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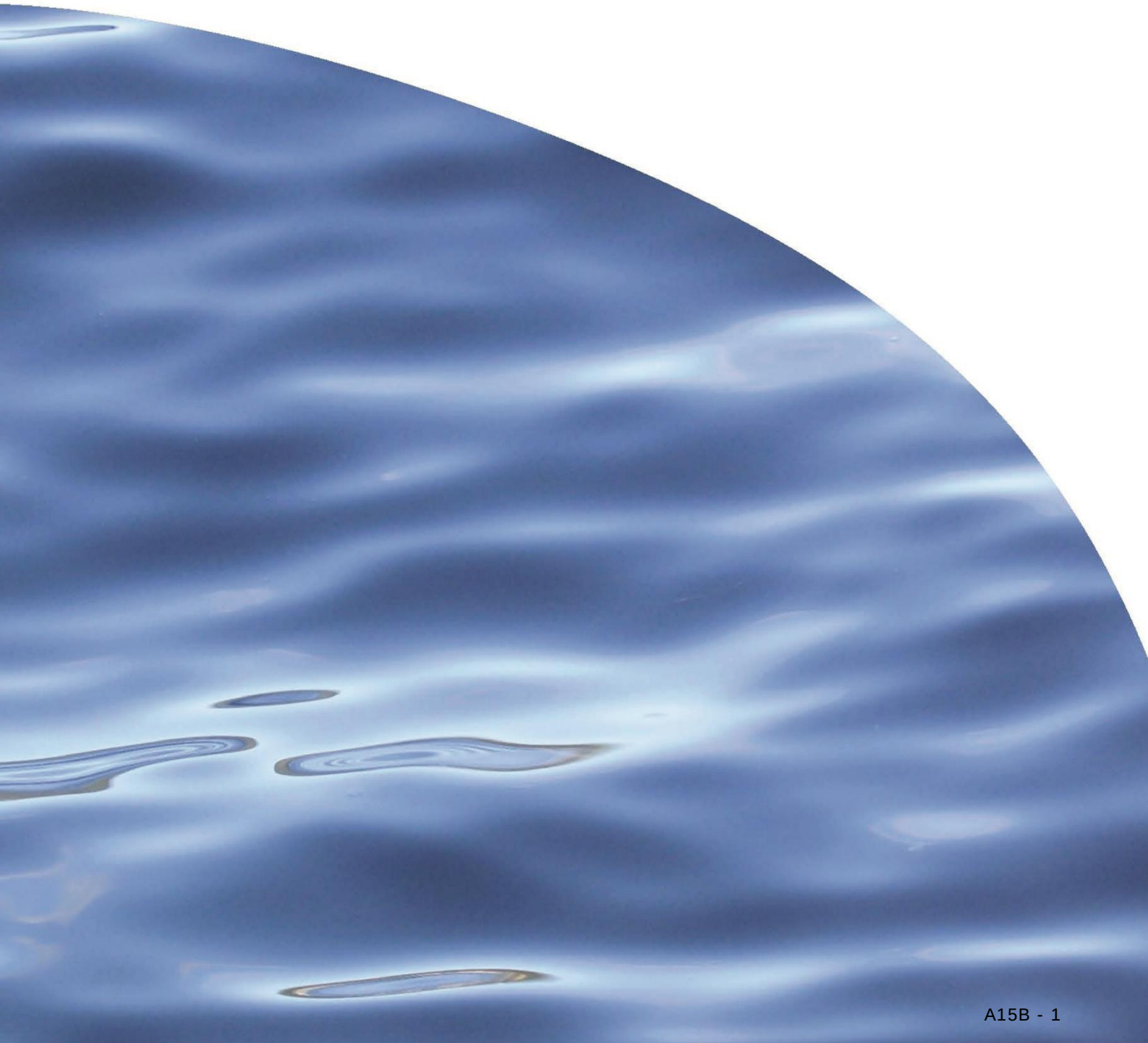
LYTTELTON HARBOUR AND BANKS PENINSULA SHORELINE REEF ECOLOGY: FIELD SURVEY DATA REPORT (FEBRUARY 2016)



LYTTELTON HARBOUR AND BANKS PENINSULA SHORELINE REEF ECOLOGY: FIELD SURVEY DATA REPORT (FEBRUARY 2016)

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Prepared for Lyttelton Port of Christchurch Ltd

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. CONTEXT AND SCOPE

Lyttelton Port of Christchurch Ltd (LPC) proposes to deepen and extend its existing dredged approach channel in Lyttelton Harbour. The Cawthron Institute was contracted by LPC to conduct field surveys along the Banks Peninsula coastline of Pegasus Bay and within Lyttelton Harbour to characterise the benthic substrate and ecological communities, as part of the production of a full Assessment of Environmental Effects (AEE) for the dredging and spoil disposal operations.

This data report collates the findings from subtidal and intertidal benthic field surveys conducted over 22–29 February 2016. These results will be incorporated, interpreted and discussed in full in the associated AEE report (Sneddon et al. in preparation) for the proposed dredging and spoil disposal operations.

2. METHODS

2.1. Subtidal survey

A subtidal survey of hard substrate habitats (i.e. rocky reefs) was conducted over 22–29 February 2016 at 22 sites along the Banks Peninsula coastline of Pegasus Bay and within Lyttelton Harbour (Figure 1). Sites were selected from those recommended by the LPC Capital Dredge Technical Advisory Group (TAG) and were classified into four general geographical areas:

- Banks Peninsula outer coast (hereafter BP)
- The inlet of Port Levy (PL)
- The inlet of Pigeon Bay (PB)
- The coastline within Lyttelton Harbour (LH).

Within each of these four areas, between 4 and 9 sites were selected to maximise spatial coverage of the area during the fieldwork period (Figure 1). While the sites assigned by the TAG were used for guidance, decisions on final site location were made according to direct observation (by side-scan sonar and/or diver) of suitable reef habitat. Site spatial arrangement is represented in Figure 1, with site coordinates, water depths and sampling dates provided in Appendix 1.

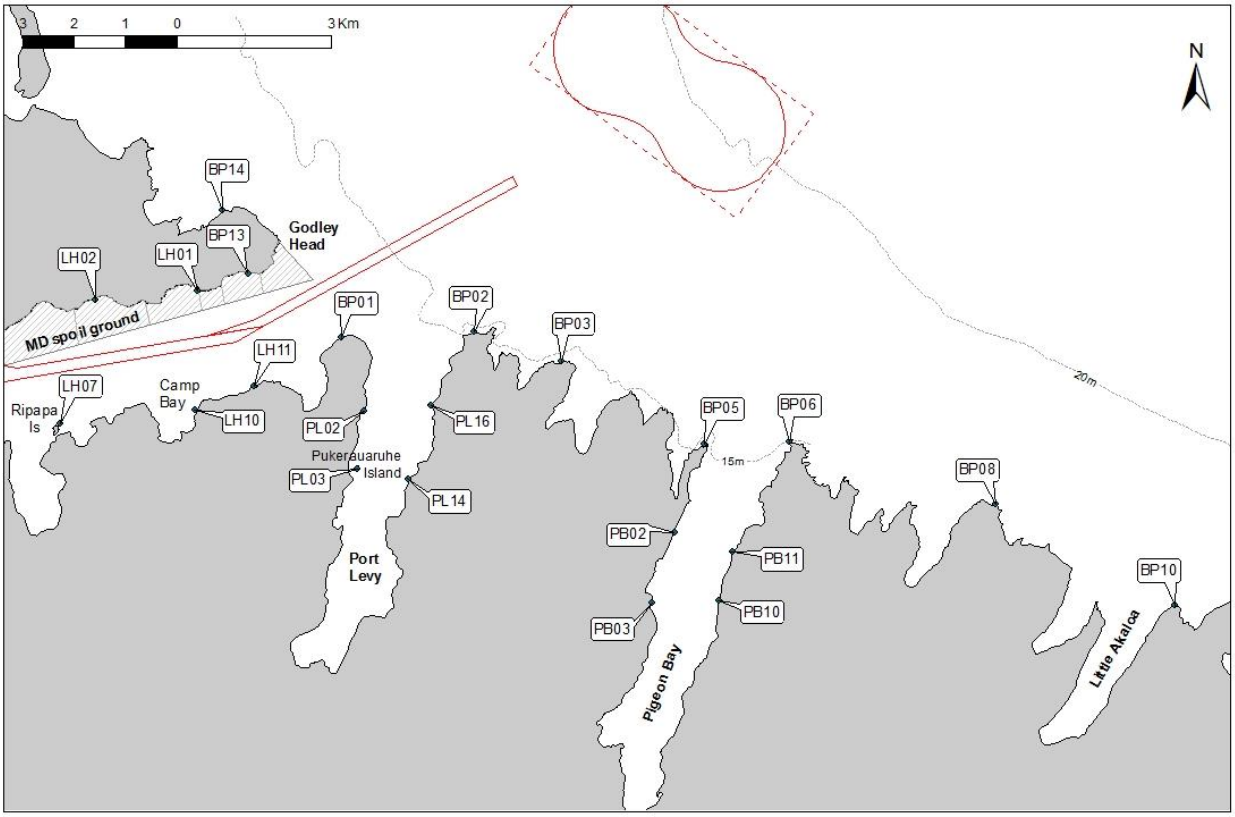

Figure 1 Map of subtidal survey sites. Sites were classified in relation to four main areas: Banks Peninsula outer coast (BP), Port Levy (PL), Pigeon Bay (PB) and Lyttelton Harbour (LH).

Subtidal survey methodology was based on standard quadrat and transect sampling using scientific SCUBA divers (Kingsford & Battershill 1998), allowing comparisons to be made with earlier surveys (Schiel & Hickford 2001; Shears & Babcock 2007).

At each site a 100 m down-shore transect line was positioned perpendicular to the shore, by anchoring one end onto high shore rocks and the other end (offshore) to the seabed using a shot weight (Figure 2). The GPS coordinates of both ends of the transects were recorded to allow relocation for repeat surveys. The dive surveys were conducted along three subtidal transect lines running transversely out from the down-shore transect at three nominal depth ranges and roughly parallel to shore:

i. **Deep transect (hereafter 7 m)**: between 6–8 m depth and 30 m in length, running near maximum extent of non-coralline macroalgae.

ii. **Shallow transect (hereafter 4 m)**: between 3–5 m depth and 30 m in length, within kelp forest habitats (where these were present).

iii. **Littoral fringe transect**: between 0–1 m depths (relative to chart datum; CD) and 50 m long, within the shallow subtidal.

Transects at all depths were located within nominal depth ranges (as above) rather than at precise depths. The reason for this is that the three-dimensional (and

sometimes near-vertical) structure of the reef did not allow precise depth control along a transect line. There was also some variation in the depth of the target habitats from site to site due to changes in substrate and exposure characteristics and it was considered important to survey habitats that were generally comparable between sites. At each site, allowance was made for tidal state to adjust general target depths for the transects. This was especially important for the littoral fringe transects, with a difference between chart datum and mean sea level (MSL) of approximately 1.3 m. The survey period coincided with a period of neap tides.

Along each 4 m and 7 m depth transect, eight 1 m^2 quadrats were haphazardly placed, determined by a pre-set interval of ~4 m between consecutive quadrat centres, with two divers alternating along the 30 m transect line. Because of the deeper extent of reef substrate at BP sites, it was possible to survey both shallow (4 m) and deep (7 m) transects at all sites, with the exception of BP13 where only a shallow transect could be sampled. Whereas, within areas LH, PL and PB, it was not possible to survey the 7 m transect due to the absence of suitable rocky reef habitats in that depth band.

For each quadrat, the following data were recorded:

- Water depth (from wrist-mounted dive computers)
- An estimate of the percentage cover of substrate type: bedrock (consolidated rock), boulders (>256 mm), cobble (64–256 mm), sand (2–0.5 mm), silt (<0.5 mm) and shell hash
- An estimate of the percentage cover of canopy forming and understory algae
- Estimates of percentage cover of encrusting invertebrates (e.g. sponges, ascidians, mussels)
- Counts of solitary epifauna (e.g. snails, sea urchins, seastars).

At each (50 m) littoral fringe transect, divers counted and measured large invertebrate and mahinga kai species within a 1 m band (i.e. over an area of 50 m^2). Due to the effective absence of kina (*Evechinus chloroticus*) in this depth range, the targeted species were limited to black foot pāua (*Haliotis iris*) and kaakara or Cook's turban (*Cookia sulcata*). Pāua were counted and measured using digital logging callipers, whereas Cook's turbans were only counted and at PB they were only recorded at four of the nine sites (BP01, BP03, BP10 and BP14). Quadrat methods could not be used for this zone due to shallow water surge conditions at most sites and the presence of large macrophytes in constant movement.

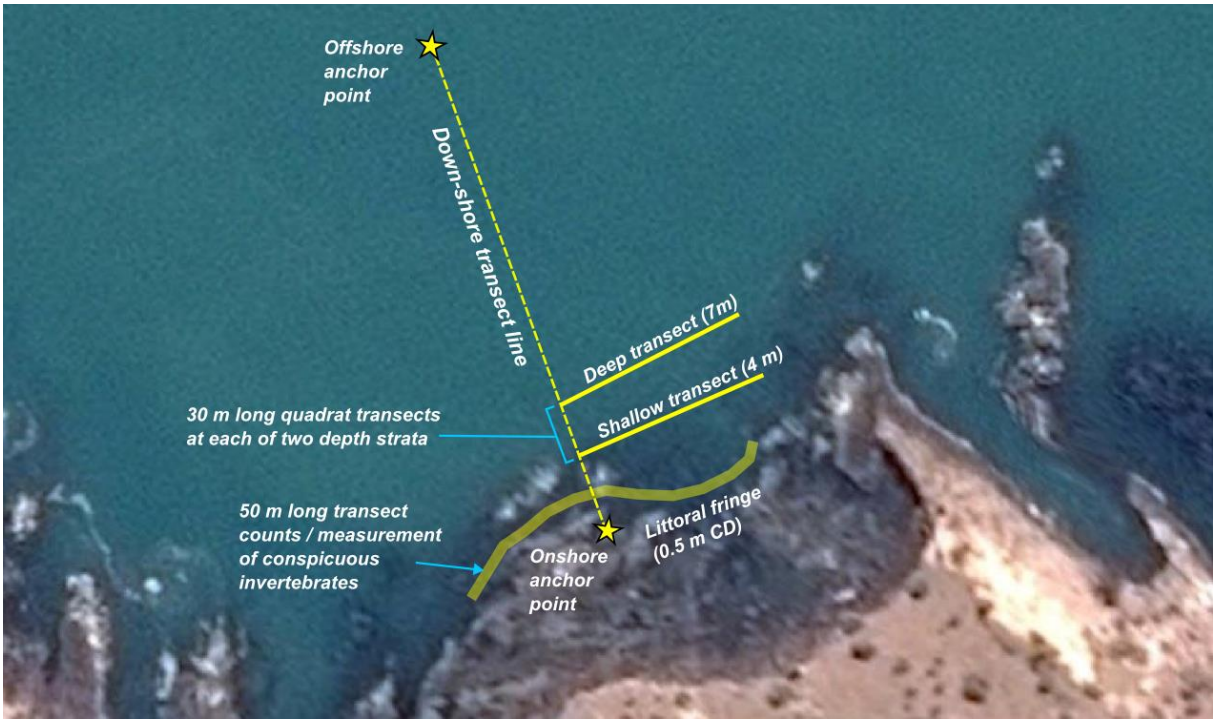

Figure 2 General layout of subtidal shoreline transects used to characterise reef habitats.

2.2. Intertidal surveys

Intertidal biological communities were surveyed semi-quantitatively at five sites at low tide during February 2016 (Appendix 2). Two sites were established in Port Levy (PL03 and PL16), representative of one of the long, sheltered, inner inlets of the Banks Peninsula. Three sites were established in Lyttelton Harbour: LH07 adjacent to Ripapa Island, LH05 at Kamautaurua Island (Shag Reef) and LH10 on the outer southern shoreline of the Harbour (Figure 3). These sites are representative of both the relatively exposed rocky shore of mid- to outer Lyttelton Harbour (LH07 and LH10), and the relatively sheltered flat rocky shore of the upper Harbour (LH05). The surveys at LH07 and LH10 were carried out over low tide on 27 and 29 February, respectively (low tide at 14:57 and 16:25 NZDT; -0.6 and -0.7 m relative to MSL, respectively); LH05 on 28 February (low tide at 15:41; -0.7 m) and PL03 / PL16 on 26 February (low tide at 14:15 NZDT; -0.6 m).

Approximately 50 m of shoreline was surveyed at each site, with substrate characteristics and zonation patterns of intertidal fauna and flora recorded. The abundance of fauna and flora was described at each intertidal zonation (high, mid, low and tidal pools) using a categorical scale, ranked subjectively as ‘rare’, ‘occasional’, ‘common’, or ‘abundant’. Representative photographs of habitats and taxa were also obtained. Where field identification was not possible, specimens of individual fauna and algae were collected and later identified. All taxonomic nomenclature was based on the World Register of Marine Species (WoRMS Editorial Board 2016).

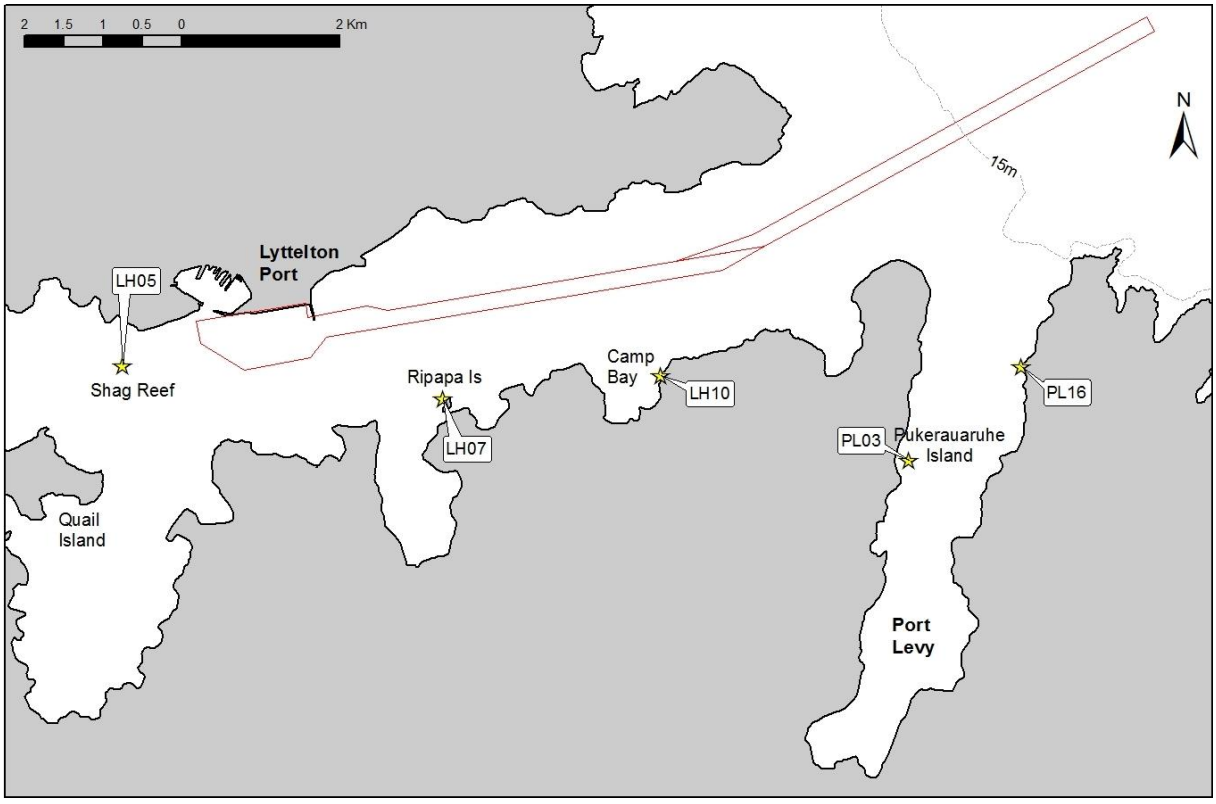

Figure 3 Map of the intertidal survey sites surveyed in February 2016 within Lyttelton Harbour (LH) and Port Levy (PL).

2.3. Statistical analyses

Subtidal quadrat data were analysed to ascertain levels of abundance (total cover and number of individuals), species richness (diversity) and standardised indices[1] of community diversity and evenness for each station (Table 1). For the purposes of the analyses, several subtidal taxa were aggregated into morphological groups (Table 2).

Differences in subtidal community structure were determined statistically with respect to water depth, area and sites using a distance-based permutational analysis (PERMANOVA, Anderson 2001) based on Bray-Curtis similarities of the log (x +1) transformed data and 9,999 permutations. Significant terms were then investigated using pair-wise comparisons with the PERMANOVA *t* statistic and 999 permutations.

[1] Similarity measures and diversity indices are not usually constructed from such "mixed" data sets, but there are no impediments to doing this (Anderson & Underwood 1994). However, there may be problems for the interpretation when data are naturally in different original scales. Thus, the data were log transformed, which preserved information concerning relative abundance or cover of species consistently across samples, but eliminated any large differences in scale among variables (Clarke, 1993).

Table 1 Descriptions of community indices.

Index	Equation	Description
No. species (S)	$\sum s$	Total number of species (s) in a sample.
No. abundance (N)	$\sum n$	Total number of individual organisms (n) in a sample. This included the sum of percentage cover of colonial organisms and solitary individuals.
Evenness (*J'*)	$J' = \frac{H'}{log_e S}$	Pielou's evenness. A measure of equitability, or how evenly the individuals are distributed among the different species. Values can theoretically range from 0.00 to 1.00, where a high value indicates an even distribution and a low value indicates an uneven distribution or dominance by a few taxa.
Diversity (*H'*)	$H' = -\sum P_i \, log_e \, (P_i)$	Shannon-Wiener diversity index describes, in a single number, the different types and amounts of taxa present in a sample. The index ranges from 0 for communities containing a single species to high values for communities containing many species each represented by a similar number of individuals.

Assemblage differences among treatment levels were visualized by Principal Coordinates Ordination (PCO). Similarity Percentages analysis (SIMPER, Clarke 1993) was used to identify the contribution of each species (or taxon) to observed differences among treatments. Taxa that consistently discriminated between treatments and had a correlation > 0.3 with the PCO axes were displayed as vectors in the PCO plots. All statistical analyses were conducted using PRIMER 6 (Clarke & Gorley 2006; Anderson et al. 2008) and R software (R Core Team 2014). Results are reported as mean ± 1 standard error (SE).

