundance sponge video segments values associated with reef edges.

Kina were restricted to a narrow band of high densities, definable as urchin barrens, on reef U#1 (Figure 3-56). Other species present in lower numbers, and more widely distributed across the reefs, included saw shells and Cooks Turban.

Main fish species: Blue cod were relatively abundant, with all size classes well represented, including 0+ juveniles, who contributed 25% of the 256 individuals counted (Table 8). Butterfly perch were also relatively abundant, occurring as small schools associated with the more abrupt bathymetric shifts (Figure 3-56). Scarlett wrasse and leatherjackets were also common, along with lesser numbers of goatfish.

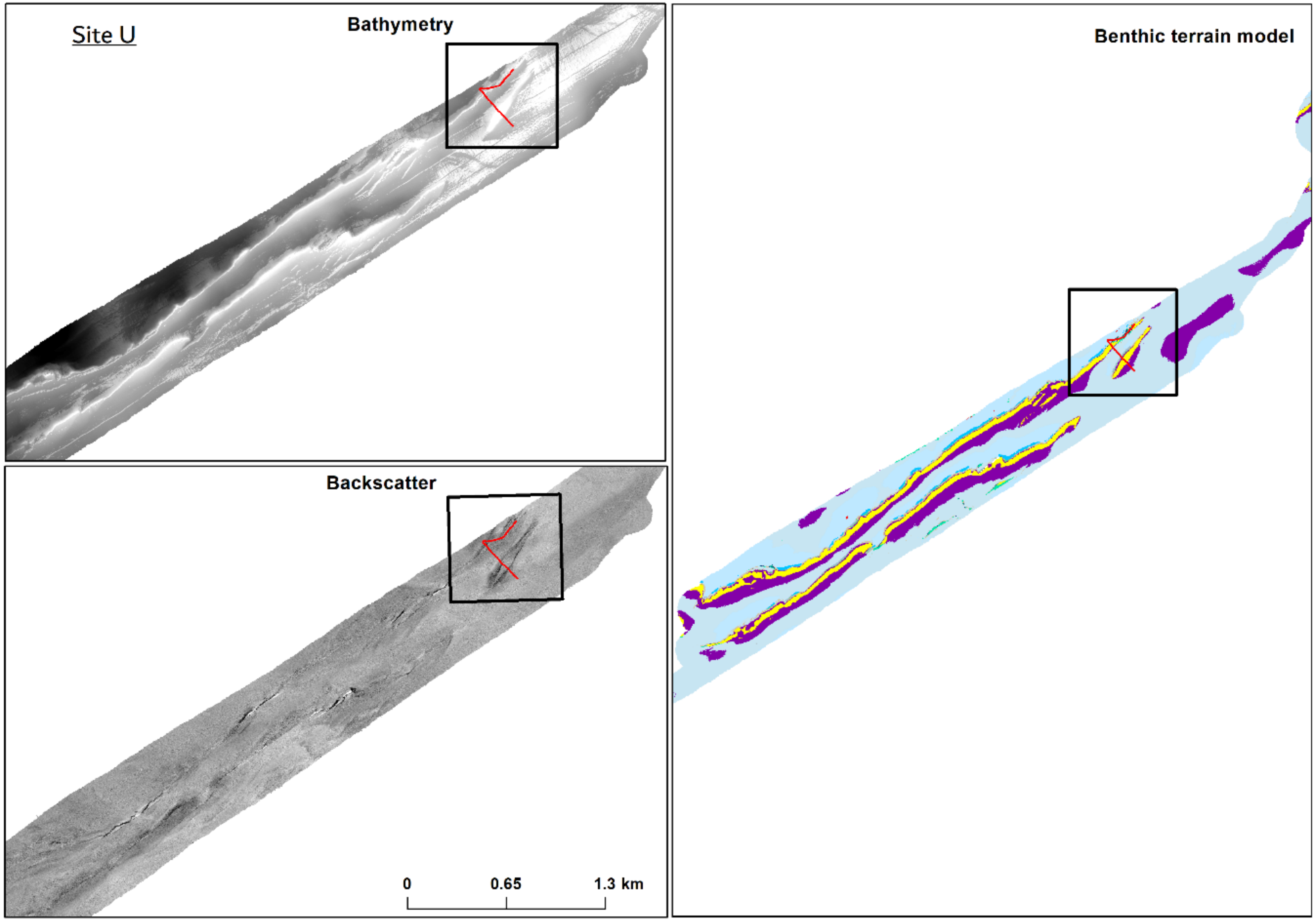


Figure 3-54: Broader extent maps of larger seafloor area mapped. (reef and other unknown features) around sites R, S and T.

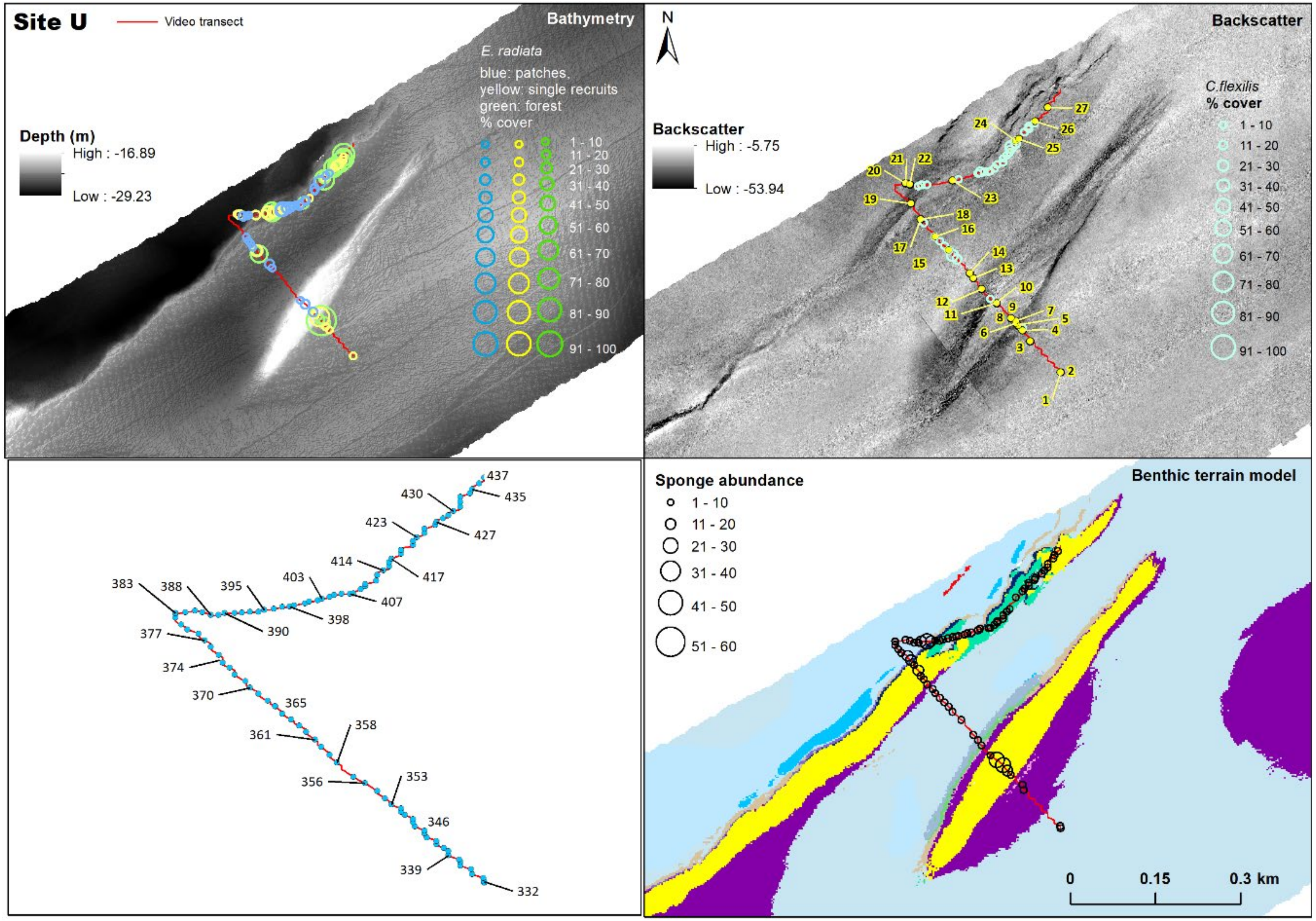


Figure 3-55: Maps of site U Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers; top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

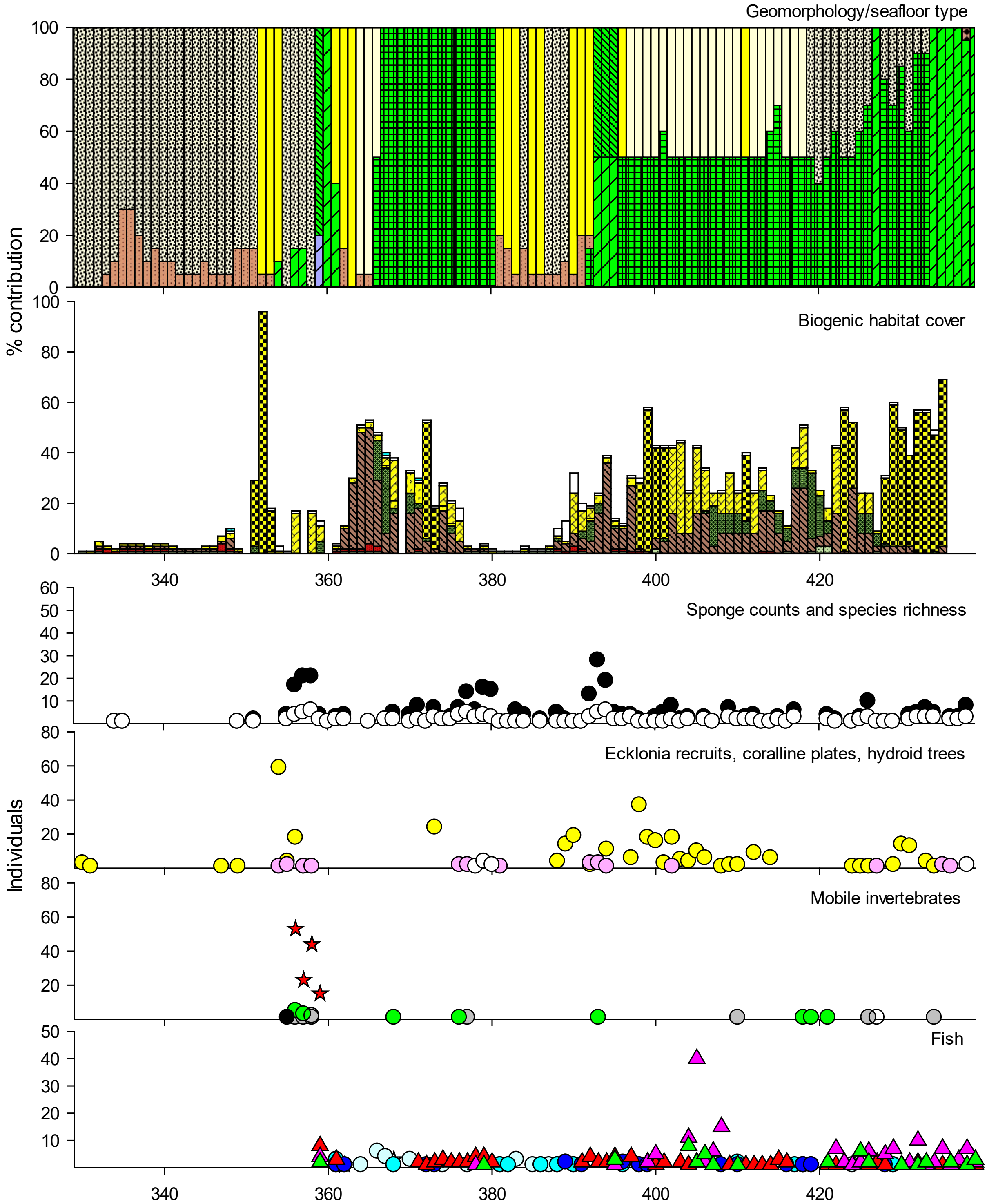


Figure 3-56: Site U CoastCam data geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-55.

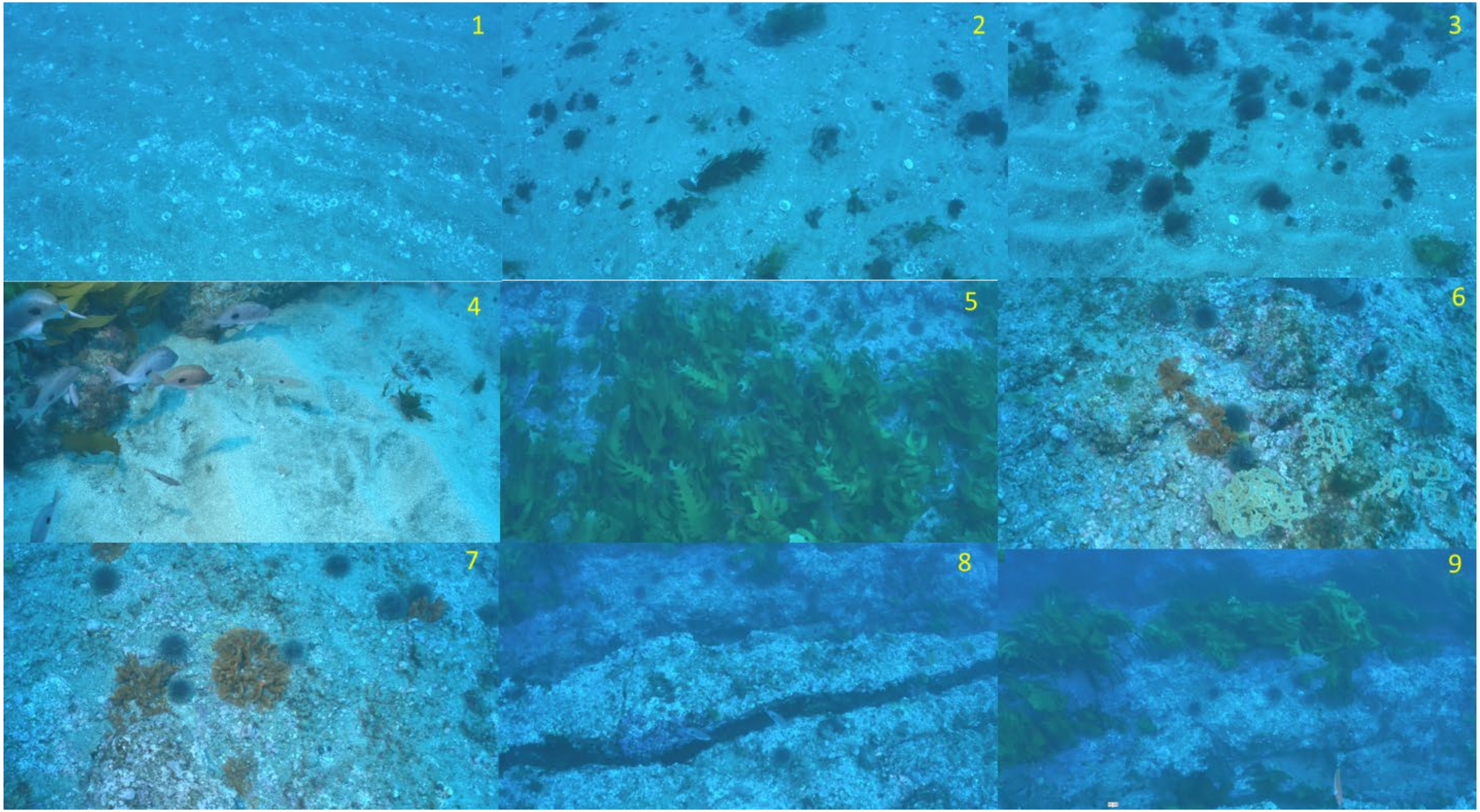


Figure 3-57: Site U seafloor images image numbers are plotted spatially in Figure 3-55 over multibeam sonar back scatter: 1) soft sediments; 2) soft sediments with associated lower density *E. radiata*, *C. maschalocarpum*, small red and brown algae species, and occasional live scallops (not shown, *Pecten novaezelandiae*); 4) reef U#1 edge with butterfly perch and start of *Ecklonia* forest; 5) *Ecklonia* forest edge adjacent to kina barren; 6–7) kina barren; 8) large crevices/fractures on top of reef; 9) reef slope with *Ecklonia*.

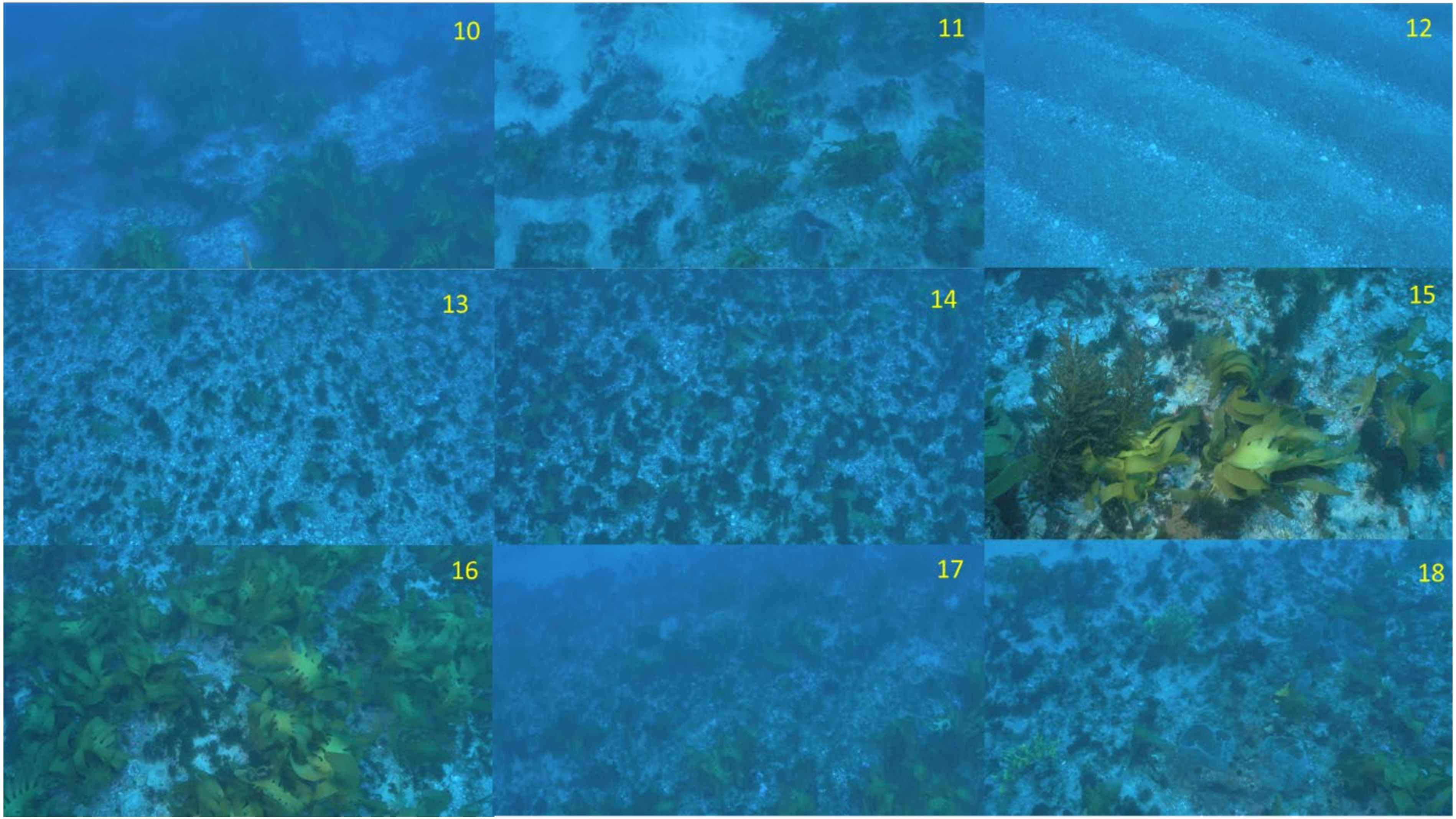


Figure 3-57: Continued 10) reef slope (large blocks) with *Ecklonia*; 11) bottom of reef slope grading into soft sediments; 12) soft sediment; 13–14) pebble/cobble field with attached macroalgae meadow; 15–16) top edge of Reef U#2 with *Ecklonia*; 17) Reef U#2 slope with *Ecklonia*; 18) bottom of Reef U#2 slope grading into soft sediments.

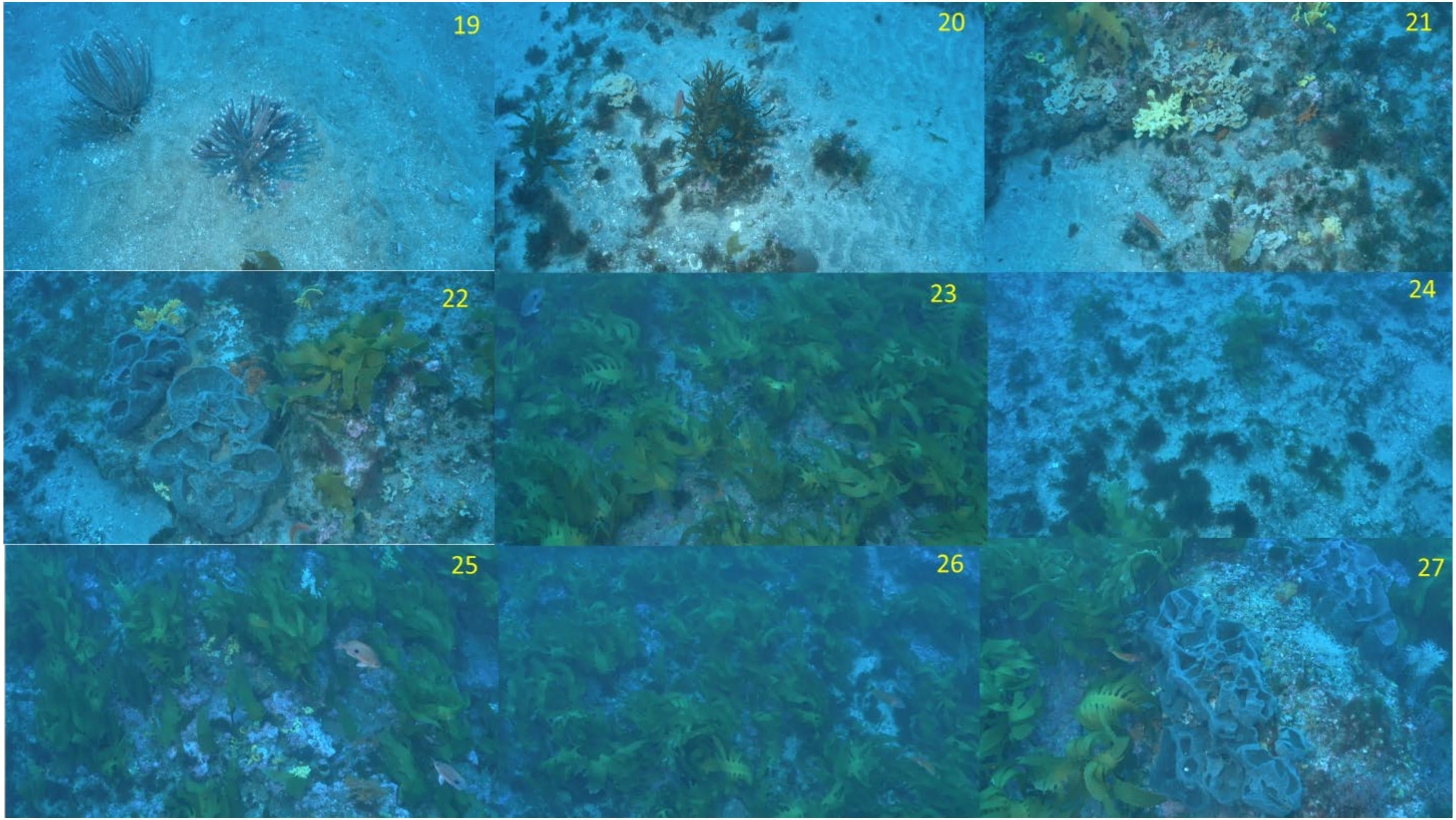


Figure 3-57: Continued 19) sediment flats with *C. ramosa* sponges; 20) patch reef with *C. maschalocarpum* kelp; 21–22) sponge clusters on the edge of Reef U#2; 23) *Ecklonia* forest; 24) green (brown) shrubby algae and *Ecklonia* singles; 25–26) *Ecklonia* forest; 27) *E. alata* sponges on rock outcrop surrounded by *Ecklonia* forest.

3.6.14 Site V

Depth range. 32.7–38.3 metres

Reef size: 14,007 m^2 (two patches, V#1 9,919 m^2, V#2 4, 088 m^2)

Form. Two separate low reef features. The larger southern feature (Reef V#1) formed a low irregular mound, around 124 x 97 metres in cross-section, with a further 115 metre long low extension eastward from its lower western edge (Figure 3-58). The reef was mainly flat sheet rock platforms with low drop-offs (40–50 cm), and an area of raised broken rock in the central area with a maximum height of around 2.5 metres from the surrounding soft-sediments. The rock appeared to be a breccia form. Numerous small reef patches and tells were present on its southern side, where the base rock slightly protruded in spots from sandy sediments.

The smaller northern reef feature (Reef V#2) was rectangular (around 132 x 48 metres) with its longest axis orientated east/west. Located around 170 metres to the north-east of Reef V#1, it was formed of the same flat breccia sheet rock as the southern reef and rose to maximum height of around 1.5 metres. The flat sheet rock was more continuous that at Reef V#1, but with 'seams' filled with soft sediment and several low terrace raises (around 30–60 cm) gaining height from west to east.

The 170 metres of seabed between the two reefs was of coarse sand across the southern half, and dog cockle shell drifts (possibly with live animals present) in the northern half.

BTM Divisions (south to north along video transect):

Flat Plains → Flat Ridge Tops → Flat Plains → Flat Ridge Tops → Rock Outcrop High, Narrow Ridges → Flat Ridge Tops → Flat Plains → Flat Ridge Tops → Rock Outcrop High, Narrow Ridges → Flat Ridge Tops → Flat Plains Flat Ridge Tops → Rock Outcrop High, Narrow Ridges → Flat Ridge Tops → Flat Plains (Figure 3-58).

Physical and biogenic habitat seafloor composition, and taxa abundances (Figure 3-58 to Figure 3-60)

Geology. Reef V#1 was formed of small rock sheet outcrops and tells (centimetres to metre scale) emerging from sand (1–5), sometimes with small overhangs (centimetres scale) (3). These small rock features were present along the southern side of the reef for the first 185 metres of the video transect, before the seafloor changed to purely sand. The video transect then turned to transverse the reef proper, which was formed of flat large rock slabs, raised in height from the surrounding seafloor (6–13), some of which were flat, and some gently sloped. An area of slightly higher reef area was present just north of the transect path (as seen by the attached Go-Pro camera as the towed camera turned, not shown here).

Reef V#2 was very similar in form and structure to Reef V#1. At the approach to the reefs, dog cockle shell drifts dominated (15–19), with some small occasional rock sheet outcrops/tells (17–19) embedded in the shell matrix. The reef proper was formed of low slabbed rock surfaces (21–26), with some low terrace rises (going east) (22, 24). The end of the video transect dropped off the raised reef edge to a sandy seafloor with scattered dog cockle shells (26,27). Dog cockle shell drifts covered 9.4%

of the transect (all rock and non-rock segments included) (Table 4). No mudstone/Papa rock tells were seen.

Biogenic habitats: The small rock outcrops/tells on poorly sorted coarse sand and shell seafloor, present along the south side of Reef V#1, supported a high diversity of sponge species with a patchy distribution (Figure 3-59). The species diversity and structure provided by this sponge assemblage, and its spatial extent, qualified this area to be defined as a sponge garden.

On the reef proper, the reef edge rose as a low platform about 50 cm in height and was dominated by a diversity of sponges (6). Heading west, the reef was composed of a series of low height flat and sloping rock slabs, interspersed with soft sediments. These slabs supported a further sponge assemblage, as well as low density large *E. radiata* kelp plants (7–13) and could also be defined as sponge garden. A lost anchor (11,12) that appeared to have been on the seafloor for some time suggested that this small extent reef has been previously discovered.

Adjacent to the second reef (Reef V#2) were dog cockle shell drifts, on both the south-west and east sides (which the towed camera traversed). Little live biogenic habitat was seen to be associated with the shells, but the south-east bed also had small rock outcrops/tells which supported low sponge densities. Reef V#2 supported low sponge densities (25), that did not approach the diversity and abundance/cover seen on Reef V#1. *Ecklonia* was also present, and formed occasional small patches (21,22), which were not present on Reef V#1.

Main invertebrate species: Sponges were the most common sessile invertebrates, with an overall cover of 5.57%, the highest percent cover across all 14 reef sites surveyed (Table 6). The dominant sponge taxa were Chondropsidae species 2, the grey spiral sponge *Cymbastela lamellata*, the slender purple finger sponge *Callyspongia ramosa*, the orange/grey/yellow ball sponge *Tedania* sp. indet., and the yellow foamy sponge *Darwinella oxeata* (Table 7). Most notable was the spiral sponge *Cymbastela lamellata*, absent from all the other 13 reef sites except Site A (one individual observed), with 178 individuals counted. Juvenile blue cod were repeatedly observed perched on the top of *C. lamellata* sponges (1). *C. ramosa* finger sponges were also most abundant at this site, with 125 individuals counted (61% of all individuals surveyed). Mobile invertebrates were not common and were dominated by large gastropod species that were not identifiable to species (23 individuals seen) (Table 7). Two Cooks Turban *C. sulcata*, and one saw shell *A. heliotropium* were counted; along with two *A. luctuosa* sea-slugs.

