CAWTHRON

REPORT NO. 3761

ECOLOGICAL TRANSECT SURVEYS OF PANIA AND TOWN REEFS: DECEMBER 2021

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ISSUE DATE: 15 June 2022

RECOMMENDED CITATION: Sneddon R 2022. Ecological transect surveys of Pania and Town reefs: December 2021. Prepared for Port of Napier Ltd. Cawthron Report No. 3761. 87 p. plus appendices.

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 third survey conducted during the dredging phase of the project, and follows surveys completed in October 2020 and May 2021. Prior to these, three baseline surveys of Pania Reef were 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 of both reef systems was conducted in December 2021.

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 were bracketed into 10-m segments for 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. 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 transect depth profiles and substrates. The compiled abundance data for all surveys was also analysed statistically.

All lines of evidence from the Pania Reef monitoring record suggested that there has been no deterioration since the baseline in the marine communities the Reef supports. Diver observations and the photographic and video record also gave no indication of an ecologically significant change in the prevalence of sand and silt accumulations on the reef.

While the data indicated changes in the abundance of some reef taxa, the pattern of these changes across surveys are likely to primarily reflect background variability influenced by natural seasonal and inter-annual drivers. Importantly, these changes did not constitute a decrease in ecological diversity, nor did they suggest the action of stressors potentially associated with the capital dredging project.

Similarly, the presence/absence and photographic record of communities compiled for the three Town Reef transects indicated that its ecological status remains effectively unchanged from the 2019 baseline.

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GLOSSARY

Item	Description / meaning	Category
ΔAS	Absolute change in abundance score (AS) relative to the mean baseline value	Abbreviation
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 or centimetres	Unit
g	Grams	Unit
GPS	Global Positioning System	Acronym
ha	Hectare	Unit
HOA	Heads of Agreement	Acronym
km	Kilometre	Unit
LoS	Level of similarity	Acronym
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
tAS	Total (survey) abundance score (sum of AS over eight transects)	Acronym

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 present 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 is being 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 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.

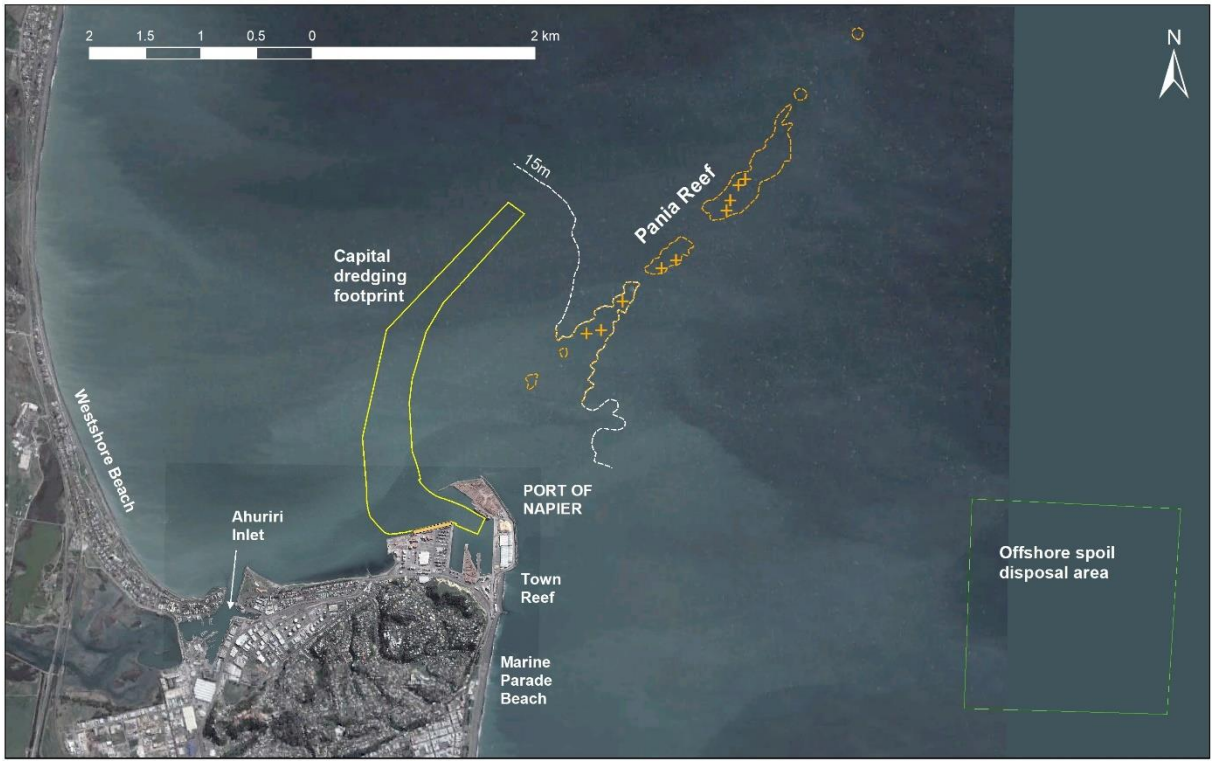

Figure 1. Composite aerial photograph of Port of Napier, showing the scale and layout of the proposed project elements.

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). The first survey during the dredging phase of the project was conducted in October 2020 (Sneddon & Dunmore 2021) and the second in May 2021 (Sneddon 2021).

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 third survey 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).

The report first presents a descriptive characterisation of each reef transect, with a detailed listing of notable changes in substrate and communities since the baseline surveys. In following sections, it provides a broader examination and statistical analysis of the data compiled across all surveys to date to identify discernible trends in reef habitats and communities.

2. METHODS

2.1. Reef transects

The current surveys of Pania and Town reefs were undertaken over 21–23 December 2021 by four Cawthron Institute scientific divers working from the 6.5 m work boat *Rampant*. At each reef location, a 100-m transect line was laid according to pre-established GPS waypoints and compass bearings. The weighted 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.

2.2. Pania Reef

The survey comprised eight 100-m dive transects spaced out along the length of the reef (PR1–PR8: Figure 2). The locations of the transects were the same as those used in all surveys conducted since 2016. Prior to the April 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).

2.2.1. Data collection

Two divers descended to the deepest point of the transect then swam along the transect line, one recording the presence and relative abundance of conspicuous biota, the other taking quadrat photographs and recording video. Abundance data and observations were compiled 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. The data were entered using a categorical scale, ranked subjectively as ‘rare’, ‘occasional’, ‘common’, or ‘abundant’. Guidelines used for assessment of these abundance categories are listed in Table 1.

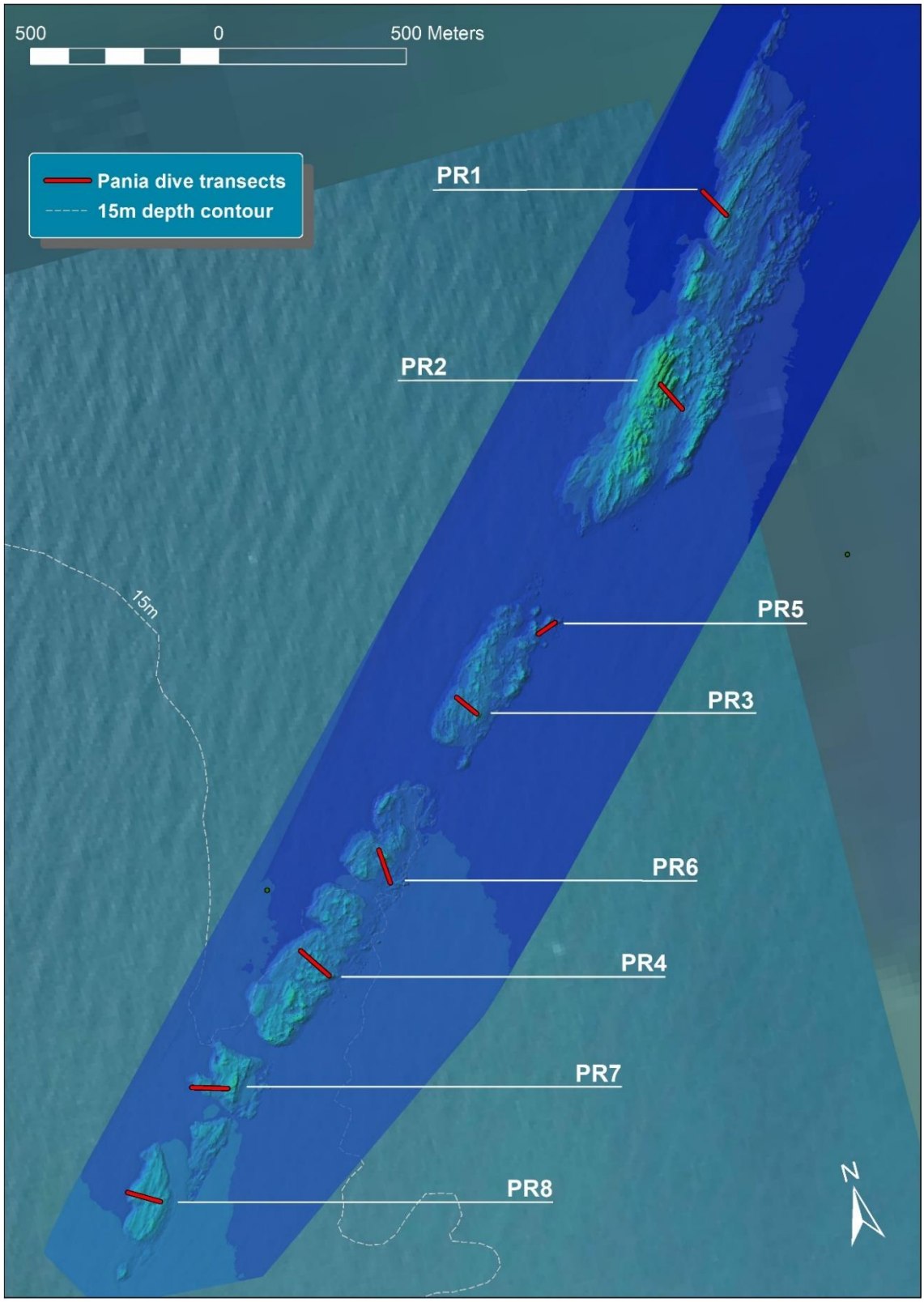

Figure 2. Multi-beam Echo-Sounder (MBES) image of Pania Reef showing locations of survey transects.

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.

At each of the 10-m interval marks along the transect, five photoquadrats were taken using a 10-megapixel digital camera attached at a fixed distance from a 41 cm x 61 cm (0.25 m^2) rectangular quadrat frame. One image 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. Both divers also used compact hand-held cameras to collect additional close-up images of biota.

The categorical abundance data and photographic/video information was used to compile a description of the habitats and the community of epibiota[1] occurring at the transect locations.

2.2.2. Taxonomy

Identifications were made to the lowest practicable taxonomic level. The accurate identification of encrusting taxa in the field or from a photographic record can be challenging, especially when that record is generated in conditions of low underwater visibility. For some groups of reef organisms (such as sponges and some algae), the range of image-based taxonomic references available is limited. Even with such resources, species-level identification may be very difficult without sample collection and laboratory examination. Where necessary, tentative classifications have been made from taxonomic references based on morphologically similar species or higher-order groups (e.g. order, family). In some instances, only descriptive classifications have been possible within phylum or class. Example photographs of such descriptive or uncertain classifications for key organisms were provided in the final baseline and first dredging phase reports (Sneddon 2020 and Sneddon & Dunmore 2021, respectively).

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

A project-specific taxonomic image library has been developed during the baseline monitoring, using input from all divers involved in fieldwork. Hence the indeterminate taxonomic status of some organisms does not prevent a subsequent assessment of the nature and scale of any change in these communities. This photographic reference is carried in hard-copy form on all field surveys, discussed in regard to all identification issues, and amended and / or added to as required.

2.2.3. 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 details can be easily missed.
- Through video review, divers can effectively ‘re-experience’ the transect, fleshing out detail of reef topography and other physical habitat components.
- The quadrat and close-up image sets are complementary. While the latter are taken opportunistically, both sets are bracketed with shots of transect distance tags to allow placement within each 10-m section. Together they provide a reasonably comprehensive record of the habitats and conspicuous biota occurring along each transect.
- In close-up shots, compact cameras can resolve significantly greater detail than the human eye since a very short focal distance is enabled.
- 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 diver bias and improve future capability.

There are, however, certain 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 record.
- It is more difficult to gauge actual abundance with a limited photographic record, especially with taxa too small to be conspicuous in the more systematically generated video or quadrat photographs. Hence interpretation of abundance has

been necessarily conservative and all changes[2] to the diver transcript are flagged accordingly.

Further notes on the use and limitations of the photographic record are provided in Appendix 1.

Depth profile plots were generated for each transect from the diver-recorded depths at each of the 11 distance tags. These were adjusted for tidal variation (to mean sea level—MSL) and fitted to a spline curve. This enabled comparison with those from previous surveys.

2.2.4. 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 with a potential maximum value of 40. These could then be compared across the eight transects and between surveys to evaluate spatial and temporal variability. The key values for comparison were the mean baseline abundance scores (data averaged across the three baseline surveys).

A total or survey abundance score (tAS) was also generated for key taxa from summing the AS across the eight transects; this gave a broader overview of population status across the whole of Pania Reef, effectively smoothing out some of the spatial 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. Such a change may also be represented by the increasing dominance of a single taxon or small group of taxa that can exploit a competitive advantage under stressed conditions.

Limitations

The semi-quantitative nature of the AS 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 surveys to date,

[2] Abundance scores for a transect segment were never changed from the diver record, only added where photographic evidence shows presence where non was recorded. This was conservative, in that the default for a photographic image would be a category of ‘Rare’, only moving to ‘Occasional’ when present in more than two photographs.

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 helps 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, in turn 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). 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. The interpretation of statistical analysis of overall community changes therefore needs to consider carefully the form of the data (how numerical data are generated) to achieve an appropriate and meaningful weighting for the categorical variables.

Statistical analyses

Multivariate statistical analysis of reef community AS data was conducted using the PRIMER v7 software package (Clarke & Gorley 2015; Anderson et al. 2008). The untransformed categorical data were compared based on Bray-Curtis similarities. Differences in community structure between transects and surveys were visualised using non-metric multidimensional scaling (nMDS) plots. Taxa contributing to variability and yielding a (Pearson) correlation greater than 0.65 with the spatial distribution of points were represented as vector overlays on the plot. Similarity Percentages Analysis (SIMPER, Clarke at al. 2014) was used to identify the species contributing most to any observed differences highlighted by the plots.

2.3. 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. Poor conditions in October

2020 meant that only the shallower TR1 transect could be completed. All three transects were completed successfully during the current survey, making it the first post-baseline record for TR2 and TR3.

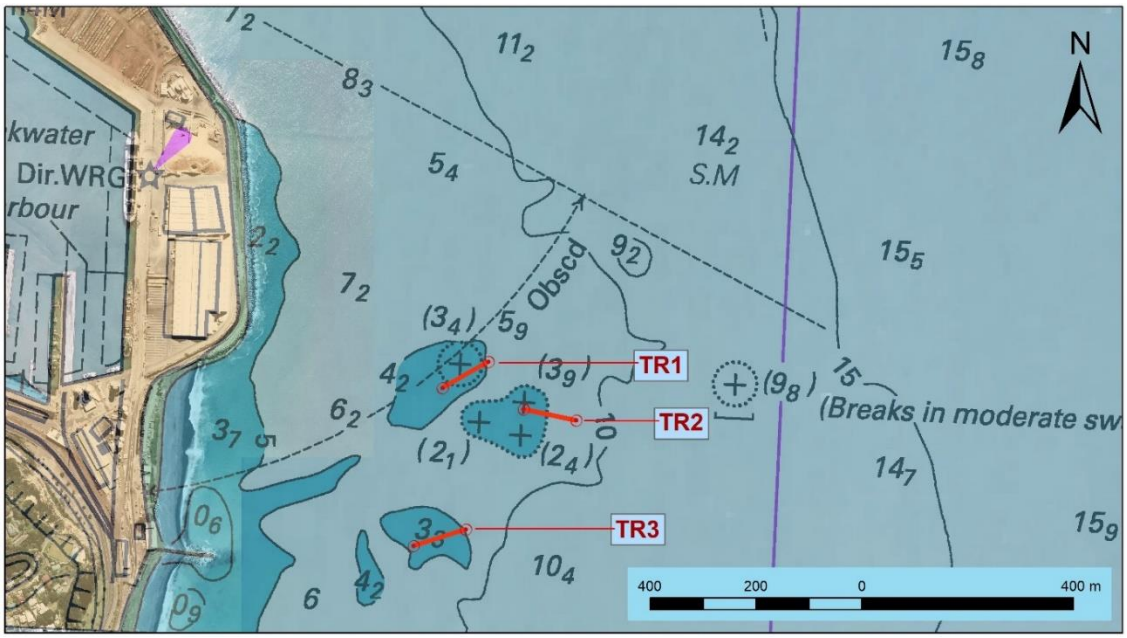

Figure 3. Locations of the three Town Reef dive transects (bold red lines), overlaid upon part of chart NZ5712a. Due to turbid conditions below 8-m depths, only the shallower TR1 transect could be surveyed in October 2020. All three transects were completed during the December 2021 survey.

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 and video were taken of each 10-m distance tag, thereby bracketing the collected imagery 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 adjusted for tidal state (to mean sea level; MSL) and 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. SURVEY RESULTS

3.1. Survey conditions and photographic record

Similar to the May 2021 survey, underwater visibility during the current (December 2021) survey was generally better than that encountered in surveys prior to 2021. As well as facilitating the compilation of the reef community record by divers, this resulted in a comprehensive high-quality photographic and video record for review purposes. The prevalence of entrapped and embedded silt in encrusting communities meant that the quadrat photographs continued to be of limited use for identification of the many smaller and less conspicuous organisms, so their primary value remains that of providing a consistent perspective and scale to benchmark physical and biological habitat characteristics. Use of hand-held compact cameras by divers enabled the collection of a set of clear images at close range for more detailed review and validation of the community record.

3.2. Individual transects: Description of habitats and communities

The following sections present descriptions and graphics that characterise the communities and habitats along each transect. 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 in the left-hand column to give a narrative overview. Summary data from the December 2021 (D21) survey are presented in the far-right column. Generally, the focus was placed on differences in the prevalence of taxa compared to the baseline, particularly with regard to the more dominant, abundant or habitat-forming organisms.

The abundance score (AS) for the transect is the sum of the abundance rankings from each 10-m section (converted from the categorical scale 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 not observed 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.
- The number of taxa newly recorded on the transect (absent from previous surveys). These taxa are listed if present at AS > 3.
- Taxa less prevalent than during the baseline where the AS was lower than that recorded over all three baseline records, and the difference from the mean baseline AS was greater than three (ΔAS > 3). These are ordered from most to least abundant rather than according to taxonomic group.
- Taxa more prevalent in the current survey than during the baseline are listed if AS exceeded that of all three baseline surveys and exceeded the mean baseline

value by more than three (ΔAS > 3). These are ordered from most to least abundant rather than according to taxonomic group.

- Since mean baseline scores are an average of three values, they are specified to a single decimal place whereas scores from a single survey are left as whole numbers.

The complete AS data for the current survey, along with the mean baseline values, is listed for all taxa in the Reef inventory in Appendix 2.

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, compared in each figure with those recorded during all previous 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.

To accompany the depth profile, a series of eight photographs was selected from those taken by divers. These were chosen as representative of substrate, habitats and biota, and are shown in the figures with their locations along each transect. Note that, since the photographs were post-processed with colour-balancing software to increase contrast and bring out detail, the colour in some images may appear oversaturated and hence can misrepresent the visibility and colour observed by the divers (see further notes in Appendix 1).

3.2.1. 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 surveys and the current survey. 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 (April 2016, May 2019, February 2020).

PR1	Baseline surveys 2016–2020	December 2021
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 generally consistent with the baseline observations. However, similar to the May 2021 survey, the soft sediment featured in the first half of the transect appeared more prevalent as a primary substrate, finer and siltier than during the baseline.
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 algae (Corallinales) were also common above 14 m depth. *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.	7 taxa recorded. The prevalence of both *E. radiata* (AS 18) and *P. cirrhosum* (AS 1) were essentially unaltered from the baseline. Two algal taxa recorded from at least 2 baseline surveys were absent: • *Halopteris* sp. had been consistently rare (baseline AS 1.3) but recorded its greatest abundance in May 2021 (AS 8). • *C. costata* - had been recorded at very low levels in May 2019 (AS 2) and February 2020 (AS 2). There were no algal taxa recorded that were new to transect PR1 and of those that had been consistently present during the baseline, none had decreased more than AS 1 relative to the baseline mean. Four algal taxa had increased in prevalence: D21 Baseline • Grass-like green alga 16 3.7 • *Dictyota* sp. 13 0.0 • Small-bladed red 13 1.7

PR1	Baseline surveys 2016–2020	December 2021
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 (*Steginoporella neozelanica*), 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 amoenum*), 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 viridis*), 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.	53 taxa recorded. Two taxa were absent that had been recorded from two of the baseline surveys. However, neither had recorded a baseline mean of greater than AS 3. Six taxa recorded that were new to PR1, but none of these were more abundant than AS 2. Relative to the mean baseline, two bryozoans had decreased in prevalence by ∆AS >3: • Bryozoan Catenicellidae (clown's hair) — AS D21: 5; AS Baseline: 14.0 • Bryozoan encrusting — AS D21: 3; AS Baseline: 7.7 Taxa in greater prevalence (mean ∆AS > 3) than during any baseline survey: • Bryozoan cf. *Cellaria tenuirostris* — AS D21: 21; AS Baseline: 8.0 • Sponge *Cliona* cf. *celata* — AS D21: 15; AS Baseline: 5.3 • Bryozoan cf. *Margaretta barbata* — AS D21: 13; AS Baseline: 0.3 • Lilac sponge Demospongia D — AS D21: 8; AS Baseline: 1.3 • Holothurian *Australostichopus mollis* — AS D21: 8; AS Baseline: 3.3 • Colonial ascidian cf. *Synoicum otagoensis* — AS D21: 7; AS Baseline: 1.3 • Yellow breadcrumb sponge Demospongia E — AS D21: 6; AS Baseline: 0.0 • Feather hydroid cf. *Aglaophenia* spp. — AS D21: 6; AS Baseline: 1.0 • Grey massive sponge Demospongia B — AS D21: 4; AS Baseline: 0.0 • Grey sponge cf. *Suberites perfectus* — AS D21: 4; AS Baseline: 0.3 • Small red ascidian Ascidiacea sp. A — AS D21: 4; AS Baseline: 0.0 Note that three of these were absent from the baseline record.

PR1	Baseline surveys 2016–2020	December 2021
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.	13 species recorded. There was no species now absent that had been present (at mean AS > 3) across two or more baseline surveys. No species recorded a decrease in abundance score greater than ΔAS 3, although leather jackets (*P. scaber;* baseline mean AS 2.7) were absent. No species new to PR1 were observed. Species recorded in greater abundance (mean ΔAS > 3) than during any baseline survey: • Blue cod — AS D21: 12; AS Baseline: 6.7 • Scarlet wrasse — AS D21: 7; AS Baseline: 2.7

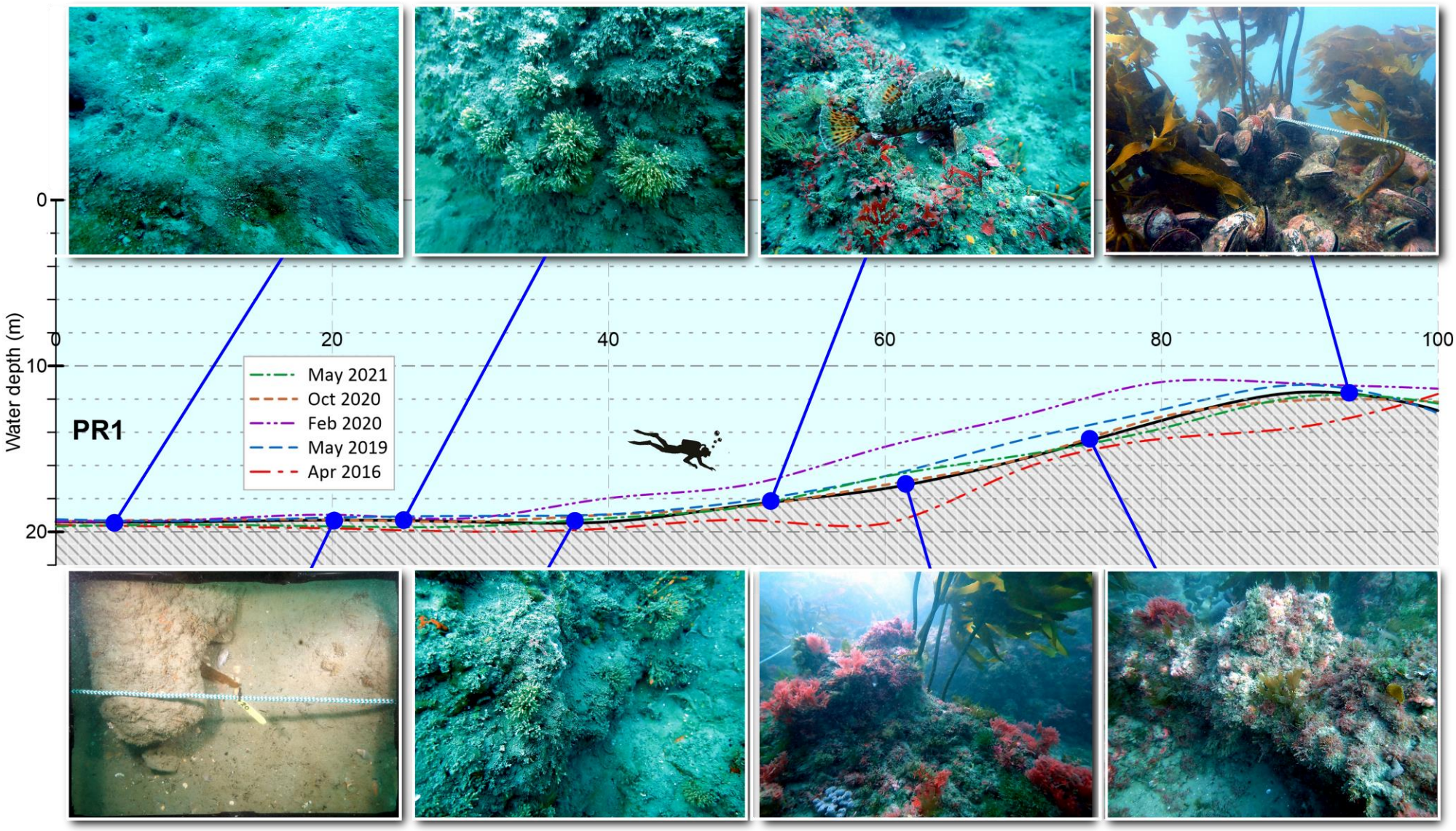

Figure 4. Depth profile with photographs of representative habitat and biota along transect PR1 in December 2021. The photographs are aligned with the transect profile; the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

3.2.2. Transect PR2

PR2 is located on the southwest 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 4–5 m depth (Figure 5).

Table 3. Notes on the physical and biogenic habitats and reef communities of transect PR2 for the three baseline surveys and the current survey. 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	December 2021
SUBSTRATE	The substrate along the first 10 m of the transect comprises 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 baseline surveys.	The progression of substrate along the transect was generally consistent with baseline observations, except the first 20 m were free of sand deposits. Thereafter, well-sorted sand was present in troughs between outcrops. Throughout the transect, there was no evidence of silt veneers. Reef crests were all but obscured by dense *C. maschalocarpum*.
ALGAE	8–11 taxa were recorded across the baseline surveys. Macrophyte communities are dominated by abundant kelp (*Ecklonia radiata*) and encrusting corallines. 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 (*Plocamium 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 the end of the transect.	14 taxa recorded. The prevalence of *E. radiata* (AS 37), *C. maschalocarpum* (AS 18) and coralline algae (AS 39) were similar to levels recorded during the baseline and subsequently. The only previously recorded algal taxa not observed was the red encrusting alga (cf. *Ralfsia* sp.) This had been present at low levels in May 2019 (AS 4) February 2020 (AS 5) and May 2021 (AS 3). Two algae new to the Pania Reef survey record were observed at PR2; the brown alga *Microzona velutina* (AS 2) and a fine green alga (AS 1), both have been previously recorded from Town Reef. Of the algal taxa consistently present during the baseline, only one (*C. costata;* AS 3) had decreased more than AS 3 relative to the baseline mean (AS 11.7).

