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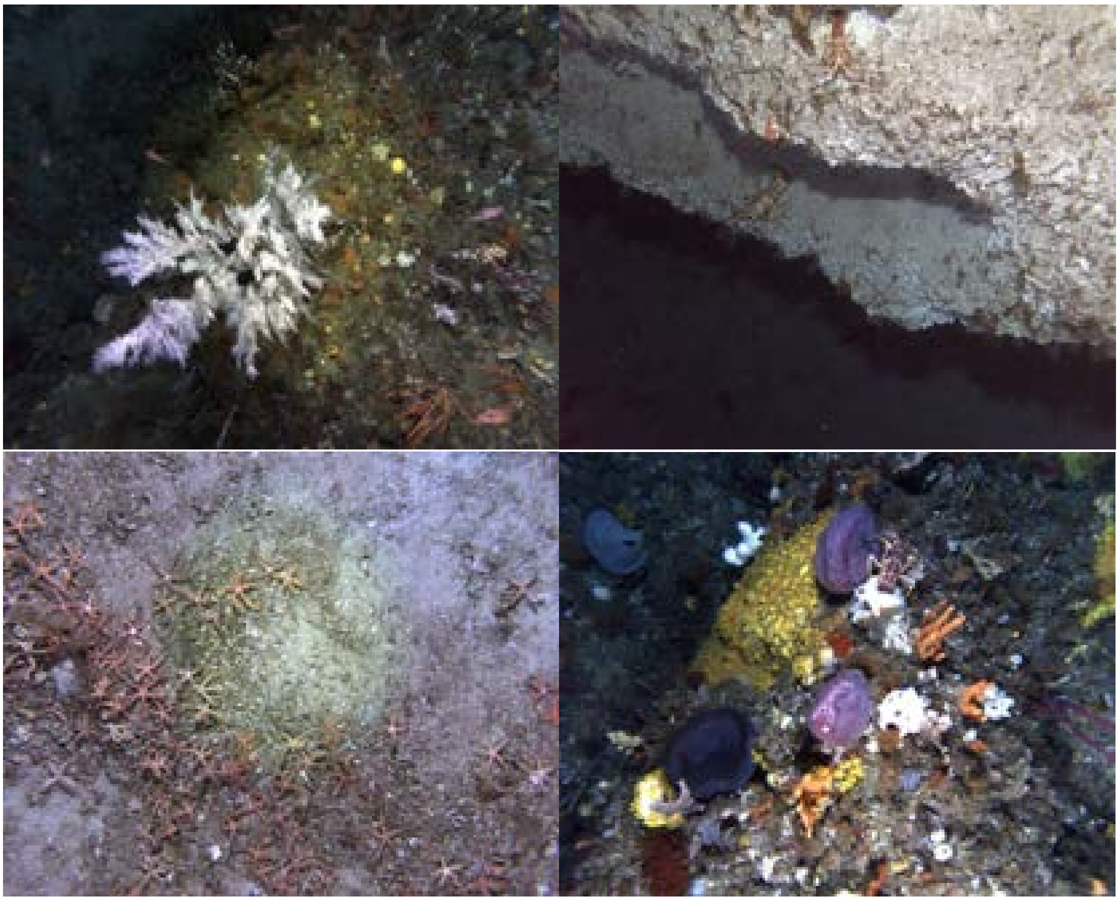
Autonomous Underwater Vehicle-based benthic fauna surveys and monitoring of Huon Marine Park and Freycinet Marine Park shelf habitats 2022/2023



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June 2024

UNIVERSITY of TASMANIA

IMAS
INSTITUTE FOR MARINE & ANTARCTIC STUDIES

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Acknowledgement

This work was undertaken for Parks Australia. We thank the Integrated Marine Observing system (IMOS) for their support with AUV monitoring program and Understanding of Marine Imagery (UMI) for their contribution towards the national annotation repository used in this work. IMOS is enabled by the National Collaborative Research Infrastructure Strategy (NCRIS). This Australian Centre for Field Robotics at University of Syndey is also thanked for operating the AUV. This research acknowledges the support provided by the Director of National Parks, particularly Drs Cath Samson, Natalie Bool, and Daniel Murphy from Parks Australia/Australian Marine Parks. The views expressed in this document do not necessarily represent the views of the Director of National Parks or the Australian Government.

Important Disclaimer

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Executive Summary

Autonomous Underwater Vehicle (AUV) image-based surveys of benthic habitats and the biological communities that inhabit them were conducted in the Huon Marine Park (HMP) Multiple Use Zone and the Freycinet Marine Park (FMP) Multiple Use Zone within the South-east (SE) Marine Park (MP) Network in 2022 and 2023 respectively. These surveys represent (1) a continuation of the time-series of repeated cross-shelf surveys in Australian Marine Parks (AMPs) conducted as part of the Integrated Marine Observing System (IMOS) AUV facility in Tasmania (see Perkins et al. 2021), and (2) an extension of the program to survey and represent newly mapped habitats not represented by prior surveys. For the HMP, in 2022 we conducted AUV surveys at two long-term monitoring sites, as well as AUV surveys at four new sites further offshore. The current work at HMP long-term monitoring sites builds on the existing monitoring program with the two sites now having been surveyed four times: in 2009, 2010, 2014 and 2022. In the FMP, AUV surveys in 2023 were conducted at three long-term monitoring sites as well as six new survey locations, with two on the shelf and four on the shelf break. AUV surveys at FMP continue monitoring work that began in 2009, with revisits conducted in 2010, 2011, 2012, 2014, 2016 and 2023. However, in the FMP not all sites were surveyed in each time step. Joe's Reef, the dominant granite reef feature within the FMP has now been surveyed four times: in 2011, 2014, 2016 and 2023.

The long-term AUV monitoring sites were initially established under the IMOS AUV program on representative seabed features in shelf waters of each MP based on multibeam mapping undertaken by Geoscience Australia (Nichol et al. 2009) of portions of the shelf in each MP prior to the baseline biological surveys. The AUV sites were primarily targeted on reef-like features identified from the mapping in both Huon and Freycinet MPs. Additional multibeam mapping on the shelf conducted in 2019 in each MP considerably expanded the knowledge of the benthic topography and reef features in each of these parks, allowing an opportunity to undertake further AUV surveys for both describing the biodiversity of these habitats and underpinning potential future monitoring. Subsequently, additional AUV survey sites were identified for the 2022/23 campaign, with four additional AUV surveys being undertaken in both MPs. The four new sites in HMP were primarily targeted on reef features identified further offshore from the long-term monitoring sites, extending the maximum depth of coverage from around 75 m to over 100 m, the deepest extent of mapped reefs in shelf waters in this park. The four new sites in FMP were primarily focussed on shelf break reef features in depths of 100-140 m (i.e. in the rariphotic zone), offshore from sites previously surveyed and representing deeper reef habitats not previously examined in the park, allowing the full depth range of reefs to be represented by AUV surveys.

This report therefore has two major points of focus: (I) to describe the habitats and biological communities present in the previously unsurveyed sites in both HMP and FMP, and (ii) to explore the time series at the repeat survey sites in both HMP and FMP to describe temporal change.

In the HMP the four new survey sites revealed the reef habitat and associated biota on the deeper mesophotic to rariphotic reefs were generally similar to that found on the prior sites, which were further inshore, with the new sites providing spatial replication and greater understanding of the depth relationships of key species. In the FMP the four new survey sites at the shelf-break in the rariphotic zone provided a first habitat characterisation of this region and the associated biota. Much of this area was characterised by extensive beds of bryozoan rubble and shell rubble amongst soft sediments, with relatively rare outcropping reef. Typically, the cover of emergent biota was very sparse regardless of the habitat type, even on outcropping reef, particularly where this was composed of mudstone. The two new surveys conducted on mid-shelf locations in the rariphotic zone over the common dune-like features showed them to be similar to existing mid shelf survey locations, with a sand-inundated seabed with little to no emergent bedrock or reef-like features and very little emergent fauna other than the fine biological matrix (presumably predominantly bryozoan in composition) that was also commonly encountered during most of the deeper shelf surveys in the FMP.

The time-series in the FMP had two key components; (1) repeat surveys of the complex reef associated fauna on Joe's Reef, the only major shelf reef identified in this park spanning lower mesophotic to rariphotic zones, and (2) repeat surveys of the mid-shelf dune-like features in the rariphotic zone. The fauna on Joe's Reef was relatively stable over the decadal period of the study, although several key morphospecies such as gorgonian red *Pteronisis*-like octocorals and repent yellow sponges did vary in order of magnitude over this period, though they were typically less than 2% individual cover, and as there were no consistent patterns of variation shared across these, presumably they are each responding to different (yet unknown) environmental drivers. On the dune-like mid shelf seabed, the cover of readily identifiable morphospecies was extremely sparse and remained that way over the period of the study at these sites (2009-2023). At one survey location, MPA site 2, the overall cover of fine biological matrix did increase notably over this period, although further time-series data will be required to determine whether this is an ongoing response to protection or a result of a lengthy period without storm-related seabed disturbance.

The sites associated with the time-series in the HMP were established on complex reef systems primarily in the mesophotic zone. These showed a somewhat similar pattern to that observed in the FMP on rocky reef. Most morphospecies remained at less than 2% average cover, and although some varied at up to an order of magnitude over the period of the study (2009-2022), as found at FMP, there was no consistent trend and trends were often in opposite directions to that seen in the same morphospecies in the FMP. For both the FMP and HMP a longer-term time series coupled with the recording of oceanographic and climatic variables is required to determine the likely key drivers of observed variation, as this can be derived from a wide range of physical drivers, including severe storms through to changing ocean current systems with corresponding influences on food availability and water temperature.

General introduction

At the time of establishment of the Huon and Freycinet Marine Parks (HMP and FMP respectively) within the South-east Marine Parks Network, little was known about the range of habitats found in shelf waters within these parks, nor the distribution and abundance of the associated benthic biota. Recognising this gap, initial exploratory surveys were undertaken in both of these parks by the Commonwealth environment research facilities (CERF) Marine biodiversity Hub in 2008-2009 as an offshore extension of more detailed coastal surveys, providing the first description of some of these habitats (Nichol et al. 2009). These surveys included multibeam mapping of portions of these parks and subsequent deployment of autonomous underwater vehicles (AUVs) and towed video for initial habitat and benthic biota description. In the HMP these surveys in 2009 were on a section of mesophotic rocky reef in the NW sector of the park, ranging in depth from 40 m to around 75 m. These reefs were found to be relatively complex dolerite structures, characterised by an extensive cover of wave-pruned sessile invertebrates dominated by sponge cover, and typically occupied by a significant abundance of southern rock lobsters (*Jasus edwardsii*). In the FMP, initial multibeam mapping by Geoscience Australia in 2008 (Nichol et al. 2009) indicated that the main offshore structures on the shelf were long, linear consolidated dune-like features that ran parallel to the coast in mesophotic depths of 70-80 m. While not fully reef-like, lacking extensive exposed bedrock and any obvious crevices, these dune-like structures were found to support a range of reef-associated fish species. Hence, these were targeted for AUV surveys to describe the associated biota. The initial surveys in 2009 revealed the dune-like features to be primarily sand-inundated but with more structure (notable slopes) and sediments lacking the rippled surface of adjacent soft sediments (Nichol et al. 2009). These features were associated with a distinct but sparse sessile biota, typically characterised by small sponges.

Subsequent to the initial AUV-based sampling, further opportunistic mapping of the seabed in the FMP was undertaken by the National Environment Research Program (NERP) Marine Biodiversity Hub, discovering and mapping Joe's Reef, an isolated granite feature of approximately 400 m x 200 m, rising from 80 m depth to a height of 60 m depth. This reef consists of a significant number of large granite blocks that create a mosaic of vertical walls and complex crevice features that support a wide range of sessile invertebrates, including black corals, sea whips, sea fans and sponges (Perkins et al. 2021), as well as large schools of planktivorous fish (typically butterfly perch, *Caesioperca lepidoptera*) plus a range of reef fish species including striped trumpeter (*Latris lineata*), jackass morwong (*Nemadactylus macropterus*), and reef ocean perch (*Helicolenus percoides*). This mapping informed AUV-based sampling of the area. Because of the unique complexity of Joe's Reef, it was incorporated into the 2011, 2014, and 2016 AUV-based sampling surveys under the Integrated Marine Observing System IMOS AUV-based benthic monitoring program. With support from Parks Australia, initial sampling at Joe's Reef was undertaken in 2011 and during subsequent surveys (2011, 2014, 2016, and 2023) in the park (Perkins et al. 2021).

While preliminary analysis of the AUV-based imagery datasets from these parks was limited to initial biodiversity pattern reporting (Nichol et al. 2009), wider-scale analysis of biotic relationships (e.g. James et al. 2017), climate change prediction (Marzloff et al. 2016), and impacts of marine heat waves (Perkins et al. 2022b), a more detailed time series analysis of changes in Huon, Freycinet, Flinders, and Beagle SE MPs was undertaken by Perkins et al. (2021). This analysis provided an opportunity to examine the extent that such monitoring programs can detect biologically meaningful changes in key species/morphospecies, as well as the sampling strategies needed to underpin this (Perkins et al. 2022a). Overall, multivariate analysis (see Perkins et al. 2021) revealed that there were no significant shifts in broad community composition within FMP and HMP over the survey period

(2009-2017); however, several individual morphospecies underwent significant change, including a reduction in a common red gorgonian (currently identified to the genus-level as '*Pteronisis*-like') at locations such as Joe's Reef, and an increase in soft bryozoans. While the common assumption is that deeper water marine species are relatively stable compared to shallower water species, the data collected during 2009-17 indicated that a subset of deeper water sessile invertebrate species around Tasmania can exhibit considerable fluctuations in abundance over time periods less than ten years (Perkins et al. 2021). Understanding these dynamics has important implications for the management and ongoing monitoring of these communities; however, extended time-series and improved physical data are needed to determine the overall drivers of much of this observed change. Hence, a core aim of this study was to continue the time-series of monitoring within the Huon and Freycinet MPs to both improve understanding of natural variability and the drivers of variability in these systems, as well as to inform park managers of any significant changes or observations within these systems that may require management intervention. This is intimately linked with the development of the Monitoring, Evaluation, Reporting and Improvement (MERI) framework system developed by Parks Australia to underpin adaptive management of the SE MP Network (e.g., Hayes et al. 2019).

Further mapping in both the Huon and Freycinet Marine Parks in 2019 for Parks Australia by IMAS/CSIRO (Heaney and Davey 2019) provided a wider examination of shelf seabed habitats that was then used to plan the development of more representative inventory and monitoring programs. In the FMP, the dune-like features mapped previously by the CERF and NERP Hubs extend throughout much of the shelf waters of the MP, hence our initial AUV-based sampling sites were representative of these. The subsequent mapping survey in 2019 validated that Joe's Reef was a unique feature within the park, and revealed other low-lying reef outcrops in the vicinity of Joe's Reef (yet to be fully mapped), though no further significant outcrops were found on the shelf. Joe's Reef spans lower mesophotic to the upper rariphotic zone and holds the only reef in the mesophotic zone in FMP, hence it is a key focus in the present work as well as ongoing monitoring efforts. Also, the 2019 mapping revealed the presence of several isolated reef systems at the shelf-break in the rariphotic zone, where presumably strong currents associated with shelf-edge canyon-derived upwelling prevent reef patches from being buried in sediment in this otherwise low energy environment. Given the unique nature and very restricted extent of these shelf-break reefs, description of their associated biota was a priority for this AUV survey.

In the HMP mapping undertaken in 2019 revealed that complex dolerite reefs extend southward of the region previously mapped by the CERF Hub in 2008-2009 (Nichol et al. 2009), to depths of around 100 m with some patches extending to around 110 m (Heaney and Davey 2019). The mapping extended on the previous mapped depths that were limited to around 75 m, allowing planning for AUV surveys that described the biota on these deeper sections of reef, to significantly improve our understanding of the depth range of many of the sessile benthic biota found in the park. Hence, surveying these deeper reef areas was also a priority for this study. Examination of existing bathymetry mapping data collected within HMP (see Seamap Australia's Bathymetry of AMPs), revealed that there are few, if any, significant reef features in the deeper mid and outer-shelf areas, hence surveying these newly mapped reef regions. The current work aims to substantially increase understanding of the current biodiversity values and health of shelf reef systems within the HMP.

The key aims of this study were therefore to: (1) continue ongoing monitoring of benthic biota assemblages on reference reef and reef-like habitat locations in the Huon and Freycinet MPs in shelf waters to help inform natural variability and report on any significant long-term trends, and (2) to extend the current knowledge of the mesophotic and rariphotic benthic biota within the Huon and

Freycinet MPs by undertaking new AUV-based seabed imagery surveys within recently mapped areas such as the shelf-break reef systems in FMP and the further offshore reef systems in HMP.

In doing so, we aim to generate a fuller understanding of the biota on the shelf reefs and reef like features of shelf waters in both these MPs, to inform understanding of the biological values of the parks and the processes that structure variability in space and time.

Huon Marine Park

Survey design, image sampling, and annotation

Surveys were successfully completed at the two core long-term survey locations (Huon_12 and Huon_13, previously surveyed in 2009, 2010, and 2014) and four new sites (Huon_01_new-Huon_04_new) using the AUV "Nimbus", an IMOS supported facility operated by the Centre for Field Robotics at the University of Sydney. The AUV was deployed from the vessel "Shlick" chartered for this work, with operations extending over several weeks due to operational difficulties with the AUV. However, despite technical limitations, an additional four sites were surveyed (Huon_01-New_1 to 4) covering deeper reefs than sampled at the earlier locations (Figure 1). Survey of the Huon_12 site was completed on 8th August 2022, and surveys of Huon_13 and the four new sites were completed on 6th September 2022. All images were subsequently post-processed and made available on Squidle.org for open access and subsequent annotation. Images are also visible via Seamapaustralia.org/map/ under the seafloor imagery menu as Squidle+ imagery deployments by image count.

Image sampling and annotation protocols followed standard operating protocols for AUV imagery (Monk et al. 2020), aligning with methodology used during previous surveys (Table 1). Images were systematically selected to ensure that at least 100 images containing reef were included along each transect. The exception to this was Huon_12, where historical sampling of 200 images had been conducted, and this level of image sampling was maintained. Images were overlain with 25 random points, and annotation was completed by experienced scorers using the Squidle+ online annotation platform. A thorough quality assurance/quality control (QA/QC) process was undertaken prior to data analysis.

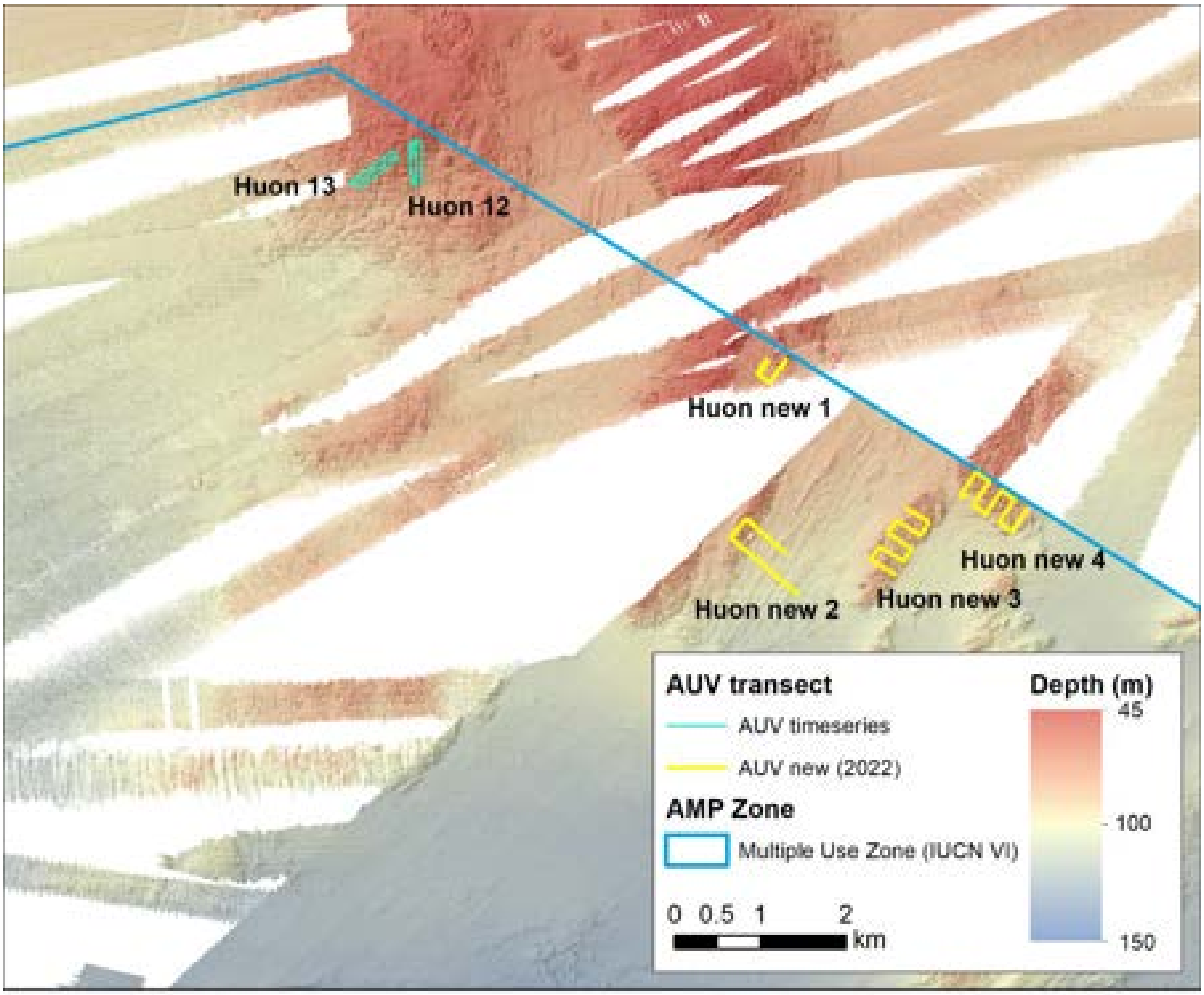


Figure 1. Locations of AUV transects in Huon Marine Park, including repeat time series and new extended coverage.

Table 1. AUV transects conducted at Huon Marine Park, including year surveyed, depth range of survey, Parks Australia depth-based ecosystem, number of images annotated, and the number of random points used.

Transect	Year	Depth range (m)	Parks Australia depth-based ecosystem	Total number of images	Number of images annotated	Number of random points
Huon_12	2009	50-79	Mesophotic	9473	100	50
	2010	49-70		10452	100	25
	2014	50-74		9649	100	25
	2022	49-73		9067	125	25
Huon_13	2009	54-86	Mesophotic-rariphotic	8699	125	50
	2010	51-73		10652	205	25
	2014	51-73		14903	202	25
	2022	52-81		5467	230	25
Huon_new_01	2022	54-73	Mesophotic-rariphotic	8185	100	25
Huon_new_02	2022	68-101	Mesophotic-rariphotic	12617	103	25
Huon_new_03	2022	74-94	Rariphotic	11484	100	25
Huon_new_04	2022	65-92	Mesophotic-rariphotic	10656	101	25

Description of habitats present

Transects in HMP were dominated by flat sand, mixed habitats and low profile (< 1m) reef, interspersed with smaller sections of moderate (1-3 m) and high reef (> 3 m) and walls (Figure 2). Example images of each habitat type is given in the Appendix.

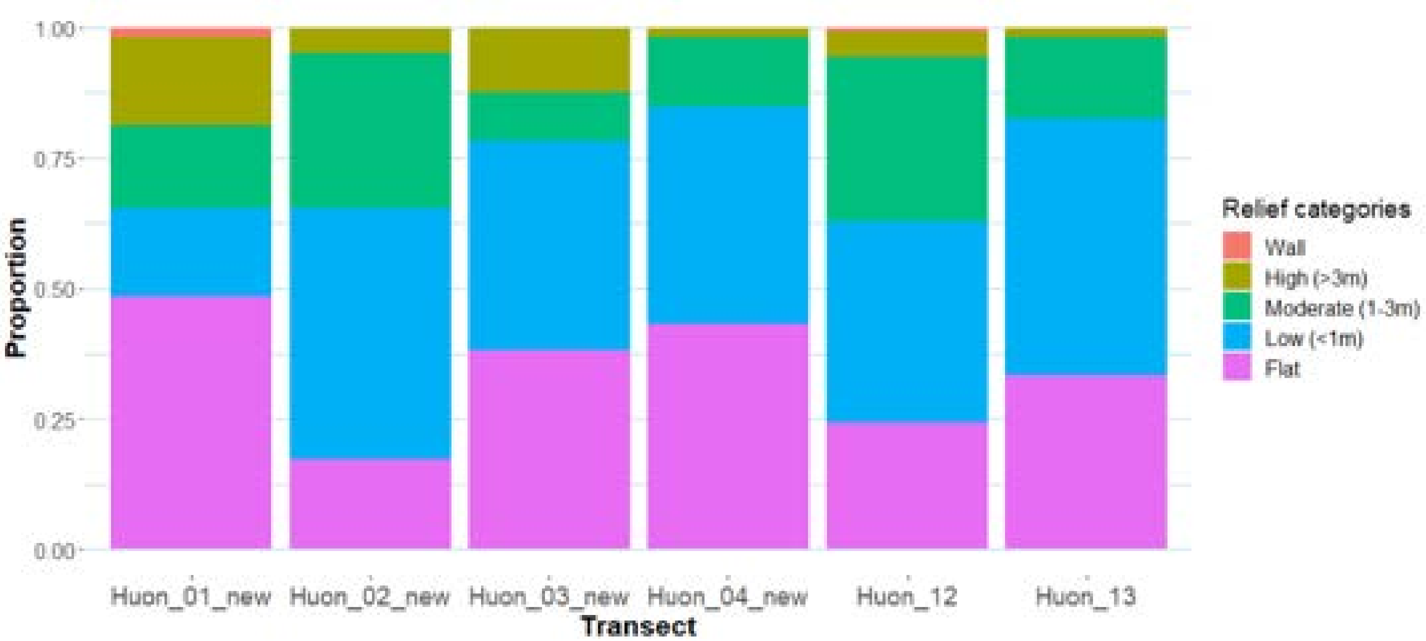


Figure 2. Proportions of different relief categories present across each transect in Huon Marine Park.

Description of biota present

Broad dominant categories of physical and biological cover were used to classify the annotated data and provide an overview of the physical and biological cover. These broad categories were sand, bare rock (either rock, cobble, or pebble), sessile biota, and "biological matrix", a matrix of invertebrate cover likely to be primarily bryozoa, cnidaria, hydroid, and sponge which cannot be further differentiated in the resolution of imagery available. Reef areas were dominated by a cover of low profile biological matrix, which accounted for between ~35% and 65% of the annotated points across all transects (Figure 3). Other biota accounted for between ~15% and 40% of the annotated points in each transect (Figure 3). This more identifiable biota (due to being larger and more distinct) was dominated by a mixture of soft bryozoans, encrusting algae, encrusting sponges, massive sponges, branching sponges, palmate sponges, cup sponges, gorgonian corals, bramble corals, sea whips, and colonial anemones. Characteristic imagery for each transect is provided in the Appendix. A detailed description of the dominant biota present in each transect is provided below.

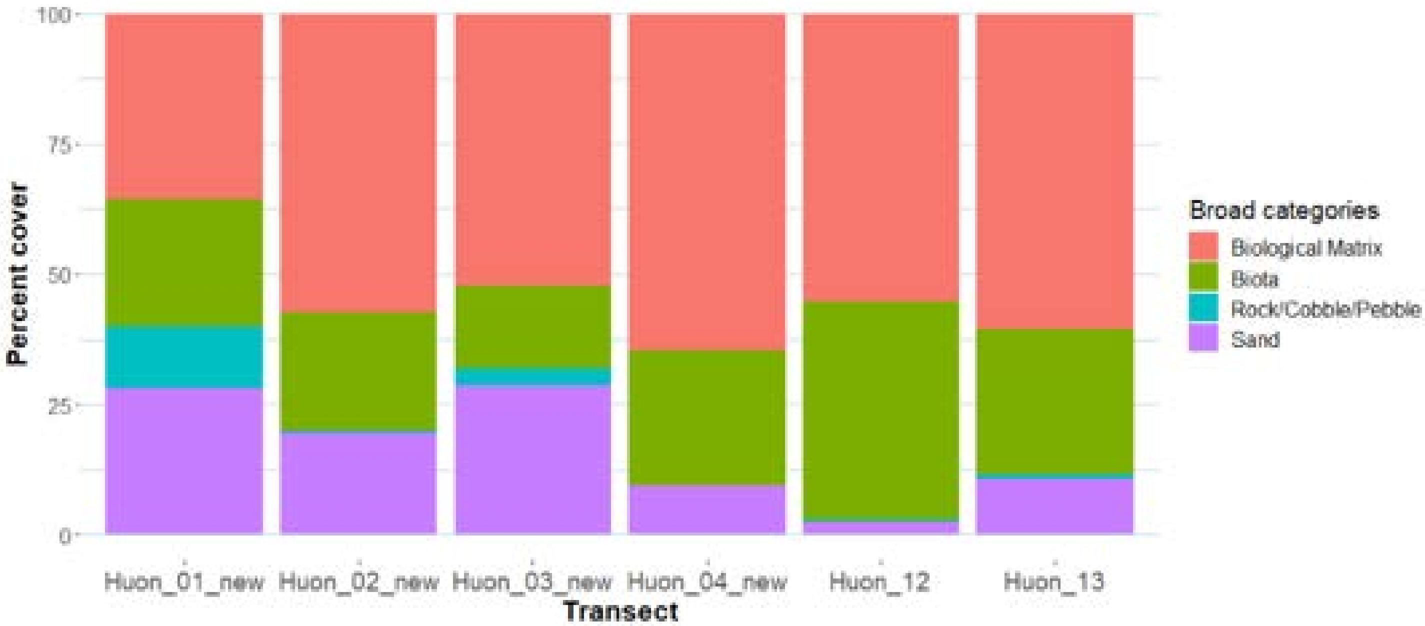


Figure 3. Broad categories of physical and biological characteristics present in each AUV transect in the Huon Marine Park

Huon_01_new

Dominant morphospecies in the Huon_01_new transect included soft bryozoans (morphospecies merged), encrusting orange sponge, calcareous and non-calcareous encrusting red algae, gorgonian red *Pteronisis*-like, *Parazoanthus* colonial anemones, sea whips, and a variety of encrusting, branching, massive, and cup sponges (Figure 4). Biological matrix accounted for 36% of annotated points on reef images in the Huon_01_new transect. Only 7 morphospecies had cover greater than 1%. Characteristic images containing some of these dominant species are contained in the Appendix.

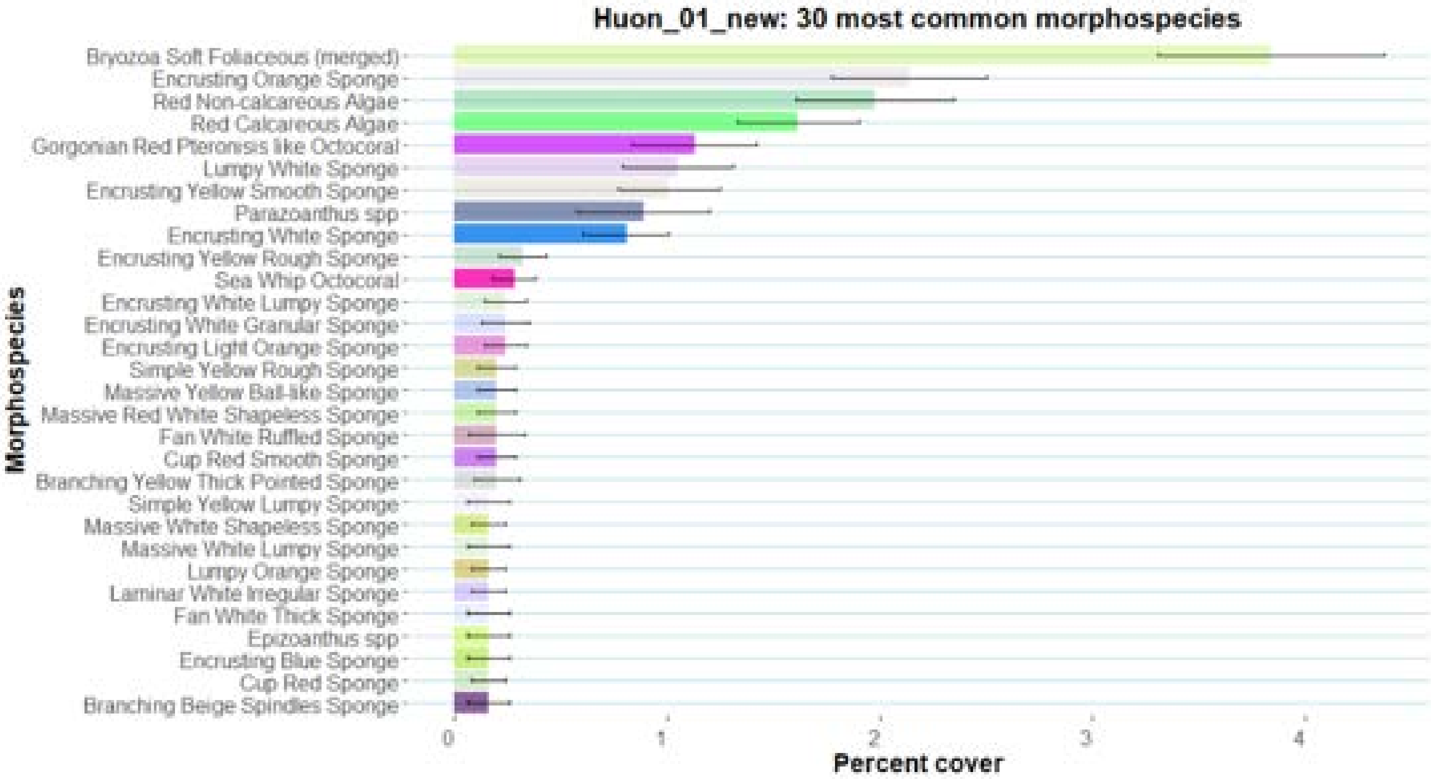


Figure 4. Percent cover (and standard error) of the 30 most common morphospecies annotated in the Huon_01_new transect in Huon Marine Park AUV imagery. The biological matrix category was excluded from the plot for improved visualisation.

Huon_02_new

Dominant morphospecies in the Huon_02_new transect included encrusting orange sponge, soft bryozoans (morphospecies merged), hydroid white, encrusting white and encrusting white lumpy sponge, *Epizoanthus* colonial anemones, lace bryozoans, gorgonian red *Pteronisis*-like, bramble coral, and a variety of encrusting, branching, massive, and cup sponges (Figure 5). Biological matrix accounted for 57% of annotated points on reef images in the Huon_02_new transect. Only three morphospecies had cover greater than 1%. Characteristic images containing some of these dominant species are given in the Appendix.

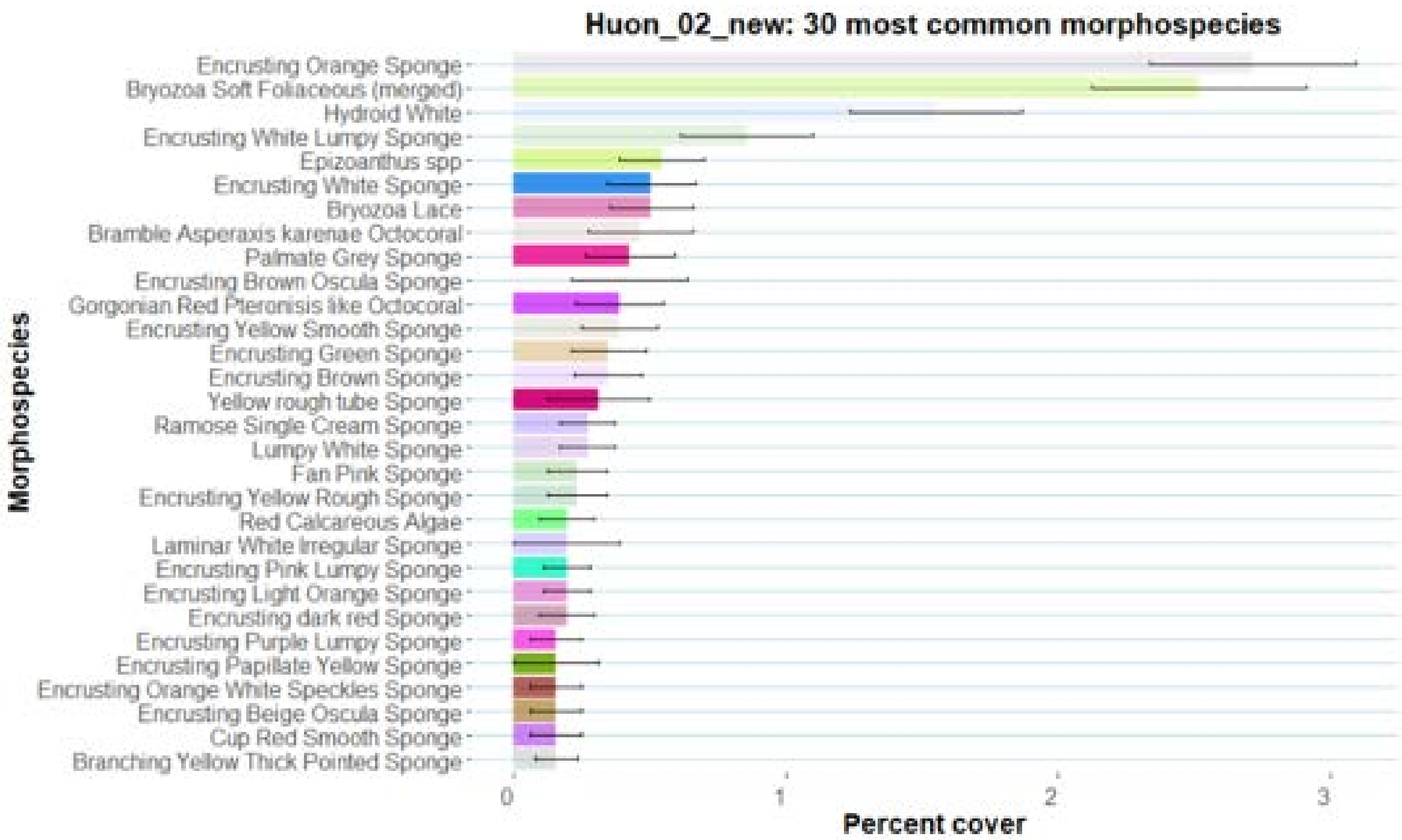


Figure 5. Percent cover (and standard error) of the 30 most common morphospecies annotated in the Huon_02_new transect in Huon Marine Park AUV imagery. The biological matrix category was excluded from the plot for improved visualisation.

Huon_03_new

Dominant morphospecies in the Huon_03_new transect included encrusting orange sponge, encrusting yellow smooth sponge, soft bryozoans (morphospecies merged), encrusting white, encrusting white lumpy and encrusting white granular sponges, hard bryozoa including lace bryozoans, stumpy hard and hornera robusta bryozoans, gorgonian red *Pteronisis*-like, bramble coral, and a variety of encrusting, branching, massive, and cup sponges (Figure 6). Biological matrix accounted for 52% of annotated points on reef images in the Huon_03_new transect. Only three morphospecies had cover greater than 1%. Characteristic images containing some of these dominant species are given in the Appendix.

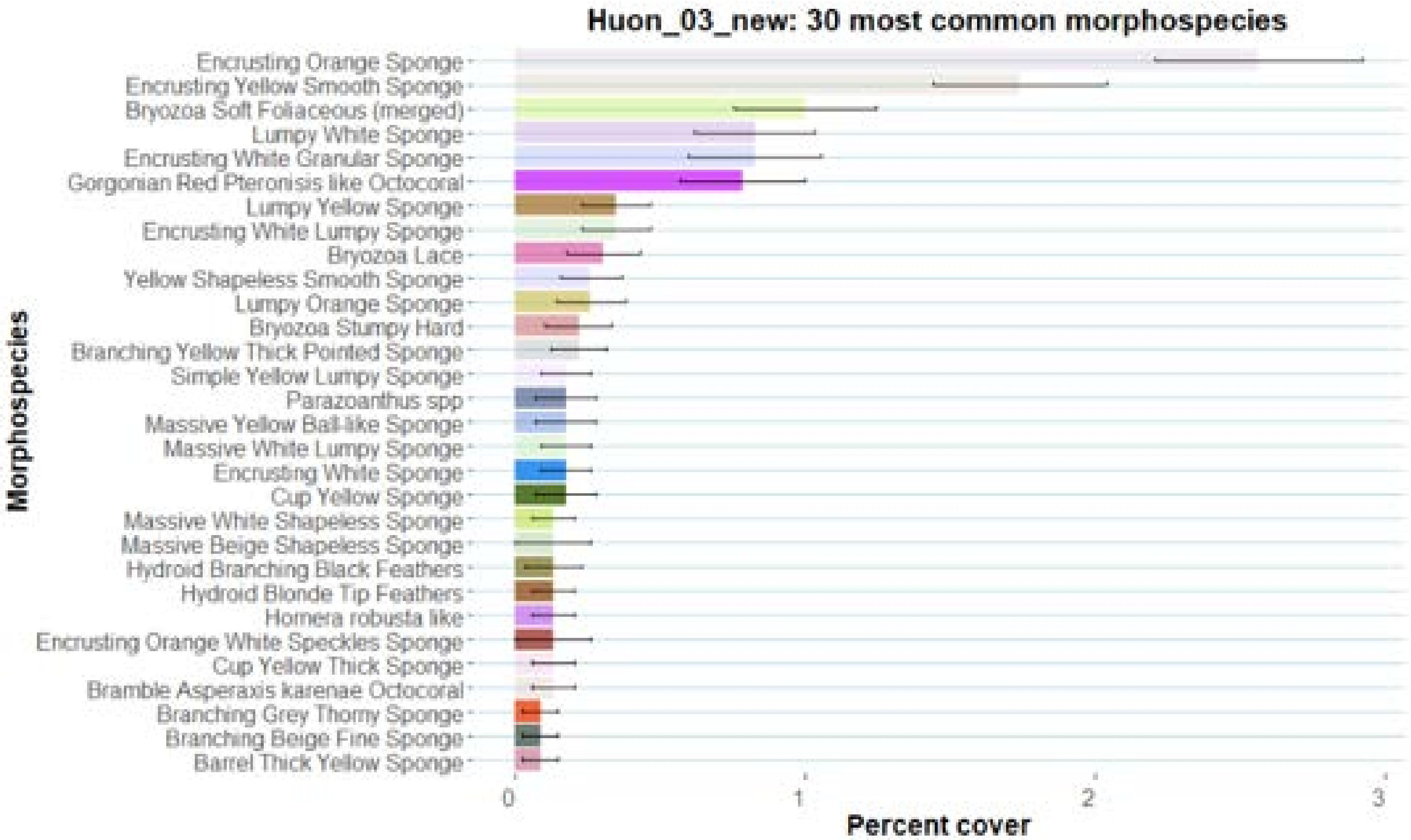


Figure 6. Percent cover (and standard error) of the 30 most common morphospecies annotated in the Huon_03_new transect in Huon Marine Park AUV imagery. The biological matrix category was excluded from the plot for improved visualisation.

Huon_04_new

Dominant morphospecies in the Huon_04_new transect included gorgonian red *Pteronisis*-like (approximately 3% cover), soft bryozoans (morphospecies merged), encrusting orange sponge, *Epizoanthus* colonial anemones, lace bryozoans, encrusting white lumpy sponge, lace bryozoans, a variety of hydroids, red calcareous algae, and a variety of encrusting, branching, massive, and cup sponges (Figure 7). Biological matrix accounted for 65% of annotated points on reef images in the Huon_04_new transect. Only four morphospecies had covers greater than 1%. Characteristic images containing some of these dominant species are contained in the Appendix.

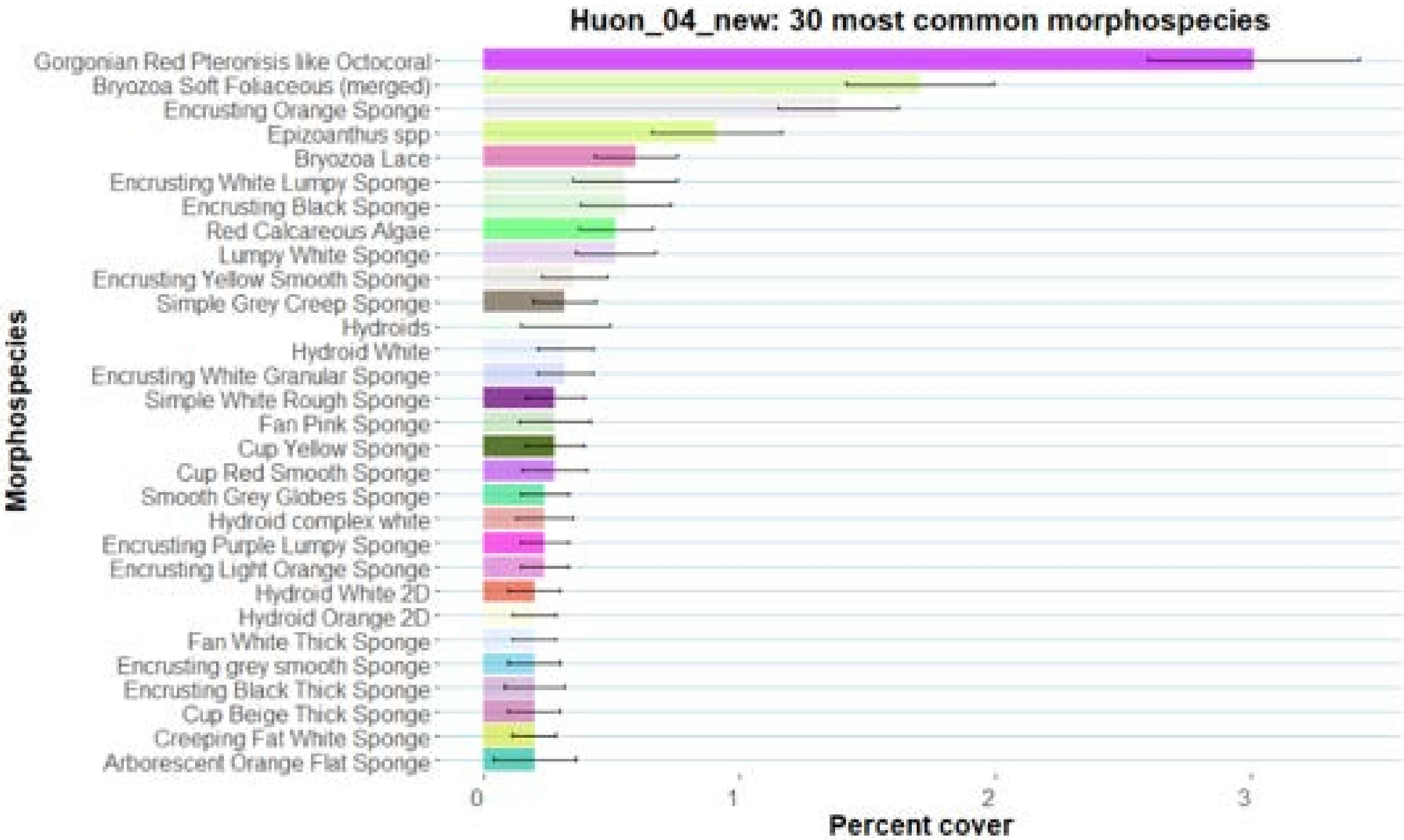


Figure 7. Percent cover (and standard error) of the 30 most common morphospecies annotated in the Huon_04_new transect in Huon Marine Park AUV imagery. The biological matrix category was excluded from the plot for improved visualisation.

Huon_12

Dominant morphospecies in the Huon_12 transect included calcareous and non-calcareous red algae (approximately 12% cover), soft bryozoans (morphospecies merged), encrusting white and orange sponges, gorgonian red *Pteronisis*-like, *Parazoanthu*s colonial anemones, sea whips, and a variety of encrusting, branching, massive, fan, and cup sponges (Figure 8). Biological matrix accounted for 55% of annotated points on reef images in the Huon_12 transect. Only seven morphospecies had covers greater than 1%. Characteristic images containing some of these dominant species are provided in the Appendix.