Main fish species: Blue cod were the dominant fish species, with 391 individuals counted (Table 8). Over half of these (59%, 231 fish) were 0+ juvenile fish which were strongly associated with the sponge garden on rock outcrops, the reef edge with associated sponges, and the dog cockle shell drifts (especially where rock outcrops were also present). These close (biogenic) habitat associations, high density of 0+ juveniles, and relatively large areas of these habitats, can be defined as 0+ blue cod nursery habitats. Larger blue cod juveniles (nominally 1+/2+, 13–20 cm) were also common, contributing a further 23% of blue cod present; with the remaining fish >21 cm in size (18%).

Butterfly perch were the second most abundant fish species, and occurred as large schools over the reef proper, especially reef V#1 (see Figure 3-6, Figure 3-59). Tarakihi were common in the same area, occurring as smaller discrete schools that intermingled with the butterfly perch schools. Small groups of goatfish were present over the reef-sand interface. Other species present included leatherjackets, scarlet wrasse and several blue moki. Most of the scarlet wrasse were small juveniles, found in the same biogenic habitat areas as the 0+ blue cod juveniles. Large conger eels were present tucked under slab overhangs, with their heads showing, on both reefs. Several carpet sharks were also seen sleeping on the two reefs, both on open rock, and tucked up around the low terrace walls present at Reef V#2. Two resting rig were also seen on the second reef.

The dense multi-species aggregations seen at Reef V#1 (Figure 3-6) of butterfly perch and tarakihi, were highly likely to have been underestimated in their abundance. Footage from the forward facing Go-Pro camera indicated some components of the butterfly perch and tarakihi schools were higher in the water column than the field of view of the main high resolution camera. An educated guess from comparing the two camera fields of view was an underestimation of abundance for these school/s of 20–30%.

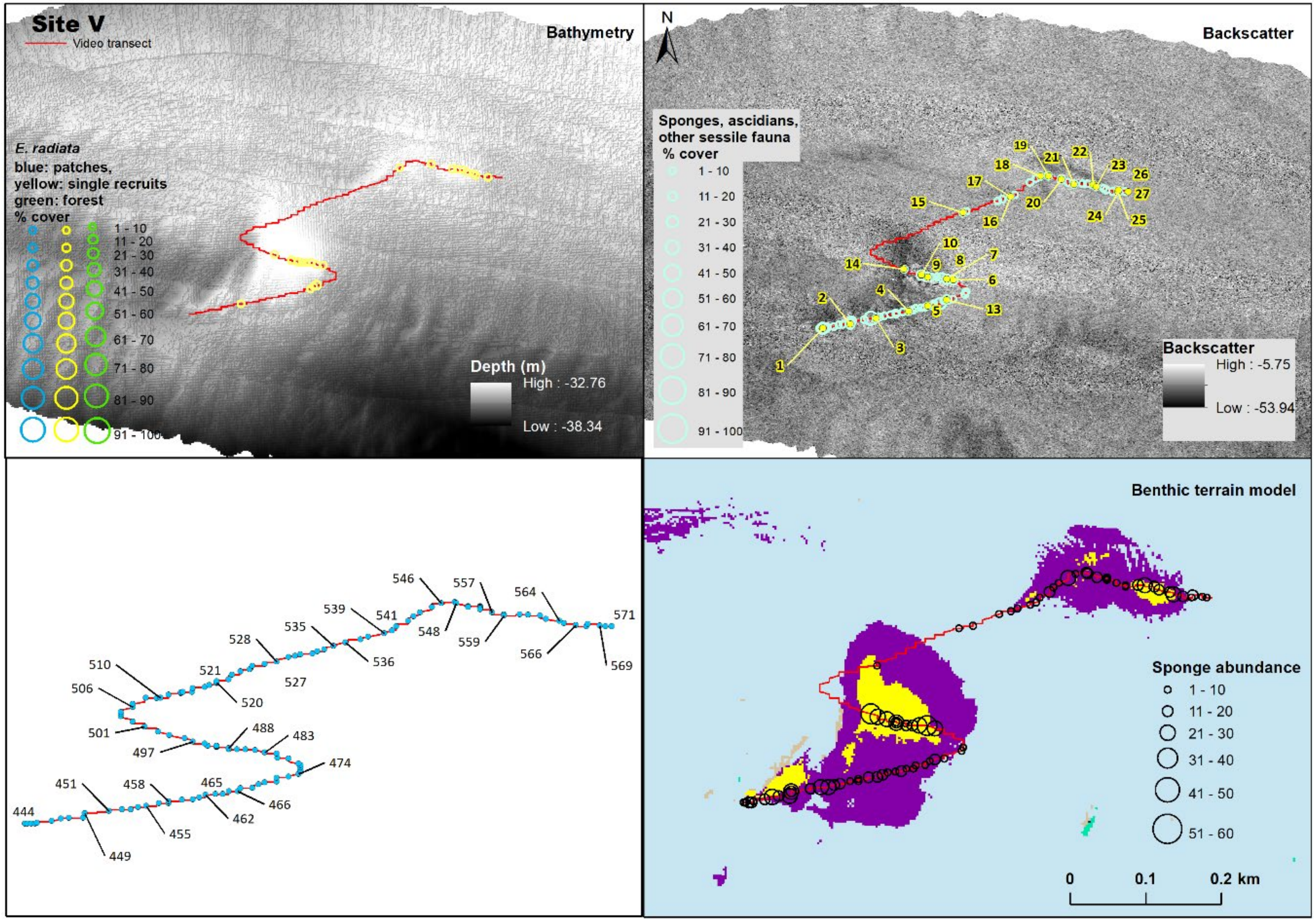


Figure 3-58: Maps of site V Top left) multibeam sonar bathymetry and *E. radiata* kelp %covers;) top right) multibeam beam backscatter and *C. flexilis* green algae %covers; lower left) towed video transect with video segment sequential numbers; lower right) multibeam sonar derived Benthic Terrain Model (BTM) seafloor classes, with sponge abundance (individuals per 20-second video segment).

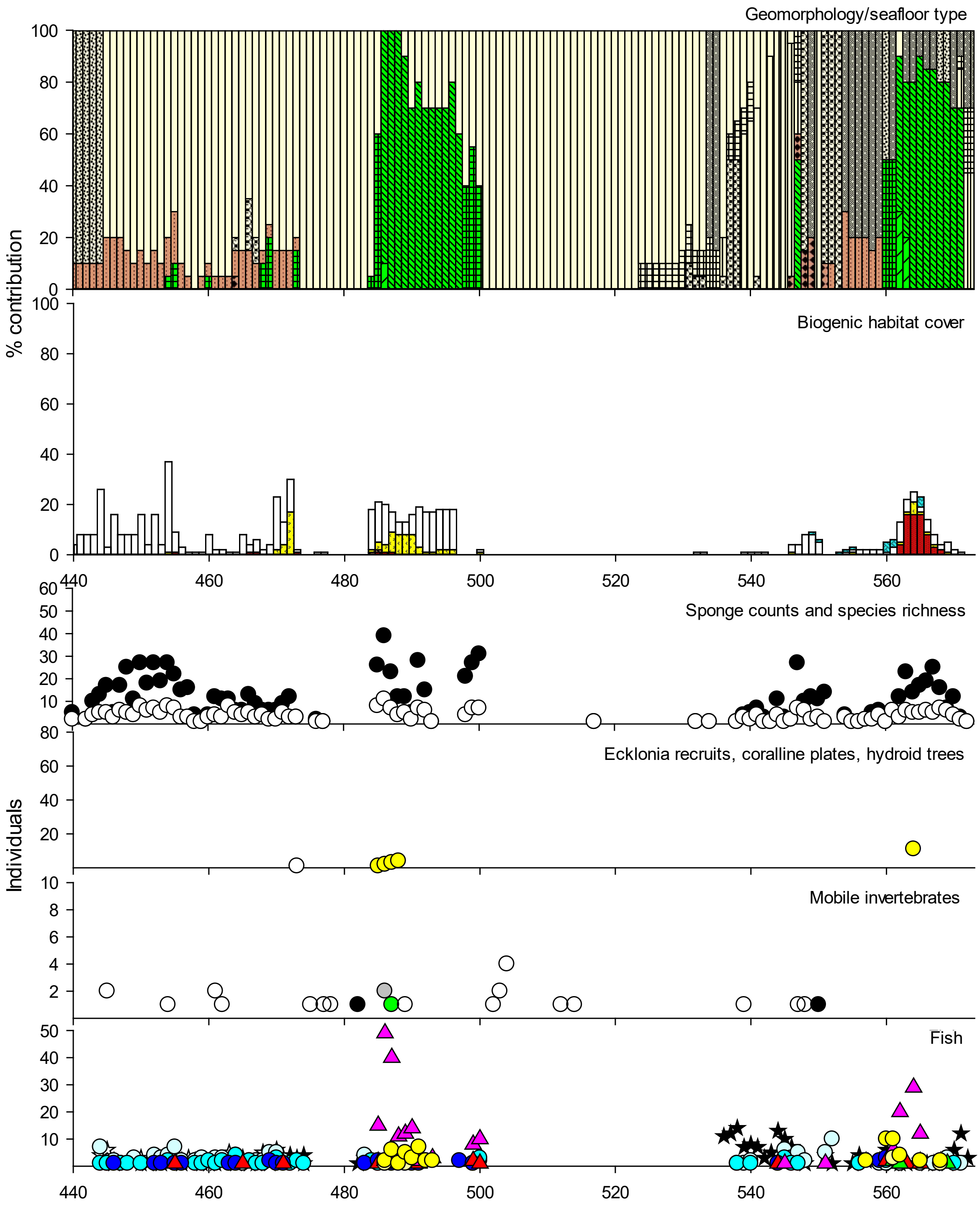


Figure 3-59: Site V CoastCam data: geomorphology/seafloor type, biogenic habitat cover, sponge counts (black) and species richness (white); *Ecklonia* recruits (yellow), coralline plates (pink), and hydroid trees (white); mobile invertebrates; and fish. Class keys are given in Figure 3-11. The x axis plots the sequential spatial position index of the 20-second video segments, which are shown in map form in Figure 3-58.

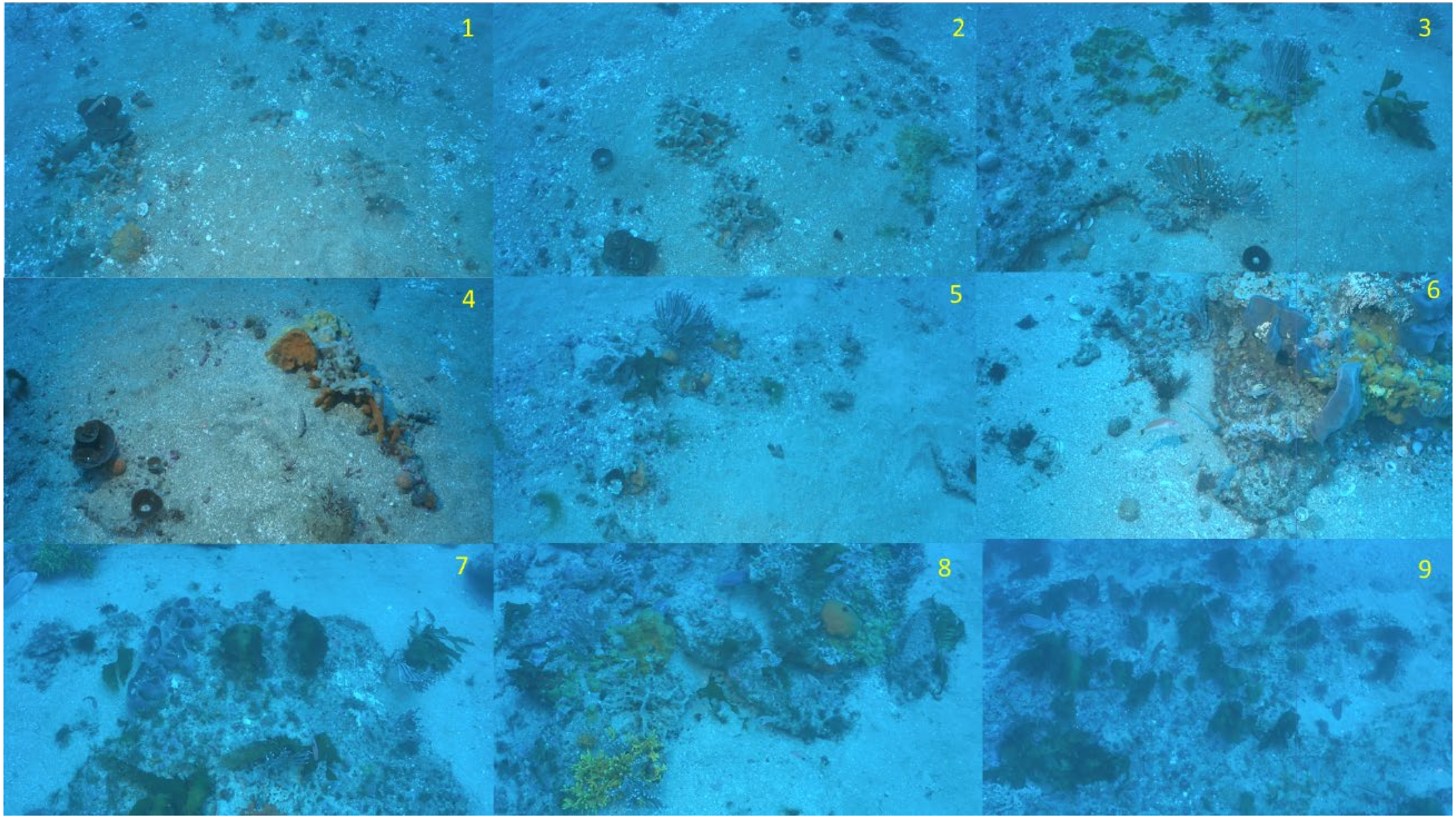


Figure 3-60: Site V seafloor images image numbers are plotted spatially in Figure 3-58 over multibeam sonar back scatter: 1–5) rock outcrops/tells with high sponge diversity and abundance, and associated 0+ and older juvenile blue cod (difficult to see at this image page scale); 6) reef edge with 0+ juvenile cod (see Figure 6 for the same image at larger size, with fish marked up); 7–9) flat slab reefs of Reef V#1 with sponges and large *Ecklonia* singles.

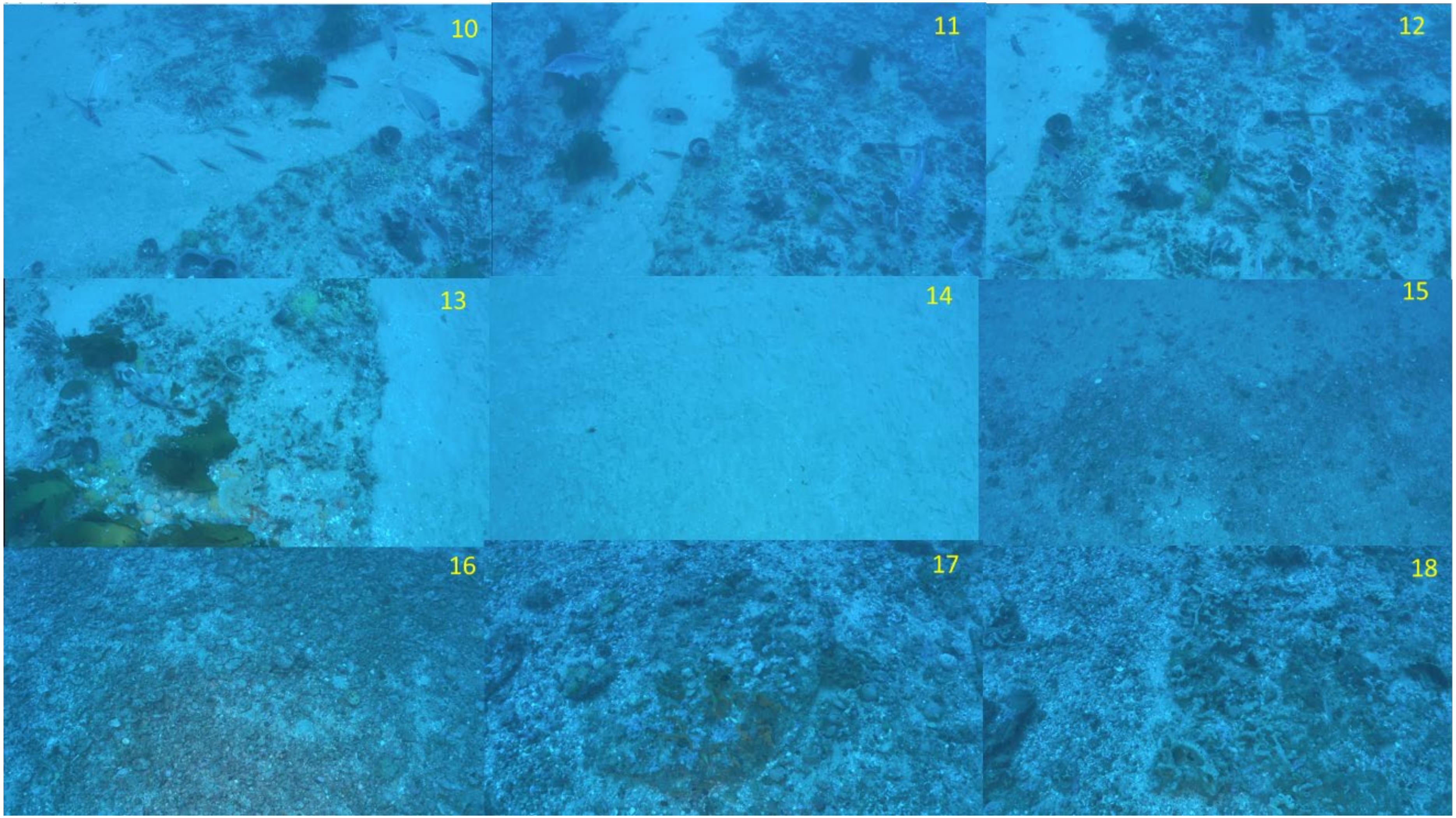


Figure 3-60: Continued 10–12) flat slab reef at Reef V#1 with blue cod, goatfish, tarakihi, butterfly perch and blue moki shown, and a lost anchor in images 11 and 12 – middle right; 13) resting carpet shark; 14) soft sediments; 15–17) dog cockle shell drifts and rock outcrop tells; 18) flat basement reef.

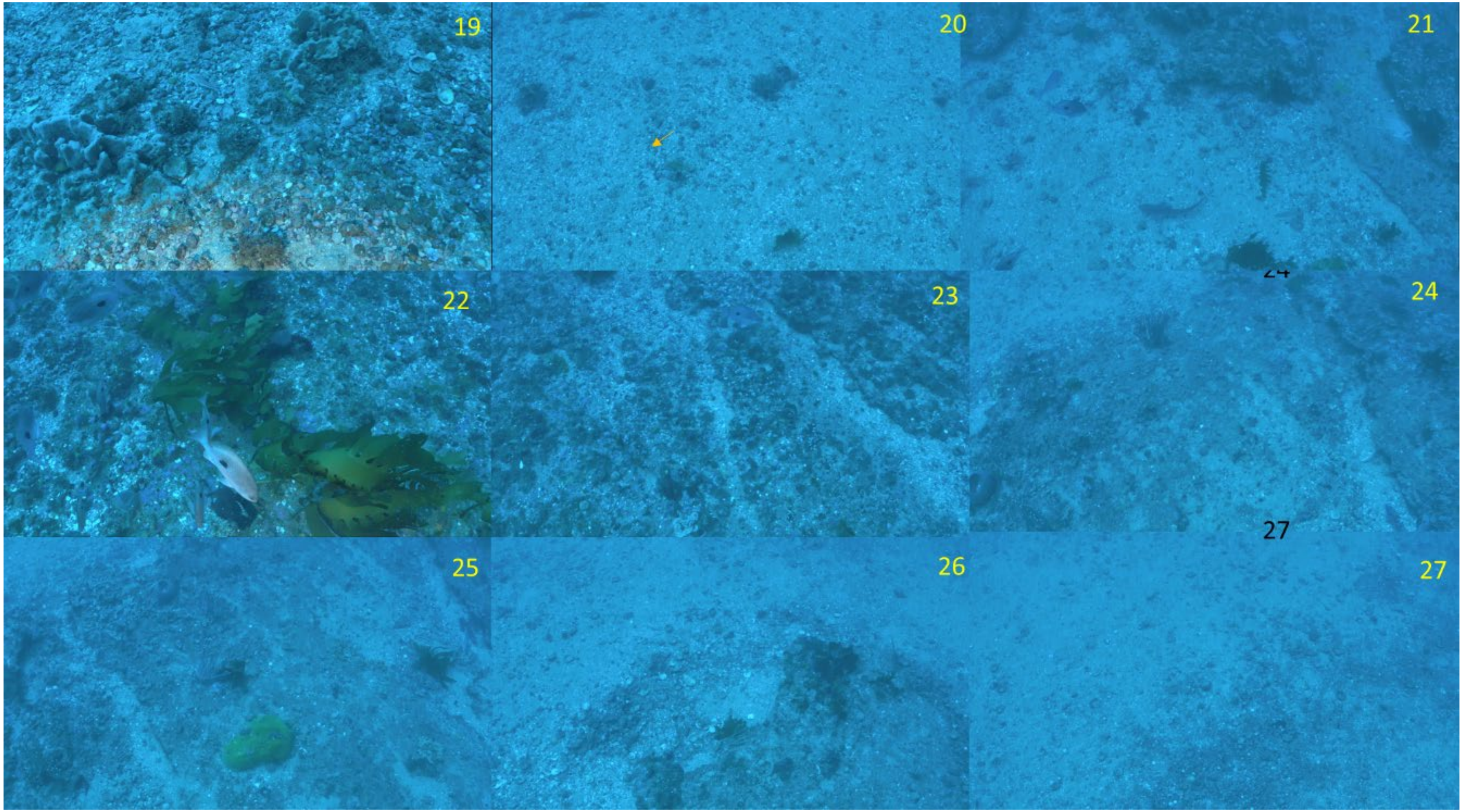


Figure 3-60: Continued 19) dog cockle shell drifts and rock outcrop with sponges; 20–21) start of Reef V#2; 22–26) Reef V#2 low slab reef with ‘seams’ and low terraces, sponges and *Ecklonia* singles; 26) eastern end of Reef V#2, with adjacent dog cockle shell drifts; 27) off-reef dog cockle drifts.

4 Summary across the 14 reefs

The 14 reefs surveyed have greatly increased our knowledge of the reef structures and their biological assemblages within the South Taranaki Bight. However, this was not a comprehensive survey and the reefs surveyed are just a sample of the overall reef number and complexity on Pātea Bank. Figure summarises the current science knowledge of where reefs are present/may be present on Pātea Bank. The next obvious step will be formal statistical analyses, which will include a formal assessment of what biogenic habitat landscape elements/features are present, where, and in what spatial configurations. In this report, we have presented biogenic habitats largely as percent cover estimates of individual species (e.g., *E. radiata*, *C. flexilis*) or species groups (e.g., macroalgae, and sponge and other sessile invertebrates) at the 20-second video segment scale. Terms such as forest, field, meadow have also been used informally in this report to describe patterns at scales larger than that of the 20-second video segments. These terms describe biogenic habitat features, i.e., how biogenic habitats are described at the large scale of habitat landscapes.

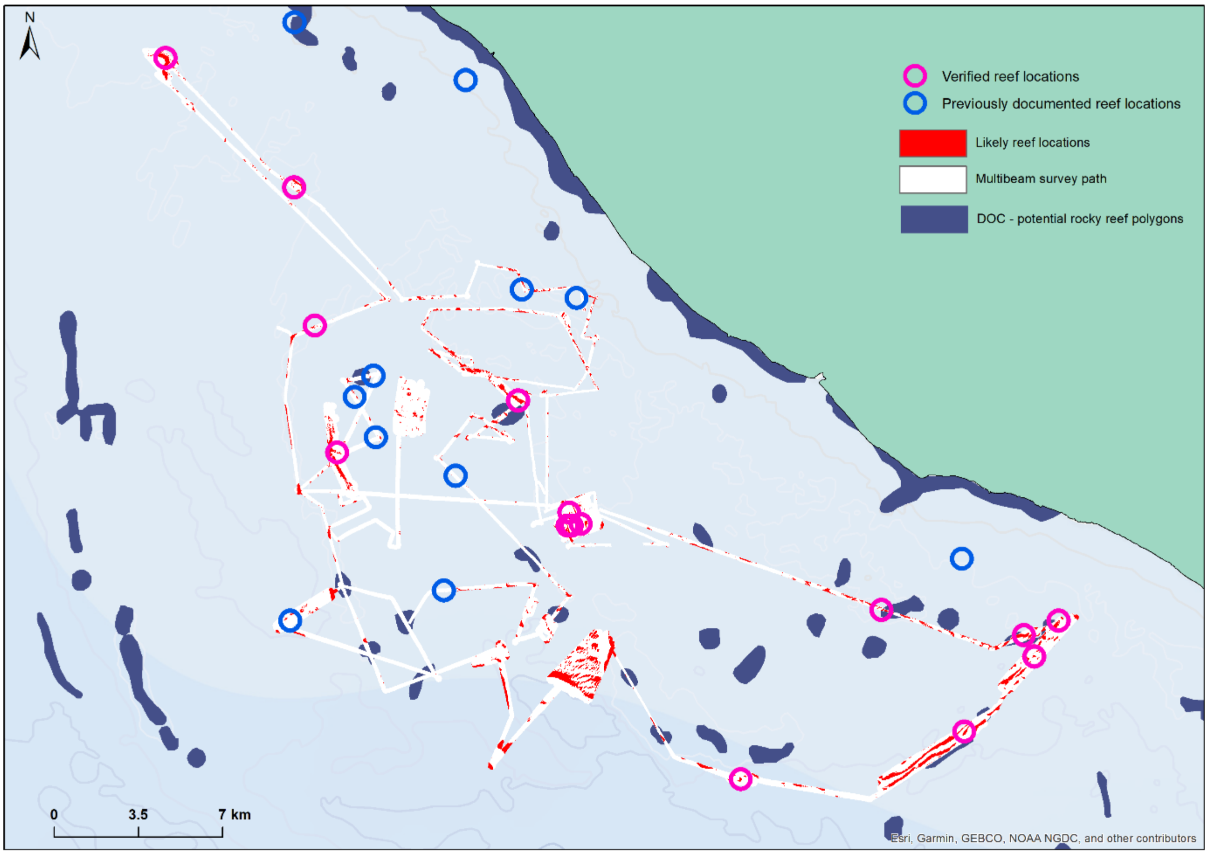


Figure 4-1: Known and likely reefs (by science survey) of Pātea Bank circles denote reefs verified with cameras, red polygons are other likely reefs encountered during multibeam sonar mapping, and the blue polygons putative reefs from DOC assessment of abrupt bathymetric changes on old fairing sheets.

In this report we have used such land-scape terms to describe areas where we have seen selected species occur at sufficient abundance and spatial extent to be considered landscape elements (e.g., *E. radiata* kelp forests, versus *E. radiata* patches and singles). While semi-quantitative only, Table 14 provides an informal summary of those assessments, across the 14 reef sites surveyed, to provide a first broad-brush view of what South Taranaki subtidal reef complexes hold. There are two scales of observations in Table 14: that derived from the multibeam sonar across the full reef; and that derived from the towed video transect, which is a much smaller area of the full reef. It is important to remember that while data from the video transect can give a good proxy of the overall habitat cover of a reef, the numbers derived from it (e.g., spatial extents, percent biogenic over, and species richness) have not yet been scaled to the full reef by depth band, rugosity etc using the multibeam sonar data for scaling.

The data presented in Table 14 are ordered by increasing water depth. There was no obvious depth-related trends in Species Richness (number of species observed) for the three taxon groups listed, but this was unsurprisingly as the overall average depth range across all sites was only 14 m (and individual sites varied in their internal depth ranges from 1.8 to 14.7 m). The two mudstone sites (Papa, D) had the lowest sponge richness values, and some of the lowest mobile invertebrate values; but site D fared better for fish richness (site Papa scored lowest, tied with site O). An important caveat to note is that species richness is a function of the area sampled (the greater the area, the more species are likely to be encountered); these values have not been standardised to area sampled, so direct comparisons should be made with caution.

The semi-quantitative application of biogenic habitat feature designations across the 14 sites revealed seven obvious biogenic habitat features: *Ecklonia* forest (6 sites, one or more per site), *Caulerpa* meadow (3 sites) Macroalgae garden (4 sites), Bryozoan (uncalcified species) field (3 sites), Sponge garden (1 site), Urchin barren (2 sites), and Bivalve bed (1 site). Each biogenic habitat feature will have a preferred/obligate depth range, which may vary spatially with environmental conditions (e.g., light climate at the seafloor for macroalgae). The narrow depth range of this survey will not have encompassed those ranges, with perhaps the exceptions being the lower depth boundary for *Caulerpa* meadows and sea urchin barrens (in the context of Pātea Bank).

In terms of ecological function, four sites provided a habitat function for juvenile blue cod (sites D, K, U, and V), although the small spatial extent of Site K limits its possible contribution to local blue cod populations. Biogenic habitat features that supported these nursery functions were sponge gardens, dog cockle shell drifts/beds, some reef edges, and some cobble and shell zones adjacent to reef edges. Other ecological functions are not included here (e.g., primary production, oxygen production, nutrient recycling, provision of prey for larger predators), but may also be significant.

Table 14: Summary of the 14 sites surveyed Sites are ordered by increasing median water depth (the midpoint of the range occupied by rock-based habitats at site). Depths from the multibeam sonar data for rock-based habitat at each site are given in metres (Med, median; Min, Minimum; Max, Maximum). *, reef extent only partially mapped. The transect area calculated only includes video segments where rock was present. %biogenic cover was the sum of all biogenic habitat classes present. Biogenic habitat features are marked as 'Yes' if present at a site. Blue cod nursery function, ^, denotes sufficient abundance but reef extent too limited. Species richness (Sp. R) is the proportion of the overall species pool (survey level) present at a site, for sponges (39 species), mobile invertebrates (14 species), and fish (24 species). A colour ramp visualises differences (bright yellow (low values) through to dark green (high values). Mudstone/Papa rock reefs are grey high-lighted.

