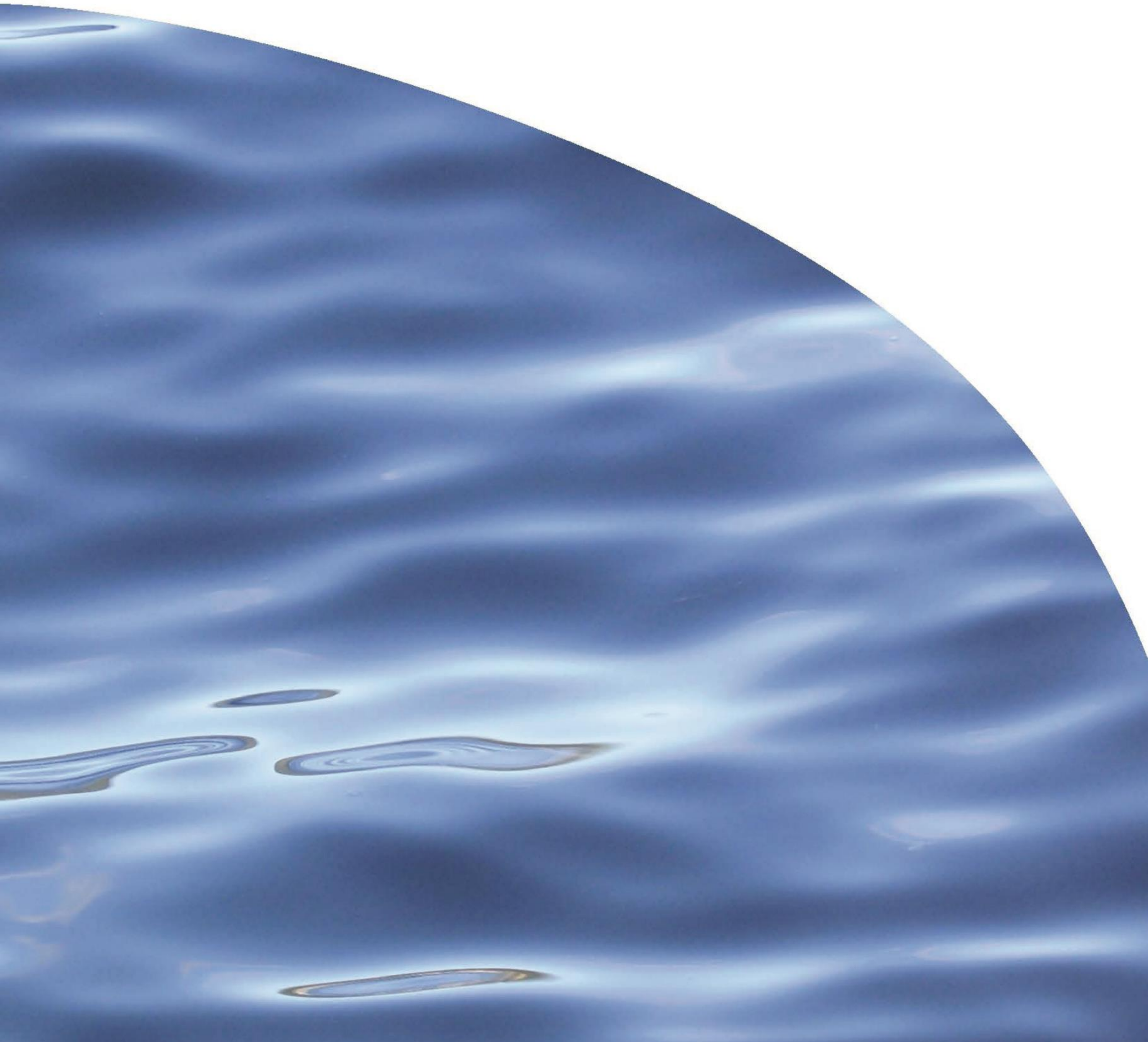
REPORT NO. 3648

ECOLOGICAL TRANSECT SURVEY OF PANIA REEF: MAY 2021



ECOLOGICAL TRANSECT SURVEY OF PANIA REEF: MAY 2021

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EXECUTIVE SUMMARY

Port of Napier Limited (PONL) is deepening its existing approach channel to accept deeper draft vessels and establishing a new berth (No.6 berth) on the northern face of the main Port reclamation. As part of the resource consents covering capital dredging and spoil disposal, PONL is required to complete a series of ecological dive surveys of Pania Reef.

This report covers the second survey conducted during the dredging phase of the project, and follows a survey completed in October 2020. The three baseline surveys of Pania Reef were conducted in April 2016, May 2019 and February 2020. Capital dredging for the project commenced in June 2020 and was ongoing when the current survey was conducted in May 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 of each transect. The relative abundance data from diver transcripts was augmented with a review of the photographic record and compiled to generate abundance scores for each taxon on each transect, and these were compared to the baseline data to evaluate changes that have occurred in Reef communities. Changes were interpreted in the context of baseline variability, survey conditions, and transect depth profiles and substrates. Additionally, multivariate statistical analysis of the combined abundance data for all surveys was performed.

Diver observations and the photographic and video record indicated that the physical characteristics of the Reef, including the prevalence of sand and silt substrates, had not changed from the baseline. Although the data indicated changes in the abundance of some reef taxa, the pattern of these changes across surveys generally did not implicate effects from the capital dredging project. Allowing for the effects of improvements in survey methodology across surveys (in particular, the collection of a more comprehensive photographic record), little change was observed in populations of taxa considered characteristic of the Reef, including important habitat-forming species and fish. Statistical analysis showed that temporal variability in community structure (across surveys) has remained generally lower than spatial variability (across transects) and suggested no consistent shift in community composition has occurred since the baseline.

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GLOSSARY

Item	Description / meaning	Category
∆AS	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	Unit
g	Grams	Unit
GPS	Global Positioning System	Acronym
ha	Hectare	Unit
HOA	Heads of Agreement	Acronym
km	Kilometre	Unit
LoS	Level of similarity	
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 Reef survey.

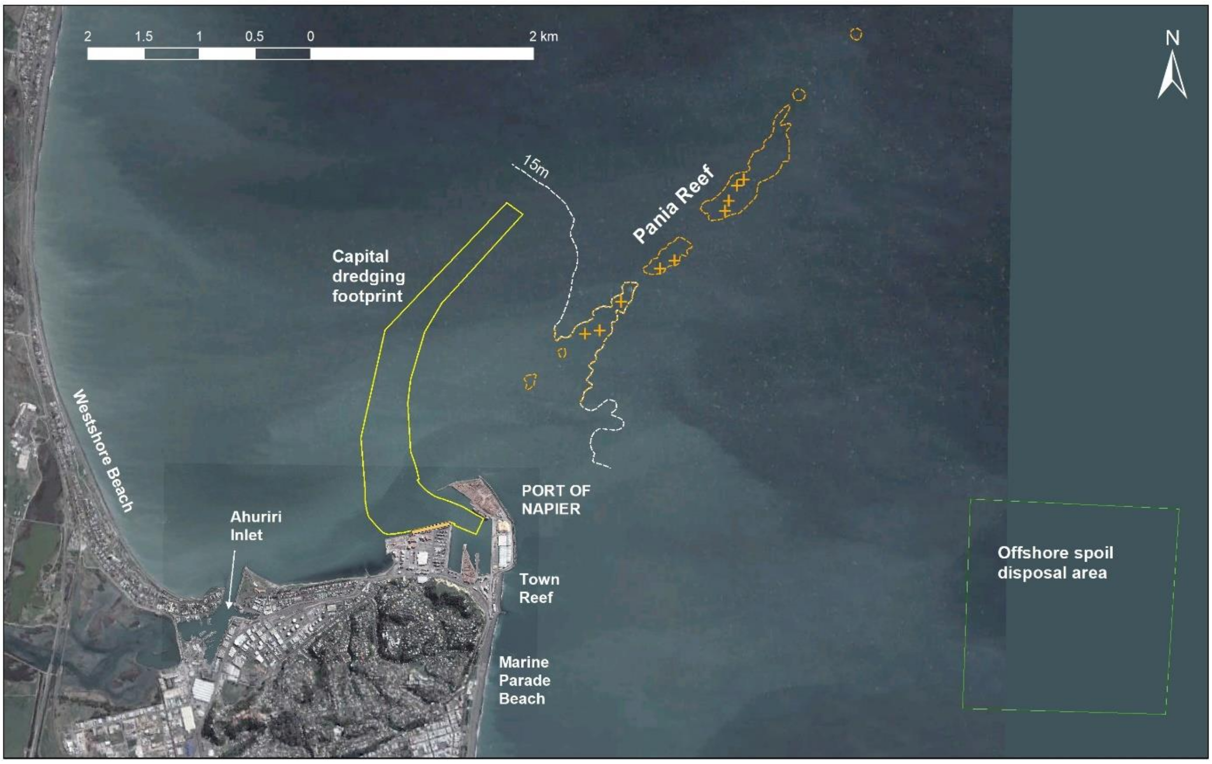

Figure 1. Composite aerial photograph of Port of Napier, showing the scale and layout of the proposed project elements.

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).

1.2. Scope

This report covers ecological survey work undertaken to meet the requirements of condition 11(f) of resource consent CL180009E. The report describes and interprets the findings of the second 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 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 survey of Pania Reef was undertaken over 9–10 May 2021 by four Cawthron Institute scientific divers working from the 6.5 m work boat *Rampant*. The survey comprised eight 100 m-long dive transects spaced out along the length of the reef (PR1–PR8: Figure 2).

The weighted 100-m transect line was tagged at 10-m intervals along its length. The transects were set up by dropping the weighted end of the transect line at the established start waypoint (generally a point on or near the reef crest) and running the remaining length of line out towards the finish waypoint until taut, from where the deeper end was lowered on a second weighted shot line. All transect lines were laid according to pre-established GPS waypoints and compass bearings.

The locations of the transects were identical to those used in the three 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).

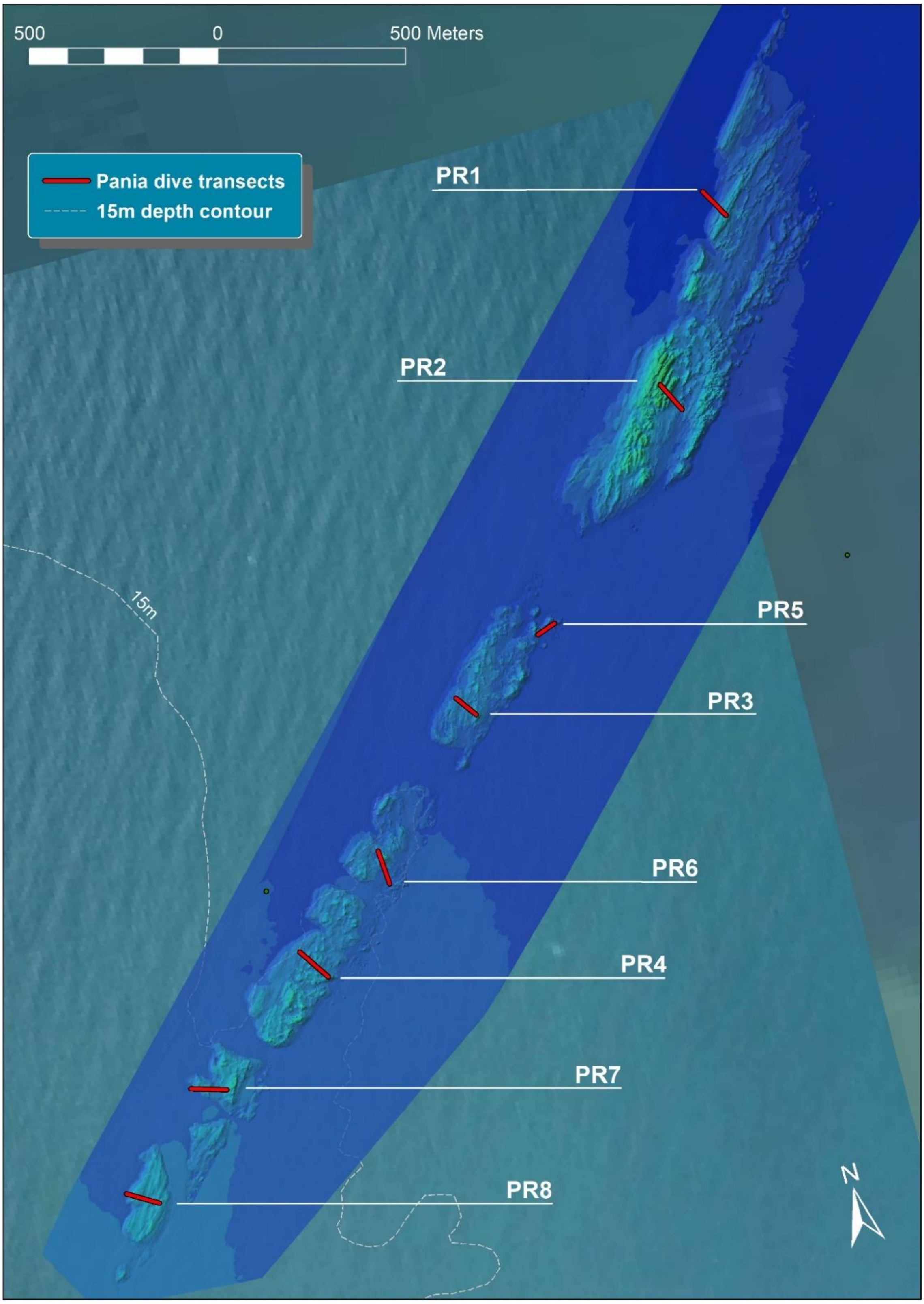

Figure 2. Multi-beam Echo-Sounder (MBES) image of Pania Reef showing locations of survey transects.

2.2. 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.

At each of the 10-m interval marks along the transect, five 41 cm x 61 cm (0.25 m^2) rectangular photoquadrats were taken using a 10-megapixel digital camera attached at a fixed distance from a quadrat frame. One was taken at the transect line distance tag, while the remaining four were taken within the four compass sectors around it at a radial distance of approximately one metre. Between each of the 10-m distance tags, video footage was collected using a GoPro Hero camera. 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.

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.

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

2.2.1. 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 phyla 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).

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.

2.2.2. Post-fieldwork review and data augmentation

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

- Divers are significantly time-constrained during the surveys, working against both dive table (blood nitrogen) and air capacity limits. They are also often working in conditions of limited underwater visibility and sometimes moderate surge. Under these conditions, some 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 to the diver transcript are flagged accordingly.

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

2.3. Data analysis

To analyse the compiled relative abundance data for each transect, the categories were converted to numerical values according to the assigned rank values listed in Table 1. Summations of these values across the ten 10-m intervals for each transect gave an abundance score (AS) for each taxon 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 the 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, 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 carefully consider 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 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.

3. SURVEY RESULTS

3.1. Survey conditions and photographic record

Underwater visibility during the current (May 2021) survey was largely superior to that encountered in previous surveys. However, the quadrat photographs were still frequently affected by suspended particulate matter between the lens and the subject that obscured some detail. This was exacerbated by particulate-reflected light from the strobes, despite their physical offset from the camera. Hence, while the quadrat photographs are useful to benchmark both physical and biological habitat characteristics, they were mostly of limited use for identification of any but the most conspicuous organisms. Nonetheless, as with previous surveys, use of hand-held compact cameras by divers enabled the collection of a set of clear images at close range.

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 to give an overview. Summary data from the current 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 is lower than that recorded over all three baseline records, and the difference from the mean baseline AS is greater than three (ΔAS > 3).
- Taxa more prevalent in the current survey than during the baseline are listed if AS exceeds 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, generated from diver-recorded depths at each of the 11 transect distance tags and adjusted for tidal variation (to mean sea level—MSL). The profile is compared in each figure with those recorded during the three baseline surveys. In places, the Reef has very uneven bathymetry over small spatial scales and exact transect line placement along its entire length is impossible. Therefore, the comparison serves as a check on transect consistency between the surveys and assists with interpretation of the ecological data where locally significant differences in profile may have occurred.

The depth profile for the transect was generated by fitting the water depths at the 10-m transect nodes to a spline curve. A series of eight photographs (generally a mix of quadrat and compact camera close-ups), was selected as representative of substrate, habitats and biota, and these are shown located along each transect profile. 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 3).

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.

PR1	Baseline surveys 2016–2020	May 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, in reviewing video footage, the soft substrate featured in the first 50 m of the transect appeared finer and siltier than during the baseline and October 2020 surveys.
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 corallines (Corallinales) were also common above 14 m. *Carpomitra costata* was recorded occasionally in the shallower sections. In Feb 2020, a grass-like green alga (noted previously from other transects) was common on sloping sections in depths shallower than 15 m and a newly recorded fine tufted red alga was also common in the last 50 m of the transect.	7 taxa recorded. All algal species that were recorded consistently across the three baseline surveys were present. The prevalence of both *E. radiata* (AS 18) and *P. cirrhosum* (AS 15) was unaltered from the baseline. Two previously recorded algal taxa were absent: • Red fine tufted alga – had only previously been recorded in February (AS 15) and October (AS 2) 2020. • Green grass-like alga - had only previously been recorded in February 2020 (AS 11) and October 2020 (AS 13). The small-bladed red alga (AS 1) was previously most prevalent in October 2020 (AS 12) but was unrecorded before the last baseline survey (Feb 2020; AS 5). Red encrusting alga (cf. *Hildenbrandia* sp. AS 1) was newly recorded in PR1. Two algal taxa had increased in prevalence: AS M21 / AS Baseline • Encrusting coralline: 19 / 14.0 • The brown alga *Halopteris* sp.: 8 / 1.3

<table>
<tr><th>PR1</th><th>Baseline surveys 2016–2020</th><th>May 2021</th></tr>
<tr><td>INVERTEBRATE COMMUNITIES</td>
<td>
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 amoena), the siphon whelk (P. sulcatus) and C. rubiola as well as several sponge species.
As the profile becomes shallower (< 15 m depth), large patches of green-lipped mussels (Perna canaliculus), along with gastropods such as the green top shell (Trochus viridus), tiger top shell (Calliostoma tigris) and Cook's turban (Cookia sulcata) were also present amongst the kelp. Varied sponge communities remained present in the troughs and under the overhangs.
The most notably variable taxa across the baseline surveys have been the fine branching hydroid (absent in 2019) and most of the bryozoans.
</td>
<td>
48 taxa recorded.
Five taxa previously recorded from more than a single instance at PR1 were absent. None had been recorded consistently across the three baseline surveys.
No taxa were recorded as less prevalent than in all three of the baseline surveys.
Branching hydroids (AS 3) had decreased relative to the mean baseline (AS 6.3) but had been absent from the May 2019 baseline survey.
4 taxa were newly recorded at PR1. However, those exceeding AS 3 were limited to:
Ascidian Ascidiacea sp. A (AS 4)
<table>
<tr><th>Taxa in greater prevalence (ΔAS > 3) than during the baseline:</th><th>AS M21</th><th>AS Baseline</th></tr>
<tr><td>• Bryozoan Steginoporella neozelanica</td><td>27</td><td>11.7</td></tr>
<tr><td>• Bryozoan cf. Cellaria tenuirostris</td><td>26</td><td>8.0</td></tr>
<tr><td>• Bryozoan Catenicellidae</td><td>19</td><td>14.0</td></tr>
<tr><td>• Sponge Cliona cf. celata</td><td>18</td><td>5.3</td></tr>
<tr><td>• Encrusting bryozoan</td><td>18</td><td>7.7</td></tr>
<tr><td>• Bryozoan cf. Margaretta barbata</td><td>11</td><td>0.3</td></tr>
<tr><td>• Ascidian cf. Cnemidocarpa sp.</td><td>7</td><td>3.3</td></tr>
<tr><td>• Holothurian Australostichopus mollis</td><td>7</td><td>3.3</td></tr>
<tr><td>• Lilac sponge Desmospongia D</td><td>5</td><td>1.3</td></tr>
<tr><td>• Colonial ascidian cf. Synoicum otagoensis</td><td>5</td><td>1.3</td></tr>
<tr><td>• Sponge cf. Suberites perfectus</td><td>4</td><td>0.3</td></tr>
<tr><td>• Gastropod Muracidae unid.</td><td>4</td><td>0.3</td></tr>
</table>
</td></tr>
</table>