3. RESULTS

3.1. Subtidal community structure

3.1.1. General patterns

Substrate

On average, all areas were dominated by boulders (46.1% ± 2.7) and bedrock (40.6% ± 2.8), with lower proportions of cobble (8.1% ± 1.0), silt (6.2% ± 1.2) and shell hash (2.9% ± 0.5, Figure 4). Sand was recorded only at Site BP14 (7.9% ± 2.3). In general, substrate composition was similar among areas, although Lyttelton Harbour (LH), recorded higher bedrock and lower boulder cover relative to other areas (68.7% ± 4.9 and 15.7% ± 5.7, respectively, Figure 4). Of note was a frequent silt veneer of varying thickness evident on the surface of bedrock, boulders and dominant biota (e.g. macroalgae and solitary ascidians), particularly in more sheltered areas.

Benthic communities

An inventory of benthic taxa recorded during the subtidal surveys is provided in Table 2 along with abundance/coverage data averaged over each of the four areas. Rocky reefs in all four areas supported communities considered representative of the wider bioregion, being comparable to those previously found in the Banks Peninsula region (Schiel & Hickford 2001; Shears & Babcock 2007; Hepburn et al. 2010).

Average richness (total number of taxa), abundance (total cover and number of individuals), community evenness (Pielou's index) and diversity (Shannon-Weiner index) at each site are presented in Figure 5. Sites were characterised by a relatively high and uniform taxa richness across sites (71 taxa overall), ranging between 9.3 and 16.4 taxa/m^2 (Figure 5A). Average abundance of organisms classified as non-encrusting ranged from 72 to 216 individuals/m^2 (Figure 5B), with highest abundance and richness recorded at site LH02 in Livingstone Bay. Shannon-Weiner diversity was relatively uniform across all sites, with averages ranging from 1.2 to 2.1 (Figure 5C). Similarly, Pielou's index was comparable across sites and areas, ranging between 0.48 and 0.74 (Figure 5D), indicative of evenly distributed communities (i.e. not numerically dominated by just a few taxa).

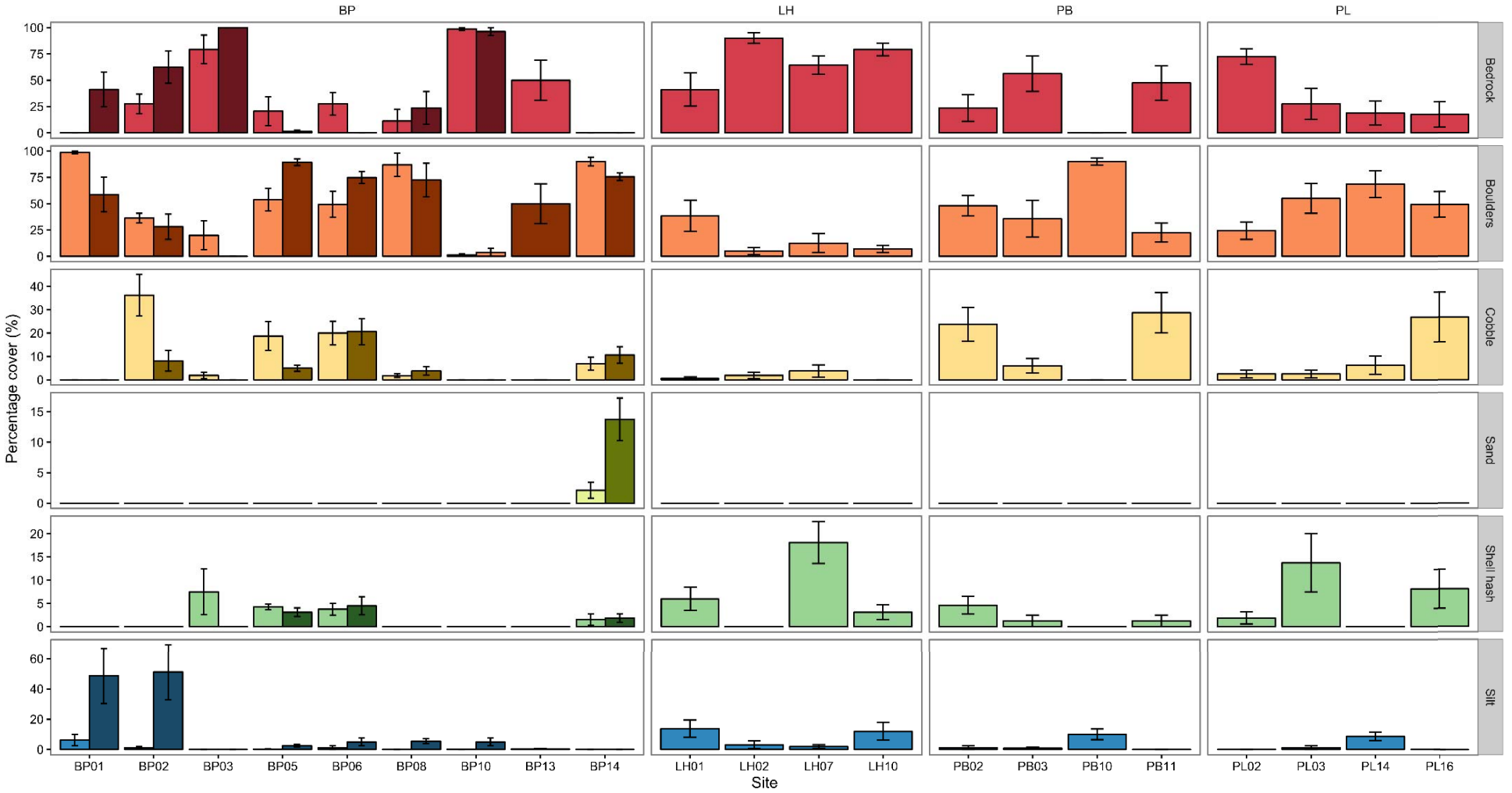

Figure 4 Mean percentage cover (± S.E.) of substrate type along shore 4 m (light coloured bars) and 7 m (dark coloured bars) depth transects: bedrock (consolidated rock), boulder (> 256 mm), cobbles (64–256 mm), sand (2–0.5 mm), silt (< 0.5 mm) and shell hash recorded during the subtidal survey within each of four areas: Banks Peninsula outer coast (BP), Port Levy (PL), Pigeon Bay (PB) and Lyttelton Harbour (LH).

Table 2 List of taxa recorded during subtidal surveys in February 2016 at each surveyed area: Banks Peninsula (BP, 4 m and 7 m), Lyttelton Harbour (LH, 4 m), Pigeon Bay (PB, 4 m) and Port Levy (PL, 4 m). Shaded cells represent values in the form of percentage cover. All others are counts.

			BP (4 m)		BP (7 m)		LH (4 m)		PB (4 m)		PL (4 m)	
GROUP	**Taxa**	**Common name**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**
CHROMOPHYTA	*Macrocystis pyrifera*	Bladder kelp	4.27	2.06	0.52	0.25	3.00	1.07	9.17	3.93	4.56	1.61
(Brown Algae)	*Ecklonia radiata*	Common kelp	18.85	2.48	1.37	0.80	23.13	2.83	26.09	3.73	32.34	4.80
	Halopteris sp.		0.83	0.33	1.84	0.50	0.06	0.06	0.03	0.03		
	Ralfsia sp.	Brown encrusting algae	1.40	0.30	1.68	0.36	3.05	1.01	2.28	0.61	6.19	1.50
	Undaria pinnatifida	Asian kelp					0.25	0.16			0.03	0.03
	Carpophyllum flexuosum	Flapjack			0.20	0.16	1.56	0.99	0.63	0.49		
	Carpophyllum maschalocarpum	Narrow flapjack	2.10	1.03	0.39	0.32	0.09	0.09	0.81	0.38		
	Landsburgia quercifolia		0.02	0.02								
	Microzonaria sp.		0.08	0.04	0.02	0.02						
	Dyctiotaceae				0.06	0.04	0.09	0.09				
RHODOPHYTA	Unid. red filamentous algae	Red filamentous algae	0.77	0.56	2.85	1.39	0.13	0.09	0.03	0.03	0.06	0.04
(Red Algae)	Unid. coralline encrusting algae	Coralline encrusting algae	52.04	3.69	19.34	3.22	39.06	5.44	59.69	3.34	62.66	4.83
	Unid. feathery red algae	Feathery red algae	1.01	0.36	2.00	0.69			0.03	0.03		
	Unid. red branching algae	Red branching algae					0.03	0.03				
	Unid. coralline turf	Coralline turf	1.27	0.39	0.37	0.19	2.34	1.58	0.06	0.06	9.06	4.34
	Unid. foliose red algae	Foliose red algae	0.76	0.18	2.07	0.55	4.22	0.80			0.34	0.18
PORIFERA	*Ecionemia alata*	Vase sponge			0.30	0.18						
(Sponges)	Unid. encrusting sponge	Encrusting sponge	0.92	0.19	0.94	0.16	1.16	0.35	1.73	0.36	2.69	0.85
	Unid. erect sponge	Erect sponge	0.03	0.02								
	Tethya bergquistae	Gold ball sponge	0.06	0.03	0.05	0.04						
CNIDARIA	Unid. hydrozoan	Hydroids	2.42	1.09	0.77	0.40	3.72	1.15	2.20	0.50	2.53	0.76
(Anemones)	*Anthothoe albocincta*	White-striped anemone	1.19	0.30	4.84	1.05	4.44	1.29	0.92	0.38	0.05	0.03
	Oulactis muscosa	Sand anemone	0.33	0.13	0.14	0.05	0.06	0.04	0.06	0.04	0.09	0.05
	Unid. Anthozoan	Anthozoan	1.19	0.30	4.84	1.05	4.44	1.29	0.92	0.38	0.05	0.03

			BP (4 m)		BP (7 m)		LH (4 m)		PB (4 m)		PL (4 m)	
GROUP	**Taxa**	**Common name**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**
POLYCHAETA	Unid. Serpullidae	Serpulid worm					0.25	0.16			0.03	0.03
(Bristle worms)	Unid. Spirobidae	Spirobid worm					0.25	0.16			0.03	0.03
ARTHROPODA	Unid. barnacle	Large barnacle	0.01	0.01	0.09	0.04	0.00	0.00	0.00	0.00	0.00	0.00
(Crustaceans)	Unid. barnacle	Small barnacle	7.52	2.47	3.84	0.83	2.34	0.80	0.41	0.15	0.84	0.62
	Paguridae	Hermit crab	0.40	0.32	0.14	0.05	0.09	0.05	0.06	0.04	0.03	0.03
MOLLUSCA												
Polyplacophora	*Eudoxochiton nobilis*	Noble chiton	0.01	0.01					0.03	0.03		
(chitons)	*Chiton glaucus*	Green chiton					0.09	0.09			0.03	0.03
	Cryptoconchus porosus	Butterfly chiton	0.28	0.08	0.19	0.06	0.53	0.23	0.28	0.14	0.22	0.07
Gastropoda	*Cellana stellifera*	Limpet	0.01	0.01	0.13	0.13					0.03	0.03
(snails, limpets,	Patelloidea	Limpet	0.13	0.07	0.11	0.07			0.19	0.09	0.19	0.09
pāua)	*Patiriella* sp.	Limpet										
	Scutus breviculus	Ducksbill limpet	0.04	0.03	0.03	0.02	0.16	0.07			0.06	0.04
	Sigapatella novaezelandiae	Slipper limper	0.03	0.03	0.06	0.04						
	Maoricolpus roseus	Turret shell	0.06	0.03	0.03	0.03					0.03	0.03
	Cookia sulcata	Cook's turban	1.26	0.19	0.42	0.10	0.31	0.14	1.94	0.53	1.00	0.28
	Trochus viridis	Top shell	2.57	0.45	2.19	0.36	2.88	0.64	1.75	0.41	1.88	0.48
	Haliostis iris	Blackfoot pāua	0.76	0.18	2.07	0.55	4.22	0.80			0.34	0.18
	Haliotis australis	Yellow-foot pāua			0.02	0.02			0.03	0.03		
	Cantharidus sp.	Opal top shell	0.01	0.01			0.16	0.11	0.03	0.03	0.03	0.03
	Calliostoma spp.		0.11	0.05	0.08	0.04	0.09	0.05	0.03	0.03		
	Turbo smaragdus	Cat's eye	0.17	0.08	0.02	0.02	0.41	0.13	0.16	0.07	0.53	0.18
	Penion sp.	Whelk	0.29	0.08	0.27	0.07	0.06	0.04	0.13	0.07	0.13	0.07
	Buccinulum linea	Lined whelk	1.40	0.30	1.68	0.36	3.05	1.01	2.28	0.61	6.19	1.50
	Unid. whelk	Whelk	0.07	0.07	0.02	0.02	0.09	0.07	0.06	0.06	0.03	0.03
	Aphelodoris luctuosa	Nudibranch			0.05	0.05			0.03	0.03		

			BP (4 m)		BP (7 m)		LH (4 m)		PB (4 m)		PL (4 m)	
GROUP	**Taxa**	**Common name**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**	**mean**	**S.E.**
Bivalvia	*Perna canaliculus*	Green lipped mussel	3.58	0.86	2.85	0.85	33.30	7.02	0.19	0.08	2.45	1.34
	Mytilus galloprovincialis	Blue mussel	0.15	0.14								
	Ostrea chilensis	Flat oyster	0.35	0.14	0.34	0.11	0.06	0.04	0.14	0.06	0.39	0.13
	Aulacomya maoriana	Ribbed mussel					1.25	0.40				
BROACHIPODA (Lantern shells)	*Calloria inconspicua*	Lantern shell	0.17	0.09	0.17	0.07						
BRYOZOA	Unid. bryozoan	Encrusting bryozoan	0.59	0.23	1.14	0.29	0.02	0.02	0.42	0.22	0.13	0.07
	Unid. bryozoan	Branching bryozoan	0.58	0.26	2.53	0.78	1.44	0.67	0.53	0.25	1.63	0.69
ECHINODERMATA	*Australostichopus mollis*	Sea cucumber			0.06	0.03			0.09	0.05	0.28	0.10
(seastars, urchins,	*Coscinasterias muricata*	11-armed seastar	0.11	0.04	0.03	0.02	0.19	0.08	0.03	0.03		
sea cucumbers)	*Stegnaster inflatus*	Ambush seastar	0.03	0.02	0.05	0.03			0.03	0.03	0.03	0.03
	Sclerasterias mollis				0.02	0.02						
	Pentagonaster pulchellus	Biscuit seastar	0.04	0.02	0.05	0.03						
	Diplodontias dilatatus		0.03	0.02	0.16	0.07						
	Patiriella regularis	Cushion star	1.19	0.16	1.06	0.14	1.59	0.25	1.78	0.28	1.34	0.32
	Evechinus chloroticus	Kina	0.14	0.05	0.09	0.04	0.03	0.03	0.19	0.08	0.09	0.05
ASCIDIACEA	*Cnemidocarpa* sp.	Saddle sea squirt	12.32	1.84	32.50	3.04	15.89	3.03	5.95	1.12	5.28	0.76
(Sea Squirts)	*Pyura pachydermatina*	Sea tulip	4.17	0.68	1.38	0.32	0.63	0.21	0.25	0.11	0.13	0.06
	Unid. colonial ascidian	Colonial sea squirt					0.25	0.16			0.03	0.03
	Didemnum jucundum	Colonial sea squirt	0.31	0.17	0.34	0.14	0.19	0.10	1.13	0.40	0.75	0.23
	Didemnum sp.	Colonial sea squirt	0.94	0.20	1.48	0.29	2.11	0.43	1.61	0.38	2.27	0.63
	Aplidium benhami	Colonial sea squirt					0.06	0.04			0.09	0.05
	Unid. solitary ascidian	Sea squirt					0.25	0.16			0.03	0.03
OSTEICHTHYES (Fish)	Tripterygiidae	Triple fins	0.99	0.13	1.20	0.18	3.56	0.46	3.03	0.37	3.03	0.32
Total no. of taxa		72	55		57		49		43		46	

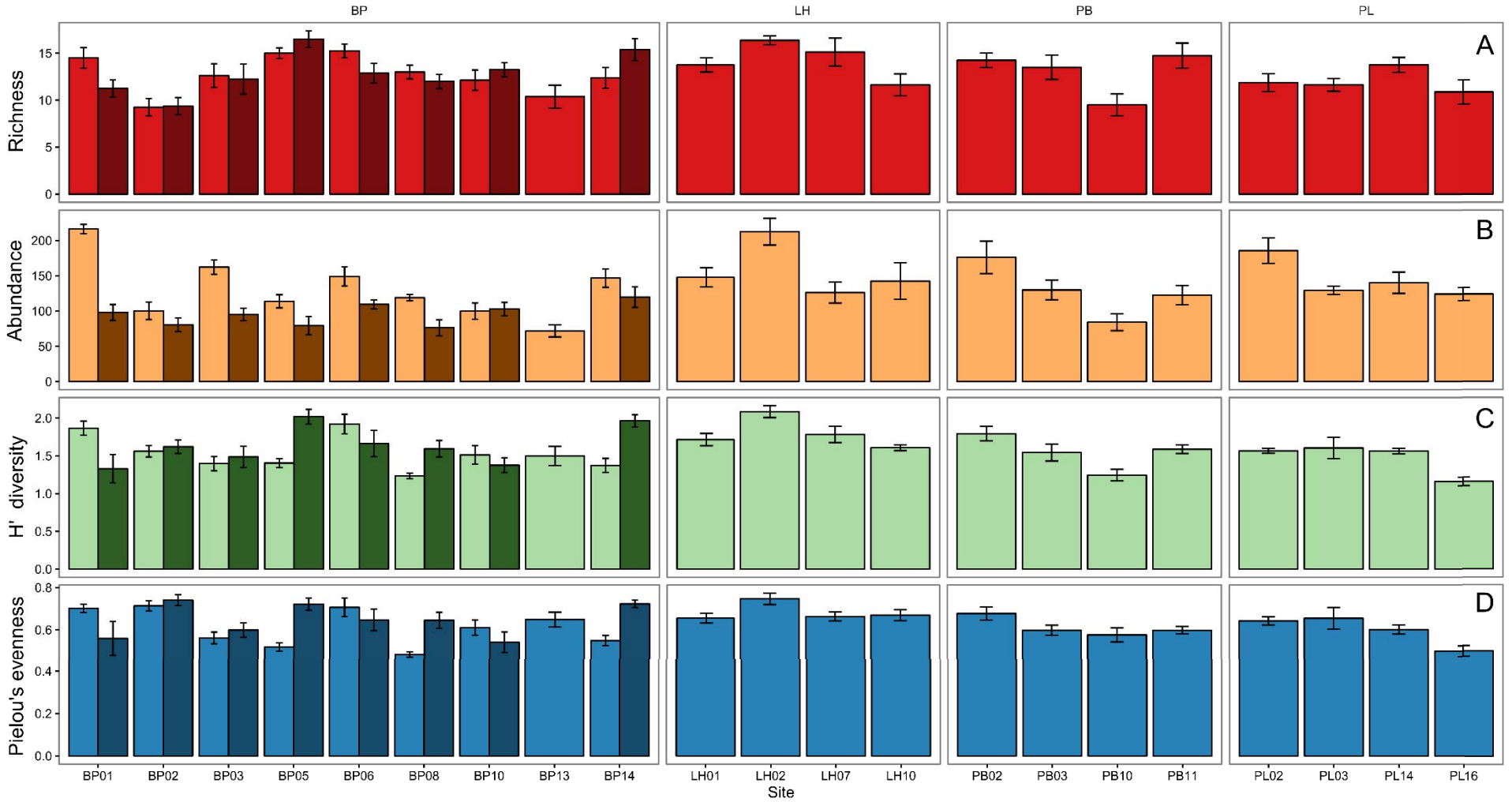

Figure 5 Mean diversity (± S.E.) indices for each 4 m (light bars) and 7 m (dark bars) transect (*n* = 4). A: Number of taxa per quadrat. B: Abundance per quadrat. C: Pielou's Evenness. D: H' Shannon-Weiner Diversity index within each of the four general areas surveyed: Banks Peninsula outer coast (BP), Port Levy (PL), Pigeon Bay (PB) and Lyttelton Harbour (LH).

Reef communities at the 4 m depth level were characterised by 'kelp forest' habitats dominated by the common kelp *Ecklonia radiata* (17% ± 1.4, range 0–90%, Figure 6) and the bladder kelp *Macrocystis pyrifera* (3.8% ± 0.9). Other canopy-forming macroalgae included the flapjack *Carpophyllum flexuosum* and the narrow flapjack *C. maschalocarpum*, however these were recorded at less than 1% cover on average.

A wide range of understory organisms were found amongst kelp forest habitats. Dominant taxa on rocky habitats at ~4 m depths included encrusting coralline algae (53.0% ± 2.2), whereas the saddle sea squirt *Cnemidocarpa* sp. (32.5% ± 3.0) frequently formed an extensive cover on bedrock and boulders across the deeper (7 m) transects (Figure 6). These habitats also frequently supported an algal understory that included a range of red macroalgae (*e.g.* coralline turf, filamentous, feathery, foliose and branching forms) and brown macroalgae (e.g*. Halopteris* sp., *Ralfsia* sp., *Landsburgia quercifolia* and *Microzonaria* sp.).

Invertebrates included green-lipped mussels (*Perna canaliculus*), barnacles, top shells (*Trochus viridis*), white striped anemones (*Anthothoe albocincta*), hydroids, sea tulips (*Pyura pachydermatina*), branching bryozoans, colonial ascidians (*Didemnum* spp.), pāua (*Haliotis iris*) and various species of encrusting sponges. Fish observed around kelp forest habitats during survey dives included triplefins (family Tripterygiidae), spotted wrasse (*Notolabrus celidotus*), blue cod (*Parapercis colias*), leather jackets (*Parika scaber*), blue moki (*Latridopsis ciliaris*) and banded wrasse (*Notolabrus fucicola*).

