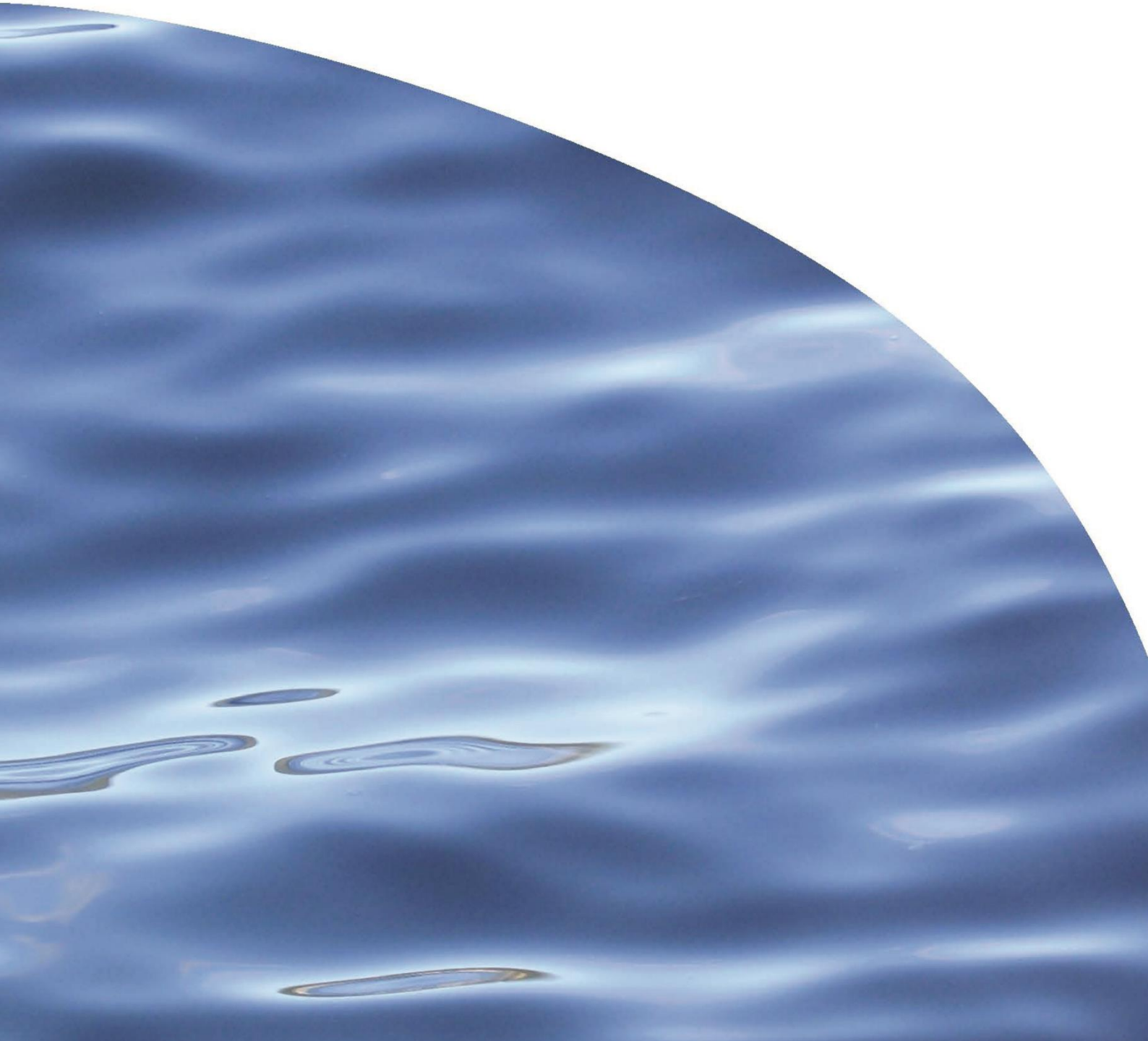
REPORT NO. 3587

ECOLOGICAL TRANSECT SURVEYS OF PANIA AND TOWN REEFS: OCTOBER 2020



ECOLOGICAL TRANSECT SURVEYS OF PANIA AND TOWN REEFS: OCTOBER 2020

ROSS SNEDDON AND ROBYN DUNMORE

Prepared for Port of Napier Ltd

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Don Morrisey

APPROVED FOR RELEASE BY:
Grant Hopkins

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EXECUTIVE SUMMARY

Port of Napier Limited (PONL) is deepening its existing approach channel to accept deeper draft vessels and establishing a new berth (No.6 berth) on the northern face of the main Port reclamation. As part of the resource consents covering capital dredging and spoil disposal, PONL is required to complete a series of ecological dive surveys of Pania Reef. In addition, under a Heads of Agreement between PONL and Legasea Inc., there is an undertaking to provide visual and photographic surveys of the habitats and the sediment and turbidity characteristics of Town Reef.

This report covers the first survey conducted during the dredging phase of the project, and follows a series of three baseline surveys of Pania Reef conducted in April 2016, May 2019 and February 2020. The second of these had included a baseline survey of Town Reef. Capital dredging for the project commenced in June 2020 and was ongoing when the current survey was conducted over 28–30 October 2020.

Using a methodology identical to the baseline, the survey comprised a series of eight 100-m diver transects of the seabed, spread out along the Pania Reef axis. Divers took systematic notes of the depth, substrate and relative abundance of conspicuous biota, and employed video, still and quadrat photography to document habitats and communities. All data was bracketed into 10-m segments of each transect. The relative abundance data from diver transcripts was augmented with a review of the photographic record and compiled to generate abundance scores for each taxon on each transect, and these were compared to the baseline data to evaluate changes that have occurred in Reef communities. Changes were interpreted in the context of baseline variability, survey conditions, and habitat and community characterisations of the transects.

The physical characteristics of the Reef, including the prevalence of sand and silt, were effectively unchanged from the baseline. Habitat-forming species such as kelp and green-lipped mussels were at similar abundance levels. While some changes in the Reef community were identified, these were consistent with the temporal variability observed across the three baseline surveys. All taxa considered characteristic of the Reef were present and previously established spatial gradients in their distribution had been maintained. Several taxa new to the Pania Reef survey inventory were either present in very low numbers or their appearance could be attributed to seasonal cycles.

Due to the action of swell waves, conditions on Town Reef were too poor for photography or visual observation on two of the three transects established during the 2019 baseline survey. The single completed transect was shallower, with adequate underwater visibility, although moderate surge hampered divers and compromised their ability to record the occurrence of fish species. Nonetheless, the compiled notes, photographs and underwater video were sufficient to establish that the state of Town Reef habitats and communities on the transect was consistent with the baseline record.

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GLOSSARY

Item	Description / meaning	Category
A	Abundant - an abundance category	Abbreviation
AS	Abundance score. Generated from compiled categorical abundance across a transect.	Acronym
C	Common - an abundance category	Abbreviation
cf.	Compare. In taxonomy used to express a possible identity, or at least a significant resemblance	Abbreviation
cm	Centimetre	Unit
g	Grams	Unit
GPS	Global Positioning System	Acronym
ha	Hectare	Unit
HOA	Heads of Agreement	Acronym
km	Kilometre	Unit
m	Metre or metres	Unit
MBES	Multibeam echo-sounder	Acronym
O	Occasional - an abundance category	Abbreviation
PONL	Port of Napier Ltd	Acronym
R	Rare - an abundance category	Abbreviation

1. INTRODUCTION

1.1. Background

Port of Napier Limited (PONL) is deepening its existing approach channel to accept deeper draft vessels and establish a new berth (the No.6 berth) on the northern face of the main Port reclamation. This entails widening the current dredged channel and extending it seaward by approximately 1.3 km. The swing basin at the Port entrance is also being extended approximately 120 m westward and 220 m southward and deepened to serve the new berth. Over multiple stages, the dredging project will generate approximately 3.2 million m^3 of dredge spoil and this will be deposited in a consented 346-ha disposal area located approximately 3.3 km south-east of Pania Reef and 4 km offshore in water depths of 20–23 m. The spatial footprint for the dredging work and the proposed disposal area for the dredge spoil, in relation to the principal features of the coastline, are depicted in Figure 1. Capital dredging for the project commenced in June 2020 and was ongoing at the time of the current Pania and Town Reef surveys.

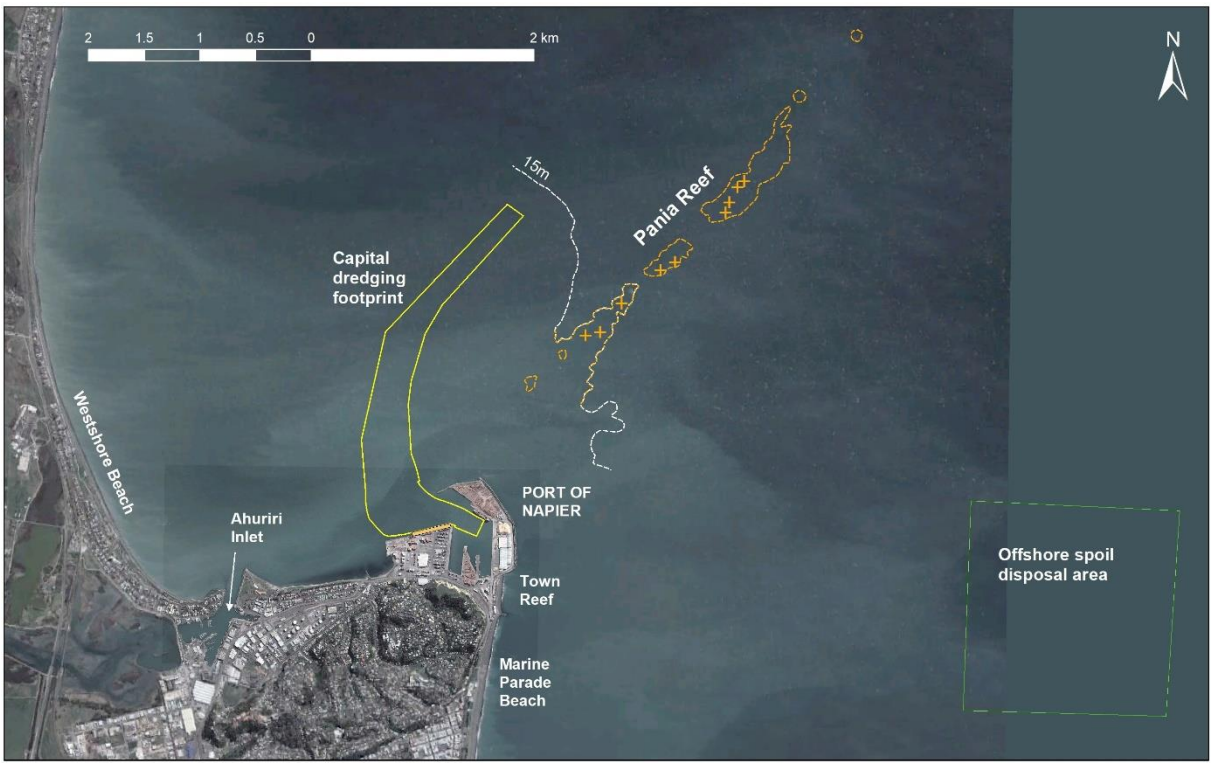

Figure 1. Composite aerial photograph of Port of Napier, showing the scale and layout of the proposed project elements.

Pania Reef is the major seabed feature in southern Hawke Bay (Duffy 1992). It extends in a north-easterly direction, beginning approximately 800 m from the Port of

Napier. It is widest (~400 m) at the south-western end, approximately 1 km northeast of the main Port breakwater, where the boulder and rock substrate emerges gradually from a 15 m deep sand bottom. Toward the seaward end, the topography becomes progressively steeper with large rocks, fissured with crevices, protruding from a sandy seabed at 18 m water depth. At its closest points, the Reef is approximately 0.9 km south-east of the capital dredging footprint and 3.3 km north-west of the offshore spoil disposal area (Figure 1).

As part of the assessments conducted for the project resource consent application, the ecology of Pania Reef was surveyed in April 2016 (Sneddon et al. 2017). Consent for the dredging project was granted in November 2018, imposing requirements on PONL to complete additional monitoring on Pania Reef over the course of the project, including second and third baseline surveys, conducted 24-25 May 2019 and 17-18 February 2020, respectively. The results of these surveys have been reported by Sneddon (2019 and 2020).

Town Reef is located adjacent to the base of the main Port breakwater at the northern end of Marine Parade Beach (Figure 1). It represents the inshore section of a formerly continuous reef system with Pania Reef. It is approximately 2 km to the south of the channel deepening operations and 4 km from the offshore spoil ground. Like Pania Reef, it is a relatively well-flushed, high-energy environment due to exposure to both wave action and along-shore currents.

In addition to the surveys of Pania Reef, there is a requirement, under a Heads of Agreement (HOA) between PONL and Legasea Inc., to provide a *visual survey and photographic record of the existing habitats and the sediment and turbidity characteristics of … Town Reef.*

1.2. Scope

This report covers ecological survey work undertaken to meet the requirements of condition 11 (f) of Resource Consent CL180009E and the HOA between PONL and Legasea. The report describes and interprets the findings of the first surveys conducted following the commencement of the dredging project in June 2020.

The principal approach to the survey of Pania Reef was set by methodology established for the 2016/17 assessment that accompanied PONL's consent application (Sneddon et al. 2017). The methodology for the photo- and video-transect survey of Town Reef was developed for the May 2019 survey and reported in Sneddon (2019).

2. METHODS

The current surveys of Pania and Town reefs were undertaken over 28–30 October 2020 by four Cawthron Institute scientific divers working from the 7.8 m alloy work boat *FinFinder*. All transect lines were laid according to pre-established GPS waypoints and compass bearings. The weighted 100-m transect line was tagged at 10-m intervals along its length. The transects were set up by dropping the weighted end of the transect line at the established start waypoint (generally a point on or near the reef crest) and running the remaining length of line out towards the finish waypoint until taut, from where the deeper end was lowered on a second weighted shot line.

2.1. Pania Reef

The survey employed eight 100 m-long dive transects spaced out along the length of the reef (PR1–PR8: Figure 2). The locations of these transects were identical to those surveyed in April 2016, May 2019, and February 2020 (Sneddon et al. 2017, Sneddon 2019, Sneddon 2020, respectively). Prior to the 2016 survey, transects PR1, PR2, PR3 and PR4 had also been surveyed in 2005 (Cawthron unpublished data). Transects PR1 and PR2 were, in turn, positioned according to those surveyed by Duffy (1992).

Two divers descended to the deepest point of the transect then swam along the transect line, one recording notes on the presence and relative abundance of conspicuous biota, the other taking quadrat photographs and recording video. At each of the 10 m interval marks along the transect, five 41 cm x 61 cm (0.25 m^2) rectangular photoquadrats were taken using a 10-megapixel digital camera attached at a fixed distance from the quadrat. One was taken at the transect line distance tag, while the remaining four were taken within the four compass sectors around it at a radial distance of approximately one metre. Between each of the 10 m distance tags, video footage was collected using a GoPro Hero camera.

The second diver compiled ecological notes using a field sheet template based on the reef habitat / taxa inventory established by the previous surveys. A separate record was compiled for each 10-m section of the transect within a 2-m band (1 m each side of the transect line). Each record included water depth, habitat / substrate type, and the relative abundance / percentage cover of algal and faunal species, including fish and conspicuous surface-dwelling or encrusting organisms. Abundance / coverage data were entered using a categorical scale, ranked subjectively as ‘rare’, ‘occasional’, ‘common’, or ‘abundant’. Guidelines used for these abundance categories are listed in Table 1. This information was used to compile a description of the habitat and the community of epibiota[1] occurring at these locations on the reef.

[1] Organisms living on or above the substratum surface.

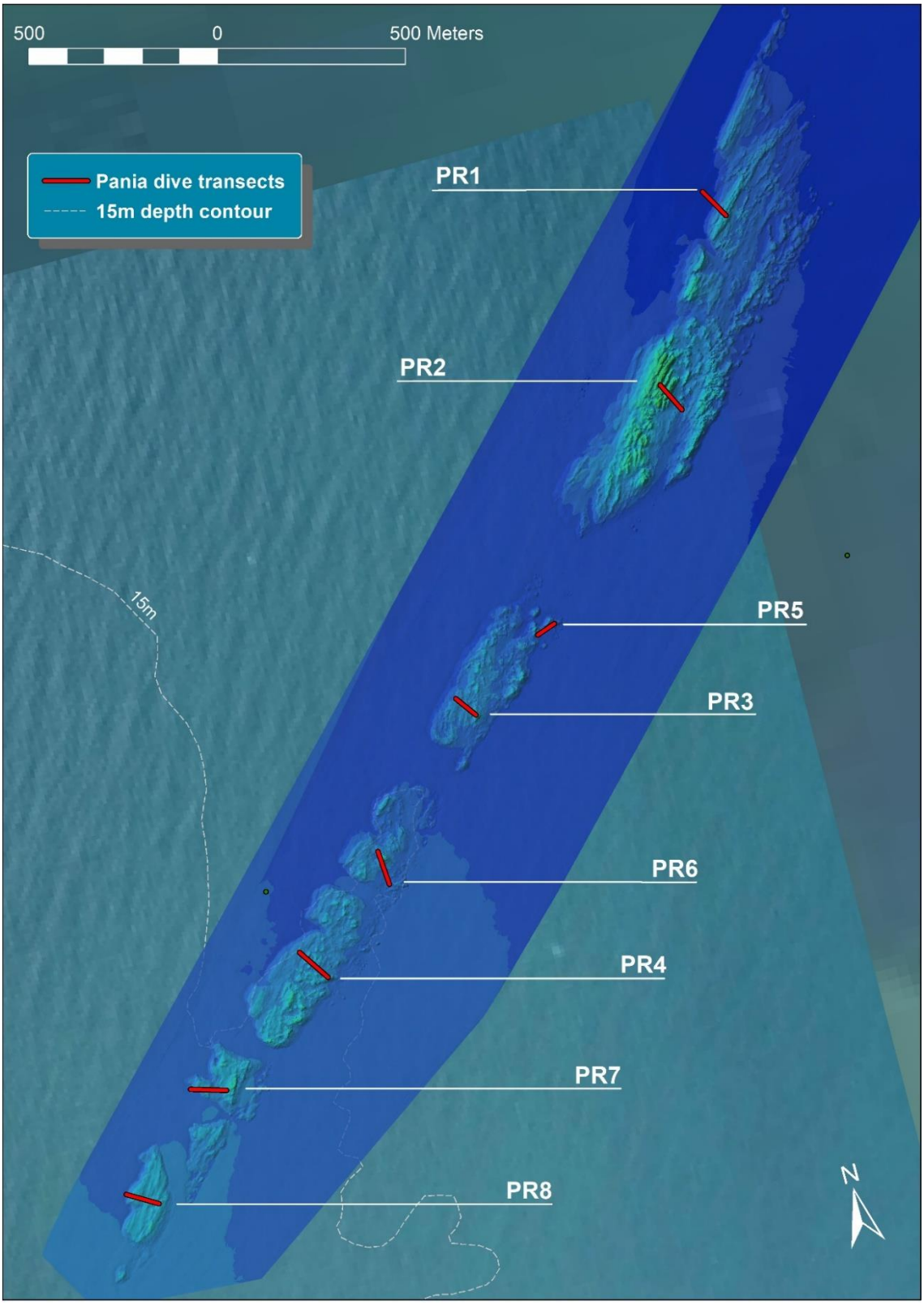

Figure 2. Multi-beam Echo-Sounder (MBES) image of Pania Reef showing locations of survey transects.

Table 1. Description of the categorical scale used to survey the intertidal sites.

Category	Rank value	Description
Absent	0	Not observed.
Rare	1	1–2 individuals, or a single cluster or patch of individuals in one small area (e.g. small patch of sponge or algae).
Occasional	2	3–10 individuals throughout the (2 m x 10 m) area of assessment
Common	3	> 10 individuals throughout the (2 m x 10 m) area of assessment.
Abundant	4	Individuals abundant enough to form a distinct zone or habitat (e.g. mussels, barnacles and some algae), or hundreds to thousands of individuals per m^2.

Both divers also used compact hand-held cameras to collect additional close-up images of biota. To avoid reflection interference from suspended particulates, strobe illumination was not used for the compact camera images.

2.1.1. Taxonomy

Identifications were made to the lowest practicable taxonomic level. For some groups of reef organisms (such as sponges and some algae), species level identification is very difficult without sample collection and laboratory examination. Where necessary, tentative classifications have been made based on morphologically similar species or higher-order groups (e.g. order, family) from taxonomic references. In some instances, classifications have been made according to description based on careful photographic documentation. Example photographs of such descriptive or uncertain classifications for key organisms were provided in the final baseline report (Sneddon 2020). Photographs of additional taxa described herein are provided in Appendix 1.

To minimise the potential for diver bias, a project-specific taxonomic image library has been developed during the baseline monitoring, using input from all divers involved. This photographic reference is carried in hard-copy form on all field surveys, discussed in regard to all identification issues, and amended and / or augmented as required.

2.1.2. Post-fieldwork review and data augmentation

For all of the dive surveys conducted since 2016, the photographic and video record has been used to augment the abundance data compiled by divers in the field. This work has been undertaken solely by, and in consultation with, the divers involved and as soon as possible following the fieldwork. There are several reasons for the efficacy of this approach:

- Divers are significantly time-constrained during the surveys, working against both dive table (blood nitrogen) and air capacity limits. They are also often working in conditions of limited underwater visibility and sometimes moderate surge. Under these conditions, some detail can be missed.
- Through video review, divers can effectively ‘re-experience’ the transect, fleshing out detail of reef topography and other physical habitat components.
- In close-up shots, compact cameras can resolve significantly greater detail than the human eye due to the very short focal distance.
- Photographic image manipulation (colour balance and saturation) can bring out still further detail of encrusting communities.
- The reviews have the benefit of time and immediate access to taxonomic resources, as well as additional expertise if necessary.
- Since the reviews are collaborative, they serve to mitigate any diver bias and improve future capability.

There are, however, certain limitations and caveats with such reviews:

- The photographic coverage with compact cameras is not randomised and often is itself limited by the time constraints of the divers. This can lead to unevenness in the extent of the photographic record.
- It is more difficult to gauge actual abundance with a limited photographic record, especially with taxa too small to be conspicuous in the video or photo-quadrat record. Hence interpretation of this has been necessarily conservative and all changes to the diver transcript are flagged accordingly.

Further notes on the use and limitations of the photographic record are provided in Appendix 2.

2.1.3. Data analysis

To analyse the compiled relative abundance data for each transect, the categories were converted to numerical values according to the assigned rank values listed in Table 1. Summations of these values across the ten 10-m intervals for each transect gave an abundance score (AS) for each taxon. These could then be compared across the eight transects and between surveys to evaluate spatial and temporal variability. Adverse impact may be indicated by an obvious deterioration in community structure and / or notable die-off of conspicuous macrobiota relative to the baseline data.

2.2. Town Reef

Three transects were established at Town Reef during the May 2019 survey. These were arranged spatially to cover three shallower areas of reef substrate marked on

nautical chart NZ5712a (Figure 3). The approach used to survey Town Reef is more qualitative, with an emphasis on compiling a comprehensive photographic and video record from which an inventory of reef taxa can be generated.

The near-shore location of Town Reef results in frequently turbid conditions which can significantly limit the efficacy of more quantitative methods. The slight swell during the current survey was enough to result in near-zero visibility at depths below 8 m and only the shallower TR1 transect could be completed.