PR1	Baseline surveys 2016–2020	May 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.	9 species recorded. Fish abundances were generally high compared to the baseline, no doubt helped by favourable underwater visibility. As in the October 2020 survey, spotted wrasse were absent, having been present in all three baseline surveys. No other species recorded a decrease in abundance score greater than three. Species more prevalent than the mean baseline (∆AS >3) were: — AS M21 / AS Baseline • Butterfly perch — 15 / 9.3 • Dwarf scorpion fish — 7 / 2.7

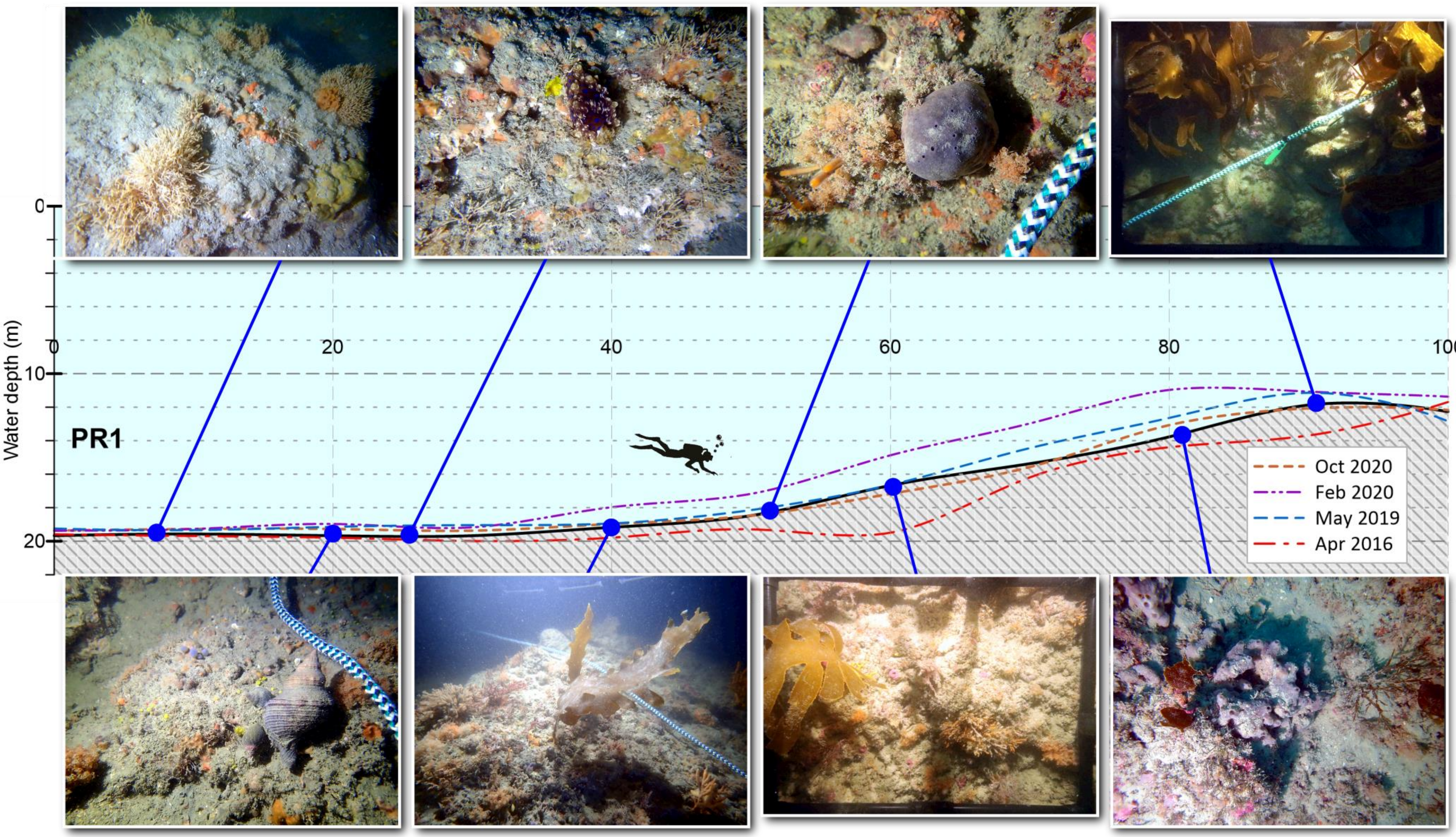

Figure 3. Depth profile with photographs of representative habitat and biota along transect PR1 in May 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during 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 4).

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	May 2021
SUBSTRATE	The substrate along the first 10 m of the transect is comprised of bedrock covered in extensive sand patches and can exhibit a fine layer of silt. Thereafter, rock outcrops become more common and there is a mix of cobble, boulder, bedrock and sand with conspicuous scattered shell in places. Scattered boulder / cobble material continues until the 50–60 m marks. At 50–60 m, the reef profile becomes steeper and very uneven; featuring ridges and rock ledges with deep guts between. There are associated crevices and overlying sediment is much less a feature. The transect ends on top of Pania Rock, the shallowest point on the reef. In the shallowest sections, the surge effectively keeps reef surfaces free of fine settled silt. The presence of silt veneers in the deeper first sections has been variable across baseline surveys.	The progression of substrate along the transect was consistent with the baseline observations. No evidence of silt veneers. Moderate surge in shallower sections at end. Mussel shell hash was a feature of deep guts between rock ridges towards the end of the transect.
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 end of the transect.	10 taxa recorded. All algal species recorded consistently across the three baseline surveys were present. The prevalence of both *E. radiata* (AS 39) and *C. maschalocarpum* (AS 16) was unaltered from the baseline. One previously common algal taxon was absent: • small-bladed red alga – was previously most prevalent in February (AS 9) and October 2020 (AS 14) but had not been recorded in the first survey of the baseline (April 2016). One other algal taxon had decreased in prevalence: • *C. costata* (AS 6 vs baseline 11.7). There were no newly recorded algal taxa.

PR2	Baseline surveys 2016–2020	May 2021
	Little variability in the prevalence of the key algal species has been observed across surveys.	Three algal taxa had increased in prevalence: (AS M21 / AS Baseline) • Encrusting corallines — 40 / 36.0 • The brown alga *Halopteris* sp. — 17 / 11.3 • *P. cirrhosum* — 18 / 13.3
INVERTEBRATE COMMUNITIES	28–34 taxa recorded across the baseline surveys. The variable substrate of the first half of the transect supports a range of invertebrate taxa in low abundances. These include sponges such as *Cliona* sp. (usually associated with coralline algae), vase sponge (*E. alata*), the emergent cf. *Ciocalypta* sp. (in sandier areas) and a grey massive sponge (Desmospongia). More variable is the presence of bryozoans such as *S. neozelanica*, cf. *Margaretta barbata*, cf. *Cellaria tenuirostris* and Catenicellidae. The occurrence of hydroids (e.g. feather hydroid [*Aglaophenia* sp.] and mussel beard [*Amphisbetia bispinosa*]) has also varied across surveys. Colonial ascidians have been less prevalent at PR2 than at other transects, although solitary ascidians (*Cnemdiocarpa* sp.) have been occasional. Conspicuous mobile fauna include gastropods (Cook's turban shell [*Cookia sulcata*], siphon whelk [*Penion sulcatus*], white rock shell [*Dicathais orbita*], lined whelk [*Buccinulum lineum*]). While never abundant, kina (*Evechinus chloroticus*) were more common at PR2 than on other transects. There is generally lower diversity on the surge-affected reef top (depths shallower than 10 m) with tightly packed beds of large *Perna canaliculus* predominating, along with sometimes dense *Carphophyllum maschalocarpum*.	39 taxa recorded. Sixteen taxa previously recorded from more than a single instance at PR2 were absent. Only two of these had been recorded consistently across all three baseline surveys. • Sponge *Raspailia topsenti* (mean baseline AS 2.7) • Sponge *Latrunculia* cf. *procumbens* (mean baseline AS 2.0) For the taxa recorded, a decrease in abundance score of more than 3 occurred for only one: • Anemone *Anthothoe albocincta* (AS 1 vs mean baseline 4.7) and this was less prevalent than during all three of the baseline surveys. Six taxa were newly recorded at PR2. However, those exceeding AS 3 were limited to: • Encrusting bryozoan (AS 8) Taxa in greater prevalence (∆AS > 3) than during the baseline: (AS M21 / AS Baseline) • Sponge *Cliona* cf. *celata* — 25 / 16.3 • Gastropod *Cookia sulcata* — 12 / 4.3 • Orange encrusting sponge cf.*Tedania* sp. — 11 / 3.7 • Orange golfball sponge *Tethya burtoni* — 5 / 1.3 • Bryozoan cf. *Margaretta barbata* — 5 / 1.7 • Sponge cf. *Stylopus australis* — 4 / 0.7 All of these were recorded as more prevalent than during any of the baseline surveys.

<table>
<tr><th>PR2</th><th>Baseline surveys 2016–2020</th><th>May 2021</th></tr>
<tr><td>FISH</td><td>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).</td><td>19 species recorded.

There were no species absent that had been consistently present across the baseline surveys.

No species recorded a decrease in abundance score greater than three.

Species more prevalent than the mean baseline (∆AS > 3) were:

<table>
<tr><th></th><th>AS M21</th><th>AS Baseline</th></tr>
<tr><td>• Blue cod</td><td>11</td><td>2.7</td></tr>
<tr><td>• Leather jacket</td><td>10</td><td>6.7</td></tr>
<tr><td>• Scarlet wrasse</td><td>10</td><td>6.7</td></tr>
<tr><td>• Butterfly perch</td><td>7</td><td>1.0</td></tr>
<tr><td>• Banded wrasse</td><td>6</td><td>1.3</td></tr>
<tr><td>• Blue-eyed triplefin Notoclinops segmentatus</td><td>4</td><td>0.3</td></tr>
</table></td></tr>
</table>

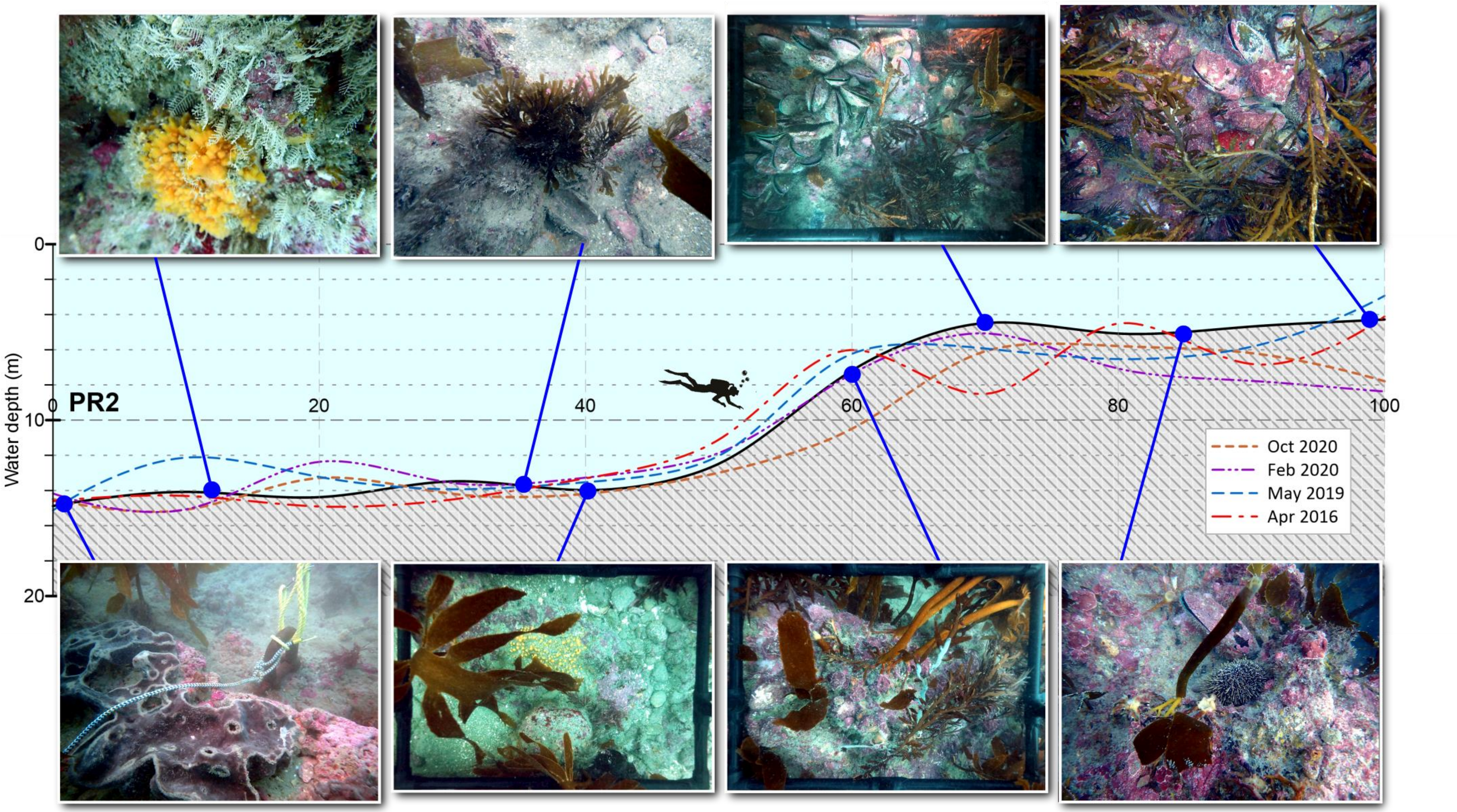

Figure 4. Depth profile with photographs of representative habitat and biota along transect PR2 in May 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during 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 5).

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	May 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. Rippled mobile sand in first 10 m and from 55-75 m. Notable embedded silt cover on hard substrates.
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.). Coraline algae was notably absent.	4 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). The brown alga *Dictyota* sp. was again absent after being recorded only in October 2020 (AS 6). Only one algal taxon had decreased in prevalence relative to the baseline; — AS M21 / AS Baseline • small-bladed red alga — 1 / 6.0 Encrusting corallines were newly recorded in PR5 but only from a single instance (AS 1). There were no other notable increases in prevalence.

<table>
<tr><th>PR5</th><th>Baseline surveys 2016–2020</th><th>May 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 (Desmospongia E) and golfball (*Tethya burtoni*) were also always present. The orange encrusting sponge (cf.*Tedania* sp.) also occurred.
Characteristic bryozoans included clowns hair, branching, (cf. *Cellaria tenuirostris*) and orange finger bryozoan (*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 amoena*), siphon whelks and hermit crabs were frequently present.</td><td>48 taxa recorded.
Only two taxa that were previously recorded from more than a single survey event were absent; however, neither had been recorded consistently across all three baseline surveys.
A decrease in abundance score (ΔAS > 3) occurred only for a fine hydroid recorded just from the February 2020 survey (AS 15), suggesting that its presence may be ephemeral.
Seven taxa were newly recorded at PR5. However, of these, only crayfish (*Jasus edwardsii*; AS 4) exceeded an abundance score of 3. An orange lobed sponge (AS 4) and a colonial ascidian (*Didemnum* species complex-white; AS 4) had previously been recorded at PR5 only in October 2020 (AS 3 and AS 2, respectively) but not during the baseline. However, the sponge had been recorded during the baseline from PR3 (AS 1; February 2020) and the ascidian from all other transects except PR1.
<table>
<tr><th>Taxa recorded in greater prevalence (ΔAS >3) than during the baseline:</th><th>AS M21</th><th>AS Baseline</th></tr>
<tr><td>• Bryozoan *Steginoporella neozelanica*</td><td>17</td><td>7.7</td></tr>
<tr><td>• Sponge *Raspailia topsenti*</td><td>14</td><td>9.7</td></tr>
<tr><td>• Branching hydroid</td><td>14</td><td>3.3</td></tr>
<tr><td>• Lilac sponge Desmospongia D</td><td>12</td><td>2.7</td></tr>
<tr><td>• Sponge *Cliona* cf. *celata*</td><td>9</td><td>0.7</td></tr>
<tr><td>• Yellow breadcrumb sponge Desmospongia E</td><td>9</td><td>4.0</td></tr>
<tr><td>• Small red ascidian Ascidiacea sp. A</td><td>9</td><td>0.7</td></tr>
<tr><td>• Colonial stony coral *Culicea rubiola*</td><td>8</td><td>1.3</td></tr>
<tr><td>• Gastropod *Penion sulcatus*</td><td>7</td><td>1.3</td></tr>
<tr><td>• Flat oyster Ostreidae</td><td>6</td><td>1.3</td></tr>
<tr><td>• Feather hydroid cf. *Aglaophenia* sp.</td><td>5</td><td>1.3</td></tr>
<tr><td>• Encrusting bryozoan</td><td>4</td><td>0.3</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>PR5</th><th>Baseline surveys 2016–2020</th><th>May 2021</th></tr>
<tr><td>FISH</td><td>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).</td><td>14 species recorded.
There was no species absent that had been consistently present across the baseline surveys.
No species recorded a decrease in abundance score greater than three.
Two species with AS > 3, recorded for the first time at PR5, were:
• Goat fish (Upeneichthys lineatus; AS 6)
• Banded wrasse (N. fucicola; AS 4).
Species more prevalent than the mean baseline (∆AS > 3) were: — AS M21 / AS Baseline
• Butterfly perch — 15 / 6.0
• Scarlet wrasse — 10 / 1.3
• Blue cod — 9 / 3.3</td></tr>
</table>

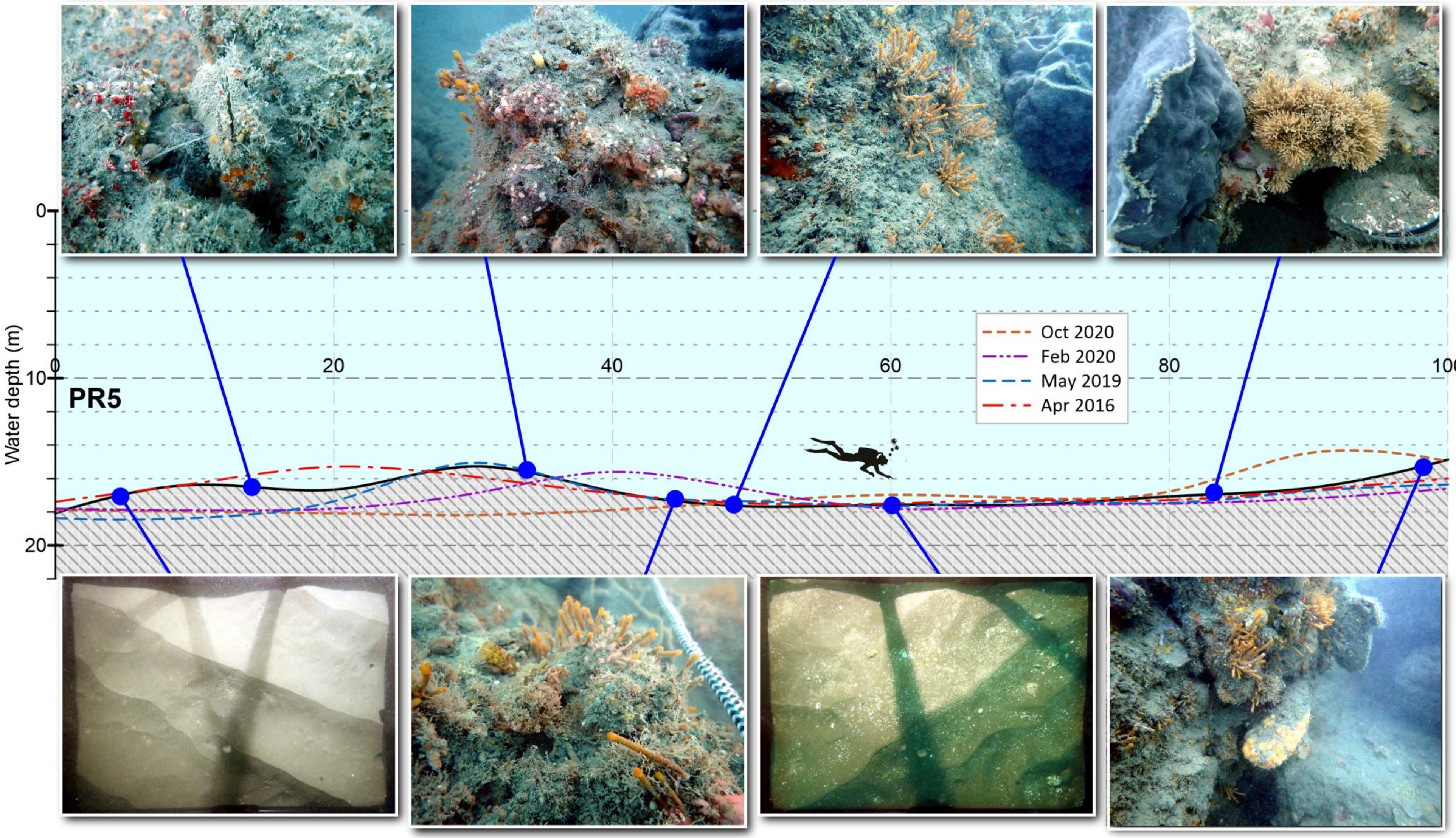

Figure 5. Depth profile with photographs of representative habitat and biota along transect PR5 in May 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during 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 6).