PR2	Baseline surveys 2016–2020	December 2021
	Little variability in the prevalence of the key algal species has been observed across surveys.	Five algal taxa had increased in prevalence by ΔAS >3: • Red fine algae — AS D21: 19; AS Baseline: 0.3 • Small-bladed red alga — 15; 3.3 • Chlorophyta (grass-like) — 15; 4.3 • *Dictyota* sp. — 7; 0.0 • *Pterocladia capillacea* — 5; 1.7
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 (Demospongia). More variable is the presence of bryozoans such as *S. neozelanica*, cf. *Margaretta barbata*, cf. *Cellaria tenuirostris* and Catenicellidae. The occurrence of hydroids (e.g. feather hydroid [*Aglaophenia* spp.] 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 (*Cnemidocarpa* 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 linea*]). 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*.	42 taxa recorded. Three taxa were absent that had been recorded from two or more baseline surveys. Two of these had a baseline mean AS > 3: Orange encrusting cf.*Tedania* sp. (baseline AS 3.7) and bryozoan Catenicellidae (baseline AS 10.0). The gastropod *Calliostoma punctulatum* (AS 2) was the only inertebrate taxon new to transect PR2. Relative to the mean baseline, only the emergent sponge cf. *Ciocalypta* sp. (AS 2 vs baseline 7.0) had decreased in prevalence by ΔAS >3. Taxa in greater prevalence (mean ΔAS > 3) than during any baseline survey: • Vase sponge *Ecionemia alata* — AS D21: 25; AS Baseline: 19.7 • Mussel *Perna canaliculus* — 22; 16.7 • Gastropod *Cookia sulcata* — 20; 4.3 • Ascidian *Cnemidocarpa* sp. — 14; 5.3 • Gastropod *Dicathais orbita* — 11; 4.0 • Stony coral *Culicea rubeola* — 6; 2.3 • Ascidian *Didemnum* complex (white) — 6; 1.0 • Bryozoan cf. *Margaretta barbata* — 5; 1.7 • Hermit crab Paguridae — 4; 0.3

PR2	Baseline surveys 2016–2020	December 2021
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*), marblefish (*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*).	17 species recorded. There was no species now absent that had been present (at mean AS > 3) across two or more baseline surveys. No species recorded a decrease in abundance score greater than ΔAS 3. No species new to PR2 were recorded. Species recorded in greater abundance (mean ΔAS > 3) than during any baseline survey: • Banded wrasse — AS D21: 12; AS Baseline: 1.3 • Sweep — AS D21: 9; AS Baseline: 2.7 • Red moki — AS D21: 6; AS Baseline: 1.0 • Dwarf scorpionfish — AS D21: 6; AS Baseline: 2.3

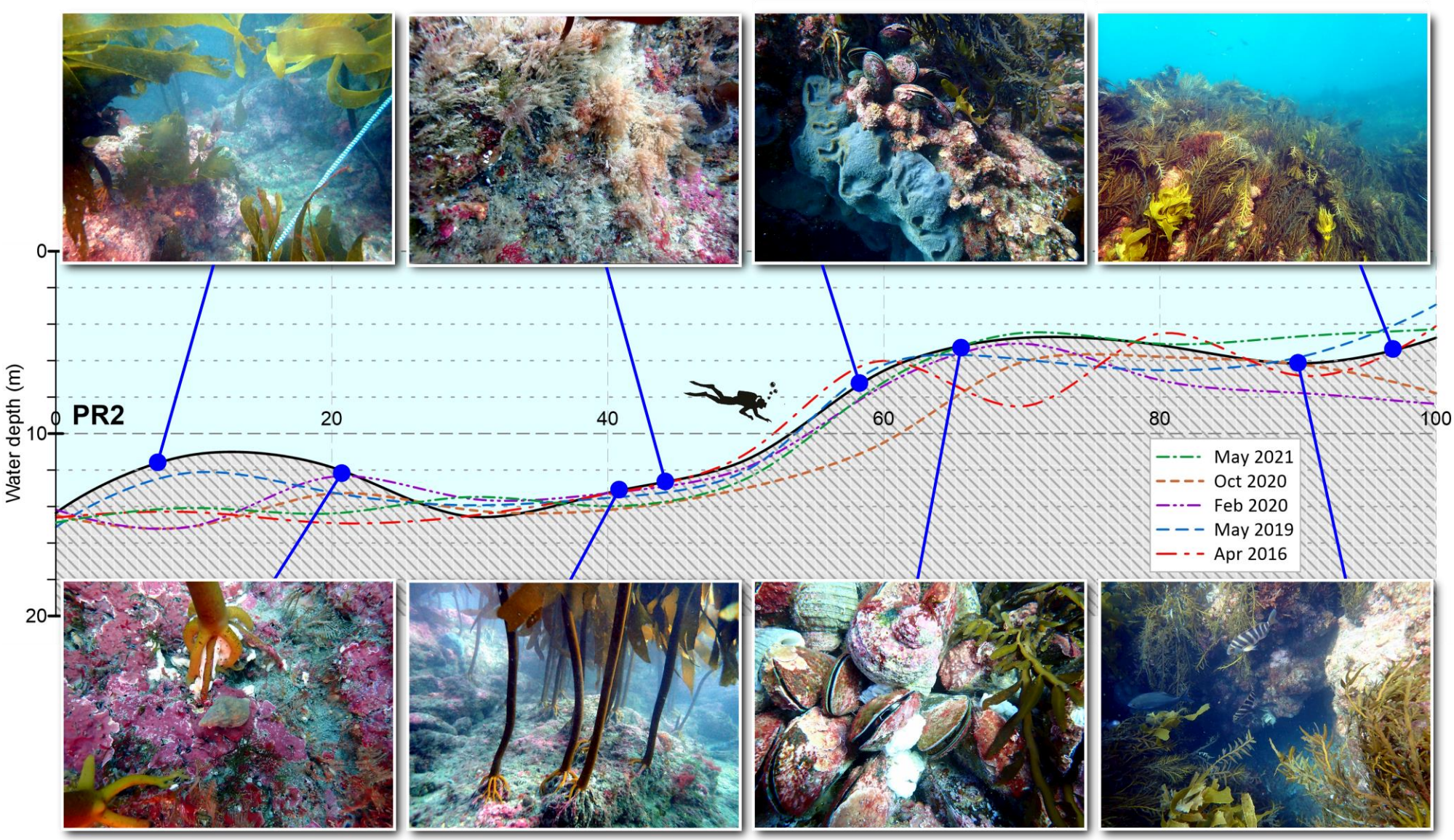

Figure 5. Depth profile with photographs of representative habitat and biota along transect PR2 in December 2021. The photographs are aligned with the transect profile; the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

3.2.3. 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 surveys and the current survey. 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	December 2021
SUBSTRATE	The greater prevalence of silty sand and frequent low visibility encountered at this transect are 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.	Generally consistent with baseline observations, but a greater prevalence of rippled mobile sand was noted. This comprised the entire first 25 m of the transect, 5-m expanses from the 35 m and 50 m marks, and a 10-m stretch from 60 m. However, emergent bedrock outcrops were usually in view to the side and some cobble field was notable at the 75 m mark. Embedded silt was a feature of encrusting communities throughout the transect.
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.). Coralline algae was notably absent.	3 taxa recorded. The only algal species recorded consistently across the three baseline surveys was *E. radiata.* This continues to be present at low levels (AS 2). *P. cirrhosum* was absent, having been recorded in two baseline surveys: April 2016 (AS 5) and February 2020 (AS 2). It was also recorded in May 2021 (AS 3). There were no algae new to PR5, although *Dictyota* sp. had not been recorded during the baseline. No algal taxa had decreased more than ΔAS 3 relative to the mean baseline. Relative to the mean baseline, two algal taxa had increased in prevalence by ΔAS > 3: • Small-bladed red alga — AS D21: 18; AS Baseline: 6.0 • *Dictyota* sp. — AS D21: 10; AS Baseline: 0.0

<table>
<tr><th>PR5</th><th>Baseline surveys 2016–2020</th><th>December 2021</th></tr>
<tr><td>INVERTEBRATE COMMUNITIES</td><td>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 (Econemia alata) yellow tubular (Ciocalypta sp.) and finger sponge (Raspailia topsenti), although lilac (Demospongia D) yellow breadcrumb (Demospongia 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 (S. neozelanica). 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 amoenum), siphon whelks and hermit crabs were frequently present.</td><td>44 taxa recorded.
Two taxa were absent that had been recorded from two baseline surveys - Tethya bergquistae and a white/green sponge. However, neither had attained an abundance score of greater than 2.
Three taxa new to PR5, a hydroid, a zoanthid and a gastropod, were recorded only from single individuals.
The grey vase sponge Ecionemia alata (AS 10) was the only taxon recorded consistently across the baseline (mean AS 16.3) that had decreased more than ΔAS 3.

Taxa recorded in greater prevalence (mean ΔAS > 3) than during any baseline survey:
• Bryozoan Steginoporella neozelanica — AS D21: 16; AS Baseline: 7.7
• Ascidian Cnemidocarpa sp. — 15; 3.7
• Sponge Raspailia topsenti — 14; 9.7
• Colonial ascidian cf. Synoicum otagoensis — 12; 4.3
• Yellow breadcrumb sponge Demospongia E — 10; 4.0
• Feather hydroid cf. Aglaophenia spp. — 9; 1.3
• Branching hydroid — 9; 3.3
• Bryozoan encrusting — 8; 0.3
• Sponge Cliona cf. celata — 7; 0.7
• Lilac sponge Demospongia D — 7; 2.7
• Small red ascidian Ascidiacea sp. A — 7; 0.7
• Ascidian Didemnum complex (white) — 7; 0.0
• Grey sponge cf. Suberites perfectus — 5; 0.7
• Mussel beard Amphisbetia bispinosa — 5; 1.3
• Holothurian Australostichopus mollis — 4; 0.0</td></tr>
</table>

PR5	Baseline surveys 2016–2020	December 2021
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).	11 species recorded. There was no species absent that had been present (at mean AS > 3) across two or more baseline surveys. No species recorded a decrease in abundance score greater than ΔAS 3. No species new to PR5 were recorded, although banded wrasse and banded triplefin had not been obseved on this transect during the baseline. Species recorded in greater abundance (mean ΔAS > 3) than during any baseline survey: • Blue cod — AS D21: 11; AS Baseline: 3.3 • Scarlet wrasse — AS D21: 6; AS Baseline: 1.3 • Banded wrasse — AS D21: 4; AS Baseline: 0.0 • Banded triplefin — AS D21: 4; AS Baseline: 0.0

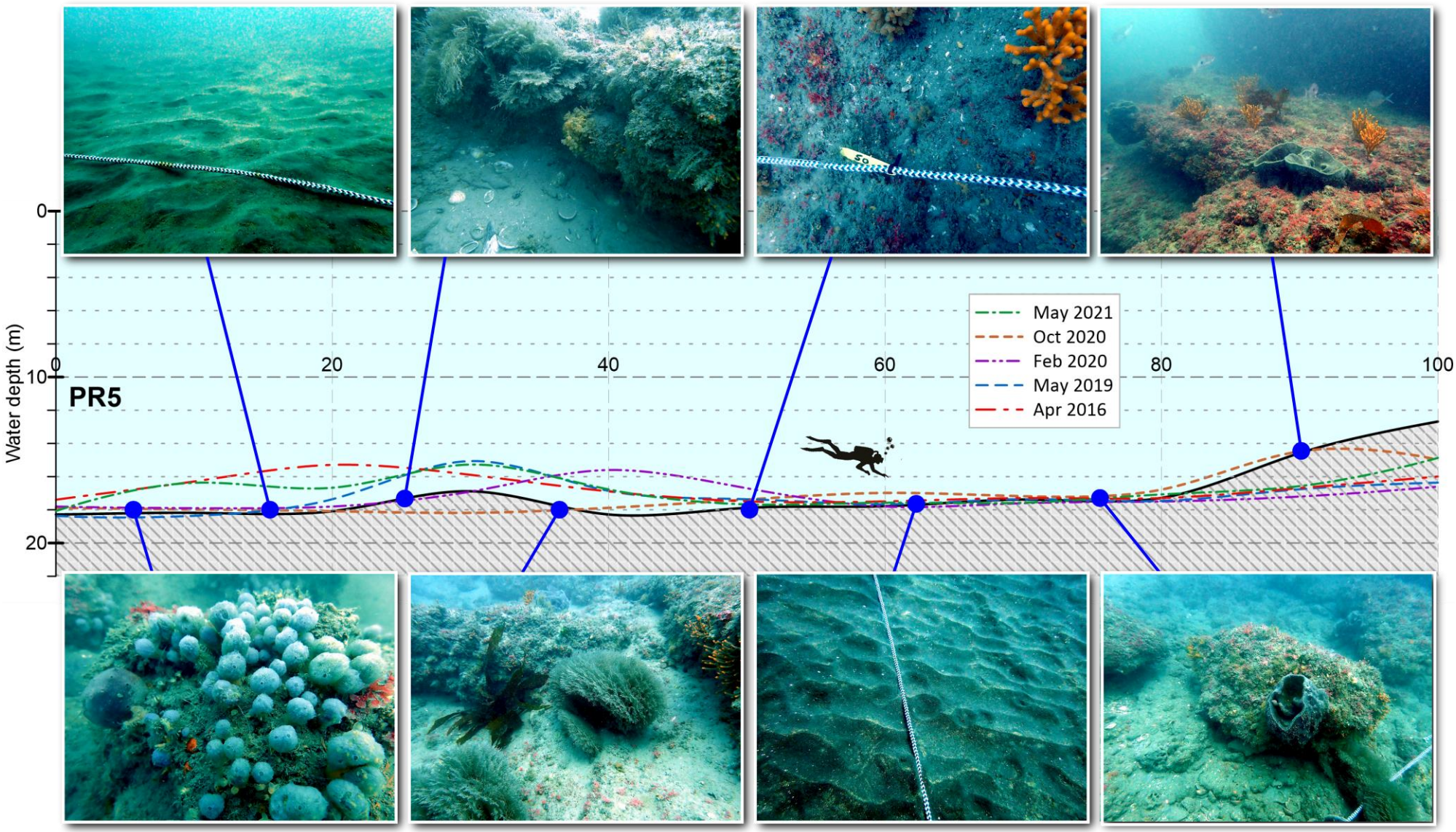

Figure 6. Depth profile with photographs of representative habitat and biota along transect PR5 in December 2021. The photographs are aligned with the transect profile; the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

3.2.4. 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 surveys and the current survey. 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	December 2021
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 only 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 the baseline. Embedded silt featured throughout, but less so in the last 40 m. Patches of coarser silty sand with shell and gravel from 40–50 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 encrusting corallines 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.	7 taxa recorded. No algal species that were recorded consistently across the three baseline surveys were absent. The prevalence of *E. radiata* (AS 33) was effectively unaltered from the baseline. Only coralline algae (AS 24) had decreased in prevalence (ΔAS > 3) relative to the baseline (mean AS 29.3): Relative to the mean baseline, four algal taxa had increased in prevalence by ΔAS > 3: (AS M21 / AS Baseline) • *Dictyota* sp. 22 / 4.7 • Small-blade red 21 / 0.0 • Grass-like green alga 18 / 7.7 • Red fine algae 5 / 1.7

PR3	Baseline surveys 2016–2020	December 2021
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 encrusting corallines. 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 *S. neozelanica*, although the fan-like cf. *Caberea zelandica* could also be present in low numbers. Feather hydroids (*Aglaophenia* spp.) 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 amoenum*), siphon whelk (*Penion sulcatus*) and tiger (*Calliostoma tigris*) and green (*Trochus viridus*) topshells. Hermit crabs and sea cucumbers (*Australostichopus mollis*) were usually also present in low numbers.	40 taxa recorded. Three taxa previously recorded from two or more baseline surveys with mean AS>3 were absent: • Pink Demospongia C (baseline mean AS 4.3) • *Culicea rubiola* (baseline mean AS 3.7) • *Cnemidocarpa* sp. (baseline mean AS 9.7) Only one other taxon, the emergent sponge cf. *Ciocalypta* sp. (AS 6), recorded a decrease in abundance (ΔAS > 3) from the mean baseline (AS 13.3). Two taxa new to PR3 (kina and a zoanthid) were recorded as rare (AS 1). Taxa recorded in greater prevalence (mean ΔAS > 3) than during any baseline survey: • Feather hydroid cf. *Aglaophenia* spp. AS D21: 17, AS Baseline: 8.3 • Sponge *Raspailia topsenti* AS D21: 16, AS Baseline: 12.0 • Branching hydroid AS D21: 14, AS Baseline: 1.0 • Hermit crab Paguridae AS D21: 8, AS Baseline: 2.3 • Holothurian *Australostichopus mollis* AS D21: 7, AS Baseline: 1.3 • Yellow breadcrumb sponge Demospongia E AS D21: 5, AS Baseline: 1.3

PR3	Baseline surveys 2016–2020	December 2021
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.	17 species recorded. Spotted wrasse were absent, having been recorded from the April 2016 (AS 11) and May 2019 (AS 2) baseline surveys. They were, however, recorded in May 2021 (AS 4). Sweep was the only other species to have recorded a decrease in abundance score (relative to the mean baseline) greater than three: • Sweep — AS D21: 4; AS Baseline: 10.7 Two new species (red cod and giant boarfish) did not exceed AS 3. Banded triplefin were not recorded during the baseline. Species recorded in greater abundance (mean ΔAS > 3) than during any baseline survey: • Red moki — AS D21: 7; AS Baseline: 3.3 • Banded triplefin — AS D21: 5; AS Baseline: 0.0

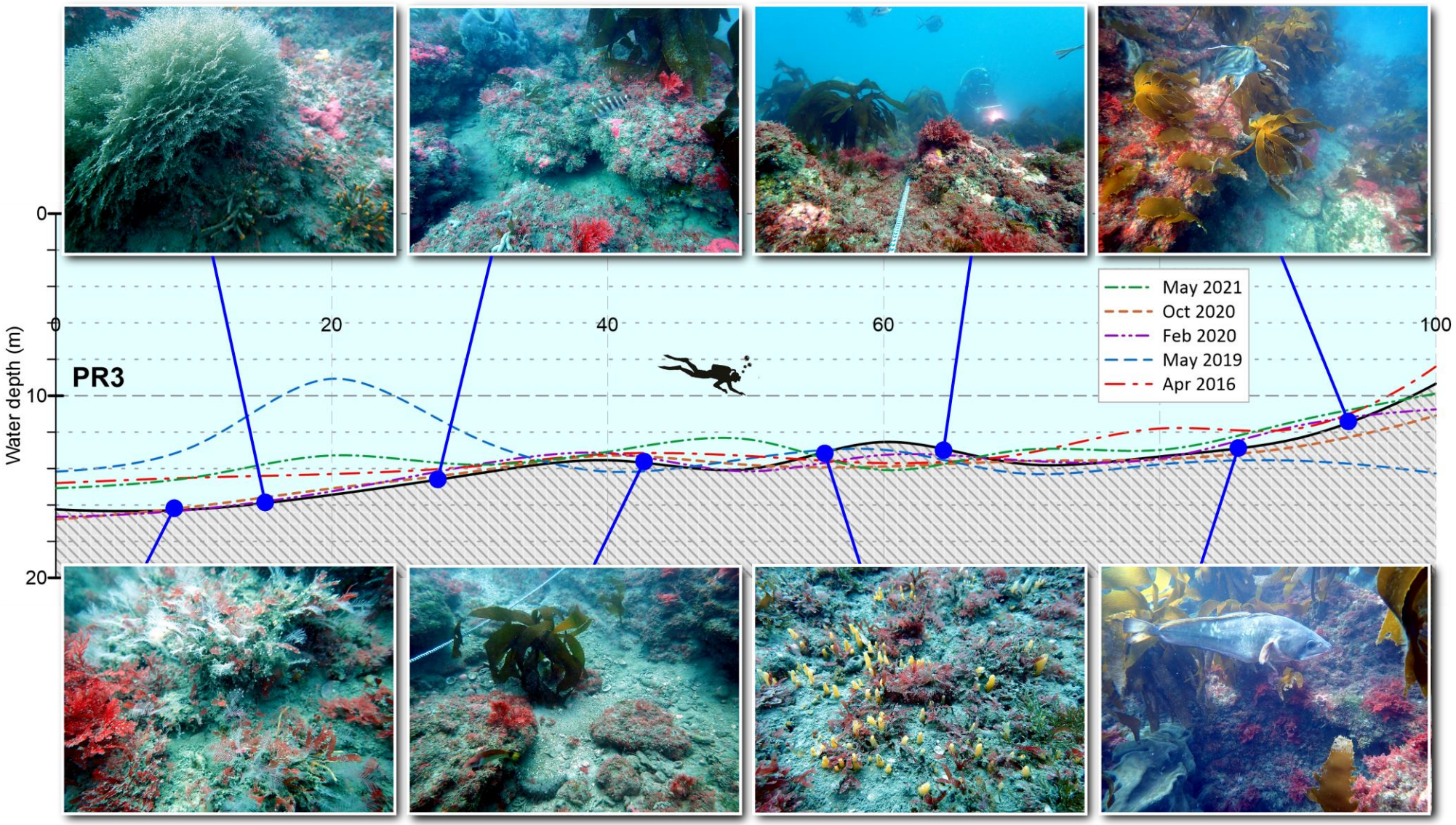

Figure 7. Depth profile with photographs of representative habitat and biota along transect PR3 in December 2021. The photographs are aligned with the transect profile; the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

3.2.5. 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 surveys and current survey. 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	December 2021
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 occurs only in small pockets and niches. Occasionally, ledges occur for the 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.	Largely consistent with the baseline description. Some boulder and cobble in first 20 m. At 30 m, ledges with entrapped cobble/pebble/shell material in the troughs. Much embedded silt in flatter areas of bedrock, but little after the 70 m mark. Transect ended a little past the reef crest.
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 sometimes occurred as recruits (up to ~30 cm high) along the entire transect. Encrusting corallines were present at low levels. *Plocamium cirrhosum* and small-bladed red alga also occurred throughout but were variable from year to year.	7 taxa recorded. No algal taxa that were recorded consistently across the three baseline surveys were absent. No decrease in abundance score exceeded ΔAS 3. All algal taxa have been quite variable across surveys, including the baseline. However, the more predominant *E. radiata* (AS 14) and *P. cirrhosum* (AS 15) were at similar levels to the mean baseline scores (both AS 16). Two algae new to PR6 (a fine red and a fine green) were both recorded as rare. The seasonal *Dictyota* sp. (AS 17) had not been recorded during the baseline. Apart from this, only the small-bladed red alga (AS 27) had increased (by more than AS 3) relative to its mean baseline (mean AS 12.7).

PR6	Baseline surveys 2016–2020	December 2021
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 globosa*). Prominent bryozoans included clowns hair (Catenicellidae) and *S. neozelanica*, 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) appeared 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 amoenum*), siphon whelk (*Penion sulcatus*), hermit crabs and sea cucumbers. The top shells *Calliostoma tigris* and *Trochus viridis* also featured, as well as kina (*Evechinus chloroticus*) in 2019 only.	55 taxa recorded. Only one taxon that had been recorded from more than a single baseline survey was absent (a maroon sponge), although this had been consistently rare. A decrease in abundance score (ΔAS > 3) relative to the baseline mean was recorded for three taxa: • Emergent sponge cf. *Ciocalypta* sp. — AS D21: 10; AS Baseline: 14.3 • Sponge orange encrusting cf.*Tedania* sp. — AS D21: 3; AS Baseline: 10.3 • Stony coral *Culicea rubiola* — AS D21: 1; AS Baseline: 4.3 However, only for *Ciocalypta* sp. was AS less than in all three baseline surveys. Of three taxa newly recorded at PR6, none exceeded AS 2. Taxa recorded in greater prevalence (mean ΔAS > 3) than during all baseline surveys: • Vase sponge *Ecionemia alata* — AS D21: 22; AS Baseline: 18.3 • Bryozoan *Steginoporella neozelanica* — AS D21: 22; AS Baseline: 11.3 • Branching hydroid — AS D21: 20; AS Baseline: 10.0 • Lilac sponge Demospongia D — AS D21: 19; AS Baseline: 14.3 • Small red ascidian Ascidiacea sp. A — AS D21: 19; AS Baseline: 5.7 • Feather hydroid cf. *Aglaophenia* spp. — AS D21: 13; AS Baseline: 1.3 • Bryozoan cf. *Cellaria tenuirostris* — AS D21: 12; AS Baseline: 5.0 • Orange golfball sponge *Tethya burtoni* — AS D21: 11; AS Baseline: 1.7 • Holothurian *Australostichopus mollis* — AS D21: 11; AS Baseline: 3.7 • Gastropod *Penion sulcatus* — AS D21: 10; AS Baseline: 3.3 • Sponge *Cliona* cf. *celata* — AS D21: 9; AS Baseline: 4.0 • Sponge *Latrunculia* cf. *procumbens* — AS D21: 7; AS Baseline: 1.0 • Grey massive sponge Demospongia B — AS D21: 4; AS Baseline: 0.0 • Bryozoan encrusting — AS D21: 4; AS Baseline: 0.0 • Anemone *Anthothoe albocincta* — AS D21: 4; AS Baseline: 0.3 • Gastropod *Trochus viridis* — AS D21: 4; AS Baseline: 0.7 • Gastropod *Argobuccinum pustulosum* — AS D21: 4; AS Baseline: 0.7 • Crayfish *Jasus edwardsii* — AS D21: 4; AS Baseline: 0.0

PR6	Baseline surveys 2016–2020	December 2021
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.).	13 species recorded. Banded wrasse and leather jackets were absent although neither had recorded a mean baseline abundance greater than AS 3. Scarlet wrasse (AS 1) was the only fish species to have been consistently present during the baseline and to have decreased by more than 3 (from a baseline mean of AS 5.7). Marblefish were new to PR6 but were recorded as just a single individual (AS 1). Species recorded in greater abundance (mean ΔAS > 3) than during any baseline survey: • Butterfly perch (AS D21: 24; AS Baseline: 14.3) • Blue cod (11; 3.7) • Dwarf scorpion fish (5; 1.7) • Banded triplefin *Forsterygion malcomi* (4; 0.7)

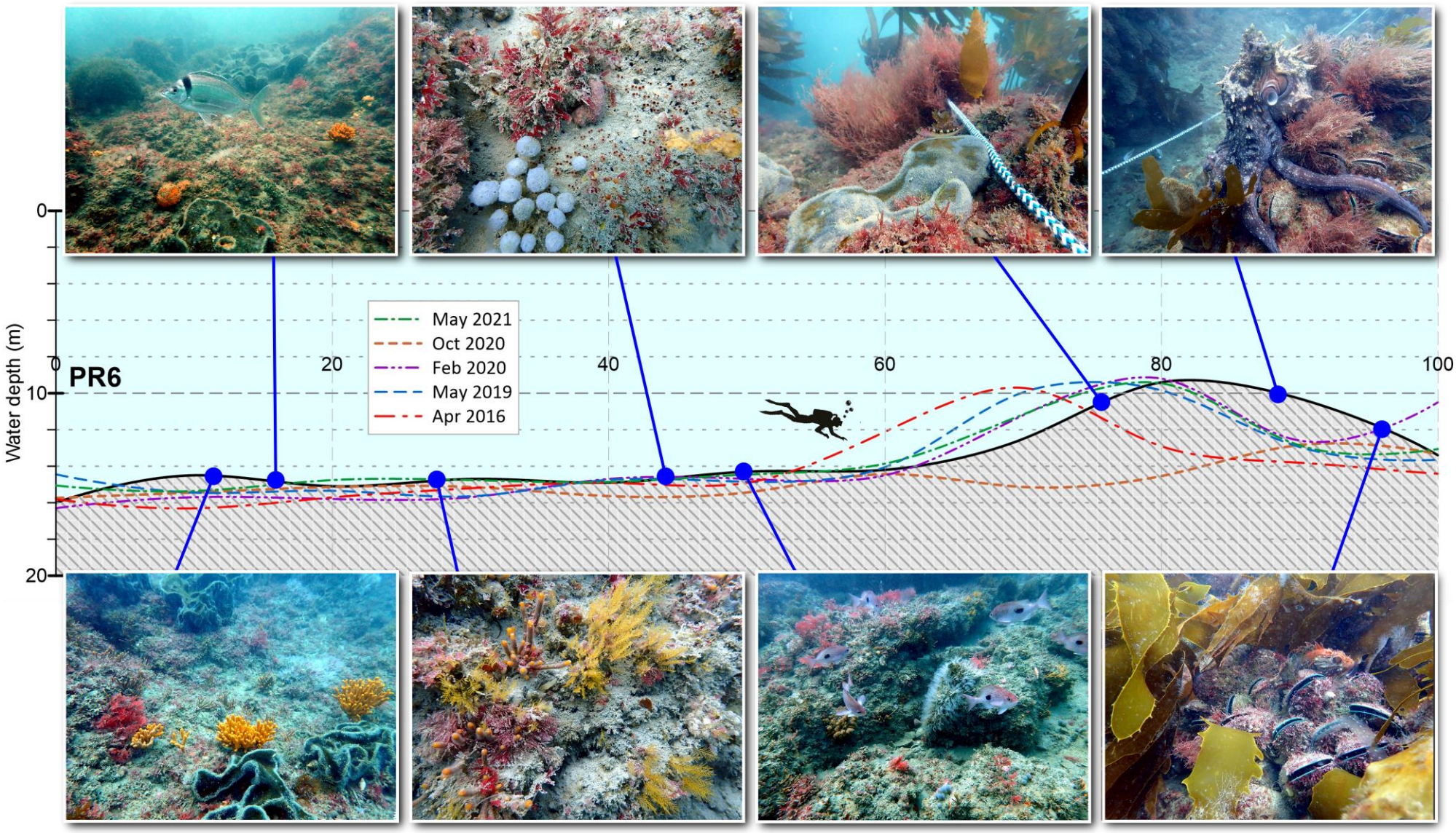

Figure 8. Depth profile with photographs of representative habitat and biota along transect PR6 in December 2021. The photographs are aligned with the transect profile; the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

3.2.6. 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 surveys and current survey. 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	December 2021
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.	Consistent with the baseline descriptions. No loose settled silt (except in protected niches) or veneers. Cobble/shell patches not infrequent. Embedded silt a consistent feature except on higher outcrops/reef crest.
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. Encrusitng corallines were more prevalent at the shallow end of the transect.	5 taxa recorded. No algal taxa that were recorded from two or more baseline surveys were now absent and no algae had decreased in prevalence more than ΔAS 3 relative to the baseline. There were no newly recorded algal taxa, although *Dictyota* sp. (AS 20) had not been present during the baseline. *E. radiata* (AS 22) was at similar levels to those recorded across the baseline surveys (mean AS 25). Relative to the mean baseline, four algal taxa had increased in prevalence by ΔAS > 3: • Small-bladed red alga (AS D21: 30; AS Baseline: 19.7) • *P. cirrhosum* (AS D21: 29; AS Baseline: 23.3) • *Dictyota* sp. (AS D21: 23; AS Baseline: 0.0) • Coralline algae (AS D21: 18; AS Baseline: 8.0) However, both small bladed red and *P. cirrhosum* reached the current prevalence in the April 2016 baseline survey.