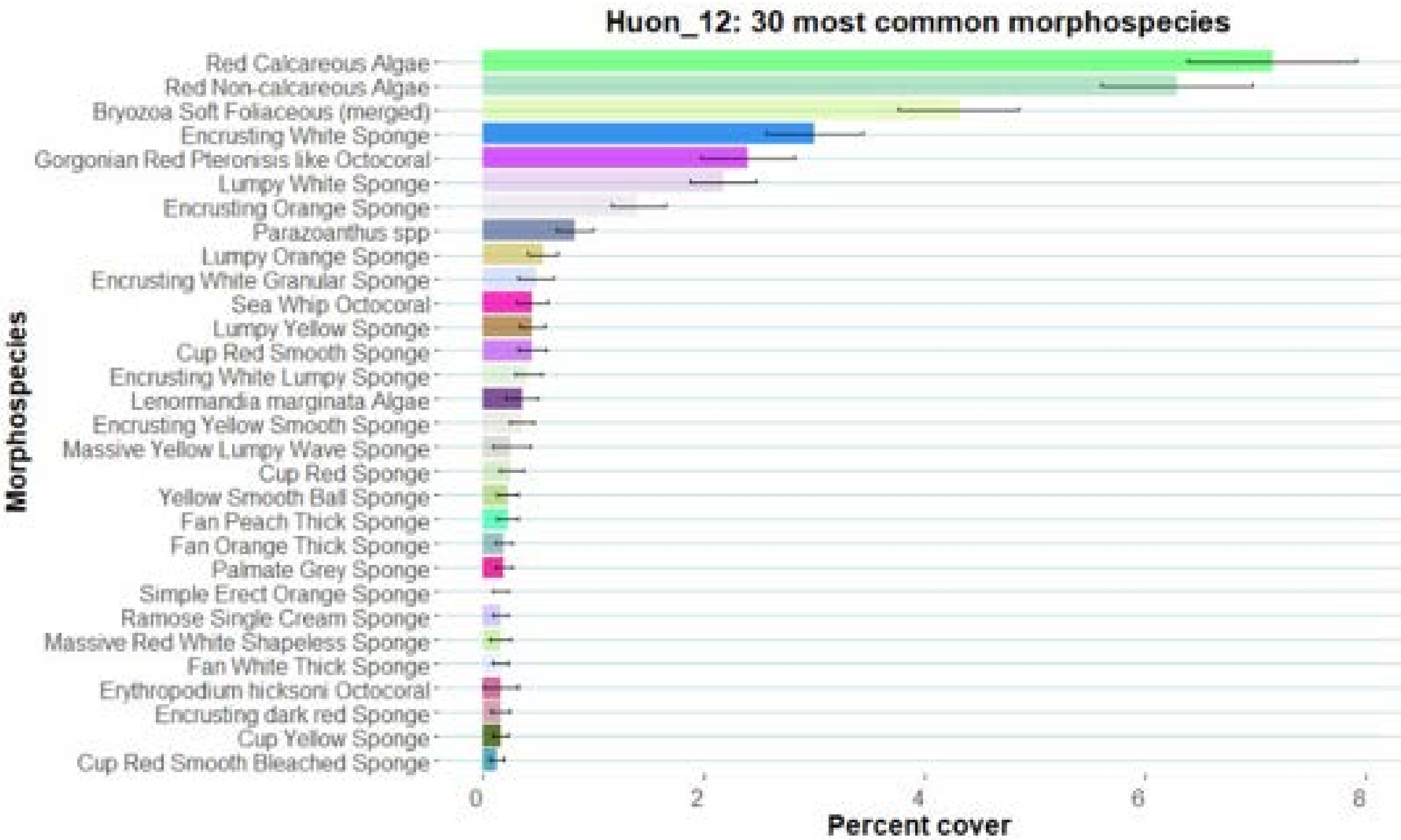


Figure 8. Percent cover (and standard error) of the 30 most common morphospecies annotated in the Huon_12 transect in Huon Marine Park AUV imagery. The biological matrix category was excluded from the plot for improved visualisation.

Huon_13

Dominant morphospecies in the Huon_13 transect included calcareous and non-calcareous red algae, gorgonian red *Pteronisis*-like, soft bryozoans (morphospecies merged), encrusting white and orange sponges, *Epizoanthus* colonial anemones, and a variety of encrusting, branching, massive, fan, and cup sponges (Figure 9). Biological matrix accounted for 61% of annotated points on reef images in the Huon_13 transect. Only five morphospecies had covers greater than 1%. Characteristic images containing some of these dominant species are contained in the Appendix.

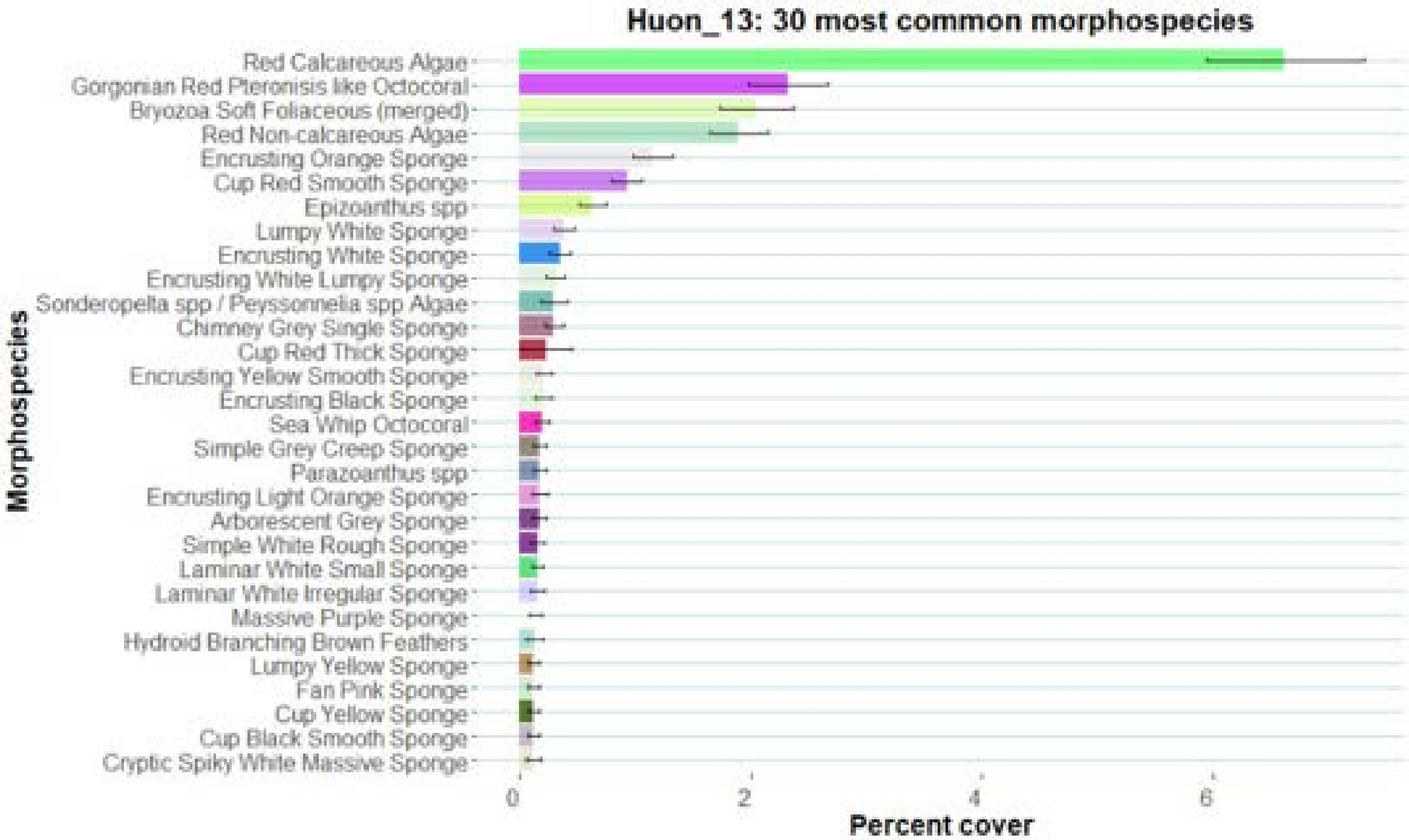


Figure 9. Percent cover (and standard error) of the 30 most common morphospecies annotated in the Huon_13 transect in Huon Marine Park AUV imagery. The biological matrix category was excluded from the plot for improved visualisation.

Time-series analysis

Huon_12 and Huon_13 transects were surveyed in 2009, 2010, 2014, and 2022. This time series was analysed for multivariate (i.e., community-level) temporal changes over the 13-year survey period. Dominant morphospecies were also selected to examine temporal changes in percent cover.

Multivariate analysis was conducted in PRIMER v6 software (Clarke and Gorley 2006). The percent morphospecies cover was calculated for each survey/year using the annotated images. All non-sessile morphospecies data was removed. This included the removal of physical categories (e.g., sand and rock) as well as mobile species such as fish and rock lobster. The percent cover data was then log transformed to down-weight the dominant morphospecies to give more weighting to the rarer morphospecies. Log transformation is considered a fairly extreme transformation but was necessary due to the dominance of the biological matrix, which is an important biological component of the system, but comprises > 55% of the data on the repeated transects. Using the log-transformed data a Bray-Curtis similarity matrix was produced for each transect. Non-metric multidimensional scaling (nMDS) ordination plots were produced to allow visualisation of the community similarities across the survey years. Similarity percentage (SIMPER) analysis was conducted to explore which morphospecies were driving the observed patterns between and within sites. Finally, a permutational multivariate analysis of variance (PERMANOVA) test was conducted to test for significant differences in community structure within each transect across years.

Results from the multivariate analysis as well as previous data exploration conducted in this report (i.e., exploration of the dominant morphospecies) was used to help determine a subset of morphospecies to conduct univariate analysis on. This subset comprised of 7 morphospecies and the biological matrix conglomerate:

- Biological matrix
- Calcareous Encrusting Red Algae
- Encrusting White Sponge
- Bryozoa Soft (merged)
- Non-Calcareous Encrusting Red Algae
- Gorgonian Red *Pteronisis* like
- Encrusting Orange Sponge
- Cup Red Smooth Sponge

A spatial generalised linear model (GLM) was used for analysis of temporal trends in individual morphospecies, with a similar model structure that has been used in previous work across the SE MP Network (see Perkins et al. 2021). These GLMs incorporate spatial autocorrelation in the cover of morphospecies between images, which has been shown to be an important consideration for image-based benthic surveys along transects (Perkins et al. 2017, Perkins et al. 2018). Covariates of depth and depth-squared were included to capture depth related trends in the cover of morphospecies. Depth-squared captures the non-linear portion of the trend, such as when a morphospecies is more abundant in mid-depths. Survey year was treated as a categorical variable, so that the mean cover for each morphospecies could be estimated for a given survey year. Five-hundred posterior samples were taken from the fitted models, and for each survey year the mean cover was calculated with credible intervals of the estimate. For these calculations the mean depth of each transect was used, and spatial effects were ignored. Note that where a strong depth gradient occurs in cover (e.g., for algal species which are typically more abundant in shallower depths) mean cover in more extreme depths (shallower or deeper) is likely to differ from that calculated at the mean depth. Plots of the time series were produced as well as plots of the estimated depth relationships. From the model outputs, the coefficient for the 2022 survey was compared to the intercept (representing the first survey year, 2009) to test whether there was a significant increase or decrease between the 2009 and 2022 surveys.

Multivariate analysis results

Multivariate analysis of the time-series at the Huon_12 transect revealed that later survey years (2009 – 2022) had a large overlap in multivariate community composition (Figure 10). A small number of images in 2009, and some in 2022 showed differences in community composition. However, this is to be expected as images were used as samples and represent a relatively small sample compared to the area surveyed with the potential for large differences between images. Important morphospecies driving differences across years were biological matrix, soft bryozoa, encrusting white sponge and calcareous and non-calcareous algae. PERMANOVA revealed that community composition was significantly different across years in the Huon_12 transect (Pseudo-F = 16.88, P < 0.001). SIMPER analysis reinforced that the differences across years were driven by changes in the cover of the dominant morphospecies previously mentioned, and to a lesser extent morphospecies such as encrusting orange sponge, cup red smooth sponge, and gorgonian red *Pteronisis* like.

Multivariate analysis of the time-series at the Huon_13 transect showed similar patterns to the Huon_12 transect (Figure 11). However, community composition overlapped more, and thus was more similar, across years in the Huon_13 transect than the Huon_12 transect with less outlying images. SIMPER analysis revealed that differences in cover of the same morphospecies driving differences for Huon_12 were also important in Huon_13. PERMANOVA revealed that community composition was significantly different across years in the Huon_13 transect (Pseudo-F = 23.36, P < 0.001).

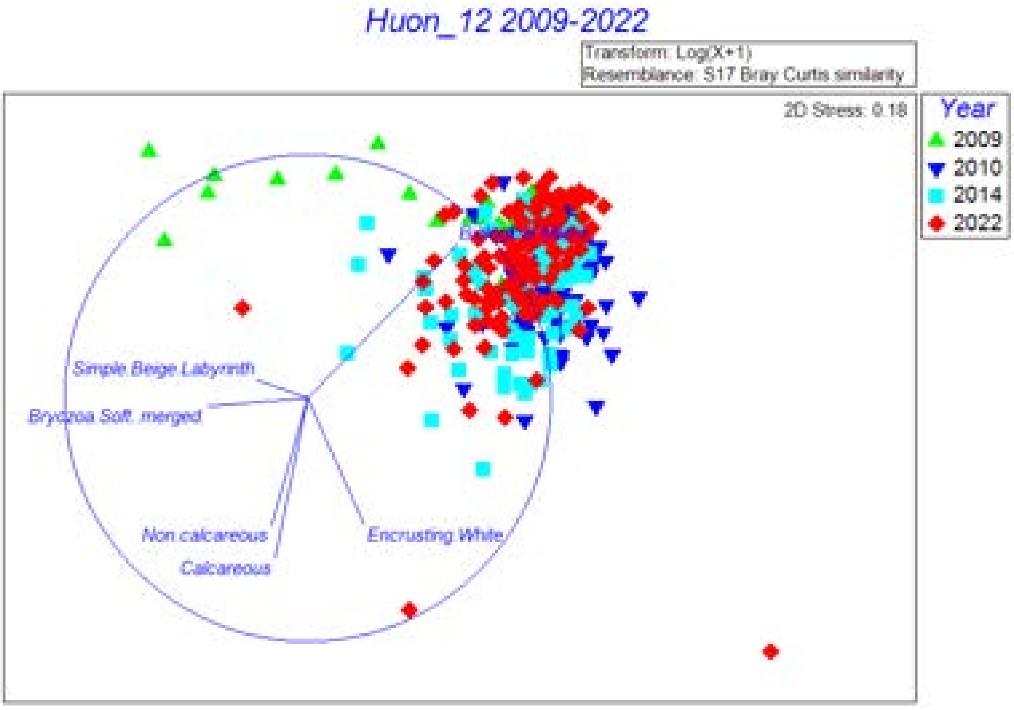


Figure 10. Non-metric multidimensional scaling plot showing community composition in Huon_12 transect across survey years.

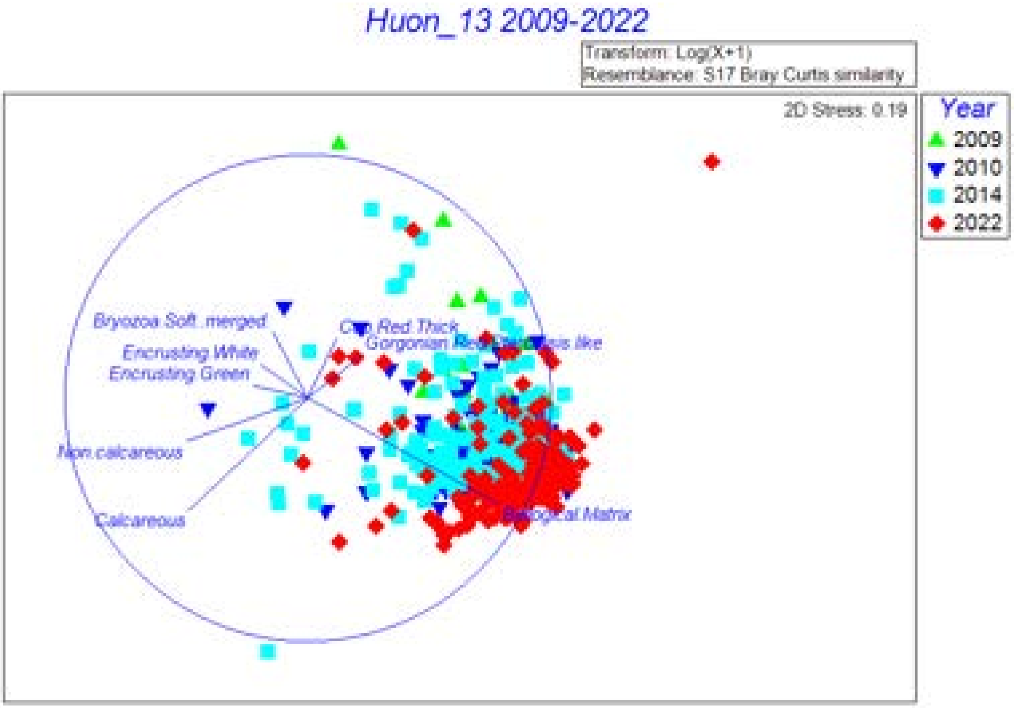


Figure 11. Non-metric multidimensional scaling plot showing community composition in Huon_13 transect across survey years.

Univariate analysis results: Huon_12

Model-based estimates for the fixed effects of survey year and depth, as well as the parameters describing the spatial random effects (spatial range and standard deviation) for cover data at the Huon_12 and Huon_13 sites are given in Table 2. Summary plots of the temporal trends and the depth effects for each morphospecies are given in Figure 12 and Figure 13 respectively. A short description of the results for each morphospecies at the Huon_12 site follows.

Table 2. Model coefficient estimates for year, depth, depth-squared, spatial range, and spatial standard deviation for cover data at the Huon_12 and Huon_13 sites. Mean estimates are given on the first line of each cell, with 95% credible intervals for the estimates given in brackets on the line below. The intercept estimate represents the first survey year (2009), with other year estimates representing deviations from the estimate for 2009. For the fixed effect estimates (year and depth terms) the statistical significance is highlighted in red for negative estimates, and green for positive estimates. 95% CIs that contain zero are considered non-significant.

Site	Morphospecies	Intercept	year2010	year2014	year2022	depth	depth2	Spatial_Range	Spatial_Stdev
Huon_12	Biological Matrix	1.62 (1.12 ,2.12)	-0.85 (-1.2 ,-0.49)	-0.97 (-1.33 ,-0.61)	-0.88 (-1.24 ,-0.52)	-0.19 (-0.52 ,0.14)	-0.37 (-0.56 ,-0.18)	64.03 (48.18 ,85.16)	1.3 (1.12 ,1.52)
	Calcareous Encrusting Red Algae	-3.59 (-4.47 ,-2.72)	0.61 (0.1 ,1.12)	0.86 (0.33 ,1.38)	0.37 (-0.15 ,0.89)	0.56 (0.08 ,1.05)	-0.96 (-1.3 ,-0.61)	237.91 (84.08 ,659.93)	1.32 (0.84 ,2.14)
	Encrusting White	-5.83 (-6.53 ,-5.13)	3.25 (2.56 ,3.93)	3.17 (2.47 ,3.87)	2.07 (1.35 ,2.79)	-0.41 (-0.7 ,-0.12)	-0.07 (-0.34 ,0.2)	27.31 (16.73 ,42.85)	0.81 (0.63 ,1.03)
	Bryozoa Soft (merged)	-4.9 (-5.36 ,-4.44)	0.08 (-0.49 ,0.64)	1.51 (1 ,2.02)	1.11 (0.62 ,1.61)	-0.59 (-0.86 ,-0.32)	0.38 (0.2 ,0.56)	14.9 (6.38 ,31.43)	1.19 (0.92 ,1.52)
	Non-Calcareous Encrusting Red Algae	-4.16 (-4.69 ,-3.63)	0.81 (0.28 ,1.34)	0.67 (0.11 ,1.22)	0.91 (0.39 ,1.43)	-0.99 (-1.4 ,-0.59)	-0.57 (-0.95 ,-0.18)	101.87 (38.73 ,234.13)	0.67 (0.43 ,0.99)
	Gorgonian Red Pteronisis like	-3.3 (-4.4 ,-2.21)	-0.09 (-0.64 ,0.45)	-0.43 (-1.03 ,0.16)	-0.16 (-0.7 ,0.37)	-0.74 (-1.29 ,-0.19)	-0.44 (-0.76 ,-0.12)	247.73 (117.88 ,464.18)	1.29 (0.87 ,1.82)
	Encrusting Orange	-5.09 (-5.81 ,-4.37)	1.14 (0.39 ,1.89)	0.84 (0.05 ,1.63)	1.09 (0.33 ,1.84)	0.78 (0.26 ,1.3)	-0.24 (-0.53 ,0.05)	183.75 (50.42 ,465.2)	0.67 (0.38 ,1.09)
	Cup Red Smooth	-5.78 (-6.58 ,-4.98)	1.49 (0.66 ,2.32)	1.56 (0.71 ,2.42)	0.08 (-0.86 ,1.01)	-0.28 (-0.8 ,0.23)	-0.38 (-0.83 ,0.07)	100.31 (14.78 ,373.2)	0.79 (0.51 ,1.18)
Huon_13	Biological Matrix	0.81 (0.51 ,1.11)	-0.33 (-0.56 ,-0.09)	-0.4 (-0.64 ,-0.17)	0.19 (-0.07 ,0.45)	-0.3 (- 0.45 ,- 0.16)	-0.28 (-0.37 ,-0.18)	44.69 (36.55 ,54.56)	1.22 (1.09 ,1.38)
	Calcareous Encrusting Red Algae	-3.23 (-3.6 ,-2.87)	0.21 (-0.18 ,0.6)	0.5 (0.1 ,0.89)	0.41 (-0.01 ,0.82)	-0.62 (-0.85 ,-0.4)	-0.58 (-0.78 ,-0.38)	36.58 (26.77 ,49.44)	1.1 (0.91 ,1.31)
	Encrusting White	-4.05 (-4.33 ,-3.76)	1.32 (1.03 ,1.6)	1.18 (0.9 ,1.47)	-1.73 (-2.25 ,-1.21)	-0.52 (-0.66 ,-0.37)	-0.1 (-0.26 ,0.06)	15.45 (9.55 ,23.94)	0.68 (0.54 ,0.85)
	Bryozoa Soft (merged)	-4.75 (-5.14 ,-4.35)	-0.66 (-1.15 ,-0.17)	0.77 (0.35 ,1.19)	0.2 (-0.24 ,0.64)	-0.43 (-0.62 ,-0.23)	0.2 (0.04 ,0.35)	18.75 (10.13 ,33.43)	1.09 (0.9 ,1.32)
	Non-Calcareous Encrusting Red Algae	-3.97 (-4.34 ,-3.61)	0.19 (-0.2 ,0.57)	0.32 (-0.06 ,0.71)	-0.2 (-0.62 ,0.22)	-0.66 (-0.87 ,-0.45)	-0.14 (-0.32 ,0.05)	29.64 (21.66 ,39.83)	0.96 (0.8 ,1.16)
	Gorgonian Red Pteronisis like	-4.99 (-5.41 ,-4.56)	0.3 (-0.17 ,0.77)	0.86 (0.41 ,1.32)	0.78 (0.33 ,1.24)	-0.42 (-0.64 ,-0.21)	0.06 (-0.12 ,0.23)	20.91 (13.09 ,32.97)	1.03 (0.85 ,1.24)
	Encrusting Orange	-4.54 (-5.01 ,-4.07)	0.29 (-0.18 ,0.75)	-0.27 (-0.76 ,0.22)	-0.13 (-0.6 ,0.35)	-0.19 (-0.47 ,0.09)	-0.09 (-0.29 ,0.11)	79.45 (47.88 ,127.42)	0.8 (0.57 ,1.09)
	Cup Red Smooth	-4.87 (-5.33 ,-4.4)	0.27 (-0.2 ,0.73)	0.19 (-0.29 ,0.68)	0.18 (-0.31 ,0.67)	-0.64 (-0.94 ,-0.34)	-0.44 (-0.74 ,-0.13)	141.12 (32.81 ,442.2)	0.51 (0.28 ,0.83)

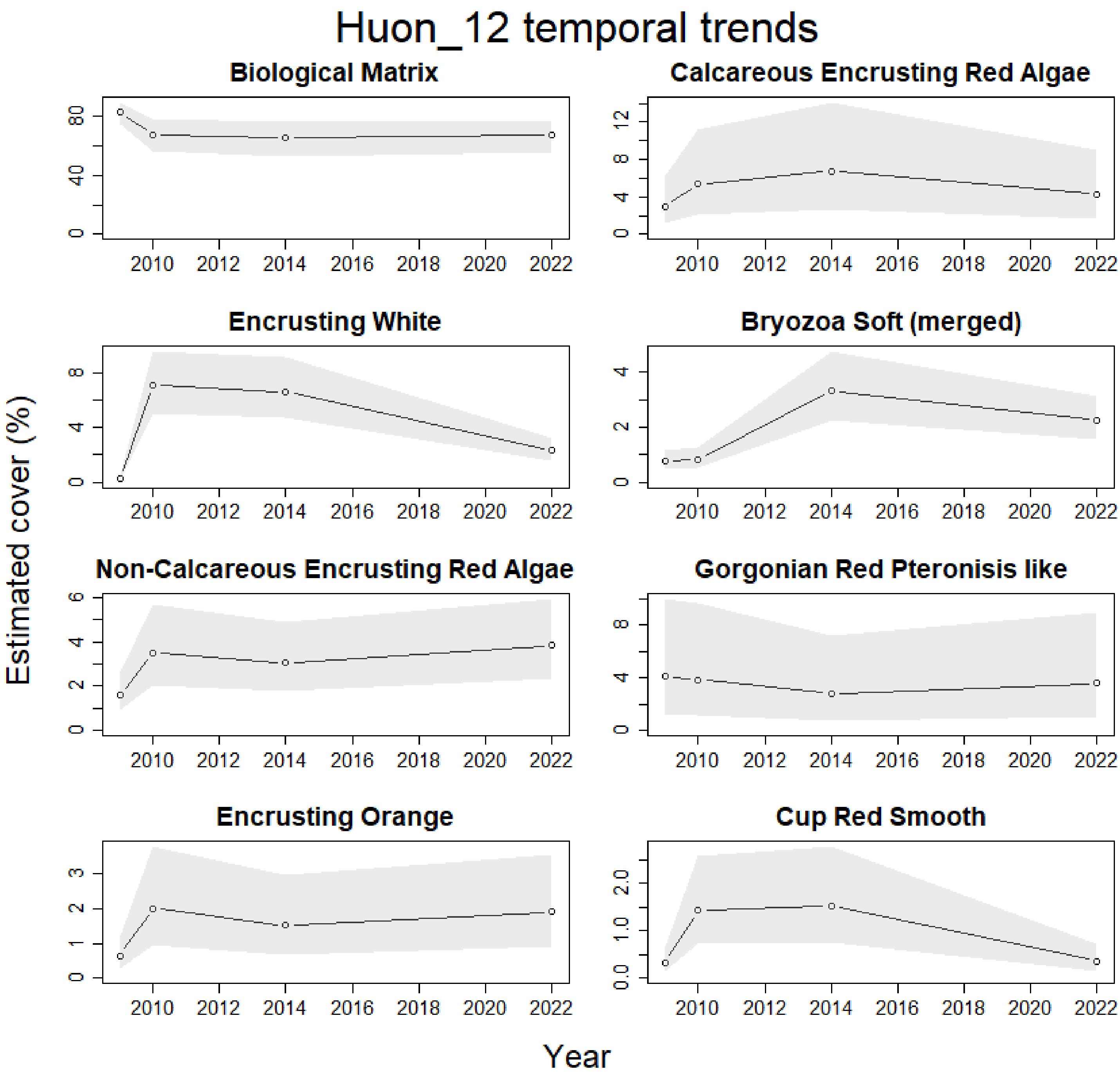


Figure 12. Model-based estimate of the temporal trend in the cover of the eight dominant morphospecies (including the grouping of biological matrix and soft bryozoa) in the Huon_12 transect. Points and lines show the mean and shaded area shows the 95% credible intervals. Estimates were made at the mean depth of the transect, ignoring any spatial effects.

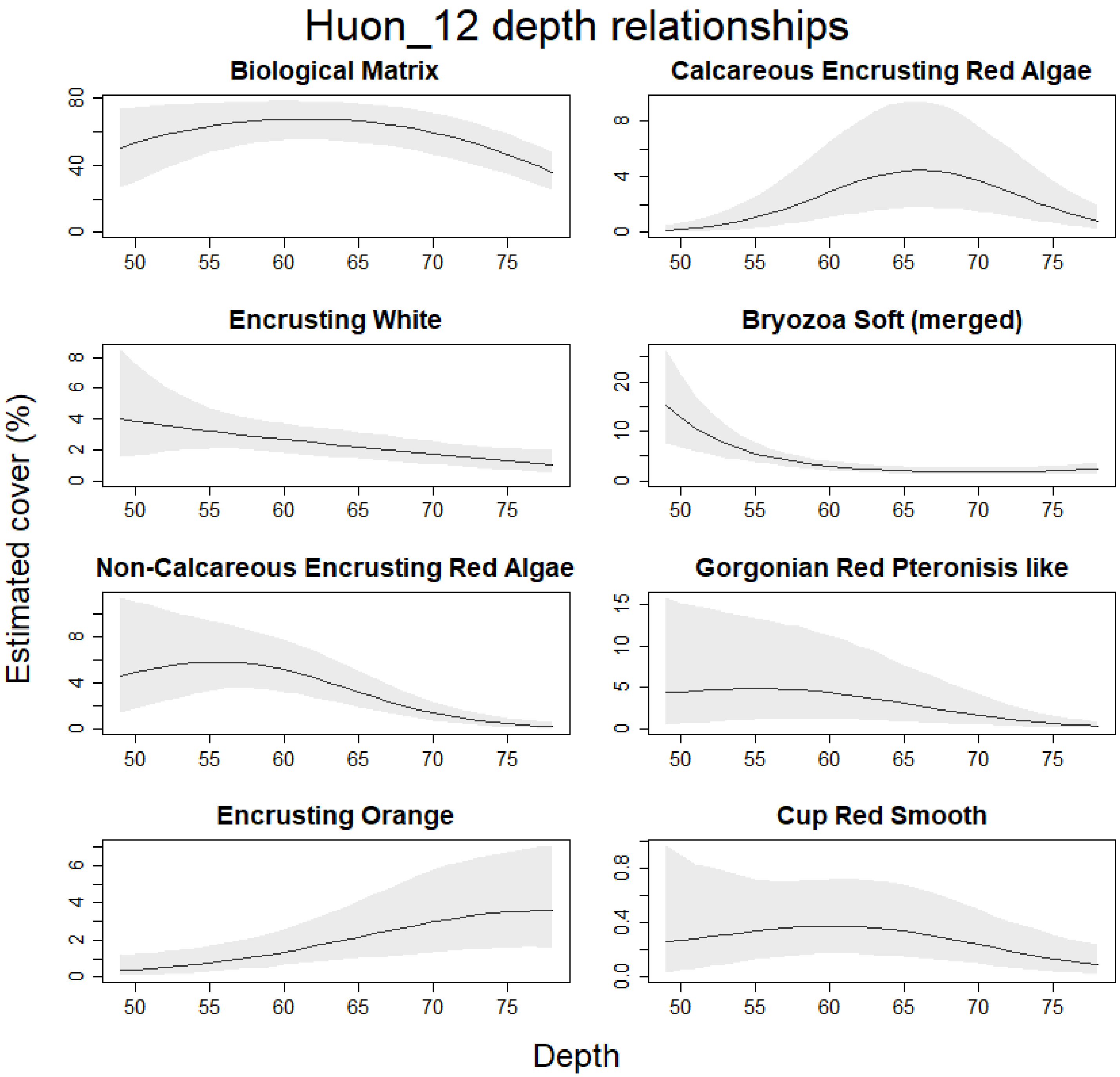


Figure 13. Relationship between the cover of the eight dominant morphospecies (including the grouping of biological matrix and soft bryozoa) with depth in the Huon_12 transect. Line shows the mean and shaded area shows the 95% credible intervals.

Biological matrix

GLM outputs showed that biological matrix at Huon_12 had a lower cover through time compared to an initial high cover in 2009, with significant negative coefficients for all years (Table 2 and Figure 12). Biological matrix dominated the cover in Huon_12, with an estimated cover of > 80% in 2009, dropping to around 70% in subsequent years. Cover of biological matrix tended to be higher in mid-depths surveyed, with a negative coefficient for depth squared and a non-significant coefficient for depth (Table 2 and Figure 13).

Calcareous Encrusting Red Algae

Calcareous encrusting red algae at Huon_12 showed no significant difference in cover between 2009 and 2022, although cover varied through time with higher cover in both 2010 and 2014 compared to 2009 (Table 2 and Figure 12). Cover of calcareous encrusting red algae tended to be higher in the mid-depths surveyed in Huon_12, with a negative coefficient for depth-squared (Table 2 and Figure 13).

Encrusting White Sponge

Model outputs showed that cover of encrusting white sponge at Huon_12 fluctuated through time (min, max, mean), with significant positive coefficients for all years indicating higher cover compared to an initial low in 2009 (% cover). Cover peaked in 2010 with a high of approximately 7% , with cover decreasing in subsequent surveys but remained higher than the initial 2009 survey (Table 2 and Figure 12). Cover of encrusting white sponge tended to be higher in shallower depths surveyed, with a negative coefficient for depth (Table 2 and Figure 13).

Bryozoa Soft (merged)

Cover of soft bryozoa at Huon_12 fluctuated through time, with significant positive coefficients for 2014 and 2022 compared to 2009. Cover was initially low in 2009 (% cover) and highest in 2014 (3% cover) and slightly decreased to approximately 2% in 2022 (Table 2 and Figure 12). Cover of soft bryozoa tended to be higher in shallower depths surveyed, with a negative coefficient for depth, but also a positive coefficient for depth squared indicating relatively high cover in deeper areas compared to mid-depths (Table 2 and Figure 13).

Non-Calcareous Encrusting Red Algae

Cover of non-calcareous encrusting red algae at Huon_12 increased from a low of 1.5% in 2009, with significant positive coefficients for all following years at the mean depth to a cover approximately 3% (Table 2 and Figure 12). Cover of non-calcareous encrusting red algae tended to be higher in shallower to mid-depths surveyed, with a negative coefficient for depth, and also a negative coefficient for depth squared (Table 2 and Figure 13).

Gorgonian Red Pteronisis like

Cover of gorgonian red *Pteronisis* like at Huon_12 remained relatively stable throughout the survey period with no significant year coefficients, but with considerable uncertainty around mean cover estimates as evidenced by the wide credible intervals (Table 2 and Figure 12). Cover of gorgonian red *Pteronisis* like tended to be higher in shallower to mid-depths, with a negative coefficient for both depth and depth squared (Table 2 and Figure 13).

Encrusting Orange

Encrusting orange sponge at Huon_12 increased in cover from an initial low of approximately 0.5% in 2009 to around 1% cover throughout the remainder of the survey period with positive year coefficients for all years (Table 2 and Figure 12). Cover of encrusting orange sponge tended to be higher in deeper areas surveyed, however this relationship was not statistically significant (Table 2 and Figure 13).

Cup Red Smooth

Cup red smooth sponge at Huon_12 increased in cover to ~1.25% from an initial low of ~0.25% in 2009 at the mean depth, before decreasing in cover in 2022 to a level that was not significantly different to 2009 (Table 2 and Figure 12). Cover of cup red smooth sponge tended to be slightly higher in shallower areas surveyed, however this relationship was not statistically significant (Table 2 and Figure 13).

Huon_13

Plots of the temporal trends and depth relationships of the eight dominant morphospecies (including the grouping of biological matrix and soft bryozoa) are given in Figure 14 and Figure 15 respectively. A description of the trends for each morphospecies (or grouping) follows.

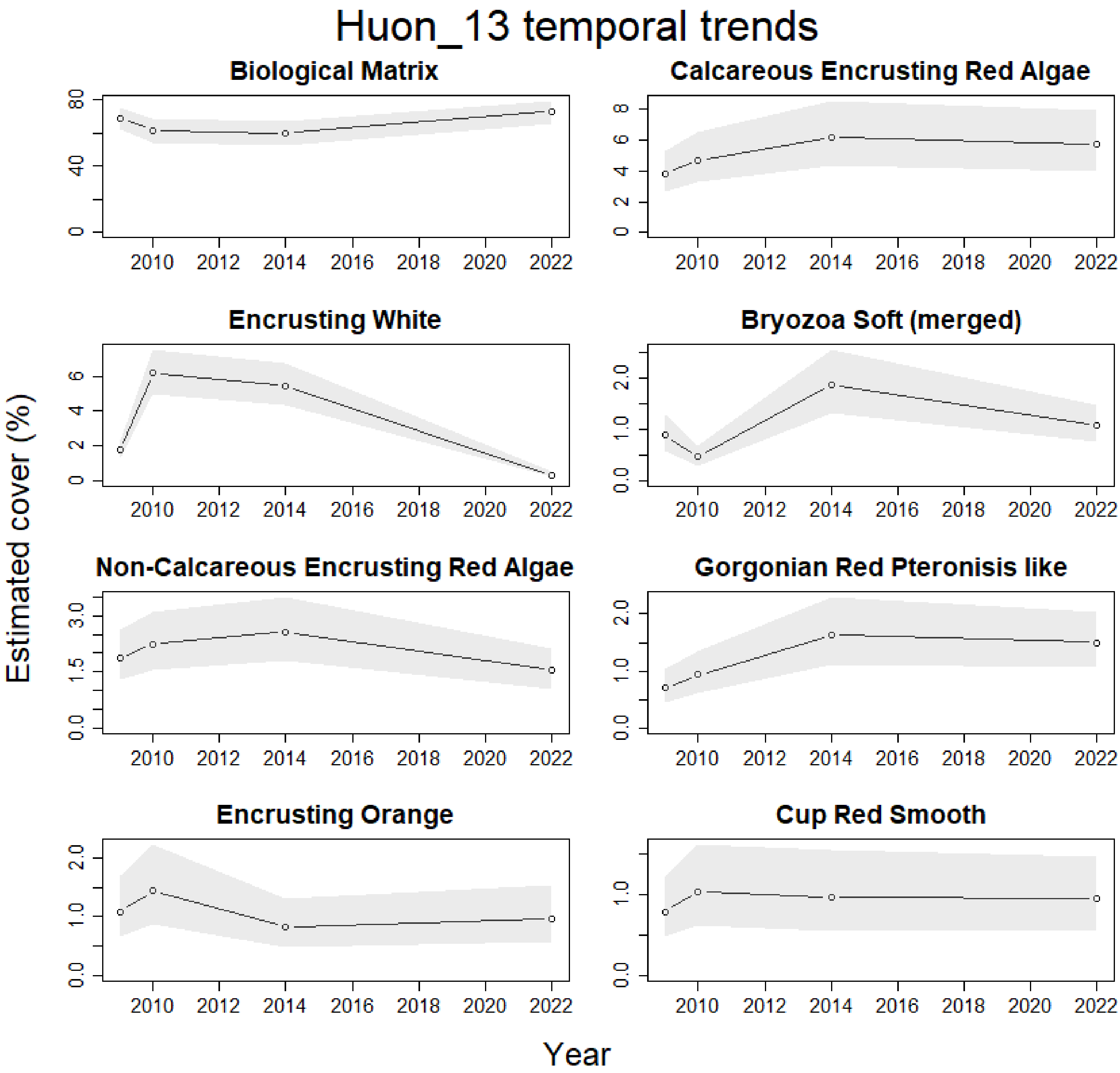


Figure 14. Model-based estimate of the temporal trend in the cover of the eight dominant morphospecies (including the grouping of biological matrix and soft bryozoa) in the Huon_13 site. Points and lines show the mean and shaded area shows the 95% credible intervals. Estimates were made at the mean depth of the transect, ignoring any spatial effects. Note the differing scales on the y-axes.

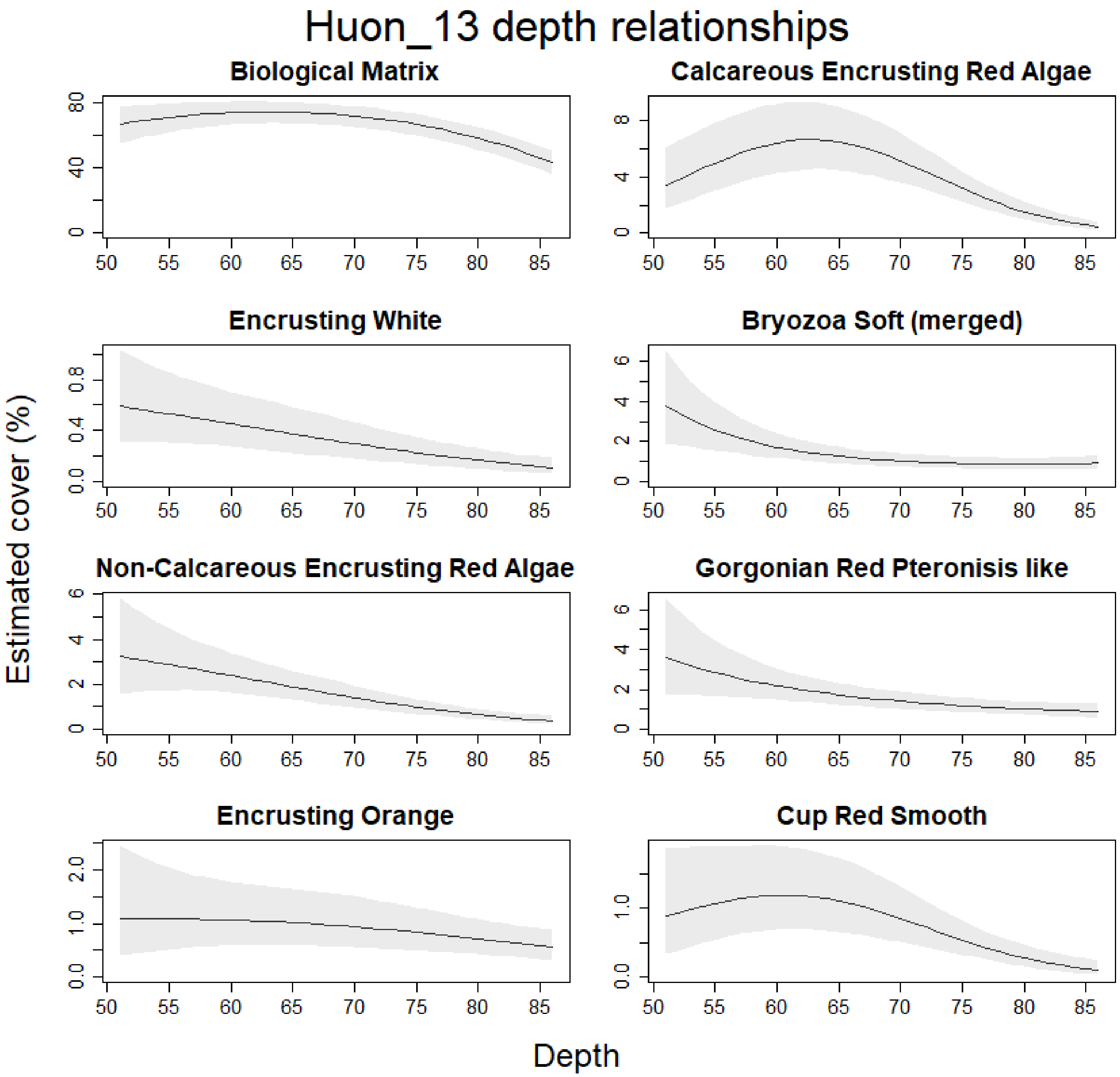


Figure 15. Relationship between the cover of the eight dominant morphospecies (including the grouping of biological matrix and soft bryozoa) with depth at the Huon_13 site. Line shows the mean and shaded area shows the 95% credible intervals. Note the differing scales on the y-axes.

Biological Matrix

biological matrix at Huon_13 had a high cover that remained relatively stable through time, with lower cover in 2010 and 2014 compared to 2009, followed by an increase in cover in 2022 to levels similar to 2009 (Table 2 and Figure 14). Biological matrix dominated the cover in Huon_13, with an estimated cover of > 60% across the time-series at the mean depth of the transect. Cover of biological matrix tended to be higher in deeper and mid-depths surveyed, with a negative coefficient for depth and depth squared (Table 2 and Figure 15).

Calcareous Encrusting Red Algae

Calcareous encrusting red algae at Huon_13 remained relatively stable in cover of around 5%, with only 2014 showing a statistically significant higher cover when compared to 2009 (Table 2 and Figure 14). Cover of calcareous encrusting red algae tended to be higher in shallow to mid-depths surveyed, with a negative coefficient for depth and depth squared.

Encrusting White

Encrusting white sponge at Huon_13 fluctuated significantly in cover over the time series from an initial cover of around 2% in 2009, with 2010 and 2014 having statistically significant higher covers of around 5-6%, followed by a large decline in 2022 (%) where cover fell below the level of 2009 (Table 2 and Figure 14). Cover of encrusting white sponge tended to be higher in shallower depths surveyed, with a negative coefficient for depth (Table 2 and Figure 15).

Bryozoa Soft (merged)

Soft bryozoa at Huon_13 fluctuated significantly in cover over the time series dropping significantly from approximately 1% to 0.5% between 2009 and 2010, increasing to around 2% in 2014, followed by a decline in 2022 where cover was not statistically different to the level of 2009 (Table 2 and Figure 14). Cover of encrusting white sponge tended to be higher in shallower depths surveyed, with a negative coefficient for depth (Table 2 and Figure 15).

Non-Calcareous Encrusting Red Algae

Non-calcareous encrusting red algae at Huon_13 remained relatively stable in cover of around 2% at the mean depth of the transect across the time series, with no significant differences between any survey year and the initial survey in 2009 (Table 2 and Figure 14). Cover of non-calcareous encrusting red algae was higher in shallower depths surveyed, with a negative coefficient for depth (Table 2 and Figure 15).

Gorgonian Red Pteronisis like

Gorgonian red *Pteronisis* like at Huon_13 increased in cover over the time-series from an initial low of around 0.6% in 2009 to 1.5%, in 2014 and 2022 at the mean depth (Table 2 and Figure 14). Cover of non-calcareous encrusting red algae was higher in shallower depths surveyed, with a negative coefficient for depth (Table 2 and Figure 15).

Encrusting Orange

Encrusting orange sponge at Huon_13 remained relatively stable through time, fluctuating around 1% cover at the mean depth, with no significant differences to the 2009 cover (Table 2 and Figure 14). Cover was slightly higher in shallower depths although no significant depth relationship was found (Table 2 and Figure 15).

Cup Red Smooth

Cup red smooth sponge at Huon_13 remained relatively stable in cover of around 0.7% at the mean depth of the transect across the time series, with no significant differences between any survey year and the initial survey in 2009 (Table 2 and Figure 14). Cover of cup red smooth sponge was higher in shallower to mid-depths surveyed, with a negative coefficient for both depth and depth squared (Table 2 and Figure 15).

Targeted scoring

In addition to the broad biodiversity scoring undertaken using 25 random points on a subset of imagery, targeted scoring for a subset of morphospecies was also completed for HMP transect 13. Targeted scoring involves complete counts for each target morphospecies across a subset of imagery. Targeted scoring was undertaken for five morphospecies across all survey years: cup red smooth sponges (including the presence of bleaching), massive purple sponges, cup yellow sponges, cup black smooth sponges, and fan pink sponges. These morphospecies were selected as they are conspicuous, easily identified in imagery and geographically widespread. These species were also target scored at FMP (see targeted scoring in FMP section). Bleaching was only scored for the cup red smooth morphospecies, as it was the morphospecies where bleaching was most obvious. A target sample size of 200 reef images was annotated each year (Table 3). This level of sampling was based on previous power analysis that showed 200 images was typically sufficient to capture changes for most morphospecies (Perkins et al. 2022a). Each subset of imagery for each survey year was created by sytematically subsampling imagery along sections of transect that contained reef, with the sampling intensity set to achieve the desired number of images. Note that a different (larger) transect design was used at this location in 2009 compared to subsequent years.