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	May 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.
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.	6 taxa recorded. No algal species that were recorded consistently across the three baseline surveys were absent. The prevalence of both *E. radiata* (AS 33) and coralline algae (AS 28) was effectively unaltered from the baseline. *C. costata* was once again absent after being recorded in February (AS 3) and October (AS 4) 2020. Only one algal taxon had decreased in prevalence (ΔAS >3) relative to the baseline: (AS M21 / AS Baseline) • *P. cirrhosum* — 18 / 22.3 There were no newly recorded algal taxa. The brown alga *Halopteris* sp. (AS 7) was unrecorded during the baseline but had been present in October 2020 (AS 4).

<table>
<tr><th>PR3</th><th>Baseline surveys 2016–2020</th><th>May 2021</th></tr>
<tr>
<td>INVERTEBRATE COMMUNITIES</td>
<td>
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 coralines. 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 sp.) and branching hydroids occurred occasionally, along with mussel beard (Amphisbetia bispinosa) where there were beds of green-lipped mussels (Perna canaliculus).
The most commonly occurring ascidian has been the grey / white stalked colonial ascidian (cf. Synoicum otagoensis), usually in deeper sections. Two of the Didemnum species complex also occured in some years, as did solitary ascidians (Cnemidocarpa sp.), but none of these conspicuously.
After the 80-m mark, P. canaliculus could be common to abundant. However, this varied depending on how well the shotline had been placed relative to the reef crest where they occurred.
The most commonly occurring mobile epifauna were gastropods. These included clown nudibranch (Ceratosoma amoena), siphon whelk (Penion sulcatus) and tiger (Calliostoma tigris) and green (Trochus viridus) topshells. Hermit crabs and sea cucumbers (Australostichopus molis) were usually also present in low numbers.
</td>
<td>
44 taxa recorded.
Seven taxa previously recorded from more than a single survey event at PR3 were absent; however, none had been recorded consistently across all three baseline surveys.
<table>
<tr><th>A decrease in abundance score of more than 3 was recorded for the following taxa:</th><th>AS M21</th><th>AS Baseline</th></tr>
<tr><td>• Mussel Perna canaliculus</td><td>3</td><td>9.7</td></tr>
<tr><td>• Ascidian cf. Cnemidocarpa sp.</td><td>5</td><td>9.7</td></tr>
<tr><td>• Pink massive sponge Demospongia C</td><td>1</td><td>4.3</td></tr>
</table>
Four taxa were newly recorded at PR3. However, of these, only crayfish (Jasus edwardsii; AS 6) exceeded an abundance score of 3. A small red ascidian (Ascidiacea sp. A; AS 10) had previously been recorded at PR3 only in October 2020 (AS 2) but not during the baseline. However, this taxon had been recorded during the baseline from all other transects except PR1. Its prevalence has been observed to be temporally highly variable.
<table>
<tr><th>Taxa recorded in greater prevalence (ΔAS >3) than during the baseline:</th><th>AS M21</th><th>AS Baseline</th></tr>
<tr><td>• Vase sponge Ecionemia alata</td><td>29</td><td>24.3</td></tr>
<tr><td>• Sponge Cliona cf. celata</td><td>25</td><td>12.0</td></tr>
<tr><td>• Bryozoan Catenicellidae</td><td>21</td><td>16.0</td></tr>
<tr><td>• Bryozoan Steginoporella neozelanica</td><td>20</td><td>7.7</td></tr>
<tr><td>• Lilac sponge Desmospongia D</td><td>17</td><td>9.7</td></tr>
<tr><td>• Sponge Raspailia topsenti</td><td>16</td><td>12.0</td></tr>
<tr><td>• Bryozoan cf. Cellaria tenuirostris</td><td>14</td><td>9.0</td></tr>
<tr><td>• Fan bryozoan cf. Caberea zelandica</td><td>8</td><td>1.3</td></tr>
<tr><td>• Green topshell Trochus viridus</td><td>6</td><td>0.7</td></tr>
<tr><td>• Sponge Latrunculia cf. procumbens</td><td>5</td><td>1.0</td></tr>
<tr><td>• Holothurian Australostichopus mollis</td><td>5</td><td>1.3</td></tr>
<tr><td>• Orange encrusting sponge cf.Tedania sp.</td><td>4</td><td>0.7</td></tr>
<tr><td>• Orange lobed sponge</td><td>4</td><td>0.3</td></tr>
<tr><td>• Encrusting bryozoan</td><td>4</td><td>0.7</td></tr>
<tr><td>• Flat oyster Ostreidae</td><td>4</td><td>0.7</td></tr>
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</table>

PR3	Baseline surveys 2016–2020	May 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.	15 species recorded. There were no species absent that had been consistently present across the baseline surveys. Two species recorded a decrease in abundance score (relative to the mean baseline) greater than three: — AS M21 / AS Baseline • Butterfly perch — 12 / 23.3 • Sweep — 4 / 10.7 No new species with AS > 3 were observed. Species more prevalent than the mean baseline (ΔAS > 3) were: — AS M21 / AS Baseline • Scarlet wrasse — 11 / 7.3 • Leather jacket — 8 / 2.3

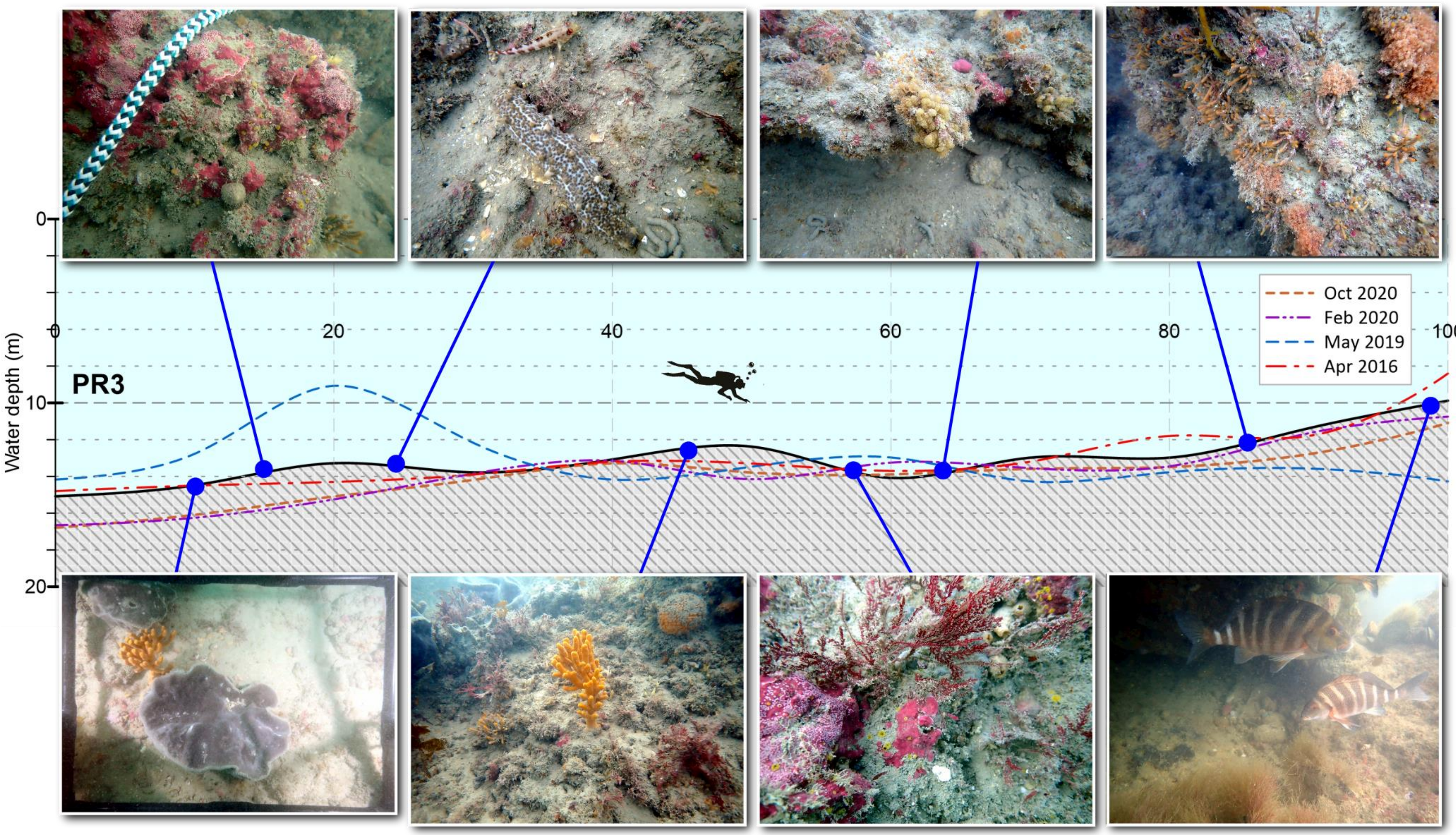

Figure 6. Depth profile with photographs of representative habitat and biota along transect PR3 in May 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during 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 7). 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	May 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.	Little departure from the baseline description. Some boulder and cobble noted. Pockets of sand /shell /cobbles in low-lying areas
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.	4 taxa recorded. No algal taxa that were recorded consistently across the three baseline surveys were absent. All algal taxa have been quite variable across surveys, including the baseline. However, the more predominant *E. radiata* (AS 18) and *P. cirrhosum* (AS 13) were at similar levels to the mean baseline scores. The small-bladed red alga (AS 7) had decreased relative to the mean baseline, but was not recorded at PR6 in April 2016. There were no newly recorded algal taxa. Encrusting corallines (AS 17) had increased against the mean baseline (AS 11) but was similar to April 2016 (AS 16).

PR6	Baseline surveys 2016–2020	May 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 globosum*). 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 amoena*), siphon whelk (*Penion sulcatus*), hermit crabs and sea cucumbers. The top shells *Calliostoma tigris* and *Trochus viridus* also featured, as well as kina (*Evechinus chloroticus*) in 2019 only.	51 taxa recorded. Eight taxa absent that were previously recorded from more than a single survey event at PR6; however, none had attained an abundance score of more than three or been recorded consistently across all three baseline surveys. A decrease in abundance score of more than 3 was recorded for the following taxa: • Lobed grey sponge cf. *Thorecta* sp. (AS 1 vs baseline 5.0) • Bryozoan Catenicellidae (AS 4 vs baseline 7.7) Eleven taxa were newly recorded at PR6. However, of these, only three exceeded an abundance score of 3: • Crayfish (*Jasus edwardsii*; AS 8) • Encrusting bryozoan (AS 5) • Orange lobed sponge (AS 4) Taxa recorded in greater prevalence ((ΔAS > 3) than during the baseline: — AS M21 / AS Baseline • Vase sponge *Ecionemia alata* — 30 / 18.3 • Bryozoan *Steginoporella neozelanica* — 25 / 11.3 • Sponge *Raspailia topsenti* — 21 / 15.0 • Lilac sponge Desmospongia D — 21 / 14.3 • Branching hydroid — 19 / 10.0 • Small red ascidian Ascidiacea sp. A — 15 / 5.7 • Sponge *Cliona* cf. *celata* — 14 / 4.0 • Mussel beard hydroid *Amphisbetia bispinosa* — 10 / 5.7 • Orange golfball sponge *Tethya burtoni* — 9 / 1.7 • Colonial ascidian *Didemnum* spp complex-white — 4 / 4.7 • Feather hydroid cf. *Aglaophenia* sp. — 5 / 1.3 • Hydroid tree *Solandria ericopsis* — 4 / 0.3

<table>
<tr><th>PR6</th><th>Baseline surveys 2016–2020</th><th colspan="3">May 2021</th></tr>
<tr><td rowspan="7">FISH</td><td rowspan="7">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.).</td><td colspan="3">14 species recorded.

There were no species absent that had been consistently present across the baseline surveys. Neither had any species notably decreased in abundance (ΔAS > 3) relative to the mean baseline.

No species new to PR6 were recorded with AS > 3.</td></tr>
<tr><td>Species recorded as more prevalent than the mean baseline (ΔAS > 3) were:</td><td>AS M21</td><td>AS Baseline</td></tr>
<tr><td>• Butterfly perch</td><td>24</td><td>14.3</td></tr>
<tr><td>• Sweep</td><td>21</td><td>3.0</td></tr>
<tr><td>• Scarlet wrasse</td><td>10</td><td>5.7</td></tr>
<tr><td>• Dwarf scorpion fish</td><td>5</td><td>1.7</td></tr>
<tr><td>• Banded triplefin Forsterygion malcomi</td><td>4</td><td>0.7</td></tr>
</table>

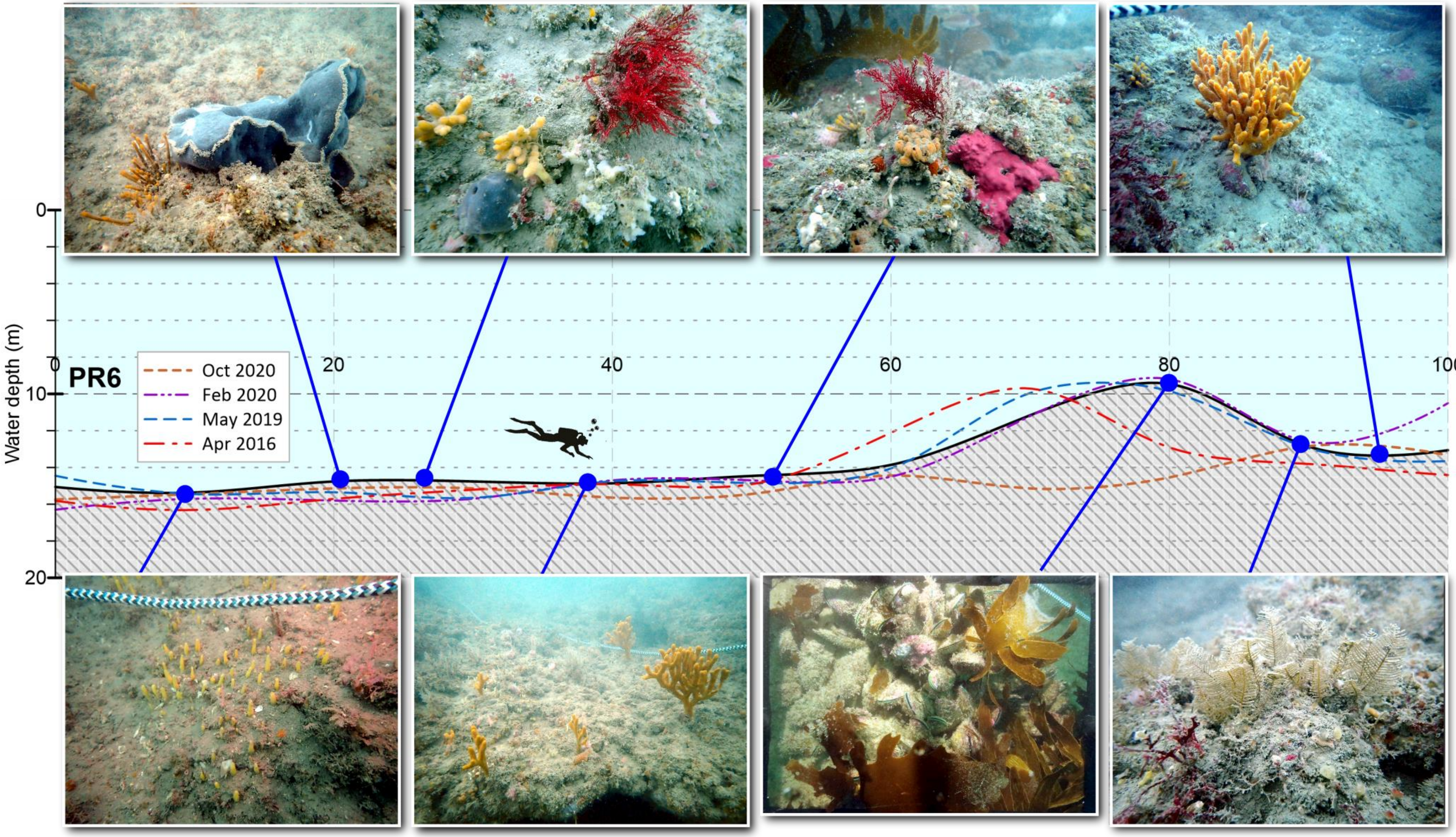

Figure 7. Depth profile with photographs of representative habitat and biota along transect PR6 in May 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during 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 8).

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	May 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.	No notable change from the baseline.
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 consistently across the three baseline surveys were absent. *E. radiata* (AS 24) and *P. cirrhosum* (AS 25) were at similar levels to those recorded across the baseline surveys. The small-bladed red alga (AS 4) had decreased markedly relative to the mean baseline (AS 22) but was equal to its May 2019 prevalence. There were no newly recorded algal taxa. Encrusting corallines (AS 22) had increased notably in prevalence relative to the baseline (mean AS 8.0).

