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Author
Neville Barrett, Nicholas Perkins, Jacquomo Monk, Justin Hulls, Ashlee Bastiaansen

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Fish assemblages on the continental shelves of Freycinet and Huon Marine Parks: Insights from stereo BRUV and ROV surveys

Nicholas Perkins, Jacquomo Monk, Ashlee Bastiaansen, Justin Hulls, Neville Barrett

Institute for Marine and Antarctic Studies, University of Tasmania

Enquiries should be addressed to:

Dr Jacquomo Monk, Institute for Marine and Antarctic Studies, University of Tasmania.
Email: jacquomo.monk@utas.edu.au

Associate Professor Neville Barrett, Institute for Marine and Antarctic Studies, University of Tasmania.
Email: neville.barrett@utas.edu.au

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Important Disclaimer

Executive summary

Our comprehensive Baited Remote Underwater Stereo Video (stereo BRUV) and Remote Operated Video (ROV) surveys in the Huon and Freycinet Marine Parks (HMP and FMP, respectively) have significantly improved the understanding of the benthic/demersal fish assemblages of shelf to shelf-break habitats in these waters, particularly on mesophotic and rariphotic rocky reefs. Extensive surveys were conducted across different management zones, habitats, and depths, both inside and outside of the FMP and within the HMP. These datasets provide a robust quantitative baseline for monitoring future changes to fish communities and the abundance and size structure of key benthic and demersal fish species in the parks. For the FMP, these allowed for comparison of relative changes between zones (Multiple use Zone – MUZ, and Recreational Use Zone – RUZ), and between the FMP zones and adjacent habitats outside the park. Further, this information provides a solid quantitative reference point to assess the effectiveness of Marine Park zoning in the future, including protection from benthic trawling (both parks) and protection from commercial fishing in the Recreational Use Zone (RUZ) of the FMP.

Importantly, the outcomes from these studies provide robust information on the current abundance and size structure of key recreationally and commercially targeted species, including jackass morwong (*Nemadactylus macropterus*), striped trumpeter (*Latris lineata*) and ocean perch (*Helicolenus percoides*) in both parks, as well as rock lobsters (*Jasus edwardsii*), in the HMP where lobsters were particularly abundant on the complex dolerite reef systems of the inner shelf. For all the targeted species above, there were sufficient individuals recorded and with sufficient length measurements made, to underpin future monitoring programs aimed to detect biologically meaningful change through time and between habitats and park zones.

The most significant patterns in overall fish communities observed within the parks were strongly driven by habitat features rather than zoning. Generally, the distinct reef systems, including Joe's Reef and the shelf-break reefs in the FMP, the extensive inner-shelf reef systems in the HMP, and the complex reef in the northern fished area outside the FMP, all had markedly differing fish communities to the adjacent soft sediments, or the extensive dune-like features found throughout much of the FMP. As Joe's Reef is the only significant complex reef structure in the shelf waters within the MUZ of the FMP, and the only habitat to extend into the mesophotic zone, it is not surprising that it also hosts a unique fish assemblage, characterised by large numbers of planktivorous species like butterfly perch. Likewise, the shelf-break reefs within the MUZ in FMP constituted only a small proportion of reef habitat in this region, but also had distinct communities, including rock lobsters and large numbers of eastern orange perch, that were observed utilising small holes in the mudstone reef on the Remote Operated Vehicle (ROV) transects. Several handfish individuals were also observed on rubble adjacent to these reefs, raising the potential importance of these shelf-break systems to some rare and unique species.

The survey design employed for the stereo BRUV and ROV surveys, which covered both mesophotic (30 - 70 m) and rariphotic (70 – 200 m) depths has allowed quantification of fish communities across important environmental gradients that exist in these Marine Parks, both with respect to depth and key habitat types. In the HMP many species were shown to have strong reef affinity (including striped trumpeter, butterfly perch (*Caesioperca lepidoptera*) and rosy wrasse (*Pseudolabrus rubicundus*)), while others like jackass morwong had a clear reef affinity but were also distributed more widely. Notably though, in the FMP where reef outcrops were rare, the widespread dune-like features that cover most of the rariphotic shelf waters of the park hosted moderate abundances of both striped trumpeter and jackass morwong in places, demonstrating the importance of this distinct habitat type to several commercially targeted species.

As well as establishing a sound baseline for future monitoring, an initial comparison of fish on the shelf was also undertaken between the Multiple Use Zone (MUZ) and the RUZ in the FMP. While some small differences were observed between zones, it appears that most differences observed were primarily driven by habitat rather than protection-related differences within the park. Likewise, a comparison was made between soft bottom habitat inside and outside of the FMP as trawling is not permitted in the FMP. This showed a markedly greater abundance of jackass morwong within similar habitat in the park relative to adjacent fished areas, although in the absence of baseline studies when the park was established, this cannot conclusively be attributed to protection effects.

A key component of this study was to trial the use of a remotely operated vehicle (ROV) to inventory and monitor shelf fish communities across the two AMPs with the aim of comparing to results generated by baited remote underwater stereo-video (stereo BRUV). While ROV-based sampling was primarily targeted at reef communities, the results demonstrate that this quantitative sampling method has a significant role to play in future inventory and monitoring studies. ROV sampling increased the range and number of fish species seen that are not attracted to bait, including rare species such as handfish, as well as providing more fine scale information on species/habitat associations. However, stereo BRUV sampling yielder greater numbers of length measurements per deployment, important when tracking biomass and size structure changes in response to protection levels. Overall, the two methods are highly complementary and would ideally be utilised in initial inventory and baseline studies such as this.

As this study, coupled with prior multibeam mapping programs (Nichol et al. 2009b, Heaney and Davey 2019), has yielded a significant amount of new information on the distribution of fish species and their preferred habitats within both parks, it is important for management agencies such as Parks Australia to be aware of the likely impact of such new knowledge on future fishing pressure. Locations such as Joe's Reef and the shelf-break reef habitat within the Freycinet Marine Park are some examples of spatially constrained high value habitats that may need additional spatial protection in the future if such information drives an increase in use. We note, that from our ROV footage of the shelf-break reef systems we surveyed, there was already an extensive coverage of snagged ropes and fishing lines, due to these systems being spatially small, but high value targets.

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General introduction

The Freycinet and Huon Australian Marine Parks in Commonwealth waters were established in 2007 as part of the wider South-east (SE) Marine Park Network (formally called Commonwealth Marine Reserves). These parks cover a wide range of habitats, ranging from shelf reef and soft sediments to shelf-break and continental slope reef and soft sediments, to abyssal plains. The Huon Marine Park (HMP) also provides protection to offshore seamounts. At the time of their declaration, very little was known of the species and overall habitat distribution in most of the area represented by these parks, hence building the knowledge base was a core component of the initial 10-year management plan for all parks within the SE Network.

For shelf waters, the focus of this study, initial work to improve this knowledge gap was undertaken in both these parks by the Commonwealth Environment Research Facilities (CERF) Marine Biodiversity Hub in association with the National Oceans Office (Now Parks Australia) to trial new multibeam mapping techniques in shelf waters and validate this with both towed video and deployment of the new Integrated Marine Observing System (IMOS) Autonomous Underwater Vehicle (AUV) facility (Nichol et al. 2009b). These initial maps were gradually built upon via occasional transits through shelf waters in these parks by the National Facility vessels RV Southern Surveyor and RV Investigator, as well as through targeted mapping during transits through these parks by the National Environmental Research Program (NERP) and National Environmental Science Program (NESP) Marine Biodiversity Hubs. This latter mapping identified the presence of Joe's Reef in the Freycinet Marine Park (FMP) and characterised the wider extent of apparent drowned coastal dune systems in the FMP, identified during earlier CERF Hub mapping. This information was used to underpin ongoing AUV-based monitoring in both parks (Perkins et al. 2021) building a baseline understanding of the nature of seabed flora and fauna in the region, particularly that associated with reef and "drowned dune" systems on the shelf. More recently, a Parks Australia funded mapping project undertaken by IMAS and CSIRO (Heaney and Davey 2019) significantly expanded the mapped areas in the FMP and HMP. Approximately 80% of the FMP shelf-break reef systems has now been multibeam mapped, hence, knowledge of the extensive coverage of "drowned dune" style habitat in the park that covers most rariphotic shelf depths between 80-120 m has expanded significantly over the life of the park, from a baseline in 2007 where the only mapping was several incidental vessel transits along the shelf. Despite this significant increase in mapped cover, Joe's Reef remains the sole known outcrop of complex high profile (>1m elevation) mesophotic to rariphotic reef on the shelf.

A smaller area of the shelf was mapped in the HMP as part of the recent mapping program (Heaney and Davey 2019) but importantly this extended the previously mapped coverage of known reef in the park completed by the CERF Marine Biodiversity Hub (Nichol et al. 2009a), from mesophotic depths of around 45 m to 65 m, down to the outer margin of coastally-associated rariphotic reef systems in this region at around 100 m depth. It also compliments much lower resolution mapping in the NW corner of the park undertaken by CSIRO in 2006 that also revealed the presence of mesophotic reef outcrops in that area. Together, this work showed that the complex dolerite reef found in earlier CERF Hub mapping continued to approximately 100-120 m depth, before grading to sand out to the shelf-break. While difficult to quantify, we estimate that around 80% of the shelf reef in both mesophotic to rariphotic depths has now been mapped at low to high resolution, based on the combination of targeted mapping and many incidental vessel transits (see: https://seamapaustralia.org/map/#896222fa-fef4-4bb9-8d53-0e6592c0f53d). All this reef appears to be on the inner shelf region of the park. The complexity of this dolerite reef is known to support a significant rock lobster fishery in this sector of the HMP. In late 2019, the RV Investigator mapped parts of the outer shelf and upper shelf-break region of the HMP, demonstrating the absence of shelf break reef in this area, although some likely reef systems were noted on the upper slope at approximately 200-300 m, at or just below the shelf-break depth of around 200 m in this park. Compilation of the multiple vessel transits across the shelf in this region show that it is unlikely that any significant additional reef will be found on the shelf at depths below 120 m, or further offshore than the inner shelf.

By the end of 2019 there was sufficient habitat knowledge to underpin planned demersal/benthic fish assemblage surveys in key shelf habitats within HMP and FMP for the current project to be able to target and adequately sample the range of habitats found within each park, and to do so using spatially-balanced sampling designs to underpin sound quantitative baselines for overall park-wide abundance estimation and for comparison as a part of ongoing monitoring. This survey was therefore planned both as an initial inventory and as a pilot/baseline for potential future park-focussed monitoring. It was designed to enable contrasts with adjacent external fished areas or zones with differing levels of protection within the parks where relevant. Shelf waters within the HMP are designated as multiple use zone (MUZ) where commercial fishing operations, including midwater trawl is permitted. Benthic trawling is not permitted to ensure that the seafloor and associated structures are protected. In the FMP shelf waters, there is a MUZ and a Recreational Use Zone (RUZ) where commercial fishing is prohibited but recreational fishing is allowed.

The aim of this study was to use the conventional baited remote underwater stereo-video (BRUV) technique to i) quantitatively document the demersal fish communities in both parks, ii) examine variation across habitats (e.g., reef, soft-sediments, shelf-break reef) iii) compare fish abundance and assemblage between zones (where applicable), iv) undertake a pilot study to contrast fish communities, abundances, and size structures in the FMP and adjacent external fished areas; and v) compliment the stereo BRUV-based work described above by a trial of remote-operated video (ROV)-based stereo-video transects, to contrast fish communities observed on rocky reef systems by both stereo BRUV and ROV techniques, to evaluate the relative effort required to monitor key species using these methods, and to collect promotional video for use in communication and education products in the future.

The overall objective was to use the information collected during this study to develop an initial quantitative inventory of key natural values in terms of fish populations, identify potential indicator species and determine the sample sizes required to detect significant changes to populations to inform the development of future monitoring programs.

Freycinet Marine Park: Stereo BRUV survey of fish populations

Background and methods

Recreational fishing is allowed in the MUZ and RUZs, but demersal trawling is not permitted. Because demersal trawling in these zones is not permitted it was expected this could have a potential effect on the fish size structure of benthic fish populations that have been previously targeted by demersal trawl fisheries, particularly jackass morwong and flathead species, compared to the external fished areas where demersal trawling still occurs. A second potential effect that may be observed in shelf habitats may occur between the MUZ where midwater commercial and recreational fishing is permitted and the RUZ where only recreational line fishing is permitted. Hence, the experimental designs chosen for these surveys reflect both the need to establish a sound baseline within each park and zone and across key habitat types, as well as establishing the ability to contrast fish assemblages within the parks with external areas through time. As the priority for this study was establishing a robust initial baseline and understanding of fish assemblages within the parks, rather than a contrast with external areas, most of the sampling was undertaken within the parks. Given that the shelf areas of the HMP are open to most fishing activities, the current study did not establish a contrast between the park and adjacent areas. However, as the FMP has an RUZ in addition to the MUZ, a limited amount of sampling effort was also allocated to nearby external habitats to provide an initial contrast of patterns, being aware that the sampling replication in external areas was only sufficient to detect large differences, if present.

Stereo BRUV surveys

Stereo BRUV surveys were conducted between 24 August and 12 October 2021 to provide a baseline description of demersal fish populations and assemblages across the Recreational Use Zone (RUZ; IUCN IV), Multiple Use Zone (MUZ; IUCN VI) and external fished areas of the Freycinet Marine Park (FMP; Figure 1). A total of 288 successful stereo BRUV deployments were completed, comprising 165 drops in the MUZ, 57 in the RUZ, and 66 in external fished areas. Sampling was designed to sample a balance of hard bottom rocky reefs and sediment in each zone and in the external fished areas to fully describe and compare assemblage compositions, abundances and size structures of individual species across different habitats. Canyon-associated reef features along the shelf break across both zones and external fished areas were sampled to describe the assemblages associated with these features. As an add-on to the study, sampling was also conducted across the sediment bottom inside the western boundary of the FMP MUZ in an area that would have previously been subject to demersal trawling, and in an inshore area outside the park where benthic trawling is still permitted and was observed during our sampling program. Additional stereo BRUV drops were targeted on Joe's Reef, a complex granite high relief reef and Patch Reef, a lower relief feature in the MUZ as these were predicted to be fish "hot spots" in the FMP. The breakdown of the 288 deployments across these locations is shown in Table 1 and Figure 1. All stereo BRUV deployments followed standardised protocols outlined in NESP Hub guidelines (Langlois et al. 2020), with one-hour deployments using ~ 800 g of hand crushed pilchards for bait.

Table 1. Locations surveyed with stereo BRUVs and the number of successful stereo BRUV drops across the Freycinet Marine Park.

Location	Number of successful stereo BRUV drops
MUZ Shelf	42
MUZ Canyon	63
MUZ Patch Reef	24
Joe's Reef (MUZ)	24
Trawl AMP (MUZ)	12
RUZ Shelf	51
RUZ Canyon	6
North Northern external fished area (fished)	54
Trawl reference (fished)	12

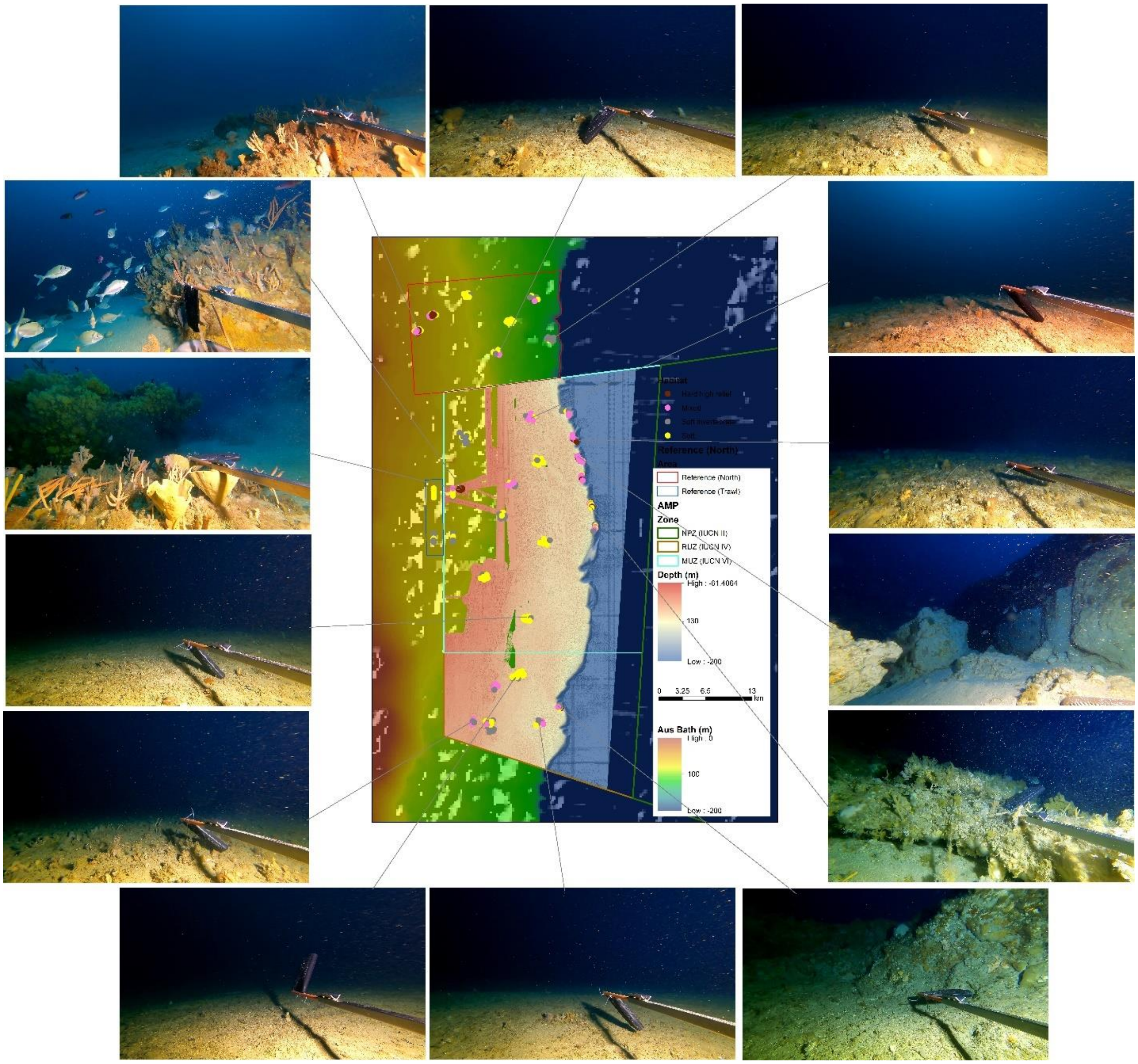


Figure 1. Location of stereo BRUV sampling sites within the Freycinet Marine Park Multiple Use Zone, Recreational Use Zone and the external fished areas outside of the park. The photos provide examples of the diversity of habitats within FMP.

Measures of abundance and fish length

The parameter MaxN was used as the abundance measure for all subsequent abundance analyses and summaries. MaxN is the maximum number of fish of a given species seen in a segment frame of video where all fish can be identified as different individuals. This prevents repeated counting of the same individual and provides a relative index of abundance to allow comparison between sites and times. The lengths of all individuals comprising the MaxN frames were also measured using the stereo imagery in EventMeasure software. Lengths were converted to weights using length-weight coefficients for each species. The visible habitat associated with each stereo BRUV drop was also recorded to include in subsequent analyses. Biomass conversions and data quality checking was completed using CheckEM (https://marine-ecology.shinyapps.io/CheckEM/). Length-frequencies were standardised by the number of drops in each zone (MUZ, RUZ and external fished areas – see Table 2) prior to plotting to allow comparison that takes into account sampling effort.

Comparison of fish abundance and size in external fished areas to within Freycinet MP

To determine if management zoning effects the size-structures of populations of commercially important species we compared findings from the RUZ, MUZ and external fished areas surveyed. Specifically, we compared jackass morwong (*Nemadactylus macropterus*), flathead species (combined, *Platycephalus spp*.), ocean perch (*Helicolenus percoides*), morid cod (combined, *Pseudophycis spp.)* and striped trumpeter (*Latris lineata*) populations which are subject to benthic commercial trawling in the external fished areas. The latter three species usually associate more with reef features so are less likely to have been impacted by historical benthic trawling within the MUZ but are still actively targeted by recreational fishers in the park and by commercial fishers in the MUZ. They were included due to their importance as commercially and recreationally targeted species both inside and outside of the park and to allow comparison with future stereo BRUV surveys conducted in and out of this park and for similar contrasts to patterns observed in other parks within the SE Parks Network.

To examine the potential effect of historical benthic trawl effort on jackass morwong and flathead (combined species) abundance, all trawlable stereo BRUV sites on the shelf both inside and outside the FMP in the external fished areas were included in analyses. Jackass morwong and flathead were chosen as they are a target species for the benthic trawl fishery and were in sufficient abundance for the analyses. Striped trumpeter were considered for analysis, but were not in sufficient abundance when considering the subset of trawlable sites. All stereo BRUV drops on targeted soft sediment were included, rocky reef sites were excluded including Joe’s Reef, the reef features in the northern external fished area, the shelf break sites, and an area including reef in the patch reef in the RUZ. In total 150 stereo BRUV drops were included in this analysis, with 42 drops in outside fished areas, 30 in the RUZ and 78 in the MUZ. For this analysis, all 108 stereo BRUV drops inside the FMP were treated as “protected” from trawling, whereas the reference outside drops were “unprotected”. The binary effect of protection was included as a factor to assess any significant differences in the abundance, mean length, and abundance of large fish (> 250 mm, for jackass morwong only). The abundance of large fish analysis was not completed for flathead as combined species were used due to the small sample size, and the different species have markedly differing size ranges.

Results

Distribution of habitats validated during stereo BRUV and ROV surveys

As discussed previously, approximately 75-80% of the shelf area of the FMP has now been surveyed by multibeam sonar (Figure 2) and this study provided the opportunity to visually validate some of the habitat features inferred from the sonar data. Only one significant reef feature (Joe's Reef) on the shelf within the park, a large 200x200 m granite structure rising from 80 m to 60 m in the western margin of the MUZ (Figure 2) has been identified from this mapping so far. That proved to be both structurally complex from the imagery acquired here, and with a significant cover of attached invertebrate cover. Anecdotal evidence from local fishermen, coupled with imagery collected by stereo BRUV-based validation in this study has also shown the presence of lower-profile and fragmented/isolated reef in the NW sector of the MUZ in approximately 80 m, in an area yet to be mapped by multibeam sonar (Figure 2). However, this is nowhere near the complexity of reef found at Joe's Reef or in the more extensive region to the north of the park where we undertook the reference stereo BRUV deployments. Other small, isolated, low-profile reef fragments (presumed to be limestone pavement) appear to be scattered throughout the shelf waters of the park associated with "dune-like" features that were identified in the bathymetry, and were occasionally seen in stereo BRUV footage, explaining the presence of reef-associated species in otherwise sandy habitat, but these were typically too small to be evident in the multibeam data, at least when gridded at 2x2m scale (Figure 2). More distinct reef features were evident at multiple locations at and immediately below the shelf-break, presumably scoured of sand cover by currents associated with shelf-intrusions of adjacent canyons (Figure 2). Imagery from both stereo BRUV and ROV indicates that these are primarily steep mudstone ledges/cliffs, without significant reef complexity. Example imagery of characteristic habitats from both stereo BRUV and ROV footage is provided in the Appendix.

Notable conspicuous dune-like features intermediate between reef and soft sediment were observed during stereo BRUV and ROV surveys. These cover much of the shelf water between 80 to 120 m are orientated north to south, parallel to the coast and rise and fall approximately 5 m in height over 50 m scales across-shelf. They are presumed to be relic glacial coastal dune features that have consolidated and been drowned following the last glacial period. Despite this likely consolidation, hard-rock outcropping was rarely evident, and they were usually covered in at least a fine layer of sand/silt. These dune-like features, however, were clearly differentiated from nearby soft sediments by the presence of emergent fauna such as small sponges and bryozoan/hydroid turf matrix, and the absence of distinct sand rippling. Adjacent soft sediments usually are rippled and contain notably less emergent fauna. This habitat is absent of complex habitat required by many reef species, so it is likely to have been trawled historically as it resembles soft sediments in many ways, and typically had a fish fauna closer to soft sediments than rocky reef.

The final major habitat component in the FMP is soft sediment as identified using all available bathymetric data (see Figure 2). Pure soft sediment habitat appears to be mostly predominant in the inner, western margin of the park at depths from approximately 70 m to 80 m. This is evident as areas of low-profile seabed in habitat mapping, without the characteristic dune features of the habitat described above. Similar habitat exists on the outer margin of the shelf, presumably below historical coastal depths and in places burying the dune features described above.

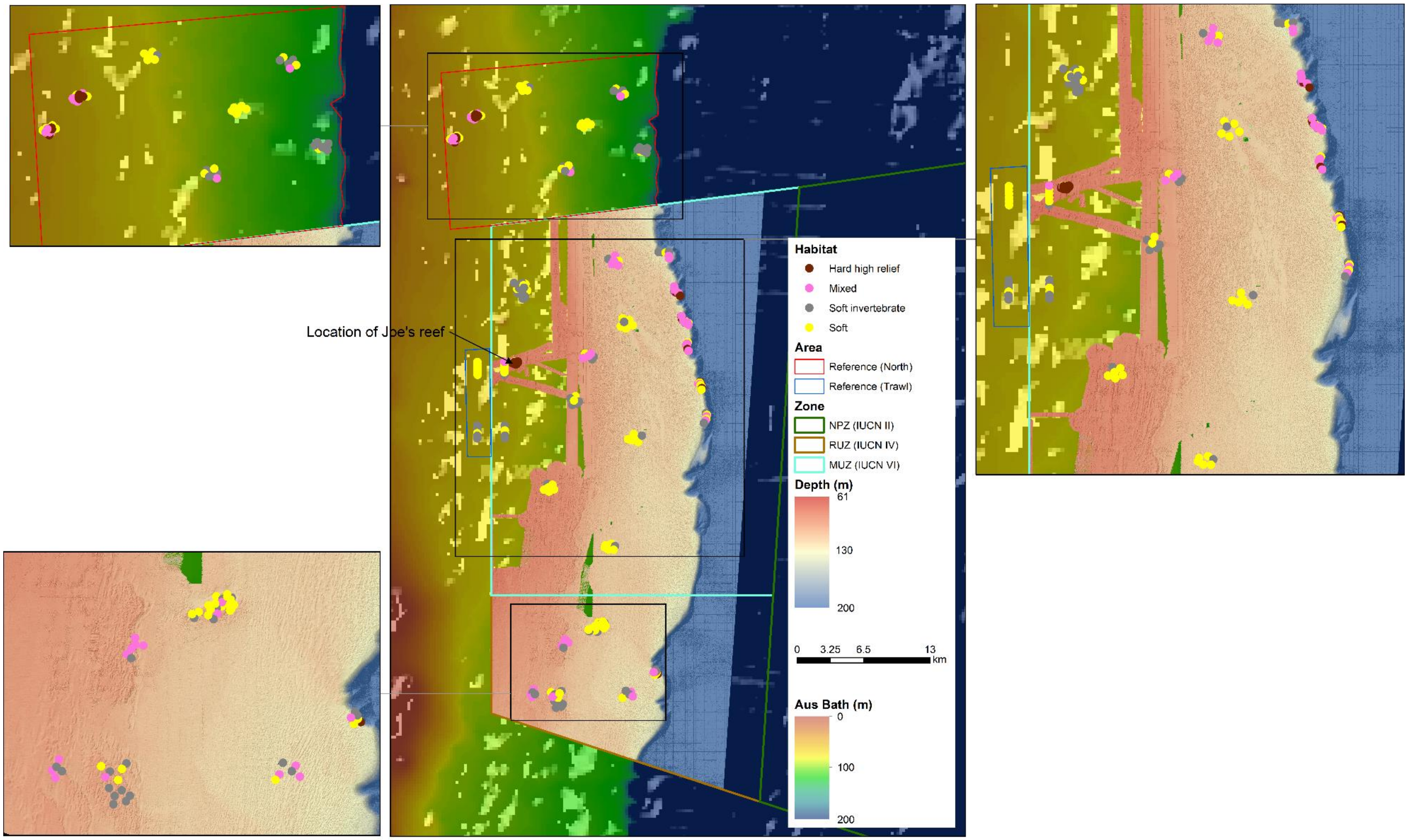


Figure 2. Distribution of habitats observed on stereo BRUVs..

Stereo BRUVs data: General description

A total MaxN of 9841 fish and 65 species (or species identifiable to genera/family only) were observed over 288 successful stereo BRUV drops, excluding baitfish and mackerel species (Table 2). Dominant species included jackass morwong, ocean perch, butterfly perch, splendid perch, and cosmopolitan leatherjacket (especially in the external fished areas). There were a wide range of species seen across all zones, with species associated with both soft sediments and rocky reef found within each zone. More soft sediment associated species were observed in FMP than other South-east Marine Parks sampled to date, in part due to the targeted sampling of soft sediment habitats, and mostly due to the much larger extent of soft sediment habitats sampled in the FMP compared to elsewhere, where stereo BRUV surveys have typically been reef focussed.

Important commercially and recreationally fished species observed included striped trumpeter, a variety of flathead species, jackass morwong and morid cod species (Table 2). Example imagery of species observed in stereo BRUV videos is provided in the Appendix. Striped trumpeter were typically found associated with significant habitat structure, such as the shelf-break reefs and Joe's Reef in the MUZ, and the reef outcrops in the northern fished reference sites external to the park. Overall, abundance was similar between the MUZ and the northern fished reference sites, but was lower in the RUZ, presumably due to a lack of suitable reef-like habitat. Flathead were distributed across all zones surveyed, although with higher observed numbers on the sandy "benthic trawled" habitat inshore of the park boundary. There was marked difference in distributions of individual flathead species, with these likely driven by depth and habitat preferences. Jackass morwong were found across all zones and habitats, but were noted to be particularly abundant adjacent to or on reef habitats irrespective of zoning, particularly on complex reef such as Joe's Reef and the shelf-break reefs. In comparable habitat, the cross-shelf dune features, abundances were approximately double in the RUZ compared to the MUZ. Morid cod were also found across all zones, and like jackass morwong and striped trumpeter, were mostly associated with significant reef features such as Joe's Reef and the shelf-break reef systems, hence differences in abundance between the various levels of protection was driven more by habitat differences between areas rather than types and levels of protection.

Of note, a single handfish was observed (but unable to be identified to species because of poor image resolution) in the northern external fished area, and a relatively high abundance of shark species were observed in the FMP in general, including broadnose seven gill sharks, draughtboard sharks, gummy sharks, and spikey dogfish (Table 2).

Table 2. List of species observed and counts across each zone in stereo BRUV drops in Freycinet Marine Park.

Family	Scientific name	Common Name	IUCN IV (RUZ) Canyon	IUCN IV (RUZ) Shelf	IUCN VI (MUZ) Canyon	IUCN VI (MUZ) Patch reef	IUCN VI (MUZ) Shelf	Joes reef (MUZ)	North Reference	Trawl AMP (MUZ)	Trawl Ref.
	Number of stereo BRUV drops		6	52	63	24	42	24	54	12	12
Berycidae	*Centroberyx affinis*	Redfish	0	0	0	0	0	0	1	0	0
Berycidae	*Centroberyx spp*	Redfish spp.	0	0	1	0	0	0	0	0	0
Brachionichthyidae	*Brachionichthyidae spp*	Handfish spp	0	0	0	0	0	0	1	0	0
Callanthiidae	*Callanthias australis*	Splendid perch	1	0	49	1	0	182	237	0	0
Callionymidae	*Callionymidae sp*	Dragonet sp.	0	0	0	1	0	0	0	0	0
Callorhinchidae	*Callorhinchus milii*	Elephantfish	0	0	0	0	0	0	0	1	0
Centrolophidae	*Seriolella brama*	Blue warehou	0	0	1	0	0	0	0	0	0
Cheilodactylidae	*Nemadactylus douglasii*	Grey morwong	0	0	0	0	0	0	8	0	0
Cheilodactylidae	*Nemadactylus macropterus*	Jackass morwong	266	415	2161	633	159	1633	715	113	20
Cyttidae	*Cyttus australis*	Sliver dory	0	2	9	1	3	1	11	0	0
Dasyatidae	*Bathytoshia brevicaudata*	Smooth stingray	0	0	0	0	0	0	1	0	0
Dinolestidae	*Dinolestes lewini*	Longfin pike	0	0	0	0	0	0	7	0	0
Gempylidae	*Thyrsites atun*	Barracouta	0	0	0	0	0	0	0	0	5
Gerreidae	*Parequula melbournensis*	Silverbelly	0	0	0	0	0	0	13	0	0
Hexanchidae	*Notorynchus cepedianus*	Broadnose sevengill shark	0	2	0	0	3	0	0	0	0
Labridae	*Pseudolabrus rubicundus*	Rosy wrasse	0	0	0	1	0	40	25	0	0
Latridae	*Latris lineata*	Striped trumpeter	3	7	79	1	8	47	66	0	0
Macroramphosida	*Notopogon lilliei*	Crested bellowsfish	14	0	4	0	0	0	0	0	0
Monacanthidae	*Acanthaluteres vittiger*	Toothbrush leatherjacket	0	1	0	0	0	0	0	0	0
Monacanthidae	*Eubalichthys cyanoura*	Bluetail leatherjacket	0	0	0	0	0	1	0	0	0
Monacanthidae	*Eubalichthys gunnii*	Gunn's leatherjacket	0	0	1	0	0	0	2	0	0

Monacanthidae	*Meuschenia australis*	Brownstriped leatherjacket	0	0	0	0	0	0	7	0	0
Monacanthidae	*Meuschenia freycineti*	Sixspine leatherjacket	0	0	0	0	0	0	1	0	0
Monacanthidae	*Meuschenia scaber*	Cosmopolitan leatherjacket	0	11	0	6	20	23	190	2	1
Monacanthidae	*Thamnaconus degeni*	Degen's leatherjacket	0	4	0	0	0	2	8	0	2
Moridae	*Lotella rhacina*	Rock cod	0	0	1	0	0	8	11	0	0
Moridae	*Pseudophycis bachus*	Red cod	3	7	35	3	0	75	28	0	0
Moridae	*Pseudophycis barbata*	Southern codling	0	2	23	6	2	48	35	0	1
Moridae	*Pseudophycis spp*	Cod spp.	0	5	0	0	0	40	0	0	0
Mullidae	*Upeneichthys vlamingii*	Bluespotted goatfish	0	0	0	0	0	0	5	0	0
Neosebastidae	*Neosebastes scorpaenoides*	Common gurnard perch	1	22	5	24	17	5	20	10	18
Paraulopidae	*Paraulopus nigripinnis*	Blacktip cucumberfish	0	2	3	9	14	0	1	27	9
Pempherididae	*Pempheris multiradiata*	Bullseye	0	0	0	0	0	0	31	0	0
Pinguipedidae	*Parapercis allporti*	Barred grubfish	0	34	13	76	40	1	38	48	21
Platycephalidae	*Platycephalus aurimaculatus*	Toothy flathead	0	23	8	5	22	0	21	4	10
Platycephalidae	*Platycephalus bassensis*	Sand flathead	0	0	0	5	2	0	7	3	38
Platycephalidae	*Platycephalus richardsoni*	Tiger flathead	0	1	4	0	13	0	1	2	2
Platycephalidae	*Platycephalus spp*	Flathead spp.	0	0	0	0	12	0	2	0	0
Rajidae	*Dentiraja lemprieri*	Thornback skate	0	0	0	0	0	0	0	1	0
Rajidae	*Dipturus cerva*	Whitespotted skate	1	0	0	0	0	0	0	0	1
Rajidae	*Spiniraja whitleyi*	Melbourne skate	0	4	5	0	1	1	3	0	3
Scorpaenidae	*Scorpaena papillosa*	Southern red scorpionfish	0	0	0	0	0	5	0	0	1
Scyliorhinidae	*Asymbolus rubiginosus*	Orange spotted catshark	4	33	6	2	5	0	3	2	0
Scyliorhinidae	*Asymbolus sp*	Catshark sp.	0	0	0	0	1	0	0	0	0
Scyliorhinidae	*Cephaloscyllium laticeps*	Draughtboard shark	2	5	3	5	8	1	7	2	4
Scyliorhinidae	*Figaro boardmani*	Sawtail catshark	0	0	6	0	0	0	1	0	0
Sebastidae	*Helicolenus percoides*	Ocean perch	38	28	155	66	11	164	170	1	3

Serranidae	*Caesioperca lepidoptera*	Butterfly perch	0	0	23	0	0	304	235	0	0
Serranidae	*Caesioperca spp*	Perch spp	0	0	6	0	0	0	0	0	0
Serranidae	*Hypoplectrodes maccullochi*	Halfbanded seaperch	0	0	1	0	0	0	0	0	0
Serranidae	*Hypoplectrodes sp. (nsw)*	Seaperch sp.	0	0	1	0	0	0	0	0	0
Serranidae	*Lepidoperca pulchella*	Eastern orange perch	6	0	67	0	0	3	1	0	0
Serranidae	*Plectranthias maculicauda*	Spot-tail perchlet	0	0	1	0	0	0	0	0	0
Sphyraenidae	*Sphyraena novaehollandiae*	Snook	0	0	0	0	0	0	2	0	0
Squalidae	*Squalus acanthias*	Whitespotted dogfish	0	1	0	0	1	0	0	0	0
Squalidae	*Squalus megalops*	Spikey dogfish	0	12	0	9	15	0	9	12	9
Syngnathidae	*Solegnathus spinosissimus*	Spiny pipehorse	0	0	0	0	2	0	0	0	0
Trachichthyidae	*Paratrachichthys macleayi*	Sandpaper fish	0	0	42	0	0	1	22	0	0
Triakidae	*Mustelus antarcticus*	Gummy shark	0	4	2	5	2	0	6	6	4
Triglidae	*Chelidonichthys kumu*	Red gurnard	0	0	0	0	3	0	0	0	0
Triglidae	*Lepidotrigla mulhalli*	Roundsnout gurnard	0	0	0	0	0	0	2	0	0
Triglidae	*Lepidotrigla spp*	Gurnard spp	0	0	1	0	0	0	1	0	0
Triglidae	*Lepidotrigla vanessa*	Butterfly gurnard	0	0	0	0	1	0	0	0	0
Triglidae	*Pterygotrigla polyommata*	Latchet	0	2	5	1	1	0	0	0	0
Urolophidae	*Trygonoptera testacea*	Common stingaree	0	0	1	0	0	0	0	0	0
Urolophidae	*Urolophus cruciatus*	Banded stingaree	0	1	0	0	0	0	0	0	0
										Total	9841

BRUVs data: Size-frequency distributions and abundance maps

Jackass morwong

Length-frequency distributions for jackass morwong indicated that there was a higher proportion of legal-size fish (> 250 mm) in the RUZ (81% of fish > 250 mm) compared to both the MUZ and external fished area which both had 57% of fish > 250 mm (Figure 3). Mean size in the MUZ was 269 mm, with minimum size 35 mm and maximum size 548 mm. Mean size in the RUZ was 290 mm, with minimum size 165 mm and maximum size 524 mm. Mean size in the external fished areas was 256 mm, with minimum size 47 mm and maximum size 530 mm.

All areas displayed bi-modal distributions, with this being especially evident in the MUZ, likely indicating different cohorts present in the populations surveyed in those areas.

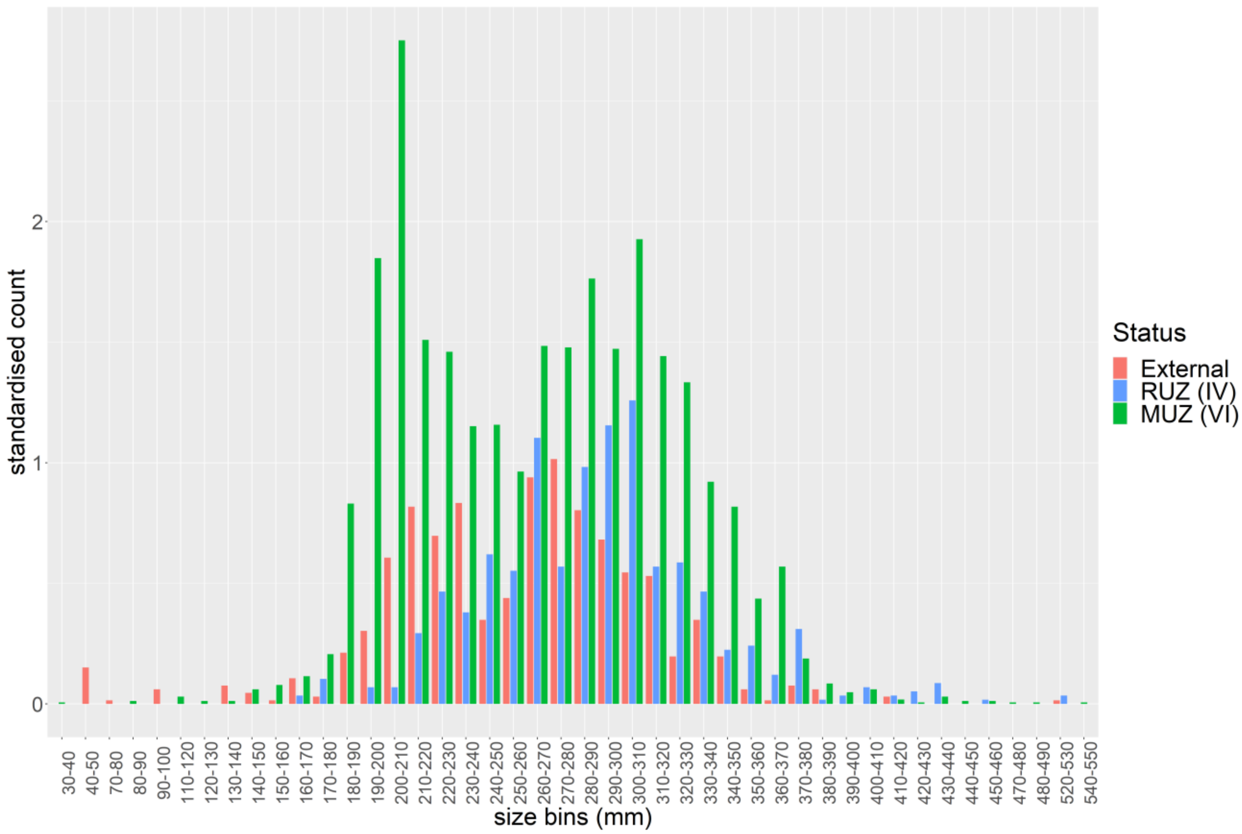


Figure 3. Size-frequency distribution for jackass morwong across Freycinet Marine Park Multi-Use Zone (MUZ), Recreational-Use Zone (RUZ) and external fished areas. Counts have been standardised by the number of stereo BRUV drops in each zone.

Jackass morwong were distributed over many of the sampled stereo BRUV locations across FMP, including shelf sites which are sediment dominated (Figure 4). Although higher abundance areas were typically reef-associated, including Joe's Reef, the northern patch reef and the canyon shelf break areas.

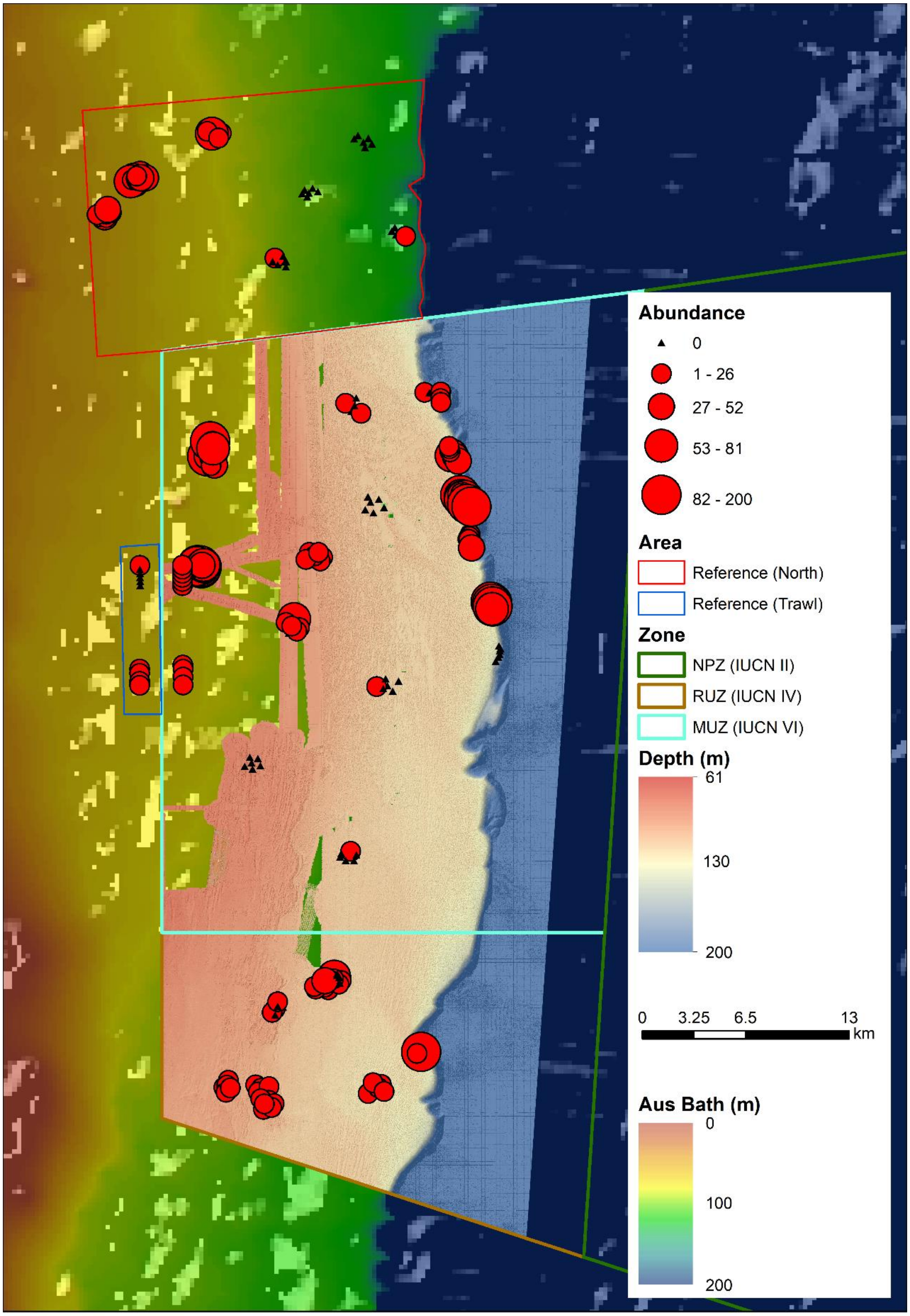


Figure 4. Abundance distribution of Jackass morwong.

Flathead species (combined)

The overall abundance of combined flathead species was not sufficient to draw robust conclusions about the differences in size distributions between management zones and external fished areas (Figure 5). Mean size in the MUZ was 441 mm with a minimum size of 270 mm and a maximum size of 612 mm. Mean size in the RUZ was 443 mm with a minimum size of 344 mm and a maximum size of 530 mm. Mean size in the external fished areas was 382 mm with a minimum size of 240 mm and a maximum size of 557 mm. Thus, current data suggests a higher abundance of smaller size-classes in the external fished areas outside the park. It should be noted however, that this is for combined species, and that the individual species observed have differing maximum sizes.

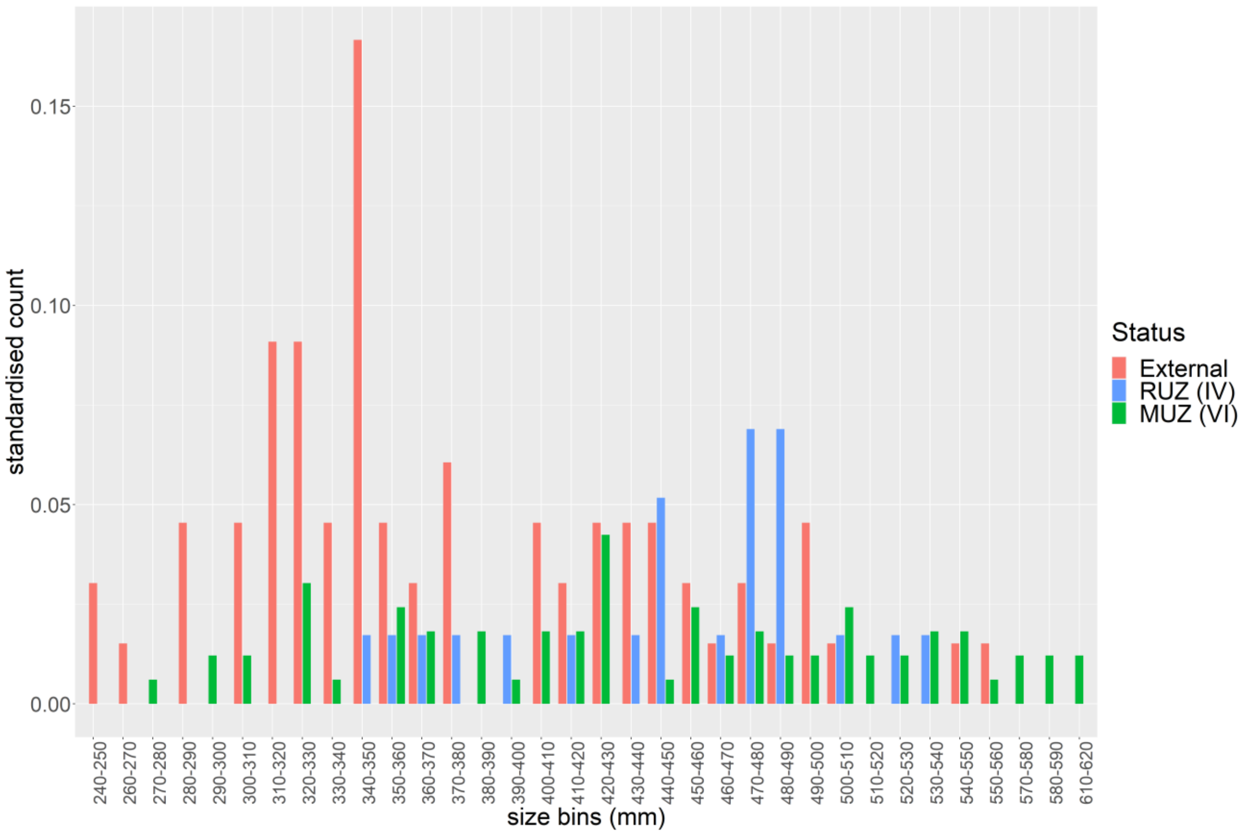


Figure 5. Size-frequency distribution for flathead species (combined) across Freycinet Marine Park Multi-Use Zone (MUZ), Recreational-Use Zone (RUZ) and external fished areas. Counts have been standardised by the number of stereo BRUV drops in each zone.

Individual flathead species were mainly associated with shelf sites on soft sediments, but also on sediment dominated sites in close proximity to reef (Figure 6). Toothy flathead (*P. aurimaculatus*) were the most common and widely distributed across the shelf. Tiger flathead (*P. richardsoni*) were also found across the shelf to the shelf breaks, but predominantly in the MUZ and in lower numbers. Sand flathead (*P. bassensis*) were only found in shallower shelf stereo BRUV sites in the MUZ and the trawl reference (to the west of the park boundary) and northern reference sites. Being a smaller species, this may partly account for the greater abundance of smaller flathead in the external fished areas sampled.

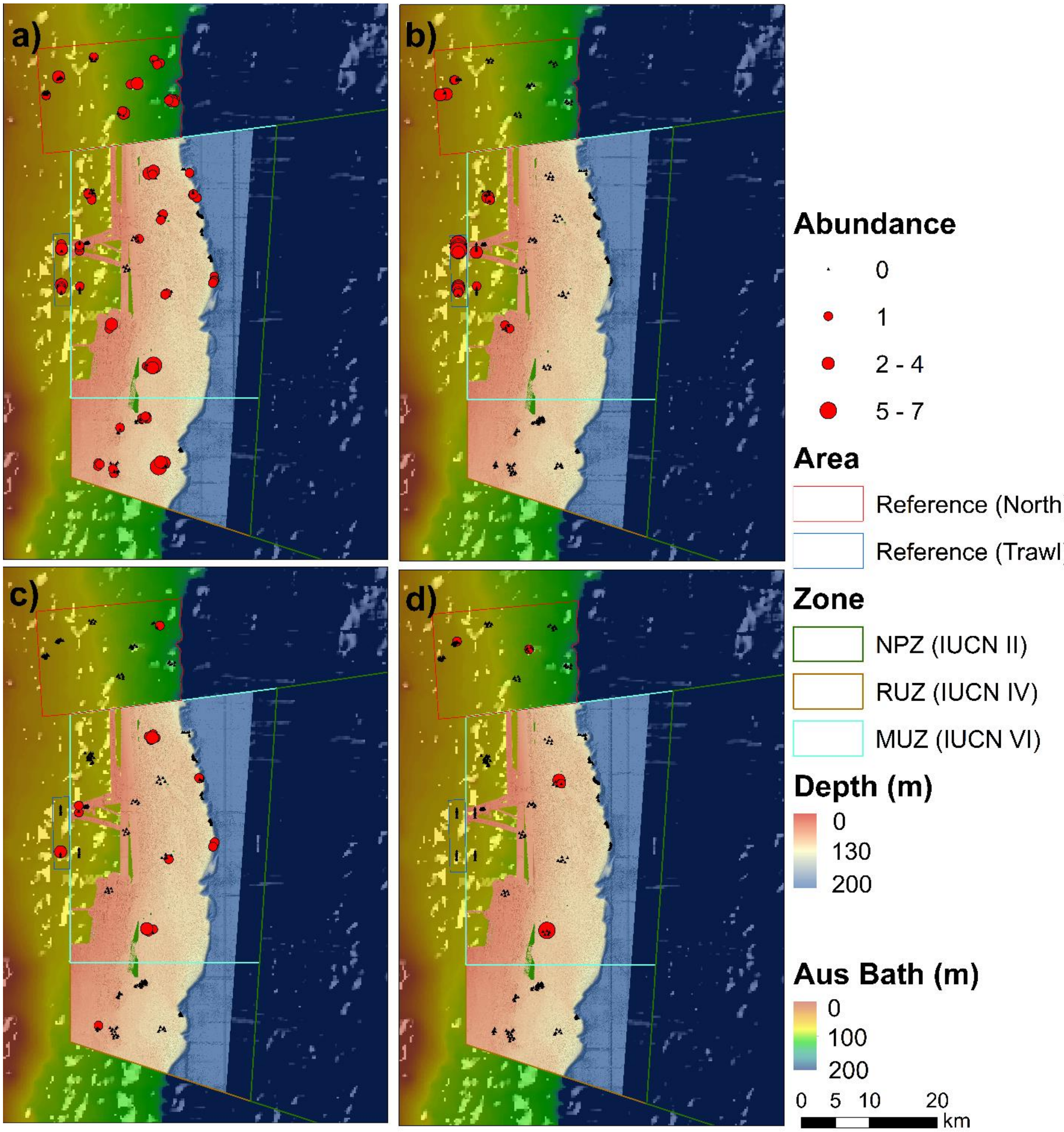


Figure 6. Abundance distribution for flatheads. a) P. aurimaculatus, b) P. bassensis, c) P. richardsoni, d) unidentifiable flathead.

Ocean perch

Size distributions of ocean perch in each zone showed a roughly normal distribution (Figure 7). Mean size in the MUZ was 193 mm with a minimum size of 33 mm and a maximum size of 325 mm. Mean size in the RUZ was 188 mm with a minimum size of 34 mm and a maximum size of 335 mm. Mean size in the external fished areas was 212 mm with a minimum size of 54 mm and a maximum size of 385 mm. Thus, size distributions within FMP and the external fished areas were similar. Sample sizes across the size spectrum were relatively small.