Table 3. Number of reef images annotated for targeted scoring at the Huon_13 transect for each survey year.

Year	Number of reef images annotated
2009	200
2010	250
2014	241
2022	223

Modelling of the targeted scoring used the same model framework used in the biodiversity (i.e. point) scored data, however a negative binomial distribution, which is appropriate for count data, was used rather than a binomial distribution.

Targeted scoring results

Model-based estimates for the fixed effects of survey year and depth, as well as the parameters describing the spatial random effects (spatial range and standard deviation) for the targeted scoring at the Huon_13 site are given in Table 4. Summary plots of the temporal trends and the depth effects for each morphospecies are given in Figure 16 and Figure 17 respectively. A description of the results for each morphospecies at the Huon_13 site along with maps of the temporal distributions follows.

Table 4. Model coefficient estimates for year, depth, depth-squared, spatial range, and spatial standard deviation for targeted scoring at the Huon_13 site. Mean estimates are given on the first line of each cell, with 95% credible intervals for the estimates given in brackets on the line below. The intercept estimate represents the first survey year (2009), with other year estimates representing deviations from the estimate for 2009. For the fixed effect estimates (year and depth terms) the statistical significance is highlighted in red for negative estimates, and green for positive estimates. 95% CIs that contain zero are considered non-significant.

Morphospecies	Intercept	year2010	year2014	year2022	depth	depth2	Spatial_Range	Spatial_Stdev
Cup Red Smooth	0.76 (-0.28 ,1.79)	-0.26 (-0.64 ,0.12)	-0.11 (-0.5 ,0.27)	0.59 (0.19 ,0.99)	-1.32 (-1.6 ,-1.04)	-0.76 (-0.95 ,-0.57)	413.19 (194.07 ,792.74)	1.02 (0.67 ,1.49)
Cup Red Smooth Bleaching	-3.28 (-3.79 ,-2.77)	-0.62 (-1.3 ,0.06)	0.62 (0.04 ,1.2)	1.21 (0.68 ,1.74)	0.86 (0.64 ,1.08)	0.49 (0.21 ,0.77)	23.8 (6.86 ,63.13)	0.49 (0.26 ,0.8)
Massive Purple	-1.83 (-2.3 ,-1.35)	-0.31 (-0.89 ,0.27)	-0.12 (-0.68 ,0.45)	0.61 (0.11 ,1.12)	-0.25 (-0.47 ,-0.03)	-0.04 (-0.25 ,0.16)	49.43 (14.5 ,135.74)	0.56 (0.33 ,0.83)
Cup Yellow	-0.61 (-0.98 ,-0.24)	0.05 (-0.38 ,0.49)	-0.04 (-0.48 ,0.39)	0.26 (-0.15 ,0.66)	0.15 (-0.03 ,0.33)	-0.39 (-0.56 ,-0.22)	14.81 (7.55 ,27.73)	0.88 (0.56 ,1.26)
Cup Black Smooth	-2.53 (-3.2 ,-1.86)	-1.28 (-2.23 ,-0.33)	-0.27 (- 1.07 ,0.52)	0.2 (-0.53 ,0.94)	-0.18 (-0.52 ,0.16)	-0.3 (-0.65 ,0.06)	26.41 (10.81 ,53.38)	1.03 (0.7 ,1.47)
Fan Pink	-2.39 (-2.95 ,-1.83)	-1.5 (-2.46 ,-0.53)	0.02 (-0.65 ,0.68)	1.6 (1.05 ,2.15)	-0.1 (-0.31 ,0.11)	-0.01 (-0.22 ,0.19)	19.55 (8.76 ,37.6)	0.71 (0.45 ,1.05)

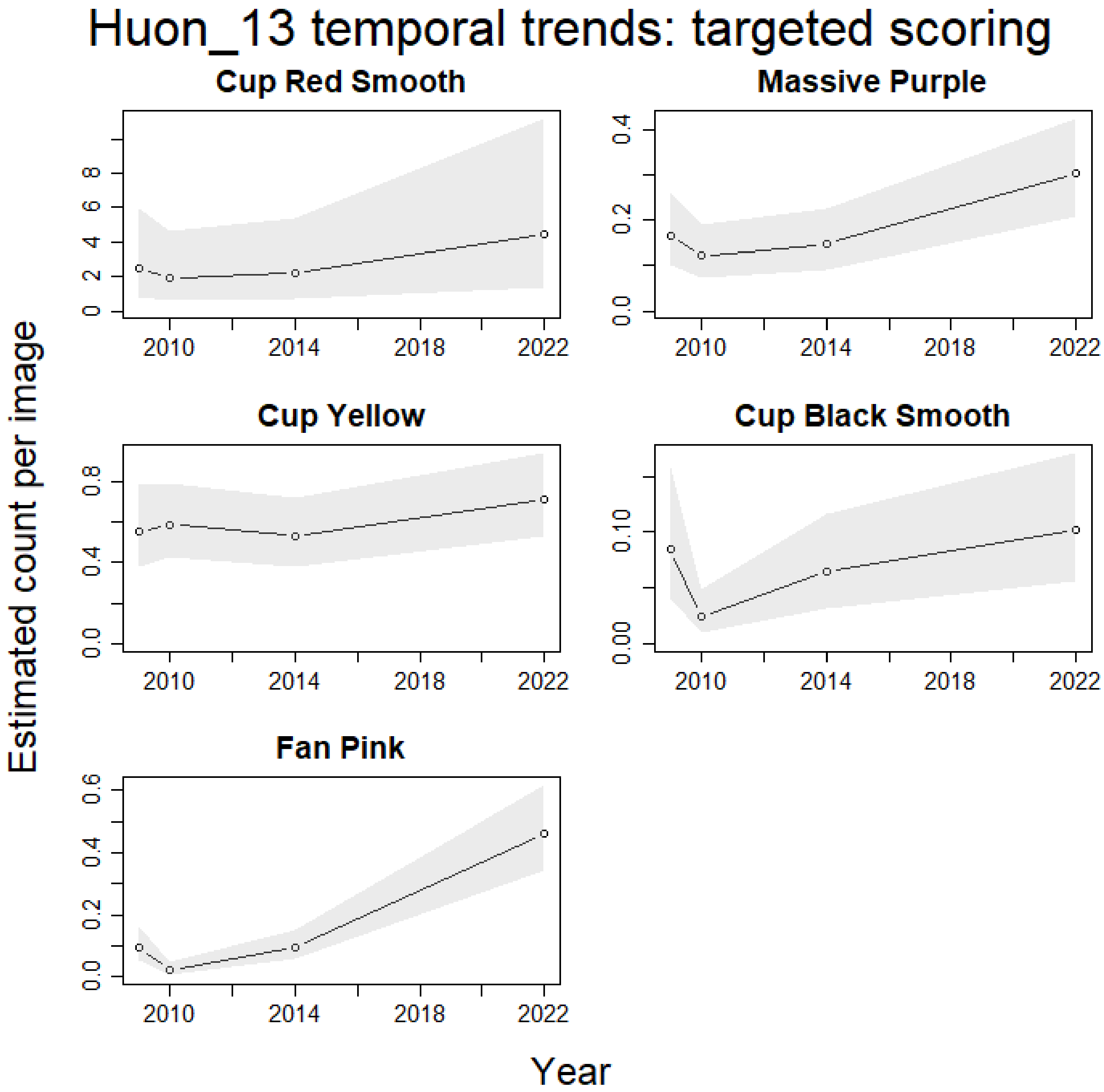


Figure 16. Model-based estimate of the temporal trend in the abundance of the five morphospecies target scored at the Huon_13 site. Points and lines show the mean and shaded area shows the 95% credible intervals. Estimates were made at the mean depth of the transect, ignoring any spatial effects.

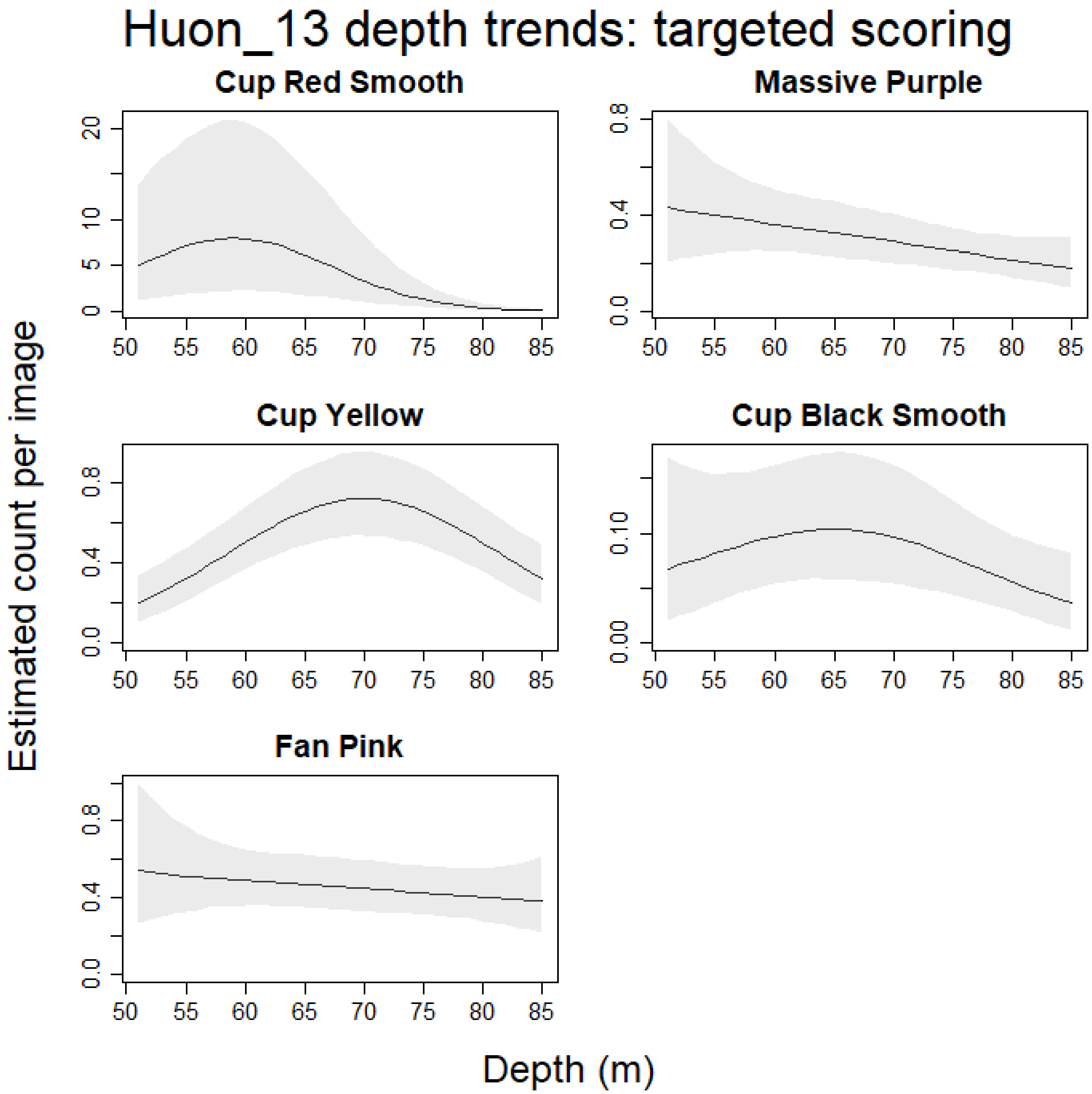


Figure 17. Relationship between the abundance of the five target scored morphospecies with depth at the Huon_13 site. Line shows the mean and shaded area shows the 95% credible intervals.

Cup Red Smooth

Cup red smooth sponge abundance at Huon_13 remained relatively stable between 2009 and 2014, increasing significantly in 2022 compared to 2009 (Table 4, Figure 16, and Figure 18). There was a significant negative association with depth and depth-squared, indicating a preference for shallow to mid-depth across those surveyed (Table 4 and Figure 17).

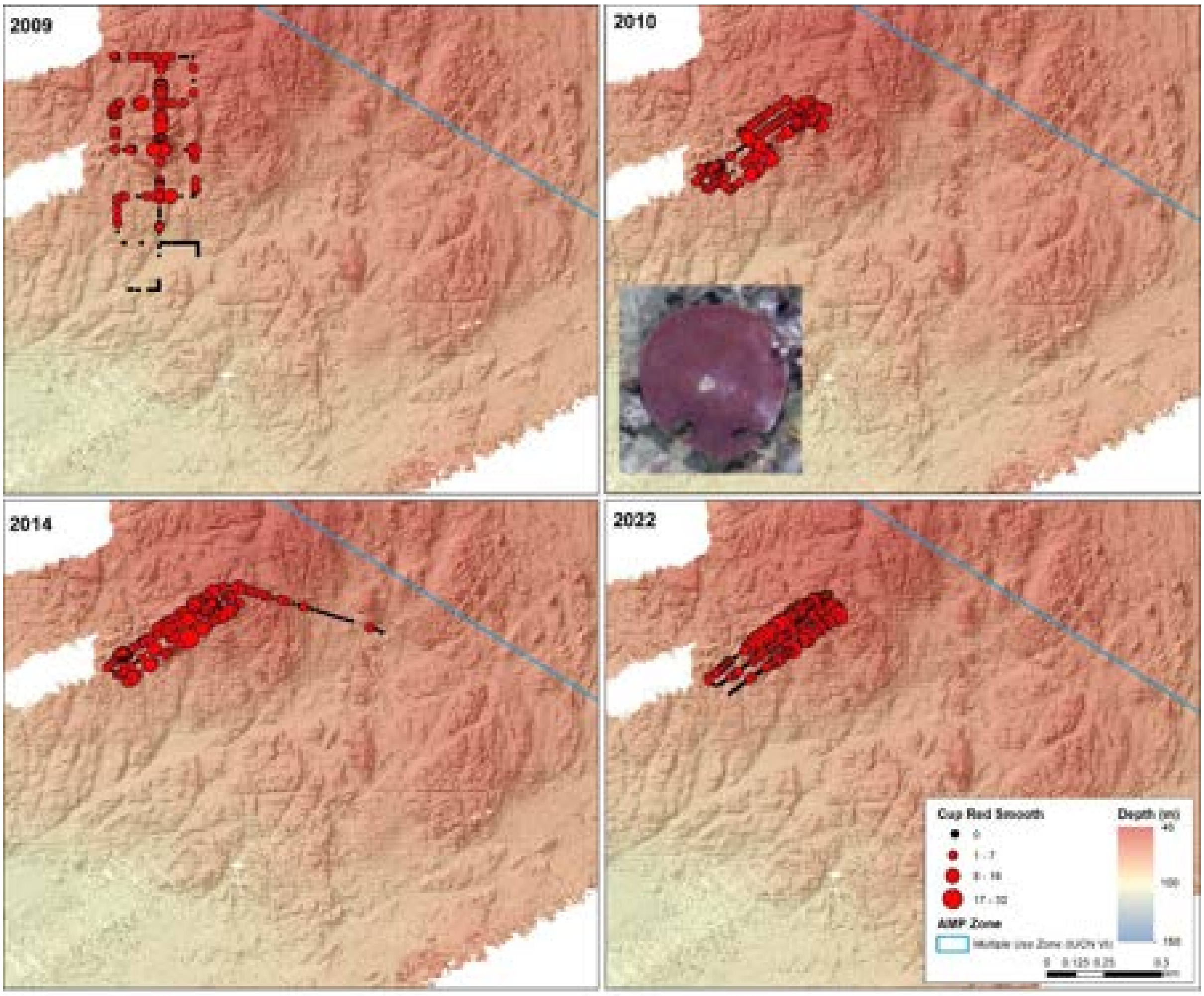


Figure 18. Changes in the spatial distribution in abundance (count per image) of cup red smooth sponges at Huon_13 transect from targeted scoring. Note that a different transect design was used in the 2009 survey compared to subsequent surveys.

Cup red smooth bleaching prevalence

Bleaching prevalence was similar between 2009 and 2010, yet increased significantly in 2014 and then again in 2022, where the bleached proportion was approximately three times higher than in 2009 (Table 4, Figure 20). There was a significant positive association with both depth and depth-squared, indicating bleaching proportions were higher in shallow and deep depths compared to mid-depths across those surveyed (Table 4 and Figure 21).

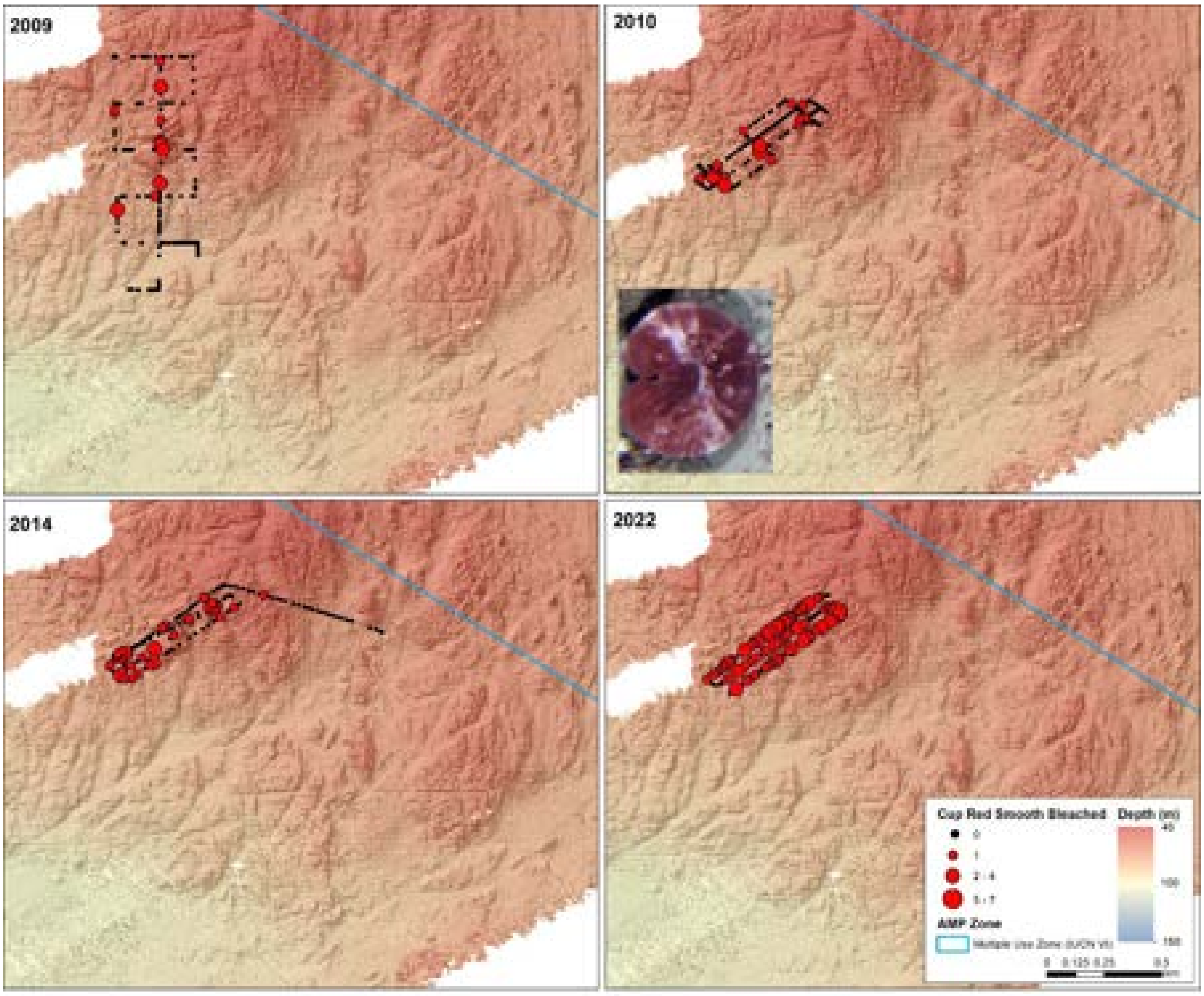


Figure 19. Changes in the spatial distribution in abundance (count per image) of bleached cup red smooth sponges at Huon_13 transect from targeted scoring. Note that a different transect design was used in the 2009 survey compared to subsequent surveys.

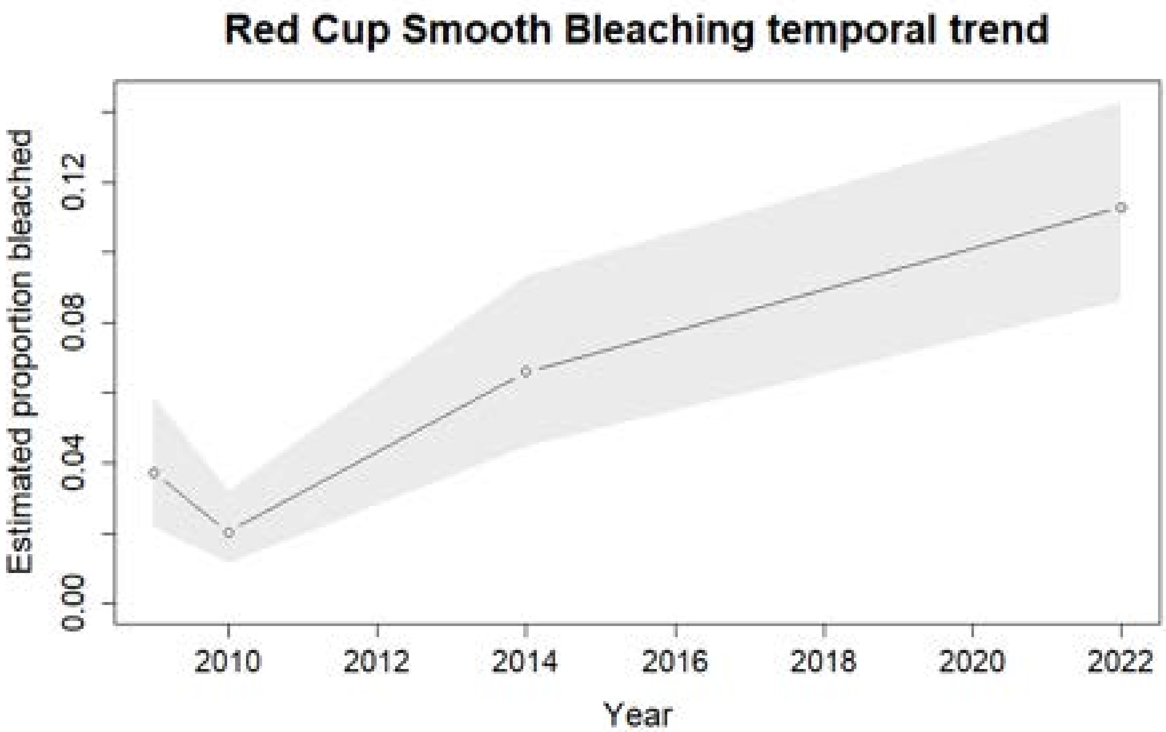


Figure 20. Temporal trend in the proportion of bleaching in cup red smooth sponges at the Huon_13 site from targeted scoring.

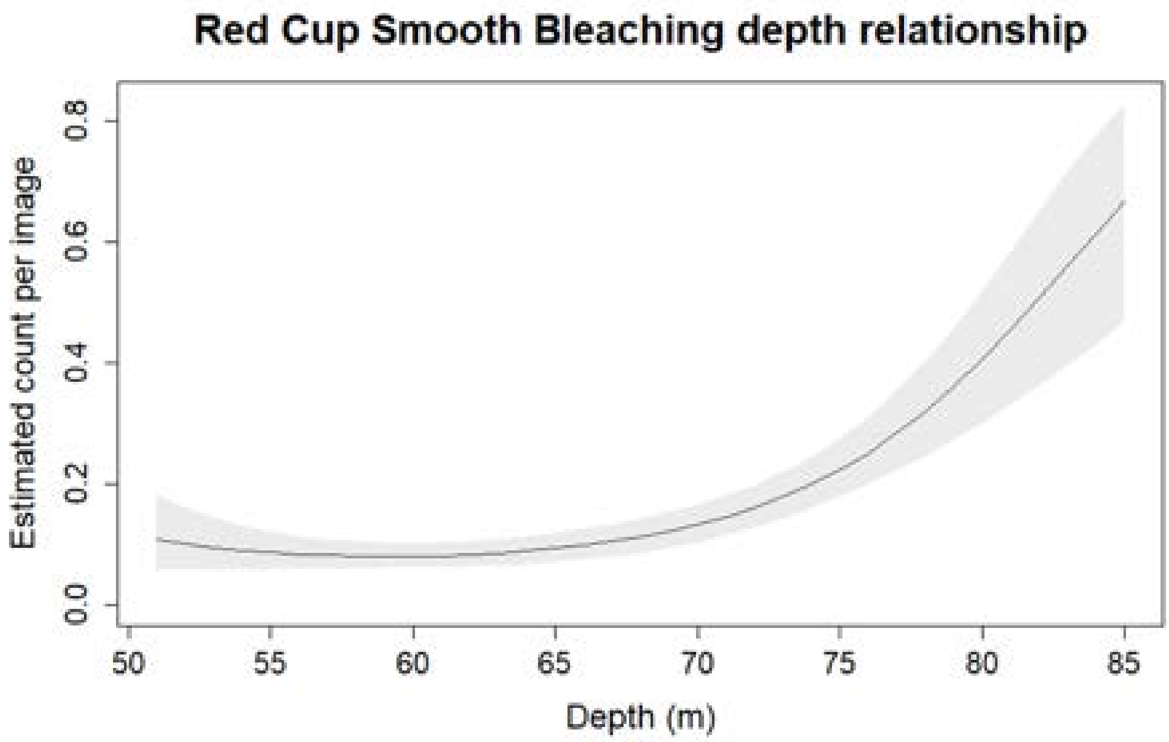


Figure 21. Depth relationship with the proportion of bleaching in cup red smooth sponges at the Huon_13 site from targeted scoring.

Massive purple

Massive purple sponges at Huon_13 abundance remained fairly stable between 2009 and 2014, but abundance was significantly higher in 2022 compared to 2009 (Table 4, Figure 16, and Figure 22). There was a significant negative association with depth indicating a preference for deeper areas across those surveyed (Table 4 and Figure 17).

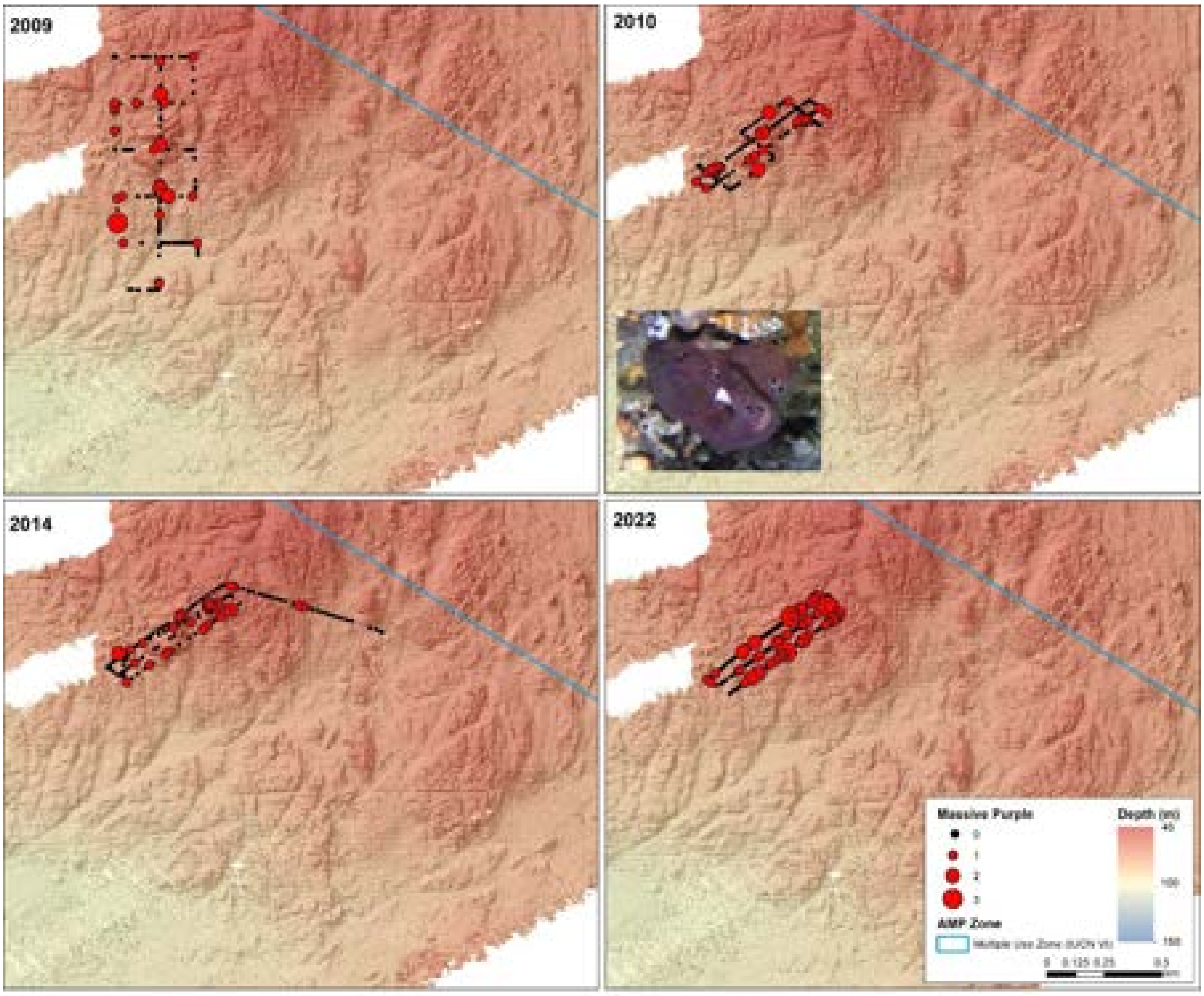


Figure 22. Changes in the spatial distribution in abundance (count per image) of massive purple sponges at Huon_13 transect from targeted scoring. Note that a different transect design was used in the 2009 survey compared to subsequent surveys.

Cup Black Smooth

Cup black smooth sponge abundance at Huon_13 declined significantly between 2009 and 2010, however by 2022 had returned to 2009 levels (Table 4, Figure 16, and Figure 23). There were no significant associations with depth indicating cup black smooth was relatively evenly spread across the depths surveyed (Table 4 and Figure 17).

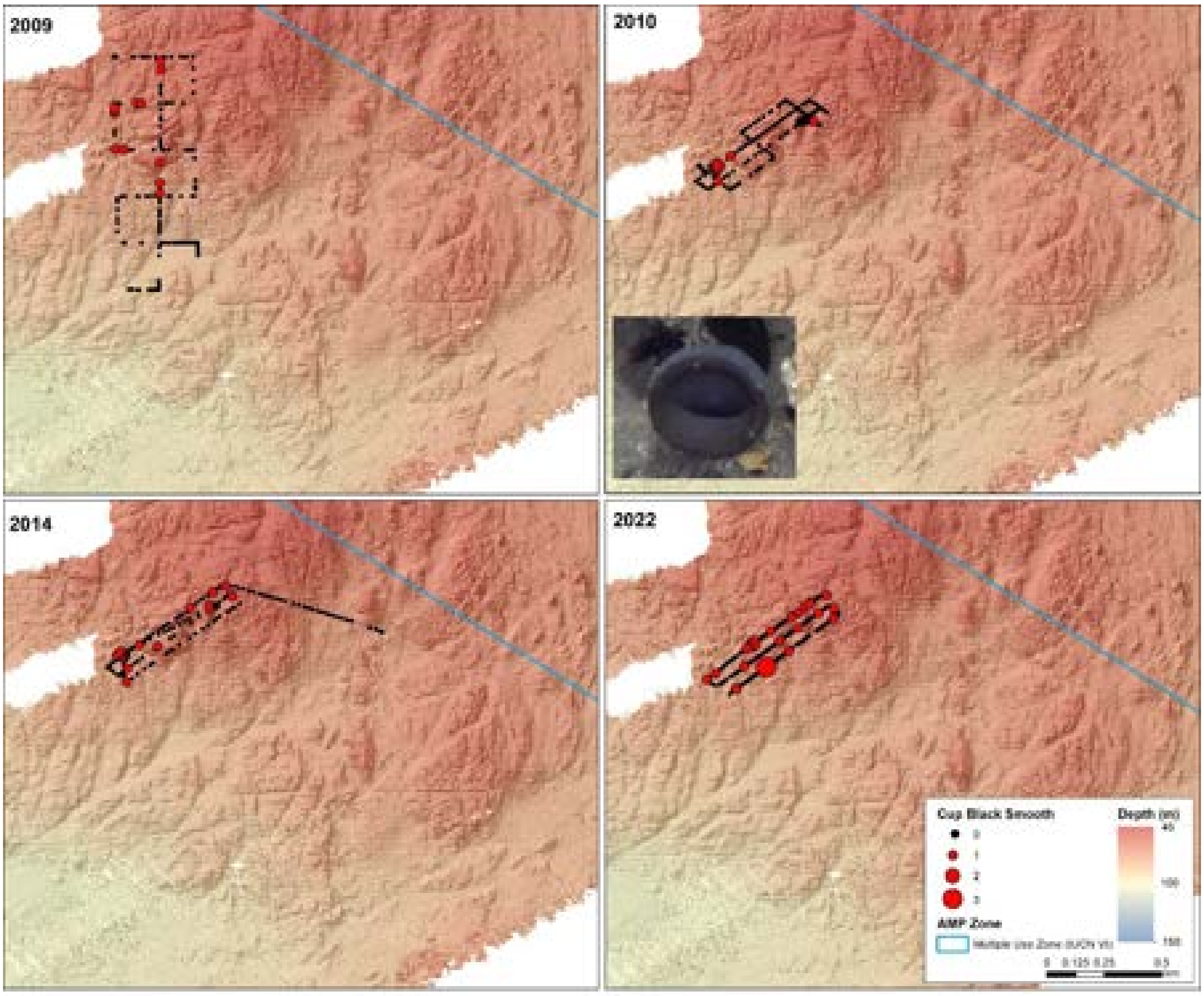


Figure 23. Changes in the spatial distribution in abundance (count per image) of cup black smooth sponges at Huon_13 transect from targeted scoring. Note that a different transect design was used in the 2009 survey compared to subsequent surveys.

Cup Yellow

Cup yellow sponges at Huon_13 abundance remained fairly stable between 2009 and 2022 with no significant differences across the time series and only relatively small fluctuations between years surveyed (Table 4, Figure 16, and Figure 24). There was a significant negative association with depth-squared, indicating a preference for mid-depth across those surveyed (Table 4 and Figure 17).

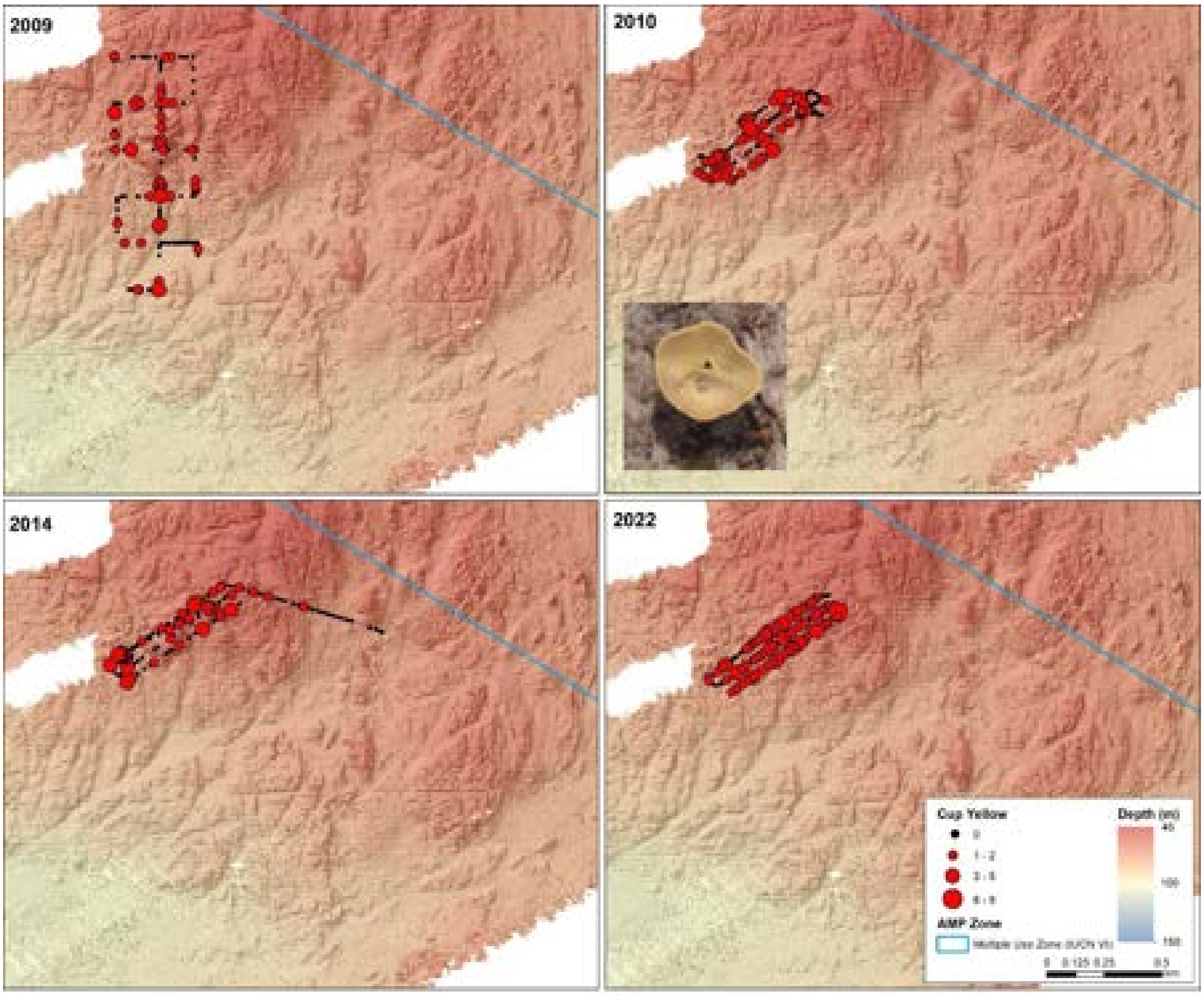


Figure 24. Changes in the spatial distribution in abundance (count per image) of cup yellow sponges at Huon_13 transect from targeted scoring. Note that a different transect design was used in the 2009 survey compared to subsequent surveys.

Fan Pink

Fan pink sponges at Huon_13 abundance showed a small but significant decline between 2009 and 2010, followed by a trajectory of increased abundance, with the abundance in 2022 being approximately 5 times higher than that of 2009 (Table 4, Figure 16, and Figure 25). There were no significant associations with depth indicating there was relatively evenly spread across the depths surveyed, with a slight preference for shallower depths (Table 4 and Figure 17).

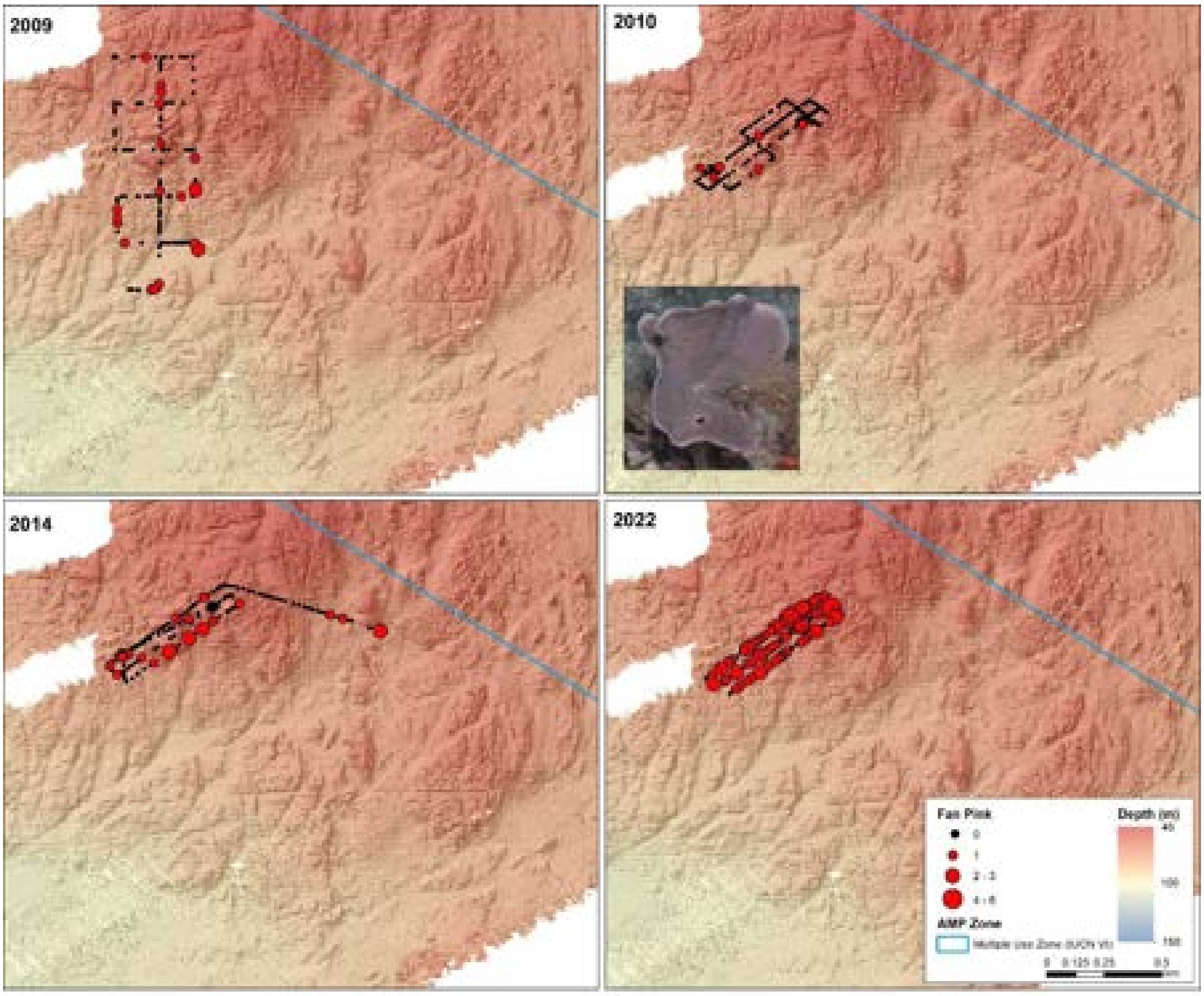


Figure 25. Changes in the spatial distribution in abundance (count per image) of fan pink sponges at Huon_13 transect from targeted scoring. Note that a different transect design was used in the 2009 survey compared to subsequent surveys.

Discussion

The AUV surveys of the HMP undertaken in 2022 have: (1) considerably expanded our knowledge of the spatial/depth extent of shelf reef associated sessile fauna in the park by increasing both the spatial extent of shelf reef sampled and the depth range covered by these surveys, and (2) allowed continued time-series sampling of core survey sites to provide further indication of how the fauna on these deep mesophotic reefs change over decadal time scales. Four new AUV transects were surveyed across recently mapped rocky reef areas further offshore than previously surveyed in the lower mesophotic to rariphotic zone. The new transects contain a diverse benthic community consisting of a wide range of invertebrate fauna including sponge morphospecies, soft corals, hydroids, bryozoa and ascidians, with several algal morphospecies present at shallower depths. Due to the exposure to southerly swell at this location, much of the invertebrate fauna is relatively small compared to that found in more sheltered locations, such as the Beagle MP in central Bass Strait (Barrett et al. 2021).

Like many deep reef systems surveyed in this region (e.g., Perkins et al. 2022c) “biological matrix”, a mix of small/fine invertebrate fauna such as bryozoans and hydroids that cannot be further taxonomically identified in imagery, predominates on reefs, accounting for 60% of cover on most reefs surveyed. As found in deep mesophotic to rariphotic reef surveys elsewhere (Perkins et al. 2021), the majority of the more readily identifiable morphospecies each contributed an overall cover of less than 2%, with typically only the top 3 morphospecies in any one survey individually providing greater than 1% cover below photic depths. Even here, the predominant “morphospecies” in the survey was the lumped grouping of soft foliaceous bryozoans that were not readily differentiated further. At the shallower locations primarily in the mesophotic zone (Huon 12 and 13), the reefs had a moderate component of red calcareous algae (up to 7%) and a lesser component of encrusting non-calcareous red algae (up to 6%). The most common invertebrate morphospecies across survey locations were the combined soft bryozoans, up to 4.5% cover, encrusting sponges (red, white and yellow) ranging up to 3% cover, gorgonians (the red *Pteronisis*-like form) up to 2% cover, and *Parazoanthus/Epizoanthus* morphospecies to approximately 0.5% cover. The remaining morphospecies were generally quite variable between survey locations and were individually never greater that 0.5% cover and typically were far less.

Analysis of the time-series of imagery collected four times between 2009 and 2022 across two transects (Huon 12 and 13) within the HMP revealed that overall, the benthic community in mesophotic depths of approximately 50 to 80 m remained relatively stable over the 13 years of monitoring at these locations. Although community composition had not shifted significantly over this period, cover of some of the dominant morphospecies changed, including biological matrix (declining from around 80% to 70% cover), soft bryozoans (varying between 1 and 3% cover), non-calcareous encrusting red algae (varying between 1.5 and 2.5 % cover), and encrusting white sponge (varying between 0.2 and 7% cover). Univariate analysis of the cover of these morphospecies revealed that some had undergone notable changes over the survey period, with some showing an overall trajectory of decreasing cover (e.g. biological matrix), others showing a trajectory of increasing cover (gorgonian red *Pteronisis* like, e.g., 0.5 to 1.5% at Huon 13) and others fluctuating in cover over this time period (soft bryozoa and encrusting white sponge). This is largely in agreeance with previous time-series analysis work undertaken in the HMP and elsewhere across the SE MP Network (Perkins et al. 2021). Soft bryozoa and gorgonian red *Pteronisis* like, along with a number of encrusting sponges, appear to fluctuate in abundance at different sites over relatively short (5-10 year) time cycles (Perkins et al. 2021). However, it should be noted that there was a significant gap in the time series of eight years from the 2014 and the most recent 2022 surveys. Therefore, morphospecies that have been noted to fluctuate in cover over this time scale may have gone through a cycle of high to low abundance during the intervening years. Indeed, both soft bryozoa and gorgonian red *Pteronisis* like had roughly similar levels of cover between 2014 and 2022 which may not reflect stability over this time period but is more likely to be coincidental with the timing of surveys with fluctuations in cover likely over this length of time. Certainly, further surveys at regular periods, including a mix of shorter-term repeats (annual) to longer term sampling are required to better understand the drivers of variation in mesophotic to rariphotic benthic assemblages given the paucity of studies globally to help infer likely patterns.

Many of the less dominant (in terms of space occupation) but characteristic or biologically interesting morphospecies are difficult to quantify using the point scoring approach used here, at least in a quantitative sense at levels of certainty necessary to underpin monitoring programs (Perkins et al. 2022a). Therefore, a targeted scoring approach was also conducted for a smaller subset of morphospecies to better quantify their abundance and change through time. This analysis, based on the number of individuals seen per image, revealed that there were significant changes in the abundance of several of the morphospecies across the 13-year time-series. Three of the target scored morphospecies had significant increases in abundance from 2009 to 2022, including cup red smooth (2 to 4.2), massive purple (0.12 to 0.3), and fan pink (0.02 to 0.4) sponges. Whereas cup yellow sponges remained fairly stable in abundance over the survey period, and cup black smooth sponges showed a fluctuation in abundance over time (0.08 to 0.025 to 0.1), but with abundances in 2022 being similar to 2009. Also, bleaching prevalence in cup red smooth sponges increased across the time-series, with the highest levels of bleaching observed in 2022. The targeted scoring analysis provides better quality data than the randomised point scoring approach (which is primarily focussed on describing wider biodiversity patterns and detecting major changes in the more abundant morphospecies) and showed that many of the key easily identifiable morphospecies present in HMP do change in abundance over decadal time scales and at scales of up to an order of magnitude.