PR4	Baseline surveys 2016–2020	December 2021
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, *S. neozelanica* and cf. *Cellaria tenuirostris*) and a feather hydroid (*Aglaophenia* spp.). 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 amoenum*), 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.	50 taxa recorded. Four taxa previously recorded at PR4 from more than two baseline surveys were absent, but none had reached a mean baseline abundance of greater than AS 2. Only one taxon (*Didemnum* species complex; AS 1) had decreased more than ΔAS 3 relative to the baseline (mean AS 6.7). Two taxa were newly recorded at PR4, an anemone and a gastropod, but neither exceeded abundance AS 2. Taxa recorded in greater prevalence (mean ΔAS > 3) than during all baseline surveys: • Small red ascidian Ascidiacea sp. A — AS D21: 27; AS Baseline: 1.0 • Feather hydroid cf. *Aglaophenia* spp. — 25; 3.0 • Bryozoan *Steginoporella neozelanica* — 20; 6.0 • Colonial ascidian cf. *Synoicum otagoensis* — 10; 2.0 • Sponge lobed grey cf. *Thorecta* sp. — 9; 1.7 • Bryozoan cf. *Cellaria tenuirostris* — 9; 2.3 • Holothurian *Australostichopus mollis* — 9; 0.3 • Bryozoan Catenicellidae — 8; 4.0 • Branching hydroid — 8; 1.7 • Grey massive sponge Demospongia B — 5; 0.7 • Gastropod *Trochus viridis* — 5; 0.7 • Hermit crab Paguridae — 5; 1.7

PR4	Baseline surveys 2016–2020	December 2021
FISH	3–10 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.	14 species recorded. There were no species absent that had been recorded from two or more of the baseline surveys. No species notably decreased in abundance (ΔAS > 3) relative to the mean baseline. Spectacled triplefin (Ruanoho whero; AS 2) and red cod (AS 1) were new to PR4. Species recorded in greater abundance (mean ΔAS > 3) than during any baseline survey: (AS D21 / AS Baseline) • Butterfly perch 20 / 2.3 • Blue cod 14 / 2.7 • Scarlet wrasse 13 / 2.3 • Dwarf scorpionfish 6 / 1.3 • Banded wrasse 6 / 0.3 • Banded triplefin *F. malcolmi* 5 / 0.7

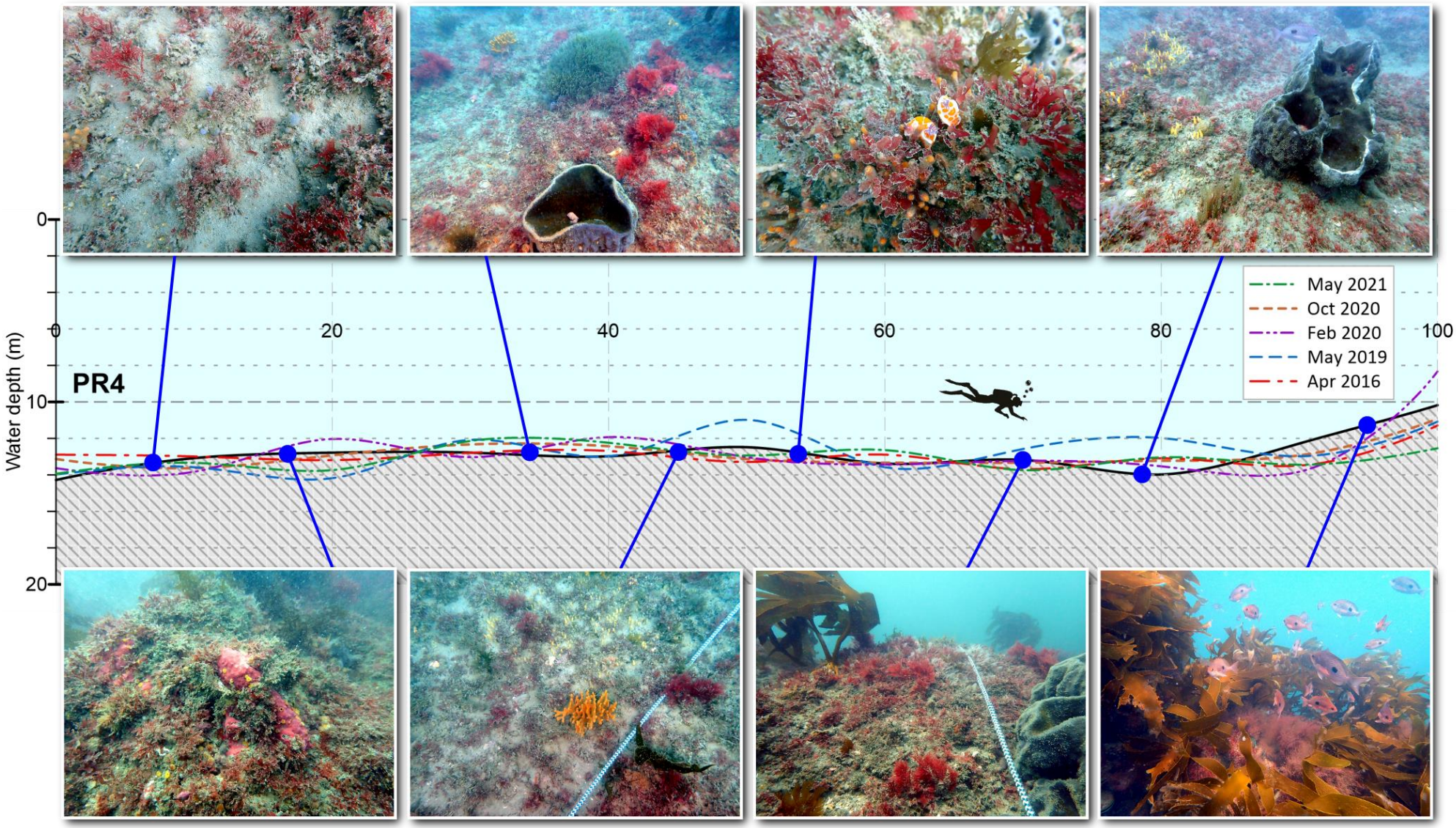

Figure 9. Depth profile with photographs of representative habitat and biota along transect PR4 in December 2021. The photographs are aligned with the transect profile; the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

3.2.7. 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 surveys and current survey. 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	December 2021
SUBSTRATE	The substrate comprises 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, then low- to moderate relief bedrock, ledges, occasionally bouldery. 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 expanses of mobile sand. Less sand generally, except a patch of cobble/sand/shell at the 45 m mark. Otherwise consistent with baseline descriptions. Embedded silt a feature throughout the transect except at the end.
ALGAE	3–4 taxa recorded across the baseline surveys. *Ecklonia radiata* occurred all along the transect but, until the last 30 m, this was 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.	6 taxa recorded. No algal taxa that were recorded from two or more baseline surveys were absent and no algae had decreased in prevalence more than ΔAS 3 relative to the baseline. *E. radiata* (AS 18) was at a similar prevalence to that recorded across the baseline surveys (mean AS 16). One taxon new to PR7 (a red fine algae) was recorded from a single instance (AS 1). Relative to the mean baseline, four algal taxa had increased in prevalence by ΔAS > 3: • *P. cirrhosum* — AS D21: 28; AS Baseline: 18.3 • Small-bladed red alga — AS D21: 28; AS Baseline: 13.0 • *Dictyota* sp. — AS D21: 20; AS Baseline: 0.0 • Coralline algae — AS D21: 6; AS Baseline: 2.0

<table>
<tr><th>PR7</th><th>Baseline surveys 2016–2020</th><th>December 2021</th></tr>
<tr><td>INVERTEBRATE COMMUNITIES</td><td>
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 globosa) 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 S. neozelanica. 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 spp.) 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 (P. 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 amoenum) along with other gastropods (Penton sulcatus, Buccinulum linea, 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.
</td><td>
54 taxa recorded.

Three taxa recorded from more than two baseline surveys at PR7 were absent, with two having reached a mean baseline abundance score of 3; the globose sponge cf. Aaptos sp. and the soft coral Alcyonium cf. aurantiacum.

Taxa where abundance score decreased (ΔAS > 3) relative to the baseline mean:
• Emergent sponge cf. Ciocalypta sp. — AS D21: 9; AS Baseline: 20.3
• Globose sponge cf. Aaptos sp — AS D21: 0; AS Baseline: 4.0
• Alcyonium cf. aurantiacum — AS D21: 0; AS Baseline: 3.3

One taxon newly recorded at PR7 (sponge cf. Dendrilla rosea) occurred as a single individual (AS 1).

Taxa recorded in greater prevalence (mean ΔAS > 3) than during any baseline survey:
• Anemone Anthothoe albocincta — AS D21: 24; AS Baseline: 13.7
• Small red ascidian Ascidiacea sp. A — AS D21: 22; AS Baseline: 8.0
• Vase sponge Ecionemia alata — AS D21: 21; AS Baseline: 16.0
• Branching hydroid — AS D21: 17; AS Baseline: 5.7
• Bryozoan Steginoporella neozelanica — AS D21: 15; AS Baseline: 6.0
• Feather hydroid cf. Aglaophenia spp. — AS D21: 15; AS Baseline: 8.3
• Orange golfball sponge Tethya burtoni — AS D21: 12; AS Baseline: 2.7
• Sponge Cliona cf. celata — AS D21: 10; AS Baseline: 2.0
• Bryozoan Catenicellidae — AS D21: 7; AS Baseline: 3.3
• Grey massive sponge Demospongia B — AS D21: 5; AS Baseline: 0.3
• Sponge Latrunculia cf. procumbens — AS D21: 5; AS Baseline: 1.0
• Red sponge cf. Stylopus australis — AS D21: 4; AS Baseline: 0.3
• Sponge Callyspongia cf. annulata — AS D21: 4; AS Baseline: 0.0
• Mussel beard Amphisbetia bispinosa — AS D21: 4; AS Baseline: 0.7
</td></tr>
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PR7	Baseline surveys 2016–2020	December 2021
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.	16 species recorded. Leather jackets were the only species absent that had been recorded from two or more baseline surveys (at mean AS 0.7). However, no species had notably decreased in abundance (ΔAS > 3) relative to the mean baseline. Species newly recorded on PR7 included tarakihi (*Nemadactylus macropterus*), butterfish (*Odax pullus*), blue moki (*Latridopsis ciliaris*) and marble fish (*Aplodactylus arctidens*), but all were observed as single individuals. Species recorded in greater abundance (mean ΔAS > 3) than during any baseline survey: AS D21 / AS Baseline • Butterfly perch 24 / 4.7 • Spotted wrasse 6 / 2.0 • Banded triplefin 5 / 0.3

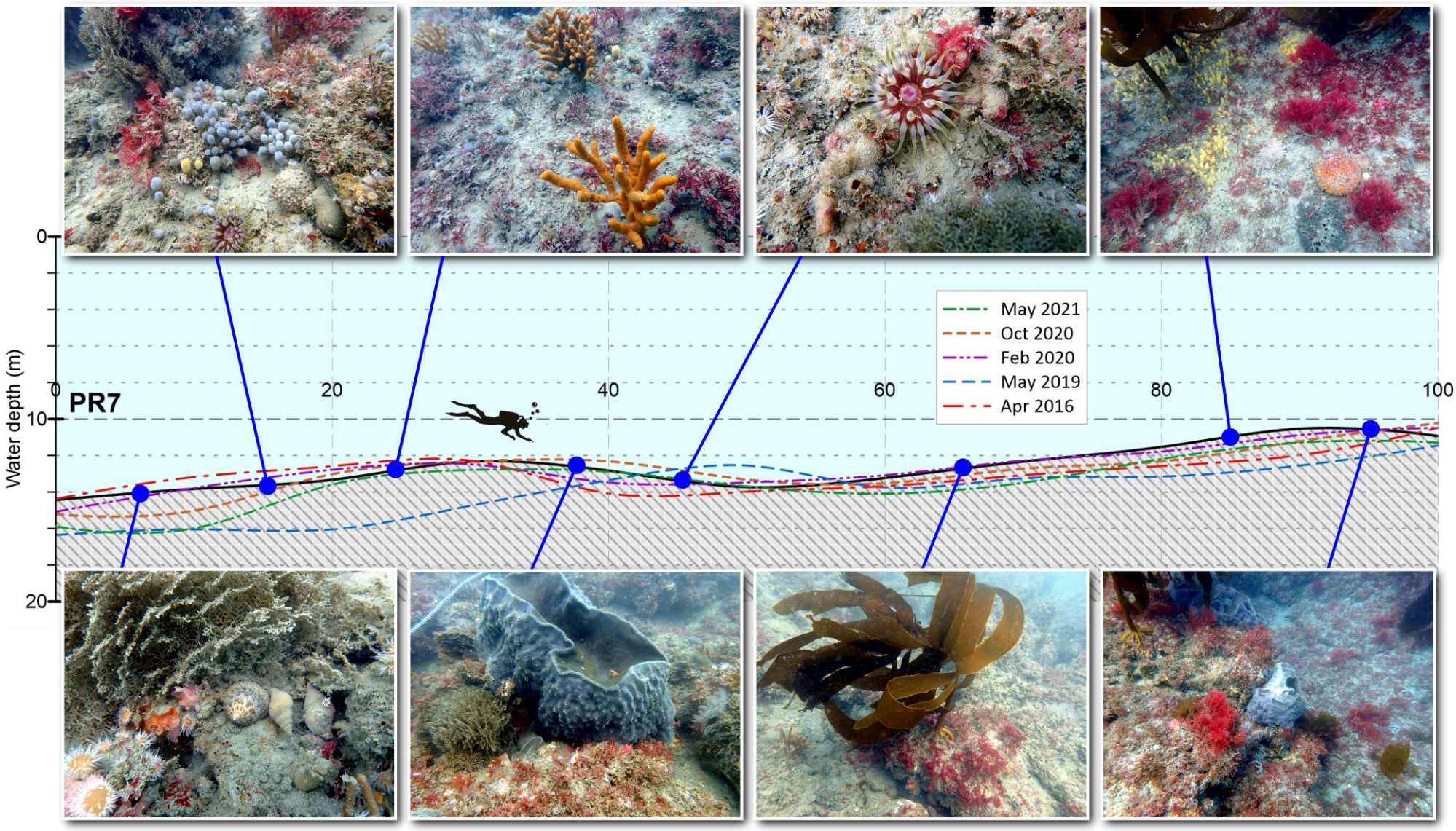

Figure 10. Depth profile with photographs of representative habitat and biota along transect PR7 in December 2021. The photographs are aligned with the transect profile; the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

3.2.8. 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 surveys and current survey. 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	December 2021
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) was consistently present along the full transect length but an easily disturbed silt layer was also recorded in 2019.	Uniform rippled sand in the first 10 m. Embedded silt prevalent but no loose silt or settled veneers. Some cobble/gravel/shell in pockets; also silty sand in small niches. Mostly low relief bedrock, consistent with baseline descriptions.
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). Encrusting corallines were recorded (as rare) from the 2016 survey only. *Ecklonia radiata* was conspicuously absent.	3 taxa recorded. No algal taxa that were recorded in two or more baseline surveys were absent, and none had decreased (ΔAS > 3) relative to the mean baseline. *P. cirrhosum* (AS 13) was present at similar levels as during the baseline (mean AS 12). *Dictyota* sp. (AS 18) had been recorded only once before in October 2020 (AS 9), but not during the baseline. The small-bladed red alga (AS 17) had increased relative to the mean baseline (AS 13), but had reached higher abundance in the last baseline survey (February 2020; AS 20).

PR8	Baseline surveys 2016–2020	December 2021
INVERTEBRATE COMMUNITIES	34–44 taxa recorded acroos the baseline surveys. Similar communities to those of PR7. The most common sponges were *Eciomonia alata*, *Ciocalypta* sp., *Raspailia topsenti*, lilac Demospongiae D, yellow Demospongiae E, and 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 (*S. neozelanica*) 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 was 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 (*P. canaliculis*) was 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 occured in low numbers: clown nudibranch (*C. amoenum*), *P. sulcatus* and lined whelk (*Buccinulum linea*), *Calliostoma punctulatum, Trochus viridis,* sea cucumber (*Australostichopus mollis*) and hermit crabs.	55 taxa recorded. Of three taxa previously recorded from two baseline surveys and now absent, only the nudibranch *Ceratosoma amoenum* had reached a mean baseline abundance score (AS 4.3) greater than three. Other taxa where abundance score decreased (ΔAS > 3) relative to the baseline mean: • Vase sponge *Ecionemia alata* — AS D21: 18; AS Baseline: 21.3 • Lilac sponge Demospongia D — AS D21: 13; AS Baseline: 18.0 • Colonial ascidian cf. *Eudistoma* sp. — AS D21: 7; AS Baseline: 11.7 • Sponge orange encrusting cf.*Tedania* sp. — AS D21: 2; AS Baseline: 8.7 The only newly recorded invertebrate taxon on PR8 was a zoanthid (cf. *Epizoanthus* sp.) observed as a single instance (AS 1). The gastropod *Calliostoma tigris* (AS 7) had been recorded in May 2021 (AS 4) but not during the baseline. Taxa recorded in greater prevalence (mean ΔAS > 3) than during any baseline survey: • Anemone *Anthothoe albocincta* — AS D21: 26; AS Baseline: 16.3 • Feather hydroid cf. *Aglaophenia* spp. — AS D21: 22; AS Baseline: 13.7 • Branching hydroid — AS D21: 20; AS Baseline: 4.3 • Bryozoan *Steginoporella neozelanica* — AS D21: 19; AS Baseline: 10.0 • Colonial ascidian cf. *Synoicum otagoensis* — AS D21: 17; AS Baseline: 13.0 • Yellow breadcrumb sponge Demospongia E — AS D21: 14; AS Baseline: 7.7 • Holothurian *Australostichopus mollis* — AS D21: 9; AS Baseline: 2.3 • Gastropod *Calliostoma tigris* — AS D21: 7; AS Baseline: 0.0 • Crayfish *Jasus edwardsii* — AS D21: 7; AS Baseline: 2.0 • Bryozoan cf. *Cellaria tenuirostris* — AS D21: 6; AS Baseline: 0.7 • Bryozoan encrusting — AS D21: 6; AS Baseline: 0.7 • Sea star *Astrostole scabra* — AS D21: 6; AS Baseline: 1.3

PR8	Baseline surveys 2016–2020	December 2021
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).	14 species recorded. There was no species absent that had been recorded from two or more baseline surveys. Neither had any species notably decreased in abundance relative to the mean baseline (ΔAS > 3). Marblefish (AS 1) was the only species new to PR8. Species recorded in greater abundance (mean ΔAS > 3) than during any baseline survey: (AS D21 / AS Baseline) • Dwarf scorpion fish 7 / 0.3 • Red moki 4 / 0.0 • Banded triplefin 4 / 0.0 Red moki and banded triplefin had both been recorded during surveys since the baseline.

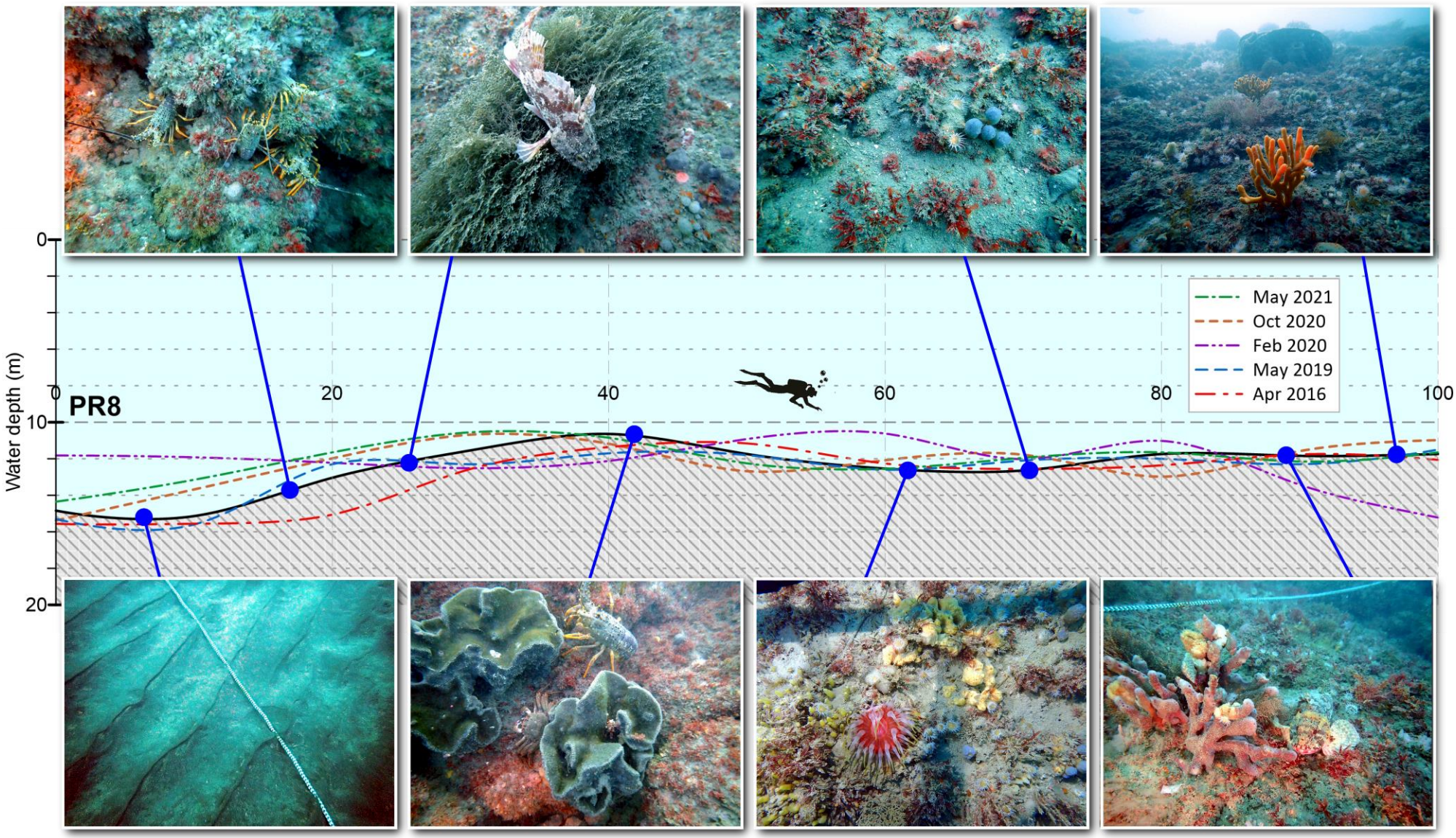

Figure 11. Depth profile with photographs of representative habitat and biota along transect PR8 in December 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during the previous surveys. Vertical grey dashed lines and numbers show distance along transect in metres.

4. DATA ANALYSIS AND DISCUSSION

4.1. Reef sediments

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

4.1.1. Silt

During the current survey, there was no evidence of recently settled silt veneers[4] on reef surfaces or encrusting biota. However, the presence of such veneers is more dependent upon the recent absence of water movement from wave action than on changes in the quantity of fine material suspended in the water column. While some loose settled silt material was observed on the reef as isolated niches and small pockets with greater protection from wave shear (Figure 12B), the overall impression from divers was that these occurrences were slightly less common than in previous surveys. Nonetheless, the presence of deeper accumulations of soft silt were still notable at greater water depths off the edge of the outer reef (Figure 12A).

The primary form of silt accumulated on the Reef is that which has been entrapped and retained by the textured surfaces upon which it settles (Figure 12C). A proportion of this silt becomes embedded and consolidated within encrusting communities to the point that it is resistant to resuspension by water movement (Figure 12D). The prevalence of such embedded silt is considered to be dependent upon three factors:

- the availability of silt (from the water column),
- the level of water movement and
- the types of encrusting biota (how their morphology serves to trap and retain settled silt).

Changes in any of these factors will result in a change in the quantity of silt observed. However, direct measurement of the quantity and distribution of such silt on the Reef presents a significant challenge and no feasible methods have been developed. Nonetheless, diver observations and the photographic and video record suggest that there has been no conspicuous change in its prevalence relative to the baseline.

[3] Silt is generally defined as sediment for which particle diameter is less than 63 µm. Sand comprises particles that are between 63 µm and 2 mm.
[4] Very thin layer of silt (< 1 mm) that can only remain temporarily while conditions are quiescent.

Exposure to water movement (in the form of surge) dominates in the shallower areas of the reef crests, where fine sediments are quickly resuspended in all but conditions of very low surge.

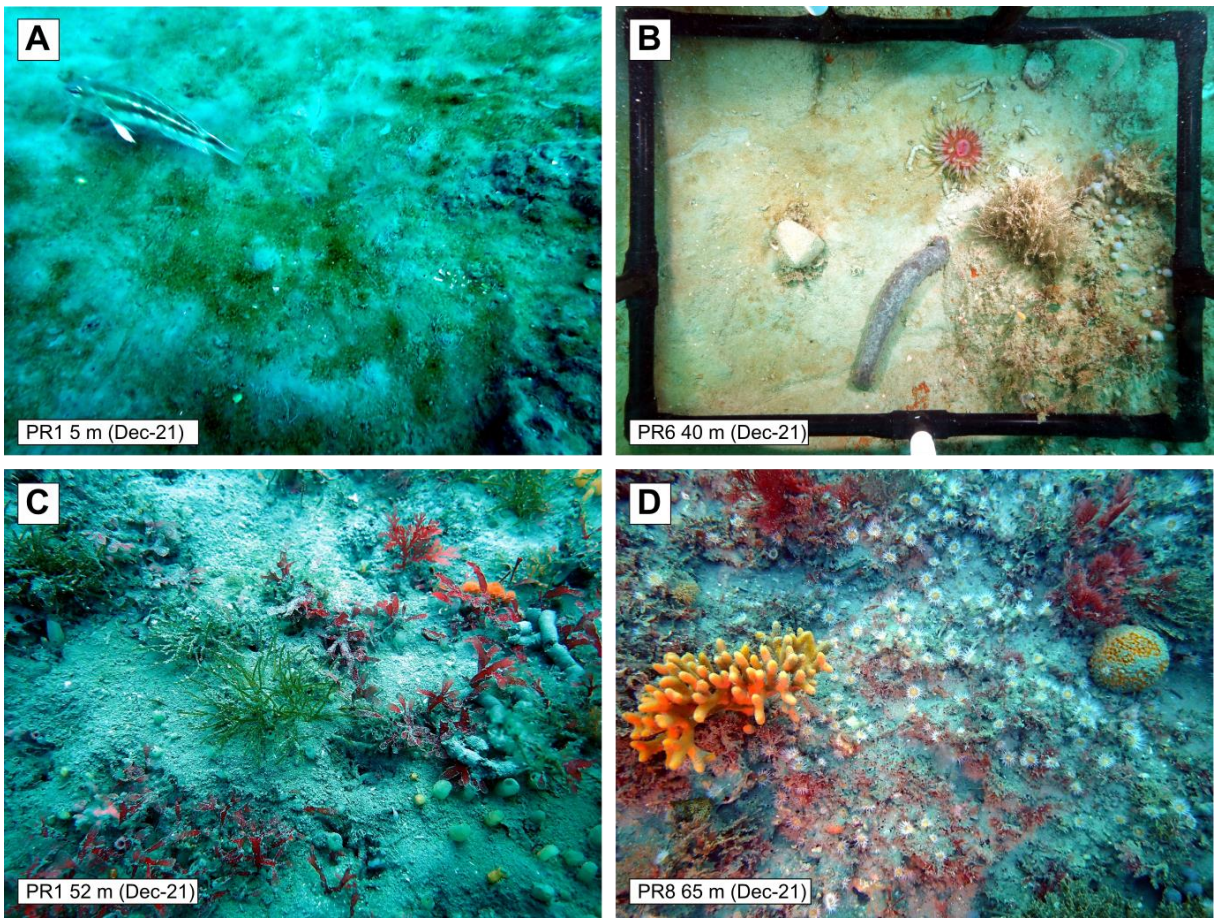

Figure 12. Examples of silt occurrence on Pania Reef during the current survey. **A:** Soft silt with benthic microalgae at the start of PR1. **B:** Niche silt pocket PR6. **C:** Entrapped silt stabilised by encrusting communities. **D:** Silt embedded within hard substrate encrusting communities. Metre values are distances along the 100-m transect.