PR4	Baseline surveys 2016–2020	May 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* sp.). Branching hydroids, notable in 2019, were variable between surveys but *Amphisbetia bispinosa* was usually associated with mussel beds. Colonial ascidians were also a consistent presence, with white *Didemnum,* the translucent cf. *Eudistoma* sp. and the stalked cf. *Synoicum otagoensis* recorded. Solitary ascidians such as *Cnemidocarpa* sp. and the small Ascidiacea sp. A were variable across surveys. Green-lipped mussels (*Perna canaliculus*) were consistently recorded from the shallower final 10 m of the transect, but in 2019, a dense bed was also observed on a low reef crest at the 50 m mark. Mobile epifauna were sparse, with only a few species that are common to the rest of the reef. These include the gastropods clown nudibranch (*Ceratosoma amoena*), siphon whelk (*Penion sulcatus*), top shells (*T. viridus*) and occasionally the swollen trumpet (*Argobuccinum pustulosum*). As elsewhere, hermit crabs were generally present in low numbers but sea cucumbers were seldomly recorded.	50 taxa recorded. Seven taxa previously recorded from more than a single survey event at PR4 were absent; however, only two had previously attained an abundance score of more than three or been recorded consistently across all three baseline surveys. • Mussel (*Perna canaliculus;* notably also absent from the October 2020 record; mean baseline AS 5.3) • Stalked ascidian *Pyura spinosissima* (mean baseline AS 1) Apart from *P. canaliculus*, no taxa recorded a decrease in abundance score of greater than three. Nine taxa were newly recorded at PR4. However, of these, only two exceeded an abundance score of 3: — AS M21 / AS Baseline • Crayfish *Jasus edwardsii* — 8 / 0 • Sponge white/green Demospongia A — 4 / 0
		Taxa recorded in greater prevalence (∆AS > 3) than during the baseline: — AS M21 / AS Baseline • Lilac sponge Desmospongia D — 24 / 13.7 • Bryozoan *Steginoporella neozelanica* — 19 / 6.0 • Small red ascidian Ascidiacea sp. A — 18 / 1.0 • Emergent sponge cf. *Ciocalypta* sp. — 16 / 12.3 • Sponge *Cliona* cf. *celata* — 15 / 8.3 • Branching hydroid — 8 / 1.7 • Grey massive sponge Desmospongia B — 6 / 0.7 • Hermit crabs Paguridae — 5 / 1.7 • Anemone *Anthothoe albocincta* — 4 / 0.3 • Colonial stony coral *Culicea rubiola* — 4 / 0.7 • Holothurian *Australostichopus mollis* — 4 / 0.3

PR4	Baseline surveys 2016–2020	May 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.	10 species recorded. There were no species absent that had been consistently present across the baseline surveys. Neither had any species notably decreased in abundance (ΔAS > 3) relative to the mean baseline. Banded perch (*Hypoplectrodes huntii*; AS 5) was the only species new to PR4 but had been commonly observed on other transects in May 2019 and Feb 2020 of the baseline. Species recorded as more prevalent than the mean baseline (ΔAS > 3) were:: — AS M21 / AS Baseline • Butterfly perch — 12 / 2.3 • Scarlet wrasse — 10 / 2.3 • Variable triplefin *F. varium* — 5 / 1.0

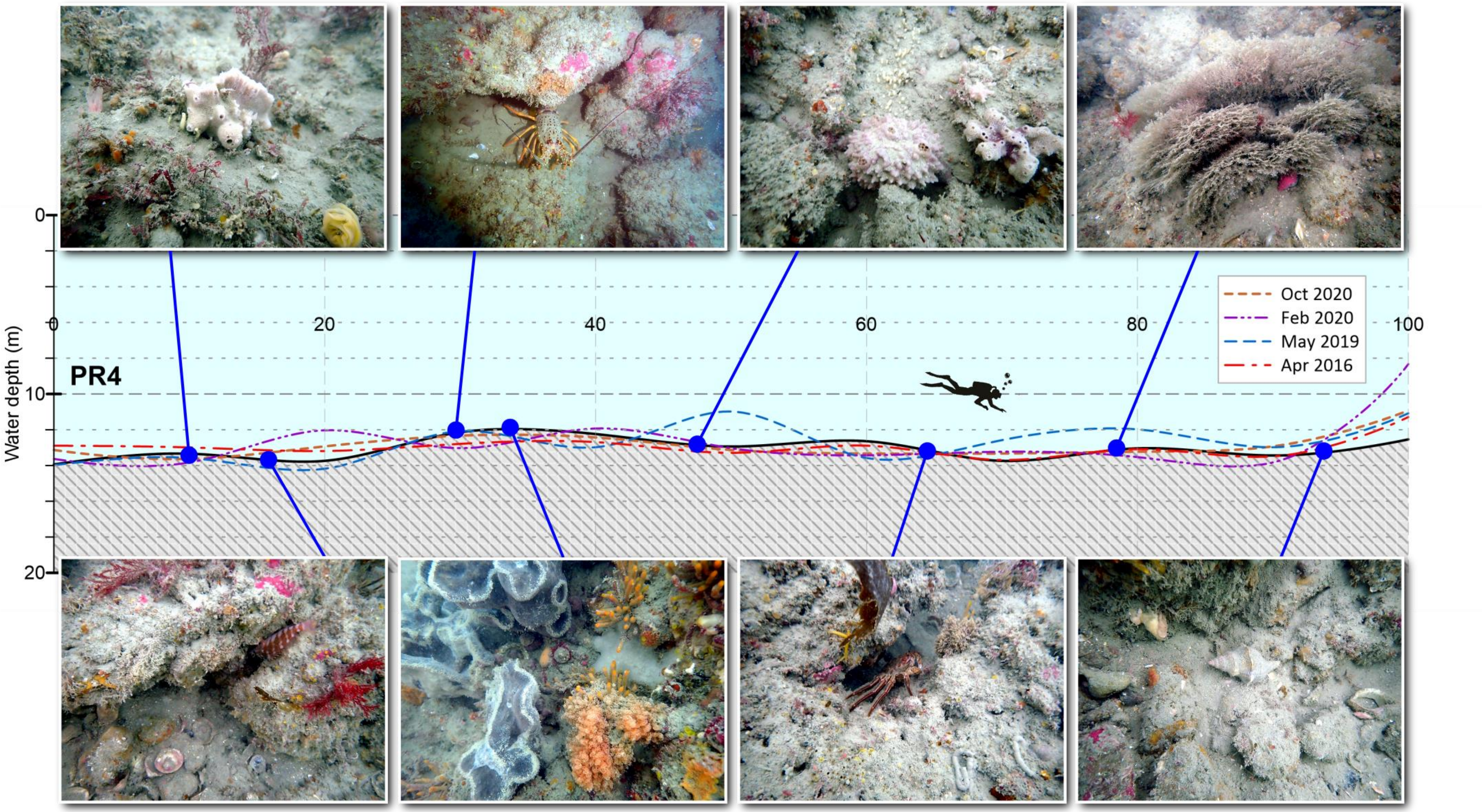

Figure 8. Depth profile with photographs of representative habitat and biota along transect PR4 in May 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during 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 9).

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	May 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.	Rippled mobile sand only for the first 7 m, then emergent rock / boulders. ~5 m stretch of silty sand with embedded pebble / cobble material from 45 m. Otherwise no notable change from the baseline. Heavy embedded silt prominent.
ALGAE	3–4 taxa recorded across the baseline surveys. *Ecklonia radiata* occurred all along the transect but, until the last 30 m, these were sporadic and often stunted plants or recruits. In the shallower waters at the end of the transect, it became abundant. *Procamium cirrhosum* and the small bladed red alga both also occur along the entire transect. Coralline algae occurs sparsely in the last 30 m.	5 taxa recorded. No algal taxa that were recorded consistently across the three baseline surveys were absent. *E. radiata* (AS 16) and *P. cirrhosum* (AS 19) were at similar levels to those recorded across the baseline surveys. *Dictyota* sp., recorded only in October 2020 (AS 13) was once again absent. The small-bladed red alga (AS 6) had decreased relative to the mean baseline (AS 13) but was slightly more prevalent than in May 2019 (AS 4). The brown alga *Halopteris* sp. was newly recorded on PR7 but from just a single instance. No notable increases relative to the baseline (ΔAS > 3) were recorded for any algal taxa.

PR7	Baseline surveys 2016–2020	May 2021
INVERTEBRATE COMMUNITIES	26–49 taxa recorded across the baseline surveys. Sponges were the most commonly occurring conspicuous taxa. *Eciomonia alata*, *Ciocalypta* sp., *Raspailia topsenti*, lilac sponge (Demospongiae sp. D), yellow breadcrumb (Demospongiae sp. E) and both golfball sponges (*Tethya bergquistae* and *T. burtoni*) have been consistently present. Also frequently recorded were orange encrusting (cf.*Tedania* sp.), globose (cf. *Aaptos globosum*) and lobed grey (cf. *Thorecta* sp.) sponges. *Cliona* cf. *celata* and a conspicuous yellow finger sponge (cf. *Iophon minor*) were newly recorded in Feb 2020. As on other southern Pania Reef transects, three bryozoans were common: clowns hair (Catenicellidae), branching (cf. *Cellaria tenuirostris*) and *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* sp.) and branching hydroids, soft coral (*Alcyonium* cf. *aurantiacum*) and stony coral (*Culicea rubiola*). Ascidians were also more prevalent than on the northern Reef: Colonial (cf. *Synoicum otagoensis Eudistoma* sp. and *Didemnum* spp.) and solitary (*Cnemidocarpa* sp., Ascidiacea sp. A, *Pyura spinosissima*). Green-lipped mussels (*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 amoena*) along with other gastropods (*Penton sulcatus, Buccinulum lineum, Calliostoma tigris*) and hermit crabs. The sea cucumber (*Australostichopus mollis*) was more common than on the northern Reef. Spiny rock lobster (*Jasus edwardsii*) were also more often observed on the southern Reef transects.	59 taxa recorded. Six taxa previously recorded from more than a single survey event at PR7 were absent. However, among these only the mussel *Perna canaliculus* had attained an abundance score of more than three and been present consistently across all three baseline surveys. Notably though, it had been recorded from just a single individual in May 2019. A decrease in abundance score of more than 3 was recorded for the following taxa: (AS M21 / AS Baseline) • Emergent sponge cf. *Ciocalypta* sp. — 17 / 20.3 • Green-lipped mussels *P. canaliculis* — 2 / 6.0 • Colonial ascidian cf. *Synoicum otagoensis* — 8 / 13.7 • Yellow breadcrumb sponge Demospongia E — 6 / 11.0 Six taxa were newly recorded at PR7. However, of these, only two exceeded an abundance score of 3: • Sponge -orange honeycomb (AS 5) • Sponge – orange lobed (AS 4) Taxa recorded in greater prevalence (ΔAS > 3) than during the baseline: (AS M21 / AS Baseline) • Small red ascidian Ascidiacea sp. A — 29 / 8.0 • Anemone *Anthothoe albocincta* — 24 / 13.7 • Lilac sponge Desmospongia D — 19 / 15.3 • Encrusting bryozoan — 15 / 5.7 • Colonial ascidian *Eudistoma* sp. — 15 / 11.3 • Bryozoan *Steginoporella neozelanica* — 14 / 6.0 • Holothurian *Australostichopus mollis* — 13 / 8.0 • Branching hydroid — 9 / 5.7 • Sponge *Cliona* cf. *celata* — 7 / 2.0 • Flat oyster Ostreidae — 7 / 1.7 • Emergent sponge cf. *Stylopus australis* — 5 / 0.3 • Bivalve embedded unid. — 4 / 0.3

PR7	Baseline surveys 2016–2020	May 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.	15 species recorded. There was no species absent that had been consistently present across the baseline surveys. Neither had any species notably decreased in abundance (∆AS > 3) relative to the mean baseline. Spectacled triplefin (*Ruanoho whero*; AS 4) was the only species new to PR7 but had been commonly observed on other transects throughout the baseline and subsequently. A related species, *R. decemdigitatus*, and trevally (*Pseudocaranx dentex*), both recorded from single individuals, were new to the Reef transect data set. Species recorded as more prevalent than the mean baseline (∆AS > 3) were:: — AS M21 / AS Baseline • Spotted wrasse (AS 10 vs baseline 2.0) — 10 / 2.0 • Butterfly perch (AS 9 vs baseline 4.7) — 9 / 4.7 • Leather jacket (AS 4 vs baseline 0.7) — 4 / 0.7

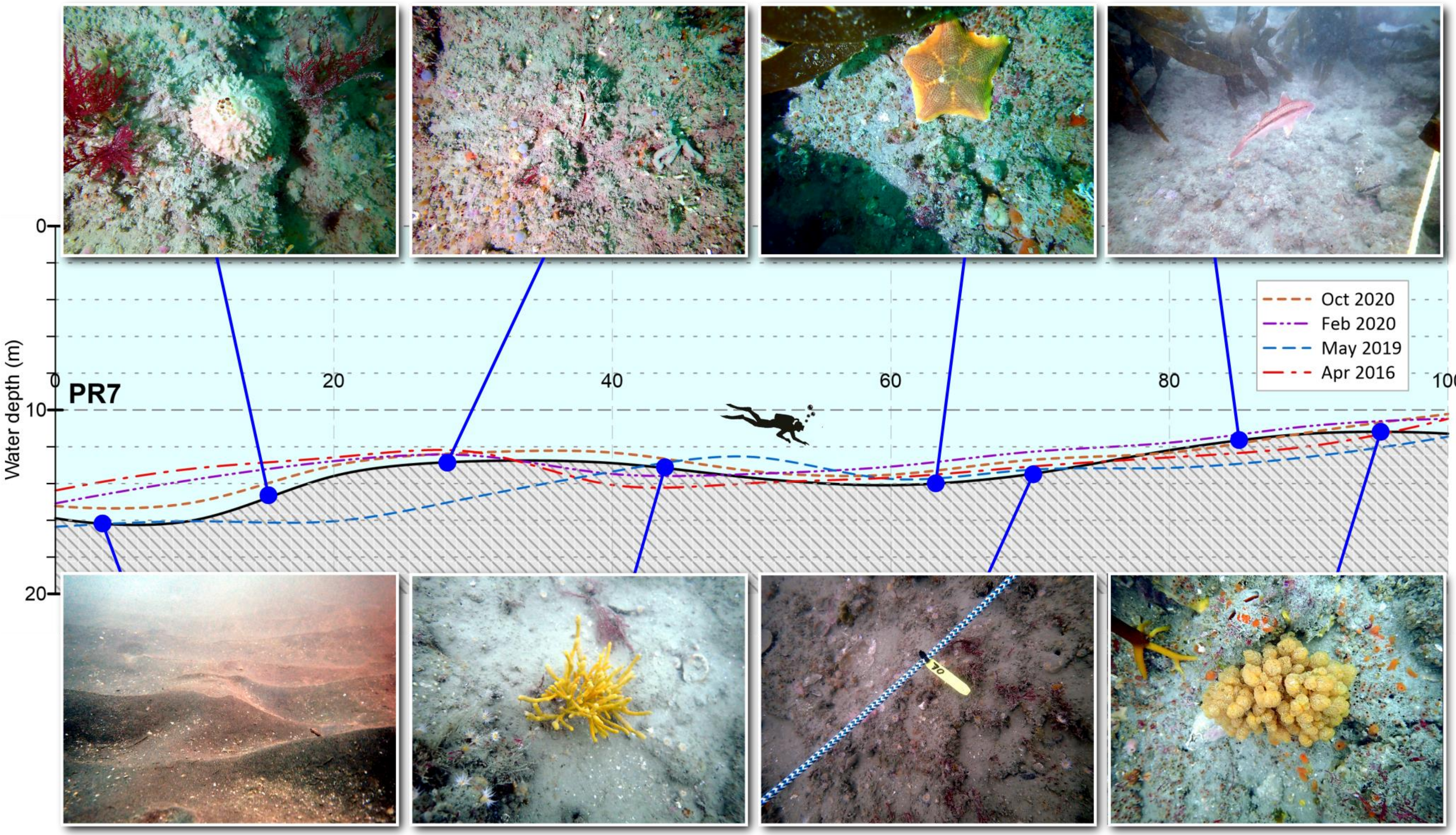

Figure 9. Depth profile with photographs of representative habitat and biota along transect PR7 in May 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during 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 10).

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	May 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.	As in Oct 2020, no sand substrate was recorded along PR8 as a distinct substrate. However, scattered hollows and pockets had accumulated some silty sand along with shell/sand/pebble material. Otherwise, there was no difference in the character of the reef surface to that recorded during the baseline.
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.	4 taxa recorded. No algal taxa that were recorded consistently across the three baseline surveys were absent. *Dictyota* sp., recorded only in October 2020 (AS 9) was once again absent. The small-bladed red alga (AS 7) had decreased relative to the mean baseline (AS 13) but recorded a higher score than in May 2019 (AS 4). *E. radiata* (AS 1) was newly recorded on PR8 but from just a single instance. *P. cirrhosum* (AS 16) had increased relative to the mean baseline (AS 12) but was equal to the score recorded in April 2016.

<table>
<tr><th>PR8</th><th>Baseline surveys 2016–2020</th><th>May 2021</th></tr>
<tr>
<td>INVERTEBRATE COMMUNITIES</td>
<td>
34–44 taxa recorded acroos the baseline surveys.
Similar communities to those of PR7. The most common sponges being Eciomonia alata, Ciocalypta sp., Raspailia topsenti, lilac Demospongiae D, yellow Demospongiae E, orange encrusting (cf. Tedania sp.), Also consistently occurring were golfball sponges (Tethya burtoni and T. bergquistae) and lobed grey sponge (cf. Thorecta sp.). The yellow boring sponge (Cliona cf. celata) has been recorded and an erect branching sponge (cf. Callyspongia ramosa) that is also more common on Town Reef. A red emergent/encrusting sponge (cf. Stylopus australis) and an unidentified orange sponge with an an apparent honeycomb structure were notable in 2019. A lobed lavender sponge (Callyspongia cf. annulata) was occasional in Feb 2020.
The clowns hair (Catenicellidae) and orange finger (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. amoena), P. sulcatus and lined whelk (Buccinulum lineum), Calliostoma punctulatum, Trochus viridus, sea cucumber (Australostichopus mollis) and hermit crabs.
</td>
<td>
61 taxa recorded.
No taxa previously recorded from more than a single survey event at PR7 were now absent. Neither did any taxon record a decrease in abundance score of greater than three.
Four taxa were newly recorded at PR8. However, only the tiger top shell (Calliostoma tigris; AS 4) exceeded an abundance score of 3. The jewel anemone (Corynactis australis; AS 6) was not recorded at PR8 during the baseline but was present in October 2020 (AS 2).
<table>
<tr><th>Twenty seven taxa recorded an increase in abundance score relative to the baseline of more than three (ΔAS > 3) Taxa for which ΔAS exceeded five were:</th><th>AS M21</th><th>AS Baseline</th></tr>
<tr><td>• Small red ascidian Ascidiacea sp. A</td><td>34</td><td>7.7</td></tr>
<tr><td>• Anemone Anthothoe albocincta</td><td>31</td><td>16.3</td></tr>
<tr><td>• Bryozoan Steginoporella neozelanica</td><td>20</td><td>10.0</td></tr>
<tr><td>• Branching hydroid</td><td>18</td><td>4.3</td></tr>
<tr><td>• Orange golfball sponge Tethya burtoni</td><td>17</td><td>9.7</td></tr>
<tr><td>• Colonial ascidian Eudistoma sp.</td><td>17</td><td>11.7</td></tr>
<tr><td>• Ascidian cf. Cnemidocarpa sp.</td><td>16</td><td>10.7</td></tr>
<tr><td>• Yellow breadcrumb sponge Demospongia E</td><td>14</td><td>7.7</td></tr>
<tr><td>• Branching sponge cf. Iophon minor</td><td>11</td><td>3.0</td></tr>
<tr><td>• Soft coral Alcyonium cf. aurantiacum</td><td>11</td><td>4.0</td></tr>
<tr><td>• Grey sponge cf. Suberites perfectus</td><td>10</td><td>1.0</td></tr>
<tr><td>• Flat oyster Ostreidae</td><td>10</td><td>1.3</td></tr>
<tr><td>• Brancing bryozoan cf. Cellaria tenuirostris</td><td>9</td><td>0.7</td></tr>
<tr><td>• Crayfish Jasus edwardsii</td><td>9</td><td>2.0</td></tr>
<tr><td>• Pink golfball sponge Tethya bergquistae</td><td>7</td><td>1.7</td></tr>
<tr><td>• Sponge -orange honeycomb</td><td>7</td><td>1.3</td></tr>
<tr><td>• Encrusting bryozoan</td><td>6</td><td>0.7</td></tr>
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<table>
<tr><th>PR8</th><th>Baseline surveys 2016–2020</th><th>May 2021</th></tr>
<tr><td>FISH</td><td>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).</td><td>13 species recorded.

There was no species absent that had been consistently present across the baseline surveys. Neither had any species notably decreased in abundance relative to the mean baseline (ΔAS > 3).
Two species with abundance score greater than three were new to PR8:
• Banded triplefin (F. malcomi; AS 8)
• Banded perch (Hypoplectrodes huntii; AS 6)
• Red moki (AS 4) had been absent from the baseline but observed in October 20920 (AS 2).
All three had been commonly observed on other transects throughout the baseline and subsequently. The scaly-headed triplefin (Karalepis stewarti), observed at PR8 as a single individual, was new to the Reef transect data set.