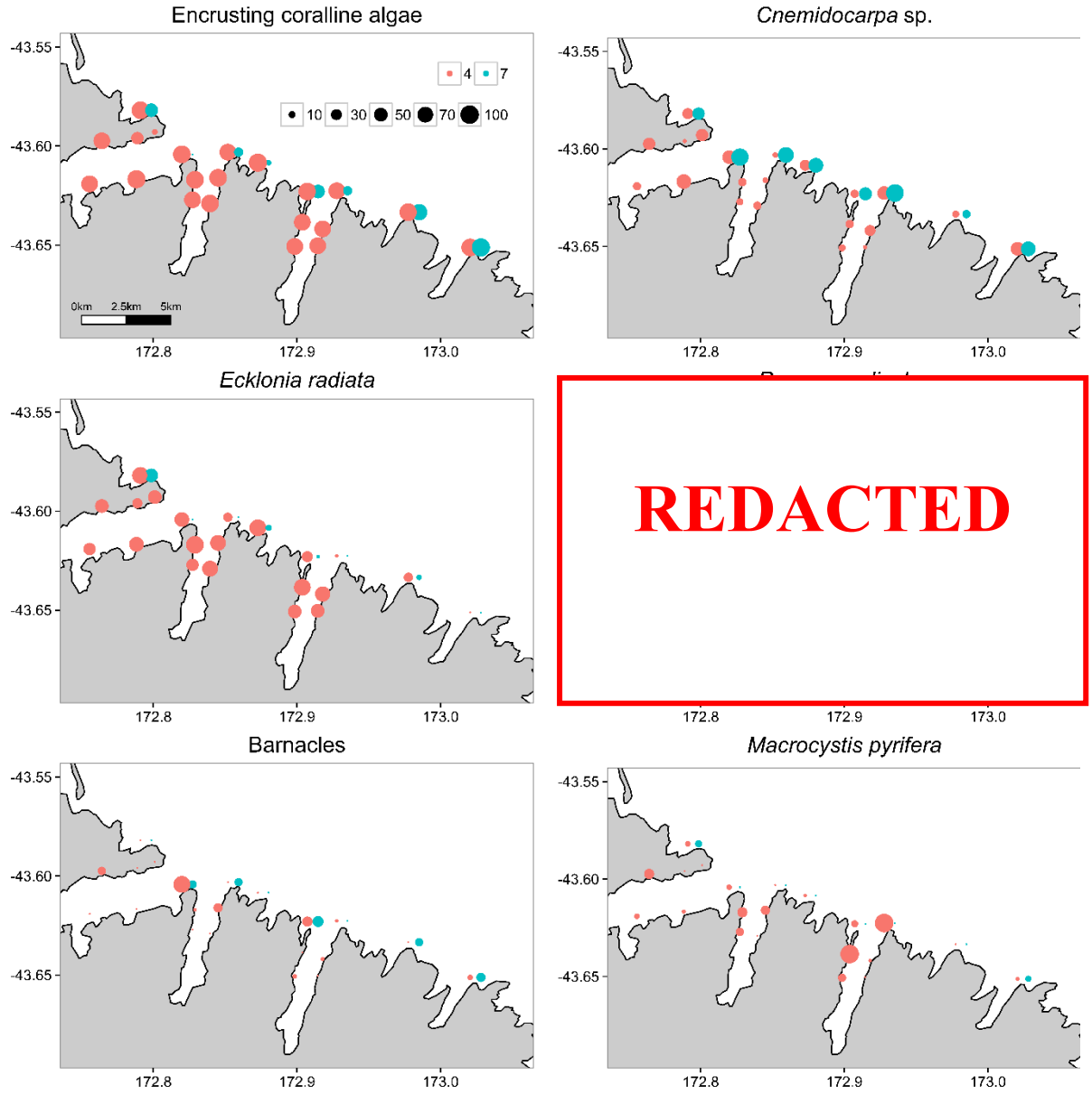

Figure 6 Maps showing the percentage cover and spatial distribution of six dominant taxa by depth: 4 m (red circles) and 7 m (green circles) at each site within the surveyed area.

Permutational analysis using PERMANOVA indicated significant differences between the structure of communities found at 4 m and 7 m water depths ($P < 0.001$). The PCO plot (Figure 7A) illustrates this pattern, showing a separation in the transect data according to depth. The differences were mainly due to the consistently higher cover of *Eklonia radiata* (9.3% contribution to the overall dissimilarity), encrusting coralline algae (8.2%) and green-lipped mussels (4.3%) at the 4 m level. Conversely, communities at 7 m depth had higher cover of *Cnemidocarpa* (7.0% contribution to the overall dissimilarity), the anemone *Anthothoe albocincta* (4.3%) and barnacles (3.7%) compared to those found at 4 m (Figure 7A).

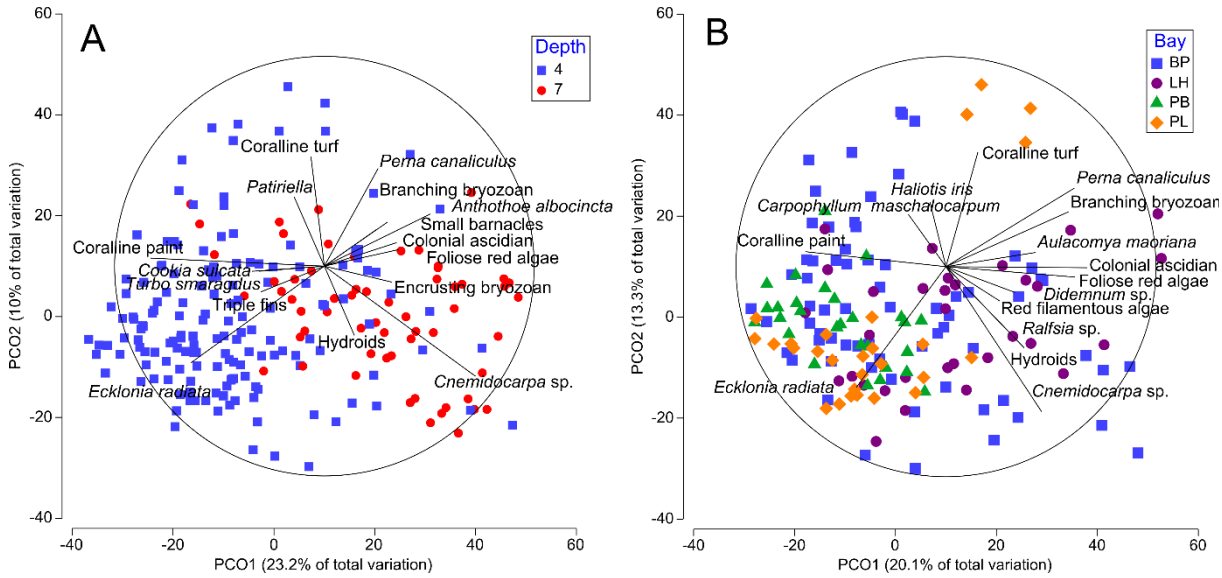

Figure 7 Principal Coordinates Ordination (PCO) plots of individual 1 m^2 quadrats on the basis of Bray-Curtis similarities of the log (x +1) transformed data of subtidal assemblages at: (A) 4 m (blue squares) and 7 m depth (red circles), and (B) at each of the four areas: Banks Peninsula (BP, blue squares), Lyttelton Harbour (LH, purple circles), Pigeon Bay (PB, green triangles) and Port Levy (PL, orange diamonds). Taxa that consistently discriminated between depths and areas are displayed as vectors.

The PERMANOVA analysis also identified significant differences in community structure between the four different survey areas (P<0.05). However, the greatest variability in community structure was detected among sites nested within areas, indicating a significant spatial variation at the scale of sites within each area (P<0.001) and leading to a high degree of overlap in the quadrat data points on the PCO plot (Figure 7B). Nonetheless, communities within Lyttelton Harbour were distinguishable from others areas. SIMPER analyses showed that this difference was due to a higher cover of green-lipped mussels in LH compared to PB and BP (9.4 and 7.8% contribution to the overall dissimilarity, respectively). The two sites on the northern shore of Lyttelton Harbour (LH01 and LH02) supported extensive mussel beds, with an average cover of greater than 55%. To a lesser extent, other taxa contributing to the observed differences between areas included the saddle sea squirt, common kelp, encrusting coralline algae and foliose red algae.

3.2. Individual survey areas

Marginal visibility at many sites made underwater photography during the survey challenging. For this reason, the recording of photoquadrat images was not possible. However, divers were sometimes able to take acceptable close up photographs of a number of encrusting communities using a wide angle lens. A selection of these images from the individual sites within each area (BP, LH, PB, PL) are included in Appendix 3. These photographs were taken with natural light but have been processed with image manipulation software to correct colour balance and enhance detail. Due to the limited depth to which shoreline reefs extended for all but the outer coast sites, transects at the 4 m depth level only were surveyed for sites within Lyttelton Harbour, Pigeon Bay and Port Levy.

3.2.1. Banks Peninsula outer coast (BP)

A total of 63 taxa were recorded at the nine rocky reef sites surveyed at the outer coast BP sites. The reef habitat at the 4 m depth level was characterised by kelp forest, dominated by common kelp (*Ecklonia radiata;* 18.5 ± 2.5%), bladder kelp (*Macrocystis pyrifera*; 4.3 ± 2.0%) and narrow flapjack (*Carpophyllum maschalocarpum*; 2.1% ± 1.0). Bedrock and boulders were covered mainly by crustose coralline algae (52.0 ± 3.7%), saddle sea squirts (*Cnemidocarpa* sp.; 12.3 ± 1.8%), small barnacles (7.5 ± 2.5%) and green lipped mussels (*Perna canaliculus*; 3.6 ± 0.9%). Other epifauna commonly found among the kelp were sea tulips (*Pyura pachydermatina*; 4.2 ± 0.7 individuals/m^2), top shells (*Trochus viridis*; 2.6 ± 0.5 individuals/m^2), Cook's turban (*Cookia sulcata*; 1.3 ± 0.2 individuals/m^2) and pāua (*Haliotis iris*; 0.8 ± 0.2 individuals/m^2)

Deeper reef habitats (7 m) were characterised by sparser canopy-forming algae, including *Ecklonia* (1.4% ± 0.8), and *Macrocystis* and *C. maschalocarpum* (< 1% cover). Understory algae were represented by filamentous and feathery red algae (2.9% ± 1.4 and 2.0% ± 0.7, respectively), coralline crustose algae (78% ± 4.6) and the brown crustose alga *Ralfsia* sp. (1.7% ± 0.4 cover). Dominant epifauna included *Cnemidocarpa*, recorded at significantly higher coverage (33% ± 3.0) than at 4 m, and the anemone *Anthothoe albocincta* (4.8 ± 1.1 individuals/m^2). Other common invertebrates included small barnacles, branching bryozoans, *Perna* and *Trochus*.

Despite often limited visibility, a range of fish species were also observed within the kelp forest habitats of BP sites, including triplefins, spotted and banded wrasse, blue cod, leather jackets and blue moki. Fish were more frequently observed at outer sites (*e.g.* BP08 and BP10) and at Taylor's Mistake Bay (BP14).

Findings from the survey work on the outer coastline area are consistent with earlier studies of the area (Schiel & Hickford 2001; Shears & Babcock 2007). In their study of subtidal reef habitats on the east coast of the South Island, Schiel & Hickford (2001) described reef habitats at Godley Head and Taylors Mistake (within the vicinity of

BP13 and BP14) describing rocky reef kelp forests dominated by common kelp with a canopy cover between 10–30%, and a thick layer of crustose coralline algae covering the rocky substrate in the understory. The authors also found high abundance of *Pyura* and mobile gastropods, such as *Trochus*, pāua and *Cookia*. Furthermore, they reported fish assemblages similar to those observed during the current survey, most notably including spotted and banded wrasse and leather jackets.

3.2.2. Lyttelton Harbour (LH)

Across the four Lyttelton Harbour sites, there were a total of 50 taxa recorded. As on the outer coast, the reef habitat was characterised by kelp forest, largely dominated by *Ecklonia* (23.1% ± 2.8) and *Macrocystis* (3.0% ± 1.0), and to a lesser extent *C. maschalocarpum* (1.6% ± 1.0). Higher cover of *Perna* (33.3% ± 7.0) was recorded relative to other areas and these formed dense and extensive beds at sites **REDACTED** of the Harbour, with mean coverage at 72% and 55%, respectively. Interspersed within these beds, the ribbed mussel (*Aulacomya maoriana*) was recorded at relatively low cover (1.3% ± 0.4), but was not recorded from other survey areas. Bedrock and boulders were mainly covered by a mix of crustose coralline algae (39.1% ± 5.4), *Cnemidocarpa* (15.9% ± 3.0), red foliose algae (4.2% ± 0.8), hydroids (7.5% ± 1.3) and *Ralfsia* (3.0% ± 1.0). The anemone *A. albocincta* was also more common (4.4 ± 1.3 individuals/m^2) and pāua were less often recorded in quadrats; however, these are believed to be due to the prevalence of *Perna* coverage which in places effectively replaced the underlying substrate.

3.2.3. Pigeon Bay (PB)

A total of 44 taxa were recorded from quadrats at the four sites in Pigeon Bay. Reef habitats at 4 m depth were characterised by kelp forest comprising *Ecklonia* (26.1% ± 3.7) and *Macrocystis* (9.2% ± 3.9), the latter being recorded at a particularly high percentage cover (mean 33%) at site PB02 on the western shoreline. Understory communities were dominated by crustose coralline algae (59.7% ± 3.3), with *Cnemidocarpa* (6.0% ± 1.1), *Ralfsia* (2.3% ± 0.6) and hydroids (2.2% ± 0.5) also present at lower coverage. Red turfing algae appeared to be less common in Pigeon Bay than elsewhere. Mobile invertebrates included pāua, *Cookia sulcata* and the cushion star *Pateriella regularis*, all at densities of less than 4 individuals/m^2.

3.2.4. Port Levy (PL)

A total of 43 taxa were recorded in quadrats at the four Port Levy sites. Relative to other areas surveyed, Port Levy featured the greatest cover of *Ecklonia* recorded (32.3% ± 4.8), but mixed with *Macrocystis* (4.6% ± 1.6). Understory communities were largely dominated by a high coverage of crustose coralline algae (62.7% ± 4.8). Red coralline turf was recorded at a particularly high coverage (36.3%) at one site (PL02 on the western shoreline) but was not recorded from the other three sites within the inlet. The Port Levy quadrat data-set differed from those of Lyttelton Harbour and Pigeon Bay with an absence of the two *Carpophyllum* species, but otherwise

supported communities very similar to those of Pigeon Bay. *Cnemidocarpa*, *Ralfsia*, hydroids and *Perna* were present at < 5% coverage on average. Triplefins were also commonly recorded, generally at densities ~3 individuals/m^2.

3.3. Littoral fringe transects: Mahinga kai species

3.3.1. Pāua (Haliotis iris)

A total of 1,413 pāua were measured within the littoral fringe transects (0.5 m CD) across all sites (Figure 8). Pāua size within these transects ranged between 60.5 mm and 132.5 mm, with densities ranging between 12 and 185 individuals per 50 m^2 (Table 3).

Only 30 individuals (2.1%) were measured at above the legal size limit of 125 mm (Figure 9). Average pāua length was greatest within **REDACTED**. However the largest individual pāua (134 mm) was recorded in **REDACTED**. These results are consistent with earlier surveys undertaken within Port Levy (Hepburn et al. 2010), where an average pāua length of 100 mm was reported and only 0.38% were above the legal size limit.

Figure 10 shows the spatial distribution of pāua densities at each of the surveyed sites. The highest density of 185 pāua /50 m^2 at 0.5 m CD was recorded for the outermost western site in **REDACTED**. Lowest average density was recorded within Pigeon Bay (48.3 ± 14.5 individuals/50 m^2). However densities were highly variable. Perhaps most importantly, the greatest densities of pāua observed were frequently at depths 1 m–2 m below the 0.5 m CD transect.

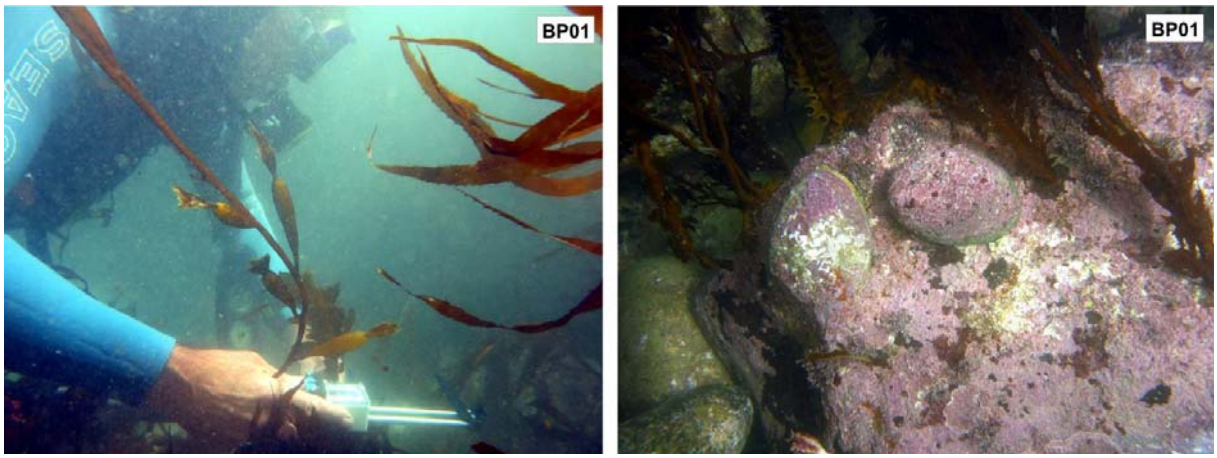

Figure 8 Diver collecting size frequency distribution data of pāua using logging digital callipers (left), and pāua on coralline crustose algae (right).

Table 3 Summary statistics for size frequency distribution and density (individuals/50 m^2) of pāua within the littoral fringe transects of each surveyed area: Banks Peninsula (BP), Lyttelton Harbour (LH), Pigeon Bay (PB) and Port Levy (PL).

	Length (mm)					Density (individuals/50 m^2)				
Area	Mean	Minimum	Maximum	S.E.	n	Mean	Minimum	Maximum	S.E.	n
BP	101.0	60.5	127.5	0.5	509	65.8	16	139	16.6	8
LH	107.2	60.5	132.5	0.8	320	80.0	42	140	21.1	4
PB	100.8	60.5	134.0	1.0	193	48.3	12	79	14.5	4
PL	102.5	69.5	127.5	0.5	391	93.5	27	185	36.9	4

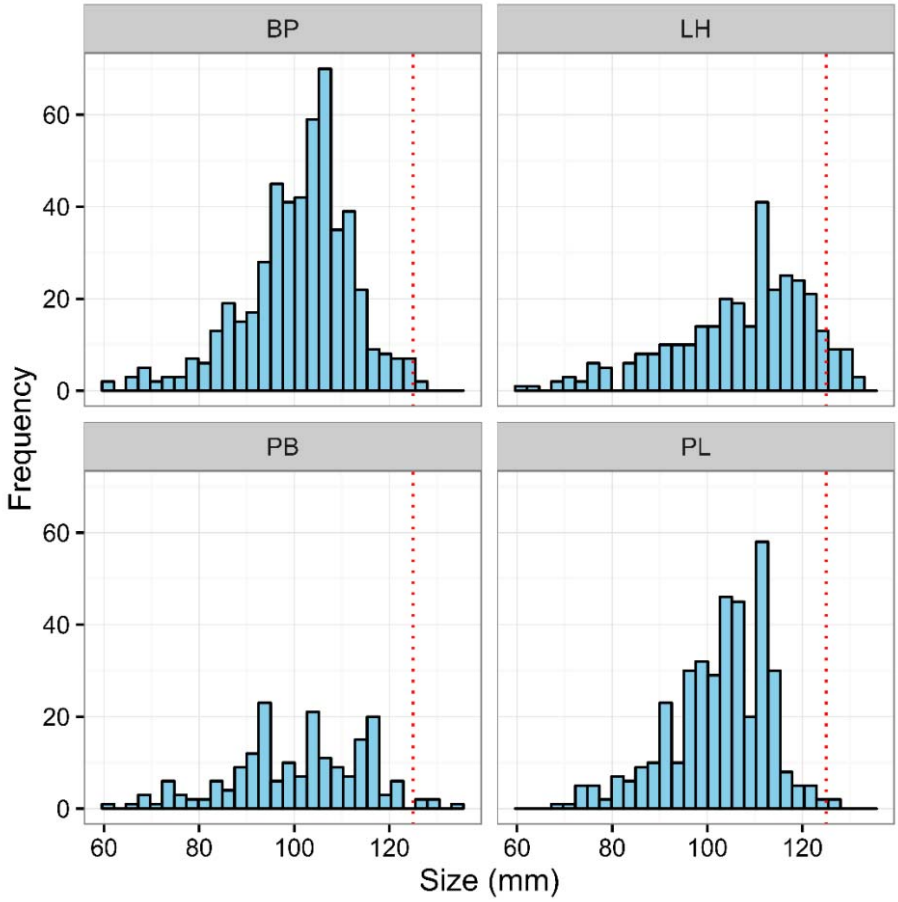

Figure 9 Size frequency (no. of individuals) distribution of pāua within the littoral fringe transects of each survey area: Banks Peninsula (BP), Lyttelton Harbour (LH), Pigeon Bay (PB) and Port Levy (PL). The red dotted line indicates the legal size limit of 125 mm.

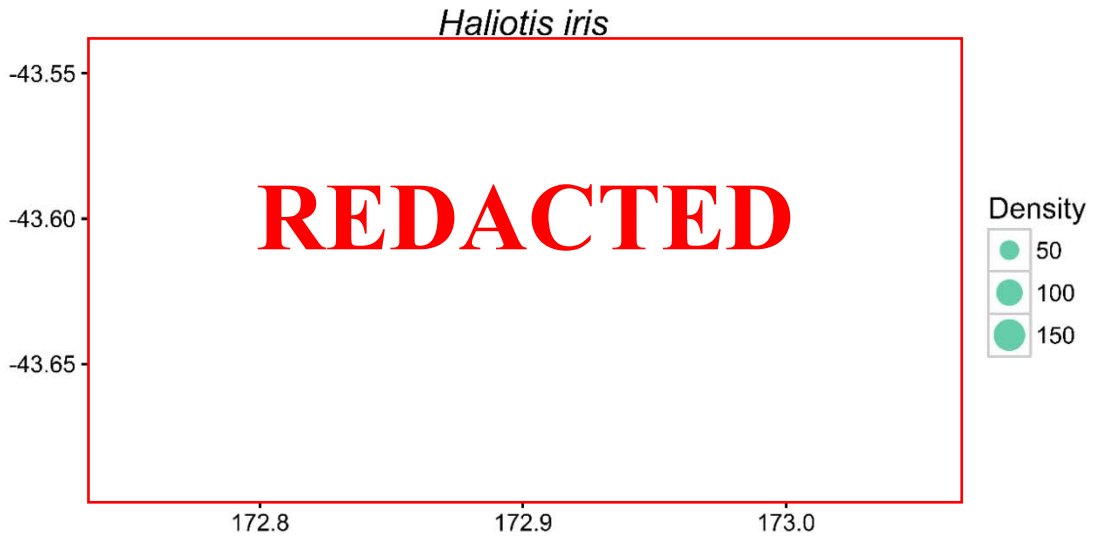

Figure 10 Density (individuals/50 m^2) of pāua within the littoral fringe transects at each site within the surveyed area.