		Multibeam						Video									Sp. R		
Site	Description	Depth (m)				Transect Area (m²)	Reef area (m²)	% biogenic	*Ecklonia* forest	*Caulerpa* meadow	Macroalgae meadow	Bryozoan field	Sponge garden	Urchin barren	Bivalve bed	Blue cod nursery	%present		
		Med	Min	Max	Range												Sponges	Inverts.	Fish
Q	Raised reef with terraced slopes and finger-gutter reef morphology	17.3	9.9	24.6	14.7	85,794	1,452	22.1	Yes					Yes			54%	14%	38%
A	Large reef composed of bedrock and cobbles, arranged as long escarpment	19.4	13.9	24.8	10.9	425,000	3,486	23.4	Yes	Yes							64%	71%	33%
S	Large oblong rock with stepped terraces	19.5	12.7	26.3	13.6	29,393	1,478	11.4		Yes		Yes					74%	57%	38%
J	Low ridge of broken rock and irregular mixed cobbles	21.3	18.4	24.1	5.7	*38,990	453	6.7			Yes						38%	21%	21%
K	Low reef composed of low terrace rock, and irregular mixed cobbles	21.3	19.9	22.6	2.7	2,933	1,993	11.4								Yes^	59%	7%	33%
R	Large, multi-faulted tilted rock block with slopes and ridges.	21.5	16.6	26.4	9.8	136,726	1,813	28.5	Yes	Yes		Yes					67%	43%	29%
O	Long ridge >1.61 km, composed of low rock and irregular cobbles	22.5	19.6	25.4	5.8	176,692	955	18.0	Yes		Yes						54%	36%	13%

Site	Description	Multibeam						Video									Sp. R		
		Depth (m)				Transect Area (m²)	Reef area (m²)	% biogenic	*Ecklonia* forest	*Caulerpa* meadow	Macroalgae meadow	Bryozoan field	Sponge garden	Urchin barren	Bivalve bed	Blue cod nursery	%present		
		Med	Min	Max	Range												Sponges	Inverts.	Fish
Papa	Sparse mudstone patches of broken slabs/boulder piles, low basement	22.6	21.7	23.5	1.8	-	296	0.0									21%	21%	13%
L	Long 1.17 km ridge feature, composed of low rock and irregular cobbles	23.0	20.05	25.9	5.8	301,673	689	15.2	Yes								51%	36%	21%
U	1. Large elongated rocky reef. 2. Sloping large boulder/rock slab field	23.1	16.9	29.2	12.3	226,950	1,379	20.4	Yes		Yes			Yes		Yes	36%	29%	29%
B	Extensive low mixed reef, cobble, and coarse sediment field with knolls	23.6	21.2	25.9	4.7	*211,957	1,715	37.2			Yes						62%	21%	33%
T	Large triangular rock, with five terraces and drops	23.7	18.7	28.7	10	7,101	443	6.7				Yes					56%	50%	17%
D	Largely continuous north-south reef terrace drop (scarp), 3.45 km long	25.2	22.3	28	5.7	399,750	1,241	2.2								Yes	33%	14%	38%
V	Two low reef composed of large flat rock slabs, composed of breccia	35.5	32.7	38.3	5.6	14,007	943	7.9					Yes		Yes	Yes	59%	43%	54%

5 Regional context

To put this survey in a wider context, this section provides a summary of wider regional subtidal reef focussed work (including North Taranaki), and relevant comparisons with the findings of this 14 site Pātea Bank survey. Figure shows the North Taranaki reef sites covered in this section, as well as a mudstone reef site off Whanganui. The site names are as used in the various contributing reports and thesis; Sugarloaf Islands encompass several discrete subtidal rocky reefs areas.

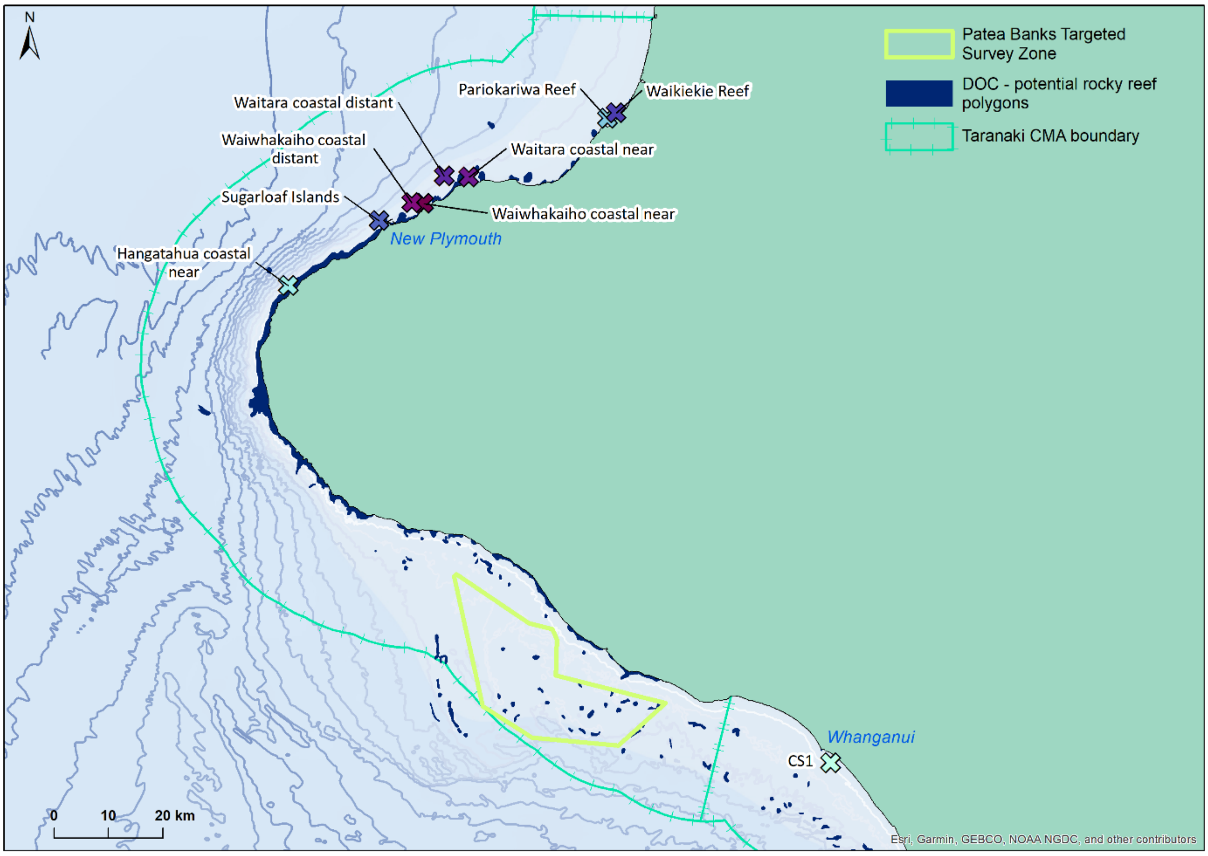


Figure 5-1: Broader subtidal rocky reef research sites in the Taranaki coastal marine area DOC potential reef polygons are shown. In North Taranaki, the Waitara, Waiwhakaiho, and Hangatahua sites are all volcanic boulder-based reefs with no bedrock (Cormack 2021), the Sugarloaf Islands are a range of volcanic bedrock and boulder reefs, and the Pariokariwa/Waikiekie reefs formed of mudstones. For South Taranaki, the work area of this report is shown as a light green polygon, along with a mudstone reef site located further south, off Whanganui.

5.1 South Taranaki reefs

5.1.1 South Taranaki-Wanganui marine area review 2006

A DOC project called "*Netting coastal knowledge: a report into what is known about the South Taranaki-Whanganui marine area*", used a literature review, interviews, workshops, and a questionnaire to learn more about the region. A range of useful information was included in the associated report (DOC 2006).

Fishers most common catches were dominated by blue cod and snapper; with kahawai and gurnard also common but to a lesser degree. Other species caught included tarakihi, barracouta, john dory, and trevally. Rarer caught species included groper and kingfish, while spiky dogfish was the most caught shark. Divers visiting the North and South Traps reported regularly seeing terakihi, red moki, blue cod, snapper, rock lobster, Spanish lobsters and packhorse crayfish, kingfish, blue moki, big eye, leather jacket, conger eels, banded wrasse, parrotfish (presumably scarlet wrasse and spotties), and triplefins on the reefs (Figure 5-2).

Figure 5-2: Diver photos of species at the Traps reefs. (Source: J. O'Leary, in DOC 2006).

Divers mentioned diving off Pātea, Waverley and Waitotara. They described rock 'mounds' sitting on the sand which were papa rocks with shell layers, about knee high, in 8–10 m water depths. They also described "*papa rock structures running out from the coast like fault lines or a papa uplift*", and that "*Off Waverley and north of Waitotara there are papa rock ledges and gutters running about 0.5 km long on a 45 degree angle to the sea floor, perpendicular to the coast. Rock lobster hide there (clinging under the roof of the rock formation). It's in water from 8m – 20m deep*.". Other divers described further areas off Pātea and further along the coast "*…papa ridges – scattered – long ridges of reef with bits broken off and cracks once off ring plain area*.". Graham Bank was also mentioned "*On the edge of the Graham Bank there's a steep drop off with a ridge of papa. Good visibility*.", but also "*Graham Bank is pure sand. There is nothing on it*.". Note that Site V described in this report was located on the south-east side of Graham Bank (Figure 3-1).

DOC (2006) described a south to north transition, from mudstone and sandstone dominated coastline, to volcanic lahar and breccia materials, near the Kapuni Stream and Waingongoro River mouths. This volcanic geology extended around the Taranaki Peninsula, as part of the 'ring plain' (built by multiple volcanic eruptions). Coastal reefs are composed of large boulder-platform reefs, extending up to several kilometres offshore at a gentle gradient. DOC (2006) described a 2005 survey for a pipeline by Origin Energy, using video cameras to view the seafloor, from the shoreline to 2.65 km offshore. At 1,200 m offshore, the seafloor was dominated by the eroded remnants of a volcanic debris avalanche deposit. Volcanic rock formed of rock material was once bound together with ash and mud; however, the soft materials had been washed away, leaving boulders, cobbles, and gravel. Those had been then eroded to more rounded forms. Patches of sand were also present in the video. The next 300 metres heading offshore were occupied by "*hard reef of intact volcanic rock comprised of angular cobbles and gravels, with some pockets of sand. No large boulders were observed on the hard reef*.", which was assessed as the "*margin of the* [volcanic] *debris avalanche*". Beyond this margin, the seafloor changed to "*mudstone, typically covered by a thin veneer of sand, and occasional cobbles and boulders*.".

DOC (2006) also noted the presence of ancient river channels ('paleo-channels') off the Taranaki coastline, carved rivers in the last Ice Age (20 000 years B.P.), when sea level was lower and the coastline 100 km further south. This might explain the presence of the smooth grey cobbles of site A, which bear a very strong resemblance to stones from stony rivers.

Knowledge of the South Taranaki seafloor and its biological species and assemblages was viewed by DOC (2006) as being very limited. Kelp's were reported as present, but never dominant. *C. maschalocarpum* was the main species to around 5 m water depth, where *E. radiata* replaced it, extending out to depths of at least 20 m. High water turbidity was suggested as a limiting factor. In the present study. C. *maschalocarpum* occurred as occasional plants at site U, at 20–23 m metres, while *E. radiata* was present as healthy plants at 32 m depth at site V (the deepest reef surveyed). While water clarity was not measured during the present survey, it appeared that inshore reefs (e.g., site A) had reduced water clarity relative to those further offshore (e.g., sites D, U, and V) – a gradient that is readily seen across the camera imagery in this report.

It was stated that along the "*mudstone and sandstone dominated coast, good fishing grounds exist around reefs, which provide abundant food species for fish. Sizeable reefs out from Pātea have been described as being responsible for some of the best fishing in Taranaki. These <u>'rubble-strewn platforms'</u>* [our emphasis] *have been described as containing abundant food species for fish such as corals, bryozoans, sponges, crustacea, mollusca and polychaetes. These organisms are an intricate part of the marine ecosystem and draw the demersal fish such as snapper, tarakihi, blue cod and gurnard near to shore*" (DOC 2006).

5.1.2 South and North Traps drop camera survey 2005

In 2005, a drop camera survey was undertaken on the North and South Trap reefs (see Figure 3-1 for locations), with up to 2 minutes of video footage collected for each drop, with 145 and 124 sites surveyed respectively across fixed grids (ASR Ltd, no report available). These were classified into six habitat classes: sand, sand-covered reef, kina barrens, *Ecklonia*, mixed algae, and diverse reef. Bombosch (2008) re-analysed these 269 clips in more detail, looking to improve the information outputs for macro-algae and invertebrates, and to "*develop an easily extendable benthic habitat classification scheme that can be used for future mapping projects of the shallow subtidal zones of New Zealand*". It was noted that limitations of the video footage included a lack of a visual scale (e.g., paired lasers) and inconsistent video quality (Bombosch 2008). The lack of a visual scale means that the field of view could not be calculated (the width of the video imagery). No apparent record was made by ASR Ltd of the distance the survey vessel drifted during each up to 2-minutes video drop (likely to vary with tide times, wider currents, and wind), meaning that video swept area (m^2) could also not be calculated.

Bombosch (2008) defined nine physical habitat classes for the Traps (Table 15), very similar to the classes used in this report. Figure (images 1–5) shows representative seafloor imagery as given by Bombosch; equivalent present survey imagery is shown in Figure 3-43. While the older imagery is of lower resolution (older technology) and the original video could not be located, features such as the gutters/finger-and-gutter reef type are clearly the same. There is some variation in how Bombosch (2008) and this report defined these seafloors. For example, Bombosch (2008) defined three levels/mixes of reef complexity (high, mixed, low), all of which appear to be composed of broken gutter morphology (Table 15). In contrast, we separated broken gutters as a separate rock class ('finger-and-gutter' reef) in its own right; separate from high relief (= 'broken rock high') and low relief reef (= 'broken rock low') rock classes. This report also used the class 'flat basement' to describe flat reef with little to no local relief variation. All four of these classes were encountered by the towed camera transect.

Table 15: North and South Trap geomorphology classes of Bombosch (2008), and present survey equivalents. Bombosch (2008) term definitions: rubble, mixture of pebble and cobble as video resolution too poor to distinguish; sparse, not touching. An * shows which classes were absent at South Trap/site Q , relative to the present study. Soft sediment ripple/wave (and other) features were present but not scored. (Source, table 1 of Bombosch 2008).

Bombosch (2008) classes	Present study geomorphology classes
High relief reef, broken gutters	Broken rock high. Broken gutters split off as a separate class (finger-and-gutter reef)
Mixed relief reef, broken gutters	Not specifically classified, is an emergent variable/class from using a segmented video transect. Broken gutters split off as a separate class (finger-and-gutter reef)
Low relief reef, broken gutters	Broken rock low. Broken gutters split off as a separate class (finger-and-gutter reef)
(no equivalent)	Flat basement, low pillow reef*, low patch reef, fallen slabs*, boulder, smooth grey cobbles*, bare raw rock*, tell*
Reef-sand transition	Not specifically classified, is an emergent variable/class from using a segmented video transect
Rubble field	Mixed irregular cobbles (sparse/field cobble density estimated at 20-second video scales as % cover)
Sand, ripples	Sand
Sand, ripples, sparse rubble	Sand
Sand, waves	Sand
Sand, waves, sparse rubble	Sand

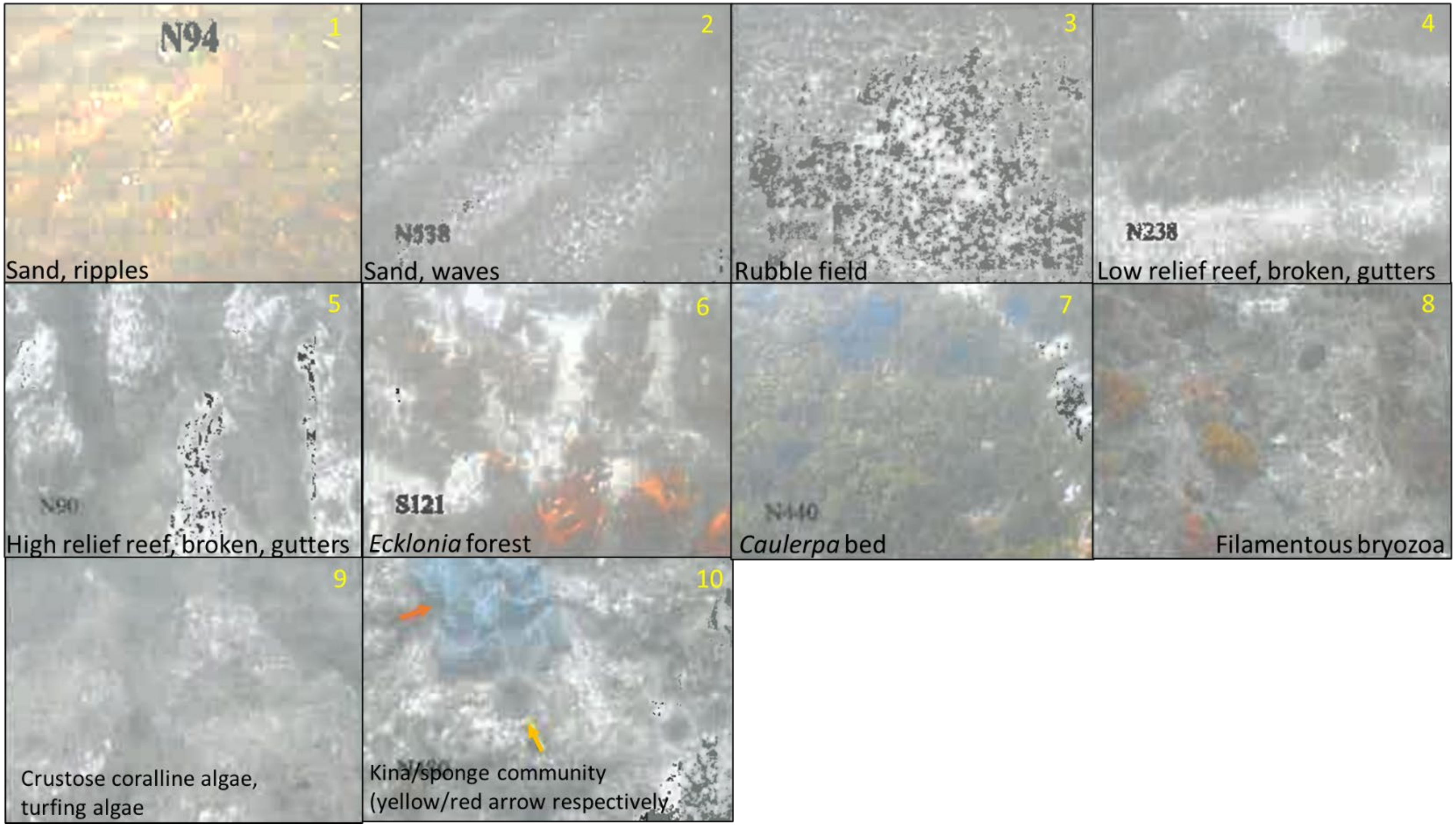


Figure 5-3: Representative seafloor images given by Bombosch (2008) 1–5) geomorphology classes; 6–10) biological habitat classes (Source: figures 2, 3, Bombosch 2008).

Bombosch (2008) assigned each of the 269 video drops to one of these nine geomorphological classes (Table 16, Figure 5-4). For the South Trap, 51.6 of the video drops were classed as reef gutter geomorphology (Table 16). In the present study (noting the different percent cover estimation approach, continuous versus point sampling, and much smaller spatial area sampled), the site Q gutter reef estimate was very similar (55.7%, Table 4). For the North Trap, 64.5% of the video drops were classed as reef gutter geomorphology (note: none of these three contribution estimates removed non-reef site (sand) contributions).

Table 16: Classification of the 269 video drops into nine classes, by Trap %cover was estimated at the Trap survey scale, as the proportion of stations assigned to each of the nine classes (Bombosch 2008).

Physical habitat	North Trap		South Trap	
	Drops	%cover	Drops	%cover
High relief, broken, gutters	5	3.4	10	8.1
Low relief reef, broken, gutters	26	17.9	22	17.7
Mixed relief reef, broken, gutters	44	30.3	48	38.7
Reef-sand transition	7	4.8	7	5.6
Rubble	17	11.7	3	2.4
Sand, ripples	18	12.4	10	8.1
Sand, ripples, sparse rubble	9	6.2	1	0.8
Sand, waves	13	9.0	22	17.7
Sand, waves, sparse rubble	6	4.1	1	0.8

With respect to biological assemblages, Bombosch (2008) was able to identify the following 15 taxa from the 2005 video footage: 4 macroalgae (*E. radiata*, *Caulerpa brownii**, *C. flexilis*, *Caulerpa gracialaris**); 7 sessile invertebrates (sea anemone *Ulactis* sp., jewel anemone *Corynactis* sp., soft coral (Order Alcyonacea*), the sponges *Tethya* sp. (ball sponge) and *Ancorina* sp. (now *Ecionemia*, massive sponge), ascidian *Cnemidocarpa* sp*.; and 4 mobile invertebrates (biscuit sea star *Pentagonaster pulchellus**, kina, Cooks Turban, the large slit limpet *Scutus breviculus**, and reef octopus *Pinnoctopus cordiformis** [*, seven species not seen in the present survey).

All other species were only able to be assessed at higher levels as four group morphologies – filamentous/foliose macroalgae, turfing algae, bryozoans (soft uncalcified Catenicellid spp.), and sponges (with 5 sub-groups – branching, encrusting, globular, massive, papillate (with bumps). The terms 'turfing algae' and 'foliose/filamentous macro-algae' were defined essentially by height:

> *"Turfing algae – used as a general descriptor of small algae having a lower height than bryozoans or kina. All major algal taxa, e.g., Rhodophyceae, Phaeophyceae, and Chlorophyceae could be represented. It has to be noted that turfing algae described all algae species being smaller than bryozoans or kina. Thus, some of the Phaeophyceae and Chlorophyceae could include Caulerpa sp. and Ecklonia radiata that were assumed to be grazed or re-growing, as fully grown individuals were found in the vicinity. Even though they are not turfing algae as defined in the literature, it was not chosen to count those as Caulerpa sp. and Ecklonia radiata as clip quality did not allow for a reliable identification." (Bombosch 2008).*

"*Foliose/filamentous macro-algae – this term was used to identify algae of all three taxa, which were higher than turfing algae, but smaller than Caulerpa sp., and the canopy species Ecklonia radiata.*" (Bombosch 2008).

Based on the dominance of the species/groups present in the two minute video drops, eight 'dominant biological community' classes were defined (Table 17). Figure (images 6–10) provides visual examples of some classes.

Table 17: North and South Trap's nine dominant biological habitat classes and a list of associated sub-dominant species/groups (Source: table 4 of Bombosch 2008).

Dominant biological community	Associated biological communities
Ecklonia forest	Turfing algae
	Crustose coralline algae
	Bryozoa
	Sponges
	Small *Caulerpa* patches
	Kina in varying densities
Filamentous bryozoa	Turfing algae
	Occasional filamentous/foliose brown/red algae
	Kina in varying densities
Filamentous bryozoan with sparse *Ecklonia*	Sparse *Ecklonia*
	Turfing algae
	Occasional filamentous/foliose brown/red algae
	Kina in varying densities
Caulerpa beds	Bryozoa
Ecklonia/Caulerpa mixed	Turfing algae
	Bryozoa
	Kina in varying densities
Coralline crustose algae, turfing algae	No macrofauna
	Occasional sparse bryozoan
Kina/sponge community	Turfing algae
	Bryozoa
	Juvenile *Caulerpa*
Kina/sponge community with *Caulerpa* patches	Turfing algae
	Bryozoa
	Caulerpa patches

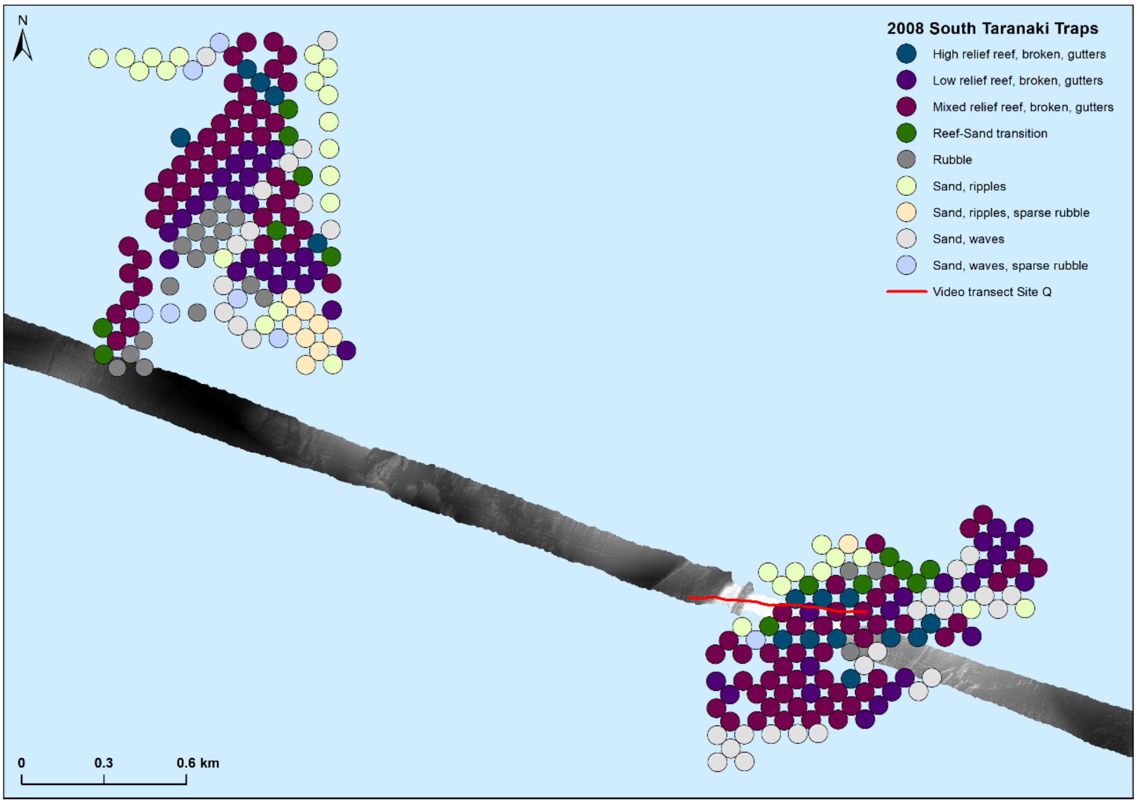
Bombosch (2008) assigned each of the 269 video drops to one of these eight dominant biological communities (Table 18, Figure 5-4). The percent cover of these nine classes was similar between the North and South Trap; with the North Trap having higher kina/sponge community (urchin barren) (20.7 vs. 12.1%) and turfing algae (18.6% vs. 4.8%) cover. The South Trap had higher crustose coralline algae/turfing algae (16.1 vs. 4.1%) and filamentous bryozoa (26.6 vs. 15.9%) cover. *Caulerpa* bed (2.8%, 5%) *Ecklonia* forest (5.5%, 5%) and *Ecklonia/Caulerpa* mixed (4.1%, 7%) cover was very similar.

The present survey covered only a small area of the South Trap (Figure 5-4). Seven ASR Ltd video drop sites fell to each side of the site Q transect, which were all classified by Bombosch (2008) as kina/sponge community (urchin barrens). In contrast, the present study found the same sub-area to be around 50% *Ecklonia* forest (western half), and 50% urchin barrens (eastern half). These two estimates, 16 years apart, suggest that these habitat classes (as probable alternative states) may vary in their extent (percent cover) over time. Here the kelp forest (2021) replaced urchin barren habitat (2005), but with only 2 time points, nothing can be inferred regarding the temporal dynamics of kelp forests vs. urchin barrens.

As a general note, Bombosch (2008) noted that in many of the video clip the reefs were white (North Trap 25.5%, South Trap 20%), whereas in other clips "*the visibility seemed to be highly reduced and the reef appeared to be covered by sediment*" (North Trap 20%, South Trap 39.5%). These estimates were not used in the percent cover estimates, with their cause/s unknown, and were suggested to need direct investigation by divers (Bombosch 2008). This white coloration was seen in the 2021 video footage also (Figure , images 12,14–18), and is white-coloured non-geniculate coralline algae.

Table 18: Classification of the 269 video drops into nine classes, by Trap %cover was estimated at the Trap survey scale, as the proportion of stations assigned to each of the nine classes (source: appendix 4 of Bombosch 2008).