The initial 2009 survey was undertaken over a much broader area at each location as it was an initial trial of AUV-based technology and intended as an initial pilot to understand habitat variation and characteristics in this park. Hence, many of the reef images generated by these surveys were in deeper sections where low profile reef was typically sand inundated. While the spatial model used in our analysis can account for some of this spatial difference, it should be noted that some of the reef was qualitatively different and may influence the overall reliability of the 2009 estimates. This highlights the need for repeat transects on a fixed-transect design where possible, as has been the case in subsequent surveys.

Finally, AUV imagery offers the opportunity to examine a wider range of attributes of these reef systems, including reef complexity, the distribution of other benthic fishes (including ocean perch, *Helicolenus percoides*) and mobile invertebrates. While these were not examined as part of this study, it was noted that there were extensive numbers of rock lobster across all shelf reef areas in this Marine Park. This is significantly in excess of that seen in reef habitats in other AMPs in the region, including the Tasman Fracture MP, presumably related to the complex nature of the dolerite reef found in this park, coupled with much of this reef being in optimal depth range of lobsters (40-100 m). Whereas in the Tasman Fracture MP most reef is at 100-145 m (Perkins et al. 2022c), or the FMP where, with the exception of Joe's Reef and a few small, isolated reef outcrops (including shelf-break reefs), there is little suitable habitat (Perkins et al. 2023). This pattern was also noted in the HMP by Perkins et al. (2023), as lobsters were strongly attracted to BRUVS used in that survey.

Freycinet Marine Park

Survey design, image sampling and annotation

The FMP survey was undertaken from the IMAS vessel "Noctiluca" in March 2023 after extensive delays due to AUV failures. This included undertaking repeat surveys at three locations (MPA site 1, MPA site 2, and Joe's Reef), as well as six new locations in the rariphotic zone including Midshelf_1 and Midshelf_2. A further four survey locations were established on the shelf-break at Shelfbreak_1 to 4 (Figure 26). The location Midshelf_1 was included to capture isolated patch reefs that were found during BRUV surveys and initial survey planning by Perkins et al. (2023), with the aim of including more shelf reef in the monitoring program where possible. Midshelf_2 was added to increase understanding and spatial representation of the biota associated with the dune-like features that appear to extend throughout much of the shelf waters in the park (Heaney and Davey 2019). One proposed re-survey location (Patch Reef) could not be surveyed due to AUV failure and unsuitable weather that terminated the survey earlier than planned.

Image sampling and annotation protocols for the 2023 AUV surveys in the FMP followed standard operating protocols for AUV imagery (Monk et al. 2020). The same image sampling and annotation framework used for the 2023 survey data followed that used in previous surveys (Perkins et al. 2021). For initial annotation, images were systematically selected along the transect so that 100 images were sampled along each transect (Table 26). The exception to this was Joe's Reef, where historical sampling of 200 reef images had been conducted. This level of image sampling was maintained by systematically sampling within transect sections containing reef so that a sample size of 200 reef images was obtained. An additional 50 images containing reef were scored for the four new shelf break transects except Shelf_break_1, which had insufficient reef. This was done to better describe these newly surveyed areas by delineating the reef sections along the transect and then systematically spacing images in the reef section to achieve 50 additional images. Images were overlain with 25 random points. Annotation was completed by experienced scorers using the Squidle+ online annotation platform. A thorough QA/QC process was undertaken prior to data analysis.

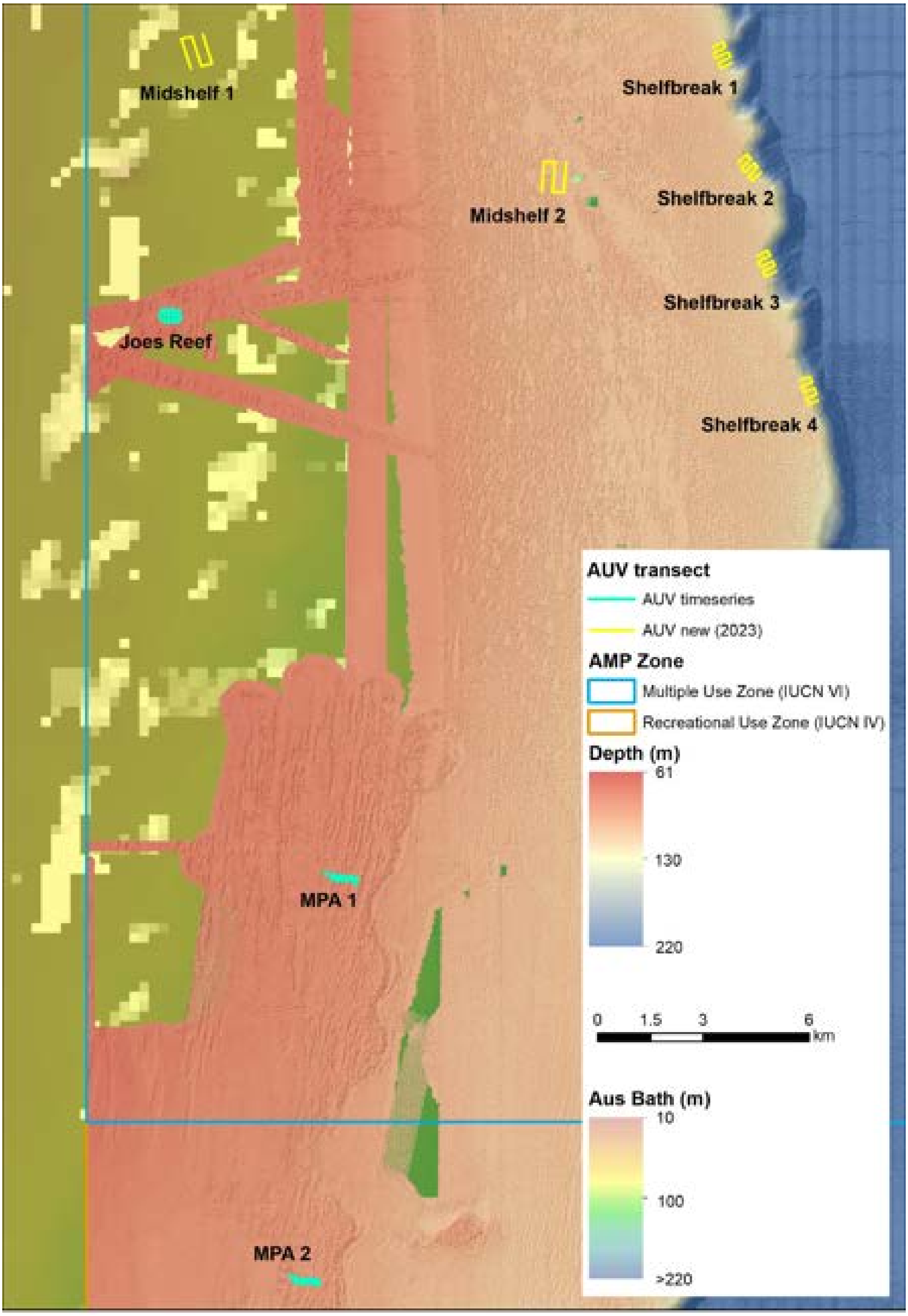


Figure 26. Locations of AUV transects in FMP, including repeat time series and new extended coverage.

Table 5. AUV transects conducted at Freycinet Marine Park, including year surveyed, depth range of survey, Parks Australia defined depth-based ecosystem, number of images annotated, and the number of random points used. Note that for MP site 1 no annotation was conducted for 2010, 2012, and 2016 survey years.

Transect	Year	Depth range (m)	Parks Australia depth-based ecosystem	Number of images annotated	Number of random points
Joes_ Reef	2011	62-82	Mesophotic-rariphotic	201	25
	2014	62-83		252	25
	2016	61-83		200	25
	2023	58-83		214	25
Shelf_break_1	2023	123-184	Rariphotic	100	25
Shelf_break_2	2023	118-184	Rariphotic	154	25
Shelf_break_3	2023	123-197	Rariphotic	151	25
Shelf_break_4	2023	126-202	Rariphotic	150	25
Midshelf_1	2023	80-83	Rariphotic	99	25
Midshelf_2	2023	112-117	Rariphotic	100	25
MPA_site_1	2009	87-101	Rariphotic	101	50
	2010	-		-	-
	2012	-		-	-
	2016	-		-	-
	2023	90-96	Rariphotic	92	25
MPA_site_2	2009	96-109		88	50
	2010	96-101		142	25
	2012	96-102		150	25
	2016	96-101		173	25
	2023	96-101		100	25

Description of habitats present

The newly surveyed shelf break transects in FMP were typically dominated by flat sand, bryozoan rubble, beds of bivalve shells, mixed habitats, and low (< 1m) to moderate profile mudstone or limestone reef with occasional small cliffs and overhangs. A significant observation was that much of the lower profile reef, and even much of the steeper cliffy areas were often bare rock (Figure 27 and also see Figure 28, plus Appendices), particularly where this reef outcrop was mudstone (as seen at Shelfbreak 2 and 3). Notably though, the reef at Shelfbreak 4 was limestone reef and was invariably covered in biota or trapped sediment/biota matrix. Generally, most of the mudstone reef patches were typically smooth rock, rather than having any form of complexity such as boulder fields or isolated boulders, whereas the limestone reef at Shelfbreak 4 (see Appendices) often had clearly eroded overhangs and holes, as well as numerous isolated boulder structures.

The two new mid-shelf transects (Midshelf 1 and 2) in the rariphotic zone appeared generally flat and sediment dominated (Figure 27 and Table 5) despite these transects occurring in regions where consolidated dune-like features are present (rising and falling 5 m in height over 50 m scales). As the scale of an individual image is relatively small (approx. 1.5 x 2 m) any small slope appears flat. Despite this, some reef outcrops were encountered at Midshelf_1 (Figure 26, Appendices) but these were only in the order of 2% of the overall seabed in this area. Overall, the habitats observed on these new transects were similar to those at the MPA site 1 and MPA site 2 (Figure 26) and that found at the historical site “Patch Reef”, a site not able to be completed in this survey.

The notable mid-shelf exception to this pattern is Joe’s Reef, the large isolated offshore granite reef outcrop that has been previously described (e.g., see Perkins et al. 2021), and is the standout reef feature in FMP and contains the only reef spanning the mesophotic to rariphotic zone (~60-80 m), with significant structural complexity including large sections of moderate to high/wall features that resist the siltation seen elsewhere at these depths. The lack of siltation and steep wall structures in this area of moderate ocean current flow allow a significant sessile invertebrate and demersal fish community to persist, one dominated by filter feeders and planktivores. Example images of each habitat type are given in the Appendix.

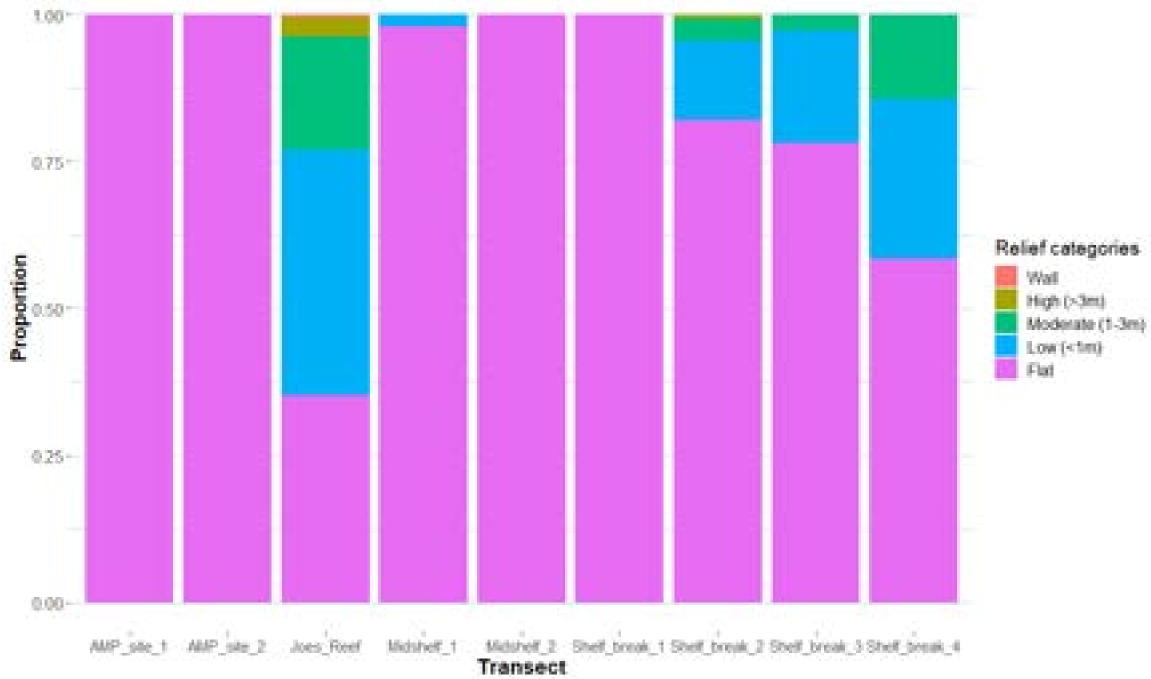


Figure 27. Summary of relief categories for images scored across each transect in Freycinet Marine Park.

Description of biota present

Reef areas on the newly surveyed shelf break transects were dominated by a cover of low profile "biological matrix" comprised of a mixture of bryozoa, cnidaria, hydroids and sponge (that could not be further categorized in the resolution of the imagery), and other biota (Figure 28). There was a progression to higher cover of biota heading south in the shelf break transects, with the two southernmost transects (Shelf_break_3 and Shelf_break_4) having the highest cover of biota. On the shelf itself, the new Midshelf_1 transect was sediment dominated (despite having around 2% of outcropping reef) with the occasional sessile invertebrate and a low cover of bryozoan/hydroid matrix. The Midshelf_2 transect was also sediment dominated with the occasional sessile invertebrate, but with a dominant patchy cover of bryozoan/hydroid matrix. The two other shelf sites (AMP_site_1 and AMP_site_2) were sand dominated, with some bryozoan rubble present in both sites. Sparse low-height cover of bryozoa/cnidaria matrix was present in both AMP_site_1 and AMP_site_2 also, with only a small amount of other biota such as occasional sponges on rubble, and solitary ascidians and anemones. The reef surveyed at Joe's Reef had a more significant cover of distinct biota and was dominated by a mixture of encrusting sponges, soft bryozoans, massive sponges, branching sponges, palmate sponges, cup sponges, gorgonian corals, bramble corals, sea whips, and encrusting corals. Characteristic imagery for each transect is provided in the Appendix. A detailed description of the dominant biota present in each transect is provided below.

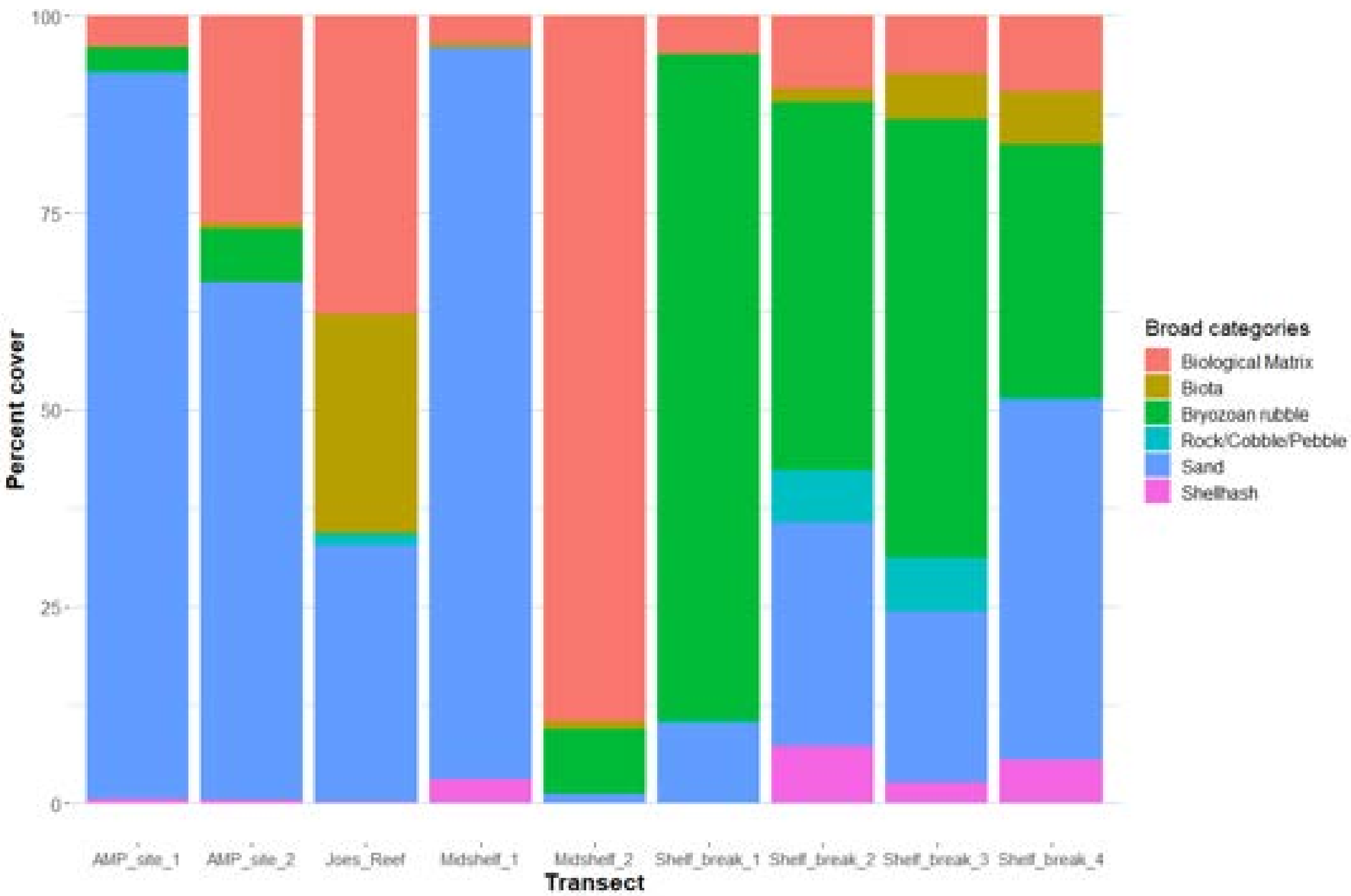


Figure 28. Summary of broad categories of physical substrate and biota scored across each transect in Freycinet Marine Park.

Joe's Reef

Joe's Reef shows high biodiversity, with relatively high cover of biota, consisting of a large number of morphospecies making up the overall cover with only one morphospecies (encrusting orange sponge) having greater than 1% cover. Dominant morphospecies at Joe's Reef included encrusting orange sponge, gorgonian red *Pteronisis*-like, soft bryozoans (morphospecies merged), encrusting octocoral (*Clavularia* like), hydroids, and a variety of encrusting, branching, massive, fan, and cup sponges (Figure 29). Biological matrix accounted for 38% of annotated points on reef images from Joe's Reef. Characteristic images containing some of these dominant species are given in the Appendix.

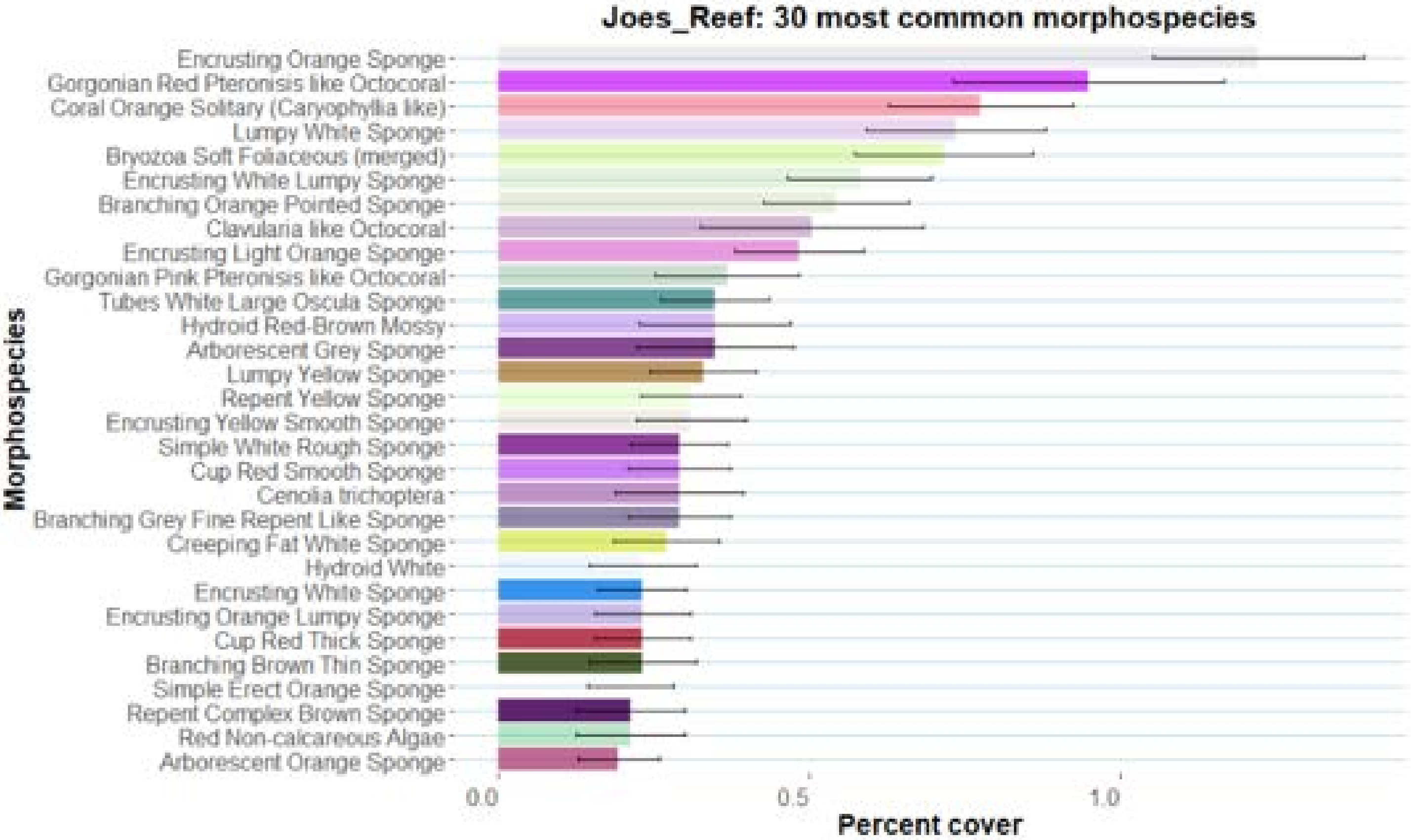


Figure 29. Percent cover (and standard error) of the 30 most common morphospecies at Joe's Reef. Biological matrix was excluded for improved visualisation.

Shelf break 1

The Shelf break 1 transect was sediment and rubble dominated with no reef features present. The only four non-biological matric morphospecies recorded were massive white shapeless sponge, *Hornera robusta* -like bryozoa, soft bryozoa, and ball white sponge (Figure *30*). The limited biota was present on bryozoan rubble habitat. Biological matrix accounted for 5% of annotated points.

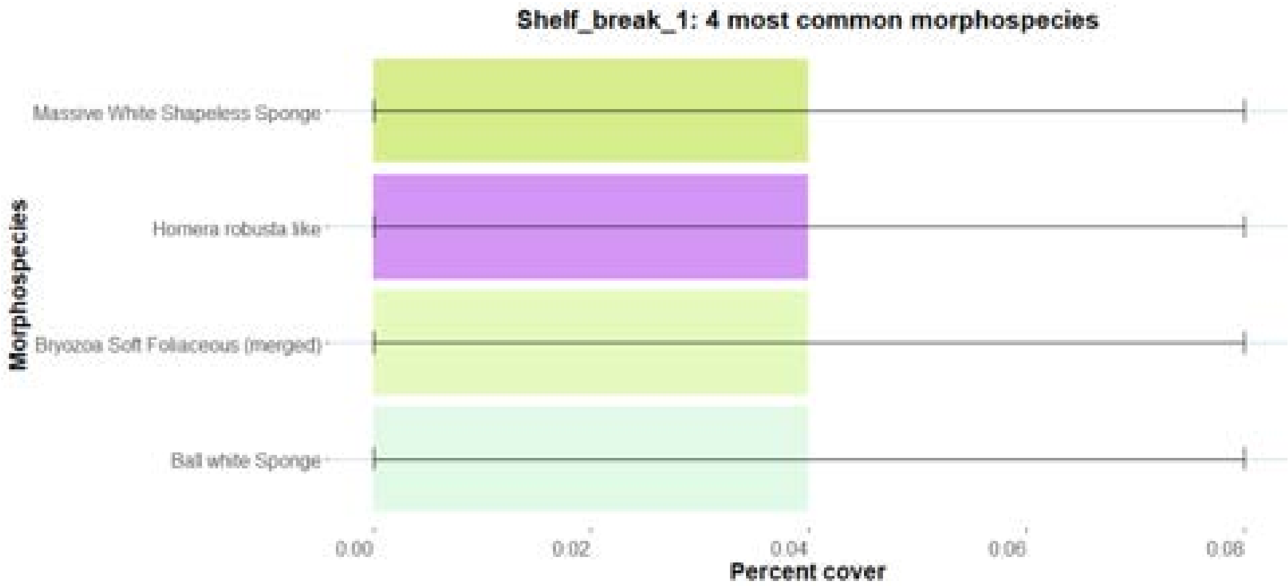


Figure 30. Percent cover (and standard error) of the four most common morphospecies at the Shelf break 1 transect. Biological matrix was excluded for improved visualisation.

Shelf break 2

The Shelf break 2 transect was sediment dominated, interspersed with small sections of mudstone reef and rubble. Only 23 non-biological matrix morphospecies and a few sessile invertebrates were recorded. These dominant morphospecies included encrusting yellow smooth sponge, ascidian colonial white translucent, soft bryozoa, bryozoa dendroid tan, hydroids, and a variety of encrusting and massive sponges (Figure 31). Biological matrix accounted for 9% of annotated points.

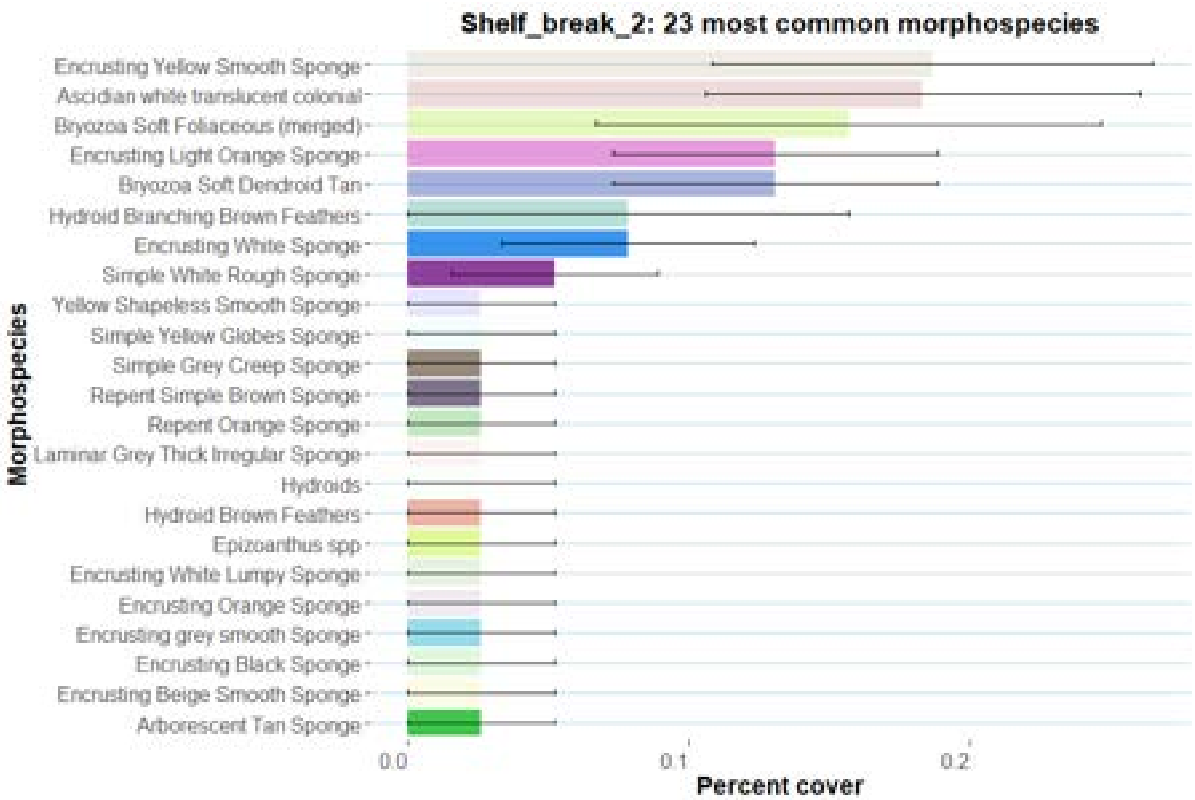


Figure 31. Percent cover (and standard error) of the twenty-three most common morphospecies at the Shelf break 2 transect. Biological matrix was excluded for improved visualisation.

Shelf break 3

The Shelf break 3 transect had a larger section of outcropping mudstone reef with a larger cross-section of invertebrates compared to the shelf break 1 and 2 transects. Dominant morphospecies included encrusting yellow smooth sponge, encrusting beige smooth sponge, lumpy yellow sponge, soft bryozoa, a variety of ascidians, hydroids, and a variety of encrusting, branching, barrel, and massive sponges (Figure 32). However, cover of any single morphospecies remained low, with only encrusting yellow smooth sponge having a cover greater than 0.5%. Biological matrix accounted for 7% of annotated points. Characteristic images containing some of these dominant species are given in the Appendix.

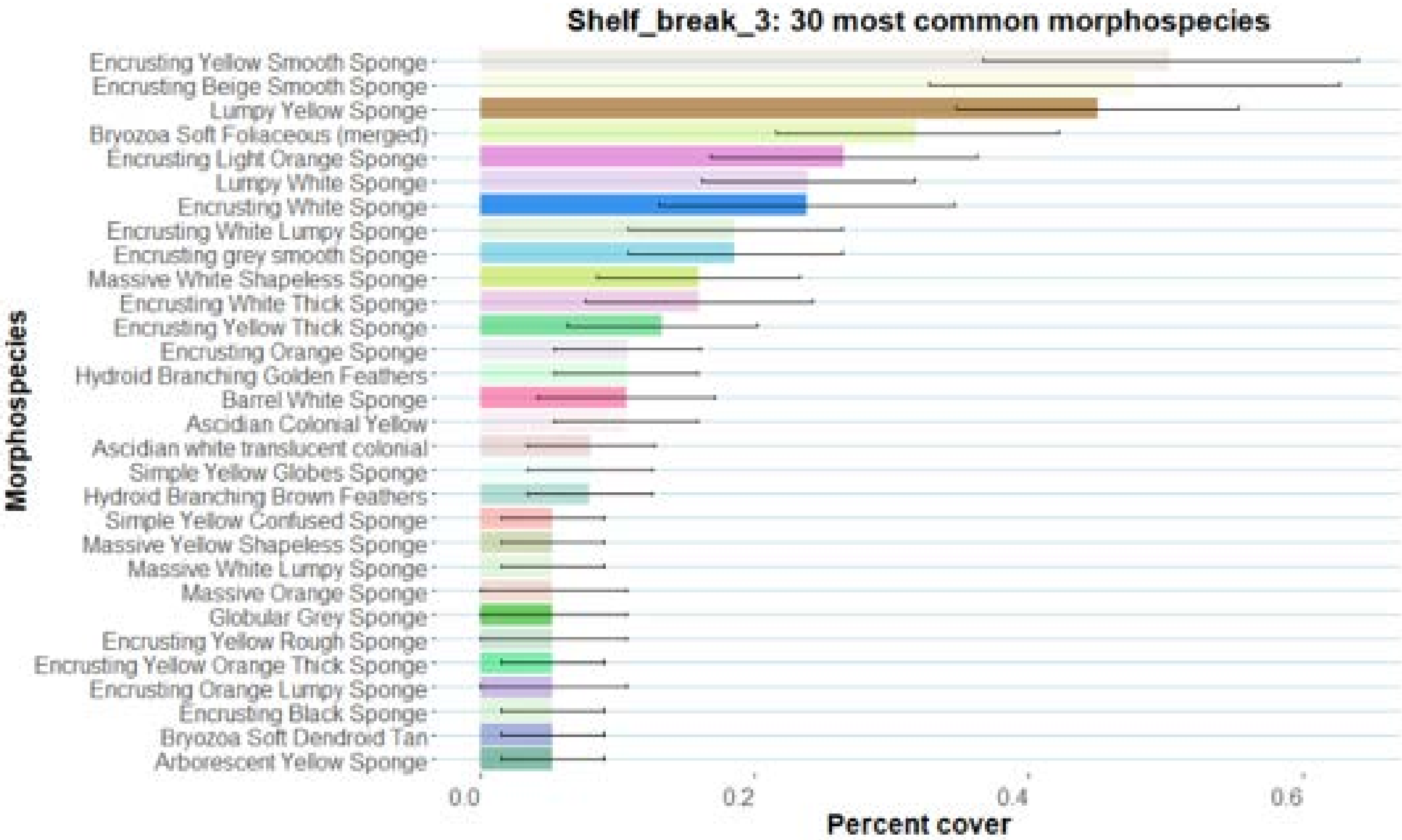


Figure 32. Percent cover (and standard error) of the thirty most common morphospecies at the Shelf break 3 transect. Biological matrix was excluded for improved visualisation.

Shelf break 4

The Shelf break 4 transect had the largest sections of outcropping reefs and largest cross-section of invertebrates compared to any of the other shelf break transects. Unlike the reefs noted at Shelf Break 2 and 3, the reefs encountered on this survey appeared to be predominantly limestone and more block-like rather than cliffs or low-profile flat bottom. These reefs were typically covered with emergent biota, contrasting sharply with the reefs at the other sites that often had no biotic cover. Dominant morphospecies included encrusting white sponge, soft bryozoa, encrusting yellow smooth sponge, encrusting beige smooth sponge, lumpy yellow sponge, bryozoa dendroid tan, a variety of hydroids, and a variety of encrusting, branching, and massive sponges (Figure 33). However, cover of any single morphospecies remained low, with only the top three most dominant morphospecies having a cover greater than 0.5%. Biological matrix accounted for 10% of annotated points. Characteristic images containing some of these dominant species are given in the Appendix.

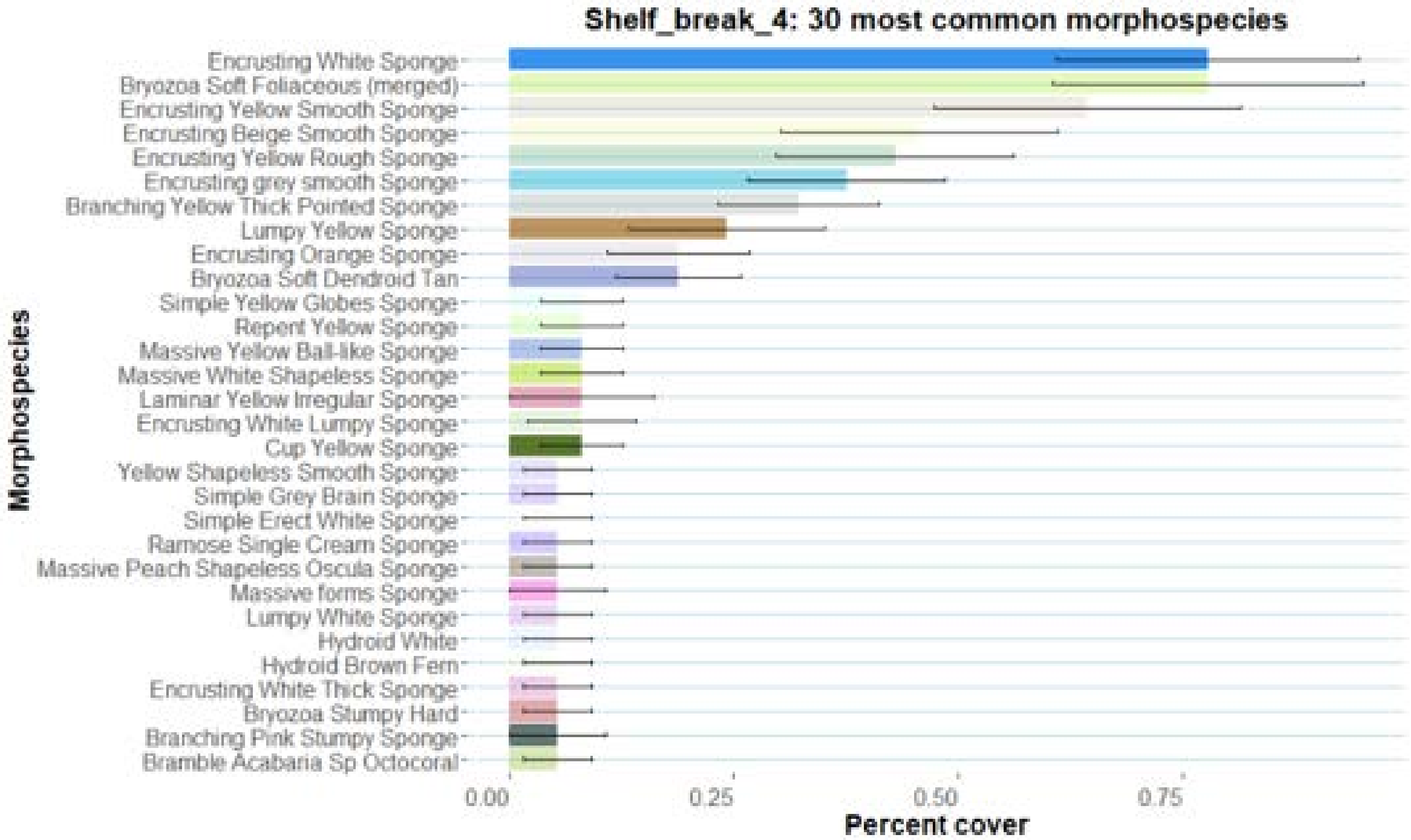


Figure 33. Percent cover (and standard error) of the 30 most common morphospecies at the Shelf break 4 transect. Biological matrix was excluded for improved visualisation.

Midshelf 1

The Midshelf 1 transect was sediment and rubble dominated with a single outcropping reef feature (see Appendix) that accounted for most of the biota recorded. Occasional sessile invertebrate associated with rubble habitat were also recorded. Only five non-biological matrix morphospecies were recorded. These five dominant morphospecies were *Epizoanthus* colonial anemones, lumpy white sponge, simple orange rough sponge, and simple orange confused sponge (Figure *34*). Biological matrix accounted for 3% of annotated points.

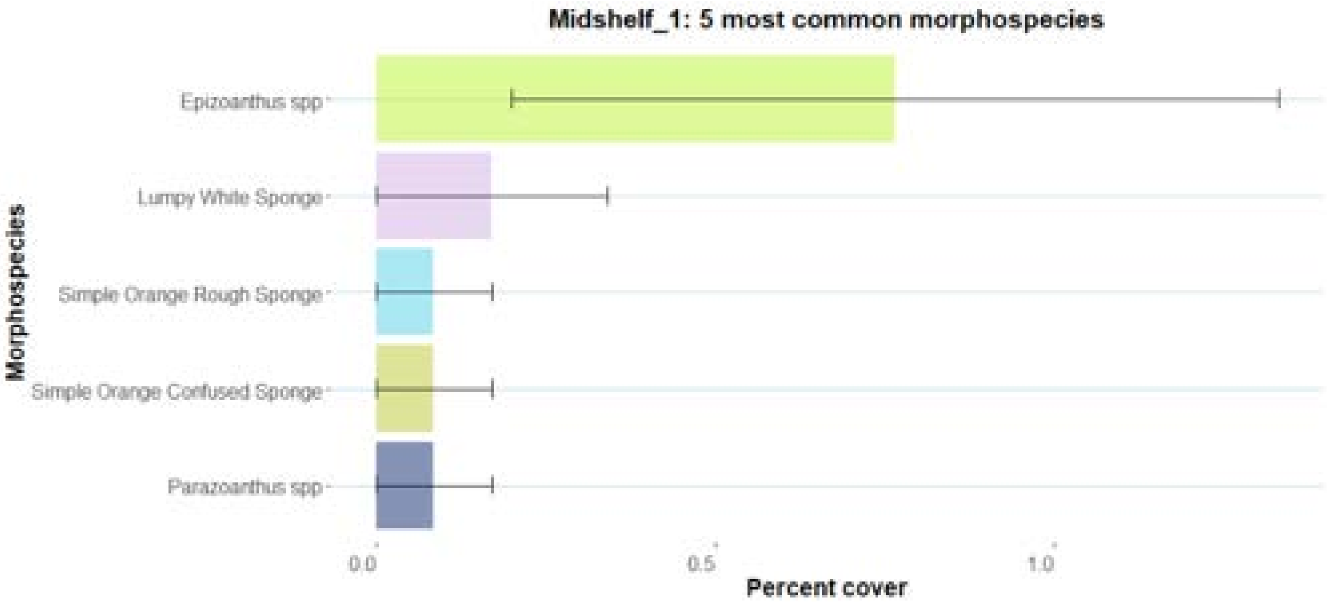


Figure 34. Percent cover (and standard error) of the five most common morphospecies at the Shelf break 1 transect. Biological matrix was excluded for improved visualisation.

Midshelf 2

The Midshelf 2 transect was sediment dominated. Very occasional non-biological matrix sessile invertebrate associated with rubble habitat and only 14 non-biological matrix morphospecies were recorded. These 14 dominant morphospecies included soft bryozoa, lumpy and encrusting sponges, a single cup sponge, and hydroids (Figure 35). Biological matrix accounted for 90% of annotated points on non-sand dominated images, forming a low cover often associated with rubble habitats.

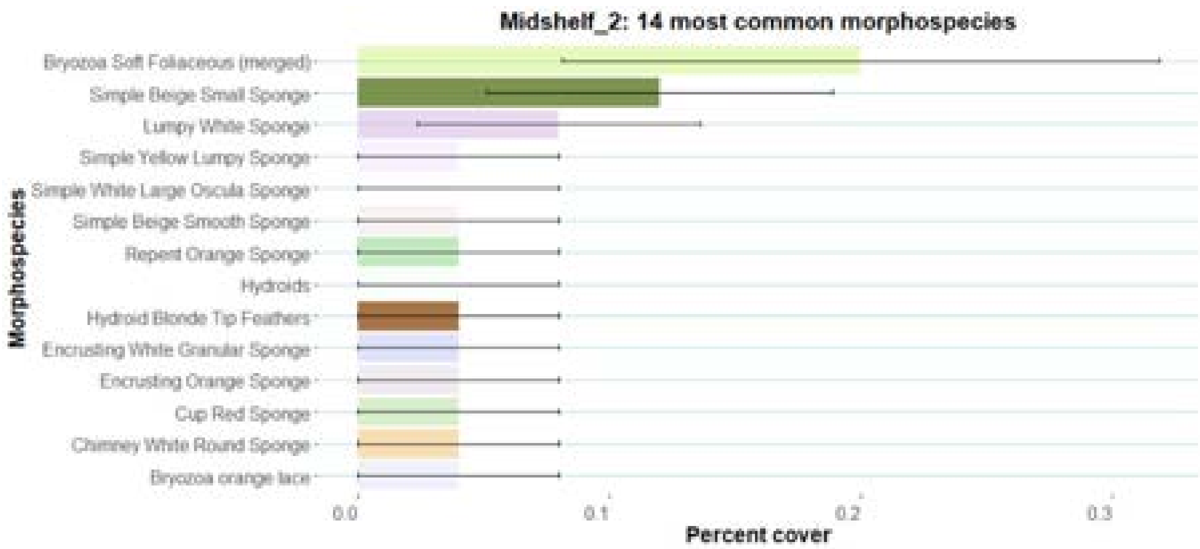


Figure 35. Percent cover (and standard error) of the fourteen most common morphospecies at the Shelf break 1 transect. Biological matrix was excluded for improved visualisation.

MPA site 1

No biota other than biological matrix was annotated at MPA site 1.

MPA site 2

The MPA site 2 transect was sediment dominated. Very occasional non-biological matrix sessile invertebrate associated with rubble habitat and only eight non-biological matrix morphospecies were recorded. These eight dominant morphospecies included lumpy white sponge, and a number of small erect sponges, ascidians and an octocoral (Figure 36). Biological matrix accounted for 90% of annotated points on non-sand dominated images, forming a low cover often associated with rubble habitats.

Figure 36. Percent cover (and standard error) of the eight most common morphospecies at the AMP site 2 transect. Biological matrix was excluded for improved visualisation.

Time-series analysis

Joe's Reef

Joe's Reef was surveyed in 2011, 2014, 2016, and 2023 making a total of four repeat surveys. This time series was analysed for multivariate (i.e., community-level) changes across time, and for a number of selected dominant morphospecies to examine how their cover had changed over the 12 years of survey data.

Multivariate analysis followed the same methodology employed for HMP.

Results from the multivariate analysis as well as previous data exploration was used to help determine a subset of morphospecies to conduct univariate analysis on. This subset comprised of eight morphospecies:

- Biological matrix
- Encrusting Orange Sponge
- Gorgonian Red *Pteronisis* like
- Bryozoa Soft (merged)
- Coral Orange Solitary (*Caryophyllia* like)
- Repent Yellow Sponge
- Hydroid White
- Arborescent Grey Sponge

The same spatial generalised linear model (GLM) was used for the analysis of the Joe's Reef data as was used for the HMP time-series analysis (see Time Series Analysis section in Huon Marine Park).

Multivariate analysis results

Multivariate analysis of the time-series at Joe's Reef showed a high degree of overlap in community structure across years, except for a few outlying images (Figure 37). Examination of the annotated images showed they contained data for just a small number of relatively rare morphospecies. SIMPER results showed that the important morphospecies driving differences across years were biological matrix, gorgonian red *Pteronisis* like, Coral Orange Solitary (*Caryophyllia* like), encrusting orange sponge, repent yellow sponge. However, the SIMPER analysis contained a large number of species contributing to small amounts of difference, suggesting subtle differences that may be related to sampling intensity rather than real differences. PERMANOVA revealed that community composition was significantly different across years (Pseudo-F = 7.53, P < 0.001).