4.1.2. Sand

Apart from transect PR4 (for which no sand was recorded), the overall prevalence of sand during the current survey (as reflected by abundance score) was generally comparable to the range established by the three baseline surveys (Figure 13). However, PR5 recorded slightly greater incidence (AS 30) than the previous maximum in February 2020 (AS 27), and PR7 and PR8 recorded slightly less (AS 2 and AS 5, respectively) than their respective baseline minima (AS 4 in April 2016 and AS 7 in May 2019).

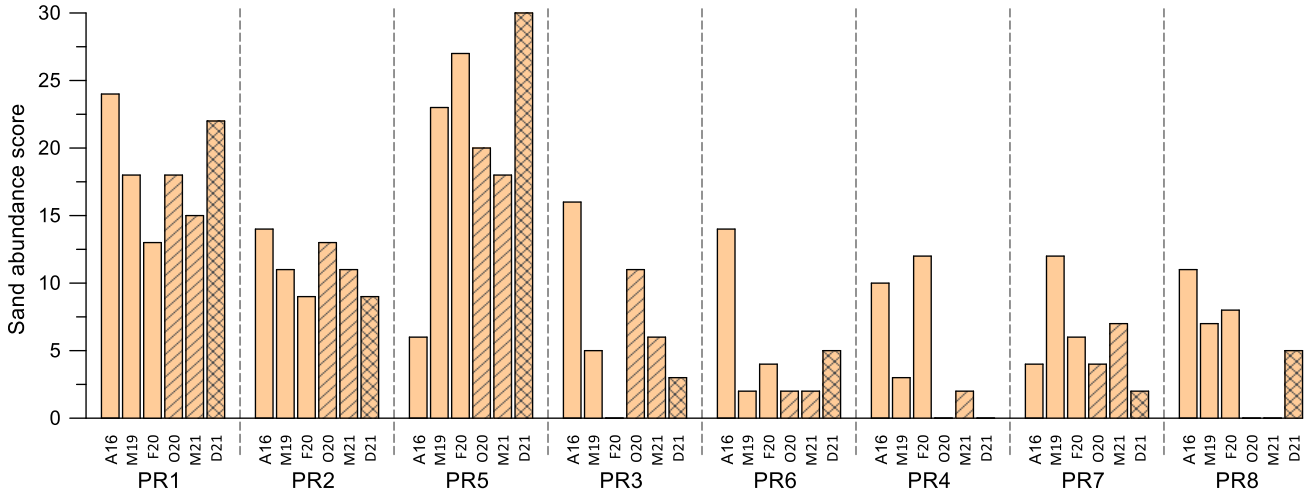

Figure 13. Prevalence of sand substrate across the six surveys to date for each transect. Abundance scores (AS) are summations of the ranked values across the ten 10-m intervals for each transect (max. 40, see Table 1). Hatched fill denotes the post-baseline surveys (cross-hatching for current survey).

Sand deposits on the Reef occur in three general forms:

1. mobile sand that abuts the reef margins in intermediate depths and occasionally overlies low flat areas of bedrock
2. silty sand, stabilised by shell and pebble material, on the deeper reef margins, and
3. coarse sand that has accumulated in reef niches and pockets

Stretches of mobile sand have most often been encountered on transect PR5 and this was again the case for the current survey (Figure 14A). While the rippled surface of these sand deposits indicates that they are constantly shifted by wave motion, their locations along transect PR5 has been notably consistent across surveys, with a patch in the first 20 m followed by a second, wider area between 50 m and 70 m (see Figure 6). This suggests that the conditions that mediate their presence have also been relatively stable over this (six-year) timeframe.

Both in the current survey and historically, patches of mobile sand have also been recorded on the reef margins at PR6 and PR8 during the baseline. While these are likely to be somewhat ephemeral, responding to the influence of larger swell events, they may also be quasi-stable[5] over longer time-periods. Frequent or recent incursions of mobile sand will impact upon the reef communities in the areas where they occur. However, the inexact placement of transect lines during surveys makes it difficult to clearly identify such areas. Hence, the variability in recorded sand prevalence cannot be assumed to arise solely from changes in the actual extent of this substrate between surveys.

[5] Stable over a finite time period, after which conditions may alter as a result of an extreme event such as a storm.

Areas of more stable silty sand, often mixed with shell material, occur on the reef margin at the deeper ends of several transects, most notably PR1. However, diver observations during the current survey suggested that sediments at the PR1 reef edge were finer and softer than in previous surveys (Figure 12A).

Stable pockets of coarser material are common where bedrock outcrops form natural traps for such material, and these have been a consistent feature of transect PR2 (Figure 13D), but have also been observed at PR3 (Figure 13B) and PR4. The nature of these accumulations appears dependent upon local hydrodynamic conditions mediated by water depth and reef topography.

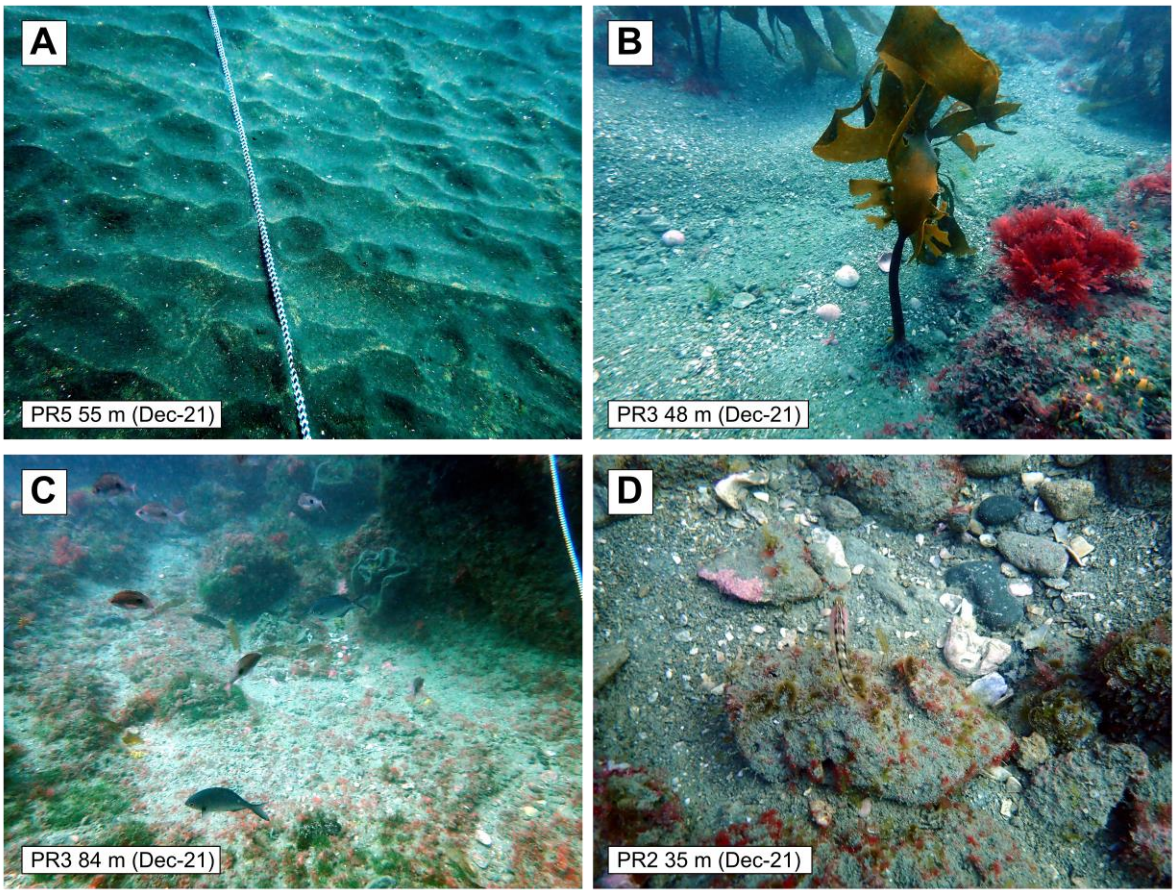

Figure 14. Examples of different forms of sand substrates on Pania Reef during the current survey. **A:** Rippled mobile fine sand. **B:** Accumulated coarse sand and shell in low points. **C:** Shallow sand layer over bedrock. **D:** Pocket of coarse sand, grave, shell and pebble material. Metre values are distances along the 100-m transect.

Reef sediments: Key findings

While recently settled silt veneers have sometimes been observed on rock surfaces and biota in previous surveys, these were largely absent from the current survey. Their occurrence is likely to be episodic rather than cumulative, being highly dependent upon swell and turbidity conditions in the period immediately prior to the survey.

Consistent with observations across all surveys to date, accumulated silt on the Reef was most widespread in a form trapped by or embedded within textured surfaces, principally those of encrusting reef biota. Such silt was present on all transects, absent only in water depths shallow enough to expose reef surfaces to vigorous water movement.

The photographic and video record and documented reef communities continue to suggest no conspicuous change in silt prevalence from the baseline condition.

Sand material occurs in three principal forms on Pania Reef. These forms are exemplified by the three transects with the consistently greatest sand occurrence:

- PR1 - silty sand on the deeper reef margins, often stabilised by shell and pebble material.
- PR2 - stable pockets of coarser sand and shell where bedrock outcrops form natural traps in the presence of greater water movement
- PR5 – rippled mobile sand on reef margins in intermediate and shallower depths.

High variability in sand occurrence across surveys means that clear temporal trends have not been discernible. Most of this variability is likely attributable to the inexact nature of transect line placement, although swell-mediated variability in mobile sand incursions on low-lying reef margins may occur.

In general, though, the prevalence of sand on the Reef has shown no indication of a distinct change or trend since the baseline.

4.2. Reef benthic communities

4.2.1. Newly recorded taxa

Only two epibiotic taxa recorded from the December 2021 survey, both algae, were completely new to the Pania Reef inventory (Table 10). Both were present in very low abundance.

Table 10. Epibiota newly added to the Pania Reef surveys taxa inventory from the current survey. Score (tAS) is the sum of the abundance scores across all transects.

Group	Name / description	Score (tAS)	Transects	Incidence
Phaeophyceae	*Microzonia velutina*	2	PR2	Occasional in one 10-m segment
Chlorophyta	Fine green alga	2	PR2, PR6	Individual occurrences

4.2.2. Previously recorded taxa absent from the current survey

Of the 98 epibiotic taxa in the monitoring inventory compiled from the baseline surveys, 88 were recorded from the December 2021 survey. None of the ten absent taxa had been recorded from all three baseline surveys but four had been recorded from two surveys (Table 11). Of these four, only an unidentified embedded bivalve had been present on any transect with an abundance score of greater than four (PR1 in April 2016; AS 6). It is one of several less common bivalve species on the Reef that are cryptic in nature and easily overlooked. All four of these taxa have been recorded at similar levels (to the baseline surveys in which they occurred) from one or both of the previous post-baseline surveys (October 2020 and May 2021).

Table 11. Epibiota absent from the current survey that had been recorded from two of the baseline surveys. The score tAS is the sum of the abundance scores across all transects.

Group	Name / description	Baseline		
		Survey	Transect/s	tAS
Rhodophyta	Red encrusting alga	May 2019	PR2	4
		Feb 2020	PR2,6	6
Bivalvia	Unid. embedded bivalve	Apr 2016	PR1	6
		May 2019	PR1,2,5,7	4
Gastropoda	*Cabestana spengleri*	May 2019	PR2	1
		Feb 2020	PR2	1
Echinodermata	*Coscinasterias muricata*	Apr 2016	PR3,7	3
		Feb 2020	PR2,6	2

4.2.3. Taxa inventory and richness across surveys

An inventory of the conspicuous epibiota recorded across all surveys to date is provided in Appendix 2, together with mean baseline and current survey abundance scores (AS) generated for each of the eight transects. While only seven taxa have been added to this inventory since the baseline, the number of taxa recorded on each transect has shown a progressive increase across surveys (Figure 15). As noted for the previous survey report (Sneddon 2021), this has resulted largely from the generation of more comprehensive photographic and video records from successive surveys, which are then used to augment the diver-generated record (Section 2.2.3). This has meant that scarce or cryptic taxa are less likely to have been missed in the more recent surveys. While this trend needs to be allowed for in the interpretation of the data[6], it is less likely to affect the record of characteristic taxa—those which are either locally common or abundant or are consistently present in low numbers during any survey.

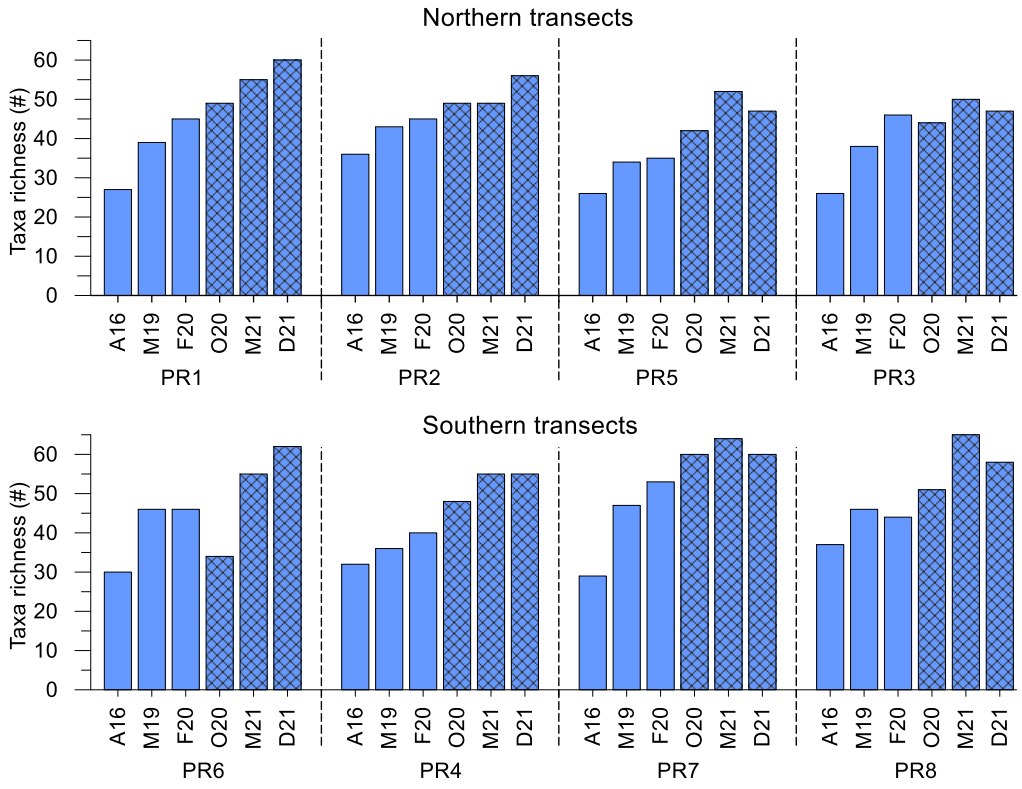

Figure 15. Taxa richness in reef communities for each transect showing the increasing trend across surveys (excludes fish). Survey labels designate month and year of successive surveys (e.g. A16 = April 2016).

[6] All changes made to the diver record subsequent to the field survey are flagged as such. However, consideration of the diver record in isolation is complicated by the fact that time-constrained divers may document scarce taxa by photograph only, in the knowledge that it will be added as a record entry later.

4.2.4. Changes in reef characteristic taxa across surveys

A broad overview of temporal variability in Reef populations was generated by examining differences in total abundance scores (tAS) across surveys. Table 12 shows changes in tAS for those taxa abundant enough to be considered 'characteristic' of the Reef.

The pattern of maxima vs minima for the list of characteristic taxa in Table 12 highlights the sometimes-high variability between surveys and especially the generally greater abundance scores from the most recent two surveys. While it is possible that increases in abundance have occurred for some species as a result of changing conditions on the Reef, such changes (whatever the driver) would likely favour only some taxa while reducing the competitive advantage for others. Hence a general increase in most characteristic taxa (in the absence of notable decreases in others) is unlikely.

The progressive increase in total summations of survey abundance scores in Table 12 suggests the influence of refinements in survey methodology. There are three likely components to this:

1. The increasing capability across surveys for augmentation of the field data-set from the photographic record (Section 2.2.3). While this will mostly affect the abundance scores of taxa that are not abundant enough to qualify as 'characteristic' of the Reef, some common organisms that are small or inconspicuous and may be missed by divers will also be affected.
2. Greater familiarity of field personnel with the habitat and community—the development of a 'trained eye' across successive surveys—may contribute to increases in AS for widespread though less conspicuous taxa.
3. Increasing ability to predict suitable conditions for survey. Underwater visibility is likely to have a bias effect on assessments of relative abundance, even when divers are working to a clear set of guidelines (Table 1). Although the transect corridor is only 2 m wide, the ability to see further in clear water will tend to push assessed scores up, simply because there is more within the diver's field of vision.

While the above methodological influences need to be considered in interpretation of the data, it is notable that there were no taxa for which minima tended to cluster within the three post-baseline surveys[7]. Nonetheless, several other temporal patterns in Table 12 can be identified. These are documented below with the affected taxa listed.

[7] An apparent decrease in abundance of green-lipped mussels (*Perna canaliculus*) since the baseline was investigated in the last survey report (Sneddon 2021). It was concluded that this likely resulted from the patchy distribution of mussel beds in relation to the placement of transect lines. The return of the tAS value to baseline levels in the current survey tends to support this explanation.

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

		Apr 2016	May 2019	Feb 2020	Oct 2020	May 2021	Dec 2021
Algae	*Ecklonia radiata*	153	129	**163**	138	151	144
	Plocamium cirrhosum	124	91	**146**	115	127	**144**
	Coralline algae	106	89	107	99	**134**	114
	Small-bladed red alga	62	23	137	**156**	32	**170**
Porifera	*Ecionemia alata*	160	153	155	165	**172**	160
	Ciocalypta sp.	**132**	101	111	**130**	114	84
	Raspailia topsenti	**106**	77	91	**111**	103	103
	Lilac Demospongia D	64	70	94	**118**	**120**	89
	Cliona cf. *celata*	19	67	69	87	**121**	84
	Tethya burtoni	40	39	20	55	55	**65**
	Yellow Demospongia E	**56**	26	24	45	44	**57**
	cf. *Tedania* sp.	27	41	**48**	**47**	**48**	19
Bryozoa	*Steginoporella neozelanica*	30	90	61	**135**	**142**	**130**
	cf. *Cellaria tenuirostris*	**81**	20	24	68	**79**	**76**
	Catenicellidae	63	**84**	42	37	71	46
Cnidaria	Branching hydroid	35	28	34	50	75	**99**
	cf. *Aglaophenia* spp.	52	28	45	36	46	**113**
	Anthothoe albocincta	38	34	37	31	**63**	**60**
Ascidiacea	Ascidiacea sp. A	1	65	8	36	**119**	**102**
	Cnemidocarpa sp.	**89**	46	25	29	63	71
	cf. *Synoicum otagoensis*	58	33	35	63	35	**76**
	cf. *Eudistoma* sp.	**54**	31	21	18	46	25
Bivalvia	*Perna canaliculus*	**68**	62	52	40	44	**64**
Gastropoda	*Ceratosoma amoenum*	4	23	**65**	30	31	18
	Penion sulcatus	24	20	21	**28**	**29**	**30**
	Trochus viridis	7	15	10	13	**22**	**24**
	Cookia sulcata	2	7	11	18	15	**24**
	Calliostoma tigris	6	5	1	**21**	11	**19**
	Buccinulum linea	**8**	2	6	**8**	**8**	**8**
Crustacea	Paguridae	21	12	24	25	22	**39**
	Jasus edwardsii	2	7	1	2	**34**	16
Echinodermata	*Australostichopus mollis*	20	14	30	34	43	**58**
Sum of abundance scores		1712	1532	1718	1988	2219	2331
Number of minima		10	19	16	7	3	4
Number of maxima		8	1	4	9	13	19

Apparent **increases in abundance since the baseline** have occurred for:

- Boring sponge (*Cliona* cf. *celata*; Figure 16A) – despite its yellow colouring, this can be less conspicuous to divers and the record has likely been bolstered by the more comprehensive photographic record.
- Finger bryozoan (*Steginoporella neozelanica;* Figure 16B) – an increase in prevalence that has been relatively stable over the post-baseline surveys but has been noticeable to divers.
- Orange golfball sponge (*Tethya burtoni*)
- Branching hydroid; Figure 16C – appears to have become progressively more abundant since the baseline.
- Orange/white anemone (*Anthothoe albocincta*; Figure 16D) – stable across the first four surveys but notably more abundant in the most recent two surveys.
- Crayfish (*Jasus edwardsii*) – notably common in the two most recent surveys.
- Holothurian (*Australostichopus mollis*) (Figure 16E) – increasing numbers from the second baseline survey. Noticeable to divers in the current survey.
- Gastropods and hermit crabs (Paguridae) can be small and somewhat cryptic in habit. An apparent increase in their numbers is likely an artefact of the more comprehensive photographic record in later surveys.

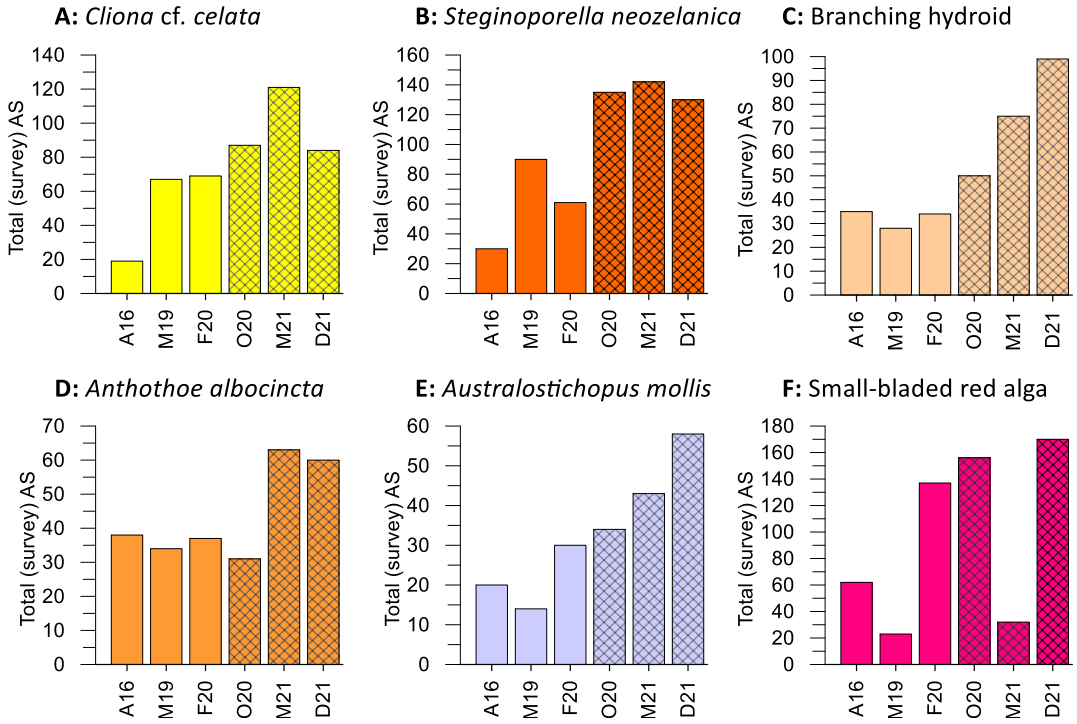

Figure 16. Total (survey) abundance scores (tAS) for selected taxa that in the current survey have exhibited divergence from the baseline mean. Solid bars represent the 3 baseline surveys. Dredging phase surveys denoted by cross-hatching.

Seasonality in occurrence is implicated for several taxa in Table 12:

- Small-bladed red alga (Figure 16F) – lower abundance was recorded in autumn months (April 2016, May 2019 and May 2021).
- Clowns' hair bryozoan (Catenicellidae) – lowest prevalence has occurred in the spring-summer months
- Colonial ascidian cf. *Eudistoma* sp. – also appears more abundant in autumn-winter months

High inter-annual variability in others may reflect 'boom and bust' cycles, possibly influenced by seasonal conditions:

- Branching bryozoan (cf. *Cellaria tenuirostris*) – maxima recorded in the first baseline survey (April 2016) and the current survey.
- Small solitary ascidian (Ascidiacea sp. A) – The record has been highly variable between surveys. The fact that this ascidian is inconspicuous and quite often missed by divers means it may have been under-reported during the baseline.
- Lilac sponge (Demospongia D) – more abundant over the first two post-baseline surveys but notably less abundant in the current survey.
- Stalked colonial ascidian cf. *Synoicum otagoensis* – generally variable but notably abundant in the current survey.

Several characteristic taxa in Table 12 are notable for exhibiting distinct changes in abundance related only to the current survey.

Less abundant solely in the current survey:

- Emergent sponge *Ciocalypta* sp. – the decrease in abundance was noticeable to divers
- Orange encrusting sponge (cf. *Tedania* sp.) – although commonly seen on the Reef, individuals have been consistently small; hence, coverage has always been low.

More abundant solely in the current survey:

- Feather hydroid (cf. *Aglaophenia* spp.) – diver observations suggest that feather hydroids have been historically more abundant on Town Reef than Pania Reef.

While it is difficult to draw a clear linkage between the taxa that appear to have increased in abundance since the baseline and changes in Reef conditions potentially arising from the dredging programme, holothurians such as *A. mollis* tend to occur in siltier conditions. Others, such as the anemone *A. albocincta,* the sponge *T. burtoni* and feather hydroids have historically occurred in greater numbers on the southern transects and Town Reef. However, the absence of visual evidence for fine sediment accumulation on the reef does not support siltation as a primary driver.

4.2.5. Current survey: Comparisons to the baseline by transect

To highlight changes in abundance that may have occurred differentially along the Reef axis, data for individual transects were examined to provide a list of taxa where changes from the mean background had occurred. Since a degree of natural variability (including some sampling error) is evident within the data, changes in AS were screened to include only those taxa for which shifts in abundance score of greater than 3 have occurred ($\Delta AS > 3$) and where such changes have been consistent across at least two of the eight transects. Given the inter-survey variability observed, these thresholds are considered relatively conservative. The resultant taxa list and their changes in AS across transects are presented in Table 13.

Many of the taxa listed in Table 13 are common to the list of characteristic taxa in Table 12. It again shows that the most widespread changes from the baseline have been increases in recorded abundance. Of 37 listed taxa, 26 were noted only for increases and a further five recorded decreases at just a single transect. Decreases in abundance tended to be spread along the Reef axis.

Only three taxa were identified solely for decreases at two or more transects:

- Encrusting sponge cf. *Tedania* sp. – three transects spread along the Reef axis but decreasing most in the south.
- Emergent sponge *Ciocalypta* sp. – four transects along the Reef axis but decreasing most at PR7 towards the southern end.
- Colonial ascidian cf. *Eudistoma* sp. – decreasing at PR7 and PR8, at the southern end of the Reef.

Although little is known of specific sensitivities to sedimentation for these taxa, all have been more characteristic of the southern Reef and notably occur in the more turbid environment of Town Reef (Section 5.1.1).

Taxa for which the greatest overall increases were identified showed little differential along the Reef axis. However, such spatial gradients did occur for some taxa:

- The grass-like green alga and a fine red alga increased in the northern transects. The former has historically been more prevalent on the northern Reef and both are likely to respond to seasonal drivers.
- Sponge cf. *Suberites perfectus* – increased on two of the northern transects
- Sponge *T. burtoni* – increased on three southern transects
- Clowns' hair bryozoan (Catenicellidae) – decreased on the northernmost two transects and increased in the south (PR4, PR7)
- Increases in the branching hydroid, small solitary ascidian (Ascidiacea sp. A), and anemone *A. albocincta* were concentrated in the southern transects (where they have been historically more prevalent).