3.3.2. Cook's turban (Cookia sulcata) density

The spatial distribution of recorded densities for *Cookia sulcata* across the surveyed sites is shown in Figure 11. Overall, densities were lower and more variable than for pāua. At 32.0 ± 10.4 individuals/50 m^2, the highest densities were recorded within Port Levy and the lowest at Pigeon Bay (3.5 ± 1.2). Densities at the outer coast (BP) sites were also relatively high (21.0 ± 11.6 individuals/50 m^2); however counts were recorded for this species only at five of the nine sites (BP01, BP03, BP10, BP13 and BP14).

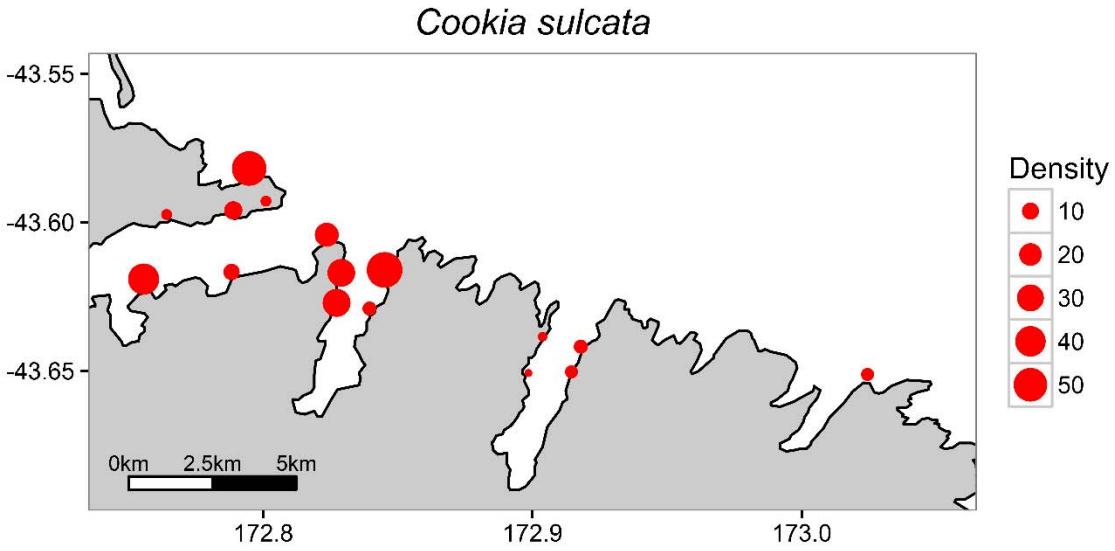

Figure 11 Density (individuals/50 m^2) of cook's turban recorded within littoral fringe transects at sites in the surveyed area.

3.4. Intertidal community structure

The following sections present a description, by site, of the flora and fauna observed during intertidal surveys. The tables are structured according to four general zones; high-shore, mid-shore, low-shore and tidal pools, with the latter restricted to the mid- to low-shore. A description of the physical nature of the substrate and the dominant taxa within each zone is provided. Although it is intended that these shoreline elevations should match up with the generally accepted definitions of such zones, it should be noted that the surveys were carried out during a period of neap tides. This restricted the ability of scientists to survey the low-shore at the level of spring low tides.

3.4.1. Lyttelton Harbour (LH)

Three intertidal reef sites were surveyed in Lyttelton Harbour; two representative of the relatively exposed rocky shores of the outer Harbour (LH07 and LH10), and one (LH05) at Shag Reef within the upper to mid-Harbour region (refer Figure 3).

Mid-harbour site (LH05: Shag Reef or Kamautaurua Island)

Site LH05 was representative of the relatively sheltered rocky shore of the upper Harbour. Upper Harbour sites are generally sheltered from long-period wave action, and may be subject to greater fluctuations in salinity, temperature and turbidity. Shag Reef is low-lying and relatively flat in profile. Very little of its total area occurs in the high-shore zone. Tide pools are restricted to the low shore and are generally shallow and silt-lined. The site supported a relatively impoverished intertidal community compared to the Lower Harbour sites (LH07 and LH10), with a total of 32 taxa recorded (Table 4). The upper intertidal was dominated by barnacles (*Chamaesipho columna, Elminius modestus*), the little black mussel (*Xenostrobus pulex*) and the blue mussel (*Mytilus galloprovincialis*). Limpets (*Cellana ornata and C. radiata*) were also abundant in the high shore zone. The red seaweed Karengo (*Clymene coleana*) was categorised as occasional on the mid- and high-shore.

Grazing and predatory gastropods featuring in the mid-shore included limpets, cat's eye snails (*Turbo smaragdus*), spotted topshells (*Diloma aethiops*) and whelks (*Cominella adspersa*). Barnacles, the Neptune's necklace weed (*Hormosira banksii*) and several species of chitons were also abundant in the mid-shore. Polychaete tubeworms (*Spirobranchus cariniferus*) and blue mussels were common from the low- to-mid shore.

The low-shore, shallow-subtidal and tidal pools featured frequent patches of the green-lipped mussel (*Perna canaliculus*). Several species of macroalgae were commonly or occasionally found, including *H. banksii*, flapjack (*Carpophyllum maschalocarpum*), zig-zag weed (*Cystophora scalaris*), *Gelidium* sp., intestine weed (*Ulva intestinalis*) and the encrusting velvet weed *Codium adherens*. Spotted topshells were abundant and the snakeskin chiton (*Chiton pelliserpentis*) was common on the

low-shore. The relative scarcity of tidal pools at Shag Reef will have contributed to the overall lower taxa richness recorded at the site (Table 4).

Lower Harbour sites (LH07, LH10)

The intertidal zones of sites LH07 (Ripapa Island) and LH10 (Camp Bay east) consisted of steep, sometimes narrow (< 5 m wide) bedrock, boulder and cobble reef habitats, and had similar physical characteristics (intertidal rock platform / shelf, some standing water pools) and exposure.

A total of 64 taxa were found across both sites (52 taxa at LH07 and 51 at LH10), with taxa richness increasing down the shore profile (Table 4). The upper-intertidal zones of both sites were dominated by barnacles (*C. columna* and *E. plicata*), the brown periwinkle (*Austrolittorina cincta*) and blue-banded periwinkle (*A. antipodum*), cat's eye snails, the oyster borer whelk (*Haustrum scobina*), spotted top shell (*D. aethiops*) and the little black mussel (*X. pulex*). Limpets (*Cellana ornata*) were also abundant in the high shore zone. The intestine green weed (*U. intestinalis*) was categorised as scarce, while flat oysters were recorded as being occasional on the high-shore.

The mid-shore supported a variety of grazing and predatory gastropods; including limpets (*C. ornata* and *C. radians*) and whelks (*Haustrum haustorum* and *H. scobina*). Barnacles, spotted top shells, Neptune's necklace weed (*H. banksii*) and several species of chitons (*Acanthochiton zelandica*, *Chiton pelliserpentis* and *C. glaucus*) were also abundant in the mid-shore. The polychaete tubeworm *S. cariniferus* and blue mussels (*M. galloprovincialis*) were common from the mid- to low shore.

The low-shore, shallow-subtidal and tidal pools had abundant patches of the green-lipped mussel, a wide diversity of green, brown and red macroalgae; including encrusting coralline algae, Neptune's necklace, bladder kelp, narrow flapjack, flapjack (*Carpophyllum flexuosum*), the zig-zag weed (*C. scalaris*), *Halopteris* sp., *Gelidium* sp., crustose coralline algae, turfing coralline algae and filamentous red algae. Cat's eye snails, spotted topshells and chitons were also common on the low-shore. Additionally, underneath the cobbles, particularly in tidal pools, there were a variety of invertebrates; including porcelain crabs (*Petrolisthes elongatus*), slipper limpets (*Sigapatella novaezelandiae*), cushion seastars (*Patiriela regularis*), white stripped anemone (*Anthothoe albocincta*) and chitons (Table 4).

Table 4 Relative abundance of conspicuous intertidal taxa recorded in Lyttelton Harbour. Shore elevation: H = High, M = Mid-shore, L = Low and P = Tidal pools/shallow subtidal. Abundance scale: A = abundant; C = common, O = occasional, R = rare/scarce (usually single individuals observed).

			LH05				LH07				LH10			
	Species	**Common name/description**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**
PHAEOPHYTA	*Hormosira banksii*	Neptune's necklace		O	O			A	A				A	A
(Brown Algae)	*Macrocystis pyrifera*	Bladder kelp				C				A				C
	Cystophora scalaris	Zig-zag weed			O	O			A	A			C	C
	Ralfsia sp.	Brown encrusting algae			O	O			C	C			C	
	Carpophyllum maschalocarpum	Narrow Flap Jack							O	O				C
	Carpophyllum flexuosum	Flap jack			O	O			O	O				C
	Splachnidium rugosum	Gummy weed								O			C	C
	Halopteris sp.	Brown fine branching algae								C				
	Scytothamnus australis								O					O
	Colpomenia sp.	Bubble weed											O	
	Undaria pinnatifida	Asian kelp											R	R
	Leathesia sp.								O				C	C
	Microzonia velutina												O	
RHODOPHYTA	*Gelidium* sp.	Brown turf-like		C	C	C			C	C		C	C	
(Red Algae)	*Clymene coleana*	Karengo	O	O								O		
	Gigartina sp.								C					
		Encrusting coralline algae			O					C			C	C
		Coralline turf											C	C
	Hildenbrantia sp.	Red encrusting algae										A	A	
CHLOROPHYTA	*Codium adherens*	Velvet weed							O				O	O
(Green Algae)	*Chaetomorpha coliformis*	Sea emerald								O				
	Ulva intestinalis	Intestine weed		O			R			R				
	Cladophora sp.													O
	Codium fragile			O										
	Codium adherens			R	O									
PORIFERA (Sponges)	*Tethya bergquistae*	Orange sponge								R				

			LH05				LH07				LH10			
	Species	**Common name/description**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**
		Yellow sponge								R				O
ANTHOZOA	*Diadumene neozelanica*	Brown-striped anemone			O									
(Anemones)	*Oulactis mucosa*	Sand anemone												O
	Anthothoe albocincta	White-striped anemone			O				O	O				
HYDROIDA	*Hydroids*	Small feathery hydroids												
POLYCHAETA	*Spirobranchus cariniferus*	Tubeworms	C	C	C			C	C			C	C	
BRYOZOA		Encrusting bryozoan			O					O				O
	Watersipora subtorquata	Encrusting bryozoan			O				C	C				
BRACHIPODA (Lantern shells)	*Calloria inconspicua*	Lantern shell												
POLYPLACOPHORA	*Acanthochiton zelandica*	Hairy chiton						R	R			O	O	
(Chitons)	*Chiton pelliserpentis*	Snakeskin chiton			C			A	A			C	C	
	Chiton glaucus	Green chiton						A	A			O	O	
GASTROPODA	*Scutus breviculus*									R				
(Snails)	*Cellana radians*	Radiate Limpet	C	A	A			A	A			A	A	
	Cellana ornata		C	A	A		A	A	A			A	A	
	Sigapatella novaezelandiae	Slipper limpet			O					C				
	Siphonaria sp.			O										
	Cominella adspersa	Speckled whelk		O				O						O
	Calliostoma spp.								O	O				
	Haustrum scobina							C					C	
		Microgastropods								C				A
	Haustrum haustorium								O			C	C	
	Diloma aethiops	Spotted topshell		A	A		A	A	A			A	A	
	Turbo smaragdus	Cat's Eye snail		A			A	A	A			C	C	
	Austrolittorina antipodum	Blue-banded periwinkles					A				A			
		Nudibranch												R
	Austrolittorina cincta	Brown periwinkles					A				A			
BIVALVIA (Bivalves)	*Aulacomya maoriana*	Ribbed mussel											O	

			LH05				LH07				LH10			
	Species	**Common name/description**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**
	Xenostrobus pulex	Small black mussel	A	A			C	C				A		
	Perna canaliculus	Green Lipped Mussel		O	O				C	C				C
	Ostrea chilensis	Dredge/Bluff oyster			O		O	O					O	
	Protothaca crassicosta													
	Mytilus galloprovincialis	Blue mussel	A	C	C			C	C				C	
DECAPODA (Crabs)	*Pagurus* sp.	Hermit crab												O
	Petrolisthes elongatus	Half crab			O				R					O
ISOPODA (Sea slaters)	*Isopod*									R				
CIRRIPEDIA	*Epopella plicata*			O			C	C			A	A		
	Chamaesipho columna		A	A	A		A	A				A	A	
	Elminius modestus		A	A	A			O	O					C
ASCIDIACEA	*Cnemidocarpa* sp.	Saddle ascidian								O			O	O
(Sea Squirts)	*Pyura pachydermatina*	Sea tulip												R
	Corella eumyota									R				
ECHINODERMATA		*Snakestar*								R				O
(Seastars, urchins)	*Patiriela regularis*	Cushion seastar								O				O
OSTEICHTHYES (Fish)	*Forsterygion* sp.	Triplefin								C				
Total number of taxa			8	20	23	5	10	17	26	27	3	15	28	27
					32				52				51	

3.4.2. Port Levy (PL)

The intertidal regions surveyed in Port Levy consisted mainly of bedrock with some boulder substrate. The two surveyed sites, PL03 and PL16 (on the western and eastern sides of the inlet, respectively) are in the mid-outer areas of the inlet and have similar physical characteristics (intertidal rock platform / shelf, some tidal pools) and exposure. PL03 was situated on the seaward side of the small Pukerauaruhe Island and featured a relatively broad and level mid-tidal rock platform. The reef shoreline at PL16 was steeper in profile and significantly narrower (< 5 m wide).

A total of 66 taxa were found at the two sites (57 taxa at PL03 and 35 at PL16), with species richness increasing down the tidal profile (Table 5). The greater overall species richness at PL03 was related to the much greater width of its intertidal zone and especially the higher prevalence of tidal pools on its rock platform. However, the two sites were similar in terms of zonation patterns, assemblage structure and dominant taxa recorded and were comparable to the lower-Lyttelton Harbour sites (Ripapa Island, Camp Bay).

The upper intertidal zones were dominated by barnacles and both the brown and blue-banded periwinkle. Limpets were also common in the high-shore zone. The little black mussel (*X. pulex*) was observed to be abundant in the high to mid-shore at PL03, but was not recorded from PL16.

There was a range of grazing and predatory gastropods present in the mid-shore zone; including limpets and the whelk *Haustrum haustorium*. Barnacles, spotted topshells and snakeskin chitons were also abundant in the mid-shore. The tubeworm *Spirobranchus cariniferus* were common-to-abundant from the mid- to low-shore.

The low-shore, shallow-subtidal and tidal pools supported abundant patches of green-lipped and blue mussels, and a range of macroalgae; including encrusting coralline algae, *H. banksii*, *M. pyrifera*, *C. torulosa* and filamentous red algae. A greater range of algae was recorded from the low-shore of PL03 (including abundant *C. maschalocarpum* and *C. flexuosum*; this being due to the greater prevalence of tidal pools. Cat's eye snails, spotted topshells and chitons were also common on the low-shore. The immediate subtidal featured cobbles encrusted with coralline and brown algae, patches of mussels, and a conspicuous fringe of *C. maschalocarpum* and *C. flexuosum*. Additionally, underneath the cobbles there was a variety of invertebrates; including porcelain crabs, slipper limpets and chitons (Table 5).

Table 5 Relative abundance of conspicuous taxa recorded at two intertidal sites (PL03 and PL16) surveyed in Port Levy. Shore elevation: H = High, M = Mid-shore, L = Low and P = Tidal pools/shallow subtidal. A = abundant; C = common, O = occasional, R = rare/scarce (usually single individuals observed).

			PL03				PL16			
	Species	**Common name/description**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**
PHAEOPHYTA (brown algae)	*Hormosira banksii*	Neptune's necklace	A	A	A				A	
	Macrocystis pyrifera	Bladder kelp				A				A
	Cystophora scalaris	Zig-zag weed				A				O
	Ralfsia sp.	Brown encrusting algae	C	C	C		O			
	Carpophyllum maschalocarpum	Narrow Flap Jack				A				
	Carpophyllum flexuosum	Flap jack				A				
	Splachnidium rugosum	Gummy weed			R					
	Halopteris sp.	Brown fine branching algae				R				
	Unident. Brown algae	Brown algae		C						
	Scytothamnus australis					O				
	Colpomenia sp.	Bubble weed							O	
	Leathesia sp.					R				
	Microzonia velutina									R
RHODOPHYTA (red algae)	*Gelidium* sp.	Brown turf-like			C				C	
	Clymene coleana	Karengo	O							
	Gigartina sp.					O				
	Unident. encrusting coralline algae	Encrusting coralline algae			C					O
	Unident. coralline turf	Coralline turf								
	Hildenbrantia sp.	Red encrusting algae							C	
CHLOROPHYTA (green algae)	*Codium adherens*	Velvet weed			C				O	
	Chaetomorpha coliformis	Sea emerald				R				
	Ulva intestinalis	Intestine weed				O				
	Ulva spp.	Sea lettuce				O				
	Cladophora sp.	Mermaid's Hair				O				
PORIFERA (sponges)	*Tethya bergquistae*	Gold ball sponge				R				
	Unident. sponge	Orange sponge			R					
	Unident. sponge	Yellow sponge								

			PL03				PL16			
	Species	**Common name/description**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**
ANTHOZOA (anemones)	*Actinia tenebrosa*	Red anemone			R					
	Corynactis australis	Jewel anemone								R
	Oulactis mucosa	Sand anemone								O
	Anthothoe albocincta	White-striped anemone				O			O	
HYDROIDA (hydroids)	Hydroids	Small feathery hydroids				R				
POLYCHAETA (polychaetes)	*Spirobranchus cariniferus*	Tubeworms		A	A				C	
	Spirorbidae	Spiral tubeworm				O				
BRYOZOA (bryozoans)	Unident. encrusting bryozoan	Encrusting bryozoan				O				
	Watersipora subtorquata	Encrusting bryozoan				O				
BRACHIPODA (lantern shells)	*Calloria inconspicua*	Lantern shell				R				
POLYPLACOPHORA (chitons)	*Acanthochiton zelandica*	Hairy chiton				R				R
	Chiton pelliserpentis	Snakeskin chiton		C	C			A	A	
	Chiton glaucus	Green chiton				O		C	C	
	Large unid chiton	Chiton						O	O	
GASTROPODA (snails)	*Cellana radians*	Radiate Limpet	C	C	C			A	A	
	Cellana ornata	Limpet	C	C	C			A	A	
	Sigapatella novaezelandiae	Slipper limpet				R				
	Cominella adspersa	Speckled whelk				R				
	Calliostoma spp.					R				
	Haustrum scobina	Oyster borer whelk						C		
	Haustrum haustorium	Whelk	C	C	C			C	C	
	Diloma aethiops	Spotted topshell		A	A			A	A	
	Turbo smaragdus	Cat's Eye			A			C	O	
	Austrolittorina antipodum	Blue-banded periwinkles	A				A			
		Nudibranch								
	Austrolittorina cincta	Brown periwinkles	A				A			
BIVALVIA (bivalves)	*Aulacomya maoriana*	Ribbed mussel		O					C	
	Xenostrobus pulex	Small black mussel	A	A						
	Perna canaliculus	Green Lipped Mussel		A	A			O	O	
	Ostrea chilensis	Dredge/Bluff oyster				O	R			

			PL03				PL16			
	Species	**Common name/description**	**H**	**M**	**L**	**P**	**H**	**M**	**L**	**P**
	Protothaca crassicosta	Clam				O				
	Mytilus galloprovincialis	Blue mussel		C	C				A	
DECAPODA (decapods)	*Pagurus* sp.	Hermit crab		R	R					
	Petrolisthes elongatus	Half crab				R				
CIRRIPEDIA (barnacles)	*Epopella plicata*	Barnacle	A	A					O	
	Chamaesipho columna	Barnacle	A	A			A	A		
	Elminius modestus	Barnacle						R		
ASCIDIACEA (sea Squirts)	*Cnemidocarpa* sp.	Saddle sea squirt				R				
		Solitary ascidian								R
	Aplidium sp.	Orange colonial ascidian				R				
ECHINODERMATA (seastar, urchins)	*Evechinus chloroticus*	Kina				R				
OSTEICHTHYES (fish)	*Forsterygion* sp.	Triplefin				O				R
Total number of taxa – by zone			11	16	18	31	5	12	19	9
Total number of taxa – by site				57				35		

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5. APPENDICES

Appendix 1 Location details of subtidal sites surveyed in February 2016 within each of four areas; Banks Peninsula outer coast (BP), the inlets of Port Levy (PL) and Pigeon Bay (PB), and the coastline within Lyttelton Harbour (LH).

Area	Station	Transects	Latitude	Longitude	Date
BP	BP01	0.5 m, 4 m, 7 m	-43.6042°	172.8236°	24-Feb
	BP02	4 m, 7 m	-43.6031°	172.8556°	22-Feb
	BP03	0.5 m, 4 m, 7 m	-43.6084°	172.8765°	23-Feb
	BP05	0.5 m, 4 m, 7 m	-43.6230°	172.9110°	23-Feb
	BP06	0.5 m, 4 m, 7 m	-43.6226°	172.9315°	24-Feb
	BP08	0.5 m, 4 m, 7 m	-43.6334°	172.9814°	23-Feb
	BP10	0.5 m, 4 m, 7 m	-43.6512°	173.0244°	24-Feb
	BP13	0.5 m, 4 m	-43.5929°	172.8010°	25-Feb
	BP14	0.5 m, 4 m, 7 m	-43.5819°	172.7948°	28-Feb
LH	LH01	0.5 m, 4 m	-43.5960°	172.7889°	26-Feb
	LH02	0.5 m, 4 m	-43.5974°	172.7641°	27-Feb
	LH07	0.5 m, 4 m	-43.6191°	172.7556°	27-Feb
	LH10	0.5 m, 4 m	-43.6167°	172.7882°	27-Feb
	LH11	*	-43.6126°	172.8026°	29-Feb
PB	PB02	0.5 m, 4 m	-43.6385°	172.9038°	25-Feb
	PB03	0.5 m, 4 m	-43.6507°	172.8985°	28-Feb
	PB10	0.5 m, 4 m	-43.6503°	172.9145°	28-Feb
	PB11	0.5 m, 4 m	-43.6418°	172.9179°	25-Feb
PL	PL02	0.5 m, 4 m	-43.6170°	172.8290°	25-Feb
	PL03	0.5 m, 4 m	-43.6271°	172.8273°	26-Feb
	PL14	0.5 m, 4 m	-43.6290°	172.8395°	28-Feb
	PL16	0.5 m, 4 m	-43.6160°	172.8451°	25-Feb

* LH11 was not surveyed quantitatively due to insufficient water clarity. Diver notes only.