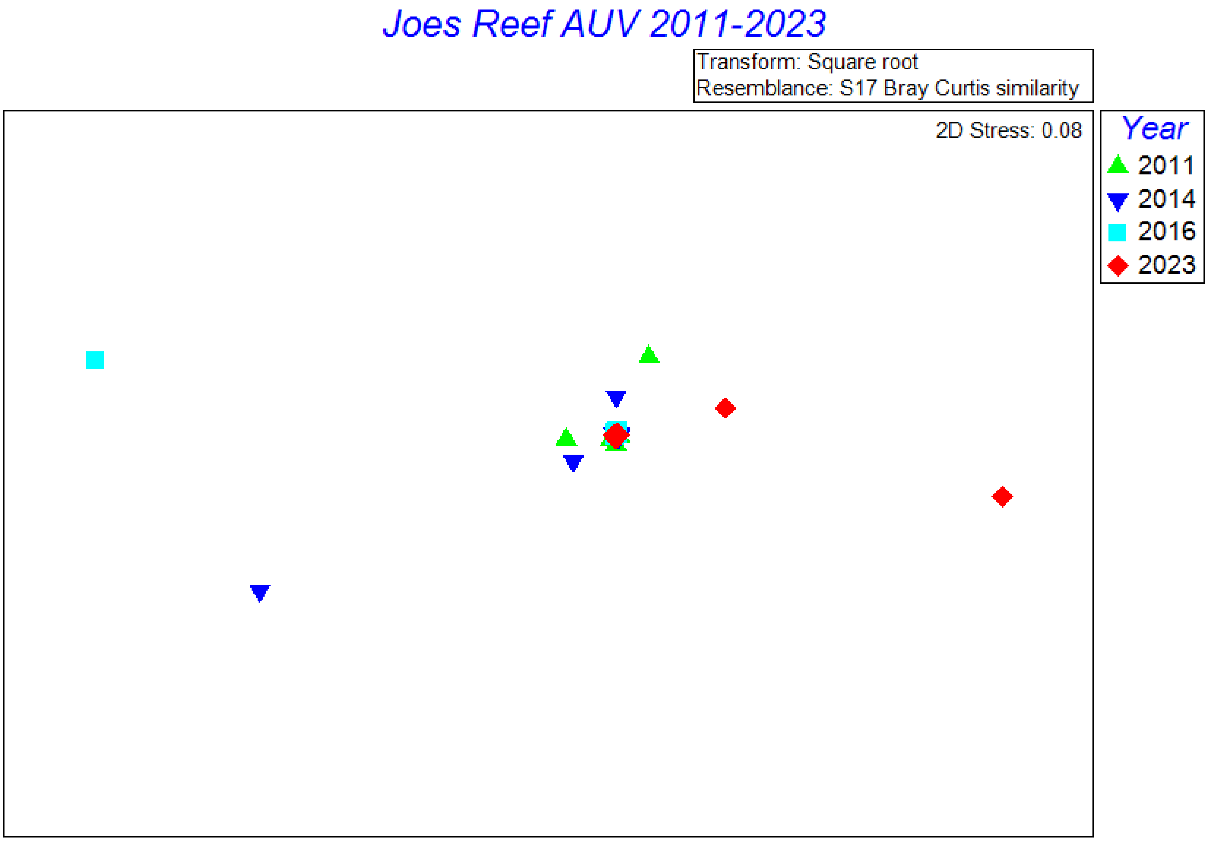


Figure 37. Non-metric multidimensional scaling plot showing community composition at Joe's Reef across survey years. Note that the majority of images are centred in the middle cluster (where symbols from all years are shown), with very few significant outliers between years.

Univariate analysis results

Model-based estimates for the fixed effects of survey year and depth, as well as the parameters describing the spatial random effects (spatial range and standard deviation) for the cover of morphospecies at Joe's Reef are given in Table 7. Summary plots of the temporal trends and the depth effects for each morphospecies are given in Figure 40 and Figure 41 respectively. A short description of the results for each morphospecies at Joe's Reef follows.

Table 6. Model coefficient estimates for year, depth, depth-squared, spatial range, and spatial standard deviation for cover data at Joe's Reef . Mean estimates are given on the first line of each cell, with 95% credible intervals for the estimates given in brackets on the line below. The intercept estimate represents the first survey year (2011), with other year estimates representing deviations from the estimate for 2011. For the fixed effect estimates (year and depth terms) the statistical significance is highlighted in red for negative estimates, and green for positive estimates. 95% CIs that contain zero are considered non-significant.

Morphospecies	Intercept	year2014	year2016	year2023	depth	depth2	Spatial_Range	Spatial_Stdev
Biological Matrix	-0.97 (-1.23 ,-0.71)	0.19 (0.06 ,0.33)	-0.1 (-0.28 ,0.07)	0.01 (-0.15 ,0.16)	-0.76 (-0.88 ,-0.65)	-0.36 (-0.43 ,-0.28)	23.36 (18.43 ,29.42)	1.18 (1.04 ,1.34)
Encrusting Orange	-4.33 (-4.67 ,-3.98)	0.69 (0.35 ,1.03)	0.39 (-0.01 ,0.78)	-0.35 (-0.77 ,0.07)	-0.68 (-0.88 ,-0.48)	-0.29 (-0.44 ,-0.13)	13.61 (9.04 ,19.66)	0.97 (0.78 ,1.19)
Gorgonian Red Pteronisis like	-3.3 (-3.73 ,-2.87)	-0.76 (-1.05 ,-0.47)	-2.7 (-3.24 ,-2.16)	-2.71 (-3.18 ,-2.23)	-0.6 (-0.88 ,-0.31)	-0.25 (-0.44 ,-0.06)	22.19 (11.84 ,37.47)	1.52 (1.29 ,1.78)
Bryozoa Soft (merged)	-7.53 (-8.31 ,-6.75)	1.59 (0.82 ,2.36)	1.73 (0.89 ,2.56)	1.75 (0.94 ,2.57)	-0.13 (-0.48 ,0.22)	-0.01 (-0.28 ,0.25)	14.13 (8.58 ,22.33)	1.81 (1.48 ,2.19)
Coral Orange Solitary (Caryophyllia like)	-4.43 (-4.84 ,-4.02)	-0.26 (-0.66 ,0.13)	0.33 (-0.05 ,0.72)	-0.71 (-1.16 ,-0.26)	-0.62 (-0.88 ,-0.36)	-0.42 (-0.6 ,-0.23)	51.4 (20.7 ,113.63)	0.69 (0.45 ,0.99)
Repent Yellow	-4.69 (-5.09 ,-4.3)	-0.53 (-0.95 ,-0.11)	-1.51 (-2.11 ,-0.91)	-1.61 (-2.22 ,-0.99)	-0.03 (-0.28 ,0.22)	-0.04 (-0.25 ,0.17)	15.25 (6.77 ,30.89)	1.09 (0.82 ,1.41)
Hydroid White	-6.68 (-7.42 ,-5.94)	1.07 (0.38 ,1.75)	0.49 (-0.29 ,1.27)	-0.49 (-1.39 ,0.41)	-1.25 (-1.74 ,-0.76)	-0.3 (-0.62 ,0.02)	26.72 (13.57 ,49.85)	1.34 (1.01 ,1.76)
Arborescent Grey	-6.29 (-6.93 ,-5.64)	0.53 (-0.13 ,1.18)	-0.91 (-1.79 ,-0.02)	-0.47 (-1.26 ,0.33)	-0.67 (-1.08 ,-0.25)	-0.15 (-0.43 ,0.12)	19.39 (7.67 ,44.43)	1.51 (1.18 ,1.93)

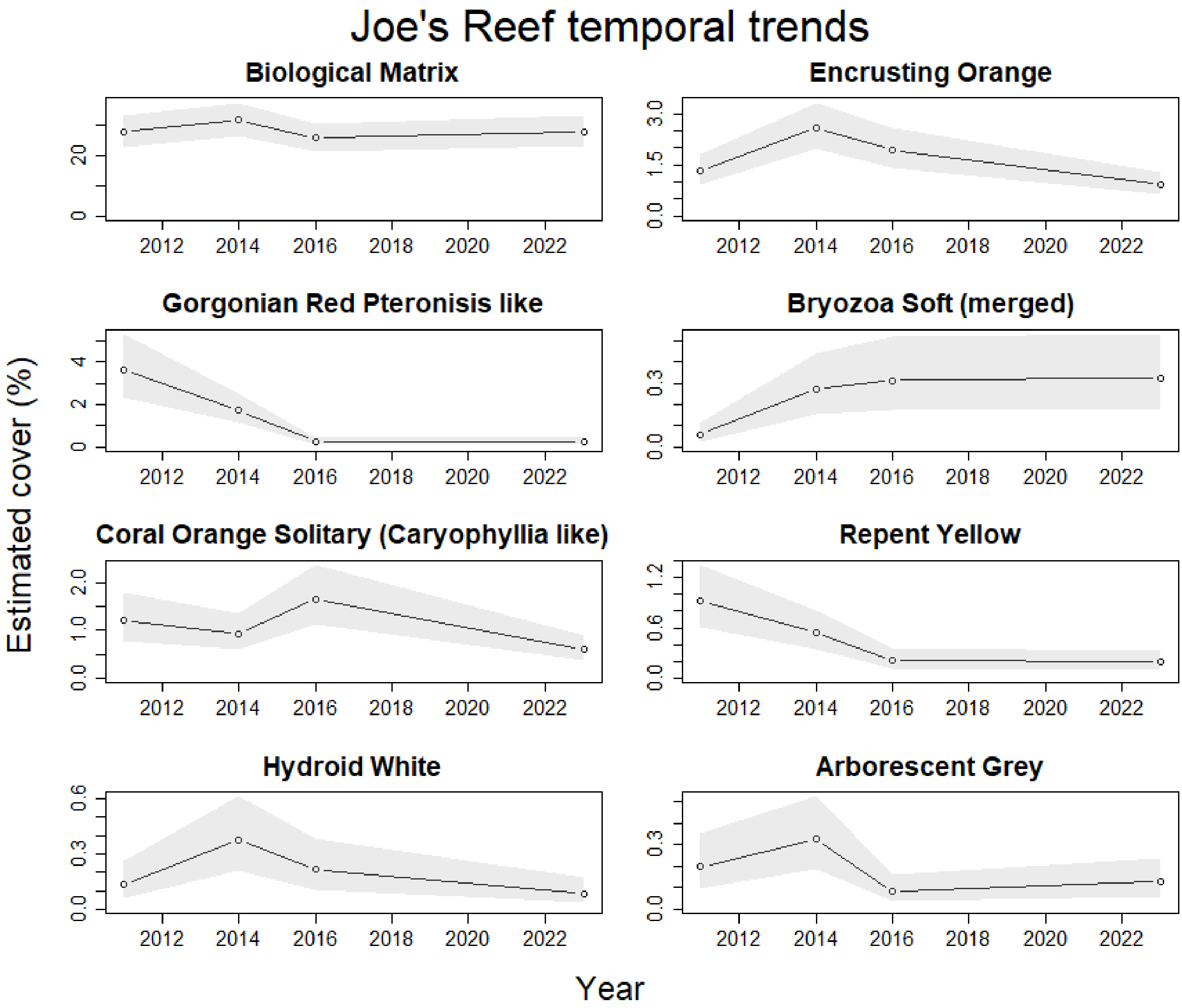


Figure 38. Model-based estimate of the temporal trend in the cover of the eight dominant morphospecies (including the grouping of biological matrix and soft bryozoa) at Joe's Reef. Points and lines show the mean and shaded area shows the 95% credible intervals. Estimates were made at the mean depth of the transect, ignoring any spatial effects. Note the differing scales on the y-axes.

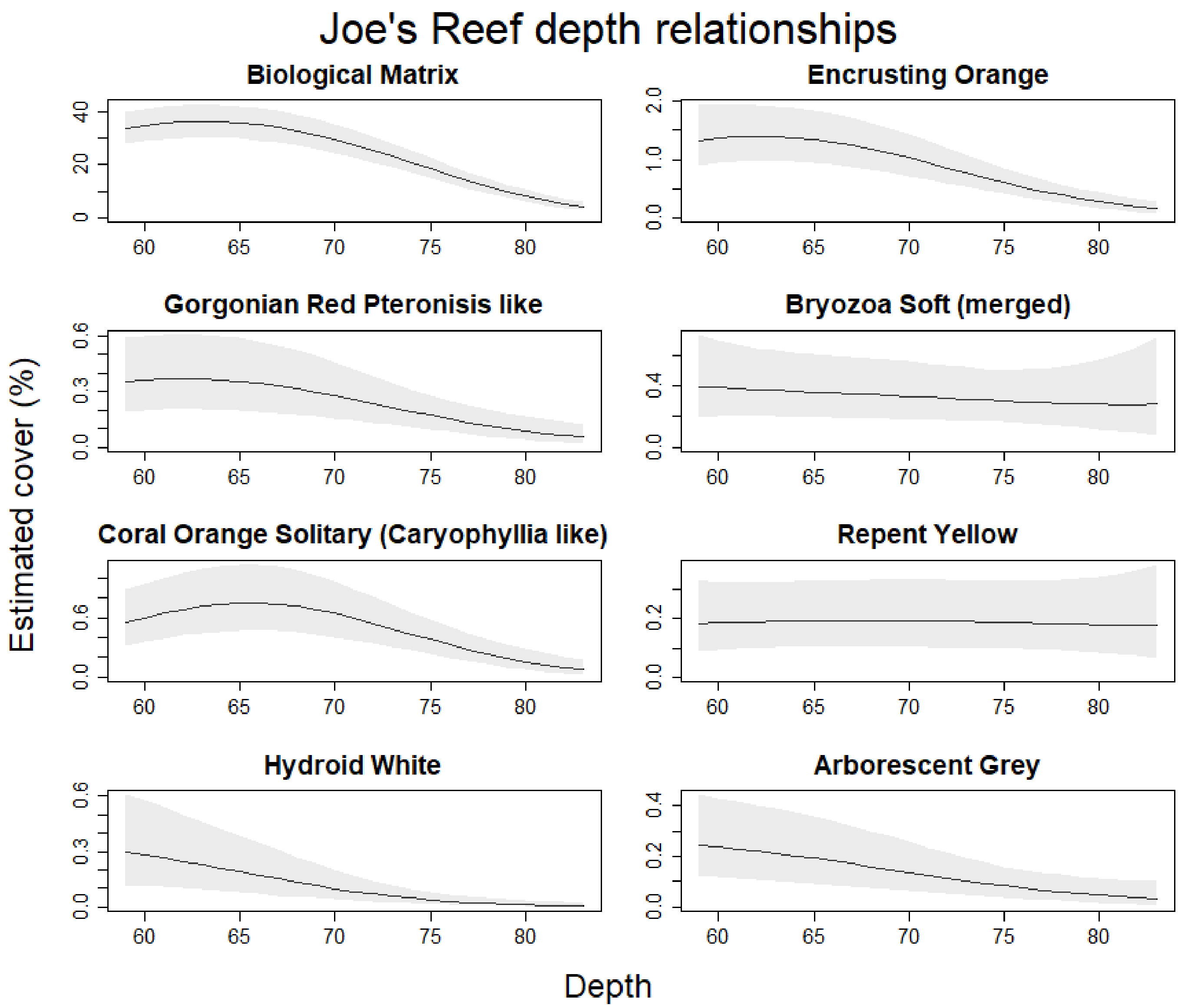


Figure 39. Relationship between the cover of the eight dominant morphospecies (including the grouping of biological matrix and soft bryozoa) with depth at Joe's Reef. Line shows the mean and shaded area shows the 95% credible intervals. Note the differing scales on the y-axes.

Biological Matrix

Biological matrix at Joe's Reef had a relatively high cover that remained relatively stable through time, with a significant positive coefficient for 2014 indicating a higher cover after 2011 and a non-significant coefficient for the remainder of the years indicating similar levels to 2011 (Table 6 and Figure 38). Cover of biological matrix tended to be higher in shallower to mid-depths surveyed, with a negative coefficient for depth and for depth squared (Table 6and Figure 39).

Encrusting Orange

Encrusting orange sponge at Joe's Reef had an initial increase in cover from approximately 1.5% in 2011 to 2.5% in 2014, with a significant positive coefficient for 2014, and a non-significant coefficient for the remainder of the years indicating similar levels to 2011 (Table 6 and Figure 38). Cover of Encrusting Orange sponge tended to be higher in shallower to mid-depths, with a negative coefficient for depth and for depth squared (Table 6 and Figure 39).

Gorgonian Red Pteronisis like

Gorgonian red *Pteronisis* like at Joe's Reef showed a rapid decrease in cover from an initial high in 2011 of approximately 4% cover at the mean depth, with all subsequent year coefficients being significantly negative. In 2023 estimated cover was only around 0.5% (Table 6 and Figure 38). Cover of gorgonian red *Pteronisis* like tended to be higher in shallower to mid-depths , with a negative coefficient for depth and for depth squared (Table 6 and Figure 39).

Bryozoa Soft (merged)

Model outputs showed that bryozoa soft (merged morphospecies) at Joe's Reef rapidly increased in cover from an initial low of approximately 0.1% in 2011 to an estimated 0.3% in 2023, with all year coefficients being significantly positive (Table 6 and Figure 38). Cover of bryozoa soft (merged morphospecies) did not show any significant associations with depth (Table 6 and Figure 39).

Coral Orange Solitary (Caryophyllia like)

Cover of coral orange solitary (*Caryophyllia* like) at Joe's Reef, albeit small, was abundant enough to be well captured. Despite fluctuating in cover by approximately 1% through time, only 2023 showed a significantly lower cover compared to 2011 (Table 6 and Figure 38). Cover of coral orange solitary (*Caryophyllia* like) tended to be higher in shallower to mid-depths surveyed, with a negative coefficient for depth and for depth squared (Table 6 and Figure 39).

Repent Yellow

Repent yellow sponge at Joe's Reef showed a rapid decrease in cover from an initial high of approximately 1% cover in 2011 to an estimated cover of 0.2% in 2023, with all year coefficients being significantly negative (Table 6 and Figure 38). No significant depth relationship was found between the cover of repent yellow sponge and depth (Table 6 and Figure 39).

Hydroid White

Cover of hydroid white at Joe's Reef fluctuated around 0.2% through time, with an initial significant increase from 2011 to 2014 and then levels remaining non-significantly different to 2011 in 2016 and 2023 (Table 6 and Figure 38). Cover of hydroid white tended to be higher in shallower depths surveyed, with a negative coefficient for depth (Table 6 and Figure 39).

Arborescent Grey

Cover of arborescent grey sponge at Joe's Reef fluctuated around 0.2% through time, with an initial non-significant increase from 2011 to 2014, followed by a significant decrease from 2011 levels in 2016, and then cover returning to non-significantly different levels (i.e., similar estimated cover) to 2011 in 2023 (Table 6 and Figure 38). Cover of arborescent grey sponge tended to be higher in shallower depths surveyed, with a negative coefficient for depth (Table 6 and Figure 39).

MPA sites 1 & 2

MPA sites 1 and 2 were surveyed in 2009, 2010, 2012, 2016, and 2023 making a total of five repeat surveys. However, annotation for MPA site 1 was only conducted in 2009 (as part of initial surveys under the CERF program) and 2023. Scoring in 2009 for both sites was done with 50 random points (Table 5). Both these sites are sediment dominated, with very low cover of all sessile biota apart from bryozoa/cnidaria/hydroid matrix (grouped as "biological matrix"). Therefore, multivariate analysis of the time series of surveys was not conducted for these sites, and only the time-series of the cover of biological matrix was analysed.

Univariate analysis results

MPA site 1 and MPA site 2: Biological Matrix

Model outputs showed that biological matrix at MPA site 1 remained stable in cover between the survey in 2009 and 2023 at around 2% mean cover (Table 7 and Figure 40). Cover of biological matrix was higher in shallower depths surveys with a significant negative effect for depth (Table 7 and Figure 41). The shallower depths surveyed were primarily the shallower part of the more spatially extensive large grid which was surveyed in 2009, but not in subsequent surveys.

Biological matrix at MPA site 2 had a relatively low cover of 5% in both the initial 2009 and 2010 survey. Following 2010, all subsequent survey years had significantly higher cover with a peak of approximately 30% cover in 2016 (Table 7 and Figure 42). Cover of biological matrix was relatively even across the small depth gradient at MPA site 2, with a significant positive depth effect indicating higher cover in both shallower and deeper depths surveyed rather than mid-depths (Table 7 and Figure 43).

Table 7. Model output summary for biological matrix at MPA site 1 and MPA site 2 in FMP.

Site	Intercept	year2010	year2012	year2016	year2023	depth	depth2	Spatial_Range	Spatial_Stdev
MPA site 1	-3.99 (-5.02,-2.987)	-	-	-	-0.06 (-0.584 ,0.473)	-0.744 (-1.99 ,-0.296)	0.025 (-0.02 ,0.497)	179.06 (103.58 ,157.42)	1.92 (1.39 ,1.83)
MPA site 2	-2.81 (-3.06 ,-2.56)	0.05 (-0.29, 0.41)	1.23 (0.90,1.56)	2.040 (1.38,1.74)	-0.35 (-0.77 ,0.07)	-0.09 (-0.29 ,1.03)	0.08 (0.01 ,0.14)	22.54 (18.82 ,26.76)	1.65 (1.48,1.82)

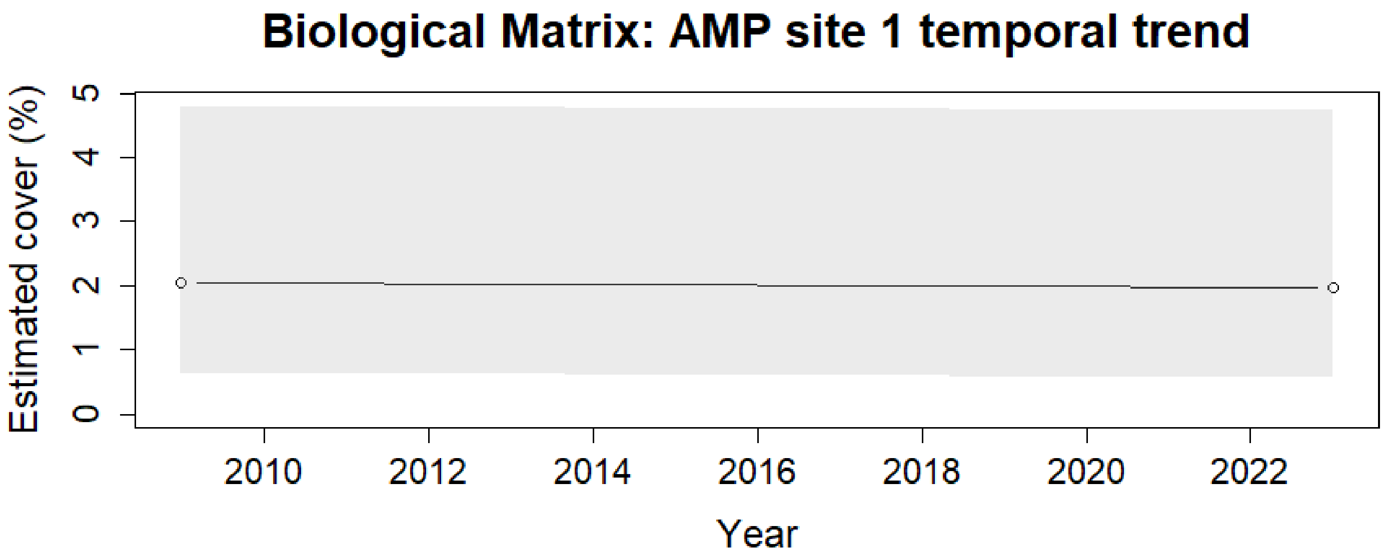


Figure 40. Model-based estimate of the temporal trend in the cover of Biological Matrix at AMP site 1. Points and lines show the mean and shaded area shows the 95% credible intervals. Estimates were made at the mean depth of the transect, ignoring any spatial effects.

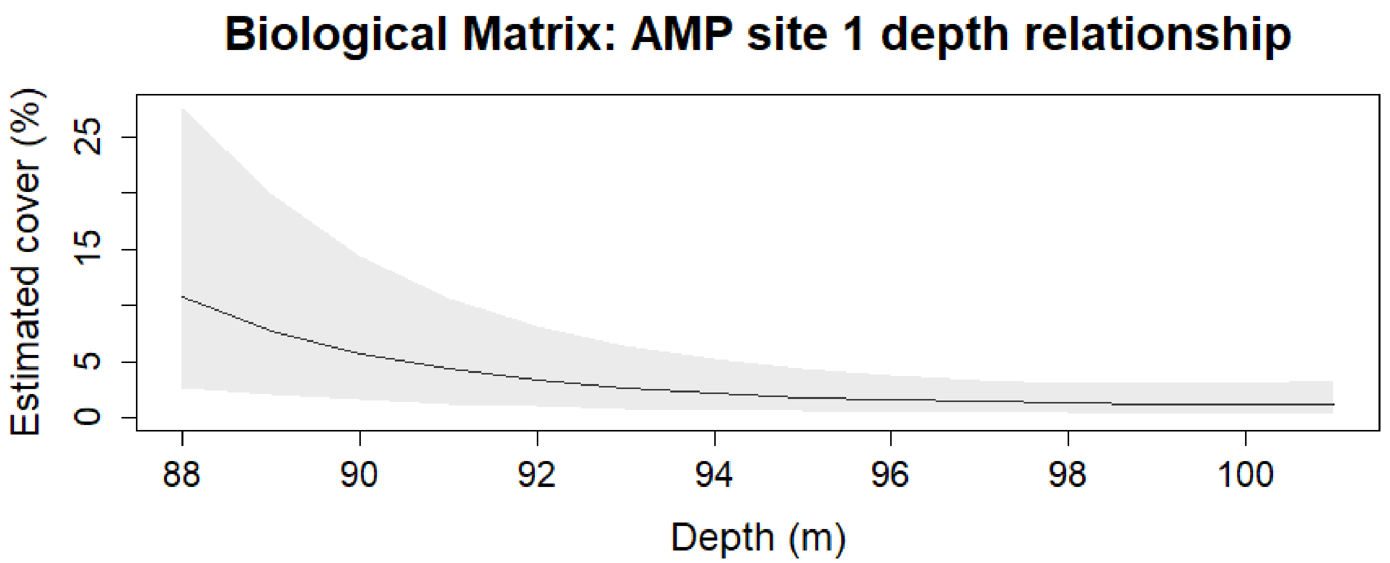


Figure 41. Relationship between the cover of biological matrix and depth at AMP site 1. Line shows the mean and shaded area shows the 95% credible intervals.

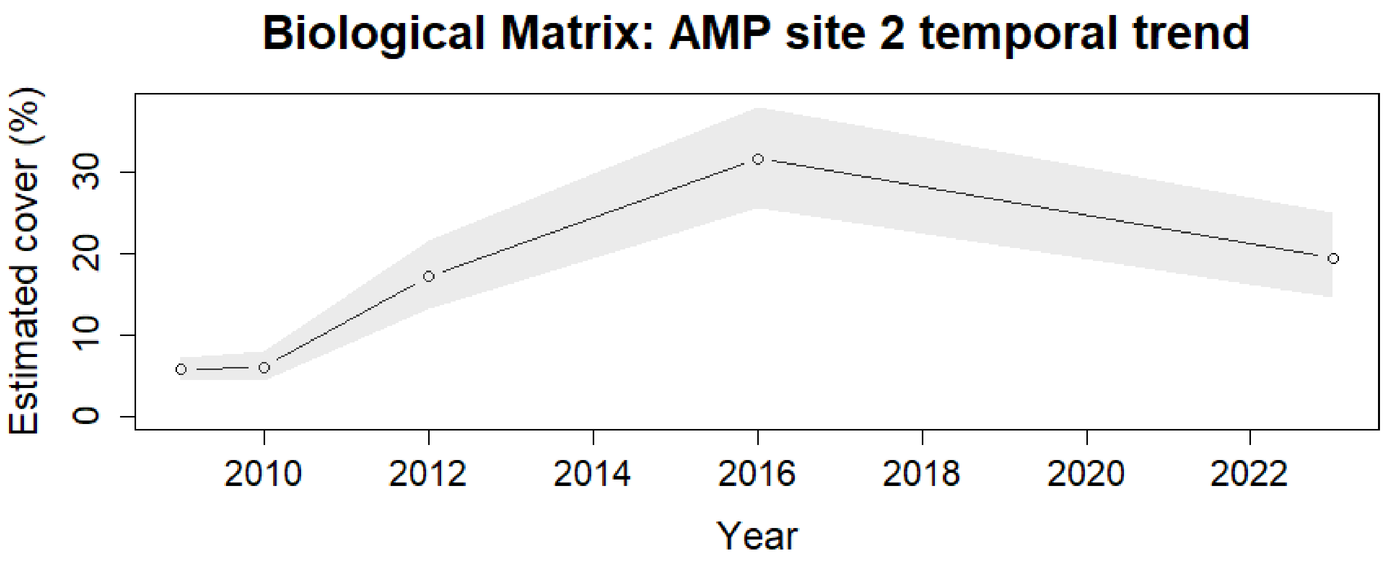


Figure 42. Model-based estimate of the temporal trend in the cover of Biological Matrix at AMP site 2. Points and lines show the mean and shaded area shows the 95% credible intervals. Estimates were made at the mean depth of the transect, ignoring any spatial effects.

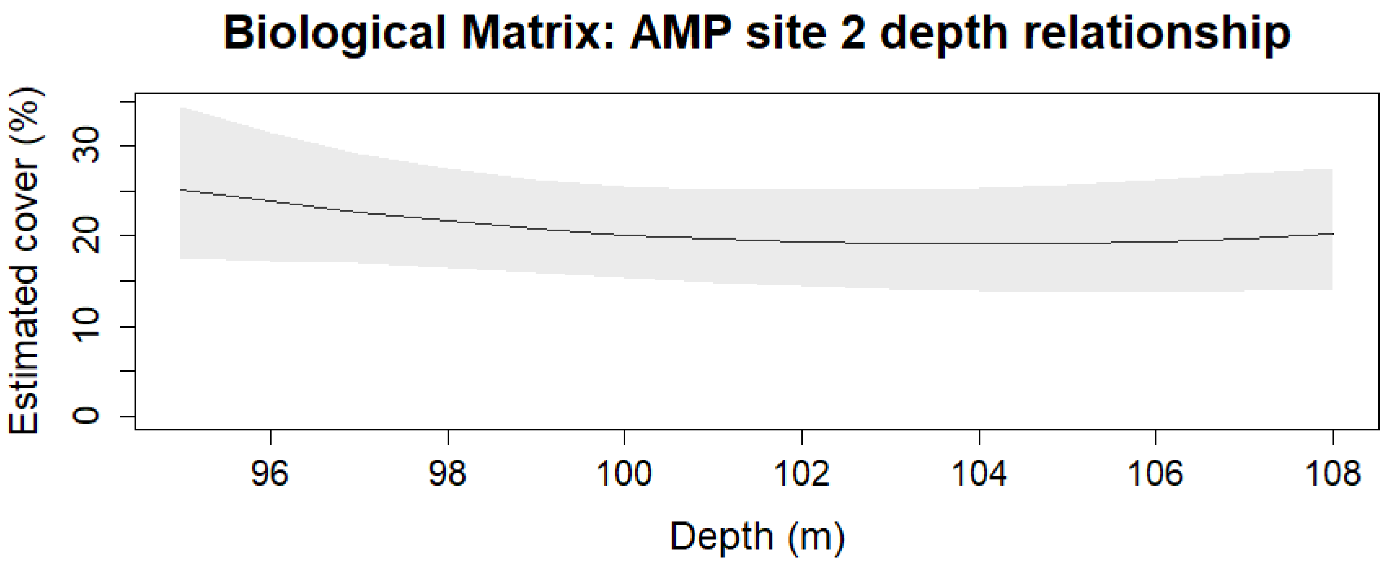


Figure 43. Relationship between the cover of biological matrix and depth at AMP site 2. Line shows the mean and shaded area shows the 95% credible intervals.

Targeted scoring

In addition to the broad biodiversity scoring undertaken with 25 random points on a subset of imagery, targeted scoring for a subset of morphospecies was also completed at Joe's Reef. Targeted scoring involves complete counts for each target morphospecies across a subset of imagery, with the quantity of interest being counts per image rather than percent cover. Targeted scoring in FMP was restricted to Joe's Reef, where there was a time series of imagery allowing temporal changes in targeted morphospecies to be explored, and individual morphospecies were suffciently abundant to be able to describe quantitative patterns. While repeat surveys were also completed at the mid-shelf MPA1 and 2 sites, overall morphospecies abundance on these sediment covered systems was very low (Figure 36) and unlikely to show any significant pattern through time.

Importantly, targeted scoring had been completed on the time-series of imagery at Joe's Reef prior to the 2023 survey for cup red smooth (including bleaching), black corals, and massive purple sponges, with previous results reported elsewhere (Perkins et al. 2021, Perkins et al. 2022b). Targeted scoring for the 2023 data included building on the time-series for this same subest of morphospecies. Also, four additional morphospecies, not previously annotated, were scored across all years: cup yellow sponges, cup black smooth sponges, fan pink sponges, and repent yellow sponges. These additional morphospecies were selected as they are conspicuous and easily identified in imagery, and in the case of repent yellow had shown a decline in the biodiversity scoring data. A smaller number of images was used for targeted scoring of the 2023 imagery and the scoring of the additional four species across the time series compared to earlier targeted scoring (Table 8). This was based on previous power analysis that showed 200 images was typically sufficient to capture changes for most morphospecies (Perkins et al. 2022a). The subset of imagery used in 2023 was created by sytematically subsampling imagery along sections of transect that contained reef, and comprised 340 images in total with > 200 of those on reef.

Table 8. Morphospecies selected for targeted scoring and the number of images scored in each survey year. The number of images scored includes sand images but included a minimum of 200 reef images.

Morphopecies	Year	Number of images scored
Cup Red Smooth (and bleaching)	2011	1465
	2014	1450
	2016	2210
	2023	340
Massive Purple	2011	1561
	2014	1463
	2016	2222
	2023	340
Black Coral	2011	1561
	2014	1463
	2016	2222
	2023	340
Cup Yellow	2011	793
	2014	807
	2016	795
	2023	340
Cup Black Smooth	2011	793
	2014	807
	2016	795
	2023	340
Fan Pink	2011	793
	2014	807
	2016	795
	2023	340
Repent Yellow	2011	793
	2014	807
	2016	795
	2023	340

Modelling of the targeted scoring used the same model framework used in the biodiversity (i.e. point) scored data, however a negative binomial distribution, which is appropriate for count data, was used rather than a binomial distribution.

Targeted scoring results

Targeted scoring analysis was restricted to Joe's Reef as all other long term monitoring locations were on the mid-shelf which had too few distinct morphospecies other than biological matrix, resulting in a low possibility of detecting biological meaningful change through time. While historical surveys in these locations (MPA1 and MPA2, Figure 26) were not annotated for overall biodiversity patterns in all years, initial inspection with historical annotation from 2009 suggests that there had not been any notable change in cover over this period.

Model-based estimates for the fixed effects of survey year and depth, as well as the parameters describing the spatial random effects (spatial range and standard deviation) for the targeted scoring at Joe's Reef are given in Table 9. Summary plots of the temporal trends and the depth effects for each morphospecies are given in Figure 44 and Figure 45 respectively. A description of the results for each morphospecies at the Joe's Reef along with maps of the temporal distributions follows.

Table 9. Model coefficient estimates for year, depth, depth-squared, spatial range, and spatial standard deviation for targeted scoring at Joe's Reef. Mean estimates are given on the first line of each cell, with 95% credible intervals for the estimates given in brackets on the line below. The intercept estimate represents the first survey year (2011), with other year estimates representing deviations from the estimate for 2011. For the fixed effect estimates (year and depth terms) the statistical significance is highlighted in red for negative estimates, and green for positive estimates. 95% CIs that contain zero are considered non-significant.

Morphospecies	**Intercept**	**year2014**	**year2016**	**year2023**	**depth**	**depth2**	**Spatial_Range**	**Spatial_Stdev**
Cup Red Smooth	-3.56 (-4.38 ,-2.74)	0.66 (0.38 ,0.94)	0.22 (-0.07 ,0.51)	1.06 (0.71 ,1.41)	-2.13 (-2.49 ,-1.76)	-0.58 (-0.71 ,-0.45)	106.48 (60.97 ,179.8)	1.53 (1.11 ,2.07)
Cup Red Smooth Bleaching	0.05 (-0.39 ,0.49)	-0.76 (-1.24 ,-0.29)	0.22 (-0.07 ,0.51)	-1.11 (-1.65 ,-0.58)	0.73 (0.32 ,1.15)	0.22 (0.05 ,0.39)	11.1 (5.07 ,21.32)	0.93 (0.58 ,1.4)
Massive Purple	-3.42 (-4.33 ,-2.51)	0.18 (0 ,0.36)	0.04 (-0.15 ,0.24)	-0.93 (-1.24 ,-0.62)	-1.37 (-1.69 ,-1.04)	-0.35 (-0.47 ,-0.23)	106 (71.28 ,154.21)	1.71 (1.26 ,2.29)
Black Coral	-6.37 (-7.12 ,-5.62)	0.76 (0.04 ,1.48)	0.9 (0.21 ,1.58)	1.44 (0.67 ,2.2)	-2.89 (-3.65 ,-2.14)	-0.8 (-1.09 ,-0.52)	7.53 (3.57 ,13.57)	1.51 (1.04 ,2.11)
Cup Yellow	-3.05 (-3.75 ,-2.35)	0.24 (-0.08 ,0.56)	-0.02 (-0.36 ,0.33)	0.22 (-0.14 ,0.57)	-1.61 (-2 ,-1.22)	-0.39 (-0.52 ,-0.26)	81.09 (50.55 ,126.79)	1.55 (1.16 ,2.05)
Cup Black Smooth	-3.53 (-3.95 ,-3.1)	0.26 (-0.14 ,0.65)	-0.27 (-0.71 ,0.16)	-0.75 (-1.27 ,-0.24)	-1.99 (-2.44 ,-1.54)	-0.41 (-0.57 ,-0.24)	50.45 (14.69 ,129.56)	0.81 (0.55 ,1.15)
Fan Pink	-4.62 (-5.17 ,-4.08)	1.11 (0.58 ,1.63)	0.65 (0.07 ,1.23)	0.3 (-0.34 ,0.94)	-2 (-2.5 ,-1.5)	-0.4 (-0.58 ,-0.22)	31.97 (11.81 ,72.64)	1.16 (0.89 ,1.48)
Repent Yellow	-3.89 (-4.77 ,-3.02)	0.15 (-0.28 ,0.58)	-0.78 (-1.29 ,-0.27)	-2.04 (-2.75 ,-1.32)	-1.24 (-1.83 ,-0.64)	-0.32 (-0.53 ,-0.11)	77.12 (54.4 ,107.78)	1.89 (1.45 ,2.44)

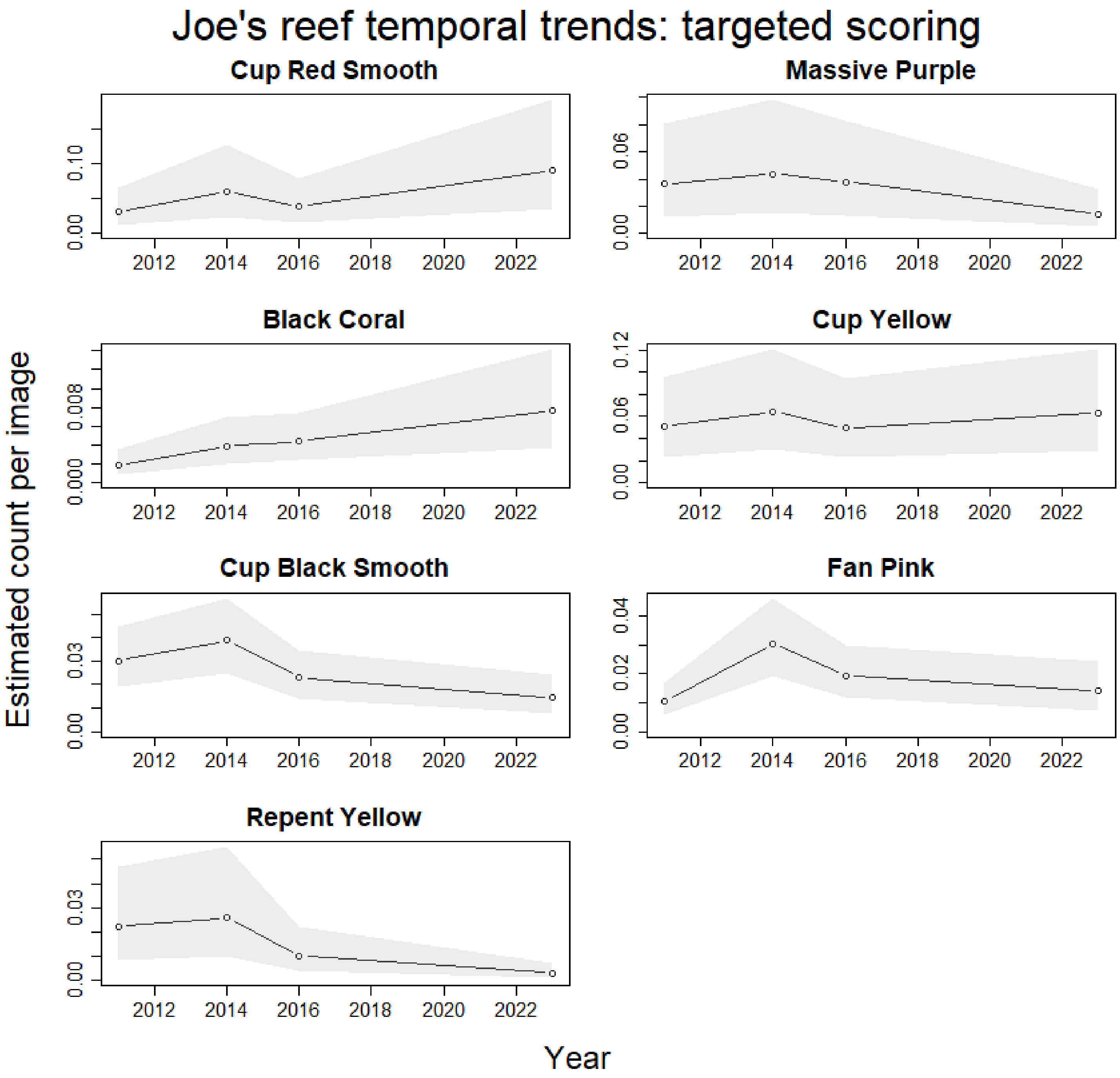


Figure 44. Model-based estimate of the temporal trend in the abundance of the seven morphospecies target scored at Joe's Reef. Points and lines show the mean and shaded area shows the 95% credible intervals. Estimates were made at the mean depth of the transect, ignoring any spatial effects. Note the different y-axes scales.

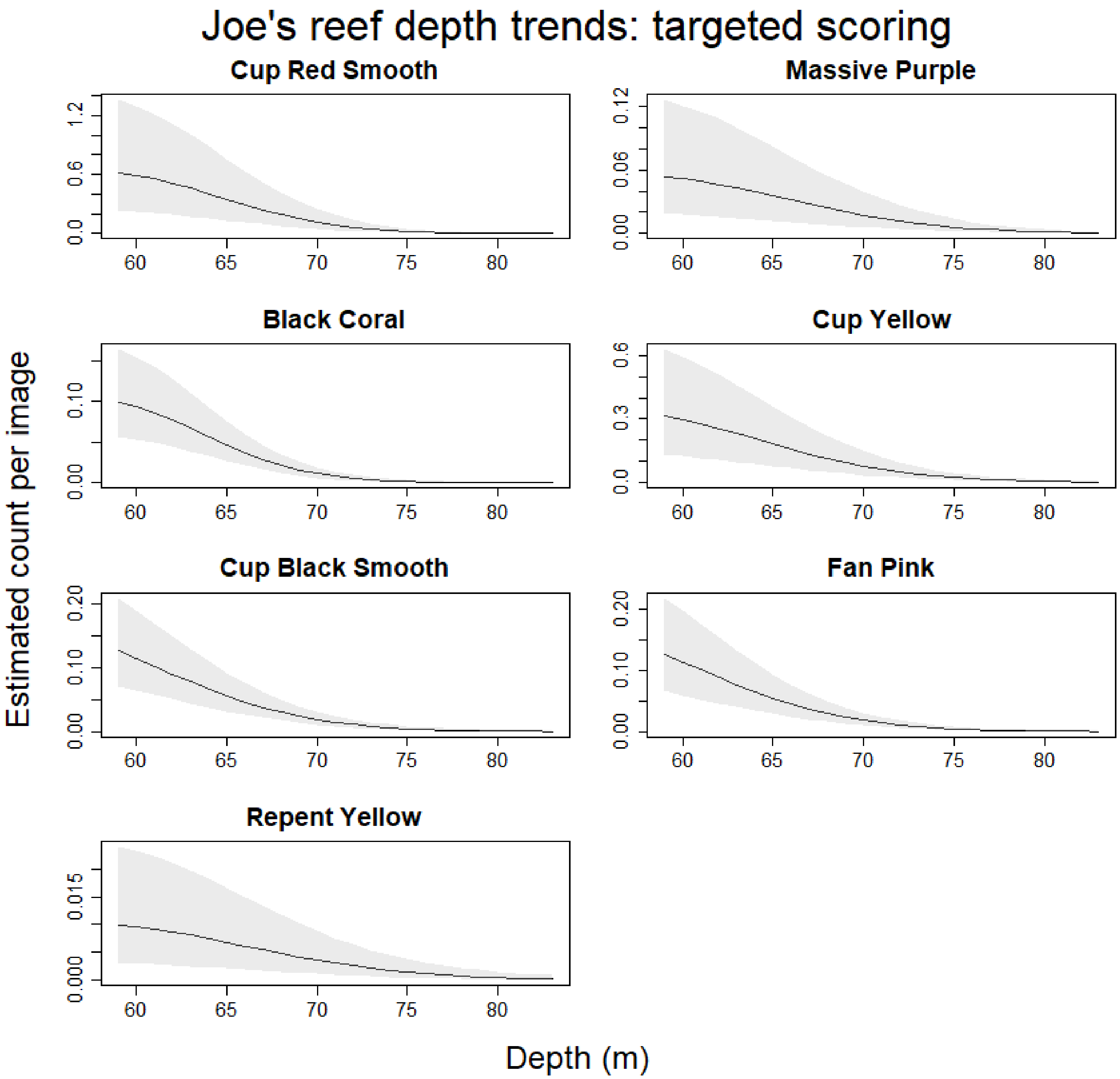


Figure 45. Relationship between the abundance of the seven target scored morphospecies with depth at Joe's Reef. Line shows the mean and shaded area shows the 95% credible intervals. Note the different y-axes scales.

Cup Red Smooth

Model results for the targeted scoring of cup red smooth sponges at Joe's Reef showed that the abundance fluctuated significantly across the time-series, with a significant increase from 2011 to 2014, followed by a decline in 2016, and then another increase in 2023 with the abundance being significantly higher than 2011 (Table 9, Figure 44, and Figure 46). There was a significant negative association with depth and depth-squared, indicating a preference for shallow to mid-depth across those areas surveyed (Table 9 and Figure 45).

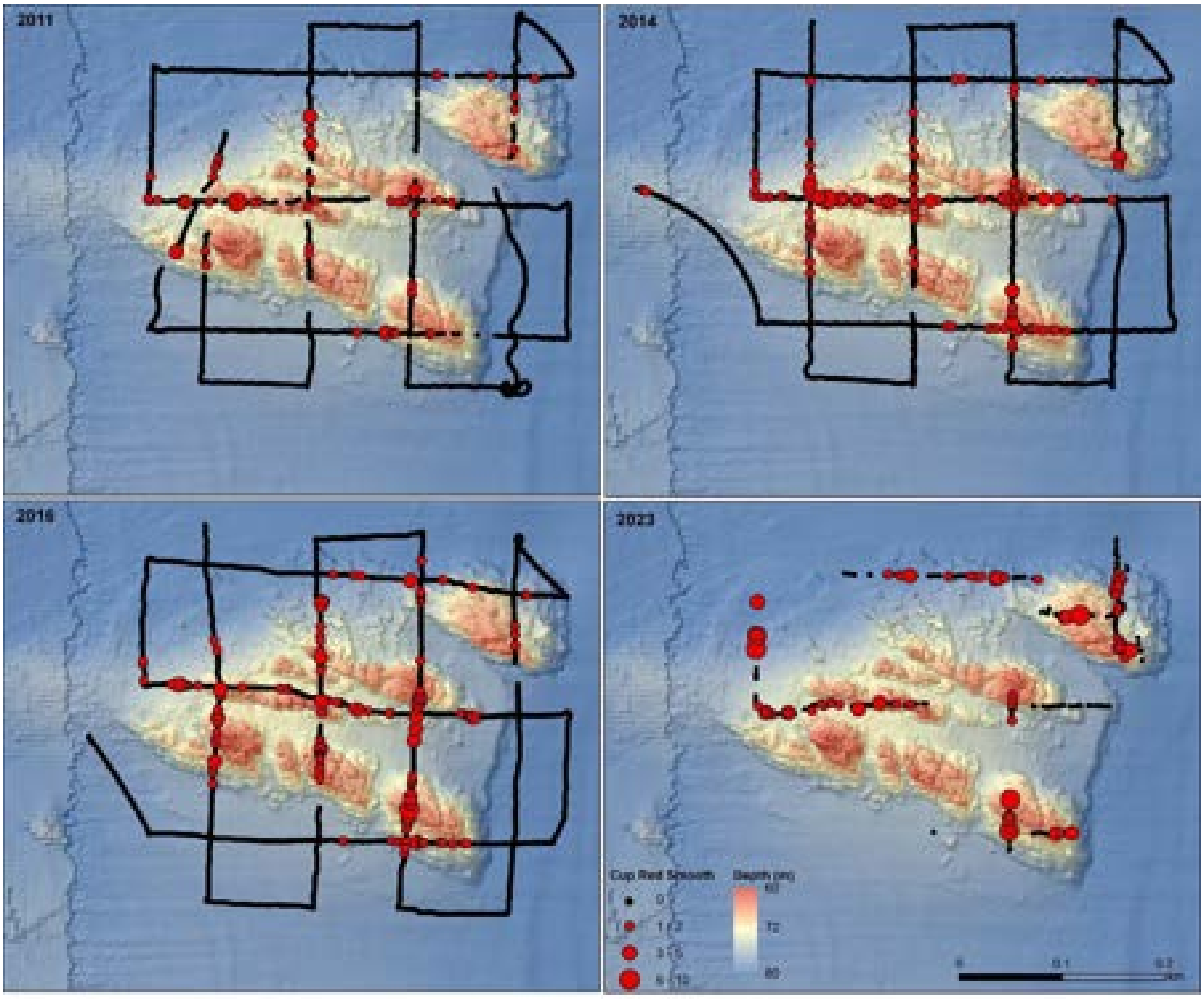


Figure 46. Changes in the spatial distribution in abundance (count per image) of cup red smooth sponges at Joe's Reef from targeted scoring. Note that the 2023 survey had incomplete coverage due to regular AUV failure in this complex terrain.