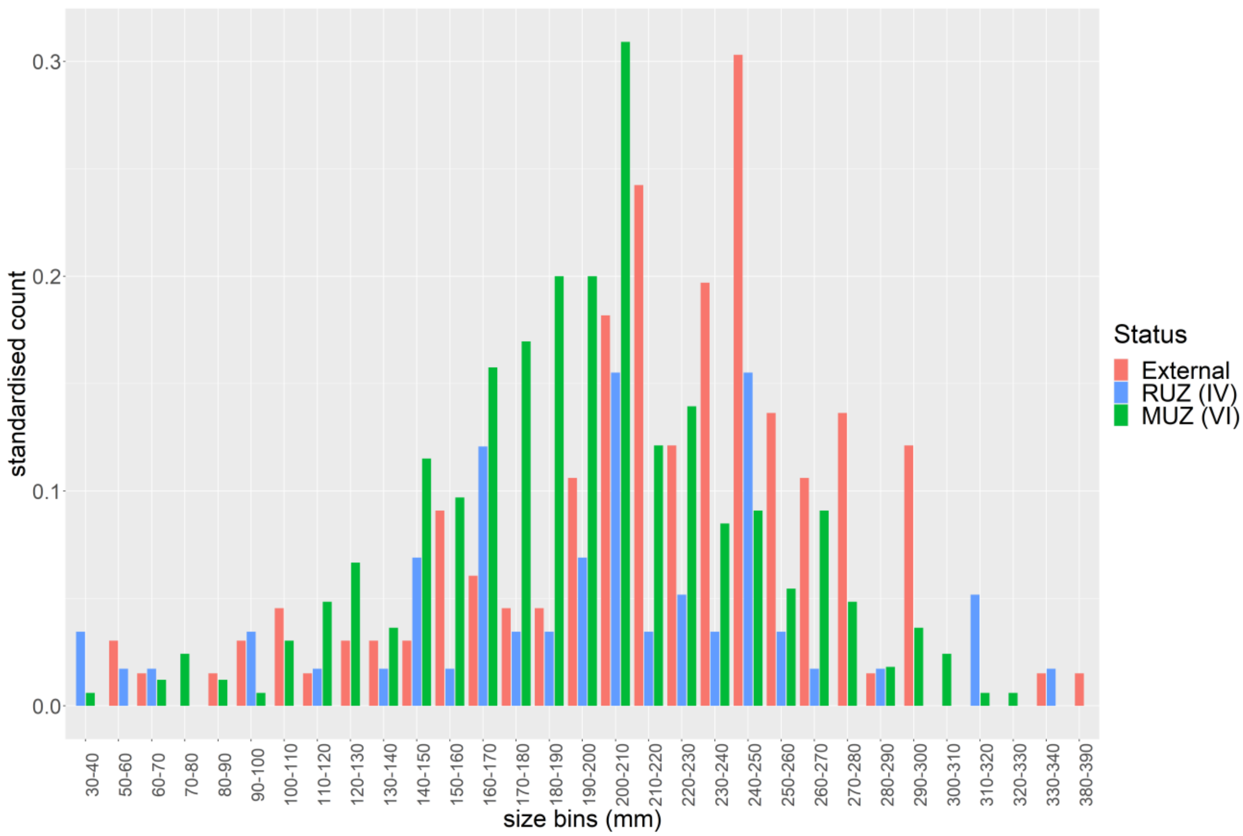


Figure 7. Size-frequency distribution for ocean perch across Freycinet Marine Park Multi-Use Zone (MUZ), Recreational-Use Zone (RUZ) and external fished areas. Counts have been standardised by the number of stereo BRUV drops in each zone.

Ocean perch were widely distributed and predominantly associated with reef features such as Joe's Reef, the northern patch reef, reef sections of the northern reference site and shelf break canyon sites in the MUZ (Figure 8). However, reasonable abundances (typically maxN's of ~5-20 fish per stereo BRUV deployment) were observed in shelf stereo BRUV sites in the RUZ, many of which are "hummocky" sediment habitats which appear to support fishes such as ocean perch which are typically rocky reef associated.

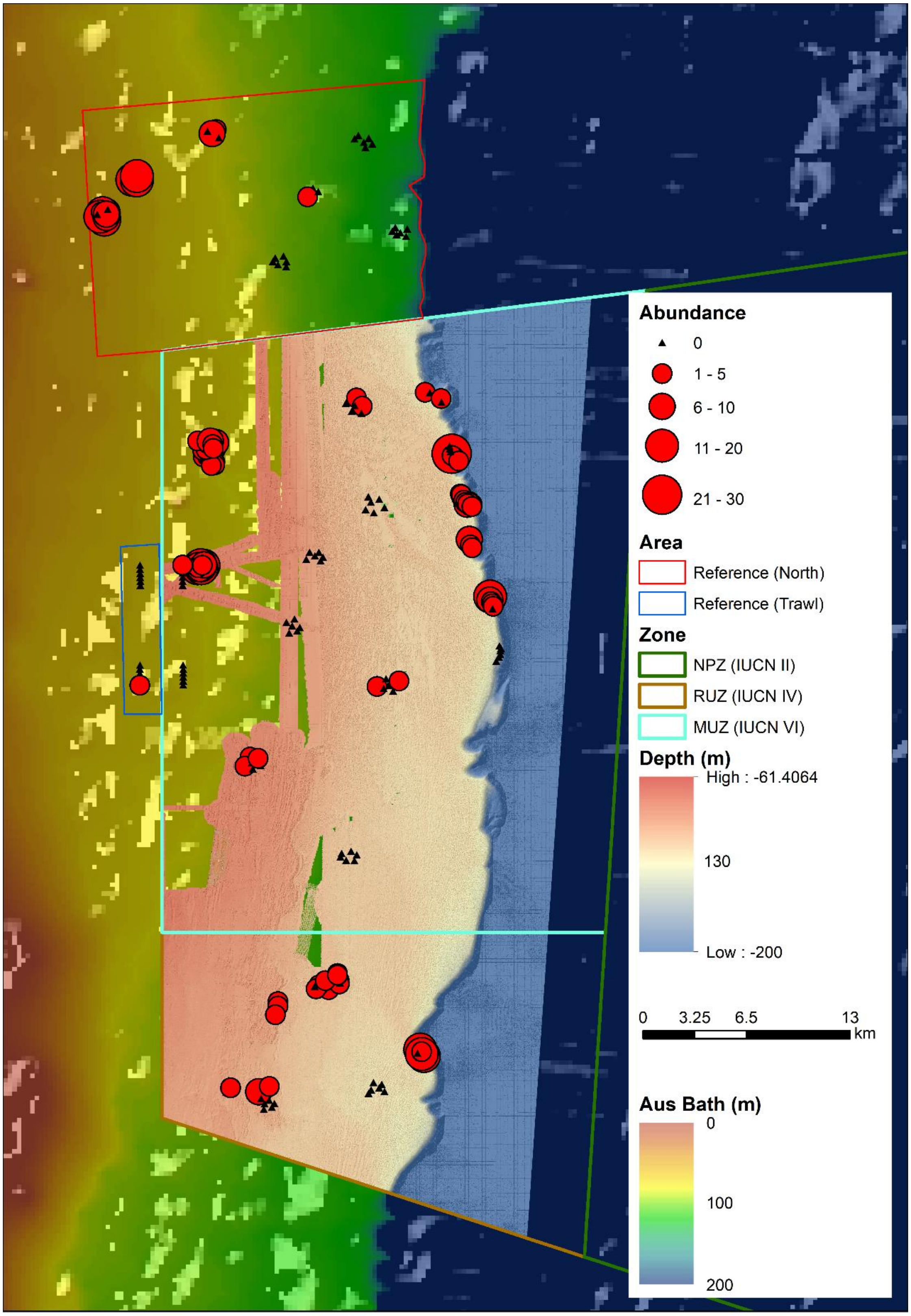


Figure 8. Abundance distribution of ocean perch.

Morid cod (combined species)

Morid cod species (combined *Pseudophycus* species) displayed a reduced range of size in the RUZ, with less small and large size classes compared to the MUZ and external fished areas (Figure 9). Mean size in the MUZ was 364 mm with a minimum size of 198 mm and a maximum size of 613 mm. Mean size in the RUZ was 372 mm with a minimum size of 316 mm and a maximum size of 422 mm. Mean size in the external fished areas was 398 mm with a minimum size of 236 mm and a maximum size of 500 mm. The reduced size range and overall abundance in the RUZ is likely driven by the absence of reef or reef-like habitat in the RUZ relative to the MUZ and external fished areas, as these species displayed a strong preference for structured habitats, particularly for larger sized individuals.

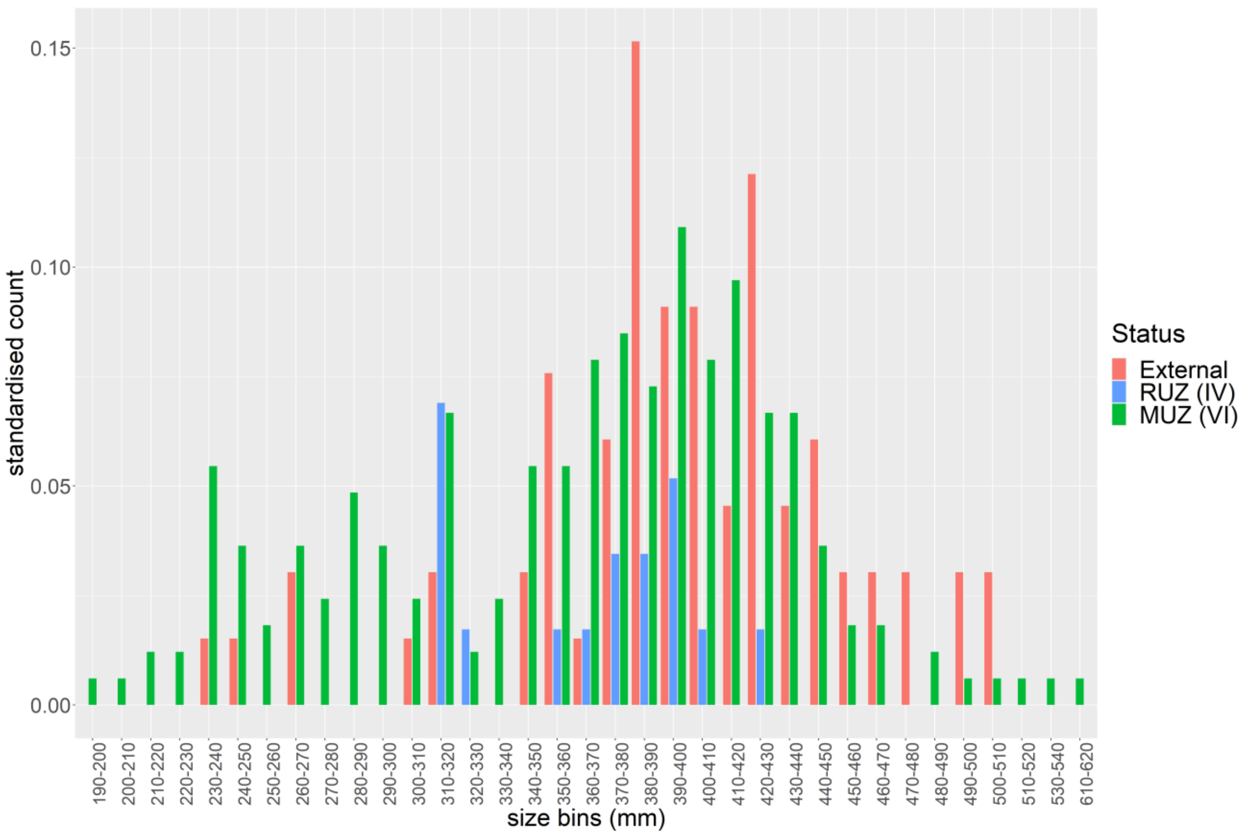


Figure 9. Size-frequency distribution of morid cod (combined species) across Freycinet Marine Park Multi-Use Zone (MUZ), Recreational-Use Zone (RUZ) and external fished areas. Counts have been standardised by the number of stereo BRUV drops in each zone.

Morid cod were distributed widely across the shelf in stereo BRUV drops on or close to reef features such as Joe's Reef, the northern external fished area, reef sections of the northern reference site and shelf break canyon sites in the MUZ (Figure 10). However, morid cod were also observed in shelf sites in the RUZ that are sediment dominated indicating that there are nearby features there that support this reef associated species.

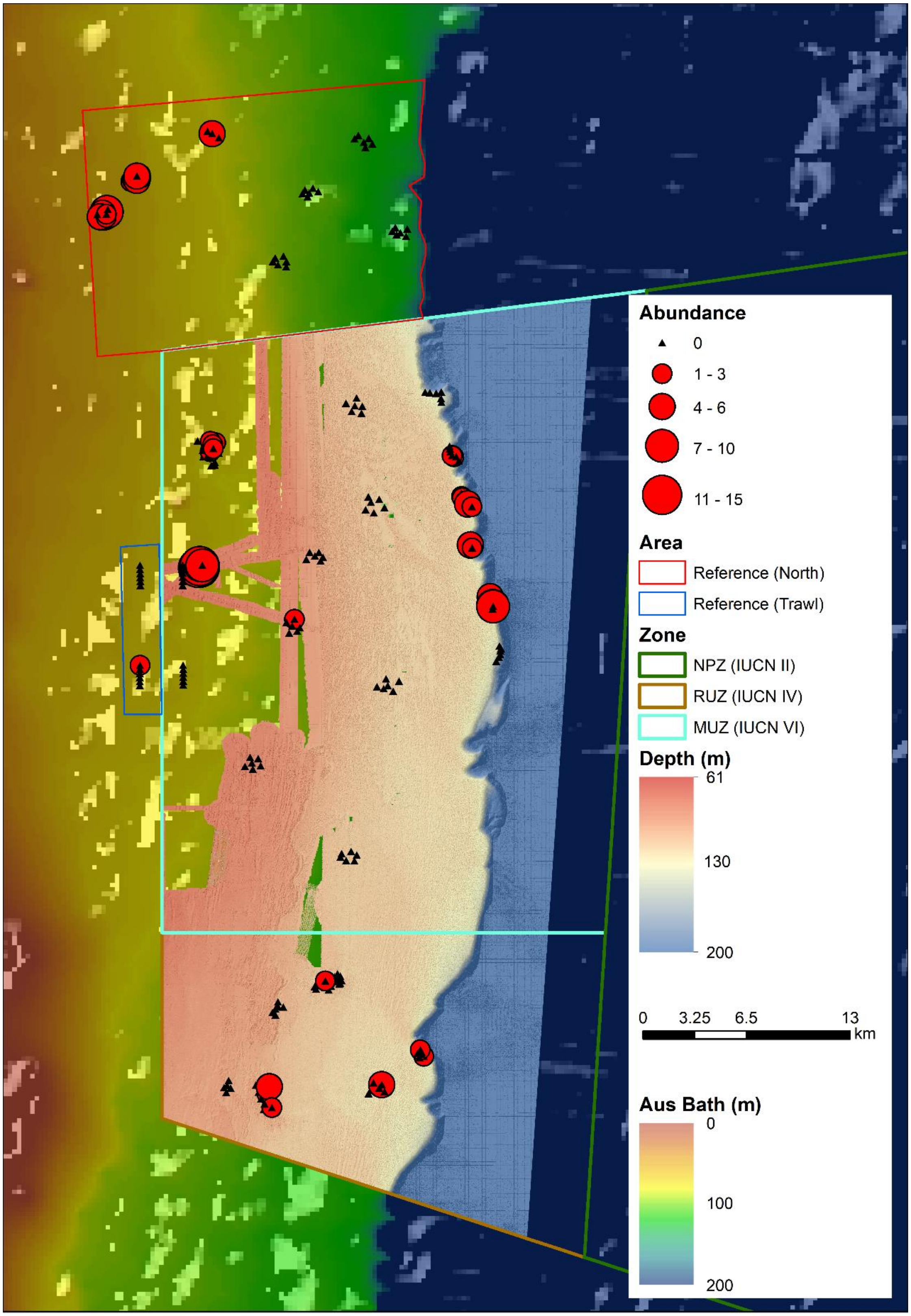


Figure 10. Abundance distribution of morid cods.

Striped trumpeter

Striped trumpeter sample sizes across the size spectrum were relatively low, making robust conclusions regarding any differences in size-structure between management zones within the park and the external fished areas problematic. However, the proportion of larger size classes (> 55 cm, the legal minimum-size limit) in the RUZ was 11%, which was lower than both the MUZ (38%) and external fished areas (23%) (Figure 11). Mean size in the MUZ was 536 mm with a minimum size of 366 mm and a maximum size of 915 mm. Mean size in the RUZ was 458 mm with a minimum size of 394 mm and a maximum size of 581 mm. Mean size in the external fished areas was 508 mm with a minimum size of 352 mm and a maximum size of 773 mm. Again, like ocean perch, patterns may be strongly driven by the relative absence of reef or reef-like features in the RUZ relative to the MUZ and external fished areas, as this species prefers reef-like habitats over un-differentiated soft sediments.

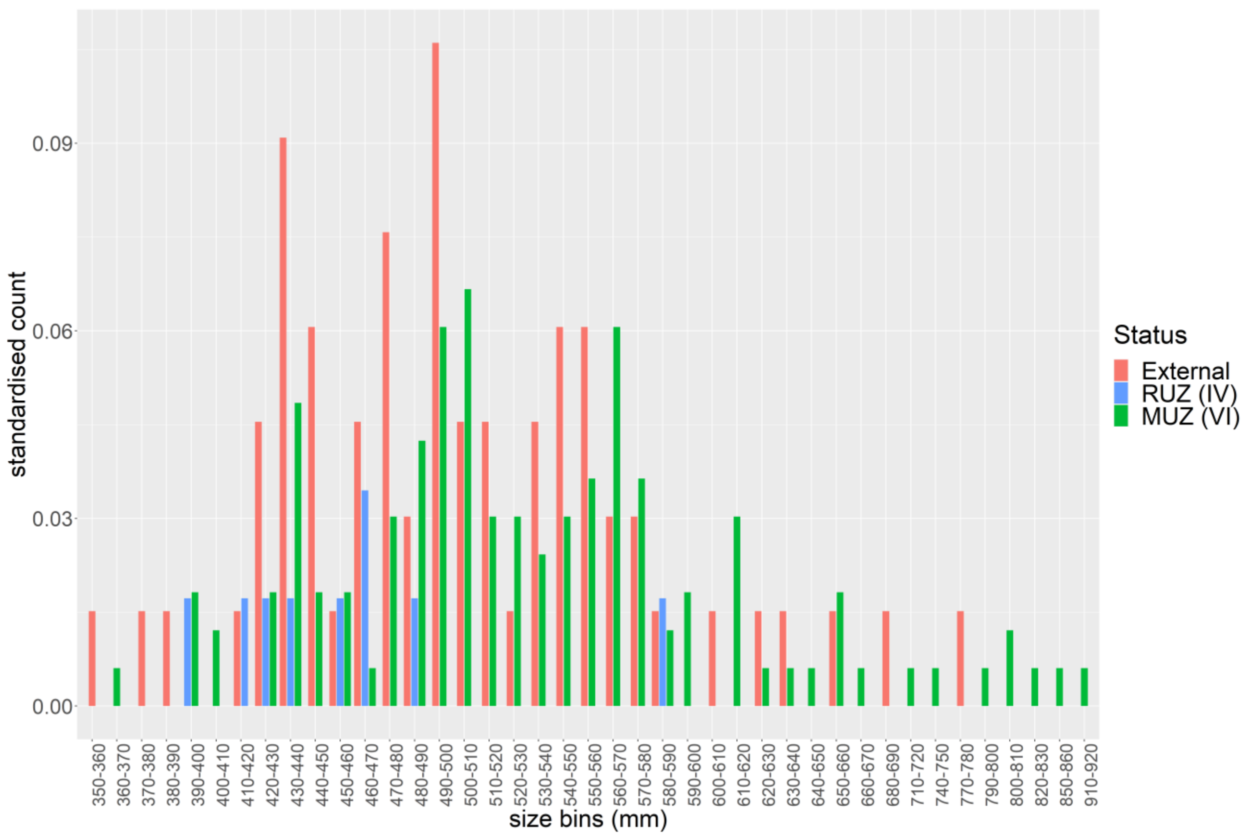


Figure 11. Size-frequency distribution for striped trumpeter across Freycinet Marine Park Multi-Use Zone (MUZ), Recreational-Use Zone (RUZ) and external fished areas. Counts have been standardised by the number of stereo BRUV drops in each zone.

Striped trumpeter were typically found on or close to reef features across the surveyed region (Figure 12). Areas of higher abundance included the northern external fished area (greatest abundances shown in Figure 11 are from areas of more substantial reef habitat), the shelf-break canyon reef sites and Joe's Reef in the MUZ and a single shelf site in the central MUZ that had isolated reef features visible in the stereo BRUV imagery.

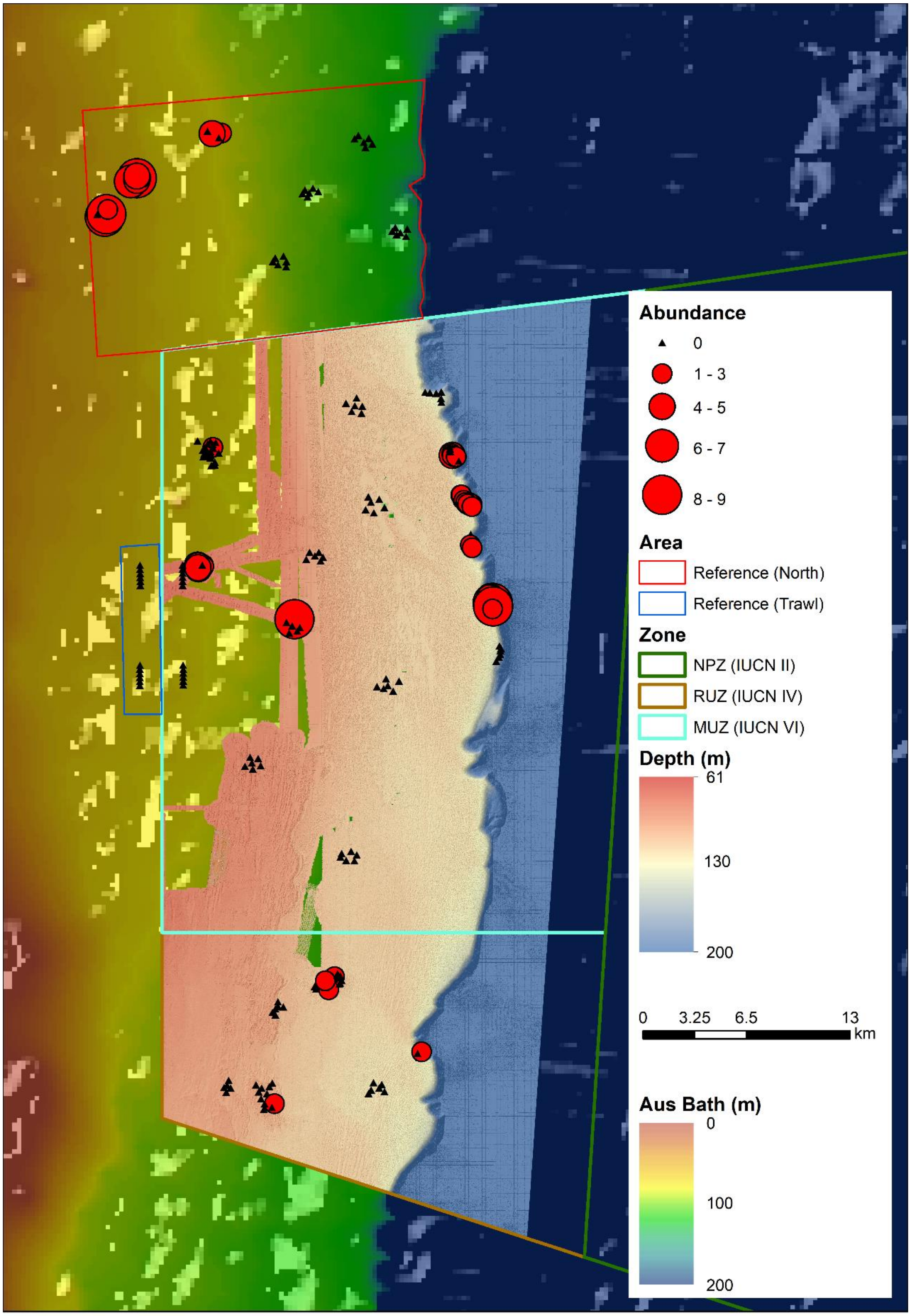


Figure 12. Abundance distribution of striped trumpeter.

Zonal comparison of commercially and recreationally important fish species abundance and size - detailed analysis

Detailed analyses were conducted to determine whether there were detectable differences of key species inside the MUZ, RUZ and external fished areas that may have been impacted by historical and ongoing trawl fisheries as well as other species of interest that may be targeted by commercial and recreational fishers in the MUZ relative to only recreational fishers in the RUZ. The species chosen for these analyses were jackass morwong and combined flathead species as these are both species that are subject to trawling impacts and line fishing. In addition, striped trumpeter, ocean perch, and morid cod (combined species) were included in analyses as they are targeted by both recreational and commercial fishers. Metrics of abundance, and mean length were assessed for each species. The abundance of larger fish (> 250 mm for jackass morwong, > 550 mm for striped trumpeter, based on recreational size limits) was assessed for jackass morwong and striped trumpeter due to their status as key targeted species. Also, an additional analysis was conducted for jackass morwong and flathead (combined species) considering trawlable benthic habitat only inside and outside the park due to their historical (inside the park before closure) and ongoing (outside the park) targeting by trawl fisheries (see "Comparison of fish abundance and size in external fished areas to within Freycinet MP" section above).

The same Bayesian model-based approach used in previous modelling of stereo BRUVs data in the Tasman Fracture Marine Park (TFMP) was employed (Perkins et al. 2022). These models take into account spatial autocorrelation present in the data along with environmental covariates such as depth and habitat. Unlike the TFMP, seafloor mapping was not available for all of FMP, and therefore variables such as rugosity and slope derived from mapping were not used in the analyses. Instead, habitat was classified into reef and non-reef based on visual classification from the stereo BRUV drops. Drops containing reef were classified as reef for modelling. Both depth and depth-squared (to capture non-linear effects) were used. A negative binomial distribution was used for general abundance and the abundance of larger fish, and a Gaussian distribution was used for mean length.

The model intercept represents the mean estimated count (on the log scale) for non-reef stereo BRUV drops in the external fished areas. Model coefficient estimates for the MUZ and RUZ represent deviations from the external fished areas, with significant differences being those where the posterior 95% credible intervals do not include zero. The estimate for reef quantifies the difference in the assessed metric between reef and sediment dominated stereo BRUV drops based on the visual assessment. Depth estimates quantify the overall effect of depth, with positive effects indicating an increase in the metric with depth and negative effects indicating a decrease with depth. Depth-squared estimates quantify whether there is an increase in the metric in mid-depths (a negative quadratic effect) or on shallow and deep areas surveyed (positive quadratic effect). All significant effects are highlighted in green for positive effects and red for negative effects, with unhighlighted effects indicating no statistically significant effect. Plots are provided where significant depth effects were found to allow visualisation of the effect across the depth range. Mean effects and credible intervals were calculated by taking posterior sample draws from the model while ignoring spatial effects.

Jackass morwong

Abundance

No significant effects were found for the abundance of jackass morwong in stereo BRUV drops across FMP, with no significant differences in abundance between the different zones (Table 3; MUZ, RUZ and external fished area). Also, depth and reef were not found to have significant effects on the abundance of jackass morwong.

Table 3. Model-based estimates of the abundance of jackass morwong across Freycinet Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	-0.454	0.572	-1.582	0.663
IUCN IV (RUZ)	1.232	0.804	-0.344	2.811
IUCN VI (MUZ)	0.828	0.670	-0.485	2.145
RUZ – MUZ	0.405	0.725	-1.016	1.825
Reef	0.011	0.163	-0.309	0.331
Depth	0.120	0.315	-0.498	0.738
Depth-squared	0.065	0.154	-0.237	0.367

Abundance of large fish

The RUZ was found to have significantly higher abundance of large jackass morwong compared to the external fished area (Table 4), with on average 5.4 times (i.e., exp (1.686)) more large fish in the RUZ compared to the external fished area. There was no statistically significant difference between the external fished area and the MUZ or between the RUZ and the MUZ. Reef was found to have a positive effect on the abundance of larger jackass morwong, with the abundance of large fish 1.7 times (i.e., exp (0.520)) higher on average in reef stereo BRUV drops than sediment drops. Depth-squared was also found to have a positive effect, indicating a higher abundance of large fish in both shallow and deeper depths compared to mid depths surveyed.

Table 4. Model-based estimates of the abundance of large (>250 mm) jackass morwong across Freycinet Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	-2.410	0.607	-3.616	-1.232
IUCN IV (RUZ)	1.686	0.820	0.081	3.299
IUCN VI (MUZ)	1.173	0.692	-0.178	2.537
RUZ – MUZ	0.514	0.722	-0.902	1.929
Reef	0.520	0.234	0.061	0.980
Depth	-0.233	0.359	-0.938	0.472
Depth-squared	0.465	0.199	0.075	0.855

Mean length

No significant effects were found for the mean length of jackass morwong in stereo BRUV drops across FMP when considering the different zones (Table 5). The mean length in the external fished areas was 24 cm, with model coefficient indicating that on average fish were 3.5 cm larger in the RUZ, and 0.7 cm larger in the MUZ, but these differences were not statistically significant. Depth was found to have a positive effect on mean length, with larger fish more likely at greater depths (Figure 13).

Table 5. Model-based estimates of the mean length of jackass morwong across Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	24.093	1.969	20.235	27.952
IUCN IV (RUZ)	3.488	3.289	-2.958	9.3935
IUCN VI (MUZ)	0.748	1.836	-2.850	4.346
RUZ – MUZ	2.741	3.098	-3.331	8.812
Reef	0.436	0.577	-0.695	1.568
Depth	2.484	1.125	0.279	4.690
Depth-squared	0.020	0.421	-0.805	0.846

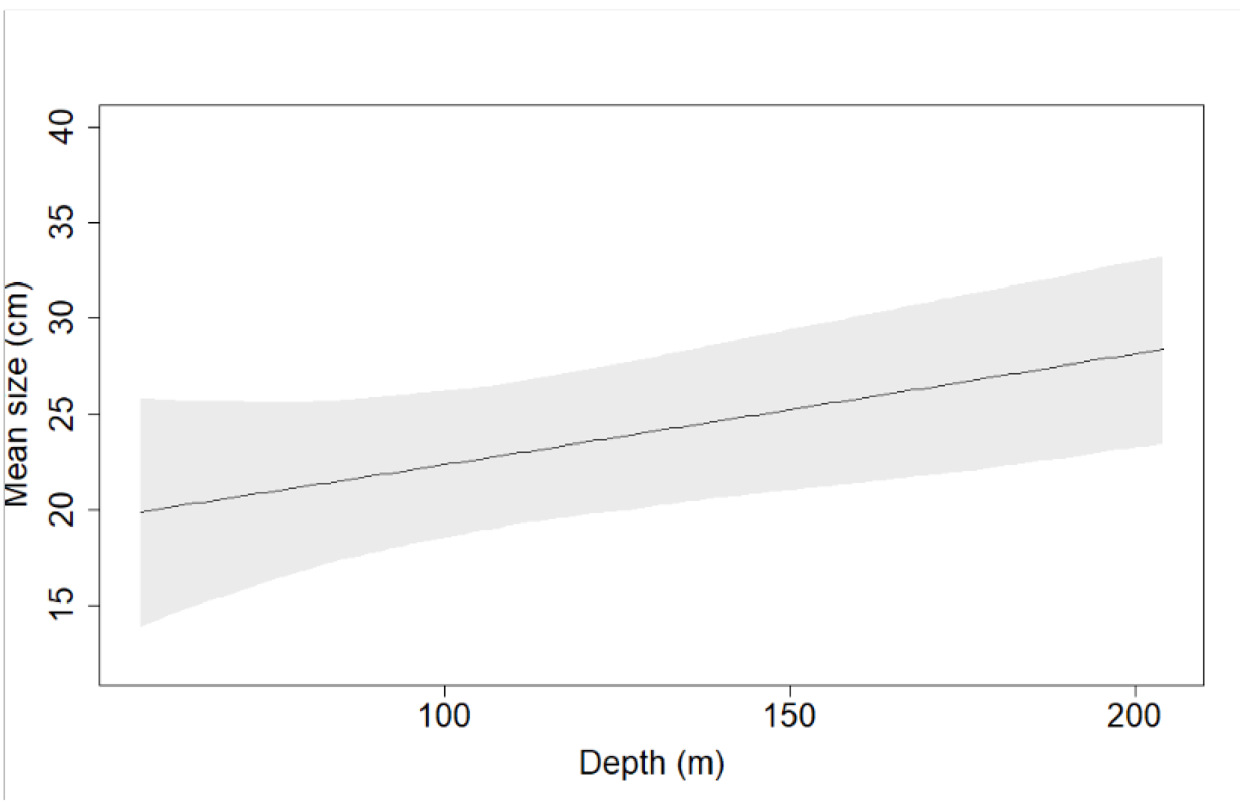


Figure 13. Model-based estimate of the relationship between mean length and depth for jackass morwong in Freycinet Marine Park

Abundance of jackass morwong in trawlable habitat within FMP compared to the external fished areas

A positive effect was found for the FMP on the abundance of all jackass morwong in trawlable habitat compared to external fished areas (Table 6). The coefficient for FMP of 1.582 indicates a multiplicative effect of 4.9, that is, on average stereo BRUV drops in the FMP had 4.9 times higher abundance than those outside, ignoring any depth effects. Depth was found to have a negative effect on abundance in trawlable habitat, indicating higher abundance in shallower depths.

Table 6. Model-based estimates of the abundance of jackass morwong in trawlable habitat in external fished areas compared to those inside Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-1.882	0.789	-3.448	-0.352
FMP	1.582	0.788	0.045	3.138
Depth	-3.300	0.914	-5.117	-1.528
Depth-squared	-1.660	1.185	-3.992	0.658

Mean length of jackass morwong in trawlable habitat inside/outside FMP

No significant effect of the FMP was found for mean length of jackass morwong in trawlable habitat when compared to trawlable external fished areas outside the FMP (Table 7). A positive effect of depth and a negative effect of depth-squared was found for mean length indicating larger fish were found at mid to deeper depths surveyed.

Table 7. Model-based estimates of the mean length of jackass morwong in trawlable habitat in external fished areas compared to those inside Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	28.683	1.657	25.435	31.931
FMP	-0.141	1.401	-3.160	2.332
Depth	3.930	1.552	0.888	6.972
Depth-squared	-11.165	2.993	-17.032	-5.299

Abundance of large jackass morwong in trawlable habitat inside/outside FMP

No significant effect of the FMP was found for the abundance of large jackass morwong in trawlable habitat when compared to fished habitat outside the FMP (Table 8). A negative effect of depth-squared was found for the abundance of larger fish indicating a higher abundance of large fish was found at mid depths surveyed.

Table 8. Model-based estimates of the abundance of large (> 250 mm) jackass morwong in trawlable habitat in external fished areas compared to those inside Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-1.107	1.037	-3.158	0.913
FMP	1.182	1.033	-0.829	3.226
Depth	-0.434	0.588	-1.577	0.729
Depth-squared	-2.389	0.637	-3.668	-1.169

Striped trumpeter

Abundance

No significant effects were found for the abundance of striped trumpeter in stereo BRUV drops across FMP, with no significant differences in abundance between the different zones (Table 9; MUZ, RUZ and external fished areas). Also, depth and reef were not found to have significant effects on the abundance of striped trumpeter. However, there was an effect for visually assessed reef which had a positive coefficient and was marginally non-significant.

Table 9. Model-based estimates of the abundance of striped trumpeter across Freycinet Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	-3.151	0.766	-4.680	-1.672
IUCN IV (RUZ)	-0.873	1.126	-3.095	1.326
IUCN VI (MUZ)	-0.772	0.934	-2.603	1.062
RUZ – MUZ	-0.102	1.127	-2.311	2.108
Reef	0.450	0.234	-0.003	0.915
Depth	0.523	0.462	-0.381	1.432
Depth-squared	0.105	0.168	-0.226	0.433

Abundance of large fish

There were no significant differences in the abundance of large striped trumpeter found between the different zones in FMP (Table 10). Reef was found to have a positive effect on the abundance of large fish, with on average the abundance of large fish 1.8 times (i.e., exp(0.596)) higher on reef stereo BRUV drops. Depth was not found to have a significant effect.

Table 10. Model-based estimates of the abundance of large (>550 mm) striped trumpeter across Freycinet Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	-3.067	0.710	-4.500	-1.712
IUCN IV (RUZ)	-1.273	1.168	-3.633	0.949
IUCN VI (MUZ)	0.267	0.793	-1.257	1.854
RUZ – MUZ	-1.541	1.172	-3.838	0.757
Reef	0.596	0.302	0.023	1.206
Depth	0.002	0.403	-0.789	0.791
Depth-squared	0.197	0.139	-0.082	0.463

Mean length

A significant difference was found between the mean length of striped trumpeter between the RUZ and the MUZ, with fish on average 8.8 cm smaller in the RUZ than the MUZ (Table 11). Differences between the external fished areas and the RUZ and MUZ were not found to be significant. No significant effects of depth or reef was found for mean length of striped trumpeter.

Table 11. Model-based estimates of the mean length of striped trumpeter across Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	53.796	3.444	47.045	60.546
IUCN IV (RUZ)	-8.331	5.034	-18.198	1.535
IUCN VI (MUZ)	0.492	2.958	-5.306	6.289
RUZ – MUZ	-8.823	4.225	-17.103	-0.543
Reef	-1.060	2.140	-5.255	3.135
Depth	0.748	1.512	-2.216	3.712
Depth-squared	0.028	0.996	-1.924	1.980

Morid cod

Abundance

No significant differences were found in abundance of morid cod between the zones across FMP or when these were contrasted with the external fished areas (Table 12). Reef was found to have a positive effect on abundance, with stereo BRUV drops on reef having an average of 2.1 times (i.e., exp(0.734)) higher counts of morid cod than those on sediment. Depth was not found to have a significant effect on the abundance of morid cod.

Table 12. Model-based estimates of the abundance of morid cod (combined species) across Freycinet Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	-2.809	0.728	-4.256	-1.400
IUCN IV (RUZ)	-0.379	1.067	-2.474	1.713
IUCN VI (MUZ)	-0.181	0.896	-2.576	0.941
RUZ – MUZ	0.439	1.065	-1.649	2.527
Reef	0.734	0.197	0.359	1.119
Depth	0.362	0.382	-0.385	1.112
Depth-squared	0.011	0.157	-0.304	0.314

Mean length

Significant differences were found in the mean length of morid cod in both the RUZ and MUZ compared to the external fished area, with mean lengths 9.9 cm smaller in the RUZ and 8.2 cm smaller in the MUZ compared to the external fished zone (Table 13). The average size in the fished zone was estimated to be 46.1 cm. Depth was found to have a significant effect on mean size (Figure 14).

Table 13. Model-based estimates of the mean length of morid cod across Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	46.119	2.702	40.823	51.415
IUCN IV (RUZ)	-9.898	3.101	-15.975	-3.821
IUCN VI (MUZ)	-8.156	1.837	-11.756	-4.556
RUZ – MUZ	-1.742	2.278	-6.206	2.722
Reef	-1.052	1.319	-3.636	1.532
Depth	3.614	1.192	1.277	5.951
Depth-squared	-1.176	1.083	-3.298	0.946

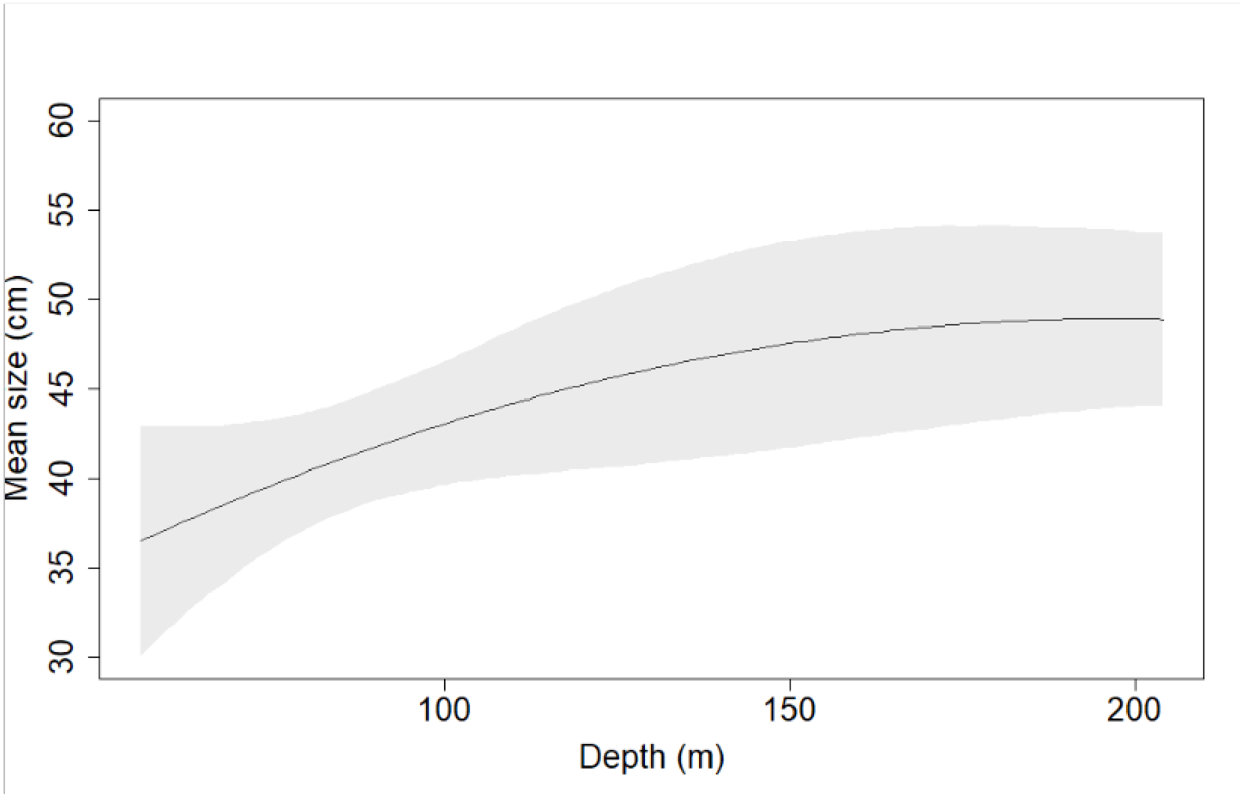


Figure 14. Model-based estimate of the relationship between mean length and depth for morid cod (combined species).

Ocean perch

Abundance

No significant effects were found for the abundance of ocean perch in stereo BRUV drops across FMP, with no significant differences in abundance between the different zones or when these were compared with external fished areas (Table 14; MUZ, RUZ and external fished areas). Also, depth and reef were not found to have significant effects on the abundance of ocean perch. However, the effect of visually assessed reef had a positive coefficient and was marginally non-significant.

Table 14. Model-based estimates of the abundance of ocean perch across Freycinet Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	-2.270	0.625	-3.511	-1.058
IUCN IV (RUZ)	0.373	0.881	-1.356	2.103
IUCN VI (MUZ)	0.190	0.738	-1.253	1.644
RUZ – MUZ	0.182	0.808	-1.402	1.766
Reef	0.347	0.193	-0.031	0.726
Depth	0.089	0.348	-0.593	0.772
Depth-squared	0.197	0.156	-0.109	0.502

Mean length

No significant effects were found for the mean length of ocean perch in stereo BRUV drops across FMP when considering the different zones (Table 15). The mean length in the external fished areas was 19.7 cm, with model coefficient indicating that on average fish were 4.2 cm smaller in the RUZ, and 1.9 cm smaller in the MUZ, but that both these differences were not statistically significant.

Table 15. Model-based estimates of the mean length of ocean perch across Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	19.652	2.380	14.988	24.316
IUCN IV (RUZ)	-4.202	3.133	-10.343	1.939
IUCN VI (MUZ)	-1.881	2.577	-6.931	3.170
RUZ – MUZ	-2.321	2.252	-6.736	2.093
Reef	1.126	1.030	-0.894	3.145
Depth	1.775	1.253	-0.680	4.231
Depth-squared	0.228	0.579	-0.907	1.363

Flathead species (combined)

Abundance

No significant differences were found for the abundance of flathead in stereo BRUV drops between the different zones across FMP (Table 16). Reef was found to have a significant negative effect on the abundance of flathead, with the number of flathead approximately half (i.e., exp(-0.641) = 0.53) that on reef associated stereo BRUV drops compared to sediment dominated drops. Depth was not found to have a significant effect on the abundance of flathead.

Table 16. Model-based estimates of the abundance of flathead (combined species) across Freycinet Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	0.201	0.530	-0.838	1.241
IUCN IV (RUZ)	-1.027	0.807	-2.613	0.555
IUCN VI (MUZ)	-0.851	0.574	-1.979	0.275
RUZ – MUZ	-0.175	0.765	-1.675	1.324
Reef	-0.641	0.274	-1.187	-0.112
Depth	0.086	0.354	-0.608	0.779
Depth-squared	-0.450	0.277	-1.017	0.069

Mean length

No significant effects were found for the mean length of flathead in stereo BRUV drops across FMP when considering the different zones (Table 17). The mean length in the external fished areas was 42.0 cm, with model coefficient indicating that on average fish were the same size in the RUZ, and 0.9 cm larger in the MUZ, but these differences were not statistically significant. Depth was found to have a positive effect on the mean length of flathead, with larger flathead found at greater depth (Table 17 and

Figure 15).

Table 17. Model-based estimates of the mean length of flathead (combined species) across Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (External fished areas)	42.045	1.523	39.061	45.029
IUCN IV (RUZ)	0.000	2.389	-4.683	4.683
IUCN VI (MUZ)	0.905	1.677	-2.381	4.192
RUZ – MUZ	-0.905	2.148	-5.116	3.305
Reef	2.793	1.897	-0.924	6.511
Depth	5.950	1.122	3.751	8.150
Depth-squared	-0.612	1.211	-2.985	1.761

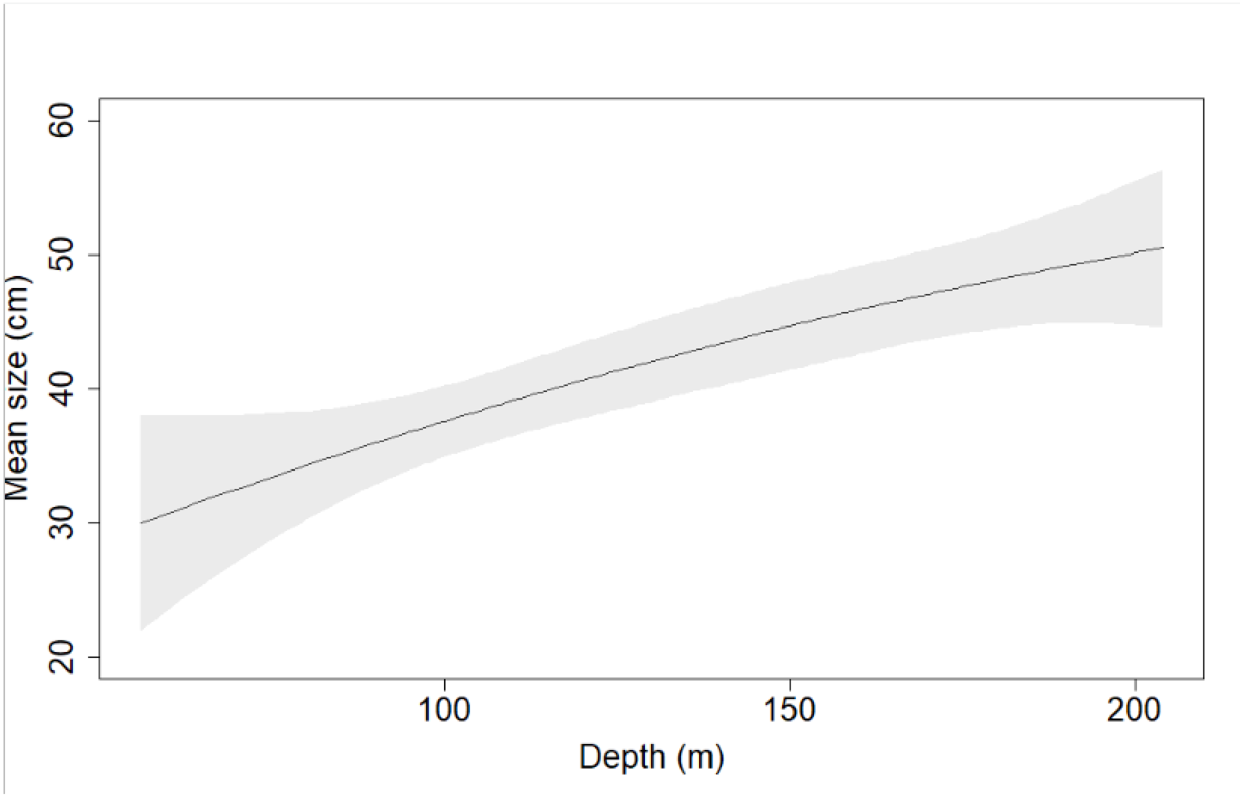


Figure 15. Model-based estimate of the relationship between mean length and depth for flathead (combined species).

Abundance of flathead in trawlable habitat inside/outside FMP

No significant effect was found for the FMP on the abundance of flathead in trawlable habitat compared to external fished areas (Table 18). Depth was found to have no significant effect on abundance in trawlable habitat.

Table 18. Model-based estimates of the abundance of flathead in trawlable habitat in external fished areas compared to those inside Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-0.165	0.596	-1.335	1.004
FMP	-0.792	0.559	-1.891	0.304
Depth	0.852	0.641	-0.409	2.107
Depth-squared	0.893	0.901	-0.876	2.659

Mean length of flathead in trawlable habitat inside/outside FMP

No significant effect of the FMP was found for mean length of jackass morwong in trawlable habitat when compared to fished habitat outside the FMP (Table 19). A positive effect of depth was found for mean length indicating larger fish were found in deeper depths surveyed.

Table 19. Model-based estimates of the mean length of flathead in trawlable habitat in external fished areas compared to those inside Freycinet Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	40.061	2.420	35.318	44.804
FMP	2.634	2.028	-1.341	6.609
Depth	7.440	1.629	4.247	10.633
Depth-squared	2.745	4.180	-5.447	10.937

Stereo BRUVs data: Multivariate analysis of fish communities

Methods

To contrast the fish assemblages associated with each zone, location (see Table 1) and habitat, a multivariate analysis was conducted using PRIMER software. Baitfish (order *clupeiformes*) and mackerel (*Trachurus* spp.) were removed prior to analysis as they are pelagic species often present in large numbers but are transitory and therefore add ecological noise rather than help in describing communities associated with different habitats or locations. MaxN abundances of each species from each drop were square-root transformed prior to analysis to down-weight the dominance of more abundant species. Bray-Curtis similarity matrices were computed across stereo BRUV drops. Non-metric multi-dimensional scaling (MDS) plots were produced to explore the similarity of communities across locations and habitats. SIMPER analysis was conducted to examine the species that were responsible for the differences between locations and habitats. Visual identification of habitats from each stereo BRUV drop were used to classify habitats into four broad categories: soft (sand dominated), soft with invertebrate cover, hard high relief, and mixed habitat. Habitat scoring followed the method outlined in Langlois et al. (2020). The soft class was determined as drops which had low relief and no invertebrate cover; soft invertebrate was low relief with some invertebrate cover scored; hard high relief was determined as any drops with higher relief features (categories 2,3 or 4 from Langlois et al. (2020)). Permutational analysis of variance (PERMANOVA) was conducted to test for significant effects of location and habitats nested within locations on the multivariate communities.

Results

MDS plots showed that habitat types drive differences in fish assemblages within FMP, with a clear separation of rocky reef dominated and sediment dominated habitats, with mixed habitats having intermediate fish communities (

Figure 16). There was a large overlap between zones (MUZ, RUZ, and external fished areas), demonstrating that overall fish communities were quite similar across the park once habitat was taken into account (Figure 16). Complex rocky-reef dominated locations such as Joe’s Reef, reef sections of the northern external fished area, and reef sections of the shelf breaks in the RUZ were dominated by reef associated species such as striped trumpeter, jackass morwong, butterfly perch and ocean perch (trajectory overlays,

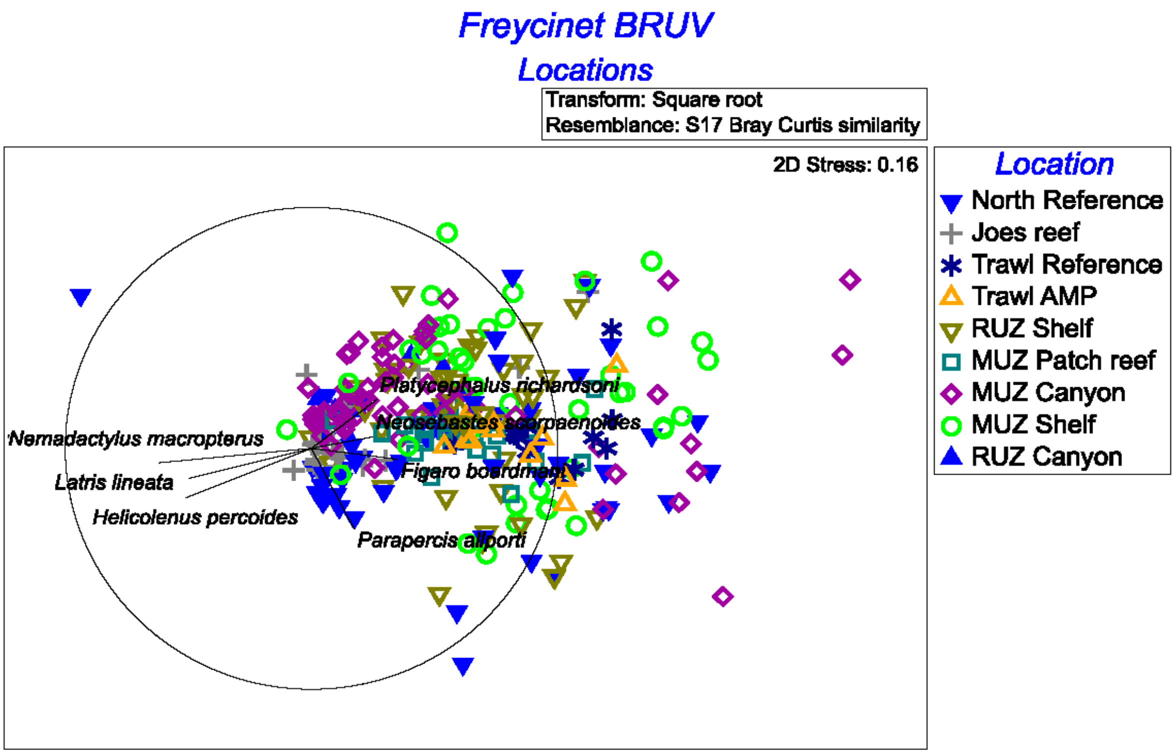
Figure 16). Locations that were dominated by soft sediments or drops within locations that were located on soft sediment, contained species such as flathead (e.g., *P. richardsoni*,

Figure 16) and barred grubfish (*P. allporti*,

Figure 16). Some depth effect was also noticeable, with species such as the sawtail catshark (*F. boardmani*,

Figure 16) that tend to occur in depths > ~100 m being found in the deeper shelf and canyon locations.

SIMPER analysis confirmed the differences between locations were largely driven by the amount and quality of rocky reef habitat. Joe’s Reef was exceptional in this respect with the highest abundances of reef associated species such as jackass morwong, ocean perch, butterfly perch, splendid perch, rosy wrasse, and striped trumpeter. The canyon locations had relatively high abundances of jackass morwong, ocean perch and striped trumpeter. The shelf and trawl sites tended to be dominated by soft sediment species such as barred grubfish and flathead, and also species that are likely to range over a larger area such as jackass morwong, common gurnard perch, squalus shark species (spikey and whitespotted dogfish), and draughtboard sharks. The Patch Reef location in the RUZ had a higher abundance of sediment associated species compared to the higher quality reef habitats at locations such as Joe's Reef and the northern external fished area, likely because this area has only small amounts of exposed rocky reef and the dominance of lower-relief sand-inundated reef features. The northern external fished area had a mixture of hard and soft bottom associated species, with relatively high abundances of reef-associated species such as ocean perch, jackass morwong, butterfly perch, splendid perch and striped trumpeter. The higher quality reef habitat at the northern external fished area indicates that it could be used as a potential reference area for Joe's Reef if the level of protection was increased at Joe's Reef under future management scenarios. PERMANOVA tests showed that both location (Pseudo-F = 4.18, P = 0.001) and habitats nested within locations (Pseudo-F = 2.22, P = 0.001) were significant in determining the multivariate assemblages found.