- The colonial ascidian *Didemnum* species complex (white) increased at two transects in the north while decreasing at Transect PR4.

Table 13. Changes in abundance score (ΔAS) 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. To aid visual interpretation, colour shading is proportional to the magnitude of change—red for a decrease (max. -15), blue for an increase (max. +15). Transects are listed in north to south order.

Group	Taxon	PR1	PR2	PR5	PR3	PR6	PR4	PR7	PR8
Phaeophyceae	*Dictyota* sp.	13.0	7.0	10.0	21.0	17.0	23.0	20.0	18.0
Rhodophyta	Coralline algae				-5.3		10.0	4.0	
	Plocamium cirrhosum	4.3	4.7				5.7	9.7	
	Small-bladed red alga	11.3	11.7	12.0	17.3	14.3	10.3	15.0	4.0
	Red fine algae		18.7		3.3				
Chlorophyta	Grass-like green alga	12.3	10.7		10.3				
Porifera	*Ecionemia alata*		5.3	-6.3		3.7		5.0	-3.3
	Cliona cf. *celata*	9.7		6.3		5.0	3.7	8.0	
	cf. *Tedania* sp.		-3.7			-7.3			-6.7
	Tethya burtoni					9.3		9.3	4.3
	Ciocalypta sp.		-5.0		-7.3	-4.3		-11.3	
	Raspalia topsenti			4.3	4.0		3.3		
	Grey Demospongia B	4.0				4.0	4.3	4.7	
	Lilac Demospongia D	6.7		4.3	3.3	4.7			-5.0
	Yellow Demospongia E	6.0		6.0	3.7				6.3
	Latrunculia cf. *procumbens*					6.0		4.0	
	cf. Suberites perfectus	3.7		4.3					
Bryozoa	Catenicellidae	-9.0	-10.0				4.0	3.7	
	cf. *Cellaria tenuirostris*	13.0				7.0	6.7		5.3
	Steginoporella neozelanica	7.3		8.3	9.3	10.7	14.0	9.0	9.0
	Encrusting bryozoan	-4.7		7.7		4.0			5.3
	cf. *Margaretta barbata*	12.7	3.3						
Cnidaria	cf. *Aglaophenia* spp.	5.0		7.7	8.7	11.7	22.0	6.7	8.3
	Amphisbetia bispinosa			3.7				3.3	
	Branching hydroid	4.7		5.7	13.0	10.0	6.3	11.3	15.7
	Anthothoe albocincta					3.7		10.3	9.7
	Culicea rubeola		3.7		-3.7	-3.3			
Ascidiacea	*Cnemidocarpa* sp.		8.7	11.3	-9.7		5.0		
	Ascidiacea sp. A	4.0		6.3		13.3	26.0	14.0	12.3
	cf. *Synoicum otagoensis*	5.7		7.7		6.0	8.0		4.0
	cf. *Eudistoma* sp.							-5.3	-4.7
	Didemnum (white)		5.0	7.0			-5.7		
Gastropoda	*Trochus viridis*					3.3	4.3		
	Penion sulcatus					6.7	3.3		
Crustacea	*Jasus edwardsii*					4.0			5.0
	Paguridae		3.7		5.7		3.3		
Echinodermata	*Australostichopus mollis*	4.7		4.0	5.7	7.3	8.7		6.7

For the most part, such change gradients were consistent with pre-existing baseline distribution gradients, i.e. the greatest changes occurred on transects with greater baseline abundance. These patterns suggest that any generalised shift in Reef conditions towards those associated with either end of the Reef axis during the baseline was quite weak.

4.2.6. Multivariate statistical analysis

The range in community structure across the eight transects for the six surveys to date is represented by a non-metric multidimensional scaling (nMDS) plot of transect abundance scores in Figure 17. The associated vector plot shows taxa that were correlated with the nMDS space[8]. The moderate stress value (0.16) associated with the nMDS plot means that distances between individual points give a reasonable representation of the real magnitude of differences in community composition[9] and, most importantly, reliably portray general patterns and groupings of transect data.

The nMDS data points continue to cluster together according to transect rather than survey. This indicates that temporal variability has been less than the underlying spatial variability between transects. Hence, the differences in reef communities between transects identified from the baseline have largely been retained during the post-baseline surveys (dredging phase of the project). As has been previously observed, the patterns in the nMDS plot suggest that, while it is somewhat accommodating of the increasing comprehensiveness of successive survey datasets, the plot nonetheless consistently represents differences in community structure between points along the reef axis.

Six of the eight transects (except for the April 2016 survey point for transect PR1) group together in Figure 17 (Group A) at the 52% level of similarity (LoS). Communities on transect PR2 were distinct enough to form their own separate cluster (Group B). The survey points for transect PR5 show by far the most temporal variability, being split across three separate groups at the 52% LoS (Groups C, D, E).

In April 2016, *S. neozelanica*, encrusting bryozoans, cf. *Cellaria tenuirostris*, *Cliona* cf. *celata* and *P. cirrhosum* were either absent from PR1 or observed at much lower abundance. The reasons for this are unclear but the 2016 depth profile differed somewhat from subsequent surveys, with the ascent from initial 20-m depths delayed until 60 m along the transect (Figure 4), so transect position may have been a factor.

[8] The vector plot of taxa correlated with the principal axes of the nMDS plot does not necessarily show all of the organisms contributing significantly to dissimilarity across samples. This is because the correlation assumes linearity in the change in abundances across the space represented. Hence, the featured taxa are those that exhibit consistent gradients across the plotted data.

[9] Distances on the nMDS plot have only relative, not absolute, meaning. The stress value is a dimensionless quantity and is a measure of the difficulty involved in compressing the sample relationships into two dimensions. A stress value of < 0.1 corresponds to a good ordination with no real prospect of a misleading interpretation, while a stress value of < 0.2 still gives a potentially useful 2-D picture. Stress values within the range of 0.2 to 0.3 should be treated with caution, particularly if in the upper half of this range and for sample sizes of < 50.

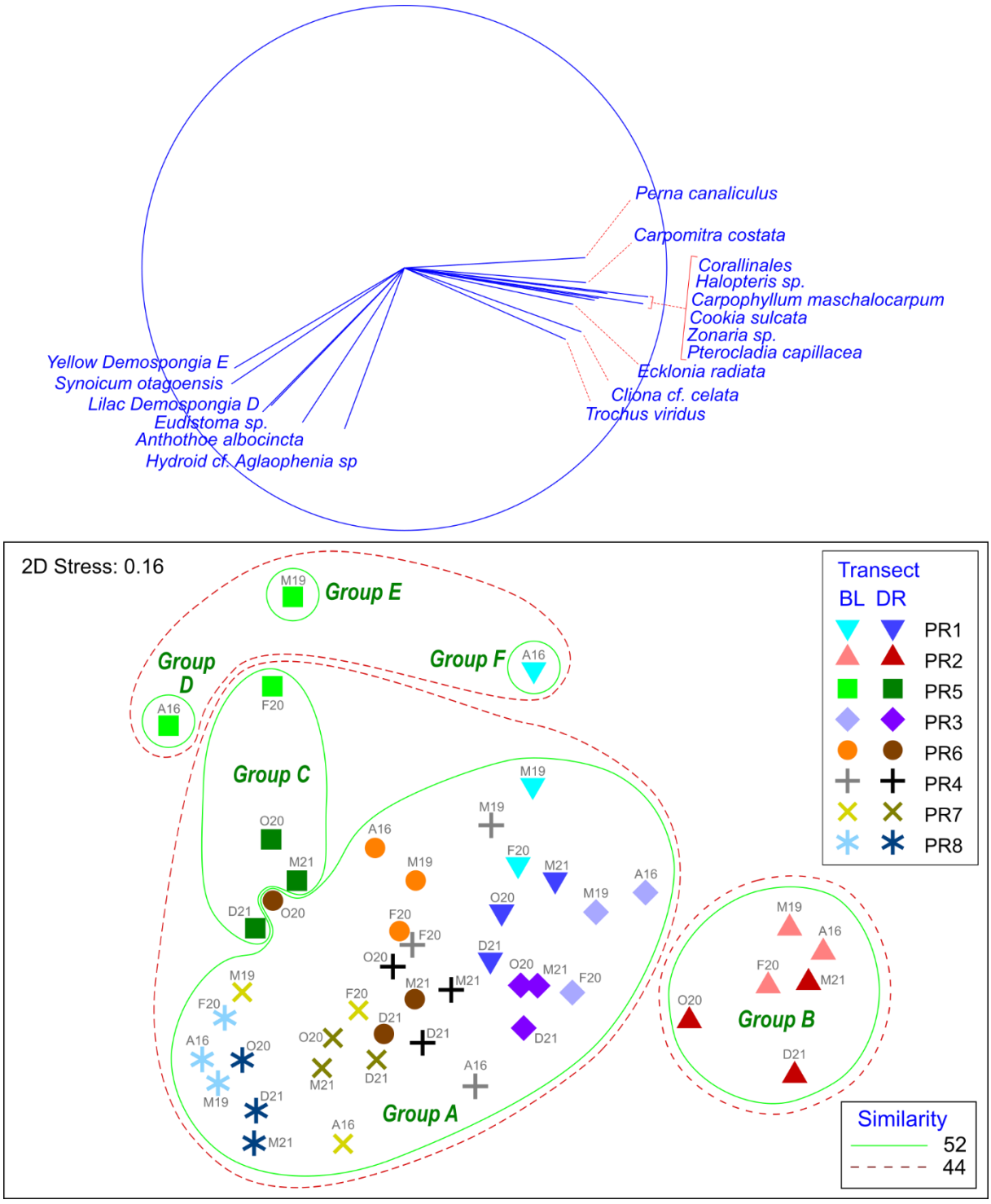

Figure 17. Differences in community structure between transects and surveys shown by non-metric multidimensional scaling (nMDS) plot of reef community data. BL = baseline (3 surveys); DR = dredging phase (3 surveys-darker shade symbols). Plot based on a Bray-Curtis similarity matrix of untransformed transect abundance scores. Label identifiers designate month and year (e.g. A16 = April 2016). Vector overlay above the plot shows taxa correlated to plot coordinates with (Pearson) r > 0.65.

The tendency for the April 2016 data points for several transects to separate from or lie on the edge of the cluster formed by subsequent surveys may reflect later familiarisation and refinements in methodology.

The Group B data points comprise all of the PR2 survey points, setting this transect apart from the others. The shallower depths occurring around Pania Rock subjects much of transect PR2 to greater water movement and consequently lower levels of settled and entrapped silt. This results in a relatively distinct community composition with greater prevalence of several algal taxa associated with these conditions. Hence, SIMPER analysis showed that coralline algae, *Ecklonia radiata, Carpophyllum maschalocarpum,* and *Halopteris* sp. cumulatively accounted for 19% of the dissimilarity between groups A and B. Conversely, PR2 supports smaller populations of taxa associated with deeper and more depositional areas of the Reef (*S. neozelanica, Raspailia topsenti,* lilac sponge [Demospongia D], small-bladed red alga, cf. *Cellaria tenuirostris*).

Group C, comprising the post-baseline and February 2020 surveys for PR5, differed from Group A by lower prevalence of several algal taxa: *E. radiata,* encrusting corallines, *P. cirrhosum* and small-bladed red, accounting cumulatively for 24% of the dissimilarity. The high variability in community structure at transect PR5 during the baseline surveys possibly resulted from inconsistencies in exact transect placement, exacerbated by the greater proportion of mobile sand substrate at this transect (Figure 13). Frequently higher turbidity at the seabed than was encountered at other mid-reef transects was also a noted difficulty at PR5 during the baseline and this is likely to have affected the record. Another notable feature of Figure 17 is the relative separation of the October 2020 data point for transect PR6, this resulting from the transect missing a prominent reef crest at the 80 m mark (see Figure 8).

Since the varying background turbidity and depositional environment along the reef axis is believed to be a key influence on benthic community composition, an increase in either of these conditions should have the effect of shifting community structure towards that of the southernmost transects. While the nMDS plot gives little indication that such a shift (towards the left of the plot) has occurred, there is nonetheless an identifiable vertical separation between baseline and dredging phase surveys for several transects in Figure 17, with the latter generally positioned lower on the plot. This grouping is most pronounced for transect PR5, but is also visible for PR1, PR3 and PR6. Although not as consistent for the remaining transects, it is noted that the centroids for their baseline and dredging phase surveys also conform to this general pattern.

To further investigate the changes in communities indicated in Figure 17, SIMPER analyses were run comparing the baseline to the post-baseline surveys for each transect. The post-baseline vs baseline SIMPER output for a combined data set of the northernmost five transects (PR1, PR2, PR3, PR5 and PR6; representing those which

are spatially bracketed by transects exhibiting a downward shift in Figure 17) is shown in Table 14. Many of the taxa most responsible for these changes have been identified in the previous sections, mostly due to increases in abundance. Of those listed, the only taxa to have exhibited a decrease in abundance were Catenicellidae, the sponge *Ciocalypta* sp. and mussels (*P. canaliculus*; see footnote p 52).

Table 14 Taxa contributing most to dissimilarity between dredging phase (DR) and baseline (BL) data sets for transects on the northern Reef (combined data for PR1, PR2, PR5, PR3 and PR6). Output from SIMPER routine, calculated from the Bray-Curtiss dissimilarity matrix, PRIMER v7. Average dissimilarity = 37.9%.

	Average AS		Av.	Diss/	Contrib	Cum.
Taxa	**DR**	**BL**	**Diss**	**SD**	**%**	**%**
Small-bladed red alga	13.1	5.7	1.8	1.2	4.9	4.9
Steginoporella neozelanica	16.7	7.7	1.7	1.4	4.4	9.3
Bryozoan cf. *Cellaria tenuirostris*	11.0	6.3	1.5	1.4	4.0	13.3
Sponge *Cliona* cf. *celata*	14.4	7.7	1.4	1.5	3.7	17.1
Dictyota sp.	5.9	0.0	1.1	1.0	2.8	19.8
Lilac Demospongia D	10.6	5.8	1.0	1.3	2.7	22.6
Branching hydroid	8.0	4.1	1.0	1.1	2.7	25.3
Cnemidocarpa sp.	6.1	5.6	1.0	1.3	2.7	27.9
Grass-like green alga	7.6	3.1	1.0	0.9	2.6	30.5
Bryozoan Catenicellidae	8.0	10.6	1.0	1.3	2.5	33.0
Plocamium cirrhosum	13.9	13.3	0.9	1.4	2.4	35.4
Ascidiacea sp. A	5.0	1.6	0.9	1.0	2.3	37.7
Orange encrusting cf. *Tedania* sp.	4.7	4.7	0.9	1.1	2.3	40.0
Ecionemia alata	20.2	18.6	0.8	1.1	2.1	42.1
Ciocalypta sp.	11.7	12.7	0.8	1.2	2.1	44.1
Encrusting bryozoan	4.0	1.7	0.8	0.8	2.0	46.1
Feather hydroid cf. *Aglaophenia* spp.	5.5	3.3	0.7	1.2	1.9	48.1
Yellow Demospongia E	4.9	2.6	0.7	1.0	1.9	50.0
Ceratosoma amoenum	3.9	3.9	0.7	1.0	1.9	52.0
Ascidian cf. *Synoicum otagoensis*	4.8	2.7	0.7	1.0	1.8	53.8
Tethya burtoni	5.9	2.5	0.7	1.9	1.8	55.6
Raspalia topsenti	12.6	10.3	0.6	1.3	1.7	57.2
Perna canaliculus	8.8	9.8	0.6	1.3	1.7	58.9
Australostichopus mollis	5.1	2.1	0.6	1.6	1.6	60.5

Given the lack of seasonal balance between baseline and post-baseline surveys, it is notable that three of the ten taxa contributing most to community difference in Table 14 are algae exhibiting seasonal variation in prevalence (small-bladed red alga, *Dictyota* sp. and grass-like green alga). Seasonal influences on some hydroids,

ascidians and bryozoans are also possible, e.g. Catenicellidae appears to be less abundant in the spring-summer months (Table 12).

Reef benthic communities: Key findings

An important feature of the compiled data is a progressive increase in the number of taxa recorded per transect across surveys. This mostly reflects methodological improvements in survey execution, primarily greater use of recorded imagery by divers and its subsequent review. While this mostly affects the record for scarcer taxa, it is also reflected in the abundance score summations for more prevalent species and must be allowed for when interpreting temporal trends.

Examination of the record for taxa abundant enough to be considered characteristic of the Reef continues to show quite high variability between surveys. Patterns across surveys were identified and attributed as follows:

- seasonal variability in populations
- interannual variability with no clear trends
- increases in the prevalence of some taxa since the baseline, including some for which progressive increases were indicated. These changes do not appear to have occurred at the expense of Reef diversity overall.

While there has been no indication of a general decline in the population of any commonly occurring taxon since the baseline, there were two characteristic sponges that were recorded as less abundant solely in the current survey.

For the post-baseline surveys, spatial gradients in taxa prevalence along the Reef axis have been generally consistent with those observed during the baseline. Moreover, this spatial variability in communities has largely exceeded the temporal variability observed across surveys.

Although some changes in community structure since the baseline are apparent, these have been mostly associated with observed increases in the abundance of a few key taxa. There has been no indication of a clear shift in communities towards those of the southern end of the Reef, such as may be expected from an increase in turbidity or fine sediment depositional flux associated with dredging or spoil deposition operations.

Overall, the minor trends in community structure exhibited by the multi-survey dataset are not considered adverse in terms of diversity and are largely attributable to seasonal influences and interannual variability. There is little evidence in the changes observed to suggest an influence from the dredging project.

4.3. Reef fish

The complete record of fish abundance from the current survey is presented in Appendix 3 (Table A4.1) where abundance scores for the current survey are contrasted with the average from the baseline. Total abundance scores across all species indicated that fish numbers were of a similar magnitude to those observed during the previous (May 2021) survey. As well as the greatest abundances, these two most recent surveys also recorded a greater number of fish species than in previous surveys, including all of those seen commonly on the Reef during the baseline. Species newly recorded in December 2021 were red cod (*Pseudophycis bachus*; PR3, PR4, PR7 and PR8) and giant boarfish (*Paristiopterus labiosus*, PR3). Only at PR3 were more than single individuals of either of these species observed, although abundance was recorded as occasional only.

Table 15 shows the variation in total abundance scores (tAS) across surveys for fish species considered characteristic of the Reef. Greater scores than the mean baseline were recorded from the current survey for all characteristic species except sweep (*Scorpis lineolatus;* tAS 22), spotted wrasse (*Notolabrus celidotus;* tAS 21) and leatherjackets (*Parika scaber;* tAS 11) but for none of these was the decrease large.

Table 15. Variation between surveys for 11 fish species considered characteristic of Pania Reef (mean baseline survey abundance score [sum of all transects] > 5). A further three species that have met this criteria for the three surveys since the baseline are listed at bottom. To aid visual interpretation, cell shading varies according to value.

Species	Common name	Apr 2016	May 2019	Feb 2020	Oct 2020	May 2021	Dec 2021
Caesioperca lepidoptera	Butterfly perch	96	51	75	19	103	136
Parapercis colias	Blue cod	57	30	32	25	65	73
Pseudolabrus miles	Scarlet wrasse	39	28	24	16	65	50
Notolabrus celidotus	Spotted wrasse	29	9	33	8	36	21
Forsterygion varium	Variable triplefin	44	7	18	15	21	23
Scorpis lineolatus	Sweep	26	11	30	2	29	22
Scorpaena papillosa	Dwarf scorpion fish	14	7	21	27	32	37
Parika scaber	Leather jacket	11	10	19	11	31	11
Cheilodactylus spectabilis	Red moki	13	3	9	11	24	27
Notolabrus fucicola	Banded wrasse	8	5	7	7	14	30
Nemadactylus macropterus	Tarakihi	6	1	9	1	9	11
Forsterygion malcolmi	Banded triplefin	2	2	3	0	22	32
Hypoplectrodes huntii	Banded perch	0	1	9	4	28	13
Ruanoho whero	Spectacled triplefin	1	1	4	1	7	10
Total no. species observed		**21**	**15**	**21**	**20**	**27**	**23**

The three species where abundance appears to have increased notably since the baseline mostly owe this to improved underwater visibility in the last two surveys, especially the two triplefins (*F. malcolmi* and *R. whero*) which are small benthic species that are easily missed in turbid conditions.

Better underwater visibility conditions will result in a more comprehensive fish record generally as the ability of the diver to see further ahead on the transect means that more of the fish present will be observed. However, as has been previously noted, the progressively more comprehensive photographic and video record will also have contributed to greater total abundance from the more recent surveys. Nonetheless, the settled conditions that are associated with clearer water (such as low swell and preceding calm weather) are also likely to have an influence upon actual fish abundance and/or activity on the Reef.

Reef fish: Key findings

In the two most recent surveys, fish were observed in generally greater numbers and diversity than during the baseline. However, this was considered to result more from better underwater visibility and a more comprehensive photographic and video record than an actual increase in prevalence on the Reef.

Two fish species new to the Reef inventory were recorded although neither of these were present as more than occasional individuals.

There was no indication in the data that any species had declined in numbers since the baseline.

5. TOWN REEF SURVEY

The three Town Reef transects were dived 22–23 December 2021. Low swell conditions and relatively good underwater visibility meant that all three transects were able to be completed despite moderate WNW wind conditions on the first day. The depth profiles were taken from one diver's wrist-mounted computer and adjusted to mean sea level. Since they assume a constant rate of progress along the transect, the profiles should be taken as indicative only.

5.1.1. Description of habitats and communities

For each transect, a descriptive characterisation was compiled from post-dive notes on observations, and photographs and video bracketed into 10-m transect intervals. These are presented in the following sections, together with associated depth profile figures for each 25-m section of the transect. The descriptions comprise general observations. Where conditions and abundances differed notably from those of the baseline survey these differences are referred to specifically. The subsets of 32 photographs for each transect (Figures 19–21) were selected as broadly representative of the communities and habitats observed. Photograph locations along the depth profile were established from bracketing between the transect distance tags and from the EXIF time stamp for each image. The complete inventory of taxa recorded from Town Reef transects is listed in Appendix 4.

Dive transect TR1

Profile: Water depths varied between 4.8 m and 7.2 m (msl) with little overall gradient along the transect. A brief shallower section (4.8 m) occurred 15–20 m along the transect (Figure 18). This had been absent from the October 2020 survey.

Conditions: Good underwater visibility during the dive (3–5 m) with good light penetration. Very little surge compared to previous surveys.

Terrain: As for the baseline in 2019, the terrain was similar throughout the transect. Low rock outcrops, ledges and small overhangs formed recesses against surrounding bedrock and gravel pockets. Some open bedrock and 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* sp.). There were frequent small expanses of mobile gravelly sand in between rock outcrops. Also, occasional small patches of cobble material, sometimes embedded within finer sediments.

Silt presence: There was no incidence of loose settled silt. As in the preceding surveys, the prevalence of silt embedded in turfing biota was low.

Macroalgae: As with the baseline, *E. radiata* was common along the transect, occasionally forming an open canopy. The foliose red alga (*Plocamium* sp.) was also common, at a density consistent with the baseline survey. The brown alga *Dictyota*

sp., a seasonal summer species, was conspicuously common. Small patches of the brown alga *Microzonia velutina* featured in some photographs but was not plentiful.

Encrusting algae: Pink coralline alga was present as small scattered patches but was not as plentiful as in the previous two surveys. The dark-red non-coralline encrusting red algae (cf. *Hildenbrandia*), that had been frequently interspersed with coralline algae during the baseline, was all but absent.

Encrusting fauna: A dense bed of green-lipped mussels (noted during the 2019 survey) was recorded on the shallower bedrock outcrop at the 15 m mark (Figure 18). This outcrop had been missed by the transect line in May 2021.

The colonial ascidian cf. *Synoicum otagoensis* was common but *Didemnum* spp. and *Eudistoma* sp. occurred only occasionally. Dense aggregations of the small red ascidian (Ascidiacea sp. A) were again notable in small patches. *Pyura spinosissima* was recorded but occurred in very low numbers.

Feather hydroids (*Aglaophenia* spp.) were common but not as prevalent as during the baseline survey.

Sponges: *E. alata* was common, as were patches of yellow and cream *Ciocalypta* sp. A bright orange emergent / encrusting sponge was occasional 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*) was present but at much lower levels than in previous surveys.

Mobile invertebrates: Echinoderms included biscuit stars (*Pentagonaster pulchellus*), seven-armed stars (*Astrostole scabra*) and reef stars (*Stichaster australis*). The cushion star (*Patiriella regularis*) was recorded from a single individual and the previously unrecorded sea cucumber (*Australostichopus mollis*) was present but not common. Aggregations of kina (*Evechinus chloroticus*) were again present. Gastropods were quite sparse but Cook's turban shell (*Cookia sulcata*), *Xymene* sp. and siphon whelk (*Penion sulcatus*) were observed. Crayfish were present and the red crab (*Guinusia chabrus*) was unusually common. Small hermit crabs were numerous on *E. alata.*

Fish life: Triplefins (mainly *Forsterygion varium*), spotted wrasse and blue cod were common. Good underwater visibility contributed to more species (13) being recorded than during the baseline (10), but several of these were limited to observations of single individuals.

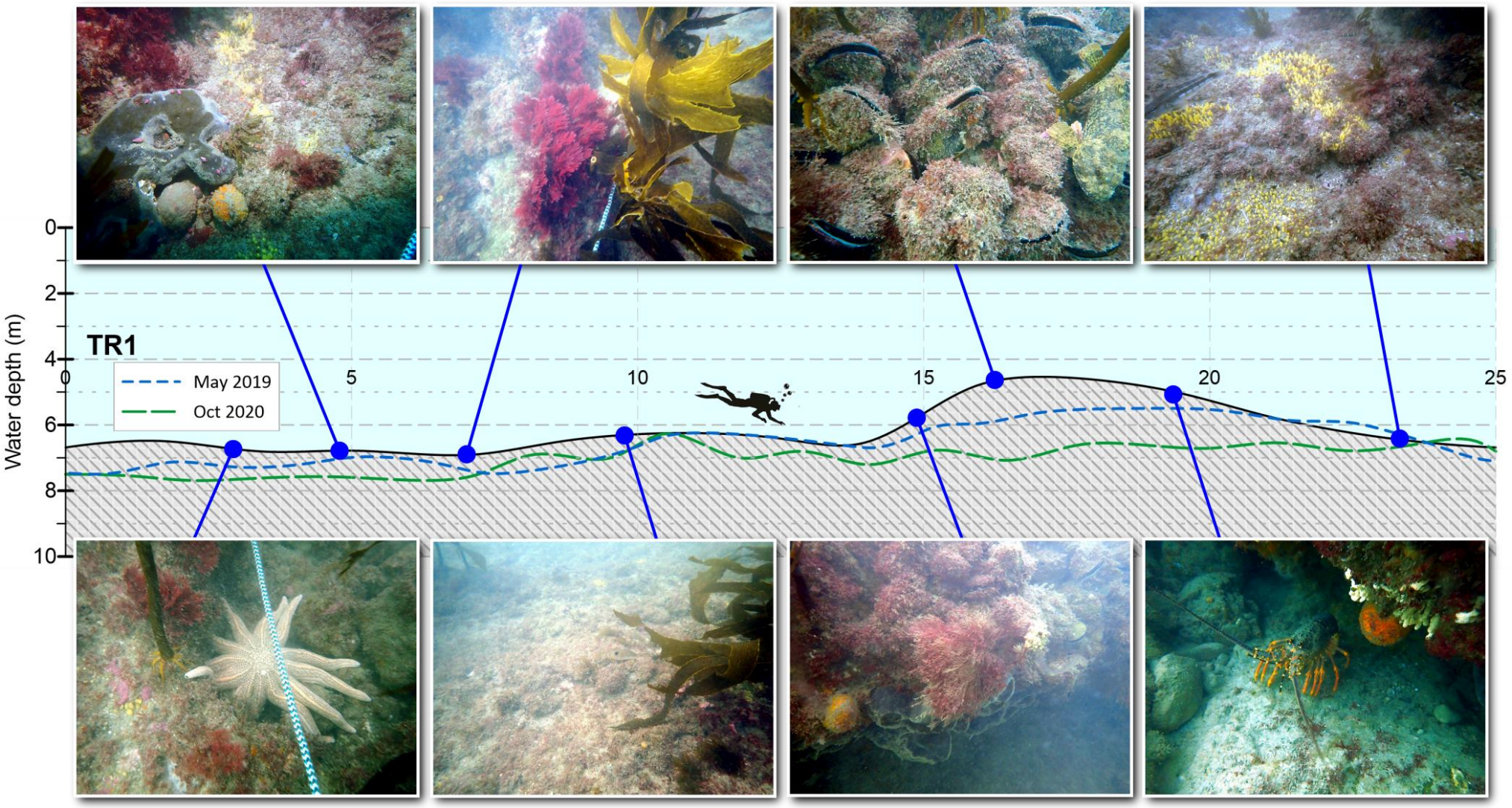

Figure 18. Depth profile and photographs for transect TR1, dived in December 2021. **A:** First 25 m section (0–25 m). The photographs were chosen to illustrate representative habitat and located (blue pointers) according to transect tag photographs and digital image time stamps. Dashed lines show depth profiles for the previous (May 2019 and October 2020) surveys. Vertical grey dashed line and numbers show distance along transect.