	North Trap		South Trap	
	Drops	%cover	Drops	%cover
Absent	33	22.8	29	23.4
Caulerpa bed	4	2.8	5	4
Crustose coralline algae, turfing algae	6	4.1	20	16.1
Ecklonia forest	8	5.5	5	4
Ecklonia/*Caulerpa* mixed	6	4.1	7	5.6
Filamentous bryozoa	23	15.9	33	26.6
Filamentous bryozoa with sparse *Ecklonia*	5	3.4	3	2.4
Kina/sponge community	30	20.7	15	12.1
Kina/sponge community with *Caulerpa* patches	3	2.1	1	0.8
Turfing algae	27	18.6	6	4.8



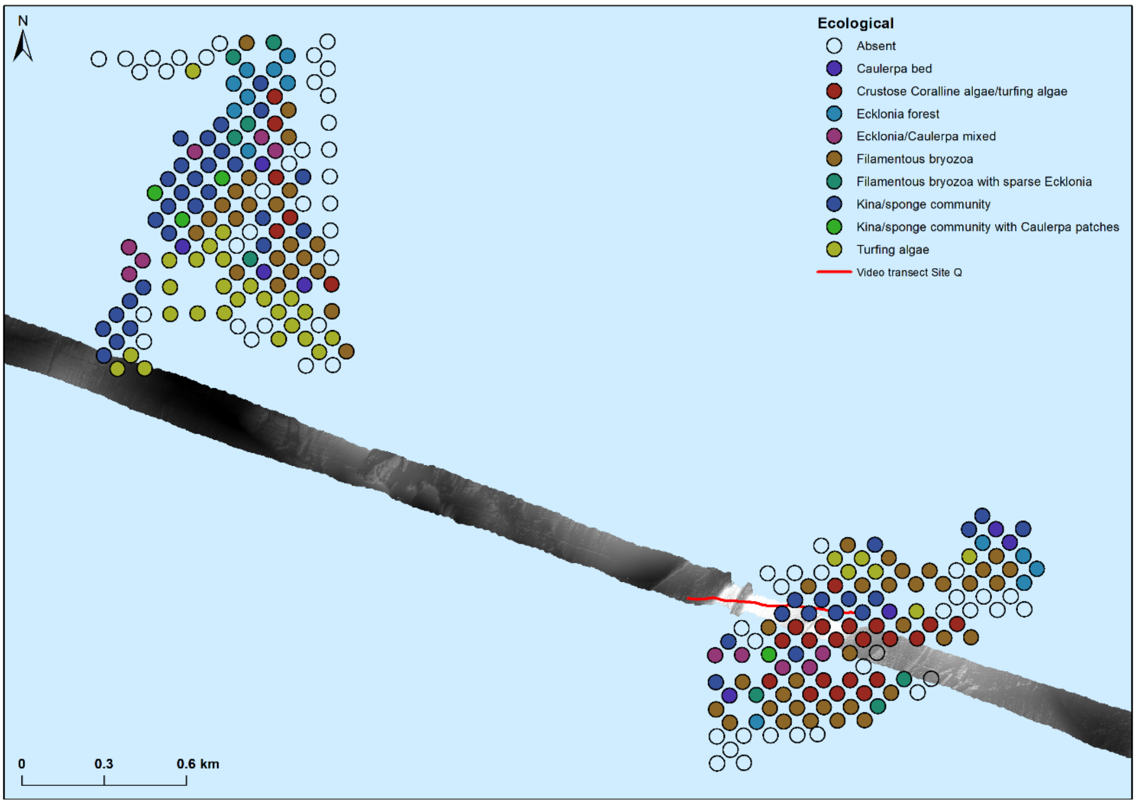


Figure 5-4: North and South Trap video drop grid Also shown are the multi-sonar transect (bathymetry plotted over South Trap in the 2021 survey (site Q transect shown as red line), and the North Trap's southern boundary (Source: figures 4, 5, appendix 3 of Bombosch 2008).

5.1.3 Broad scale benthic surveys of Pātea Bank and adjacent areas 2011–13

Two benthic surveys were conducted for Trans Tasman Resources Ltd. as part of a proposed iron-sand mining project off Pātea Bank. A large survey in 2013 sampled at 145 sites with a range of methods (144 towed videos each 300 m long, 116 epifaunal dredges, and 331 sediment cores from 103 sites) (Beaumont et al. 2015). Each station was assigned a benthic habitat identity, of which seven included rock/reef contributions (Figure 5-5). The seven rock 'point sites' were used to inform the survey design of the 2020 multibeam sonar mapping transit route (see Figure 3-1), All seven rock-sites fell inside the 12 nautical mile limit (Figure 5-5). A second smaller 2013 survey using 100 m-long camera transects (12 photo-quadrats taken within each and analysed for seafloor percent cover), and some dredging, sampled a further 36 sites closer inshore, including 10 sites off Whanganui, with five found to hold rock habitats (12.8–22.3 m water depth) (CS1 – see Figure 5-1) (Anderson et al. 2015).

Table 19 gives short descriptions of the rock habitats recorded in these surveys; while Figure 67 shows the relevant seafloor images from the two reports. The seven sites of Beaumont et al. (2015) fell within the range of rock geomorphologies and benthic assemblages quantified in the present report, but probably at the lower end of complexity and species assemblage abundance (based on data in Table 19). The 2020 multibeam sonar survey did not pick up significant seafloor structure at any of these seven sites (except for the large multibeam sonar block which site #20 fell within (Figure 3-1). The five sites of Anderson et al. (2015) revealed reefs to be present in shallower water (Figure 3-1). Three of these were of harder rock, with associations of sponges, *Ecklonia*, red algae, and bryozoans depending on site. The other two were composed of mudstone / Papa rock, with low to no associated biodiversity (Figure , images 7–8; one off Whanganui, see Figure 5-1).

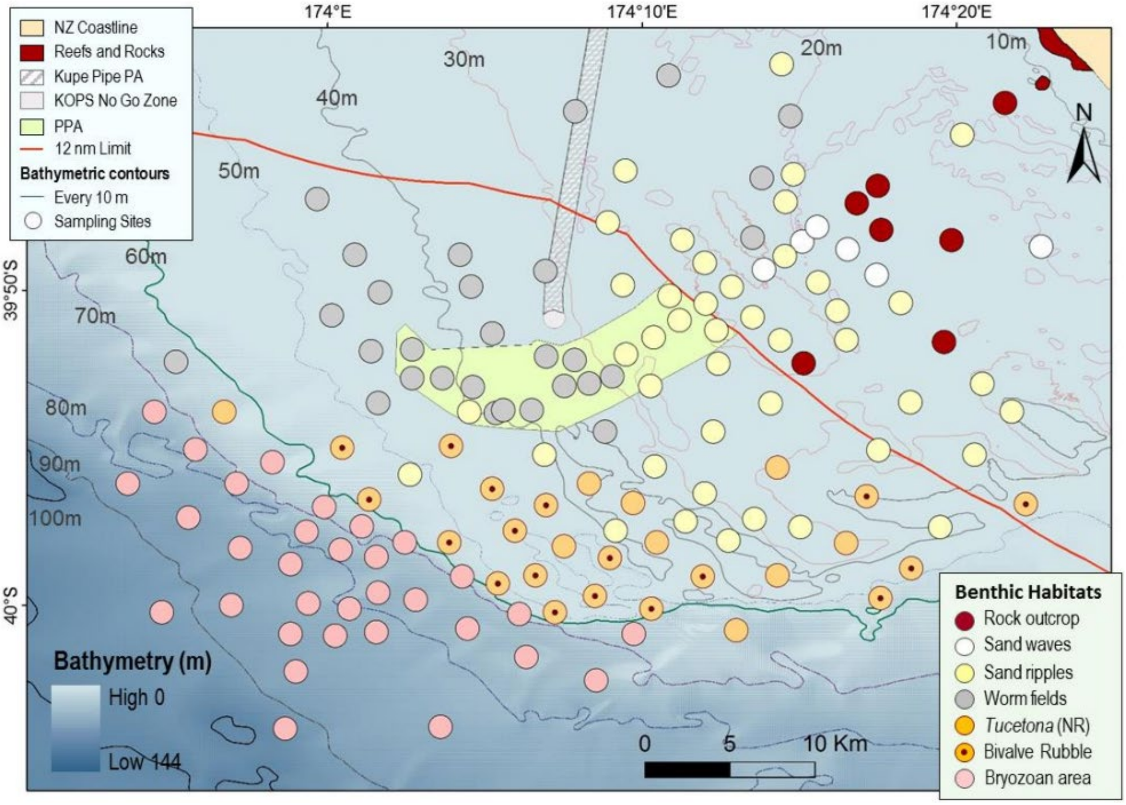


Figure 5-5: Sites and associated habitat types for the 145 stations sampled as part of iron-sand mining proposal investigations Seven sites where rock was observed are shaded as dark red circles (stations also shown on Figure 1). *Tucetona* (NR) are sites where live dog cockles (*Tucetona laticostata*) were present but with little to no associated dead shell (referred to here as 'rubble') (Source: figure 7 of Beaumont et al. 2015).

Table 19: Brief descriptions of the seven rock associated sites sampled by Beaumont et al. (2015), and five rock sites by Anderson et. al (2015). (Source: appendix B, Beaumont et al. 2015; appendix A, Anderson et al 2015). A prefix of “#" indicates offshore sites (Beaumont et al 2015), a prefix of “+” indicates inshore sites (Anderson et al 2015).

Site	Depth (m)	Geomorphology	Seafloor assemblage notes	Fish
#5		Low relief outcrop with rippled sands	Bryozoans and macroalgae	
#7	26	Low relief bedrock, boulders, cobbles, and pebbles partially covered by iron-sand/shell hash	Filamentous and turfing red algae, sponges (encrusting, massive, ball), sponges, fan worms sp1, star fish x1	Blue cod x10, spotties x1, cardinalfish x1
#20	–	Low relief outcrop partially buried by rippled sand, shell debris and gravel/pebbles in troughs, mudstone cobble		Opalfish x5, small fish x1.
#42	26	Low bedrock and cobbles, partially covered in coarse sand and shell hash; adjacent to linear-rippled sand with shell-hash and gravel/pebbles in troughs	Bedrock with sponges (encrusting, massive, ball), coralline algae, ascidian, star fish (*Coscinasterias*), filamentous red algae	
#46	–	Coarse sands with gravels, pebbles, cobbles and shell hash, shell hash. Possible shallow buried reef as sponges caught in dredge	3 sponges in dredge sample	
#50	–	Buried bedrock outcrop, boulders, cobbles		
#53	–	Buried rock/Rippled sands. Shell-debris flats. Adjacent to iron-rich rippled sands with heavy shell-debris and gravel/pebbles in troughs.	Small tufts of filamentous red algae growing on underlying bedrock. Large shell debris encrusted with coralline paint	
+5	21.7–22.3	Rocky outcrop (low-relief mix of boulders, cobbles, sand), mixed algae, and blue cod	Mixed algae, bryozoans, anemones	Blue cod
+6	21–20.3	Rocky outcrop (moderate/low relief, bedrock, boulders, cobbles, and sands with shell gravel);	Bryozoans, mixed algae, yellow sponges (*Halichondria*).	
+7	12.8–13.0	Rocky outcrop (contiguous moderate relief bedrock with boulders, adjacent to coarse sediments);	*Ecklonia*, red algae, bryozoans, and sponges	
+14	13.8–14.2	Mudstone outcrop (Low-lying partially covered in coarse sands), mean rock cover 10.35% ± 5.35%	No visible biota	
+CS1	13.5–13.7	Mudstone outcrop (moderate relief mudstone adjacent to rippled sediments);	Benthic diatoms, red algae, and a few small sponges.	

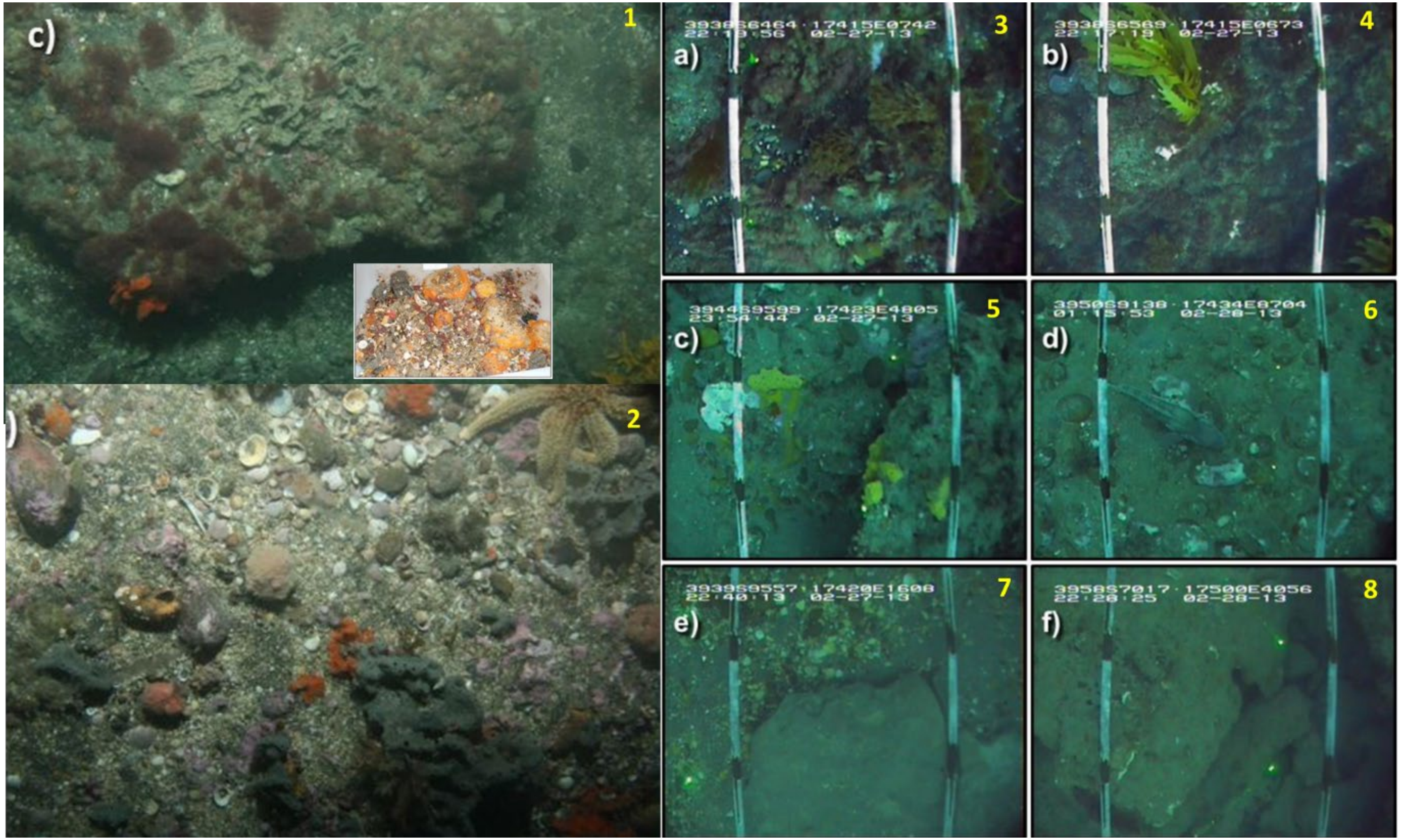


Figure 5-6: Seafloor images of other South Taranaki rock/reef sites Beaumont et al. (2015) 1) site #7 (26 m), low-lying rock outcrop (7.35% transect cover) (insert; dredge sample at site). Species visible are grey sponge Family Chondropsidae species 2, orange and yellow sponges (and either filamentous red algae or bryozoans); 2) site #42 (26 m), low-lying rock outcrop (<1% transect cover). Anderson et al. (2015). 3–4) site +7 (13 m), rock with bryozoans, *E. radiata* kelp and grey sponge *E. alata*; 5) site +6 (20 m), yellow *Halichondria* sp. sponges; 6) site +5 (22 m), encrusting sponges and blue cod; 7) pale grey mudstone with no visible biota (top half of image is soft sediment); 8) site +CS1 (13 m) offshore of Whanganui, mudstone outcrop with patches of benthic diatoms and red filamentous algae.

Three of the five inshore rock sites of Anderson et al. (2015) were physically sampled with a dredge, and taxa identified to species where possible. The mudstone site (+14, Table 19) displayed heavily eroded surfaces, and notably had records of the rock-boring bivalve, *Barnea similis*.This species in part might be responsible for the rock boring seen at sites Papa and D.

On the three rock sites the following were recorded: 3 brown algae species (including *E. radiata*), 2 green algae (*C. flexilis*, *C. brownii*), 10 red algae species, 27 bryozoan species, 6 sponge species (*A. globosum*, *C. ramosa*, *Haliclona* (*Adocia) ventistina*, *Hymedesmia* cf *microstrongyla**, *Leucettusa lancifera**, *Halichondria* sp., *Iophon proximum*) (*, not observed in present survey), 2 amphipod taxa, 2 crab species, 1 shrimp, 2 ophioroids (not *O. maculata*), 1 starfish (cushion star *Patiriealla mortensoni*), 1 bivalve (*B. similis*), and 3 gastropods (small-bodied species). Blue cod were also caught (size/s not given).

Site +6 was located in the most inshore area covered by the 2020 multibeam sonar mapping transects (Figure 3-1), which revealed many reef patches and potentially large reefs in this area (Figure , Appendix A). This area was initially included within the plan for the 2021 CoastCam survey but these sites were not completed due to time constraints.

Site +7 traversed the north-west side of a large rock outcrop (around 3.8 x 0.8 km, 2.45 km^2, based on the DOC putative reef polygon, see Figure 3-1), which based on the site +5 video footage (noting that only covered a 100 metre distance) was thought to be extensive consolidated reef (Anderson et al. 2015).

Collectively, these limited site observations suggest that extensive rock/reef habitat exists inshore of the extent of the surveys reported on here (2020 multibeam and 2021 CoastCam). Note, however, that the 2020 multibeam sonar survey revealed numerous reef targets north and east of site J (Figure 3-1).

The large and extensive 145 site survey of Beaumont et al (2015) sampled numerous species over soft sediment habitats, and revealed extensive offshore dog cockle beds, associated shell drifts (‘rubble’), and calcified bryozoan species fields (Figure 5-5). Soft sediment habitats are not the focus of this report, but some of the species seen on the 14 reefs sampled in the current study also occurred on soft sediments. A few interesting contrasts included:

- The saw shell *A. heliotropium* was the most numerically dominant mollusc species sampled (579 individuals, 27 sites), with the highest numbers on deeper water dog cockle rubble. The present survey counted 43 individuals on rock/reef.
- The snake star *O. maculata* was the numerically dominant ophiuroid sampled (260 individuals, 18 sites) also associated with dog cockle rubble (42–74 m water depth). The present survey counted one individual, despite it being common on reefs elsewhere.
- The sea cucumber (holothurian) *Australostichopus mollis* (49 individuals, 12 sites) was also strongly associated with dog cockle rubble (28–80 m). The present survey saw none, despite it being common on reefs elsewhere.

5.2 North Taranaki reefs

The Taranaki Catchment Commission (1980) sampled the 'Waitara Reefs', in 14 to 18 metres water depth, with ten quadrats, and reported a low cover of organisms, with species richness ranging up to eight per metre square (species not known, cited in Cole & McComb 2001). They provided a species list of fish observed in the area, with blue cod and scarlet wrasse being the most common of the 28 species reported.

Willan (1980) provided detailed investigations from Tataraimaka and Oaonui, both south of New Plymouth (cited in Cole & McComb 2001), looking at shallow water boulder-reef habitat (depths not given, but appear <10 m). The sponges *Ecionemia alata* and *Iophon minor* were the most common, along with the mussel *Modiolus areolatus*. *E. radiata* was described as rare, small (<25 cm) height), and only occurring in more than 5 metres water depth. *Carpophyllum* was restricted to depths of less than five metres. Kina were present in low densities (maximum 0.08 m^2), with the more common gastropods being *Trochus viridis*, *Cantharidus purpureus*, *Cellana stellifera* (a limpet) and *Cookia sulcata*. A discrete large rock (four metres tall, in seven metres water depth) was described as having its upper reaches covered by *C. maschalocarpum* and *E. radiata*), with a small red and brown algae understorey. Large, green-lipped mussel's *Perna canaliculus* was abundant (160 per $1m^2$), along with lower densities of their predator, the starfish *Stichaster australis* (~ 3 per $1m^2$).

The Taranaki Catchment Commission (1982) surveyed a shallow area (to 9 metres water depth) northeast of the Waiwhakaiho River mouth, along around 600 m of shoreline (cited in Cole & McComb 2001). Using quadrats along five transects extending offshore, animal and plant cover generally reduced with increasing water depth; while species richness increased with distance from the river mouth. *C. maschalocarpum* was most abundant in shallow water, with deeper areas being dominated by the coralline turf *Corallina officinalis*. *E. radiata* was also more common in deeper water, with the highest abundances being observed 800–1200 m offshore. Encrusting species were generally low in their percent cover, with only six of 61 occurrences exceeding 10% cover, and 21 of 61 occurrences contributing less than 1 % average cover (species identities were not given). The authors suggested that sediment from the Waiwhakaiho River mouth was negatively affecting sponge diversity, with grazers (gastropods) possibly controlling the distribution of small individuals. Fish noted as present included spotty, banded wrasse, marblefish, red moki, blue moki, blue cod, and kahawai.

5.2.1 Sugarloaf Islands subtidal reefs

North Taranaki reefs, in particular the Sugar Loaf Islands (Ngä Motu) and associated reefs off New Plymouth, have received significantly more science attention (e.g., Miller et al 2003a,b, Green et al (DOC)., unpubl data), than South Taranaki reefs. Now protected by the Tapuae Marine Reserve (since 2008), and more broadly the Sugar Loaf Islands Marine Protected Area (SLIMPA), these reefs continue to be a focus of marine research in the region. The area was fully multibeam sonar habitat mapped for Port Taranaki and DOC in 2021 (Figure 5-7), as well as a wider area (not shown) (DML 2021).

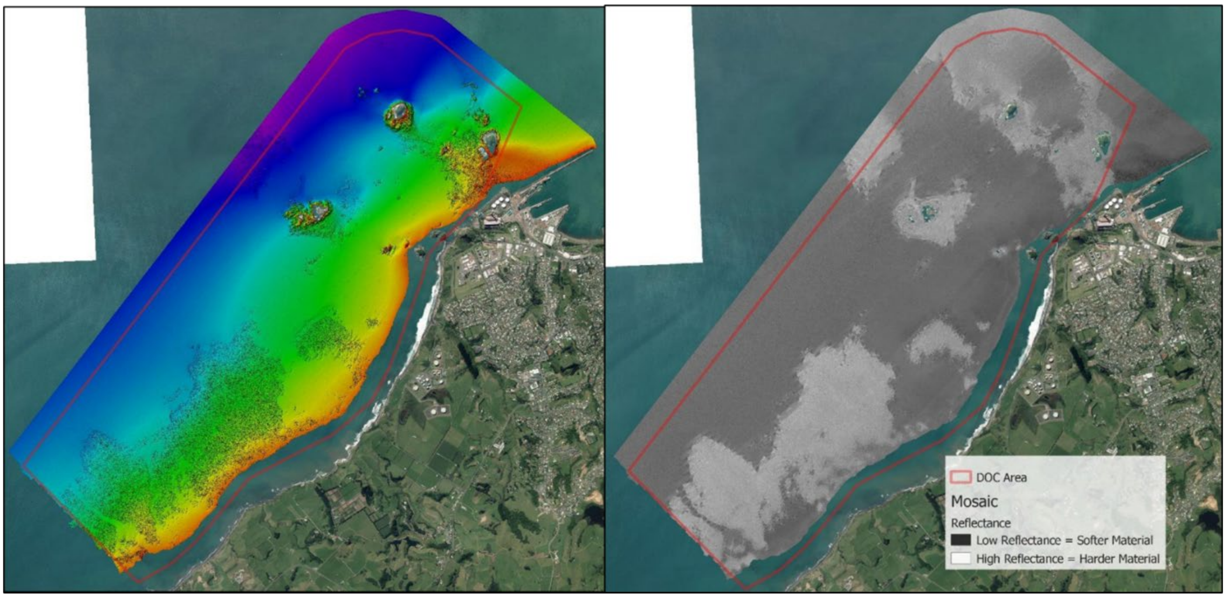


Figure 5-7: Multibeam sonar bathymetry and backscatter maps for the reef systems off New Plymouth, North Taranaki (Source: DML 2021). The mapped area extends out to 40 metres water depth and covers 20.28 km². The southern half holds extensive boulder fields. Left: bathymetry (red is shallow, blue/purple is deep; Right: backscatter plot showing areas of hard (light grey) and soft sediment (dark grey).

An earlier seafloor map created with sidescan sonar delineated the subtidal reefs, with 16 of those individually named and provided with a brief text description and photograph (Figure , Figure , Table 20; DOC/UoW undated). The reefs were of volcanic origin with many characterised as having cliffs, caves, drop-offs, overhangs, and guts (Figure , image 3), while others were composed of large boulders (Figure , image 1). Vertical faces were a common element. This volcanic rock geology and often sharp topographies differs from that of the South Taranaki reef sites, which had lower relief, were composed of mudstone/sandstone/limestone, and had fewer pronounced walls and drops; with most of those in the form of step terraces with between-terrace drops of 1–2 metres.

Ecklonia was mentioned as being present at 10 of the 16 sites, but data on percent cover (singles, patches, forest) and feature associations (e.g., depth, what rock topologies) was not available (DOC/UoW undated). *Carpophyllum* (presumed to be *C. maschalocarpum*) was present at 9 sites and appeared common (unlike the current report's South Taranaki sites). However, many of the Sugarloaf Islands reefs extended into shallower water and had some degree of storm protection (preferred conditions for *Carpophyllum* spp.); so, the comparison is probably confounded by depth and shelter differences. DOC (2006) noted *Carpophyllum* to be common on reefs in less than five metres water depth on the South Taranaki coast.

Zoanthids (Order: Zoanthidea), visually striking and colourful yellow anemones which can form dense clumps, were present at four Sugarloaf sites. Although these species can occur down to more than 50 metres depth; none were seen in the South Taranaki surveys. Urchin barrens (e.g., Figure , image 4) were also present at four Sugarloaf sites. These were recorded from two reef sites within the South Taranaki survey (note that urchin barrens tend to occur on shallower reefs and the Sugarloaf Islands have more extensive shallow reefs relative to the 14 South Taranaki sites).

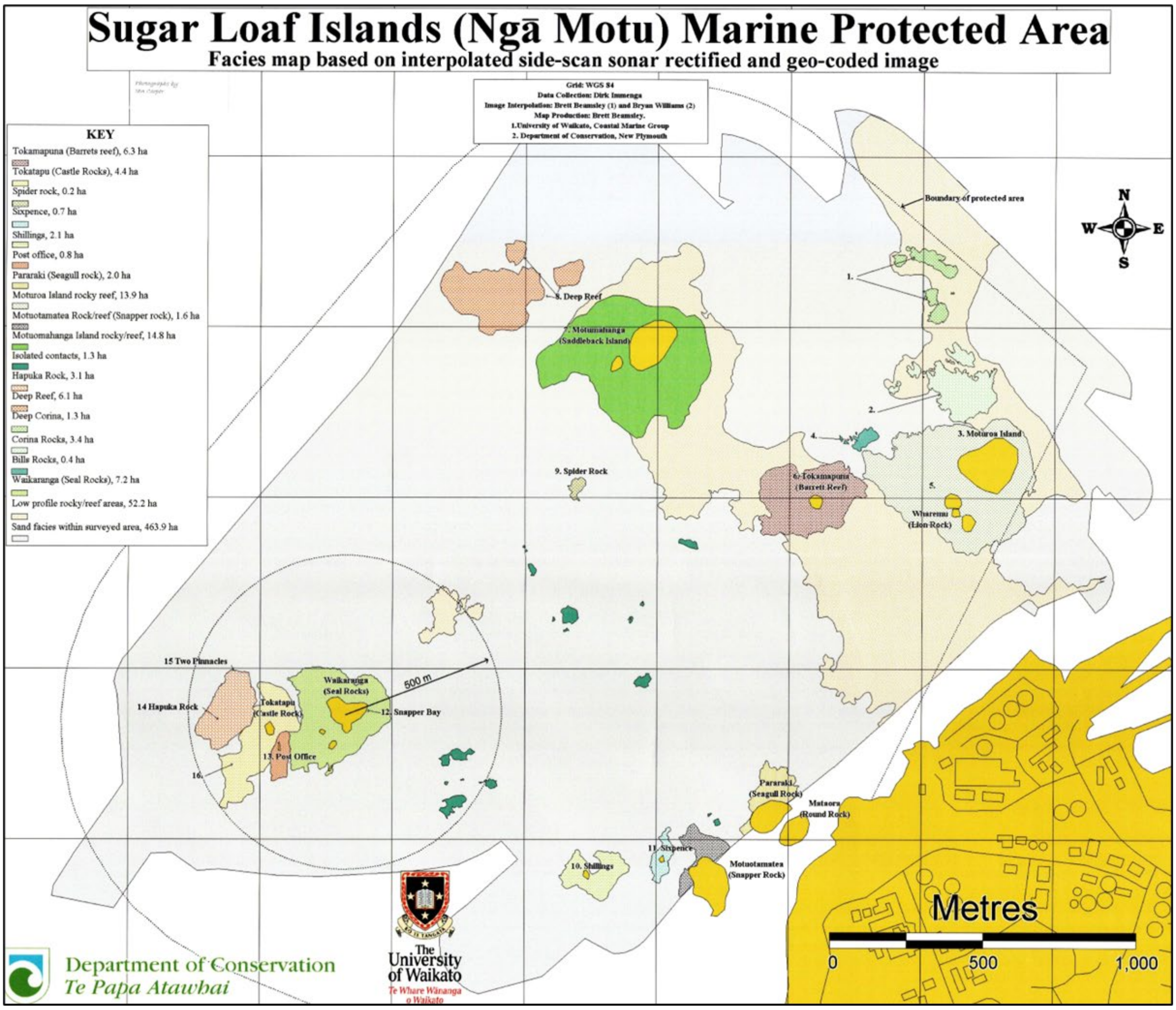


Figure 5-8: Sidescan sonar derived map of the Sugar Loaf Islands area See Table 20, Figure 5.9 for reef descriptions.

Table 20: Sixteen named reefs brief descriptions from DOC/UoW (undated) numbers match labelled and spatially delineated reefs of Figure 69. The sponge *Ecionemia* was previously known as *Ancorina*.