<table>
<tr><th>Species recorded as more prevalent than the mean baseline (ΔAS >3) were::</th><th>AS M21</th><th>AS Baseline</th></tr>
<tr><td>• Blue cod (AS 13 vs baseline 7.3)</td><td>13</td><td>7.3</td></tr>
<tr><td>• Spotted wrasse (AS 11 vs baseline 3.7)</td><td>11</td><td>3.7</td></tr>
<tr><td>• Scarlet wrasse (AS 8 vs baseline 1.0)</td><td>8</td><td>1.0</td></tr>
<tr><td>• Dwarf scorpion fish (AS 4 vs baseline 0.3)</td><td>4</td><td>0.3</td></tr>
</table></td></tr>
</table>

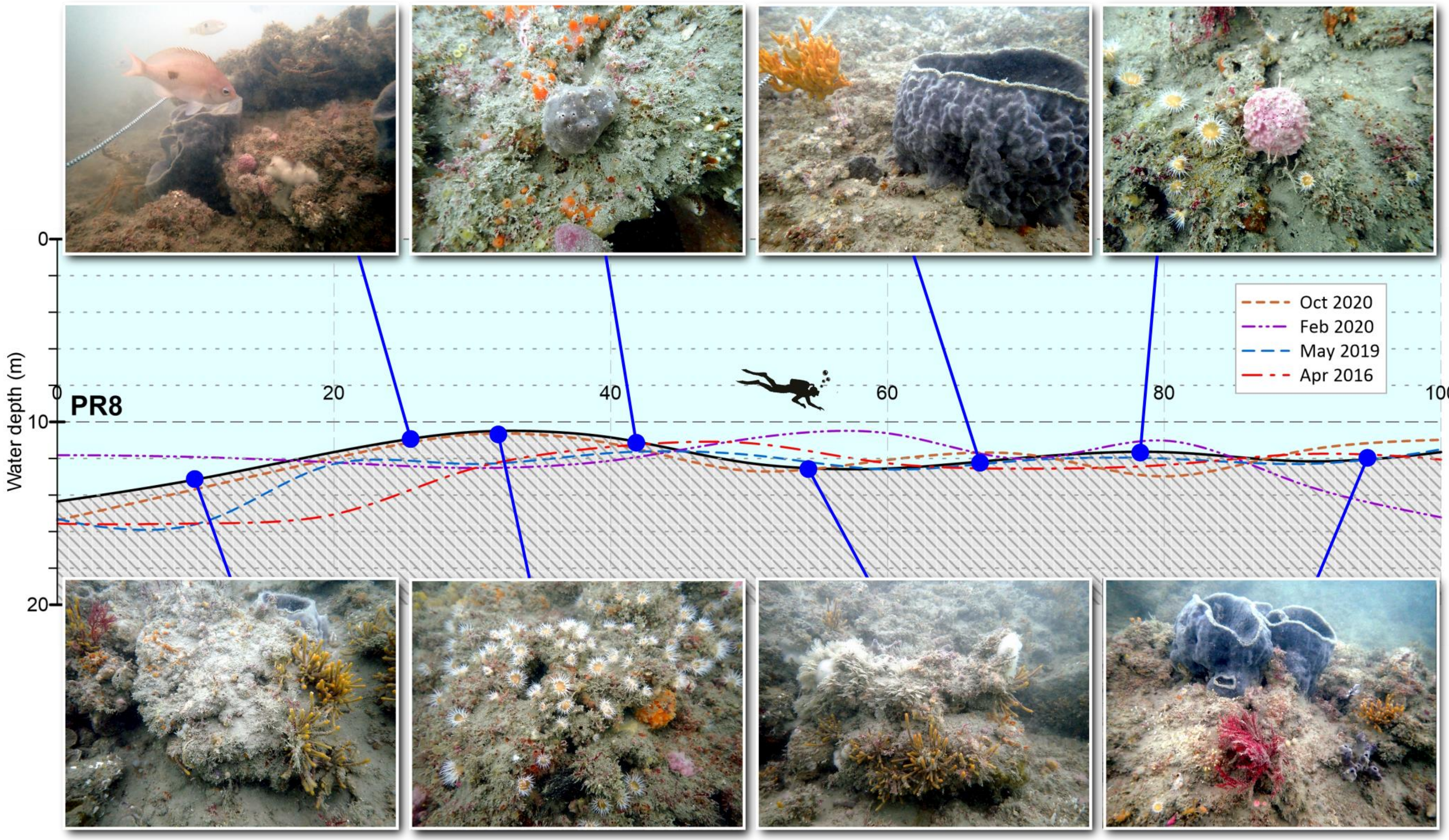

Figure 10. Depth profile with photographs of representative habitat and biota along transect PR8 in May 2021. The photographs are aligned with the transect profile, the solid blue lines indicating the location at which they were taken. Coloured dashed lines represent the depth profiles recorded during 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 the three baseline surveys, the dominant substrate along all transects except PR5 has been bedrock (abundance score 32–40) with varying levels of 3-dimensional structure. Small pockets of boulder/cobble material have also occurred sporadically on some transects (e.g. PR3, PR5). Silt and sand occurred widely in several forms.

4.1.1. Silt

During the current survey, there was little evidence of recently settled silt veneers on reef surfaces or encrusting biota. However, as was noted from the baseline surveys, the presence of such veneers is primarily dependent upon the absence of water movement from wave action rather than the quantity of fine material suspended in the water column. As in past surveys, some loose settled silt material was observed on the reef as isolated niches and small pockets protected from wave shear (Figure 11B).

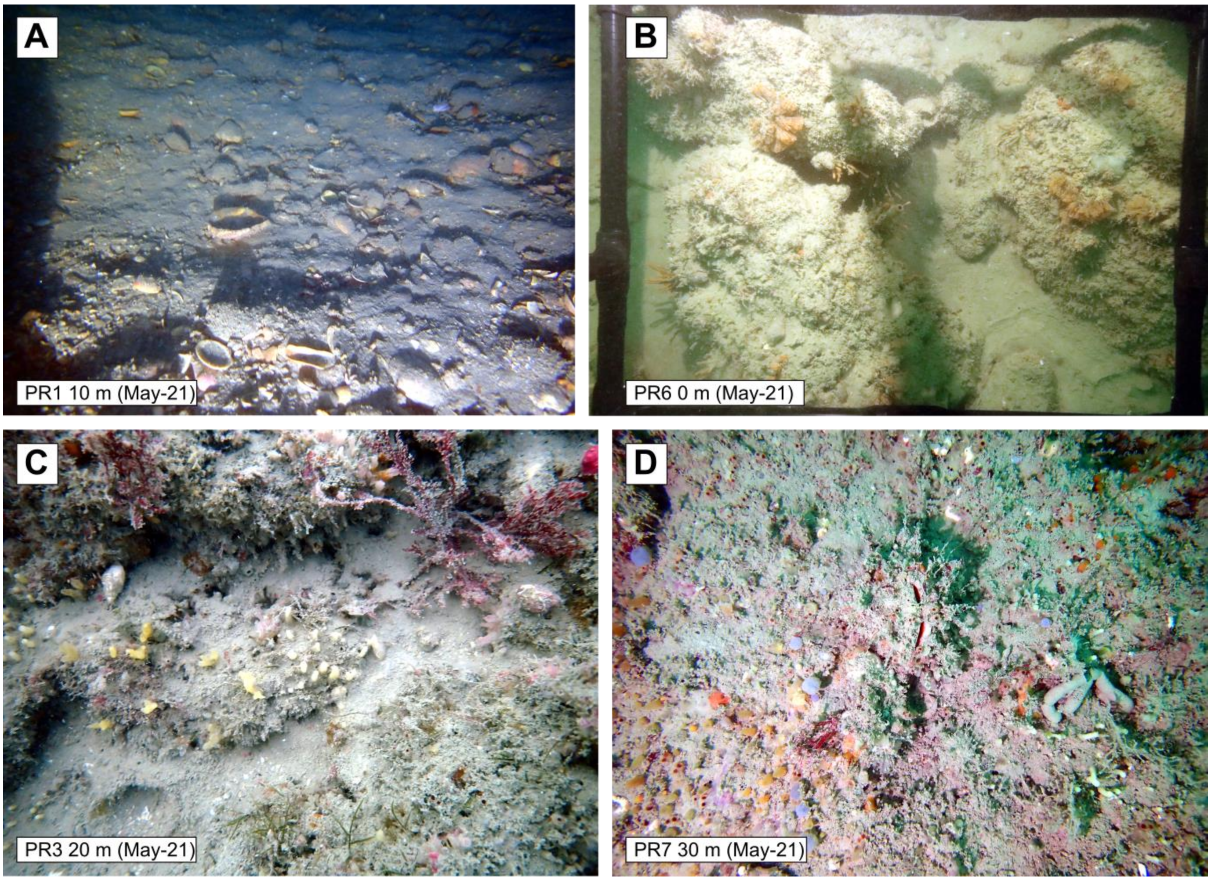

Figure 11. Examples of silt occurrence on Pania Reef during the current survey. **A:** Mixed silt/sand/shell substrate at the start of PR1. **B:** Niche silt pockets PR6. **C:** Entrapped silt stabilised by encrusting communities. **D:** Silt embedded within hard-substrate encrusting communities. Metre values are distances along the 100-m transect.

The primary form of silt occurring on the Reef is that which has been entrapped and retained by the textured surfaces upon which it settles (Figure 11C). A proportion of this silt becomes embedded and consolidated within encrusting communities to the point that it is very resistant to resuspension by surge (Figure 11D). Since most of this embedded silt is mediated by the surface roughness provided by encrusting communities, there is likely an equilibrium between the availability of silt (from the water column), the level of water movement and the types of encrusting biota. It was noted during the baseline that conditions at greater water depths appeared to favour silt-tolerant taxa (e.g. a range of sponges and ascidians) and emergent forms that benefit from the accumulation of a sediment layer on rock surfaces (e.g. the sponge *Ciocalypta* sp.), especially on the southern Reef (Sneddon 2020). To varying extents, these substrate conditions were again observed during the current survey on all transects. While the predominance of such embedded silt is difficult to measure directly or otherwise quantify, observations and the photographic record suggest that there has been no conspicuous change in prevalence relative to the baseline.

4.1.2. Sand

Sand deposits on the Reef generally take two forms; mobile sand that occasionally overlies low flat areas of the reef near its margins and sand that has accumulated in reef niches and pockets (usually with pebble, shell and silt). Apart from transects PR8 (which recorded no sand) and PR4, the overall prevalence of sand during the current survey was within the range established by the three baseline surveys (Figure 12). PR4 recorded only slightly lower incidence (AS 2) than was observed in May 2019 (AS 3).

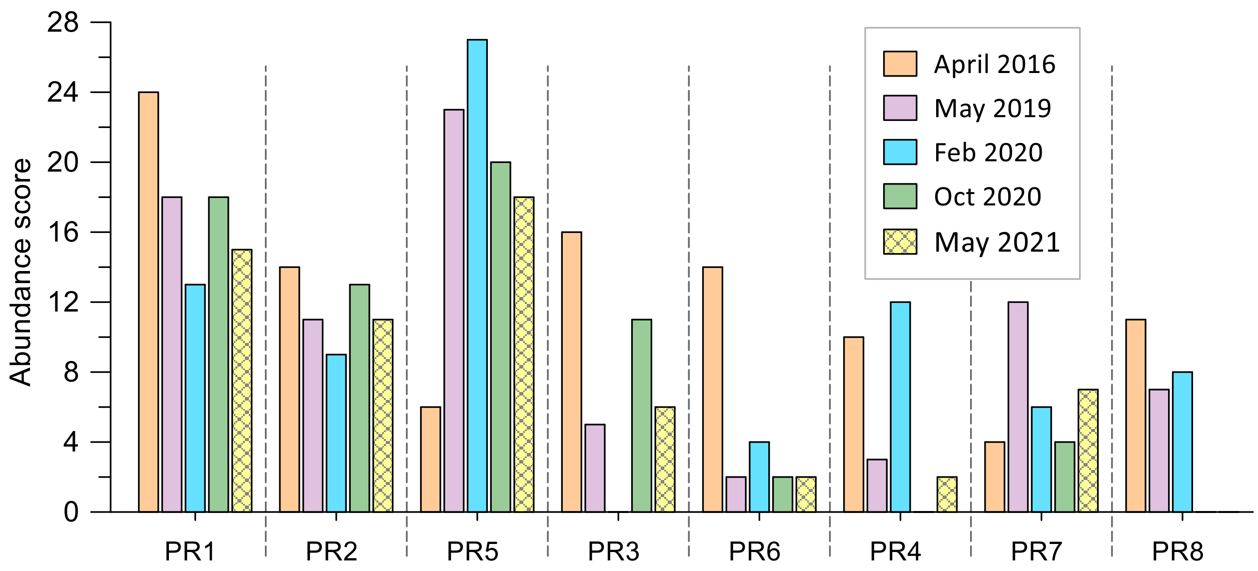

Figure 12. Prevalence of sand substrate across the five surveys to date for each transect. Abundance scores (AS) are summations of the ranked values across the ten 10-m intervals for each transect (see Table 1).

Mobile sand has most often been encountered on transect PR5 and this was again the case for the current survey (Figure 13A). However, it has also been recorded on the reef margins at PR6 and PR8 during the baseline. It is by nature ephemeral in reef areas so its variability across baseline surveys is not unexpected. While frequent or recent incursions of mobile sand will impact upon the reef communities in the areas where it occurs, the inexact placement of transect lines makes it difficult to clearly identify such areas. Hence, the variability at PR5 in Figure 12 cannot be assumed to arise solely from changes in the actual extent of this substrate between surveys.

Areas of more stable silty sand, often mixed with shell material, occur on the reef margin at transect PR1 (Figure 11A) and in transitional zones of PR5 (Figure 12B). Elsewhere, relatively large pockets of coarser sands have been observed to accumulate in low points and these have been a consistent feature at PR2 (Figure 12C) but have also been observed at PR3 and PR4. The nature of these accumulations appears dependent upon local hydrodynamic conditions and the presence of encrusting taxa that structurally modify the depositional environment.

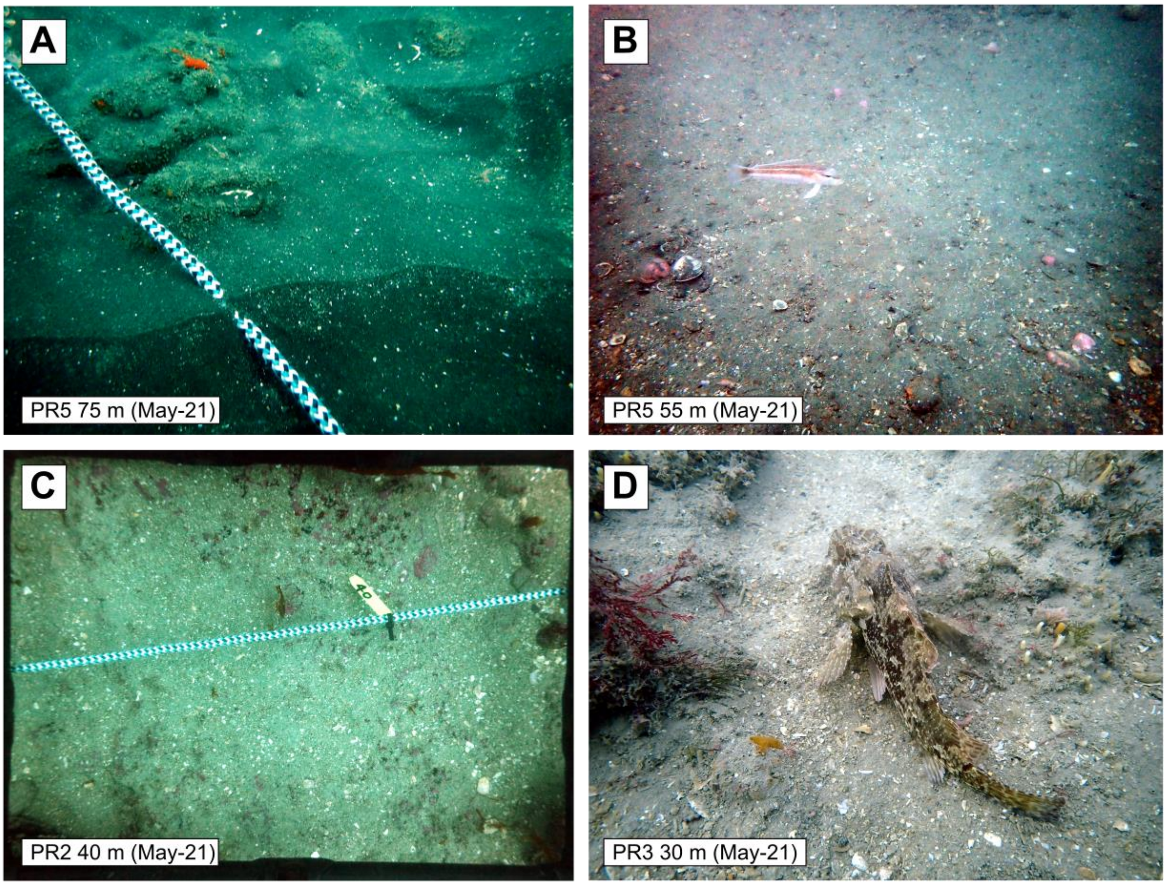

Figure 13. Examples of the different forms of sand substrates on Pania Reef during the current survey. **A:** Rippled mobile fine sand with emergent bedrock. **B:** Stable sand flat with shell. **C:** Shallow sand layer over bedrock. **D:** Accumulated silty sand within reef niche/pocket. Labelled values are distances along the 100-m transect.

Reef sediments: Key findings

As was observed during the baseline surveys, accumulated silt on the Reef was widespread only in a form trapped by or embedded within textured surfaces, principally those of encrusting reef biota.

Recently settled silt veneers were largely absent from rock surfaces and biota.

The visual record continues to suggest no conspicuous change in silt prevalence from the baseline condition.

Similarly, despite some temporal variability—some of which may arise from inexact relocation of transects—the prevalence of sand showed no indication of a distinct change or trend since the baseline.

4.2. Reef benthic communities

4.2.1. Taxa inventory and richness

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 five taxa have been added to this inventory since the baseline, the number of taxa recorded on each transect has shown a steady increase across surveys (Figure 14). The principal reason for this is the generation of larger photographic and video records from successive surveys, which are then used to augment the diver-generated record (Section 2.2.2). This has improved the comprehensiveness of the record, especially for scarce or cryptic taxa, which in more recent surveys are less likely to be overlooked. While the record of characteristic taxa (those which are either locally common or abundant or are consistently present in low numbers) will be less influenced by this effective increase in monitoring effort, interpretation of the data needs to allow for this trend[2].

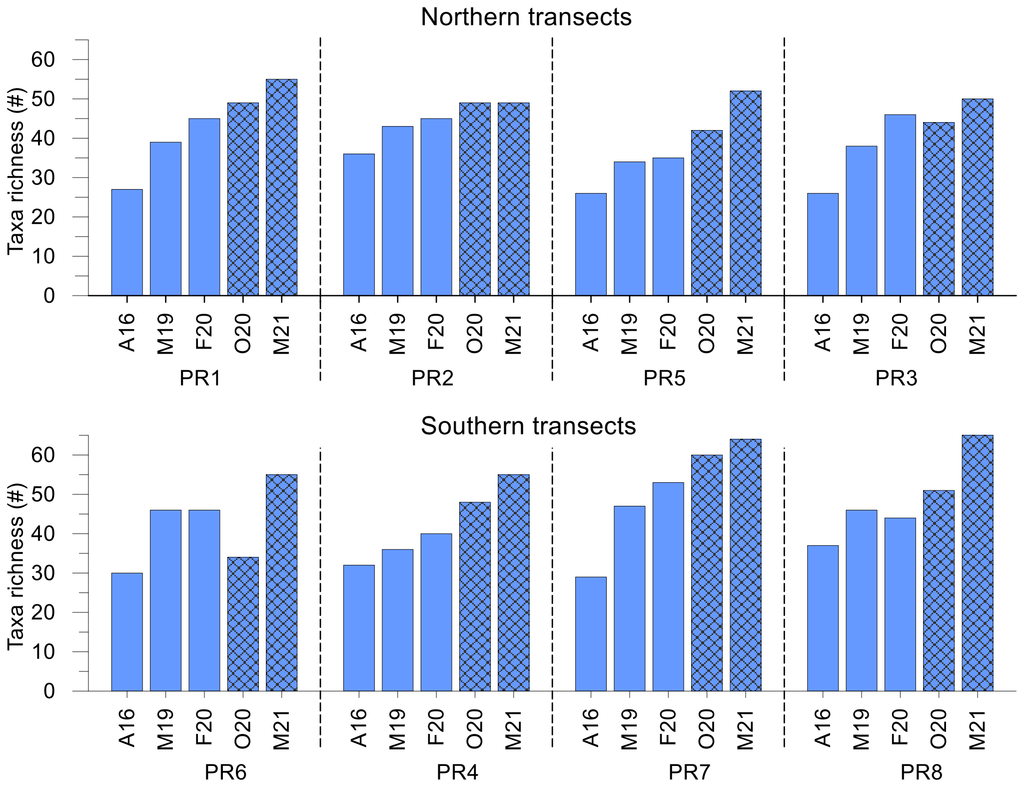

Figure 14. Taxa richness in reef communities for each transect showing the increasing trend across the five surveys to date. Excludes fish. Survey labels designate month and year of successive surveys (e.g. A16 = April 2016).