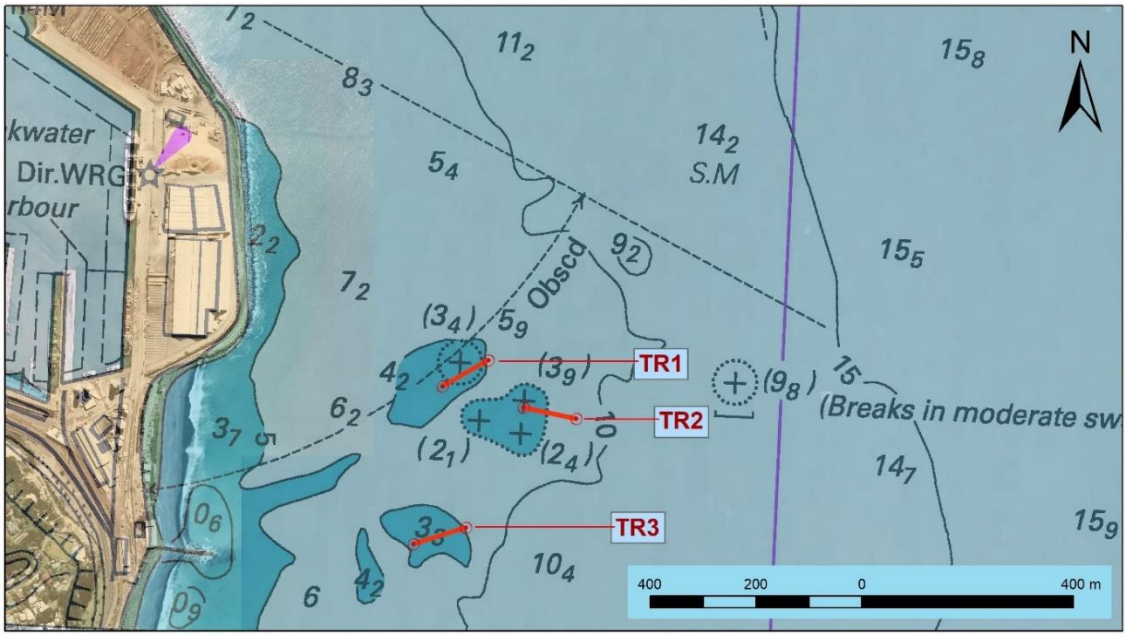

Figure 3. Locations of the three Town Reef dive transects (bold red lines), overlaid upon part chart NZ5712a. Due to turbid conditions below 8-m depths, only the shallower TR1 transect could be surveyed in October 2020.

For Town Reef, the two divers were each equipped with a compact hand-held camera and one diver with an additional GoPro underwater video camera. The divers swam on either side of the transect line, photographing biota and substrate within approximately 2 m of the line. This resulted in the record representing a 4-m wide swathe. Photographs were taken of each 10-m distance tag, thereby bracketing the photographs into distance intervals along the transect. By having the divers cover the transect at an approximately constant speed, the depth record from their wrist-mounted computers could later be used to generate a depth profile for the transect.

On completion of the dive, additional notes were compiled on the prevalence of the major fauna and flora and the nature of the habitats observed. By reviewing the photographs and video, these notes could later be expanded into a descriptive characterisation of reef habitats and communities.

3. PANIA REEF SURVEY

3.1. Pania Reef transects

3.1.1. Notes on underwater photographs

As has been the case for all previous surveys, underwater visibility in October 2020 was problematic for quadrat photography. Suspended particulate matter between the lens and the subject invariably obscured some detail and this was exacerbated by particulate-reflected light from the strobes, despite their physical offset from the camera. Hence, while the quadrat photographs are useful to benchmark both physical and biological habitat characteristics, they were mostly of limited use for identification of any but the most conspicuous organisms. Nonetheless, as with previous surveys, use of hand-held compact cameras by divers enabled the collection of a set of clear images at close range. While these close-up images were taken opportunistically rather than systematically, they were bracketed with shots of transect distance tags to allow placement within each 10-m section. Taken together, the two photographic image sets are complementary, providing a reasonably comprehensive record of the habitats and conspicuous biota occurring along each transect.

3.1.2. Description of habitats and communities

The following sections present descriptions and graphics that characterise the communities and habitats along each transect. These have been generated from the diver record and associated notes, and reviews of the photographic and video record. Tables are presented that systematically cover substrate characteristics, algal and epifaunal communities, and fish observations. Each table summarises the findings from the three baseline surveys to give an overview. Interpretation of data from the current survey is presented in the far-right column. Generally, the focus was placed on differences in the prevalence of taxa compared to the earlier surveys, particularly with regard to the more dominant, abundant or habitat-forming organisms.

The abundance score (AS) for the transect is the sum of abundance for each 10-m section (converted from categorical records as per Table 1). The conventions used for the table entries concerning changes from the baseline for algae and invertebrates on each transect are as follows:

- The number of taxa newly recorded at the transect. These taxa are listed if present at AS > 3.
- The taxa not recorded that have been present in at least two of the three baseline surveys. These are listed if they were consistently present across all three baseline surveys. The baseline mean abundance score is reported.
- Taxa more prevalent in the current survey than during the baseline are listed if AS exceeds the mean baseline value by more than 3.

- Taxa less prevalent than during the baseline (provided the AS is lower than that for all three baseline records and the difference from the mean baseline AS is greater than 3).

Transects are presented in their spatial (north to south) sequence rather than in numerical order (Figure 2). The associated figures depict the transect depth profile, generated from diver-recorded depths at each of the 11 transect distance tags and adjusted for tidal variation (to mean sea level—MSL). The profile is compared in each figure with those recorded during the three baseline surveys. In places, the Reef has very uneven bathymetry over small spatial scales and exact transect line placement along its entire length is impossible. Therefore, the comparison serves as a check on transect consistency between the surveys and assists with interpretation of the ecological data where locally significant differences in profile may have occurred.

A series of eight photographs (generally a mix of quadrat and compact camera close-ups), were selected as representative of substrate, habitats and biota, and these are shown located along each transect profile. Photographs were post-processed with colour-balancing software to increase contrast and bring out detail. For this reason, the colour in some photographs presented in the transect figures may appear oversaturated and they frequently misrepresent the visibility and colour observed by the divers (see further notes in Appendix 2).

Dive Transect PR1

Dive transect PR1 is situated on the northern end of the reef system. It begins at a depth of 20 m and runs in a south-easterly direction to finish at a depth of 12 m (Figure 4).

Table 2. Notes on the physical and biogenic habitats and reef communities of transect PR1 for the three baseline and the current surveys. AS = transect abundance score, which may range from zero (not present) to 40 (abundant in every 10-m section). Baseline AS values refer to the mean of three surveys.

PR1	Baseline surveys 2016–2020	October 2020
SUBSTRATE	The first 60 m of the transect comprises undulating bedrock overlaid with settled sand and silt. Bedrock consistently present but sand patches common in the first 30 m and in small pockets until the 50 m mark. From 50–60 m onwards along the transect, the reef topography steepens with greater 3-dimensional structure and many crevices and holes. Although there was less silt, small amounts were still observed amongst the encrusting biota. The reef crest occupies the last ~20 m of the transect, is affected by surge and is mostly free of sediments. The prevalence of sand and silt has varied only slightly across the baseline surveys.	The progression of substrate along the transect was entirely consistent with the baseline observations.
ALGAE	4–9 taxa recorded across the baseline surveys. The red alga *Plocamium cirrhosum* was the most common macroalga recorded in the first 60 m, but occurred throughout the transect. An unidentified small-bladed red alga was distributed sparsely amongst the encrusting communities. From 60 m onwards, kelp (*Ecklonia radiata*) forest became the dominant habitat, increasingly abundant in depths shallower than 14 m. Pink encrusting coralline paint (Corallinales) was also common above 14 m. *Carpomitra costata* was recorded occasionally in the shallower sections. In Feb 2020, a grass-like green alga (noted previously from other transects) was common on sloping sections in depths shallower than 15 m and a newly recorded fine tufted red alga was also common in the last 50 m of the transect.	8 taxa recorded. The prevalence of *E. radiata* (AS 21) was unaltered from the baseline. Presence of coralline paint and *P. cirrhosum* was also consistent with the baseline. The brown alga *Dictyota* sp. was recorded (in low abundance – AS 5) for the first time at PR1. *C. costata* was now absent but had not been consistently recorded across the baseline. The small-bladed red alga was more prevalent than in Feb 2020 (AS 12 vs AS 5), but was not recorded from the first two baseline surveys. The fine tufted red alga first noted in Feb 2020 (AS 15) was present but at very low levels (AS 2).

PR1	Baseline surveys 2016–2020	October 2020
INVERTEBRATE COMMUNITIES	23–37 taxa recorded across the baseline surveys. The most prevalent sessile invertebrates in the first 60 m were the orange finger sponge (*Raspailia topsenti*), the yellow tubular sponge (*Ciocalypta* sp.), a fine-branching hydroid (Leptothecata), clowns-hair bryozoan (Catenicellidae sp.) the orange finger bryozoan (cf. *Steginporella*), and a branching bryozoan (cf. *Cellaria* sp.). Smaller organisms such as sea tulip (*Pyura spinosissima*), stony coral (*Culicea rubeola*), white striped anemone (*Anthothoe albocincta*), siphon whelk (*Penion sulcatus*), hermit crab (*Pagurus* sp.) and holothurian (sea cucumber—*Australostichopus mollis*) were also present in low numbers. From the 60 m mark, there was a greater diversity of sessile invertebrates including the grey vase sponge (*Ecionemia alata*) and the boring sponge *Cliona* sp. Occasional taxa included saddle squirt (*Cnemidocarpa* sp.), orange encrusting sponge (cf.*Tedania* sp.) and encrusting bryozoans. Less common, but consistently present, taxa included the clown nudibranch (*Ceratosoma amoena*), the siphon whelk (*P. sulcatus*) and *C. rubiola* as well as several sponge species. As the profile becomes shallower (< 15 m depth), large patches of green-lipped mussels (*Perna canaliculus*), along with gastropods such as the green top shell (*Trochus viridus*), tiger top shell (*Calliostoma tigris*) and Cook's turban (*Cookia sulcata*) were also present amongst the kelp. Varied sponge communities remained present in the troughs and under the overhangs. The most notably variable taxa across the baseline surveys have been the fine branching hydroid (absent in 2019) and most of the bryozoans.	41 taxa recorded. 11 taxa newly recorded at PR1. However, those exceeding AS 3 were limited to: • Grey massive sponge – (Desmospongia B; AS 5) The nudibranch *Dendrodoris denisoni* (AS 1) was entirely new to the Reef inventory. Nine taxa previously recorded from PR1 were absent. Those that had been consistently present across the baseline were: • Ascidian *Cnemidocarpa* sp. (baseline mean AS 3.3) Taxa in greater prevalence than during the baseline: • Sponge *Raspailia topsenti* (AS 20 vs baseline 12.3) • Lilac sponge (Desmospongia D; AS 9 vs baseline 1.3) • Sponge cf. *Suberites perfectus* (AS 6 vs baseline 0.3) • Bryozoan cf. *Cellaria tenuirostris* (AS 23 vs baseline 8) • Bryozoan cf. *Steginporella* sp. (AS 23 vs baseline 11.7) • Bryozoan cf. *Margaretta barbata* (AS 5 vs baseline 0.3) • Colonial ascidian cf. *Synoicum otagoensis* (AS 8 vs baseline 1.3) • Gastropod *Cookia sulcata* (AS 6 vs baseline 2) • Holothurian *Australostichopus mollis* (AS 9 vs baseline 3.3) None of the taxa present were recorded as less prevalent than in all of the baseline surveys.
FISH	7–15 species recorded across the baseline surveys. Numerous demersal fish species (living and feeding on or near the seabed) were encountered along the transect including blue cod (*Parapercis colias*), dwarf scorpion fish (*Scorpaena papillosa*), scarlet wrasse (*Pseudolabrus miles*) and a variety of triple fins (common [*Fortserygion lapillum*], variable [*Forsterygion varium*] and yellow-black [*Forsterygion flavonigrum*]). In the water column, butterfly perch (*Caesioperca lepidoptera*), leatherjackets (*Parika scaber*), and spotted wrasse (*Notolabrus celidotus*) were commonly observed above the kelp canopy. Some variability across surveys has been observed. While this may be seasonal, the key factor in the record is likely to relate to underwater visibility.	8 taxa recorded. The prevalence and variety of fish was generally quite low. This was supported by a review of the video footage. Spotted wrasse were absent. Species present were generally less abundant than during the baseline, notaby including: • Butterfly perch • Sweep • Leatherjacket

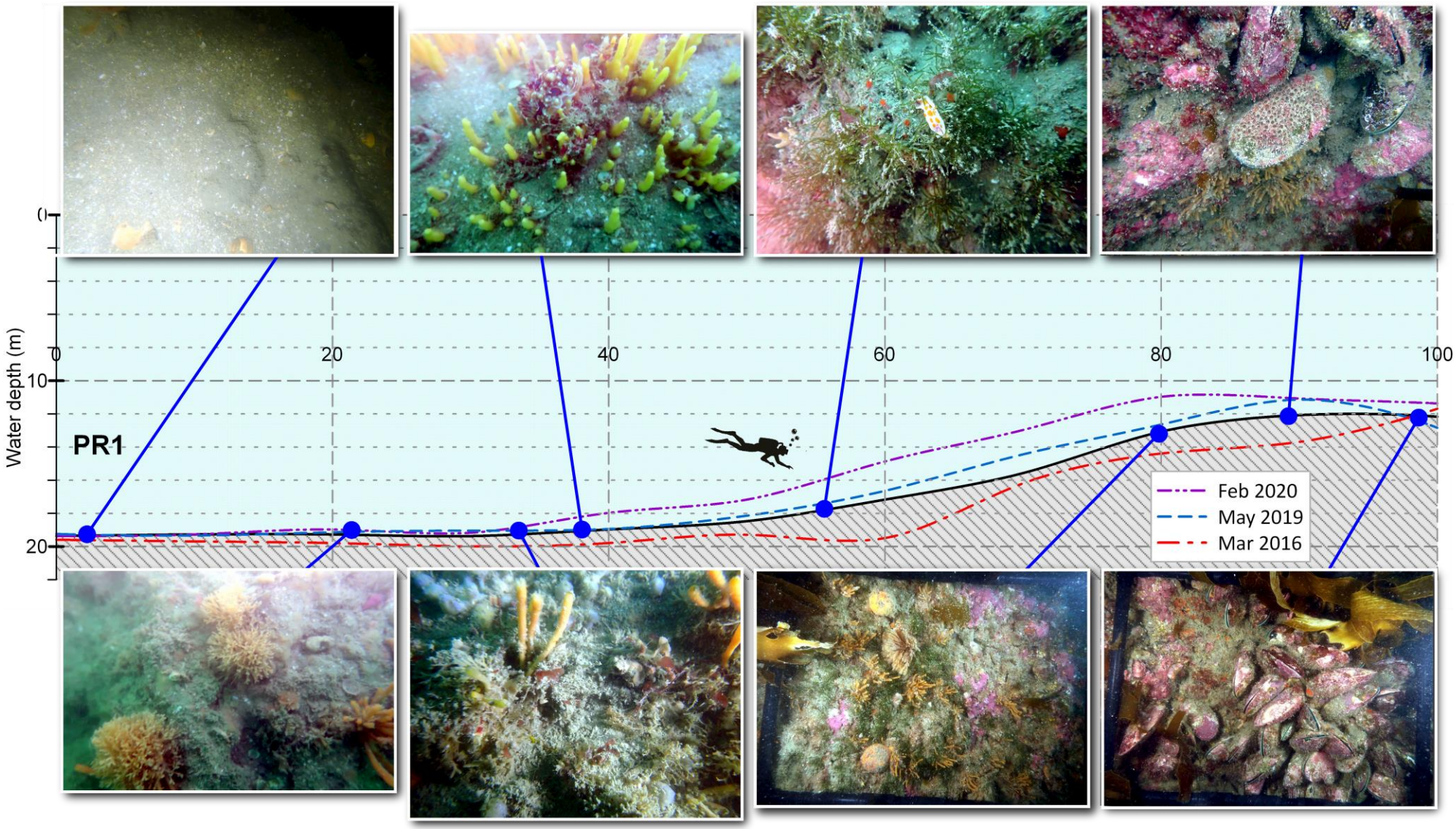

Figure 4. Depth profile with photographs of representative habitat and biota along transect PR1 in October 2020. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

Dive Transect PR2

PR2 is located on the south west side of Pania Rock. The transect begins in 14 m water depth and progresses in a north-westerly direction towards the top of Pania Rock at 4 m depth (Figure 5).

Table 3. Notes on the physical and biogenic habitats and reef communities of transect PR2 for the three baseline and the current surveys. AS = transect abundance score, which may range from zero (not present) to 40 (abundant in every 10-m section). Baseline AS values refer to the mean of three surveys.

PR2	Baseline surveys 2016–2020	October 2020
SUBSTRATE	The substrate along the first 10 m of the transect is comprised of bedrock covered in extensive sand patches and can exhibit a fine layer of silt. Thereafter, rock outcrops become more common and there is a mix of cobble, boulder, bedrock and sand with conspicuous scattered shell in places. Scattered boulder/cobble material continues until the 50–60 m marks. At 50–60 m, the reef profile becomes steeper and very uneven; featuring ridges and rock ledges with deep guts between. There are associated crevices and overlying sediment is much less a feature. The transect ends on top of Pania Rock, the shallowest point on the reef. In the shallowest sections, the surge effectively keeps reef surfaces free of fine settled silt. The presence of silt veneers in the deeper first sections has been variable across the baseline surveys.	An offset of around 10 m in transect placement can be seen in Figure 5 at the point were the profile steepens up towards Pania Rock. This has resulted in an apparent shift in the occurrence of the key reef substrates relative to the baseline surveys. Otherwise, there was no observed difference to the baseline.
ALGAE	8–11 taxa were recorded across the baseline surveys. Macrophyte communities are dominated by abundant kelp (*Ecklonia radiata*) and coralline paint. Kelp forest reached highest densities in the shallower second half of the transect. Algal communities were relatively diverse with a variety of other brown (*Zonaria angustata*, *Carpomitra costata, Halopteris* sp.) and red (*P. cirrhosum*, *Pterocladia capillacea*) seaweeds occurring. A grass-like green alga (Chlorophyta) was recorded from 2019, becoming quite common in this and other northern transects by Feb 2020. PR2 is the only transect where *Carpophyllum maschalocarpum* occurred in any density, but this was restricted to the shallow section at end of the transect. Little variability in the prevalence of the key algal species was been observed across surveys.	11 taxa recorded. The ~10 m transect shift resulted in a shift in the distribution of algae for which depth is a key influence (*E. radiata, C. maschalocarpum*). The newly recorded brown alga *Dictyota* sp. was present in low abundance (AS 2). *C. costata* was less prevalent (AS 5 vs baseline 11.7). *Halopteris* sp. was slightly more prevalent (AS 15 vs baseline 11.3). The small-bladed red alga was more prevalent (AS 14 vs AS 9 in Feb 2020), but was not recorded from the first baseline survey and was at AS 1 in the second. *C. maschalocarpum* was slightly less prevalent (AS 13 vs baseline 16.7) but possibly due to being spatially constrained by depth.

PR2	Baseline surveys 2016–2020	October 2020
INVERTEBRATE COMMUNITIES	28–34 taxa recorded across the baseline surveys. The variable substrate of the first half of the transect supports a range of invertebrate taxa in low abundances. These include sponges such as *Cliona* sp. (usually associated with coralline algae), vase sponge (*E. alata*), the emergent cf. *Ciocalypta* sp. (in sandier areas) and a grey massive sponge (Desmospongia). More variable is the presence of bryozoans such as *Steginoporella* sp., cf. *Margaretta barbata*, cf. *Cellaria tenuirostris* and Catenicellidae. The occurrence of hydroids (e.g. feather hydroid [*Aglaophenia* sp.] and mussel beard [*Amphisbetia bispinosa*]) has also varied across surveys. Colonial ascidians have been less prevalent at PR2 than at other transects, although solitary ascidians (*Cnemdiocarpa* sp.) have been occasional. Conspicuous mobile fauna include gastropods (Cook's turban shell [*Cookia sulcata*], siphon whelk [*Penion sulcatus*], white rock shell [*Dicathais orbita*], lined whelk [*Buccinulum lineum*]). While never abundant, kina (*Evechinus chloroticus*) were more common at PR2 than on other transects. There is generally lower diversity on the surge-affected reef top (depths shallower than 10 m) with tightly packed beds of large *Perna canaliculus* predominating, along with sometimes dense *Carphophyllum maschalocarpum*.	38 taxa recorded. The ~10 m transect shift resulted in a shift in the distribution of biota for which depth is a key influence (principally *P. canaliculus*). Six taxa newly recorded at PR2. Those exceeding AS 3 were: • Maroon sponge (Desmospongia F; AS 4) • Bryozoan cf. *Steginoporella* sp. (AS 6). Nine taxa previously recorded from PR2 were now absent. Those that had been consistently present across the baseline were: • Clown's hair bryozoan (Catenicellidae-baseline mean AS 10) • Sponge *Latrunculia* cf. *procumbens* (baseline mean AS 2). Taxa in greater prevalence than the baseline: • Bryozoan cf. *Cellaria tenuirostris* (AS 6 vs baseline 1.0) • Holothurian *Australostichopus mollis* (AS 8 vs baseline 2.3) None of the taxa present were identified as being less prevalent than during all of the baseline surveys.
FISH	11-14 species recorded across the baseline surveys. Due to generally clearer water, PR2 has historically presented better opportunities for observing fish life. The greater water movement also likely attracts schooling species such as butterfly perch (*Caesioperca lepidoptera*), and sweep (*Scorpis lineolatus*). The dense kelp forest also attracts species such as butterfish (*Odax pullus*) marble fish (*Aplodactylus arctidens*), leatherjackets (*P. scaber*), spotted wrasse (*N. celidotus*) and red moki (*Cheilodactulus spectabilis*). Common benthic species include the variable triplefin (*Forsterygion varium*) and the dwarf scorpion fish (*Scorpaena papillosa*). Wider ranging demersal species seen occasionally include a range of other wrasses, blue cod (*Parapercis colias*), banded perch (*Hypoplectrodes huntii*) blue moki (*Latridopsis ciliaris*), and snapper (*Pagrus auratus*).	13 species recorded. Dwarf scorpion fish, blue cod and banded wrasse (AS 11, AS 8 and AS 6, respectively) were all more abundant than during the baseline surveys. No fish species observed were consistently less abundant than during baseline.
NOTES	The northerly location and shallower depths associated with PR2 means that it generally offers the best underwater visibility of the eight transects. This has implications especially for fish observation.	Good underwater visibility (2–3 m) throughout the transect.

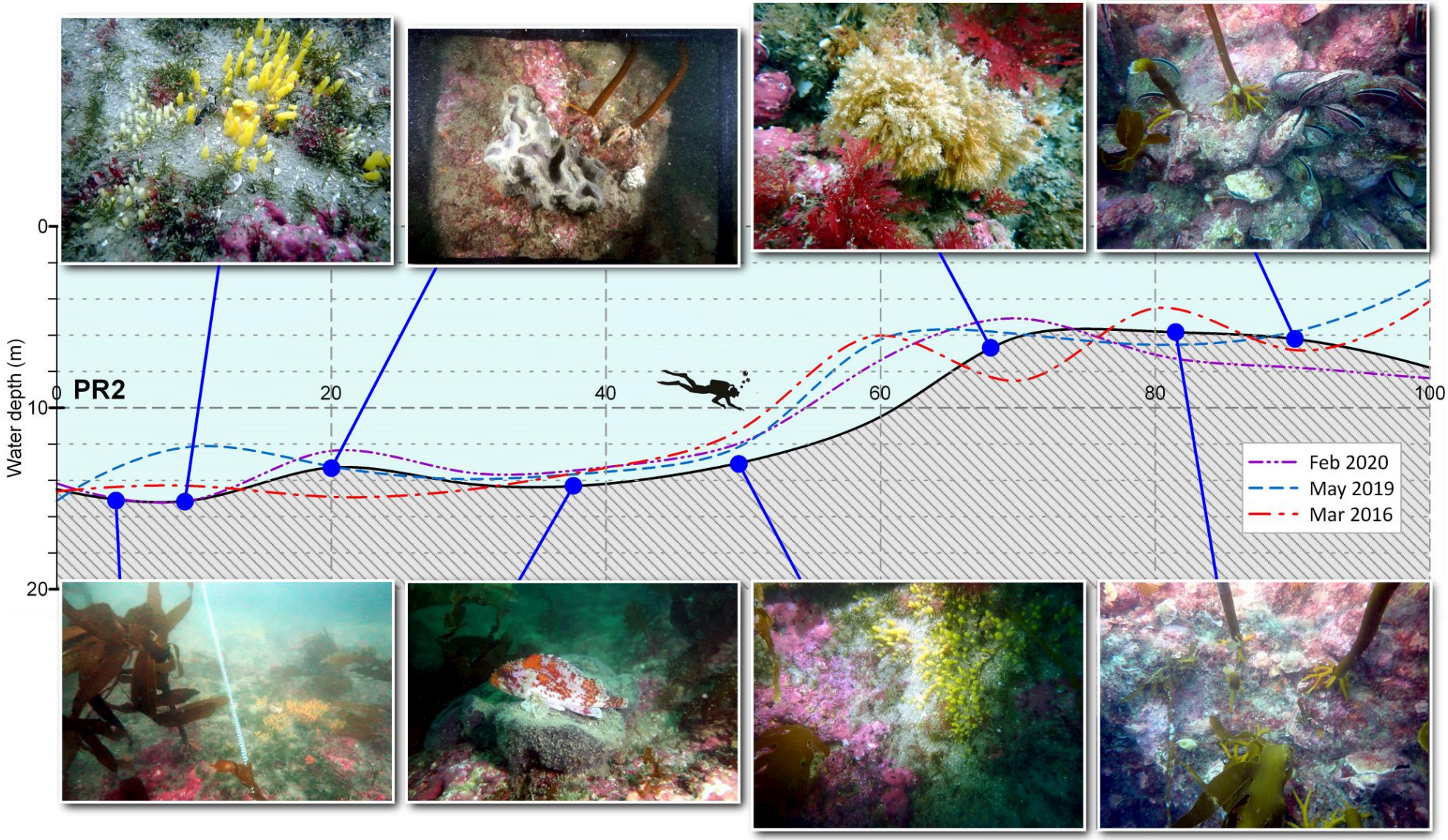

Figure 5. Depth profile with photographs of representative habitat and biota along transect PR2 in October 2020. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

Dive Transect PR5

PR5 is situated on the eastern side of the middle section of Pania Reef and runs in a south-westerly direction. The transect profile is relatively flat, fluctuating between a water depth of 18–14.5 m, with the highest point varying between surveys (Figure 6).