Site #	Name	Physical description	Biological assemblage
1	Deep Corina	Three deep volcanic reefs, rocks, structures, 27 m at base. Caves, drop-offs, overhangs, guts, silt deposits.	Finger sponges, yellow-orange encrusting, *Ecionemia*, green algae, hydroids
2	Corina	Extends out from Moturoa Island. Long volcanic reef with several small rock-reef areas separate from the main reef. 25 m at base, 8 m at top, silt deposits.	Finger sponges, green algae, *Ecklonia*, bryozoa, urchin, green-lipped mussels (*P. canalicus*), paua (few), *Ecionemia.*
3	Moturoa Island	Extends out from Moturoa Island. Long volcanic reef with several small rock-reef areas separate from the main reef. 25 m at base, 8 m at top, silt deposits.	Generally shallow around island. Lava outcrops, patchy *Ecklonia*, *Carpophyllum*, golf ball and finger sponges. Encrusting brown and yellow sponges. Polymastid sponges, bryozoan, paua, and mussels

Site #	Name	Physical description	Biological assemblage
4	Bills Rock	Volcanic reef surrounded by mud/sand. 20 m to 8 m depth at top of reef, gut overhangs, large cave on eastern face. Face 12 m high. Silt deposits.	*Ecklonia* forest on western slope, finger sponges, anemones, zooanthids, bryozoa, yellow and orange encrusting sponges, algae and *Ecionemia*
5	Area south of Wharemu (Lion Rock).	Conglomerate rock, volcanic rock, some guts running se/nw, silt deposits. Out to Barrett's reef lave rock, large boulders.	Patches of *Ecklonia*, encrusting sponges (red/yellow), brown coral, finger sponges, *Ecionemia*
6	Tokamapuna Reef	Large volcanic reef. Caves, overhangs, and archway (seaside)	*Ecklonia* and *Carpophyllum*, anemones, encrusting sponges (green).
7	Motumahanga Reef	Shallow on e/se corner, 8 to 20 m, rock slabs close to island, guts, and large boulder banks. Deep on north side (30 m), with boulder bank. Exposed to weather	Urchin barren, *Ecklonia* forest, encrusting sponges (yellow/red and orange). *Carpophyllum*.
8	Deep Reef	Isolated reef surrounded by sand and mud. Extends to 35 m, volcanic reef, rock structures. Caves, drop-offs, guts, some silt (3 separate reefs)	Anemone, hydroids
9	Spider Rock	Deep reef extending to 20-26 m. Some cuts, small face with overhang. Silt deposits.	Finger sponges, algae, anemones, *Ecionemia*.
10	Koruanga (Shilling Reef) outer	Volcanic habitat with some caves and guts.	Largely urchin barren with some *Ecklonia* and *Carpophyllum*
11	Sixpence (inner reef)	Volcanic rock with a hole.	Urchin barren with some *Ecklonia*, encrusting orange anemones (very colourful) and *Carpophyllum*
12	Snapper Bay	Boulder bank on se corner of Waikaranga. Large boulders.	Large *Ecklonia* forest. *Ancorina*, anemones, hydroids, *Carpophyllum*. Urchin barrens
13	Post Office	Volcanic reef in 8-20 m. Large crevasse and the boulder bank to the se are often full of rock lobster. *Ecklonia* forest out to 20 m, zooanthids, anemones, encrusting sponges, urchin, paua, chitons, *Carpophyllum*. Urchin barren at back of reef.	*Ecklonia* forest out to 20 m, zooanthids, anemones, encrusting sponges, urchin, paua, chitons, *Carpophyllum*. Urchin barren at back of reef.
14	Hapuka Rock	Large cave extending from 16 to 30 m, Some guts, overhangs, and rock faces. Top of reed in 6 m water depth.	Anemones, sponges, zooanthids, encrusting sponges, *Carpophyllum* (very colourful). Large number of rock lobster.
15	Two Pinnacles	Off northern corner of Hapuka rock. Rises 27 m.	Anemones, sponges, zooanthids, encrusting sponges, *Carpophyllum* (very colourful).
16	Area southeast of Hapuka Rock	Caves, rock faces, large boulders, some sand and mud.	Finger sponges, anemones, sponges, encrusting sponges.

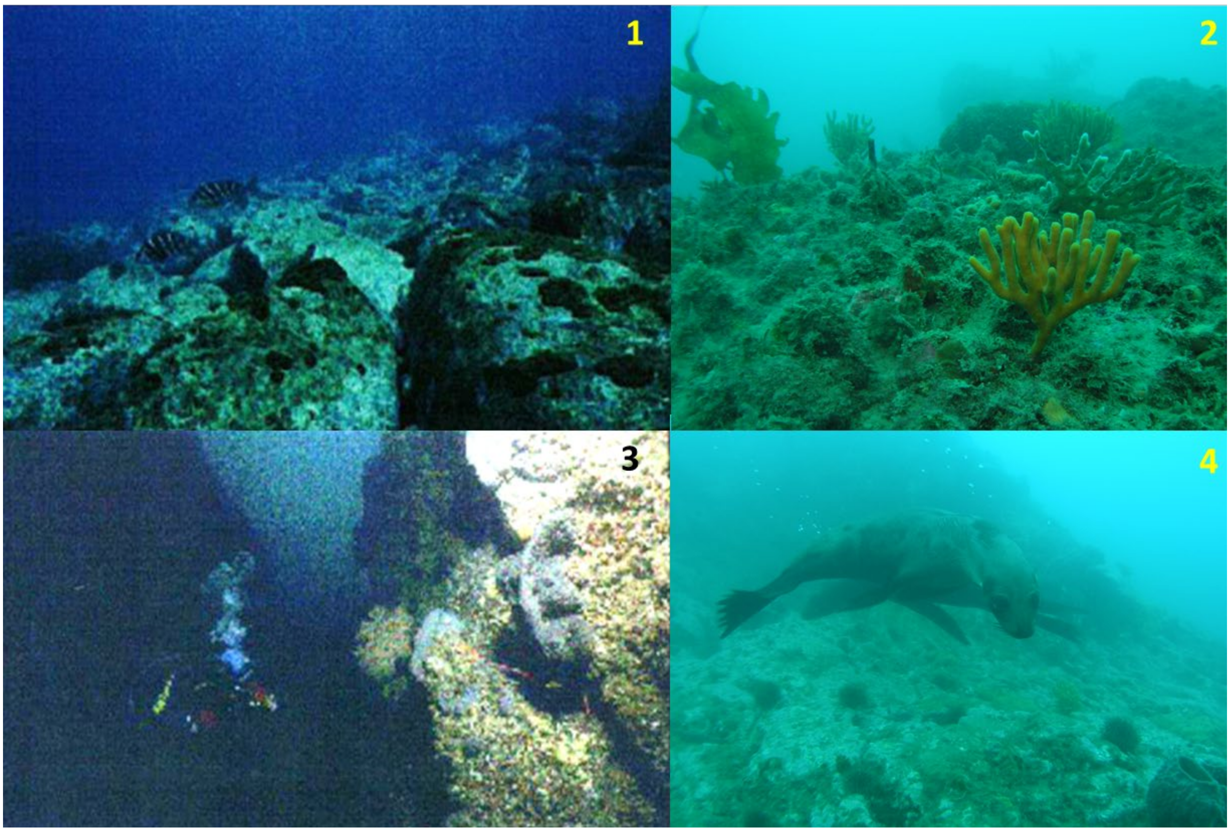


Figure 5-9: Seafloor images from the Sugar Loaf Islands reefs 1) Boulder field with red moki, site 7 of Figure , Table 18; 2) sponge assemblage on reef (source C. Lilly, DOC); 3) Reef cliffs with sponges and zooanthids, site 1 of Figure , Table 18); 4) Sloping reef with New Zealand fur seal (source C. Lilly, DOC).

Sugarloaf Islands monitoring surveys from 2001–2003 examined seafloor (Miller et al. 2005) and fish assemblages (Miller et al. 2013), with sites both in and outside the SLIMPA (Tapuae Marine Reserve not established until 2008). Six sites were assessed, with two assigned to each of three levels of protection (full, partial, none). Focal species were rock lobster, kina urchins and three gastropods (*C. sulcata*, *Trochus viridis* (see Figure 5-10) and *Calliostoma punctulatum*), as drivers of subtidal reef habitat structure within SLIMPA. Non-focal species were estimated at the group levels of sessile invertebrates, coralline algae, and Chlorophyta and Rhodophyta species.

One-metre square quadrats were randomly placed on the seafloor, and substrate type, depth, grazing invertebrates counts, percentage cover of algae and encrusting invertebrates, and kelp density recorded for each quadrat. Lobsters were counted using a search time method, with the same diver consistently searching all known rock lobster shelters at each site. The overall finding across the three years was that the "*densities of many of the benthic species surveyed significantly differed between survey sites and years, but in many cases a significant site-by-year interaction resulted in observed patterns being inconsistent. There were significant associations between kina and species such as coralline algae, suggesting that kina were associated with 'barrens' habitat*" (Miller et al. 2005). Lobster CPUE and sizes were higher inside the 'Conservation Area'.

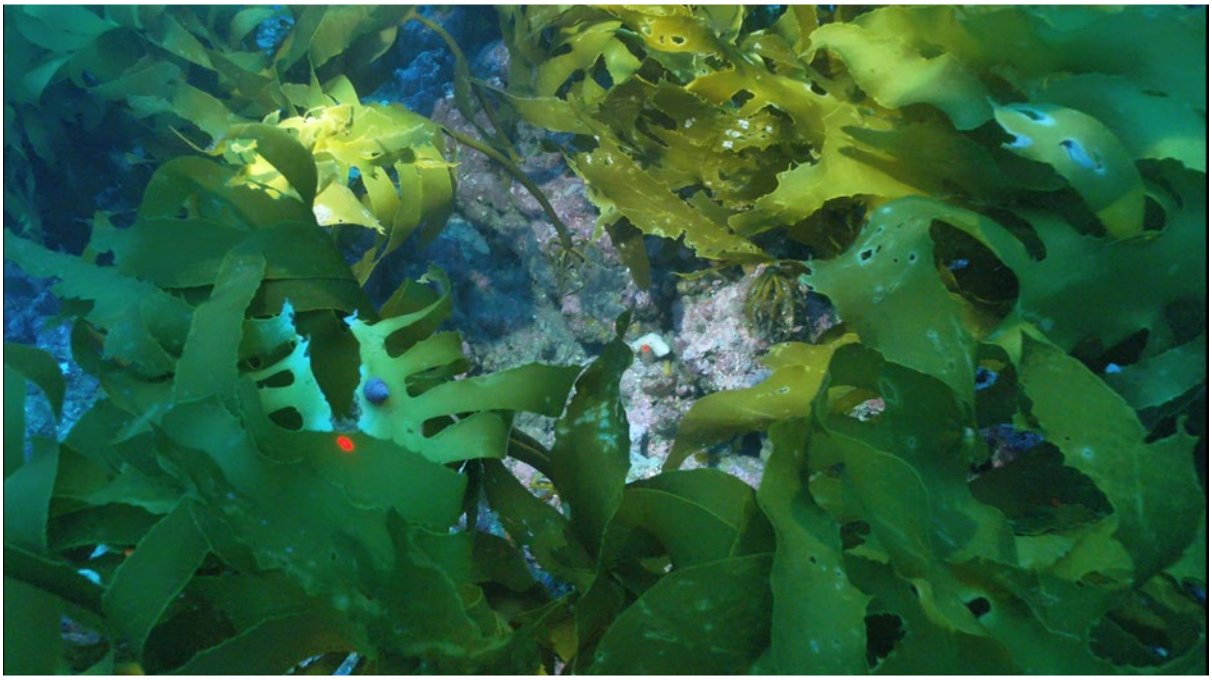


Figure 5-10: Likely *Trochus viridis* (now *Coelotrochus viridis*) seen on *Ecklonia* frond at site U, South Taranaki. The red circle mark is one of the scaling lasers, the second laser end can be seen in the central image area.

Fish assemblages were assessed across the same six sites using diver censused 25 x 5 metre transects, with around 20 transects per site (Miller et al. 2013). Eighteen species were observed, with the summed count of individuals given in Table 21. These numbers can only broadly be compared to those of 14 South Taranaki reef sites in the present study; due to the different census methods, shallower depths, different overall swept/sampled extents, and the Sugarloaf Island sites being fixed multi-year sites (sampled repeatedly), versus the much larger scale, one-year South Taranaki survey (sampled once).

The most striking fish species difference between the two survey regions was the dominance of jack mackerel (*Trachurus* spp.) at the Sugarloaf Islands, which were completely absent from the South Taranaki sites. Jack mackerel are very common on north-eastern New Zealand coastal reefs as juveniles, often as large schools over *Ecklonia* forests. However, they were present in only two of the three years sampled by Miller et al. (2013), with no jack mackerel recorded in 2001 for unknown reasons; they may have similarly been temporally missing from the 2021 South Taranaki survey. They have been seen at Project Reef (e.g., see https://www.youtube.com/watch?v=QX_eAeyZgTE)

Only repeated temporal sampling will address whether this absence is constant or varies over time with unknown factors. The other notable difference was the presence of two-spot demoiselles (*Chromis dispilus*) on the Sugarloaf reefs; none were seen in South Taranaki. This species is endemic to warm-temperate waters of New Zealand, and its range is considered to be the north-eastern New Zealand coastline and the Kermadec Islands. The New Plymouth presence may represent its most southern distribution; it was seen in numbers across all three survey years. Of note, silver drummer (*Kyphosus sydneyanus*) were also mentioned as present; this shallow reef herbivorous species is also a warm temperate species.

Sweep (*Scorpis lineolata*) are a planktivorous fish species often seen in small schools around reef outcrops and over *Ecklonia* forest, in shallow waters. Large numbers were counted at the Sugarloaf Islands (2,079 individuals, Table 17), compared with only 23 individuals counted across the 14 South Taranaki reefs (sites A and Q/South Trap, Table 10) (and a further Nmax of 7 sweep from a site Q trap video, Table 11, Figure 8). These two South Taranaki reef sites (A, Q) were the shallowest reef areas sampled in the present report (up to 9 metres water depth). The preference for shallower water reef by sweep may explain much of this large abundance difference, given the shallower focus of the Sugar Loaf Islands reef sites. Site A (Four-Mile Reef) is reported by locals to large schools of sweep (Karen Pratt, pers. comm.).

Large similar differences for other species might also be a depth effect e.g., red moki (393 vs. 11), banded wrasse (123 vs. 3), spotty (117 vs. 11), and marblefish (76 vs. 2), through water temperature differences might also influence the distribution of some species.

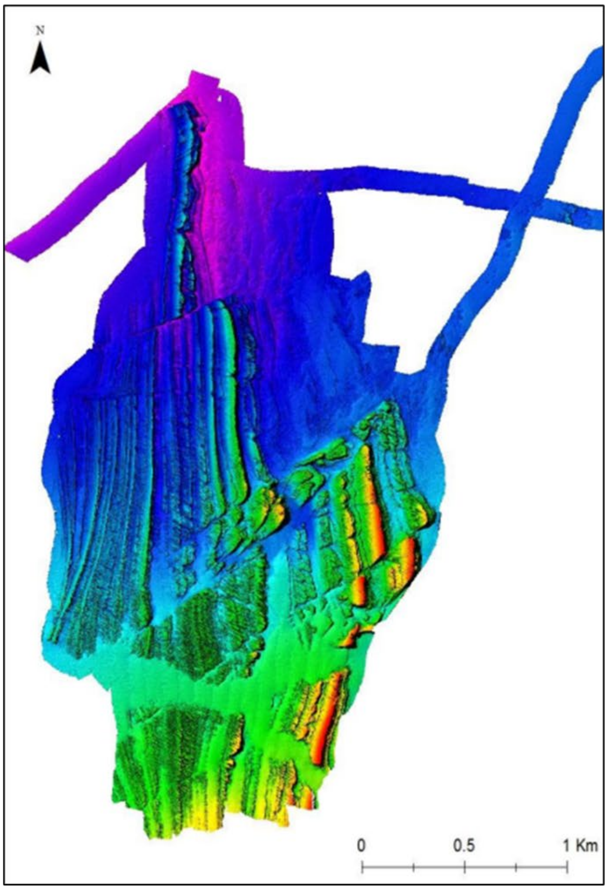
The other large contrast between the Sugarloaf and STB data was for blue cod (Sugarloaf 191 fish, seventh most abundant, vs. 2,200, highest abundance, South Taranaki). One potentially major driver of this difference was that fish diver surveys set up to assess habitat type, and/or marine protection effects, try to select sites that are as internally consistent as possible (i.e., are not mosaics, and do not have major habitat transitions such as reef/soft sediment boundaries running their centre). Blue cod are known to have a strong association with such mosaics and edges, and to be relatively uncommon up on reefs proper, and around *Ecklonia* forests (patterns clearly present in the CoastCam transect plots of reef geomorphologies, biogenic habitats, and fish occurrences). Hence, towed camera transect across the full seafloor habitat landscape, especially when specifically placed to cross over as much seafloor variation as possible, favour species such as blue cod. These method/habitat effects can be assessed by segmenting the video transects by habitat, depth, and other variables such as slope, rugosity etc in formal statistical analyses – one of the future use plans for the South Taranaki 14-site survey data. Of note, scarlet wrasse, a species that inhabits the reef proper (unlike blue cod) had high abundances in both studies (Sugarloaf 2782 fish, 2nd most abundant, vs. 744, 3rd most abundant, South Taranaki).

Table 21: Fish counts from diver census, at six reef sites, over three years The rock cod is *Lotella rhacinus*. Other species noted as present were kingfish, magpie morwong, silver drummer (*Kyphosus sydneyanus*)*, slender roughy, and scorpion fish (*, species not seen in other studies) (Source; table 7 of Miller et al. 2013).

Species	Total Count
Jack mackerel	5,075
Scarlett wrasse	2,782
Sweep	2,079
Butterfly perch	454
Red moki	393
Demoiselle	269
Blue cod	191
Banded wrasse	123
Spotty	117
Marblefish	76
Snapper	52
Leatherjacket	50
Tarakihi	26
Eagle ray	18
Blue moki	10
Rock cod	6
Goatfish	2
Kahawai	1

5.2.2 Pariokariwa Reef

This large coastal reef was surveyed with multibeam sonar in 2014, along with the smaller nearby Waikiekie Reef (Figure 5-11) (Sturgess 2015). Pariokariwa Reef is around 4.8 km long, by 1.5 km wide, and is orientated north-east. It ranges from 4 to 20 metres in depth, with its shallower areas containing more complex features including ridges, overhangs, and saw-tooth reef forms. Sturgess (2015) identified three distinct benthic habitats; bedrock with complex topography, sediment inundated reef, and mud and siltstone. Four fault lines run through the reef, seen in Figure as NE/SW line features. The faulting has pushed some reef areas up, while others have remained in their original position, and others worn away (if composed of siltstone or other softer rock). The saw-tooth structures, prominent across the reef, are known as a flysch sequence (Sturgess 2015). Alternating stacked layers of harder and softer (here siltstone and mudstone) rock are differentially eroded by the sea, creating undercuts as the softer material is removed; creating the saw-tooth structures, which are also warped through tectonic faulting. A nearby smaller reef (Waikiekie Reef) has undergone the same processes, but has a simpler morphology with single ridge top and a deep overhang running the length of the reef on the landward side (Figure 5-11) (Sturgess 2015)



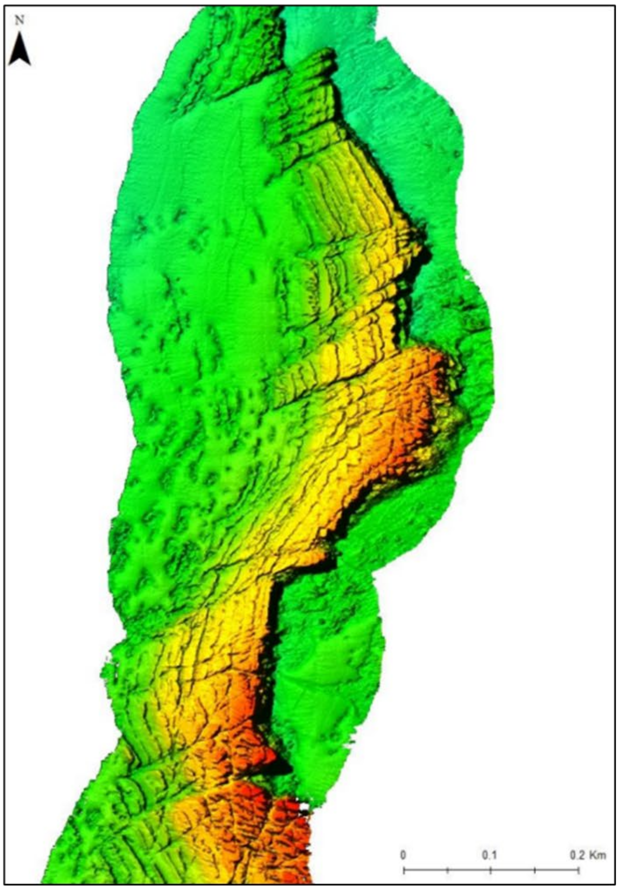


Figure 5-11: Multibeam sonar bathymetry maps of Pariokariwa Reef (depth range 4–20 m) and Waikiekie Reef Note that the two reefs are shown at different scales (a factor of 5x, Waikiekie Reef is only around 20% the length of Pariokariwa Reef). (Source: figures 2.4, 2.7 of Sturgess 2015).

The first ecological survey of Pariokariwa Reef was completed in 1995, with a one-day diving survey focussed on sponge assemblages (Battershill & Page 1996). Five dives (5–20 metres depth) were made across the reef, with observations made of the seafloor and species, and photographs and specimens collected. Three key geomorphological reef types were identified (Table 22). The first two were rocky outcrop and boulder reef areas at 5–10 m, and 10–15 m water depth, each with a different biogenic habitat assemblage. The first reef type supported a bryozoan and filamentous algae assemblage; and the second, had sponge gardens dominated by the sponge *Polymastia crassa* with a percent cover of 70% or more (Figure , images 1–2). The third geomorphological reef types, deep broken rock at 10–25 m, supported three distinct biogenic habitat assemblages; a) low density *Ecklonia* forest intermixed with finger sponges; b) Axinellid sponge gardens; and c) underhang communities of extremely dense encrusting sponges and some ascidians (Table 22, Figure 5-12).

Table 22: Pariokariwa Reef geomorphology and biogenic habitat classes (Battershill et al. 1996).

Geomorphology	Depth	Description		Ecological assemblages
Rock outcrop and boulder reef	5–10 m	Sand sweeps around boulders and rock outcrops, abrading the sides.		Base rock is barren. The rock outcrop and boulder tops are 100% covered with a relatively small variety of hardy bryozoan (*Bugula* spp.) and filamentous algae (*Polysiphonia* spp.) species
Rock outcrop and boulder reef	10–15 m	Sediments are not as deep or as mobile between rock outcrops		**Sponge garden**. Community characterised by bright orange sponge *Polymastia crassa*, densities of 70% cover or more on the top surfaces of boulders. Interspersed are other sponge species (*Polymastia* (n. sp. 2, or former *granulosa*), *Tethya aurantium*, *Aaptos aaptos*.
Deep broken rock	10–25 m	Rocky reef outcrops, platforms, and boulders. Several sub-habitats present	A	**Ecklonia forest**. Patches of *Ecklonia* forest occur, but canopy cover <30%. Often 1 per m^2 plant density. Densely encrusting subcanopy of turfing bryozoans and hydroids, many finger sponges. Finger sponge density appears inversely related to macroalgal density; two sub habitats separated on this basis, together with aspects of reef topography (finger sponges more prevalent in more dissected reef areas).
			B	**Axinellid sponge gardens**. In slightly deeper water (10-20 m), where extensive and dense sponge community, characterised by finger sponges (*Raspailia topsenti*, *Raspailia* n. sp., *Axinella* spp.) and massive sponges (*Ecionemia alata*) Often finger sponges densities >10 per m^2 of finger sponges). High sponge biomass. No bare rock present. Smaller sponges, turfing bryozoans, and hydroids present. Patches of large numbers of hydroid trees *Solanderia* (possibly two new species).
			C	**Underhang Communities.** Many under hangs, tunnels and shaded canyons supported extremely dense community of encrusting sponges and some ascidians. Characterising species were sponges *Clathrina* spp., *Ircinia* spp., *Leucosolenia* spp., and *Cliona celat*a.

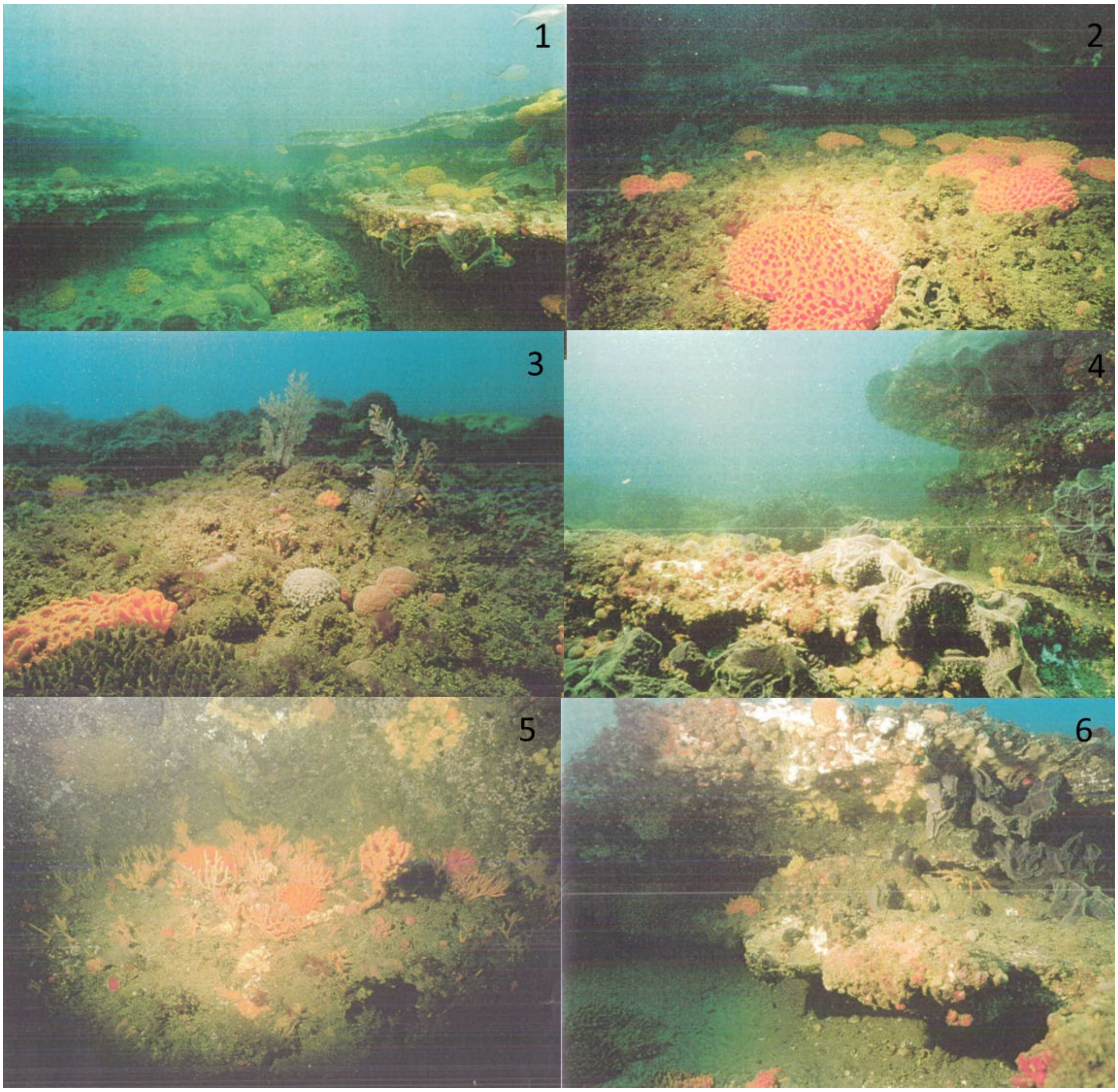


Figure 5-12: Pariokariwa Reef seafloor images 1–2) shallow reef habitat characterised by the orange sponge *Polymastia crassa*; 3–4) Slightly deeper reef with *Polymastia crassa* community giving way to *Ecionemia alata* and other sponge assemblages; 5–6) Deep-reef community characterised by finger sponges and massive sponges. (Source; plates 1–3, Battershill et al 1996).

Kina were uncommon, with densities never exceeding one urchin per 5 m^2. Large numbers of crayfish were present (red *J. edwardsii*, and packhorse *J. verreauxi*), and "*a number of extremely large crayfish were observed in deeper water*" (Battershill et al 1996). The fish assemblage was noted to have large populations of kingfish, but small populations of juvenile blue cod and other reef associated species. Thirty one other reef fish were also listed as being present, most of which were the same as those from other North and South Taranaki reefs. Notable 'new' species to this report were ruby-fish (*Plagiogeneion rubiginosum* – a commercial species usually caught in 50–600 m water depth), grouper (*Polyprion oxygeneios* – usually confined to deeper waters due to fishing out of shallow water populations), and blue maomao (*Scorpus violaceus* – a warm-temperate species usually constricted to north-eastern New Zealand; also mentioned as seen at the Traps by divers, DOC 2006). Three soft sediment fish species were also seen, as well as a further 20 smaller reef or pelagic species (e.g., triplefins, blennies, pipefish, seahorses, piper, yellow-eyed mullet etc).

The most obvious difference between Pariokariwa Reef and the 14 South Taranaki reefs was the prominent absence of dense macro-algae habitats. While *Ecklonia* forest was present, it was described as patchy, with low canopy cover and plant densities. *Caulerpa flexilis* was absent from the species presence list (*Caulerpa articulata* and *Caulerpa brownii* listed). The overall species list included 14 red algae, 8 brown algae (including *C. maschalocarpum* and *Zonaria* sp.), and 5 green algae. The location is known to experience prolonged periods of very low water visibility, which is likely to influence the local abundance and distribution of macroalgae due to limited light attenuation. Other species groups listed included 13 species of cnidarian (anemones, corals, hydroids including two hydroid tree *Solanderia* species), and molluscs (25 species including saw-shells, Cooks Turban, green-lipped mussels, octopus (*Octopus maorum*), and the sea-slugs *A. luctuosa* and *Jason mirabilis*. *J. mirabilis* is a bright purple and white animal that associates in clusters with hydroid trees and are visually obvious; none were seen at the South Taranaki sites. Other groups were bryozoans (18 species), brachiopods (1 species), crustaceans (7 including the two lobster species), echinoderms (9 species), and ascidians (13 species).

Fifty-nine species of sponge were observed by Battershill & Page (1996). The first of two sponge garden types present at Pariokariwa Reef, the strong 'sponge *Polymastia crassa* – Rock *outcrop and boulder reef (10–15 m)'* association (Table 22) was not present at any of the 14 South Taranaki sites. In fact, no *P. crassa* sponges were observed at all (Table 9).