Cup Red smooth bleaching prevalence

Model results for the targeted scoring of the bleaching prevalence in cup red smooth sponges at Joe's Reef showed that the proportion of bleaching fluctuated significantly across the time-series, with a significant decrease from 2011 to 2014, followed by an increase in 2016, and then a decrease in 2023, with the proportion in 2023 significantly lower than in 2011 (Table 9, Figure 47, and Figure 48). There was a significant positive association with depth and depth-squared, indicating increased bleaching in deeper depths across those areas surveyed as well as higher bleaching in the shallow depths compared to mid-depths (Table 9 and

Figure 49).

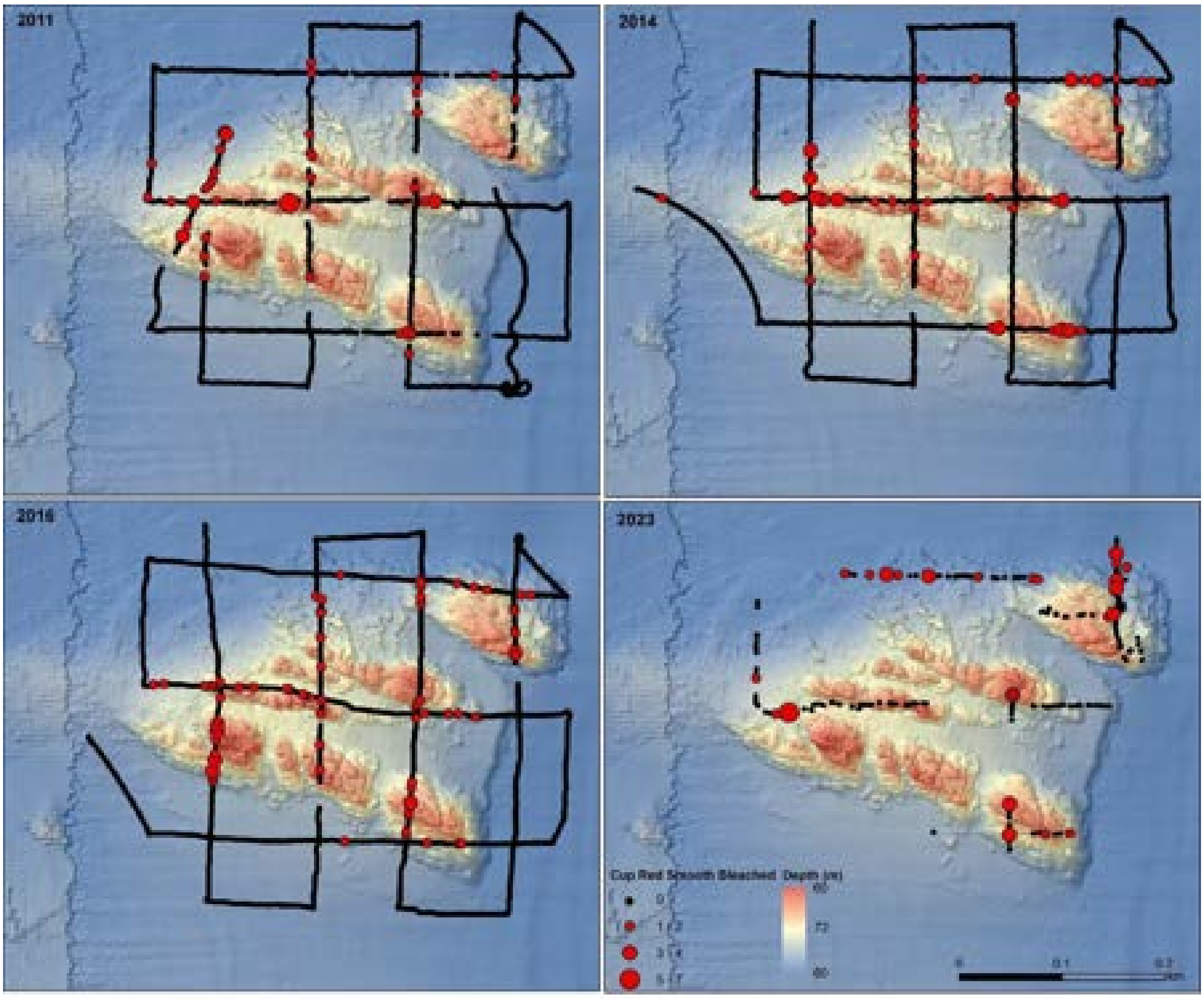


Figure 47. Changes in the spatial distribution in abundance (count per image) of bleached cup red smooth sponges at Joe's Reef from targeted scoring. Note that the 2023 survey had incomplete coverage due to regular AUV failure in this complex terrain.

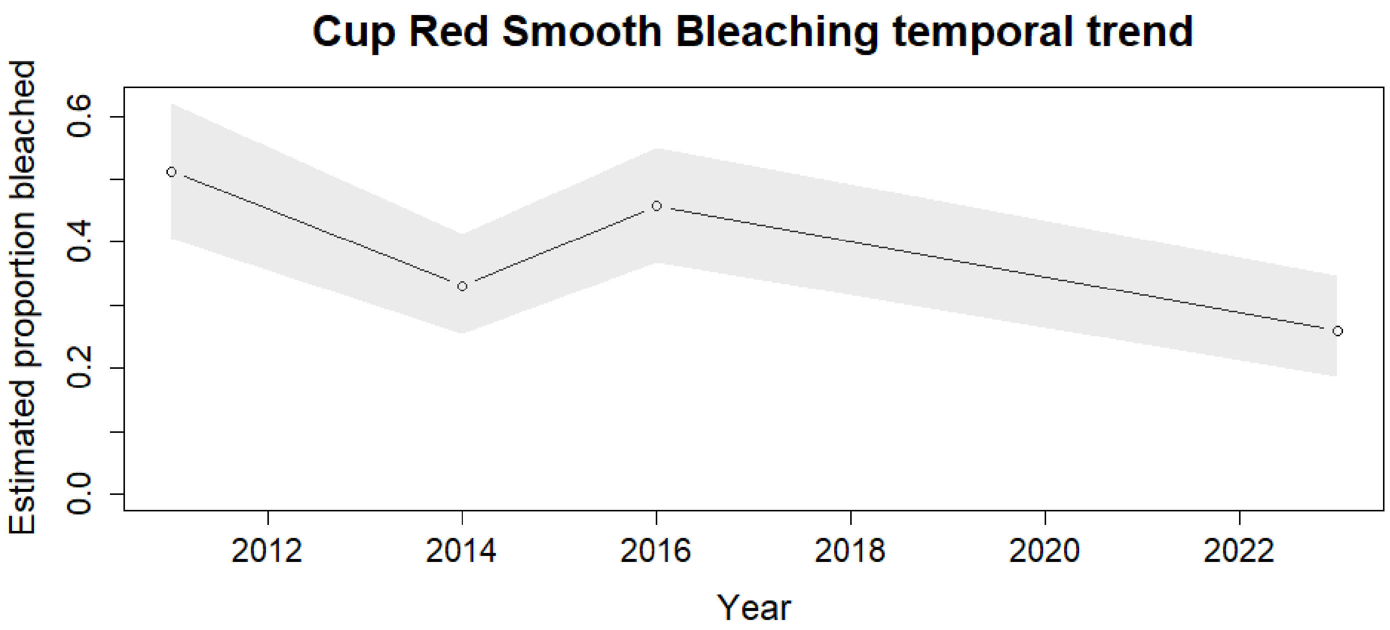


Figure 48. Temporal trend in the proportion of bleaching in cup red smooth sponges at Joe's Reef from targeted scoring.

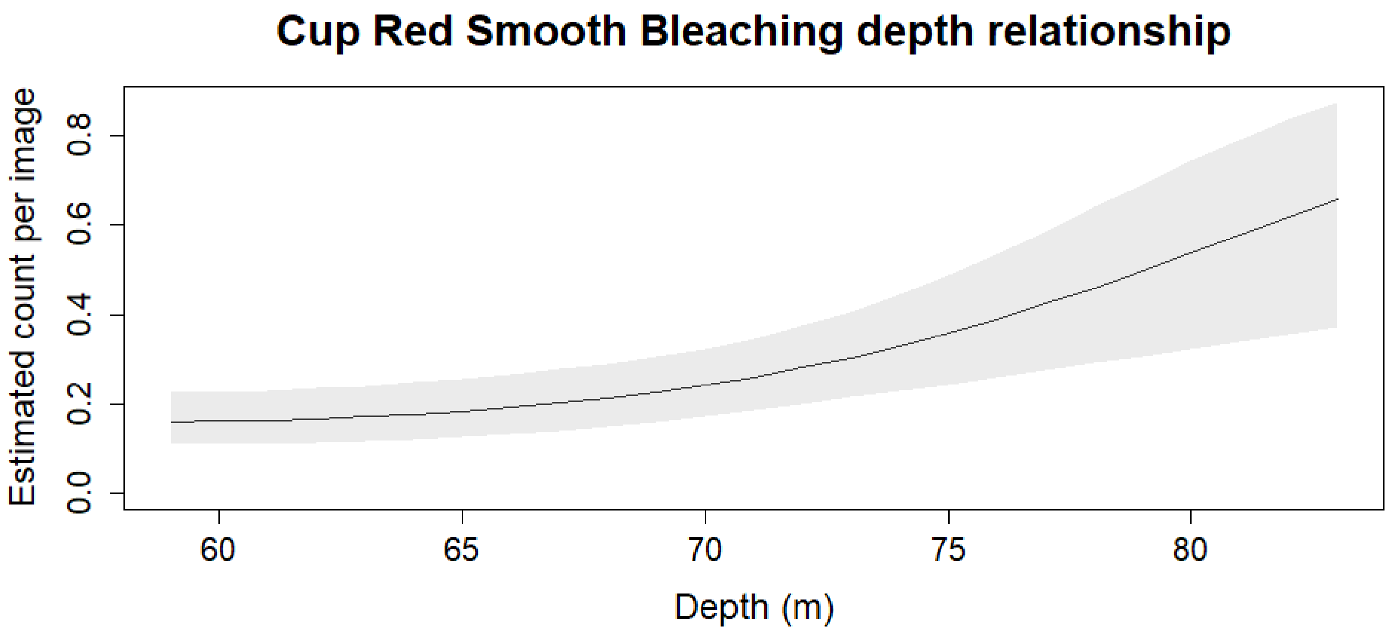


Figure 49. Depth relationship of bleaching from targeted scoring of cup red smooth sponges at Joe's Reef.

Massive Purple

Model results for the targeted scoring of massive purple sponges at Joe's Reef showed that the abundance fluctuated significantly across the time-series, with a significant increase from 2011 to 2014, followed by a declining trend to 2023 with the abundance being significantly lower in 2023 than 2011 (Table 9, Figure 44, and Figure 50). There was a significant negative association with depth and depth-squared, indicating a preference for shallow to mid-depth across those areas surveyed (Table 9 and Figure 45).

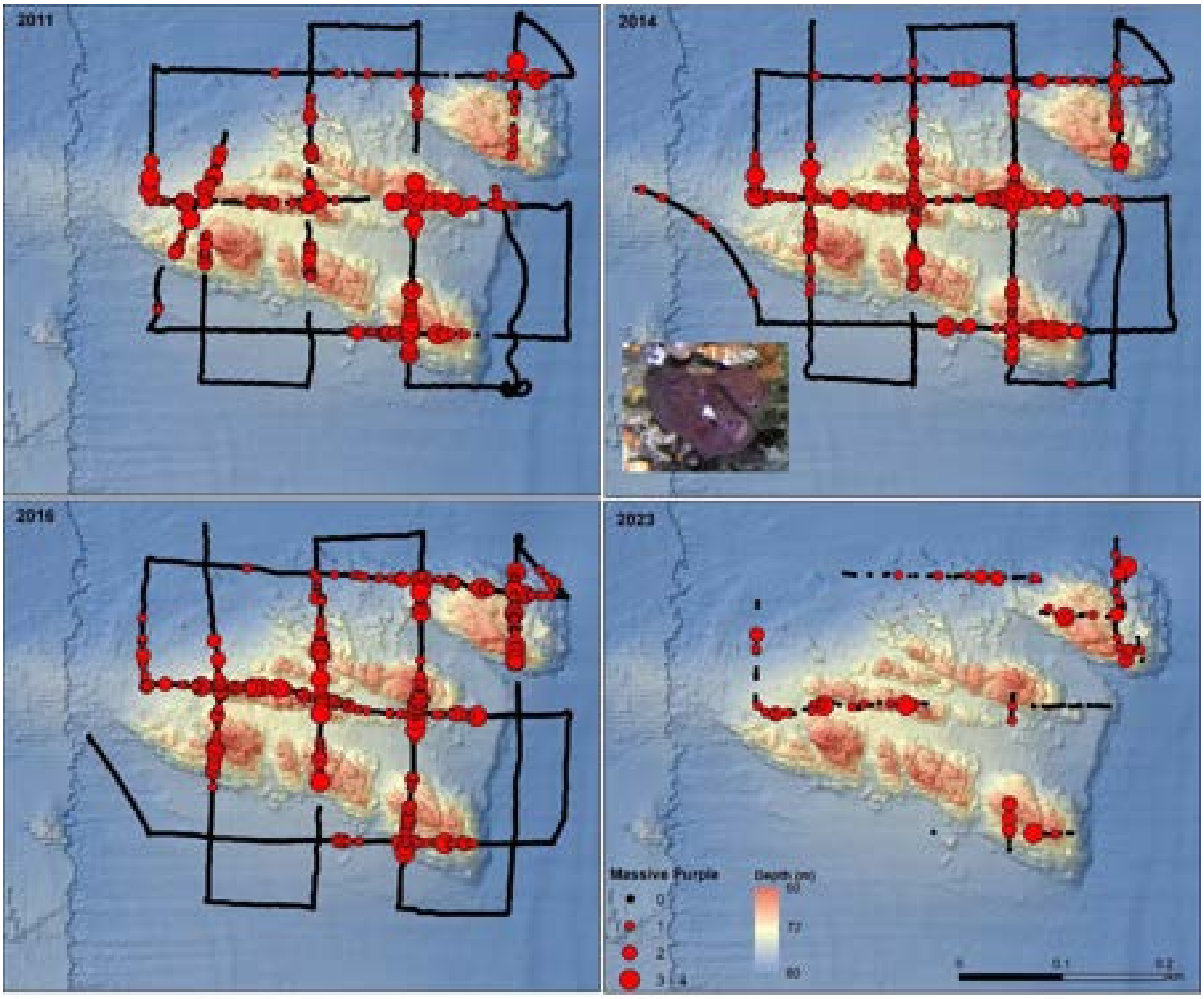


Figure 50. Changes in the spatial distribution in abundance (count per image) of massive purple sponges at Joe's Reef from targeted scoring. Note that the 2023 survey had incomplete coverage due to regular AUV failure in this complex terrain.

Black coral

Model results for the targeted scoring of black coral at Joe’s Reef showed that the abundance showed a trajectory of increase across the time-series, with all subsequent survey years having significantly higher abundance than the initial 2011 survey, with the abundance roughly double in 2023 compared to 2011 (Table 9, Figure 44, and Figure 51). There was a significant negative association with depth and depth-squared, indicating a preference for shallow to mid-depth across those areas surveyed (Table 9 and Figure 45).

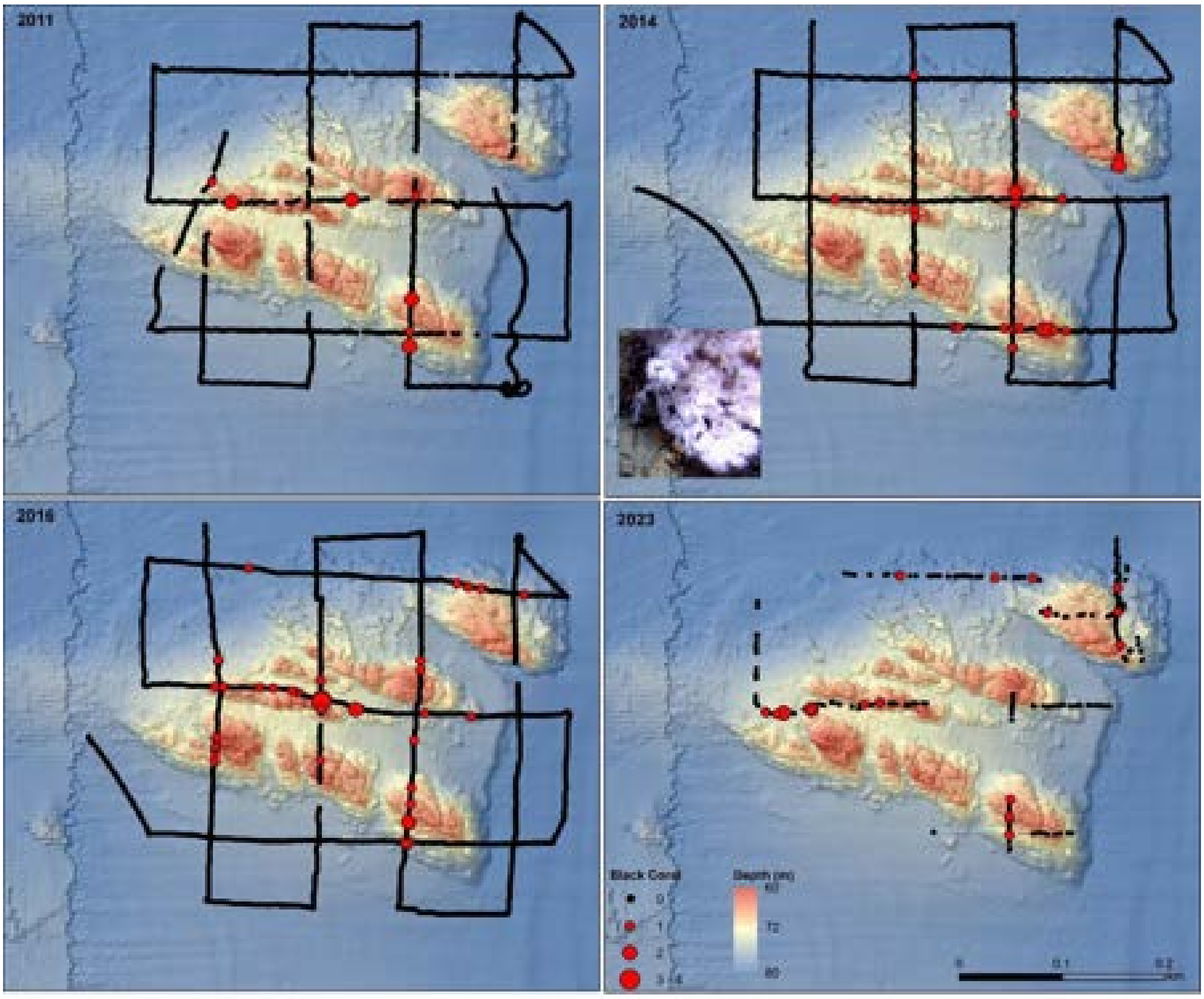


Figure 51. Changes in the spatial distribution in abundance (count per image) of black coral at Joe’s Reef from targeted scoring. Note that the 2023 survey had incomplete coverage due to regular AUV failure in this complex terrain.

Cup Black Smooth

Model results for the targeted scoring of cup black smooth sponges at Joe's Reef showed that the abundance remained relatively stable between 2011 and 2014 with no significant differences, followed by a decline from 2014 to 2023, with abundance being significantly lower in 2023 than 2011 (Table 9, Figure 44, and Figure 52). There was a significant negative association with depth and depth-squared, indicating a preference for shallow to mid-depth across those areas surveyed (Table 9 and Figure 45).

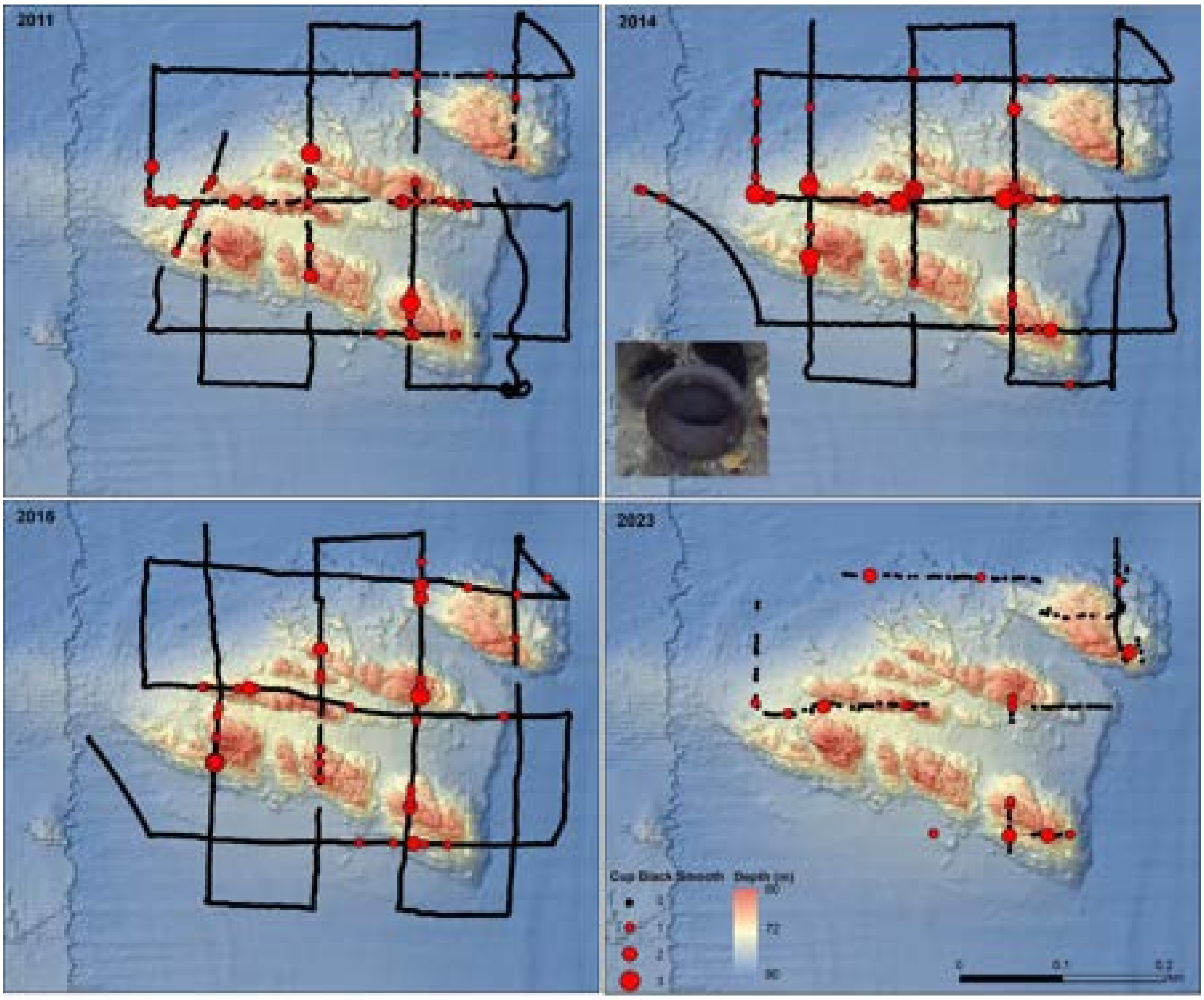


Figure 52. Changes in the spatial distribution in abundance (count per image) of cup black smooth sponges at Joe's Reef from targeted scoring. Note that the 2023 survey had incomplete coverage due to regular AUV failure in this complex terrain.

Cup Yellow

Model results for the targeted scoring of cup yellow sponges at Joe's Reef showed that the abundance remained relatively stable across the time-series, with no significant differences between the abundance in 2011 and any other survey year (Table 9, Figure 44, and Figure 53). There was a significant negative association with depth and depth-squared, indicating a preference for shallow to mid-depth across those surveyed (Table 9 and Figure 45).

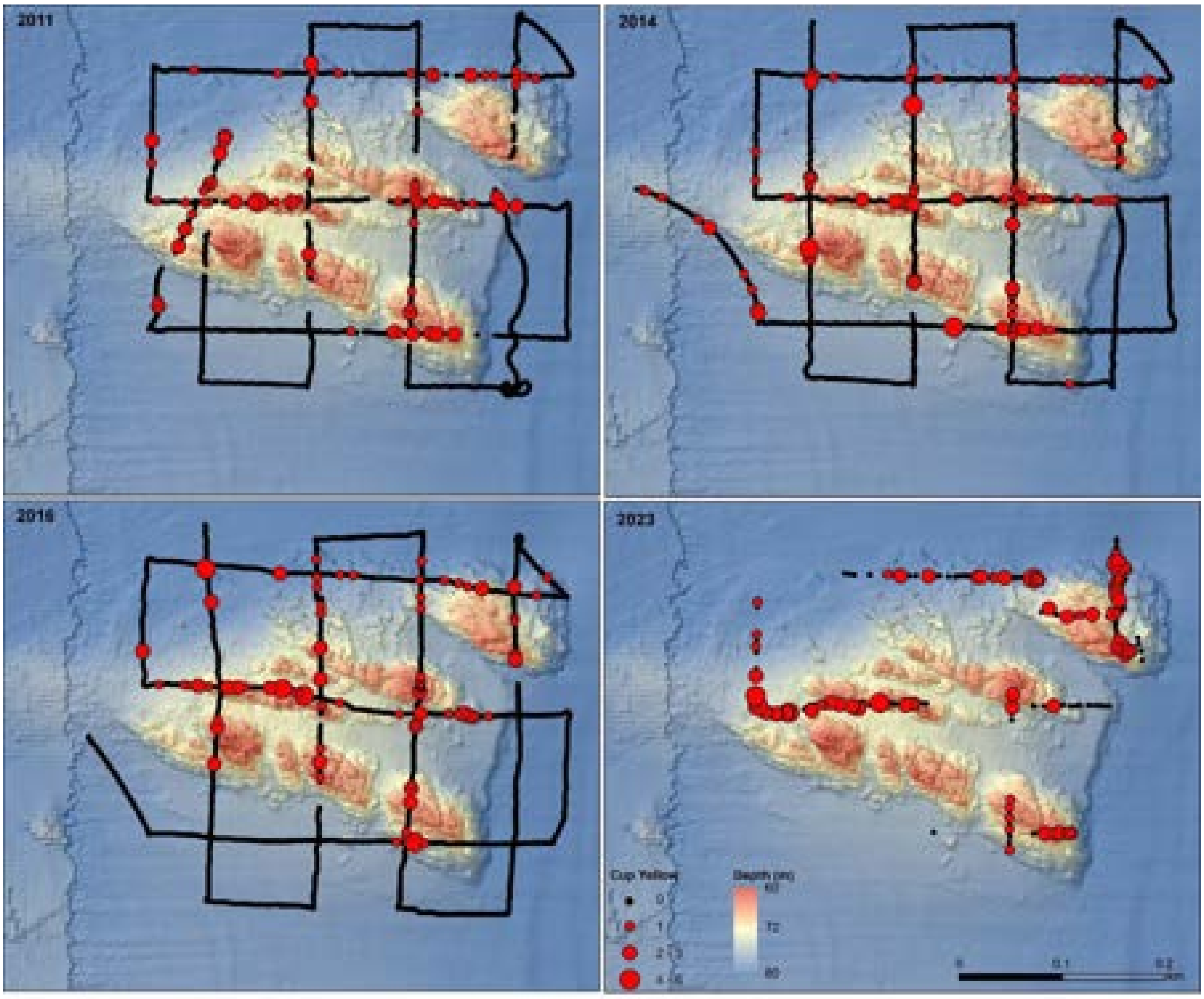


Figure 53. Changes in the spatial distribution in abundance (count per image) of cup yellow sponges at Joe's Reef from targeted scoring. Note that the 2023 survey had incomplete coverage due to regular AUV failure in this complex terrain.

Fan Pink

Model results for the targeted scoring of fan pink sponges at Joe's Reef showed that the abundance fluctuated significantly across the time-series, with a significant increase from 2011 to 2016, followed by a declining trend, with abundance in 2023 similar to 2011 (Table 9, Figure 44, and Figure 54). There was a significant negative association with depth and depth-squared, indicating a preference for shallow to mid-depth (Table 9 and Figure 45).

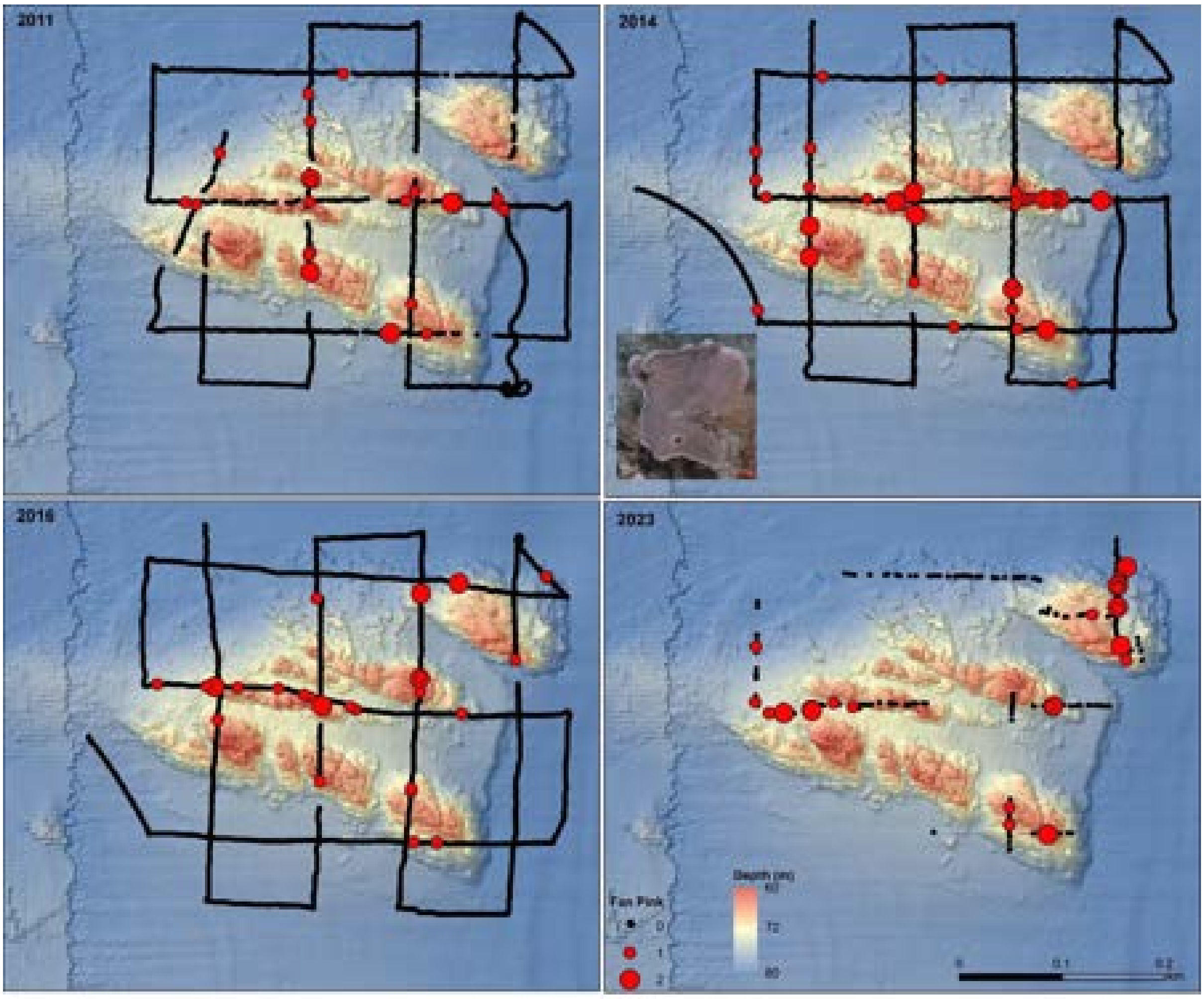


Figure 54. Changes in the spatial distribution in abundance (count per image) of fan pink sponges at Joe's Reef from targeted scoring. Note that the 2023 survey had incomplete coverage due to regular AUV failure in this complex terrain.

Repent Yellow

Model results for the targeted scoring of repent yellow sponges at Joe's Reef showed that the abundance declined significantly across the time-series, with no difference from 2011 to 2014, followed by a declining trend, with significantly lower abundance recorded in 2023 than in 2011 (Table 9, Figure 44, and Figure 55). There was a significant negative association with depth and depth-squared, indicating a preference for shallow to mid-depth across those surveyed (Table 9 and Figure 45).

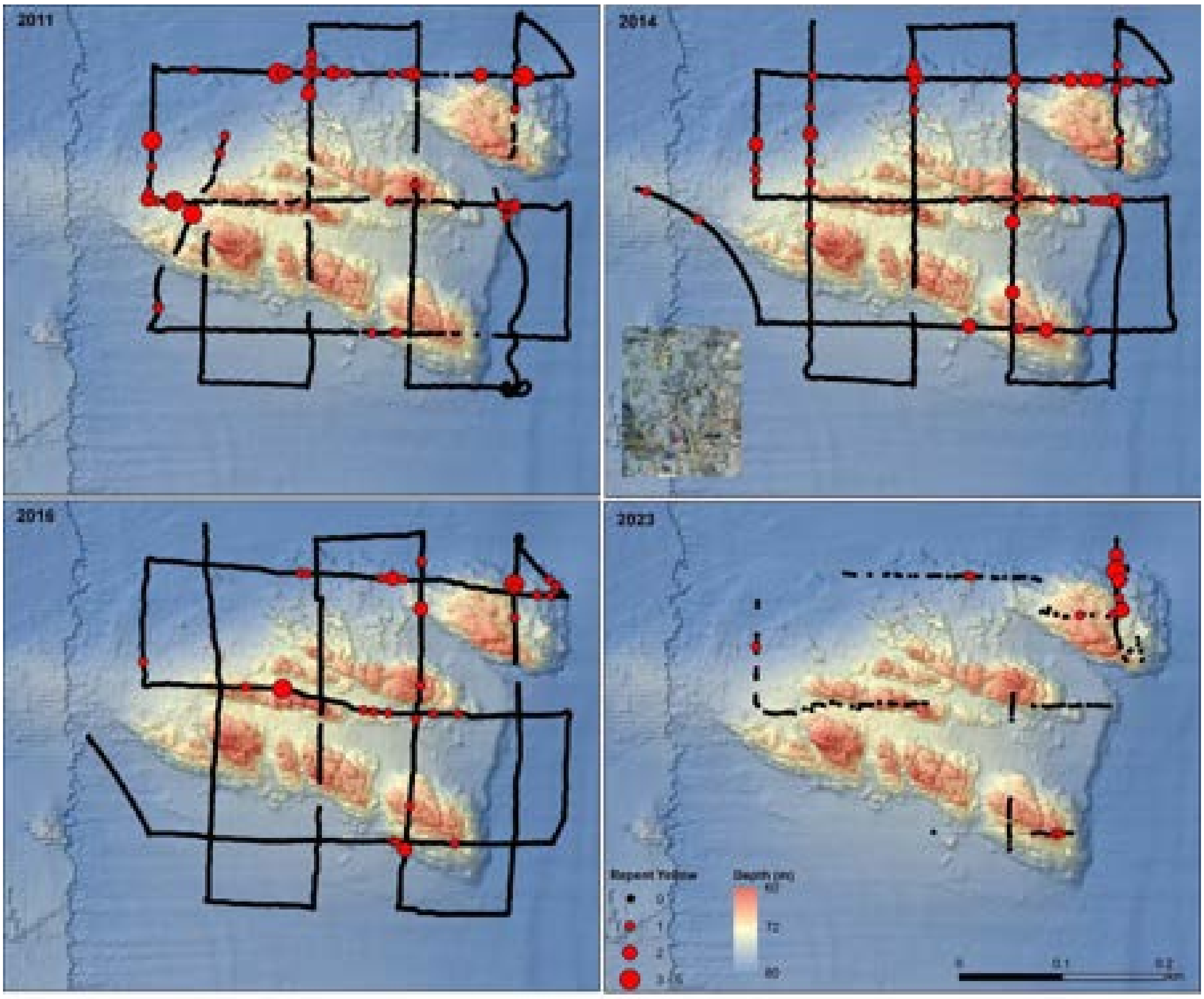


Figure 55. Changes in the spatial distribution in abundance (count per image) of repent yellow sponges at Joe's Reef from targeted scoring. Note that the 2023 survey had incomplete coverage due to regular AUV failure in this complex terrain.

Discussion

AUV surveys of the FMP in 2023 have considerably expanded the scientific knowledge of the spatial extent of mesophotic and rariphotic reef associated habitats from mid-shelf to the shelf-break, and further expanded our understanding of mid-shelf sediment dominated habitats across the rariphotic zone. This knowledge has extended our first understanding of the fauna on many of these habitats in the rariphotic zone not previously surveyed (the shelf break sites), and for previously surveyed ones, how this fauna changes over decadal time scales.

Six new survey transects were conducted in the FMP rariphotic zone, two across mid-shelf areas, and four across recently mapped shelf break features. These surveys showed that: (i) mid shelf areas in the rariphotic zone of the FMP are typically sediment dominated with low cover of invertebrate fauna, and (ii) deeper rariphotic shelf break areas in the FMP contain many unique habitats that have not been found elsewhere in the SE MP network, including outcropping mudstone and limestone reef features, but also typically have overall low cover of emergent biota.

The new shelf-break surveys in the FMP provide the first detailed insights into the fine-scale habitat features in this spatially constrained area, as well as the biota associated with them. Much of this area was often bare of fauna and included extensive bryozoan rubble and bivalve shell beds, often with shells completely intact. The mudstone reefs and cliffs at Shelf Break sites 2 and 3 have some unique invertebrate fauna including the morphospecies “bryozoan dendroid tan”, as well as a mix of other bryozoans, sponges and octocorals. Notably though, this mudstone, whether on almost vertical cliff faces or on flat low-profile seabed outcrops, was often completely devoid of attached biota. This contrasts sharply with the limestone reef at Shelf Break 4 which were typically more complex and block-like in structure, yet almost always 100% covered in emergent fauna. The reasons for this variation between reef systems are not clear, given their close proximity and that typically because biota do not respond to the geological origin of particular rock types. Even if the mudstone was particularly soft, it would be expected that many small invertebrates could readily attach. Ideally future sampling of the rocks will help better understand the geology of this region and assess characteristics such as rock hardness and possibly even toxicity/metal content that may act as an inhibitor to invertebrate growth.

For the sessile biota, annotation of imagery focussed on describing the survey location as a whole, because he reef outcrops were relatively small as an overall proportion of the total transect. Hence, overall invertebrate cover was lower than that typically found at locations such as the HMP where reefs are extensive and much of each transect is over reef habitat. Likewise, the extent and nature of the emergent reef varied markedly between the four shelf break survey locations with virtually no reef at Shelf break 1, to increasing reef content from Shelf break 2 to 4, so the results reflect this variation in overall reef cover. As noted above , the mudstone reefs at Shelf break 2 and 3 had markedly less emergent biota than the limestone reef at Shelf break 4, so while reef cover is typically the key driver of overall sessile invertebrate cover, this was not always the case at the shelf break.

Overall, the highest cover of any distinct morphospecies was at Shelf-break 4, where encrusting sponge morphospecies and bryozoa peaked at around 0.75% cover. Most other morphospecies were found at much lower percentage cover, typically around 0.1 % or less. While the fauna at Shelf break 3 was somewhat similar to Shelf break 4 but with less cover, the overall cover at Shelf break 1 and 2 was extremely low. Even the cover of biological matrix was not high overall, ranging from 5% at Shelf break 1 to 10% at Shelf break 4.

While not extensive in overall cover, the outcropping reef features at the shelf break locations do add structural complexity. Where these outcrops occurred, it was observed that it also supported populations of rock lobster and some unique fish/habitat associations recently described in BRUV and ROV surveys conducted on these systems (Perkins et al. 2023), including eastern orange perch that inhabit holes within the mudstone reef systems. Although these components of the biota were not included in the current analysis, the imagery has potential to quantitatively describe some of these components in future studies. Another notable feature in the imagery from the shelf-break reef systems, was the presence of a significant amount of rope and fishing line entangled on the reef structures. This suggests that despite these habitats being spatially very rare, they are heavily targeted by fishing activities, including lobster fishing, given the nature of the rope seen.

For the surveys on dune-like features mapped in the rariphotic zone on the mid-shelf, the overall cover of emergent biota was very low. This included repeat surveys on the sites MPA 1 and MPA 2 as well as at two new sites at Midshelf 1 and 2 that were surveyed to further explore the nature of the dune-like features typical of the shelf region of the park, allowing a fuller understanding of their overall biota and its spatial distribution at park-wide scales. Despite the survey effort, very few emergent species were found, and overall percentage cover was very low, with most morphospecies being less than 0.2% cover and even biological matrix was only around 5%, except at Shelfbreak 2 where it was 90%. Generally, these locations, despite having reef-like variations in height at 50 m scales (essentially a 5 m rise and fall of dune-like structures over 50 m), typically behave as soft-sediment seabed with respect to the ability to support emergent fauna. This habitat also lacks the crevice structure that would support many reef-associated fishes and mobile invertebrates such as lobsters. However, close examination of the imagery showed that the dune features often lacked the sand ripples evident in adjacent soft-sediment, suggesting that they are typically somewhat hardened despite the lack of fauna. While the site Shelf break 1 was targeted on a known (but not yet properly mapped) region of the park with some patchy outcropping reef, only around 2% of the overall transect encountered reef habitat, thus the overall results were dominated by the low cover found on the prevailing soft-sediment habitat. Ideally multibeam mapping of the inner region of the park yet to be mapped, would be undertaken prior to future surveys. This would allow better targeting of reef features in this region to improve the selection of potential long term monitoring locations in this park and region, with respect to reef habitat representation. However, it is acknowledged that the majority of outcropping reef on the shelf in this park is likely to be in the immediate vicinity to Joe's Reef. This recognition is based on mapping in the area, collated vessel transit data and anecdotal evidence from commercial fishers.

Analysis of the time series at AMP sites 1 and 2 was limited to describing the change in the cover of biological matrix, as there is very low cover of any other sessile biota at these sites due to a lack of any reef features. No significant change in the cover of biological matrix was found for AMP site 1 between 2009 and 2023, however the three surveys in intervening years had not been annotated for analysis. For AMP site 2, the cover of biological matrix increased significantly from the initial survey in 2010 (approximately 5%), reaching a peak that was approximately five times higher in 2016 (approximately 25%), and then remaining relatively stable at around 20% in 2023. As this site has been subjected to historical trawling pressure, the increasing cover of what is likely to be primarily soft bryozoa, could be early indications of the recovery of soft sediment shelf habitats within the FMP to pre-trawling conditions. However, no data exists regarding the state of these habitats pre-trawling, and it is unknown what the extent of other sessile fauna was. Ongoing monitoring of fish populations within these habitats using BRUV and/or ROV will give further indications of recovery from historical fishing pressure.

Joe's Reef is the notable exception to the overall lack of physical structure in shelf waters of the FMP and provides the only known reef feature that spans the lower mesophotic to rariphotic zone. This complex reef structure supports a significant diversity of sessile biota, yet, in a similar nature to that found on mesophotic to rariphotic shelf reefs in the region (e.g. Barrett et al. 2019, Perkins et al. 2022c). In the FMP during this study, only one morphospecies (encrusting orange sponge) exceeded 1% cover (at approximately 1.2% cover). Only four other morphospecies exceeded 0.5% cover (gorgonian red *Pteronosis*-like, orange solitary coral, lumpy white sponge, combined soft bryozoans, encrusting white lumpy sponge and branching orange pointed sponge). This overall pattern highlights the difficulty of monitoring changes in even the most common morphospecies in such environments, given that significant replication and annotation time is required to adequately describe overall cover and variation. Even the black coral, a morphospecies of significant biological interest, had an overall cover of only 0.008 individuals sighted per image in the 2023 survey, a level that requires substantial survey coverage, combined with extensive targeted annotation, to describe adequately.

Analysis of the time-series imagery collected between 2011 and 2023 at Joe's Reef revealed that the overall benthic community in mesophotic depths of approximately 50 to 80 m remained relatively stable; however, some individual morphospecies fluctuated significantly in abundance/cover over this period. Multivariate approaches showed that while community composition varied over this period, changes were largely related to shifts in some of the dominant morphospecies such as encrusting orange sponge, biological matrix, soft bryozoans, gorgonian red *Pteronisis* like, and repent yellow sponge. Univariate analysis of the morphospecies cover revealed that some had undergone significant changes over the survey period, with some showing an overall trajectory of decreasing cover (e.g. gorgonian red *Pteronisis* like, 3.8-0.2%, and repent yellow sponge, 0.96-0.2%), others showing a trajectory of increase (soft bryozoans, 0.07-0.35%), and others fluctuating in cover over this time period (encrusting orange, 2.5-1%, hydroid white, 0.38-0.08%, arborescent grey sponge, 0.34-0.08-1.4%, and coral orange solitary (*Caryophyllia* like), 1.7-0.6%).

Targeted scoring of a subset of morphospecies at Joe's Reef provided further evidence of significant change in the abundance of some of the dominant and easily identifiable morphospecies over the 12-year time-series (2011-2023). Massive purple (0.44-0.015), cup black smooth (0.04-0.15) and repent yellow sponges (0.026-0.0025) showed notable declines or increases in abundance over the time series, often exceeding an order of magnitude. Cup red smooth (0.03-0.08) and fan pink sponges (0.01-0.03-0.012) fluctuated in abundance over the time series but remained relatively stable in abundance. Bleaching in the cup red smooth sponges also fluctuated across time. Interestingly, a four-fold increase in abundance of black corals was found through time (0.002-0.008). However, this is based on a small number of observed individual colonies in the imagery and needs to be verified with additional work, as many of the black corals are large and likely to be many years in age, providing a form of population stability. Generally, the patterns observed for the targeted scoring were similar to that observed for the biodiversity cover approach discussed above. Thus suggesting that this level of variability may be typical of that found in deep mesophotic to rariphotic reef systems where few morphospecies exceed a cover of 2%, and most are much less, providing a biodiverse and somewhat balanced assemblage where no one morphospecies dominates.

While changes were observed through time on both reef habitats and the dune-like features found mid-shelf in mesophotic to rariphotic depths, at this early stage of ongoing monitoring it is not possible to determine the key drivers of these patterns, or likely recovery times from disturbances. Changes such as the decline of the morphospecies "gorgonian red *Pteronisis* like" from 3.3 to 0.2% over a 12-year period could be related to a wide range of causes, including decadal intense storms/swells, year to year variability in oceanography and associated food availability or even marine heatwaves. Likewise, the observed increase in biological matrix at MPA 2 site from 5% to 20% over this period may also be related to factors such as periods between storm disturbance or seabed recovery from historical trawling. Ongoing surveys at regular intervals are needed to further determine the overall drivers of change.