Table 4. Notes on the physical habitats and reef communities of transect PR5 for the three baseline and the current surveys. AS = transect abundance score, which may range from zero (not present) to 40 (abundant in every 10-m section). Baseline AS values refer to the mean of three surveys.

PR5	Baseline surveys 2016–2020	October 2020
SUBSTRATE	The greater prevalence of silty sand and frequent low visibility encountered at this transect is attributed to its generally flat profile and low-lying nature. While the substrate is principally bedrock, this can be overlain by shifting areas of rippled sand, sometimes extending for tens of metres. Where the reef emerges, it is low to moderate in relief with scattered ledges and outcrops. Embedded surface silt is usually a conspicuous feature of encrusting communities, being notably heavier than that occurring at transects PR1 and PR2. Less ephemeral sediment deposits comprise silty gravel/cobble/shell in low-lying niches.	Entirely consistent with baseline observations. Sand and shell patches beginning after 40-m mark. Uniform rippled sand between 60–80 m. Return to high-relief bedrock for the last 20 m.
ALGAE	1-3 taxa recorded across the baseline surveys. *Ecklonia radiata* was usually present but only in very low density. It may be more common in some years as recruits (Feb 2020). The macroalgae community is dominated by red algae (*P. cirrhosum* and/or small bladed red alga – Rhodophyta sp.). Corraline algae was notably absent.	3 taxa recorded. The brown alga *Dictyota* sp. was newly recorded (AS 6) from the shallower end of the transect. *P. cirrhosum* was absent, having been recorded from 2016 (AS 5) and Feb 2020 (AS 2). The red alga *Pterocladia capillacea* was absent, having been recorded from the 2019 and Feb 2020 surveys (AS 5 and AS 2, respectively). The smal-bladed red alga was at the same level as in Feb 2020 (AS 17) although it had been recorded previously only in 2016 (at AS 1).

PR5	Baseline surveys 2016–2020	October 2020
INVERTEBRATE COMMUNITIES	23-33 taxa recorded across the baseline surveys. Sessile invertebrate communites are dominated by sponges, bryozoans and ascidians. The most conspicuous sponges are grey massive (*Economia alata*) yellow tubular (*Ciocalypta* sp.) and finger sponge (*Raspailia topsenti*), although lilac (Demospongia D) yellow breadcrumb (Desmospongia E) and golfball (*Tethya burtoni*) were also always present. The orange encrusting sponge (cf.*Tedania* sp.) also occurred. Characteristic bryozoans included clowns hair, branching, (cf. *Cellaria tenuirostris*) and orange finger bryozoan (cf. Steginoporella sp.). Branching hydroids were also quite commonly recorded, and, more occasionally, feather and tree hydroids. Ascidians present were characteristically the stalked grey colonial (cf. *Synoicum otagoensis*) and saddle squirts (*Cnemidocarpa* sp.). Green-lipped mussels (*Perna canaliculis*) occurred at isolated high points along the transect. Mobile epifauna have been quite limited, but clown nudibranchs (*Ceratosoma amoena*), siphon whelks and hermit crabs were frequently present.	39 taxa recorded. Eight taxa newly recorded at PR5. Those exceeding AS 3 were: • The gastropod *Calliostoma tigris* (AS 5) Three taxa previously recorded more than once from PR5 were now absent, but none were present across all three baseline surveys. Taxa in greater prevalence than during the baseline: • Sponge *Cliona* cf. *celata* (AS 7 vs baseline 0.7) • Lilac sponge (Desmospongia D; AS 10 vs baseline 2.7) • Sponge cf. *Suberites perfectus* (AS 6) was only previously recorded from the Feb 2020 baseline survey (AS 2) • Bryozoan cf. *Steginoporella* sp. (AS 13 vs baseline 7.7) • Branching hydroid (AS 9 vs baseline 3.3) • Soft coral (*Alcyonium* cf. *aurantiacum* (AS 8 vs baseline 0.3) • Gastropod *Penion sulcatus* (AS 6 vs baseline 1.3) • Hermit crabs (Paguridae; AS 6 vs baseline 2.7) Taxa in lower prevalence than during the baseline: • Sponge *Ecionemia alata* (AS 13 vs baseline 16.3)
FISH	3-8 species recorded across the baseline surveys. Underwater visibility is often a problem for observing fish along this transect. Butterfly perch and blue cod were commonly encountered although other species were sometimes present (sweep [*S. lineolatus*], dwarf scorpion fish) or recorded as single sightings (leather jacket, red moki, and variable and common triplefins).	7 species recorded. Poor visibility for much of the transect made fish observation challenging. Butterfly perch (baseline AS 6) were not observed.
NOTES	Visibility can be very poor (0.5–1 m), sometimes marginal for good data collection. Poor light penetration to the seabed, requiring artificial lighting to adequately view and photograph benthic communities.	Poor visibility (0.5–1.0 m).

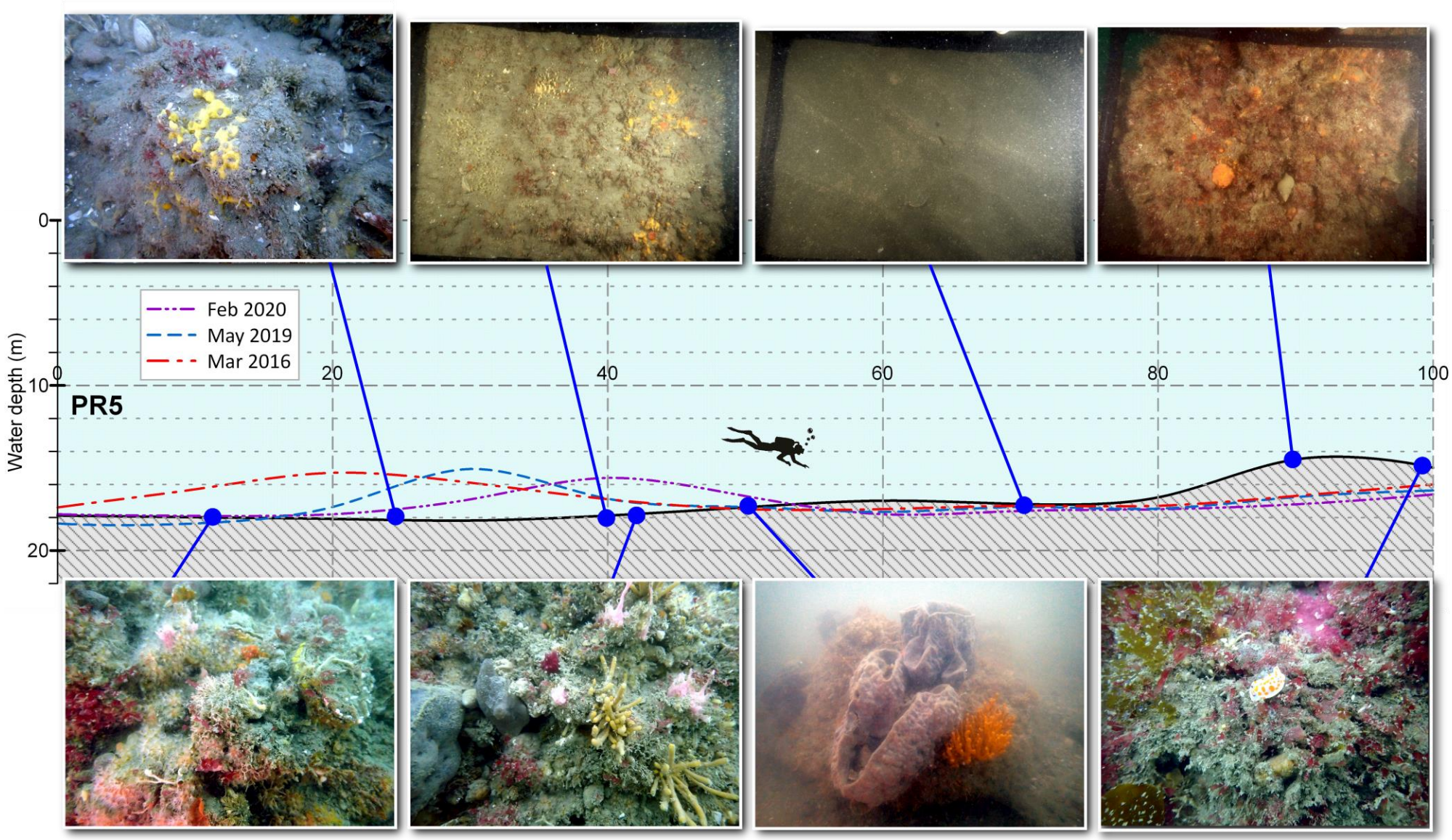

Figure 6. Depth profile with photographs of representative habitat and biota along transect PR5 in October 2020. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

Dive Transect PR3

PR3 is located on the north-west side of Pania Reef and runs in a south-easterly direction. The profile is relatively flat but varying in depth from 15 m to 9 m (Figure 7).

Table 5. Notes on the physical habitats and reef communities of transect PR3 for the three baseline and the current surveys. AS = transect abundance score, which may range from zero (not present) to 40 (abundant in every 10-m section). Baseline AS values refer to the mean of three surveys.

PR3	Baseline surveys 2016–2020	October 2020
SUBSTRATE	The seafloor is generally quite flat in profile but with moderate relief. A high point (9.5 m) was recorded at the 20-m mark in May 2019. Substrate along the transect alternates between low bedrock with ledges and some boulder/cobble material and occasional high-relief outcrops. Accumulated silty sand and shell occurs in widely dispersed pockets. Generally, there is little loose settled silt, but embedded surficial silt is a feature of encrusting communities along the profile. From 40-60 m onwards, rock surfaces are less silted but still relatively flat and overlain with sand/shell in the low points. Generally, the profile rises a little more steeply in the last 20 m of the transect, finishing in a water depth of around 10.5 m where the substrate is relatively clear of silt.	No notable change from baseline. Widely dispersed sand patches/pockets (overlying bedrock) from 50 m.
ALGAE	4-7 taxa recorded across the baseline surveys. *Ecklonia radiata* occurred over all but sometimes the last 10-m section of the transect, starting off as open canopy or scattered mature individuals but tending to decrease from the half-way mark. Of the red algae, both coralline paint and *Plocamium cirrhosum* occurred throughout the transect, with the latter at quite low density. *Carpomitra costata* and the grass-like green alga were recorded in February 2020. A fine tufted red alga was also observed, this possibly seasonal.	8 taxa recorded. No change in the prevalence of *E. radiata.* Algae newly recorded were *Halopteris* sp. (AS 4) and *Dictyota* sp. (AS 7). The small-blade red alga was more prevalent (AS 18) than previously (mean baseline AS 4.7). The grass-like green alga (AS 21) and *C. costata* (AS 4) were at similar abundance to that of Feb 2020 (AS 23 and AS 3, respectively) but neither had been recorded from the first two baseline surveys. Coralline paint was slightly less prevalent (AS 25) than during the baseline (mean AS 29.3).

PR3	Baseline surveys 2016–2020	October 2020
INVERTEBRATE COMMUNITIES	22–39 taxa recorded across the baseline surveys. Sessile invertebrate communities over most of the transect were dominated by sponges. The most visually prominent being *Ecionemia alata, Raspailia topsenti, Ciocalypta* sp., *Tethya burtoni*, with *Cliona* cf. *celata* occurring within areas of corraline paint. The lilac sponge (Demospongiae D) is generally also present throughout the transect, with the yellow breadcrumb sponge (Demospongiae E) and cf. *Suberites* sp. occurring more variably. The most conspicuous bryozoans were clowns hair (Catenicellidae), branching (cf. *Cellaria tenuirostris*) and *Steginoporella* sp., although the fan-like cf. *Caberea zelandica* could also be present in low numbers. Feather hydroids (*Aglaophenia* sp.) and branching hydroids occurred occasionally, along with mussel beard (*Amphisbetia bispinosa*) where there were beds of green-lipped mussels (*Perna canaliculus*). The most commonly occurring ascidian has been the grey/white stalked colonial ascidian (cf. *Synoicum otagoensis*), usually in deeper sections. Two of the *Didemnum* species complex also occured in some years, as did solitary ascidians (*Cnemidocarpa* sp.), but none of these conspicuously. After the 80-m mark, *P. canaliculus* could be common to abundant. However, this varied depending on how well the shotline had been placed relative to the reef crest where they occurred. The most commonly occurring mobile epifauna were gastropods. These included clown nudibranch (*Ceratosoma amoena*), siphon whelk (*Penion sulcatus*) and tiger (*Calliostoma tigris*) and green (*Trochus viridus*) topshells. Hermit crabs and sea cucumbers (*Australostichopus molis*) were usually also present in low numbers.	36 taxa recorded. Five taxa were newly recorded at PR3, but none of these exceeded AS 3 in abundance: Seven taxa previously recorded more than once from PR3 were now absent. Those that had been consistently present across the baseline were: • Ascidian *Cnemdiocarpa* sp. (baseline mean AS 9.7, although only AS 2 in Feb 2020) Taxa in greater prevalence than during the baseline: • Orange sponge cf.*Tedania* sp. (AS 5 vs baseline 0.7) • Yellow sponge (Demospongia E; AS 9 vs baseline 1.3) • Sponge, orange lobed (AS 4 vs baseline 0.3) • Bryozoan cf. *Steginoporella* sp. (AS 22 vs baseline 7.7) • Branching hydroid (AS 5 vs baseline 1.0, although it was entirely absent from the first two surveys)) Taxa in lower prevalence than during the baseline: • Mussel *P. canaliculus* (AS 1 vs baseline 7.7)
FISH	8–14 species recorded across the baseline surveys. Fish encountered along the transect have included: butterfly perch (*Caesioperca lepidoptera*), sweep (*Scorpis lineolata*), spotted wrasse and variable triplefin. At shallower depths (< 12 m) blue cod, leather jacket, dwarf scorpion fish, scarlet wrasse, red moki (*Cheilodactulus spectabilis*), banded wrasse, hiwihiwi (*Chironemus marmoratus*) and marblefish (*Aplodactylus arctidens*) have been recorded. Oblique triplefins (*Forsterygion maryannae*) were recorded in 2016 but not thereafter.	8 species recorded. Butterfly perch (AS 8) and scarlet wrasse (AS 6) were the most commonly observed. However, the former were notably less abundant than during the baseline (mean AS 23.3). Of the species recorded from at least two baseline surveys, three were absent (sweep, and spotted and banded wrasse).

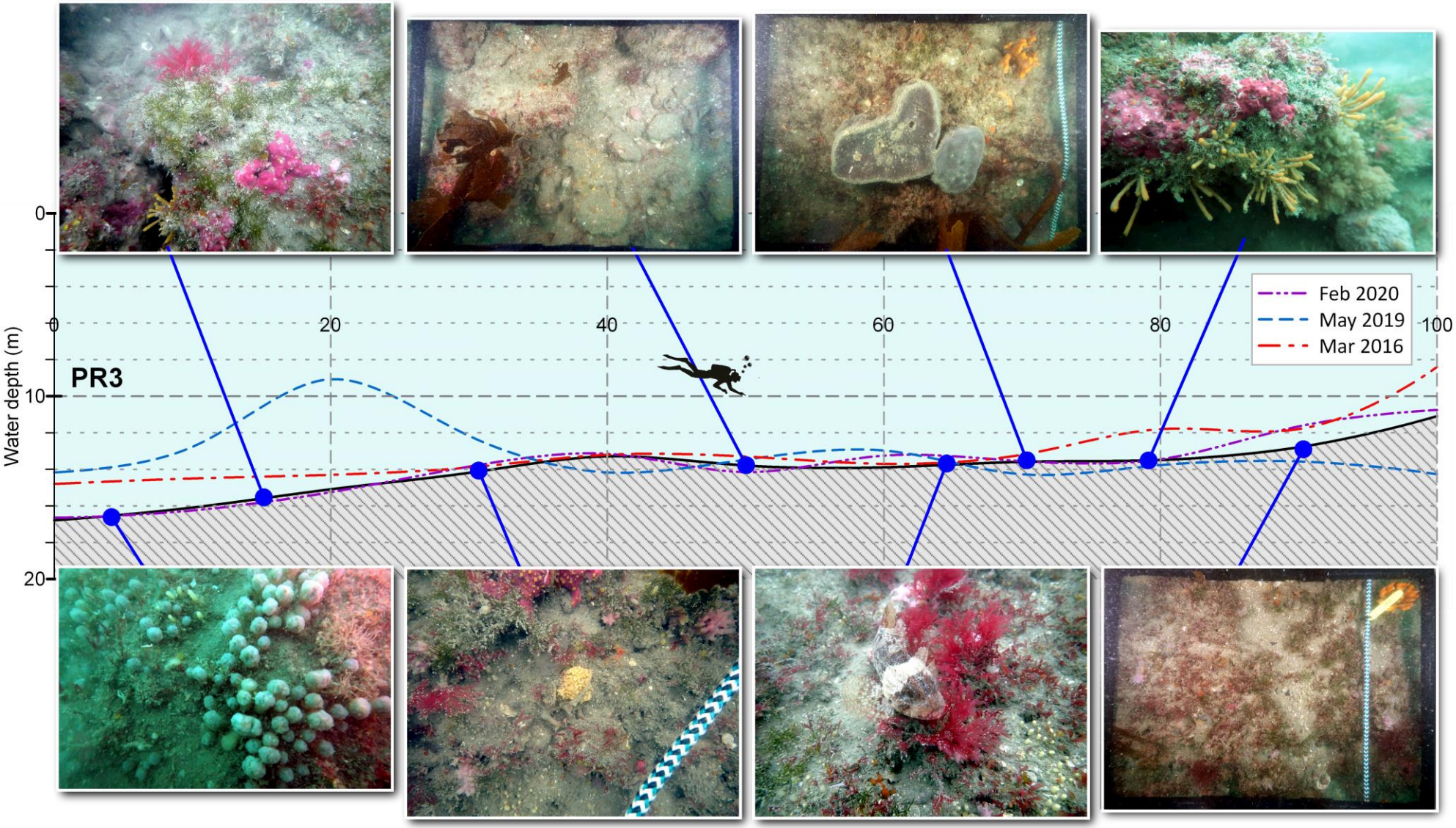

Figure 7. Depth profile with photographs of representative habitat and biota along transect PR3 in October 2020. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

Dive Transect PR6

PR6 is situated on the north-eastern side of the southern section of Pania Reef. The transect runs in a south-easterly direction and is deepest (16 m) along the first 50 m (Figure 8). After this it rises to its shallowest depth of 10 m at the 70–80 m distance marks before descending again to approximately 14 m depth at the end.

Table 6. Notes on the physical habitats and reef communities of transect PR6 for the three baseline and current surveys. AS = transect abundance score, which may range from zero (not present) to 40 (abundant in every 10-m section). Baseline AS values refer to the mean of three surveys.

PR6	Baseline surveys 2016–2020	October 2020
SUBSTRATE	The first 70 m is largely flat in profile with low to moderate relief bedrock covered in sandy patches at points. Otherwise, silty sand only in small pockets and niches. Occasional ledges occur for first 70 m but the main feature of the profile is a large vertical outcrop between the 70-80 m marks. Entrapped/embedded silt is a feature of encrusting communities but noticeably less silt occurs over the shallower section . The end of the transect was shallower in Feb 2020 (11.5 m) than recorded previously.	The October 2020 profile was most notable for the absence of the shallow point at 70-80 m. This will be related to a lateral shift in transect placement. Otherwise, the reef surface was as described for the baseline.
ALGAE	3-5 taxa recorded across the baseline surveys. *Ecklonia radiata* was the only brown alga to have been recorded and this was generally common only after the 50-m mark but may have occurred as recruits (up to ~30 cm high) along the entire transect. Coralline paint was present at low levels. *Plocamium cirrhosum* and small-bladed red alga also occurred throughout but were variable from year to year.	5 taxa recorded. The absence of the reef crest normally present at 70–80 m distance is likely to have resulted in changes in overall abundance for *E. radiata*. The brown alga *Dictyota* sp. was newly recorded at very low level (AS 1). No algae previously recorded more than once were now absent. No algae were more prevalent than during the baseline. Algae in lower prevalence were: • Kelp *E. radiata* (AS 6 vs baseline 16.0) • Encrusting coralline (AS 4 vs baseline 11.0) • *P. cirrhosum* (AS 6 vs baseline 16.0)

PR6	Baseline surveys 2016–2020	October 2020
INVERTEBRATE COMMUNITIES	27-42 taxa recorded across the baseline surveys. Sessile invetebrate communities mostly comprised sponges, bryozoans, hydroids and ascidians. The dominant sponges included: grey vase sponge (*Ecionemia alata*), orange encrusting sponge (cf. *Tedania* sp.), *Ciocalypta* sp., lilac sponge (Demospongiae sp. D), grey lobed sponge (cf. *Thorecta* sp.) and *Raspailia topsenti*. Golfball sponges (both *Tethya bergquistae* and *T. burtoni*) were usually present. Sponges occuring more variably included yellow breadcrumb sponge (Demospongiae sp. E), the boring sponge (*Cliona* cf. *celata*) and the globose sponge (*Aaptos globosum*). Prominent bryozoans included clowns hair (Catenicellidae) and *Steginoporella* sp., although both cf. *Cellaria tenuirostris* and cf. *Caberea zelandica* featured in two of the three surveys. Fine branching hydroids and mussel beard have been characteristic. The soft coral (*Alcyonium* cf. *aurantiacum*) and stony coral (*Culicea rubiola*) have been recorded from the two most recent surveys, as was a prominent zoanthid colony on the overhang beneath the reef crest at the 70 m mark. Of the ascidians, the stalked (cf *Synoicum otagoensis*) and translucent white (*Eudistoma* sp.) colonial ascidians have featured consistently. Saddle squirts (*Cnemidocarpa sp.*) and the colonial white *Didemnum* sp. have been variable in their occurrence. A small red ascidian (Ascidiacea sp. A) appears particularly variable, occurring in high numbers in 2019 only. Green-lipped mussels (*Perna canaliculus*) were consistently present as a dense bed on the reef crest between 70–90 m. Mobile invertebrates, present in small numbers, have included clown nudibranch (*Ceratosoma amoena*), siphon whelk (*Penion sulcatus*), hermit crabs and sea cucumbers. The top shells *C Calliostoma tigris* and *Trochus viridus* also featured, as well as kina (*Evechinus chloroticus*) in 2019 only.	29 taxa recorded. The absence of the reef crest normally present at 70-80 m distance is likely to have resulted in changes in overall abundance for mussels. Four taxa newly recorded at PR6. Those exceeding AS 3 were: • Sponge cf. *Suberites perfectus* (AS 4) 16 taxa previously recorded more than once from PR6 were now absent. Those that had been consistently present across the baseline were: • Sponge *Tethya bergquistae* (mean baseline AS 4) • Colonial ascidian *Eudistoma* sp. (mean baseline AS 5.3) • Hermit crabs Paguridae (mean baseline AS 4) Taxa in greater prevalence than during the baseline: • Sponge *E. alata* (AS 29 vs baseline 18.3) • Sponge *T. burtoni* (AS 7 vs baseline 1.7) • Lilac sponge (Desmospongia D; AS 20 vs baseline 14.3) • Bryozoan cf. *Steginoporella* sp. (AS 21 vs baseline 11.3) Taxa in lower prevalence than during the baseline: • Mussel *P. canaliculus* (AS 6 vs baseline 15) • Bryozoan Catenicellidae (AS 1 vs baseline 7.7)
FISH	10-14 species recorded across the baseline surveys. Fish recorded characteristically include butterfly perch, scarlet, banded and spotted wrasse, sweep, blue cod, red moki, dwarf scorpion fish, and several triplefin, species. Other species observed include tarakihi (*Nemadactylus macropterus*), leather jacket, banded perch and the pelagic schooling horse mackerel (*Trachurus* sp.).	2 species recorded. Poor visibility (0.5–1.0 m) effectively precluded fish observation. The only fish observed were two dwarf scorpion fish and a single scarlet wrasse all near the beginning of the transect.
NOTES		Compilation of the record was hindered by marginal underwater visibility (~0.5–1.0 m).