The second sponge garden type present at Pariokariwa Reef was that of 'Axinellid sponge gardens on broken reef in 10–20 m depth, with an extensive and dense sponge community characterised by finger sponges (*Raspailia topsenti*, *Raspailia* n. sp., *Axinella* spp.) and massive sponges (*Ecionemia alata*), often finger sponge densities >10 per m^2 of finger sponges)'. These species were common on the South Taranaki reefs but did not form the dense concentrations (and inferred larger spatial patch areas) described for Pariokariwa Reef by Battershill & Page (1996), sufficient to be considered sponge gardens.

Underhang communities cannot be compared between the two studies as these are inaccessible to towed cameras; through the occurrence of 'under-hangs, tunnels and shaded canyons' habitats seemed quite limited for the South Taranaki reefs (though underhangs were present).

Only one type of sponge garden was recorded in South Taranaki (30–33 m, site V), with a different sponge species composition to that observed by Battershill et al 1996 (see Table 9). The STB sponge garden included Family Chondropsidae species 2 and *Cymbastela lamellata* (species only recently identified/described), *Ciocalypta polymastia*, and *Dactylia varia*. The site V sponge garden was in waters 11–21 metres deeper than those of Pariokariwa Reef, and much further offshore, with clear waters and coarse bottom sediments suggesting low terrestrial run-off inputs. The high juvenile blue cod nursery value was also in contrast to Battershill & Pages observation of "*small populations of juvenile blue cod*" for Pariokariwa Reef.

Sturgess (2015) also sampled the Pariokariwa Reef seafloor assemblages using one-metre square photo-quadrats. At four sites images were taken of the reef, across the reefs four 'faces/planes' – bottom, vertical, overhang and top – with 10 random photo-quadrats per plane, per site. Of these images, 137 proved suitable for point-intercept analysis, and were scored for percentage cover of individual organisms (e.g., sponges, jewel anemones), mixed turf, biogenic reef, and silt deposit.

The images were dominated overall by sponges and anemones. Overhang communities were also dominated by sponges (e.g., *Ecionemia alata*) and anemones (e.g., jewel anemones *C. australis*). Bryozoans only a small percent cover and were mainly found on vertical faces. Mixed turf (Phaeophyta/Chlorophyta) and *Polysiphonia* beds (Rhodophyta) were largely associated with reef tops, where mixed turf could occupy up to 80–100% cover.

The sponges *Ecionemia alata*, *Haliclona heterofibrosa*, *Polymastia* pepo and *Tethya burtoni* were strongly associated with overhangs and vertical reef faces. The sponges *Aaptos globosum*, *Clathria macrotoxa*, *Callyspongia* sp., *Pararhaphoxya pulchra* and *Stelletta conulosa* were commonly found on the top surfaces of the reef, while the sponge species *Callyspongia conica*, *Callyspongia ramosa*, *Ciocalypta polymastia*, *Mycale* spp., *Polymastia croceus*, and *Raspailia topsenti* were commonly associated with both the top and bottom of the reef.

5.2.3 New Plymouth region *E. radiata* kelp distribution

Cole & McComb (2001) sampled an area of subtidal reef and sand (4 to 14 metres depth) (Kawaroa Reef) just east of New Plymouth port (Figure 5-13). Using a drop video, they sampled 217 sites across a 150 m spacing grid and assigned each site to one of four possible habitat types. For those sites that fell on rock/reef habitat (167 sites), the estimated percentage contribution of habitats was *Ecklonia* forest (7%), mixed algae (*E. radiata*, *C. maschalocarpum*) (10%) and coralline pavement (83%). All soft sediment sites held sand. The kelp forests were concentrated in the 5–10 metre depth zone. More intensive sampling by divers (not included here) found these kelp habitats to hold higher abundances of smaller animals (gastropods, starfish, sea cucumbers, kina, and the sponges *Tethya ingalli* and *Tethya aurantium*); while the deeper water areas (>10 m) had high covers of turfing red seaweeds, and low grazing gastropod abundances. Fishes were "*not conspicuous*".

Wider limited drop video sampling to the west (11 sites towards Oakura), and east (14 sites toward Waitara found the reefs to be dominated by coralline pavement habitat, with only three sites holding *E. radiata* forest (Figure 5-13). The fish fauna was noted to be like the main survey area.

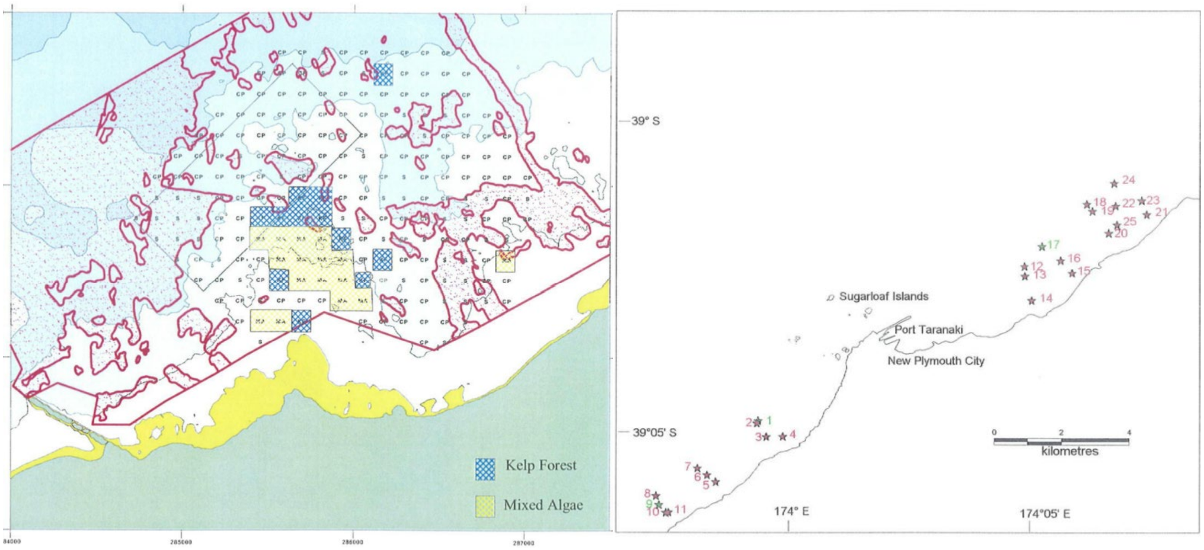


Figure 5-13: Kelp forest around New Plymouth Left) drop camera survey of Kawaroa Reef (water depth 4–14 metres), showing 5-m depth contours (blue shadings), reef (un-speckled), and sand (speckled). Right) broader regional sampling with video drop camera, with *E. radiata* kelp forest sites labelled in green (sites 1, 9, 17). (Source: figures 9 & 10 of Cole & McComb 2001).

Crofskey (2007) used the same drop camera approach as Cole & McComb (2001) to assess seafloor type, complexity, and *E. radiata* kelp cover around the Taranaki Peninsula. Video drops were made along a 60 km gradient starting from in the southern, with 804 sites located along 46 onshore-offshore transects. Each site was assigned a substate (9 classes), a topographic complexity (13 classes), and a kelp density (7 classes) identity (Figure 5-14).

Most of the coast held large reef areas, with smaller contributions of sand. These reef areas dominated along the coast, from 800 m beyond MHWS through to around 3 km offshore. The exception was the area around New Plymouth, which in contrast was dominated by sand. The highest kelp densities occurred in the southern 10 km, with the average density of kelp steadily decreased northwards from Oakura towards Motunui, aside from a few patches. Transects devoid of kelp were more often encountered in the most northern area (Waitara through to Motunui).

An assessment of potential explanatory factors found the greatest negative spatial correlation between kelp density and annual mean water turbidity (inferred from satellite-derived measures of the downward attenuation of 490 nm irradiation). These gradients of decreasing kelp cover and increasing water turbidity ran from south to north. In contrast, measures of the near bed wave kinematic energy regime found much larger ambient and storm wave velocities to be experienced in by the Cape Egmont region (the south), compared with the Motunui zone to the north. Crofskey (2007) concluded that "*that water turbidity is the primary factor that defines the Ecklonia distribution in Taranaki, although the wave energy and habitat complexity of the reef are likely to be influential as well. Wave action has the potential to limit the size and abundance of E. radiata in shallow waters, while water turbidity reduces the depth range that the kelp can occupy. The direct effects of fine terrigenous fluvial sediments was hypothesised to be the main limiting factor for kelp colonisation on the north-eastern reefs, particularly near the Waitara River*".

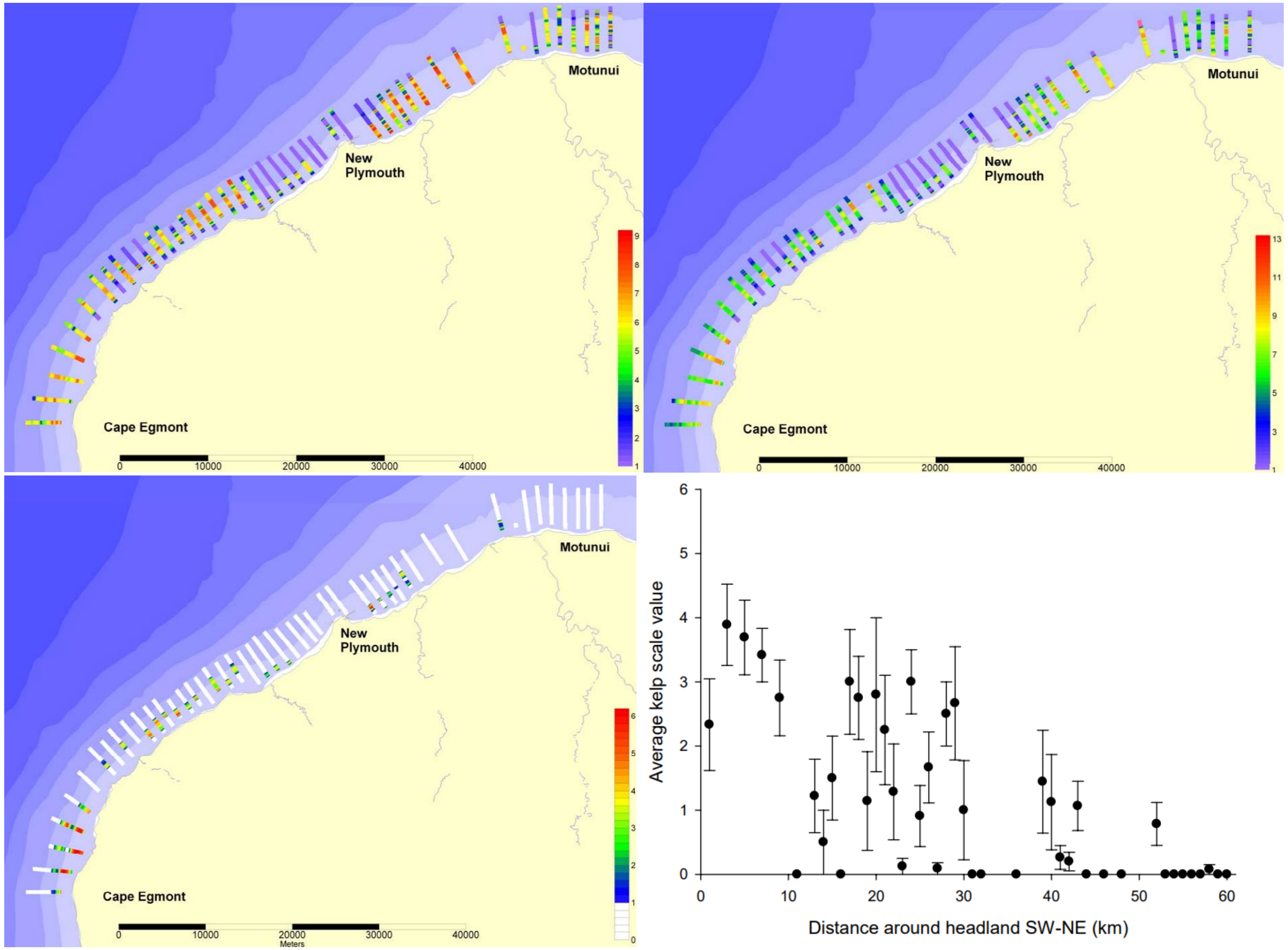


Figure 5-14: North Taranaki survey of Crofskey (2007), with transects starting in the south Upper left) substrate distributions; upper right) habitat complexity distribution; lower left) *E. radiata* kelp density; lower right) average kelp density estimate (± SE) (all sand sites excluded). Kelp densities are expressed as percentage cover classes; 0, 0%; 1, 1–5%; 2, 5–9%; 3, 10–19%; 4, 20–39%; 5, 40–79%; 6, >80%. Substrate and habitat complexity categories are given in Appendix C; increasing values indicate increasing rock proportion/increasing rock object size contributions, and rugosity/topographic variation, respectively.

5.2.4 Large scale sponge distributions, Taranaki region

A PhD thesis described the geographic distribution of sponges in the Taranaki region (Cormack 2021). To investigate the potential effects of terrestrial inputs to the sea on sponge assemblages, reef/s offshore from three North Taranaki rivers (discharging from three discrete catchments varying in their 'pristineness') were sampled for sponges. These were the Waitara reefs (near and distant to shore), the Waiwhakaiho reefs (near and distant) and Hangatahua Reef (one site only) (Figure 5-1). Sponges were collected by divers, with the goal to collect as many sponge species as practical by hand. Due to low (<4 m) visibility, sites were searched using a ten metre circle sweep. In addition, five 0.25 m^2 quadrats were haphazardly placed, and percent cover of the various phyla present visually estimated. Volumes (height × width × length) were also estimated for each individual sponge, and some algae and other invertebrate taxa. Number of taxa within each phyla, number of sponge species, and number of sponge individuals were also recorded. Identification was to species level where practical.

As well as these 5 field collection sites, three additional reefs (Pariokariwa Reef, Pātea Project Reef (site K), and Kapiti Island reefs, west Wellington coast) were added as desktop data additions, using all available literature and other information sources to assemble species lists. An overall species/taxa pool of 242 sponges was calculated. An obvious important caveat here is that sampling effort will have varied across the three locations not sampled directly by Cormack (2021), the sponge species list used for the Project Reef was also an older version that missed several sponge species confirmed as present on the reef.

Thirty-five sponge species were found to only be present at the geographic end sites (Pariokariwa Reef to the north, Kapiti Island to the south). For the Taranaki sites (Kapiti Island excluded), it was estimated that average sponge species richness (number of species) was around 9.6 per 1 m^2 of rocky reef. *Ecionemia alata* was the most widely distributed species, and the only taxa recorded at all six locations. For the Taranaki sites, Pariokariwa Reef had the largest number of unique species (44), followed by Waitara sites (36), Pātea (12), Hangatahua (9), and Waiwhakaiho (6). The Waitara reef result was considered a surprise, as the reefs were adjacent to the largest river (Waitara River) and catchment in the Taranaki region, with the catchment also being the most human-modified with high sediment discharges. The author suggested that the sponge species present at Waitara represented a sediment tolerant specialist group of sponges. It was noted that sponges collected at the site had not been identified even to a generic level and had not been recorded elsewhere in New Zealand (Cormack 2021).

Sponge diversity and abundance was higher at sites in closer proximity to river mouths. It was suggested that terrestrially derived organic matter from rivers might be driving these patterns. Sponge volumes were greater at reef sites positioned next to rivers with a relatively large coverage of indigenous terrestrial forests, versus those adjacent to modified and urbanized catchments.

Cormack (2021) also provided a brief description of the five 'new' reef sites sampled off North Taranaki. All the reefs were composed of boulders of varying sizes; bedrock was absent (Table 23).

Table 23: Descriptions of the five reef sites of Cormack (2021) All were composed of boulders, with no bed rock present. Sp%, the relative contribution of sponges to overall organism seafloor cover (as measured in 0.25 m2 quadrats. Three *E. radiata* plants were counted at the Hangatahua coastal near site (17 m depth).

Site	Depth (m)	Sp. %	Seafloor description	%Boulders		
				Large >30 cm	Medium 10-30 cm	Small <10 cm
Waitara coastal near	12	85	Predominantly large boulders (flat not regular), and sand. Small to medium boulders less common. Large quantity of suspended sediments.	36	21	21
Waitara coastal distant	19	81	Predominantly large/medium boulders, some smaller boulders. Approximately 5% gravelly shell-hash.	40	37	14
Waiwhakaiho coastal near	18	79	Boulders up to one metre wide, creating tiny caves/overhangs (caves 40 cm × 30 cm × 20 cm). Large proportion of medium and small boulders packed together. Limited sand among boulders, white to cream yellow, many tiny broken shells. Large area of rippled sand adjacent to reef. Most three-dimensional reef site.	34	37	19
Waiwhakaiho coastal distant	18	29	Large boulders dominate slightly. Sand, gravel, and broken shell also present. Large and small size boulders mixed.	35	25	27
Hangatahua coastal near	17	64	Large 1–1.5 metre boulders on sand covered seafloor. Sand was white and black colouration. Reef surrounded by sand.	84	10	1

A recent study by Harris et al. (2021) used ROV/divers to sample reefs at the Poor Knights Islands, in the Fiordland Marine Area, around the Project Reef, and at Parininihi Reef. Water depths extended from 5 to 120 metres depending on region (restricted to 15–30 metres at the Project Reef area, and 10–25 metres at Parininihi Reef). Images were extracted from the video and scored for percent cover of taxa groups. Most of the sampling effort was focussed on the Poor Knights and Fiordland. Sponges were found to dominate most of the benthic communities sampled, with their abundance varying significantly with depth at 3 out of 4 location; and their morphological composition (complexities of form) changing with depth at all locations. Of relevance here, "*sponge cover at Patea (25 m)* [water depth] *was particularly high (30% ± 3 SE)* [relative to all other locations] *and higher than macroalgae and CCA cover (3.1 ± 1.9 to 3.9% ± 0.8 SE, respectively)*"(CCA, calcified coralline algae; SE, standard error]; "*while Parininihi had lower sponge cover (19.6% ± 2.3 SE) but with high corresponding macroalgae cover (37.4% ± 3.6 SE)*" (macroalgae were only given at the Phylum level). Additionally, a measure of 'sponge assembly complexity' (how much 3D sponge complexity was present) found that "*Patea showed the highest sponge assemblage complexity score of all locations at 25 m"* [water depth]. Parininihi had a lower overall sponge complexity than Patea, but "*showed the highest overall cover of high complexity forms (2.9% ± 0.6 SE) of all locations at 25 m*", with "*the largest proportion of high complexity forms of any assemblage at 25 m across all locations*". Put another way, comparing sponge assemblages across all the areas at 25 metres water depth, Patea held the highest value for overall sponge 3D-complexity, while Parininihi Reef held the highest values for the most complex 3D-sponge contributions.

6 Recommendations

The multibeam sonar survey, and subsequent ground-truthing and examination of 14 rock/reef sites using the CoastCam towed video array, has clearly shown that rocky reef habitat is much more common and widespread on Pātea Banks than documented in the scientific literature.

The video camera data was presented here in semi-quantitative narrative form. Data were processed as 20-second video segments; the next step will be to analyse these data in relation to the area surveyed (e.g., inds./m^2 of reef), which combined with the underpinning multibeam sonar data, will enable a range of powerful formal statistical analyses to be advanced. The multibeam sonar data also provides additional landscape variables not covered in this report, such as seafloor slope, aspect, and rugosity (roughness), at fine scales (tens of metres) that can be matched to the video segments rich data sets. Combined, these ecological and geophysical data-sets should be analysed to answer a range of fundamental questions about South Taranaki's subtidal reefs (see below for examples). Predictive models can then be used to estimate likely species densities, species assemblages, and habitat types over larger reef areas (e.g., as determined by multibeam sonar mapping). Questions include:

Are important biogenic habitat forming species (e.g., *Ecklonia*, *C. flexilis*) showing recurring associations with different reef types, morphologies, depths, and other factors, e.g., *Ecklonia* forest with reef ridges, *Caulerpa* meadows with stepped terrace reefs? The reef tell sponge clusters seen for *C. ramosa* at site U? The Axinellid sponge clusters on buried rock seen at site S?

Are there recurring groups of species/taxa that collectively can be defined as discrete repeating ecological assemblages? E.g., for the sponge garden seen at site V? Or for the smaller scale sponge clusters seen on some reef edges? The *Caulerpa* 'pillow ridge reef' meadows that often have an apparent small sponge and bryozoan species association?

Are the low 'pillow reef' forms seen a result of biological carbonate production and build-up (e.g., by bryozoans)? Why does *C. flexilis* show such a strong association (100% of all ridges are occupied by this species) with these ridges, and why are they formed as such multiple linear rows? Some of these questions will require direct diver-based observations and collections.

Can we define and identify juvenile fish – nursery habitats quantitatively, e.g., the very strong 0+/larger juvenile blue cod associations with the sponge garden of site V? Scarlett wrasse and leatherjacket juveniles (although not formally separated from adults in the counts) also showed clear habitat preferences at sites where they were common (e.g., juvenile scarlet wrasse with some *Caulerpa* meadows, sponge clusters and gardens; juvenile leatherjacket with *Ecklonia* forest)., One of the objectives of the science outreach from the NIWA Juvenile fish habitat bottlenecks programme to the South Taranaki coast, was to see if 0+ blue cod habitats/nurseries could be found, what they were, and compare and contrast then to other regions such as the Marlborough Sounds. Data from the 14 sites (absences as much as presences) will help answer these questions, with the strong nursery values of the sponge garden and low reef habitat of site V being a particularly valuable discovery.

For all these questions, there is a fundamental habitat/landscape focus. If strong predictive relationships can be found and validated between these species/species assemblages/functions, and the reef and other habitat geomorphologies (which are able to be mapped by multibeam sonar) then it will become possible to use statistical models to predict where these assemblages may occur.

Knowing what is where, and how much, is a fundamental requirement for effective resource management (however 'resource' is defined).

This study surveyed 14 of an original target of 20 sites, selected using the multibeam sonar maps to maximise their geographic and depth spread. It is unlikely that all the reef types and species/species assemblages present in the survey areas were 'captured' from three days of field work. Significant new discoveries are likely yet to be made. Any new CoastCam towed camera survey work across the existing multibeam sonar mapped reefs would fundamentally strengthen the findings of this report, both through the likely discovery of new reef types and assemblages; and potential site replication of habitat types currently represented by only one site (e.g., the deeper water sponge garden and associated 0+ blue cod nursery function of site V). Systematically sampling rock seafloors/reefs across a gradient of water depths including the inshore/shallow environment would be particularly useful, there are known to be large reef extents shoreward of site J (the shallowest of the 14 sites) not yet investigated. A community inclusive approach would be to work with Citizen Scientists to deploy drop-cameras from small boats to cover a wide range of sites quickly and cost-effectively, to assign them seafloor/habitat identities. The local diver community might also be engaged with to gain underwater footage of some reefs, e.g., with head mounted Go-Pro cameras, which are left to record as the diver goes about their dive. Such approaches are very amenable to citizen science approaches. More formal technical science deployments could then subsequently be made as appropriate, targeting a subset of sites of particular interest selected from the wider reef visits.

In an ideal world, the entire Pātea Bank (and beyond) would be fully multibeam sonar mapped. That is unlikely in the short term but remains the ideal. Of note, bycatch records from MPI research trawl surveys (50–100 m water depths) suggest deeper offshore sponge garden habitats with different species assemblages may exist to the south/south-east of Pātea, although these largely fall beyond the 12 mile nautical limit in which Regional Councils have CMA responsibilities (Morrison et al., in editorial), Emma Jones, NIWA Scientist, pers. comm.).

A fundamental immediate need is to gain a better understanding of the geology of the different reefs. In this report the terms mudstone/Papa rock, and sandstone, have been used to define the different reefs. However, the Project Reef (site K) is at least in part formed of hard fossil-rich rock, and site Q (South Trap) at least partially formed of limestone (with parts of other reef sites showing very similar-looking rock and erosion forms, e.g., 'lattices' on the top of some reefs). Other rock forms are the flat grey rock surfaces, flush with soft sediments, seen adjacent to some reef boundaries. These may be newly uncovered Papa rock flats that have not yet been exposed to weathering and bioerosion but they appear different to the two mudstone reef sites (Papa, D). There is also a suggestion that there are components of harder rock small boulders at some of the more northern sites, perhaps transported south from the volcanic rock region around Taranaki Maunga. The smooth grey cobbles of site A are also an anomaly. Site V reefs appear to be formed of a breccia rock, different from all the other reefs surveyed.

Direct diver-based visits to some reefs, both to collect geological samples and to undertake targeted species collections, would fundamentally advance knowledge of these reefs. Higher priority biological targets would be the species compositions of macroalgal meadows, and the likely bio-eroding infaunal communities of sites D and Papa. Why carnivorous fish assemblages (e.g., snapper, blue cod) are associated with such fauna depleted reefs in relatively high abundances (e.g., site D) is also unclear, but could be addressed by sampling those fish to see what they are eating.

Finally, there were also a range of unusual seafloor bedforms in some areas, that may be soft-sediment based, that were partially mapped with multibeam. Camera ground-truthing of these sites is likely to produce novel new habitat types, with new species associations; some of which may (or may not) be structured in part by the presence of rock/reef components.

7 Acknowledgements

We are grateful to the fishers and divers of Taranaki that shared some of their hard won knowledge with us; having that spatial knowledge to help direct the survey route was invaluable in avoiding the issue of searching for needles in a haystack. We thank skipper Lindsay Copland and crew of the R.V. Kaharoa for their work travelling the 24/7 multibeam sonar mapping route in 2020 in the face of up to 30 knot gusts, and Craig Robinson and Richard (Dick) Leppard for their good company and able handling of the R.V. Ikatere in 2021 for the three days of CoastCam operations. Aaron Dalbeth skilfully operated the CoastCam system, in the face of at times trying sea conditions that took their toll. Nick Eton provided appreciated CoastCam set-up overview, and post-field video file handling advice. We thank Sadie Mills, NIWAs National Invertebrate Collection (NIC) manager for coordinating species identifications from images (and identifying some species), with the following taxonomists (also thanked): Dennis Gordon (bryozoans), Wendy Nelson (algae), Michelle Kelly (sponges), Kate Neil/Diana Macpherson (hydroids, anemones, starfish), Jill Burnett (gastropods and bivalves). We are especially grateful to Caroline Chin (NIWA) for training and ongoing OFOP assistance, setting up the GPS tracks for analysis, and in particular helping troubleshoot some of the very trying OFOP issues encountered. Clinton Duffy (DOC) provided appreciated advice on several fish images to confirm species identities, while Callum Lily and Monique Ladds (both DOC) are thanked for sharing some hard to find documents, and seafloor images. Jennifer Beaumont provided much appreciated refereeing of the draft report, while Jess Moffat ably formatted the report.

8 References

Anderson, T.J., MacDiarmid, A., Stewart, R. (2015) Benthic habitats, macrobenthos and surficial sediments of the nearshore South Taranaki Bight. *Unpublished NIWA Client Report* NEL2013-012 prepared for Trans-Tasman Resources Ltd. 46 p.

Battershill, C.N., Page M.K. (1996) Preliminary survey of Pariokariwa Reef North Taranaki. Report prepared for Department of Conservation, Whanganui. 15 p. + Appendices.

Beaumont, J., Anderson, T.J., MacDiarmid, A.B. (2015) Benthic flora and fauna of the Pātea Shoals region, South Taranaki Bight. *Unpublished NIWA Client Report* WLG2012-55 prepared for Trans-Tasman Resources Ltd. 200 p.

Bombosch, A. (2008) Developing a benthic habitat classification scheme. Analysis of subtidal drop camera data from the southern Taranaki coast. Unpublished report prepared in partial fulfilment of the Masters in Marine Conservation for the Department of Conservation. 45 p.

Coffey, B., Williams (1992) Coastal and marine habitats of North Taranaki. Unpublished report for the Department of Conservation by Brian. T. Coffey and Associates Ltd. 11 p.

Cole, R.C., McComb, P.J. (2001) Port Taranaki maintenance dredging consent renewal studies report 4 - Biological description and assessment. NIWA Client Report prepared for Westgate Transport Ltd.

Crofskey, E. (2007) The distribution of *Ecklonia radiata* around the North Taranaki Headland and its relationship with key physical characteristics. Unpubl. MSc Thesis, University of Auckland. 118 p.

DML (2021) Tapuae Marine Reserve and Ngā Motu / Sugar Loaf Marine protected area bathymetry survey. Report of survey for the Department of Conservation. Discovery Marine Ltd.

DOC (1998) Further Information on Parininihi Marine Reserve Application. Unpublished report prepared by the Department of Conservation, Wanganui Conservancy for the Minister of Conservation 1998.

DOC (2006) Netting coastal knowledge. A report into what is known about the South Taranaki-Whanganui marine area. Department of Conservation, Whanganui Conservancy. 224 p.

DOC/UoW (undated) Sugar Loaf Islands (Nga Motu) Marine Protected Area. Facies map based on interpolated side-scan sonar rectified and geo-coded image. Unpublished map.

Francis, M.P. (1996) Geographic distribution of marine reef fishes in the New Zealand region. *New Zealand Journal of Marine and Freshwater Research* 30(1): 35–55.

Harris, B., Davy, S.K., Bell, J.J. (2021) Benthic community composition of temperate mesophotic ecosystems (TMEs) in New Zealand: sponge domination and contribution to habitat complexity. *Marine Ecology Progress Series 671*: 21–43.

Jones, E.G., Morrison, M.A., Davey, N., Hartill, B.W., Sutton, C. (2016) Biogenic habitats on New Zealand's continental shelf. Part I: Local Ecological Knowledge. New Zealand Aquatic Environment and Biodiversity Report No. 174. 95 p.

Mc Cormack, S.P. (2021) The biogeography and trophic roles of coastal marine sponges (Porifera) from the west coast of the North Island, New Zealand: Influences of catchments. Unpublished PhD thesis, University of Waikato. 202 p.

MetOcean Solutions (2007) Parininihi Marine Reserve reef fish survey. Unpublished report prepared for Department of Conservation.

Miller, R., Williams, B., Duffy, C. (2005) Reef fish of the Sugar Loaf Islands (Ngä Motu) Marine Protected Area, New Zealand. DOC Research and Development Series 226. 26 p.

Miller, S., McDonald, S., Williams, B. (2013) Benthic invertebrate monitoring at the Ngā Motu / Sugar Loaf Islands Marine Protected Area, 2001–2003. DOC Research and Development Series 335. 63 p.