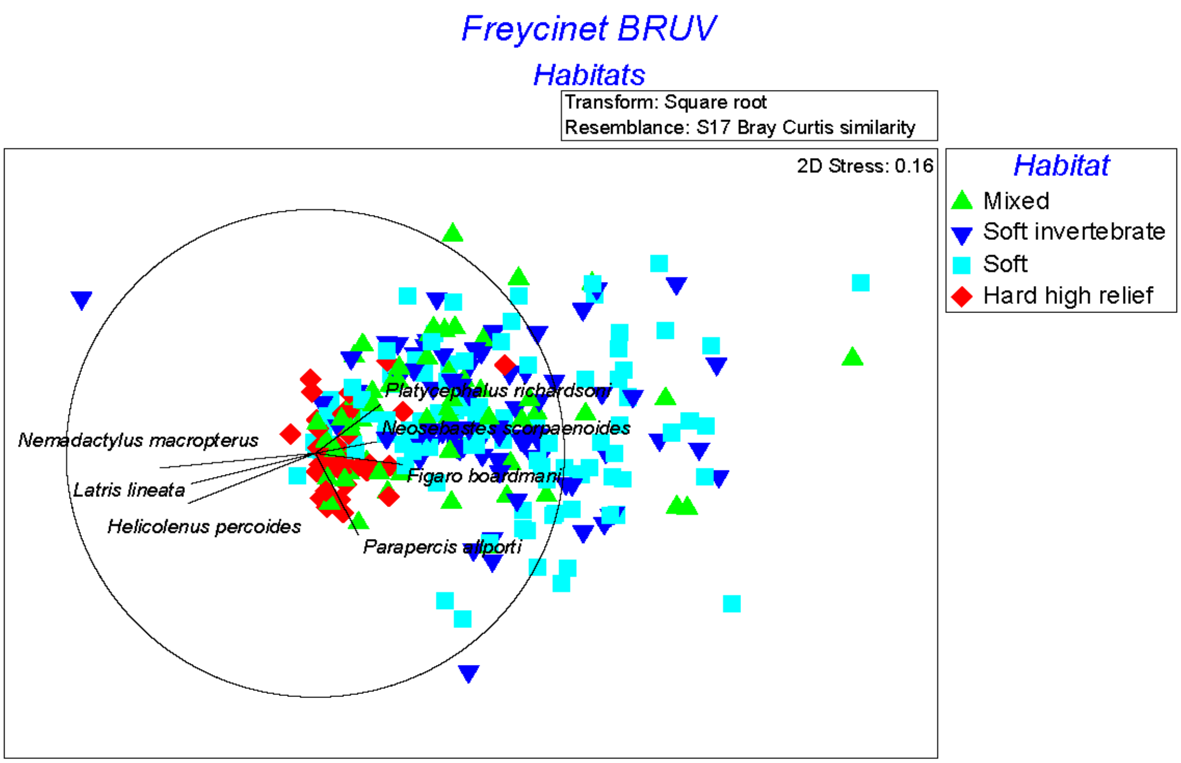


Figure 16. Non-metric multi-dimensional scaling (MDS) plots showing multivariate groupings of communities based on locations within (top panel) and habitats across (bottom panel) Freycinet Marine Park.

Discussion: Freycinet stereo BRUVs

The stereo BRUV surveys conducted in the FMP in 2021 have provided the first quantitative description of demersal fish species using the stereo BRUV methodology in this region, revealing a diverse range of species associated with a range of habitats found within the park and at several external fished areas. The results reported here are therefore important in both providing a characterisation of species present and a baseline for ongoing monitoring. A number of important commercially and recreationally fished species were found to be in moderate to high abundance (> 50 to several thousand), including jackass morwong, striped trumpeter, flathead species, ocean perch, a number of elasmobranch species and morid cod species. Areas of particularly high abundance and diversity included Joe's Reef, the shelf break canyon reef features and the northern external fished area. All these areas contained rocky reef habitat, which is known to be important for many of the species listed above, as well as being generally areas of higher fish diversity overall. Notably, the reef habitat encountered to the north of the park was significantly more comprehensive in extent and structure than any encountered within the FMP, except for Joe's Reef, an isolated structure with high relief. Hence, the abundance of reef associated species was strongly driven by reef features. While no conservation-dependent species were identified during the survey, a single handfish, unable to be determined to species level, was observed in the northern external fished area, indicating the presence of handfish species in the region.

Detailed analyses revealed that there were not many significant differences in abundance between the RUZ, MUZ and external fished areas for key species, other than the differences related to habitat variation between areas, discussed above. This is perhaps unsurprising, as current zoning allows fishing across both zones within the park, except for benthic trawling throughout the park and commercial fishing within the RUZ. However, a significant difference was found in the mean length of striped trumpeter, with smaller lengths in the RUZ than the external fished areas. While this may be indicative of additional recreational fishing pressure in the RUZ relative to other areas, the small number of striped trumpeter observed in the RUZ (10), as well as the absence of any complex reef habitat in this zone, (with the exception of a small area of shelf-break reef), means the sample size is too small to draw any reliable conclusion. The mean length of morid cod species was also found to be smaller in the RUZ and MUZ compared to the external fished areas. The reasons for this difference are currently unclear but could be partly confounded by grouping species that may have different maximum sizes, or as per the trumpeter above, related to the absence of complex reef, a habitat preferred by cod species.

When considering habitat that may have been previously trawled within the FMP compared to trawlable habitat outside the FMP, a significant difference was found in the abundance of jackass morwong, with an almost five times greater abundance in stereo BRUV drops inside the FMP. Also, a statistically significant difference was found when contrasting the abundance of large jackass morwong in the RUZ relative to the sites surveyed in similar habitats external to the park. As jackass morwong are a target species in the SE trawl fishery but are not actively targeted by other commercial or recreational effort in shelf waters in this region, this may be some initial evidence of a protection-related effect of the park for this species. Therefore, differences in the abundance and size structure of populations of jackass morwong subject to trawl fishing compared to those protected in FMP is a key metric of use for ongoing monitoring. However, it should be noted, that this difference could be related to small habitat differences, and further time-series data is required to differentiate between habitat and protection-related patterns.

Habitat associations were not as strong as might be expected for some species which are known to be strongly associated with reef, such as striped trumpeter and ocean perch. This is likely due to: (i) the use of visually assessed habitat from the stereo BRUVs video rather than use of habitat variables calculated from seafloor mapping which can take scale into account, (ii) the ability of the bait to draw fish away from preferred habitat, thus obscuring patterns, and (iii) the intermediate nature of the consolidated "dune-like" features that are widely distributed between 80-120 m in this region. Visually assessed habitat is dependent on the field of view of the cameras and the visibility. Therefore, drops may be scored as sediment despite also being near reef features where reef associated species are more abundant. For many mobile, bait-attracted species, the bait plume may draw them away from any adjacent reef patches, towards the stereo BRUV nominally placed on sediment. Where seafloor mapping is available across a surveyed area, distance-based measures can be used to capture the likely proximity to reef features and therefore provide additional insight into the range of species and the distance of attraction to bait. Unfortunately, mapping data was not available for all of the FMP and therefore mapped variables such as rugosity over varying scales, such as those used in the recent Tasman Fracture stereo BRUV surveys, could not be used here. It is recommended that mapping efforts be continued in FMP and the external fished areas to allow better characterisation of habitats and associations with fish distributions.

Finally, it is likely, that at least for some species like morid cods, jackass morwong, ocean perch and to a lesser extent striped trumpeter, the extensive dune-like features found across most of the shelf between 80-120 m act as a reef-like habitat in some respects, thus supporting some individuals. These structures, while lacking any physical hard outcrops apart from isolated individual rocks, typically have a higher cover of sessile invertebrates like sponges, bryozoans and ascidians than neighbouring soft sediments. This may offer a preferred feeding habitat, even if lacking the physical shelter that more complex reef habitat may offer.

Depth was found to be a significant factor for the mean length of both morid cod and flathead species combined, but not for any other species modelled. However, it should be noted that only a subset of species were sufficiently abundant to be modelled, and a number of observed species were either constrained to reefs in shallower depths (such as rosy wrasse and common bullseye's) or predominantly deeper reefs at the shelf break (120-140 m) (e.g., eastern orange perch *Lepidoperca pulchella*). Depth is typically an important driver for many species. However, in the case of FMP there was not a major depth gradient present in the sampled area (ranging from the top of Joe's Reef in 60 m to 140 m at the base of the shelf-break reef outcrops). Rocky reef habitat occurs in the shallower portions of the park at Joe's Reef, the "patch reef" location in the RUZ (an area of more pronounced hummocky dune features rather than rocky outcrops), the northern external fished area and at deeper locations on the shelf break. Hence, as most of the modelled species had a significant habitat preference for reef, this tended to be the key factor driving distributions over the depth range examined. For example, for large jackass morwong, a positive depth-squared coefficient indicated a preference for both shallow and deep locations, one likely to be largely driven by proximity to rocky reef at these depths.

To date, only one range-extension was noticed as part of the stereo BRUV-based component of this study. This was the spot-tailed perchlet, *Plectranthias maculicauda*, found on a shelf-break reef in the MUZ. This species is occasionally encountered in deep-shelf water trawl operations in eastern Australia, with the previous southernmost sighting until this record being in NE Bass Strait.

Freycinet Marine Park: ROV survey of fish populations

Background and methods

For rocky and coral reefs in particular, previous non-invasive surveys of fish communities in shelf waters of the AMP Network have primarily involved the use of stereo BRUVs because they attract key species of commercial and recreational fishing interest, coupled with their relative ease of use, and a well-documented standard operating protocol (Langlois et al. 2020), and widespread adoption in inshore fish surveys within state MPA networks (Harvey et al. 2021). However, this method is somewhat restricted in attracting trophic groups other than top carnivores, and attracts fish from unknown distances, so the data generated does not necessarily represent the overall fish assemblage present, relative trophic relationships, or an absolute metric of abundance (Schramm et al. 2020).

With the recent development of more cost-effective remote operated vehicles, and successful trials of ROV-based fish surveys in deep shelf environments in the US (Perkins and Lauermann 2023) and Tasmania (Sward 2022), this survey provided the opportunity to trial the use of an ROV fitted with stereo camera system to describe the reef-associated fish communities in the Huon and Freycinet Marine Parks, and to contrast the results from fish communities seen by stereo BRUV deployments in the same sampling locations. Deployments were limited to reef systems (and occasionally adjacent or within-reef sediments where this could not be avoided), due to the limited time available, which restricted exploration of adjacent soft-sediment habitats.

Here we fitted a Saab Seaeye Falcon ROV (https://www.saabseaeye.com/solutions/underwater-vehicles/falcon) with a stereo pair of Sony Action X1000V 4k digital video cameras in underwater housings supplied by SeaGIS and separated by 400 mm along a solid base-bar attached to the ROV. The ROV was fitted with a Link-quest TrackLink1500ma USBL tracking system (https://www.link-quest.com/html/tracklink_1500.htm) to accurately determine the position of the ROV on the seabed for field operations and subsequent matching of the ROV position (estimated to be with +/- 5 m accuracy in the depths surveyed) with previously acquired multibeam mapping of the area. On each transect, the ROV was flown over the seabed at approximately 0.5-1 m height, at approximately 0.5 m/s, along a pre-determined 200 m long belt transect following standardised protocols outlined in NESP Hub guidelines (Monk et al. 2020). However, due to tether drag, not all transects followed the planned line perfectly, but with the use of the USBL system, the length of 200 m was maintained. Using available daylight hours, nine to ten of the 200 m transects were completed on each of three field days for a total of 29 transects completed (Figure 17). To obtain more detailed analysis of habitat associations, habitat patches (reef, mixed habitats, and soft sediment habitats) were also delineated in one-minute intervals along each transect when annotating the videos. Mixed habitats were those that contained a mixture of reef and soft sediments in the one-minute interval.

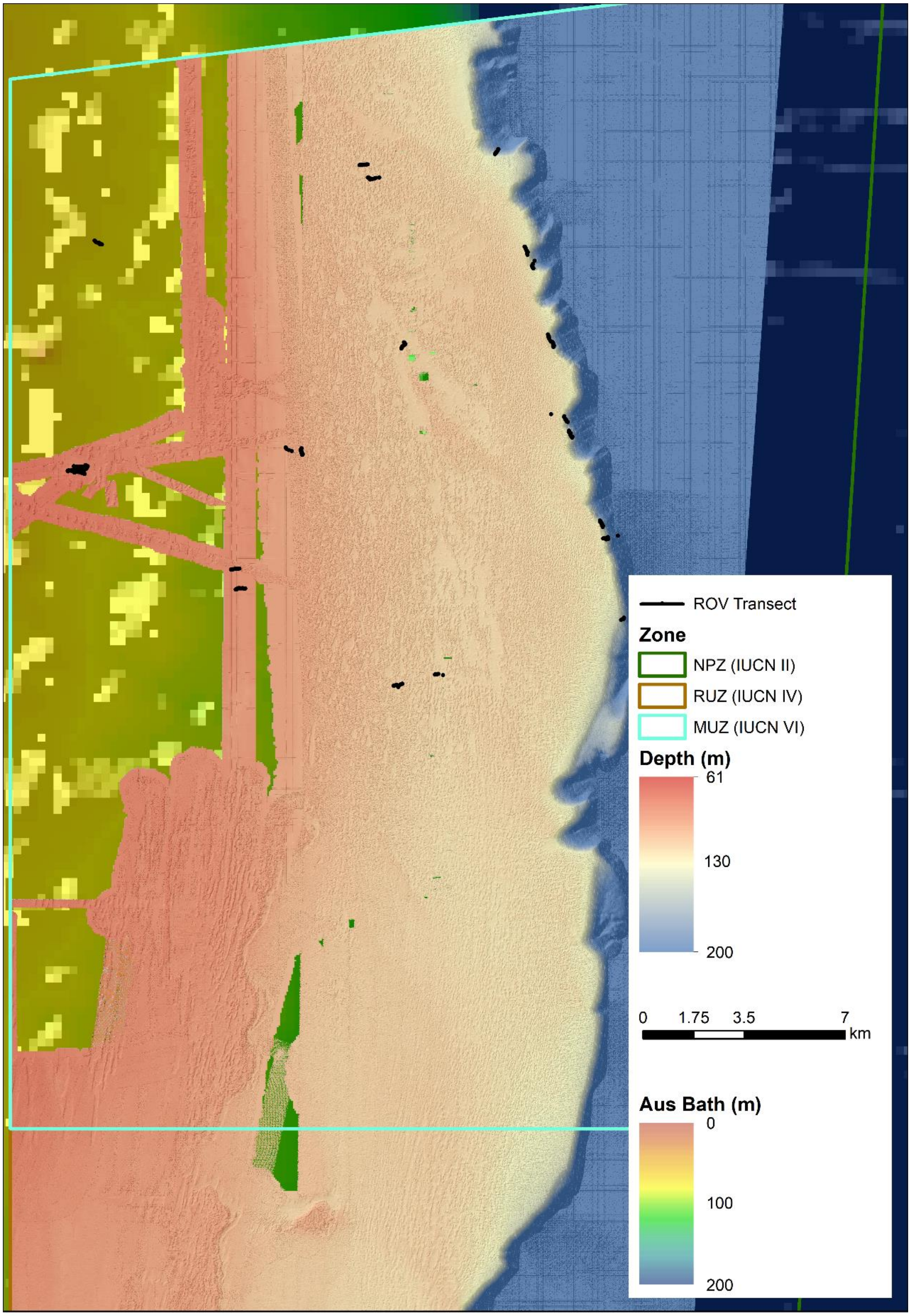


Figure 17. Location of the 29 ROV transects completed in the MUZ.

ROV data: General description

A total of 43 fish species comprising 33 families were observed across the 29 ROV transects conducted in the Freycinet MP (Table 20), excluding baitfish and mackerel species which were excluded from the counts. All observed marine invertebrates, except for southern rock lobster (*Jasus edwardsii*) were excluded from Table 20. Stereo BRUV deployments revealed that rock lobsters were present in moderate abundance on complex reef system in the Freycinet MP, so this species was included in comparisons across the two survey platforms. Species of the family Serranidae were particularly abundant, especially butterfly perch (*Caesioperca lepidoptera*), and eastern orange perch (*Lepidoperca pulchella*). Other abundant species included ocean perch (*Helicolenus percoides*), rosy wrasse (*Pseudolabrus rubicundus*), cosmopolitan leatherjacket (*Meuschenia scaber*), splendid perch (*Callanthias australis*), common bellowsfish (*Macroramphosus scolopax*), and sandpaper fish (*Paratrachichthys macleayi*). Rare and/or endangered species observed included three handfish (of unknown species due to lack of image resolution) and a single spiny pipehorse. A range extension of the redbanded grubfish (*Parapercis binivirgata*) was also recorded, with 15 individuals observed. This is the first record of this species in eastern Tasmanian waters. Example imagery of species observed in ROV videos is provided in the Appendix.

Fine-scale habitat classes were scored along each minute of ROV transect, with final habitat categories being reef, mixed (sand/rubble/reef mixture), soft (sand or rubble), mudstone cliffs, and soft rippled. Of the 312 one-minute sub-units, reef dominated with 114 (37%) sub-units of reef, 29 (9%) classed as mixed, 18 (6%) as mudstone cliffs, 91 (29%) classed as soft, and 60 (19%) classed as soft rippled. The mudstone cliffs provided a distinctly different habitat class with the nooks and crevices providing important refuge for species such as the southern rock lobster and eastern orange perch. This habitat was also important for jackass morwong, with 27 individuals (53% of the total 51 observed) seen in this habitat despite the mudstone cliffs habitat class comprising only 6% of the total surveyed habitats.

Table 20. Summary of total abundance across all species seen in ROV transects in the Freycinet MP. Percent measured is the percentage of the total number of fish observed where a length measurement was obtained. Counts are given within habitat categories along each minute of transect (see Methods).

Family	Scientific name	Common name	Count Mixed	Count Mudstone Cliffs	Count Reef	Count Soft	Count Soft rippled	Total count	Percent measured
	Number of subsamples (minutes)		**36**	**18**	**121**	**91**	**60**	**326**	
Argentinidae	*Argentina australiae*	Silverside	0	0	0	21	0	21	48%
Brachionichthyidae	*Brachionichthyidae spp*	Handfish spp	0	0	0	3	0	3	33%
Callanthiidae	*Callanthias australis*	Splendid perch	10	1	51	0	0	62	74%
Callionymidae	*Foetorepus calauropomus*	Common stinkfish	0	0	0	1	0	1	100%
Cheilodactylidae	*Nemadactylus macropterus*	Jackass morwong	23	27	67	6	3	126	91%
Cyttidae	*Cyttus australis*	Silver dory	0	0	0	3	0	3	100%
Dinolestidae	*Dinolestes lewini*	Longfin pike	0	0	17	0	0	17	29%
Diodontidae	*Diodon nicthemerus*	Globefish	0	0	1	0	0	1	100%
Emmelichthyidae	*Emmelichthys nitidus*	Redbait	0	0	0	1	0	1	0%
Labridae	*Pseudolabrus rubicundus*	Rosy wrasse	13	0	48	0	2	63	75%
	Suezichthys aylingi	Crimson cleaner wrasse	0	0	2	0	0	2	100%
Latridae	*Latris lineata*	Striped trumpeter	12	0	18	0	0	30	97%
Macroramphosidae	*Macroramphosus scolopax*	Common bellowsfish	9	0	0	65	4	78	58%
	Notopogon lilliei	Crested bellowsfish	0	1	0	3	0	4	100%
Macrouridae	*Macrouridae spp*	Grenadier spp	0	0	0	1	1	2	50%
Monacanthidae	*Meuschenia scaber*	Cosmopolitan leatherjacket	4	0	13	2	0	19	84%
Moridae	*Pseudophycis spp*	Morid cod spp	18	1	26	9	0	54	69%
Mullidae	*Upeneichthys vlamingii*	Bluespotted goatfish	0	0	1	1	0	2	100%
Narcinidae	*Narcine tasmaniensis*	Tasmanian numbfish	0	0	0	1	0	1	100%
Ostraciidae	*Aracana aurita*	Shaw's cowfish	3	0	5	0	0	8	50%
Palinuridae	*Jasus edwardsii*	Southern rock lobster	0	10	1	5	0	16	0%
Paralicthyidae	*Paralichthys spp*	Flounder spp	2	0	0	2	0	4	50%
Paraulopidae	*Paraulopus nigripinnis*	Blacktip cucumberfish	1	0	0	1	6	8	75%
Pinguipedidae	*Parapercis allporti*	Barred grubfish	1	0	0	14	2	17	69%

	Parapercis binivirgata	Redbanded grubfish	0	1	1	3	10	15	60%
Platycephalidae	*Platycephalus spp*	Flathead spp	0	0	0	1	0	1	100%
Rajidae	*Dentiraja lemprieri*	Thornback skate	0	0	0	1	0	1	100%
	Spiniraja whitleyi	Melbourne skate	0	0	0	1	0	1	0%
Scorpaenidae	*Scorpaena papillosa*	Southern red scorpionfish	0	1	2	0	0	3	67%
Scyliorhinidae	*Cephaloscyllium laticeps*	Draughtboard shark	0	0	0	1	0	1	0%
Sebastidae	*Helicolenus percoides*	Ocean perch	81	54	360	68	19	582	52%
Serranidae	*Caesioperca lepidoptera*	Butterfly perch	431	13	2592	224	1	3261	94%
	Caesioperca spp	Perch spp	89	1	343	41	0	474	78%
	Lepidoperca pulchella	Eastern orange perch	6	50	33	4	9	102	69%
	Plectranthias maculicauda	Spot-tail perchlet	0	0	0	4	0	4	0%
	Lepidoperca spp	Perch spp	35	0	30	0	0	65	0%
Syngnathidae	*Solegnathus spinosissimus*	Spiny pipehorse	0	0	1	0	0	1	0%
Trachichthyidae	*Paratrachichthys macleayi*	Sandpaper fish	14	24	69	0	0	107	85%
Triakidae	*Mustelus antarcticus*	Gummy shark	0	0	0	1	0	1	100%
Triglidae	*Lepidotrigla modesta*	Cocky gurnard	0	0	0	5	0	5	80%
Urolophidae	*Urolophus cruciatus*	Banded stingaree	5	0	3	2	0	10	30%
	Urolophus paucimaculatus	Sparsely spotted stingaree	0	0	0	2	0	2	0%
	Urolophus spp	Stingaree spp	1	0	0	0	0	1	0%

ROV data: Length frequency distributions

Jackass morwong

A total of 115 jackass morwong were measured across the 29 transects, with an average length of 25.2 cm (Figure 18). Sizes ranged from 16.6 cm to 48.4 cm.

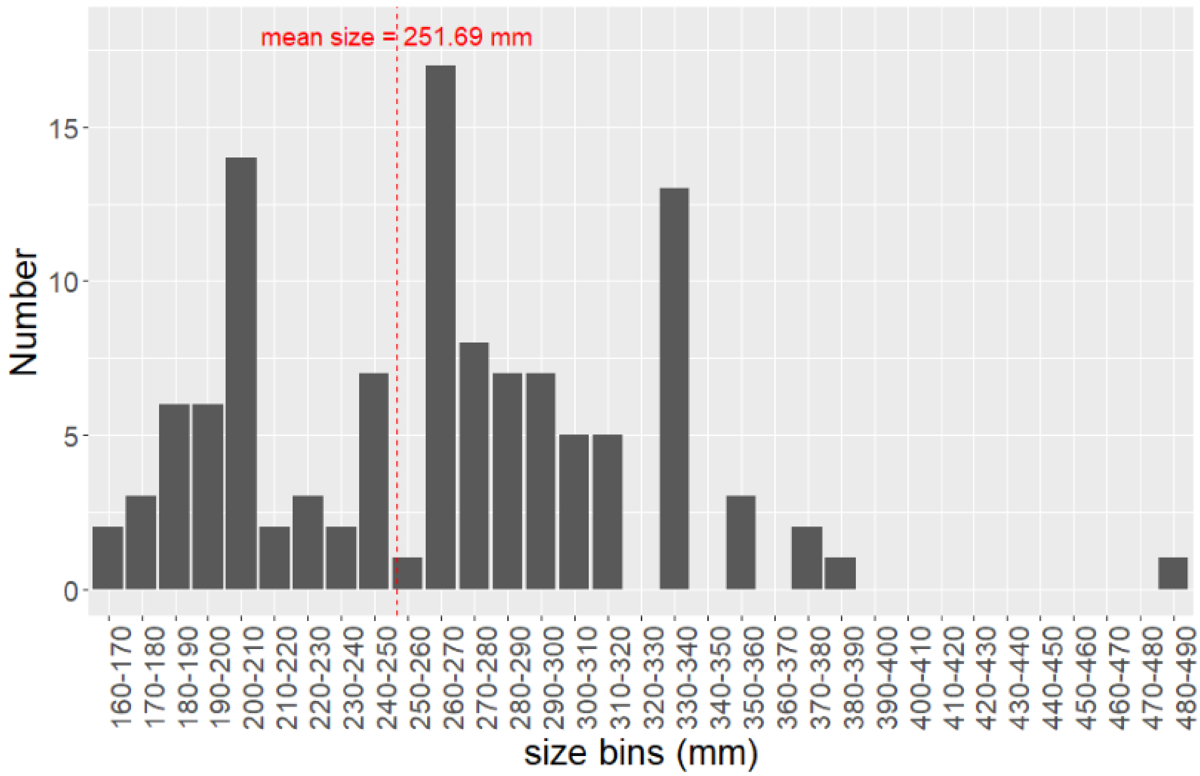


Figure 18. Length frequency distribution of measured jackass morwong from ROV surveys in the Freycinet Marine Park.

Ocean perch

A total of 305 ocean perch were measured across the 29 transects, with an average length of 15.2 cm (Figure 19). Sizes ranged from 3.4 cm to 24.9 cm. The size distribution approximated a normal distribution.

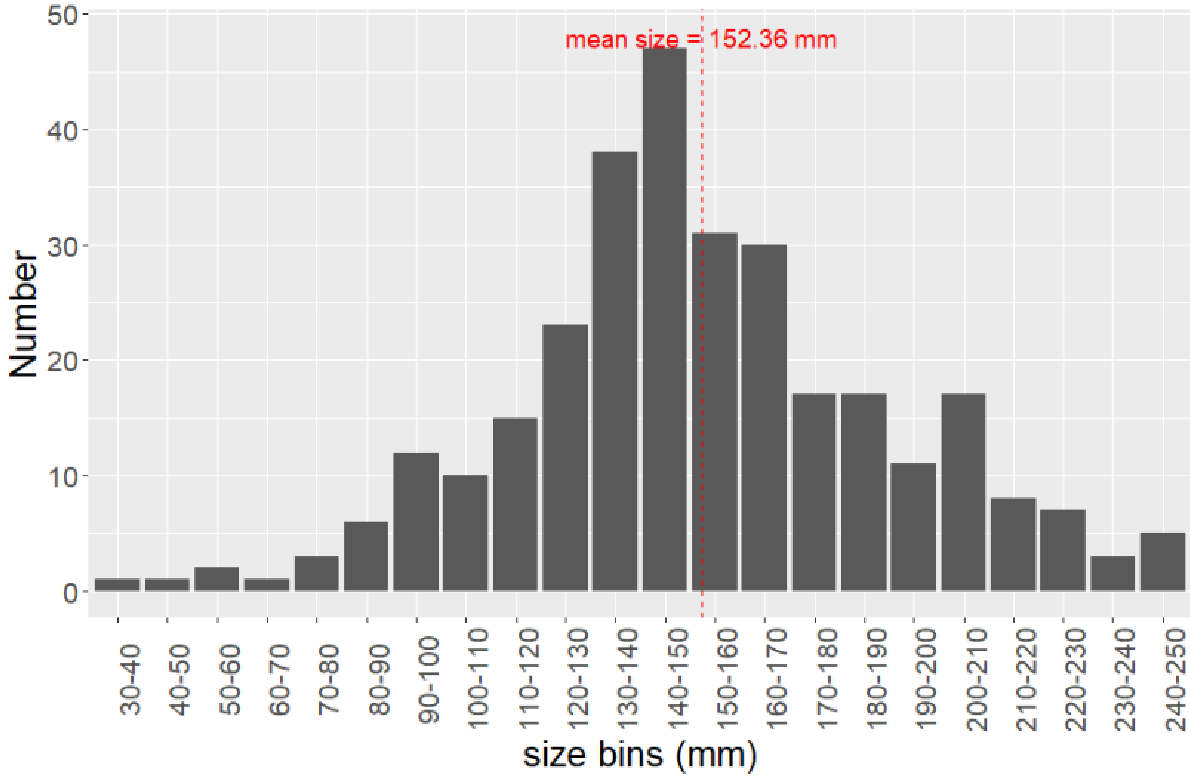


Figure 19. Length frequency distribution of measured ocean perch from ROV surveys in the Freycinet Marine Park.

Morid cod

A total of 36 morid cod (combined species) were measured across the 29 transects, with an average length of 33.9 cm (Figure 20). Sizes ranged from 20.9 cm to 45.7 cm.

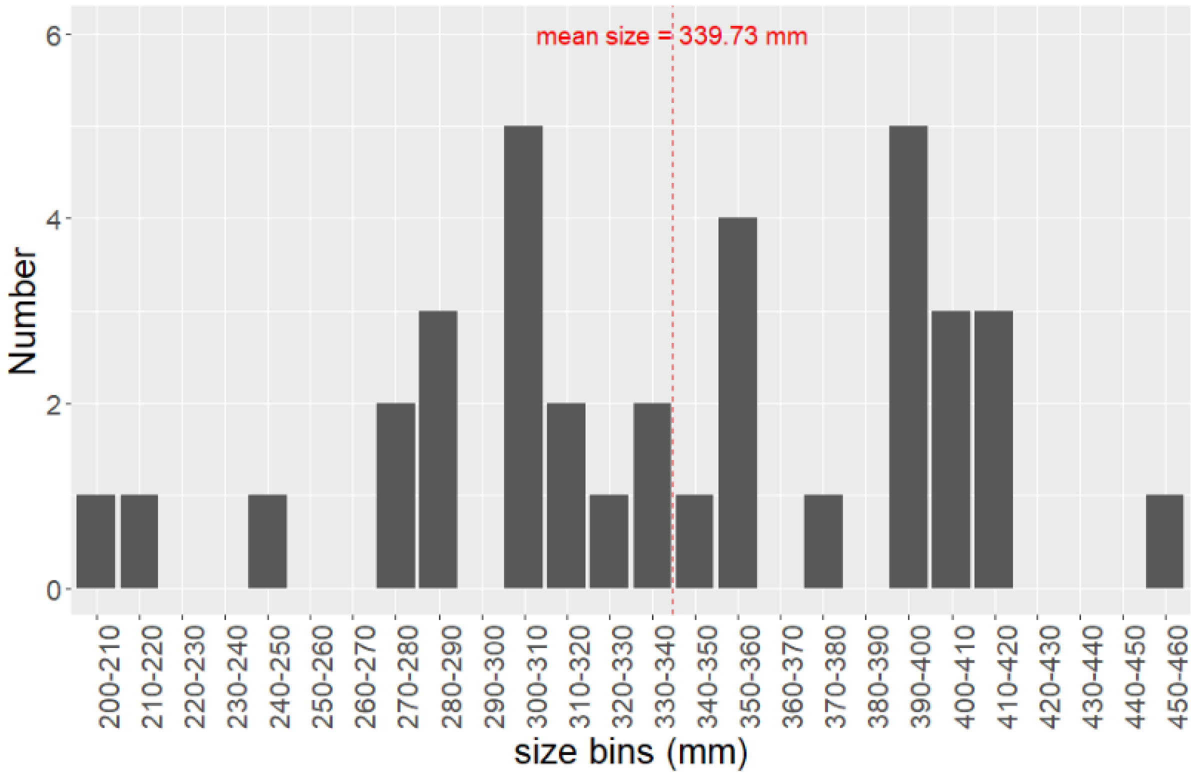


Figure 20. Length frequency distribution of measured morid cod (combined species) from ROV surveys in the Freycinet Marine Park.

Striped trumpeter

A total of 29 striped trumpeter were measured across the 29 transects, with an average length of 49.1 cm (Figure 21). Sizes ranged from 40.0 cm to 76.2 cm.

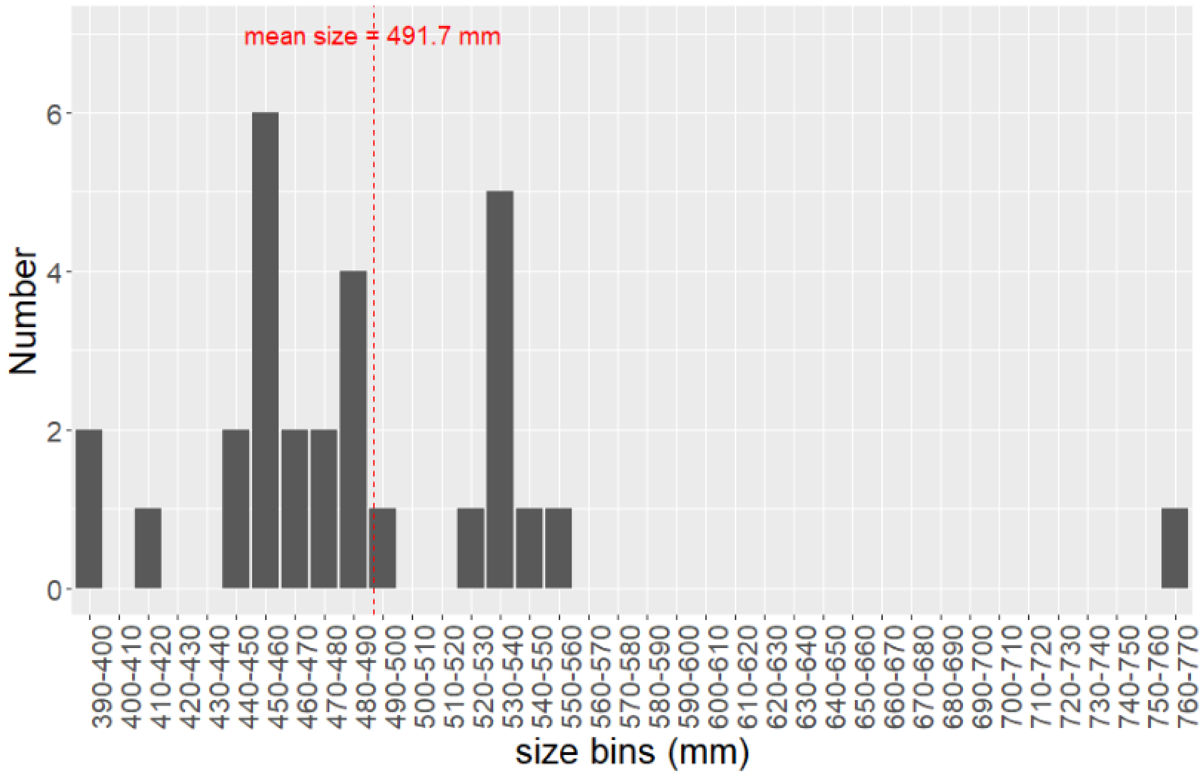


Figure 21. Length frequency distribution of measured striped trumpeter from ROV surveys in the Freycinet Marine Park.

Cosmopolitan leatherjacket

A total of 16 cosmopolitan leatherjacket were measured across the 29 transects, with an average length of 12.5 cm (Figure 22). Sizes ranged from 7.4 cm to 21.6 cm.

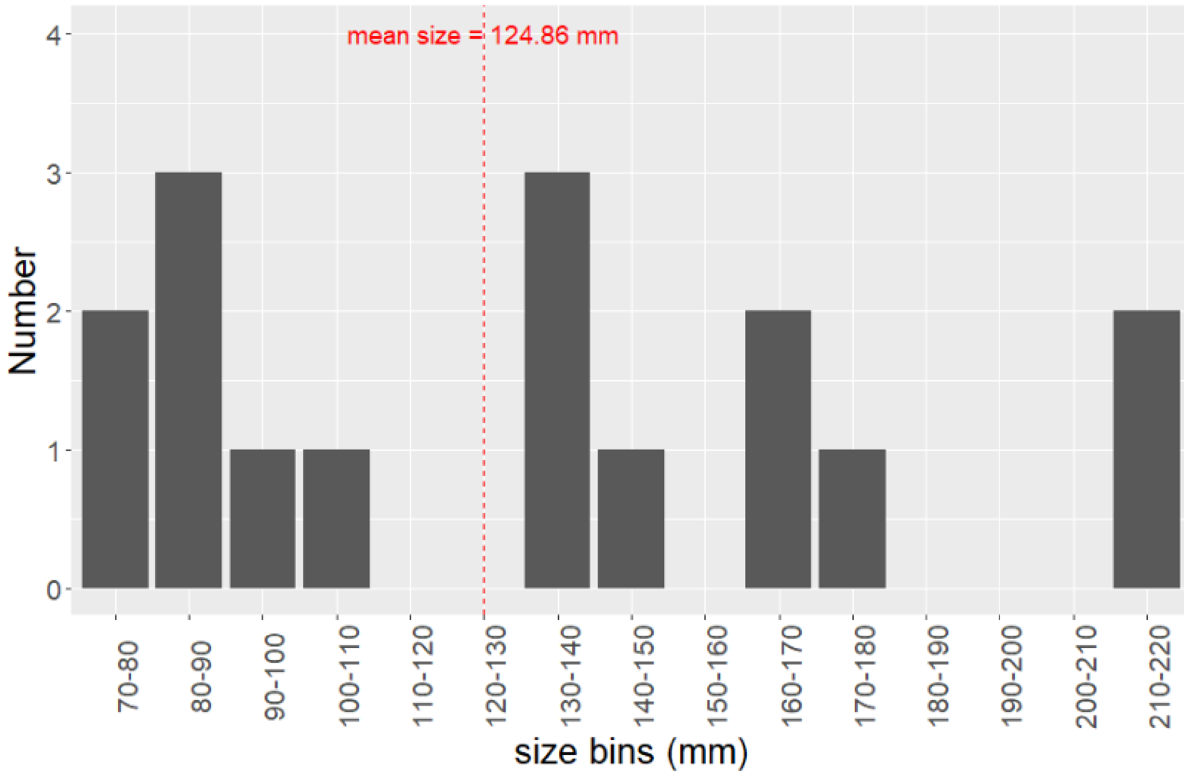


Figure 22. Length frequency distribution of measured cosmopolitan leatherjacket from ROV surveys in the Freycinet Marine Park.

ROV data: Detailed analysis of species distribution patterns

Detailed analyses were conducted to explore habitat and depth relationships for the abundance of key species observed in the ROV imagery. The species chosen for these analyses were jackass morwong, striped trumpeter, ocean perch, and morid cod (combined species) as these are key targeted recreational species and to allow direct comparison with results from the stereo BRUVs analyses. An analysis of draughtboard sharks was not conducted as only a single individual was observed (Table 20). Metrics of mean length and the abundance of larger individuals that were used in the stereo BRUV analyses were not conducted for the ROV data due to the small sample sizes for these metrics.

The same Bayesian model-based approach used in previous modelling of stereo BRUVs data in the Tasman Fracture Marine Park (TFMP) was used (Perkins et al. 2022). These models consider spatial autocorrelation present in the data with environmental covariates such as depth and habitat. Each minute of video footage along each ROV transect was classified into broad habitat types such as reef, mixed habitat, and sand ripples. These were re-classified into the proportion of reef, proportion of mixed, and proportion of soft habitat in each transect. The proportion of reef and proportion of mixed habitat were included as covariates in the model. The proportion of sand was not included as it is the remainder of the other two categories and thus does not include any additional information. Both depth and depth-squared (to capture non-linear effects) were used. To model fish abundance, a negative binomial distribution was used. To model fish length a Gaussian distribution was used. Habitat was not included in the length-based models due to the small sample sizes across each habitat category.

Model-based estimates for the proportion of reef or mixed habitat reef with significant effects (those where the posterior 95% credible intervals do not include zero) show where there was a statistically discernible difference in the metric (abundance or length) with increasing/decreasing proportions of the respective habitat. Depth estimates quantify the overall effect of depth, with positive effects indicating an increase in the metric with depth and negative effects indicating a decrease with depth. Depth-squared estimates quantify whether there is an increase in the metric in mid-depths (a negative quadratic effect) or on shallow and deep areas surveyed (positive quadratic effect). All significant effects are highlighted in green for positive effects and red for negative effects, with unhighlighted effects indicating no statistically significant effect. Plots are provided where significant depth effects were found to allow visualisation of the effect across the depth range. For significant effects, plots were created by calculating mean effects and credible intervals across 5000 posterior sample draws from the model while ignoring spatial effects. Significant effects were plotted across the range of depths and habitats in the survey data.

Jackass morwong

Abundance

Proportion reef was found to have a positive effect on the abundance of jackass morwong (Table 21 and Figure 23), although there was considerable uncertainty with this effect. No significant effect of depth, or proportion mixed habitat was found for jackass morwong.

Table 21. Model summary output for the abundance of jackass morwong in ROV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-2.176	1.237	-4.733	0.122
Proportion reef	2.244	0.771	0.793	3.819
Proportion mixed	0.683	0.472	-0.239	1.614
Depth	0.195	0.810	-1.386	1.794
Depth-squared	0.900	1.020	-1.090	2.912

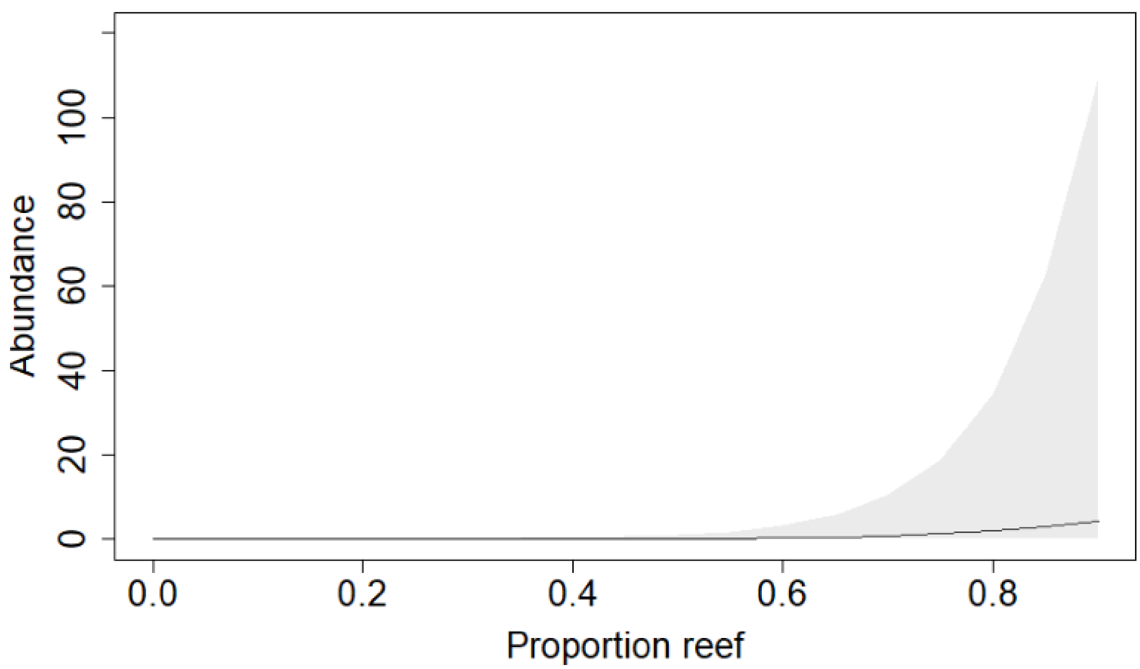


Figure 23. Modelled depth relationship with abundance for jackass morwong. Solid line shows the mean modelled response; shaded area is the 95% credible interval.

Striped trumpeter

Abundance

Proportion reef was found to have a positive effect on the abundance of striped trumpeter (Table 22 and Figure 24); however, there was considerable uncertainty in this effect, particularly at higher proportions of reef. No significant effect of depth was found.

Table 22. Model summary output for the abundance of striped trumpeter in ROV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-3.073	1.324	-5.807	-0.609
Proportion reef	2.742	0.987	0.934	4.808
Proportion mixed	-0.167	0.541	-1.302	0.819
Depth	1.008	1.098	-1.077	3.230
Depth-squared	-0.218	1.134	-2.474	1.976

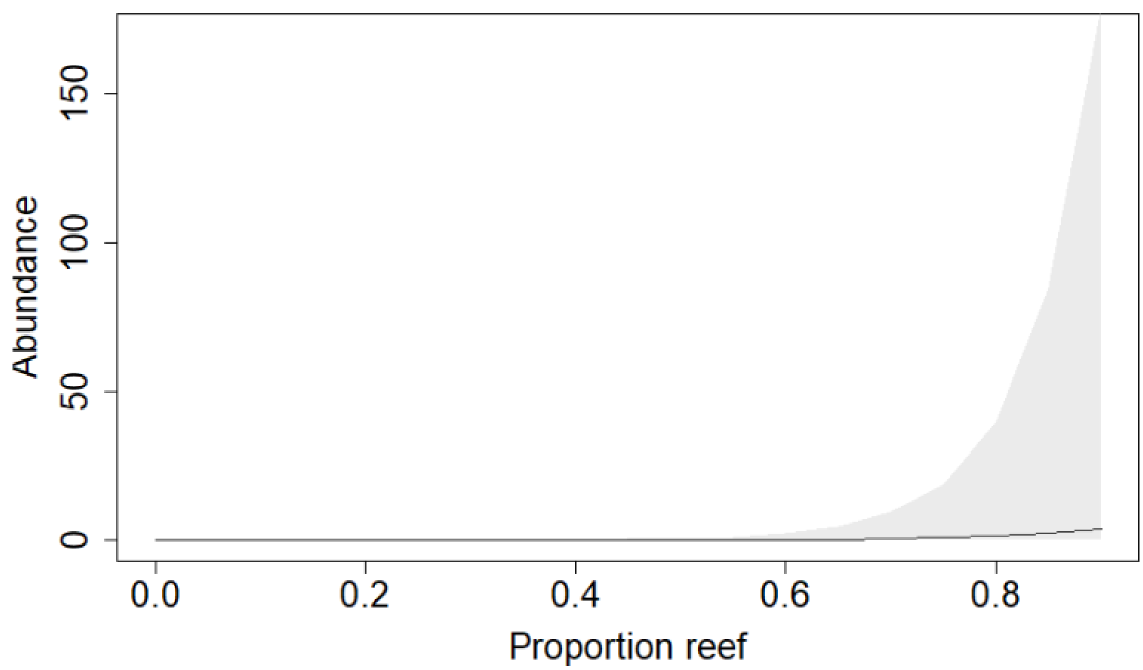


Figure 24. Modelled habitat relationship (proportion of reef in the transect) with abundance for striped trumpeter. Solid line shows the mean modelled response; shaded area is the 95% credible interval.

Morid cod (combined species)

Abundance

A significant positive effect of the proportion mixed habitat was found for morid cod, but no significant effect for depth (Table 23 and Figure 25).

Table 23. Model summary output for the abundance of morid cod in ROV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-2.402	1.071	-4.655	-0.454
Proportion reef	0.259	0.446	-0.596	1.153
Proportion mixed	1.181	0.312	0.598	1.822
Depth	-0.561	0.476	-1.500	0.368
Depth-squared	1.241	0.875	-0.444	2.988

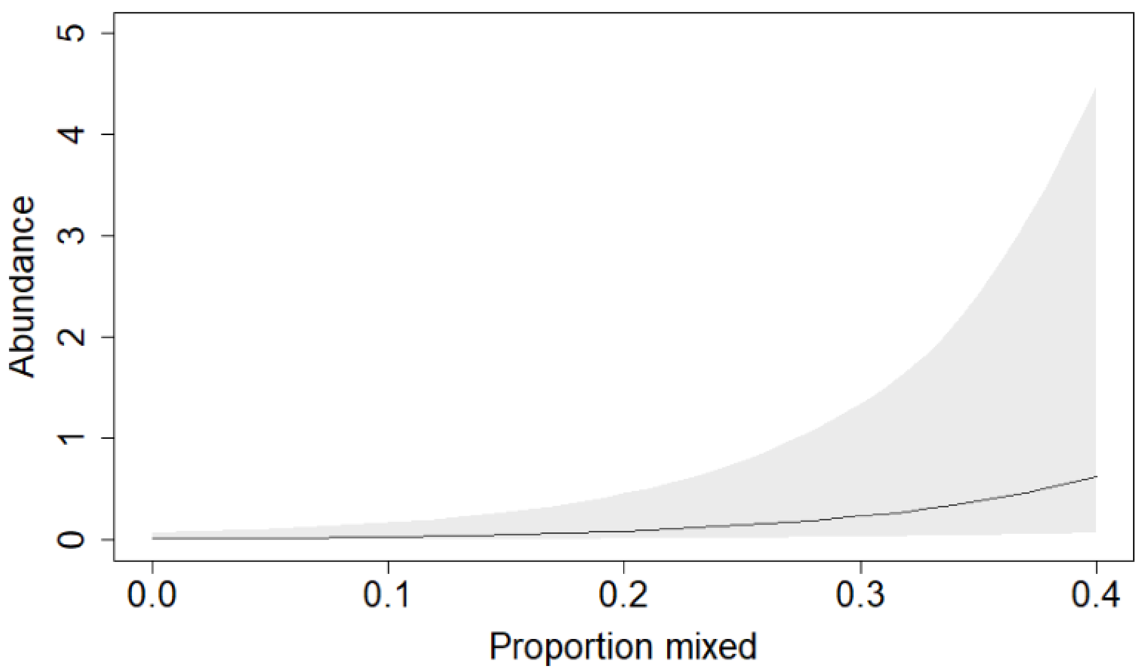


Figure 25. Modelled habitat relationship (proportion of mixed habitat in the transect) with abundance for morid cod. Solid line shows the mean modelled response; shaded area is the 95% credible interval.

Ocean perch

Abundance

A significant positive effect of proportion reef, proportion of mixed habitat, and depth squared was found for the abundance of ocean perch (Table 24, Figure 26, Figure 27, and Figure 28), indicating a higher abundance as the proportion of reef increased, higher abundances as the proportion of mixed habitat increased, and higher abundances in the shallower and deeper depths surveyed compared to mid-depths.

Table 24. Model summary output for the abundance of ocean perch in ROV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	0.521	0.564	-0.601	1.612
Proportion reef	0.920	0.276	0.380	1.464
Proportion mixed	0.364	0.181	0.010	0.719
Depth	-0.374	0.412	-1.182	0.435
Depth-squared	1.146	0.486	0.196	2.103

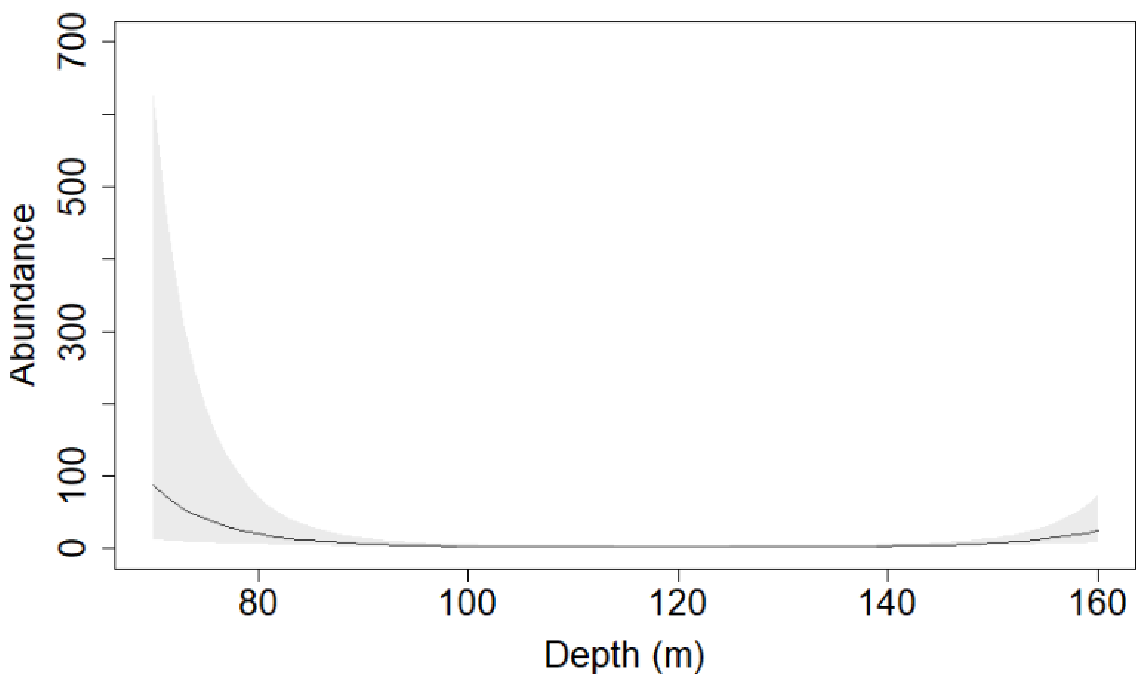


Figure 26. Modelled depth relationship with abundance for ocean perch. Solid line shows the mean modelled response; shaded area is the 95% credible interval.

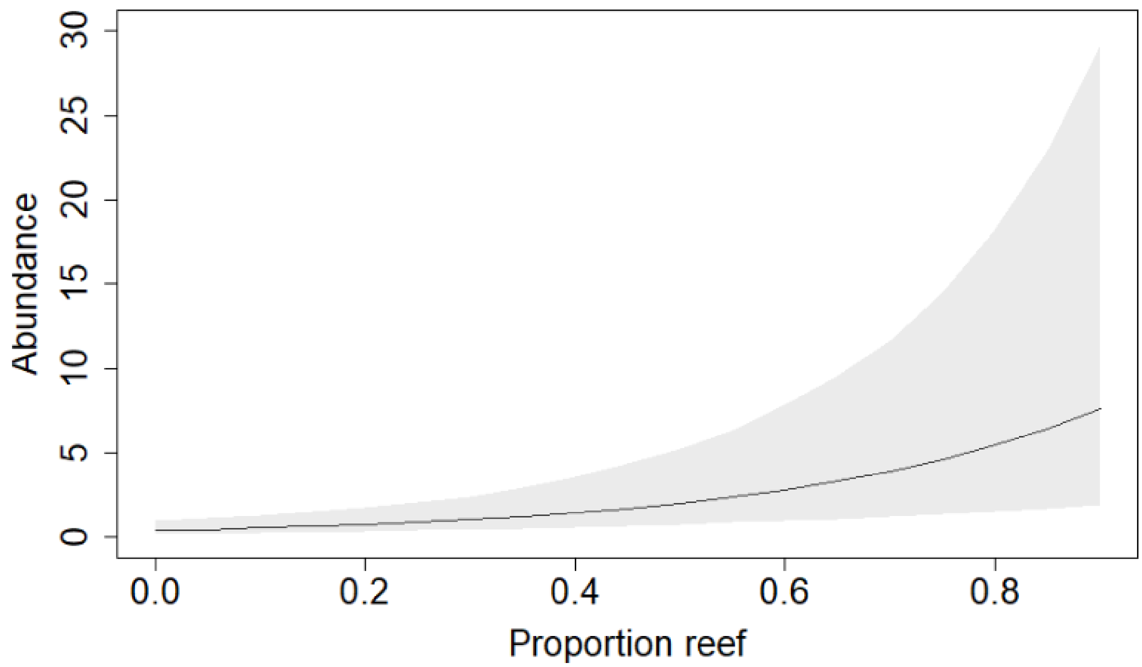


Figure 27. Modelled habitat relationship (proportion of reef in a transect) with abundance for ocean perch. Solid line shows the mean modelled response; shaded area is the 95% credible interval.