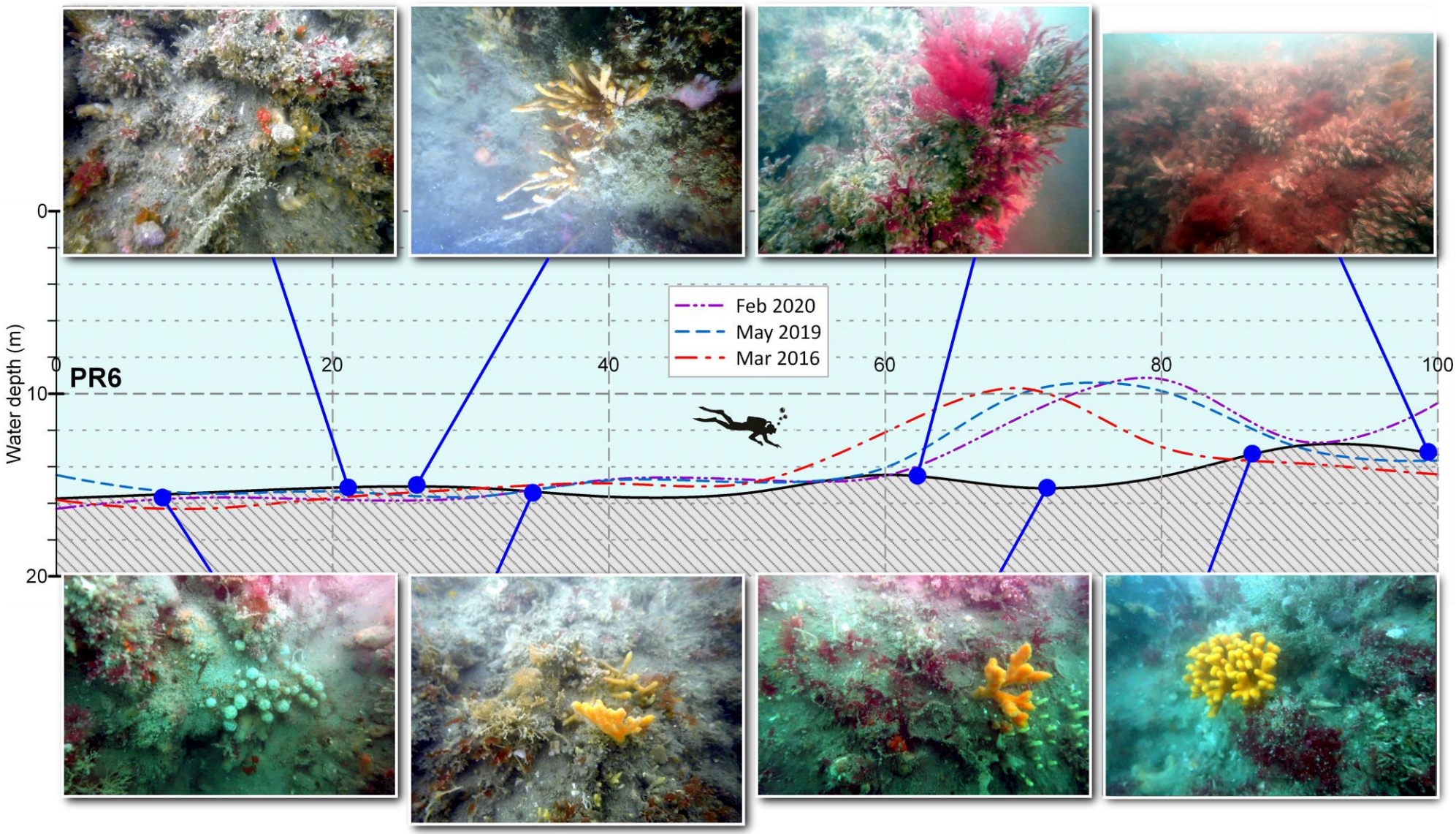

Figure 8. Depth profile with photographs of representative habitat and biota along transect PR6 in October 2020. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

Dive Transect PR4

PR4 is located on the north-westerly side of the most southern section of Pania Reef and runs in a south–easterly direction. The transect profile is relatively flat, fluctuating between 13–10 m water depth (Figure 9).

Table 7. Notes on the physical habitats and reef communities of transect PR4 for the three baseline and current surveys. AS = transect abundance score, which may range from zero (not present) to 40 (abundant in every 10-m section). Baseline AS values refer to the mean of three surveys.

PR4	Baseline surveys 2016–2020	October 2020
SUBSTRATE	The substrate along the transect largely comprises moderate- to high-relief bedrock, with some low uneven sections where there are dispersed small pockets of silty sand in niches. Some pockets of cobble material have also been noted. Heavy entrapped silt is a consistent feature of reef surfaces and encrusting communities. Settled silt veneers occur in some conditions.	Poor visibility from suspended particulate material. Previously recorded sand and cobble pockets were absent, although the reef terrain was otherwise visibly similar to baseline conditions.
ALGAE	4 taxa recorded across the baseline surveys. *Ecklonia radiata* was occasional to common along the transect length, but tended to be abundant in the last 10 m. Both *Plocamium cirrhosum* and the small-bladed red alga were consistently present. Coralline paint was more prevalent at the shallow end of the transect.	8 taxa recorded. *E. radiata* (AS 22) present at levels similar to baseline. Four newly recorded algal taxa (*Dictyota* sp., *C. costata, Halopteris* sp., grass-like green alga) but none present at AS >3). No algae previously recorded were now absent. No algae less prevalent than during baseline.

PR4	Baseline surveys 2016–2020	October 2020
INVERTEBRATE COMMUNITIES	28–36 taxa recorded across the baseline surveys. Invertebrate communities were relatively consistent along the transect, with sponges a conspicuous presence. The commonest sponges were *Ecionemia alata*, *Raspailia topsenti*, *Ciocalypta* sp. and *Thethya burtoni*. Also frequently recorded are *Cliona* cf. *celata,* yellow breadcrumb sponge (Demospongia E), the lilac sponge (Demospongia D) and an orange encrusting sponge (cf. *Tedania* sp.). In Feb 2020, the grey sponge cf. *Suberites* sp. was 'occasional'. Other conspicuous biota included bryozoans (Catenicellidae, *Steginoporella* sp. and cf. *Cellaria tenuirostris*) and a feather hydroid (*Aglaophenia* sp.). Branching hydroids, notable in 2019, were variable between surveys but *Amphisbetia bispinosa* was usually associated with mussel beds. Colonial ascidians were also a consistent presence, with white *Didemnum,* the translucent cf. *Eudistoma* sp. and the stalked cf. *Synoicum otagoensis* recorded. Solitary ascidians such as *Cnemidocarpa* sp. and the small Ascidiacea sp. A were variable across surveys. Green-lipped mussels (*Perna canaliculus*) were consistently recorded from the shallower final 10 m of the transect, but in 2019, a dense bed was also observed on a low reef crest at the 50 m mark. Mobile epifauna were sparse, with only a few species that are common to the rest of the reef. These include the gastropods clown nudibranch (*Ceratosoma amoena*), siphon whelk (*Penion sulcatus*), top shells (*T. viridus*) and occasionally the swollen trumpet (*Argobuccinum pustulosum*). As elsewhere, hermit crabs were generally present in low numbers but sea cucumbers were seldomly recorded.	40 taxa recorded. Six taxa newly recorded at PR4. Those exceeding AS 3 were: • Bryozoan encrusting (AS 4) • Gastropod *Calliostoma tigris* (AS 6) Six taxa previously recorded from PR4 were now absent. Those that had been consistently present across the baseline were: • Sponge *Tethya bergquistae* (baseline mean AS 1.7) • Mussel *P. canaliculus* (baseline mean AS 5.3) Taxa in greater prevalence than the baseline: • Lilac sponge (Desmospongia D; AS 21 vs baseline 13.7) • Bryozoan cf. *Steginoporella* sp. (AS 16 vs baseline 6.0) • Branching hydroid (AS 5 vs baseline 1.7) • Soft coral *Alcyonium* cf. *aurantiacum* (AS 7 vs baseline 0.3) • Ascidiacea sp. A (AS 5 vs baseline 1.0). Although, of the 3 baseline surveys, these were only present in 2019 (AS 3). Taxa in lower prevalence than the baseline: • White colonial ascidian *Didemnum* sp. (AS 2 vs baseline 6.7)
FISH	3 015010 species recorded across the baseline surveys. The most commonly observed fish species have been butterfly perch, blue cod, scarlet wrasse dwarf scorpion fish and spotted wrasse. Others recorded from more than a single observation were tarakihi, sweep, and variable and banded triplefins.	3 taxa recorded. Dwarf scorpion fish, tarakihi and sea horse (*Hippocampus abdominalis* – new to the Pania Reef survey inventory). Only the single sea horse was visible on reviewed video footage.
NOTES	Occasionally poor visibility (0.5 01501.0 m) affecting quality of quadrat photos and recorded video.	Underwater visibility (~0.5 m) was marginal for photography. Few usable photoquadrats were collected. Due to poor photographic results, fewer adjustments were made to the transect reef taxa record via review of the photgraphic record than for the other transects.

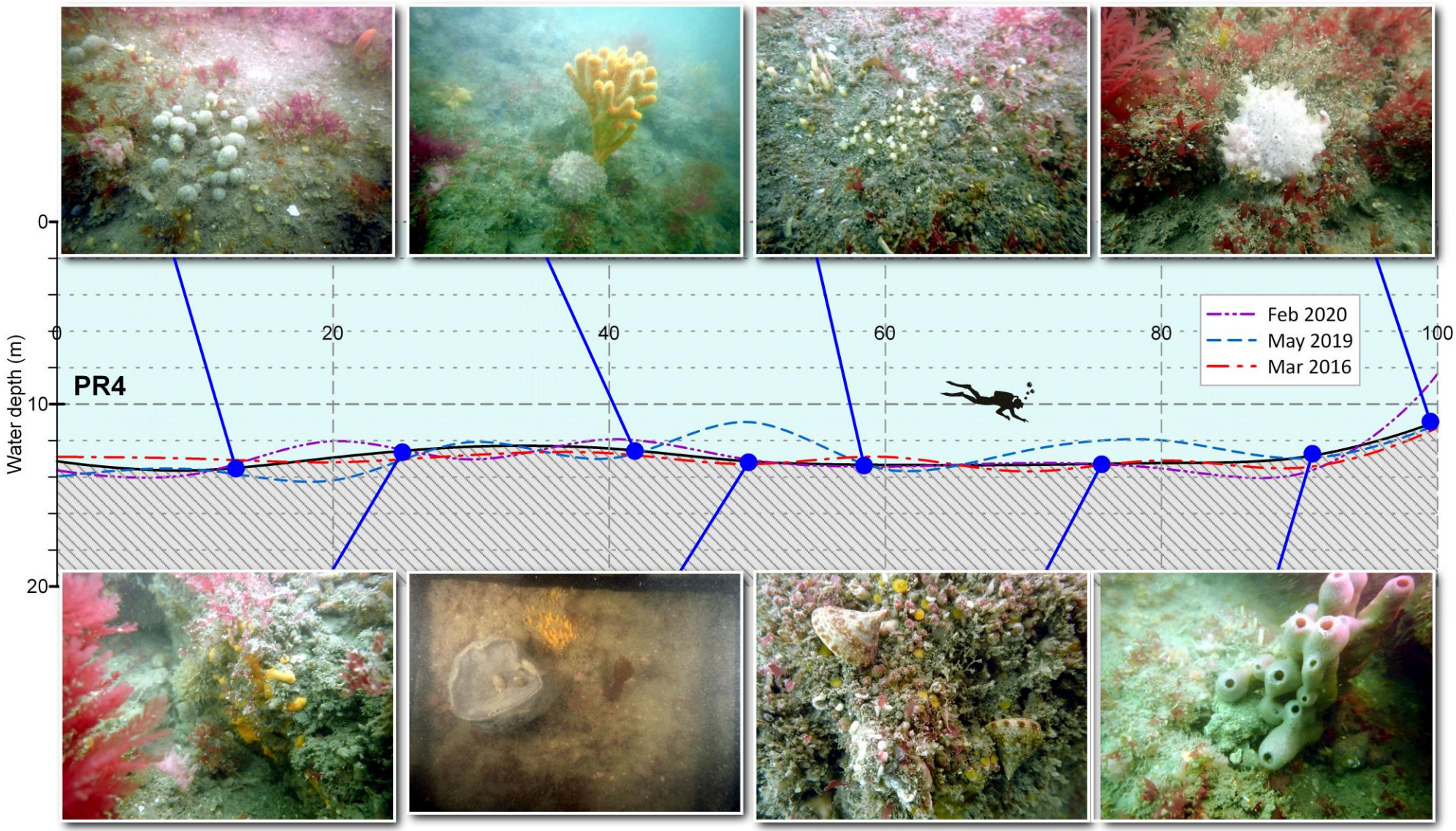

Figure 9. Depth profile with photographs of representative habitat and biota along transect PR4 in October 2020. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

Dive Transect PR7

PR7 is located on the north-eastern side of Pania Reef and runs in a south-easterly direction. The transect profile is undulating but rises gently from 16 m water depth to 11 m depth at the end (Figure 10).

Table 8. Notes on the physical habitats and reef communities of transect PR7 for the three baseline and current surveys. AS = transect abundance score, which may range from zero (not present) to 40 (abundant in every 10-m section). Baseline AS values refer to the mean of three surveys.

PR7	Baseline surveys 2016–2020	October 2020
SUBSTRATE	The substrate is low-relief uneven bedrock punctuated with ledges, holes and fissures and overlaid with a heavy covering of embedded silt. The first 20-30 m of the transect may be overlain with mobile sand with the bedrock emergent in places. Sand patches and scattered shell are found in low spots and niches. Also pockets of gravel/ pebble/ shell/ cobble. The heavy embedded silt can cause the benthos to appear superficially barren. Rising gradually up to the reef crest from the 60 m mark, low outcrops and ledges become more frequent and silt becomes slightly less pravalent.	No sections featured mobile sand. Otherwise no notable change from the baseline.
ALGAE	3-4 taxa recorded across the baseline surveys. *Ecklonia radiata* occurred all along the transect but, until the last 30 m, these were sporadic and often stunted plants or recruits. In the shallower waters at the end of the transect, it became abundant. *Procamium cirrhosum* and the small bladed red alga both also occur along the entire transect. Coralline algae occurs sparsely in the last 30 m.	5 taxa recorded. *Dictyota* sp. (AS 13) was newly recorded at PR7, most prevalent at the shallow end of the transect. All other algae occurred within the range of abundance recorded over the baseline.

PR7	Baseline surveys 2016–2020	October 2020
INVERTEBRATE COMMUNITIES	26–49 taxa recorded across the baseline surveys. Sponges were the most commonly occurring conspicuous taxa. *Eciomonia alata*, *Ciocalypta* sp., *Raspailia topsenti*, lilac sponge (Demospongiae sp. D), yellow breadcrumb (Demospongiae sp. E) and both golfball sponges (*Tethya bergquistae* and *T. burtoni*) have been consistently present. Also frequently recorded were orange encrusting (cf.*Tedania* sp.), globose (cf. *Aaptos globosum*) and lobed grey (cf. *Thorecta* sp.) sponges. *Cliona* cf. *celata* and a conspicuous yellow finger sponge (cf. *Iophon minor*) were newly recorded in Feb 2020. As on other southern Pania Reef transects, three bryozoans were common: clowns hair (Catenicellidae), branching (cf. *Cellaria tenuirostris*) and *Steginoporella* sp. An encrusting bryozoan was prominent in 2019. The common occurrence of the white-striped anemone (*Anthothoe albocincta*) separated PR7 from the more northern transects. Other cnidarians included feather (cf. *Aglaophenia* sp.) and branching hydroids, soft coral (*Alcyonium* cf. *aurantiacum*) and stony coral (*Culicea rubiola*). Ascidians were also more prevalent than on the northern Reef: Colonial (cf. *Synoicum otagoensis Eudistoma* sp. and *Didemnum* spp.) and solitary (*Cnemidocarpa* sp., Ascidiacea sp. A, *Pyura spinosissima*). Green-lipped mussels (*Perna canaliculis*) were recorded as common in the last 30 m. Flat oysters (Ostreidae) were observed occasionally. Conspicuous mobile epifauna along the transect has included the clown nudibranch (*Ceratostoma amoena*) along with other gastropods (*Penton sulcatus, Buccinulum lineum, Calliostoma tigris*) and hermit crabs. The sea cucumber (*Australostichopus mollis*) was more common than on the northern Reef. Spiny rock lobster (*Jasus edwardsii*) were also more often observed on the southern Reef transects.	55 taxa recorded. Eight taxa newly recorded at PR7. Those exceeding AS 3 were: • Sponge cf. *Suberites perfectus* (AS 4) Four taxa previously recorded more than once from PR7 were now absent, although none had been consistently present across the baseline surveys: Taxa in greater prevalence than during the baseline: • Sponge *E. alata* (AS 20 vs baseline 16.0) • Sponge *Cliona* cf. *celata* (AS 7, previously recorded only in Feb 2020 at AS 6) • Sponge *Ciocalypta* sp. (AS 26 vs baseline 20.3) • Sponge pink Demospongia C (AS 9 vs baseline 1.7) • Sponge cf. *Aaptos globosum* (AS 18 vs baseline 4.0) • Bryozoan cf. *Steginoporella* sp. (AS 13 vs baseline 6.0) • Mussel beard *Amphisbetia bispinosa* (AS 4 vs baseline 0.7) • Gastropod *Penion sulcatus* (AS 7 vs 3.0) • Hermit crabs (Paguridae; AS 6 vs baseline 2.0) None of the taxa present were identified as being less prevalent than during every one of the baseline surveys.
FISH	6-12 species recorded across the baseline surveys. The fish species most commonly encountered have been blue cod, butterfly perch, scarlet wrasse and variable triplefin. Dwarf scorpion fish, spotted wrasse and banded triplefin, are also often observed.	9 species recorded. No species recorded from at least two baseline surveys were absent, although most of the more common species were less prevalent than in Feb 2020.
NOTES	As with the southern half of Pania Reef generally, this transect is frequently subject to poor underwater visibility (0.5–1 m in 2019; ~1 m in Feb 2020).	

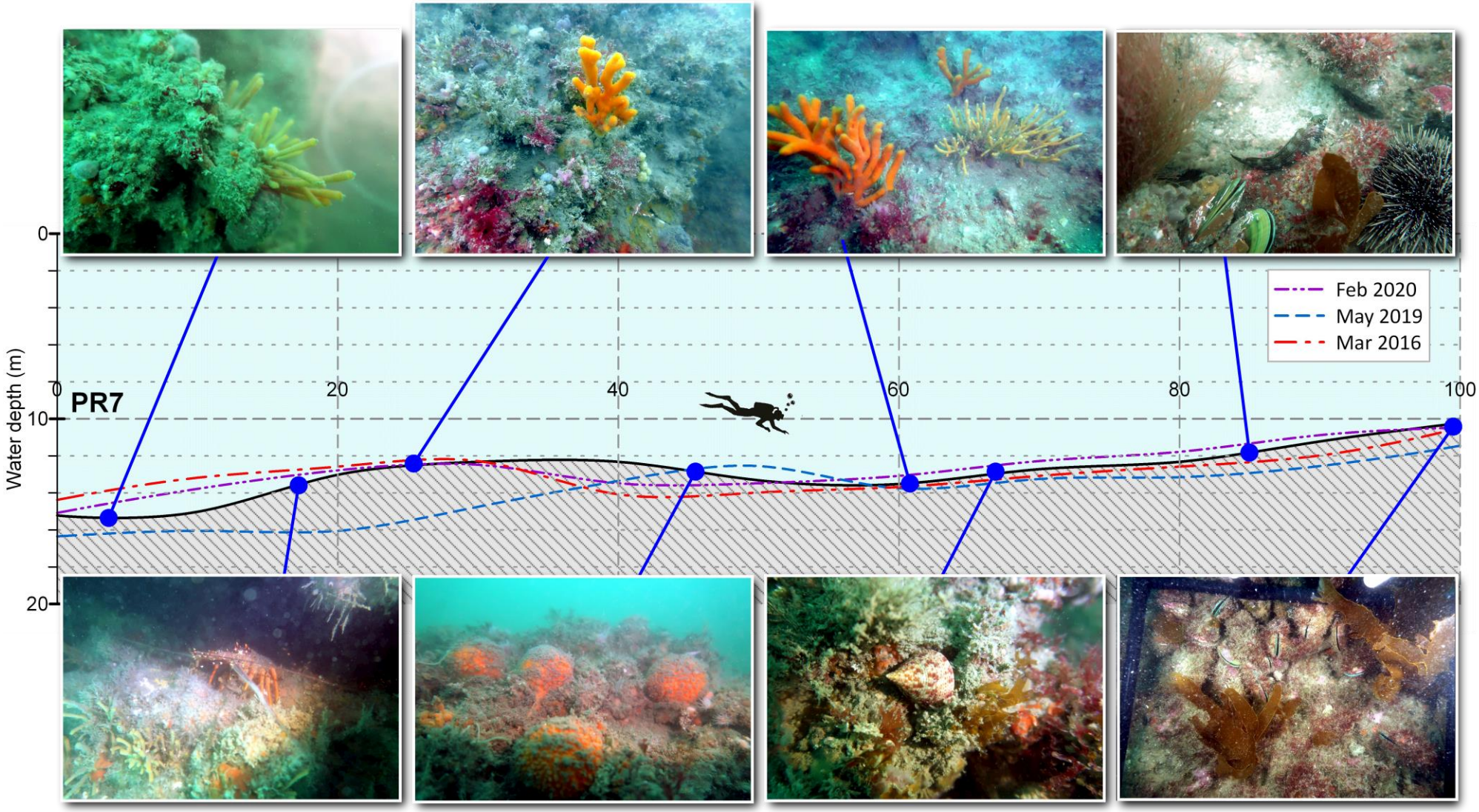

Figure 10. Depth profile with photographs of representative habitat and biota along transect PR7 in October 2020. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

Dive Transect PR8

PR8 is the southernmost transect (closest to the shore) on Pania Reef and runs in a south-easterly direction. The transect profile begins at 16 m depth and, from around the 20 m mark rises to 12 m depth after which it is relatively flat, fluctuating between 13–11 m depth (Figure 11).

Table 9. Notes on the physical habitats and reef communities of transect PR8 for the three baseline and current surveys. AS = transect abundance score, which may range from zero (not present) to 40 (abundant in every 10-m section). Baseline AS values refer to the mean of three surveys.