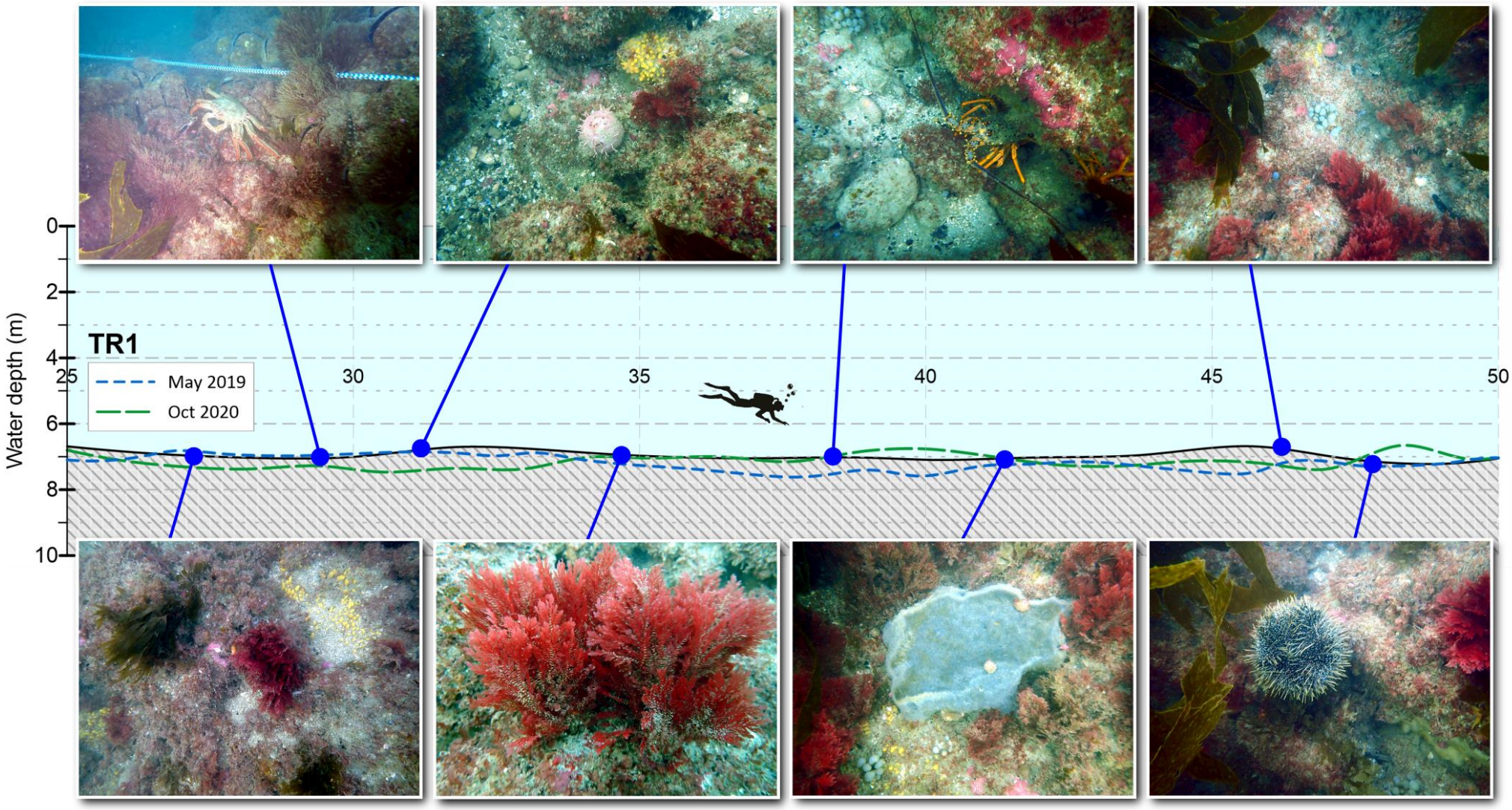

Figure 18 contd. Depth profile with photographs of representative habitat along transect TR1. **B:** Second 25 m section (25–50 m).

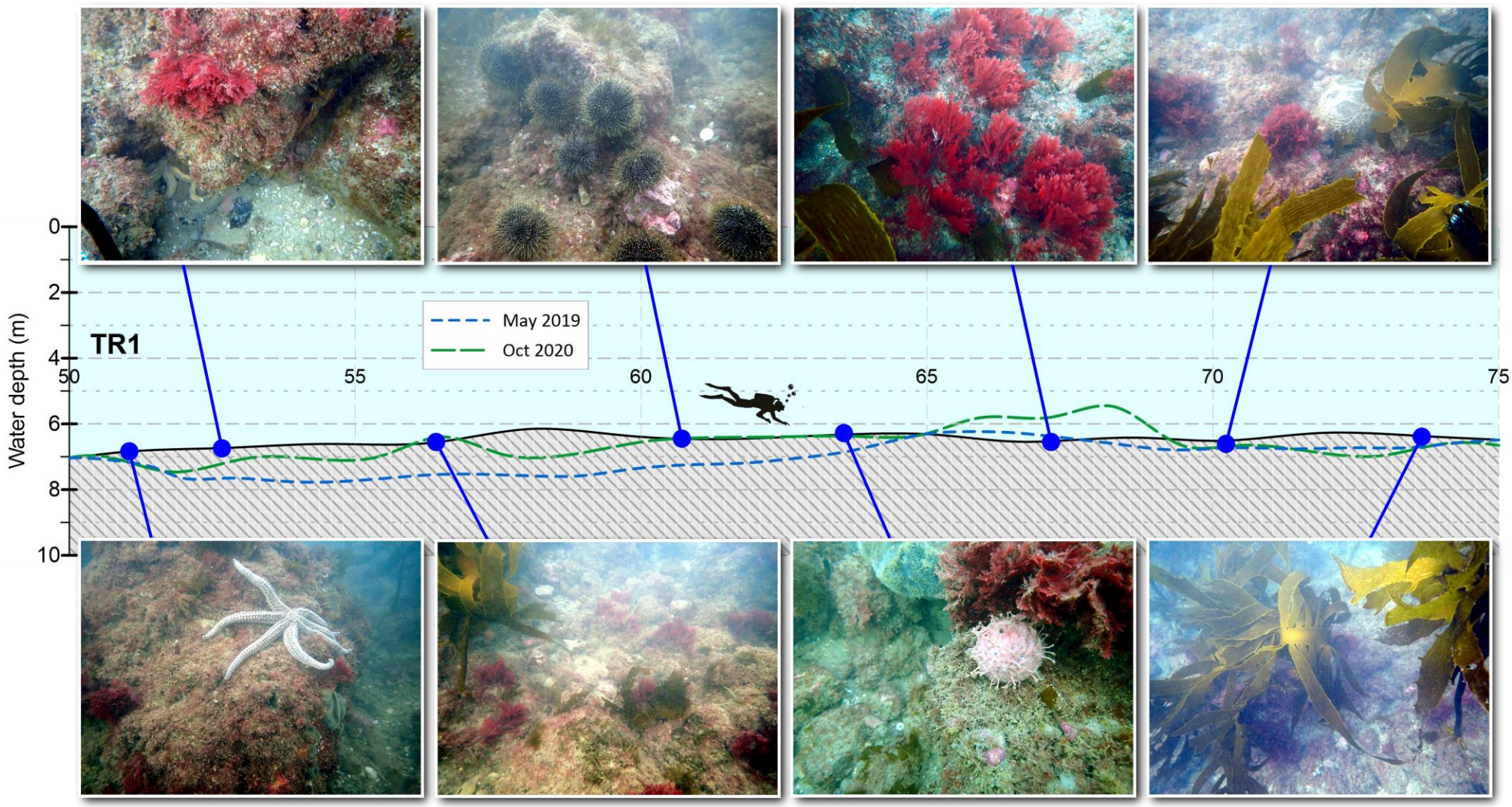

Figure 18 contd. Depth profile with photographs of representative habitat along transect TR1. **C:** Third 25-m section (50–75 m).

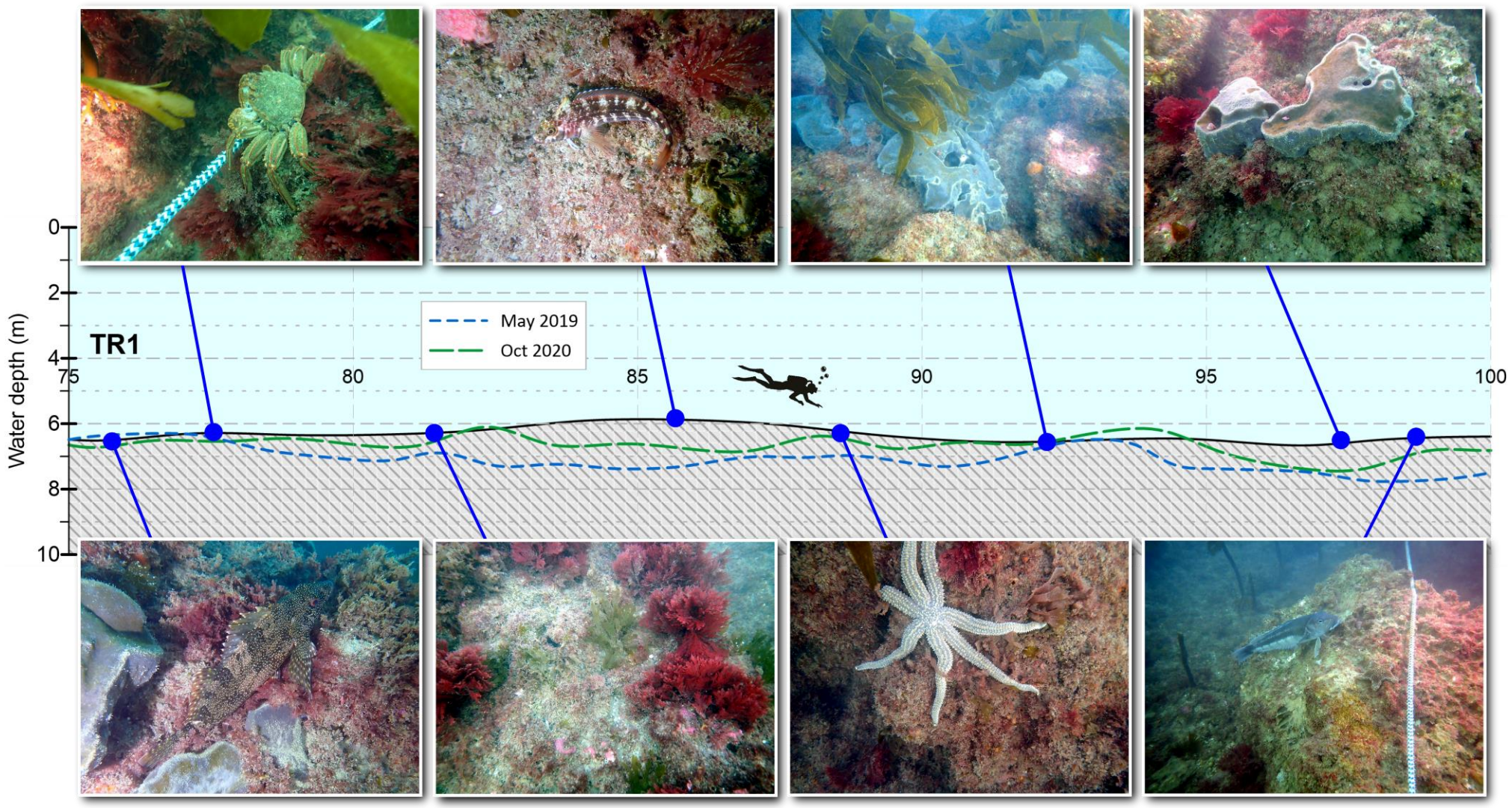

Figure 18 contd. Depth profile with photographs of representative habitat along transect TR1. **D:** Fourth 25 m section (75–100 m).

Dive transect TR2

Profile: Although depths were similar overall to those recorded in 2019, the profile did not match the earlier survey well after the 25 m mark, where it ascended to a shallower section (6.5-8.0 m MSL) between the 30 m and 55 m marks (Figure 19). Dropping below 9.0 m after the 70 m mark, it ascended to finish in water depths of 7.0–7.5 m.

Conditions: At 3–5 m, underwater visibility was better than the 1.0–1.5 m experienced in 2019. There was little surge present.

Terrain/substrate: Starting with uneven bedrock with frequent outcrops and ledges, the reef changed into flatter low-relief terrain after 20 m then up onto the shallower reef crest until the 50 m mark. On the other side of this there was flatter terrain with coarse-sand patches and pockets with a shell-hash and pebble component (often as a thin layer over bedrock). This was interspersed with larger bedrock outcrops and ledges. Sand was more prevalent between 70–80 m, with tongues of deeper deposits between ledges and outcrops. Some cobble/pebble substrate occurred in low points and niches. Collections of small boulders occurred in more uneven 3-dimensional terrain.

Silt presence: As during the baseline, TR2 was notably siltier than transect TR1, although there was no evidence of a settled silt veneer on reef surfaces or biota. Settled silt occurred in hollows and low points. Silt entrapped within encrusting biota was prevalent, especially at deeper points in the transect profile.

Macroalgae: Kelp / *Ecklonia* was not abundant along the transect but scattered individuals were consistently present, and some small stands occurred in places (Figure 19; 63 m). All were relatively stunted (typically less than 1 m high) but mature and healthy in appearance. The red alga *Plocamium* sp. was common, reaching quite high coverage in patches with a second similar foliose red alga of duller red appearance. The seasonal brown alga *Dictyota* sp. was also present at a low level (Figure 19; 90 m).

Encrusting algae: Pink coralline alga was consistently present but not abundant. Occasionally, it was quite prevalent in small, dispersed patches (Figure 19; 79 m). Non-coralline encrusting red alga (cf. *Hildenbrandia* sp.) was present but at a very low prevalence toward the end of the transect.

Notable encrusting fauna: Encrusting life was dense on most reef surfaces and bare rock was not observed except in the margins of patches of mobile sand. Green-lipped mussels were not observed for most of the transect although a small dense bed was recorded at the shallowest point in the profile (Figure 19; 45 m). Branching hydroids (previously unrecorded) were occasional (Figure 19; 12 m). Feather hydroids were commonly seen; these occasionally reached quite high densities in patches. Fine filamentous hydroids were often seen growing on *E. alata* and *Ecklonia* fronds. Jewel anemones (*Corynactis australis*) formed occasional small aggregations. Colonial ascidians (cf. *Synoicum otagoensis*, *Eudistoma* sp., *Didemnum* species complex)

were also commonly observed. Solitary ascidians of the genus *Cnemidocarpa* were common but often occurring with other encrusting species so that only their siphon openings were visible. The small, red-mouthed ascidian was occasionally abundant in patches. The orange bryozoan (cf. *Steginoporella* sp.) was present, but not as common as had been observed at south Pania Reef.

Sponges: In the absence of dense macroalgae, sponges were among the most conspicuous encrusting biota. Prevalent species included *E. alata* and *Tethya bergquistae.* More occasionally, *R. topsenti, A. globosa* and *T. burtoni* were observed, along with the lilac sponge (Demospongiae D). The erect branching sponge (cf. *Callyspongia ramosa*) was present but less common than in previous surveys. The boring sponge (*Cliona* sp.) was associated with coralline algae (Figure 19; 19 m). Emergent *Ciocalypta* sp. occurred, usually associated with thin mobile sand layers and entrapped surface silt (Figure 19; 61 m).

Mobile invertebrates: Crayfish were recorded only as a single small individual. Seven-armed star (*Astrostole scabra*), biscuit star (*P. pulchellus*), Cook's turban shell (*Cookia sulcata*) and sea cucumbers (*A. mollis*) all featured along the transect. Kina occurred in small numbers after the 70 m mark.

Fish life: The greater underwater visibility of the current survey contributed to a greater variety of fish species being observed. Butterfly perch formed small schools at points, with sweep. Triplefins and spotted wrasse were common. Blue cod, red moki and banded wrasse were occasional. Marblefish and blue moki were also observed.

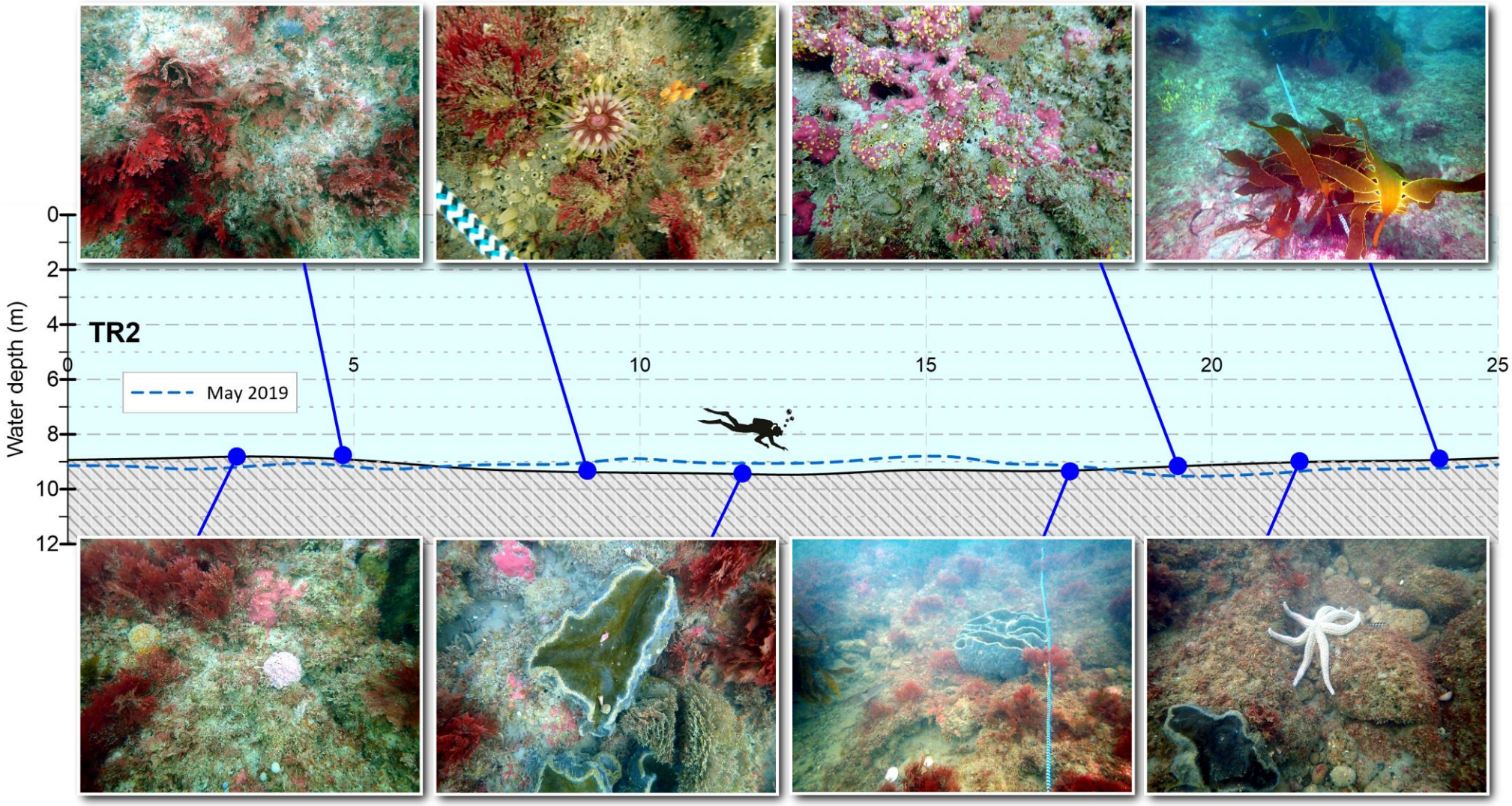

Figure 19. Depth profile and photographs for transect TR2, dived in December 2021. **A:** First 25 m section (0–25 m). The photographs were chosen to illustrate representative habitat and located (blue pointers) according to transect tag photographs and digital image time stamps. Dashed lines show depth profiles for the previous (May 2019) survey (the transect was not dived in October 2020). Vertical grey dashed line and numbers show distance along transect.

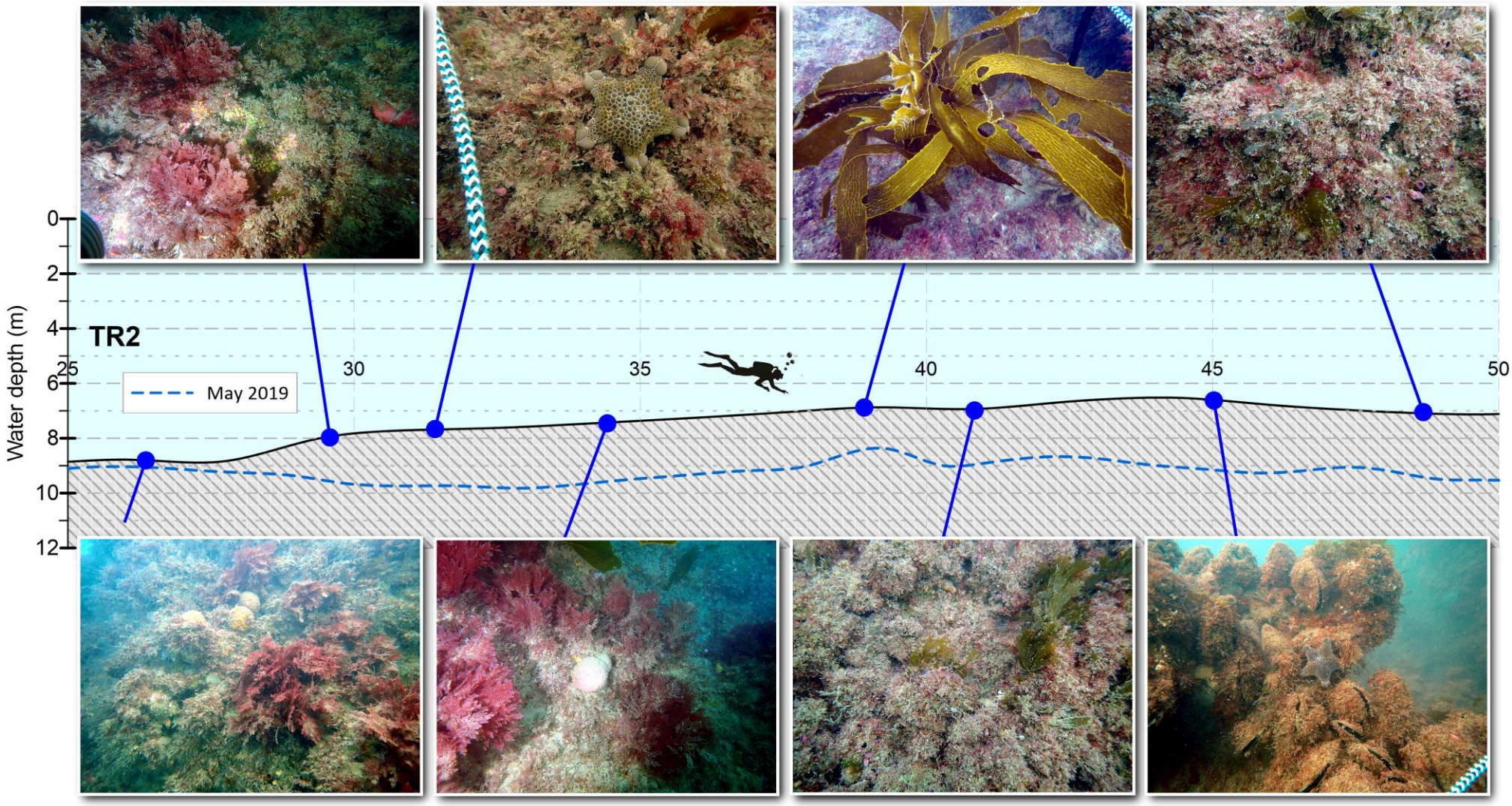

Figure 19 contd. Depth profile with photographs of representative habitat along transect TR2. **B:** Second 25 m section (25–50 m).

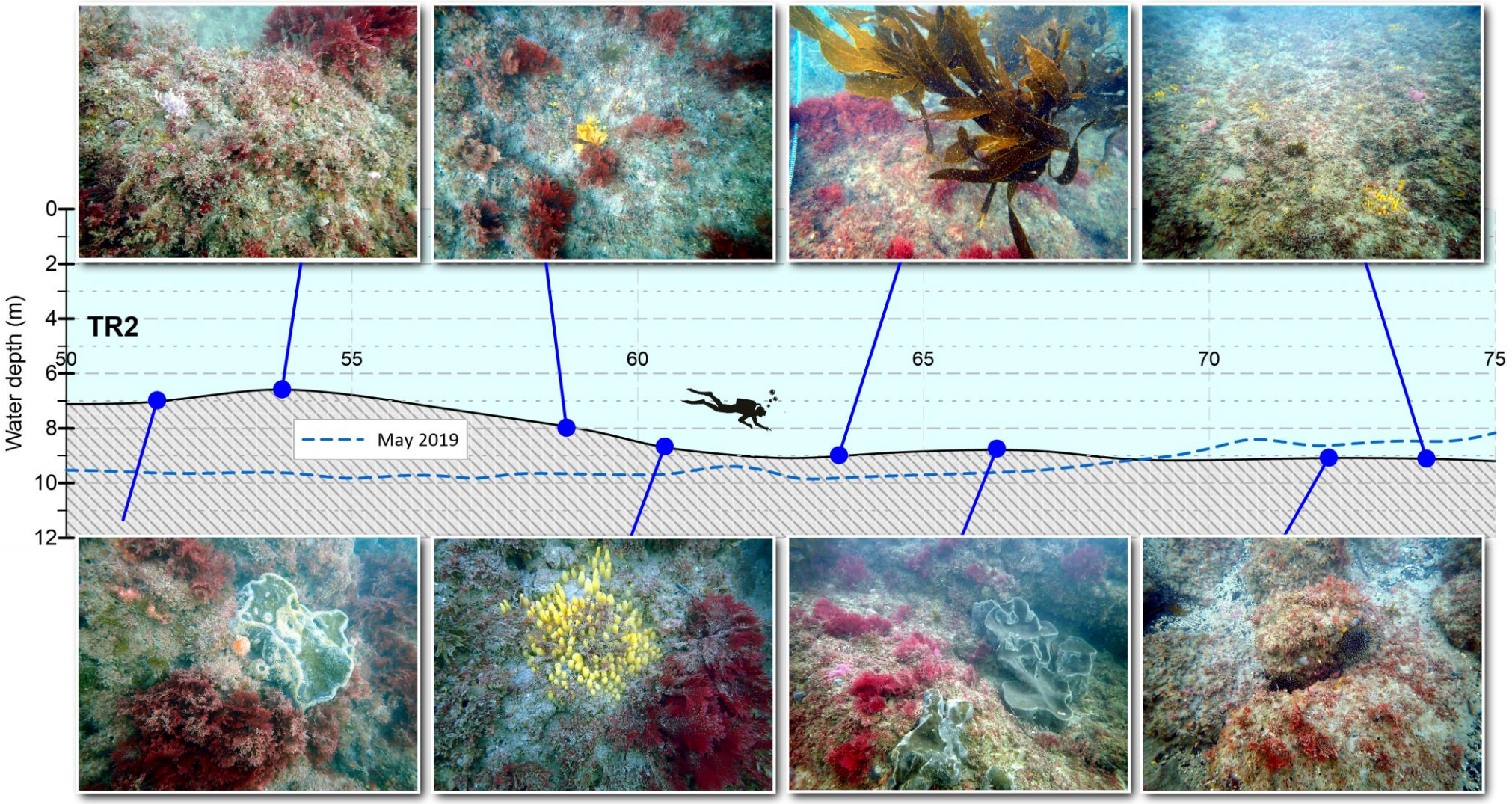

Figure 19 contd. Depth profile with photographs of representative habitat along transect TR2. **B:** Third 25 m section (50–75 m).