Morrison, M, Woolley, J.-M., Mills, S., Yeoman, J., Bian, R., Kelly, M., Tracey, D., Anderson, O., Nelson, W., Gordon, D., Read, G., Marshall, B., Jones, E. (in editorial) Deep rocky and biogenic reefs (50–300 metres) around New Zealand. Science for Conservation.

Pinkerton, M. (2014) Predicting the effects of iron sand mining on optical properties of the South Taranaki Bight. Expert evidence for Taranaki iron sand mining application, Environment Court. https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000004/Evidence/c8fd9eb306/EEZ000004-Matt-Pinkerton-Optical-properties-18-March.pdf

Shears, N.T., Babcock, R.C. (2007) Quantitative description of mainland New Zealand's shallow subtidal reef communities. Science for Conservation 280.

Shears, N.T., Babcock, R.C., Duffy, C.A.J., Walker, J.W. (2004) Validation of qualitative habitat descriptors commonly used to classify subtidal reef assemblages in north-eastern New Zealand. *New Zealand Journal of Marine and Freshwater Research 38*: 743–752

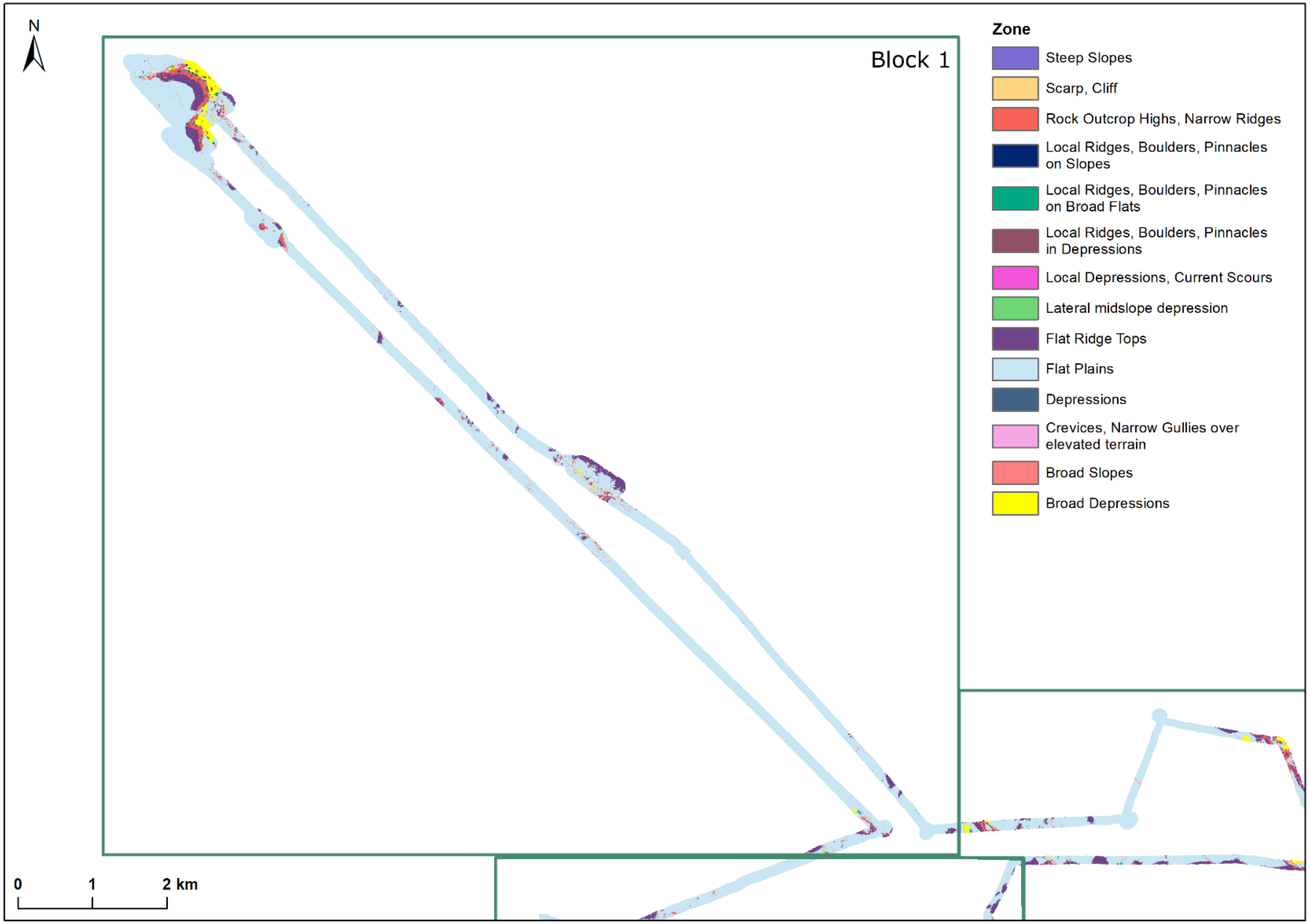
Sturgess, N. (2015) Mapping the ecological and biophysical character of seabed habitats of the Paraninihi Marine Reserve, Taranaki, New Zealand. MSc Thesis, University of Waikato.

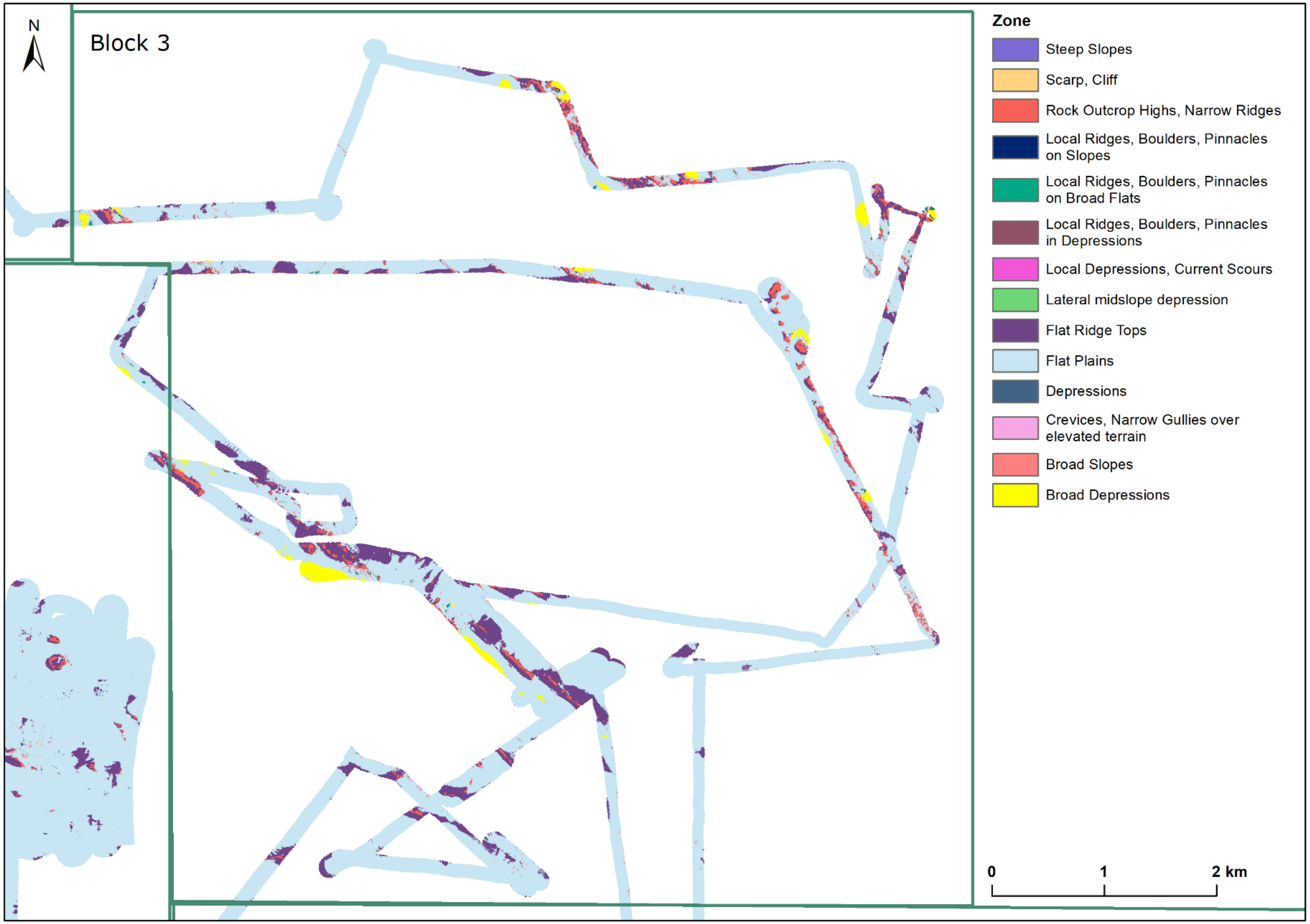
Taranaki Catchment Commission (1980) Marine ecology. Water resource investigations - Petrochemical development - Tikorangi. Taranaki Catchment Commission, Stratford. 72 p.

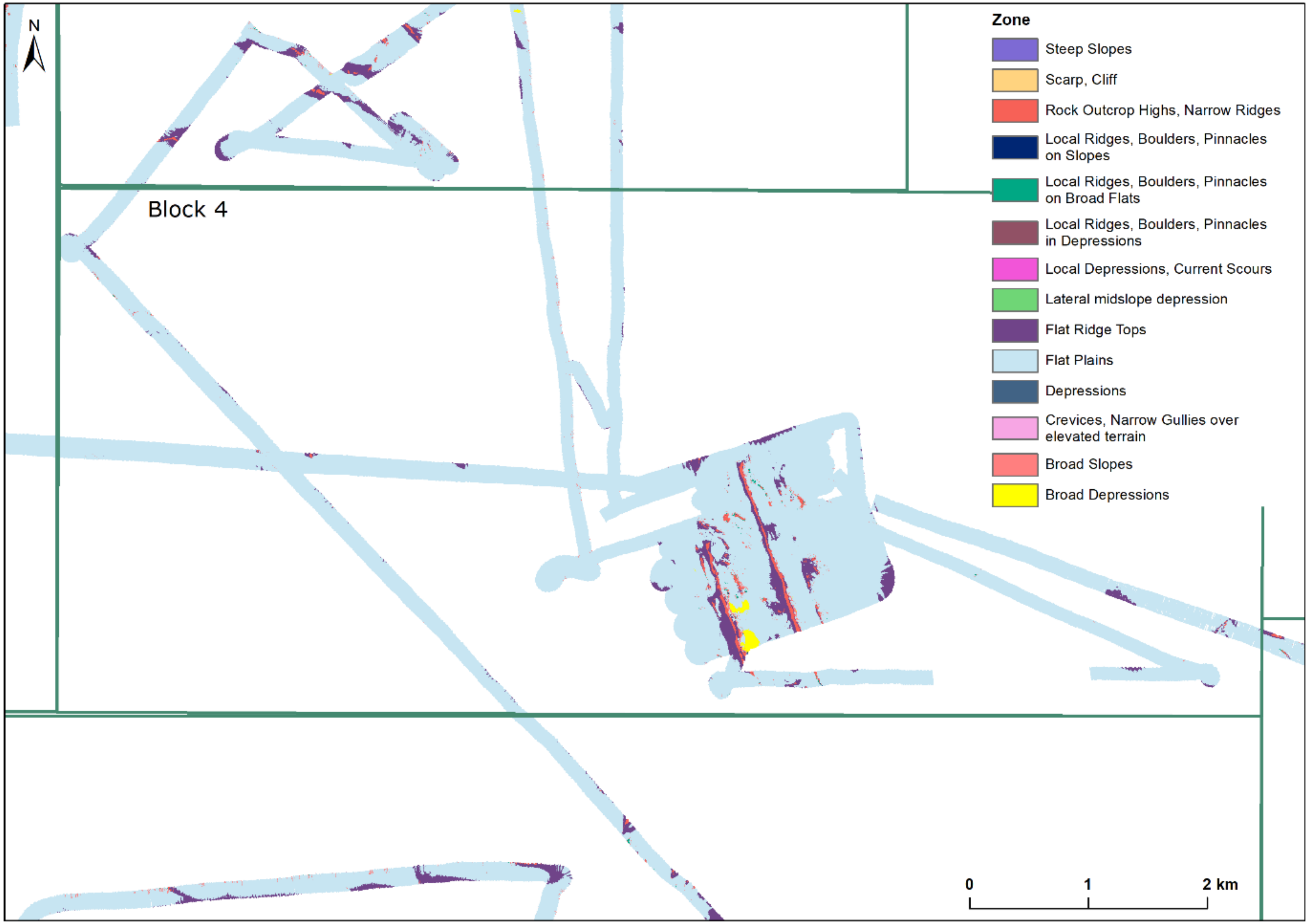
Taranaki Catchment Commission (1982) Ecological survey of the Waiwhakaiho marine and estuarine environments. Taranaki Catchment Commission, Stratford. 76 p.

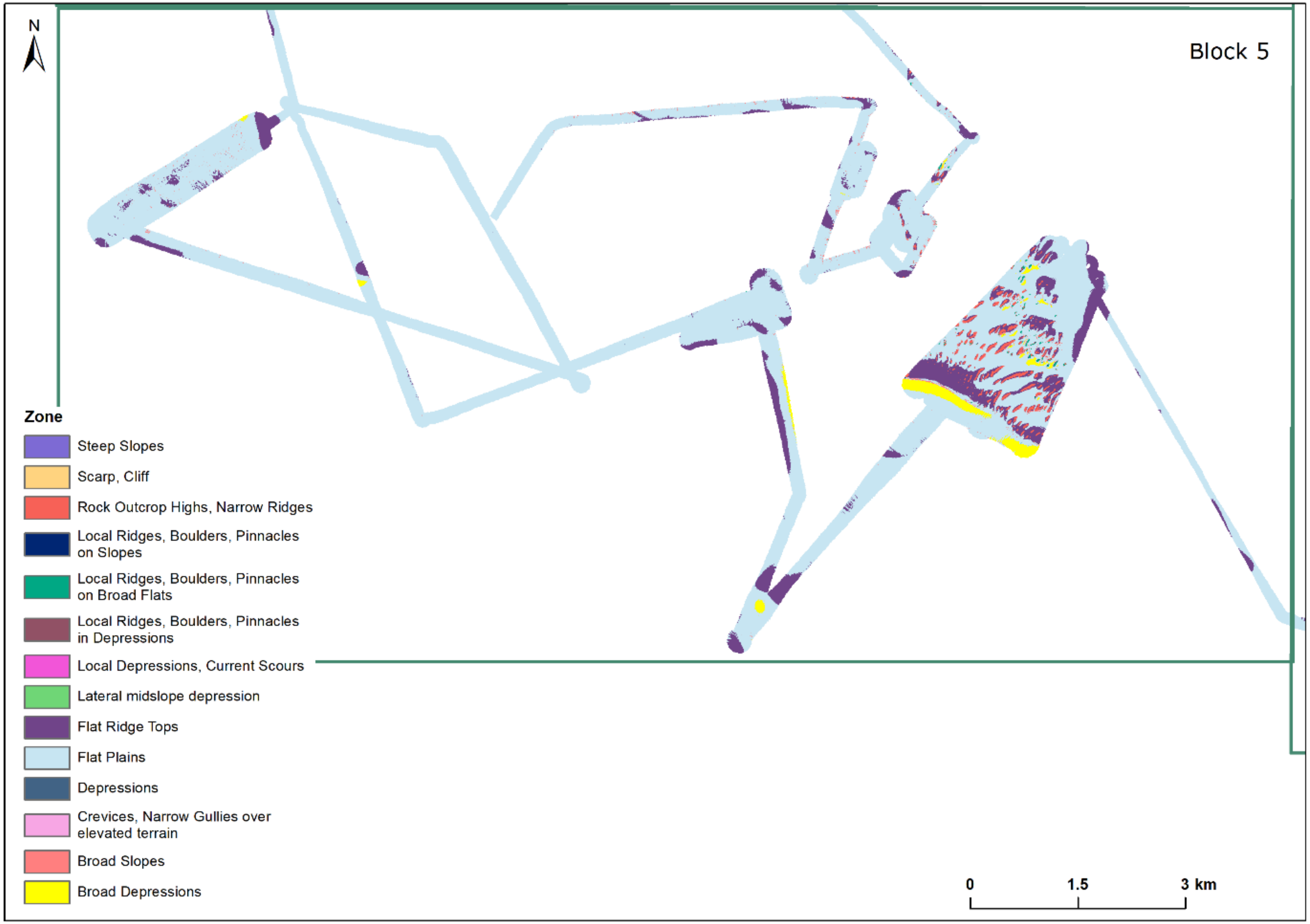
Willan, R.C. (1980) Report on the subtidal marine biological surveys in inshore waters of the Taranaki coast. Maui development environmental study Phase II. Subtidal monitoring study. Report 79–18.

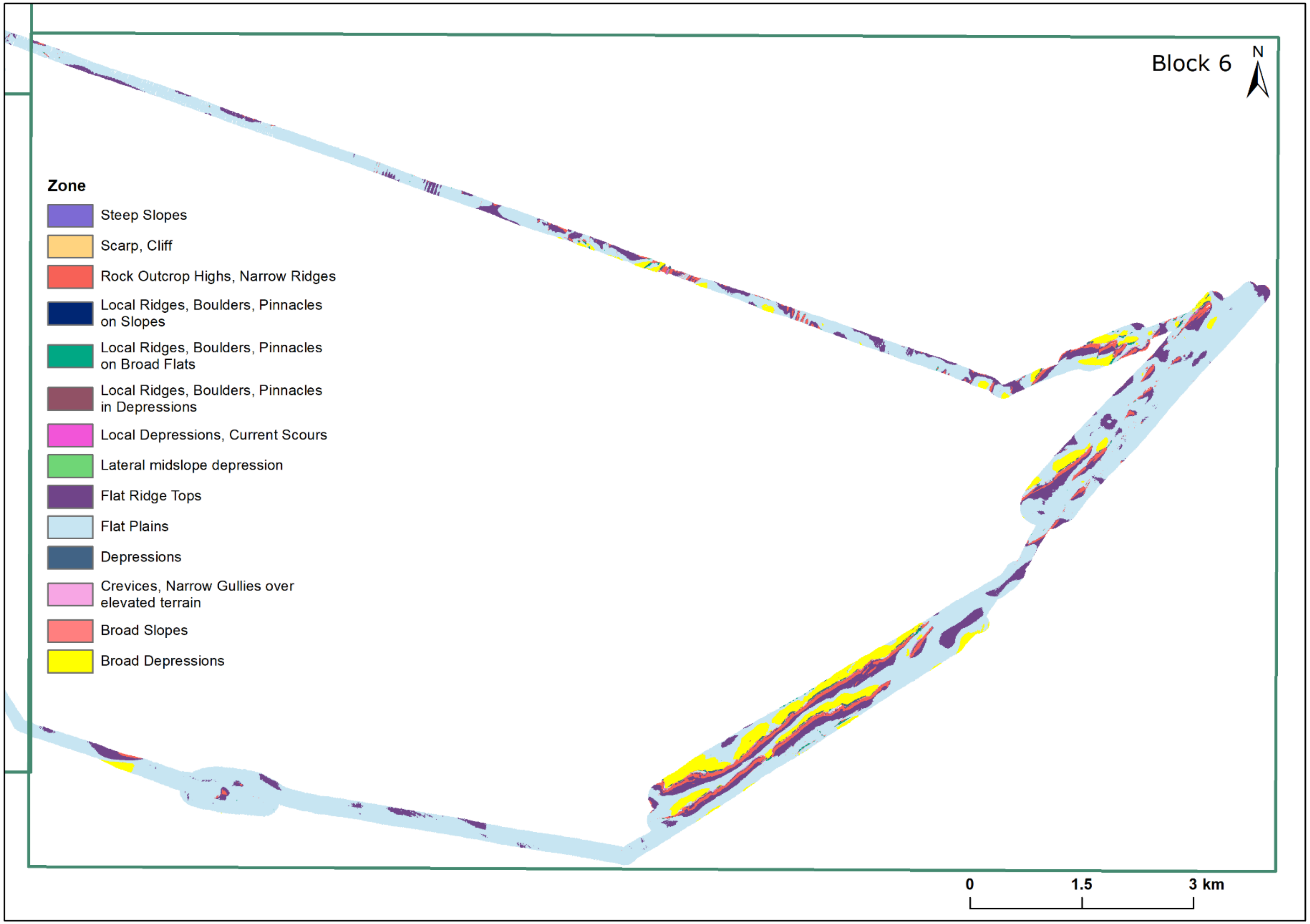
Appendix A BTM maps of Blocks 1 to 6, at closer resolution




N
Block 3
Zone
Steep Slopes
Scarp, Cliff
Rock Outcrop Highs, Narrow Ridges
Local Ridges, Boulders, Pinnacles on Slopes
Local Ridges, Boulders, Pinnacles on Broad Flats
Local Ridges, Boulders, Pinnacles in Depressions
Local Depressions, Current Scours
Lateral midslope depression
Flat Ridge Tops
Flat Plains
Depressions
Crevices, Narrow Gullies over elevated terrain
Broad Slopes
Broad Depressions
0
1
2 km


N
Block 4
Zone
Steep Slopes
Scarp, Cliff
Rock Outcrop Highs, Narrow Ridges
Local Ridges, Boulders, Pinnacles on Slopes
Local Ridges, Boulders, Pinnacles on Broad Flats
Local Ridges, Boulders, Pinnacles in Depressions
Local Depressions, Current Scours
Lateral midslope depression
Flat Ridge Tops
Flat Plains
Depressions
Crevices, Narrow Gullies over elevated terrain
Broad Slopes
Broad Depressions
0
1
2 km


N
Block 5
Zone
Steep Slopes
Scarp, Cliff
Rock Outcrop Highs, Narrow Ridges
Local Ridges, Boulders, Pinnacles on Slopes
Local Ridges, Boulders, Pinnacles on Broad Flats
Local Ridges, Boulders, Pinnacles in Depressions
Local Depressions, Current Scours
Lateral midslope depression
Flat Ridge Tops
Flat Plains
Depressions
Crevices, Narrow Gullies over elevated terrain
Broad Slopes
Broad Depressions
0
1.5
3 km


Block 6
N
Zone
Steep Slopes
Scarp, Cliff
Rock Outcrop Highs, Narrow Ridges
Local Ridges, Boulders, Pinnacles on Slopes
Local Ridges, Boulders, Pinnacles on Broad Flats
Local Ridges, Boulders, Pinnacles in Depressions
Local Depressions, Current Scours
Lateral midslope depression
Flat Ridge Tops
Flat Plains
Depressions
Crevices, Narrow Gullies over elevated terrain
Broad Slopes
Broad Depressions
0
1.5
3 km

Appendix B Figure 1 pink boxes (Z series) – not CoastCam video sampled

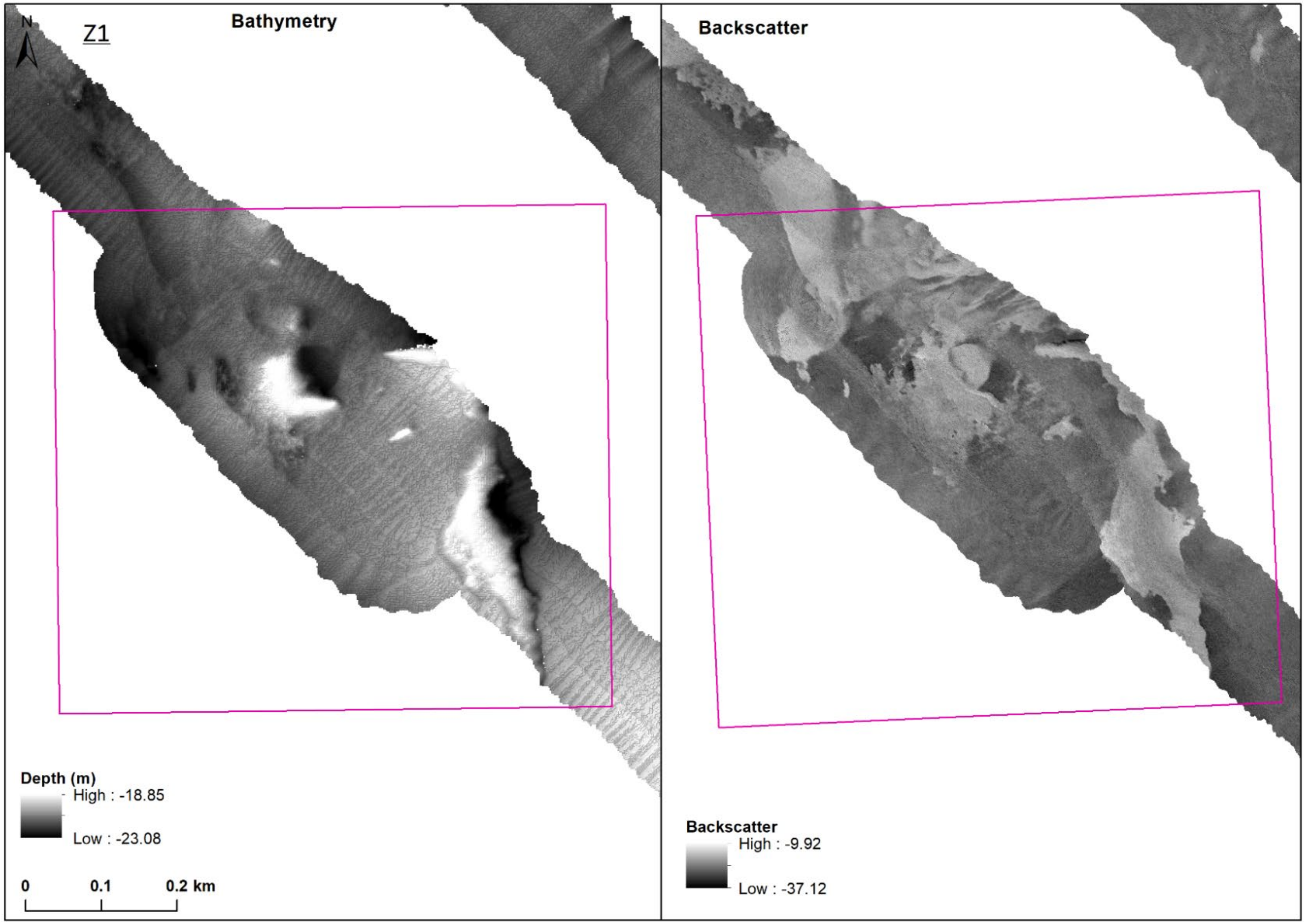


Figure B-1: Z1 – Likely raised sandstone reefs with ridges. (like site A but smaller), with backscatter suggesting central/north/south reef fields (like site B).

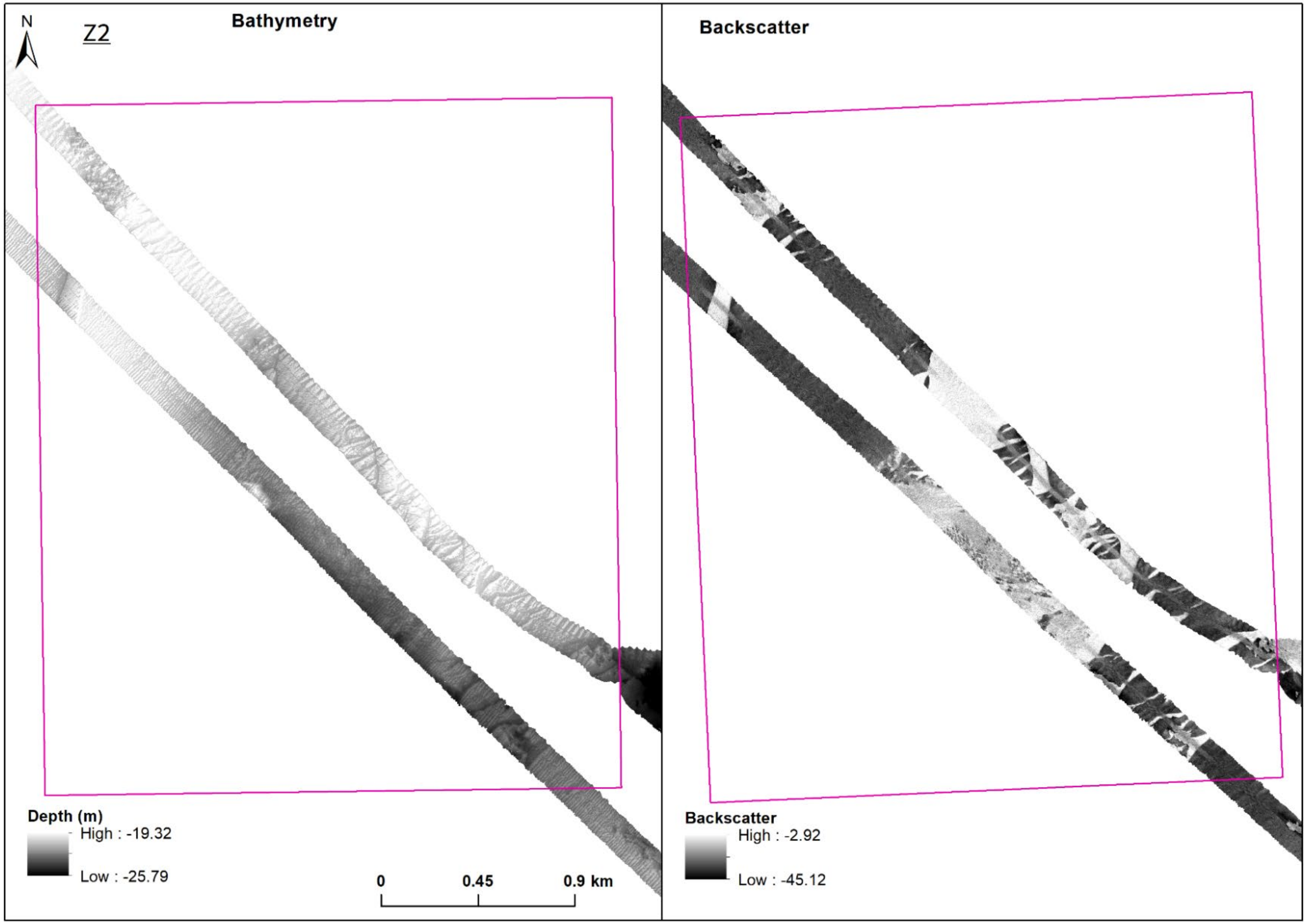


Figure B-2: Z2 – Likely to be extensive low rock/reef fields, interspersed with sand flats. (like adjacent site B, but at larger scale). Interesting channel feature in north.