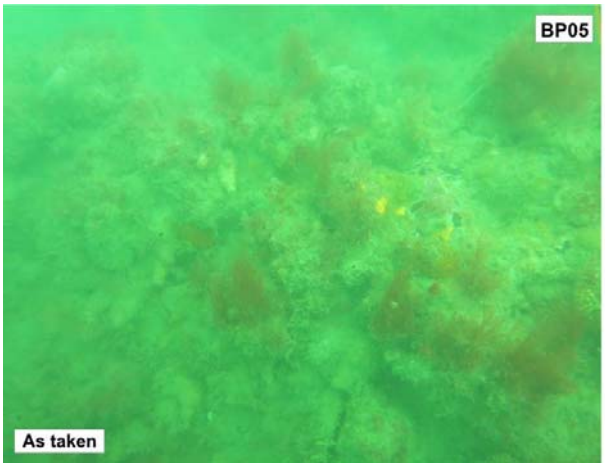
Appendix 2 Location details of intertidal sites surveyed in February 2016 within Port Levy (PL) and Lyttelton Harbour (LH).

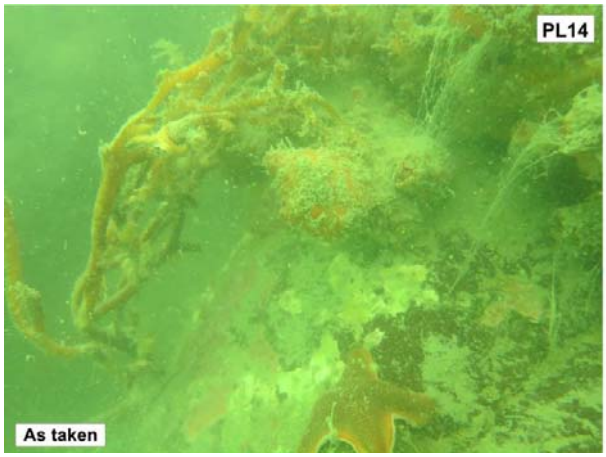
Area	Station	Latitude	Longitude	Date
PL	PL03	-43.6084°	172.6852°	26-Feb
PL	PL16	-43.6044°	172.7415°	26-Feb
LH	LH07	-43.5976°	172.7633°	27-Feb
LH	LH05	-43.5954°	172.7891°	28-Feb
LH	LH10	-43.5924°	172.8048°	29-Feb

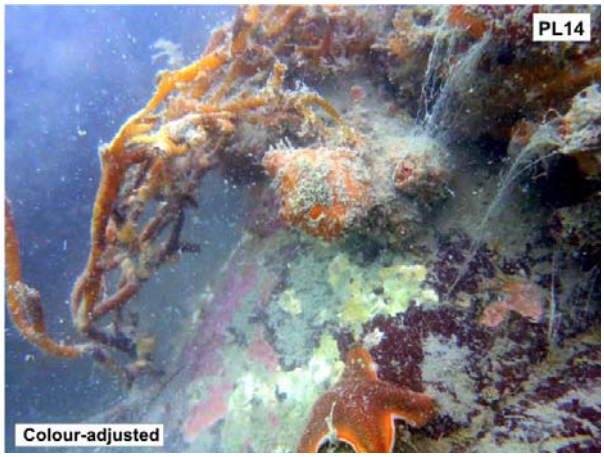
Appendix 3 Representative photographs of substrate and taxa from ecological survey dives.

Poor underwater visibility meant that the generation of a photoquadrat record was impossible. However, attempts were made to compile a photographic record of taxa and substrate using a Canon G16 PowerShot digital camera. 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 light bounce. 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.

All of the images in the following section have been colour-adjusted to enhance detail. Before-and-after images demonstrating this restoration are shown below.







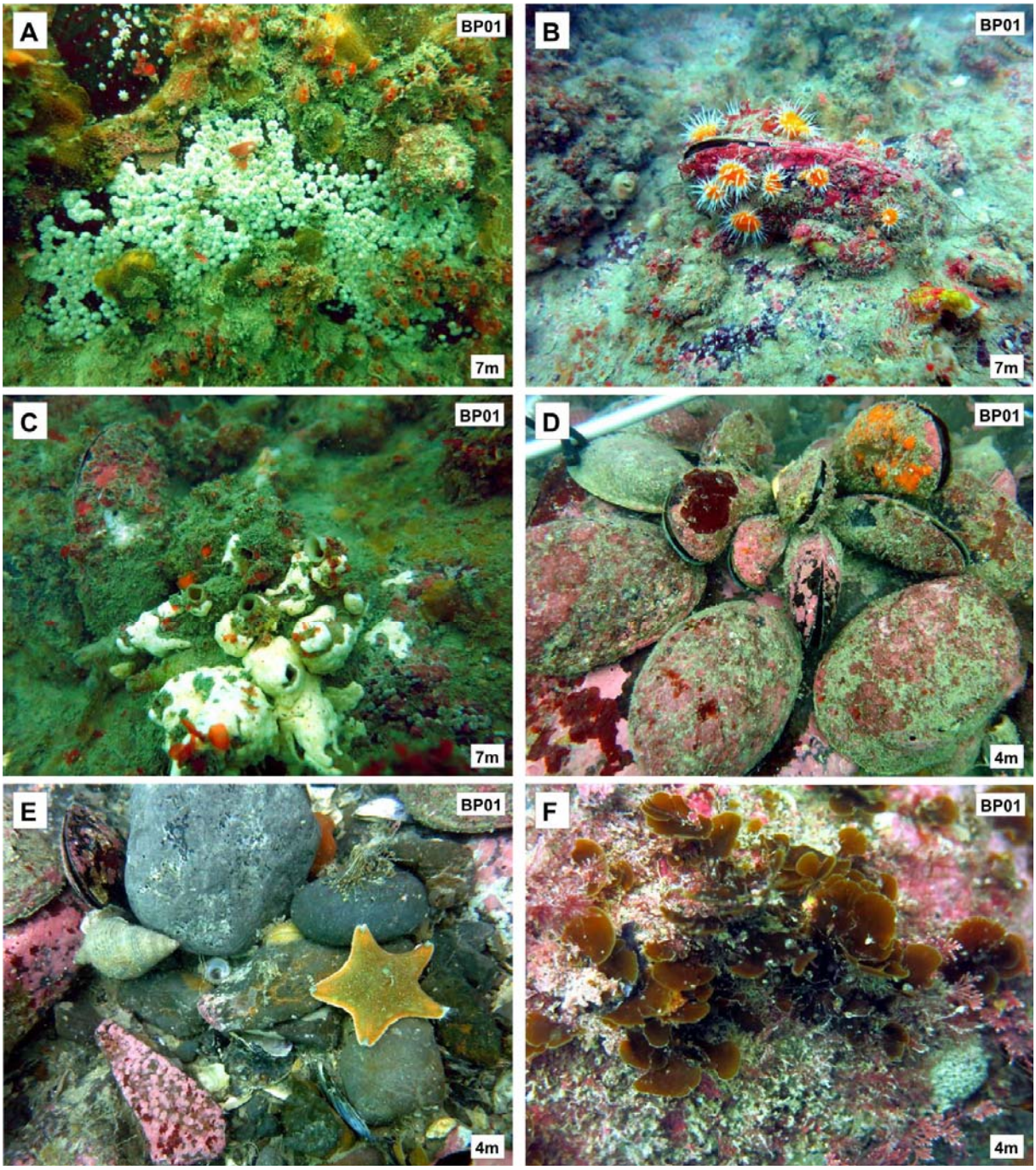
It is important to note that the colour-adjusted images in the following section are not what the diver sees; they overstate the degree of visual resolution possible with the human eye. The enhanced colours are also oversaturated in order to bring out maximum detail. Most photographs are shot in extreme close-up and a scale context may be absent. Few take in more than 0.25 m^2 (1/4 of quadrat frame). It is further important to note that the process by which the photographs were taken was subjective. Subjects were photographed because they were points of interest to the diver. There is also a possible bias towards composition (i.e. relatively featureless substrates are likely to have been passed over). These biases combine to give an impression of potentially higher ecological diversity than the reality.

Finally, the abundant macroalgae found in most areas dived is largely absent from this photographic record. This is related to scale. The turbid conditions (sometimes down to a visibility as low as 20 cm) meant that it was not possible to take photographs which could show kelp forest habitat at a large enough scale to represent its extent and density.

Kelp forest habitat in Pigeon Bay.

Note: Each photograph is identified by site in the upper right hand corner and transect in the lower left.

Appendix 3, continued



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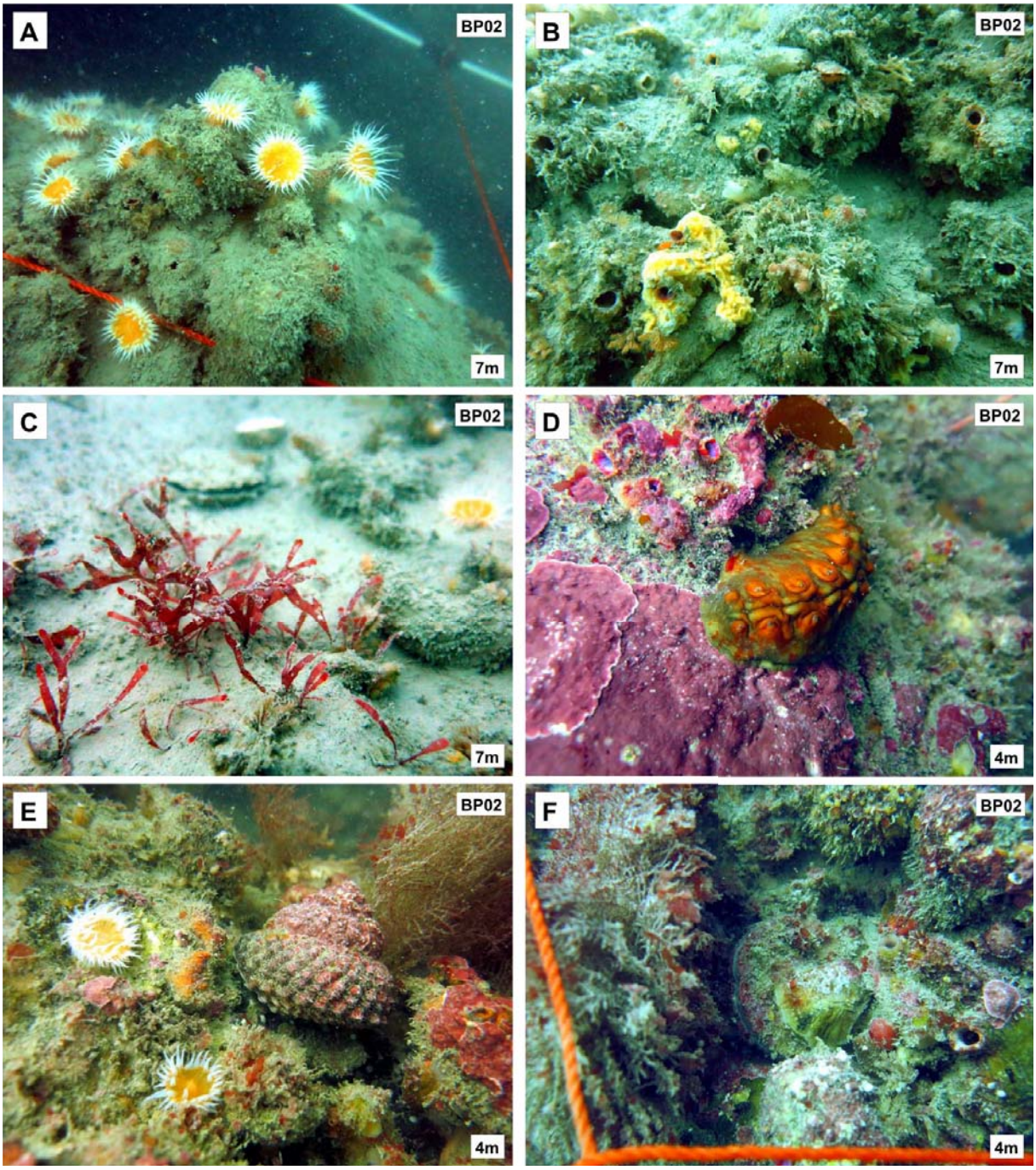

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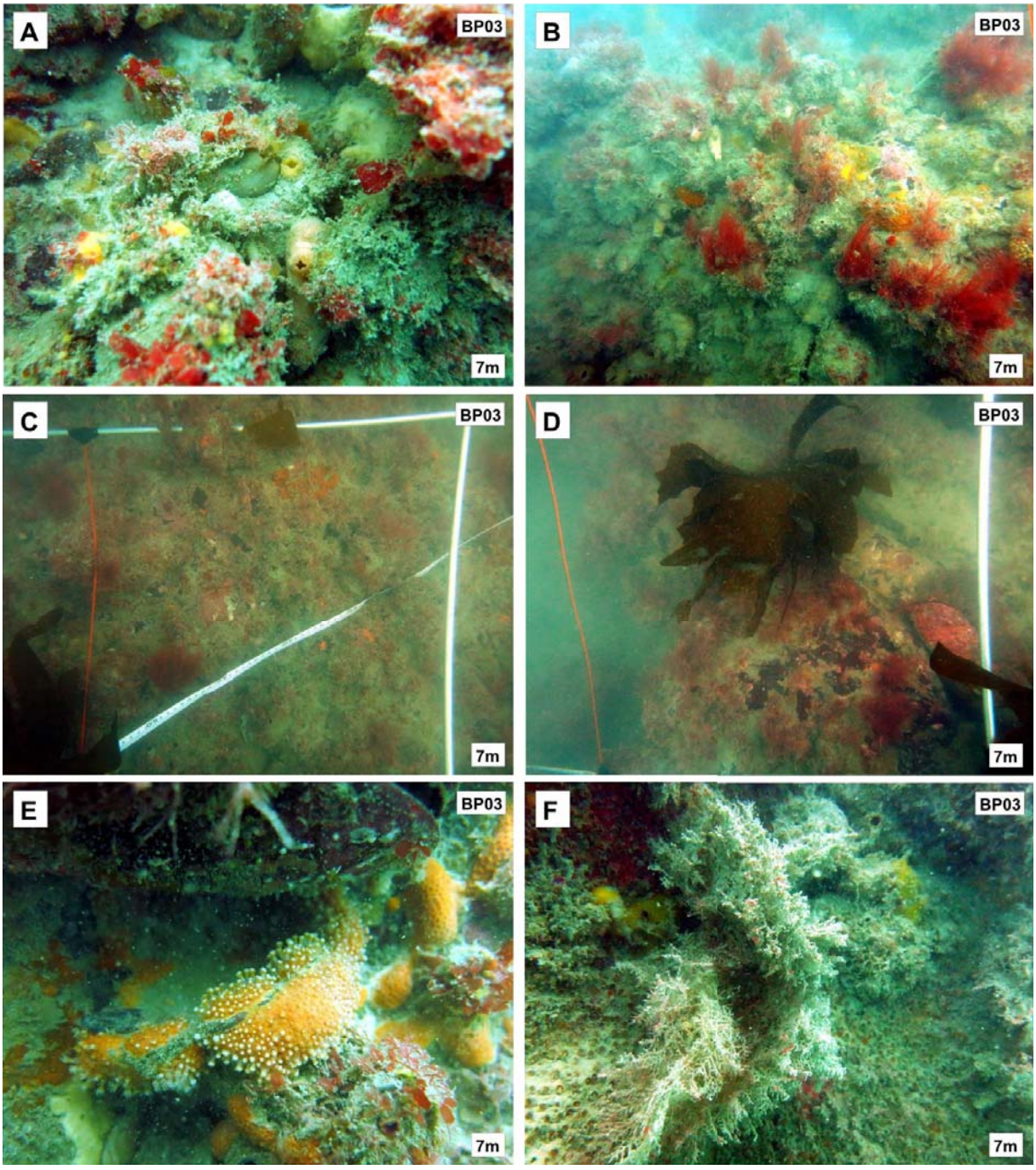

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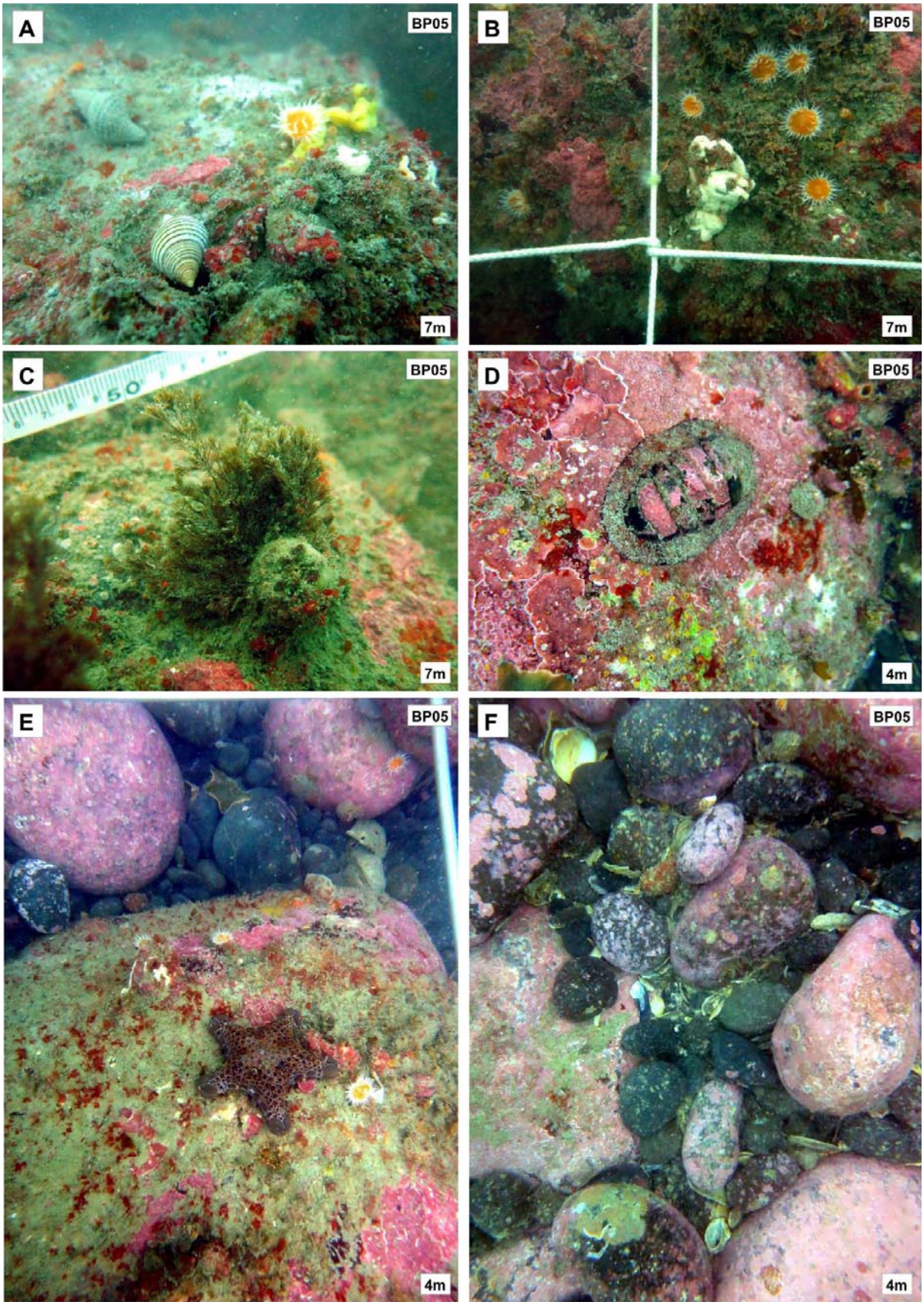

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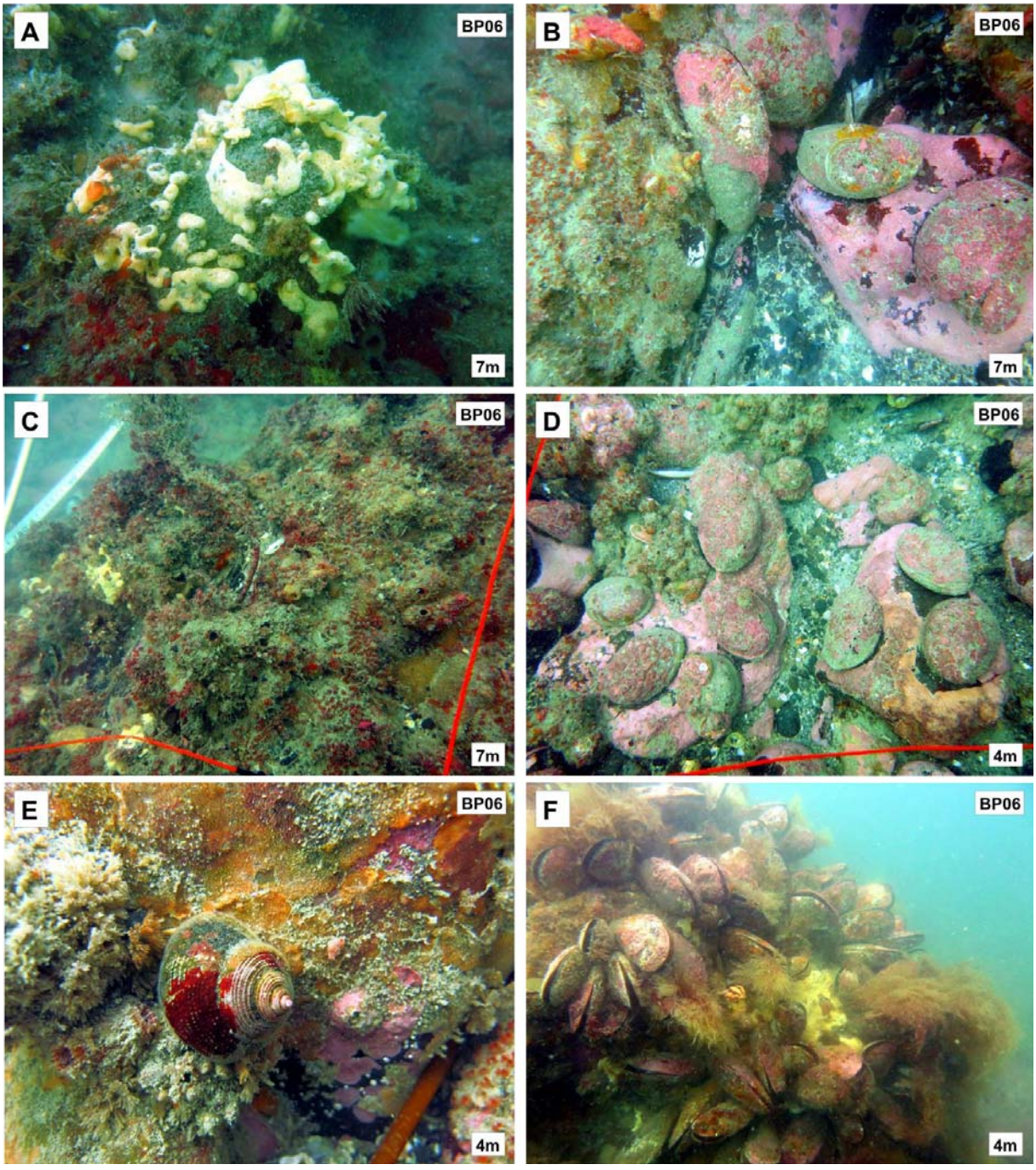