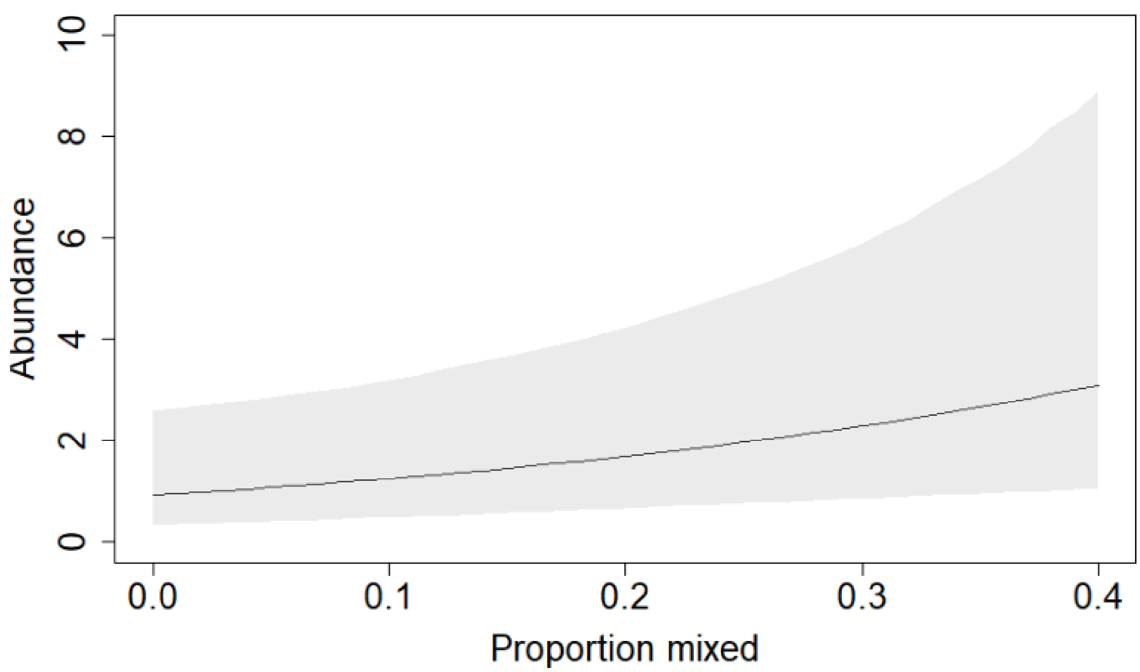


Figure 28. Modelled habitat relationship (proportion of mixed habitat in a transect) with abundance for ocean perch. Solid line shows the mean modelled response; shaded area is the 95% credible interval.

ROV data: Multivariate analysis of fish communities

Multivariate analysis was conducted using PRIMER v6 software. Analysis was done on transects rather than sub-units due to the large number of zero observations at the one-minute sub-unit level. Transects were classed as reef where > 75% of one-minute-long sub-units along the entire transect were classified as reef, soft sediment where > 75% of subunits were soft sediment, and mixed otherwise. Ecosystems were defined as either mesophotic (< 70 m) or rariphotic (> 70 m) to explore any differences in communities between these two depth-defined ecosystems. In the FMP, transects classed as mesophotic were all towards the deepest (i.e., 70 m) part of the depth range classed as mesophotic by Parks Australia. Therefore, transects that spanned depths that included the mesophotic zone were classed as mesophotic in this analysis. Furthermore, all transects that were classified as reef (> 75% of the transects with one-minute sub-units being reef) were in the mesophotic zone, hence precluding the analysis of any interaction between habitat and ecosystem.

Data was square-root transformed prior to analysis to down-weight the more abundant species such as butterfly perch, which would otherwise dominate the communities. A resemblance matrix based on Bray-Curtis similarity was produced on the transformed data. Non-metric multidimensional scaling (MDS) plots were produced to allow visualisation of the multivariate grouping of transects in relation to habitat classes and ecosystems. A selection of species was overlaid on the MDS plots to allow visualisation of important species driving the relationships. A SIMPER analysis was also conducted to further investigate the important species across ecosystem and habitat classes. A two-factor permutational multivariate analysis of variance (PERMANOVA) was conducted to examine the importance of ecosystem and habitat for the assemblage data. However, the interaction between ecosystem and habitat could not be assessed as the design was not balanced as all mesophotic transects were classed as reef.

Results of multivariate analysis

MDS plots revealed distinct clustering of communities based on habitat and depth-based ecosystems across ROV transects in the FMP (Figure 29; Figure 30). A strong correlation between deeper transects and mixed and soft habitats was observed. For HMP, complex high relief reef often transitions into sediment dominated habitats around 70-90 m, resulting in deeper rariphotic transects more often being classed as either mixed or soft habitat.

SIMPER analysis showed that species associated with deeper (rariphotic) soft bottom habitats included barred (*P. allportii*) and redbanded (*P. binivirgata*) grubfish, silverside (*A. australiae*), and common bellowsfish (*M. scolopax*). Mixed habitats, which spanned mesophotic to rariphotic depths, were dominated by species such as butterfly perch (*C. lepidoptera*), ocean perch (*H. percoides*), and rosy wrasse (*P. rubicundus*). The mesophotic ecosystem were dominated by reef associated species such as butterfly perch (*C. lepidoptera*), ocean perch (*H. percoides*), splendid perch (*C. australis*), jackass morwong (*N. macropterus*), and morid cod species (*Pseudophcis spp*). However, many species occurred in both mesophotic and rariphotic ecosystems. PERMANOVA revealed a significant effect of both habitat (Pseudo-F = 2.331, P = 0.012) and ecosystem (Pseudo-F = 3.359, P = 0.002). However, the interaction between habitat and ecosystem could not be tested as no transects that were classed as reef occurred within the rariphotic zone.

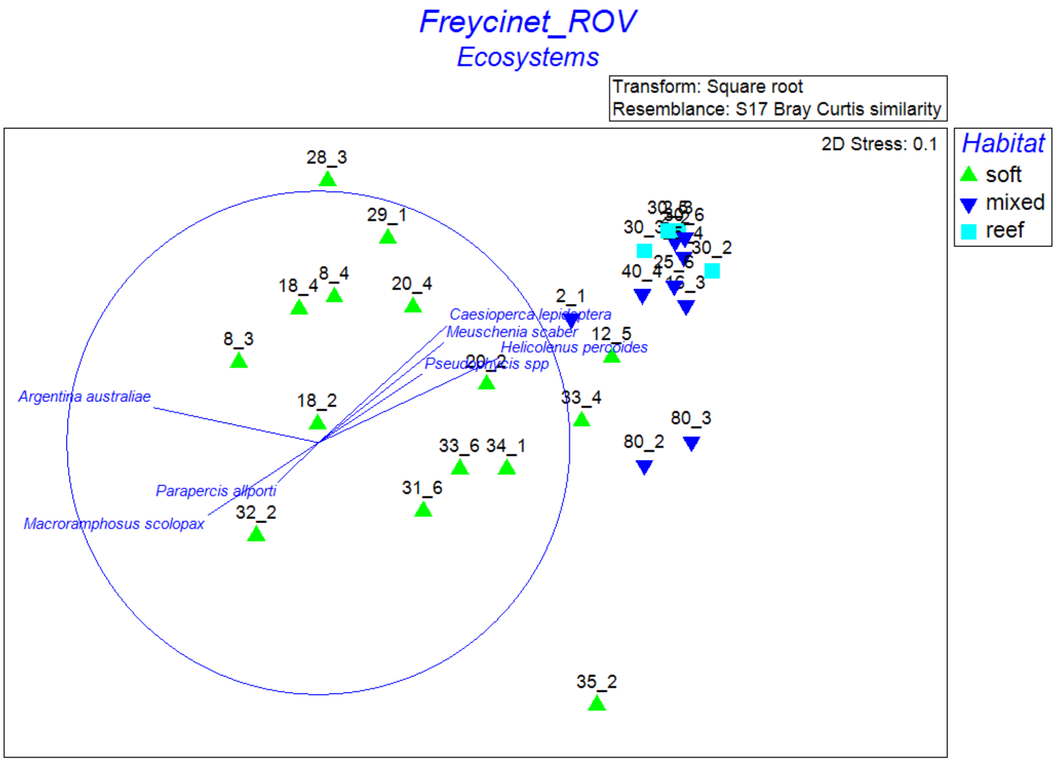


Figure 29. Non-metric multidimensional scaling plot showing the relationship between habitat classes and fish communities across ROV transects in the Freycinet Marine Park.

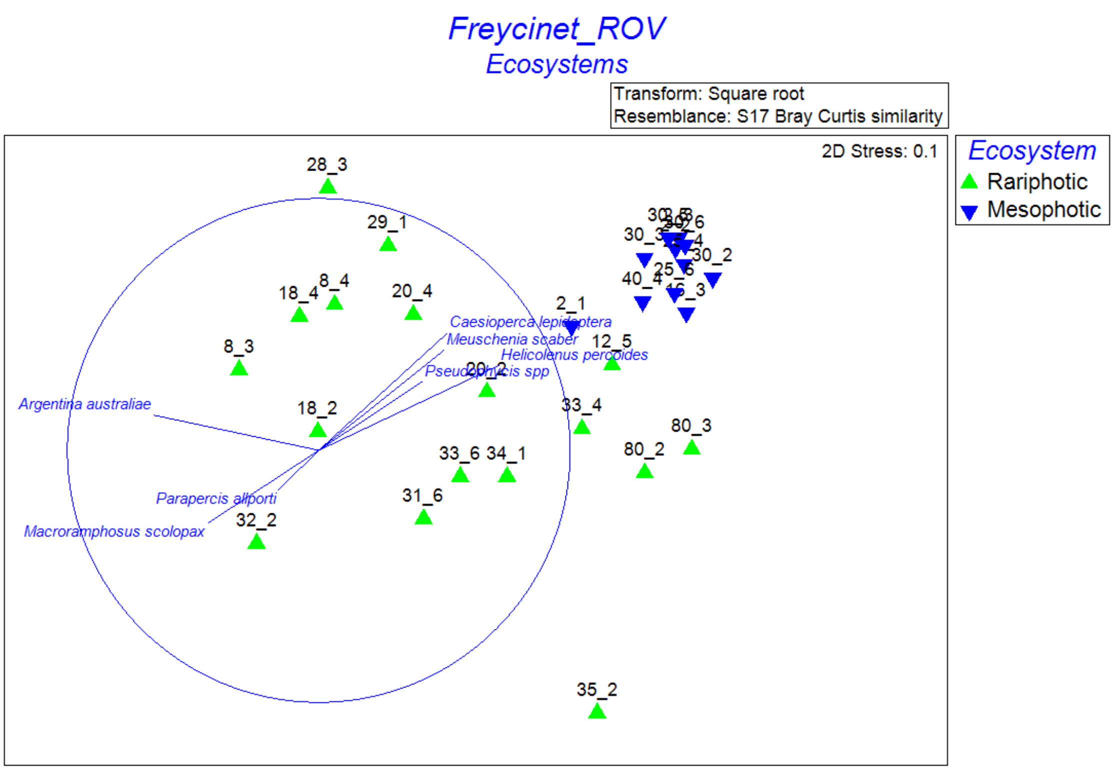


Figure 30. Non-metric multidimensional scaling plot showing the relationship between ecosystems (mesophotic < 70 m and rariphotic > 70 m) and fish communities across ROV transects in the Freycinet Marine Park.

Comparison of sampling platforms: stereo BRUV vs ROV

Data collected by ROV and stereo BRUV methodologies was compared using: (i) the length-frequency data, to explore the size-frequency distribution and abundance with each method; (ii) in a multivariate analysis to explore the differences in communities captured by each approach; and (iii) in a detailed univariate modelling approach to explore whether there were significant differences in the abundance across the different sampling platforms for a small number of species. For these analyses, data was restricted to the subset of sites that were sampled with both methodologies, as a smaller spatial spread of sampling was conducted with the ROV transects compared to the stereo BRUV drops.

For length-frequency data and the detailed analyses the same subset of commercially important species was used: jackass morwong, striped trumpeter, ocean perch, and morid cod (combined species). Butterfly perch were also included due to their high abundance across the data sets. For the length-frequency comparisons, counts (either actual counts for the ROV, or MaxN for the stereo BRUV data) were standardised by the length of the sample. For all stereo BRUVs samples the deployment time was 60 minutes, for the ROV transect times ranged from 7 minutes to 24 minutes. The standardised number of individuals recorded in 10 mm size bins was plotted to contrast the numbers seen and the shape of the size distribution.

For the multivariate analysis, the different sampling effort between the two approaches was accounted for by conducting the analysis on proportion data rather than total abundance. That is, the number of each species seen in a stereo BRUV drop or ROV transect was converted to a proportion of the total number of fish seen in that drop or transect. This proportion data was then square-root transformed to down-weight the dominant species. A Bray-Curtis similarity matrix was calculated to determine the similarity between all samples. Sampling platform (ROV or stereo BRUV) and habitat (hard, mixed, or soft) were treated as factors to quantify differences in communities between sampling platforms and habitat types. Habitat was calculated from visual assessment of stereo BRUV drops. For ROV transects, transects were classified as hard where > 75% of one minute habitat segments (see above) were reef; soft where > 75% were sand; and mixed otherwise. Non-metric multidimensional scaling (MDS) plots were produced to visually explore the differences between platforms and habitats. A similarity percentages (SIMPER) analysis was conducted to determine the species contributing most to the differences. A PERMANOVA was conducted to test for significant differences in communities between platforms and habitats and whether there was any interaction between these factors.

A similar model-based approach described in the ROV detailed analysis section above and in Perkins et al. (2022) was used for the detailed univariate analysis. The sampling platform was treated as a factor to test for significant differences between stereo BRUV and ROV methods. The length of deployment (transect time for ROV or drop time for stereo BRUV) was treated as a model offset, thus making the counts a rate (i.e., the number of fish per unit time). As with the previous modelling approach, depth and depth-squared were included to account for depth related differences. The proportion reef and proportion mixed habitat was used as a proxy for habitat either along the ROV transect, or in the region of the stereo BRUV drop. Again, significant differences were those that did not include zero in the posterior distributions. The model intercept represents the average rate for stereo BRUVs, while the "ROV" term quantifies the difference between the stereo BRUV and ROV. The magnitude of any significant difference was quantified by taking the exponential of the 'platform' coefficient, which quantifies the multiplicative effect on the response scale (number of fish observed per minute).

Length frequency comparison between stereo BRUV and ROV data

Jackass morwong

When considering the overlapping surveys, a larger number of jackass morwong were observed using stereo BRUVs (991 total of all MaxN's) when compared to ROV (115 in total). However, when taking the survey time into account these differences in abundance and the sizes observed were not as large (Figure 31). Size classes of fish captured with the ROV and stereo BRUV methodologies were similar, with generally more fish observed with the stereo BRUV methodology across all size classes.

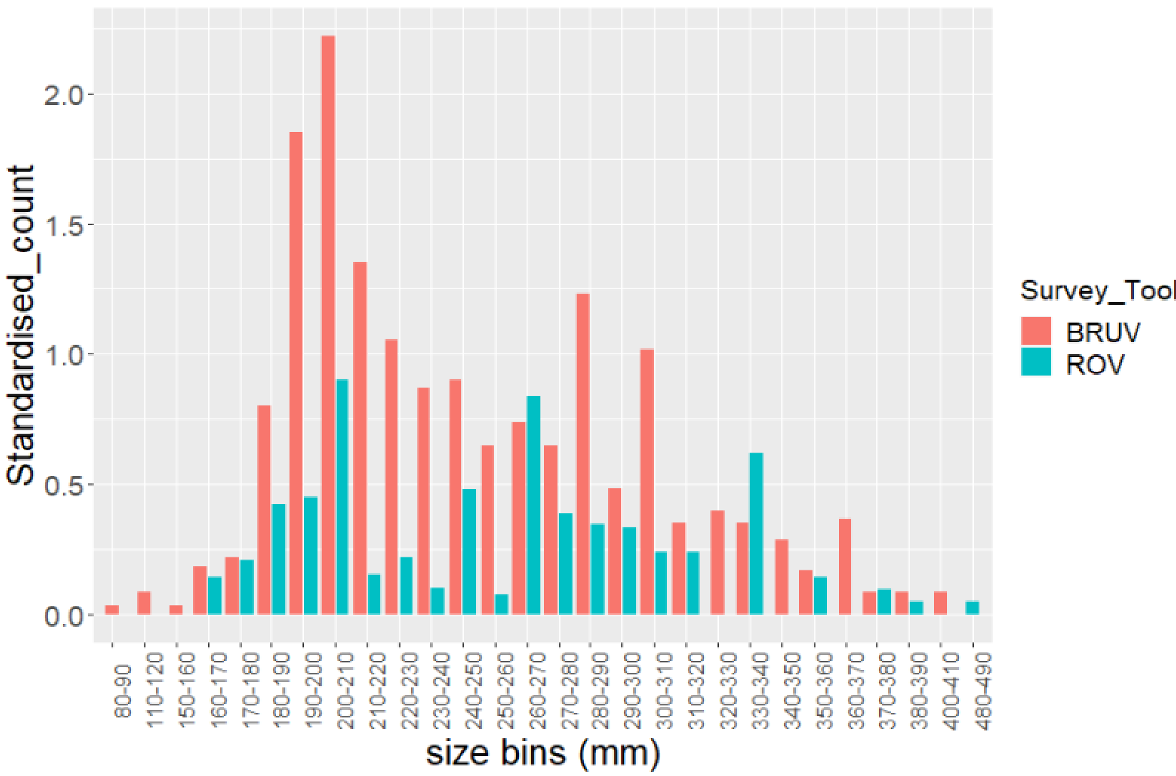


Figure 31. Comparison of the length-frequency data for jackass morwong from the stereo BRUV and ROV survey data from Freycinet Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Ocean perch

When considering the overlapping surveys, approximately one-third the number of ocean perch were observed using stereo BRUVs (107 total of all MaxN's) when compared to ROV (302 in total). These differences in abundance were further accentuated when considering the lower sampling effort (in terms of total minutes of deployment) of the ROV methodology (Figure 32). The size structure captured by each methodology also differed, with a larger proportion of smaller size-classes captured by the ROV compared to the stereo BRUVs.

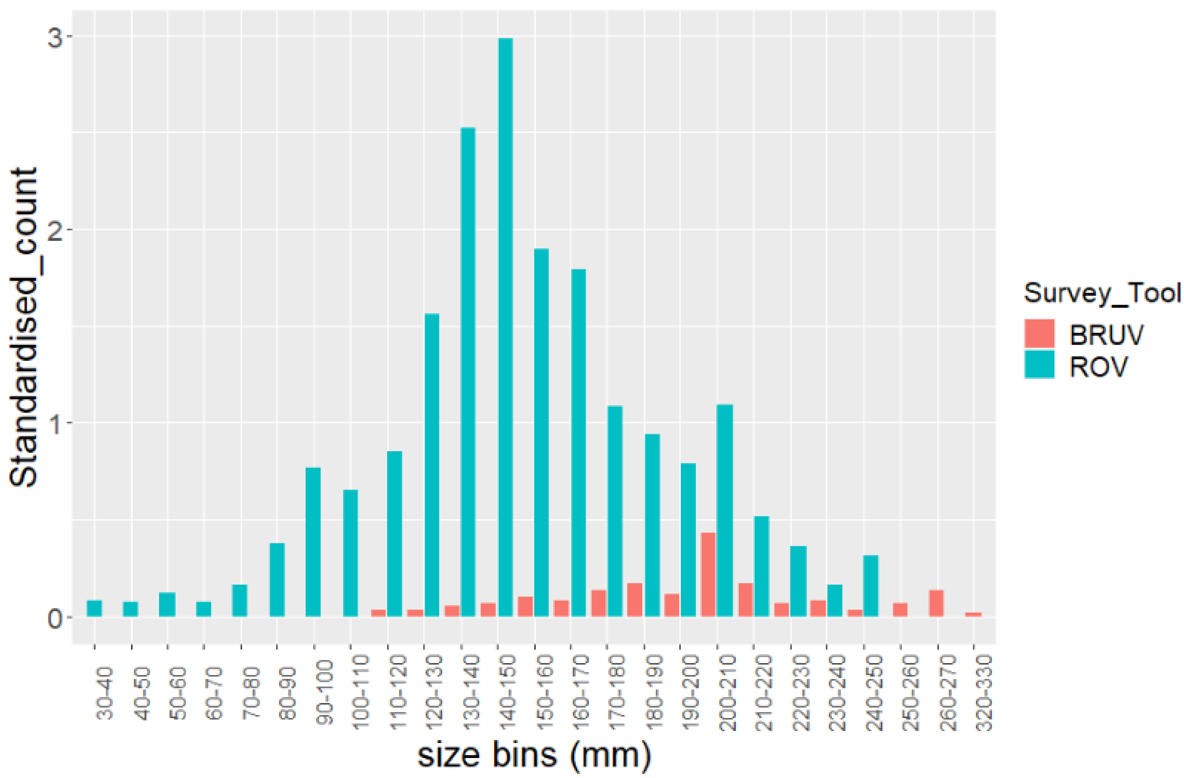


Figure 32. Comparison of the length-frequency data for ocean perch from the stereo BRUV and ROV survey data from Freycinet Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Morid cod

When considering the overlapping surveys, a larger number of morid cod were observed using stereo BRUVs (96 total of all MaxN's) when compared to ROV (36 in total). However, when taking the survey time into account these differences in abundances reversed, with more morid cod observed per unit time using the ROV compared to the stereo BRUVs approach (Figure 33). Size classes of fish captured with the ROV and stereo BRUV methodologies were largely similar, but with more of the very largest fish (> 460 mm) observed with the stereo BRUVs.

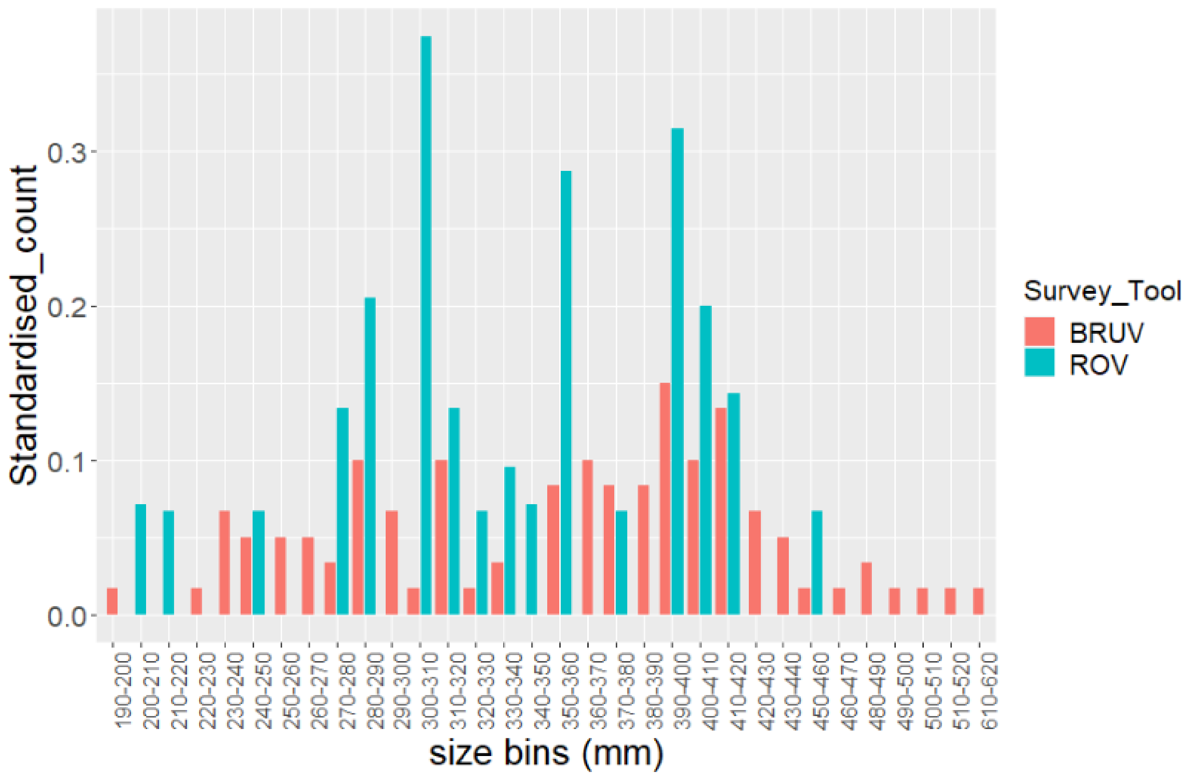


Figure 33. Comparison of the length-frequency data for morid cod from the stereo BRUV and ROV survey data from Freycinet Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Striped trumpeter

When considering the overlapping surveys, a slightly larger number of striped trumpeter were observed using stereo BRUVs (37 total of all MaxN's) when compared to ROV (29 in total). However, when taking the survey time into account these differences in abundances reversed, with more striped trumpeter observed per unit time using the ROV compared to the stereo BRUVs approach (Figure 34). Size classes of fish captured with the ROV and stereo BRUV methodologies were similar with no discernible differences given the relatively small sample size.

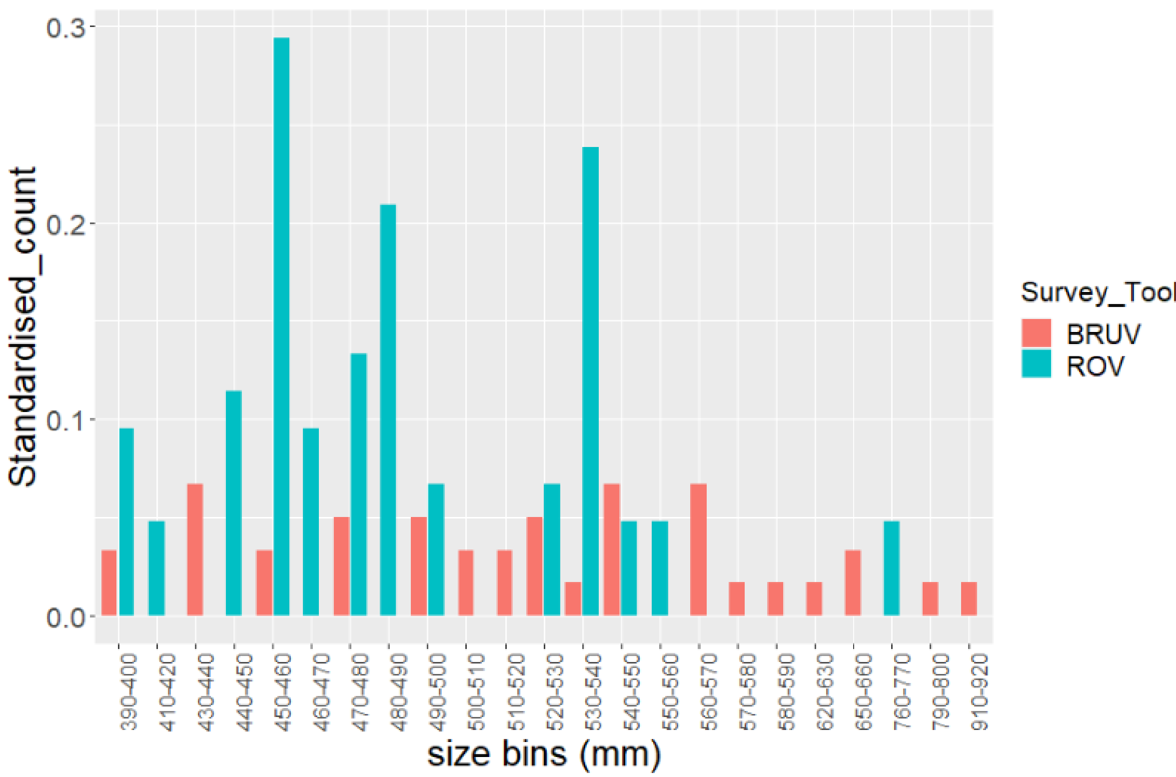


Figure 34. Comparison of the length-frequency data for striped trumpeter from the stereo BRUV and ROV survey data from Freycinet Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Butterfly perch

When considering the overlapping surveys, a much larger number of butterfly perch were observed using the ROV (3065 in total) when compared to stereo BRUVs (128 total of all MaxN's). These differences in abundances were amplified when considering the number of butterfly perch observed per unit time (Figure 35). Size classes of fish captured with the ROV and stereo BRUV methodologies were similar with an overlap in the size classes observed.

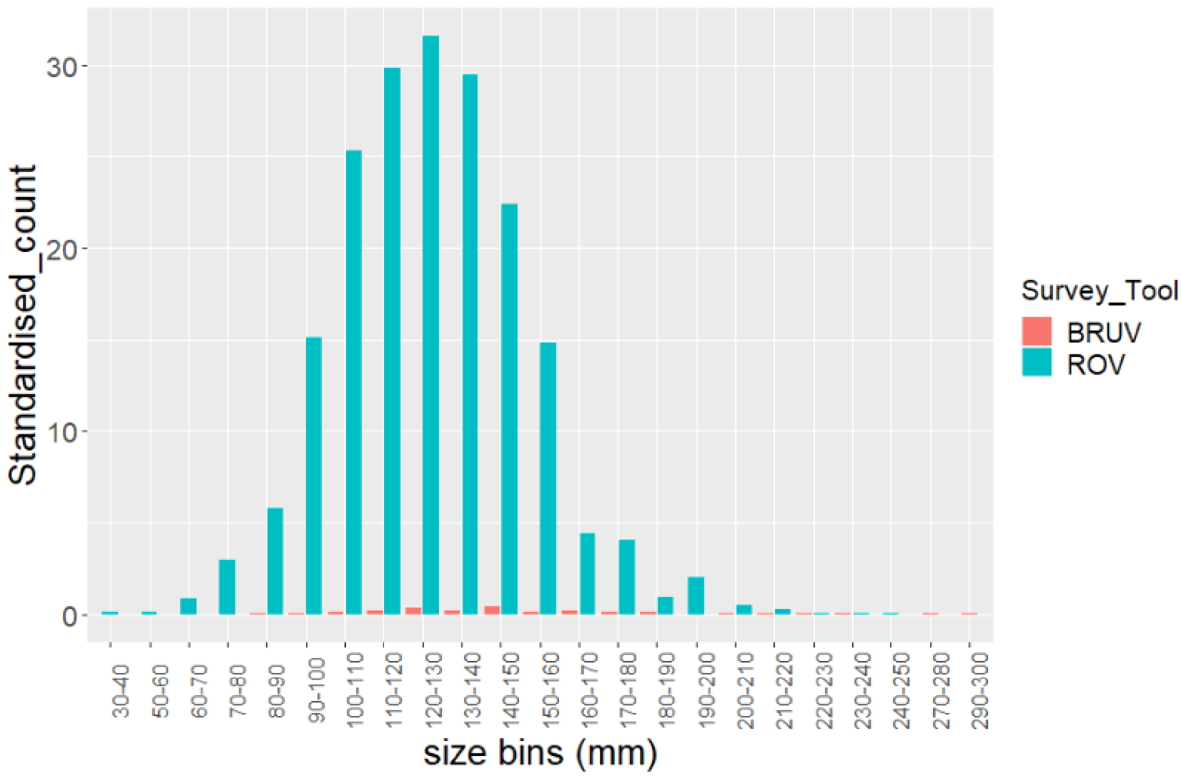


Figure 35. Comparison of the length-frequency data for butterfly perch from the stereo BRUV and ROV survey data from Freycinet Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Detailed univariate comparison of stereo BRUV and ROV data for selected species

Jackass morwong

A significant negative effect of ROV was found for the number of jackass morwong observed per unit time compared to stereo BRUV (Table 25), with the coefficient estimate indicating a mean rate of 0.15 times the number of fish observed per unit time with ROV compared with stereo BRUV. Significant positive effects were found for depth-squared and the proportion of mixed habitat, indicating a higher rate of jackass morwong were observed in areas with mixed habitats and in the shallower and deeper depths across the depths surveyed.

Table 25. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-2.945	0.637	-4.181	-1.679
ROV	-1.916	0.450	-2.815	-1.047
Depth	-0.100	0.396	-0.878	0.674
Depth-squared	1.835	0.558	0.746	2.934
Proportion reef	0.562	0.381	-0.184	1.312
Proportion mixed	0.501	0.232	0.055	0.964

Striped trumpeter

No significant effect of ROV was found for the number of striped trumpeter observed per unit time compared to stereo BRUV (Table 26). A significant positive effect was found for the proportion of reef, indicating a higher rate of striped trumpeter were observed in areas containing higher proportions of reef habitat.

Table 26. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-5.236	0.827	-6.914	-3.667
ROV	0.277	0.389	-0.507	1.019
Depth	0.669	0.582	-0.424	1.858
Depth-squared	0.384	0.682	-0.966	1.712
Proportion reef	1.254	0.477	0.370	2.243
Proportion mixed	0.044	0.232	-0.416	0.495

Morid cod

No significant effect of ROV was found for the number of morid cod observed per unit time compared to stereo BRUV (Table 27). Significant positive effects were found for the proportion of mixed habitat and depth-squared, while a significant negative effect was found for depth, indicating a higher rate of morid cod were observed in areas containing higher proportions of mixed habitat, generally in shallower depths surveyed, but also in the deepest depths surveyed.

Table 27. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-5.585	0.720	-7.082	-4.258
ROV	0.467	0.309	-0.145	1.067
Depth	-0.917	0.304	-1.522	-0.328
Depth-squared	1.580	0.566	0.504	2.724
Proportion reef	0.364	0.271	-0.167	0.896
Proportion mixed	0.744	0.182	0.394	1.107

Ocean perch

A significant positive effect of ROV was found for the number of ocean perch observed per unit time compared to stereo BRUV (Table 28), with the coefficient estimate indicating a mean rate of 18 times the number of fish observed per unit time with the ROV compared to the stereo BRUVs. No significant depth or habitat effects were found.

Table 28. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-4.572	0.590	-5.735	-3.421
ROV	2.890	0.231	2.437	3.343
Depth	-0.248	0.422	-1.076	0.581
Depth-squared	0.877	0.489	-0.083	1.838
Proportion reef	0.487	0.314	-0.127	1.104
Proportion mixed	0.293	0.190	-0.078	0.668

Butterfly perch

A significant effect of ROV was found for the number of butterfly perch observed per unit time compared to stereo BRUV (Table 29), with the coefficient estimate indicating a mean rate of 28 times the number of fish observed per unit time with the ROV compared to the stereo BRUVs. Significant positive effects were found for the proportion of both reef and mixed habitat and depth-squared, while a significant negative effect was found for depth, indicating a higher rate of butterfly perch were observed in areas containing higher proportions of reef and mixed habitat, generally in shallower depths surveyed, but also in the deepest depths surveyed.

Table 29. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-5.129	0.687	-6.512	-3.818
ROV	3.340	0.423	2.497	4.157
Depth	-0.788	0.309	-1.405	-0.193
Depth-squared	1.223	0.511	0.245	2.25
Proportion reef	1.433	0.302	0.827	2.011
Proportion mixed	0.803	0.202	0.418	1.210

Rosy wrasse

A significant effect of ROV was found for the number of rosy wrasse observed per unit time compared to stereo BRUV (Table 30), with the coefficient estimate indicating a mean rate of approximately 12 times the number of fish observed per unit time with the ROV compared to the stereo BRUVs. A significant negative effect was found for depth, indicating a higher abundance in the shallower depths surveyed.

Table 30. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Freycinet Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-5.875	0.804	-7.564	-4.410
ROV	2.451	0.266	1.947	2.991
Depth	-1.312	0.784	-3.060	-0.001
Depth-squared	-1.263	0.836	-3.043	0.237
Proportion reef	1.459	0.423	0.690	2.350
Proportion mixed	0.345	0.251	-0.139	0.845

Multivariate comparison of stereo BRUV and ROV data

The MDS plot shows a clear distinction between the communities captured with the ROV versus stereo BRUV methods (Figure 36). SIMPER analysis revealed that a much higher relative abundance of bait-attracted species such as jackass morwong (*N. macropterus*), striped trumpeter (*L. lineata*) and morid cod (*Pseudophycis spp*) in the stereo BRUV data, whereas the ROV data had a higher proportion of species that are less likely to be bait attracted such as butterfly perch (*C. lepidoptera*), silverside (*A. australiae*), barred grubfish (*P. allporti*), and common bellowsfish (*M. scolopax*). PERMANOVA showed significant differences between sampling platforms (Pseudo-F = 21.75, P = 0.001) and habitat (Pseudo-F = 4.10, P = 0.003) and a marginally non-significant interaction between platform and habitat (Pseudo-F = 2.39, P = 0.055). Only mixed and hard habitat classes were included in the subsetted data. SIMPER analysis revealed that hard habitats across both sampling platforms were typified by cosmopolitan leatherjacket, rosy wrasse, jackass morwong, and morid cod. Mixed habitats were dominated by butterfly perch, ocean perch and sandpaper fish.

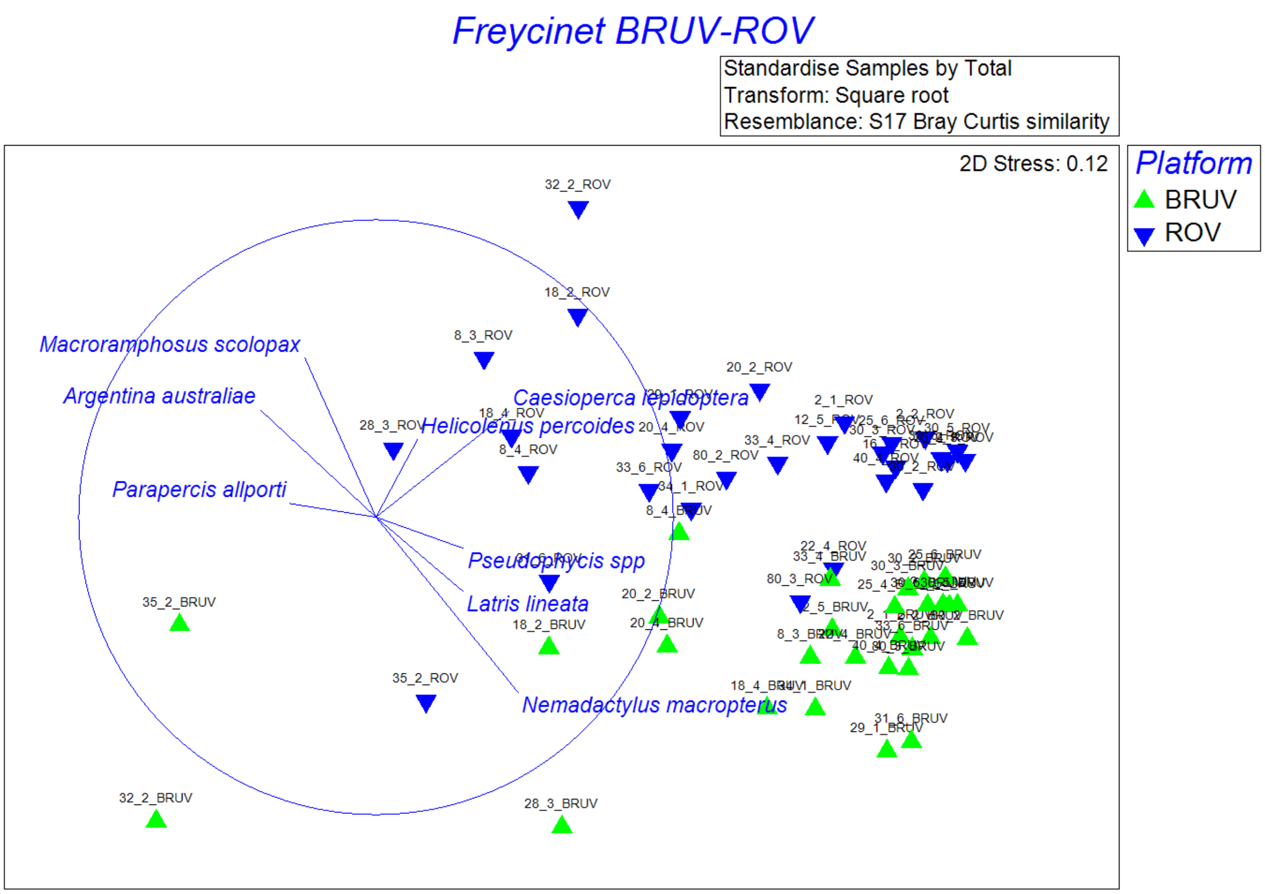


Figure 36. Non-metric multidimensional scaling plot showing the difference in communities quantified between stereo BRUV and ROV sampling platforms. Blue text and directional lines show some of species driving the differences.

Discussion: Freycinet ROV and ROV-stereo BRUV comparison

Initial testing of the ROV methodology as a tool for ongoing monitoring of fish communities in FMP has revealed that this approach is certainly capable of adequately quantifying the benthic fish populations present for many species, if sufficient sampling time was available. Some distinct differences were noted between the community composition and abundance of some key species in comparison to the stereo BRUV approach, notably around the estimates for bait attracted species such as jackass morwong (typically higher when using stereo BRUVS) and non-bait attracted species such as rosy wrasse and butterfly perch (usually markedly higher when using ROVs). Given the wide range of habitats present in the FMP, and the limited sampling by ROV due to this being a pilot/trial of this method in the region, the sample sizes achieved in this initial survey were generally too small to adequately quantify the abundance and habitat relationships of some of the important fish species. Despite this, some fine scale habitat associations such as the importance of the mudstone cliffs habitat for species such as eastern orange perch, jackass morwong, and southern rock lobster were able to be adequately described. Likewise, the method clearly demonstrated the capacity of ROV-based surveys to describe a wider overall community of species than stereo BRUV surveys, with the additional ability to quantify key bait-attracted species with sufficient replication. Overall though, stereo BRUV surveys were found to generally provide much larger sample sizes for a number of key fishery-targeted species, particularly of length frequencies (due to fish being in front of cameras for longer periods, allowing greater chance of side-profiles being observed), which may be important where detection of fishing impacts on size-structure of populations of commercially important species such as jackass morwong is a metric of interest. Conversely, the ROV methodology appears to be much more suitable for capturing fine-scale habitat associations and recording the presence of non-bait-attracted species.

From the ROV surveys, distinct differences were found in the fish communities between mesophotic (< 70 m) and rariphotic (> 70 m) ecosystems and habitat classes (either reef, mixed, or soft habitats). However, as all mesophotic transects were reef dominated (i.e. the only mesophotic habitat present in the park is the top of Joe’s Reef), the interaction between ecosystem and habitat could not be tested. Overall, it seems likely that differences are driven by a combination of both preferred habitat availability and depth. All the mesophotic depths (< 70 m) in the FMP are at the deep end (i.e., close to 70 m) of the defined mesophotic zone. Therefore, it may make sense to define communities based on habitat, rather than depth-defined ecosystems for the FMP.

A number of distinct habitats were observable in the FMP ROV and stereo BRUV footage, ranging from the high-relief reef features of Joe’s Reef, mudstone cliffs with distinct holes and crevices, lower relief reef features, mixed habitats, dune-like soft sediment features and sand and rubble habitats. Initial analysis indicates that these different habitats are likely to harbour different species assemblages. However, sample size in each habitat category were not large enough for detailed analysis, due to the pilot-study/trial nature of this initial ROV experimentation. Therefore, given this approach appears to be robust and informative, ideally a focus of future monitoring would be to increase sampling effort to gain larger sample sizes for key species of interest.

Finally, relationships with visually assessed habitat in stereo BRUVs footage may be misleading as it is difficult to quantify how far different fish were drawn from surrounding habitat. As the ROV provides the ability to directly observe species in their preferred habitats, it appears to be a more reliable way to quantify habitat relationships. Finer-scale fish habitat associations (such as relationships with particular features within-reef crevices) are likely to be more discernible with the ROV methodology compared to the stereo BRUV methodology.

Overall, as expected, bait-attracted species formed a higher proportion of the fish communities recorded in the stereo BRUV-derived data compared to the ROV data. For example, jackass morwong were significantly more abundant in stereo BRUVs footage when taking the sampling time into account; whereas ocean perch, butterfly perch and rosy wrasse were higher in abundance in the ROV observations. Interestingly, there were no significant differences found for the abundance of striped trumpeter or morid cod between ROV and stereo BRUVs. Hence, for even some of the target species of interest, the ROV-based approach has significant potential as a future monitoring tool. Of note, was that the ROV surveys, although quite limited in their overall use in this park/trial, revealed the presence and detailed habitat association of Eastern orange perch (*Lepidoperca pulchella*) and Spot-tail perchlet (*Plectranthias maculicauda*) on the outer-shelf reef systems, as well as the presence of three handfish, demonstrating the additional fish biodiversity and habitat-association knowledge gained by this approach.

Huon Marine Park: Stereo BRUV survey of fish populations

Background and methods

Stereo BRUV surveys were conducted in the Huon Marine Park (HMP) from June-July 2021 to provide baseline descriptions of demersal fish species in mesophotic (30-70 m) to rariphotic (70-200 m) depths and across representative habitats, predominantly dolerite reef and sandy sediments. Notably though, few reefs in this park have been mapped, or are expected to be present, at depths greater than 100 m, so the overall reef-focussed sampling reflects this, with sampling in this habitat restricted to the inner to early mid-shelf. Within this, the mesophotic reef sampling (i.e., reefs shallower than 70 m) was restricted to the far NE corner of the park, the only location where such habitat is found. Deployments were conducted in windows of suitable weather from 21-24 June, 8-11 July and on the 14th of July. All deployments followed the standard operating protocols for stereo BRUVs outlined in Langlois et al. (2020), with one hour deployments using ~ 800 g of pilchards for bait. The survey design was spatially-balanced with a higher inclusion probability for reef habitats, to allow better description of reef-associated species, but with some (~1/3) sites situated on soft sediment to allow the description of the species associated with these habitats. In total, 172 successful stereo BRUV drops were completed (Figure 37), with 48 drops in mesophotic depths (< 70 m) and 124 drops in rariphotic depths (71 m – 169 m). The shallowest deployment was in 35 m, and the deepest in 169 m. Soft-sediment sampling extended from the inner shelf to the shelf break, to better understand the nature of spatial patterns in habitats and soft-sediment associated species. In comparison, the spatial extent of reef habitat sampling was more restricted due to the lack of reef in the mid to outer-shelf in this park.

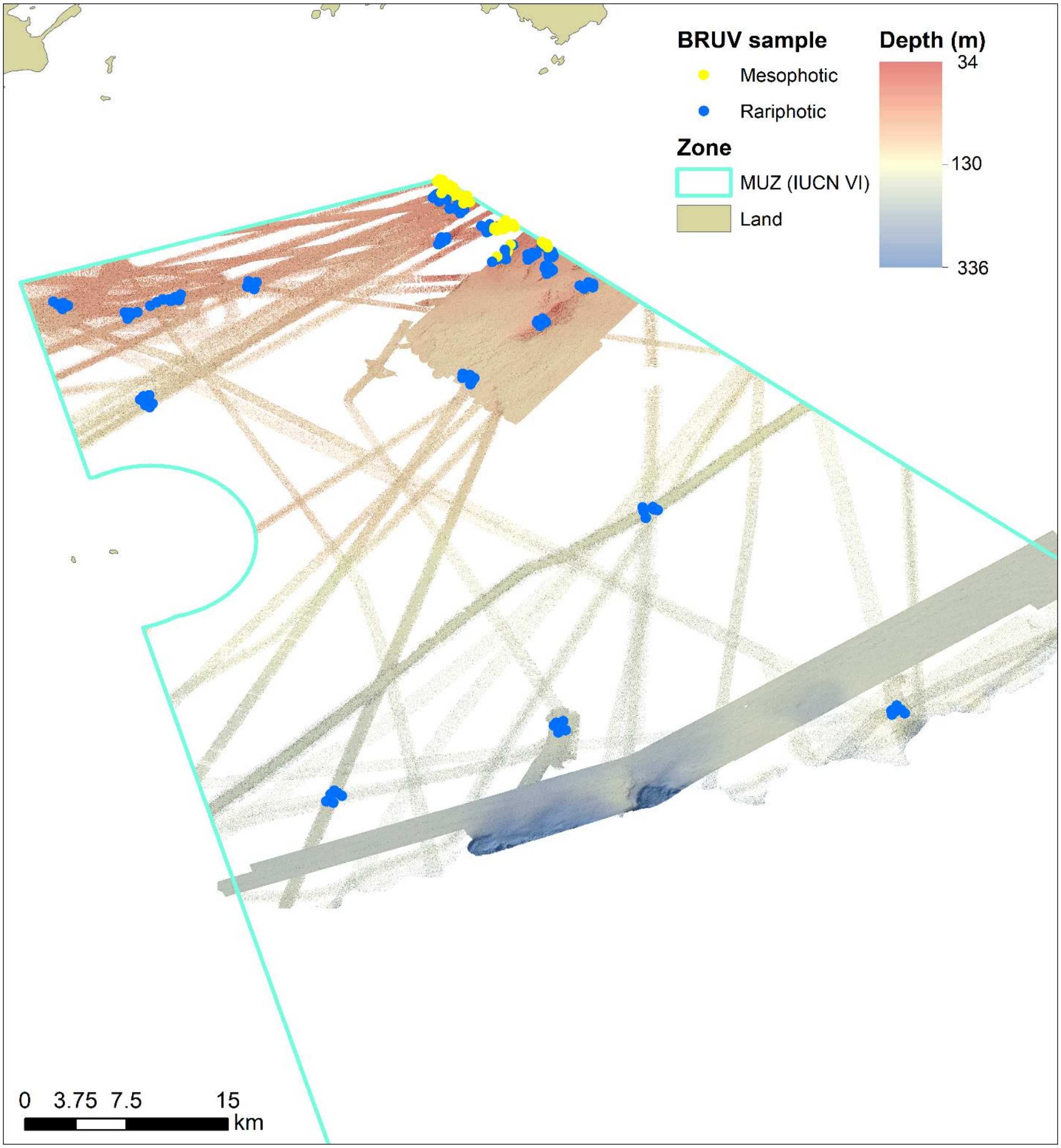


Figure 37. Location of stereo BRUV deployments in the Huon Marine Park.

Results

Distribution of habitats from stereo BRUV and ROV surveys

The HMP shelf region is primarily a wave-exposed, sediment-dominated system, with a small but important component of rocky reef evident in the shallower mesophotic region of the HMP (45-70 m depth), extending as isolated ridges and patches into the rariphotic zone from 70-100 m where most reef stopped (Figure 38). While some very low-profile reef was observed in stereo BRUV drops on the outer shelf, this was typically sand-inundated, offering very little refuge or habitat structure to the fish assemblage. The remaining reef systems were restricted to the inner shelf where they were often high relief dolerite bedrock and boulder systems with significant structural complexity. This complex reef was most evident in the NE sector of the park, forming continuous reef over an extensive area. In this region the complexity supported a high diversity of algal and invertebrate species in the mesophotic zone, including a small area (ranging from a peak at 35 m to approximately 45 m depth) supporting kelp *Ecklonia radiata* (Figure 38). In the NE sector of the park, lower resolution multibeam mapping and anecdotal evidence suggested the presence of lower complexity reef but dominated by an arc of ledge features running east/west. The stereo BRUV-based imagery validated this was the case, with the ledge feature strongly driving the distribution of reef fishes and lobsters. At deeper rariphotic sites (70-100 m+) the reefs tended to be more dominated by sediment cover, with reef typically being of lower relief with an invertebrate cover including sponges, bryozoans and gorgonians. Example imagery of characteristic habitats observed in stereo BRUV and ROV footage is provided in the Appendix.

Soft sediment habitat appears to be the primary habitat in shelf waters within the HMP and grades from approximately 70 m depth on the inner shelf to approximately 200 m on the outer shelf, immediately before the shelf-break. On the inner shelf these sediments appear to be strongly swell sculptured coarse sand with distinct ripples and no emergent fauna, although by 100 m depth, these sediments can overlay low-profile reef and have some emergent fauna. By the outer shelf the ripples were less distinct (but still present), the sediment was finer grained, and typically had a significant cover of mobile brittlestars.

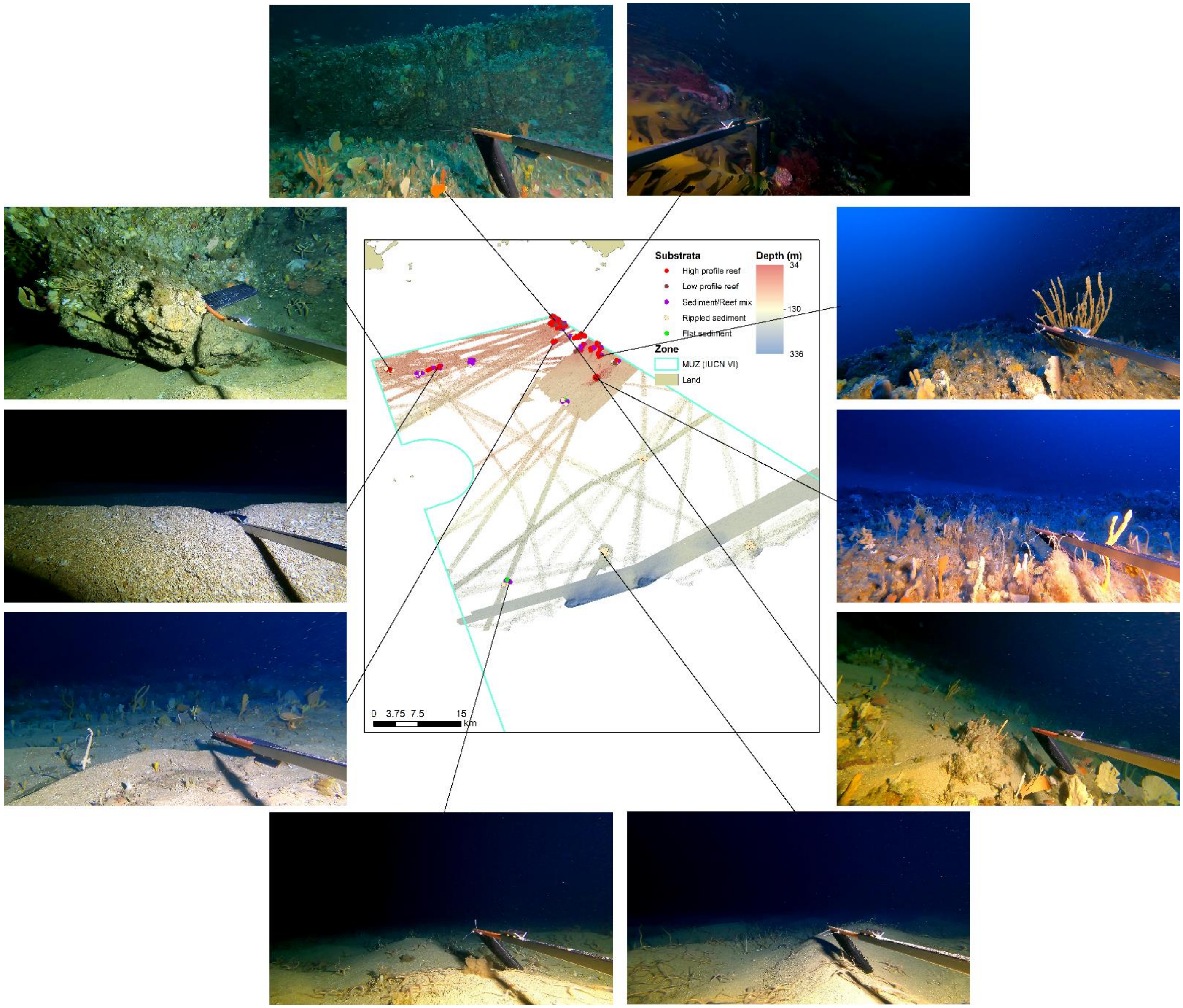


Figure 38. Example images of habitats across Huon Marine Park from stereo BRUV drops.

BRUV data: General description

The fish species composition within HMP appears similar to that described in previous stereo BRUV surveys in the nearby Tasman Fracture MP (TFMP), with many of the same characteristic deeper reef associated species being present and in similar order of contribution by abundance (*Table 31* and see Perkins et al. (2022)). Dominant species include high abundances of butterfly perch (*Caesioperca lepidoptera*), cosmopolitan leatherjacket (*Meuschenia scaber*), mackerel species (*Trachurus spp.*) in passing schools, splendid perch (*Callanthias australis*), jackass morwong *(Nemadactylus macropterus*), morid cod species (*Pseudophycis spp.*), ocean perch (*Helicolenus percoides*) and rosy wrasse (*Pseudolabrus rubicundus*). Of particular note is the significant abundance of striped trumpeter (*Latris lineata*), a key targeted species in the region, with markedly higher abundances observed here than in the nearby TFMP, presumably due to the more complex nature of reef systems found in the HMP and the overall greater extent of reefs shallower than 100 m. Likewise, jackass morwong, another key targeted species, were higher in abundance in the HMP than the TFMP. There was also high abundance of many of the key bycatch species in the rock lobster fishery, including draughtboard sharks (*Cephaloscyllium laticeps*), ocean perch (*Helicolenus percoides*) and various leatherjacket species. Example imagery of species observed in stereo BRUV videos is provided in the Appendix.

Southern rock lobster (*Jasus edwardsii*) were also abundant in stereo BRUV footage, with a total abundance (sum of MaxN) of 261 individuals sighted. Whilst the focus of the stereo BRUVs study was on the description of fish species, a brief analysis of the size structure of the lobster population is provided below. Other invertebrates observed included squid, octopus and a single giant crab (*Pseudocarcinus gigas*). Protected species observed included the observation of three spiny pipehorse (*Solegnathus spinosissimus*), a species protected under Tasmanian fisheries legislation rather than conservation-based legislation such as the EPBC act.