Overall, the 2023 AUV surveys in the FMP have extended our understanding of both the spatial distribution of habitats and the sessile fauna they support, as well as the temporal variability of this biota on shelf reef and shelf sediment dominated systems. This includes the first quantitative surveys of shelf-break reef systems and adjacent sediment habitat in the park that demonstrated marked variation in seabed geology between reef outcrops and how that influenced the associated biota. The majority of emergent biota in this region was associated with the reef outcrops, but these reefs were spatially constrained and typically supported small-sized sparse biota. This was even more so on the mudstone reef systems relative to limestone systems for a reason that is not immediately apparent. Elsewhere in shelf waters, the sampling of the dominant habitat type, dune-like features, showed that these also support little emergent fauna other than biological matrix. While two additional sampling locations were added to this survey to further explore the nature of this habitat, these were found to be relatively similar in the depauperate cover to that found at earlier Midshelf sites sampled in the park. Notably, while not quantitatively examined here due to the extensive annotation required to derive patterns from such sparce biotic coverage, the time-series obtained from historic sites surveyed initially in 2009 do not appear to show an observable increase in overall cover over this period, that might be expected if historical trawling in this area prior to protection had impacted the overall cover.

Clearly the most notable exception to the low biotic cover found elsewhere in shelf waters is Joe's Reef, that was found to have a particularly high cover of emergent fauna. Such high cover reflects the complex reef structure present, as well as the higher currents and thus planktonic food availability generated by water movements around the large reef structure. This abundance and diversity of species allowed temporal changes to be quantified in many key morphospecies, showing that individual morphospecies were often quite variable and could change by an order of magnitude in cover over decadal periods. More temporal observations will be required before the likely causes of this variation can be understood and changes due to significant stresses such as ocean warming or decadal storms/swells can be differentiated from the variation caused by year-to-year effects of food supply related to oceanographical processes, differences in recruitment success and inter-specific competition and predation.

For future monitoring, Joe's Reef offers the most promising location that provides sufficient biotic coverage to allow reliable detection of changes. Joe's Reef would ideally be a core monitoring site for regular (every 5 years or more frequently) intervals to better understand natural variability and detect major impacts. The remaining sites contain such low biotic cover that future monitoring is likely not cost-effective or informative with respect to understanding natural variability. However, less regular sampling (approximately every 10 years) may be valuable to determine if there are any detectable effects of protection from historical trawling arising.

Finally, as per the HMP analysis, the imagery provides the opportunity to examine a wider range of other attributes of these reef and dune-like systems, including reef complexity, the distribution of other benthic fishes (including ocean perch and eastern orange perch) and mobile invertebrates such as lobsters. While these were not quantitatively examined as part of this study, it was noted that there were moderate numbers of rock lobsters associated with outcropping shelf-break reef systems, and that these reefs were highly associated with the distribution of eastern orange perch that utilised the reefs as shelter, highlighting the associated values of these otherwise rare shelf break reef systems. Rope and fishing line debris was also found in imagery on the shelf break reefs indicating that despite their spatial rarity as a habitat, they were highly targeted for fishing of both lobsters and finfish species.

Presence of handfish in HMP and FMP

Following detection of handfish in recent imagery from the Tasman Fracture (Perkins et al. 2022c) and Huon Marine Parks (Perkins et al. 2024 (in review)), a subset of the AUV transects conducted in FMP and HMP were target scored for the presence of handfish species. Additionally, a recently developed machine learning approach for the automatic detection of handfish was tested on all imagery in both FMP and HMP. These latest surveys utilised a new high resolution camera system on the AUVs deployed, improving resolution 10-fold from previous surveys, allowing the detection of benthic fishes as small as 5 cm or so.

HMP

Manual annotation of imagery for handfish within HMP was completed as part of a student project where a subset of AUV transects were manually searched for handfish. Every sixth image was subsampled to reduce the number of images scored and to avoid overlapping images. In total, 18 handfish were observed across five of the six transects (Table 10 and Figure 56). Cropped images of handfish observed are provided in the Appendix. Initial examination of the imagery suggests the presence of Pink (*Brachiopsilus dainthus*) and potentially Ziebell's (*Brachiopsilus ziebelli*) handfish species. However, the top-down angle and lower resolution of the AUV images obscured the morphological characteristics that are required to positively identify to species level. The AI-based found no additional handfish to those found in the student project.

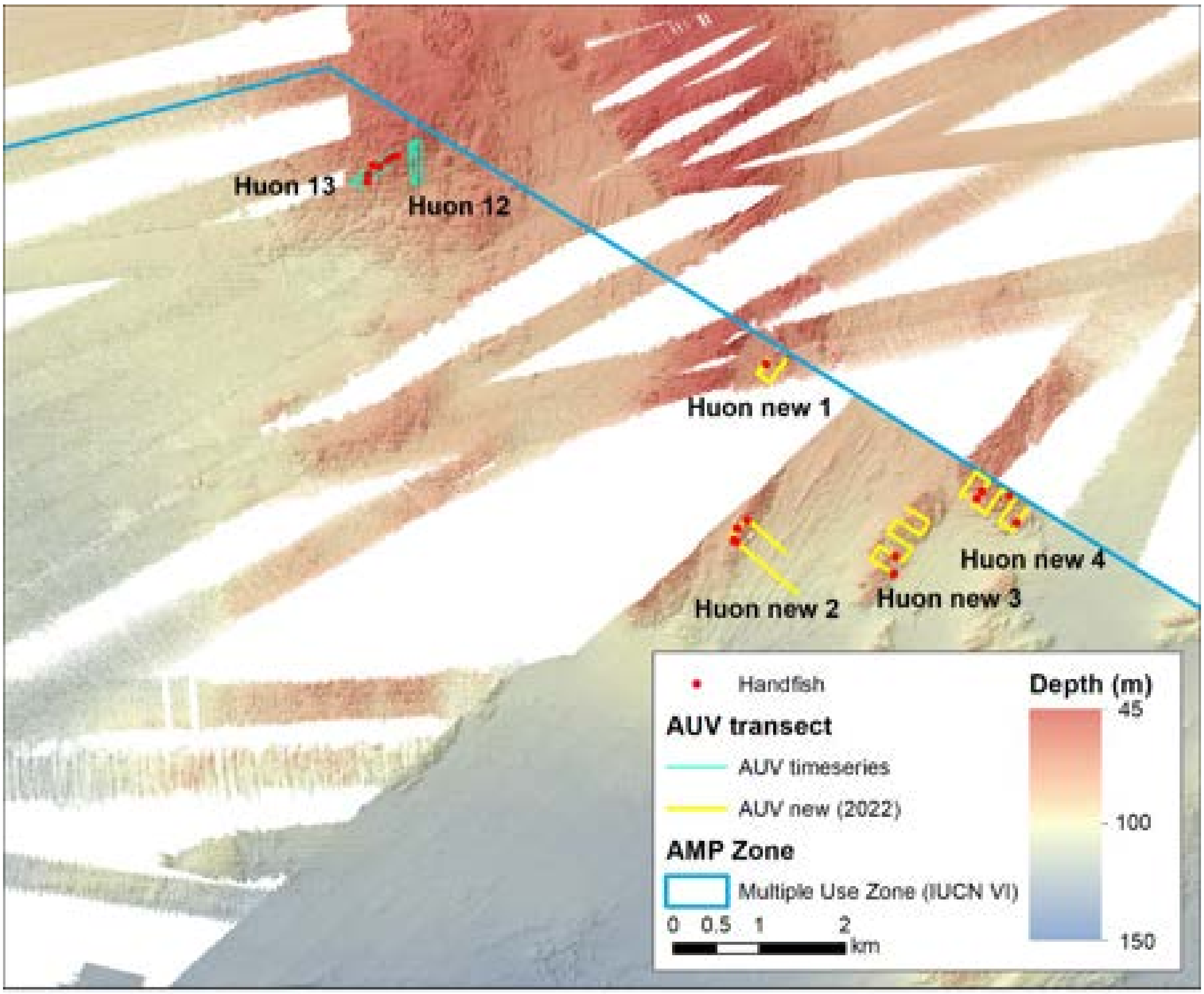


Figure 56. Location of handfish observed in Huon AMP

Table 10. Transects targeted scored for handfish in the Huon Marine Park, including the number of images annotated and the number of handfish observed in each transect.

Transect	Number of images sampled	Number of handfish observed
Huon_13	2455	7
Huon_4_new	1776	4
Huon_2_new	2103	4
Huon_3_new	1914	2
Huon_1_new	1365	1
Huon_12	1512	0

FMP

For FMP the annotation process for handfish was primarily conducted as part of initial testing of the newly developed machine learning detector for handfish, as well as manual searches for three additional transects (Shelfbreak 1-3). In total, four handfish were observed, including one on each of Joe's Reef, MPA_1, shelfbreak_3 and shelfbreak_4 (Table 11 and Figure 57). Two larger individuals were detected by the AI-based approach while two smaller individuals were detected manually. Cropped images of handfish observed in FMP are provided in the Appendix. Initial examination of the imagery suggests the potential presence of Ziebell's handfish species in this mix, as well as pink handfish.

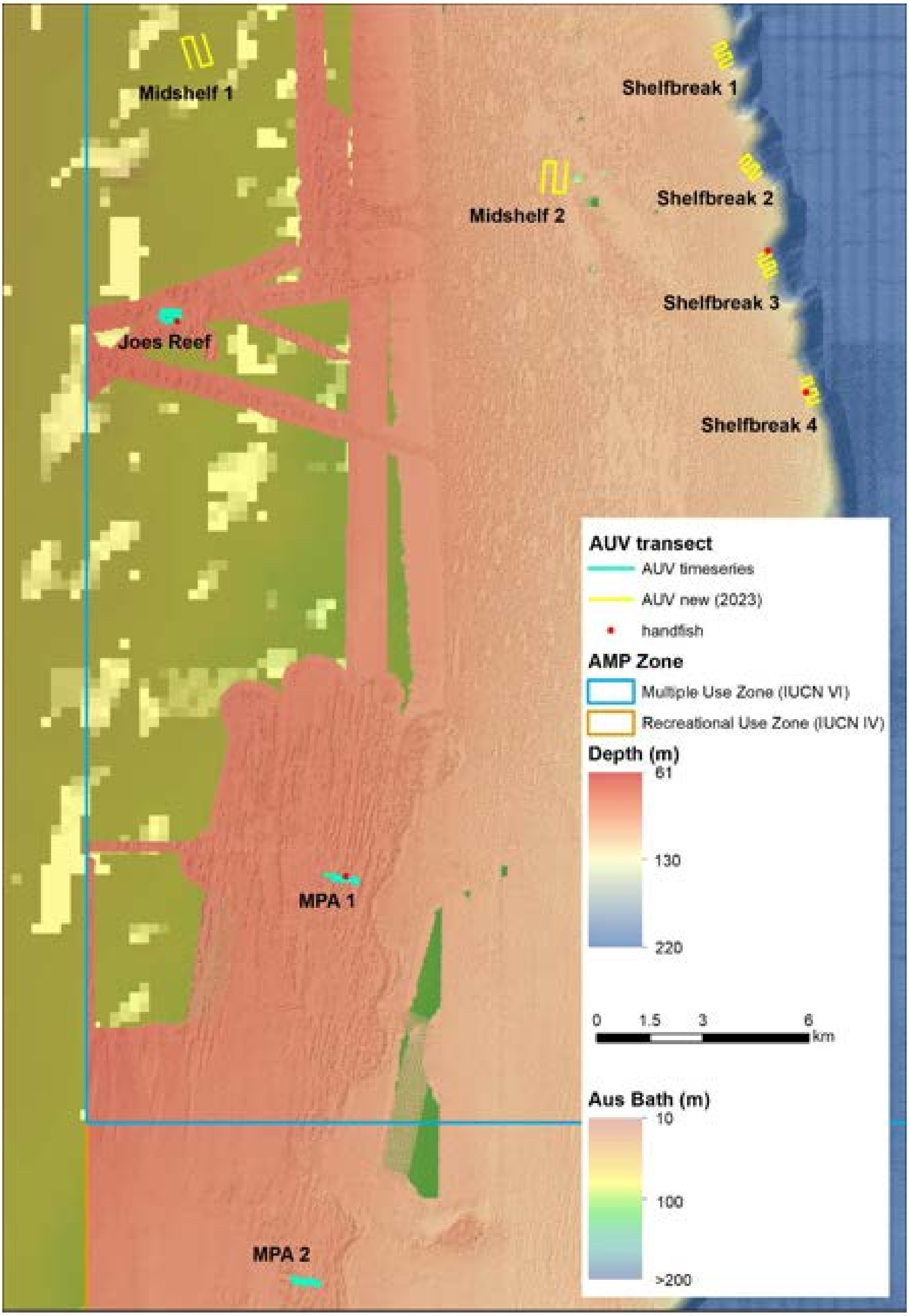


Figure 57. Location of handfish observed in FMP.

Table 11. Transects targeted scored for handfish in the FMP, including the number of images annotated and the number of handfish observed in each transect.

Transect	Number of images sampled	Number of handfish observed
Joe's Reef	40505	1
Shelf_break_1	10959	0
Shelf_break_2	12242	0
Shelf_break_3	11171	1
Shelf_break_4	12840	1
Midshelf_1	12921	0
Midshelf_2	13563	0
MPA_1	16350	1
MPA_2	9156	0

General Discussion

Recent benthic surveys of the FMP and HMPs using an autonomous underwater vehicle (AUV) have considerably expanded the knowledge of the spatial distribution of habitats and the temporal changes of associated biota across decadal time scales. New regions were surveyed in HMP in 2022 and FMP in 2023, following additional bathymetric mapping (Heaney and Davey 2019) of the shelf in both MPs. These newly surveyed areas revealed previously undescribed habitats and biota in both MPs, in particular adding information about habitats and the species present in the rariphotic zones of both MPs. The AUV surveys undertaken in the current study have extended the time-series of surveys at long-term monitoring sites in both MPs, with four repeated surveys at these sites. Analysis of the time series data at these monitoring sites revealed that while the sessile benthic communities remained relatively stable over the 12-13 year period (2011-2023), the abundance of some individual morphospecies varied considerably. There is a current lack of fundmental knowledge regarding the temporal dynamics of temperate deeper water shelf biota, both in Australia and elsewhere. This work therefore provides crucial information on rates of change in these systems, knowledge that is critical for ongoing monitoring. For some morphospecies that were present in both FMP and HMP, different trajectories of change were noted, highlighting that localised biotic (e.g., recruitment pulses) and abitoic (e.g., marine heatwaves or storm events) are likely to be important for understanding the observed dynamics.

The new areas surveyed in FMP and HMP revealed unique habitats and morphospecies and observations of handfish. Within the rariphotic zone in FMP, outcropping mudstone and limestone reef features on the shelf break reefs and rubble dominated habitat in the mid-shelf region. The shelf break reef features provide refuge for a number of mobile species, including fish and rock lobster. However, the relatively small amount of outcropping reef, and the observed low cover of sessile organisms on the mudstone reef, means that there is relatively low overall cover of sessile biota in these areas. In comparison, large areas of complex reef wih high diversity of morphospecies were found in the new survey areas in HMP, similar to those previously surveyed, with new areas spanning the lower mesophotic to rariphotic zones.

Multivariate analysis of overall comunity composition of the two long-term monitoring sites in both FMP (Joe's Reef) and HMP (Huon_13) indicated the overall stability in community composition across the 12 and 13 year survey period within each MP respctively, but that the cover/abundance of some indivdual species did change significantly. SIMPER analysis of the community composition showed that differences across time were primarily driven by the changes in the cover of the more dominant morphospecies in each MP, such as biological matrix, soft bryozoa, and gorgonian red *Pteronisis* like. However, multivariate approaches based on distance measures such as those used here are likely to have relatively low power in detecting changes across individual morphospecies with low cover, and are more likely to detect changes in taxa that have greater variability over time (or space) (Warton et al. 2012). Therefore, we also used univariate analysis approaches, including the use of targeted scoring to detect more subtle shifts in abundance through time.

Targeted scoring of a number of key easily identifiable morphospecies at both Joe's Reef and one of the Huon transects (Huon_13) revealed that the abundance of most morphospecies varied over the 12-13 survey period. Interestingly, changes were not consistent between FMP and HMP for the same morphospecies. For example, massive purple sponges showed a small but significant decrease in abundance over time at Joe's Reef, but increased in Huon_13; fan pink sponges fluctutaed in abundance at Joe's Reef, but had a large increase in abundance at Huon_13; cup red smooth fluctuated in abundance and bleaching prevalence at Joe's Reef but increased in both abundance and bleaching prevalence at Huon_13; and cup black smooth decreased in abundance at Joe's Reef but fluctuated in abundance at Huon_13. Only cup yellow sponges remained relatively stable in abundance at both sites. This shows that mesophotic invertebrate dominated systems in the SE MP Network are likely to be dynamic on 5-10 year time scales, with significant changes detectable with image-based approaches. This is new knoweldge, with deeper shelf systems such as these typically assumed to be relatively stable over these time scales (Cerrano et al. 2019). Furthermore, the differing temporal trends at these MPs indicate that localised pressures such as disturbance through storms or heatwaves, and population dynamics such as mortality of larger indivduals or recruitment events, influence abundance. Understanding how these factors influence sessile biota at these sites will be important if we are to gain a better understanding of what drives temporal trends. While some effort has been made to understand temporal changes in size structure of sponges within the FMP and HMPs (see Perkins et al. 2022a), the number of morphospecies for which information is available is not sufficient to draw conclusive between MP comparisons and temporal trends. Quantifying changes in the size structure and abundance of a larger number of morphospecies would increase our understanding of the temporal dynamics of these ecosystems and the species within them. This in turn would aid with the selection of appropriate indicators to track temporal changes at these long-term monitoring sites.

The variability in abundance of some of the individual morphospecies observed in this study, is similar to that found at other reefs in the wider SE MP Network (see Perkins et al. 2021). For example, the high variability in the cover/abundance of gorgonian red Pteronisis like octocorals and soft bryozoa was previously noted (see Perkins et al. 2021), and further confirmed with the results presented in this report. Also, some sponge morphospecies such as massive purple sponges and fan pink sponges were previously noted (see Perkins et al. 2021) to be variable in abundance over decadal time scales (increasing at some sites and decreasing at others) and were also found to have changed significantly over the extended survey period reported on here. Knowledge about the "natural" temporal variability in the abundance of potential target indicator species is important for ongoing monitoring (Larsen et al. 2001, Urquhart 2012, Perkins et al. 2017). However, data regarding the physical disturbances in these systems and the timescales of recruitment events are required to improve our understanding of the population dynamics of sessile mesophotic reef biota across the SE MP Network.

At present, we are in early stages of understanding what levels of variability is normal in these deep reef systems and the key drivers of this variability. However, building the knowledge of how individual morphospecies and communities change over time is critical to better inform the monitoring of mesophotic and rariphotic reefs across the region. Such knowledge can only be improved by undertaking ongoing monitoring at appropriate timescales to develop a more nuanced understanding of the key drivers of change. A key component to removing sampling-based noise (spatial variance) from these observations has been the use of a fixed transect design using AUVs capable of following and repeating a pre-programmed transect. This is a significant strength of AUV-based approaches and ideally such approaches would be continued in future monitoring programs.

A total of 22 handfish were detected in the AUV imagery collected as part of this project: 18 in HMP and four in FMP. This reinforces the importance of deeper shelf habitats around Tasmania for handfish species, considering that a further 70 handfish were detected during recent AUV surveys in the Tasman Fracture Marine Park (Perkins et al. 2022c). The number of handfish detections is likey to increase as more of the existing imagery is searched. While two of the handfishes seen in FMP in this study were detected via thorough manual searching of images at three survey sites, the other two were detected across the remaining sites using a new AI-based detection tool that was specifically trained to detect handfish, proving the value of this ground-breaking advance in image analysis and understanding of biodiversity values in AMPs. Given the relatively small footprint of the AUV surveys compared to the extent of reef habitat in both MPs, it seems likely that the total population of handfish is large. Image resolution from the AUV is not sufficient for species identifiaction in most cases. However, the observed handfish present a range of colours and morphologies making it likely that a number of species are present, including the possibility of undescribed species. Given that a number of handish species are on either Commonwealth or state endangered species lists, confirmation of the species present should be given priority in future survey work. Determining species level will require more targeted studies using ROVs and/or eDNA approaches to confirm the identity of the species present, including the possibility that some of the species may yet be unknown to science.

This report provides the most comprehensive analysis of temporal changes of sessile biota in MPs across the SE MP Network to date, with 4-5 repeat surveys spanning 12-13 years. Results in this report show that sessile reef biota, with the exception of cup yellow sponges, in mesophotic depths (~50 - 85 meters in the time series data) in both MPs have undergone change over time.. This is new scienitifc knowledge for both these MPs, and temperate mesophotic reefs in general, where there is current lack of knowledge regarding how the abundance of sessile biota changes over time. This knowledge could be futher built on by looking at changes in size structure over time to examine mortality of larger individuals and the timing of recruitment of new indivduals. Additionally, better physical and oceanographic data coupled with ongoing visual surveys are important to undertand the impact of major disturbances such as storm events and marine heatwaves on these ecosystems.

Recommendations

Based on the knowledge gained from surveying and analysing the sessile benthic communities across both HMP and FMP, and indeed other Marine Parks in the SE MP Network over a period of > 13 years, we can make a number of recommendations for ongoing benthic monitoring of Marine Parks in the region:

1. Some of the monitoring sites in FMP, such as AMP site 1 and Site 2 and the midshelf areas, which initially appeared to contain reef features from seafloor mapping have been shown to be sediment/rubble dominated and to have low overall biodiveristy values. These sites should be of lower prioirty for repeated monitoring and could be revisited on a 10 year schedule to examine broader changes that may arise from protection from trawling in shelf waters. The main focus of ongoing regular monitoring, ideally every 5 years or more often, in FMP should be Joe's Reef due to the high diversity and uniqueness of this reef feature.
2. Newly surveyed reef features in HMP have revealed complex habitat reef features that contain many of the biota present at the long-term monitoring sites (Huon_12 and Huon_13). Therefore, temporal changes in biota can likely be tracked well in these long-term sites with less regular vistis to the four new sites if budgets do not allow all sites to be visited each survey period. However, the four new sites do contain deeper reef (> 80 m) not covered in the long-term sites, and so ideally at least one new site should be visited in the next round of monitoring to improve overall habitat/depth representation. In this latter scenario, we would recommend Huon new site 4, as it is the furthest ofshore and extends the deepest and therefore would extend the depth profile covered by a repeat survey.
3. Targeted scoring of individual morphospecies can detect more subtle changes in abundance, with a relatively small amount of annotation effort. We therefore suggest this approach be used for identified indicator morphospecies as part of future monitoring programs both in

the HMP, FMP, and elsewhere. Indeed, due to the potential for tracking change in key abundant species, we recommend this approach be explored by other agencies and in other systems as well.

4. Surveys in both MPs have highlighted the presence of handfish. However, with the resolution and downward facing imagery collected by the AUV, species identification was not possible. Given the rarity and endangered status of many handfish species, gaining a better understanding of the species present and their population sizes is important for ongoing conservation efforts. Higher resolution imagery, such as may be collected by ROV, and eDNA samples could greatly aid in species identification. Also, the distribution of handfish across MP zones and the protection afforded these populations by MP zoning should be part of ongoing assessments and conservation efforts.
5. To better understand the results of the current time-series analysis of tageted scoring, the size structure of the morphospecies through time should be captured to help inform the timing of recruitment events or mortality of larger individuals. This task is likely to be readily achieved with little effort using current developments in AI which can harness the targeted scoring data and segment individuals to quantify their sizes. Likewise, AI-based approaches can be used to generate accurate whole of image percent cover of chosen indicator species, significantly increasing the statistical power in time-series analysis.
6. Better physical and oceanographic data is required to understand the physical drivers of disturbances in these ecosystems combined with surveys following major disturbances such as major storm events and heatwaves. In particular, temperature at depth and bottom velocity generated by large swells during storm events with follow up visual AUV or ROV surveys, would greatly improve our undertanding of the drivers of change. Both temperature and bottom velocity data could also be collected through the deployment of sensors, but would require exploration of the cost-benefit of the current available technologies. Ideally, sensors deployed on the bottom within each MP could collect data at depth, which may differ from sea surface temperature data that can be collected via satellite. Temperature data could also potentially be collected on a regular basis as part of the IMOS glider program, but would require collaboration and planning of future surveys that collect baseline data as well as data during extreme events such as marine heatwaves. Data from gliders would also only provide ‘snapshots’ of temperature during deployments, rather than continuous measures of variability.
7. For the broader SE MP Network-based approach to monitoring the FMP was identified as a priority area based on its susceptability to ocean warming and anthropgenic pressures. However, as much of the shelf area within the park is primarily composed of sand-inundated dune-like features, with little benthic cover besides biological matrix, it is suggested future monitoring of sessile fauna in this general EAC-influenced region, that the core sites be restricted to Joe’s Reef and reef outcrops in that immediate vicinity which typically have more extensive invertebrate assemblages with a number of good potential indicator morphospecies (e.g. cup sponges). Focus on these reef systems would better match the biota and patterns observed and monitored on the more distinct reef systems found in the Huon and Tasman Fracture parks, and thus allow analysis of temporal and spatial patterns across MPs.

Appendix

Example images: Habitats and morphospecies in Huon Marine Park

Huon_12

Figure 58. Branching orange sponge and soft bryozoan on flat sandy habitat

Figure 59. Dense soft bryozoan forest on high profile reef

Figure 60. Southern rock lobster, Epizoanthus colonial anemones on cup sponge and gorgonian red Pteronisis like fans on moderate profile reef

Figure 61. Large laminar sponge with Parazoanthus on low profile reef

Figure 62. Massive red sponge, soft bryozoan and Parazoanthus on high profile reef

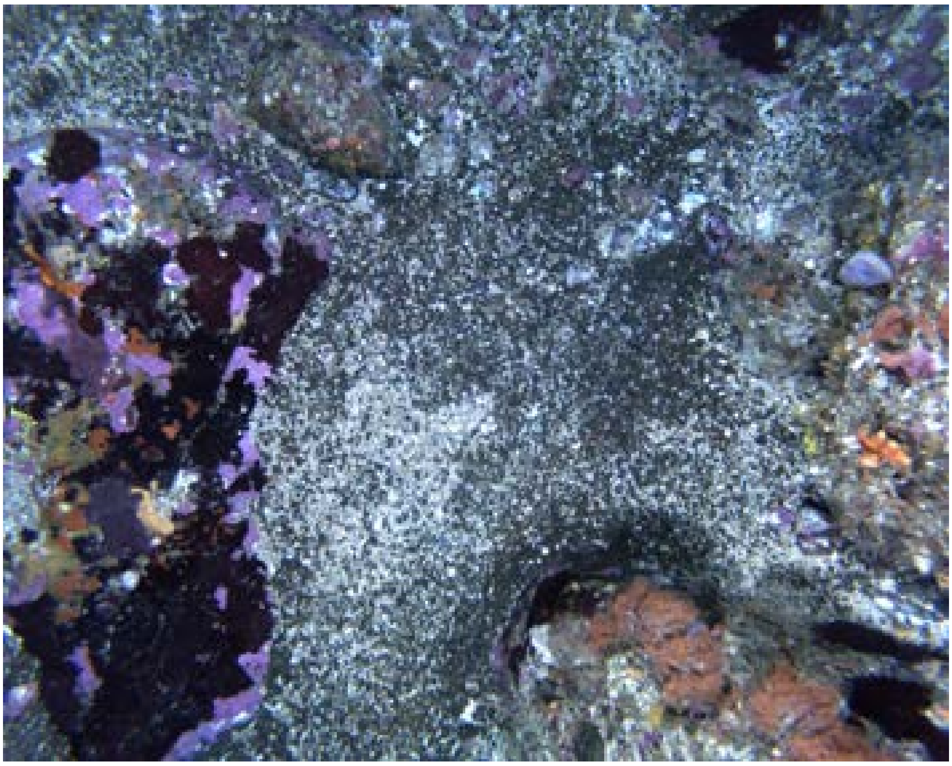


Figure 63. Non calcareous and calcareous algae and soft bryozoan dominated low profile mixed reef/gravel habitat

Huon_13

Figure 64. Southern rock lobster lobster on encrusting orange sponge and fan white sponge on low profile reef

Figure 65. Low profile reef/mixed sand habitat with biological matrix, soft bryozoa and encrusting calcareous and non-calcareous algae

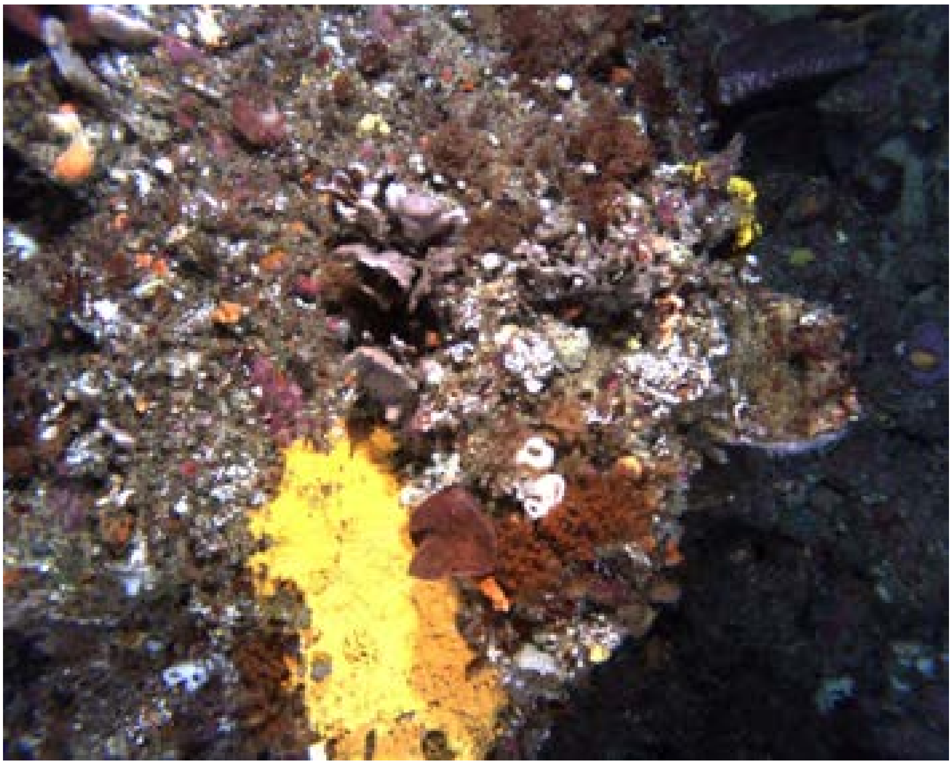


Figure 66. Matrix heavy high profile reef top with encrusting yellow smooth sponge, palmate grey and soft bryozoan

Figure 67. Southern rock lobsters amongst encrusting algae covered boulders

Figure 68. Massive orange sponge and blue cup sponge on low profile reef with other sponges, gorgonian fans and biological matrix

Huon_01_new

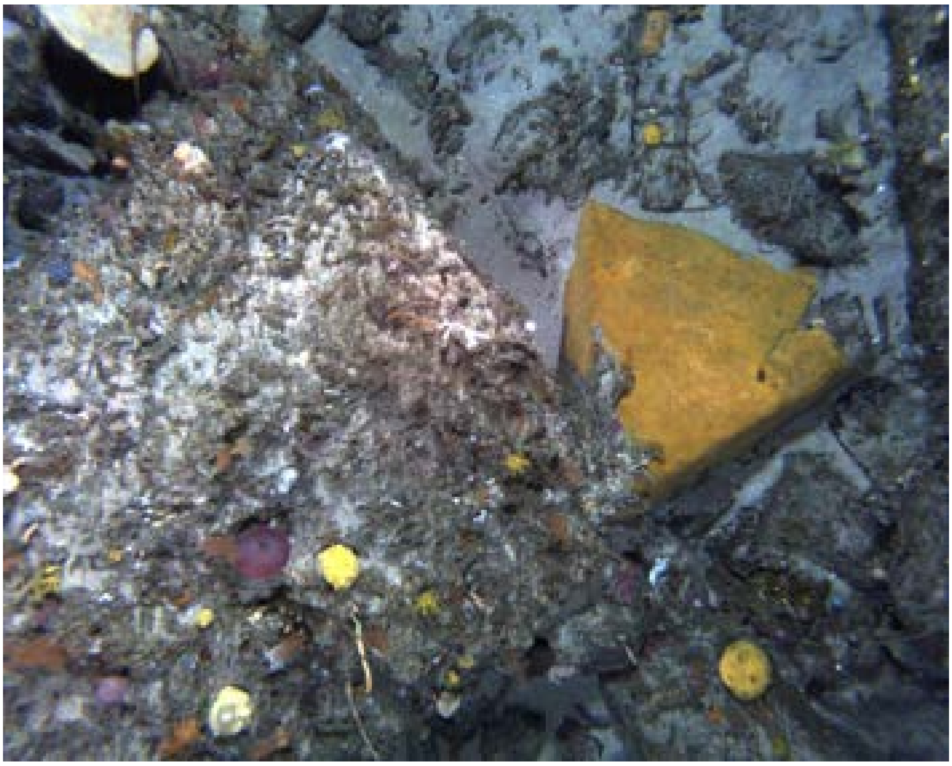


Figure 69. Moderate profile reef with encrusting yellow smooth sponge, biological matrix, red cup smooth sponge and other invertebrates

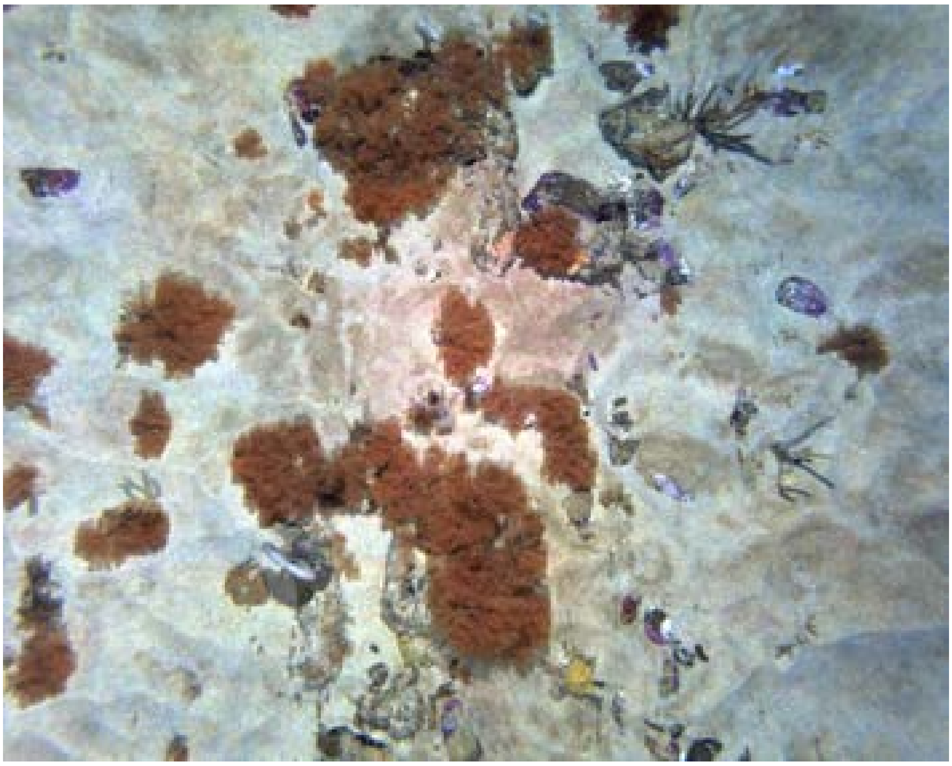


Figure 70. Low profile sand inundated reef with soft bryozoans and branching sponges

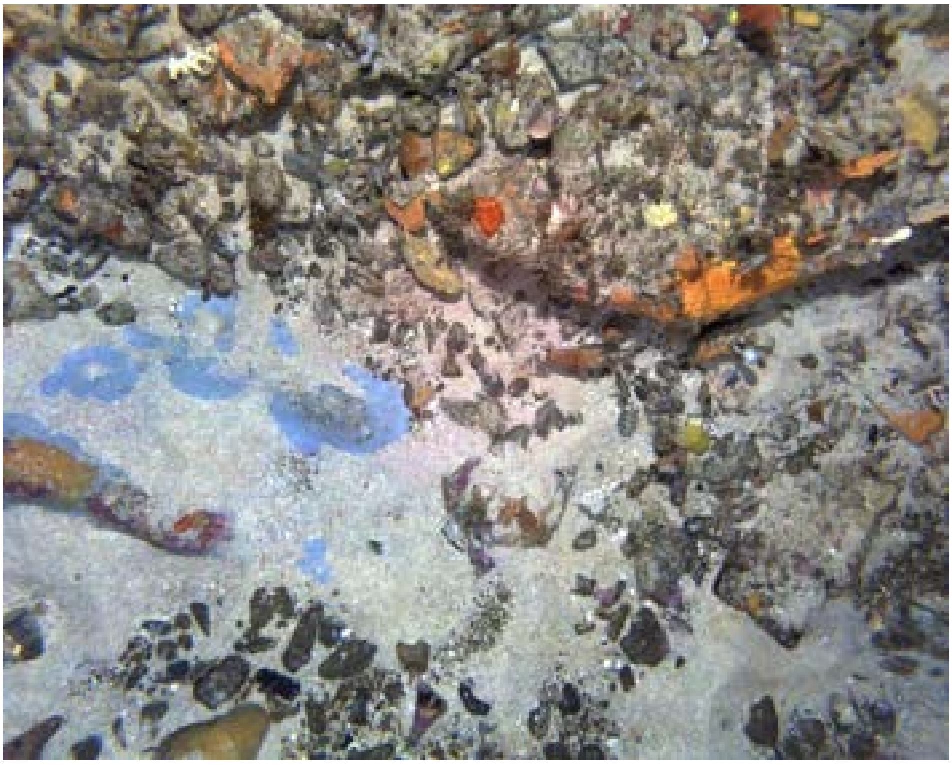


Figure 71. Low profile reef and mixed sand habitat with encrusting blue and orange sponges

Figure 72. Moderate profile reef and mixed sand habitat with large laminar irregular sponge, black smooth cup sponge, branching sponges, encrusting orange sponge, and biological matrix

Figure 73. High profile reef with epizoanthus overgrowing sponges, cup red thick sponge, and massive purple sponge

Figure 74. High profile reef with white fan thick sponge, massive purple sponge, and gorgonian red Pteronisis fans

Huon_02_new

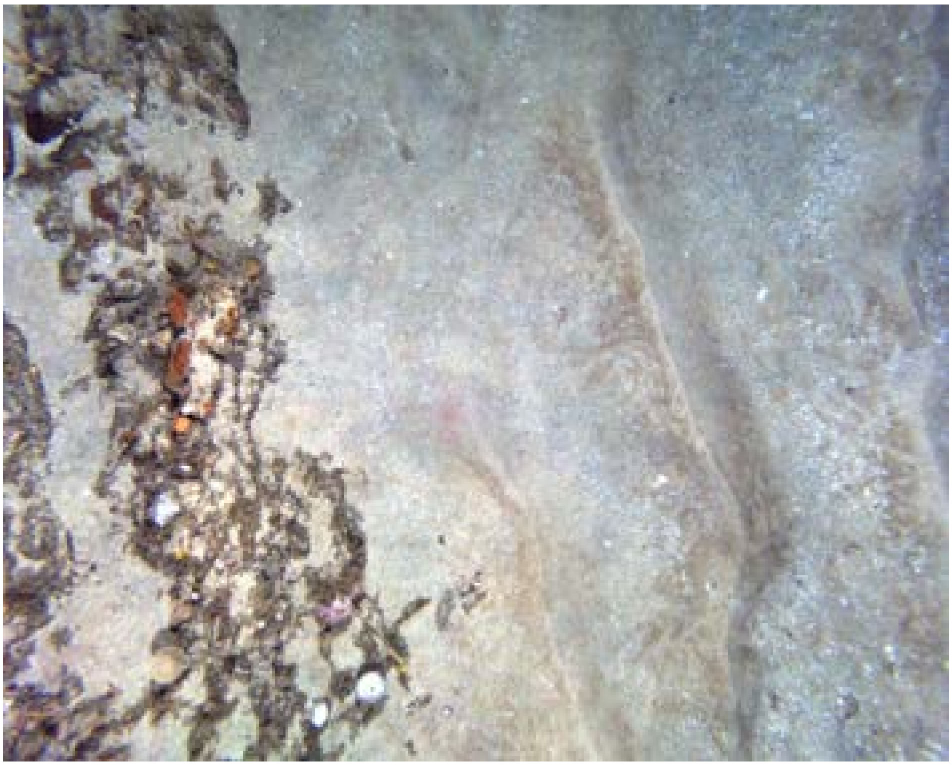


Figure 75. Low profile mixed habitat with rippled sand and sand inundated reef with sponge and biological matrix

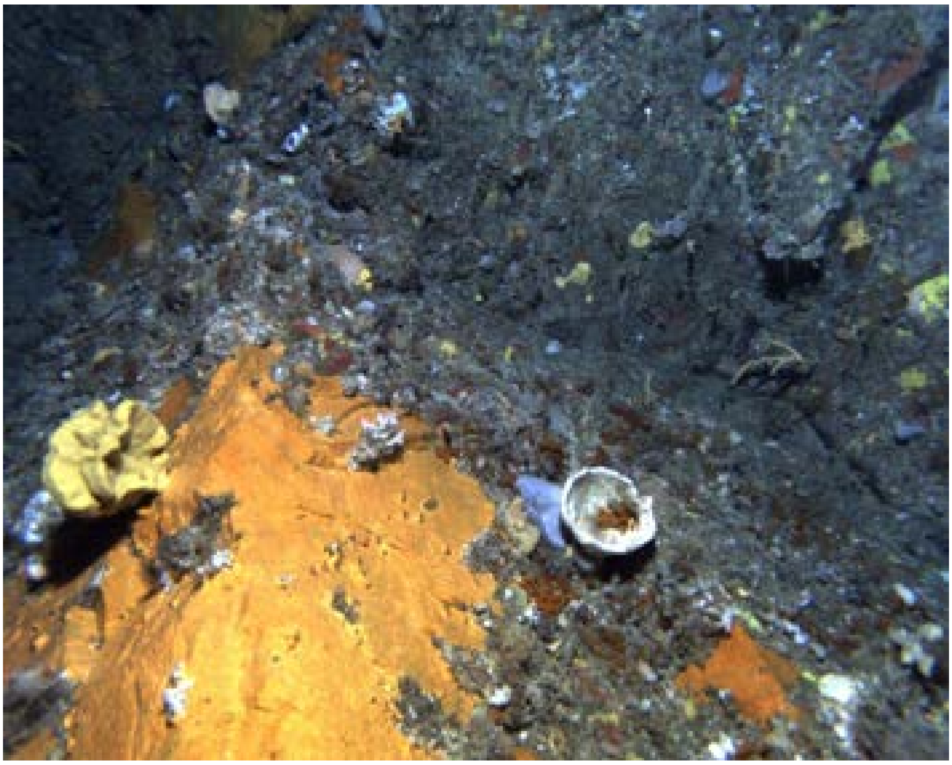


Figure 76. High profile reef with encrusting orange sponge, cup white sponge and massive yellow sponge

Figure 77. Reef with large black smooth cup sponge, soft bryozoa, bramble corals and biological matrix

Figure 78. Mixed low profile reef rippled sand habitat with prominent soft bryozoa

Huon_03_new

Figure 79. Moderate profile reef with laminar yellow sponge and a variety of small sponges and soft bryozoa

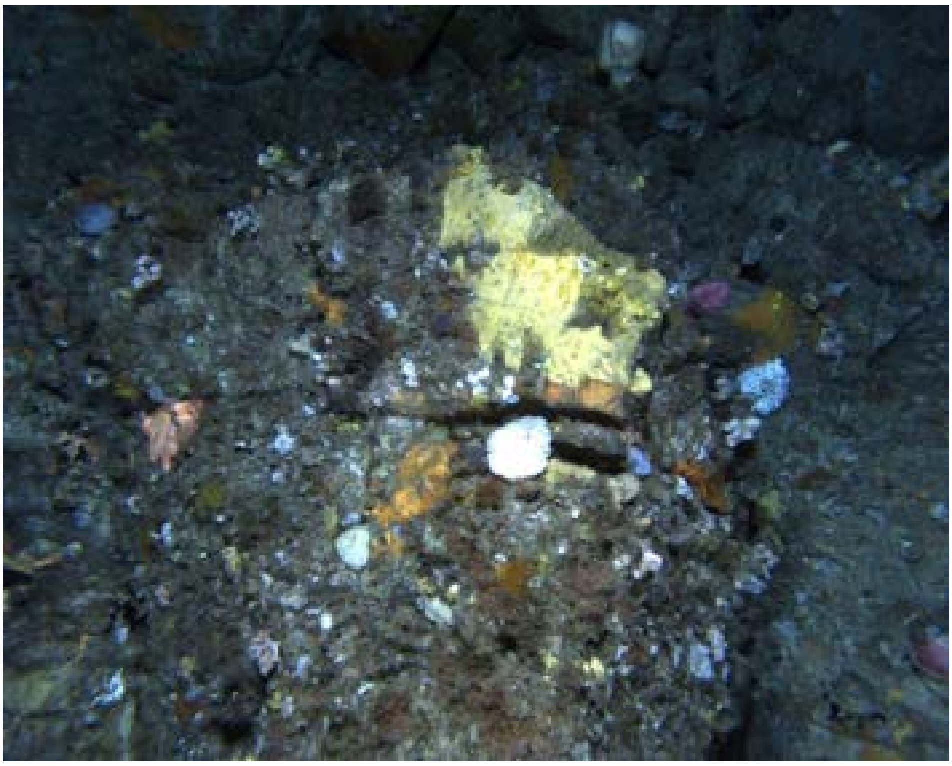


Figure 80. High profile reef with encrusting yellow smooth sponge, encrusting orange sponge, bryozoa and biological matrix

Figure 81. Mixed habitat of sand/pebble/reef with fan pink sponge and large white sponge

Figure 82. Moderate profile boulder reef habitat with rock lobster, branching and encrusting sponges and biological matrix

Huon_04_new

Figure 83. Sand inundated reef with soft bryozoa and red calcareous encrusting algae

Figure 84. High profile reef with encrusting yellow sponge with epizoanthids, rock lobster, black smooth cup sponge, and massive purple sponges

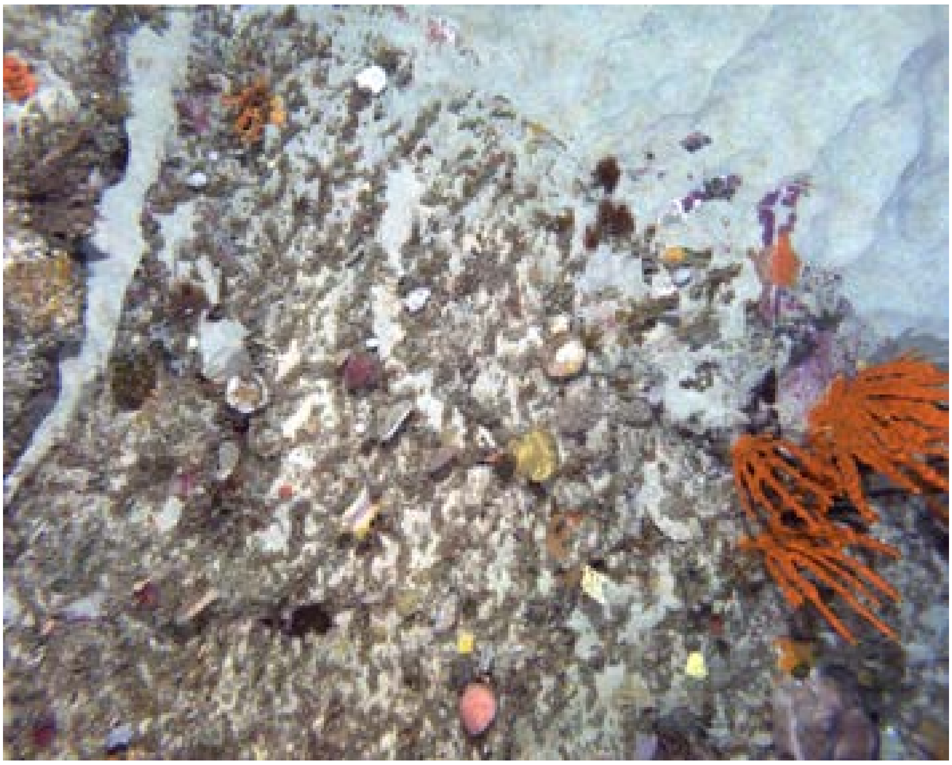


Figure 85. Reef edge with sand and sand inundated reef, palmate orange sponges, a variety of massive sponges and biological matrix