PR8	Baseline surveys 2016–2020	October 2020
SUBSTRATE	Relatively flat profile. Uniform soft silty sand has been recorded at either end of the transect but silt-covered bedrock predominates. The seabed terrain is similar to that of PR7. Low uneven bedrock (moderate relief with low ledges and outcrops) occurs throughout the transect. Patches of embedded boulders. Occasional larger boulders and outcrops. Small pockets of gravel/ pebble/ shell in low spots and niches. A heavy silt layer (primarily embedded within encrusting communities) is consistently present along the full transect length but an easily disturbed silt layer was also recorded in 2019.	Unlike in previous surveys, no sand was recorded along PR8 as a distinct substrate.However, there were, as before, scattered small niches of shell/sand/pebble material. Otherwise, there was no difference in the character of the reef surface.
ALGAE	2-3 taxa recorded across the baseline surveys. Generally a sparse macroalgal community, limited to red algae (*Plocamium cirrhosum* and the small-bladed red alga). Coralline paint was recorded (as rare) from the 2016 survey only. *Ecklonia radiata* was conspicuously absent.	4 taxa recorded. *Dictyota* sp. (AS 9) was newly recorded at PR8. Small-bladed red alga had increased in prevalence (AS 24 vs baseline 13.0). *P. cirrhosum* had decreased in prevalence (AS 7 vs baseline 12.0).

PR8	Baseline surveys 2016–2020	October 2020
INVERTEBRATE COMMUNITIES	34–44 taxa recorded acroos the baseline surveys. Similar communities to those of PR7. The most common sponges being *Eciomonia alata*, *Ciocalypta* sp., *Raspailia topsenti*, lilac Demospongiae D, yellow Demospongiae E, orange encrusting (cf. *Tedania* sp.), Also consistently occurring were golfball sponges (*Tethya burtoni* and *T. bergquistae*) and lobed grey sponge (cf. *Thorecta* sp.). The yellow boring sponge (*Cliona* cf. *celata*) has been recorded and an erect branching sponge (cf. *Callyspongia ramosa*) that is also more common on Town Reef. A red emergent/encrusting sponge (cf. *Stylopus australis*) and an unidentified orange sponge with an an apparent honeycomb structure were notable in 2019. A lobed lavender sponge (*Callyspongia* cf. *annulata*) was occasional in Feb 2020. The clowns hair (Catenicellidae) and orange finger (*Steginoporella* sp.) bryozoans were the most prevalent of this phylum, both increasing across the baseline surveys. Similar to PR7, the white-striped anemone (*Anthothoe albocincta*) was notably common, along with feather hydroids. Branching hydroids and soft coral also appeared to be more prevalent at this southern end of the Reef. The assemblage of ascidians has been similar to that of PR7: cf. *Synoicum otagoensis*, *Eudistoma* sp., cream and white *Didemnum* sp., *Cnemidocarpa* sp., *Pyura spinosissima* and Ascidiacea sp. A (prevalent in 2019). The green-lipped mussel (*Perna canaliculis*) was been mostly absent but in 2016, horse mussels (*Atrina zelandica*) were observed in the sandy habitat at the start of the transect. Flat oysters (*Ostreia* sp.) were recorded in low numbers. Just a few mobile invertebrates occur in low numbers: clown nudibranch (*C. amoena*), *P. sulcatus* and lined whelk (*Buccinulum lineum*), *Calliostoma punctulatum, Trochus viridus,* sea cucumber (*Australostichopus mollis*) and hermit crabs.	47 taxa recorded. Eight taxa newly recorded at PR8. Those exceeding AS 3 were: • Sponge Pink Demospongia C (AS 4) • Gastropod Muracidae (unid; AS 4) Seven taxa previously recorded from PR8 were now absent. Those that had been consistently present across the baseline were: • Crayfish *Jasus edwardsii* (baseline mean AS 2.0) • Holothurian *Australostichopus mollis* (baseline mean AS 2.3) Taxa in greater prevalence than during the baseline: • Sponge *Cliona* cf. *celata* (AS 8 vs baseline 3.0) • Sponge *T. bergquistae* (AS 6 vs baseline 1.7) • Lilac sponge Demospongia D (AS 23 vs baseline 18.0) • Yellow sponge Demospongia E (AS 11 vs baseline 7.7) • Branching sponge cf. *Callyspongia ramosa* (AS 7 vs baseline 3.0) • Sponge cf. *Suberites perfectus* (AS 5; previously recorded only in Feb 2020 at AS 3) • Bryozoan cf. *Steginoporella* sp. (AS 21 vs baseline 10.0) • Bryozoan encrusting (AS 7; previously recorded only in 2019 at AS 2) • Branching hydroid (AS 10 vs baseline 4.3; but was not recorded in 2016) Taxa in lower prevalence than during the baseline: • Anemone *Anthothoe albocincta* (AS 11 vs baseline 16.3) • Ascidian *Cnemdiocarpa* sp. (AS 4 vs baseline 10.7) • Colonial ascidian *Eudistoma* sp. (AS 8 vs baseline 11.7)
FISH	6–8 species recorded across the baseline surveys. Species consistently present included butterfly perch, blue cod, spotted wrasse and variable triplefin. Others commonly recorded have been scarlet wrasse (2016) and tarakihi (Feb 2020).	5 species recorded. Except for triplefins (*F. varium*), only single individuals of each species were observed. First recording at PR8 of red moki and conger eel (*Conger verreauxi*), the latter new to the Pania Reef survey inventory. Of species consistently recorded across the baseline surveys, butterfly perch and spotted wrasse were absent.

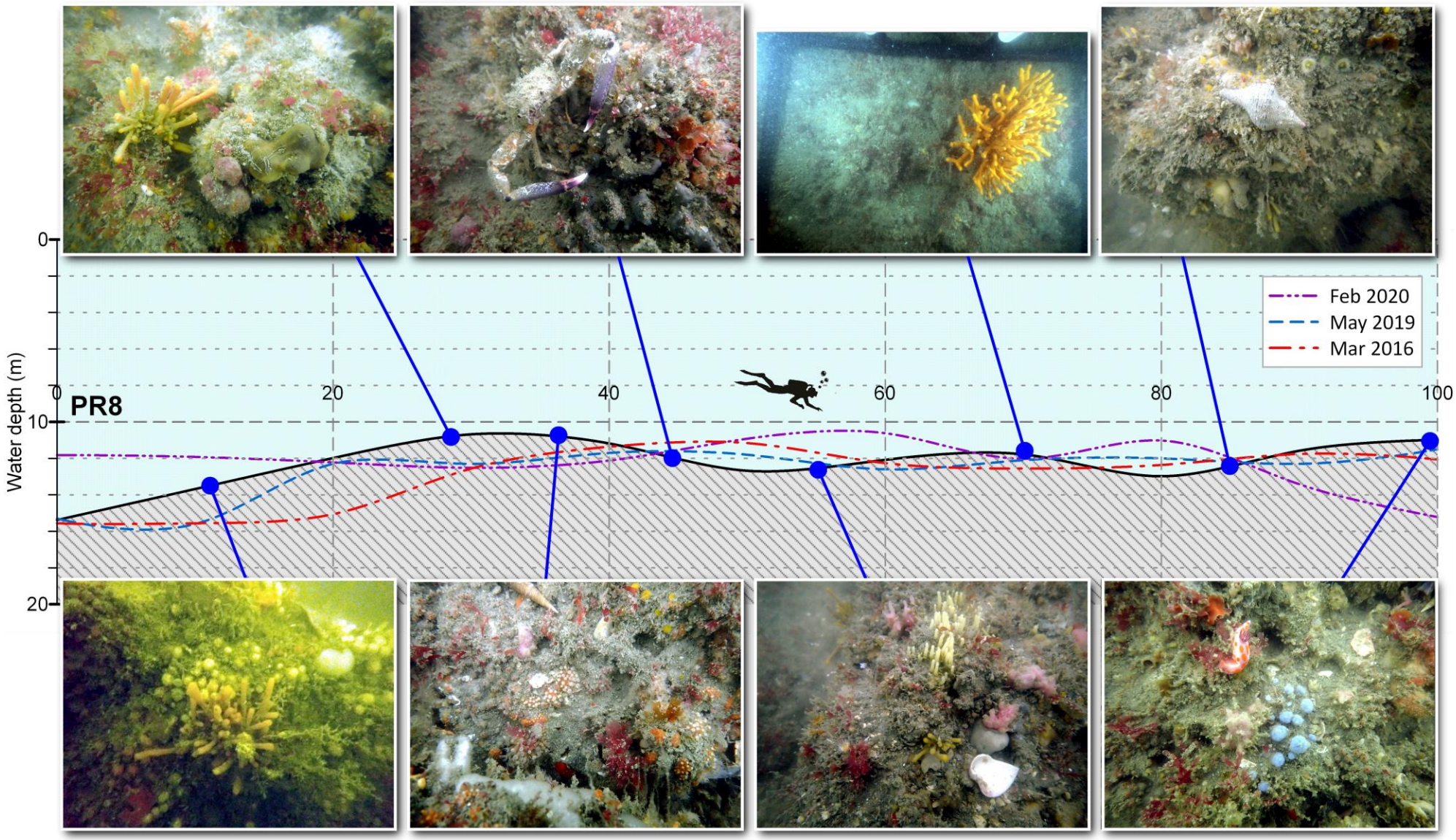

Figure 11. Depth profile with photographs of representative habitat and biota along transect PR8 in October 2020. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

3.2. Pania Reef substrates

Over the three baseline surveys, the dominant substrate along all transects except PR5 has been bedrock (abundance score 32-40) with varying levels of 3-dimensional structure. Small pockets of loose boulder/cobble material also occur sporadically on some transects (e.g. PR3, PR5). Silt and sand occur widely in several forms.

3.2.1. Silt

Although there were some areas of silty sand where fine silt could be easily resuspended by divers, there was no recently settled silt veneer on reef surfaces or encrusting biota. However, as was noted from the baseline surveys, the presence of such veneers is primarily dependent upon the absence of water movement from wave action rather than the quantity of fine material suspended in the water column. Loose settled silt material was observed on the reef during the current survey but was limited to isolated niches and small pockets protected from wave shear (Figure 12A).

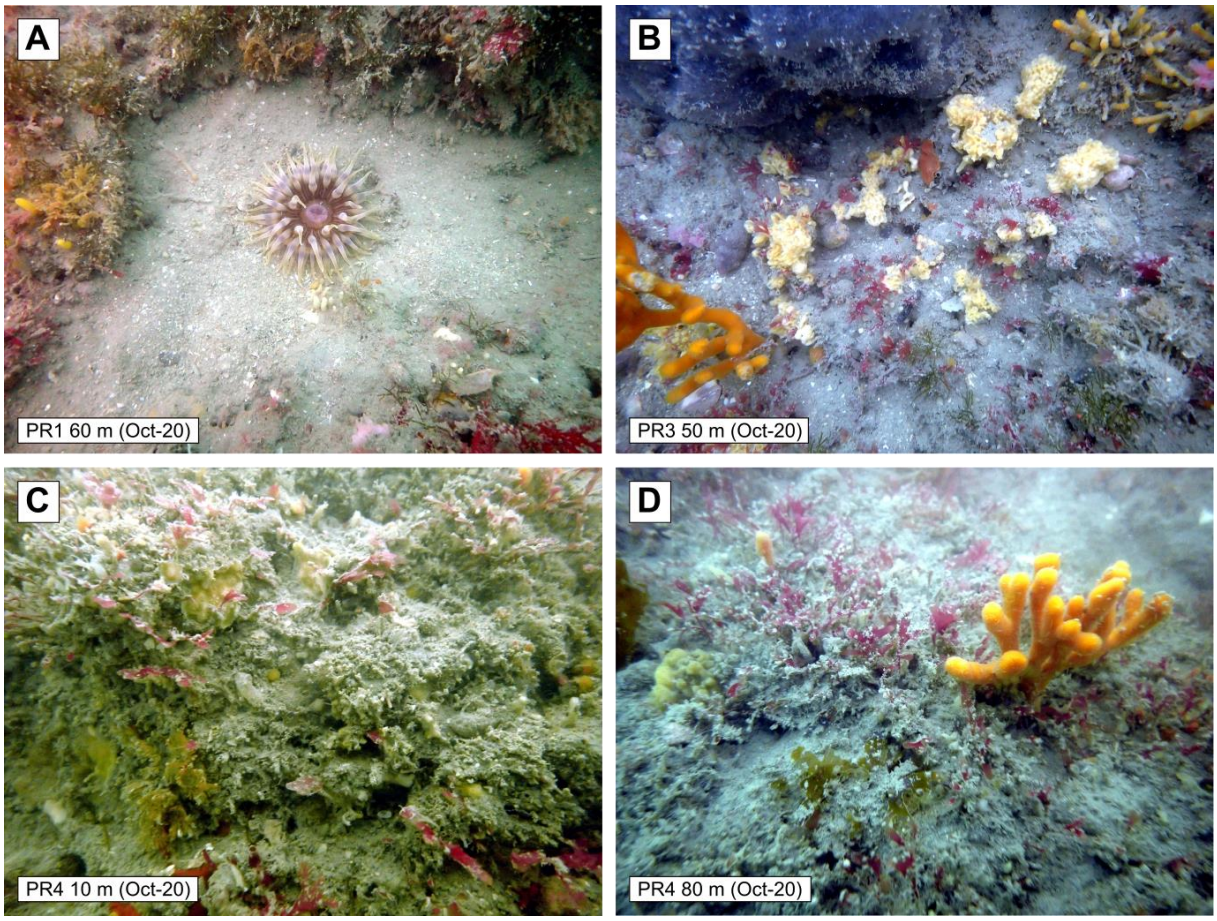

Figure 12. Examples of silt occurrence on Pania Reef during the current survey. **A:** Unconsolidated sandy silt (with anemone) in a pocket protected from wave shear. **B-D:** Embedded silt entrapped within hard-substrate encrusting communities. Metre values are distances along the 100-m transect.

The primary form of widespread silt on the Reef is that entrapped by the textured surfaces upon which it settles, becoming consolidated to the point that it is resistant to resuspension by surge. Since most of this embedded silt is mediated by surface roughness provided by encrusting communities, there is likely an equilibrium between the availability of silt (from the water column), the level of water movement and the types of encrusting biota. It was noted during the baseline that conditions at greater water depths appeared to favour silt-tolerant taxa (e.g. a range of sponges and ascidians) and emergent forms that benefit from the accumulation of a sediment layer on rock surfaces (e.g. the sponge *Ciocalypta* sp.), especially on the southern Reef (Sneddon 2020). These same conditions were observed during the current survey on all transects (see examples in Figure 12B-D). While there had been no conspicuous change in the prevalence of embedded silt relative to the baseline, this is difficult to measure directly or otherwise quantify. Possibly the best way of assessing such change is to evaluate changes in the distribution of taxa that thrive in such conditions (see Section 3.3.4).

3.2.2. Sand

Sand deposits on the Reef generally take two forms; mobile sand that occasionally overlies low flat areas of the reef near its margins and sand that has accumulated in reef niches and pockets (usually with pebble, shell and silt). Apart from transects PR4 and PR8, which recorded no sand, the overall prevalence of sand during the current survey was within the range established by the three baseline surveys (Figure 13).

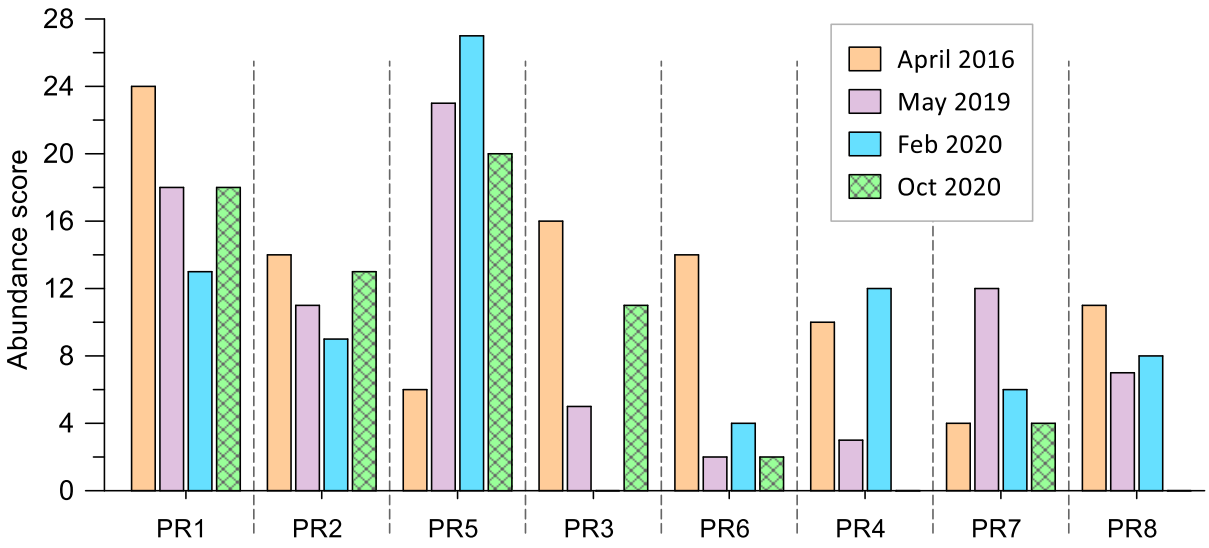

Figure 13. Prevalence of sand substrate across the four surveys to date for each transect.

Mobile sand has most often been encountered on transect PR5, including the current survey (Figure 14A) but has been recorded on the reef margins at PR6 and PR8

during the baseline. It is by nature ephemeral and its extent has varied across baseline surveys. Frequent or recent incursions of mobile sand are likely to significantly modify the reef communities in affected areas. However, because transect placement is inexact, variability such as that at PR5 in Figure 13 can occur with no way to accurately quantify the real change in extent of this substrate between surveys. Hence, it may be difficult to identify such impacts unequivocally. On the reef margin at transect PR1, extensive areas of more stable sand occur, mixed with shell material and in water depths (~21 m) sufficient to avoid mobilisation by wave shear (Figure 4). But even quite small changes in the relocation of the transect at each survey can result in the variability seen in Figure 13.

Relatively large pockets of coarser sands have been consistently observed in low points over the first half of PR1, as well as within transect PR2. They have also frequently been a feature of PR3 and PR4. The coarseness and form of these accumulations appears dependent upon hydrodynamic conditions and the presence of taxa such as the sponge *Ciocalypta* sp. that structurally modify the depositional environment (Figure 14B-D).

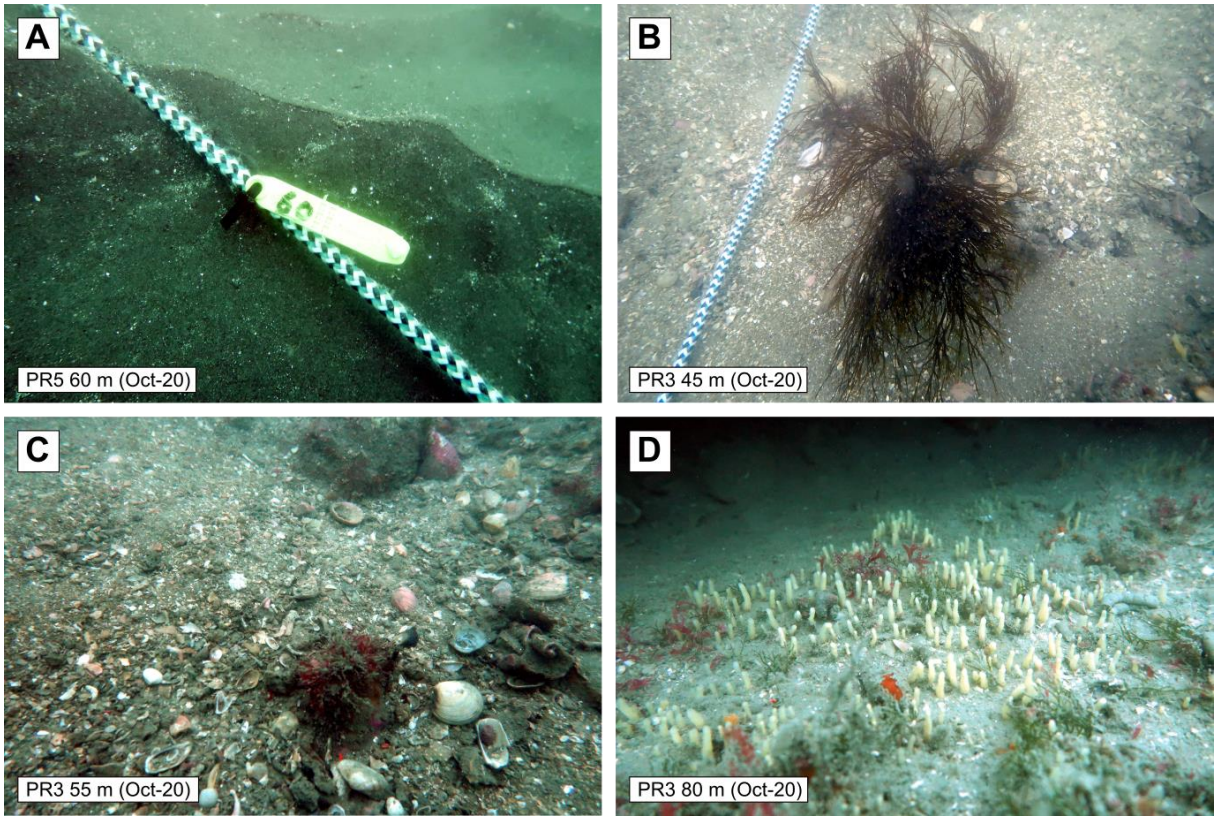

Figure 14. Examples of the different forms of sand substrates on Pania Reef during the current survey. **A:** Rippled mobile fine sand. **B:** Accumulated medium sand deposit. **C:** Coarse sand and shell pocket. **D:** Shallow sand layer stabilised by emergent encrusting biota (*Ciocalypta* sp.). Labelled values are distances along the 100-m transect.

3.3. Pania Reef communities

3.3.1. Identification of taxa

A list of the conspicuous epibiota recorded across all surveys to date is provided in Appendix 3, together with abundance scores (AS) generated for each of the eight transects. The accurate identification of encrusting taxa from a photographic record can be challenging, especially when that record is generated in conditions of low underwater visibility. Furthermore, for certain groups (e.g. sponges) the range of image-based taxonomic references available is limited. Hence many of the identifications of Pania Reef taxa are tentative or descriptive. But because a comprehensive image library for the surveys has been compiled, this indeterminate status does not prevent a subsequent assessment of the nature and scale of any change in these communities. Example photographs of the more abundant taxa to which descriptive identifications have been applied were provided in the previous survey report (Sneddon 2020). Additional taxa that are new or have become more prevalent in the current survey are illustrated in Appendix 1.

3.3.2. Abundance data: Definitions and limitations

The abundance score is a summation of the rankings assigned to each 10-m section according to the relative abundance categories in Table 1. The scores listed for the taxa inventory in Appendix 3 are given separately for the baseline (having been averaged across the three surveys) and the current survey.

The semi-quantitative nature of the data is limited in its sensitivity to changes in low-abundance taxa; that is, greater relative variability is almost certain for taxa that are consistently present in low numbers. The possibility of diver bias must also be acknowledged since assessment of relative abundance has unavoidably subjective aspects. However, active measures have been taken to minimise such bias, including having the same divers compiling the observational record in all three surveys, working rigidly to the relative abundance criteria in Table 1, and re-familiarising field workers with the compiled photographic taxonomy record before the dives.

The practice of augmenting the field survey transcript from a subsequent review of the video and photographic record also serves to identify, and mitigate, any field recording bias. However, the demonstrated value of this practice has resulted in greater emphasis placed on generating a photographic record during more recent surveys, resulting in a greater volume of higher quality images (close-ups with greater detail). Although underwater visibility plays a part in the variability in the diver transcript between surveys, the influence of the larger photographic record is reflected in the larger number of entries in the survey data in more recent surveys (i.e. more is being detected, less is being overlooked). From 985 entries in the survey record of epibiota in 2016, this increased to 1034, 1195 and 1406 in 2019, February 2020 and October 2020, respectively. Hence, interpretation of this record must allow that increases in

abundance score for small or more cryptic taxa may have occurred where there has been no real change in prevalence.

Furthermore, since the ecological significance of changes in such abundance scores varies between organisms, the comparability in such data between widely disparate taxa has little relevance. Any statistical analysis of overall community changes would therefore need to carefully consider the application of pre-analysis data transformation to achieve an appropriate and meaningful weighting for the categorical variables.

3.3.3. Changes from the baseline

Newly recorded taxa

Only five epibiotic taxa were newly recorded in the October 2020 survey (Table 10). Of these, all but a small-bladed brown alga (*Dictyota* sp.) were present in very low abundance (one or two individuals recorded across all transects). Since the baseline surveys were all conducted in late summer to autumn, it is possible that the appearance of this alga may be seasonal. The data do not suggest that it has replaced other algae within the reef community.