Table 31. Abundance (total of MaxN) of fish species recorded in stereo BRUV surveys of the Huon Marine Park in 2021 across ecosystems (mesophotic and rariphotic) and targeted habitats (reef or sand). Baitfishes (order Clupieformes) and mackerel (Trachurus spp.) were not included in this table.

Family	Scientific name	Common name	Mesophotic sediment MaxN	Mesophotic reef MaxN	Rariphotic sediment MaxN	Rariphotic reef MaxN
	Number of stereo BRUVs drops		**1**	**47**	**52**	**72**
Callanthiidae	*Callanthias australis*	Splendid perch	0	129	3	291
Centrolophidae	*Seriolella brama*	Blue warehou	0	1	0	0
Cheilodactylidae	*Nemadactylus macropterus*	Jackass morwong	0	123	214	437
Cyttidae	*Cyttus australis*	Silver dory	0	13	1	15
Dasyatidae	*Bathytoshia brevicaudata*	Smooth stingray	0	0	1	0
Gempylidae	*Thyrsites atun*	Barracouta	0	1	0	0
Gerreidae	*Parequula melbournensis*	Silverbelly	0	11	2	9
Hexanchidae	*Notorynchus cepedianus*	Broadnose sevengill shark	0	0	1	0
Labridae	*Notolabrus fucicola*	Purple wrasse	0	1	0	0
	Notolabrus tetricus	Bluethroat wrasse	0	1	0	0
	Pictilabrus laticlavius	Senator wrasse	0	1	0	0
	Pseudolabrus rubicundus	Rosy wrasse	1	250	3	134
Latridae	*Latris lineata*	Striped trumpeter	0	43	63	73
Macroramphosidae	*Notopogon lilliei*	Crested bellowsfish	0	0	50	1
Monacanthidae	*Acanthaluteres spilomelanurus*	Bridled leatherjacket	0	1	0	0
	Acanthaluteres vittiger	Toothbrush leatherjacket	0	1	0	0
	Eubalichthys gunnii	Gunn's leatherjacket	0	10	0	7
	Meuschenia australis	Brownstriped leatherjacket	0	5	0	2
	Meuschenia scaber	Cosmopolitan leatherjacket	1	509	19	395
	Meuschenia spp	Leatherjacket spp	0	1	0	0
	Thamnaconus degeni	Degen's leatherjacket	0	1	0	9
Moridae	*Lotella rhacina*	Rock cod	0	0	0	2
	Pseudophycis bachus	Red cod	0	24	8	45
	Pseudophycis barbata	Southern codling	0	94	28	113

Mullidae	*Upeneichthys lineatus*	Bluestriped goatfish	0	2	0	0
Myliobatidae	*Myliobatis tenuicaudatus*	Southern eagle ray	0	0	0	1
Neosebastidae	*Neosebastes scorpaenoides*	Common gurnard perch	0	12	21	51
Palinuridae	*Jasus edwardsii*	Southern rock lobster	1	164	1	95
Pinguipedidae	*Parapercis allporti*	Barred grubfish	2	6	49	72
Platycephalidae	*Platycephalus aurimaculatus*	Toothy flathead	0	0	7	2
	Platycephalus bassensis	Sand flathead	0	0	9	1
	Platycephalus richardsoni	Tiger flathead	0	0	1	0
	Platycephalus spp	Flathead spp	0	0	0	1
Rajidae	*Dipturus cerva*	Whitespotted skate	0	0	1	0
	Spiniraja whitleyi	Melbourne skate	0	1	0	0
Scorpaenidae	*Scorpaena papillosa*	Southern red scorpionfish	0	6	0	1
Scyliorhinidae	*Asymbolus rubiginosus*	Orange spotted catshark	0	0	13	17
	Cephaloscyllium laticeps	Draughtboard shark	0	30	15	49
Sebastidae	*Helicolenus percoides*	Ocean perch	2	63	19	142
Serranidae	*Caesioperca lepidoptera*	Butterfly perch	0	1370	14	760
	Caesioperca rasor	Barber perch	0	3	0	0
	Caesioperca spp	Perch spp	0	5	0	12
	Hypoplectrodes maccullochi	Halfbanded seaperch	0	3	0	3
Squalidae	*Squalus acanthias*	Whitespotted dogfish	0	0	5	0
	Squalus megalops	Spikey dogfish	0	0	10	3
Syngnathidae	*Solegnathus spinosissimus*	Spiny pipehorse	0	0	0	3
Trachichthyidae	*Paratrachichthys macleayi*	Sandpaper fish	0	4	0	212
Triakidae	*Mustelus antarcticus*	Gummy shark	0	1	7	1
Triglidae	*Chelidonichthys kumu*	Red gurnard	0	0	0	2
	Lepidotrigla modesta	Cocky gurnard	0	0	1	0
	Pterygotrigla polyommata	Latchet	0	0	5	1
Uranoscopidae	*Kathetostoma canaster*	Speckled stargazer	0	0	0	1
Urolophidae	*Urolophus cruciatus*	Banded stingaree	0	0	0	4
	Urolophus paucimaculatus	Sparsely spotted stingaree	0	0	2	0

BRUV data: Size frequency distributions and abundance maps

Length-frequency plots and abundance maps are shown below for selected fish species that are potentially affected by fishing pressure in the region and where enough were seen and could be measured from the stereo imagery. These included jackass morwong (*Nemadactlyus macropterus*), ocean perch (*Helioclenus percoides*), Morid cods (*Moridae*), striped trumpeter (*Latris lineata*) and draughtboard shark (*Cephaloscyllum laticeps*), a bycatch species in the lobster fishery. Additionally, size structure of southern rock lobster (*Jasus edwardsii*) measured from stereo BRUV data is also provided.

Mean lengths and range of lengths for key species were typical of those found across the region (*Table 32*). The mean size of two key targeted species, jackass morwong and striped trumpeter, were both larger than the recreational legal-size limits of 250 mm and 550 mm respectively, indicating that these species are not subject to intense "knife edge" fishing pressure in this region, with a significant proportion of the population being greater than the minimum legal size.

Table 32. Mean lengths and range of lengths measured from stereo BRUV in Huon Marine Park imagery for selected species. Lengths are in mm.

Species	**mean**	**lower**	**upper**
Cephaloscyllium laticeps	721	327	1008
Chelidonichthys kumu	217	217	217
Cyttus australis	272	170	390
Eubalichthys gunnii	299	209	418
Helicolenus percoides	220	29	373
Hypoplectrodes maccullochi	108	105	111

Jackass morwong

Jackass morwong were found in high abundance in the shallower rocky reef dominated sites where schools of up to 40 fish were observed in individual stereo BRUV drops (Figure 39). Their distribution was somewhat restricted to the inner to mid-shelf region of the park, presumably because of their reef-association in this region and the lack of exposed reef further across the shelf and at depths below 100 m. However, despite the general reef association, morwong were also found at some soft-sediment locations well away from mapped reefs, including in the mid shelf (Figure 39), indicating that they have a range of habitat preferences in this region. No morwong were seen at the outer-shelf sample sites on soft-sediment.

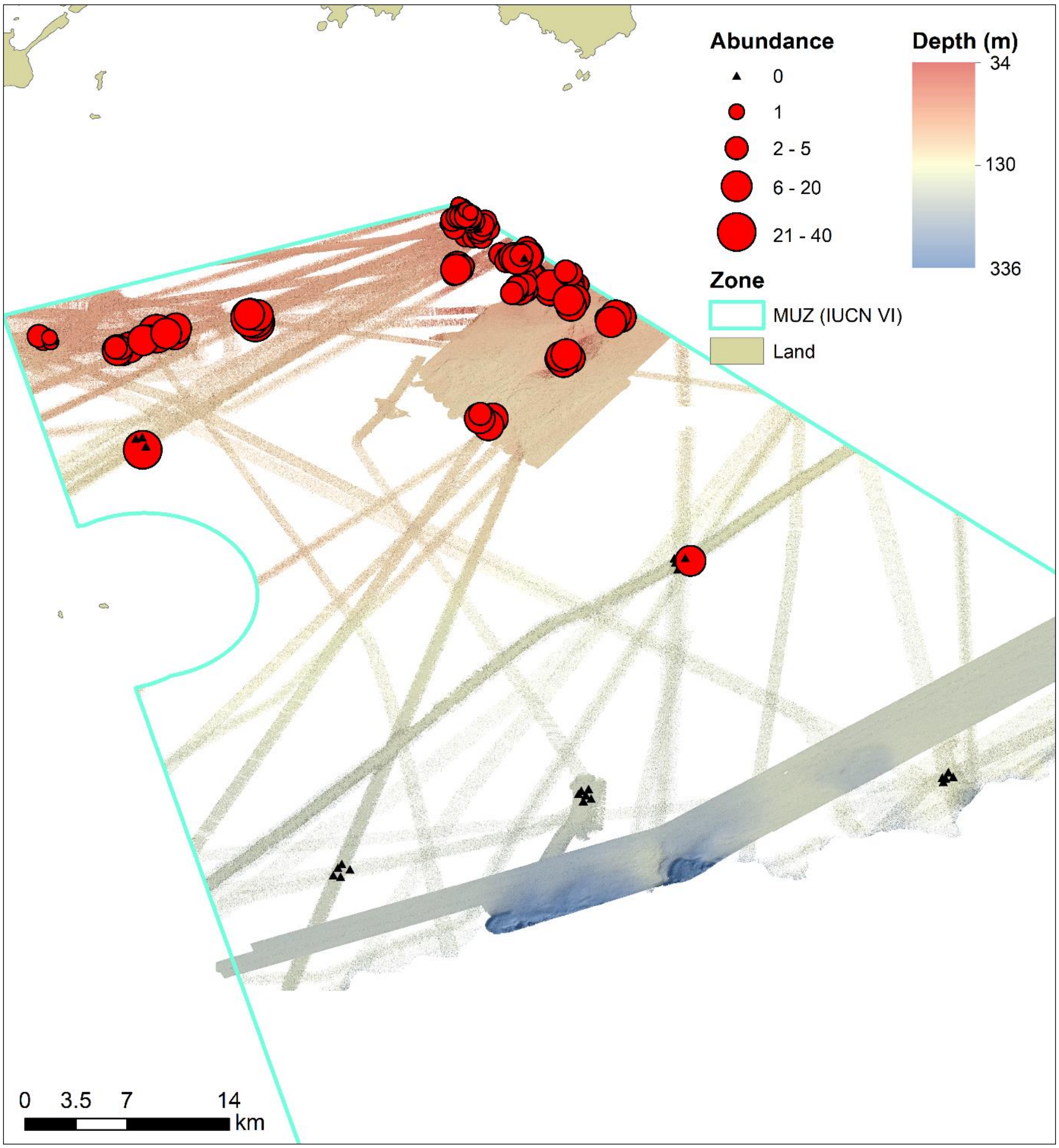


Figure 39. Abundance map for jackass morwong observed in stereo BRUV surveys across the Huon Marine Park.

The size structure of jackass morwong in HMP followed an approximate normal distribution, with lower numbers of juveniles (< 180 mm) and a reasonably high proportion of larger fish (Figure 40). Of particular note, fish > 250 mm (recreational legal-size limit) were quite frequently observed, with 67% of fish observed being legal-size. The mean size observed was 310 mm, the minimum size 143 mm, and the maximum size 634 mm.

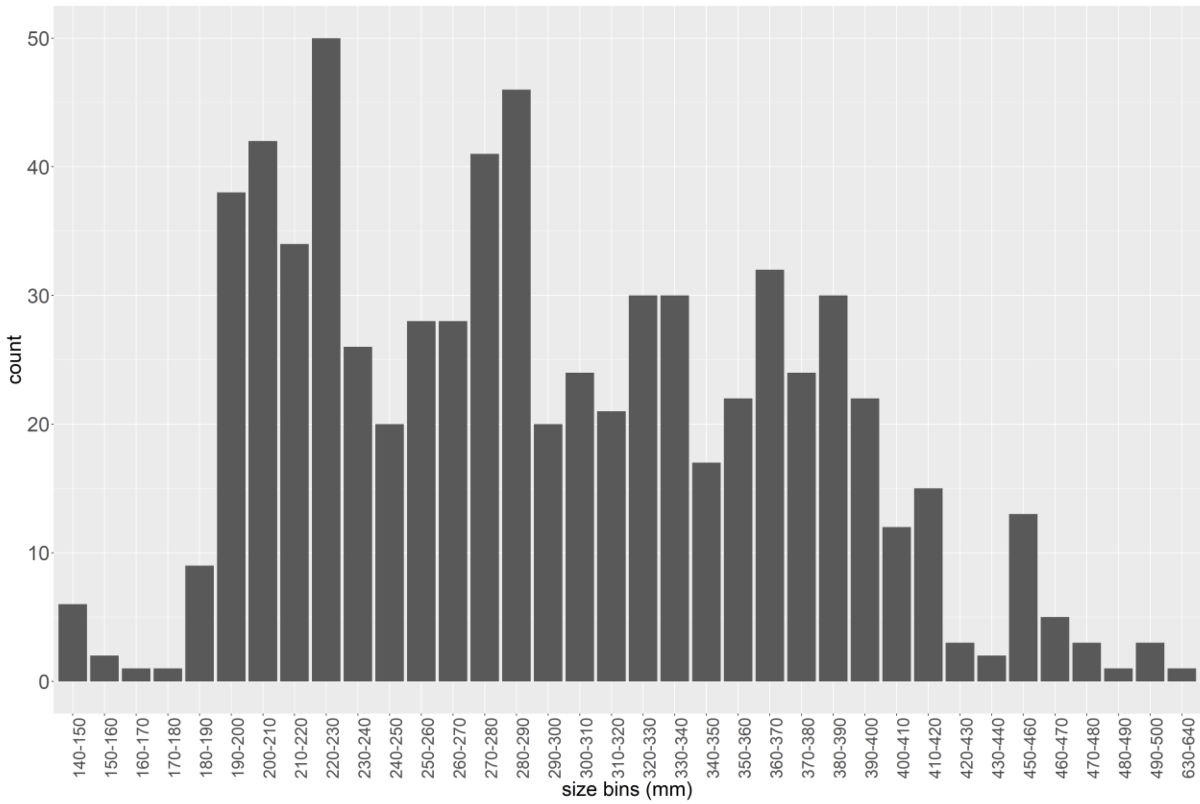


Figure 40. Length frequency distribution of jackass morwong measured in stereo BRUV surveys in the Huon Marine Park.

Striped trumpeter

Striped trumpeter were observed predominantly associated with reef at mesophotic to upper rariphotic depths extending to the lower limit of inner to mid-shelf reefs at around 100 m depth, with schools of up to 50 individuals observed (Figure 41). No individuals were seen on soft sediment sampling sites away from reef on the inner shelf, nor on soft-sediment habitat on the mid to outer shelf.

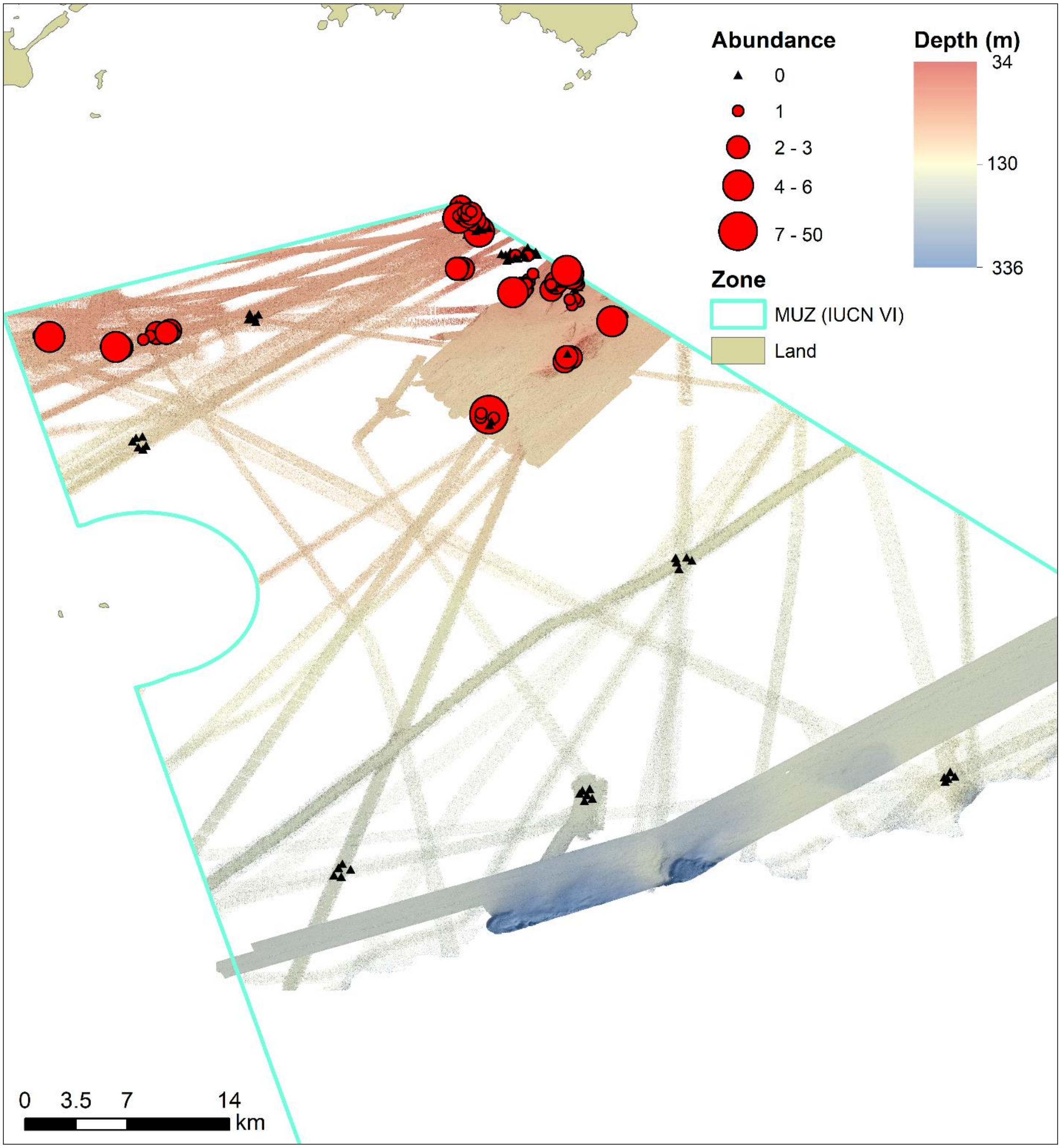


Figure 41. Abundance map for striped trumpeter observed in stereo BRUV surveys across the Huon Marine Park.

The size structure of striped trumpeter in HMP followed an approximate normal distribution, with a reasonably high proportion of larger fish (Figure 42). Of particular note, fish > 550 mm (recreational legal-size limit) were quite frequently observed, with 59% of fish observed being legal-size. The mean size observed was 582 mm, the minimum size 349 mm, and the maximum size 858 mm.

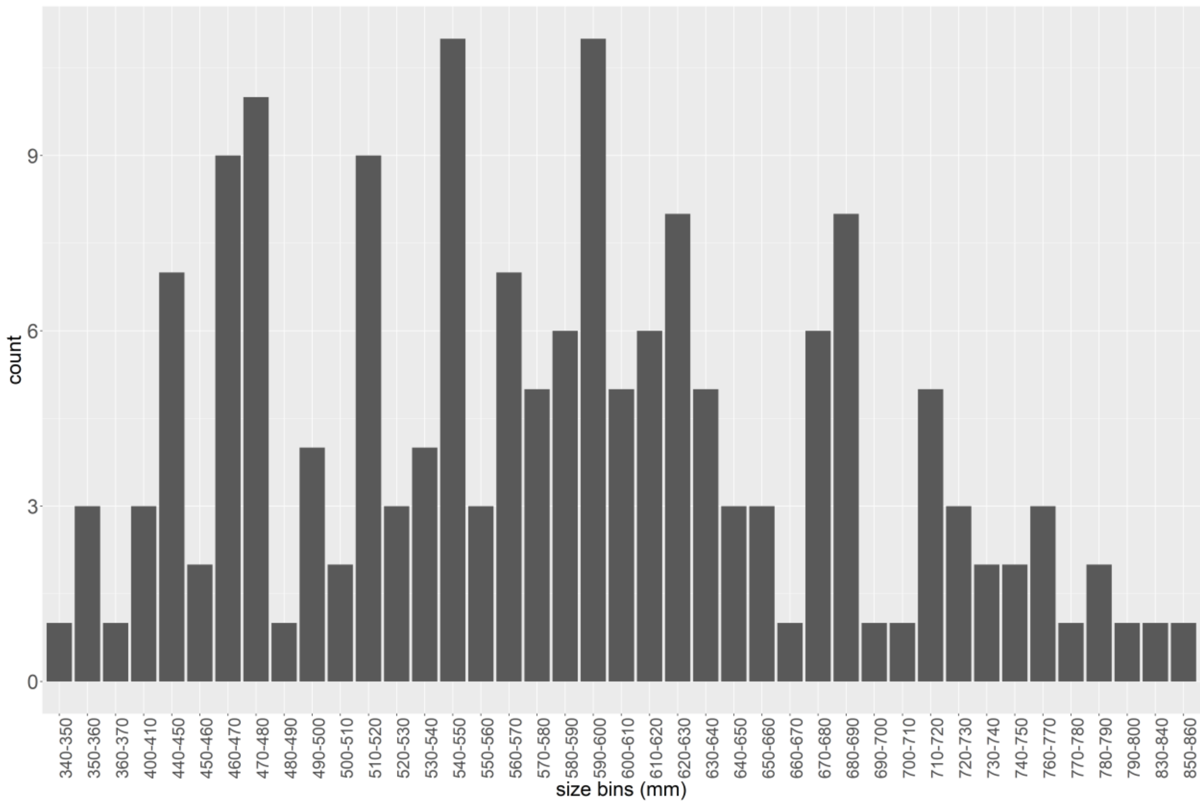


Figure 42. Length frequency distribution of striped trumpeter measured in stereo BRUV surveys in the Huon Marine Park.

Morid cod

Morid cod species (all *Pseudophycis* species) were combined for analysis due to difficulty in species level identification from imagery. Cod species were observed predominantly in shallower sites in the HMP, especially in the NE corner of the park (Figure 43) although they were generally seen in all reef habitats sampled, extending to the deepest reef depths around 100 m. They tended to be seen in lower numbers at individual sites (as measured by MaxN) but were found consistently in stereo BRUV drops across the inner-shelf component of the surveyed region, including some soft-sediment sites. No cod were found at mid to outer-shelf sites that were deeper (below 150 m) and were soft-sediment only.

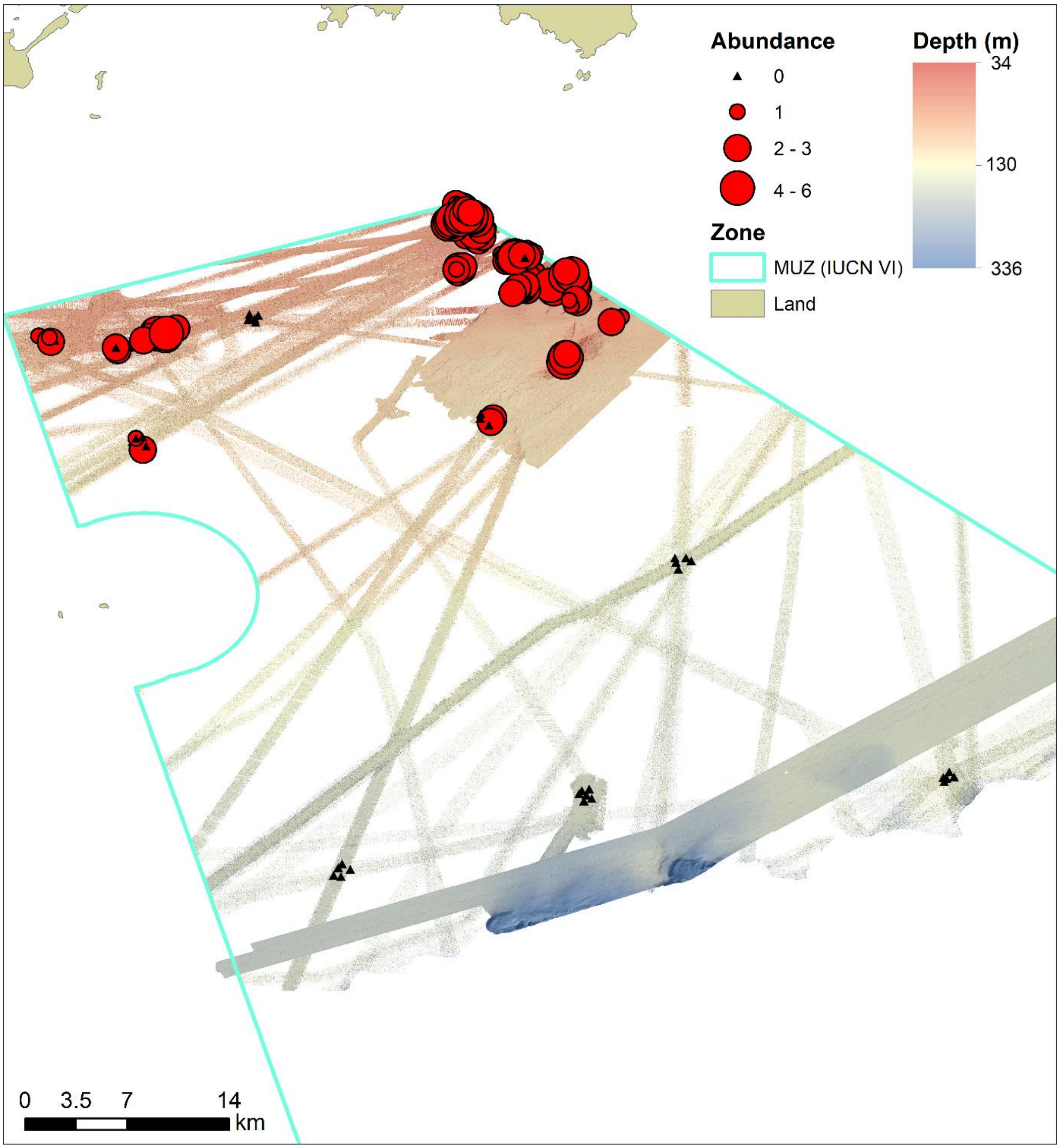


Figure 43. Abundance map for morid cod species (grouped) observed in stereo BRUV surveys across the Huon Marine Park.

The length frequency distribution of morid cod species followed a normal distribution centred on a mean of approximately 400 mm (Figure 44). The mean size observed was 393 mm, the minimum size 203 mm, and the maximum size 657 mm.

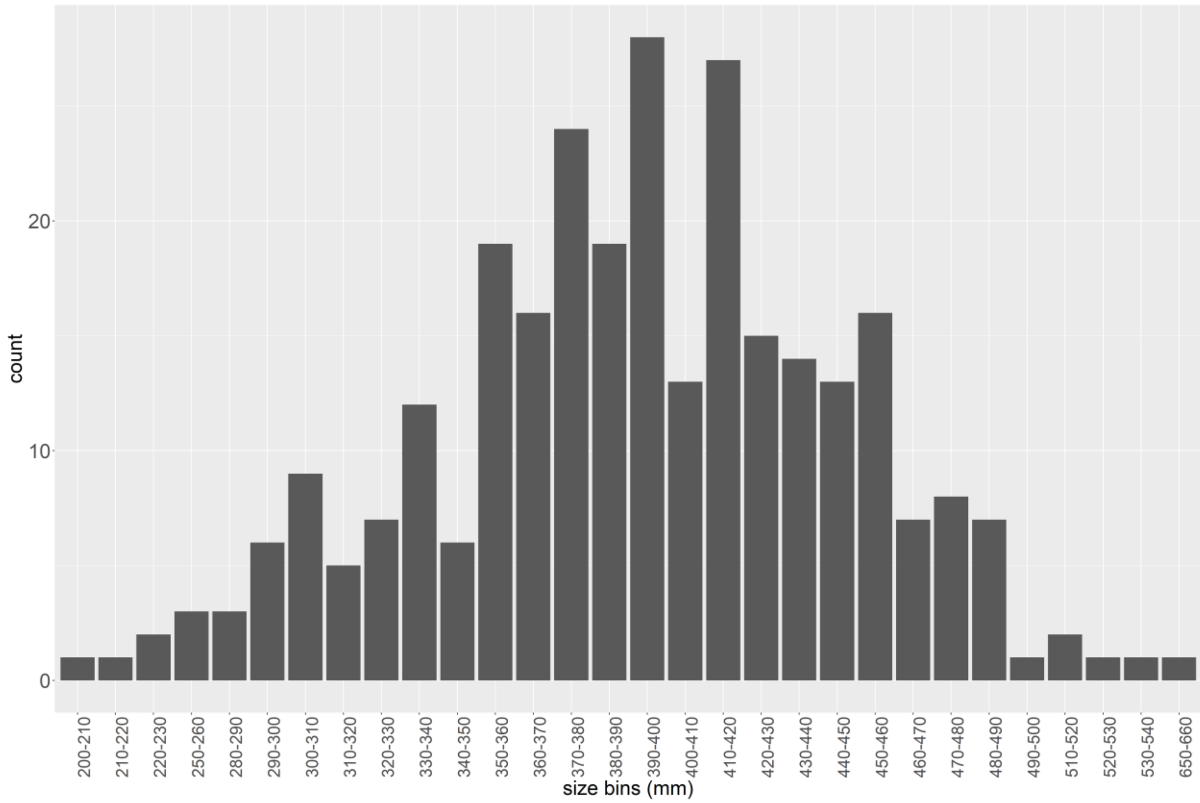


Figure 44. Length frequency distribution of morid cod species (grouped) measured in stereo BRUV surveys in the Huon Marine Park.

Ocean perch

Ocean perch were observed predominantly in shallower sites in the HMP, especially in the NE corner of the park (Figure 45), typically associated with reef and reef margin habitat but occasionally seen over areas mapped as soft sediment. They tended to be seen in lower numbers at individual sites (as measured by MaxN) but were found consistently in reef-associated stereo BRUV drops across the inner-shelf area of the surveyed region, declining markedly below 150 m towards the mid to outer shelf, potentially in response to depth but likely also in response to the absence of reef habitat beyond the inner shelf.

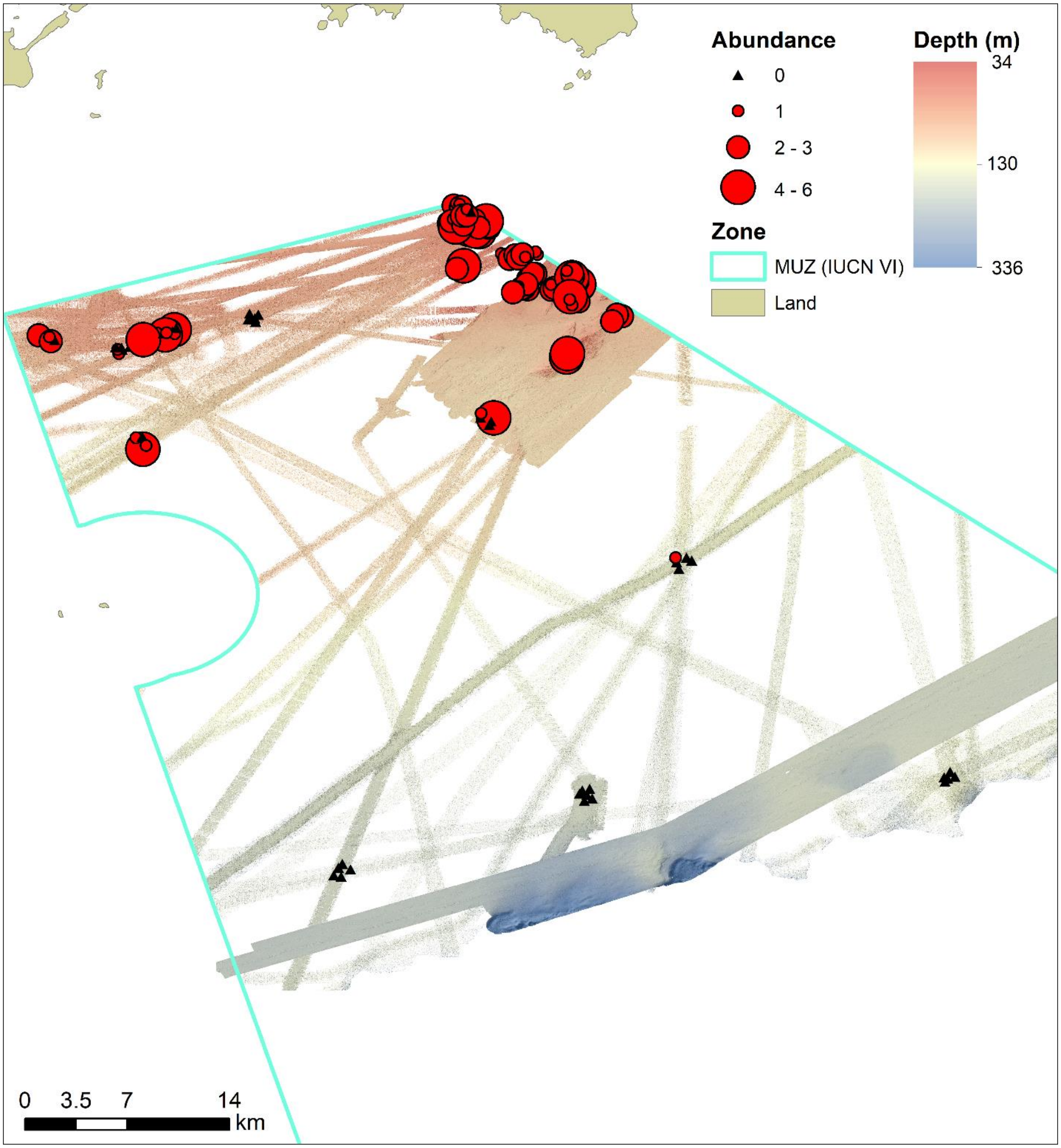


Figure 45. Abundance map for ocean perch observed in stereo BRUV surveys across the Huon Marine Park.

The length-frequency distribution of ocean perch followed a fairly normal distribution, with a slight skew towards larger individuals (Figure 46). The mean size observed was 220 mm, the minimum size 29 mm, and the maximum size 373 mm.

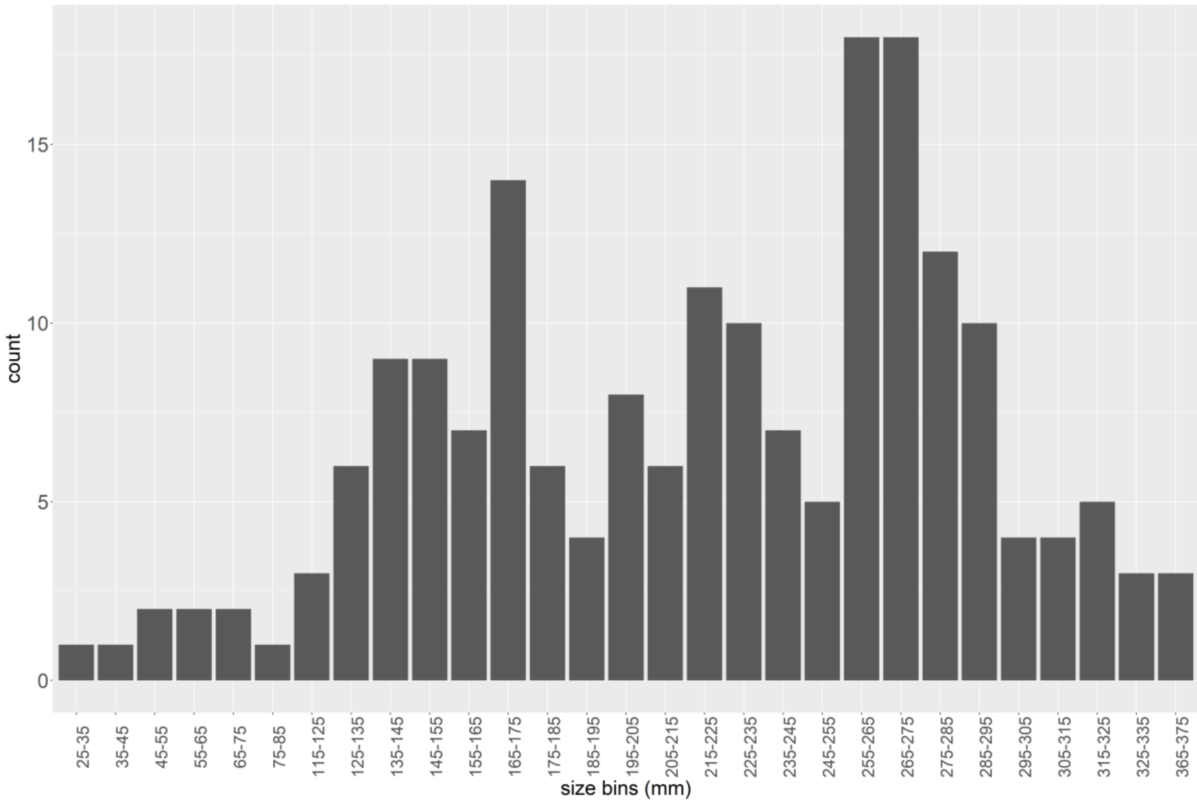


Figure 46. Length frequency distribution of ocean perch measured in stereo BRUV surveys in the Huon Marine Park.

Draughtboard sharks

Draughtboard sharks were consistently observed across most inner-shelf sites in the HMP, with up to three individuals seen per stereo BRUV drop, as measured by MaxN (Figure 47). While they were typically found on the inner shelf and reef-associated, a single draughtboard shark was also observed at one of the deepest sites surveyed at 155 m depth on soft sediment near the shelf-break on the outer shelf.

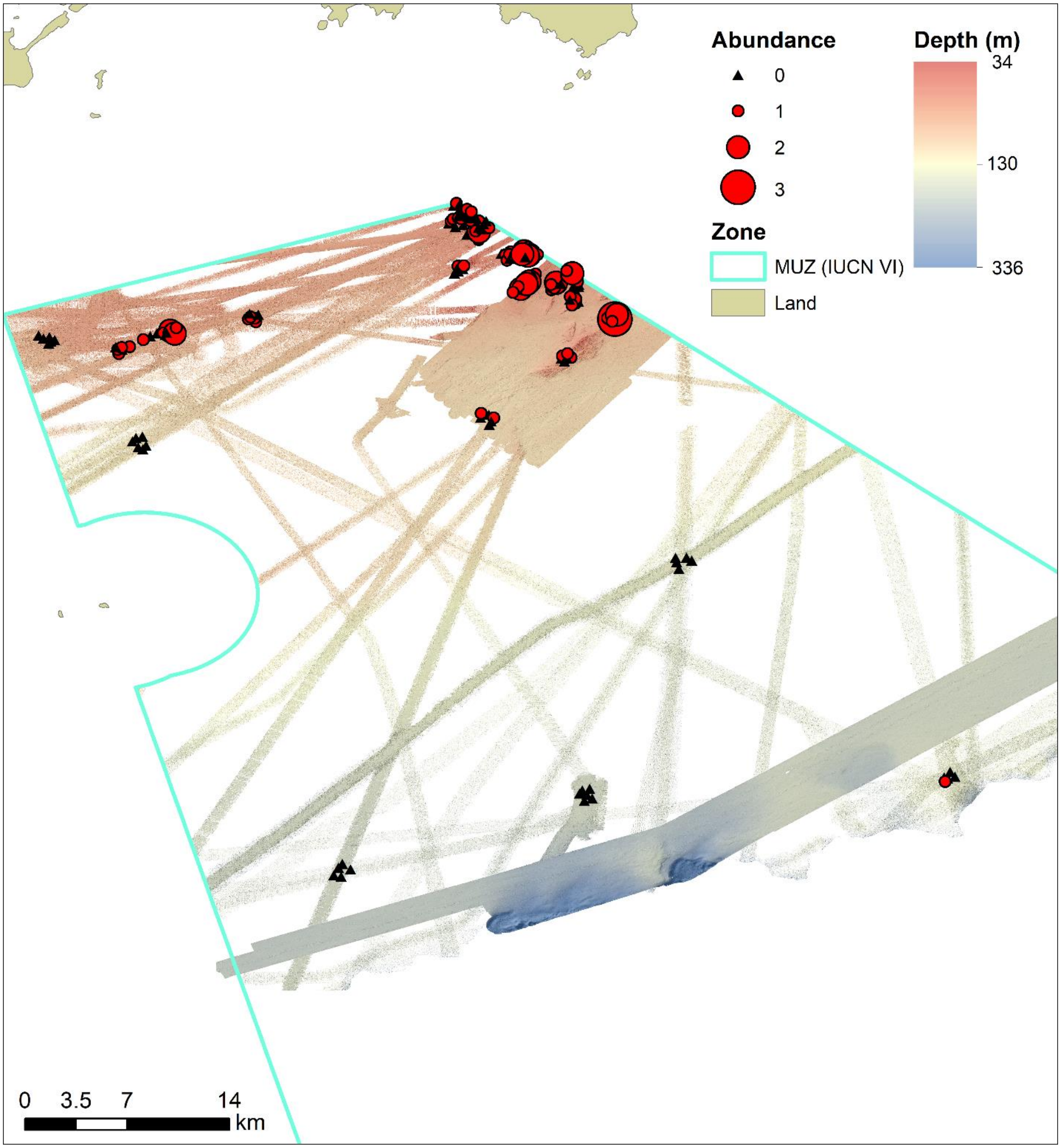


Figure 47. Abundance map for draughtboard sharks observed in stereo BRUV surveys across the Huon Marine Park.

Measured draughtboard sharks had a mean size of 721 mm, and ranged from 327 mm to 1008 mm, representing a large range of sizes from juveniles to large adults (Figure 48).

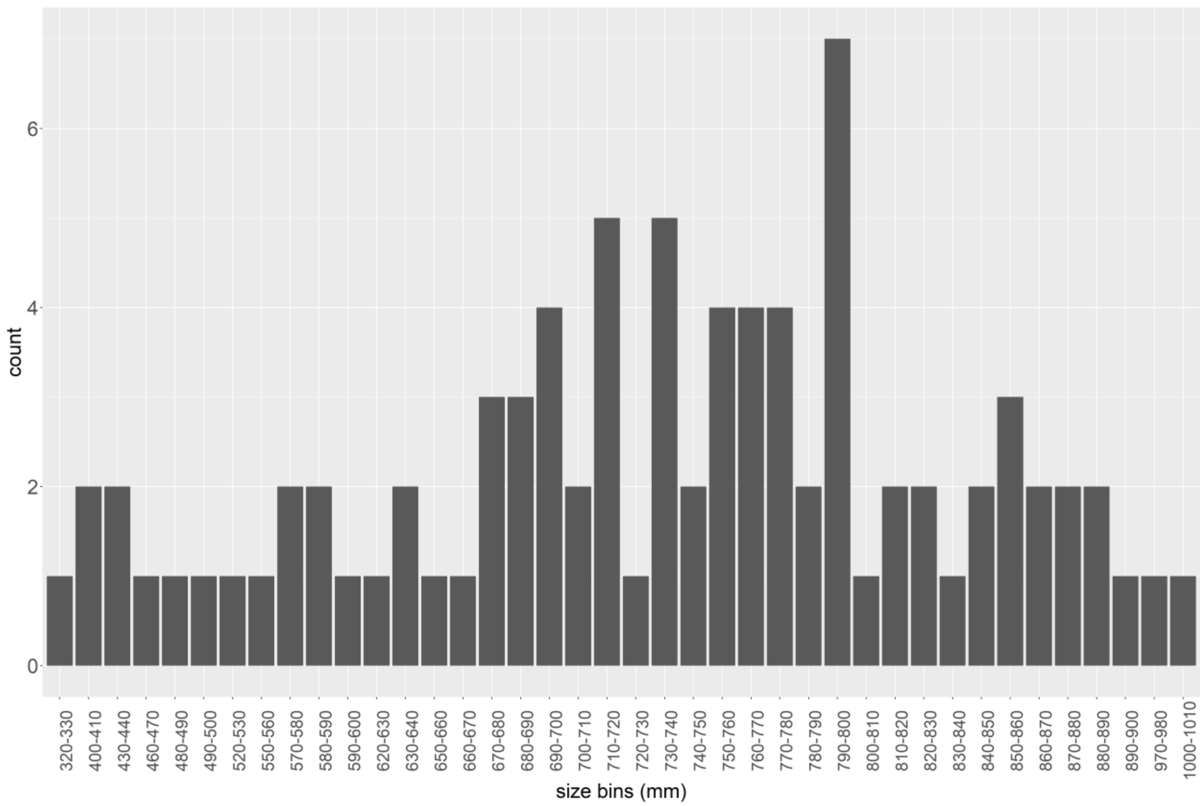


Figure 48. Length frequency distribution of draughtboard sharks measured in stereo BRUV surveys in the Huon Marine Park.

Rock lobster

Rock lobster were found predominantly in higher relief rocky reef in the shallower depths surveyed, particularly in the complex dolerite reef in NE corner of the HMP and within the extensive reef-ledge system in the NW corner of the HMP (Figure 49). They were particularly abundant in these habitats, with up to 14 individuals (as measured by MaxN) observed on an individual stereo BRUV drop. No individuals were seen on soft sediments, or beyond the inner-shelf area of the park where reef habitat was primarily restricted to.

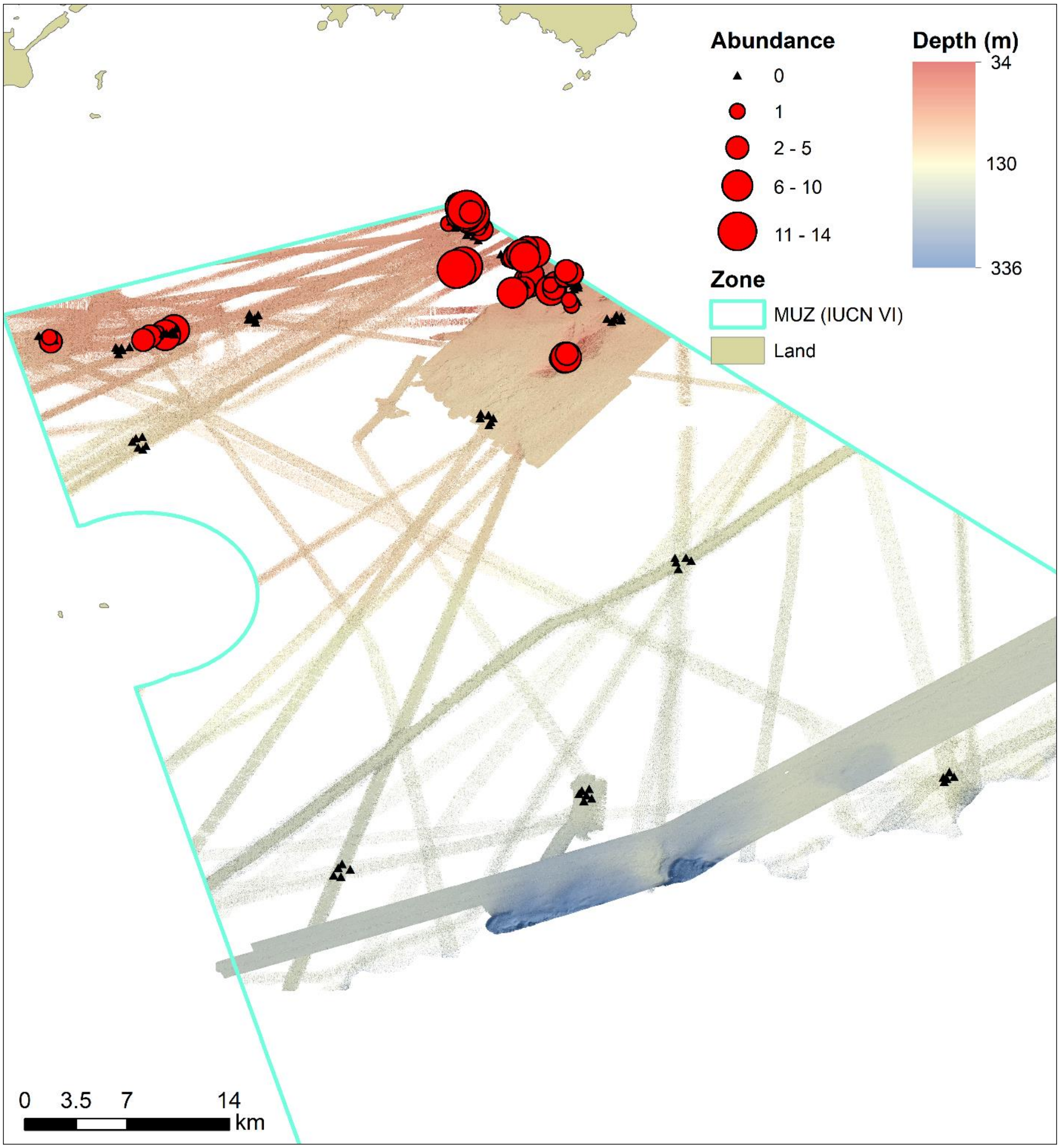


Figure 49. Abundance map for rock lobster observed in stereo BRUV surveys across the Huon Marine Park.

The length-frequency distribution of rock lobster followed a fairly normal distribution (Figure 50), with a reasonably high proportion of legal-sized individuals (105-110 mm for male/females, although sexing lobsters in stereo BRUVs imagery is typically not possible). The mean carapace size observed was 99 mm, the minimum size 59 mm, and the maximum size 167 mm.

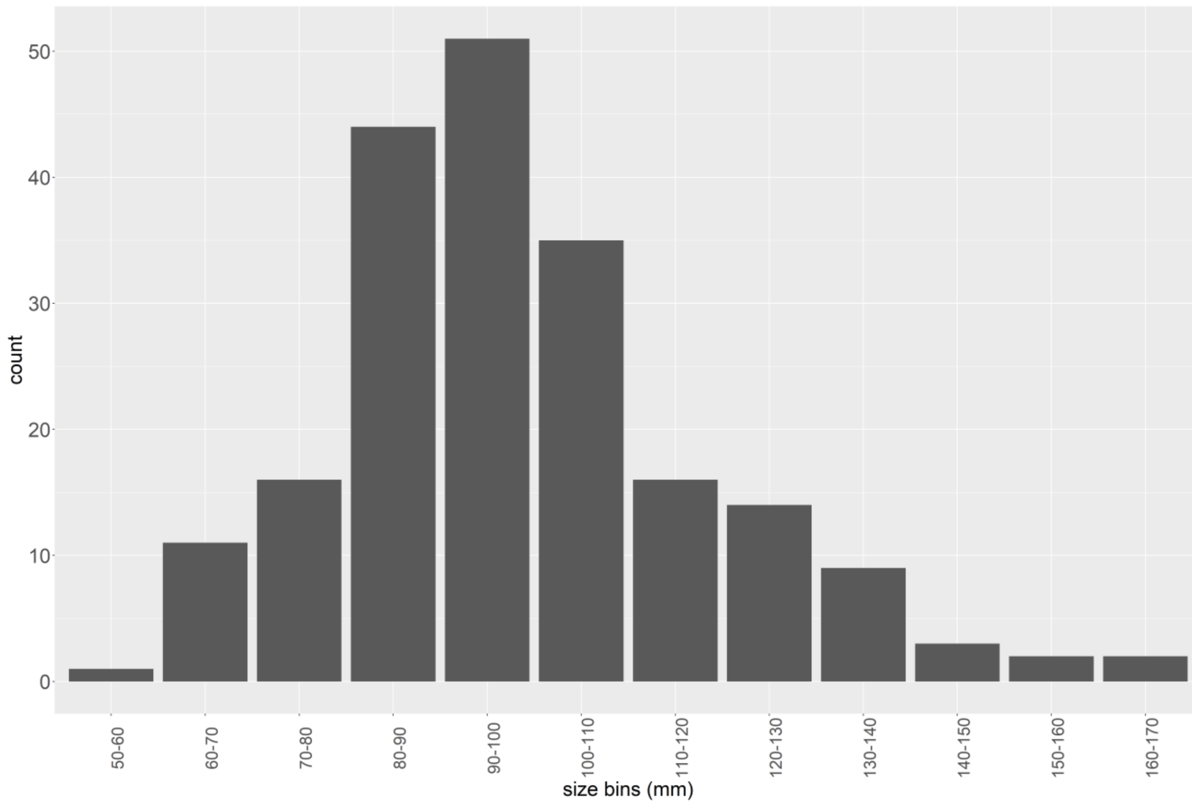


Figure 50. Length frequency distribution of rock lobster measured in stereo BRUV surveys in the Huon Marine Park.

BRUV data: Detailed statistical analysis of species distribution patterns

Detailed analyses were conducted to explore habitat and depth associations for key species across stereo BRUV surveys in the HMP. The species chosen for these analyses were jackass morwong, striped trumpeter, ocean perch, morid cod (combined species) as they are key targeted recreational species, and draughtboard sharks are a key bycatch species of rock lobster fishers. Metrics of abundance and mean length were assessed for each species. Most other species either lacked significant abundance to determine overall patterns or the abundance counts were primarily from a small number of stereo BRUV drops/sites.

The same Bayesian model-based approach used for the FMP data was employed. For HMP, the model intercept represents the model-based estimate for non-reef stereo BRUV drops. For all model coefficients, significant differences are those where the posterior 95% credible intervals do not include zero. The estimate for reef quantifies is the difference in the assessed metric between reef and sediment dominated stereo BRUV drops based on the visual assessment. Depth estimates quantify the overall effect of depth, with positive effects indicating an increase in the metric with depth and negative effects indicating a decrease with depth. Depth-squared estimates quantify whether there is an increase in the metric in mid-depths (a negative quadratic effect) or on shallow and deep areas surveyed (positive quadratic effect). All significant effects are highlighted in green for positive effects and red for negative effects, with unhighlighted effects indicating no statistically significant effect. Plots are provided where significant depth effects were found to allow visualisation of the effect across the depth range. Mean effects and credible intervals were calculated by taking posterior sample draws from the model while ignoring spatial effects.

Jackass morwong

Abundance

No significant effects of either depth or reef were found for the abundance of jackass morwong across the surveyed area in HMP (Table 33).

Table 33. Model-based estimates of the abundance of jackass morwong across Huon Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	0.610	1.129	-1.605	2.826
Reef	0.156	0.259	-0.357	0.660
Depth	-0.335	0.342	-1.007	0.336
Depth-squared	-0.278	0.208	-0.686	0.130

Mean length

The mean length of measured jackass morwong in sediment drops was found to be 35.4 cm (Table 34). A significant negative depth effect was found, indicating that larger fish tended to be found in shallow water; although a significant negative depth-squared term indicates that depth does not have a strictly linear effect (Table 34 and Figure 51)

Table 34. Model-based estimates of the mean length of jackass morwong across Huon Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	35.415	1.591	32.297	38.533
Reef	-2.810	1.523	-5.796	0.176
Depth	-2.158	0.710	-3.550	-0.766
Depth-squared	-2.430	0.601	-3.609	-1.252

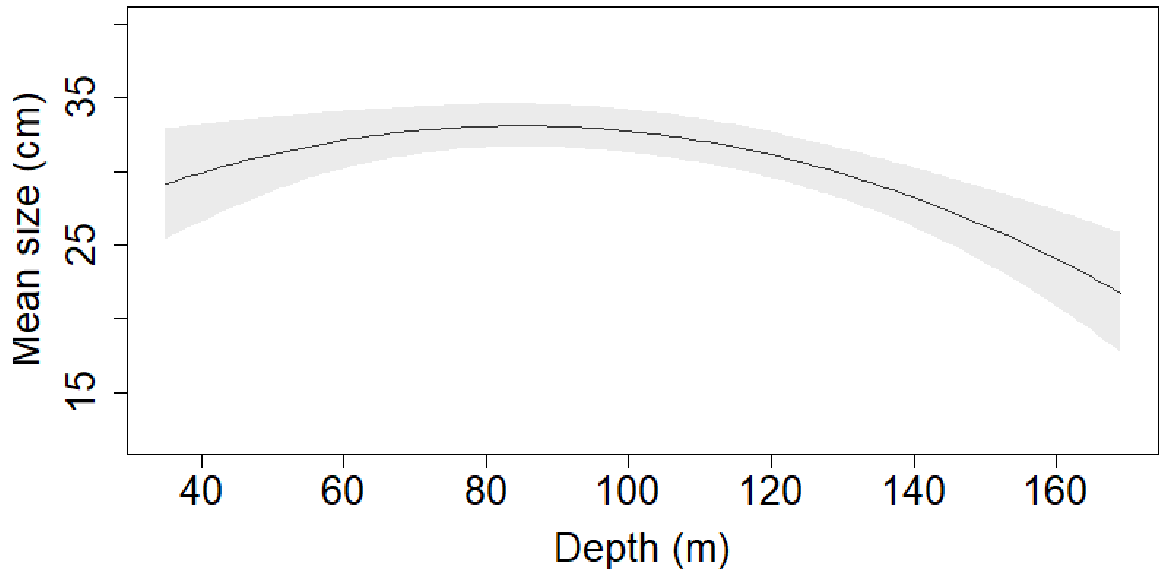


Figure 51. Model-based estimate of the relationship between mean length and depth for jackass morwong in Huon Marine Park.