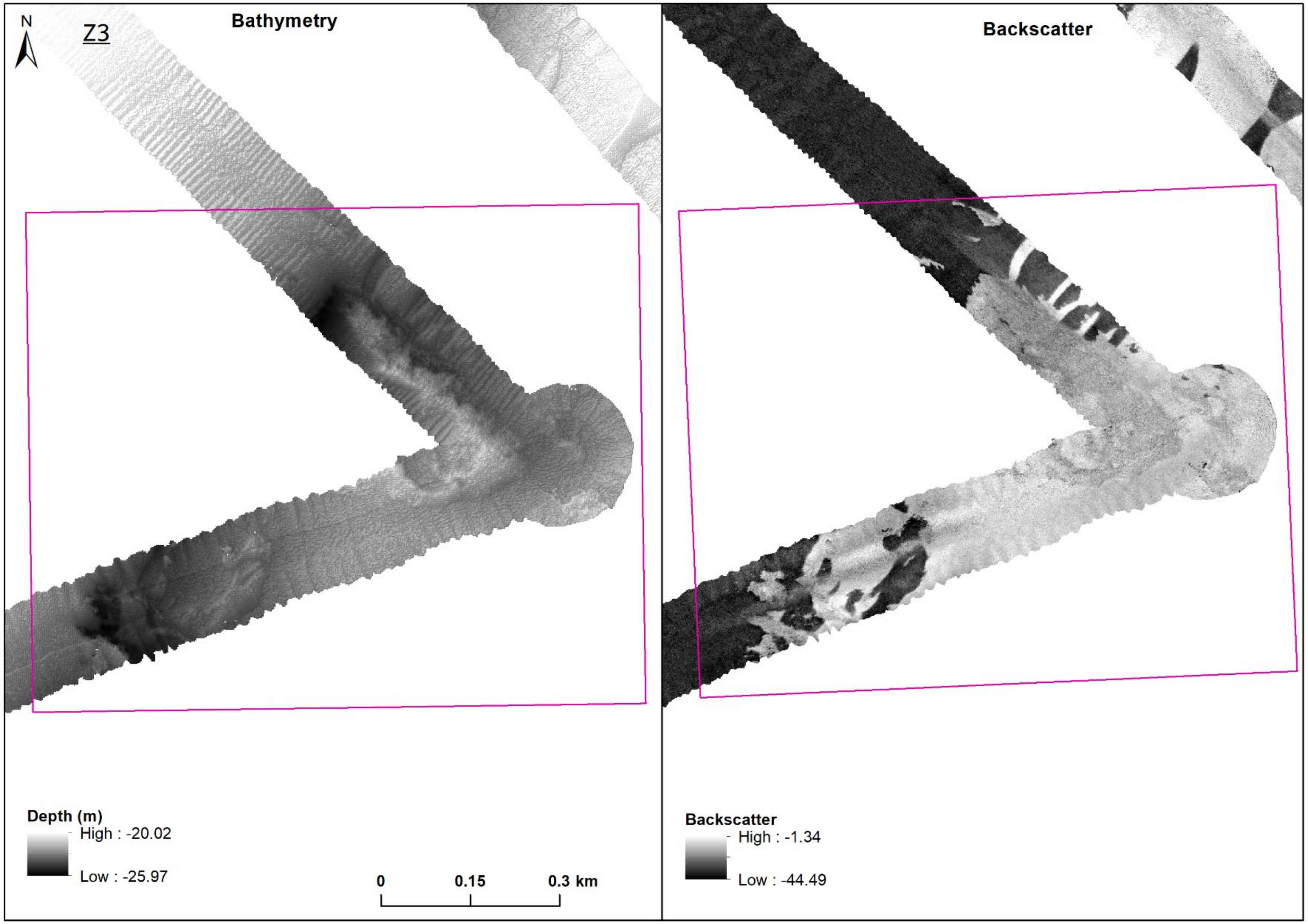


Figure B-3: Z3 – Likely to be a sandstone reef ridge feature. (centre) with low rock/reef field to the east, and lower reefs to the west (possibly mudstone).

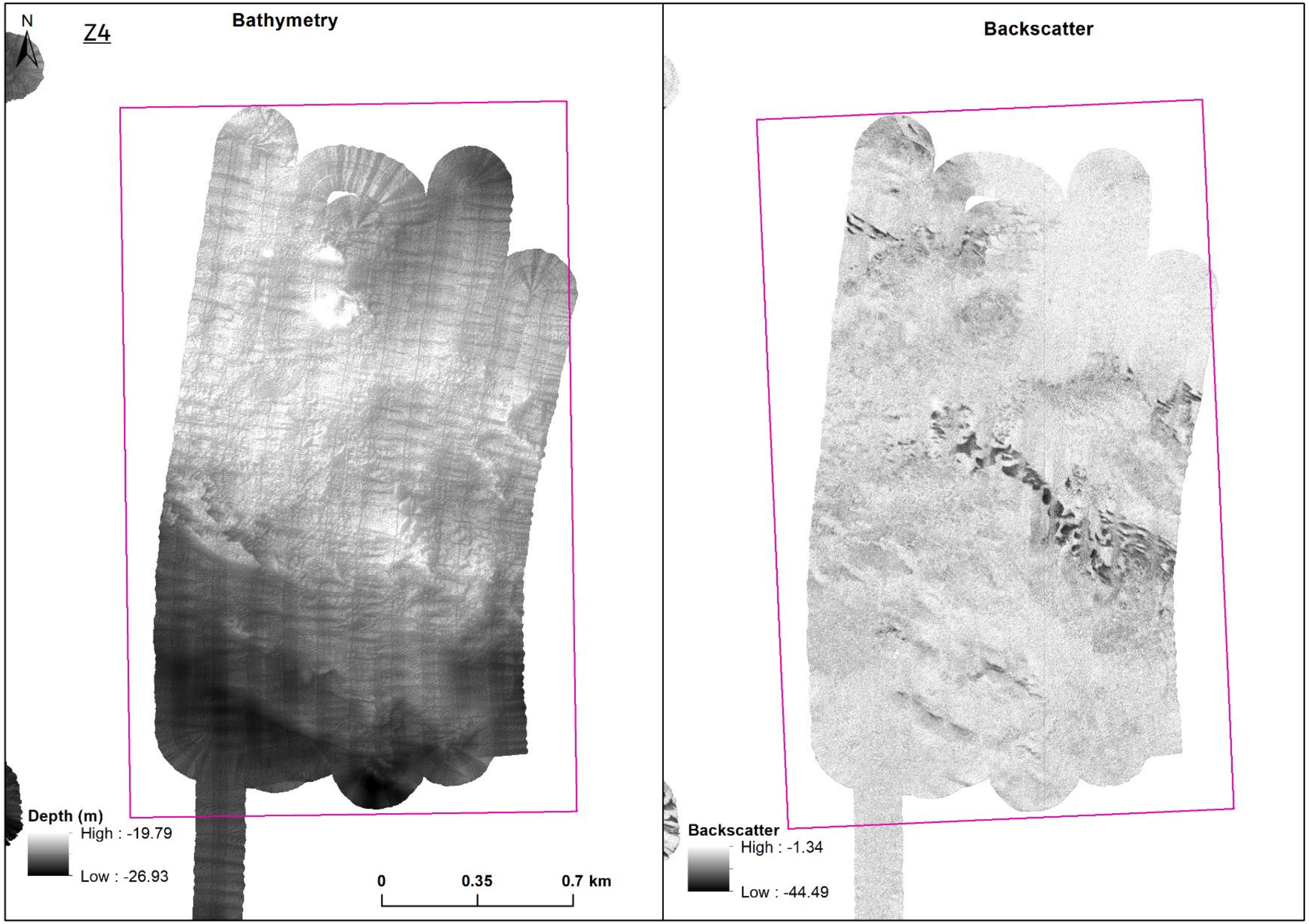


Figure B-4: Z4 – Likely be a mixed reef outcrop and cobbles complex, with knolls.

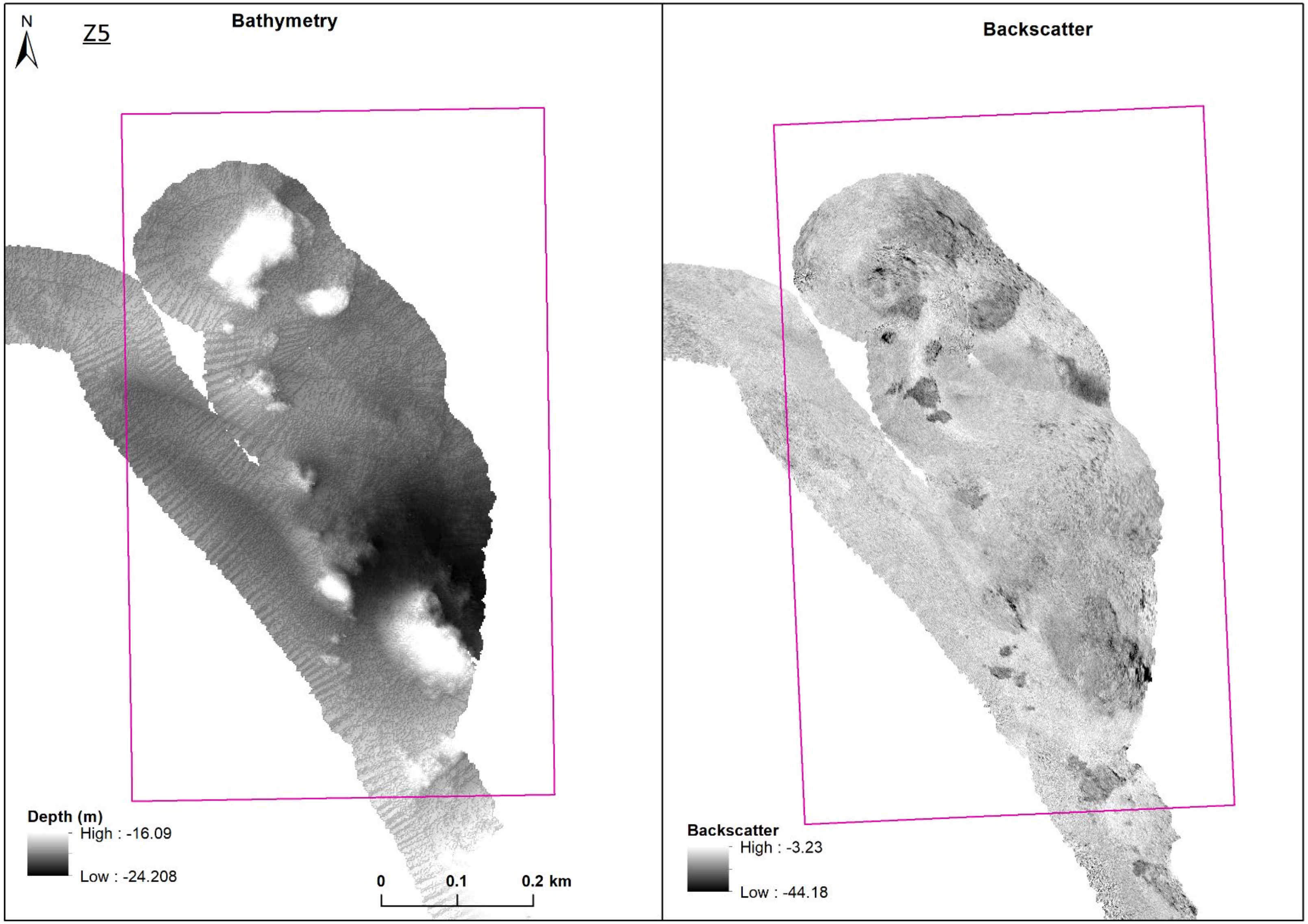


Figure B-5: Z5 – Likely to be discrete raised reefs. (note that there are extensive areas of reef to the west and south of this sub-area).

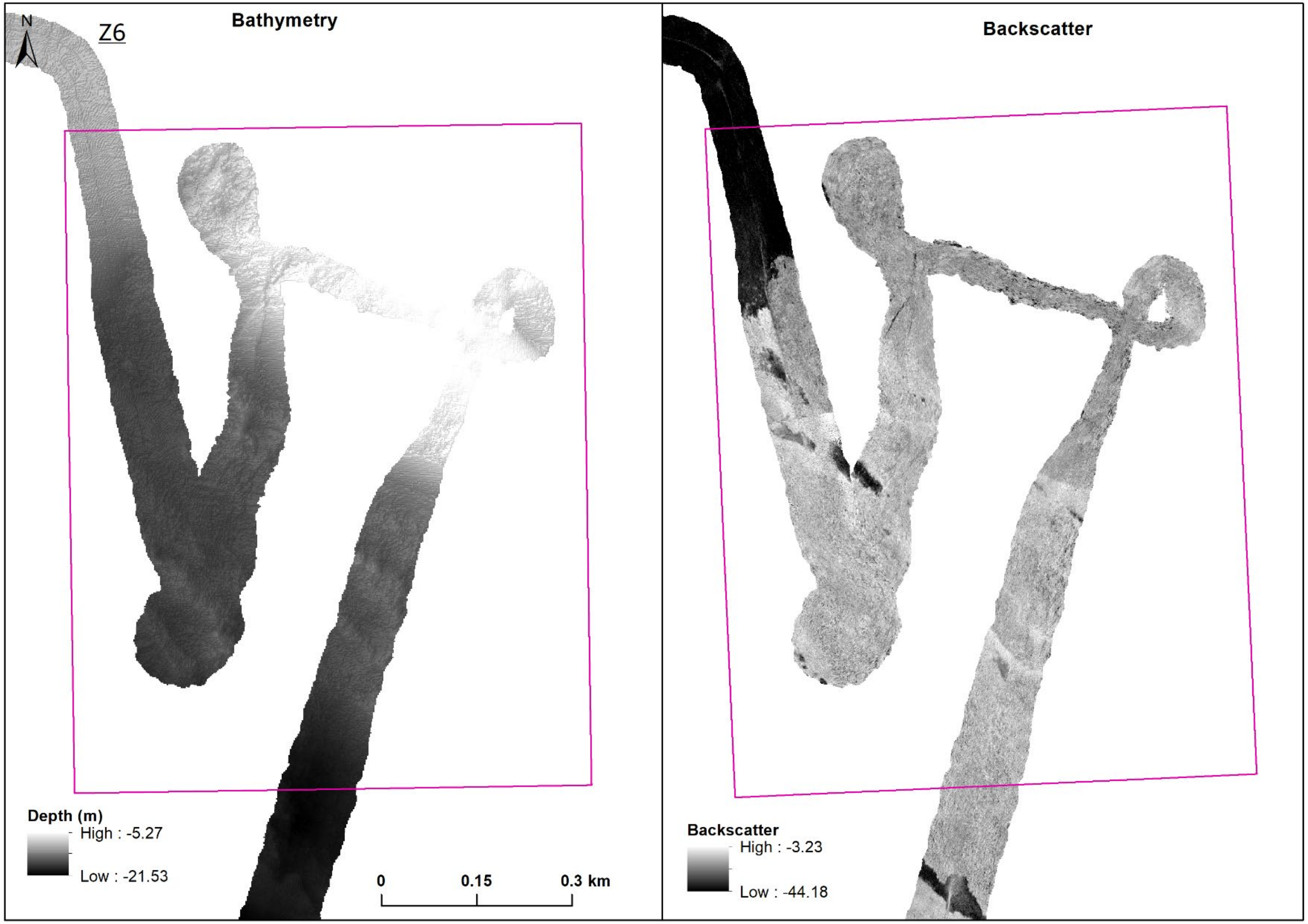


Figure B-6: Z6 – Shallowest reef mapped. (note the very narrow swathe width = shallow water). Extensive shallow rock, seen as a rising north slope.

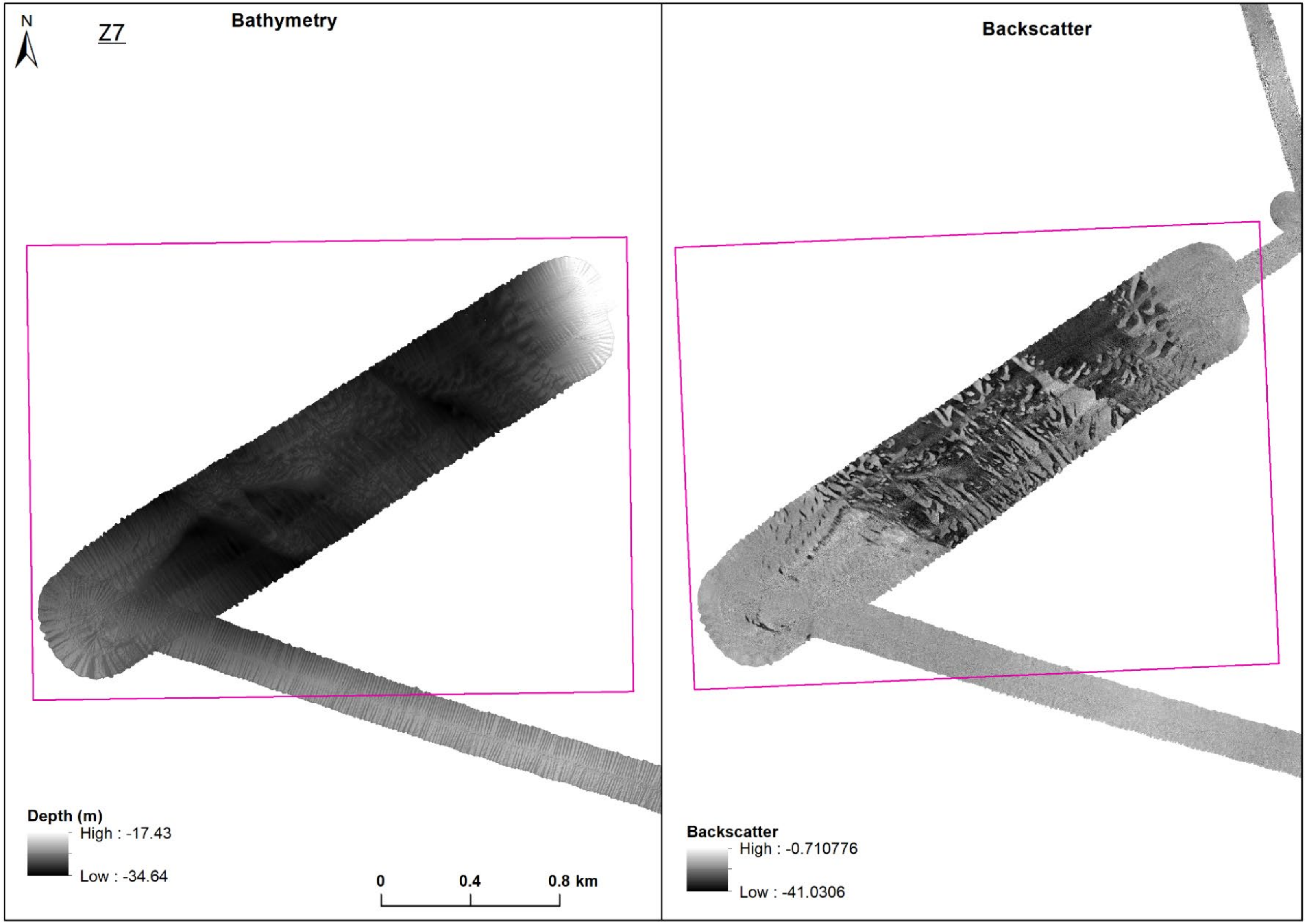


Figure B-7: Z7 – Area of large seafloor bedforms, down a bank from east to west. Possibly rock present as part of depth drop seen in western half.

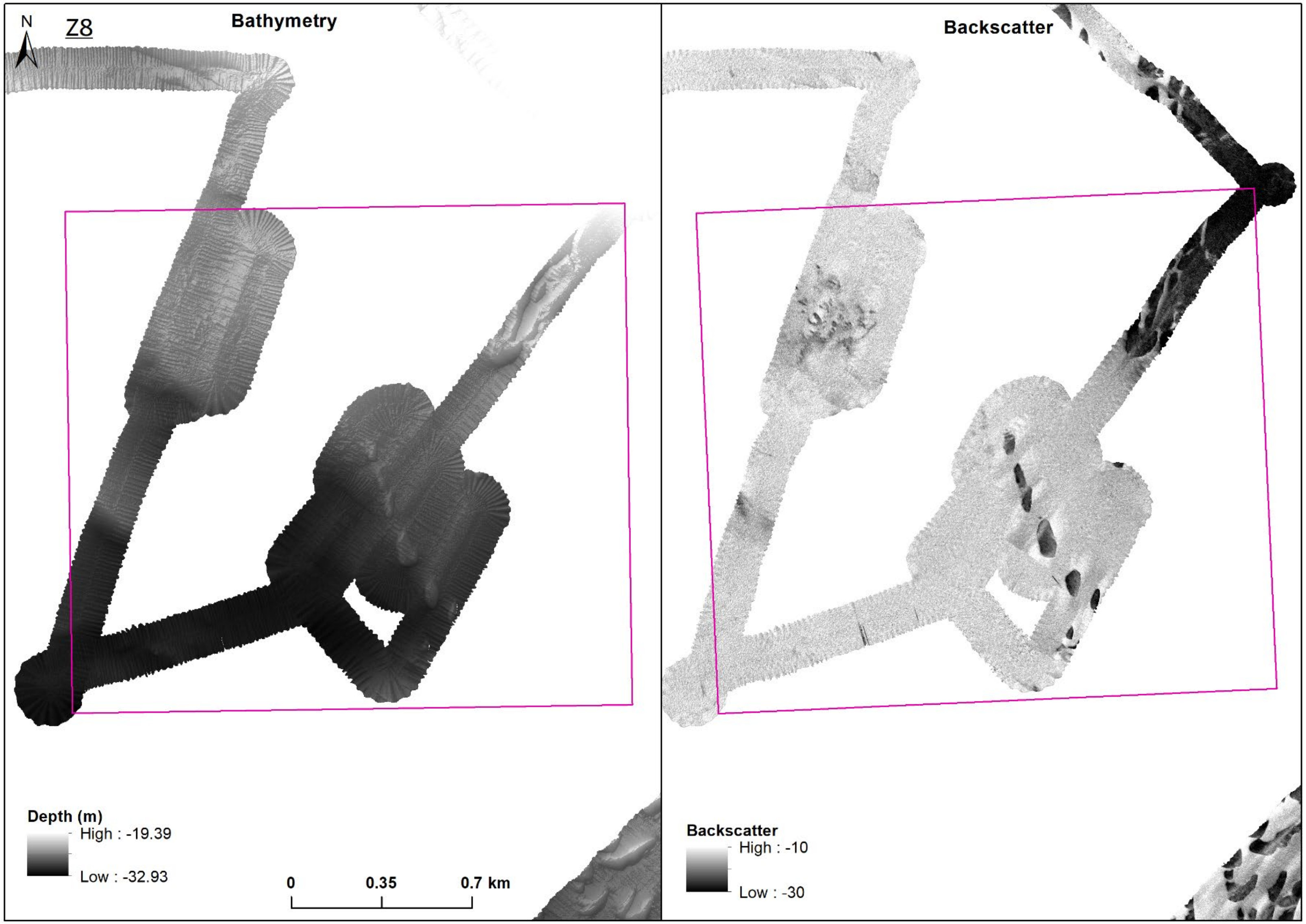


Figure B-8: Z8 – Raised seafloor bedforms. in the western block almost certainly reef, less clear for the two features in the east block and adjacent north transect.

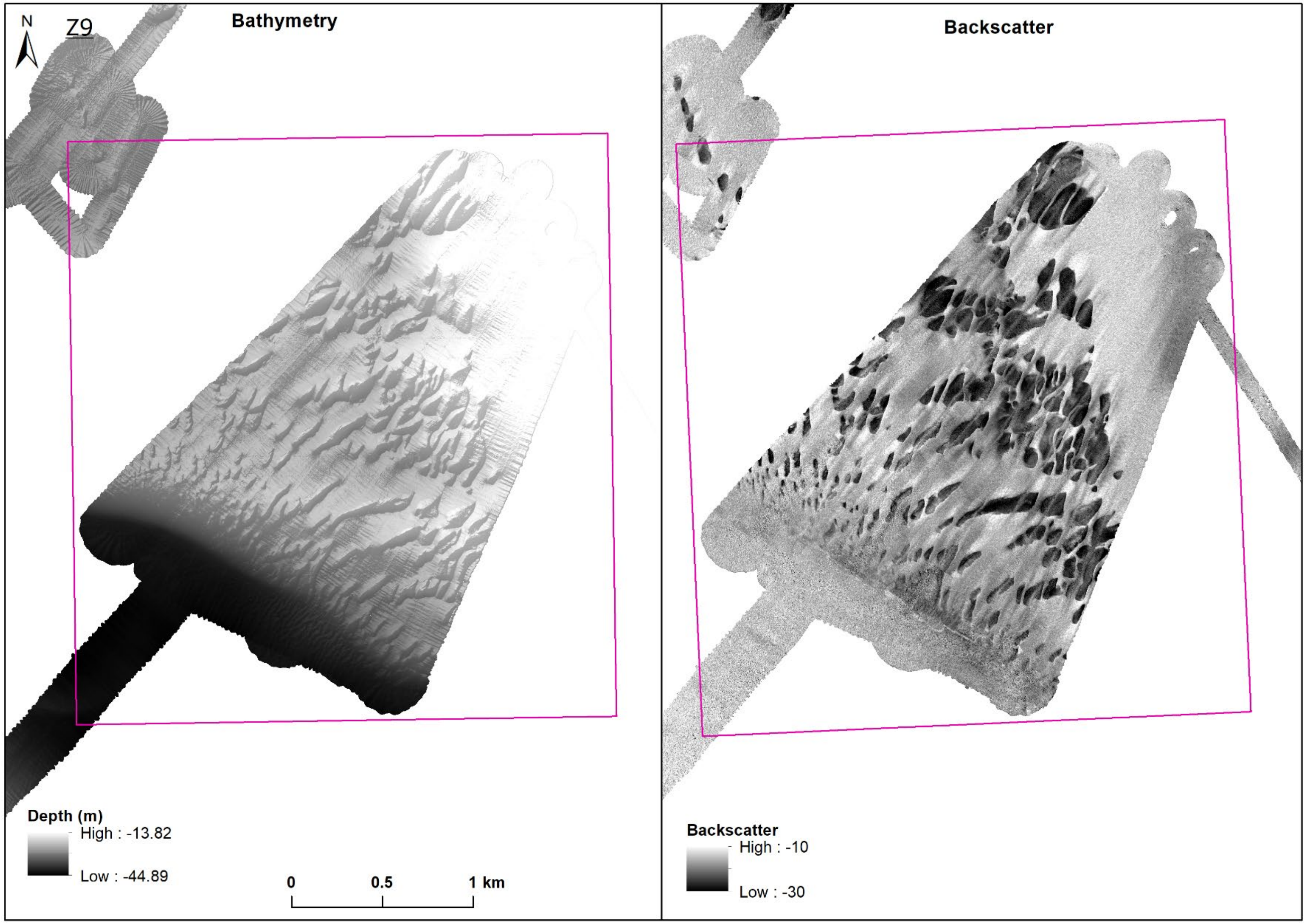


Figure B-9: Z9 – Large field of raised bedforms extending down a slope, identity unknown. Likely to join with Z8, present to the north-west.

Appendix C Crofskey (2007) classifications

Table 3.2 Habitat substrate and sea-bed topography index, adapted from Willan *et al*., (1979) and Wentworth (1922).

Class	*Substrate type*	*Substrate sub-class*
1	Sand. Ranging from mud to gravel (maximum particle diameter *c*. 16 mm); rocks absent	Sand
2	Sediment covered rock flats. Again flat in character, with quite extensive sand patches which may merge into each other, or a sand mantle. There should, however, be a continuous rock basement	Mobile reef
3	Mixed rock and sand. Flat. Rock basement interspersed with equal areas of surface sand in discrete patches; requires a continuous rock floor	Mobile reef
4	Pebbles. Rocks with diameter of 16 – 64 mm. All rocks are mobile and interspersed with sand.	Mobile reef
5	Cobbles. Rocks up to c. 256 mm in diameter interspersed with a sand matrix. All rocks must be mobile	Mobile reef
6	Small boulders (256 – 512 mm). Rocks less then 512 mm high, fixed or mobile; shape irregular, no undercutting. Requires a more or less continuous sand basement	Rock reef
7	Large boulders > 512 mm. Rocks more than 512 mm high, fixed, with abundant crevices and undercutting. Sand and small boulders usually present also.	Rock reef
8	Rock flats, bedrock. Flat or gently shelving rock, devoid of sediment or with a very light covering in small depressions	Rock reef
9	Rock reefs. Massive submarine reefs with no sand; rocks highly dissected and irregular, with abundant fissures and undercutting	Rock reef

Table 3.3 Topographic habitat complexity scale and predominant habitat types used to classify the bottom topography (adapted from Mead and McComb, 2002).

Complexity scale	*Habitat type*	*Corresponding scores from previous table (1-4)*	*Complexity*
1	Sand (100%)	1	Low
2	Mainly sand (>95%) with visible cobbles or rocks	1.25	Low
3	Mainly sand (50% - 95%) with areas of rock	1.5	Low
4	Rocks and cobbles inundated with sand (<50%)	1.75	Low
5	Cobble and pebble reef	2	Low
6	Mainly cobble reef	2.25	Medium
7	Cobble and rock reef	2.5	Medium
8	Rock and small boulder reef	2.75	Medium
9	Small boulder reef	3	Medium
10	Small and large boulder reef	3.25	High
11	Large boulder reef	3.5	High
12	Large boulder reef, large rock outcrops	3.75	High
13	Complex boulders, large wall, rocky overhangs	4	High

Figure C-1: Crofskey (2007) dropped video classifications