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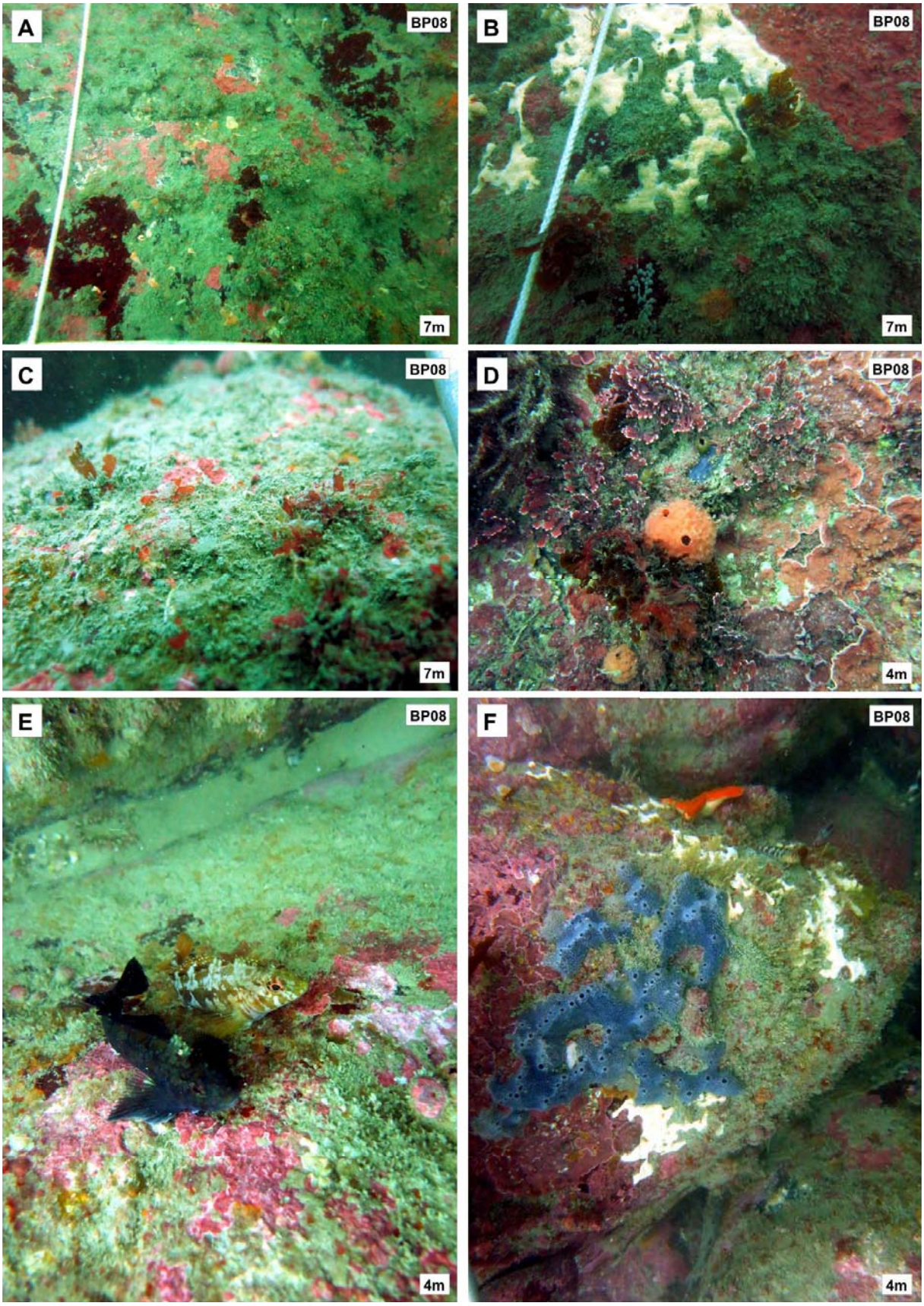

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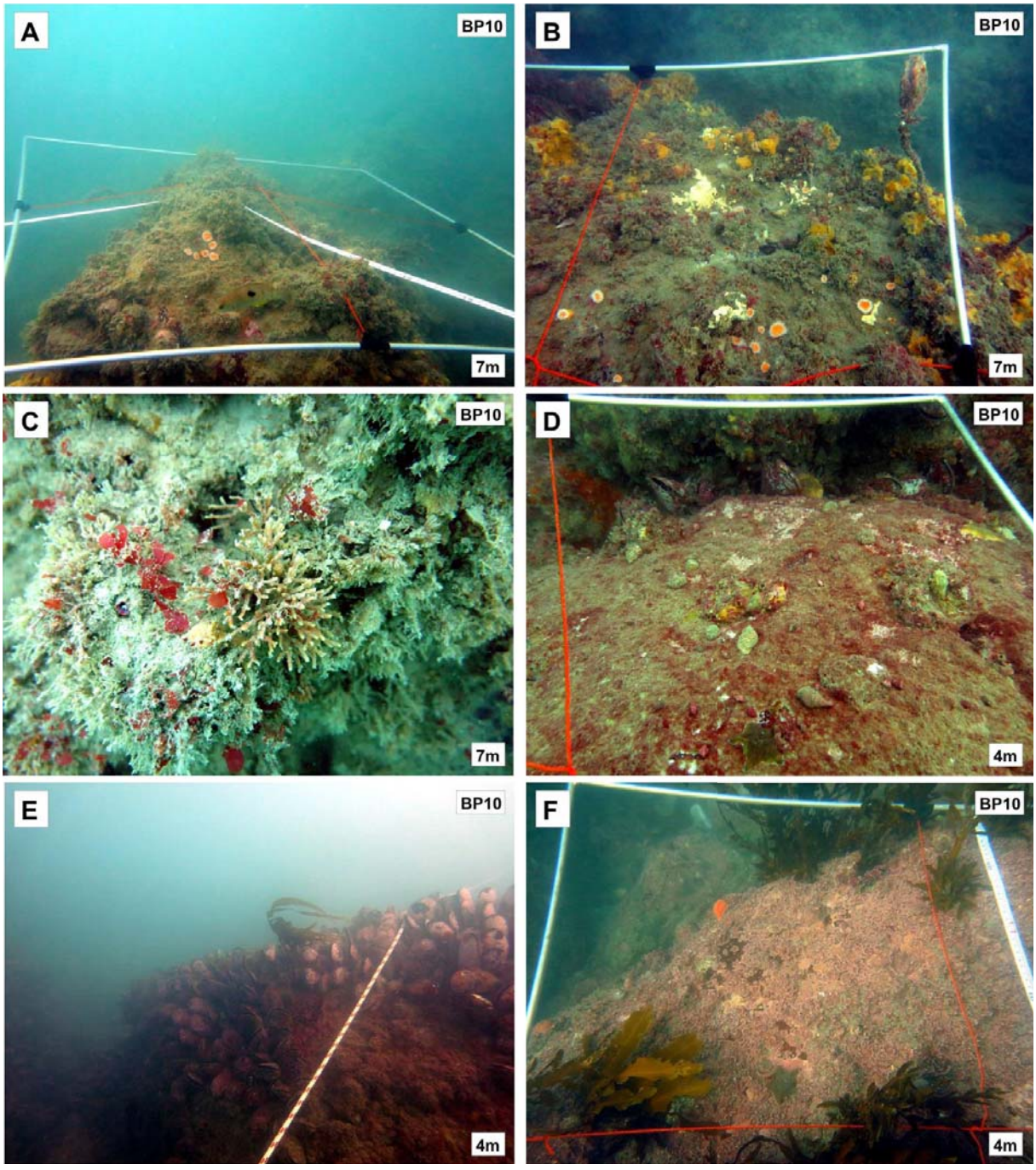
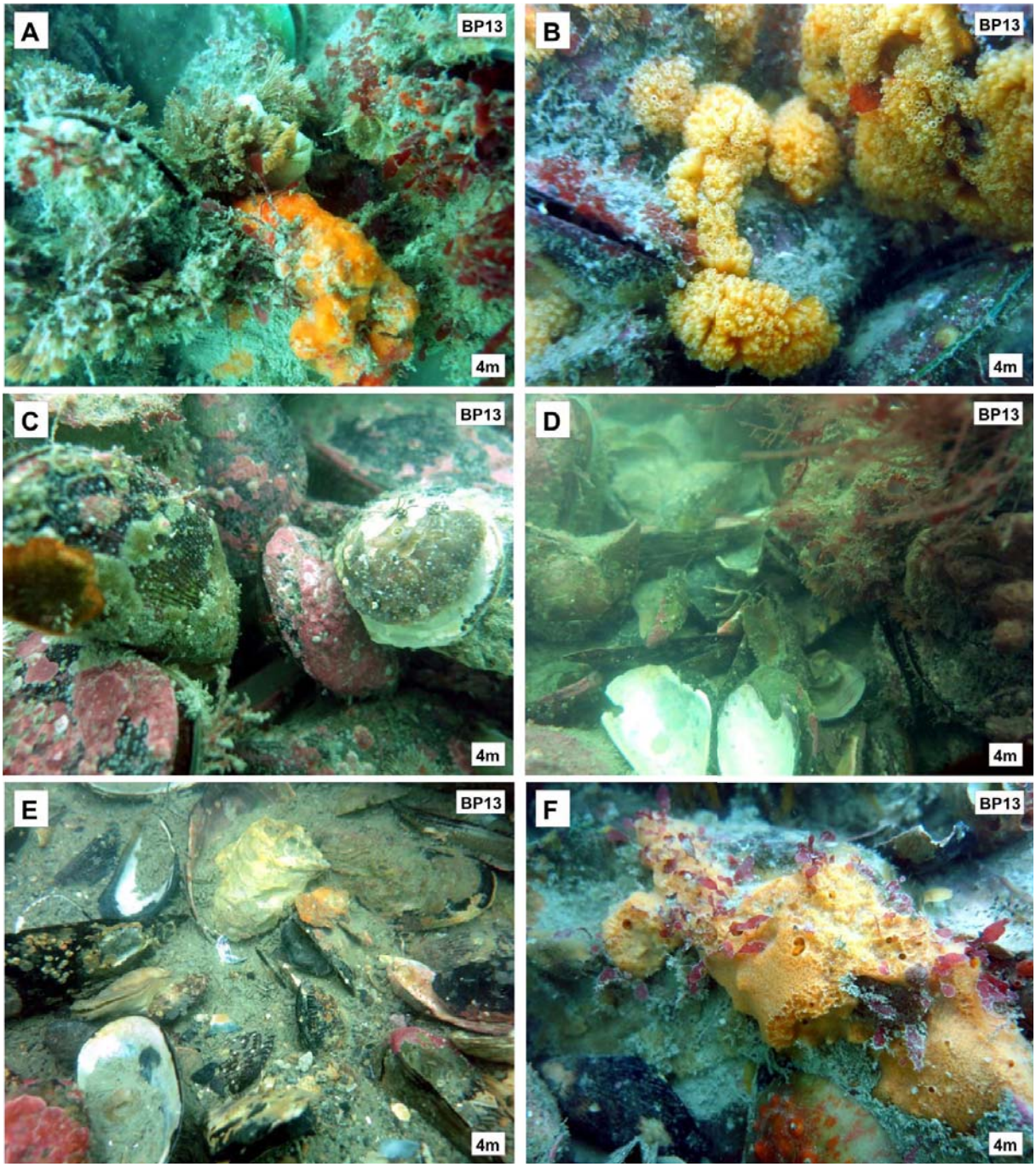


These photographs demonstrate some of the difficulties encountered in quadrat placement in very uneven benthic terrain along a laid transect.

Appendix 3, continued



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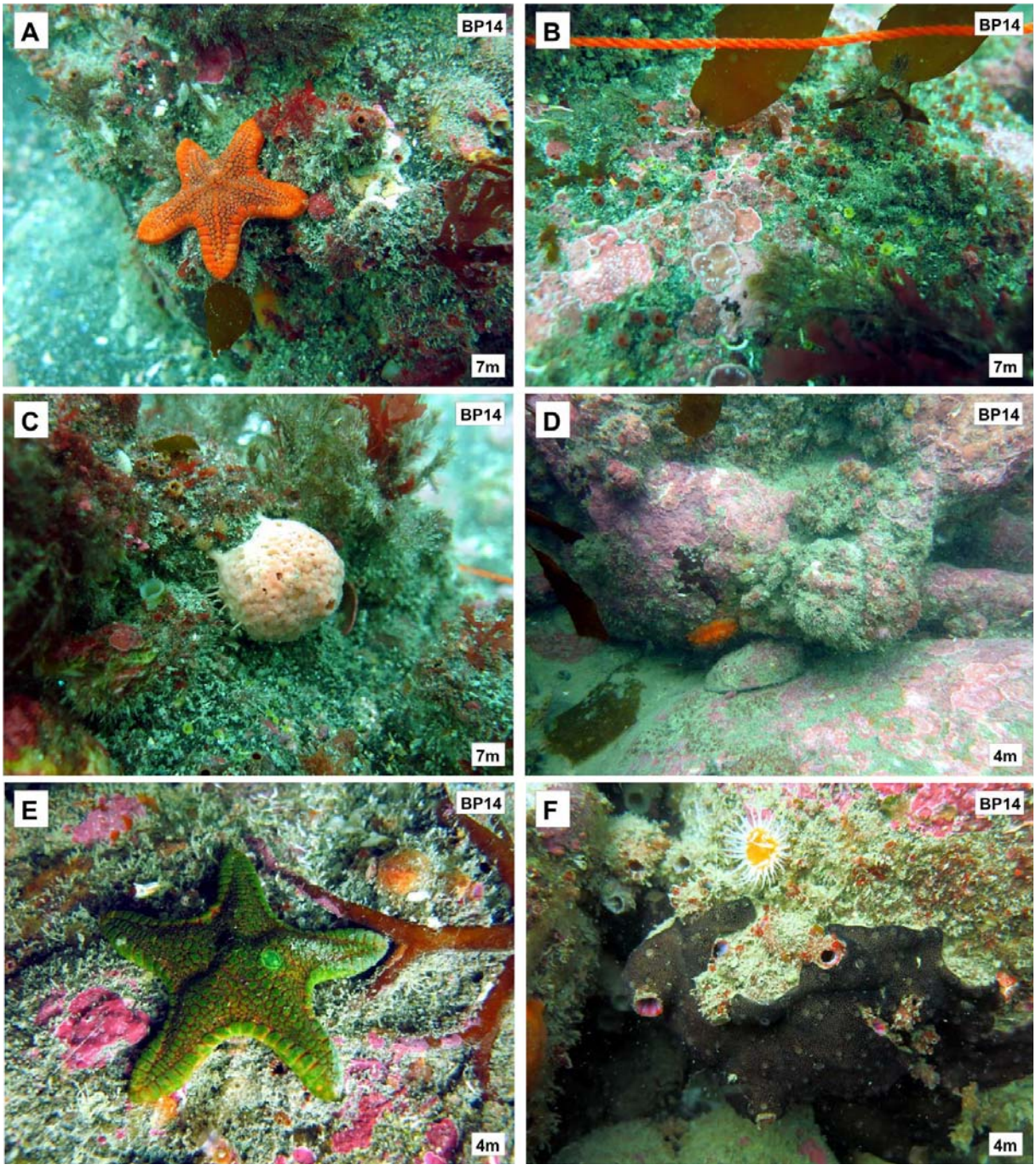

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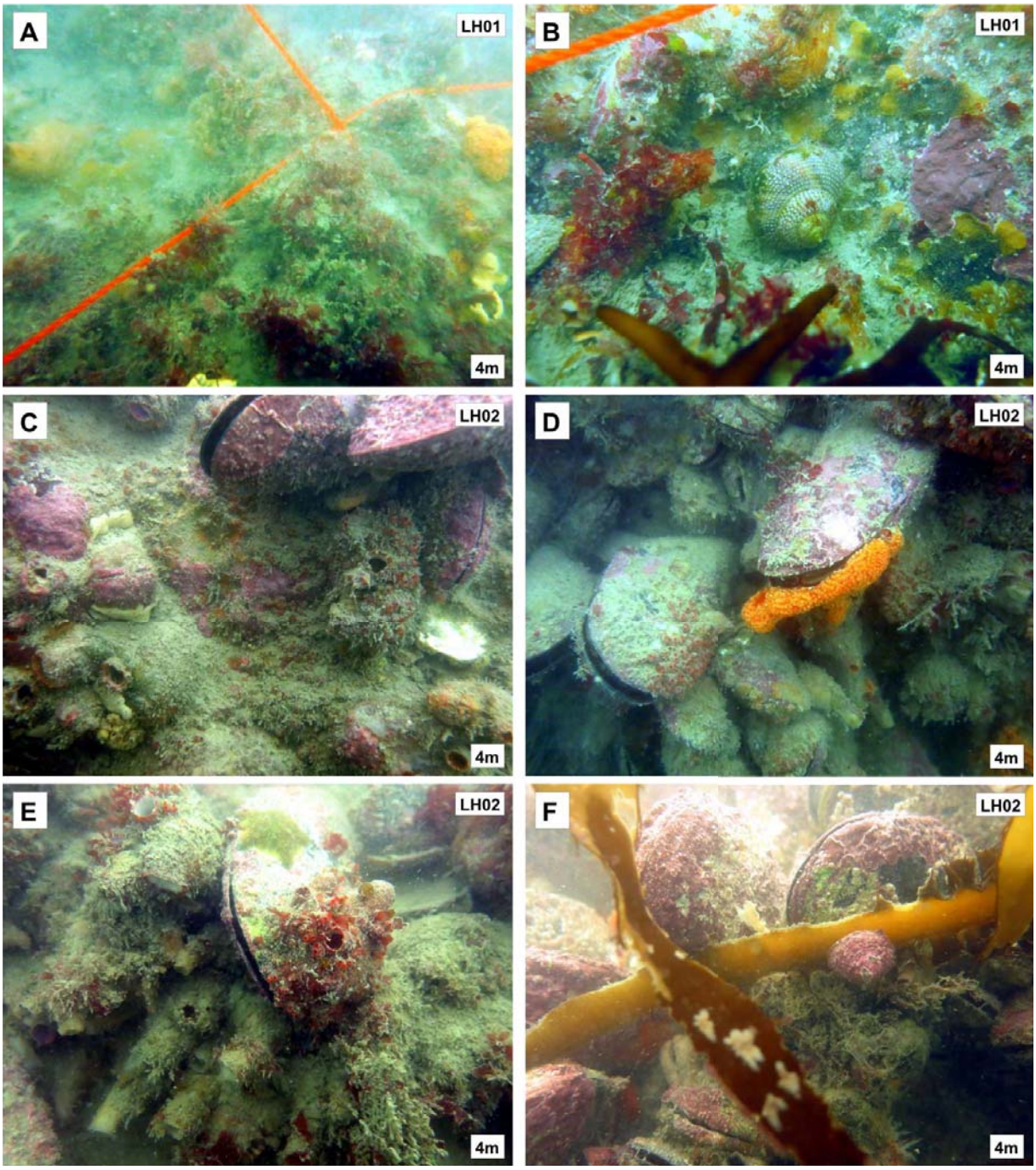

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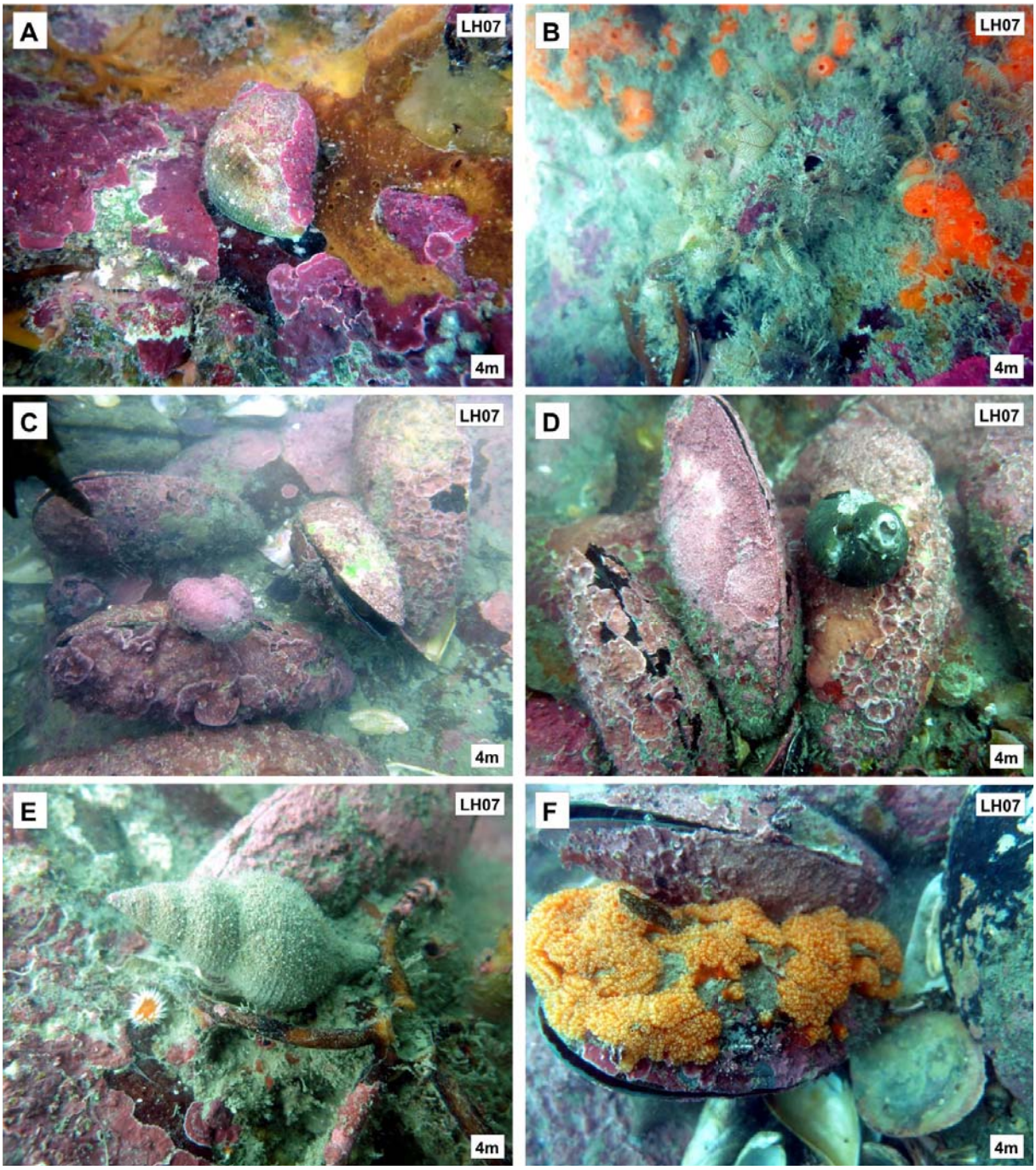