Figure 86. Mixed sand/low profile reef habitat with encrusting red calcareous algae and sponges

Figure 87. Moderate profile reef with branching pointed yellow sponges and encrusting yellow smooth and orange sponges

Figure 88. Reef with pink fans and gorgonian red Pteronisis like

Example images: Habitats and morphospecies in Freycinet Marine Park

Joe's Reef

Figure 89. High profile reef with a variety of branching, massive and fan sponges and soft bryozoa

Figure 90. Reef edge habitat with anthropogenic debris (rope) encrusted with invertebrates and ocean perch

Figure 91. Moderate profile reef with a variety of branching sponges, sea whips, gorgonian red Pteronisis like and a large pincushion sea star (Asterodiscides truncates)

Figure 92. Boulder reef habitat with encrusting white and orange sponges and cup sponges

Figure 93. Reef with encrusting octocoral (Clavularia like) and cup, massive and arborescent sponges

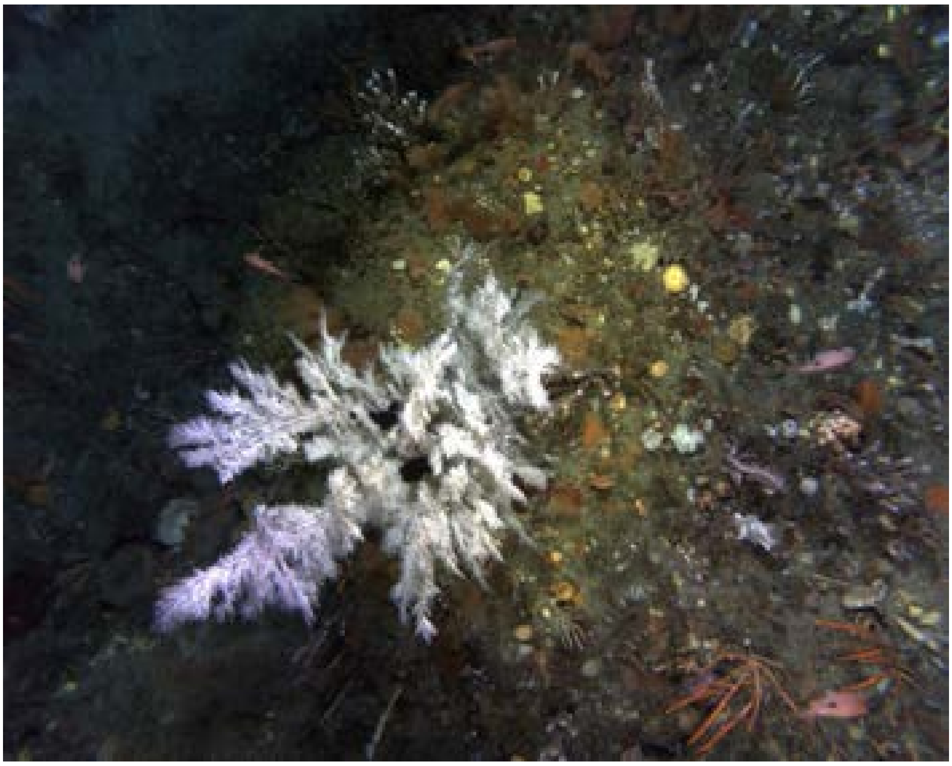


Figure 94. High profile reef with large black coral and branching sponges

Shelf break 1

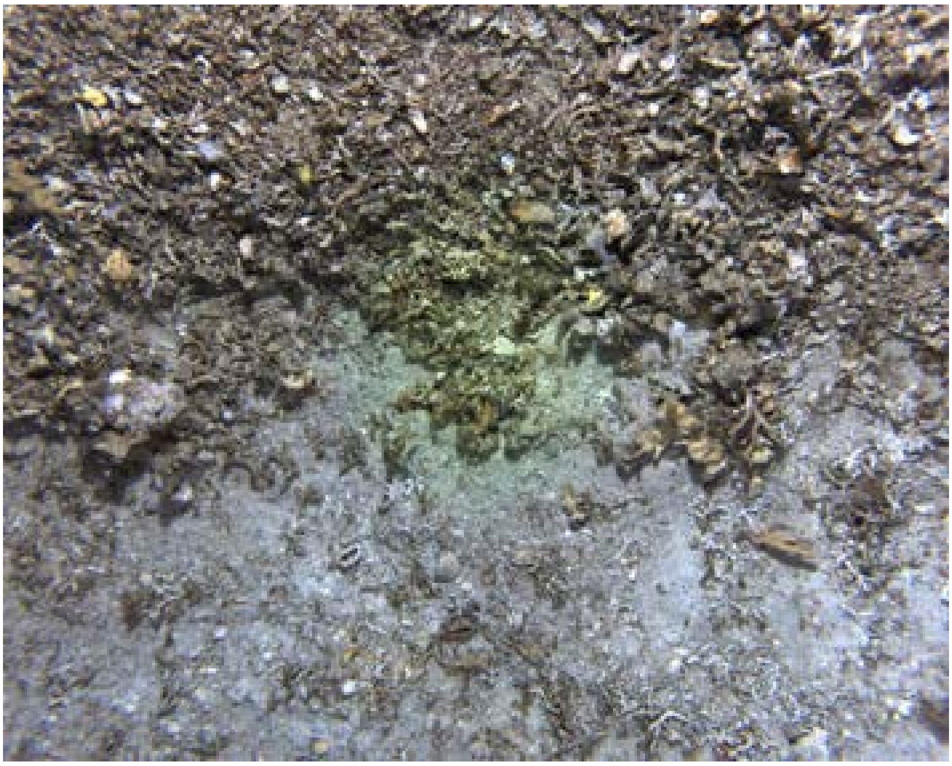


Figure 95. Bryozoan rubble and sand habitat with sponges

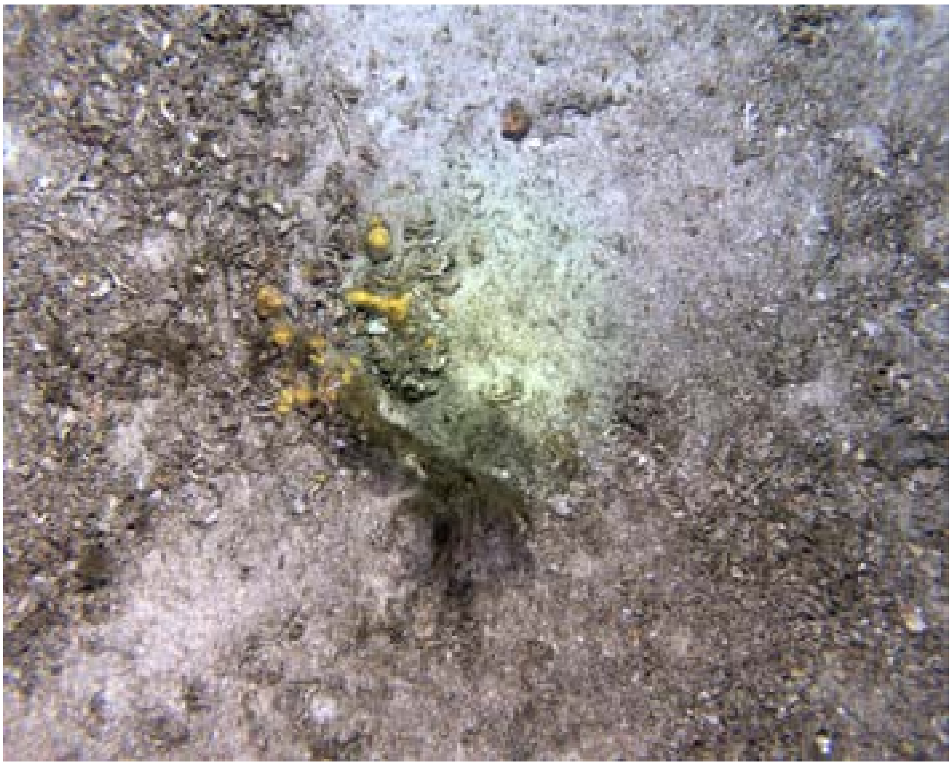


Figure 96. Bryozoan rubble and sand habitat with hydroids and sponges

Shelf break 2

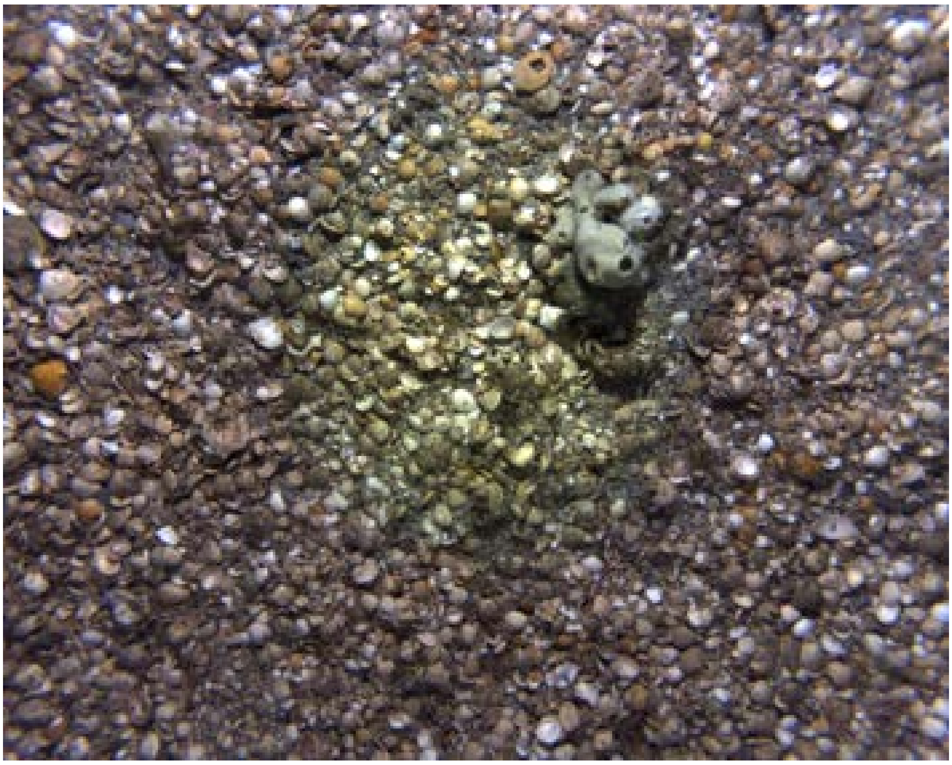


Figure 97. Bivalve shell dominated substrate with sponge

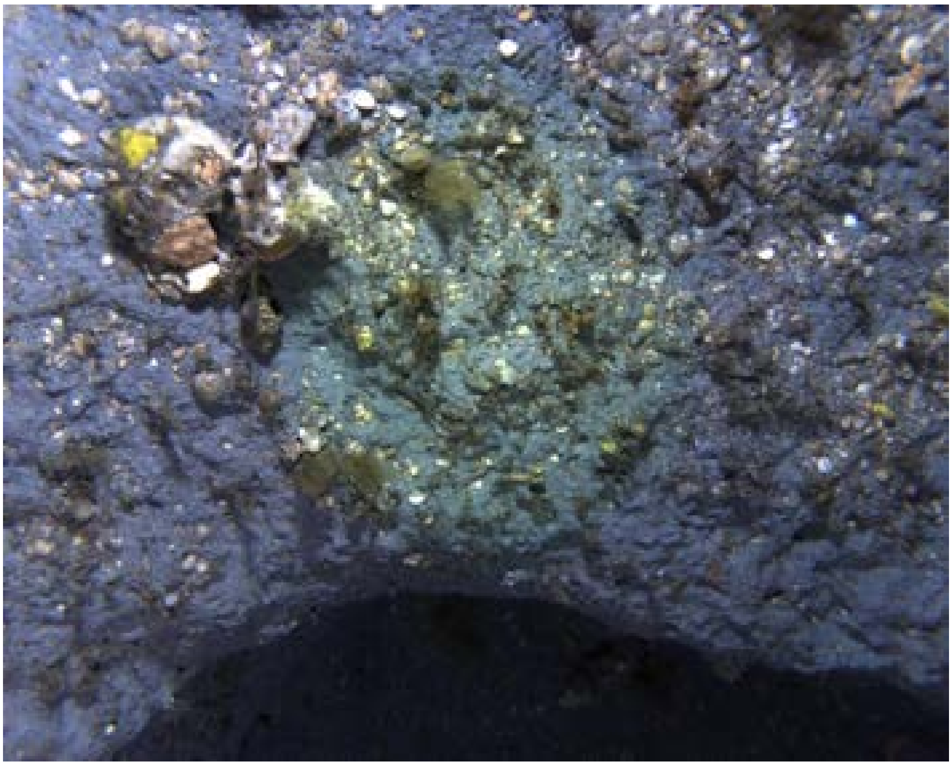


Figure 98. High profile mudstone reef edge with sponges, soft bryozoa, and bivalve shells

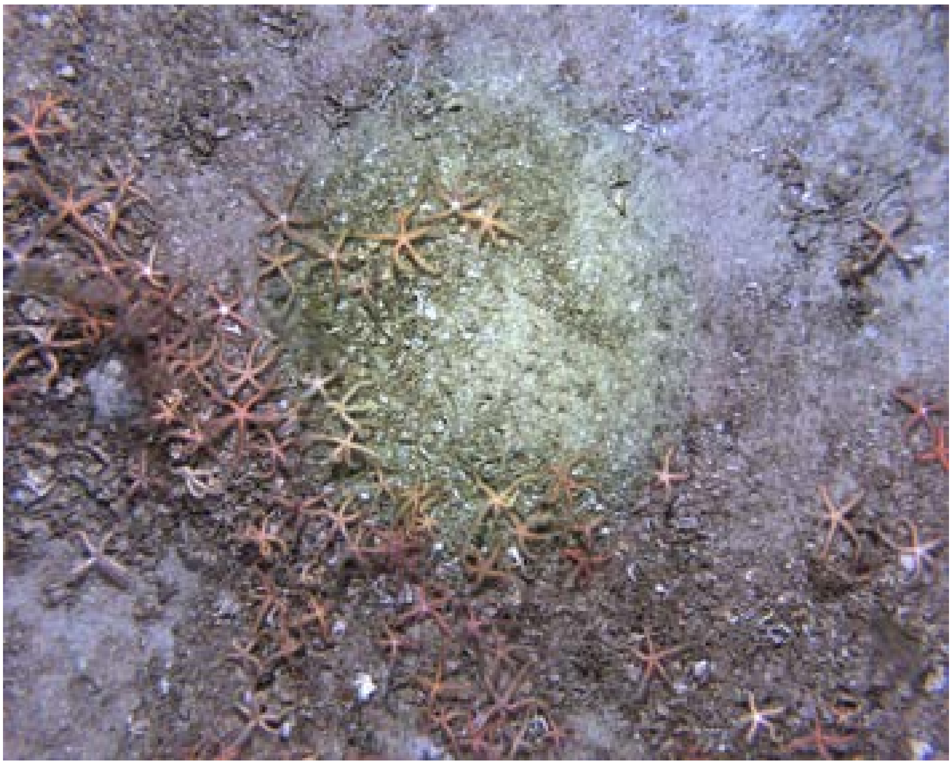


Figure 99. Sand and bryozoan rubble habitat with ophiuroids (brittle stars)

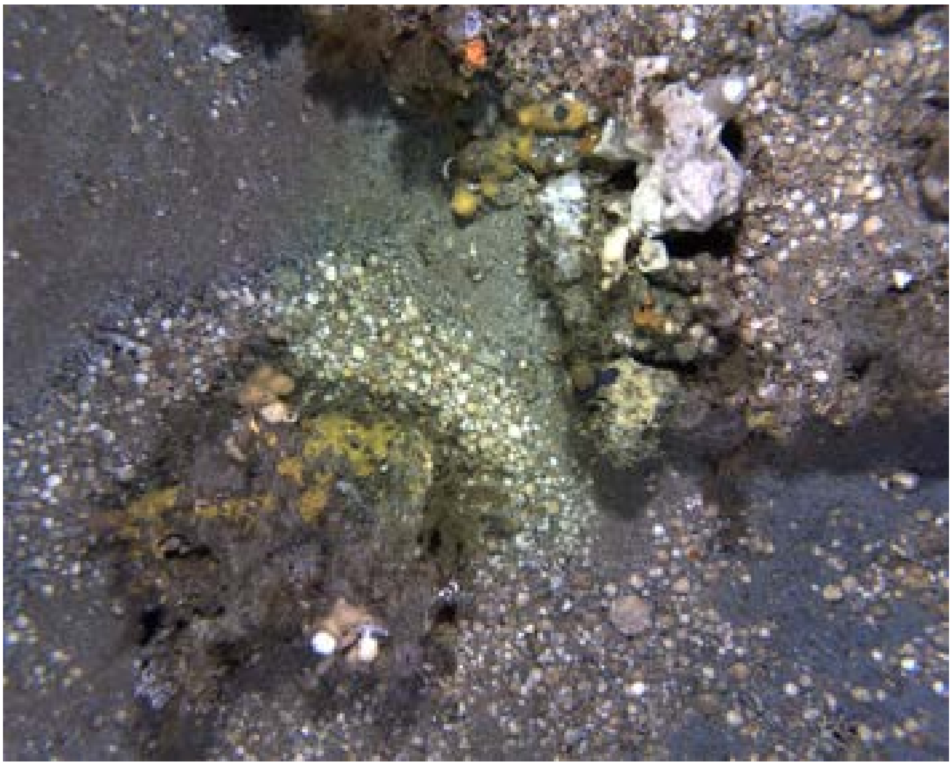


Figure 100. Mixed mudstone reef/sand/bivalve shell habitat with massive white lumpy sponge, encrusting yellow smooth sponge, and soft bryozoa including dendroid tan in the top of the image

Shelf break 3

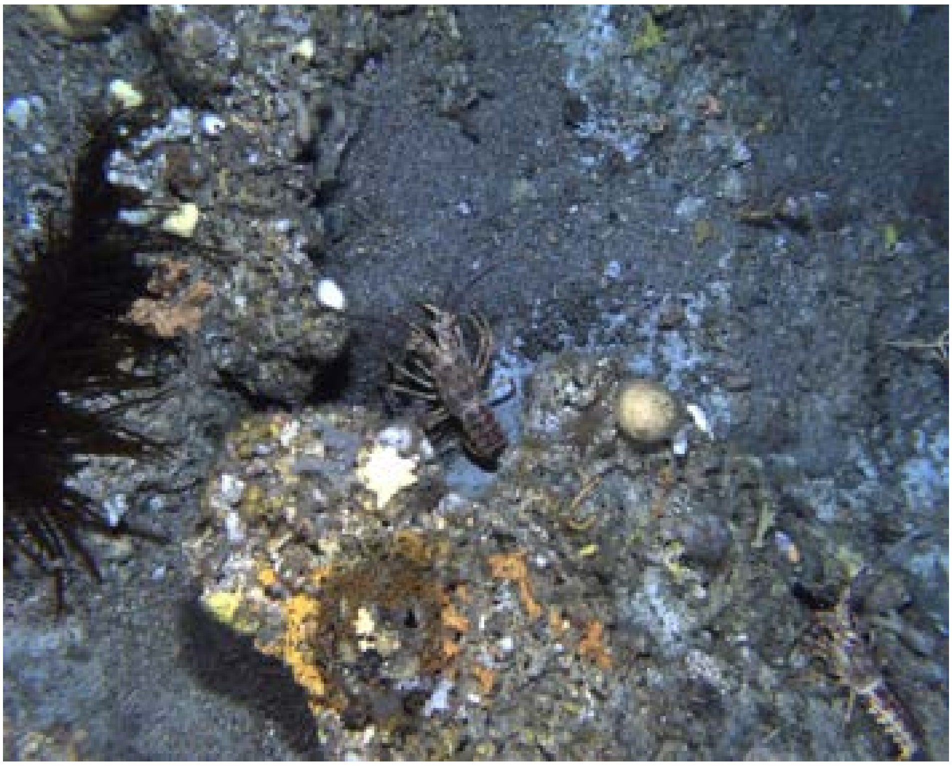


Figure 101. Low profile mudstone reef habitat with rock lobsters, encrusting sponges, and drift algae (phyllospora)

Figure 102. Massive yellow sponge and branching sponges on low profile sand inundated mudstone reef

Figure 103. Sand inundated mudstone reef edge with rock lobster, branching sponges, and anthropogenic debris (ropes)

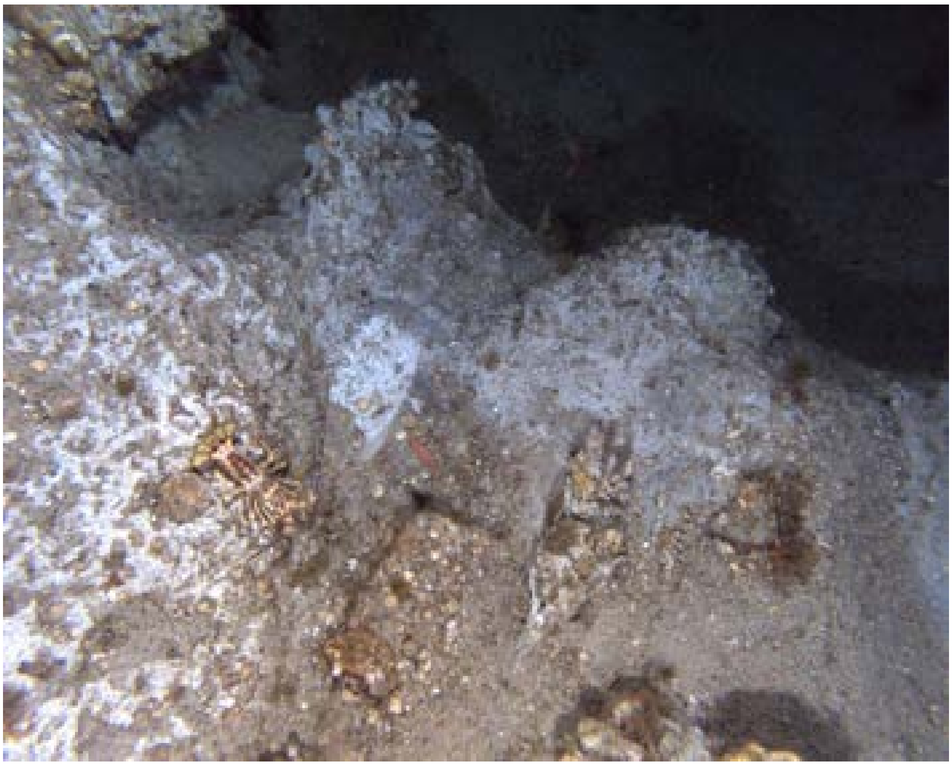


Figure 104. Bare high profile mudstone reef with rock lobster

Shelf break 4

Figure 105. Sand and bryozoan rubble habitat with sponges and anthropogenic debris (beer bottle)

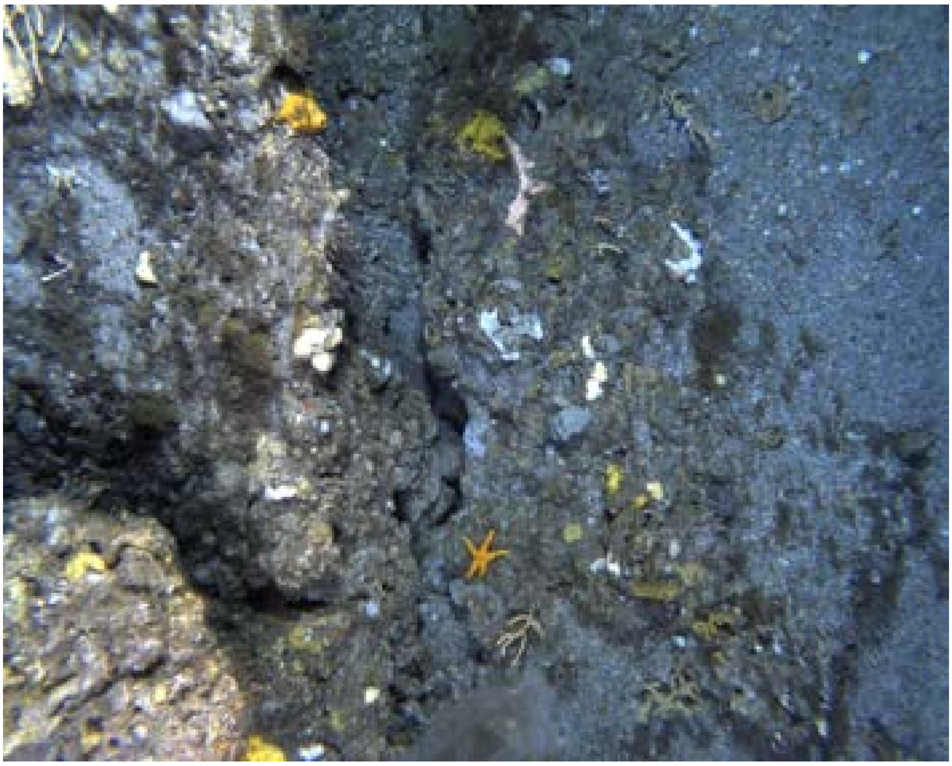


Figure 106. High profile limestone reef with soft bryozoa, a variety of branching, massive and encrusting sponges, and a sea star (Fromia polypora)

Figure 107. Moderate relief sand inundated limestone reef with branching sponges and anthropogenic debris (ropes)

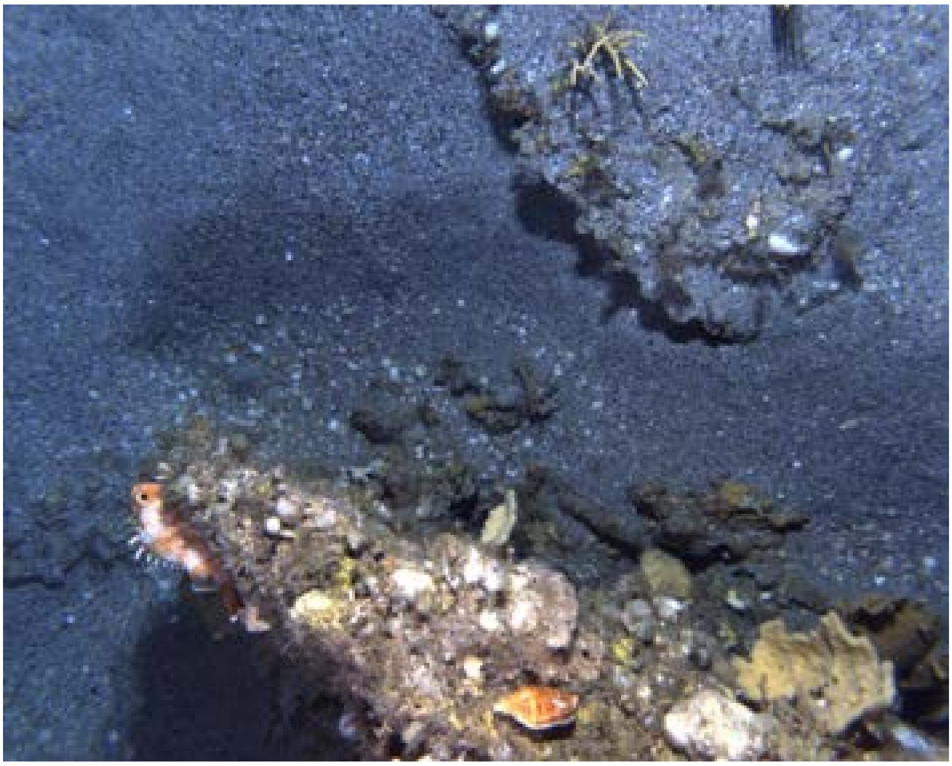


Figure 108. Moderate relief mixed habitat with laminar and branching sponges and ocean perch

Midshelf 1

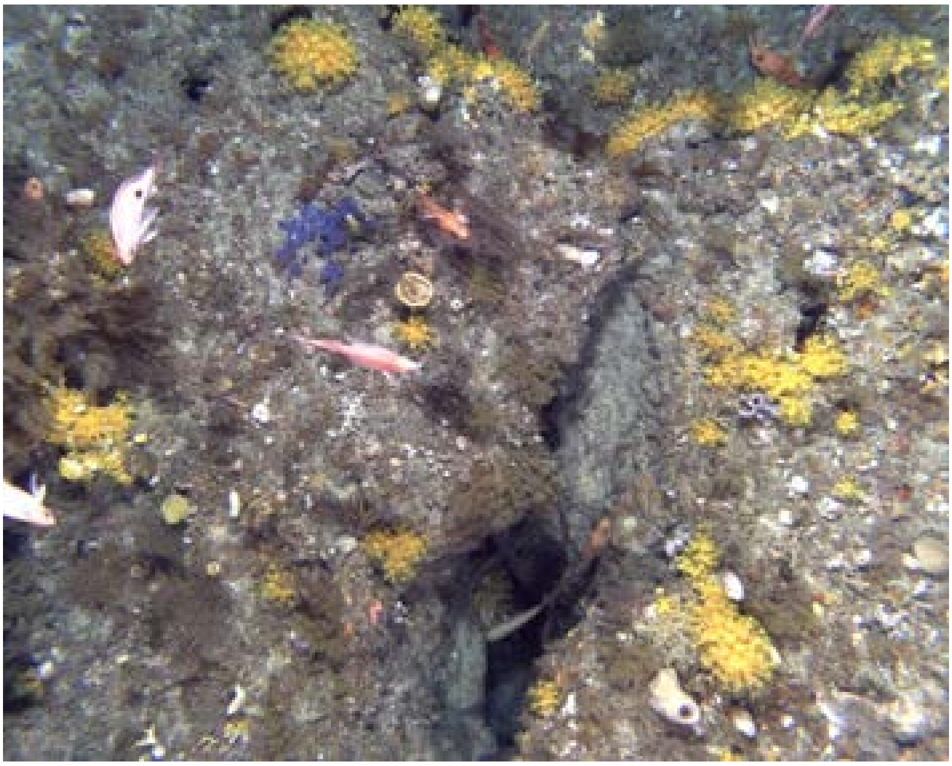


Figure 109. Rare outcropping low profile reef feature with Parazoanthids, sponges and soft bryozoa

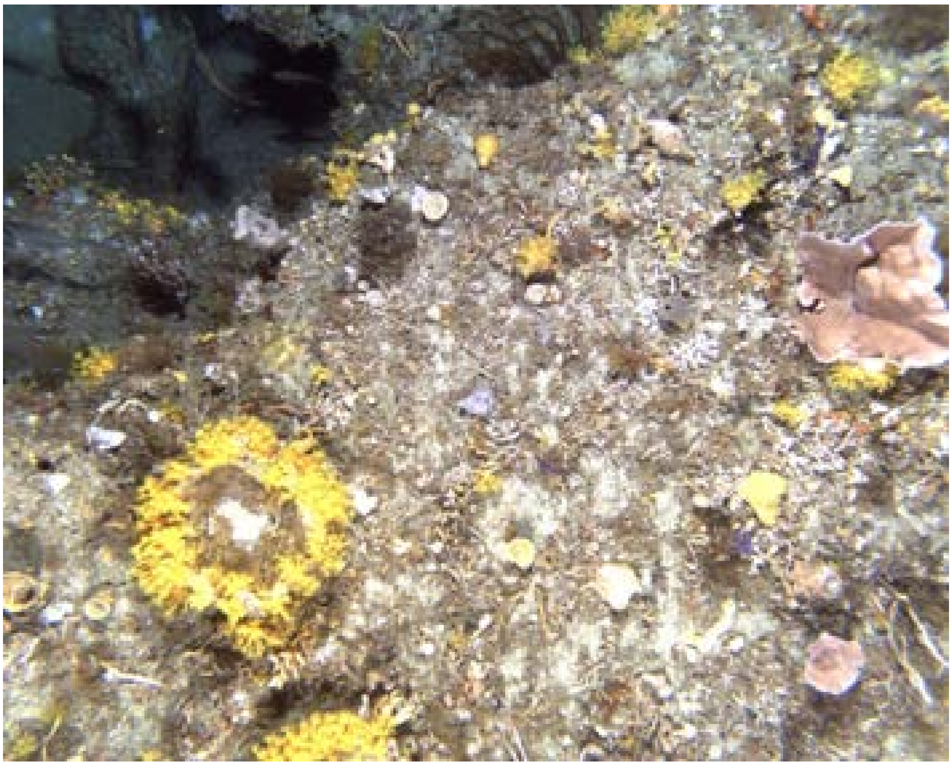


Figure 110. Rare outcropping low profile reef feature with Parazoanthids, fan pink sponges, soft bryozoa and biological matrix

Midshelf 2

Figure 111. Flat sand habitat with pipefish

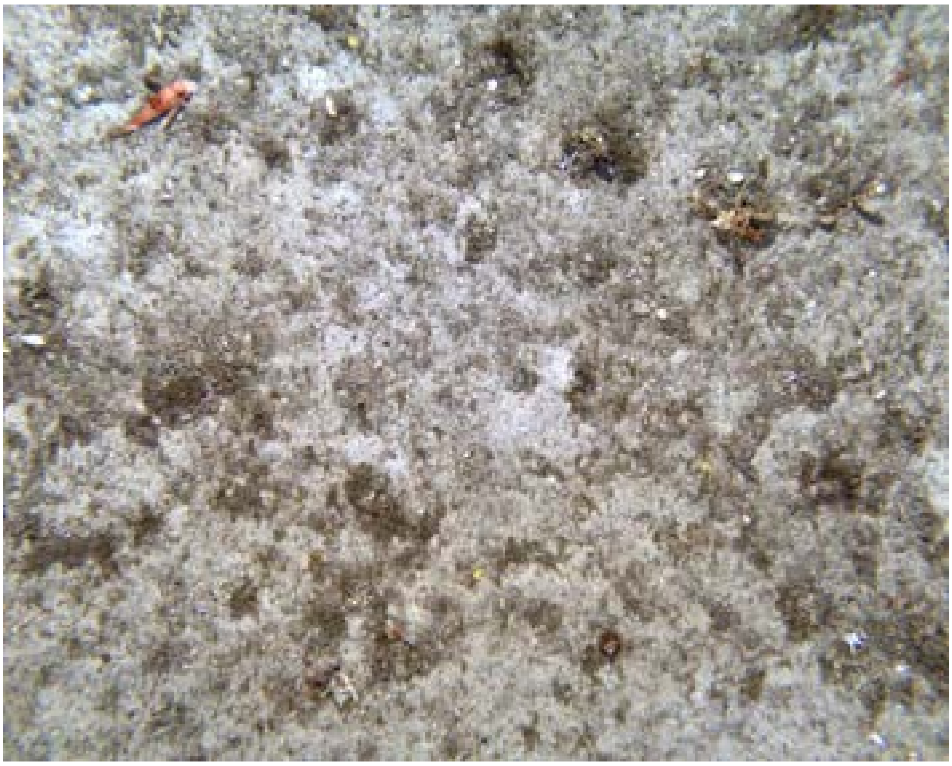
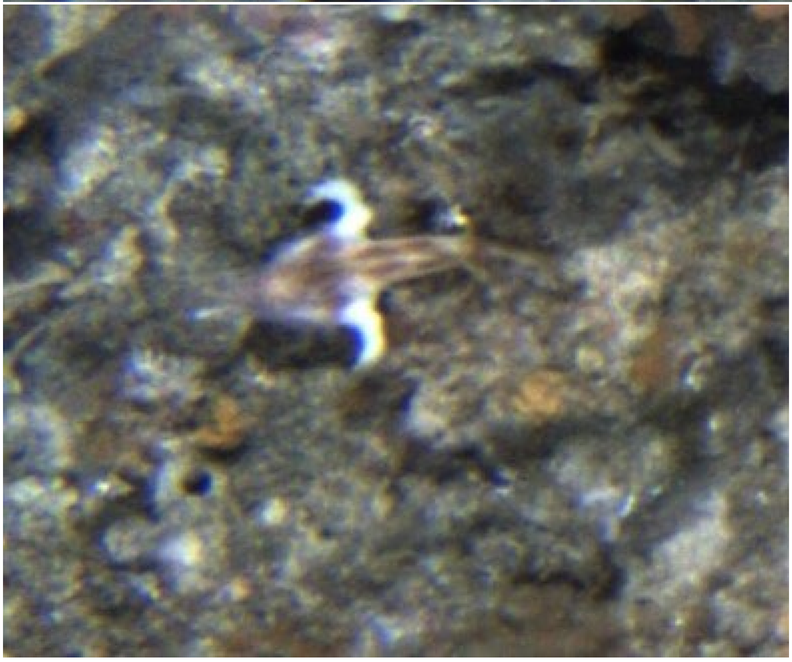
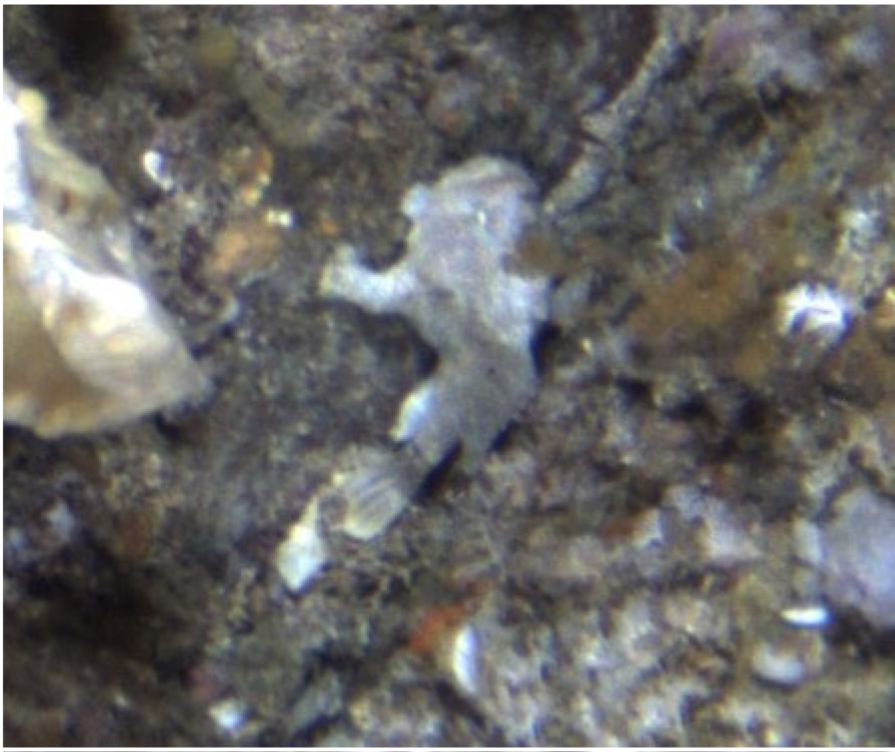
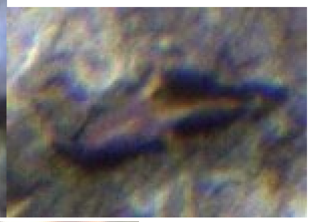


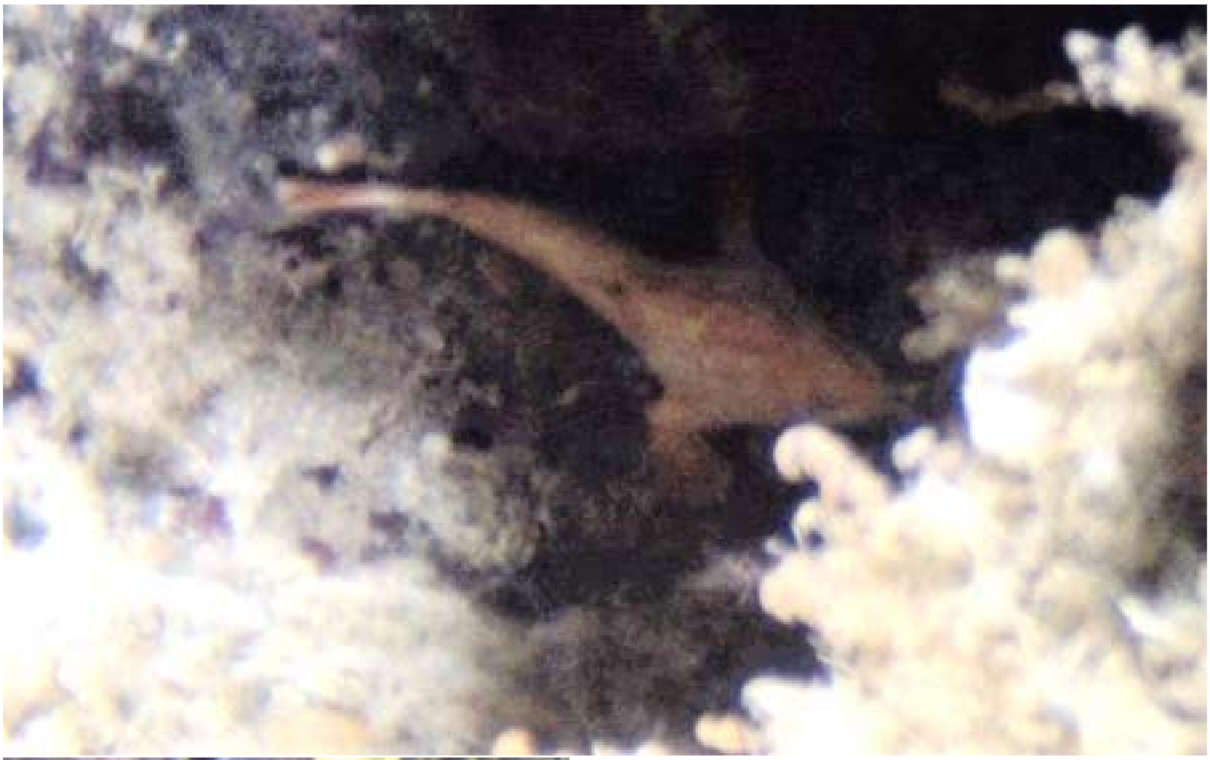
Figure 112. Sand and bryozoan rubble habitat with low cover of bryozoa/hydroid matrix and ocean perch

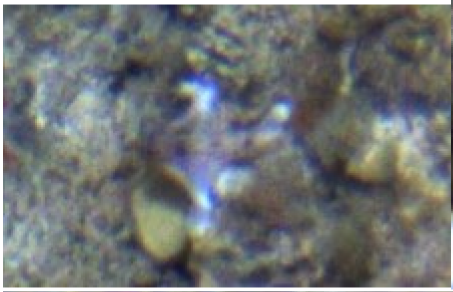
Handfish observed in the Huon Marine Park

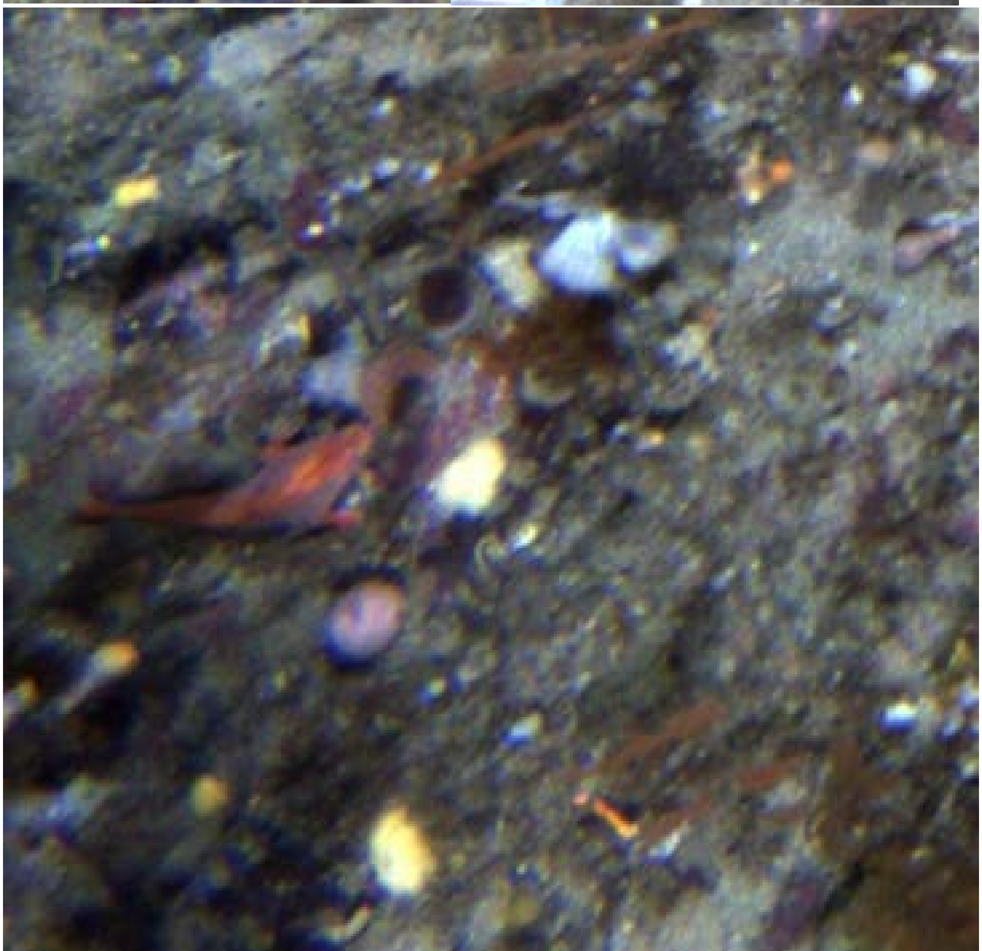


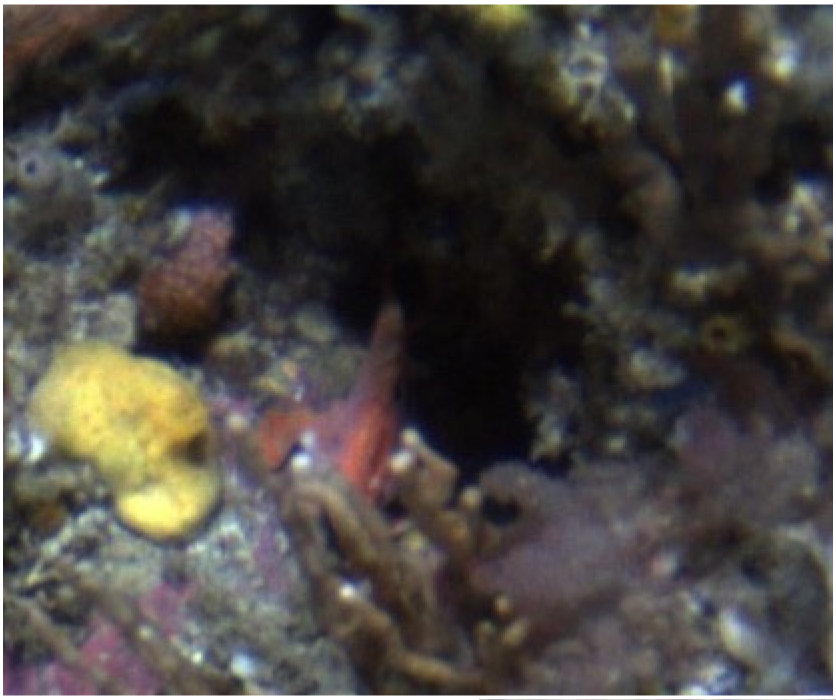




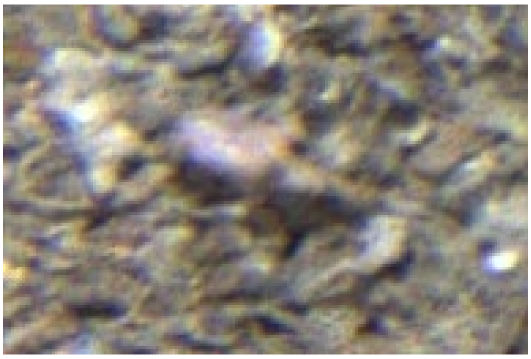








Handfish observed in the Freycient Marine Park

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