[2] 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.

4.2.2. 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 10 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 10 highlights the sometimes-high variability between surveys and especially the generally greater abundance scores from the current survey. There are several possible contributing reasons for this pattern.

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 considered unlikely. The only taxon to show an apparent decrease in abundance since the baseline surveys is the green-lipped mussel (*P. canaliculus;* Figure 15A). Taxa that have increased notably in abundance or have shown a general increasing trend since the baseline include:

- Lilac sponge (Demospongia D)
- Boring sponge (*Cliona* cf. *celata;* Figure 15C)
- Golfball sponge (*Tethya burtoni*)
- Bryozoan *Steginoporella neozelanica* (Figure 15D)
- Branching hydroid
- Orange/white anemone *Anthothoe albocincta*
- Crayfish (*Jasus edwardsii*)

Seasonal population cycles are likely to occur for some taxa. Of the surveys to date, the seasonal outlier is that of October 2020, the rest being broadly co-seasonal (late summer-autumn). However, distinct minima or maxima occurred in October 2020 only for the small-bladed red alga, the colonial ascidian cf. *Synoicum otagoensis*, and two gastropod species (*Cookia sulcata* and *Calliostoma tigris*). Hence, the patterns apparent in Table 10 do not clearly support seasonality as a principal influence on the observed variability.

The existence of inter-annual variability or 'boom and bust' cycles (possibly influenced by seasonal conditions) is suggested by the abundance data and field observations for some taxa. Such high variability between surveys has occurred for:

- Small-bladed red alga (Figure 15B, Figure 16)
- Small solitary ascidian (Ascidiacea sp. A; Figure 15E, Figure 16).

Table 10. 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 was greater than 30 for sessile biota and 5 for mobile invertebrates). Shaded cells represent years of minimum abundance (multiple years shaded if the difference between them does not exceed 10% of the mean value for sessile biota or 20% of the mean for mobile invertebrates). Similarly calculated maxima are designated by bold font.

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

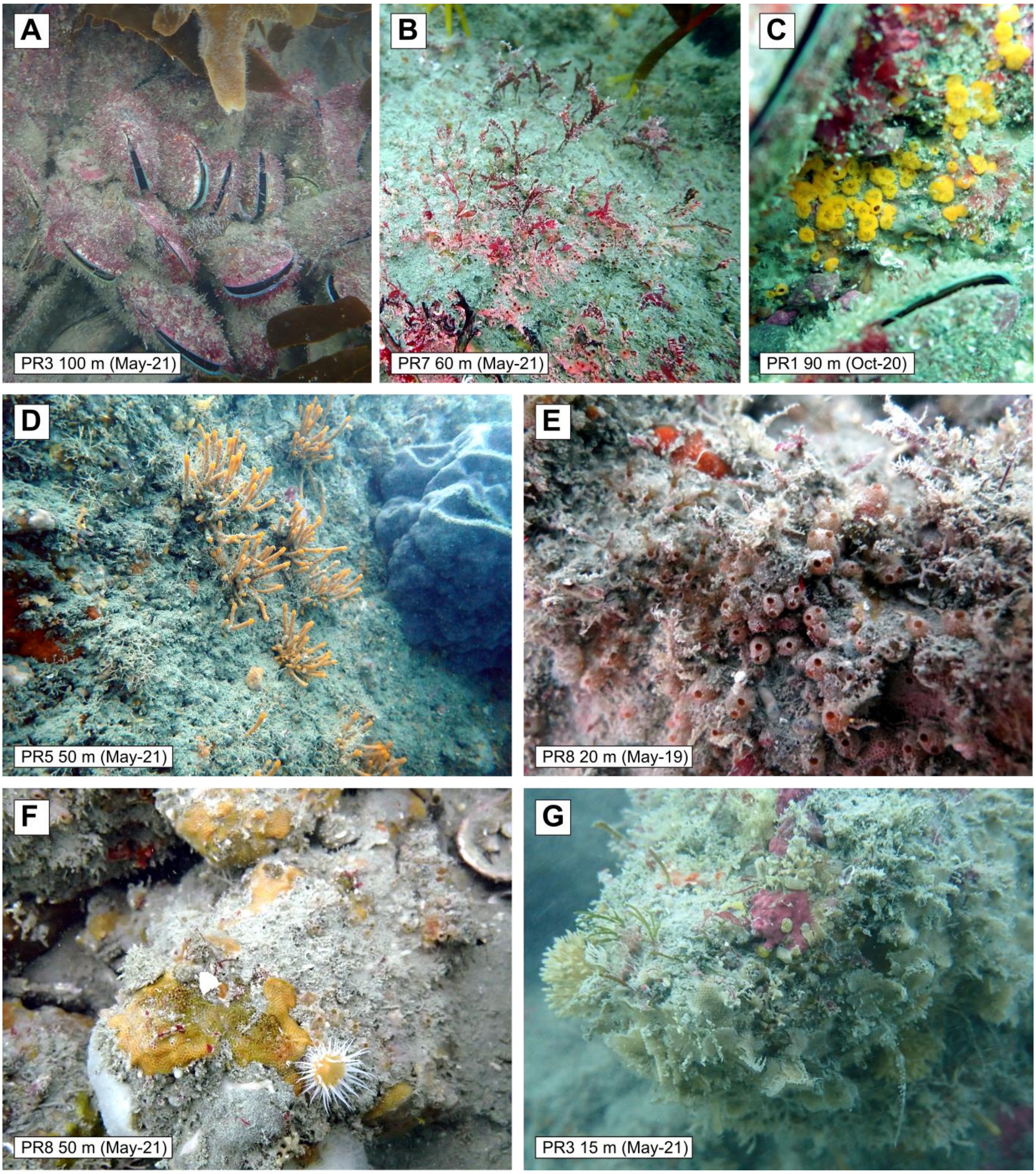

Figure 15. Photographs of selected taxa noted for variability in abundance across surveys. **A:** Dense mussel bed at the end of transect PR3. **B:** Small-bladed red alga. **C:** Boring sponge *Cliona* cf. *celata* is observed on Pania Reef only as the alpha phase, where just the bright yellow inhalant and exhalent papillae are visible. **D:** Bryozoan *Steginoporella neozelanica.* **E:** Small solitary ascidian (Ascidiacea Sp. A). **F:** Encrusting bryozoan. **G:** Encrusting bryozoan – partially erect, non-rigid form (new to Reef inventory).

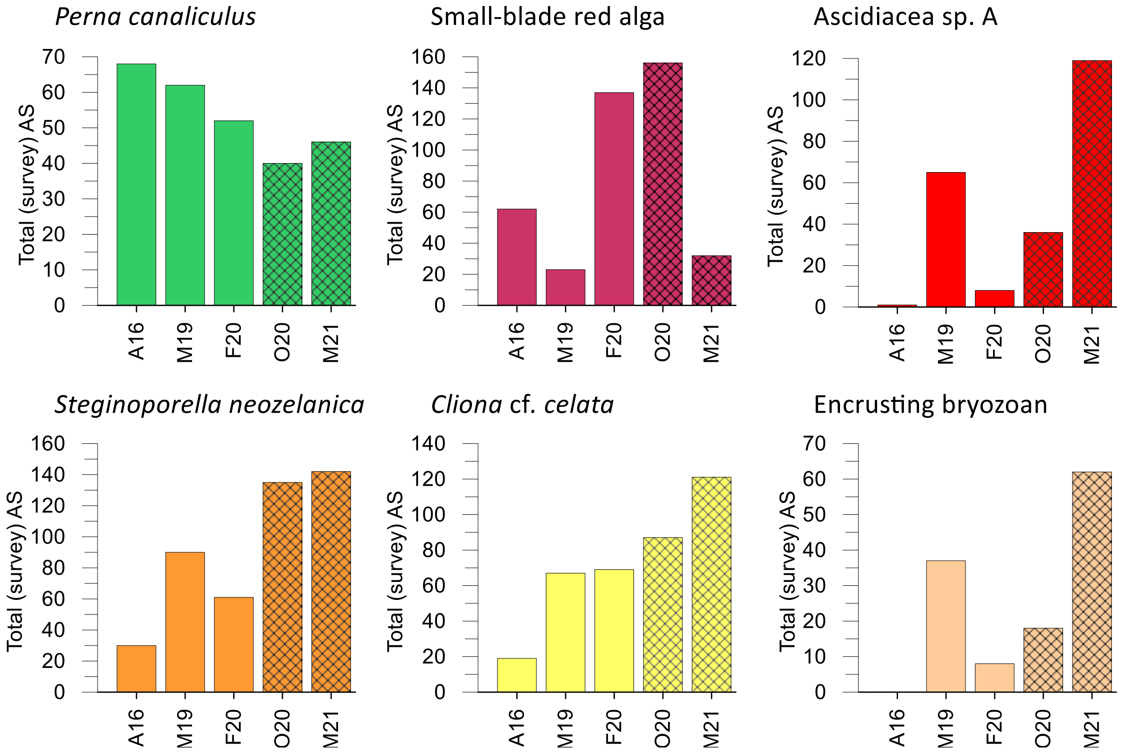

Figure 16. Total (survey) abundance scores (tAS) for selected taxa that in the current survey have diverged notably from the baseline mean. Solid bars represent the 3 baseline surveys. Dredging phase surveys denoted by cross-hatching.

The increasing capability across surveys for augmentation of the field data-set from the photographic record (section 2.2.2) will have influenced abundance scores. While this will mostly have affected taxa that are not abundant enough to qualify as ‘characteristic’ of the Reef, some common organisms that are small or inconspicuous (notably Ascidiacea sp. A and possibly *Cliona* cf. *celata*) may also have been occasionally missed by divers. At the same time, 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 such as the lilac sponge and feather hydroids.

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. This may explain the apparent greater occurrence in the current survey of the large vase sponge (*Ecionemia alata*; Table 10), a longer-lived species which is likely to be temporally quite stable.

Figure 16 shows, in graphical form, the total abundance data for several taxa selected on the basis of variability between surveys. The plots for *P. canaliculus*, *S.*

neozelanica and *Cliona* cf. *celata* suggest longer-term trends that have been in progression across all surveys rather than just since the beginning of the dredging programme. Those for small-bladed red alga and Ascidiacea sp. A show the high variability associated with seasonal or boom and bust scenarios. While encrusting bryozoans have not met the abundance criteria set in Table 10 for characteristic taxa, they were notably more abundant in the current survey, possibly because of the appearance in the current survey of a new morphologically distinct form[3]. The two forms are shown in Figure 15 (F,G). They were not differentiated in the May 2021 record.

4.2.3. Current survey transect data

Newly recorded taxa

Only two epibiotic taxa were newly recorded in the May 2021 survey (Table 11). Both were present in very low abundance (one or two individuals recorded across all transects).

Table 11. 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.

Description / common name (scientific name)	Score (tAS)	Transects	Incidence
Zoanthid (cf. *Epizoanthus* sp.)	2	PR6, PR7	Small colonies; individual occurrences
Shield slug (*Scutus breviculus*)	1	PR4	Individual occurrence

Previously recorded taxa absent from the current survey

Of the 98 epibiotic taxa in the monitoring inventory compiled from the baseline surveys, 92 were recorded from the May 2021 survey. Only one of the six absent taxa, the swollen trumpet snail (*Argobuccinum pustulosum*), had been recorded from all three of the baseline surveys (in transects PR3, PR6 and PR4), but this species had never been observed as more than three individuals in any one survey until October 2020 (post-baseline) when it recorded a total (survey) abundance score of ten. Of the remaining five absent taxa, all had been recorded from just one baseline survey. Only one of these had recorded a total abundance score exceeding five, a fine tufted red alga that that was observed across the northern transects in February 2020 (tAS 21). This alga was observed at PR1 at very low levels in October 2020 (AS 2) and is likely to be seasonal or otherwise ephemeral.

[3] Interestingly, this non-rigid encrusting bryozoan was noted for the first time in similar long-term monitoring at Banks Peninsula/Lyttelton in June 2021 (Cawthron unpublished data).

Comparison to the baseline

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 notable 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 (ΔAS > 3) and where such changes have been consistent across at least two of the eight transects (Table 12). Given the inter-survey variability observed, these thresholds are considered relatively conservative.

Table 12 shows that the most widespread changes from the baseline have been increases in abundance. Of 34 taxa where such change has occurred, 24 were noted only for increases in abundance. A further eight recorded decreases at just a single transect, although these instances were spread along the Reef axis. The small-bladed red alga and *Perna canaliculus* were the only two taxa for which decreases in AS were recorded at multiple transects and it is notable that for neither were the decreases in AS offset by increases (ΔAS > 3) at other transects.

The imbalance between increases and decreases in AS relative to the mean baseline is almost certainly influenced by the increasing comprehensiveness of the monitoring data (see section above) although some patterns in Table 12 are worth noting:

- The magnitude of AS increases was, for the most part, spread quite evenly across transects (although relatively greater increases in several bryozoan taxa at PR1 are evident).
- Several taxa stood out for consistently greater increases in AS:
  - Boring sponge (*Cliona* cf. *celata*) – decreasing gradient towards the south
  - Lilac sponge (Demospongia D)
  - Bryozoan *Steginoporella neozelanica*
  - Encrusting bryozoan
  - Ascidiacea sp. A – increasing gradient towards the south
- Although recording a slight decrease at PR1, the branching hydroid had increased at five of the other transects (ΔS > 5 at four transects).
- Increases in crayfish (*Jasus edwardsii*) were also notable although prevalence of this highly mobile species is anecdotally quite variable.
- The decrease in *P. canaliculus* at three transects was not large but is noteworthy mainly because it contrasts with generally increasing AS for most other taxa.

Both the prevalence of the bryozoan *S. neozelanica* and the relative scarcity of the small-bladed red alga were conspicuous enough to be noted by divers in the field, although these differ in that abundance of the former generally matches the record from the previous dredging phase survey (October 2020), while the latter continues a pattern of high inter-survey variability (see Figure 16).

Table 12. Changes in abundance score (∆AS) from the mean baseline for taxa where such change exceeded 3 for more than one transect. Cells are left blank where the difference from the baseline was less than 3. To aid visual interpretation, colour shading is proportional to the magnitude of change—red for a decrease, blue for an increase. Transects are listed in north to south order.

Group		**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Phaeophyceae	*Halopteris* sp.	6.7	5.7		7.0				
Rhodophyta	Corallinales	5.0	4.0			6.0	14.0		
	Plocamium cirrhosum		4.7		-4.3				4.0
	Small-bladed red alga		-3.3	-5.0		-5.7	-15.7	-7.0	-6.0
Porifera	*Ecionemia alata*				4.7	11.7			4.7
	Cliona cf. *celata*	12.7	8.7	8.3	13.0	10.0	6.7	5.0	5.0
	cf. *Stylopus australis*		3.3					4.7	3.3
	cf. *Tedania sp.*		7.3		3.3				
	Tethya burtoni		3.7			7.3			7.3
	Ciocalypta sp.						3.7	-3.3	
	Raspalia topsenti			4.3	4.0	6.0			4.3
	Lilac Demospongia D	3.7		9.3	7.3	6.7	10.3	3.7	
	Yellow Demospongia E			5.0				-5.0	6.3
	Orange honeycomb sponge							5.0	5.7
	cf. *Suberites perfectus*	3.7						4.0	9.0
	Orange lobed sponge			4.0	3.7	4.0		4.0	
Bryozoa	Catenicellidae	5.0			5.0	-3.7			
	cf. *Cellaria tenuirostris*	18.0			5.0				8.3
	Steginoporella neozelanica	15.3		9.3	12.3	13.7	13.0	8.0	10.0
	Encrusting bryozoan	10.3	8.0	3.7	3.3	5.0		9.3	5.3
	cf. *Margaretta barbata*	10.7	3.3						
Cnidaria	cf. *Aglaophenia* sp.			3.7		3.7			3.3
	Branching hydroid	-3.3		10.7		9.0	6.3	3.3	13.7
	Anthothoe albocincta		-3.7				3.7	10.3	14.7
	Culicea rubeola			6.7			3.3		
Ascidiacea	*Cnemidocarpa* sp.	3.7			-4.7				5.3
	Ascidiacea sp. A	4.0		8.3	10.0	9.3	17.0	21.0	26.3
	cf. *Synoicum otagoensis*	3.7						-5.7	
	Eudistoma sp.							3.7	5.3
	Didemnum (white)			4.0		3.3			
Bivalvia	*Perna canaliculus*				-4.7		-5.3	-4.0	
	Ostreidae sp.			4.7	3.3			5.3	8.7
Crustacea	*Jasus edwardsii*			4.0	6.0	8.0	4.0		7.0
Echinodermata	*Australostichopus mollis*	3.7			3.7		3.7	5.0	3.7

Spatial gradients in ΔAS along the Reef axis tended to follow those observed for AS during the baseline. That is, taxa that were more prevalent at the southern end of the Reef (e.g. branching hydroid, *Anthothoe albocincta*, Ascidiacea sp. A) tended to show greater net increases there (and vice versa – e.g. *Halopteris* sp., Catenicellidae, *Cliona* cf. *celata*). These countervailing patterns suggest that there has been no generalised shift in Reef conditions towards those that were associated with either end of the Reef axis during the baseline.

Changes in *Perna canaliculus*

Since, relative to the baseline, there has been an apparent decline in the mussel *P. canaliculus* across both dredging phase surveys (Figure 16), we examined the data compiled on this species more closely. Table 13 appears to suggest a decline in *P. canaliculus* abundance on the central to southern Reef transects, especially PR3 and PR4. Detailed transect data for this species on PR3, PR4 and PR7 is presented in Appendix 3.

Table 13 Transect abundance scores for *Perna canaliculus* over the five Pania Reef surveys to date. Shading proportional to cell value to aid visual interpretation. Transects in north to south order. Survey codes designate month and year.

Survey	PR1	PR2	PR5	PR3	PR6	PR4	PR7	PR8
A16	4	20	1	12	15	2	13	1
M19	7	16	6	7	17	8	1	0
F20	9	14	2	4	13	6	4	0
O20	6	18	4	1	6	0	5	0
M21	6	17	5	3	13	0	2	0

The significance of a decrease in *P. canaliculus* at PR7 since the baseline (Table 12) is offset by a minimum (AS 1) during the May 2019 baseline survey, framing the first baseline survey in 2016 as anomalously high at AS 13 (Table 13). While the reasons for this are unclear, the results of the following two baseline surveys at this transect were consistent with the later dredging phase results.

The minimum AS for *P. canaliculus* at transect PR6 in October 2020 has been explained by Sneddon and Dunmore (2021) as clearly due to the laid transect line missing a prominent reef crest (< 10 m water depth) with a dense mussel bed that has been recorded in every other survey to date (see depth profiles, Figure 7).

The effective disappearance of mussels from transect PR4 may have resulted from the transect missing slightly shallower reef crests in the middle of the transect that were recorded in May 2019 and February 2020 (see depth profiles, Figure 8 and Appendix 3). Although the data do appear to suggest a decline in *P. canaliculus* at transects PR3 and PR4, an overall decline on the Reef is refuted by the evidence from the transects where *P. canaliculus* has been historically abundant (PR2 and PR6). The monitoring data continue to indicate a high degree of consistency across surveys and dense healthy beds remain in evidence from the compiled photographic record (Figure 4 and Figure 7).

4.2.4. Multivariate statistical analysis

The range in community structure across the eight transects for the five surveys to date is represented by a non-metric multidimensional scaling (nMDS) plot of averaged transect abundance scores in Figure 17. The associated vector plot shows taxa that were correlated with the nMDS space[4]. The low to 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[5] and, most importantly, reliably portray general patterns and groupings of transect averages.