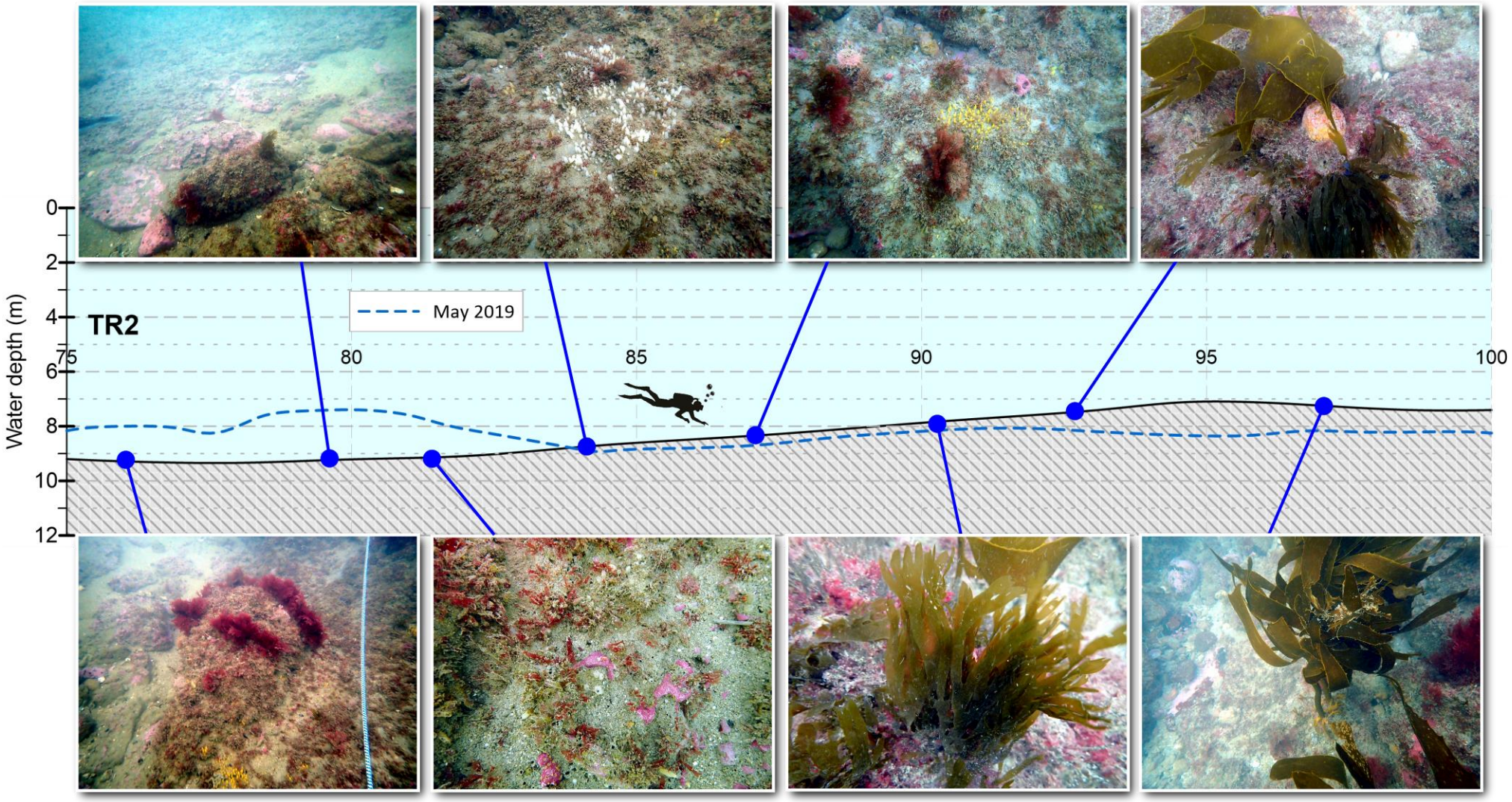

Figure 19 contd. Depth profile with photographs of representative habitat along transect TR2. **B:** Fourth 25 m section (75–100 m).

Dive transect TR3

Profile: Matched reasonably well the depth profile recorded in 2019 (Figure 20), featuring very uneven terrain, valleys and drop-offs. Varied between 6–10 m, with both the shallowest and deepest sections recorded in the first 20 m of the transect.

Conditions: Similar to conditions for transect TR2, divers had moderately good visibility (3–4 m). Some suspended particulate matter was present.

Terrain/substrate: Benthic conditions were similar to those on TR2. There were patches of coarse mobile sand (with a larger expanse between 10 m and 20 m distance tags), as well as patches of silty sand in niches more sheltered from water movement. Pockets of mobile sand occurred among bedrock ledges. Some small-boulder substrate was observed confined between ledges. Patches of wave-rippled mobile sand after the 70 m mark indicated the effects of swell at ~8 m water depth.

Silt presence: Similar to transect TR2. In places, entrapped silt was prominent within encrusting biota. Although there were deeper silt deposits collected in protected niches.

Macroalgae: In contrast to TR2 (and the baseline), no kelp / *Ecklonia* was observed. In 2019, isolated plants had been recorded. *Plocamium cirrhosum* was patchy along the transect, sometimes common but mostly less prevalent than on TR2. The seasonal *Dictyota* sp. was present (Figure 20; 61 m), but not as common as on TR2.

Encrusting algae: Coralline algae occurred consistently in sporadic patches, but was not generally abundant.

Notable encrusting fauna: The shallow (6 m) outcrop at the start of the transect was covered in a dense bed of mature green-lipped mussels with patches of mussel beard hydroid and occasional stalked ascidians (*P. spinosa*) (Figure 20; 2 m). Encrusting communities along the transect were mostly dense and highly diverse. Jewel anemones (*Corynactis australis*) were present in patches and more prevalent than at TR2. The saddle squirt *Cnemidocarpa* sp. was common along the transect, as were feather hydroids and the small red-mouthed ascidian (Ascidiacea sp. A). The stalked colonial ascidian *Synoicum* sp. was common at the end of the transect, sometimes forming dense aggregations (Figure 20; 98 m). Orange finger bryozoans (*Steginoporella* sp.) were occasional under ledges and on vertical rock faces. The clown's hair bryozoan (Catenicellidae), and the anemones *Anthothoe albocincta* and *Oulactis mucosa* were also observed, but only as isolated colonies or individuals.

Sponges: Commonly occurring sponges included *E. alata*, *Tethya burtoni, T. bergquistae* and lilac Demospongiae D. The branching sponge (cf. *Callyspongia ramosa*), *Raspalia topsenti* and *Aaptos globosa* were occasional. A yellow finger sponge (cf. *Iophon minor,* Figure 20; 7 m) was also observed. Emergent *Ciocalypta* sp. was associated with embedded silt and shallow sand layers. The yellow boring sponge (*Cliona*) was also present but mostly associated with patches of coralline algae.

Mobile invertebrates: The seven-armed star (*A. scabra*) was observed associated with mussel beds. *P. pulchellus,* and sea cucumber (*A. mollis*) were also recorded. The cushion star (*P. regularis*) occurred more commonly than on TR2. Gastropod molluscs were mostly recorded as isolated individuals, although the green topshell (*Trochus viridis*) and small coralline encrusted *Xymene* sp. were occasional. Crayfish occurred in recesses beneath ledges at the start of the transect and at the 70 m mark.

Fish life: As for transect TR2, the greater underwater visibility of the current survey contributed to a greater variety of fish species (15) being observed than in the baseline (3 species). Ten species were in common with those recorded at TR2 and all have been previously recorded from Pania Reef. The most prevalent were variable triplefins and spotted wrasse.

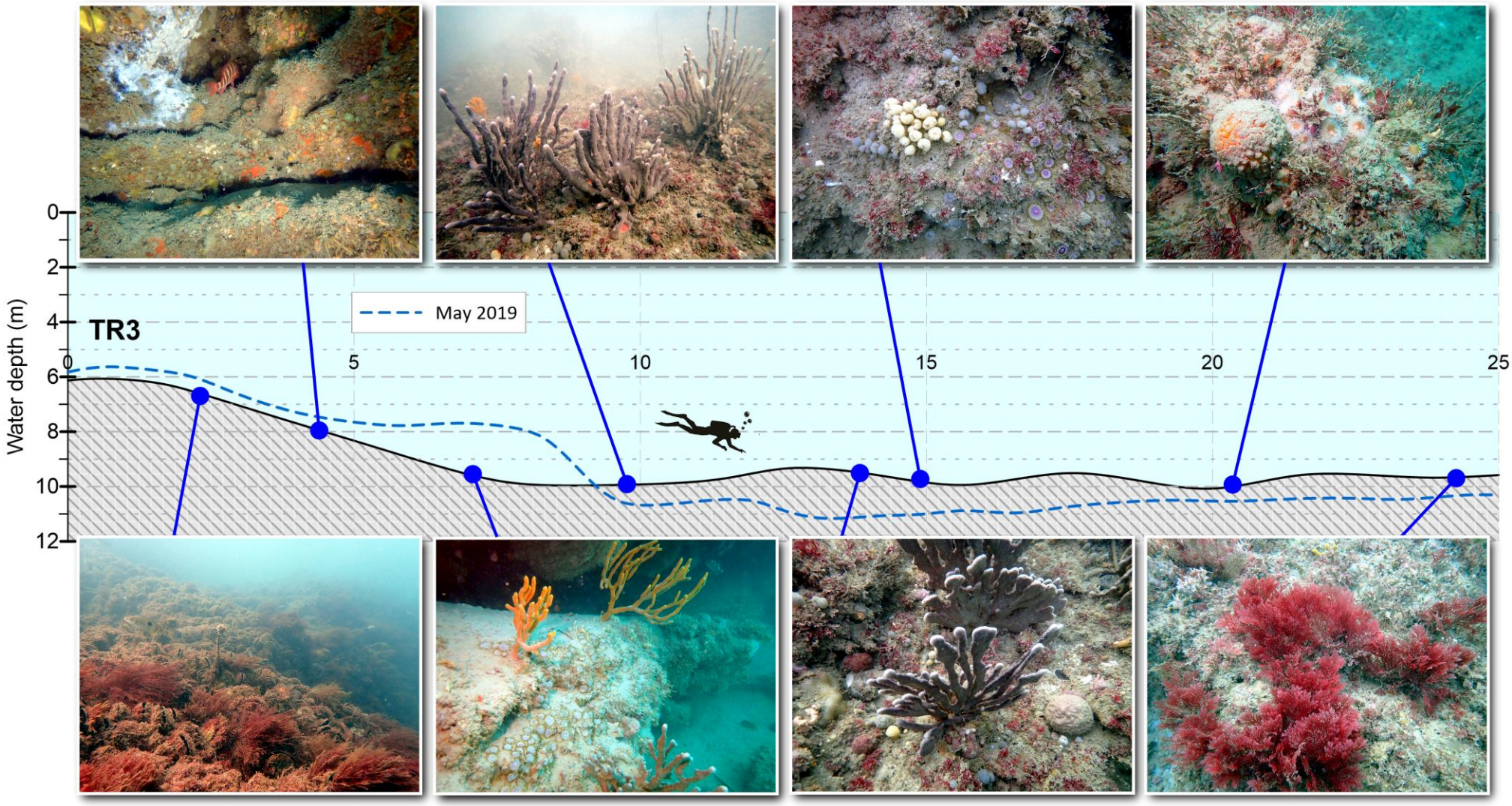

Figure 20. Depth profile and photographs for transect TR3, dived in December 2021. **A:** First 25 m section (0–25 m). The photographs were chosen to illustrate representative habitat and located (blue pointers) according to transect tag photographs and digital image time stamps. Dashed lines show depth profiles for the previous (May 2019) survey (the transect was not dived in October 2020). Vertical grey dashed line and numbers show distance along transect.

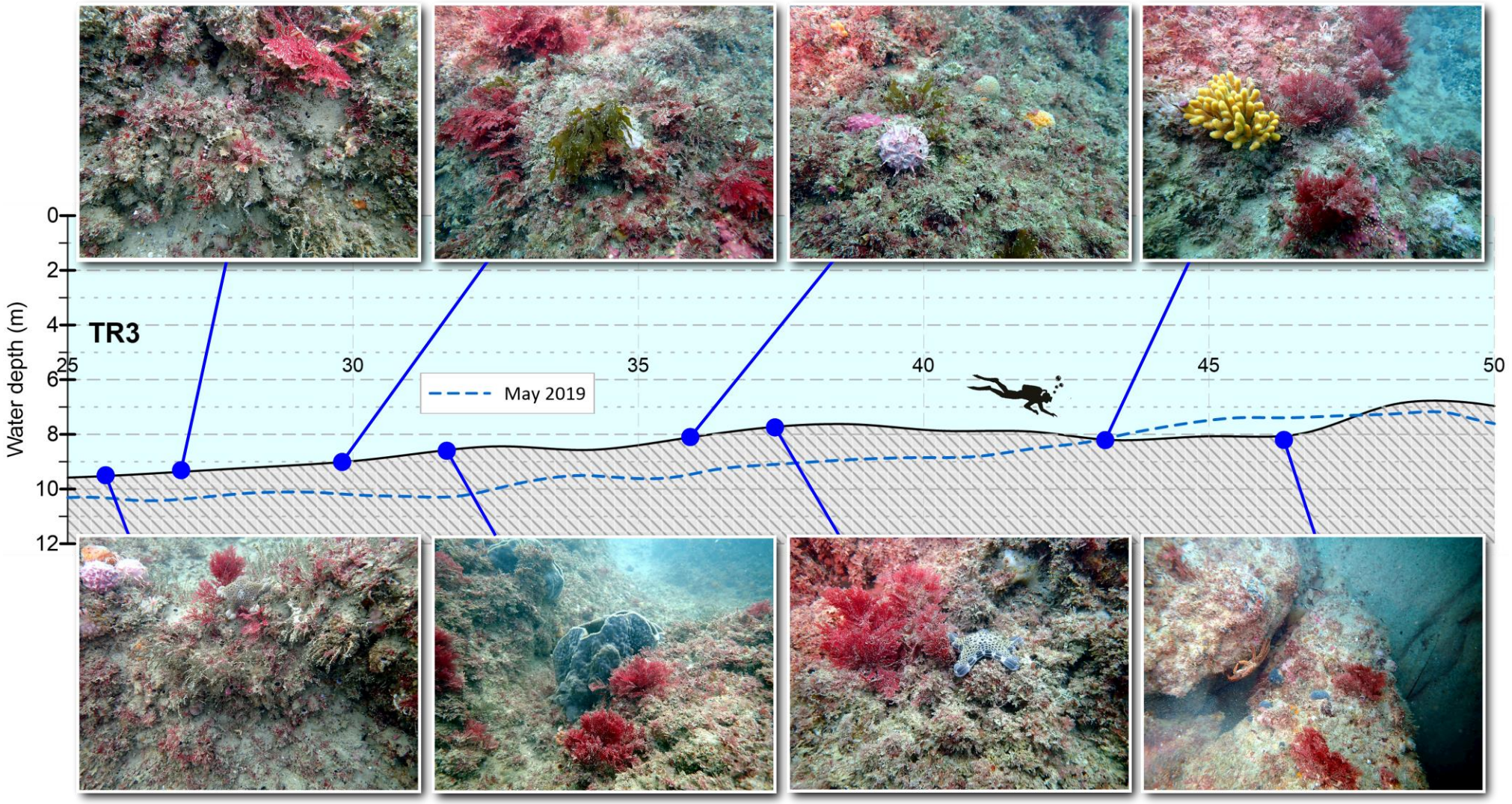

Figure 20 contd. Depth profile with photographs of representative habitat along transect TR3. **B:** Second 25 m section (25–50 m).

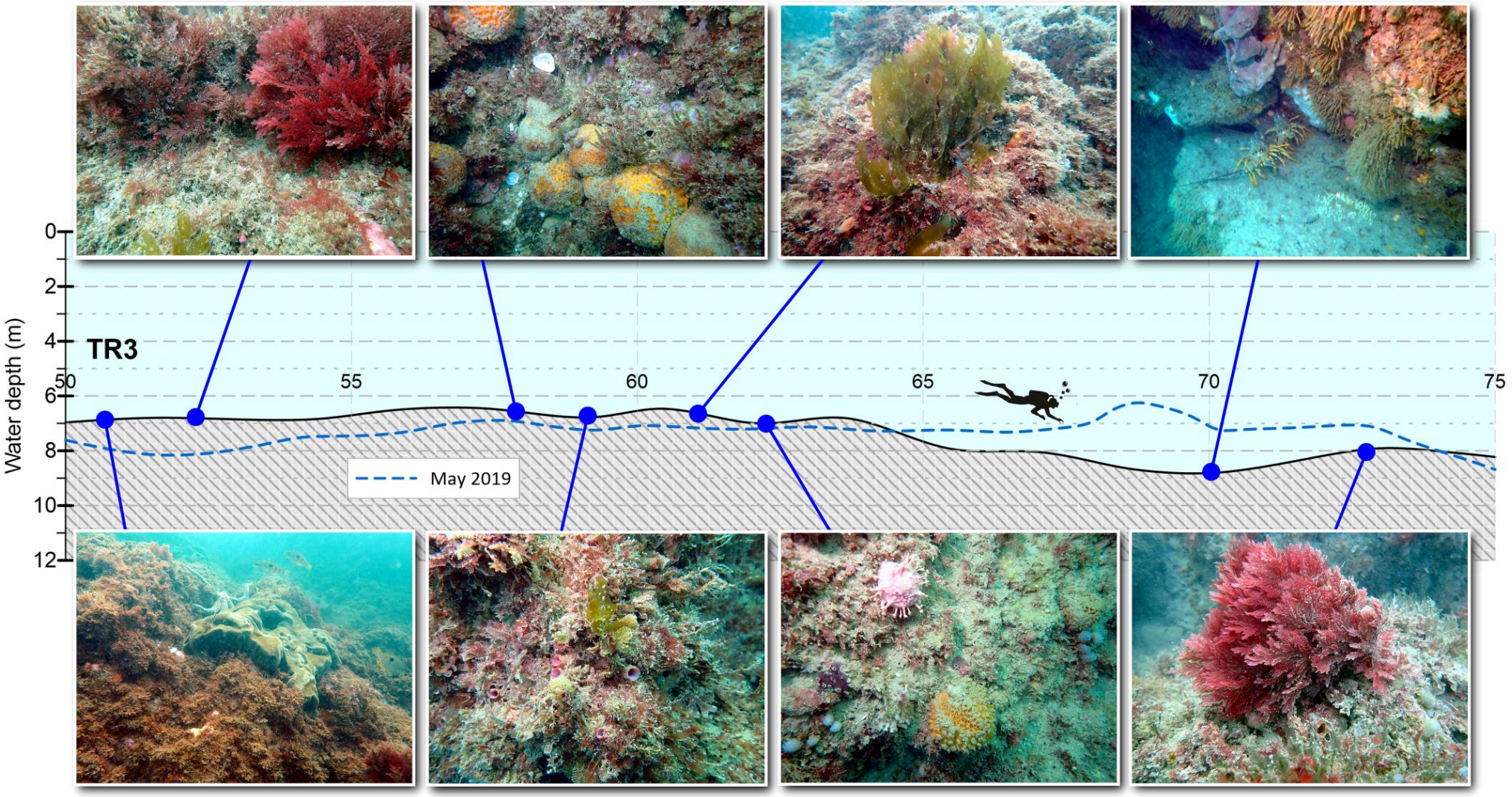

Figure 20 contd. Depth profile with photographs of representative habitat along transect TR3. **B:** Third 25 m section (50–75 m).

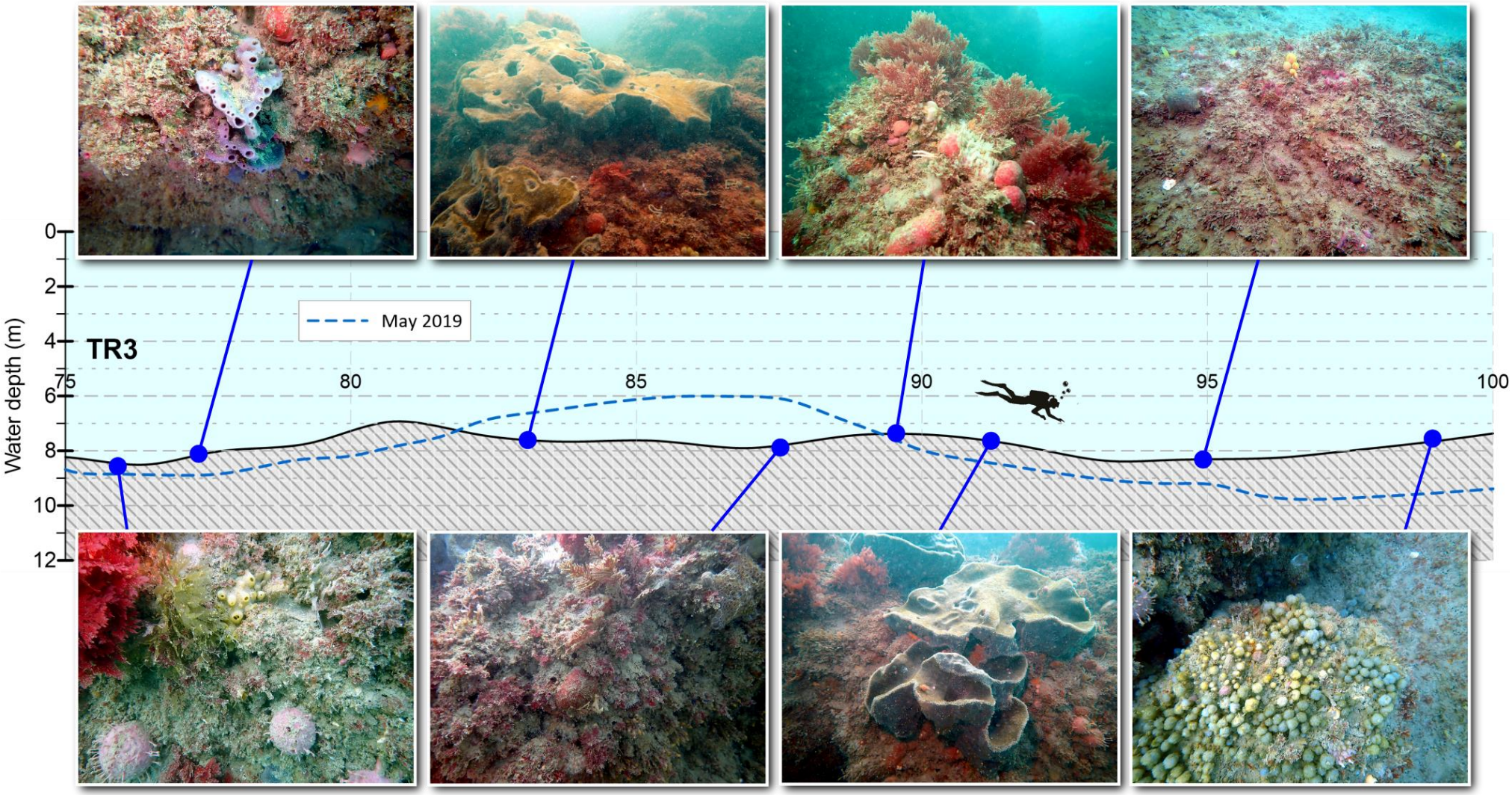

Figure 20 contd. Depth profile with photographs of representative habitat along transect TR3. **B:** Fourth 25 m section (75–100 m).

5.1.2. Comparison to the 2019 baseline survey of Town Reef

The current survey marks the first time since the baseline in May 2019 when conditions have been suitable to survey all three Town Reef transects. The inventory of taxa recorded is presented in Appendix 4 and total numbers of taxa by category in Table 16. There was no consistent trend for taxa richness across transects except for the greater number of fish species observed during the current survey. This was principally due to conditions of greater underwater visibility where fish that are frequently wary of divers could be observed (and photographed) further ahead on the transect.

Table 16. Numbers of taxa, by category, recorded on the Town Reef transects across all surveys.

	TR1			TR2		TR3	
	2019	2020	2021	2019	2021	2019	2021
Algae	6	9	8	6	8	6	4
Invertebrates	43	38	36	43	44	43	50
Fish	10	4	13	5	13	3	15

Small increases in the number of algal taxa on transects TR1 and TR2 may be due to seasonal factors. In particular, the brown alga *Dictyota* sp. was absent from the baseline but appeared on all transects in the current survey. This mirrors its seasonal occurrence on Pania Reef. Although most changes in algal taxa concerned those that appeared only rarely along their respective transects, TR3 was notable for the disappearance of the kelp *Ecklonia radiata.* However, kelp had not been particularly prevalent in 2019 and was not obviously less abundant on the other two transects during the current survey. A red encrusting alga (cf. *Hildenbrandia* sp.) was noticeably less abundant across all transects and was absent from TR3. This had been conspicuous in 2019, forming a patchwork with coralline algae in shallower areas of TR1 (Sneddon 2019).

Only two invertebrate taxa that had been present across all three transects during the baseline were absent from the 2021 record. These were a small cnidarian that had occurred in very low numbers (identified only subsequently from photographs) and the clown nudibranch (*Ceratosoma amoenum*). The conspicuousness of the latter makes its absence notable but its prevalence on Pania Reef has exhibited high variability, even during baseline surveys (see Table 12). The red rock crab (*Guinusia chabrus*) was the only taxon to appear on all three transects that was new to the Town Reef inventory. Again, this is a highly conspicuous species and, along with crayfish (*Jasus edwardsii*), has also been more prevalent on Pania Reef over the most recent two surveys.

Most changes in the presence of invertebrate taxa at individual transects have occurred for those that were observed as no more than a few individuals; hence, there is an element of chance to their observation during any survey. Of the 43 taxa recorded at TR1 during the baseline, 17 were absent from the current survey. Of these, the following are notable for being previously noted as more than occasional:

- Clown nudibranch (*C. amoenum*),
- Clowns' hair bryozoan (Catenicellidae)
- Colonial ascidian cf. *Didemnum* sp. (cream variant)

All of these have broadly followed their recorded relative abundance on Pania Reef.

Of ten taxa additional to the baseline TR1 record, six had also been absent from the October 2020 TR1 record and (as noted above) only two had been absent from the baseline record on all three transects.

Transects TR2 and TR3 are best considered together due to the overall similarities in their depth profiles and benthic conditions. Apart from those invertebrate taxa noted above as being present or absent across all transects, there were no changes on TR1/TR2 involving taxa that occurred in more than very low abundance.

Despite the markedly greater variety of fish species observed (Table 16), there were no changes in the occurrence of any species that were considered unusual or indicative of the action of particular drivers. All the species observed have been regularly recorded from Pania Reef. The most prevalent were variable triplefins and spotted wrasse, both of which appeared to be more common on Town Reef than on Pania Reef.

6. CONCLUSIONS

The current survey was undertaken in conditions of good underwater visibility and little swell and surge. Although changes in prevalence were noted for some key taxa relative to previous surveys, diver observations have identified no conspicuous deterioration in reef communities or habitats that is potentially attributable to stressors associated with the capital dredging project.

The visible presence of fine silt on the reef has not changed notably across surveys since the baseline. The quantity of settled silt is likely controlled mostly by exposure to water movement rather than by changes in flux from the water column. Nonetheless, silt entrapped and consolidated within encrusting communities is a ubiquitous feature of reef surfaces except in the vicinity of the shallow reef crests.

Although the prevalence of sand on the reef transects has been variable, the data indicate no trend across surveys since the baseline. While sand deposits may be shifted by significant swell events, some of the variability observed is likely to have arisen from the inexact relocation of transect lines.

The two taxa recorded from the current survey that were new to the Pania Reef inventory were algae that may be seasonal in occurrence. They were also at population densities too low to rule out their undetected presence during the baseline. Ten taxa from the baseline inventory were absent from the current survey record but their baseline prevalence had in all cases been low or very low; and none had been observed in all three baseline surveys.

Analysis of abundance scores across the eight transects for the entire Reef taxa inventory continues to show that the number of taxa exhibiting positive changes in abundance relative to the baseline is significantly greater than those where a decrease has been apparent. Populations of many taxa have been observed to vary seasonally and otherwise; however, this imbalance is considered to mostly reflect the increase in the comprehensiveness of the record across successive surveys, driven by greater and more effective use of photographs and video. Since scarce and inconspicuous organisms are less often overlooked, apparent taxa richness for all transects has increased progressively across surveys.

Nonetheless, variability in the populations of some characteristic reef taxa has been identified across surveys. Patterns in the data indicate that, for most taxa, this is attributable to background seasonal or inter-annual variability. Although longer-term trends are suggested for some species, there has been no indication of a general decline in the population of any commonly occurring taxon since the baseline. Neither have there been any clear shifts in spatial gradients in populations along the reef axis.

Increases in the abundance of several characteristic species have occurred since the baseline. Some of these taxa are either associated with siltier conditions or have historically been more prevalent on the southern transects and Town Reef; hence, a driver related to dredging and spoil deposition activities cannot be ruled out. However, other taxa for which increases have been observed have no such associations and none of the observed changes have coincided with discernible changes in sediment conditions on the reef.