Striped trumpeter

Abundance

A significant negative effect of depth and depth-squared was found for striped trumpeter, indicating a higher abundance in shallower depths (Table 35 and Figure 52). No significant effect of reef was found.

Table 35. Model-based estimates of the abundance of striped trumpeter across Huon Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	-0.904	0.577	-2.045	0.221
Reef	0.599	0.403	-0.167	1.414
Depth	-0.943	0.440	-1.845	-0.118
Depth-squared	-0.586	0.320	-1.266	-0.012

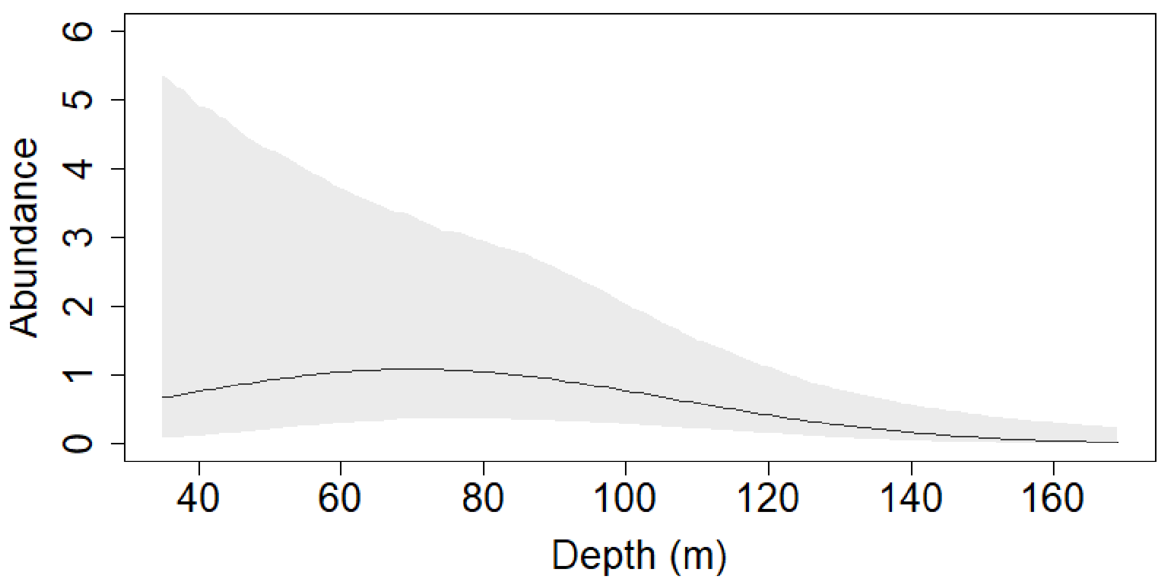


Figure 52. Model-based estimate of the relationship between abundance and depth for striped trumpeter in Huon Marine Park.

Mean length

The mean length of striped trumpeter across sediment stereo BRUV drops was found to be 52.2 cm (Table 36). A significant positive effect of depth was found for mean length, indicating that larger fish tend to be found in deeper waters (Table 36 and Figure 53).

Table 36. Model-based estimates of the mean length of striped trumpeter across Huon Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	52.239	4.831	42.772	61.707
Reef	5.644	4.700	-3.567	14.856
Depth	5.726	1.782	2.233	9.218
Depth-squared	2.252	1.784	-1.245	5.749

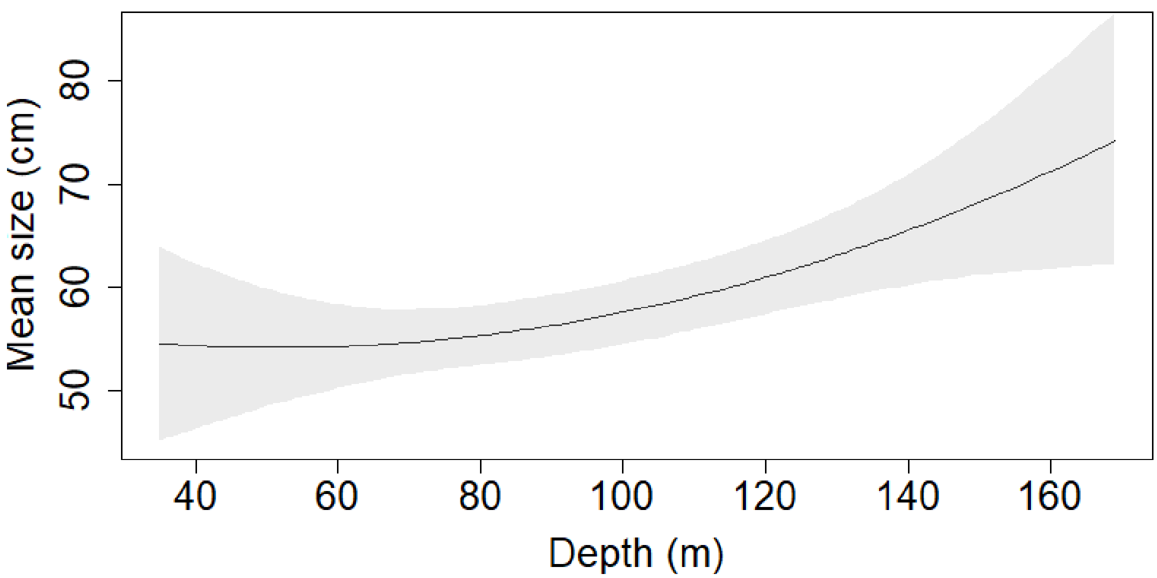


Figure 53. Model-based estimate of the relationship between mean length and depth for striped trumpeter in Huon Marine Park.

Morid cod (combined species)

Abundance

The abundance of morid cod (combined species) was found to have a significant negative relationship with depth and depth squared, indicating a higher abundance in shallower depths (Table 37 and Figure 54). No significant effect of reef was found, although the posterior distribution was marginal and indicates a positive association with reef drops.

Table 37. Model-based estimates of the abundance of morid cod across Huon Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	0.315	0.416	-0.503	1.128
Reef	0.372	0.227	-0.060	0.832
Depth	-0.777	0.253	-1.291	-0.300
Depth-squared	-0.539	0.160	-0.869	-0.243

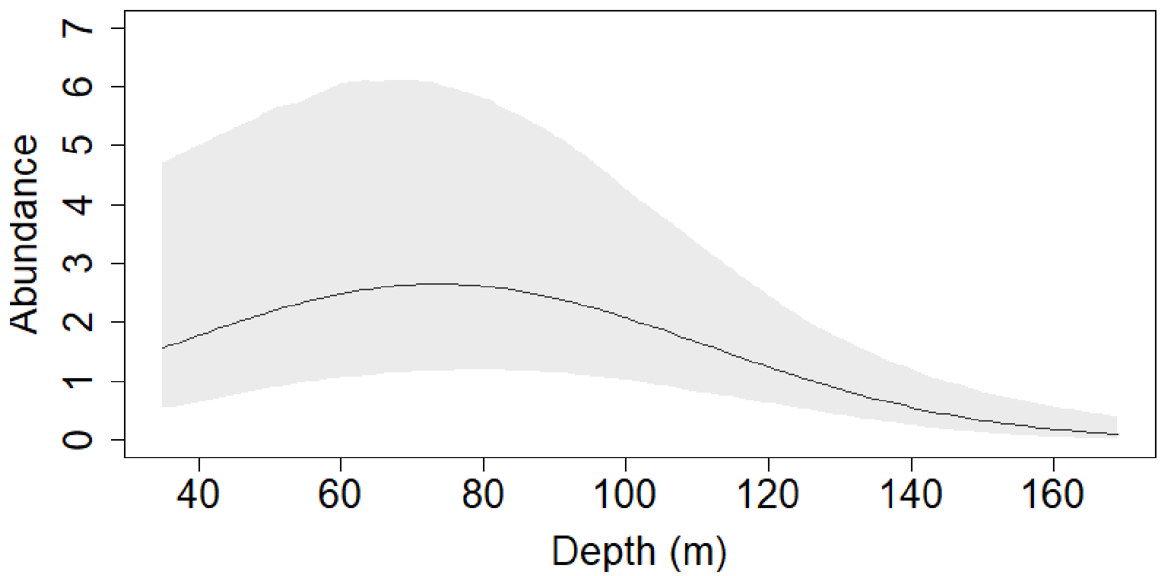


Figure 54. Model-based estimate of the relationship between abundance and depth for morid cod (combined species) in Huon Marine Park.

Mean length

The mean length of morid cod species was found to be 40.8 cm on sediment drops (Table 38). A significant negative association was found between mean length and depth, indicating larger fish were found in shallower depths (Figure 53). No significant effect of reef was found on mean length of morid cod.

Table 38. Model-based estimates of the mean length of morid cod (combined species) across Huon Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	40.816	1.883	37.125	44.507
Reef	-0.498	1.357	-3.159	2.162
Depth	-1.941	0.918	-3.741	-0.140
Depth-squared	-1.018	0.577	-2.149	0.114

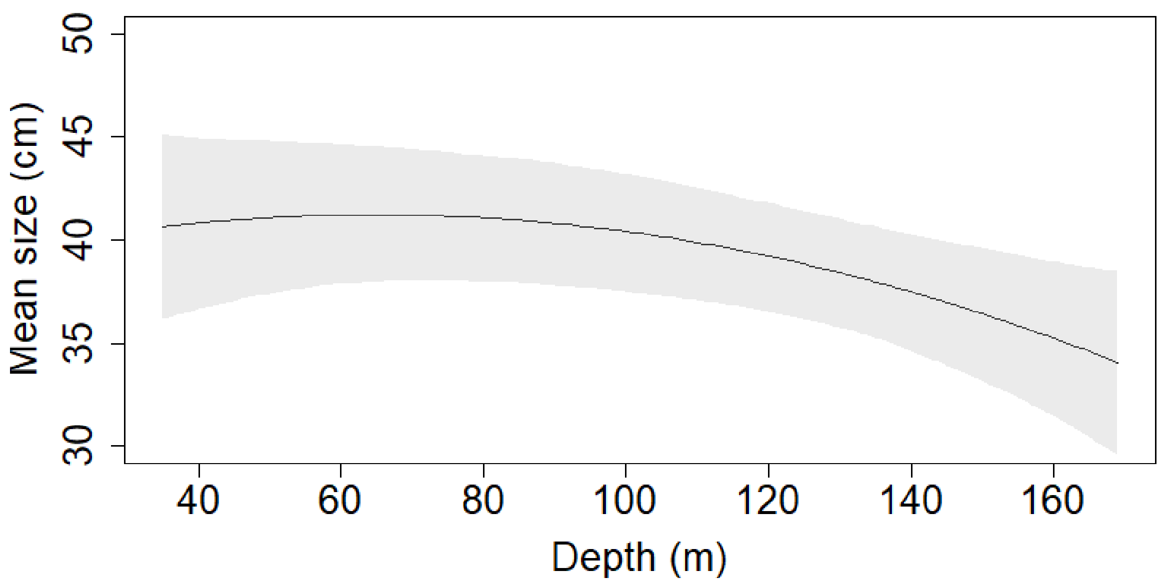


Figure 55. Model-based estimate of the relationship between mean length and depth for morid cod (combined species) in Huon Marine Park.

Ocean perch

Abundance

A significant effect of reef was found for the abundance of ocean perch, with fish 3.1 times (i.e., exp (1.136)) more likely to be found on reef stereo BRUV drops on average. A significant effect of depth-squared was found, but no significant depth effect, indicating that ocean perch were predominantly found in mid-depths surveyed (Table 39 and Figure 56).

Table 39. Model-based estimates of the abundance of ocean perch across Huon Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	-0.386	0.431	-1.242	0.449
Reef	1.136	0.298	0.579	1.746
Depth	-0.173	0.229	-0.631	0.269
Depth-squared	-0.475	0.151	-0.784	-0.192

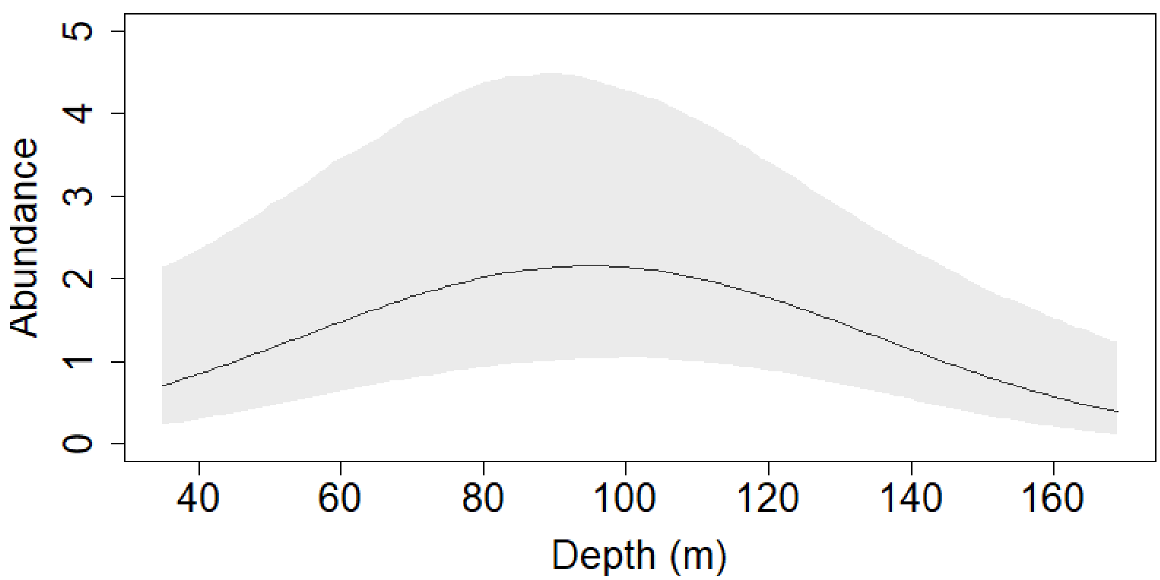


Figure 56. Model-based estimate of the relationship between abundance and depth for ocean perch (combined species) in Huon Marine Park.

Mean length

The mean length of ocean perch in sediment stereo BRUV drops was found to be 22.3 cm (Table 40). No significant effects of either reef or depth were found for the mean length of ocean perch.

Table 40. Model-based estimates of the mean length of ocean perch across Huon Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	22.260	2.562	17.239	27.281
Reef	1.142	2.433	-3.625	5.910
Depth	1.735	1.049	-0.321	3.791
Depth-squared	-0.803	0.739	-2.251	0.645

Draughtboard sharks

Abundance

A significant negative effect was found for depth and depth-squared for draughtboard sharks (Table 41), indicating a preference for shallower depths across those surveyed, but that the relationship was not linear with abundance peaking in mid-depths (Figure 57).

Table 41. Model-based estimates of the abundance of draughtboard sharks across Huon Marine Park. Estimates are on the linear predictor scale (log). Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	-0.597	0.358	-1.322	0.082
Reef	0.063	0.327	-0.552	0.730
Depth	-0.551	0.249	-1.059	-0.080
Depth-squared	-0.361	0.169	-0.719	-0.055

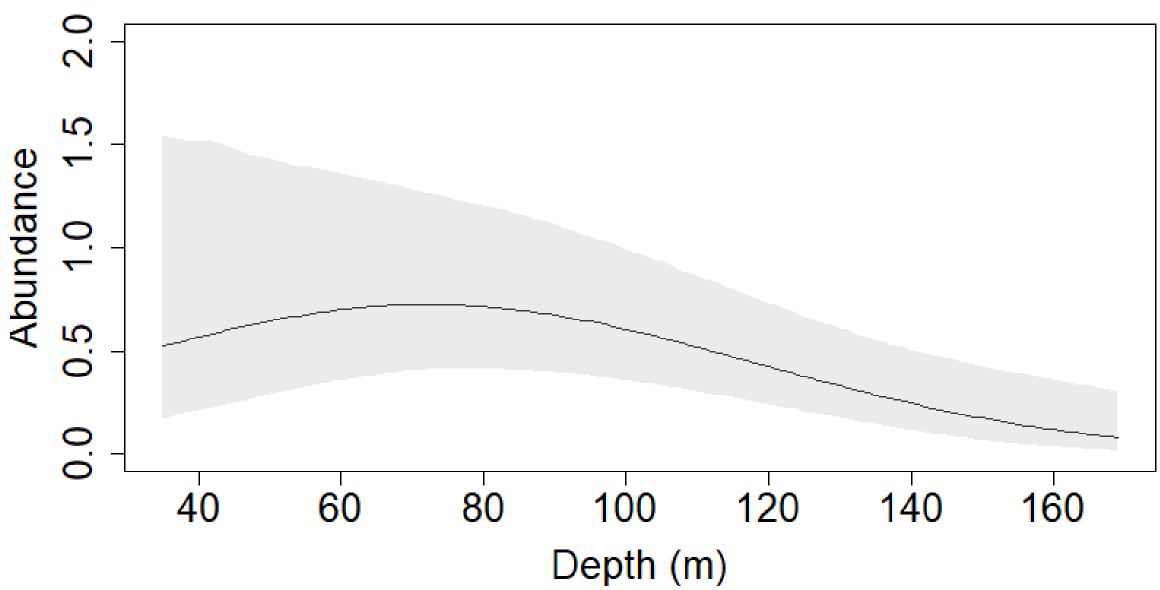


Figure 57. Model-based estimate of the relationship between abundance and depth for draughtboard sharks in Huon Marine Park.

Mean length

The mean length of draughtboard sharks on sediment stereo BRUV drops was found to be 72.1 cm (Table 42). No significant effect of reef or depth was found for mean length of draughtboard sharks.

Table 42. Model-based estimates of the mean length of draughtboard sharks across Huon Marine Park. Significant results are those that do not include zero in the posterior 95% credible intervals and are highlighted red for negative effects and green for positive.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept (Sediment stereo BRUV drops)	72.078	4.244	63.760	80.396
Reef	1.230	4.294	-7.185	9.646
Depth	-0.990	1.984	-4.878	2.899
Depth-squared	-0.985	1.885	-4.680	2.709

Discussion: Huon MP stereo BRUVs

This stereo BRUV survey is the first comprehensive habitat-structured assessment of the demersal fish assemblage in the HMP and follows from recent acquisition of sufficient mapping-based knowledge to underpin sampling designs aimed to be representative of rariphotic reefs, mesophotic reefs and associated soft sediments in shelf waters. This survey has revealed the presence of a range of fish species typical of mesophotic reefs on the south coast of Tasmania sampled in similar stereo BRUV surveys in the Tasman Fracture Marine Park (TFMP)(Barrett et al. 2022), and in waters off SE Bruny (Lyle et al. 2017). However, this quantitatively based study has found the HMP, by contrast, to have particularly high abundance of a number of key recreationally and commercially targeted species including striped trumpeter, jackass morwong and rock lobster. This is primarily driven by an extensive amount of high relief rocky reef in mesophotic and upper rariphotic depths (between 45 and 100 m), particularly in the NE corner of the park. This reef is typically composed of complex dolerite structure, including boulder fields, that provide the protective and productive habitat ideal for these and other species. Initial analysis of the size structure of some of the key species has revealed the presence of a significant proportion of larger, post minimum legal-sized individuals, with relatively high abundance of striped trumpeter and jackass morwong above legal-size limits. This is an observation of particular note, indicating that similarly to the TFMP, fishing pressure, at least for finfish, is likely to have been relatively low in the HMP in recent years, while also reflecting the reasonably remote location of this park relative to other fished habitats in this region.

While the focus of the analysis of abundances and spatial distribution of species in this report has focussed more on those that receive some form of protection within the park, or are of general commercial/recreational interest, the results also describe the relative abundances and habitat relationships of many other species, allowing for ongoing understanding of ecosystem structure and function. Typically, the reef systems supported the majority of the species observed, including planktivores such as butterfly perch, splendid perch, sandpaper fish, and meso-carnivores such as rosy wrasse, cosmopolitan leatherjackets and ocean perch. However, some species showed mixed responses to habitat, such as jackass morwong, which while showing a preference for reef habitat, were also found in some numbers across soft sediment, at least in inner shelf locations. Striped trumpeter was also a species showing some mixed-habitat preferences, (including in the detailed statistical analysis), however, when examining the spatial distribution of soft-sediment sites relative to the distribution of reef, it appears that this observation is strongly driven by the near-proximity to reef of many of the soft-sediment sites where this species was seen. So, while striped trumpeter are attracted to stereo BRUVS on soft-sediment, it is likely that this is often due either to near-reef foraging, or sufficient bait-attraction to attract fish from nearby reef systems, rather than a distinct lack of habitat specificity. A similar, although weaker pattern was apparent for jackass morwong. Few species showed a strong attraction to soft-sediment habitats only, and those that were, were typically found in relatively low abundances. These species included dogfish species, gummy sharks, bellowsfish and grubfish.

On the whole, this initial baseline has indicated that a survey with this level of sampling intensity (162 successful deployments of stereo BRUVS) is more than sufficient to obtain a robust quantitative estimate of the abundance of a range of key species of recreational and commercial interest, as well as rock lobsters, that may be valuable indicators for assessment of protection-related effects of this park. In particular, jackass morwong, a historically targeted trawl species, appear to be flourishing in this park at present, which, while potentially a response to protection from trawling given the reported low stock-level overall in this species at present (https://www.afma.gov.au/species/jackass-morwong; Edgar et al. 2018), needs validation against similar surveys from adjacent trawled habitat to assess the extent that this is a protection or habitat-related effect. Hence, ideally this baseline may be used for a future comparison of abundance and size-structure of this species in the park with similar habitats in adjacent fished waters, particularly on the trawled soft-sediment habitats to examine the extent that trawl protection may be influencing the abundance of trawl-vulnerable species within the park. Importantly though, it provides an initial snapshot of the current condition of reef fish communities and lobster stocks in the park, from which to assess the extent to which future management of fishing pressure in the region is influencing the biological values of the TFMP and inform future management responses.

Huon Marine Park: ROV survey of fish populations

Background and methods

The survey methodology employed for the ROV in the HMP followed that employed in the FMP, with a total of 27 ROV transects, with a standard length of 200 m being maintained (Figure 58).

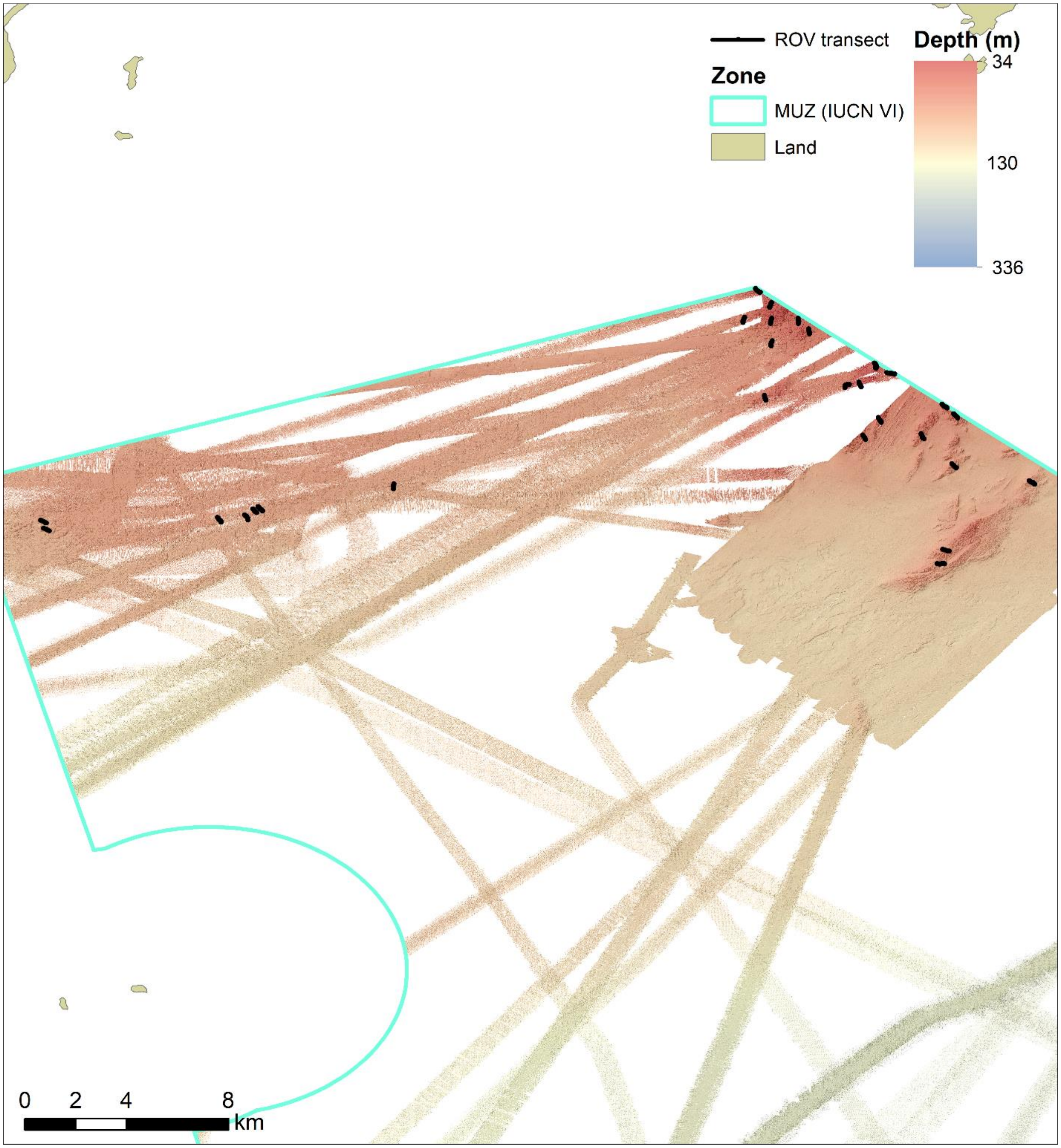


Figure 58. Location of the 27 ROV transects.

Results

ROV data: General description

A total of 32 fish species comprising 23 families were observed across the 27 ROV transects conducted in the Huon MP (Table 43). All observed marine invertebrates, except for southern rock lobster (*Jasus edwardsii*) were excluded from Table 43. Rock lobsters were included due to their high abundance in the Huon MP, which was also observed in stereo BRUV deployments, to allow comparison across the two survey platforms. Other mobile invertebrates observed included southern calamari (*Sepioteuthis australis*), octopus, spider crabs (*Leptomithrax gaimardii*), and hermit crabs. Species of the family Serranidae were particularly abundant, especially butterfly perch (*Caesioperca lepidoptera*). Other abundant species included rosy wrasse (*Pseudolabrus rubicundus*), ocean perch (*Helicolenus percoides*), cosmopolitan leatherjacket (*Meuschenia scaber*), and sandpaper fish (*Paratrachichthys macleayi*). Rare and/or endangered species observed included a single handfish species (identified as likely a pink handfish) and six spiny pipehorse. Example imagery of species observed in ROV videos is provided in the Appendix.

Fine-scale habitat classes were scored along each minute of ROV transect, with final habitat categories being reef, mixed (sand/reef), and sand. Of the 447 one-minute sub-units, reef dominated with 379 (85%) sub-units of reef, 54 (12%) classed as mixed and 14 (3%) classed as sand. Mixed habitats appear to be important for striped trumpeter with one-quarter (5 individuals out of a total of 20) of observations being on mixed habitats.

Table 43. Summary of total abundance across all species seen in ROV transects in the Huon AMP. Percent measured (Perc. measured) is the percentage of the total number of fish observed where a length measurement was obtained. Counts are given within habitat categories along each minute of transect (see Methods).

Family	Scientific name	Common name	Count sand	Count mixed	Count reef	Total Count	Percent measured
	Number of sub samples		14	54	379	447	
Brachionichthyidae	*Brachionichthyidae spp*	Handfish species			1	1	100%
Callanthiidae	*Callanthias australis*	Splendid perch		4	48	52	67%
Callionymidae	*Foetorepus calauropomus*	Common stinkfish		1		1	100%
Cheilodactylidae	*Cheilodactylus spectabilis*	Banded morwong			1	1	100%
	Nemadactylus macropterus	Jackass morwong	1	1	16	18	67%
Cyttidae	*Cyttus australis*	Silver dory			7	7	100%
Fishes (multi-family groups)	*Blenniidae, Gobiidae, Tripterygiidae spp*			5		5	0%
Gerreidae	*Parequula melbournensis*	Silverbelly			1	1	0%
Labridae	*Ophthalmolepis lineolata*	Southern Maori wrasse			1	1	100%
	Pseudolabrus rubicundus	Rosy wrasse	4	15	380	399	87%
Latridae	*Latris lineata*	Striped trumpeter		5	15	20	70%
Monacanthidae	*Acanthaluteres vittiger*	Toothbrush leatherjacket			4	4	50%
	Eubalichthys gunnii	Gunn's leatherjacket			2	2	50%
	Meuschenia scaber	Cosmopolitan leatherjacket		5	99	104	90%
Moridae	*Pseudophycis spp*	Morid cod species			18	18	67%
Mullidae	*Upeneichthys vlamingii*	Bluespotted goatfish			1	1	100%
Neosebastidae	*Neosebastes scorpaenoides*	Common gurnard perch		1		1	100%
Ostraciidae	*Aracana aurita*	Shaw's cowfish			2	2	100%
Palinuridae	*Jasus edwardsii*	Rock lobster		2	43	45	0%
Pinguipedidae	*Parapercis allporti*	Barred grubfish	4	17	9	30	87%
Scorpaenidae	*Scorpaena papillosa*	Southern red scorpionfish			1	1	100%
Scyliorhinidae	*Asymbolus rubiginosus*	Orange spotted catshark		1	3	4	100%
	Cephaloscyllium laticeps	Draughtboard shark			1	1	0%
Sebastidae	*Helicolenus percoides*	Ocean perch	1	15	126	142	61%
Serranidae	*Caesioperca lepidoptera*	Butterfly perch	38	788	6480	7306	92%
	Caesioperca spp	Perch spp	102	262	5739	6103	67%
	Hypoplectrodes maccullochi	Halfbanded seaperch			2	2	50%
	Lepidoperca pulchella	Eastern orange perch			2	2	100%
Syngnathidae	*Solegnathus spinosissimus*	Spiny pipehorse			6	6	0%
Trachichthyidae	*Paratrachichthys macleayi*	Sandpaper fish	17	5	389	411	76%
Triglidae	*Lepidotrigla vanessa*	Butterfly gurnard		1		1	100%
Urolophidae	*Urolophus paucimaculatus*	Sparsely spotted stingaree			1	2	0%
	Urolophus spp	Stingaree spp	1		1	1	0%

ROV data: Length frequency distributions

Jackass morwong

A total of 12 jackass morwong were measured across the 27 transects, with an average length of 34.0 cm (Figure 59). Sizes ranged from 24.5 cm to 45.6 cm.

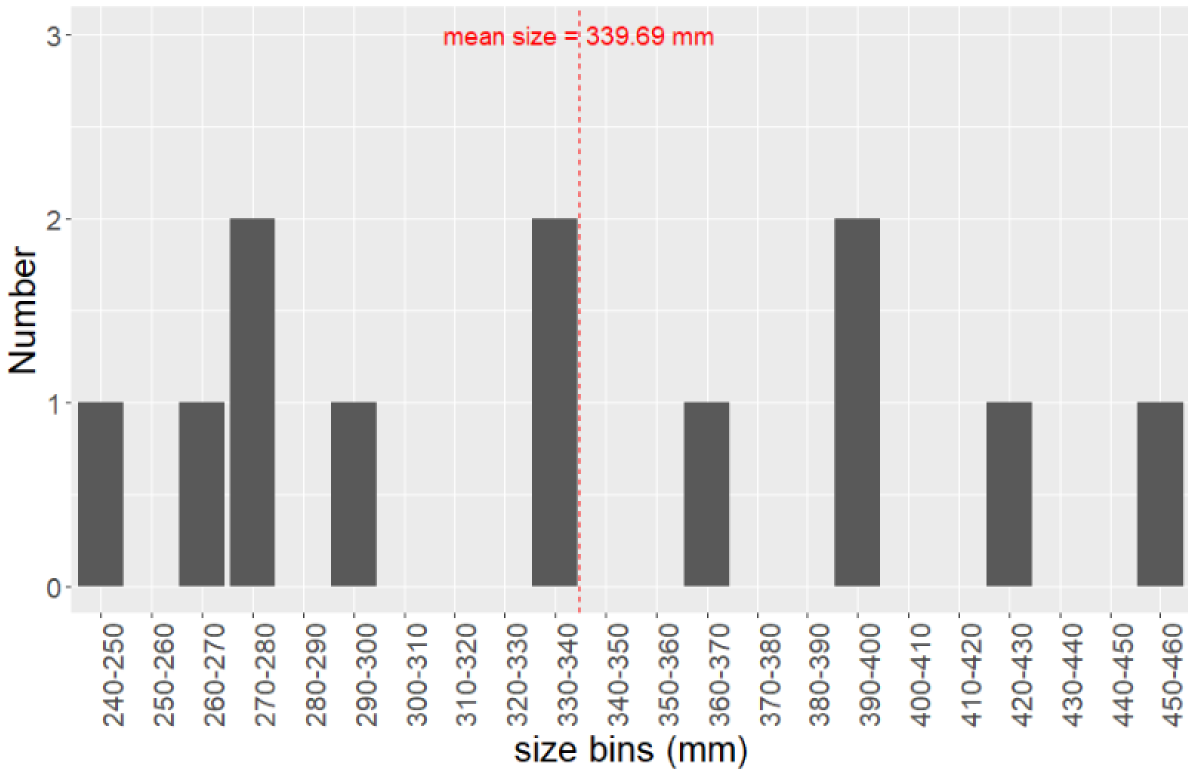


Figure 59. Length frequency distribution of measured jackass morwong from ROV surveys in the Huon Marine Park.

Ocean perch

A total of 87 ocean perch were measured across the 27 transects, with an average length of 17.3 cm (Figure 60). Sizes ranged from 3.4 cm to 34.6 cm.

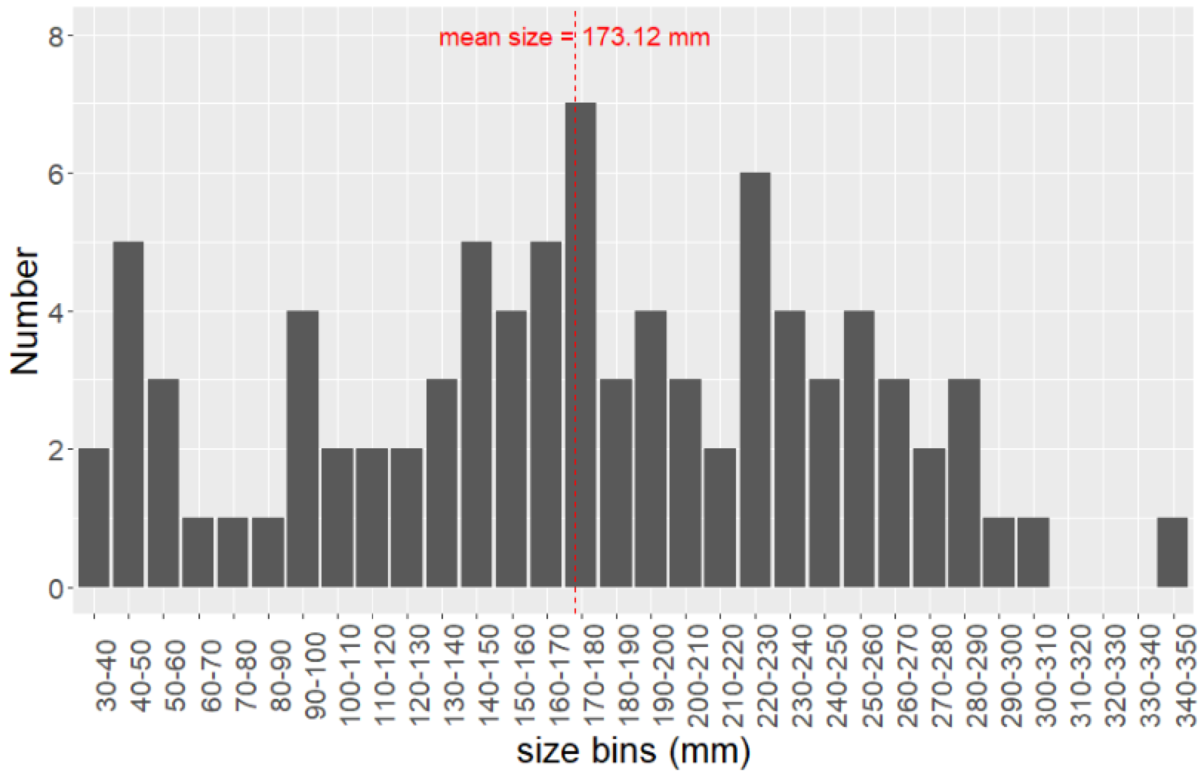


Figure 60. Length frequency distribution of measured ocean perch from ROV surveys in the Huon Marine Park.

Morid cod

A total of 12 morid cod were measured across the 27 transects, with an average length of 38.9 cm (Figure 61). Sizes ranged from 28.2 cm to 49.8 cm.

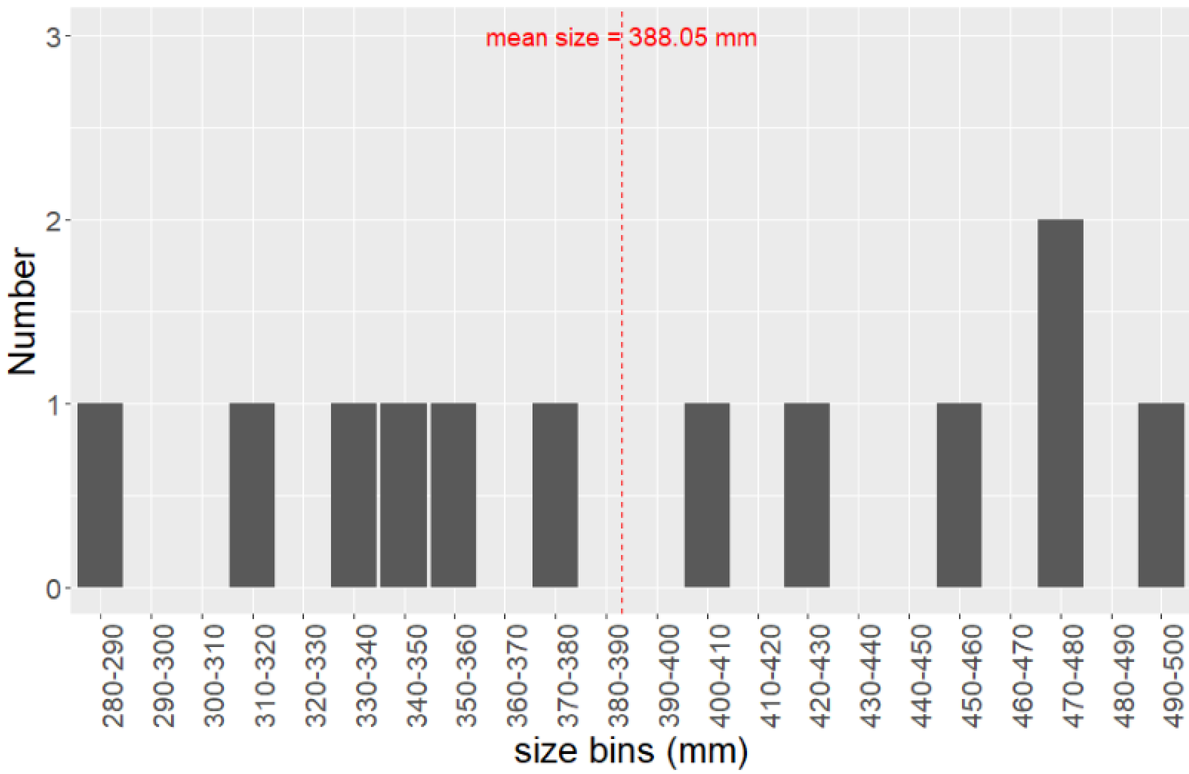


Figure 61. Length frequency distribution of measured morid cod (combined species) from ROV surveys in the Huon Marine Park.

Striped trumpeter

A total of 14 striped trumpeter were measured across the 27 transects, with an average length of 55.8 cm (Figure 62). Sizes ranged from 38.2 cm to 81.1 cm.

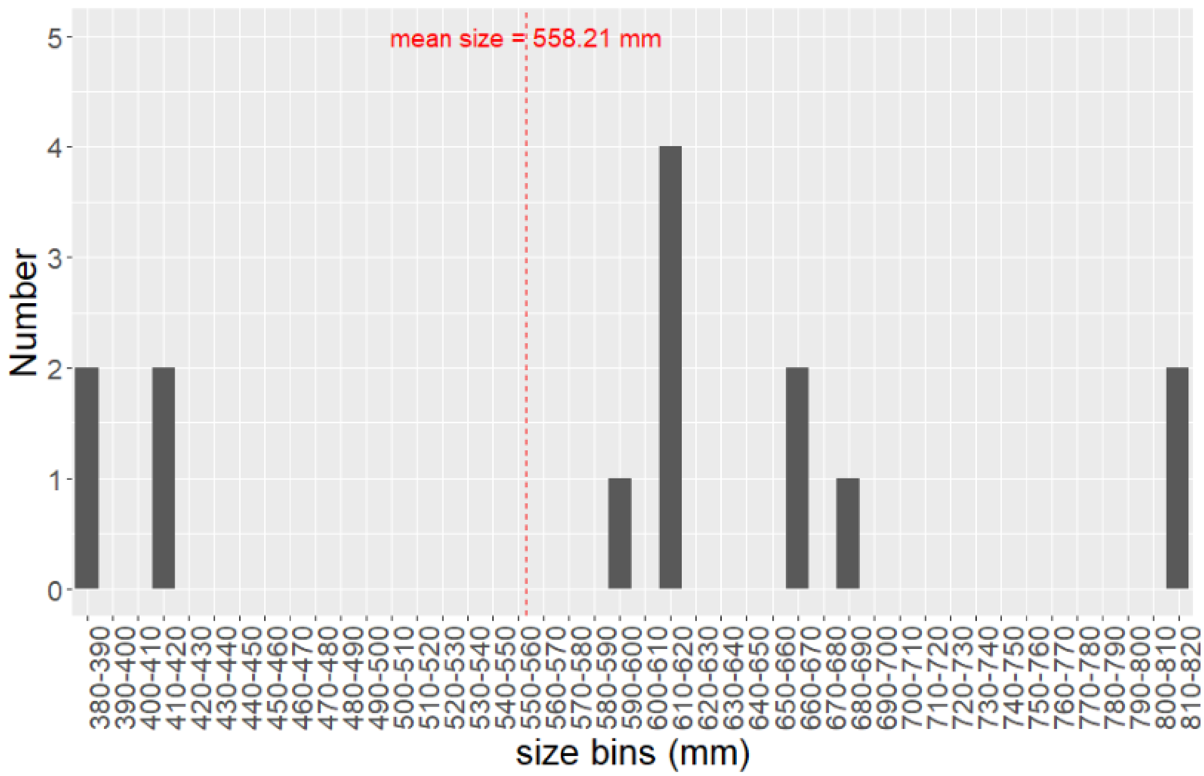


Figure 62. Length frequency distribution of measured striped trumpeter from ROV surveys in the Huon Marine Park.

ROV data: Detailed statistical analysis of species distributions

The same modelling approach outlined for the FMP was used for the HMP ROV data. Results are presented below.

Jackass morwong

Abundance

No significant effect of depth, proportion reef or proportion mixed habitat was found for jackass morwong (Table 44).

Table 44. Model summary output for the abundance of jackass morwong in ROV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-1.608	0.497	-2.613	-0.664
Proportion reef	-0.303	0.673	-1.622	1.019
Proportion mixed	-0.737	0.549	-1.874	0.280
Depth	0.308	0.544	-0.759	1.376
Depth-squared	0.389	0.328	-0.259	1.027

Striped trumpeter

Abundance

No significant effect of depth, proportion reef or proportion mixed habitat was found for striped trumpeter (Table 45).

Table 45. Model summary output for the abundance of striped trumpeter in ROV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-1.226	0.532	-2.286	-0.196
Proportion reef	-0.303	0.704	-1.684	1.081
Proportion mixed	-0.493	0.570	-1.652	0.587
Depth	0.527	0.592	-0.630	1.693
Depth-squared	-0.152	0.442	-1.085	0.649

Morid cod (combined species)

Abundance

No significant effect of depth, proportion reef or proportion mixed habitat was found for striped trumpeter (Table 46).

Table 46. Model summary output for the abundance of morid cod in ROV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-0.398	0.413	-1.222	0.401
Proportion reef	-0.400	0.607	-1.589	0.795
Proportion mixed	-0.149	0.472	-1.084	0.767
Depth	0.287	0.505	-0.691	1.292
Depth-squared	-0.683	0.442	-1.620	0.113

Ocean perch

Abundance

A significant positive effect of depth was found for the abundance of ocean perch (Table 47 and Figure 63), indicating a higher abundance at greater depths surveyed in the HMP.

Table 47. Model summary output for the abundance of ocean perch in ROV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	1.195	0.258	0.688	1.700
Proportion reef	0.501	0.442	-0.364	1.370
Proportion mixed	0.105	0.285	-0.454	0.664
Depth	0.915	0.332	0.265	1.568
Depth-squared	0.026	0.218	-0.416	0.439

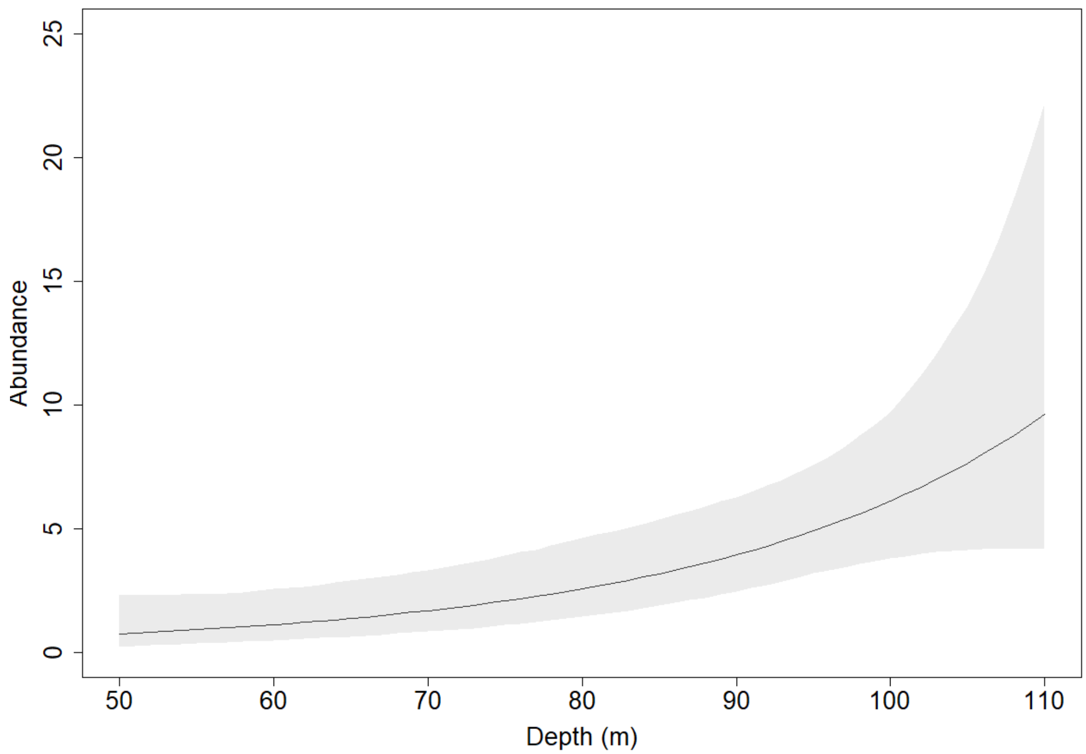


Figure 63. Modelled depth relationship with abundance for ocean perch.

ROV data: Multivariate analysis of fish communities

Methods

Multivariate analysis was once again conducted using PRIMER v6 software and followed the same approaches outlined for the FMP. A two-factor permutational multivariate analysis of variance (PERMANOVA) was conducted to examine the importance of ecosystem and habitat for the assemblage data. However, the interaction between ecosystem and habitat could not be assessed as the design was not balanced as all mesophotic transects were classed as reef.

Results

MDS plots revealed distinct clustering of communities based on habitat and depth-based ecosystems across ROV transects in the HMP (Figure 64 and Figure 65). However, there is a strong correlation between deeper transects and mixed habitats where complex high relief reef transitions into sediment dominated habitats resulting in deeper rariphotic transects more often being classed as mixed habitat. SIMPER analysis showed that species associated with deeper mixed (rariphotic) habitat transects included ocean perch (*H. percoides*), barred grubfish (*P. maclaeyi*), jackass morwong (*N. macropterus*), and striped trumpeter (*L. lineata*). Species associated with shallower reef dominated mesophotic transects included cosmopolitan leatherjacket (*M. scaber*), rosy wrasse (*P. rubicundus*), toothbrush leatherjacket (*A. vittiger*) and splendid perch (*C. australis*). However, many species occurred in both mesophotic and rariphotic ecosystems. PERMANOVA revealed a significant effect of habitat (Pseudo-F = 2.310, P = 0.048), but a non-significant effect of ecosystem (Pseudo-F = 0.702, P = 0.616).

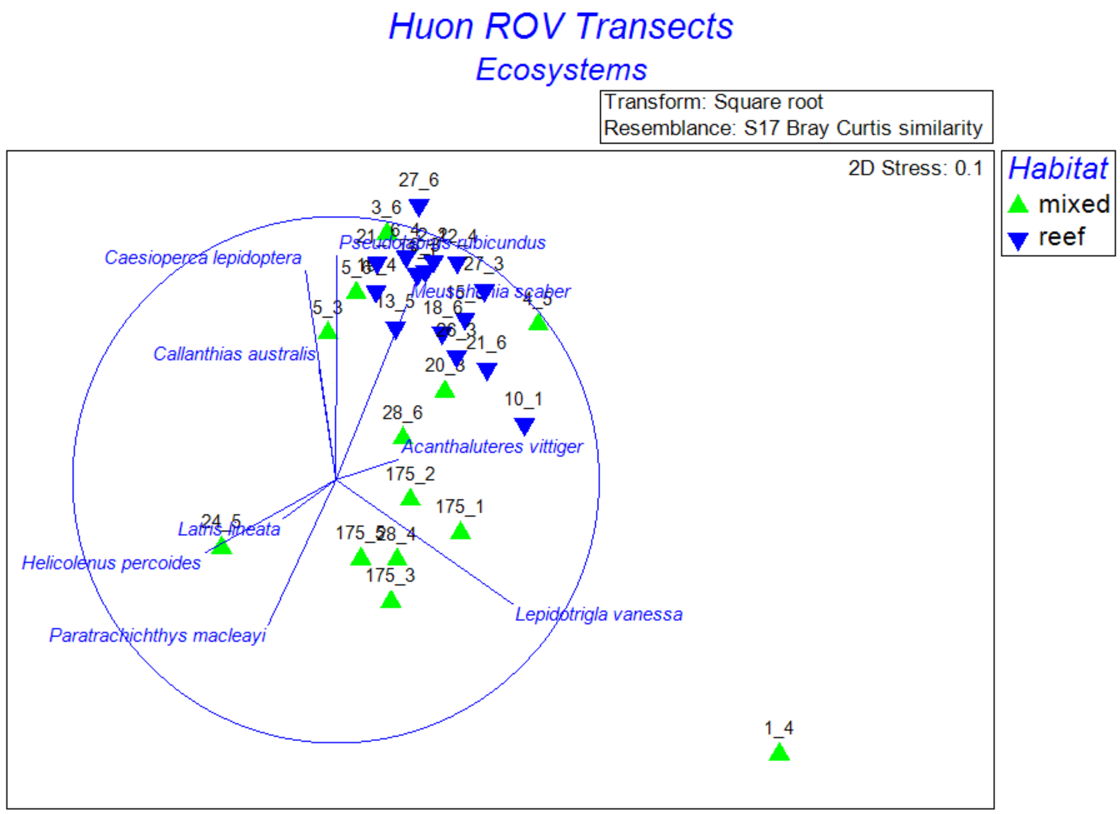


Figure 64. Non-metric multidimensional scaling plot showing the relationship between habitat classes and fish communities across ROV transects in the Huon Marine Park.

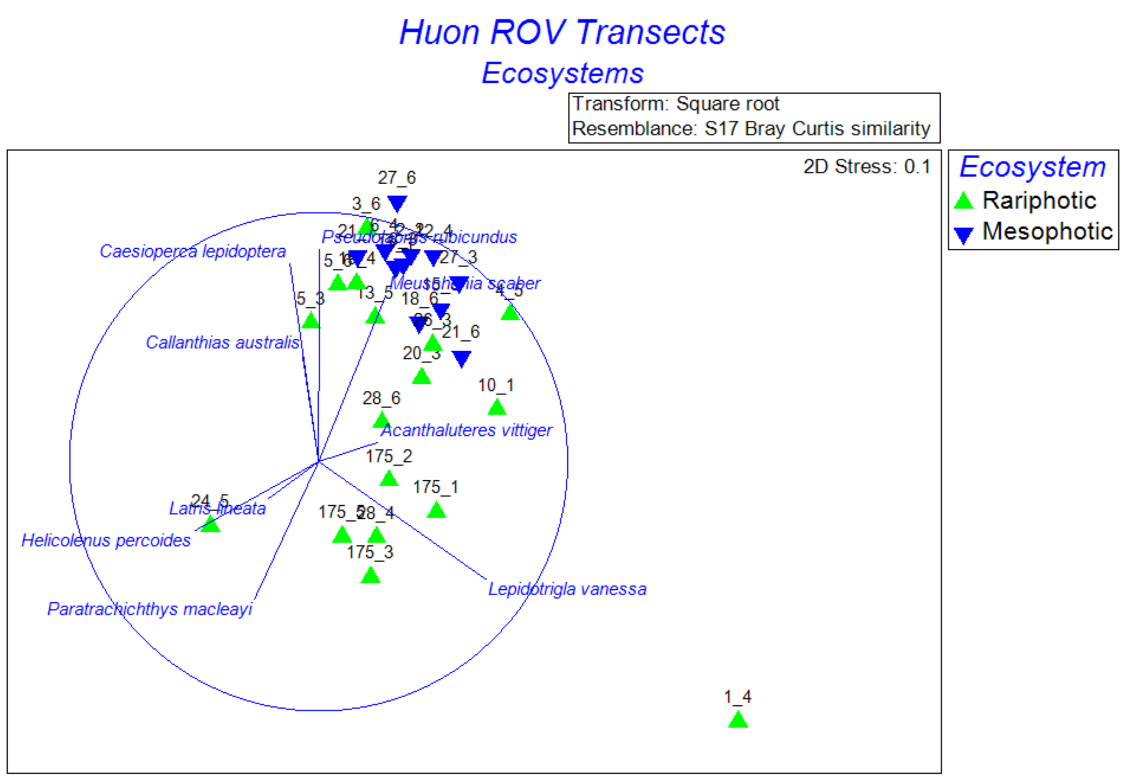


Figure 65. Non-metric multidimensional scaling plot showing the relationship between ecosystems (mesophotic < 70 m and rariphotic > 70 m) and fish communities across ROV transects in the Huon Marine Park.

Comparison of sampling platforms in Huon Marine Park: stereo BRUV vs ROV

The same approach used for the FMP was employed for comparing the stereo BRUV and ROV data in the HMP.