There was a distinct grouping pattern in the transect data. Six of the eight transects group together at the 48% level of similarity (LoS) with the remaining two (PR2 and PR5), grouped separately as effectively distinct clusters. Within the main cluster (Group A, Figure 17), there was a general north-south gradient in transects from top-right to bottom-left. The alignment of the vector plot with this nMDS axis confirms that the distribution of the listed taxa is related to location along the reef (as opposed to a more random variability of habitat characteristics across the monitored transects). This strongly reflects our prior observations of patterns of abundance for several of the same taxa along the reef axis. These had identified a declining coverage of kelp (*E. radiata*) and crustose coralline algae as the most conspicuous change moving south (Sneddon & Dunmore 2021). It was noted that a likely important influence on this community gradient was the greater inshore exposure to turbidity and suspended sediments from beach abrasion and wave resuspension processes.

It is an important feature of the nMDS that the points tend to group together based on transect rather than survey. This indicates that temporal variability has been less than the underlying spatial variability between transects. It further suggests that the nMDS is somewhat accommodating of the increasing comprehensiveness of successive survey data-sets but sensitive enough to consistently represent differences in community structure between points along the reef axis.

[4] 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.

[5] 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.

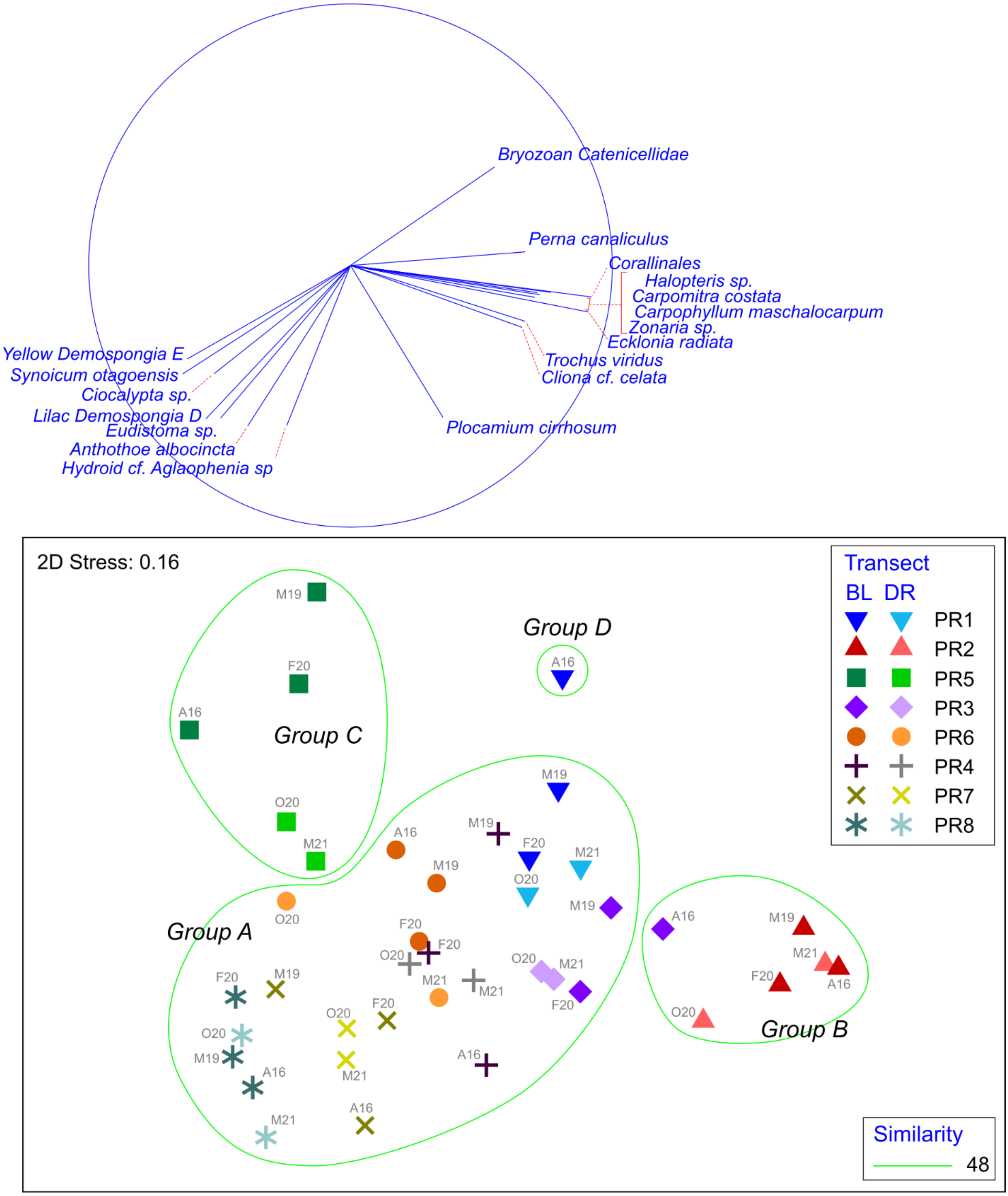

Figure 17. Differences in community structure between transects and surveys shown by non-metric multidimensional scaling (nMDS) plot of reef community data. BL=baseline (3 surveys); DR=dredging phase (2 surveys-lighter shade). Plot based on a Bray-Curtis similarity matrix of untransformed transect abundance 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.

Since the varying background turbidity and depositional environment along the reef is believed to be a key influence on benthic community composition, any consistent shift in transect points may be an indicator of fundamental change in such conditions. However, across all transects, there is little suggestion of a consistent trajectory of points since the baseline. Only for transect PR5 do the two dredging-phase survey points (O20 and M21) cluster separately to those of the three baseline surveys. At transects PR1 and PR3, a downward shift in the survey points can be seen after the second baseline survey in May 2019.

The absence of a generalised trend suggests that there has been no consistent or sustained change in community structure since the commencement of capital dredging activities in June 2020. While there was a tendency at several transects for the April 2016 survey point (A16) to be separated from the subsequent four, this possibly reflects the greater familiarisation of the survey team with the reef communities in subsequent surveys, together with refinements in methodology and approach.

SIMPER was used to further investigate features of the nMDS in Figure 17; specifically, what community changes drove the clustering patterns observed.

Group B, comprising all PR2 survey points, together with the 2016 survey of PR3, was set apart from the main cluster (Group A) by greater prevalence of coralline algae and kelp (*E. radiata*), cumulatively accounting for 13% of dissimilarity. Other taxa contributing to dissimilarity included greater prevalence of the alga *Carpophyllum maschalocarpum*, the sponge *Cliona* cf. *celata* and mussels (*P. canaliculus*), along with lower prevalence of the lilac sponge (Demospongia D), the bryozoan *S. neozelanica,* and the algae small-bladed red and *Halopteris* sp. The location of transect PR2 at Pania Rock subjects it to greater water movement and this is reflected in the relatively distinct community composition as well as lower observed levels of settled and entrapped silt.

Group C, comprising just the PR5 survey points, was set apart from Group A generally by lower prevalence of several algal taxa: *E. radiata, P. cirrhosum,* small-bladed red and encrusting corallines. It also had lower abundance of the lilac sponge but slightly greater abundance of a branching bryozoan (cf. *Cellaria tenuirostris*). These differences are likely to have arisen from a greater occurrence of mobile sand (Figure 12) and generally higher turbidity at the seabed (from field observations) than at other mid-reef transects.

Within Group C, the separation of the dredging phase surveys (O20 and M21) from those of the baseline appears to have been driven by small changes in a broad range of taxa. All but one of the key taxa contributing up to 40% of the dissimilarity had increased in abundance since the baseline and no single taxa contributed more than 5% to the total dissimilarity between data sets (Table 14). It is worth noting too that the three baseline surveys did not resolve as a distinct group; rather, the more recent surveys tend to have produced data sets of greater similarity (e.g. baseline survey F20 is more similar to the dredging phase surveys than it is to the other two baseline surveys). This suggests that the grouping may reflect either a change in background conditions over longer timescales or be an artefact of refinements in methodology.

Table 14 Taxa contributing most to dissimilarity between dredging phase (DR) and baseline (BL) data sets at transect PR5. Output from SIMPER routine, calculated from the Bray-Curtiss dissimilarity matrix, PRIMER v7. Average dissimilarity = 46.6.

	Average AS					
Taxa	**DR**	**BL**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Small-blade red alga	9.0	6.00	2.29	0.94	4.91	4.91
Lilac Demospongia D	11.0	2.67	2.22	3.00	4.77	9.68
Branching hydroid	11.5	3.33	2.18	3.22	4.67	14.35
Cliona cf. *celata*	8.0	0.67	1.97	5.67	4.21	18.56
Steginoporella neozelanica	15.0	7.67	1.93	2.31	4.14	22.71
Ceratosoma amoenum	7.0	5.33	1.88	10.23	4.03	26.74
cf. *Cellaria tenuirostris*	11.0	8.33	1.83	2.07	3.92	30.65
Sponge cf. *Tedania* sp.	7.0	6.67	1.47	1.63	3.14	33.80
Sponge cf. *Ciocalypta* sp.	11.5	12.67	1.42	1.26	3.04	36.84
Alcyonium cf. *aurantiacum*	5.5	0.33	1.42	1.75	3.04	39.88
Penion sulcatus	6.5	1.33	1.40	3.26	3.01	42.89

The taxa contributing most to the dissimilarity of the A16 community at transect PR1 (Figure 17, PR1 A16) from the subsequent surveys at this location were three bryozoans, *S. neozelanica*, encrusting bryozoans, and cf. *Cellaria tenuirostris*, along with the boring sponge (*Cliona* cf. *celata*) and the red alga *P. cirrhosum.* All of these were either absent or observed at much lower abundance in 2016.

Of the ten taxa contributing most to the separation of the three most recent surveys of PR1 and PR3 from the first two of the baseline (Figure 17), only four were shared by both transects. These included increases in *S. neozelanica,* the green grass-like alga and *Cliona* cf. *celata*. While changes in the prevalence of cf. *Cellaria tenuirostris* also contributed at both transects, this bryozoan had increased at PR1 while decreasing at PR3. A general downward progression on the nMDS plot is also indicated for transect PR6, with the outlying O20 survey point resulting from the transect missing a prominent reef crest at the 80 m mark (see Figure 7). Increases in *S. neozelanica* and *Cliona* cf. *celata* at PR6 were again among a range of taxa contributing to the change. A general increase in these two taxa on the Reef has been noted (Section 4.2.2) but their contribution to dissimilarity between surveys was not relatively much more than other changes observed. The green alga recorded greatest prevalence on the Reef over F20 and O20 (tAS of 44 and 50, respectively), so its increase predated the commencement of the dredging project. Overall, the abundance trends shared by the three transects and any inferred connection to the dredging project are quite weak at best.

Reef benthic communities: Key findings

The number of taxa recorded per transect has generally shown a steady increase across surveys, reflecting the greater comprehensiveness of the record allowed by more intensive use of still and video cameras by divers. This is driven mostly by scarce and cryptic taxa, which are less likely to be overlooked in more recent surveys.

Examination of the record for taxa abundant enough to be considered characteristic of the Reef, shows quite high variability in abundance between surveys, but with abundance scores generally at the upper end of historical ranges in the current survey. Possible reasons include:

- Real temporal trends in abundance for some species in response to environmental drivers, potentially including changes attributable to the dredging project.
- Seasonal population cycles
- Inter-annual variability or 'boom and bust' population cycles
- Increasing survey capability associated with a more comprehensive photographic record.
- Influence of greater underwater visibility in the current survey.

All of these are likely to have influenced the data record, with applicability varying across functional groups and individual taxa.

The strongest evidence for actual increases in abundance across surveys (and since the baseline) was for a bryozoan (*Steginoporella neozelanica*) and a sponge (*Cliona* cf. *celata*).

The only taxon to show an apparent decrease in abundance since the baseline surveys is the green-lipped mussel (*P. canaliculus*). However, closer examination of the record suggests that the change may relate to the patchy distribution of beds in relation to small variations in transect placement.

In the current survey, spatial gradients in the prevalence of different taxa along the Reef axis were consistent with those observed during the baseline.

Multivariate statistical analysis of benthic communities indicated that spatial variability in communities (along the Reef axis) has consistently exceeded temporal variability (across surveys). Although some changes across surveys have occurred, these have been quite subtle. There has been little consistency in changes across transects and the dredging phase surveys have not, for the most part, been distinctly different from the baseline.

4.3. Reef fish

The complete record of fish abundance from the current survey is presented in Appendix 4 (Table A4.1) where abundance scores for the current survey are contrasted with the average from the baseline. A generally greater number of fish species were observed than in previous surveys. These included all of those seen commonly on the Reef during the baseline. Species newly recorded in May 2021 were trevally (*Pseudocaranx dentex*; PR5 and PR7) and two species of triplefin (*Ruanoho decemdigitatus*, PR7 and *Karalepis stewarti*, PR8). Both triplefin species were observed as single individuals.

Table 15 shows the variation in total abundance scores (tAS) across surveys for fish species considered characteristic of the Reef. The greatest scores were recorded from the current survey for all characteristic species except the variable triplefin (*Forsterygion varium;* tAS 21) which was observed as more abundant in April 2016 (tAS 44). It is possible that misidentification of the similar banded triplefin (*F. malcolmi*) for *F. varium* in earlier surveys may explain the apparent discrepancy in numbers.

Table 15. Variation between surveys for fish species considered characteristic of Pania Reef (mean survey abundance score [sum of all transects] > 5). Shaded cells represent years of minimum abundance (multiple years shaded if the difference between them does not exceed 20% of the mean value). Similarly calculated maxima are designated by bold font.

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

The generally higher tAS values for fish species in the current survey is likely to relate to better underwater visibility conditions, although the progressively more comprehensive photographic and video record will also have contributed. Since most of the fish in the Reef inventory are highly mobile, the ability of the diver to see further ahead on the transect means that more of the fish present will be observed. Similarly, cryptic or camouflaged benthic species are more likely to be detected in clearer water. It is important to note, however, that underwater visibility and related factors, 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 current survey, fish were observed in greater numbers than in previous surveys and generally more species were recorded at each transect than during the baseline.

Three fish species new to the Reef inventory were recorded although none of these were present as more than a few individuals.

The relatively better conditions of underwater visibility in the current survey are likely to have been a key factor in the greater fish numbers observed.

5. SUMMARY AND CONCLUSIONS

Although the data have indicated changes in abundance for some reef taxa, the pattern of these changes across surveys has not implicated stressors associated with the capital dredging project as key drivers. Nor have such changes been accompanied by discernible changes in physical habitats.

Diver and photographic records continue to indicate that there has been no observable change in settled silt on Pania Reef since the baseline surveys. Even though swell and surge conditions on the Reef were less than has been experienced in most previous surveys, there was no evidence of recently deposited silt veneers, likely due to wave action in the weeks preceding the survey.

As was the case during the baseline surveys, the presence of silt on the Reef was widespread only in a form trapped by or embedded within textured surfaces, principally those of encrusting reef biota. While it is very difficult to measure or otherwise quantify the prevalence of such silt, the visual record continues to suggest no conspicuous change from the baseline condition. Similarly, despite quite high temporal variability, the prevalence of sand across all transects showed no indication of a discernible change since the baseline.

Very few taxa new to the Pania Reef inventory were observed during the current survey and these were limited to organisms at population densities too low to rule out their undetected presence during the baseline. Furthermore, inventory taxa that were absent from the current survey record had all been observed as very low in abundance during the baseline.

Analysis of abundance scores across the eight transects for the entire Reef taxa inventory showed that most changes relative to the baseline were positive. Rather than suggesting an increase in the prevalence of most taxa, this reflects an increase in the comprehensiveness of the record across successive surveys, driven by greater use of photographs and video. This effect is also reflected in a progressively greater apparent taxa richness at all transects (meaning that scarce and inconspicuous organisms are less often being overlooked).

While allowing for the trend described above, there do appear to have been changes in the prevalence of some taxa across surveys. A close examination of the data has indicated that these were mostly due to what appear to be longer-term trends or the result of high background inter-annual or seasonal variability. However, an increase in the abundance of the bryozoan *Steginoporella neozelanica* has coincided with the commencement of dredging and spoil disposal activities and greater prevalence in the current survey was indicted for encrusting bryozoans and a sponge (*Cliona* cf. *celata*).

An investigation into an apparent decline in mussels (*Perna canaliculus*) on three transects suggested that this has likely resulted from the patchy distribution of the beds. The two transects that have historically supported the most abundant mussel populations have shown no decline and beds continue to appear healthy. Transects where change is suggested by the data have not been those where dense beds occurred but rather the occurrence of isolated individuals.

For the taxa most characteristic of the Reef, there have been no patterns in recorded abundance across surveys that suggest a clear decrease in relative prevalence since the commencement of capital dredging.

Multivariate statistical analysis of the ranked abundance data indicated that, across all surveys to date, spatial variability in benthic community structure has remained greater than temporal variability. The spatial gradients in communities along the Reef axis established by the baseline have been maintained in subsequent surveys. Furthermore, the analysis has shown no consistent shift in structure across transects since the capital dredging project began.

While better underwater visibility was potentially the factor contributing most to greater fish abundance in the current survey, the continuing presence, over multiple transects, of all characteristic species from the baseline inventory suggests there has been no ecologically significant change in fish populations or diversity since the baseline.

6. ACKNOWLEDGEMENTS

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8. 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™ 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 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 (May 2021) survey. Transects in north to south order.

Table A2.1 Algae and invertebrates.