Table 10. Epibiota newly added to the Pania Reef surveys taxa inventory from the current survey. Score is the sum of the abundance scores from individual transects.

Description / common name (scientific name)	Score	Transects	Incidence
Small bladed brown alga (*Dictyota* sp.)	46	All	Mostly rare to occasional but locally common
Cream encrusting sponge	1	PR1	Individual occurrence
Nudibranch (*Dendrodoris denisoni*)	2	PR1	Two individuals
Opal top shell (*Cantharidus* sp.)	1	PR2	Single individual
Decorator crab (*Notomithrax minor*)	1	PR8	Single individual

Previously recorded taxa absent from the current survey

Of the 98 epibiotic taxa in the monitoring inventory compiled from the baseline surveys, 87 were recorded from the October 2020 survey. Only one of the eleven absent taxa (an unidentified barnacle species) had been recorded from all three of the baseline surveys, but this had never been observed as more than two individuals in any survey (survey abundance score consistently 1 or 2; Table 11). Of the ten taxa that had been recorded from just one or two previous surveys, the survey abundance score had never exceeded 6.

Two taxa had previously recorded transect abundance scores greater than 3 (Table 11). A non-coralline red encrusting alga (cf. *Hildenbrandia* sp.) had been ‘occasional’ (3–10 individuals) in sections of PR2 in the 2019 and February 2020

surveys. This alga has been observed to be far more common on Town Reef and was again common in the current survey (transect TR1—Section 4.1.1). An unidentified attached bivalve had been recorded as single individuals from several sections of PR1 in 2016. While also recorded from the 2019 survey, the dives have not produced photographs of a quality sufficient for identification. The somewhat cryptic nature of this species also means that it may easily be overlooked, especially in low-visibility conditions.

Table 11. Epibiota absent from the current survey that were recorded from at least two of the baseline surveys. Score is the sum of the abundance scores across the 10-m intervals from individual transects.

Description/ common name (scientific name)	Survey	Transects (abundance score)
Non-coralline red encrusting alga	Feb-20	PR2 (5), PR6 (1)
(cf. *Hildenbrandia* sp.)	2019	PR2 (4)
Grey encrusting sponge	Feb-20	PR1 (1), PR5 (2), PR4 (2)
(cf. *Ircinia novaezealandiae*)	2019	PR2 (1)
Attached bivalve	2019	PR1 (1), PR2 (1), PR5 (1), PR7 (1)
(unidentified)	2016	PR1 (6)
Barnacle	Feb-20	PR2 (1)
(unidentified)	2019	PR3 (1), PR7 (1)
	2016	PR2 (2)
Snake star	Feb-20	PR1 (1)
(*Ophiopsammus* sp.)	2019	PR5 (1)

Changes in abundance across surveys

A broad overview of temporal variability in Reef populations was generated by examining differences in total abundance scores (sum of all transects) for each survey. Table 12 shows changes in such scores for those taxa abundant enough to be considered ‘characteristic’ of the Reef.

There are no strong patterns evident in Table 12 that suggest the existence of ecologically significant trends or changes since the baseline. However, there were several taxa for which relative changes in abundance across surveys appeared to be quite large. There were fewer instances of minimum scores occurring for the current survey than for any of the baseline surveys (for which ‘minimum’ status was spread relatively evenly across the listed taxa). Furthermore, for the six taxa where such minima occurred for the current survey, this status was shared with at least one of the baseline surveys for all but one—green-lipped mussels (*Perna canaliculus*). This suggests that any stressors resulting in population declines have been relatively subtle in their effects and have not acted across particular groups or ranges of organisms.

Table 12. Variation in survey total abundance score for epibiota considered characteristic of Pania Reef (those for which the mean total abundance score [sum of all transects] was greater than 30 for sessile biota and 5 for mobile invertebrates). Shaded cells represent years of minimum abundance (multiple years shaded if the difference between them does not exceed 10% of the mean value for sessile biota or 20% of the mean for mobile invertebrates). Similarly calculated maxima are designated by bold font.

Group	Taxon	2016	2019	Feb 2020	Oct 2020
Algae	*Ecklonia radiata*	**153**	129	**163**	138
	Plocamium cirrhosum	124	91	**146**	115
	Corallinales	**106**	89	**107**	**99**
	Small-bladed red alga	62	23	137	**156**
Porifera	*Ecionemia alata*	**160**	**153**	**155**	**165**
	Ciocalypta cf. *penicillus*	**132**	101	111	**130**
	Raspailia topsenti	**106**	77	91	**111**
	Lilac Demospongia D	64	70	94	**118**
	Cliona cf. *celata*	19	67	69	**87**
	cf. *Tedania* sp.	27	41	**48**	**47**
	Yellow Demospongia E	**56**	26	24	45
	Tethya burtoni	40	39	20	**55**
Bryozoa	Catenicellidae	63	**84**	42	37
	cf. *Steginoporella* sp.	30	90	61	**135**
	cf. *Cellaria tenuirostris*	**81**	20	24	68
Cnidaria	cf. *Aglaophenia* sp.	**52**	28	45	36
	Anthothoe albocincta	**38**	34	**37**	31
	Branching hydroid	35	28	34	**50**
Ascidiacea	*Cnemidocarpa* sp.	**89**	46	25	29
	cf. *Synoicum otagoensis*	58	33	35	**63**
	cf. *Eudistoma* sp.	**54**	31	21	18
Bivalvia	*Perna canaliculus*	**68**	62	52	40
Gastropoda	*Ceratosoma amoena*	4	23	**65**	30
	Penion sulcatus	**24**	20	21	**28**
	Trochus viridis	7	**15**	10	**13**
	Cookia sulcata	2	7	11	**18**
	Buccinulum lineum	**8**	2	6	**8**
Crustacea	Paguridae	**21**	12	**24**	**25**
Echinodermata	*Australostichopus mollis*	20	14	**30**	**34**
Sum of abundance scores		1,703	1,455	1,708	1,929

Interestingly, although the highest value for the sum of abundance scores for the set of 'characteristic' taxa (1,929) occurred for the current survey, Table 12 does not suggest a consistent increasing progression across surveys that might be expected from greater efficiency of the survey methodology and increasing use of the photographic record. However, as noted above, such a trend is more likely to be evident for smaller or more cryptic taxa than those in this list.

Patterns of change among transects

To investigate the possibility of stressors acting differently upon communities along the Reef axis, changes in transect abundance scores from the baseline were examined (Table 13). Since a degree of natural variability (as well as sampling error) is to be expected, changes in AS were screened to include only those taxa for which marked shifts have occurred (> 3) and where such changes have been consistent across at least two transects. Given the inter-survey variability observed, these thresholds are considered relatively conservative.

Table 13 indicates that the most widespread changes since the baseline have been increases in abundance. Taxa exhibiting such increases include the small-bladed red and grass-like green algae, the brown alga *Dictyota* sp., the sponges *Cliona* cf. *celata,* lilac Demospongia D, *Tethya burtoni* and cf. *Suberites perfectus,* the bryozoans cf. *Steginoporella* sp. and cf. *Cellaria tenuirostris,* and a branching bryozoan. Three of these 10 taxa have previously shown greater prevalence at the southern end of the Reef, suggesting that they may have a greater competitive advantage in siltier conditions. In contrast, *Cliona* has in the past exhibited greater prevalence on the northern transects (see section 3.3.4).

Consistent decreases in abundance have occurred only for the clowns hair bryozoan (Catenicellidae), green-lipped mussel (*P. canaliculus*) and the colonial ascidian *Eudistoma* sp., but in each case involving three or fewer transects. Transect PR6 stands out in Table 13 as exhibiting a notably greater number of decreases since the baseline, including for these three taxa. This may be an artefact of marginal underwater visibility at PR6 during the October 2020 survey (exacerbated by a subsequently limited photographic record). In the current survey, transect PR6 also missed a previously prominent reef crest that had supported dense mussel beds (Figure 8).

The late spring timing of the current survey was predicated by consent requirements related to project commencement and contrasts starkly with the late summer / autumn timing of the baseline surveys. Hence, seasonality may play a part in some of the observed shifts in abundance, especially for algae but also possibly for some invertebrates such as ascidians. Given the variability in Reef communities documented across the three baseline surveys (Sneddon 2020), the changes observable in Table 13 do not appear unusual. There is no clear indication that they may represent anything other than background seasonal or inter-annual variability.

Table 13. Changes in abundance score (AS) from the mean baseline for taxa where such change exceeded 3 for more than one transect. Cells are left blank where the difference from the baseline was less than 3. AS is the sum of categorical abundance rankings from each 10-m section, assigned according to Table 1. To aid visual interpretation, colour shading is proportional to the change—red for a decrease, blue for an increase. Yellow shading indicates taxa unrecorded during the baseline. Transects are listed in the order of increasing distance from the seaward end of the reef (north to south).

Taxon	**Common name / Description / Scientific name**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Phaeophyceae	*Halopteris* sp.		3.7		4.0				
	Dictyota sp.	5.0		6.0	7.0			13.0	9.0
Rhodophyta	Corallinales		4.0		-4.3	-7.0			
	Plocamium cirrhosum		6.7		3.7	-10.0	-4.3	3.7	-5.0
	Small-bladed red algae	10.3	10.7	11.0	13.3	13.3		10.0	11.0
Chlorophyta	Green algae (grass-like)	9.3	10.7		13.3				
Porifera	*Ecionemia alata*			-3.3		10.7		4.0	
	Cliona cf. *celata*	6.7	6.7	6.3	8.0			5.0	5.0
	cf. *Tedania* sp.		5.3		4.3	-8.3			
	Tethya bergquistae					-4.0			4.3
	Tethya burtoni		5.7		4.0	5.3			
	Ciocalypta sp.		7.0					5.7	
	Pink Demospongia C				-4.3			7.3	4.0
	Lilac Demospongia D	7.7		7.3		5.7	7.3	4.7	5.0
	Yellow Demospongia E				7.7	-3.7			3.3
	cf. *Aaptos globosa*					-3.3		14.0	
	cf. *Suberites perfectus*	5.7		5.3		4.0		4.0	4.0
Bryozoa	Catenicellidae		-10.0			-6.7			
	cf. *Cellaria tenuirostris*	15.0	5.0	3.7	4.0	-5.0			
	cf. *Steginoporella* sp.	11.3	6.0	5.3	14.3	9.7	10.0	7.0	11.0
	Encrusting bryozoan	-3.7					4.0	-4.7	6.3
	cf. *Margaretta barbata*	4.7	3.3						
Cnidaria	*Amphisbetia bispinosa*				-5.0			3.3	
	Branching / bushy hydroid			5.7	4.0		3.3	3.3	5.7
	Anthothoe albocincta							3.3	-5.3
	Alcyonium cf. *aurantiacum*			7.7			6.7		4.0
Ascidiacea	*Cnemidocarpa* sp.	-3.3	5.7		-9.7		-7.0		-6.7
	Ascidiacea sp. A					-5.7	4.0		8.3
	cf. *Synoicum otagoensis*	6.7				6.0		7.3	
	Eudistoma sp.					-5.3		-4.3	-3.7
	Didemnum sp. (white)		5.0			-4.7	-4.7		
Bivalvia	*Perna canaliculus*				-6.7	-9.0	-5.3		
Calliostoma tigris	Tiger top shell			5.0			6.0		
Cookia sulcata	Cook's turban shell	4.0	5.7						
Penion sulcatus	Siphon whelk			4.7				4.0	
Crustacea	Paguridae			3.3		-4.0		4.0	
Echinodermata	*Australostichopus mollis*	5.7	5.7						

To further examine the apparent decline in mussels at transects PR3, PR6 and PR4, the relationship with water depth for this species is plotted for the categorical abundance data over the baseline and for the current survey (Figure 15). This shows that transect placement for the current survey has resulted in the shallow points (< 12 m MSL; where dense beds have occurred) being largely missed. Figure 15 indicates that there is an overlap in depth (12–14 m MSL) where *Perna* may still be present in densities corresponding to 'common'. While there are likely to be environmental variables other than water depth that will influence the presence of *Perna* (water movement, substrate, topography), a similar proportion of the Figure 15 transect segments from the current survey returned a category of "common" in this depth range as from the baseline surveys (11% of records vs 13%, respectively). Hence the October 2020 data for these transects are not inconsistent with the baseline record. Abundance scores for *Perna* on the other five transects had changed little relative to the baseline. Decreases of 0.7, 1.0 and 0.3 occurred for PR1, PR7 and PR8, and increases of 1.3 and 1.0 for PR2 and PR5, respectively.

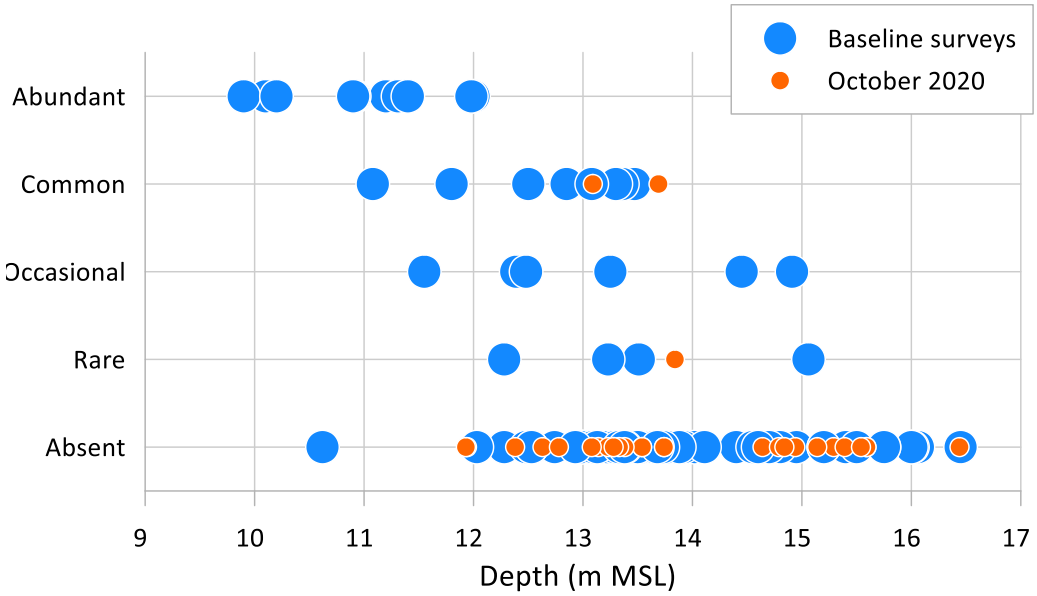

Figure 15. Water depth vs categorical abundance of *Perna canaliculus* for transects PR3, PR6 and PR4 over all surveys to date. Each symbol represents a 10-m transect segment with depths interpolated from values recorded at distance tags and adjusted for tidal variation.

3.3.4. Spatial gradients in communities

It was noted from the baseline data that several taxa exhibited spatial gradients in their occurrence along the reef axis (Sneddon 2020). Figure 16 and Figure 17 show spatial distribution patterns of AS along the reef axis for these taxa, contrasting the current survey with the mean baseline data. The patterns have essentially remained unchanged from the baseline, although the plots show the greater general abundance

of some taxa such as the small-bladed red alga and the lilac sponge (Demospongia D).

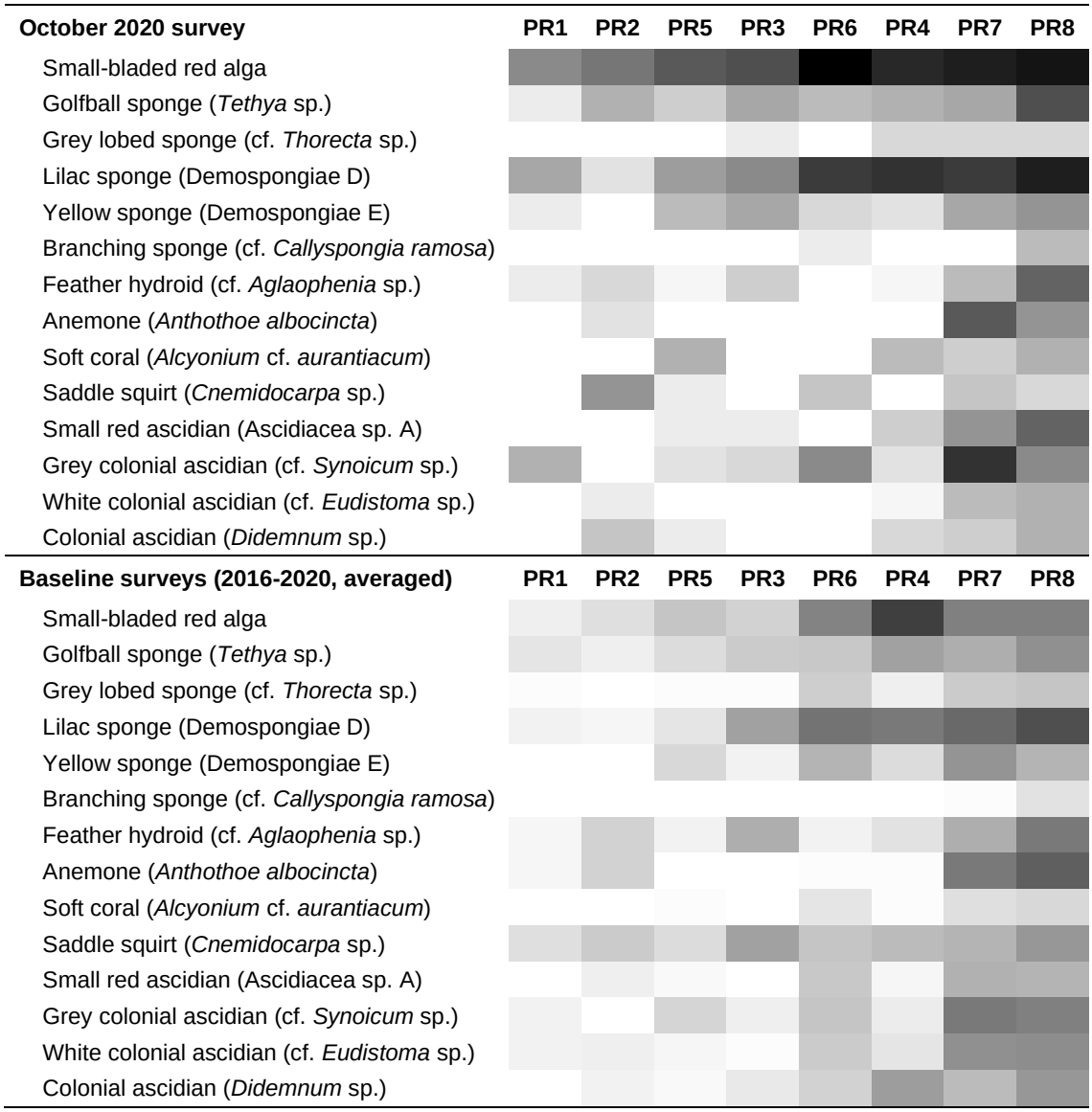

Figure 16. Shade plots showing the distribution of characteristic taxa for which a spatial gradient in abundance, increasing north to south along the Reef axis, was indicated by the compiled baseline data. Progressive shading is based on transect abundance scores (max. AS 26; averaged for the three baseline surveys – bottom plot). Note that scores for the two species of *Tethya* (*bergquistae* and *burtoni*) and the two forms of *Didemnum* sp. (cream and white) have been combined.

As was noted for the baseline, diver observations and review of video footage indicate a gradual change in community structure along the Reef axis, most conspicuous in the declining coverage of kelp (*E. radiata*) and crustose coralline algae (coralline paint). It is likely that an important influence on this gradient is the greater inshore

exposure to turbidity from beach abrasion and wave resuspension of sediments. While the observed increase in some taxa more strongly associated with the southern Reef could be evidence of an expansion of these conditions northward, a general change in conditions of this nature is not supported by the continuing prevalence of those whose populations are greatest on the more northern transects (Figure 17).

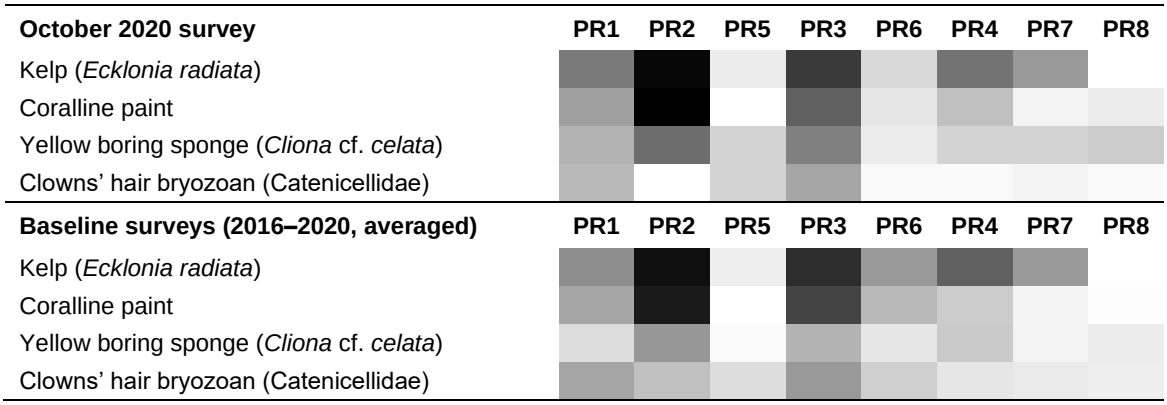

Figure 17. Shade plots showing the distribution of characteristic taxa for which a spatial gradient in abundance, decreasing north to south along the Reef axis, was indicated by the compiled baseline data. Progressive shading is based on transect abundance scores (max. AS 40; averaged for the three baseline surveys – bottom plot).

3.3.5. Fish

The complete record of fish abundance from the current survey is presented in Appendix 3 (Table A3.2) where it is contrasted with the average for the baseline. All of the same fish species seen commonly on the Reef during the baseline were observed, although there were fewer fish observed in general. Species newly recorded in October 2020 were conger eel (*Conger verreauxi*, PR8) and sea horse (*Hippocampus abdominalis*; PR4) but both were present as single individuals.

Table 14 shows the variation in total abundance scores (sum of all transects) across surveys for species considered characteristic of the Reef. It shows that, although butterfly perch were less often observed than in all previous surveys, fish abundance was otherwise comparable to that of the 2019 survey.

As in past surveys, more fish tended to be observed on transects PR2 and PR3. While habitat preference may play a part in this, it is also likely that the better underwater visibility often encountered on these two transects allows more fish to be seen. Observation of some benthic species such as dwarf scorpion fish is less sensitive to underwater visibility because they rely on camouflage and will not move until divers are very close. Species less wary of divers (banded wrasse) or actively curious (blue cod) are also more likely to be seen in low visibility conditions while

more timid demersal species such as sweep will detect divers in turbid water and move away before they are seen.

Table 14. Variation between surveys for fish species considered characteristic of Pania Reef (mean survey abundance score [sum of all transects] > 5). Shaded cells represent years of minimum abundance (multiple years shaded if the difference between them does not exceed 20% of the mean value). Similarly calculated maxima are designated by bold font.

Species	Common name	2016	2019	Feb 2020	Oct 2020
Caesioperca lepidoptera	Butterfly perch	**96**	51	75	19
Parapercis colias	Blue cod	**57**	30	32	25
Pseudolabrus miles	Scarlet wrasse	**39**	28	24	16
Forsterygion varium	Variable triplefin	**44**	7	18	15
Notolabrus celidotus	Spotted wrasse	**29**	9	**33**	8
Scorpis lineolatus	Sweep	26	11	**30**	2
Scorpaena papillosa	Dwarf scorpion fish	14	7	21	**27**
Parika scaber	Leather jacket	11	10	**19**	11
Cheilodactylus spectabilis	Red moki	**13**	3	9	11
Notolabrus fucicola	Banded wrasse	**8**	5	**7**	**7**

Given that all characteristic species appear to have been present and considering the similarities in the recorded abundance of fish between the current survey and that of 2019, it is unlikely that the results represent a decrease in the population of any species since the baseline.