Length frequency comparison between stereo BRUV and ROV data

Jackass morwong

A much larger number of jackass morwong were measured in the overlapping surveys using stereo BRUVs (108 total of all MaxNs) when compared to ROV (12 in total). However, accounting for the minutes of survey time (minutes of deployment) the stereo BRUV method only accounted for a slightly higher overall abundance (Figure 66). Size classes of fish captured with the ROV fell within the larger size distribution captured with the stereo BRUV method, with a few smaller size classes (< 240 mm) represented in the stereo BRUV data but not captured by the ROV.

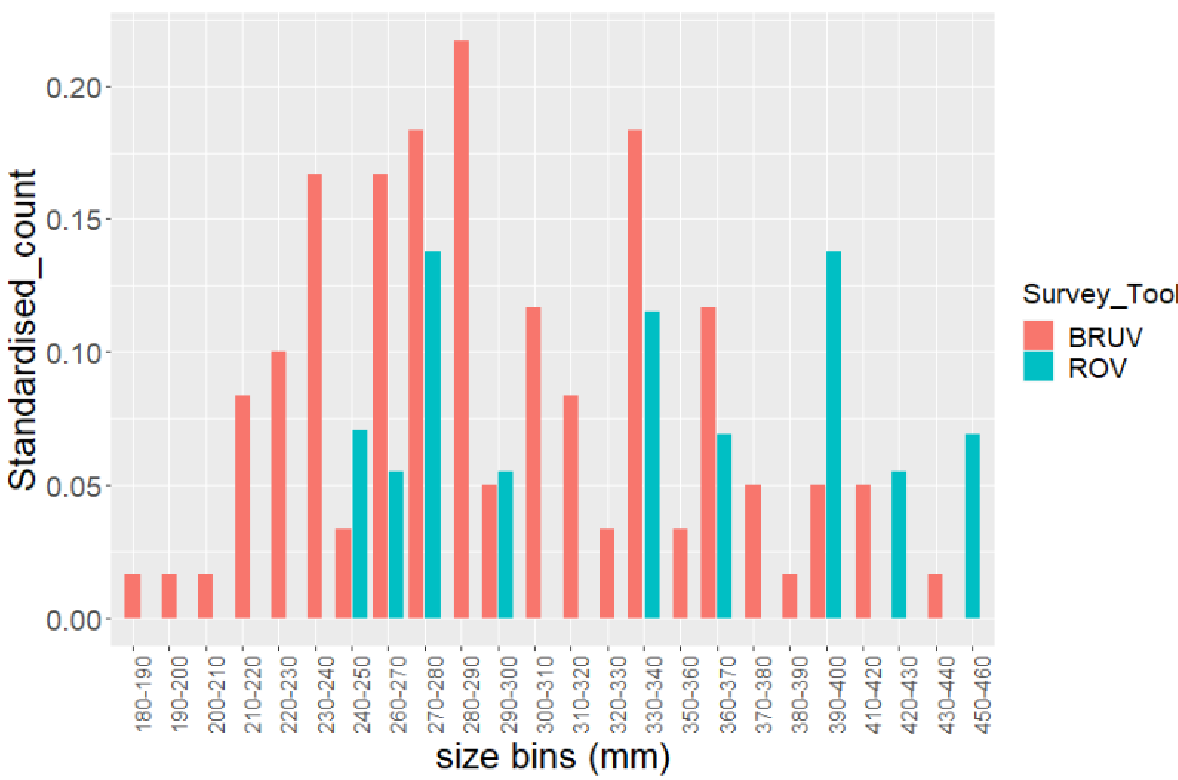


Figure 66. Comparison of the length-frequency data for jackass morwong from the stereo BRUV and ROV survey data from Huon Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Ocean perch

A larger number of ocean perch were measured using the ROV approach (87 in total) compared to the stereo BRUV approach (54 total of all MaxNs). However, accounting for survey time the ROV captured a proportionally much higher abundance of ocean perch (Figure 67). The size classes captured by both approaches were roughly similar, but with more small individuals (< 110 mm) captured with the ROV compared to stereo BRUVs.

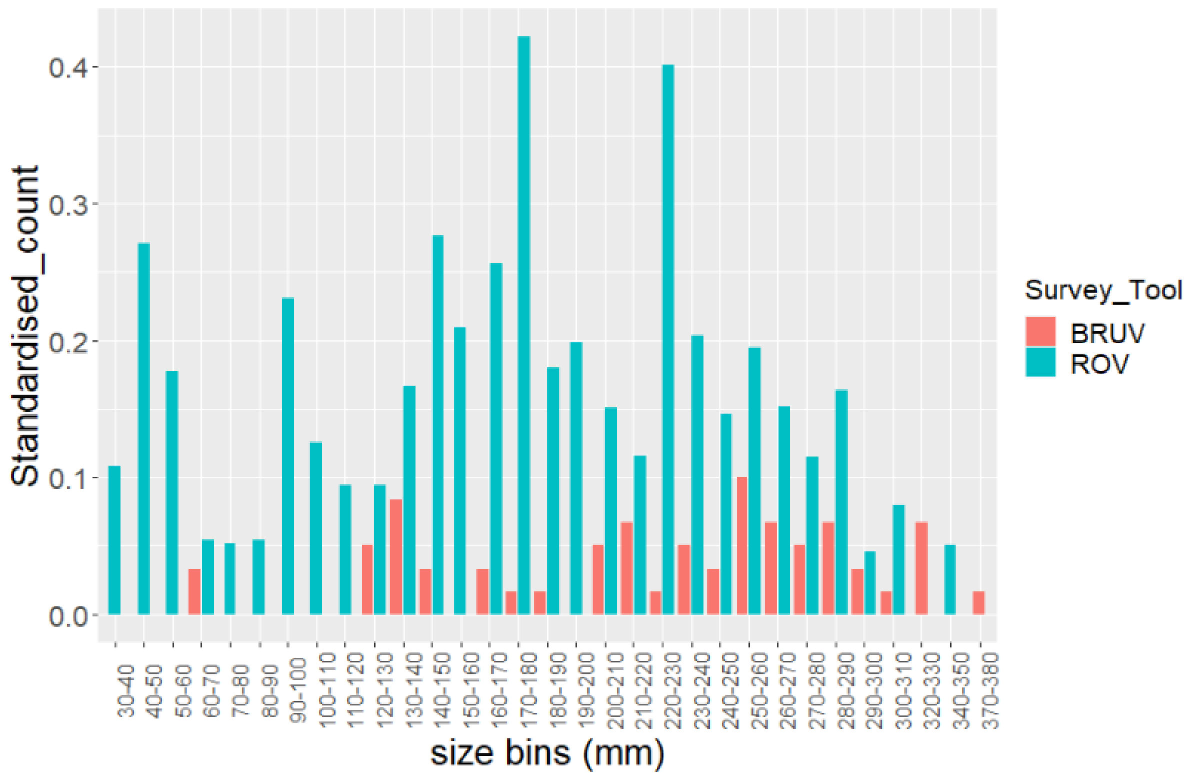


Figure 67. Comparison of the length-frequency data for ocean perch from the stereo BRUV and ROV survey data from Huon Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Morid cod

A larger number of morid cod were measured in the overlapping surveys using stereo BRUVs (53 total of all MaxNs) when compared to ROV (11 in total). However, once sampling time was considered abundances were roughly similar, with a similar set of size classes accounted for with each approach (Figure 68).

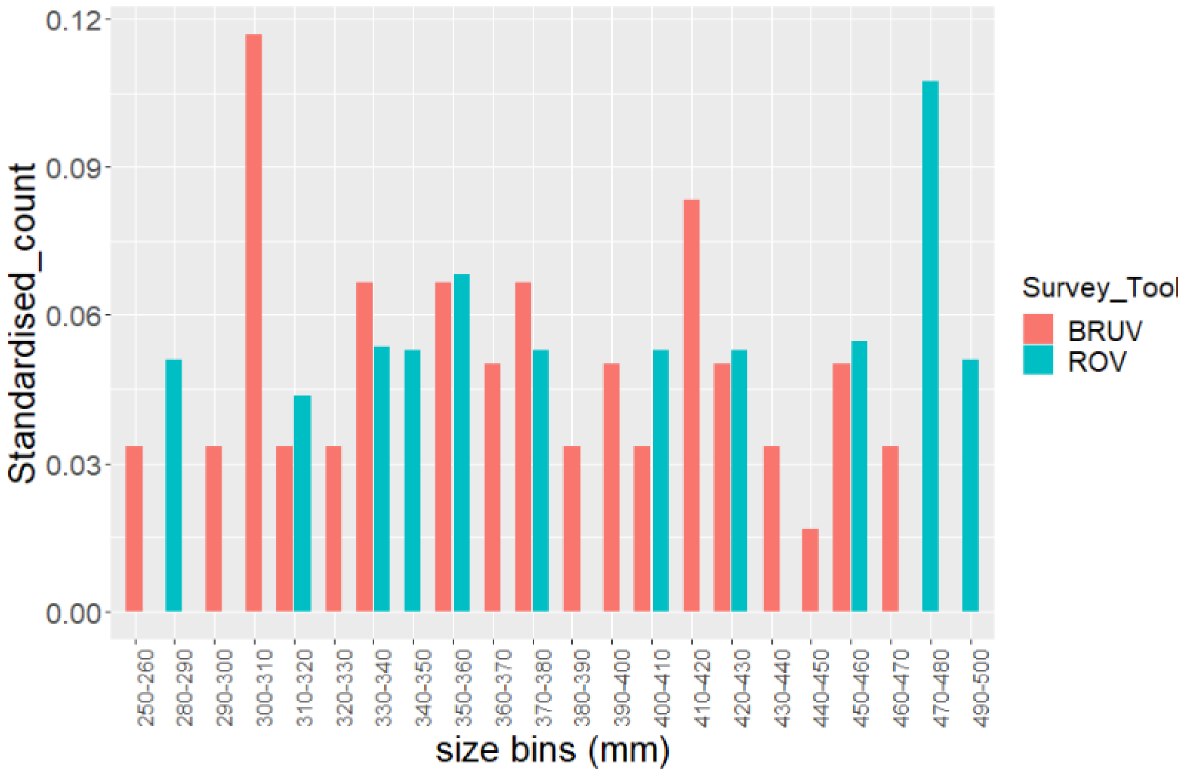


Figure 68. Comparison of the length-frequency data for morid cod from the stereo BRUV and ROV survey data from Huon Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Striped trumpeter

A slightly larger number of striped trumpeter were measured in the overlapping surveys using stereo BRUVs (21 total of all MaxNs) when compared to ROV (14 in total). However, once sampling time was accounted for abundances appear roughly similar, but with a more complete range of size classes in the stereo BRUV data because more individuals could be reliably measured (Figure 69).

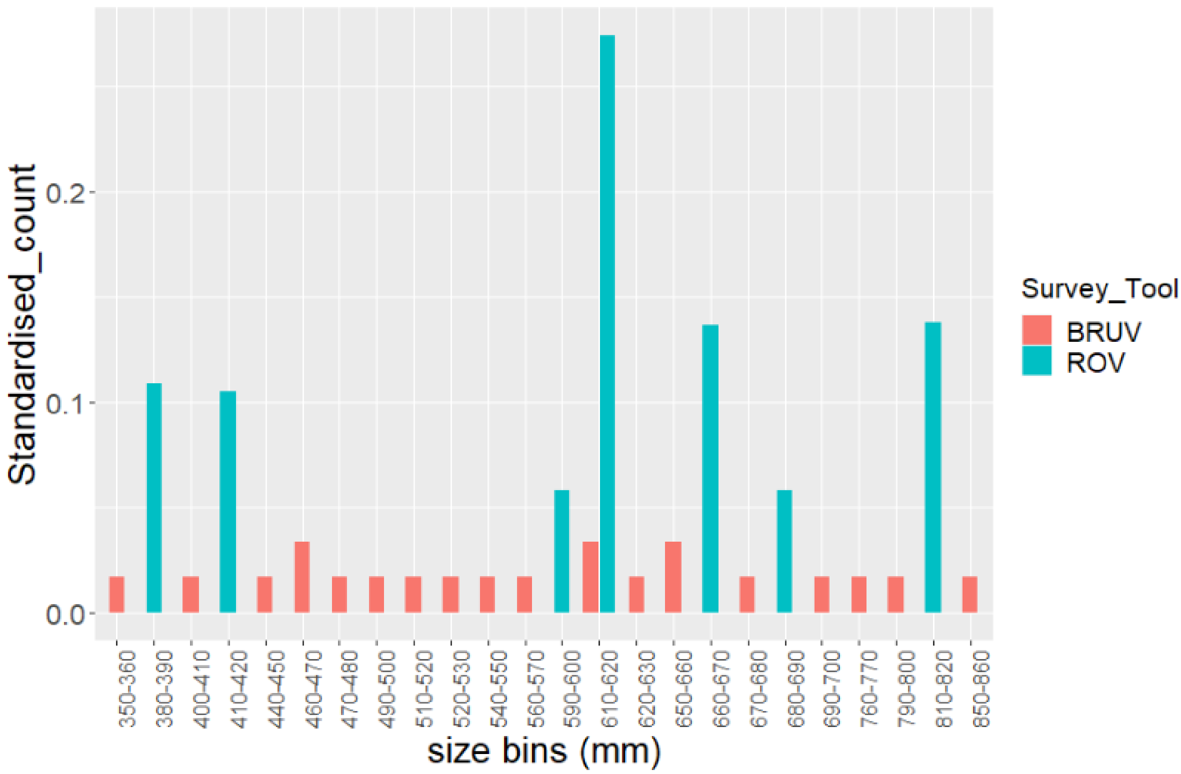


Figure 69. Comparison of the length-frequency data for striped trumpeter from the stereo BRUV and ROV survey data from Huon Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Butterfly perch

A much larger number of butterfly perch were measured in the overlapping surveys using the ROV (6758 in total) when compared to stereo BRUVs (402 total of all MaxNs). This difference was further accentuated once sampling time was accounted for, with a much higher abundance and more complete size structure captured by the ROV (Figure 70).

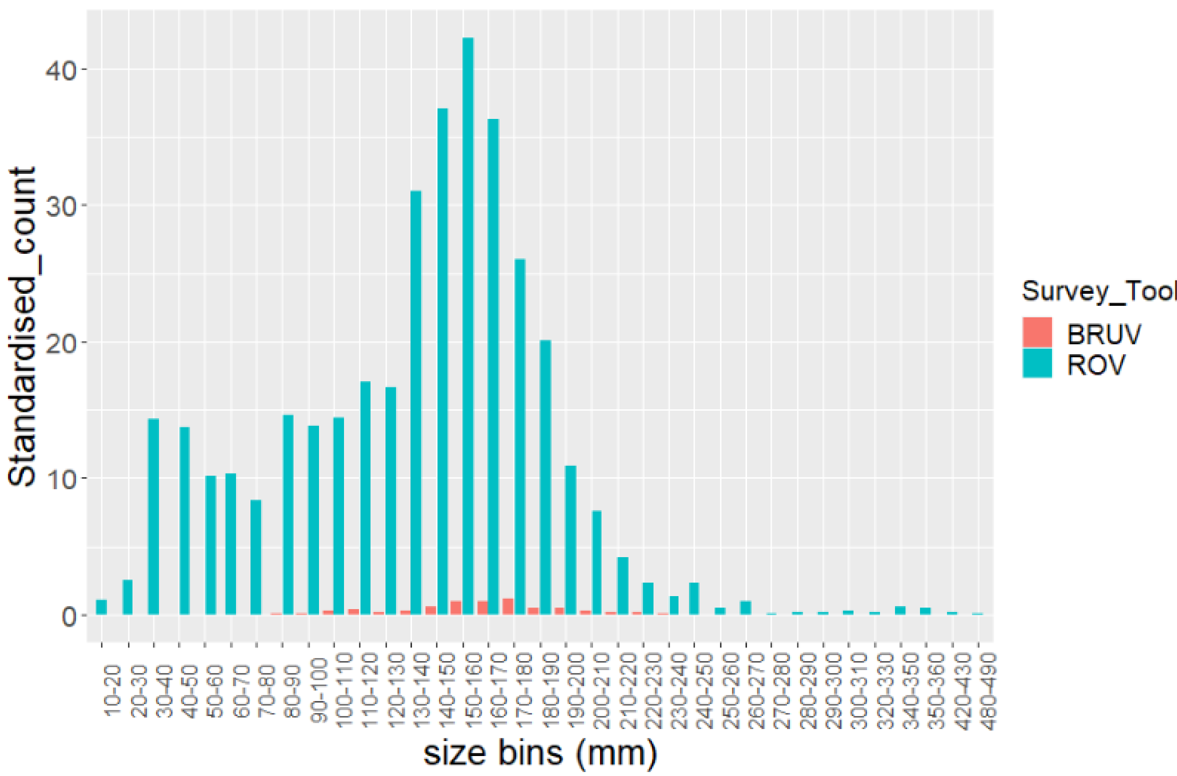


Figure 70. Comparison of the length-frequency data for butterfly perch from the stereo BRUV and ROV survey data from Huon Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Rosy wrasse

A larger number of rosy wrasse were measured in the overlapping surveys using the ROV (346 in total) when compared to stereo BRUVs (80 total of all MaxNs). This difference was further accentuated once sampling time was accounted for, with a much higher abundance and more complete size structure captured by the ROV (Figure 71).

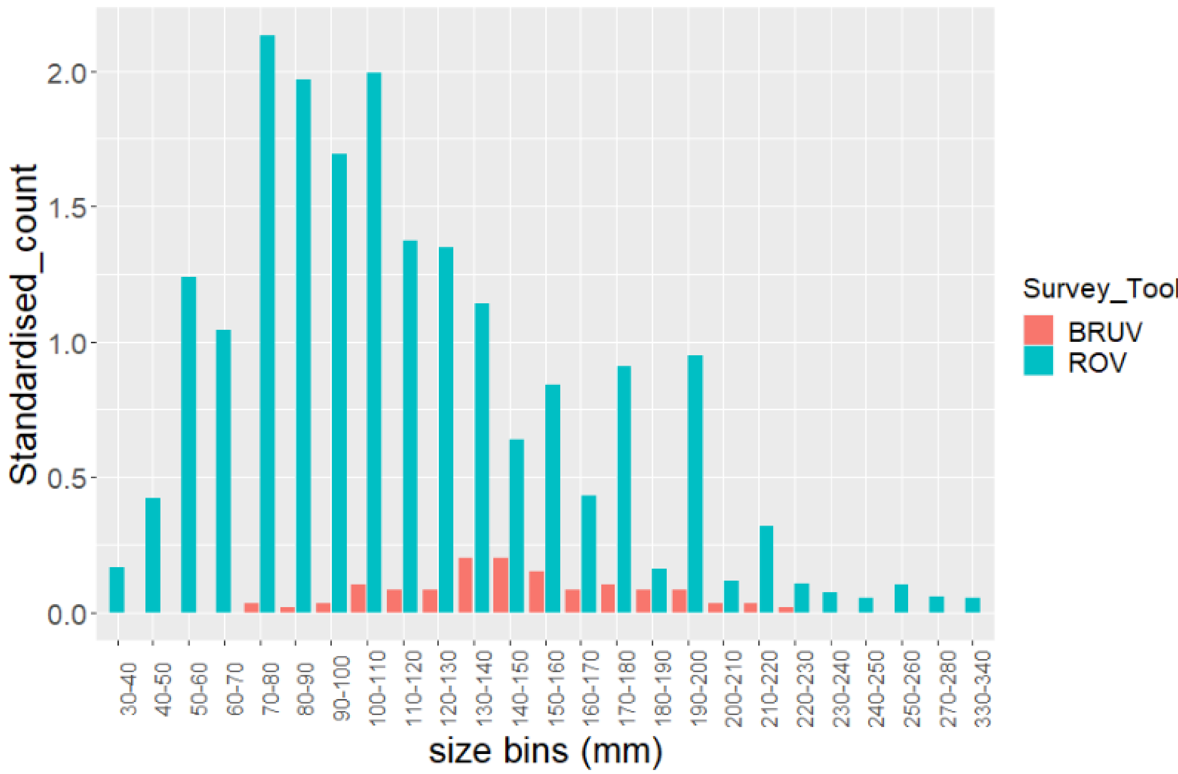


Figure 71. Comparison of the length-frequency data for rosy wrasse from the stereo BRUV and ROV survey data from Huon Marine Park. Counts in each size class were standardised by the amount of survey time (in minutes), thereby representing counts per minute.

Detailed univariate comparison of stereo BRUV and ROV data for selected species

Jackass morwong

A significant negative effect of ROV was found for the number of jackass morwong observed per unit time compared to stereo BRUV (Table 48), with the coefficient estimate indicating a mean rate of 0.14 times the number of fish observed per unit time with ROV compared with stereo BRUV. A significant positive effect was found for depth-squared, indicating a higher rate of jackass morwong were observed in the shallower and deeper depths across the depths surveyed when considering both sampling platforms.

Table 48. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	0.749	0.324	0.108	1.381
ROV	-1.967	0.313	-2.600	-1.373
Depth	0.825	0.444	-0.042	1.700
Depth-squared	0.488	0.249	0.001	0.978
Proportion reef	0.638	0.623	-0.578	1.867
Proportion mixed	0.473	0.385	-0.280	1.231

Striped trumpeter

No significant effect of ROV was found for the number of striped trumpeter observed per unit time compared to stereo BRUV (Table 49). No significant effects were found for depth or habitat categories.

Table 49. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	-0.776	0.516	-1.801	0.225
ROV	-0.304	0.363	-1.023	0.402
Depth	1.004	0.645	-0.249	2.283
Depth-squared	-0.021	0.429	-0.916	0.767
Proportion reef	0.186	0.885	-1.533	1.939
Proportion mixed	-0.595	0.595	-1.789	0.547

Morid cod

A significant negative effect of ROV was found for the number of morid cod observed per unit time compared to stereo BRUV (Table), with the coefficient estimate indicating a mean rate of 0.30 times the number of fish observed per unit time with ROV compared with stereo BRUV. Significant negative effects were found for the proportion of mixed habitat and depth-squared, indicating a lower rate of morid cod were observed in areas containing higher proportions of mixed habitat, and were also found generally in mid depths across those surveyed.

Table 50. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	1.181	0.205	0.767	1.573
ROV	-1.199	0.271	-1.750	-0.686
Depth	0.045	0.282	-0.506	0.601
Depth-squared	-0.499	0.211	-0.931	-0.105
Proportion reef	-0.540	0.378	-1.273	0.209
Proportion mixed	-0.575	0.267	-1.115	-0.068

Ocean perch

A significant positive effect of ROV was found for the number of ocean perch observed per unit time compared to stereo BRUV (Table), with the coefficient estimate indicating a mean rate of approximately 2 times the number of fish observed per unit time with the ROV compared to the stereo BRUVs. A positive significant effect of depth was found

Table 51. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	0.867	0.222	0.427	1.298
ROV	0.703	0.181	0.351	1.061
Depth	0.836	0.258	0.333	1.344
Depth-squared	-0.135	0.180	-0.500	0.206
Proportion reef	0.444	0.359	-0.256	1.151
Proportion mixed	0.006	0.225	-0.434	0.447

Butterfly perch

A significant effect of ROV was found for the number of butterfly perch observed per unit time compared to stereo BRUV (Table 50), with the coefficient estimate indicating a mean rate of 13 times the number of fish observed per unit time with the ROV compared to the stereo BRUVs. A significant negative effect was found for depth-squared, indicating a higher abundance in mid depths surveyed.

Table 50. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	3.015	0.280	2.474	3.574
ROV	2.590	0.260	2.080	3.099
Depth	-0.638	0.350	-1.325	0.048
Depth-squared	-0.470	0.199	-0.855	-0.073
Proportion reef	0.060	0.511	-0.949	1.058
Proportion mixed	-0.303	0.344	-0.982	0.368

Rosy wrasse

A significant effect of ROV was found for the number of rosy wrasse observed per unit time compared to stereo BRUV (Table 51), with the coefficient estimate indicating a mean rate of approximately 4 times the number of fish observed per unit time with the ROV compared to the stereo BRUVs. A significant negative effect was found for depth, indicating a higher abundance in the shallower depths surveyed.

Table 51. Model summary output for the abundance per-unit-time of jackass morwong from both ROV and stereo BRUV surveys in the Huon Marine Park. Effects highlighted green indicate a positive effect, red a negative effect, and black a non-significant effect.

Effect	mean	sd	0.025 quantile	0.975 quantile
Intercept	1.141	0.142	0.858	1.414
ROV	1.354	0.136	1.091	1.624
Depth	-0.464	0.162	-0.782	-0.147
Depth-squared	-0.117	0.077	-0.269	0.035
Proportion reef	0.467	0.248	-0.014	0.959
Proportion mixed	0.028	0.201	-0.366	0.423

Multivariate comparison of stereo BRUV and ROV data

The MDS plot shows a clear distinction between the communities captured with the ROV versus stereo BRUV methods (Figure 72). SIMPER analysis revealed that a much higher relative abundance of bait-attracted species such as jackass morwong, cosmopolitan leatherjacket, draughtboard sharks and morid cod were detected in the stereo BRUV data, whereas the ROV data had a higher proportion of species that are less likely to be bait attracted such as butterfly perch, rosy wrasse, and sandpaper fish. PERMANOVA showed significant differences between sampling platforms (Pseudo-F = 21.75, P = 0.001) and habitat (Pseudo-F = 4.10, P = 0.003) and a marginally non-significant interaction between platform and habitat (Pseudo-F = 2.39, P = 0.055). Only mixed and hard habitat classes were included in the subsetted data. SIMPER analysis showed hard habitats across both sampling platforms were typified by cosmopolitan leatherjacket, rosy wrasse, jackass morwong, and morid cod. Mixed habitats were dominated by butterfly perch, ocean perch and sandpaper fish.

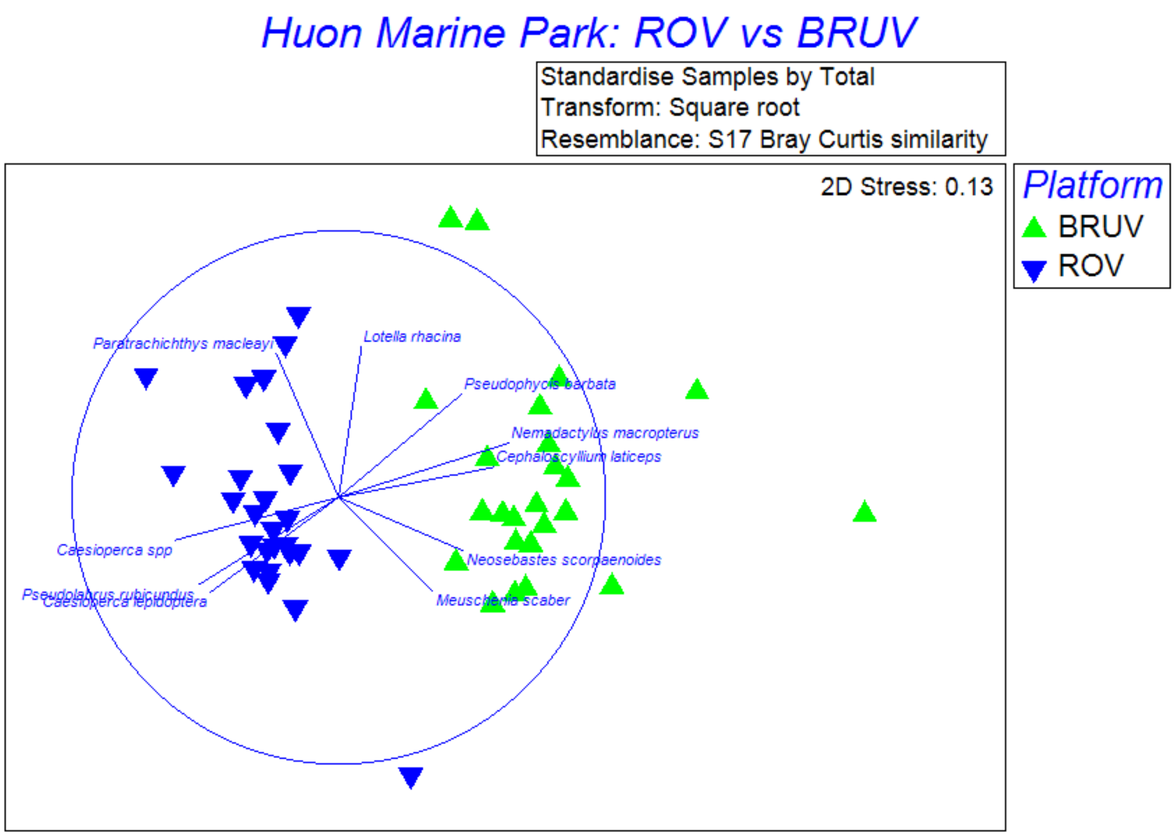


Figure 72. Non-metric multidimensional scaling plot showing the difference in communities quantified between stereo BRUV and ROV sampling platforms. Blue text and directional lines show some of species driving the differences.

Discussion: ROV and a comparison with stereo BRUVs

Initial testing of the ROV methodology as a tool for ongoing monitoring of fish communities in HMP has revealed that this approach is capable of quantitatively documenting a wide representation of the fish community present and their associated habitats. However, the sample sizes achieved in this initial trial survey (25 x 200 m transects completed over 3 days) appear to be too small to adequately quantify the abundance-habitat relationships and population size structures of some of the important fish species. It should be noted though, that this was a method trial and not intended to be the main source for a quantitative baseline. The quantitative baseline was provided by the stereo BRUV survey, with nine days of stereo BRUV deployment vs three days of ROV deployment. A particular limitation of the ROV approach at the current level of replication was related to size-structure estimation of fishes. Typically, fishes seen in ROV-footage are much less frequently able to be seen in a pose useful for length-measurement than in stereo BRUV-footage as bait-attracted fishes are in proximity of cameras for longer, increasing chances of a measurable pose. Stereo BRUV surveys are therefore capable of providing larger sample sizes of bait-attracted species, particularly where length measurements are required to generate length frequencies, which may be important where detection of fishing impacts on size-structure of populations is a metric of interest. Conversely, the ROV methodology appears to be more suitable for capturing fine-scale habitat associations and the presence of non-bait-attracted species such as butterfly perch, important community components if changes in ecosystem function is a question of interest in monitoring programs. Likewise, the ROV approach is more likely to detect the presence of rare species that are not attracted to bait. For example, a handfish (likely a pink handfish) was observed with the ROV, whereas no handfish were observed with the stereo BRUVs in the HMP, despite a significantly greater effort in stereo BRUV vs ROV deployments. Due to a lack of bias through bait attraction and the need to use MaxN as an index of abundance when using stereo BRUVs, ROVs could be more suitable for quantitatively estimating total abundances within HMP and more widely. The advantages and biases of each methodology should be considered in future monitoring designs and informed by specific management questions.

As expected, significant differences in communities were observed between the ROV and stereo BRUV sampling approaches, with a higher proportion of bait-attracted species observed in the stereo BRUV data compared to the ROV data. When taking the differences in deployment time between stereo BRUVs and the ROV into account, some of these differences in species abundances became even more apparent. Statistical analysis showed that higher abundances of jackass morwong were observed with stereo BRUVs, with less than one-third the number observed in the same time frame with the ROV. Much higher abundances of ocean perch, butterfly perch, and rosy wrasse were observed with the ROV in an equivalent sampling time. Interestingly, there was no significant difference in the number of striped trumpeters observed between the two methods. This may point to striped trumpeter not having a strong avoidance to the ROV, although further testing of this hypothesis is required.

With respect to further understanding species/habitat associations, finer-scale relationships are likely to be more discernible with the ROV methodology compared to the stereo BRUV methodology. Bait-attracted species formed a higher proportion of the communities in the stereo BRUV data compared to the ROV data indicating that such species have often been drawn from some distance away, including from differing habitats, by the bait plume. Thus, relationships with visually assessed habitat in stereo BRUVs footage may be misleading as it is difficult to quantify how far different fish have been drawn from surrounding habitat. The ROV on the other hand, provides the ability to directly observe species in their preferred habitats, and thus a more reliable way to quantify habitat relationships. However, it should be noted that some species may avoid the ROV (and associated lighting) and thus bias estimates. While no obvious attraction/repulsion behaviours were recorded, this requires further follow-up studies to examine biases in detail.

A key finding of the ROV-trial though, was that sample sizes from the pilot ROV survey for some of the target fish species were too low for reliable statistical inference, suggesting a need for increased sampling in future efforts. Sample sizes could be increased by adding additional transects or by increasing the transect length. Consideration of sub-sampling units should also be given with future efforts. In other regions developing ROV-based monitoring of fish communities, longer ROV transects are often broken into shorter sub-sections, by either length or area, prior to analysis (e.g., Karpov et al. 2012, Perkins and Lauermann 2023), hence, our current focus on undertaking replicate 200 m length transects may be able to be modified in the future to improve sampling efficiency, especially if transects cross multiple habitats. Habitat was scored in one-minute-long sub-sections of ROV transect in the initial description provided in this report. Finer-scale habitat associations are evident when considering this data; however, sample sizes were too small to analyse the data at this scale, with many zeros present in the data. This necessitated analysis using the full transect as the sampling unit, with proportion of habitat as a covariate. Habitat used in this way was found to be non-significant for the species tested. Alternative sub-sampling units could be explored in future work to test the ability to quantify habitat relationships.

Overall, the results of the ROV trial in the HMP emphasised the same patterns found in the FMP, that this approach complimented the use of stereo BRUVs in sampling fish communities, providing greater numbers of observations of non-bait-attracted species such as planktivores and site-attached micro-carnivores. This contributes to greater ecosystem understanding and provides a basis for monitoring shifts in ecosystem function through time. However, as fewer fish were seen in side-profile to enable length measurements relative to stereo BRUVs, and as stereo BRUVs typically attract larger numbers of bait-attracted species that are often species of commercial/recreational interest, wholistic monitoring and inventory programs would ideally include a mix of both methods.

General discussion

Overview:

The combined stereo BRUV and ROV-based studies in the Huon and Freycinet marine parks have significantly improved our understanding of the benthic/demersal fish communities of mesophotic to rariphotic habitats in these waters, particularly on rocky reefs. This was the first quantitative study of demersal fish assemblages in both of these parks, building on similar approaches successfully used in other parks in the SE network, including the Tasman Fracture, Flinders and Beagle marine parks, to provide an initial baseline inventory and to underpin future monitoring. In addition to the description of the fish fauna present, in combination with recent multibeam mapping of shelf to shelf-break regions of these parks, the surveys have also provided detailed visual validation of the types of habitat present. This includes the first ever imagery from deep (80-100 m) reefs in the HMP and of the shelf-break reefs in the FMP that proved to have their own distinctive fauna, including eastern orange perch that occupy small holes dug into the mudstone cliffs found there.

The core aim of the study was to provide both a quantitative description of the species present across habitats in the shelf waters of the parks, with this data to be sufficiently robust to underpin ongoing monitoring, and to provide for evaluation of current zoning arrangements. Overall, the spatially-balanced quantitative datasets acquired here for describing fish abundance and size structure provide a robust statistical baseline for monitoring future changes in the parks. This includes for examination of changes through time, between zones (where present) and, ideally, future comparisons with changes outside the parks in similar habitats.

Typically, key recreationally and commercially targeted fish species, including jackass morwong, striped trumpeter, ocean perch and even rock lobsters (in the HMP) were seen in sufficient numbers in both parks to allow detection of biologically meaningful changes in both abundance and size-structure and these are discussed in detail in the relevant sections in this report with respect to each park. As this was a baseline study, it is not possible at this stage to examine the extent that the parks or zoning within them had any marked influence on the overall fish abundance present. Despite that, we did examine a range of contrasts between the two zones in the FMP (the RUZ and MUZ) and compare those with fish abundances in similar habitats in adjacent areas open to all forms of fishing. Few clear patterns were seen, although legal sized jackass morwong were markedly more abundant in the RUZ than external fished locations, and when comparing across trawlable habitat, this species weas nearly five x more abundant in the FMP than outside. However, in the absence of a time series from when the park was implemented, it is not possible to determine if this is a protection effect or one related to subtle habitat differences.

In addition to quantifying the more common and target species discussed above, this study has provided a broad-scale understanding of fish biodiversity values of each park, that when coupled with image-based validation of the nature of habitats present, has allowed; (1) the description of a range of species/habitat relationships for individual species where sufficient abundances were recorded by the sampling methods used and; (2) an understanding of the extent that habitat features, such as shelf-break reefs and complex rocky-reef outcrops like Joe's Reef, can structure distinct fish assemblages. The extensive search effort across both parks surveyed has also allowed us to obtain a detailed overall inventory of the demersal and benthic fish present, including presence of rare species such as handfish.

A significant and unique component of this study included use of both stereo BRUV and ROV-based surveys of fish assemblages. While stereo BRUV surveys constituted the most substantial sampling effort to ensure a sound quantitative baseline of fish abundance was undertaken in both parks, the study enabled the trial of ROV-based approaches as a supplementary or alternative approach to using stereo BRUVS alone. Typically, the stereo BRUV-based approach yielded higher abundances of bait-attracted species such as jackass morwong and striped trumpeter, although for the latter the difference was marginal when compared across similar field time spent sampling. Despite this, the stereo BRUV method typically yielded greater numbers of length measurements per individual seen, as fish were usually seen for longer periods, improving chances of gaining appropriate side-on views for measurement.

For less bait-attracted species, the ROV method generally yielded much higher abundance counts, particularly for planktivores such as butterfly perch, but also small microcarnivores such as rosy wrasse and benthic carnivores such as ocean perch. It was also more effective in detecting rare species such as handfish, and in visualising fine scale habitat associations such as eastern orange perch on shelf-break reefs. Ideally future surveys would incorporate use of both methods, particularly for initial baseline inventories, with future sampling optimised across methods to track species or trophic groups of interest.

Comparison of fish abundance and size between zones and externally where appropriate

Fish size and abundance were the main metrics used to establish initial quantitative baselines in each of the parks surveyed, in each of the zones within the park where present and at external locations where appropriate. This external baseline was only made with respect to the FMP as this was the only park with notable potential differences in commercial fishing effort (apart from trawling) across zones due to the presence of the RUZ. In this park a comparison of abundance and size was made between the MUZ and RUZ for commercially and recreationally targeted shelf species, as detailed in the FMP sections earlier. Some differences were observed, such as striped trumpeter average size being slightly smaller in the RUZ compared with the MUZ and morid cod being lower in abundance in the MUZ and RUZ compared to external fished areas. However, these differences were generally small and likely primarily driven by habitat rather than zone protection differences within the park. There were no real marked differences that could be attributed to a zone effect at this stage.

Despite little in the way of differences between zones within the FMP shelf waters, there was some evidence that the restriction on benthic trawling in the FMP has resulted in a 5x positive difference of jackass morwong, a trawl targeted/bycatch species until recently (see AFMA restrictions: https://www.afma.gov.au/species/jackass-morwong). However, the survey design used in this study was targeted towards describing the habitat, ecosystem (mesophotic and rariphotic), and depth associations of fish species inside and outside FMP rather than specifically assessing potential recovery from historic trawling effort. In the absence of a before/after comparison prior to establishment of the park, it is impossible to differentiate an effect of protection from subtle habitat differences between these areas that may also explain such trends in the absence of a time series. Overall though, the results of lower abundances in the external fished areas are in agreement with observations of a significant decline in catches of this species in the trawl fishery, as well as in coastal monitoring data (Edgar et al. 2018). The abundance and length of flathead was similar within the MUZ and RUZ and in external fished areas.

However, sample sizes were relatively small and could be increased in future efforts by increased targeting of optimal habitats for these species if changes in soft-sediment species was a monitoring priority. Typically, soft-sediment species are less densely distributed than reef species and therefore require greater sampling effort.

As the HMP study was primarily based on surveying reef habitat (albeit with moderate sampling to describe species/habitat associations more widely), the survey was restricted to the park itself, as fishing activities on reef habitat are not restricted in the park relative to adjacent areas.

Habitats of the parks and their species/habitat relationships

Generally, the distinct reef systems, including Joe's Reef and shelf-break reefs in the FMP, the extensive inner-shelf reef systems in the HMP, and the complex reef in the external northern fished area of the FMP, all had markedly differing fish communities to the adjacent soft sediments or dune-like features. As Joe's Reef is the only significant reef structure in the shelf waters of the FMP, and the only habitat to extend into the mesophotic zone, it is not surprising that it has a unique fish assemblage, characterised by large numbers of planktivorous species like butterfly perch. Likewise, the shelf-break reefs in the FMP constituted only a small proportion of habitat in this region, but also had distinct communities, including large numbers of eastern orange perch that were observed utilising small holes in the mudstone reef on the ROV transects. Several handfish were also observed on rubble adjacent to these reefs, raising the potential importance of these shelf-break systems to some conservation dependant species. Likewise, these locations contained a number of other species not seen elsewhere in the FMP, including the spot-tailed perchlet and the red banded grubfish.

While it is unfortunate that the FMP does not include representation of the more comprehensive cross-shelf reef habitats found to the north of the park, the reef that is found here, most notably Joe's Reef and the isolated shelf-break systems, do provide some representation of such systems and these are certainly key natural values of this park. The shelf-break reefs are typically small linear features, with very little in overall area relative to other habitats. Despite this, they appear to be areas of concentration of species such as striped trumpeter, jackass morwong and even rock lobsters. Presumably this also concentrates recreational fishing effort, as ROV footage showed these areas to have extensive coverage of snagged ropes and fishing lines.

Although not as conspicuous as reef, the seabed in much of the FMP shelf waters is composed of hummocky dune-like features that while not outcropping as reef, do appear more consolidated than nearby rippled sediments and typically have a greater cover of turfing invertebrate matrix and small sponges than the pure sediments between them. Hence, moderate amounts of more typically reef-attracted species are still found in association with these, including striped trumpeter, jackass morwong and ocean perch, allowing this park to support moderate populations of these species, despite having very little in the way of outcropping reef.

In the HMP, the reef systems were far more extensive than found in the FMP and formed a continuum from mesophotic to rariphotic depths, with the depth association of reef species being more apparent as sampling extended from around 40 m to over 100 m depth. Likewise, there was typically a clear differentiation between fish assemblages of reef systems from those of the sandy sediments between these and the broad sandy seabed extending from the reefs of the inner shelf out to the shelf break. For the reef systems, significant effects of depth were found for species that preferred shallower mesophotic depths across those surveyed such as draughtboard sharks, rosy wrasse, and cosmopolitan leatherjacket, as well as those that preferred deeper rariphotic depths such as striped trumpeter. Far fewer species were seen across the open sand areas, and typically all were seen at low density in sandy habitat.

Overall, this study demonstrated that while some species, including target species of commercial and recreational interest, have distinct habitat affinity, some have less stringent habitat requirements, or at least can be found at times across a range of different habitat types. These include jackass morwong which despite a marked preference for reef and reef margins, were widely distributed across habitats, including the FMP dune-like features. Despite this broader habitat distribution, they were also restricted to waters less than 150 m, which includes the whole shelf area in the FMP but only the inner shelf section of the HMP. These learnings can inform future sampling and monitoring programs by enabling the design of preferential sampling programs that target the optimal habitats of species being monitored. The overall extent of sampling required for any particular species or indicator group (e.g. targeted species, or large targeted species) and the habitats targeted will depend on the questions to be answered (e.g. effects of zone type, or fishery type) so this is not examined here, but the data gathered in this study is more than sufficient as a pilot dataset to plan ongoing monitoring programs in any of the key habitats and for the majority of the species encountered.

ROV vs stereo BRUV trial

A key component of this study was to trial the use of a remote operated vehicle (ROV) for inventory and monitoring of shelf fish communities across the FMP and HMP and contrast initial results generated with baited underwater video (BRUV) data. While ROV-based sampling was restricted to a small number of days sampling in each park, and was primarily targeted at reef communities, the results demonstrate that this quantitative sampling method has a significant role to play in future inventory and monitoring studies. For some bait-attracted species such as jackass morwong and striped trumpeter, stereo BRUVS were initially anticipated to generate significantly higher abundances than ROVs for a similar amount of sampling effort. For other species, less attracted to bait, more individuals were expected to be seen by similar sampling effort by ROVs.

Despite this, when equal sampling time was accounted for, even for bait-attracted species such as striped trumpeter and jackass morwong, both approaches were relatively equal in their effectiveness when measuring overall abundances. However, for other species, such as the ocean perch, butterfly perch and rosy wrasse, ROVs sampled a significantly greater number than stereo BRUVs. Overall, t, stereo BRUVs captured imagery of a greater proportion of fish that could be measured because fish were observed for a longer period of time, and the fish were generally attracted closer to the cameras due to the bait. Countering that was the greater ability of the ROV method to observe fine scale species/habitat relationships, and sample species in trophic groups that are not bait-attracted, thus improving knowledge of the overall community presence. An additional benefit of ROVs is the ability to detect rarer species such as handfish. Imagery of four individual handfish was captured by ROV over the course of this study (including one identified as a pink handfish in the HMP) compared to only one recorded during a stereo BRUV deployment, despite the significantly greater sampling effort of the stereo BRUV surveys. Hence, such an approach may be useful for recording a range of rare benthic species in future programs.

While the use of stereo BRUVs in future sampling programs is a logical progression, based on a range of prior experiences at national scales and success in generating significant abundance counts and length measurements for species of interest here, there is certainly merit in further exploring ROVs in this space to compliment the stereo BRUVs approach. However, as sample sizes from the ROV survey for some of the target fish species in this pilot study were too low for reliable statistical inference, this suggests a need for increased sampling in future efforts if those species were also the focus of robust quantitative monitoring using this approach. Sample sizes could be increased by completing additional transects or by increasing the transect length where appropriate. Consideration of sub-sampling units should also be considered with future efforts. In recent equivalent programs in California, longer ROV transects (km scale) have been trialled (e.g., Karpov et al. 2012, Perkins and Lauermann 2023). These long transects were often subsequently broken into shorter sub-sections, by either length or area, prior to analysis. Habitat was scored in one-minute-long sub-sections of ROV transect in the initial description provided in this report. Finer-scale habitat associations are evident when considering this data; however, sample sizes were too small to analyse the data at this scale, with many zeros present in the data. This necessitated using the full transect as the sampling unit, with proportion of habitat as a covariate. Habitat used in this way was found to be non-significant for the species tested. This is due to habitat being aggregated over the entire transect (e.g., proportion of reef across the ~200 metre long transect), rather than the habitat that an individual was directly observed in being used. For example, if a reef associated fish was observed on a small patch of reef in an otherwise sediment dominated transect (say 95% soft sediment), while the direct observation was on reef, this may be lost in the analysis at the transect level which may have been summarized as only 5% reef. Alternative sub-sampling units could be explored in future work to quantify habitat relationships.

Emerging pressures and management considerations

As this study (coupled with recent multibeam mapping programs) has yielded a significant amount of new information on the distribution of species and their preferred habitats within both parks, it is important that some consideration is given to the fact that this knowledge is now widely available on a range of major communication and data platforms such as AusSeaBed and Seamap Australia. The mapping data in particular is now available on commercial fishing and charting applications (e.g. Navionics app) allowing fine-resolution visualisation of key habitat features such as isolated shelf break reefs. This publicly available information may result in increased recreational and commercial fishing pressure at high value locations through time. Locations such as Joe's Reef and the shelf-break reef habitat within the FMP are some examples of spatially constrained high value habitat that may need additional spatial protection in the future if there is evidence of an increase in use. Likewise, the northern reef sections of the HMP are home to a significant lobster and striped trumpeter resource, that while currently primarily targeted by commercial fishers, may in future experience increased recreational fishing pressure on the basis of newly created and accessible knowledge. Ideally some future research efforts would focus on understanding changing patterns in the distribution of fishing pressure, coupled with appropriate ongoing monitoring programs, to inform potential management responses by state and Commonwealth agencies if these pressures resulted in a decline in the overall values of these parks.

Overall recommendations

1. Monitor reef and soft-sediment fish communities in the Freycinet and Huon Marine Parks at 5 year intervals to inform management of changes in key species or system function.
2. Use a balanced mix of stereo BRUV and ROV-based surveys to monitor fish assemblages, with stereo BRUVs forming the basis of monitoring reef-associated species, and with ROVs forming the basis of generating a wider understanding of changes at the assemblage level.
3. Further evaluation of ROV-based approaches to describing mesophotic/rariphotic fish communities and fine scale fish/habitat relationships is required to optimise design approaches, minimise costs and maximise information gained.
4. Ideally a future sampling program would have additional replication in adjacent and matching off-marine park habitats to allow better understanding of the effectiveness of zoning where differing levels of protection are provided (e.g. the MUZ's are protected from benthic trawling even though all other fishing activities are permitted).
5. Given that rock lobsters were a key component of the species recorded on reefs in the Huon Marine Park, some consideration should be given to a targeted survey of this commercially important species beyond that recorded by stereo BRUV-based sampling. Lobsters have been shown to build resilience in inshore reef systems of this region by controlling *Centrostephanus* populations, hence understanding their size structure in the HMP and the influence that fishing may have on that, will be important for management decisions when *Centrostephanus* urchins and their associated barrens arrive on the shallower reef systems.

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Appendix: Sample imagery

In addition to the imagery provided below, representative and highlight videos from the stereo BRUV sampling are publicly available on Seamap Australia for Freycinet (https://seamapaustralia.org/map/#fc3d0184-57bd-45f9-adfa-426bc5961a4a) and Huon (https://seamapaustralia.org/map/#c5f2e8ac-7300-46c1-99c7-d786df152044) MPs.

Freycinet Marine Park: example habitat images

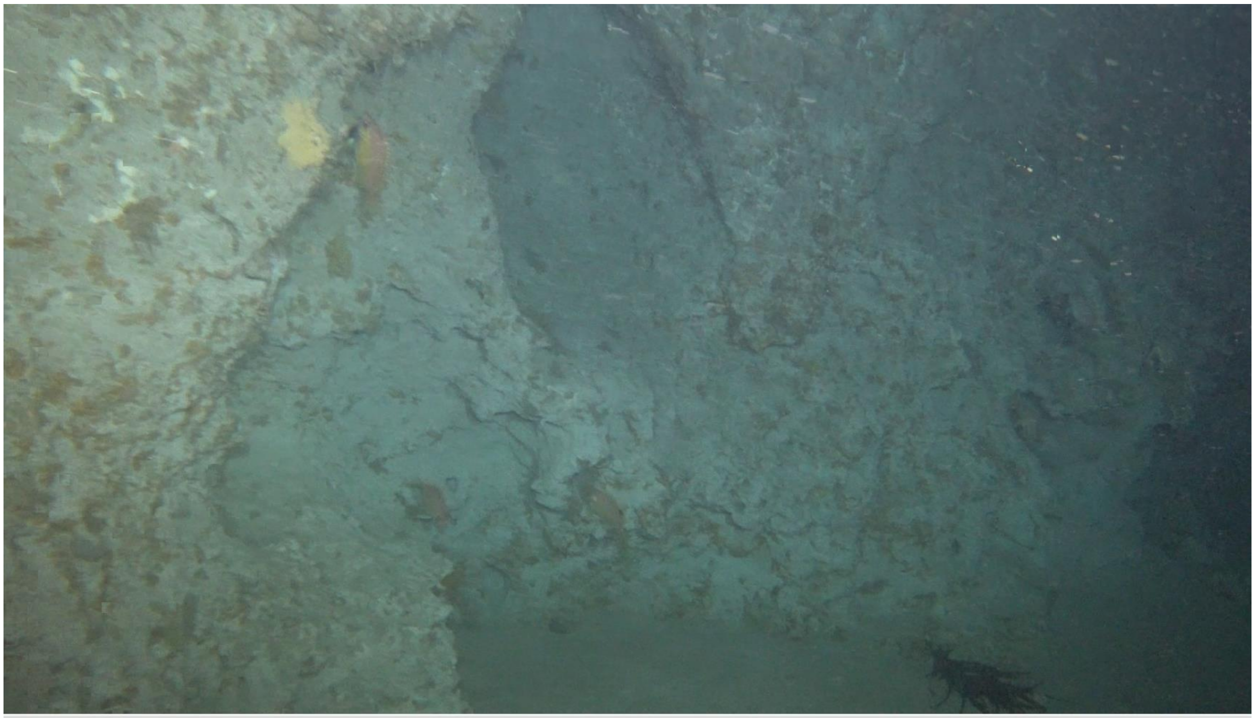

Figure 73. Mudstone cliff habitat on the shelf break in Freycinet Marine Park on ROV transect 80_2

Figure 74. High profile invertebrate covered reef at Joe's reef on ROV transect 30_5

Figure 75. High profile invertebrate covered reef, including a large black coral at Joe's reef on ROV transect 2_2.

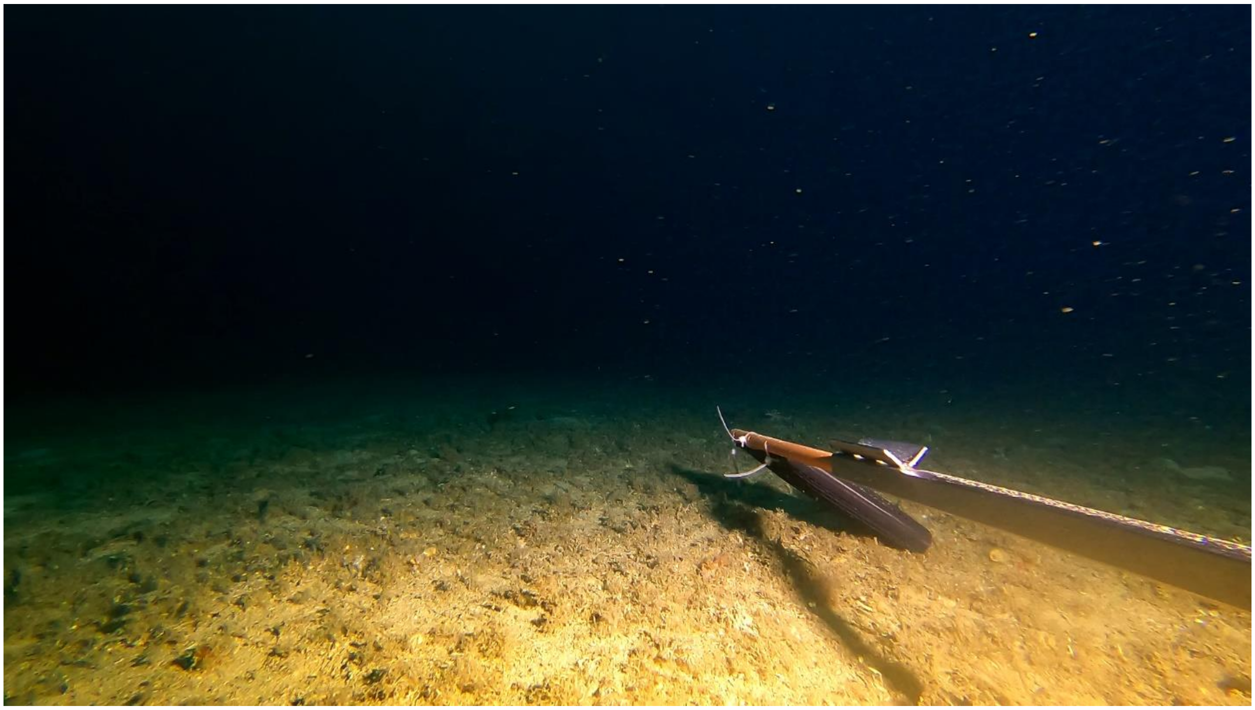

Figure 76. Freycinet stereo BRUV drop 39_6 showing an example of the flat bryozoan thickets common throughout the mid-to-outer shelf regions of the AMP.