	Survey	Baseline mean								May 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	39	2	33	18	24	16	1
Carpophyllum maschalocarpum	Flap jack		16.7								16						
Halopteris sp.		1.3	11.3							8	17		7			1	
Zonaria sp.			6.7								6						
Carpomitra costata		1.0	11.7		1.0					2	6				1		
Dictyota sp.																	
Rhodophyta	**Red algae**																
Corallinales	Encrusting corallines	14.0	36.0		29.3	11.0	8.0	2.0	0.3	19	40	1	28	17	22	5	2
Plocamium cirrhosum		12.7	13.3	2.3	22.3	16.0	23.3	18.3	12.0	15	18	3	18	13	25	19	16
Pterocladia capillacea			1.7								4						
Rhodophyta sp.	Small bladed red algae	1.7	3.3	6.0	4.7	12.7	19.7	13.0	13.0	1		1	6	7	4	6	7
cf. *Hildenbrandia* sp.	Red encrusting algae		3.0			0.3				1	3						
Red fine algae	Red fine algae	5.0	0.3		1.7												
Chlorophyta	**Green algae**																
Chlorophyta	Green algae (grass-like)	3.7	4.3		7.7						6		10				
Porifera	**Sponges**																
Ecionemia alata	Grey vase sponge	14.3	19.7	16.3	24.3	18.3	25.7	16.0	21.3	16	17	15	29	30	23	16	26

	Survey	**Baseline mean**								**May 2021**							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Cliona cf. *celata*	Yellow boring sponge	5.3	16.3	0.7	12.0	4.0	8.3	2.0	3.0	18	25	9	25	14	15	7	8
cf. *Stylopus australis*	Red emergent/encrusting sponge		0.7		0.7	0.7		0.3	3.7	1	4	1	2	2		5	7
cf. *Tedania* sp.	Orange encrusting sponge	2.0	3.7	6.7	0.7	10.3	2.0	4.7	8.7	5	11	5	4	8	5	3	7
cf. *Hymeniacidon* sp.	Orange massive sponge		1.7					0.3	0.3								1
Tethya bergquistae	Pink golf ball sponge	0.7	0.3	1.0	0.3	4.0	1.7	5.7	1.7	3		4		3	4	5	7
Tethya burtoni	Orange golf ball sponge	2.0	1.3	2.7	5.0	1.7	8.0	2.7	9.7	5	5	4	6	9	5	4	17
Ciocalypta sp.	Yellow tubular sponge	16.0	7.0	12.7	13.3	14.3	12.3	20.3	18.7	17	6	12	12	13	16	17	21
cf. *Thorecta* sp.	Lobed grey sponge	0.3		0.3	0.3	5.0	1.7	5.3	6.0		1	1		1	1	5	3
Raspailia topsenti	Orange finger sponge	12.3	2.7	9.7	12.0	15.0	12.7	13.3	13.7	10		14	16	21	12	12	18
Demospongia A (White/green)	White/green massive sp		0.3	0.7		1.7		0.3	1.0					4	4	3	3
Demospongia B (Grey)	Grey lumpy massive sp		1.7	1.0	2.3		0.7	0.3	0.3	3	4	2	3	2	6	1	3
Demospongia C (Pink)	Pink thick encrusting sp		0.3	0.3	4.3	0.3		1.7					1				2
Demospongia D (Lilac)	Lilac spiky sponge	1.3	1.0	2.7	9.7	14.3	13.7	15.3	18.0	5	2	12	17	21	24	19	20
Demospongia E (Yellow)	Yellow lumpy massive sp			4.0	1.3	7.7	3.7	11.0	7.7	2		9	3	8	2	6	14
Demospongia F (Maroon)	Maroon massive sponge	0.7		0.3		0.7	0.3	1.7			1				2		1
Latrunculia cf. *procumbens*	Green mushroom-like sp.		2.0		1.0	1.0	0.7	1.0					5	3	1	2	
cf. *Ircinia novaezealandiae*	Grey encrusting sponge	0.3	0.3	0.7			0.7					1		2			1
cf. *Polymastia massalis*	Brown massive sponge	0.7		0.3		0.7		0.7	1.0			2		1	1		4
cf. *Aaptos globosa*	Globose sponge	1.0	0.3	0.7		3.3	1.0	4.0	0.3					1	4	6	3
cf. *Iophon minor*	Cream branching sponge							0.3	3.0							1	11
Orange honeycomb sponge	Orange honeycomb sponge								1.3			1			2	5	7
cf. *Dendrilla rosea*	Pink erect conulose		0.3	0.3		0.3					1		1	1			
Callyspongia cf. *annulata*	Mauve finger sponge				0.3				2.0			2	1	3			2

	Survey	Baseline mean								May 2021							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
cf. Suberites perfectus	Grey smooth sponge	0.3	0.7	0.7	1.0		1.0		1.0	4		3	3	3	4	4	10
Orange lobed sponge	Orange lobed sponge				0.3					2		4	4	4	2	4	2
cf. *Iophon minor*	Yellow finger sponge				0.3			2.0						1		3	
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	19	10	5	21	4	7	4	1
cf. *Cellaria tenuirostris*	Branching bryozoan	8.0	1.0	8.3	9.0	5.0	2.3	7.3	0.7	26	1	10	14	7	5	7	9
cf. *Caberea zelandica*	Erect fan bryozoan		0.3	0.3	1.3	2.0	1.3	1.0	0.3	2		1	8	5	2	1	2
cf. *Steginoporella* sp.	Orange tube bryozoan	11.7		7.7	7.7	11.3	6.0	6.0	10.0	27		17	20	25	19	14	20
Encrusting bryozoan	Encrusting bryozoan	7.7		0.3	0.7			5.7	0.7	18	8	4	4	5	2	15	6
cf. *Margaretta barbata*	Erect bryozoan	0.3	1.7	0.3					0.3	11	5						
Cnidaria	**Hydroids, anemones, corals**																
cf. *Aglaophenia* sp.	Feather hydroid	1.0	4.7	1.3	8.3	1.3	3.0	8.3	13.7	1	3	5	6	5	2	7	17
Solanderia ericopsis	Hydroid tree	0.7		1.3	0.3	0.3	1.0		0.7		1	1	1	4			1
Amphisbetia bispinosa	Mussel beard hydroid	0.7	1.3	1.3	5.0	5.7	1.0	0.7		1		2	2	10			
Branching hydroid	Branching / bushy hydroid	6.3		3.3	1.0	10.0	1.7	5.7	4.3	3		14	4	19	8	9	18
Ectopleura sp.	Solitary hydroid						0.3		0.3							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	1			2	4	24	31
Solitary anemone Undescr.	Solitary anemone	1.3					0.3	2.3		3	1		2	2	1	1	2
Alcyonium cf. *aurantiacum*	Common soft coral			0.3		2.7	0.3	3.3	4.0			3	3	2		1	11
Culicea rubeola	Colonial stony coral	2.7	2.3	1.3	3.7	4.3	0.7	1.0	0.7	5	5	8	3	5	4	1	3
Monomyces rubrum	Cup coral (solitary)								0.3								
Corynactis australis	Jewel anemone		0.3			0.3					1	1				1	6

	Survey	Baseline mean								May 2021							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
cf. *Parazoanthus elongatus*	Orange zoanthid			0.3		0.7					2						
Fine hydroid	Fine hydroid	1.0	2.3	5.0	1.0	1.0	0.7	1.0	3.0		2						
cf. Epizoanthus sp.	White zoanthid													1		1	
Ascidiacea	**Tunicates, sea squirts**																
Pyura spinosissima	Sea tulip	0.7	0.7				1.0	1.7	3.0							2	2
Cnemidocarpa sp.	Saddle squirt	3.3	5.3	3.7	9.7	6.0	7.0	7.7	10.7	7	7	6	5	7	8	7	16
Ascidiacea sp. A	Small red ascidian		1.7	0.7		5.7	1.0	8.0	7.7	4		9	10	15	18	29	34
cf. *Synoicum otagoensis*	Grey colonial ascidian	1.3		4.3	1.7	6.0	2.0	13.7	13.0	5		3		3	3	8	13
Eudistoma sp.	White colonial ascidian	1.3	1.7	1.0	0.3	5.3	2.7	11.3	11.7	1		2		8	3	15	17
cf. *Didemnum densum*	Cream colonial ascidian		0.3	0.7	0.3		3.3	4.0	4.0	1			1	3	4	7	8
Didemnum species complex	White didemnum		1.0		2.0	4.7	6.7	3.0	6.7			4	5	8	4	4	9
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	17	5	3	13		2	
Atrina zelandica	Horse mussel			1.0					0.7						1	1	
Ostreidae sp.	Flat oyster	0.7		1.3	0.7		0.7	1.7	1.3	1		6	4	2	1	7	10
Bivalve (attached unid)	Attached bivalve	2.3	0.3	0.3				0.3		1	2				2	4	2
Polyplacophora	**Chitons**																
Cryptoconchus porosus	Butterfly chiton				0.7	0.3	0.3			1	1						
Gastropoda	**Snails, sea slugs**																
Trochus viridis	Green top shell	1.0	6.0		0.7	0.7	0.7	0.7	1.0	2	5	2	6	1	2	2	2
Calliostoma tigris	Tiger top shell	0.7			1.3	1.0		1.0		1		1			2	3	4
Calliostoma pellucida	Top shell			0.3	0.3		0.3		0.3			3		2	1	2	2
Calliostoma punctulatum	Beaded top shell				0.3	0.3		1.0	1.0			3			1	4	6

	Survey	Baseline mean								May 2021							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Cookia sulcata	Cook's turban shell	2.0	4.3		0.3					3	12						
Astraea heliotropium	Circular saw shell		0.7		0.7					1							
Argobuccinum pustulosum	Swollen trumpet shell				0.3	0.7	0.7										
Dicathais orbita	White rock shell	0.7	4.0		0.7						5						
Buccinulum linea	Lined whelk	0.7	1.3	0.3		1.0		0.7	1.3	2	1		1			2	2
Penion sulcatus	Siphon whelk	3.0	1.3	1.3	4.0	3.3	3.7	3.0	2.0	1	2	7	5	2	3	4	5
Cominella adspersa	Speckled whelk	0.3								2		1				2	
Whelk (Muricidae unid)	Unid. whelk	0.3	0.3							4	1	2	2		2		3
Cabestana spengleri	Spenglers trumpet shell		0.7								1						
Ceratosoma amoenum	Clown nudibranch	3.3	1.7	5.3	3.7	5.3	4.0	3.0	4.3	3		7	5	5	5	4	2
Mayena australasia	Australasian triton								0.3								1
Dendrodoris denisoni	Nudibranch									2							
Cantharidus sp.	Opal top shell																
Scutus breviculus	Shield slug														1		
Cephalopoda	**Octopus, squid**																
Octopus maorum	Octopus, squid	0.3				0.3											
Crustacea	**Crabs, lobster, barnacles**																
Jasus edwardsii	Crayfish		0.7					0.7	2.0		1	4	6	8	4	2	9
Paguridae	Hermit crab	2.7	0.3	2.7	2.3	4.0	1.7	2.0	3.3	1		5	4	1	5	2	4
Guinusia chabrus	Red rock crab				0.3			0.3	1.0		1				2	1	3
Barnacle unid.	Barnacle		1.0		0.3			0.3					1				
Notomithrax minor	Decorator crab																
Echinodermata	**Sea cucumbers, sea stars, urchins**																
Australostichopus mollis	Sea cucumber	3.3	2.3		1.3	3.7	0.3	8.0	2.3	7	2	2	5	4	4	13	6

	Survey	**Baseline mean**								**May 2021**							
Taxon	**Common name / description**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**	**PR1**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Patiriella regularis	Cushion star							0.3								1	
Pentagonaster pulchellus	Biscuit star																
Astrostole scabra	7-armed sea star		0.3		0.3	0.3		0.3	1.3				1			1	1
Coscinasterias muricata	11-armed sea star		0.3		0.3	0.3		0.7			1					1	
Ophiopsammus sp.	Snake star	0.3		0.3						1							
Evechinus chloroticus	Kina		2.7			1.0				2	5						

Appendix 3. Investigation of apparent decreases in abundance of *Perna canaliculus* since the baseline on transects PR3, PR4 and PR7.

To further examine the apparent decline in mussels in transects on the central to southern Reef (PR3, PR6, PR4 and PR7; excluding PR8), the relationship of categorical abundance to water depth is plotted for the baseline and dredging phase surveys in Figure A3.1. While the dredging phase data points generally overlie those of the baseline, there were proportionately less points where mussels were observed in shallow to mid-range water depths (< 14 m). This is illustrated in Table A3.1 where the percentages of 10-m transect intervals in each of three depth bands was almost identical between baseline and dredging phase surveys, but the mean abundance scores for *P. canaliculus* were notably less in the latter.

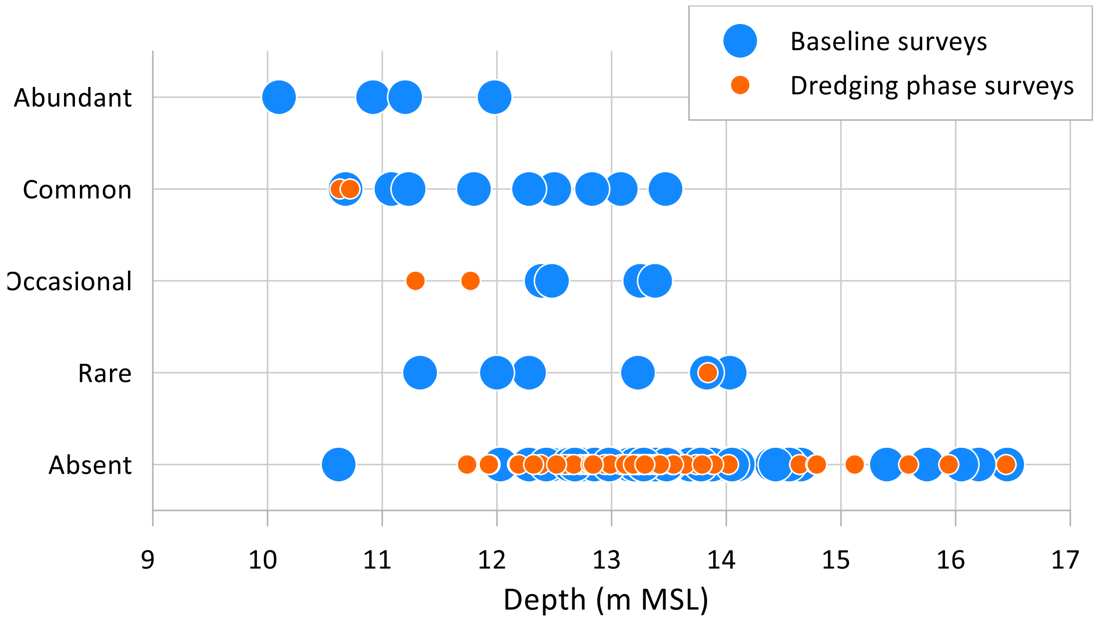

Figure A3.1 Water depth vs categorical abundance of *Perna canaliculus* for transects PR3, PR4 and PR7 over all surveys to date. Each symbol represents a 10-m transect segment with depths interpolated from values recorded at distance tags and adjusted for tidal variation.

It is worth noting, however, that the depth values in Figure A4.1 and Table A4.1 are a fairly coarse measure since they are average values calculated from the end depths for each 10-m interval along the transect. Hence, this does not allow for possible reef outcrops of lesser depths occurring entirely within an interval. The raw depth and categorical abundance data for the three transects are listed in Table A3.2. It is noteworthy that the incidence of mussels assessed as 'common' or 'abundant' did not occur at the same points along transects PR3 and PR4, even during the baseline surveys. This patchy distribution of mussel beds suggests that the apparently decreasing trend at these transects could have arisen randomly, especially in light of the stable higher abundance at PR2 and PR6 (see Section 4.2.3).

Table A3.1 Summary data for the prevalence of mussels collectively across transects PR3, PR4 and PR7 for the baseline and dredging phase surveys. 'Int.' refers to 10-m transect intervals (10 per transect). $\overline{AS}$ = mean AS. Depth band refers to the average depth across each interval calculated from the end points.

Depth band	Baseline surveys (n=3)				Dredging phase surveys (n=2)			
	#Int.	**%Int.**	**ΣAS**	$\overline{AS}$	**#Int.**	**%Int.**	**ΣAS**	$\overline{AS}$
< 12 m	10	8%	29	2.9	7	9%	10	1.4
12-14 m	67	56%	27	0.4	45	56%	1	0.0
> 14 m	13	11%	1	0.1	8	10%	0	0.0

Table A3.2 Patterns of categorical abundance for *Perna canaliculus* for transects PR3, PR4 and PR7 across all surveys to date. Numerical values are water depth (MSL) at the nodes between 10-m transect intervals. Shading (progressive with abundance) highlights where mussels were observed.

Transect	Distance	0	10	20	30	40	50	60	70	80	90	100	AS
PR3	**Apr-16**	14.8	14.5	14.3	13.9	13.2	13.3	13.7	13.2	11.8	11.8	8.4	
			-	-	-	-	O	-	-	C	C	A	12
	May-19	14.2	12.8	9.1	12.2	14.2	13.5	13.0	14.3	13.8	13.6	14.3	
			C	A	-	-	-	-	-	-	-	-	7
	Feb-20	16.7	16.3	15.3	13.9	13.2	14.2	13.3	13.6	13.5	11.7	10.8	
			-	-	-	-	-	-	-	-	-	A	4
	Oct-20	16.8	16.1	15.1	14.2	13.3	13.8	13.9	13.6	13.5	12.8	11.1	
			-	-	-	-	-	R	-	-	-	-	1
	May-21	15.1	14.5	13.3	13.8	13.1	12.4	14.1	13.0	13.0	11.4	9.9	
			-	-	-	-	-	-	-	-	-	C	3
PR4	**Apr-16**	12.9	13.0	13.2	12.8	12.7	13.3	12.9	13.7	13.1	13.5	11.3	
			-	-	-	-	-	-	-	-	-	O	2
	May-19	14.0	13.6	14.2	12.1	13.0	11.0	13.6	12.6	12.0	13.0	11.1	
			-	-	-	-	A	R	C	-	-	-	8
	Feb-20	13.6	13.8	12.0	13.0	11.9	13.0	13.4	13.2	13.5	13.8	8.3	
			-	-	-	O	-	R	-	-	-	C	6
	Oct-20	13.1	13.6	12.9	12.3	12.4	13.1	13.3	13.3	13.2	12.9	10.9	
			-	-	-	-	-	-	-	-	-	-	0
	May-21	13.9	13.3	13.7	12.1	12.2	12.9	12.6	13.7	13.0	13.4	12.5	
			-	-	-	-	-	-	-	-	-	-	0
PR7	**Apr-16**	14.4	13.2	12.6	12.3	14.1	14.0	13.7	13.1	12.6	12.0	10.5	
			-	-	-	-	R	R	O	C	C	C	13
	May-19	16.4	16.1	16.1	14.8	13.4	12.6	13.8	13.3	13.2	12.6	11.5	
			-	-	-	-	-	-	-	-	-	R	1
	Feb-20	15.1	13.8	12.8	12.5	13.5	13.5	13.1	12.3	11.8	10.9	10.5	
			-	-	-	-	-	-	-	-	R	C	4
	Oct-20	15.2	15.0	13.0	12.3	12.3	13.3	13.5	12.7	12.3	11.2	10.2	
			-	-	-	-	-	-	-	-	O	C	5
	May-21	15.9	16.0	13.6	12.8	12.9	13.7	14.1	13.5	12.2	11.3	11.3	
			-	-	-	-	-	-	-	-	-	O	2

Appendix 4. 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 (May 2021) survey. Transects in north to south order.

	Survey	Baseline mean								May 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	15	6	15	12	24	12	9	1
Parapercis colias	Blue cod	6.7	2.7	3.3	4.0	3.7	2.7	9.3	7.3	6	11	9	7	6	5	8	13
Pseudolabrus miles	Scarlet wrasse	2.7	6.7	1.3	7.3	5.7	2.3	3.3	1.0	1	1	1	11	1	1	5	8
Notolabrus celidotus	Spotted wrasse	2.3	5.3	1.0	4.3	3.7	1.3	2.0	3.7		3		4	5	3	1	11
Forsterygion varium	Variable triplefin	2.0	5.7	0.3	5.7	3.0	1.0	3.3	2.0	1	3		4	1	5	6	1
Scorpis lineolatus	Sweep	2.0	2.7	2.0	10.7	3.0	1.0	0.7	0.3		1		4	21	2	1	
Scorpaena papillosa	Dwarf scorpion fish	2.7	2.3	2.0	1.7	1.7	1.3	2.0	0.3	7	5	4	1	5	3	3	4
Parika scaber	Leather jacket	5.7	3.3	0.3	2.3	0.7	0.3	0.7		3	1	3	8	3		4	
Cheilodactylus spectabilis	Red moki	0.3	1.0	1.0	3.3	2.0	0.3	0.3			7	2	3	5	3		4
Notolabrus fucicola	Banded wrasse	0.3	1.3		1.0	2.3	0.3	1.0	0.3	1	6	4		2		1	
Nemadactylus macropterus	Tarakihi	0.3			1.0	2.0	1.0		1.0		1	1		3			4
Trachurus sp.	Mackerel		1.0			3.0					1						
Hypoplectrodes huntii	Banded perch	1.0	0.3		0.3	1.3		0.3		4	3	2	2	4	5	2	6
Forsterygion malcolmi	Banded triplefin	0.3	0.3			0.7	0.7	0.3		1	3	2	1	4	1	2	8
Forsterygion lapillum	Common triplefin	0.3	0.3	1.0		0.3			0.3				1				
Ruanoho whero	Spectacled triplefin	0.3			0.7	0.7			0.3		1	1				4	1
Latridopsis ciliaris	Blue moki		0.7		0.3				0.3								
Odax pullus	Butterfish/Green bone	0.3	0.7								1		2	1			

Survey		Baseline mean								May 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								1				
Aplodactylus arctidens	Marble fish	0.3			0.3						1		1				
Forsterygion maryannae	Oblique triplefin				0.7												
Pagrus auratus	Snapper		0.3		0.3						1						
Forsterygion flavonigrum	Yellow-black triplefin	0.3															
Notoclinops segmentatus	Blue-eyed triplefin		0.3								4						
Upeneichthys lineatus	Goat fish							0.3				6				1	
Myliobatis tenuicaudatus	Eagle ray						0.3										
Hippocampus abdominalis	Sea horse											1					
Conger verreauxi	Conger eel																1
Pseudocaranx dentex	Trevally											1				1	
Karalepis stewarti	Scaly-headed triplefin																1
Ruanoho decemdigitatus	Long finned triplefin															1	