4. TOWN REEF SURVEY

The single Town Reef transect was dived on 30 October 2020. Conditions were calm with a slight swell and although both deeper transects (TR2 and TR3) were also dived these were abandoned due to highly turbid benthic conditions. The TR1 depth profile, taken from one diver's wrist-mounted computer and adjusted to mean sea level, did not descend below a water depth of 7.7 m. This was shallower than the 8.6 m recorded for this transect in May 2019 (the two profiles are shown superimposed in Figure 18). Divers had to contend with greater surge than for the 2019 TRI dive and underwater visibility was poorer, but there was adequate light penetration to the seabed for photography in natural light.

4.1.1. Description of habitats and communities

Three hundred and five photographs and 20 minutes of video footage of substrate and biota were taken along the 100-m transect. From the review of this material, along with post-dive notes on observations, a descriptive characterisation was compiled for the transect. This is presented in the following section, together with associated profile figures for each 25-m section of the transect (Figure 18). The subset of 32 photographs were chosen as being broadly representative of observed communities and habitats. Photograph locations along the depth profile were established from bracketing between the transect distance tags and from the time stamp for each image. The complete inventory of taxa recorded for the transect is listed in Appendix 4.

Dive transect TR1

Profile: Water depths varied between 5.5 m and 7.5 m with little overall gradient along the transect.

Conditions: Adequate underwater visibility during the dive (1.5–2 m). Good light penetration to the seabed. Surge was occasionally problematic for obtaining a good photographic and video record. A lot of suspended material was in the water column as well as fragments of drift algae.

Terrain: As for the baseline, the terrain was similar throughout the transect. Plentiful low rock outcrops, ledges and small overhangs formed recesses against surrounding bedrock and gravel pockets. Some embedded boulder terrain with cobble-strewn sandy clearings amongst kelp / *Ecklonia*.

Coarse sand collected in pockets and low-lying areas, occasionally stabilised by emergent taxa such as sponges (*Ciocalypta* spp.). There were frequent small expanses of mobile gravelly sand spread in thin layers between rock outcrops. Also, occasional small patches of cobble material were found, sometimes embedded within finer sediments.

Silt presence: There was no incidence of settled silt and it could not have remained in place with the level of surge occurring on the transect at the time.

Macroalgae: As with the baseline, *E. radiata* was abundant along the transect, forming an open canopy; although occasionally dense enough to hinder diver progress at the seabed and obscure the view ahead. Foliose red alga (*Plocamium* sp.) was present at a density consistent with the baseline survey. The brown alga *Dictyota* sp. (newly recorded on Pania Reef) was common. A short, branched turfing green alga featured in some photographs but was not plentiful.

Encrusting algae: Pink coralline algae were plentiful on bedrock and boulder high points but, as with the baseline, not ubiquitous. Dark-red non-coralline encrusting red algae (cf. *Hildenbrandia*) was frequently interspersed with coralline algae and, in places, gave exposed surfaces a mosaic quality (Figure 18, 33 m).

Encrusting fauna: As with the baseline, there was evidence of scour or smothering around areas of mobile gravel and sand, but sessile communities flourished elsewhere.

In contrast to the baseline, no green-lipped mussels were recorded on the transect although these had been confined to a particular shallower bedrock outcrop during the 2019 survey, which may have been missed by the transect in the current survey.

The colonial ascidians *Didemnum* spp. and cf. *Synoicum otagoensis* were common but *Eudistoma* sp. occurred only occasionally. The small red ascidian (Ascidiacea sp. A) was again very plentiful in the patches where it occurred. *Pyura spinosissima* were conspicuous where present on exposed surfaces but occurred in very low numbers.

Feather hydroids (*Aglaophenia* spp.) were common in two forms: one a fine blue-green and the other a coarser gold form. Both were also noted during the baseline survey.

Sponges: *E. alata* was common as were patches of yellow and cream *Ciocalypta* spp. A bright orange emergent/encrusting sponge was occasional (Figure 18, 14 m) but had been more prevalent during the baseline. Both pink and orange golfball sponges (*Tethya*), were frequently observed along the transect. The yellow boring sponge (*Cliona*) again occurred mainly in association with coralline algae.

Mobile invertebrates: Unlike during the baseline, crayfish were absent from the transect but most other previously recorded mobile invertebrates were present. Echinoderms included biscuit stars (*Pentagonaster pulchellus*), seven-armed stars (*Aristole scabra*) and reef stars (*Stichaster australis*) but not the common cushion star (*Patiriella regularis*). Aggregations of kina (*Evechinus chloroticus*) were again present. Gastropods were quite sparse but Cook's turban shell (*Cookia sulcata*), *Xymene* sp. and Spengler's trumpet (*Cabestana spengleri*) were observed.

Fish life: The high surge conditions were not conducive to the observation of fish life on the transect and very few were recorded. Triplefins (*Forsterygion varium*) were occasional but observations of blue cod, banded wrasse and marblefish were limited to single individuals.

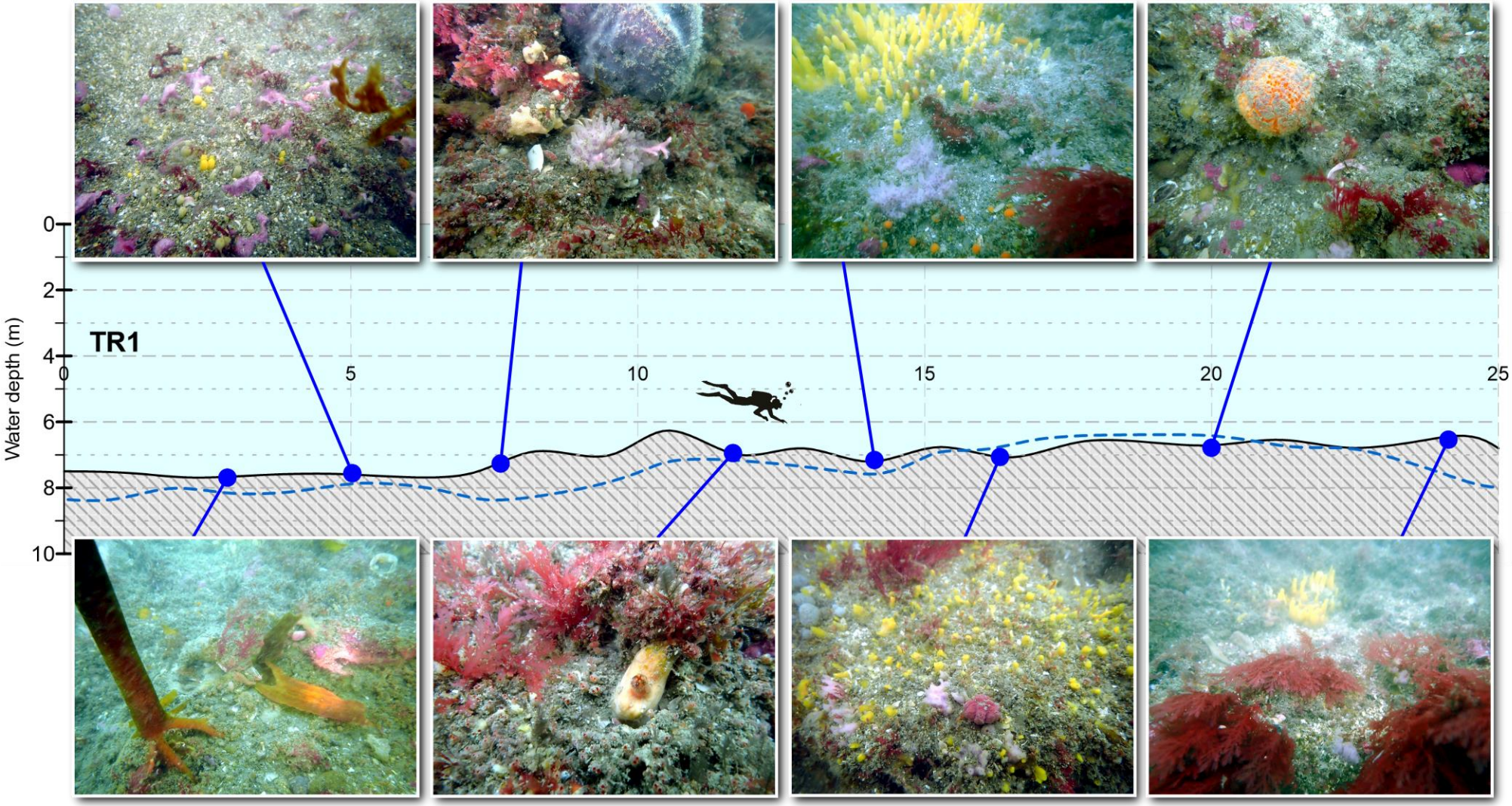

Figure 18. Depth profiles (blue dashed line from 2019 survey) with October 2020 photographs of representative habitat along transect TR1. **A:** First 25 m section (0-25 m). The photographs were chosen to illustrate representative habitat and located (blue pointers) according to the digital image time stamp and bracketed within the transect tag photographs. Blue dashed line shows the depth profile for the 2019 baseline transect. Grey dashed line and numbers show distance along transect.

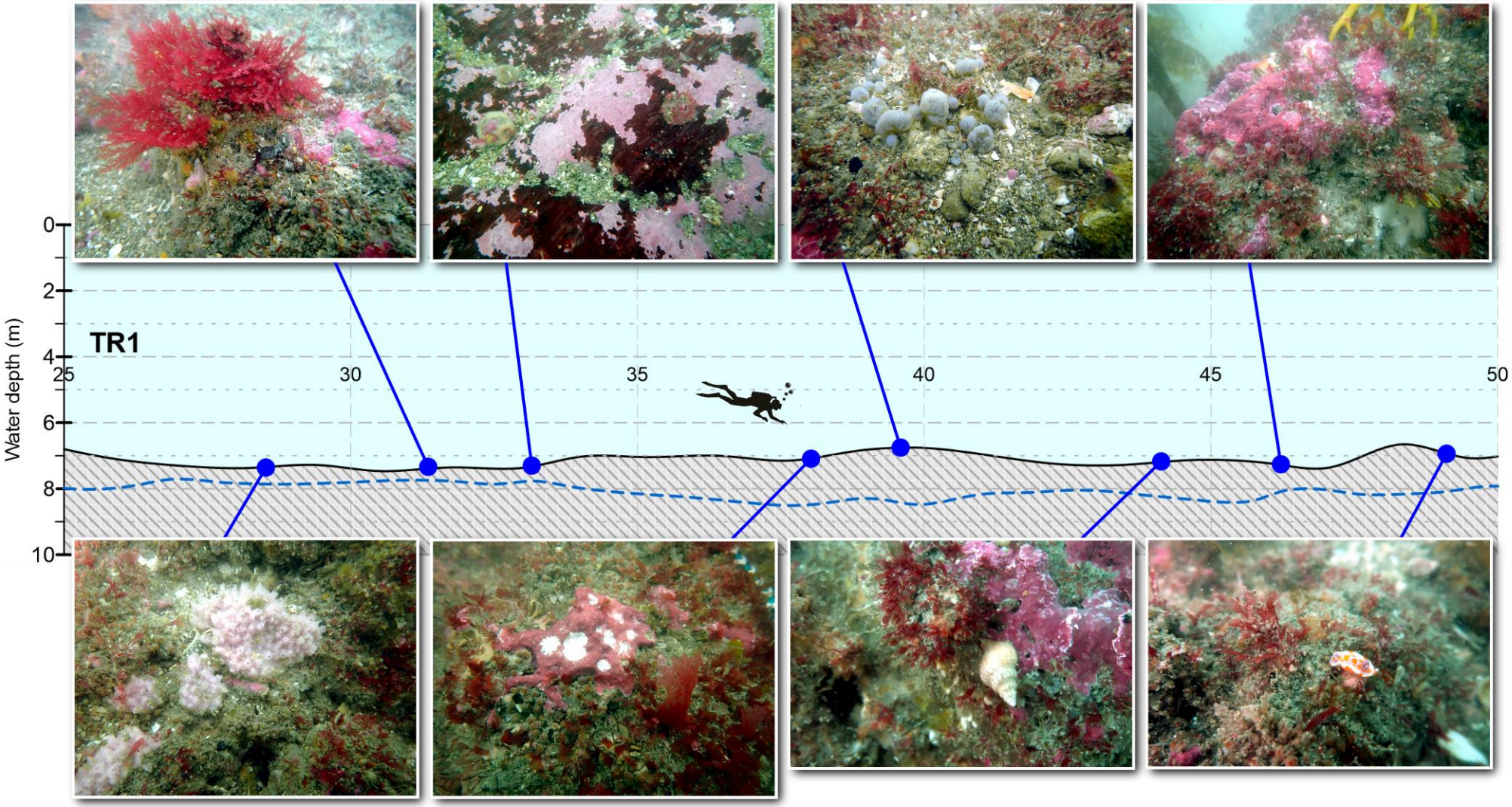

Figure 18 contd. Depth profile with photographs of representative habitat along transect TR1. **B:** Second 25 m section (25–50 m).

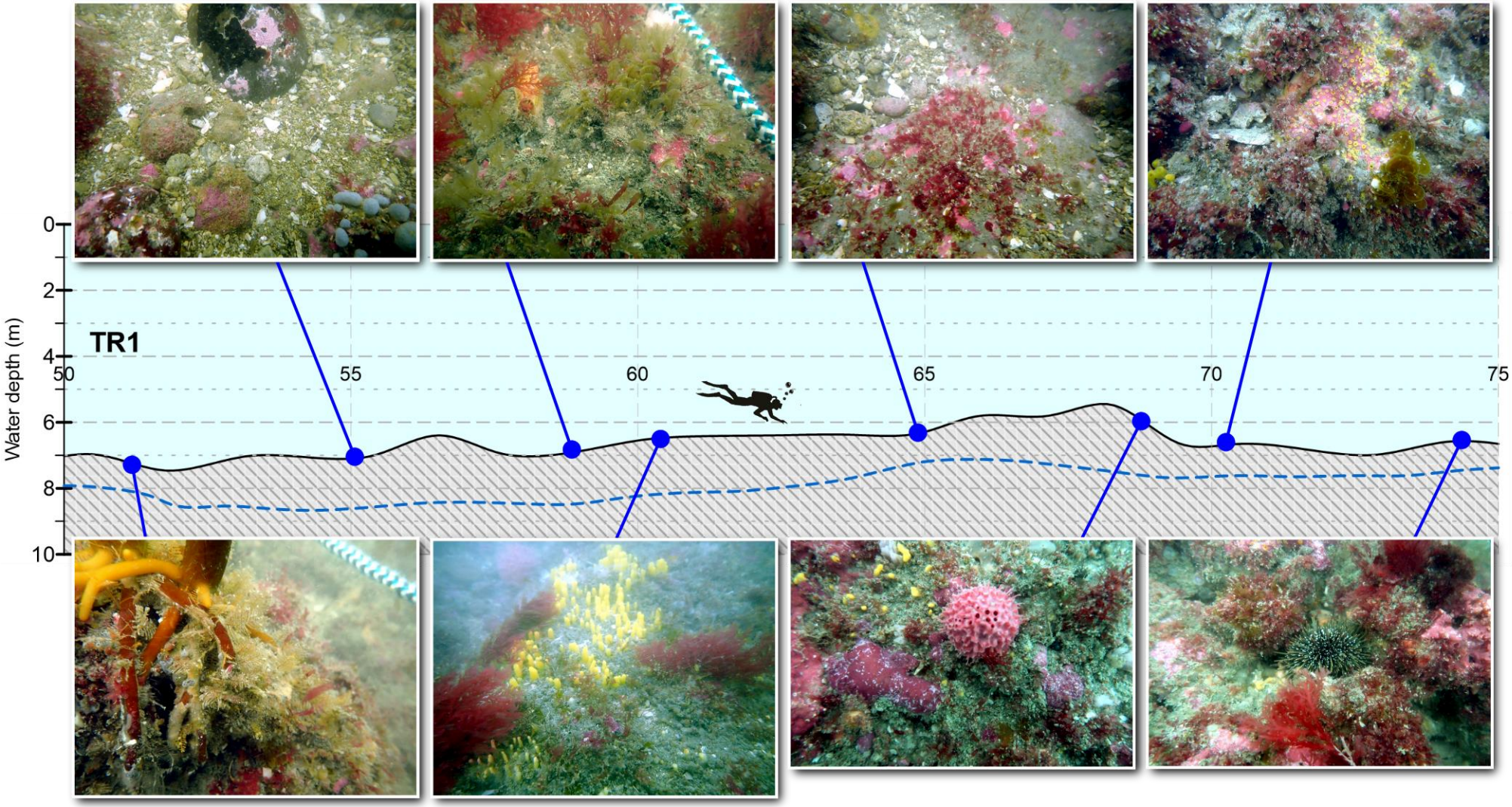

Figure 18 contd. Depth profile with photographs of representative habitat along transect TR1. **C:** Third 25 m section (50–75 m).

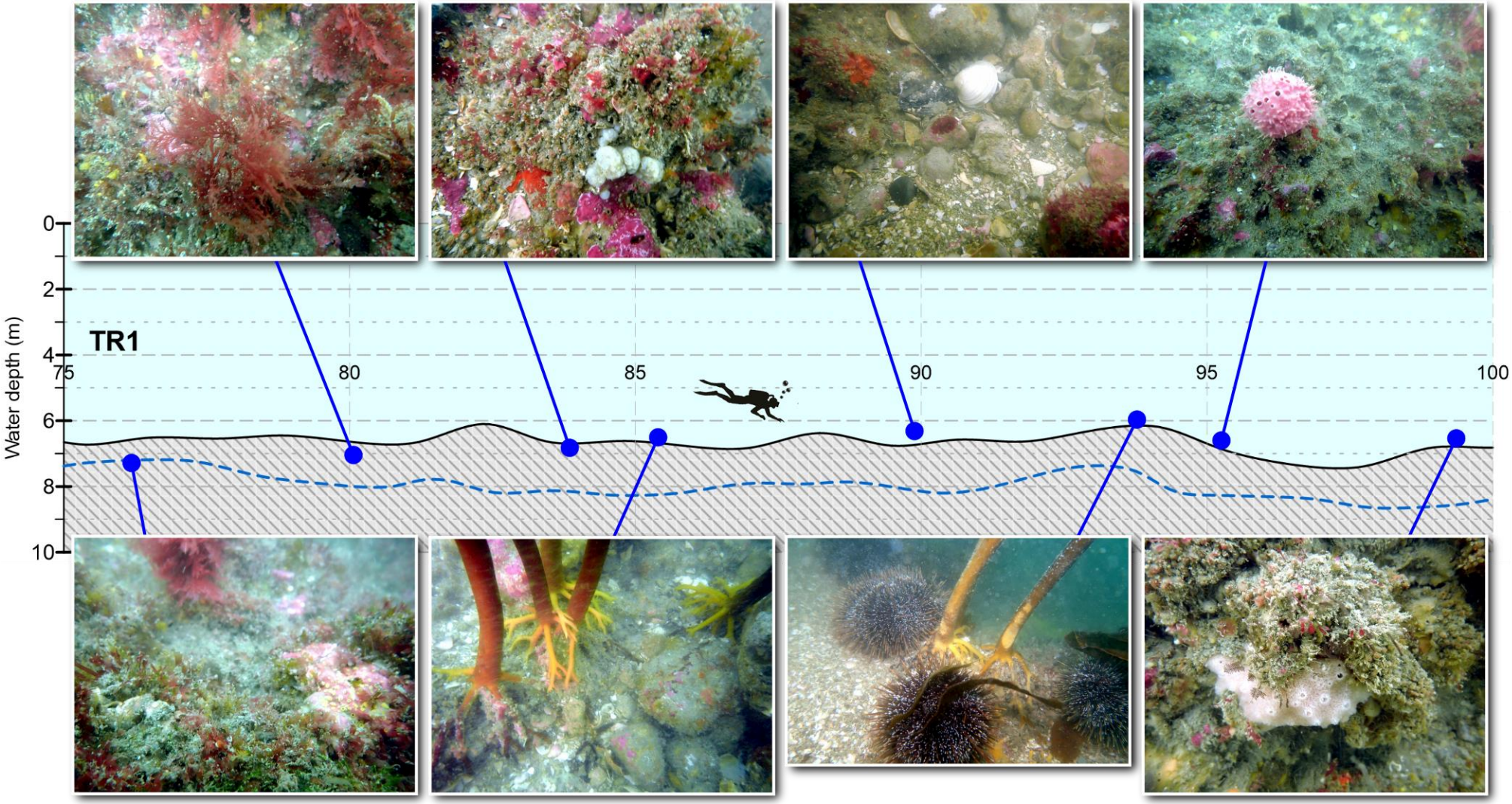

Figure 18 contd. Depth profile with photographs of representative habitat along transect TR1. **D:** Fourth 25 m section (75–100 m).

4.1.2. Comparison to the 2019 baseline survey of Town Reef

Six algal taxa were recorded from the baseline survey of TR1, all of which were present at similar density in the current survey. In addition, three new taxa were recorded: *Dictyota* sp., *Zonaria* sp. and a small branching green alga. Of these, only *Dictyota* was present in any abundance, being at similar levels to that documented on the southern transects of Pania Reef.

Of the 44 invertebrate taxa recorded on TR1 during the baseline, 11 were not observed in the current survey. These comprised four cnidarians, one polychaete worm, two bivalve molluscs, octopus, crayfish and two sea stars. Of these, only green-lipped mussels (*P. canaliculus*), the associated mussel beard hydroid (*A. bispinosa*) and a fine hydroid colonising *Ecklonia* fronds had been assessed as more than occasional. As noted, *P. canaliculus* had been limited to a single dense bed on a shallower point (near the 20-m mark) and this bed may have been missed in the placement of the transect for the current survey. It is possible that the epiphytic hydroids may be a seasonal occurrence.

Five invertebrate taxa new to the TR1 transect were recorded. These included two sponges (both recorded from southern Pania Reef), the turret snail (*Maoricolpus roseus*), hermit crabs and the reef star (*Stichaster australis*). All were observed in very low numbers or as single individuals.

Only four fish species were observed, compared to ten during the baseline. Furthermore, all except a triplefin were represented by single sightings. The change is attributed to the swell and underwater visibility conditions under which the survey was conducted rather than a decrease in prevalence.

5. CONCLUSIONS

Diver and photographic records revealed no evidence of a change in settled silt on Pania Reef during the October 2020 survey. The recently deposited silt veneers that had been sometimes observed during the baseline surveys were absent, likely due to wave action preceding and during the survey. As it was for the baseline, the presence of silt was widespread only in a form trapped and semi-consolidated by textured surfaces, principally those of encrusting reef biota. While it is very difficult to measure or otherwise quantify the prevalence of such silt, the visual record suggests no conspicuous change from the baseline condition.

There continues to be quite high temporal variability in the prevalence of sand across all transects, some of which may be attributable to small changes in transect placement. The different forms of sand deposit observed will have varying stability against redistribution by storm waves. Although there may be a seasonal aspect to mobile sand incursions at the reef margins, there is also likely to be high inter-annual variability.

The occurrence of taxa completely new to the Pania Reef inventory was generally limited to organisms at population densities too low to rule out their undetected presence during the baseline. The one exception, a small brown alga of the genus *Dictyota*, was quite widespread (including on Town Reef) and, allowing for the seasonal disparity in the timing of surveys, its appearance is quite likely to be seasonal rather than in response to changing conditions associated with other drivers.

Similarly, all previously recorded taxa that were not observed during the current survey had been consistently low in abundance during the baseline, with only one that had been recorded across all three surveys. Hence, their apparent absence is not considered to indicate any fundamental change in community structure.

Combined abundance data for the Reef as a whole showed no clear patterns across surveys to suggest ecologically significant trends or changes since the baseline for a set of the most commonly occurring taxa. Examination of the complete Reef taxa inventory for individual transects showed that most changes in abundance have been apparent increases relative to mean baseline levels. However, such increases have applied to some taxa more than others and due to an unavoidable difference in the timing of the current survey relative to the baseline surveys, some of this change may be seasonal in nature. Nonetheless, relative spatial gradients in abundance along the Reef axis identified from the baseline have been maintained and no taxa showed a general decline. Apparent decreases in the abundance of green-lipped mussels in three central-Reef transects were shown to be attributable to variability in transect placement rather than reflecting a real decline in this species.

Due to swell conditions affecting underwater visibility, only one of the three transects established for Town Reef could be surveyed. However, diver observations and the photographic and video record indicated that habitats and communities were effectively unchanged from those documented by the 2019 baseline survey.