Multivariate statistical analysis of the data set of ranked abundance continues to indicate that spatial variability in benthic community structure (between transects) has remained greater than temporal variability. The established spatial gradients in communities along the Reef axis have been maintained in surveys following the baseline.

Nonetheless, there appear to have been small shifts in community structure since the baseline that have been consistent across transects. Investigation of these shifts associates them principally with increases in the abundance of some taxa rather than decreases in diversity. Noting that there has been a seasonal imbalance between the baseline and post-baseline surveys, the data suggests that the influence of seasonal factors has played a role.

Diver observations and the photographic and video record for the three Town Reef transects indicated that habitats and communities were effectively unchanged from those documented by the 2019 baseline survey.

While the recording of fish abundance and diversity is part of the reef monitoring programme, it is acknowledged that variability in the fish record is influenced much more by the sea conditions under which surveys are undertaken than that of reef epibiota. Since, with experience, we are better able to predict suitable survey conditions, a greater range and abundance of fish species has been recorded from more recent surveys. However, the continuing presence of all characteristic species from the baseline inventory over both reef systems suggests that there has been no ecologically significant change in fish populations or diversity.

Considering all lines of evidence provided by the monitoring record, there is no indication that dredging and spoil disposal activities are causing a deterioration in the ecology of either Pania or Town reefs.

7. ACKNOWLEDGEMENTS

The author of this study would like to acknowledge the following Cawthron staff: Robyn Dunmore, Rebecca McMullin and Scott Edhouse for their assistance in the field, Rebecca McMullin for report review, and Gretchen Rasch for editorial guidance.

8. REFERENCES

Anderson MJ, Gorley RN, Clarke KR 2008. PERMANOVA+ for PRIMER: Guide to software and statistical methods. Plymouth, UK, PRIMER-E. 214 p.

Clarke KR, Gorley RN 2015. PRIMER v7: User manual/tutorial. PRIMER-E: Plymouth, UK. 296 p.

Clarke KR, Gorley RN, Somerfield PJ, Warwick RM 2014. Change in marine communities: an approach to statistical analysis and interpretation, 3rd edition. PRIMER-E: Plymouth, UK.

Duffy C 1992. Shallow rocky reef habitats in Hawke's Bay: Site descriptions and rotenone collections. Prepared for Marine Reserves Workshop: Towards achieving a marine reserve network using a scientific base.

Sneddon R, Dunmore R, Berthelsen A, Barter P 2017. Assessment of effects on benthic ecology and fisheries resources from proposed capital dredging and spoil disposal for the Port of Napier. Prepared for Port of Napier Ltd. Cawthron Report No. 2895. 154 p. plus appendices.

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.

Sneddon R, Dunmore R 2021. Ecological transect surveys of Pania and Town reefs: October 2020. Prepared for Port of Napier Ltd. Cawthron Report No. 3587. 55 p. plus appendices.

Sneddon R 2021. Ecological transect survey of Pania Reef: May 2021. Prepared for Port of Napier Ltd. Cawthron Report No. 3648. 66 p. plus appendices.

9. APPENDICES

Appendix 1. Notes on the generation and interpretation of representative photographs of substrate and taxa from ecological survey dives.

Frequently 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 G7X 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^{TM} 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 are 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 are 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 2. 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 scores recorded for 10-m intervals along each transect. Shading intensity proportional to the magnitude of the cell value. All blank cells represent zero (taxon not observed). Taxa in yellow cells are those newly identified in the current (December 2021) survey. Transects in north to south order.

Table A2.1 Algae and invertebrates.

	Survey	Baseline mean								December 2021							
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	18.0	37.7	2.7	33.0	16.0	25.0	16.0		18	37	2	33	14	22	18	
Carpophyllum maschalocarpum	Flap jack		16.7								18						
Halopteris sp.		1.3	11.3								14						
Zonaria sp.			6.7								7						
Carpomitra costata		1.0	11.7		1.0						3						
Dictyota sp.										13	7	10	21	17	23	20	18
Microzonia velutina											2						
Rhodophyta	**Red algae**																
Coralline algae	Encrusting corallines	14.0	36.0		29.3	11.0	8.0	2.0	0.3	14	39		24	13	18	6	
Plocamium cirrhosum		12.7	13.3	2.3	22.3	16.0	23.3	18.3	12.0	17	18		24	15	29	28	13
Pterocladia capillacea			1.7								5						
Rhodophyta sp.	Small bladed red algae	1.7	3.3	6.0	4.7	12.7	19.7	13.0	13.0	13	15	18	22	27	30	28	17
cf. *Hildenbrandia* sp.	Red encrusting algae		3.0			0.3											
Red fine algae	Red fine algae	5.0	0.3		1.7					4	19		5	2		1	
Chlorophyta	**Green algae**																
Green alga (grass-like)	Green alga (grass-like)	3.7	4.3		7.7					16	15		18				
Fine green alga	Fine green alga										1			1			

	Survey	Baseline mean								December 2021							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Porifera	**Sponges**																
Ecionemia alata	Grey vase sponge	14.3	19.7	16.3	24.3	18.3	25.7	16.0	21.3	12	25	10	25	22	27	21	18
Cliona cf. *celata*	Yellow boring sponge	5.3	16.3	0.7	12.0	4.0	8.3	2.0	3.0	15	17	7	12	9	12	10	2
cf. *Stylopus australis*	Red emergent/encrusting sponge		0.7		0.7	0.7		0.3	3.7	1	3		3	2	2	4	3
cf. *Tedania* sp.	Orange encrusting sponge	2.0	3.7	6.7	0.7	10.3	2.0	4.7	8.7	1		5		3	4	4	2
cf. *Hymeniacidon* sp.	Orange massive sponge		1.7					0.3	0.3		1					1	
Tethya bergquistae	Pink golfball sponge	0.7	0.3	1.0	0.3	4.0	1.7	5.7	1.7	2			1	1		3	3
Tethya burtoni	Orange golfball sponge	2.0	1.3	2.7	5.0	1.7	8.0	2.7	9.7	5	2	5	7	11	9	12	14
Ciocalypta sp.	Yellow tubular sponge	16.0	7.0	12.7	13.3	14.3	12.3	20.3	18.7	14	2	13	6	10	13	9	17
cf. *Thorecta* sp.	Lobed grey sponge	0.3		0.3	0.3	5.0	1.7	5.3	6.0	2			2	3	9	5	5
Raspailia topsenti	Orange finger sponge	12.3	2.7	9.7	12.0	15.0	12.7	13.3	13.7	11	1	14	16	16	16	15	14
Demospongia A (White/green)	White/green massive sp.		0.3	0.7		1.7		0.3	1.0					3			1
Demospongia B (Grey)	Grey lumpy massive sp.		1.7	1.0	2.3		0.7	0.3	0.3	4	2	2	5	4	5	5	2
Demospongia C (Pink)	Pink thick encrusting sp.		0.3	0.3	4.3	0.3		1.7									1
Demospongia D (Lilac)	Lilac spiky sponge	1.3	1.0	2.7	9.7	14.3	13.7	15.3	18.0	8	1	7	13	19	15	13	13
Demospongia E (Yellow)	Yellow lumpy massive sp.			4.0	1.3	7.7	3.7	11.0	7.7	6		10	5	8	4	10	14
Demospongia F (Maroon)	Maroon massive sponge	0.7		0.3		0.7	0.3	1.7			1						
Latrunculia cf. *procumbens*	Green mushroom-like sp.		2.0		1.0	1.0	0.7	1.0		2	4			7	2	5	
cf. *Ircinia novaezealandiae*	Grey encrusting sponge	0.3	0.3	0.7			0.7				1			1			
cf. *Polymastia massalis*	Brown massive sponge	0.7		0.3		0.7		0.7	1.0			2		1	1	2	4
cf. *Aaptos globosa*	Globose sponge	1.0	0.3	0.7		3.3	1.0	4.0	0.3					1			3
cf. *Callyspongia ramosa*	Cream branching sponge							0.3	3.0								3
Orange honeycomb sponge	Orange honeycomb sponge								1.3			3		1	1	1	

	Survey	Baseline mean								December 2021							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
cf. *Dendrilla rosea*	Pink erect conulose		0.3	0.3		0.3				2	2					1	
Callyspongia cf. *annulata*	Mauve finger sponge				0.3				2.0	1		1	1	3	3	4	4
cf. Suberites perfectus	Grey smooth sponge	0.3	0.7	0.7	1.0		1.0		1.0	4	1	5	2	3	4	3	4
Orange lobed sponge	Orange lobed sponge				0.3								1	1	1		1
cf. *Iophon minor*	Yellow finger sponge				0.3			2.0									
Sponge cream encr.																	
Bryozoa	**Bryozoans**																
Bryozoan Catenicellidae	Clowns hair bryozoan	14.0	10.0	5.3	16.0	7.7	4.0	3.3	2.7	5		4	13	6	8	7	3
cf. *Cellaria tenuirostris*	Branching bryozoan	8.0	1.0	8.3	9.0	5.0	2.3	7.3	0.7	21	2	11	7	12	9	8	6
cf. *Caberea zelandica*	Erect fan bryozoan		0.3	0.3	1.3	2.0	1.3	1.0	0.3	2			4	3	1	1	
cf. *Steginoporella* sp.	Orange tube bryozoan	11.7		7.7	7.7	11.3	6.0	6.0	10.0	19	2	16	17	22	20	15	19
Encrusting bryozoan	Encrusting bryozoan	7.7		0.3	0.7			5.7	0.7	3		8		4	2	3	6
cf. *Margaretta barbata*	Erect bryozoan	0.3	1.7	0.3					0.3	13	5						
Cnidaria	**Hydroids, anemones, corals**																
cf. *Aglaophenia* spp.	Feather hydroid	1.0	4.7	1.3	8.3	1.3	3.0	8.3	13.7	6	6	9	17	13	25	15	22
Solanderia ericopsis	Hydroid tree	0.7		1.3	0.3	0.3	1.0		0.7	1	1	1	2		1		1
Amphisbetia bispinosa	Mussel beard hydroid	0.7	1.3	1.3	5.0	5.7	1.0	0.7				5	4	7	4	4	
Branching hydroid	Branching / bushy hydroid	6.3		3.3	1.0	10.0	1.7	5.7	4.3	11		9	14	20	8	17	20
Ectopleura sp.	Solitary hydroid						0.3		0.3			1		2	1	1	1
cf. Bougainvillidae	Encrusting hydroid			0.7		0.3											
Anthothoe albocincta	White-striped anemone	1.0	4.7			0.3	0.3	13.7	16.3	1	3			4	2	24	26
Solitary anemone Undescr.	Solitary anemone	1.3					0.3	2.3		2			2	2	1	2	3
Alcyonium cf. *aurantiacum*	Common soft coral			0.3		2.7	0.3	3.3	4.0			1		1			6
Culicea rubeola	Colonial stony coral	2.7	2.3	1.3	3.7	4.3	0.7	1.0	0.7	2	6	3		1	1	1	2

	Survey	Baseline mean								December 2021							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Monomyces rubrum	Cup coral (solitary)								0.3								
Corynactis australis	Jewel anemone		0.3			0.3					1	1		1	2	1	1
cf. *Parazoanthus elongatus*	Orange zoanthid			0.3		0.7							1	1			1
Fine hydroid	Fine hydroid	1.0	2.3	5.0	1.0	1.0	0.7	1.0	3.0	4			2		1		2
cf. Epizoanthus sp.	White zoanthid									1		1					2
Ascidiacea	**Tunicates, sea squirts**																
Pyura spinosissima	Sea tulip	0.7	0.7				1.0	1.7	3.0		1					3	2
Cnemidocarpa sp.	Saddle squirt	3.3	5.3	3.7	9.7	6.0	7.0	7.7	10.7	4	14	15		7	12	8	11
Ascidiacea sp. A	Small red ascidian		1.7	0.7		5.7	1.0	8.0	7.7	4		7	3	19	27	22	20
cf. *Synoicum otagoensis*	Grey colonial ascidian	1.3		4.3	1.7	6.0	2.0	13.7	13.0	7		12	3	12	10	15	17
Eudistoma sp.	White colonial ascidian	1.3	1.7	1.0	0.3	5.3	2.7	11.3	11.7			2		7	3	6	7
cf. *Didemnum densum*	Cream colonial ascidian		0.3	0.7	0.3		3.3	4.0	4.0			2		2	5	1	1
Didemnum species complex	White didemnum		1.0		2.0	4.7	6.7	3.0	6.7	1	6	7		5	1	4	6
cf. *Pseudodistoma cereum*	White colonial ascidian					0.3	0.3	1.0									
Bivalvia	**Clams**																
Perna canaliculus	Green-lipped mussel	6.7	16.7	3.0	7.7	15.0	5.3	6.0	0.3	6	22	6	7	12	5	6	
Atrina zelandica	Horse mussel			1.0					0.7								
Ostreidae sp.	Flat oyster	0.7		1.3	0.7		0.7	1.7	1.3	2		1				1	
Bivalve (attached unid)	Attached bivalve	2.3	0.3	0.3				0.3									
Polyplacophora	**Chitons**																
Cryptoconchus porosus	Butterfly chiton				0.7	0.3	0.3			2							
Gastropoda	**Snails, sea slugs**																
Trochus viridis	Green top shell	1.0	6.0		0.7	0.7	0.7	0.7	1.0	4	3		3	4	5	3	2
Calliostoma tigris	Tiger top shell	0.7			1.3	1.0		1.0		2		3	2	2	1	2	7

	Survey	Baseline mean								December 2021							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Calliostoma pellucida	Top shell			0.3	0.3		0.3		0.3				3	1	2	2	1
Calliostoma punctulatum	Beaded top shell				0.3	0.3		1.0	1.0		2	1		3	1		
Cookia sulcata	Cook's turban shell	2.0	4.3		0.3					3	20		1				
Astraea heliotropium	Circular saw shell		0.7		0.7					1							
Argobuccinum pustulosum	Swollen trumpet shell				0.3	0.7	0.7				1	1		4			1
Dicathais orbita	White rock shell	0.7	4.0		0.7					1	11						
Buccinulum linea	Lined whelk	0.7	1.3	0.3		1.0		0.7	1.3	1	1				2	1	3
Penion sulcatus	Siphon whelk	3.0	1.3	1.3	4.0	3.3	3.7	3.0	2.0	1	1	3	1	10	7	5	2
Cominella adspersa	Speckled whelk	0.3								1							
Whelk (Muricidae unid)	Unid. whelk	0.3	0.3							2	2	2	2			1	1
Cabestana spengleri	Spengler's trumpet shell		0.7														
Ceratosoma amoenum	Clown nudibranch	3.3	1.7	5.3	3.7	5.3	4.0	3.0	4.3	2	3	4	1	5	2	1	
Mayena australasia	Australasian triton								0.3	1		1				1	
Dendrodoris denisoni	Nudibranch																
Cantharidus sp.	Opal top shell																
Scutus breviculus	Shield slug																
Cephalopoda	**Octopus, squid**																
Octopus maorum	Octopus, squid	0.3				0.3								1			
Crustacea	**Crabs, lobster, barnacles**																
Jasus edwardsii	Crayfish		0.7					0.7	2.0		2	1		4	2		7
Paguridae	Hermit crab	2.7	0.3	2.7	2.3	4.0	1.7	2.0	3.3	4	4	3	8	6	5	3	6
Guinusia chabrus	Red rock crab				0.3			0.3	1.0	1	1		3	2	1	1	4
Barnacle unid.	Barnacle		1.0		0.3			0.3			3						
Notomithrax minor	Decorator crab																

	Survey	Baseline mean								December 2021							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Echinodermata	**Sea cucumbers, sea stars, urchins**																
Australostichopus mollis	Sea cucumber	3.3	2.3		1.3	3.7	0.3	8.0	2.3	8	2	4	7	11	9	8	9
Patiriella regularis	Cushion star							0.3									
Pentagonaster pulchellus	Biscuit star																
Astrostole scabra	7-armed sea star		0.3		0.3	0.3		0.3	1.3		1		1			1	6
Coscinasterias muricata	11-armed sea star		0.3		0.3	0.3		0.7									
Ophiopsammus sp.	Snake star	0.3		0.3						1							
Evechinus chloroticus	Kina		2.7			1.0				3	6		1			1	

Appendix 3. Transect abundance scores for fish species from the baseline surveys (mean AS values) and the current survey. Generated according to the categorisations in Table 1.

Table A4.1 Abundance scores (AS) for fish. Listed in decreasing order of baseline abundance. 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). Taxa in yellow cells are those newly identified in the current (December 2021) survey. Transects in north to south order.

		Survey			Baseline mean					December 2021							
Species	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Caesioperca lepidoptera	Butterfly perch	9.3	6.7	6.0	23.3	14.3	2.3	4.7	7.3	12	9	8	29	24	20	24	10
Parapercis colias	Blue cod	6.7	2.7	3.3	4.0	3.7	2.7	9.3	7.3	12	4	11	7	11	14	9	5
Pseudolabrus miles	Scarlet wrasse	2.7	6.7	1.3	7.3	5.7	2.3	3.3	1.0	7	8	6	7	1	13	5	3
Notolabrus celidotus	Spotted wrasse	2.3	5.3	1.0	4.3	3.7	1.3	2.0	3.7	1	4	1		1	3	6	5
Forsterygion varium	Variable triplefin	2.0	5.7	0.3	5.7	3.0	1.0	3.3	2.0	2	7		3	1	2	3	5
Scorpis lineolatus	Sweep	2.0	2.7	2.0	10.7	3.0	1.0	0.7	0.3		9		4	6		3	
Scorpaena papillosa	Dwarf scorpion fish	2.7	2.3	2.0	1.7	1.7	1.3	2.0	0.3	4	6	4	1	5	6	4	7
Parika scaber	Leather jacket	5.7	3.3	0.3	2.3	0.7	0.3	0.7		3	4		3		1		
Cheilodactylus spectabilis	Red moki	0.3	1.0	1.0	3.3	2.0	0.3	0.3		2	6	1	7	3	2	2	4
Notolabrus fucicola	Banded wrasse	0.3	1.3		1.0	2.3	0.3	1.0	0.3	2	12	4	4		6	2	
Nemadactylus macropterus	Tarakihi	0.3			1.0	2.0	1.0		1.0		2	3	1	2	1	1	1
Trachurus sp.	Mackerel		1.0			3.0											
Hypoplectrodes huntii	Banded perch	1.0	0.3		0.3	1.3		0.3		2	2	1	2	2	2		2
Forsterygion malcolmi	Banded triplefin	0.3	0.3			0.7	0.7	0.3		3	2	4	5	4	5	5	4
Forsterygion lapillum	Common triplefin	0.3	0.3	1.0		0.3			0.3								
Ruanoho whero	Spectacled triplefin	0.3			0.7	0.7			0.3	1	1	2	1	2	2	1	
Latridopsis ciliaris	Blue moki		0.7		0.3				0.3							1	3
Odax pullus	Butterfish/Green bone	0.3	0.7								2					1	

	Survey	Baseline mean								December 2021							
Species	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Chironemus marmoratus	Kelpfish/Hiwihiwi		0.3		0.3								2				
Aplodactylus arctidens	Marble fish	0.3			0.3						3		2	1		1	1
Forsterygion maryannae	Oblique triplefin				0.7												
Pagrus auratus	Snapper		0.3		0.3						3						
Forsterygion flavonigrum	Yellow-black triplefin	0.3								1							
Notoclinops segmentatus	Blue-eyed triplefin		0.3														
Upeneichthys lineatus	Goat fish							0.3									
Myliobatis tenuicaudatus	Eagle ray						0.3										
Hippocampus abdominalis	Sea horse																
Conger verreauxi	Conger eel																2
Pseudocaranx dentex	Trevally																
Karalepis stewarti	Scaly-headed triplefin																
Ruanoho decemdigitatus	Long finned triplefin																
Pseudophycis bachus	Red cod												2		1	1	1
Paristiopterus labiosus	Giant boarfish												2				

Appendix 4. Occurrence of taxa on Town Reef transects for the three surveys conducted to date, including the pre-dredging 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. Note that, due to poor conditions, only TR1 was surveyed in October 2020.

Taxon	Common name / description	TR1			TR2		TR3	
	Survey year	2019	2020	2021	2019	2021	2019	2021
Phaeophyceae	**Brown algae**							
Ecklonia radiata	Kelp	Y	Y	Y	Y	Y	Y	
Dictyota sp.			Y	Y		Y		Y
Microzonia velutina			Y	Y				
Rhodophyta	**Red algae**							
Coralline algae	Coralline paint	Y	Y	Y	Y	Y	Y	Y
Plocamium cirrhosum		Y	Y	Y	Y	Y	Y	Y
Rhodymenia sp. A	Small red blade algae	Y	Y	Y	Y	Y	Y	Y
Rhodymenia sp. B	Red algae foliose	Y	Y		Y	Y	Y	
cf. *Hildenbrandia*	Red encrusting algae	Y	Y	Y	Y	Y	Y	
Fine red alga	Fine red alga			Y				
Chlorophyta	**Green algae**							
Fine green alga	Fine green alga					Y		
Turfing green alga	Turfing green alga		Y					
Porifera	**Sponges**							
Ecionemia alata	Grey vase sponge	Y	Y	Y	Y	Y	Y	Y
Cliona cf. *celata*	Yellow boring sponge	Y	Y	Y	Y	Y	Y	Y
Emergent red/orange sponge			Y	Y	Y	Y		Y
cf. *Tedania* sp.	Orange encrusting sponge	Y	Y	Y	Y	Y	Y	Y
cf. *Hymeniacidon* sp.	Orange massive sponge				Y	Y	Y	Y
Tethya bergquistae	Pink golfball sponge	Y	Y	Y	Y	Y	Y	Y
Tethya burtoni	Orange golfball sponge	Y	Y	Y	Y	Y	Y	Y
Ciocalypta sp.	Yellow tubular sponge	Y	Y	Y	Y	Y	Y	Y
cf. *Thorecta* sp.	Lobed grey sponge					Y	Y	
Raspalia topsenti	Orange finger sponge				Y	Y	Y	Y
White/green Demospongia A	White/green massive sponge		Y					
Pink Demospongia C	Pink thick encrusting sponge	Y	Y		Y	Y		Y
Lilac Demospongia D	Lilac spiky sponge	Y	Y		Y	Y	Y	Y
Yellow Demospongia E	Yellow breadcrumb sponge			Y				
Maroon Demospongia F	Maroon massive sponge		Y					
Latrunculia cf. *procumbens*	Green mushroom-like sponge				Y			
cf. *Ircinia novaezealandiae*	Grey encrusting sponge	Y	Y			Y		
cf. *Suberites perfectus*	Smooth grey sponge	Y	Y			Y	Y	Y
cf. *Polymastia massalis*	Brown massive sponge			Y				
cf. *Aaptos globosa*	Globose sponge	Y	Y		Y	Y	Y	Y
cf. *Callyspongia ramosa*	Cream branching sponge				Y	Y	Y	Y
cf. *Iophon minor*	Yellow finger sponge							Y
Pale orange massive	Pale orange massive sponge				Y		Y	

Taxon	Common name / description	TR1			TR2		TR3	
	Survey year	2019	2020	2021	2019	2021	2019	2021
Callyspongia cf. *annulata*	Mauve lobed/finger sponge							Y
Bryozoa	**Bryozoans**							
Bryozoan Catenicellidae	Clowns hair/moss bryozoan	Y	Y		Y		Y	Y
cf. *Steginoporella*	Orange finger bryozoan				Y	Y	Y	Y
cf. *Parasmittina delicatula*	Encrusting bryozoan	Y	Y	Y	Y			
Cnidaria	**Hydroids, anemones, corals**							
cf. *Aglaophenia* spp.	Feather hydroid	Y	Y	Y	Y	Y	Y	Y
Solanderia ericopsis	Hydroid tree							Y
Amphisbetia bispinosa	Mussel beard hydroid	Y		Y			Y	Y
Branching / bushy hydroid	Bushy hydroid					Y	Y	Y
Ectopleura sp.	Solitary hydroid					Y	Y	
Anthothoe albocincta	White-striped anemone						Y	Y
Solitary anemone Undescr.						Y		
Alcyonium cf. *aurantiacum*	Common soft coral				Y	Y		Y
Culicea rubeola	Colonial stony coral	Y			Y			
Corynactis australis	Jewel anemone	Y	Y	Y	Y	Y	Y	Y
Fine hydroid (on *Ecklonia*)		Y		Y	Y	Y	Y	
Cnidarian small green	Cnidarian small green	Y			Y		Y	
Oulactis mucosa	Sand anemone							Y
Polychaeta	**Polychaete worms**							
Serpulidae	Calcareous tube worm	Y						
Ascidiacea	**Tunicates, sea squirts**							
Pyura spinosissima	Sea tulip	Y	Y	Y		Y	Y	Y
Cnemidocarpa sp.	Saddle squirt	Y	Y	Y	Y	Y	Y	Y
Ascidiacea sp. A	Small red-mouthed ascidian	Y	Y	Y	Y	Y	Y	Y
cf. *Synoicum otagoensis*	Grey colonial ascidian	Y	Y	Y	Y	Y	Y	Y
Eudistoma sp.	White colonial ascidian	Y	Y	Y	Y	Y	Y	Y
Didemnum sp. (cream)	Cream colonial ascidian	Y	Y		Y		Y	Y
Didemnum sp. (white)	White colonial ascidian	Y	Y	Y	Y	Y	Y	Y
Bivalvia	**Clams**							
Perna canaliculus	Green-lipped mussel	Y		Y		Y	Y	Y
Ostreidae sp.	Flat oyster	Y						
Gastropoda	**Snails, sea slugs**							
Trochus viridis	Green top shell	Y	Y	Y	Y	Y	Y	Y
Calliostoma punctulatum	Beaded top shell			Y	Y			
Cookia sulcata	Cook's turban shell	Y	Y	Y	Y	Y		
Buccinulum linea	Lined whelk	Y	Y		Y	Y		Y
Penion sulcatus	Siphon whelk			Y				
Xymene sp.	Whelk	Y	Y	Y		Y	Y	Y
Cabestana spengleri	Spengler's trumpet shell	Y	Y			Y	Y	Y
Maoricolpus roseus	Turret shell		Y	Y	Y		Y	Y
Whelk unid	Unidentified small whelk	Y	Y		Y		Y	Y
Ceratosoma amoenum	Clown nudibranch	Y	Y		Y		Y	

Taxon	Common name / description	TR1			TR2		TR3	
	Survey year	2019	2020	2021	2019	2021	2019	2021
Mayena australasia	Australasian trumpet							Y
Nudibranch (unid)	White nudibranch				Y			
Cephalopoda	**Octopus, squid**							
Octopus maorum	Octopus	Y						Y
Crustacea	**Crabs, lobster, barnacles**							
Jasus edwardsii	Crayfish	Y		Y	Y	Y	Y	Y
Pagurus sp.	Hermit crab		Y	Y	Y	Y		Y
Guinusia chabrus	Red rock crab			Y		Y		Y
Echinodermata	**Sea cucumbers, sea stars, urchins**							
Australostichopus mollis	Sea cucumber			Y	Y	Y	Y	Y
Patiriella regularis	Cushion star	Y		Y			Y	Y
Pentagonaster pulchellus	Biscuit star	Y	Y	Y	Y	Y	Y	Y
Astrostole scabra	7-armed seastar	Y	Y	Y	Y	Y	Y	Y
Coscinasterias muricata	11-armed seastar	Y				Y		
Evechinus chloroticus	Kina	Y	Y	Y	Y	Y		Y
Stichaster australis	Reef star		Y	Y				
Osteichthyes	**Fish**							
Caesioperca lepidoptera	Butterfly perch					Y		
Cheilodactylus spectabilis	Red moki	Y		Y		Y		Y
Notolabrus celidotus	Spotted wrasse	Y		Y	Y	Y	Y	Y
Nemadactylus macropterus	Tarakihi			Y				Y
Parapercis colias	Blue cod	Y	Y	Y	Y	Y		Y
Scorpis lineolatus	Sweep					Y		
Scorpaena papillosa	Dwarf scorpion fish			Y		Y		Y
Notolabrus fucicola	Banded wrasse	Y	Y	Y	Y	Y		y
Pseudolabrus miles	Scarlet wrasse	Y		Y		Y		Y
Odax pullus	Butterfish/Green bone	Y						
Chironemus marmoratus	Kelpfish/Hiwihiwi	Y		Y				Y
Latridopsis ciliaris	Blue moki					Y		
Aplodactylus arctidens	Marble fish	Y	Y	Y		Y		Y
Hypoplectrodes huntii	Banded perch							Y
Forsterygion varium	Variable triplefin	Y	Y	Y	Y	Y	Y	Y
Forsterygion lapillum	Common triplefin			Y			Y	Y
Ruanoho whero	Spectacled triplefin	Y			Y	Y		Y
Forsterygion malcolmi	Banded triplefin			Y		Y		Y
Notoclinops segmentatus	Blue-eyed triplefin			Y				
Myliobatis tenuicaudatus	Eagle ray							Y