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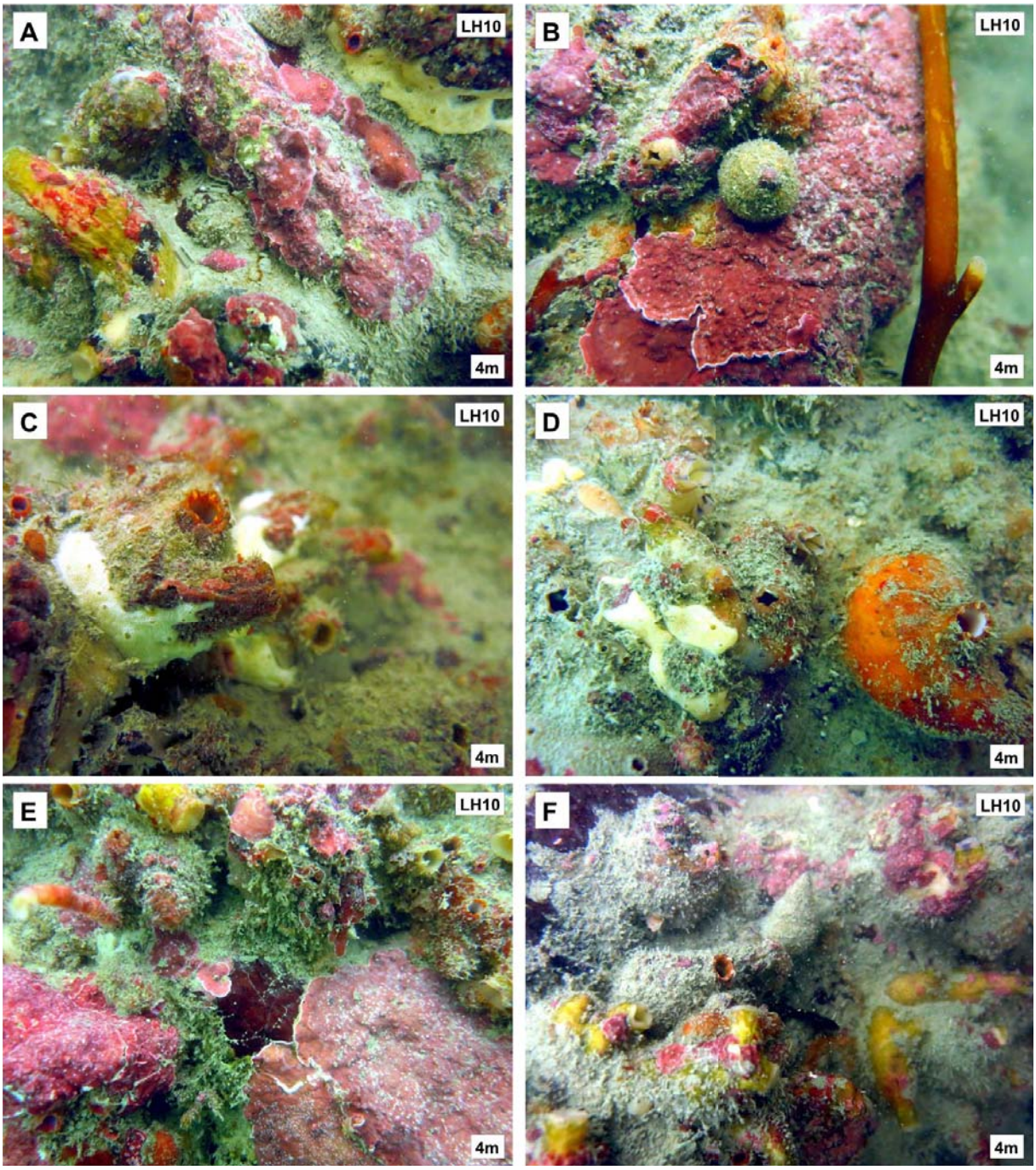

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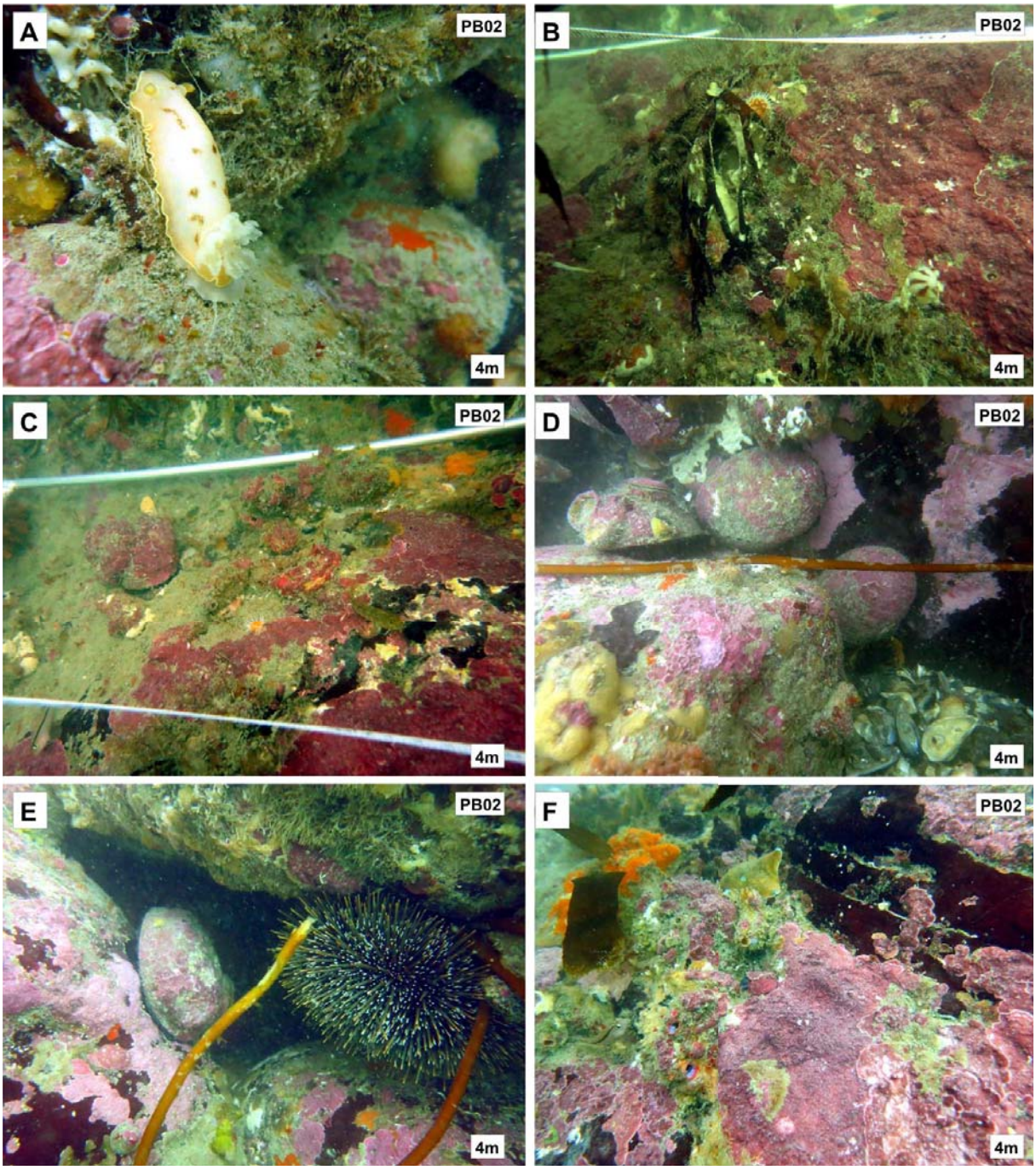

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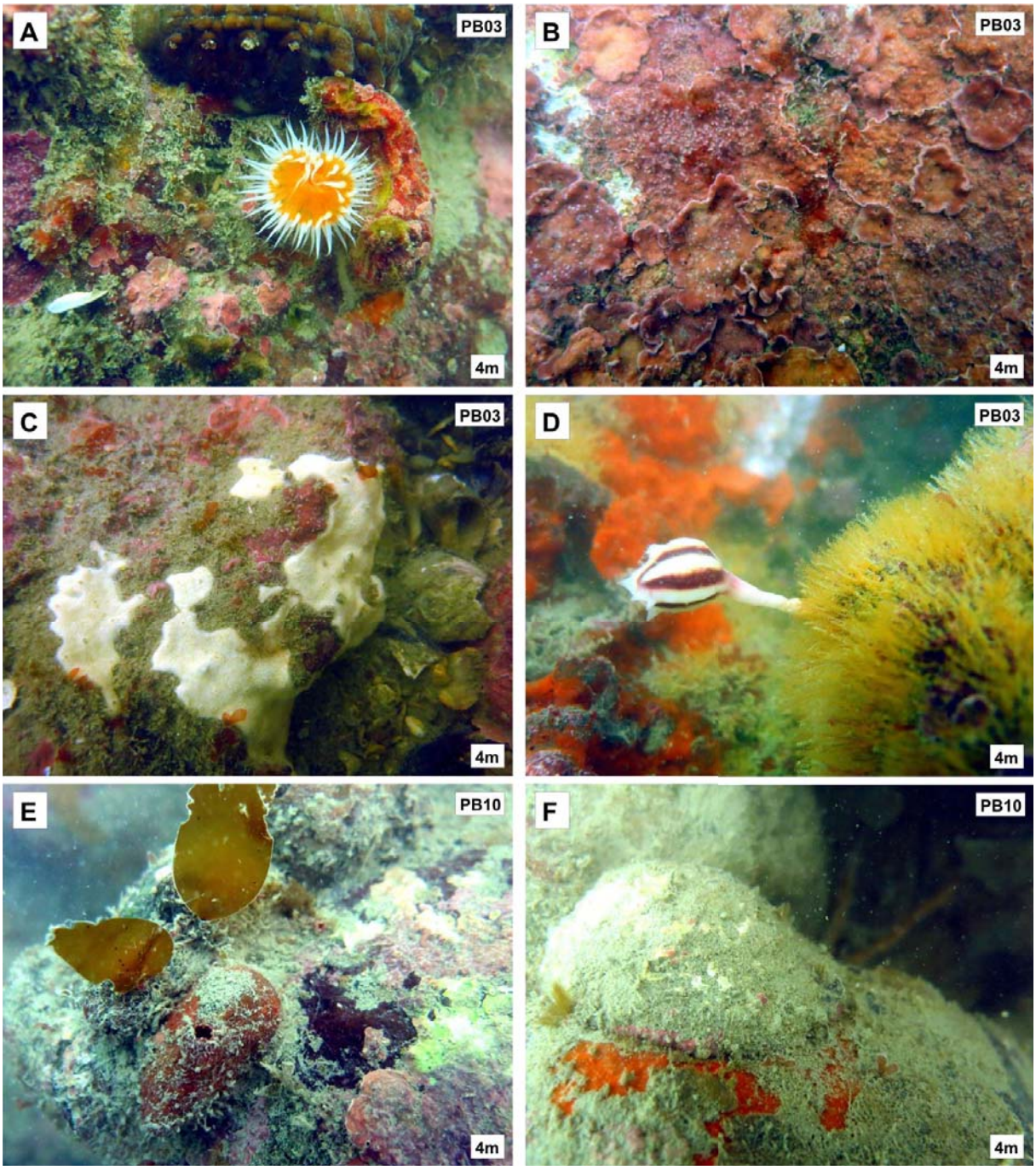

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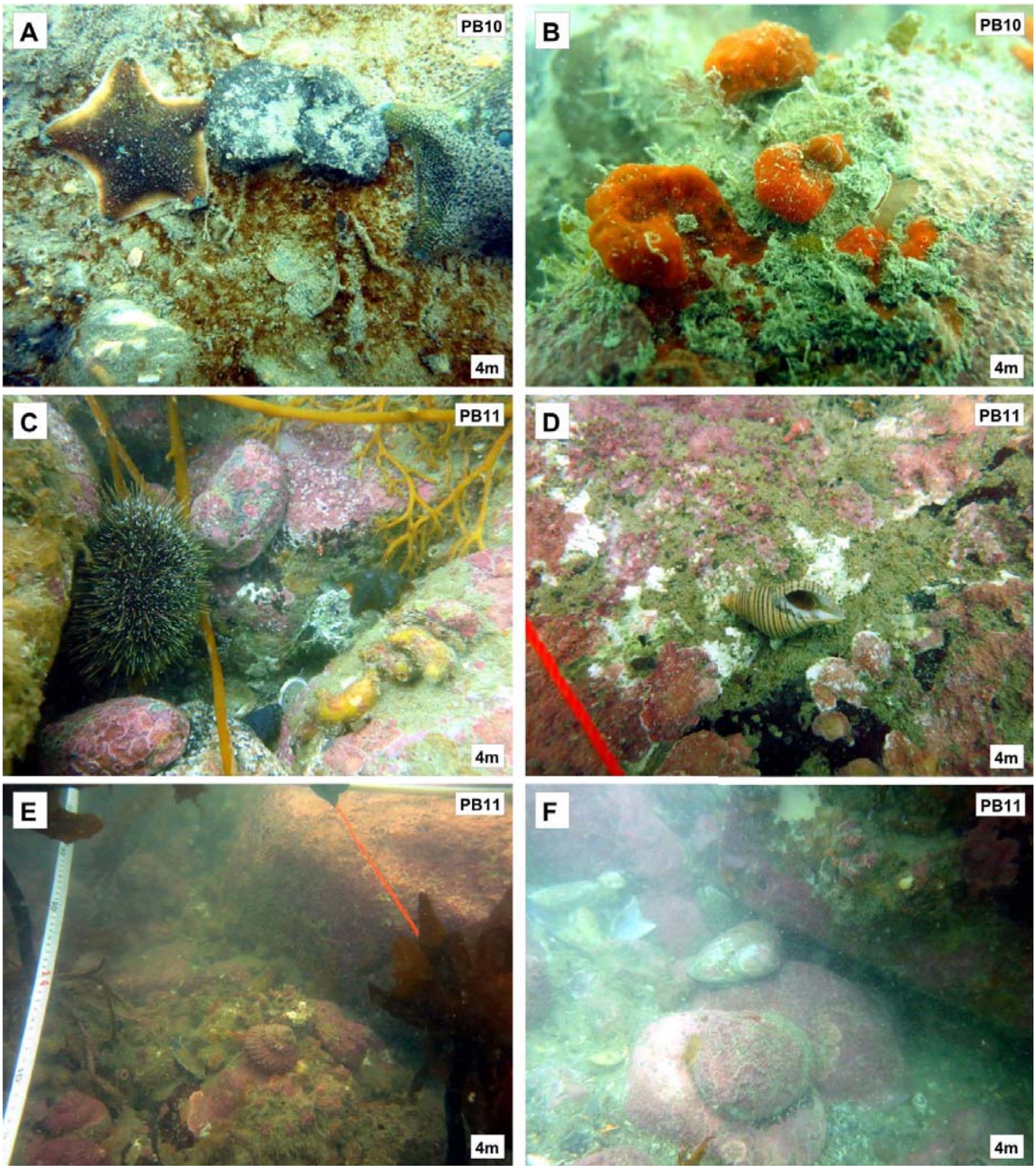

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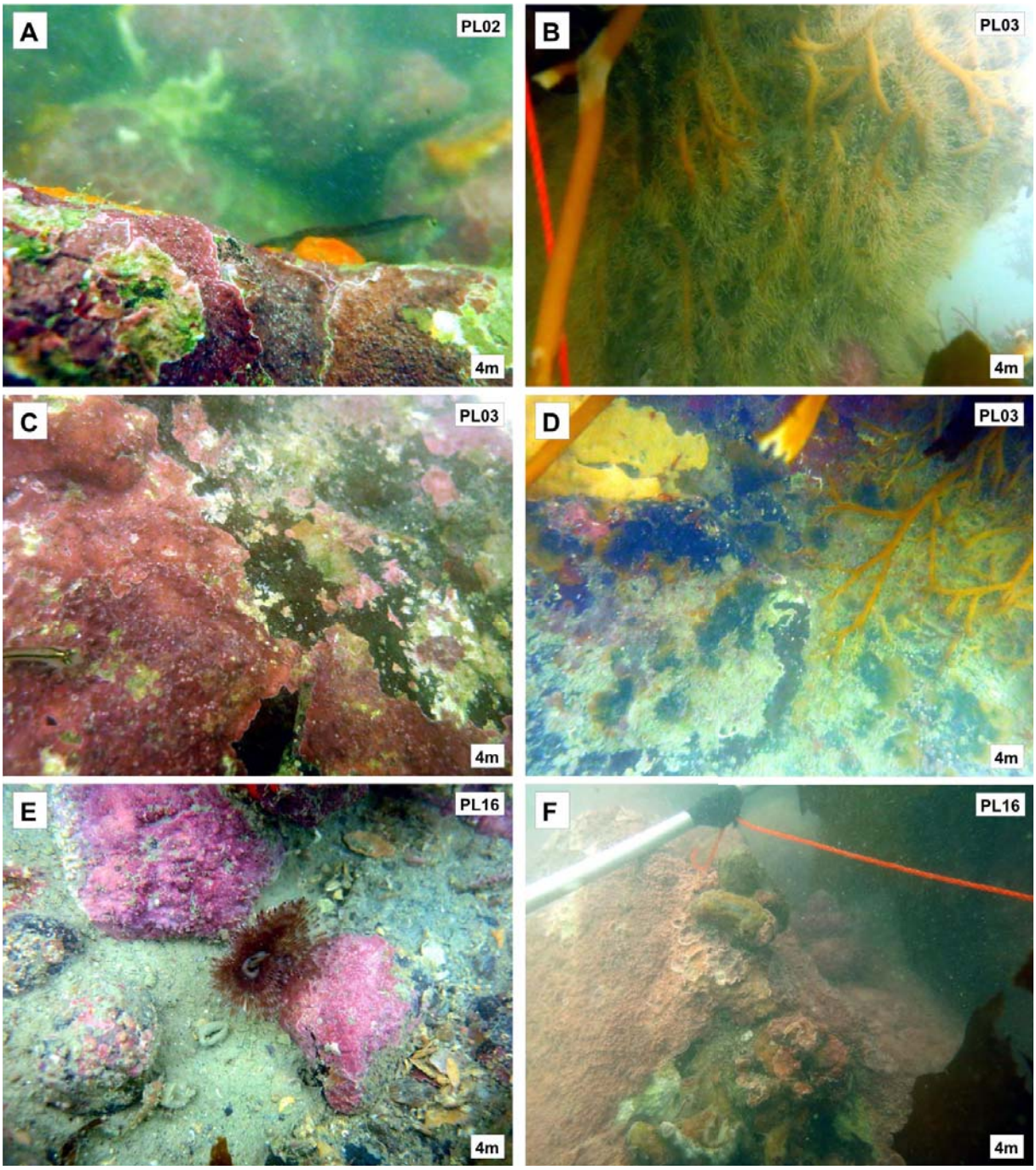