6. ACKNOWLEDGEMENTS

The authors of this study would like to acknowledge the following Cawthron staff: Javier Atalah and Dan Crossett for their assistance in the field; Don Morrisey for report review and Gretchen Rasch for editorial guidance.

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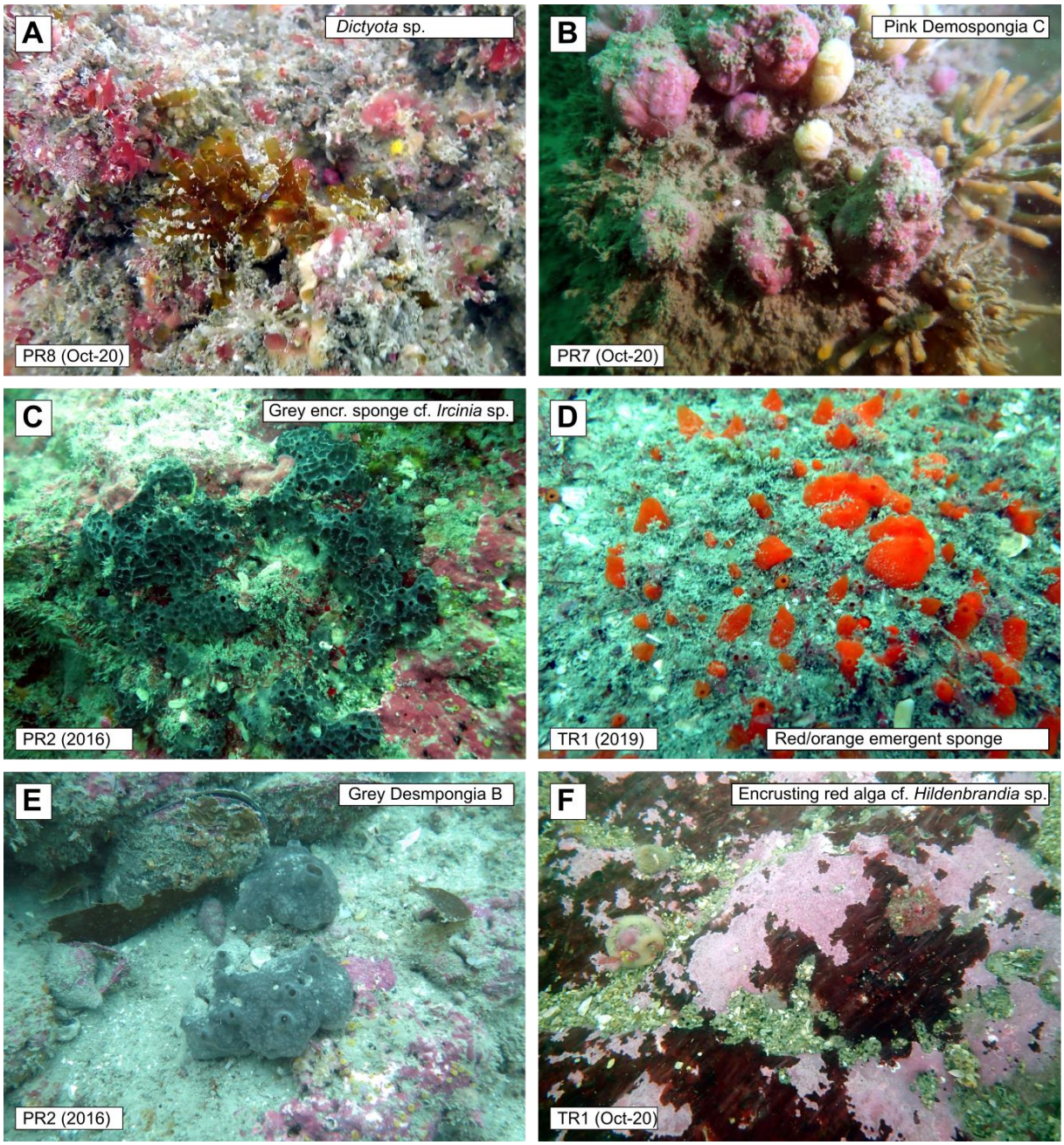
Sneddon R 2019. Second baseline ecological transect survey of Pania Reef. Prepared for Port of Napier Ltd. Cawthron Report No. 3364. 58 p. plus appendices.

Sneddon R 2020. Third baseline ecological transect survey of Pania Reef. Prepared for Port of Napier Ltd. Cawthron Report No. 3478. 51 p. plus appendices.

8. APPENDICES

Appendix 1. Example photographs for key taxa for which there is uncertainty over taxonomic classification. (Additional to those appended to Sneddon [2020]).



Appendix 2. Notes on the generation and interpretation of representative photographs of substrate and taxa from ecological survey dives.

Limited underwater visibility has meant that the Pania Reef photo-quadrat record was found to be of limited use in identifying all but the larger or more conspicuous encrusting biota. In order to provide some of the detail required at a finer scale for post-dive review purposes, an effort was made to compile a photographic record of taxa and substrate using compact digital cameras (Canon G16 PowerShot or Olympus TG6) carried by divers. Wide angle digital photography can compensate somewhat for turbid conditions by enabling subject-object distances to be minimised. However, the amount of suspended material in the water means that flash lighting cannot be used with a small compact camera due to reflection from water column particulates. This in turn makes colour (and detail) of the resulting images very subdued. By using image manipulation software (Corel™ PhotoPaint), the approximate colour balance can be restored and some of the detail brought out of the image.

It is important to note, however, that the colour-adjusted images in this report are not what the diver saw; they overstate the degree of visual resolution possible with the human eye. The enhanced colours are also oversaturated in order to bring out maximum detail. Many of the photographs are shot in extreme close-up and a scale context may be absent. Most take in less than 0.25 m^2 of the substrate.

It is further important to note that there were unavoidably subjective aspects to the process by which the photographs were taken. Subjects were photographed because they were points of interest to the diver (representative or otherwise noteworthy taxa and substrates). There is also a possible bias towards composition (i.e. relatively featureless substrates are more likely to have been passed over). These biases can combine to give an impression of potentially higher ecological diversity than the reality. In contrast, the quadrat photographs were far less likely to incorporate bias as they were constrained to a strict spatial framework that disregarded the nature of the subject being photographed.

Finally, the larger macroalga kelp (*Ecklonia radiata*) found in many of the transects is likely to be under-represented in both photo-quadrats and compact camera photographs. This is related to scale. Turbid conditions mean that it is often not possible to take photographs which could show kelp forest habitat at a large enough scale to represent its extent and density. Nonetheless, this necessarily wider visual perspective can be achieved through a review of the underwater video footage.

Appendix 3. Transect abundance scores for individual taxa from the baseline surveys (mean AS values) and the current survey, generated according to the categorisations in Table 1. Values represent summations of all abundance codes recorded along each transect. Shading intensity relates to the magnitude of the cell value. All blank cells represent zero (taxon not observed). Zero mean values indicate < 0.5. Taxa in yellow cells are those newly identified in the current (October 2020) survey. Transects in north to south order.

Table A2.1 Algae and invertebrates.

	Survey	**Baseline mean**								**October 2020**							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Phaeophyceae	**Brown algae**																
Ecklonia radiata	Kelp	18	38	3	33	16	25	16		21	39	3	31	6	22	16	
Carpophyllum maschalocarpum	Flap jack		17								13						
Halopteris sp.		1	11							3	15		4		1		
Zonaria sp.			7								4						
Carpomitra costata		1	12		1						5		4		1		
Dictyota										5	2	6	7	1	3	13	9
Rhodophyta	**Red algae**																
Corallinales	Coralline paint	14	36		29	11	8	2	0	15	40		25	4	10	2	3
Plocamium cirrhosum		13	13	2	22	16	23	18	12	15	20		26	6	19	22	7
Pterocladia capillacea			2								2						
Rhodophyta sp.	Small bladed red algae	2	3	6	5	13	20	13	13	12	14	17	18	26	22	23	24
Red encrusting algae	Red encrusting algae		3			0											
Red fine algae	Red fine algae	5	0		2					2							
Chloroophyta	**Green algae**																
Chlorophyta	Green algae (grass-like)	4	4		8					13	15		21		1		
Porifera	**Sponges**																
Ecionemia alata	Grey vase sponge	14	20	16	24	18	26	16	21	15	18	13	27	29	23	20	20
Cliona cf. *celata*	Yellow boring sponge	5	16	1	12	4	8	2	3	12	23	7	20	3	7	7	8

	Survey	Baseline mean								October 2020							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
cf. *Stylopus australis*	Red emergent/encrusting sponge		1		1	1		0	4	1					2	2	
cf. *Tedania* sp.	Orange encrusting sponge	2	4	7	1	10	2	5	9	3	9	9	5	2	4	7	8
cf. *Hymeniacidon* sp.	Orange massive sponge		2					0	0			1					
Tethya bergquistae	Pink golf ball sponge	1	0	1	0	4	2	6	2		1					4	6
Tethya burtoni	Orange golf ball sponge	2	1	3	5	2	8	3	10	2	7	5	9	7	8	5	12
Ciocalypta sp.	Yellow tubular sponge	16	7	13	13	14	12	20	19	16	14	11	15	15	14	26	19
cf. *Thorecta* sp.	Lobed grey sponge	0		0	0	5	2	5	6				2		4	4	4
Raspailia topsenti	Orange finger sponge	12	3	10	12	15	13	13	14	20	5	12	15	18	14	14	13
Demospongia A (White/green)	White/green massive sp		0	1		2		0	1		1	3		3		1	3
Demospongia B (Grey)	Grey lumpy massive sp		2	1	2		1	0	0	5	3	2	4		1	1	2
Demospongia C (Pink)	Pink thick encrusting sp		0	0	4	0		2								9	4
Demospongia D (Lilac)	Lilac spiky sponge	1	1	3	10	14	14	15	18	9	3	10	12	20	21	20	23
Demospongia E (Yellow)	Yellow lumpy massive sp			4	1	8	4	11	8	2		7	9	4	3	9	11
Demospongia F (Maroon)	Maroon massive sponge	1		0		1	0	2			4			1		1	
Latrunculia cf. *procumbens*	Green mushroom-like sp.		2		1	1	1	1					1				
Grey encr. cf. *Ircinia novaezealandiae*	Grey encrusting sponge	0	0	1			1										
Brown massive cf. *Polymastia massalis*	Brown massive sponge	1		0		1		1	1	1		1					4
Globose sponge cf. *Aaptos globosum*	Globose sponge	1	0	1		3	1	4	0	1	1		2		2	18	
Branching sponge cf. *Iophon minor*	Cream branching sponge							0	3					2			7
Orange honeycomb sponge	Orange honeycomb sponge								1								
cf. *Dendrilla rosea*	Pink erect conulose		0	0		0					2						
Callyspongia cf. *annulate*	Mauve finger sponge				0				2	2		1		1	3	2	3
cf. Suberites perfectus	Grey smooth sponge	0	1	1	1		1		1	6	2	6	1	4	3	4	5

	Survey	Baseline mean								October 2020							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Orange lobed sponge	Orange lobed sponge				0					1		3	4		2		2
cf. *Iophon minor*	Yellow finger sponge				0			2								3	
Sponge cream encr.										1							
Bryozoa	**Bryozoans**																
Bryozoan Catenicellidae	Clowns hair bryozoan	14	10	5	16	8	4	3	3	11		7	14	1	1	2	1
cf. *Cellaria tenuirostris*	Branching bryozoan	8	1	8	9	5	2	7	1	23	6	12	13		4	7	3
cf. *Caberea zelandica*	Erect fan bryozoan		0	0	1	2	1	1	0			2	4		4	3	
cf. *Steginoporella* sp.	Orange tube bryozoan	12		8	8	11	6	6	10	23	6	13	22	21	16	13	21
Encrusting bryozoan	Encrusting bryozoan	8		0	1			6	1	4		2			4	1	7
cf. *Margaretta barbata*	Erect bryozoan	0	2	0					0	5	5						
Cnidaria	**Hydroids, anemones, corals**																
cf. *Aglaophenia* sp.	Feather hydroid	1	5	1	8	1	3	8	14	2	4	1	5		1	7	16
Solandria ericopsis	Hydroid tree	1		1	0	0	1		1	1		1					
Amphisbetia bispinosa	Mussel beard hydroid	1	1	1	5	6	1	1		1	1	4		4		4	
Branching hydroid	Branching / bushy hydroid	6		3	1	10	2	6	4	4		9	5	8	5	9	10
Ectopleura sp.	Solitary hydroid						0		0								1
cf. Bougainvillidae	Encrusting hydroid			1		0											
Anthothoe albocincta	White-striped anemone	1	5			0	0	14	16		3					17	11
Solitary anemone Undescr.	Solitary anemone	1					0	2		2			2			1	1
Alcyonium cf. *aurantiacum*	Common soft coral			0		3	0	3	4			8			7	5	8
Culicea rubiola	Colonial stony coral	3	2	1	4	4	1	1	1	2		1	2				
Monomyces rubrum	Cup coral (solitary)								0								
Corynactis australis	Jewel anemone		0			0										1	2
Zoanthids	Zoanthids			0		1								1			1

	Survey	Baseline mean								October 2020							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Fine hydroid	Fine hydroid	1	2	5	1	1	1	1	3						1	1	
Ascidiacea	**Tunicates, sea squirts**																
Pyura spinosissima	Sea tulip	1	1				1	2	3						2	2	2
Cnemdiocarpa sp.	Saddle squirt	3	5	4	10	6	7	8	11		11	2		6		6	4
Ascidiacea sp. A	Small red ascidian		2	1		6	1	8	8			2	2		5	11	16
cf. *Synoicum otagoensis*	Grey colonial ascidian	1		4	2	6	2	14	13	8		3	4	12	3	21	12
Eudistoma sp.	White colonial ascidian	1	2	1	0	5	3	11	12		2				1	7	8
cf. *Didemnum densum*	Cream colonial ascidian		0	1	0		3	4	4						2	1	1
Didemnum species complex	White didemnum		1		2	5	7	3	7		6	2			2	4	7
cf. *Pseudodistoma cereum*	White colonial ascidian					0	0	1									
Bivalvia	**Clams**																
Perna canaliculus	Green-lipped mussel	7	17	3	8	15	5	6	0	6	18	4	1	6		5	
Atrina zelandica	Horse mussel			1					1	1							
Ostreidae sp.	Flat oyster	1		1	1		1	2	1			2			1		
Bivalve (attached unid)	Attached bivalve	2	0	0				0									
Polyplacophora	**Chitons**																
Cryptoconchus porosus	Butterfly chiton				1	0	0			1	1				1		
Gastropoda	**Snails, sea slugs**																
Trochus viridus	Green top shell	1	6		1	1	1	1	1		7		3	1		2	
Calliostoma tigris	Tiger top shell	1			1	1		1		2	1	5	4	2	6	1	
Calliostoma pellucida	Top shell			0	0		0		0						2	1	3
Calliostoma punctulatum	Beaded top shell				0	0		1	1			1			1	2	
Cookia sulcata	Cook's turban shell	2	4		0					6	10		2				
Astraea heliotropium	Circular saw shell		1		1						2						
Argobuccinum pustulosum	Swollen trumpet shell				0	1	1			1	2	2	2		1	1	1

	Survey	Baseline mean								October 2020							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Dicathais orbita	White rock shell	1	4		1						2						
Buccinulum lineum	Lined whelk	1	1	0		1		1	1	2			1			1	4
Penion sulcatus	Siphon whelk	3	1	1	4	3	4	3	2	3	4	6	3	2	2	7	1
Cominella adspersa	Speckled whelk	0															
Whelk (Muracidae unid)	Unid. whelk	0	0								1			1		1	4
Cabestana spengleri	Spenglers trumpet shell		1										1				
Ceratosoma amoena	Clown nudibranch	3	2	5	4	5	4	3	4	1		7	3	12	2	1	4
Mayena australasia	Australasian triton								0							1	
Dendrodoris denisoni	Nudibranch									2							
Cantharidus sp.	Opal top shell										1						
Cephalopoda	**Octopus, squid**																
Octopus maorum	Octopus, squid	0				0								1			
Crustacea	**Crabs, lobster, barnacles**																
Jasus edwardsii	Crayfish		1					1	2							2	
Paguridae	Hermit crab	3	0	3	2	4	2	2	3	2	2	6	4		3	6	2
Guinusia chabrus	Red rock crab				0			0	1				1				1
Barnacle unid.	Barnacle		1		0			0									
Notomithrax minor	Decorator crab																1
Echinodermata	**Sea cucumbers, sea stars, urchins**																
Australostichopus mollis	Sea cucumber	3	2		1	4	0	8	2	9	8	1	4	2	1	9	
Patiriella regularis	Cushion star							0									
Pentagonaster pulchellus	Biscuit star																
Astrostole scabra	7-armed sea star		0		0	0		0	1		1			1			2
Coscinasterias muricata	11-armed sea star		0		0	0		1								1	

	Survey	Baseline mean								October 2020							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Ophiopsammus sp.	Snake star	0		0													
Evechinus cloroticus	Kina		3			1				1	3					2	

Table A3.2 Fish.

	Survey	Baseline mean								October 2020							
Species	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Caesioperca lepidoptera	Butterfly perch	9	7	6	23	14	2	5	7	3	6		8			2	
Parapercis colias	Blue cod	7	3	3	4	4	3	9	7	3	8	4	4			5	1
Pseudolabrus miles	Scarlet wrasse	3	7	1	7	6	2	3	1	2	3	3	6	1		1	
Notolabrus celidotus	Spotted wrasse	2	5	1	4	4	1	2	4		4					4	
Forsterygion varium	Variable triplefin	2	6	0	6	3	1	3	2	1	5	1	2			3	3
Scorpis lineolatus	Sweep	2	3	2	11	3	1	1	0		2						
Scorpaena papillosa	Dwarf scorpion fish	3	2	2	2	2	1	2	0	4	11	3	2	2	2	3	
Parika scaber	Leather jacket	6	3	0	2	1	0	1		3	4		3			1	
Cheilodactulus spectabilis	Red moki	0	1	1	3	2	0	0		1	1	1	4			2	2
Notolabrus fucicola	Banded wrasse	0	1		1	2	0	1	0		6					1	
Nemadactylus macropterus	Tarakihi	0			1	2	1		1						1		
Trachurus sp	Mackerel		1			3											
Hypoplectrodes huntii	Banded perch	1	0		0	1		0		1		1	2				
Forsterygion malcomi	Banded triplefin	0	0			1	1	0									
Forsterygion lapillum	Common triplefin	0	0	1		0			0			1					

	Survey	Baseline mean								October 2020							
Species	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Ruanoho whero	Spectacled triplefin	0			1	1			0								1
Latridopsis ciliaris	Blue moki		1		0				0		2						
Odax pullus	Butterfish/Green bone	0	1														
Chironemus marmoratus	Kelpfish/Hiwihiwi		0		0												
Aplodactylus arctidens	Marble fish	0			0						1						
Forsterygion maryannae	Oblique triplefin				1												
Pagrus auratus	Snapper		0		0												
Forsterygion flavonigrum	Yellow-black triplefin	0															
Notoclinops segmentatus	Blue-eyed triplefin		0								1						
Upeneichthys lineatus	Goat fish							0									
Myliobatis tenuicaudatus	Eagle ray						0				1						
Hippocampus abdominalis	Sea horse														1		
Conger verreauxi	Conger eel																1

Appendix 4. Occurrence of taxa within Town Reef transect TR1 for the current (2020) survey, with comparison to the record for the 2019 baseline. "Y" designates the observation of the taxon at some point along the transect, as identified by diver notes or from the compiled photographic and video record for the dive. Yellow-shaded cells designate taxa new to the transect record.

Taxon	Common name / description	2019	2020
Phaeophyceae	**Brown algae**		
Ecklonia radiata	Kelp	Y	Y
Dictyota sp.			Y
Zonaria sp.			Y
Rhodophyta	**Red algae**		
Corallinales	Coralline paint	Y	Y
Plocamium cirrhosum		Y	Y
Rhodymenia sp. A	Small red blade algae	Y	Y
Rhodymenia sp. B	Red algae foliose	Y	Y
cf. *Hildenbrandia*	Red encrusting algae	Y	Y
Chlorophyta	**Green algae**		
Chlorophyta	Turfing green alga		Y
Porifera	**Sponges**		
Ecionemia alata	Grey vase sponge	Y	Y
Cliona cf. *celata*	Yellow boring sponge	Y	Y
Orange encrusting cf.*Tedania* sp.	Orange encrusting sponge	Y	Y
Tethya bergquistae	Pink golf ball sponge	Y	Y
Tethya burtoni	Orange golf ball sponge	Y	Y
Ciocalypta sp.	Yellow tubular sponge	Y	Y
Bright orange emergent sponge		Y	Y
Pink Demospongiae C	Pink thick encrusting sponge	Y	Y
Lilac Demospongiae D	Lilac spiky sponge	Y	Y
Grey encrusting cf. *Ircinia novaezealandiae*	Grey encrusting sponge	Y	Y
Grey massive cf. *Suberites perfectus*	Smooth grey sponge	Y	Y
Globose sponge cf. *Aaptos globosum*	Globose sponge	Y	Y
Maroon sponge			Y
White/green sponge			Y
Bryozoa	**Bryozoans**		
Bryozoan Catenicellidae	Clowns hair/moss bryozoan	Y	Y
Encrusting cf. *Parasmittina delicatula*	Encrusting bryozoan	Y	Y
Cnidaria	**Hydroids, anemones, corals**		
Feather hydroid cf. *Aglaophenia* sp.	Feather hydroid	Y	Y
Amphisbetia bispinosa	Mussel beard hydroid	Y	
Culicea rubiola	Colonial stony coral	Y	
Corynactis australis	Jewel anemone	Y	Y
Fine hydroid (on *Ecklonia*)		Y	
Cnidarian small green	Cnidarian small green	Y	
Polychaeta	**Polychaete worms**		
Serpullidae	Calcareous tube worm	Y	

Taxon	Common name / description	2019	2020
Ascidiacea	**Tunicates, sea squirts**		
Pyura spinosissima	Sea tulip	Y	Y
Cnemdiocarpa sp.	Saddle squirt	Y	Y
Ascidiacea sp. A	Small red-mouthed ascidian	Y	Y
cf *Synoicum otagoensis*	Grey colonial ascidian	Y	Y
Eudistoma sp.	White colonial ascidian	Y	Y
Cream colonial asc. cf. *Didemnum*	Cream colonial ascidian	Y	Y
Didemnum sp. (white)	White didemnum	Y	Y
Bivalvia	**Clams**		
Perna canaliculus	Green-lipped mussel	Y	
Ostreidae sp.	Flat oyster	Y	
Gastropoda	**Snails, sea slugs**		
Trochus viridus	Green top shell	Y	Y
Cookia sulcata	Cook's turban shell	Y	Y
Buccinulum lineum	Lined whelk	Y	Y
Xymene sp.	Whelk	Y	Y
Cabestana spengleri	Spenglers trumpet shell	Y	Y
Maoricolpus roseus	Turret shell		Y
Whelk unid	Unidentified small whelk	Y	Y
Ceratosoma amoena	Clown nudibranch	Y	Y
Cephalopoda	**Octopus, squid**		
Octopus maorum	Octopus	Y	
Crustacea	**Crabs, lobster, barnacles**		
Jasus edwardsii	Crayfish	Y	
Pagurus sp.	Hermit crab		Y
Echinodermata	**Sea cucumbers, sea stars, urchins**		
Patiriella regularis	Cushion star	Y	
Pentagonaster pulchellus	Biscuit star	Y	Y
Astrostole scabra	7-armed sea star	Y	Y
Coscinasterias muricata	11-armed sea star	Y	
Stichaster australis	Reef star		Y
Evechinus chloroticus	Kina	Y	Y
Osteichthyes	**Fish**		
Cheilodactylus spectabilis	Red moki	Y	
Notolabrus celidotus	Spotted wrasse	Y	
Parapercis colias	Blue cod	Y	Y
Notolabrus fucicola	Banded wrasse	Y	Y
Pseudolabrus miles	Scarlet wrasse	Y	
Odax pullus	Butterfish/Green bone	Y	
Chironemus marmoratus	Kelpfish/Hiwihiwi	Y	
Aplodactylus arctidens	Marble fish	Y	Y
Forsterygion varium	Variable triplefin	Y	Y
Ruanoho whero	Spectacled triplefin	Y	