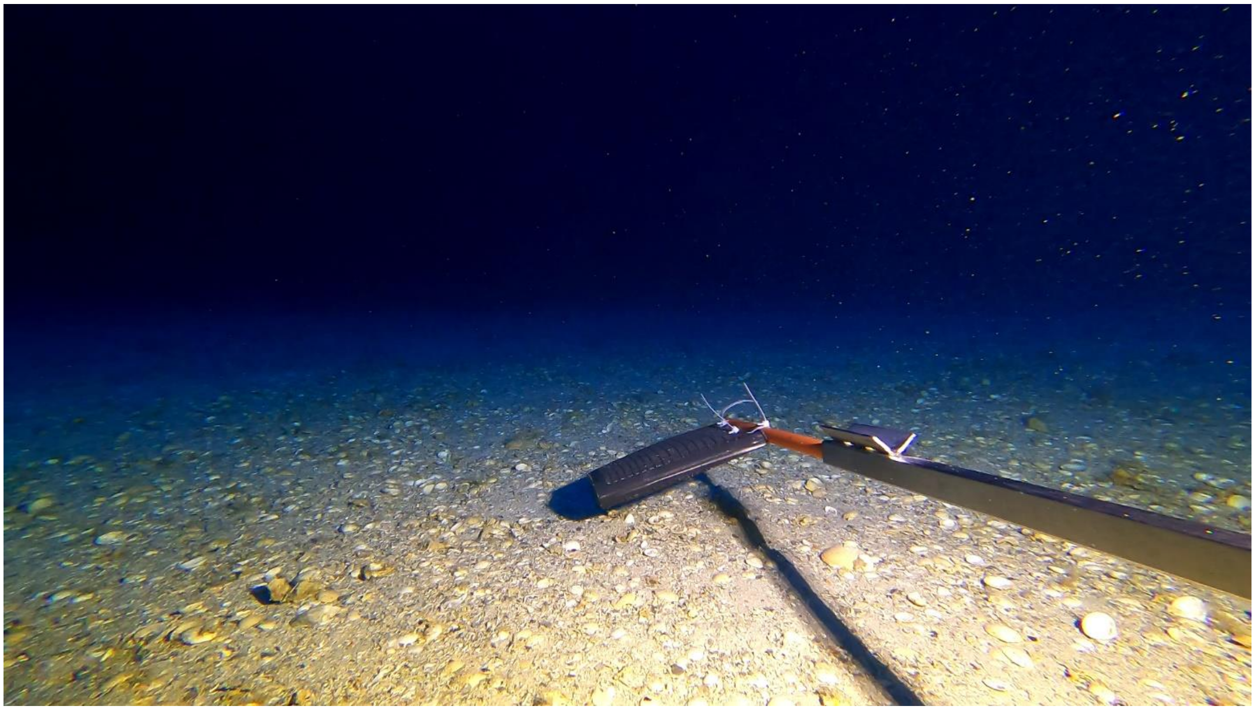

Figure 77. Freycinet stereo BRUV drop 34_1 showing heavily shelled flat sediments occasionally found throughout the outer shelf regions of the AMP.

Figure 78. Freycinet stereo BRUV drop 34_5 close-up of the usually bare mudstone cliff features shelf break regions of the AMP showing delicate hydroids

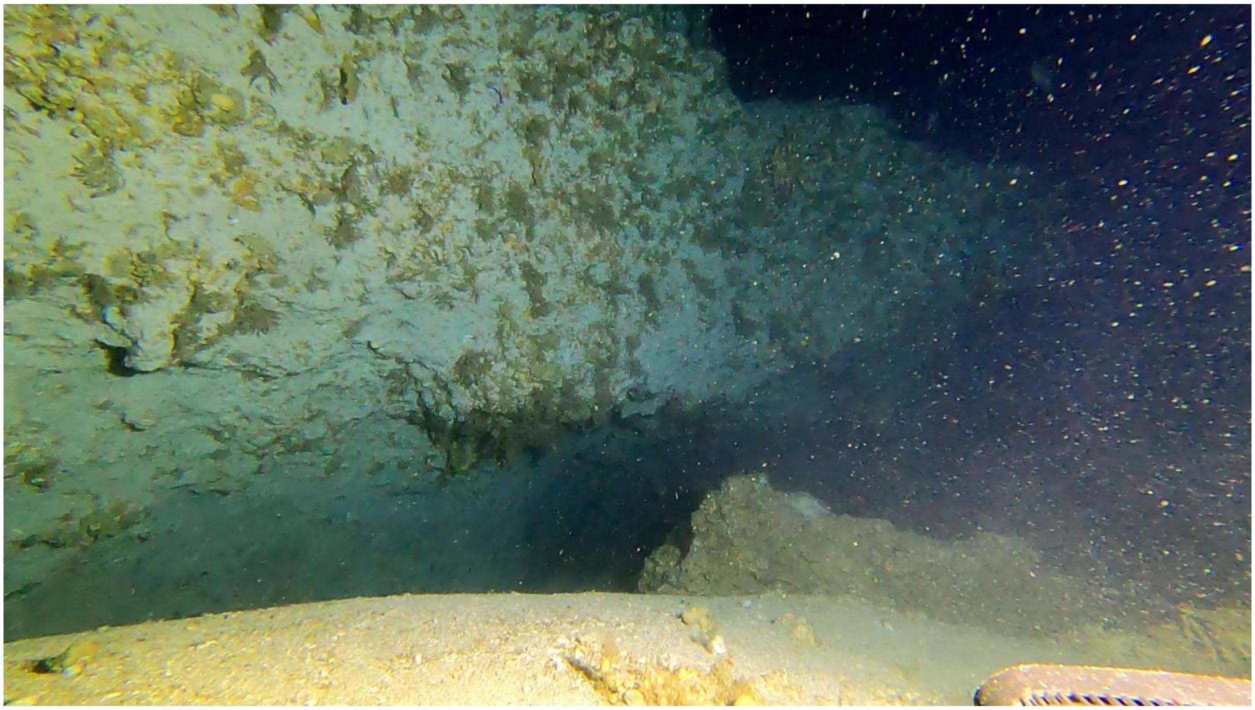

Figure 79. Freycinet stereo BRUV drop 76_2 showing comparatively bare mudstone cliff habitat on the shelf break in Freycinet AMP.

Figure 80. Freycinet stereo BRUV drop 80_2 showing large mudstone boulders at base of cliff habitat on the shelf break in Freycinet AMP, potentially indicating the dynamic nature of these cliffs.

Figure 81. Freycinet stereo BRUV drop 30_3 showing high profile nature of Joe's reef including a large black coral in background.

Figure 82. Freycinet stereo BRUV drop 36_1 showing tall branching sponges on the low-profile reefs located in the reference area to the north.

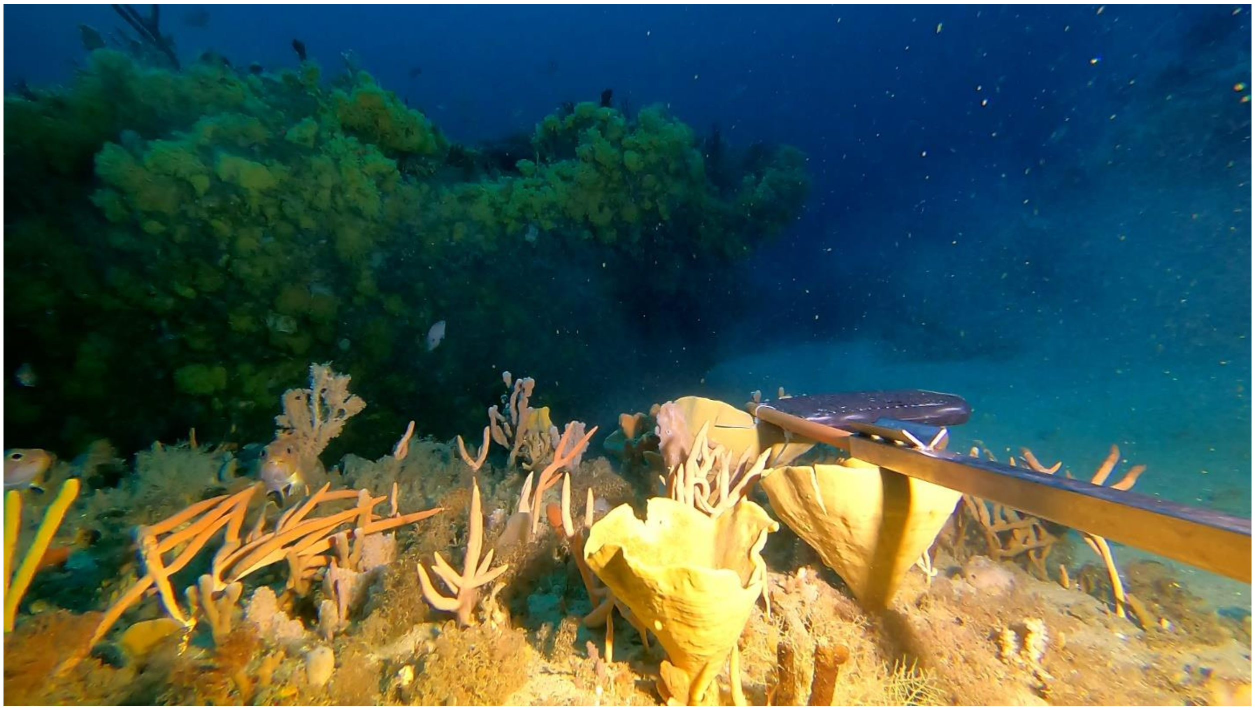

Figure 83. Freycinet stereo BRUV drop 36_6 showing diversity of cup and branching sponges on the low-profile reefs located in the northern external fished area.

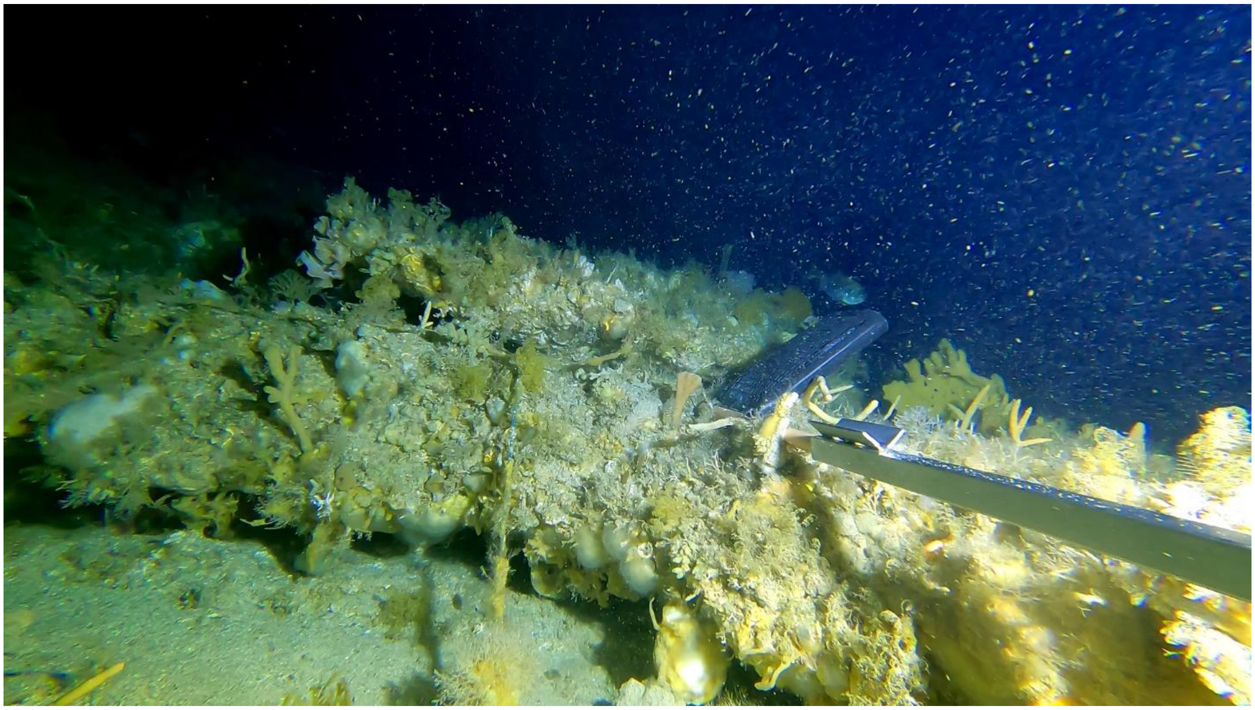

Figure 84. Freycinet stereo BRUV drop 22_4 showing low-profile reef features found shelf break. Note discarded fishing line in centre of image.

Freycinet stereo BRUV images: species highlights

Figure 85. Freycinet stereo BRUV drop 6_1 showing jackass morwong (*N. macropterus*) and ocean perch (*H. percoides*).

Figure 86. Freycinet stereo BRUV drop 6_4 showing striped trumpeter (L. lineata), jackass morwong (*N. macropterus*) and ocean perch (*H. percoides*).

Figure 87. Freycinet stereo BRUV drop 7_1 showing Melbourne skate (S. whitleyi).

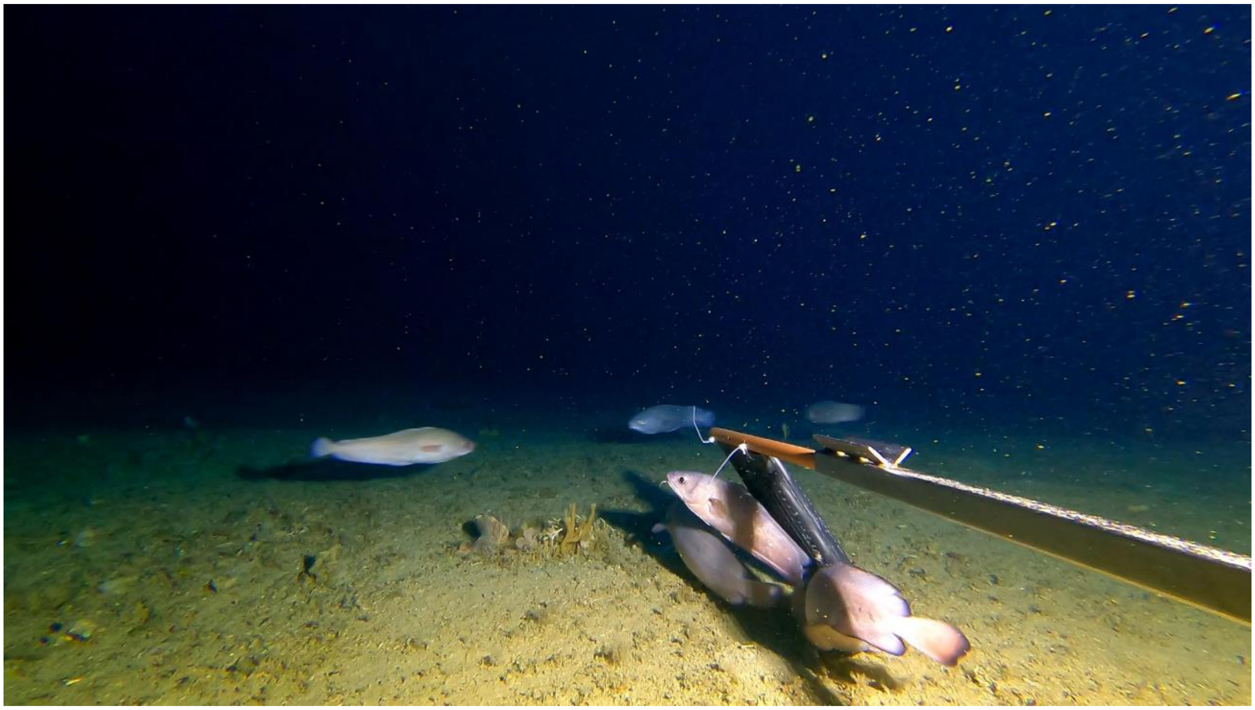

Figure 88. Freycinet stereo BRUV drop 9_2 showing morid cod (P. bachus).

Figure 89. Freycinet stereo BRUV drop 10_4 showing jackass morwong (N. macropterus) and splendid perch (C. custralis).

Figure 90. Freycinet stereo BRUV drop 12_2 showing jackass morwong (N. macropterus) and southern rock lobster (J. edwardsii).

Figure 91. Freycinet stereo BRUV drop 12_5 on a shelf-break reef system showing ocean perch (H. percoides) and jackass morwong (N. macropterus).

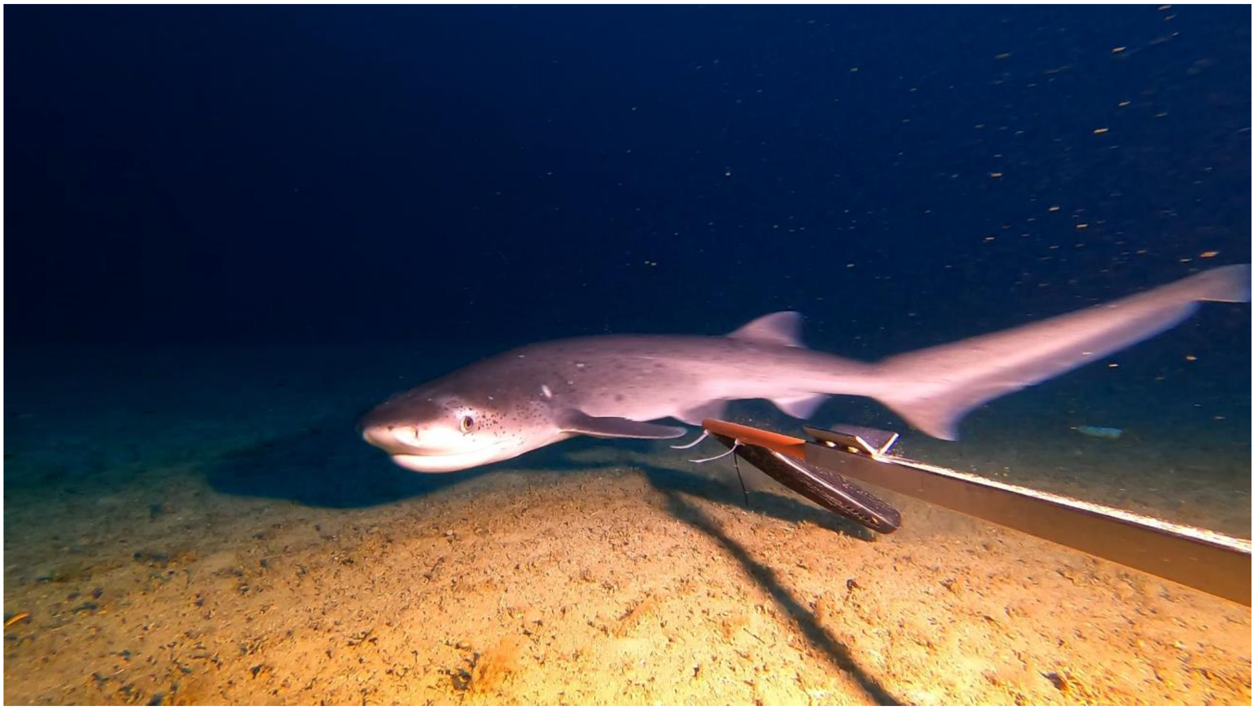

Figure 92. Freycinet stereo BRUV drop 18_5 showing broadnose sevengill shark (N. cepedianus).


Figure 93. Freycinet stereo BRUV drop 18_5 showing flathead (Platycehalidae spp.).


Figure 94. Freycinet stereo BRUV drop 25_6 showing butterfly perch (C. lepidoptera).

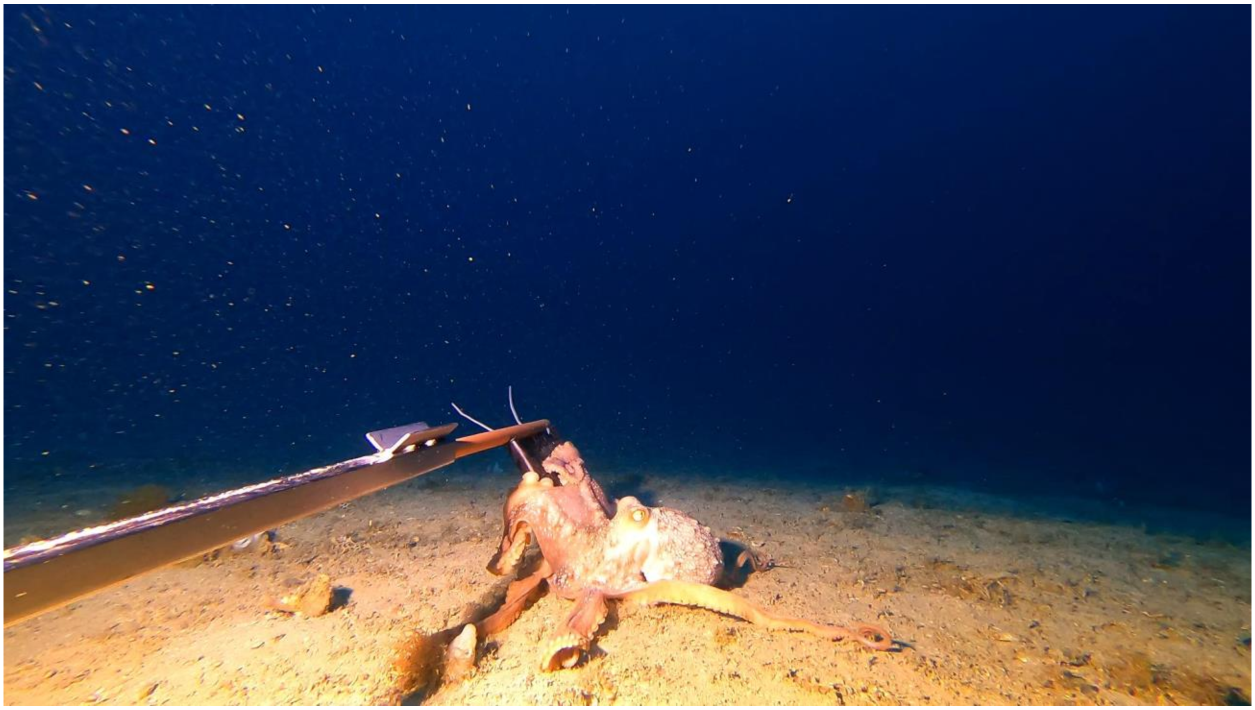
Figure 95. Freycinet stereo BRUV drop 29_3 showing octopus.

Freycinet ROV images: species highlights

Figure 96. Freycinet ROV transect 12_5 on a shelf-break reef system showing handfish (Brachionichthyidae spp).

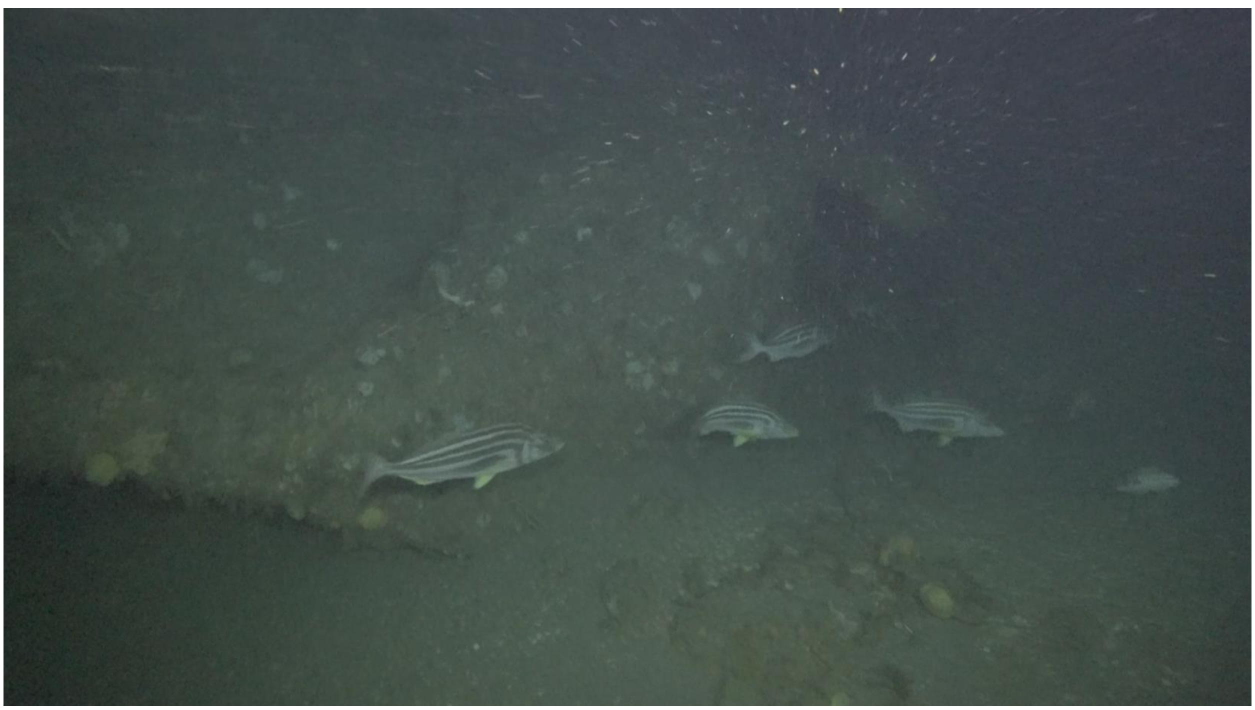

Figure 97. Freycinet ROV transect 22_4 on a shelf-break reef system showing striped trumpeter (L. lineata).

Figure 98. Freycinet ROV transect 12_5 near a shelf-break reef system showing southern rock lobster (J. edwardsii) and ocean perch (H. percoides).

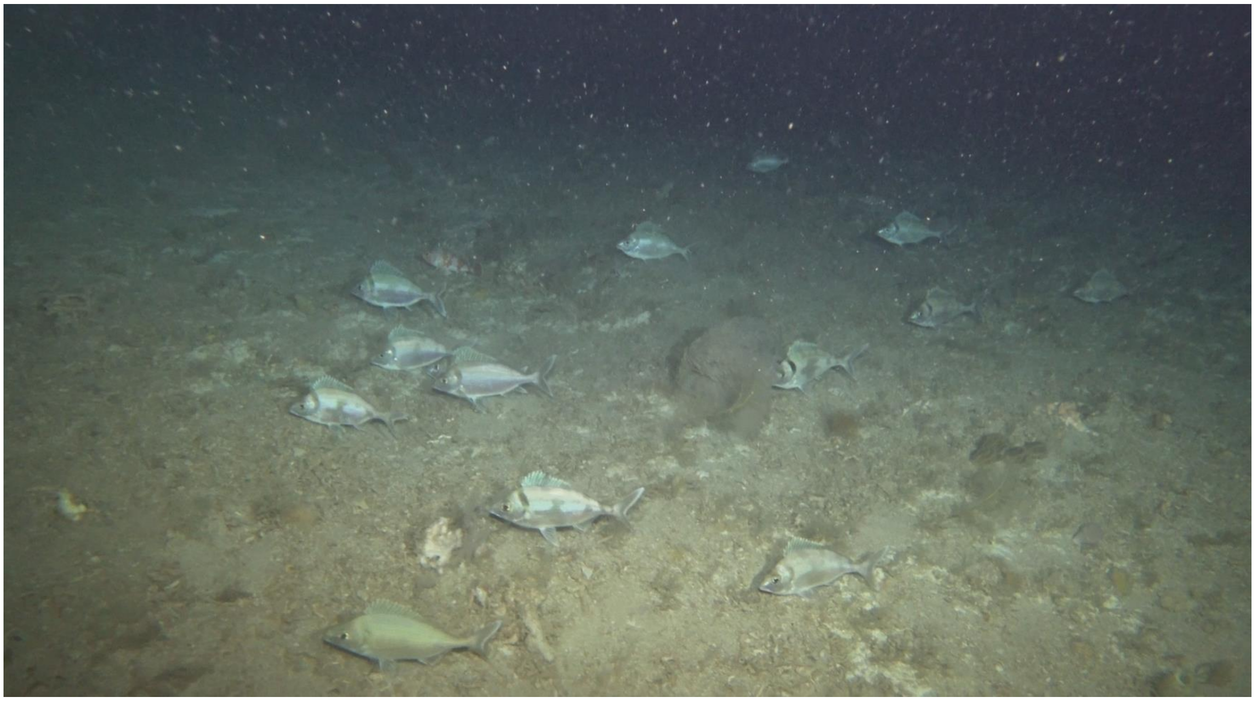

Figure 99. Freycinet ROV transect 80_3 on a shelf-break reef system showing jackass morwong (N. macropterus) and ocean perch (H. percoides).

Huon Marine Park: example habitat images

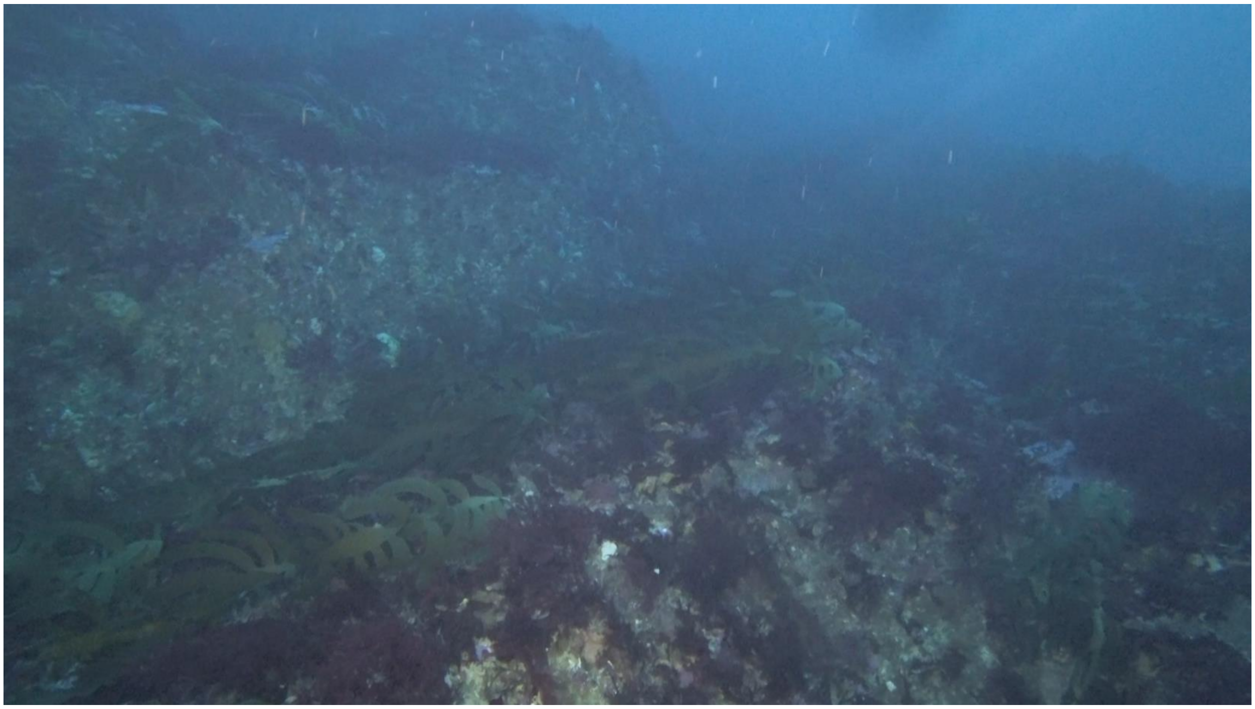

Figure 100. High-profile reef in the upper mesophotic zone (~ 40 m) which includes kelp (E. radiata) and red algae taken from ROV transect 21_6 located along the mid northern boundary of the AMP.

Figure 101. High-profile reef in the upper mesophotic zone (~ 40 m) which includes kelp (E. radiata) and red algae taken from stereo BRUV drop 21_6 located along the mid northern boundary of the AMP.

Figure 102. High-profile reef in the mid mesophotic zone (~ 50 m) which includes red algae and diversity of sponge morphology taken from stereo BRUV drop 21_5 located along the mid northern boundary of the AMP.

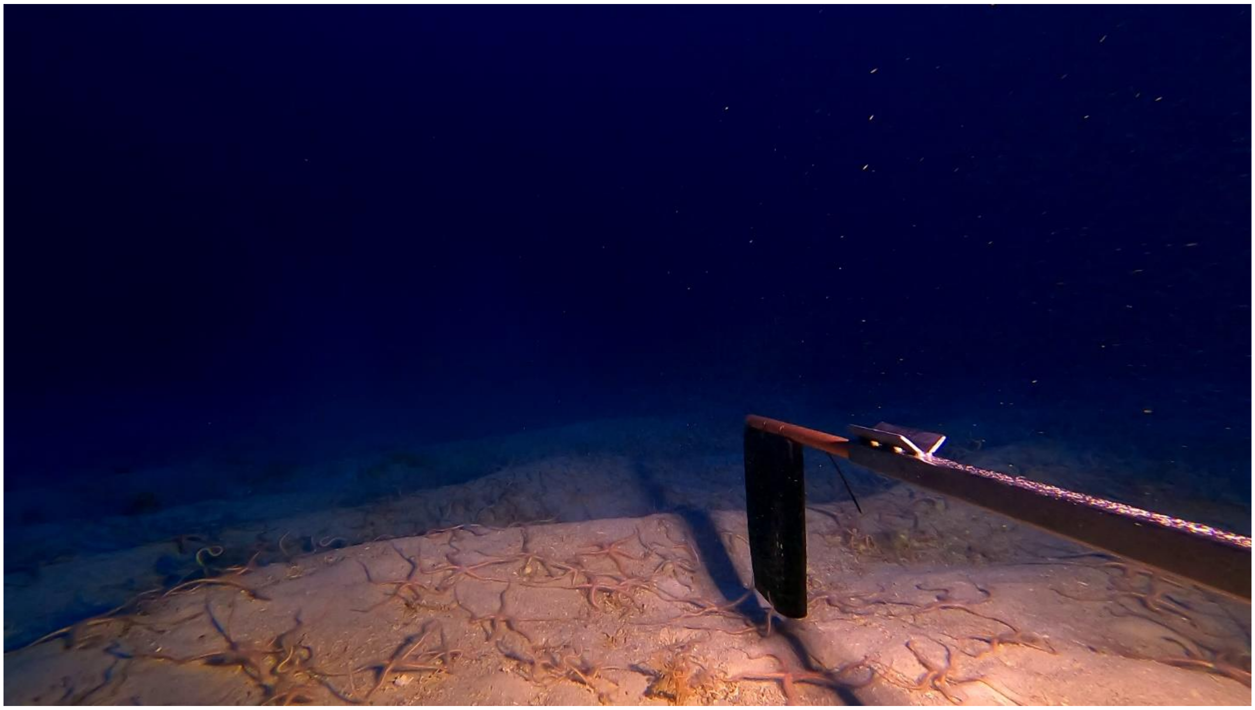

Figure 103. Bare course ripple sediments taken from stereo BRUV drop 23_5 located along the outer shelf region of the AMP. Note the high density of brittle stars.

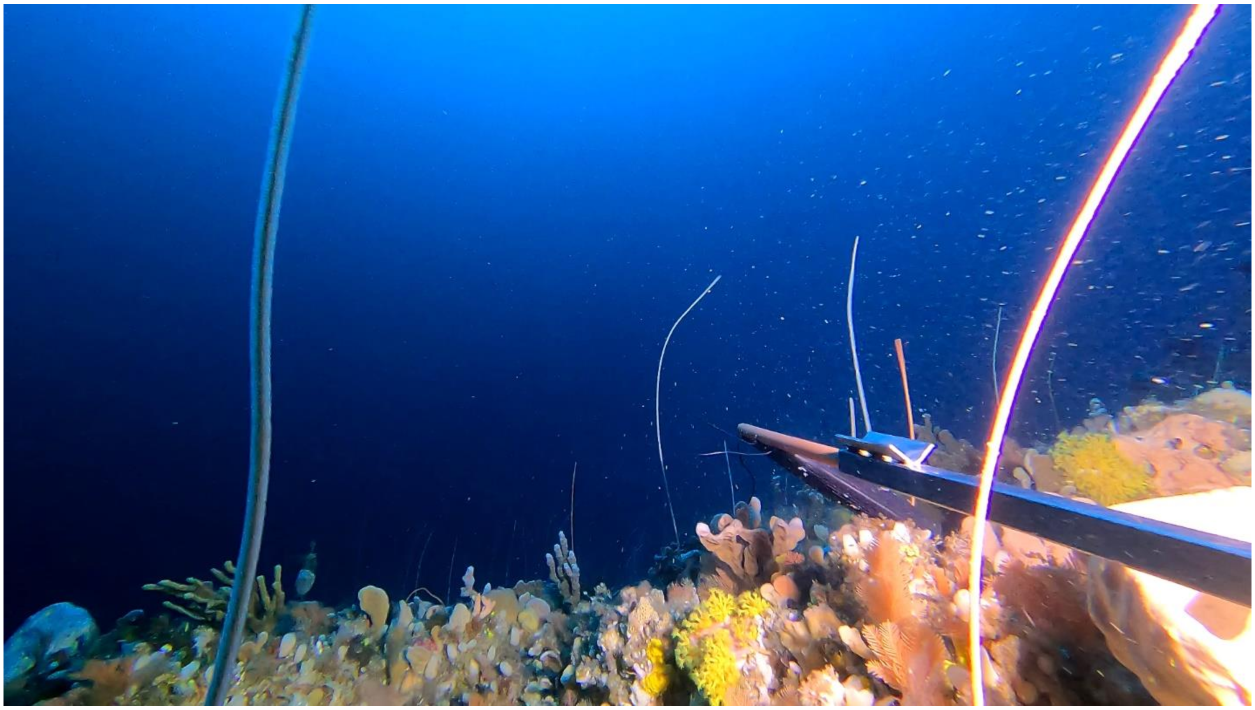

Figure 104. Example of seawhips, yellow parazoanthids and diverse short sponge morphology from stereo BRUV drop 12_4 located in the mesophotic zone along the mid shelf of the AMP.

Figure 105. Mixture of low-profile reef and bare course ripple sediments taken from stereo BRUV drop 18_3 located along in northern region of AMP.

Figure 106. Low-profile reef highlighting diversity of laminar and branching sponges and gorgonians from stereo BRUV drop 4_5 located in mesophotic zone along the outer shelf region of the AMP.

Figure 107. Low-profile reef highlighting diversity of laminar and branching sponges and gorgonians from stereo BRUV drop 6_3 located in mesophotic zone along the outer shelf region of the AMP.

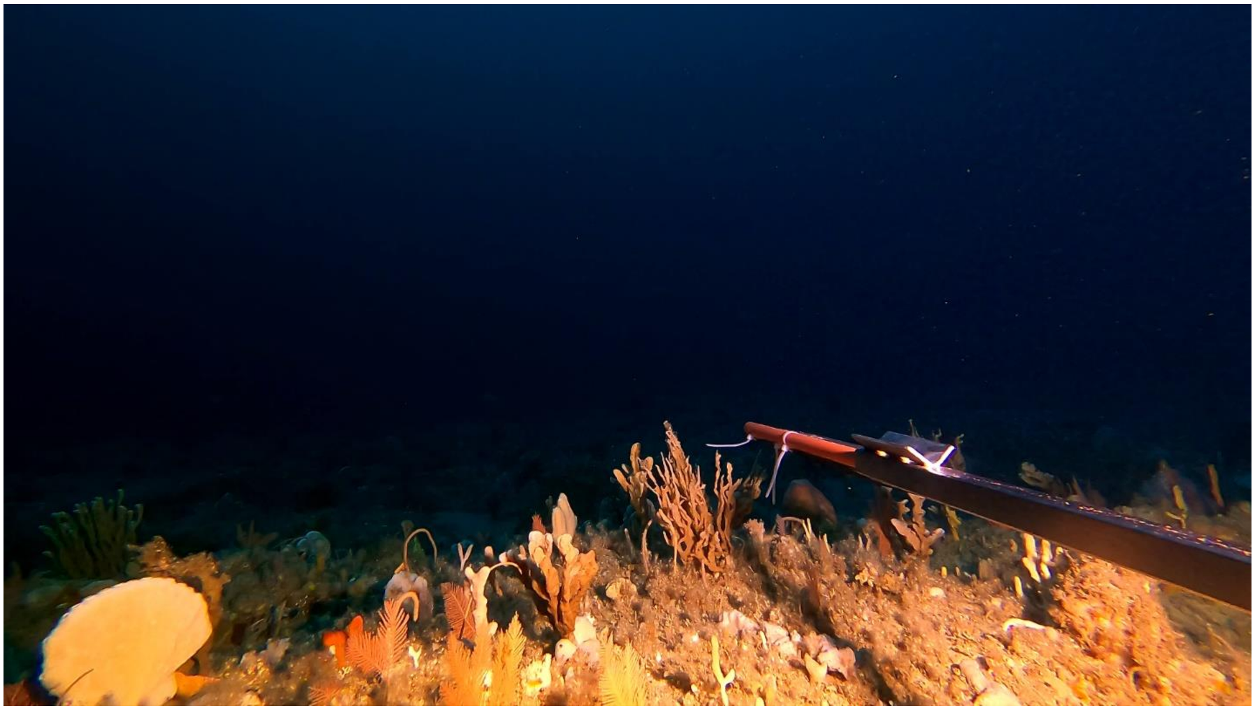

Figure 108. Example of the low profile reef highlighting diversity of gorgonians and laminar and branching sponges from stereo BRUV drop 13_3 located in rariphotic zone of the region of the AMP.

Figure 109. Sand inundated reef highlighting diversity of laminar and branching sponges from stereo BRUV drop 22_4 located in rariphotic zone along the recently identified reefs in the western region of the AMP.

Huon stereo BRUV images: species highlights

Figure 110. Huon stereo BRUV drop 2_3 showing rock lobster (J. edwardsii), striped trumpeter (L.lineata), morid cod (P. bachus), and common gurnard perch (N. scorpaenoides).

Figure 111. Huon stereo BRUV drop 2_4 showing butterfly perch (C. lepidoptera), splendid perch (C. australis), and cosmopolitan leatherjacket (M. scaber).

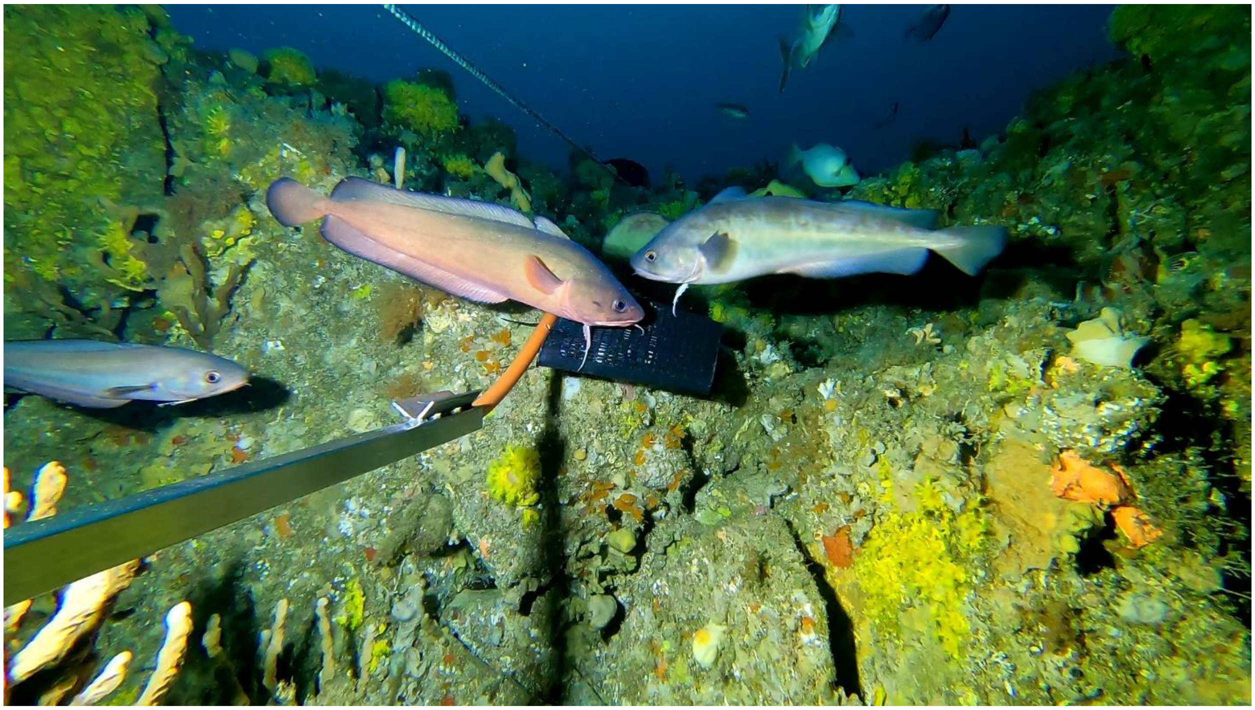

Figure 112. Huon stereo BRUV drop3_6 showing morid cod (P. barbata).

Figure 113. Huon stereo BRUV drop 9_6 showing striped trumpeter (L. lineata) and southern rock lobsters (J. edwardsii).


Figure 114. Huon stereo BRUV drop 19_2 showing striped trumpeter (L. lineata), morid cod, and ocean perch (H. percoides).

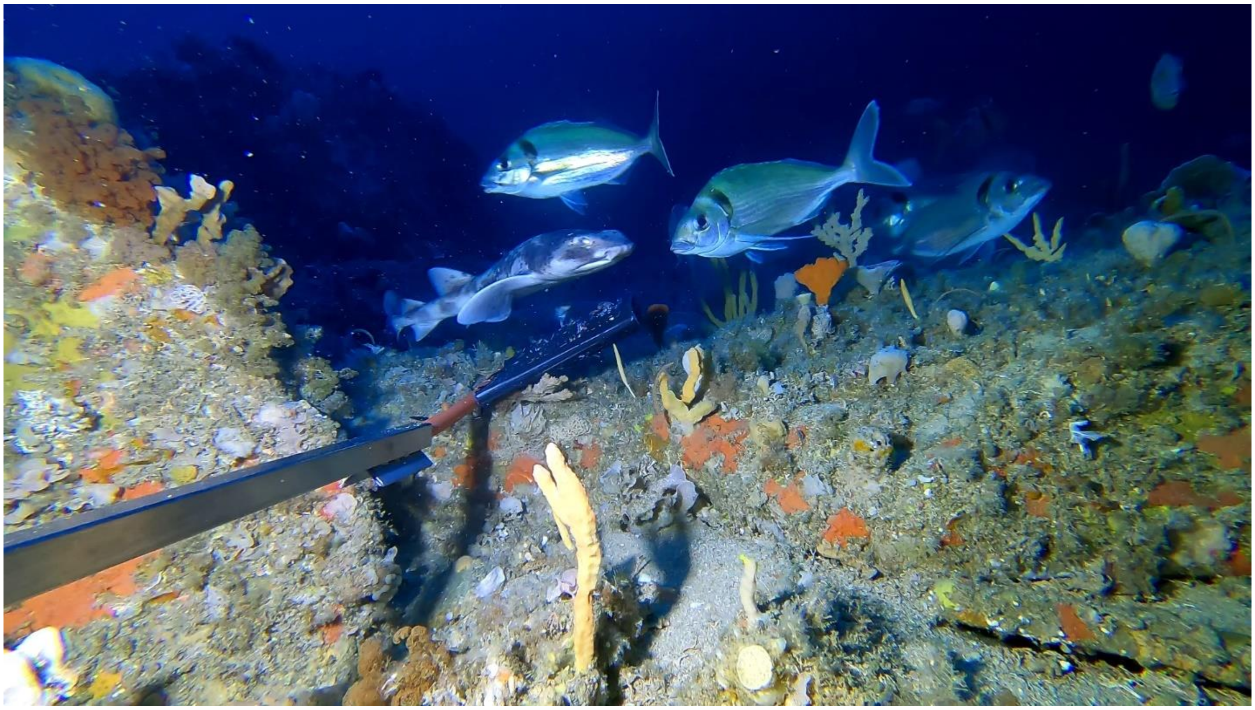
Figure 115. Huon stereo BRUV drop 20_3 showing draughtboard shark (C. laticeps) and jackass morwong (N. macropterus).


Figure 116. Huon stereo BRUV drop 25_4 near the shelf-break showing crested bellowsfish (N. lilleli).


Figure 117. Huon stereo BRUV drop 27_5 showing rosy wrasse (P. rubicundus).


Figure 118. Huon stereo BRUV drop 29_1 showing striped trumpeter (L. lineata).

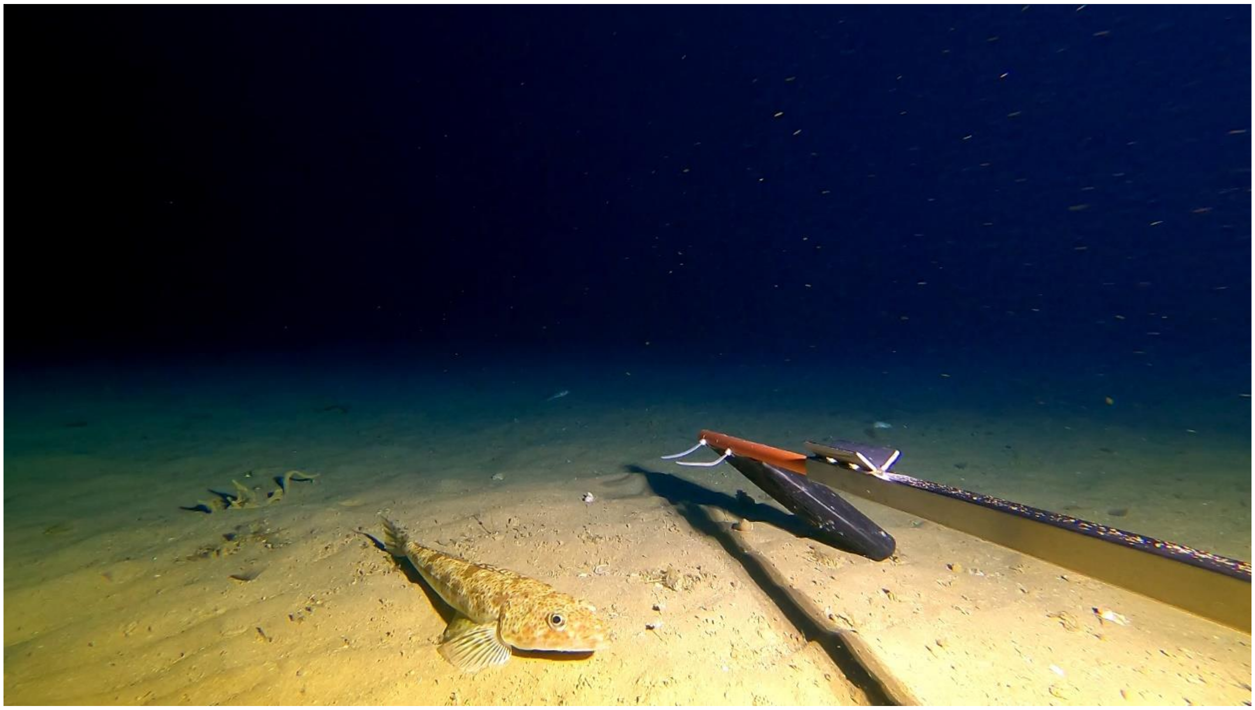
Figure 119. Huon stereo BRUV drop 29_3 showing flathead (Platycephlidae spp).

Huon ROV: species highlights

Figure 120. Huon ROV transect 21_4 showing handfish (Brachionichthyidae spp).

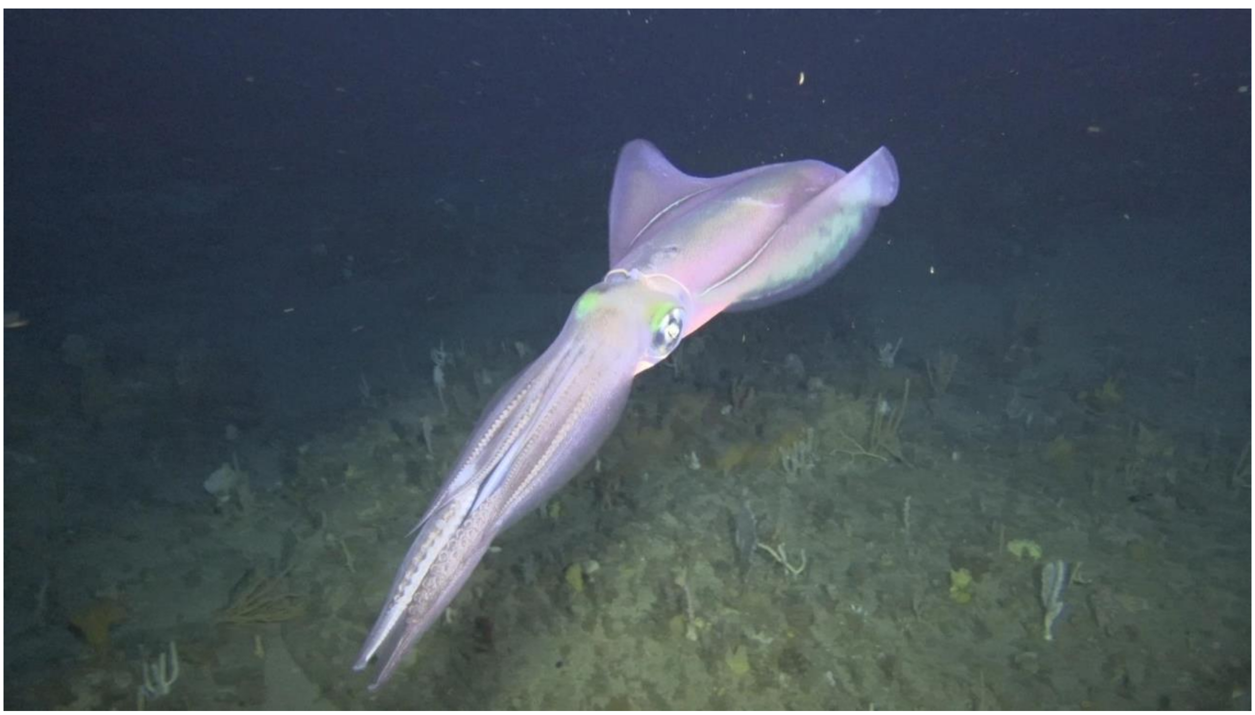

Figure 121. Huon ROV transect 24_5 showing southern calamari squid (S. australis).


Figure 122. Huon ROV transect 175_5 showing jackass morwong (N. macropterus) and ocean perch (H. percoides).

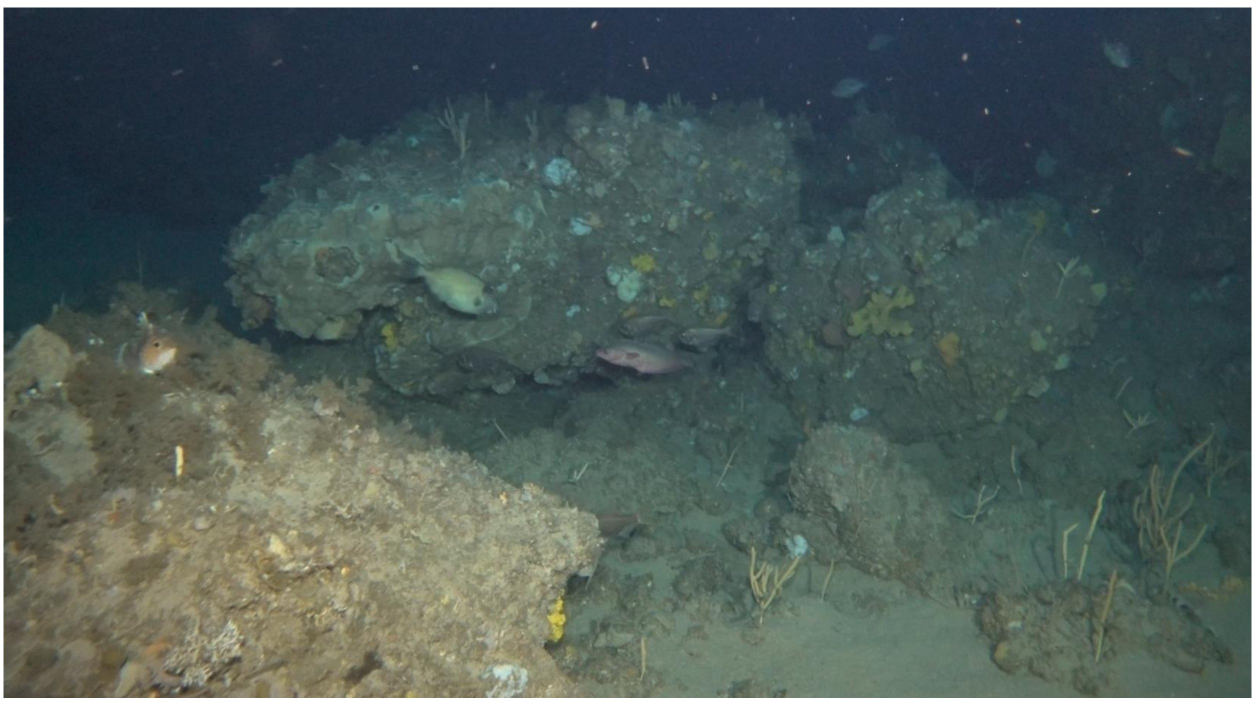
Figure 123. Huon ROV transect 175_5 showing morid cod (Pseudophycis spp), cosmopolitan leatherjacket (M. scaber), and common gurnard perch (N. scorpaenoides).