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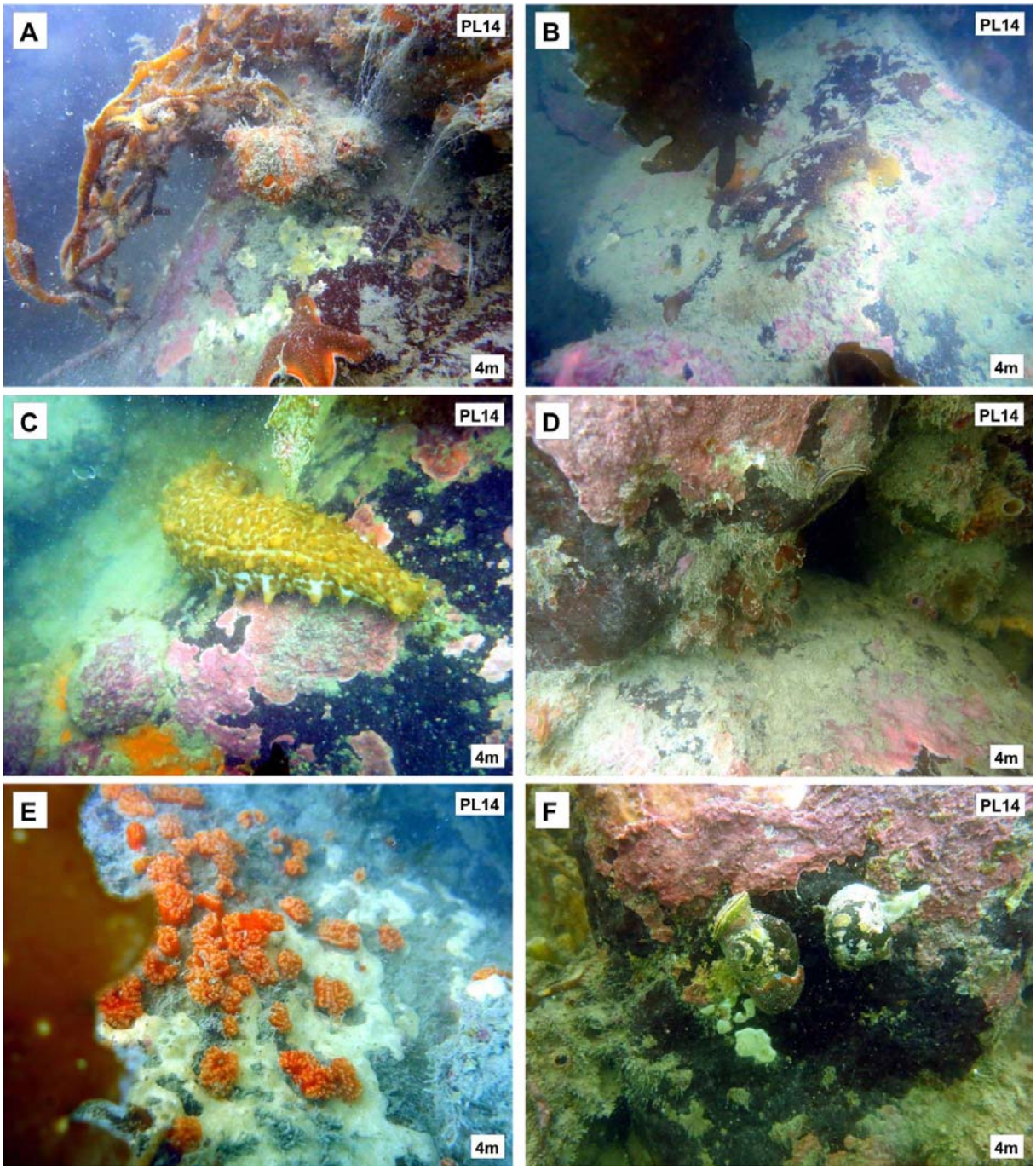
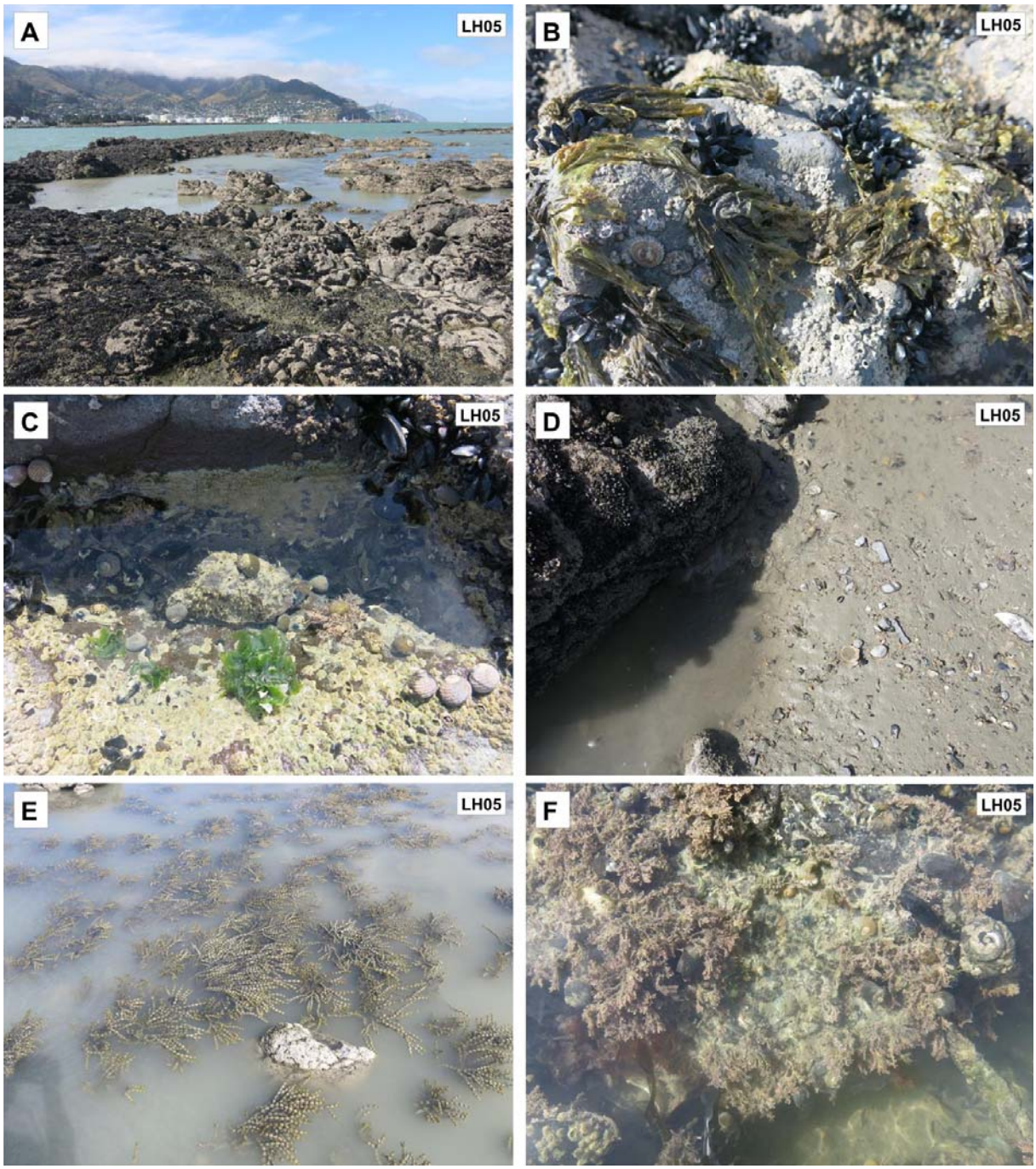
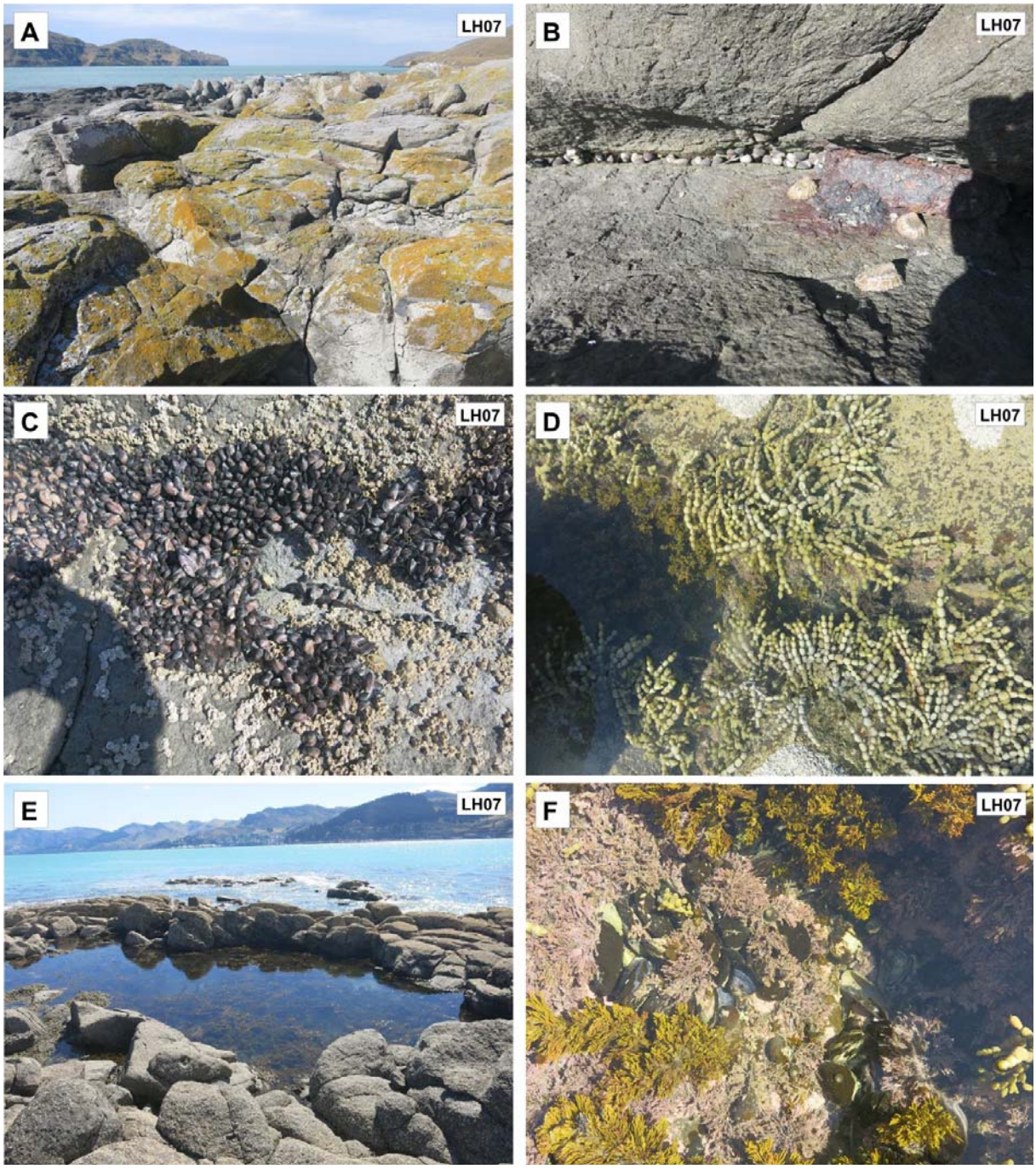


Appendix 4 Representative photographs of the five intertidal locations surveyed in February 2016.



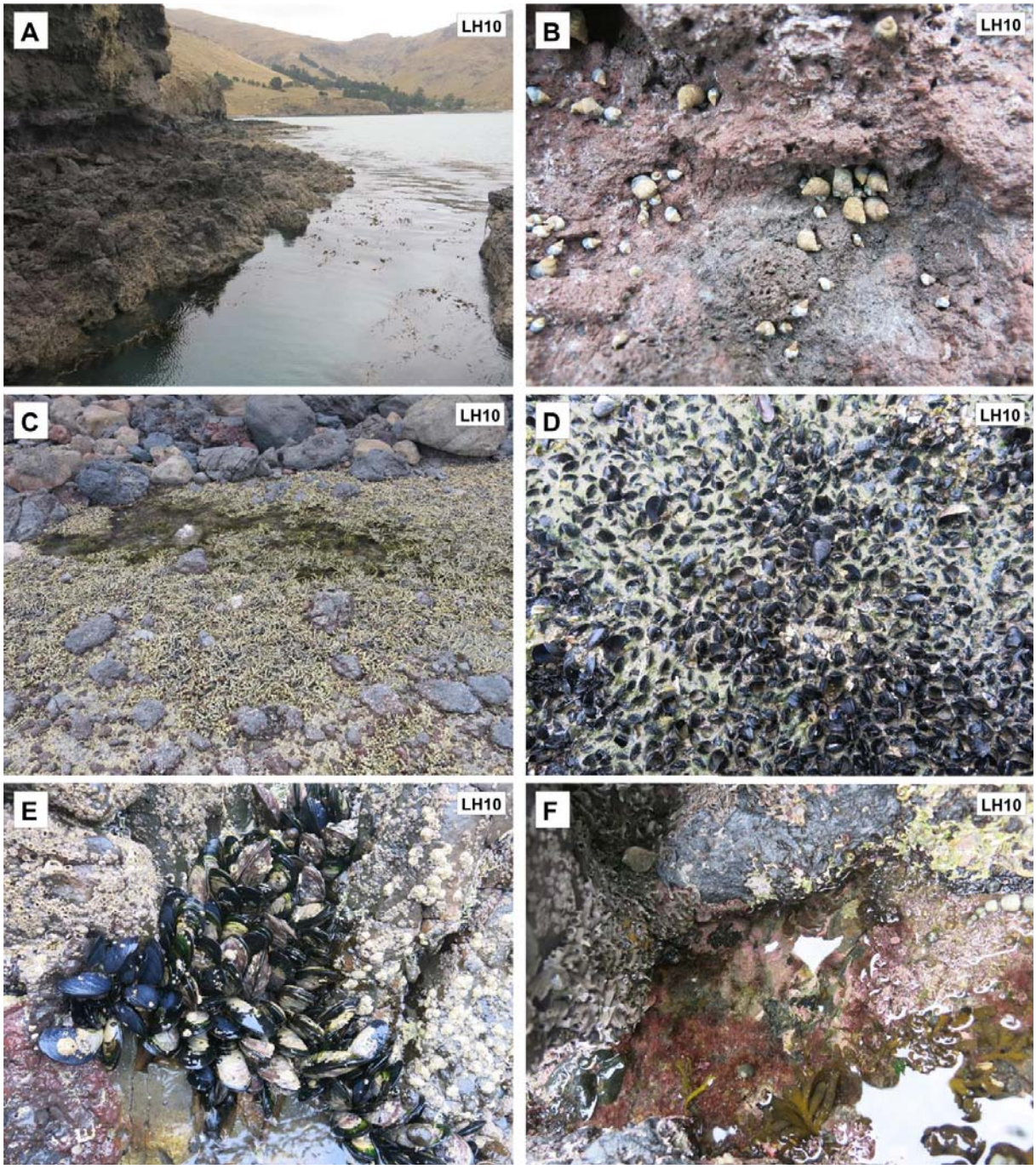
Site LH05; Shag Reef (Kamautaurua Island) in mid-Lyttelton Harbour: (A) looking onshore towards the port, (B) high- to mid-shore community, (C) Mid-shore tide pool, (D) Accumulated silt in depressions and tide pools, (E) Neptune's necklace weed in the low-shore, (F) Low shore assemblage.

Appendix 4, continued



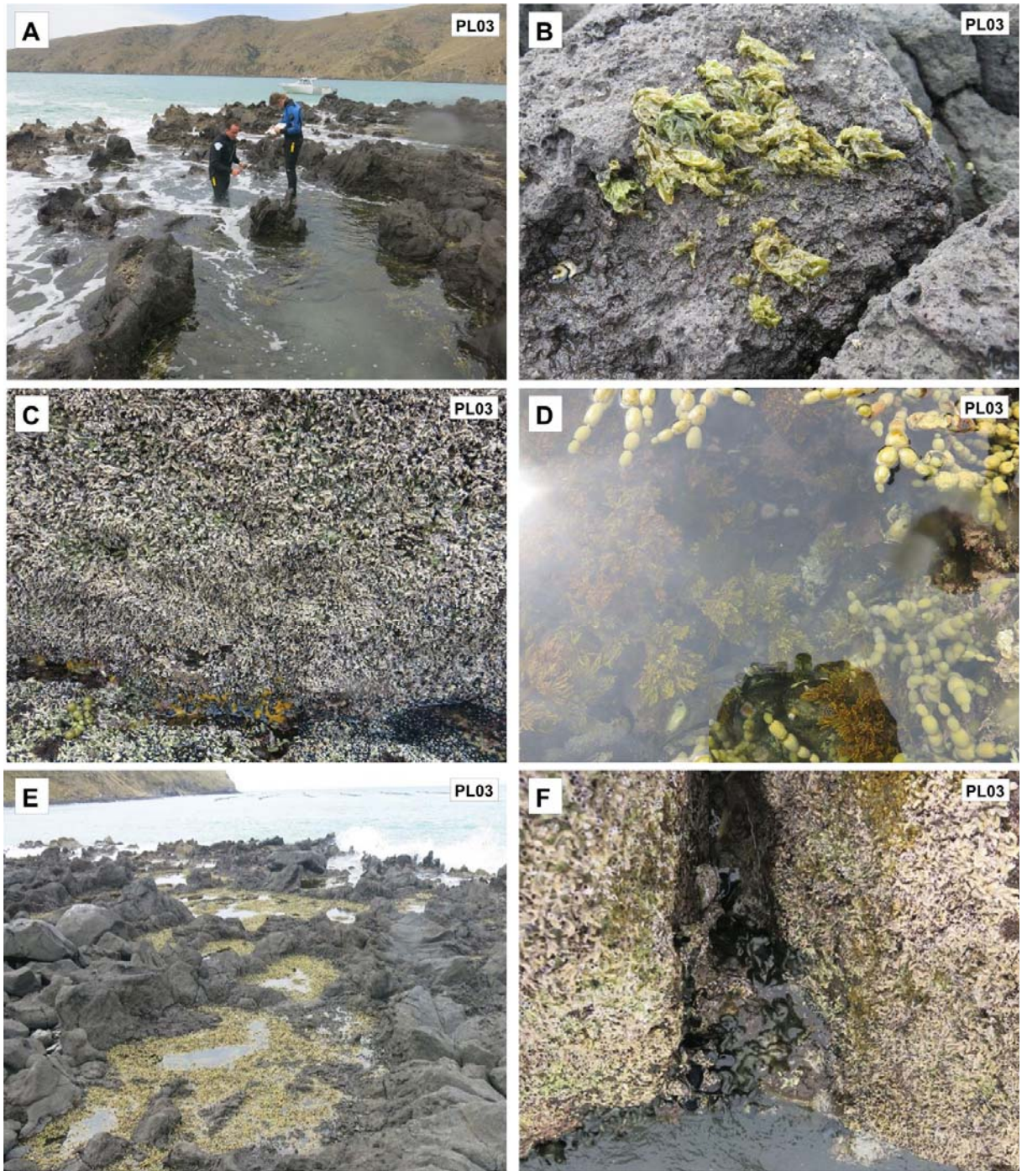
Site LH07; Ripapa Island: (A) looking towards the Harbour heads across the high shore; (B) High shore zone and organisms, (C) High- to mid-shore organisms included blue mussels and barnacles, (D) macroalgae in mid-shore rock pool, (E) Looking towards the port across the large rock pool on the NW end of the reef, (F) Low-shore tide pool assemblage.

Appendix 4, continued



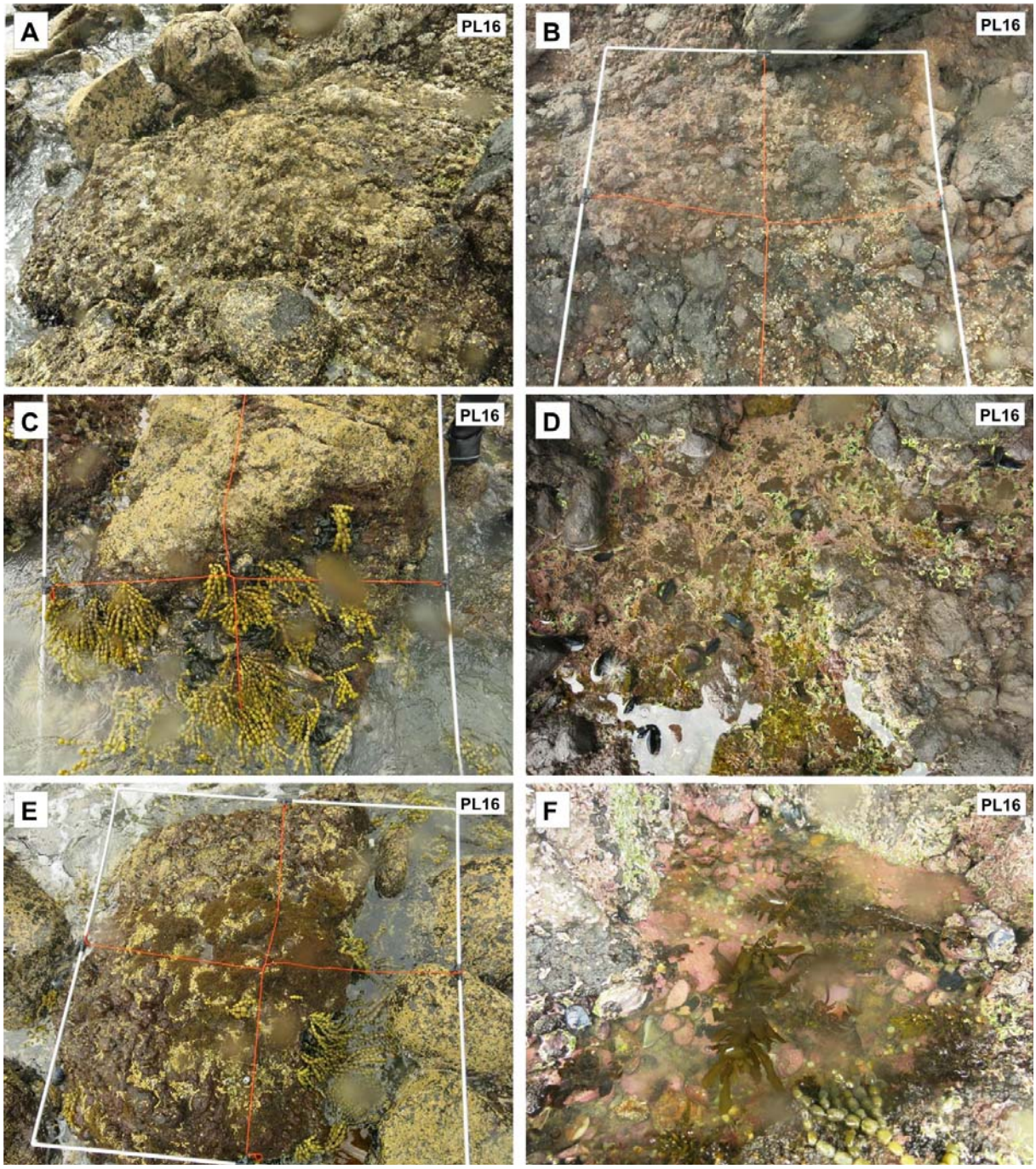
Site LH10; Camp Bay east: (A) looking WSW into the Harbour; (B) Periwinkle snails (*Nodilittorina cincta* and *N. unifasciata*) in the high-shore zone, (C) Neptune's necklace weed (*Hormosira banksii*) was conspicuous in mid-shore habitats, (D) Little black mussel (*Xenostrobus pulex*) colony with interstitial silt in the mid-shore zone, (E) the green lipped-mussel was abundant in the low shore. (F) macroalgae in low-shore rock pool.

Appendix 4, continued



Site PL03, seaward side of Pukerauaruhe Island: (A) looking NE towards Baleine Point; (B) High-shore algae (*Clymene coleana*), (C) Continuous colony of the polychaete tubeworm *Spirobranchus cariniferus* in the mid-shore zone, (D) Tide pool on the rock platform, (E) Neptune's necklace (*H. banksii*) was abundant in the mid-shore zone of the platform, (F) Velvet weed (*Codium adherens*) on the low shore.

Appendix 4, continued



Site PL16, Port Levy eastern shoreline: (A) General view of the steep and narrow profile from the mid-shore, (B) High shore substrate, (C) Low-shore *C. adherens* and *H. banksii*, (D) Mid-shore tide pool, (E) Low shore, (F) Low shore tide pool.