Tasmania's coastal reefs: deep reef habitats and significance for finfish production and biodiversity

Lyle, J.M., Hill, N., Barrett, N.S., Lucieer, V., Thomson, R., Hulls, J, Ewing, G.P.

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Researcher Contact Details

Name: Jeremy Lyle
Address: Nubeena Crescent
Taroona, TAS 7053
Phone: 03 6226 8255
Fax: 03 6227 8035
Email: Jeremy.Lyle@utas.edu.au

FRDC Contact Details

Address: 25 Geils Court
Deakin ACT 2600
Phone: 02 6285 0400
Fax: 02 6285 0499
Email: frdc@frdc.com.au
Web: www.frdc.com.au

In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

Table of Contents

List of Tables

List of Figures

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Abbreviations

BORAL	Bayesian Ordination and Regression Analysis
BRUV	Baited Remote Underwater Video
CERF	Commonwealth Environmental Research Funding
DISTlm	Distance-based linear models
EAC	East Australian Current
GAM	Generalised Additive Model
GLM	Generalised Linear Model
HPD	Highest Posterior Density
KS	Kolmogorov–Smirnov test
LOWESS	Locally Weighted Scatterplot Smoothing
maxN	Maximum Number of Individuals Present in the Field of View
MDS	Multi-Dimensional Scaling
NERP	National Environmental Research Program
ROV	Remotely Operated Vehicle
SDM	Species Distribution Models
ZC	Zeehan Current

Executive Summary

Tasmania's coastal reef habitats support important commercial and recreational fisheries and while the shallow inshore fish communities have been studied extensively, there have been relatively few studies conducted at depths below about 20 m. These deeper reef fish communities and their associations with habitat characteristics are thus poorly described. The present study was initiated the Institute for Marine and Antarctic Studies to address this gap with a focus on commercially and recreationally important reef species and the contribution of the deep reef habitats for fisheries production.

This study surveyed fish communities associated with two large patches of coastal reef that had been mapped previously using high-resolution multibeam acoustics. The reefs, located on the east and south coasts of Tasmania, are the focus of important commercial and recreational fisheries. The surveys utilised underwater video methods, including baited remote underwater video (BRUV) and remotely operated vehicle (ROV), as well as gillnets. Patterns in community composition, interactions between species and relationships with reef characteristics were described using multivariate statistical analyses. This information was assessed for its utility to develop predictive distribution and abundance maps of key species.

Objectives

The main objectives of this study are as follows:

- characterise reef fish communities on the east and south-east coasts of Tasmania by depth and habitat structure
- describe habitat associations for the key reef fish species and their links to life-history characteristics
- assess the potential to use habitat characteristics to describe and predict fish community structure
- assess the significance of reef habitats for fisheries production and fishery assessments

Methodology

Butlers Reef located on central east coast and The Friars off the south coast of Tasmania were mapped prior to this study using high-resolution multibeam acoustics, with this data re-analysed to classify the seabed at 2 m^2 resolution for depth, habitat type (reef or sand), slope and terrain variation (rugosity and aspect). Both reefs extend several kilometres offshore into relatively deep water but differ in structural complexity, exposure and prevailing oceanographic characteristics. Furthermore, the oceanic environment around Tasmania is dynamic, influenced by two boundary currents, the Eastern Australia Current and Zeehan Current, the former having greater influence on the physical oceanography of the east coast and the latter influencing the south coast marine environment.

BRUV-based sampling was the primary method used to survey the fish communities, recognising its proven success in other studies undertaken nationally, regionally and locally in Tasmania. Sampling sites were allocated in accordance with a depth stratified balanced acceptance sampling approach, enabling flexibility to address questions around habitat use and predictive habitat modelling. ROV and gillnet methods were applied to a subset of sites. Recognising that each method is subject to some sampling bias, a multi-method approach provides the ability to describe the fish communities more comprehensively. Patterns in community structure and the effects of environmental variables (reef characteristics) were tested using multivariate regression analyses.

Key findings

A wide diversity of fish, elasmobranch and cephalopod species were associated with the deep coastal reef habitats, with three families especially prominent; Serranidae (sea perches; 3 species), Labridae (wrasses; 7 species) and Monocanthidae (leatherjackets; 10 species). Collectively, these families accounted for over 80% the total numbers of reef-associated fish recorded at both reef locations. Species of commercial and recreational importance that were observed associated with the reef habitats included Banded Morwong (*Cheilodactylus spectabilis*), Jackass Morwong (*Nemadactylus macropterus*), Bluethroat Wrasse (*Notolabrus tetricus*), Purple Wrasse (*Notolabrus fucicola*), Striped Trumpeter (*Latris lineata*), Bastard Trumpeter (*Latridopsis forsteri*), Longsnout Boarfish (*Pentaceropsis recurvirostris*), Reef Ocean Perch (*Helicolenus percoides*), Blue Warehou (*Seriolella brama*) and Southern Calamari (*Sepioteuthis australis*). Of these species, however, only Jackass Morwong and Bluethroat Wrasse were commonly observed (> 65% BRUV sites); Reef Ocean Perch and Banded Morwong were occasionally recorded (>10% sites) and the remainder were rarely observed (< 10% sites), or common at only one of the reefs, e.g. Striped Trumpeter (>25% of Butlers Reef sites) and Southern Calamari (50% of Friars sites).

Depth was a highly influential factor for the fish assemblages, with over half of the reef-associated species showing significant (linear or quadratic) responses to depth (based on individual reef and combined reef assessments). None of the other reef characteristics tested (slope, rugosity and aspect) emerged as being particularly important. The regional comparison did, however, indicate differences between assemblages, with many species present in lower abundances at The Friars compared with Butlers Reef. Species richness was also consistently and significantly higher at Butlers Reef, increasing with depth at both study reefs. In contrast to some other studies, rugosity, a proxy for reef complexity, was not a significant factor influencing species richness.

In relation to species of relevance to fisheries, Bluethroat Wrasse, Reef Ocean Perch and Striped Trumpeter were significantly more abundant at Butlers Reef whereas Southern Calamari were more abundant at The Friars. Region was not a significant factor for any of the other species of interest. Within the depth range of the studied reefs (to almost 80 m), however, depth was significant for Bluethroat Wrasse, Purple Wrasse, Jackass Morwong, Striped Trumpeter, Reef Ocean Perch and Southern Calamari (at The Friars). Highest abundance of Purple Wrasse occurred at depths of less than 30 m whereas Bluethroat Wrasse abundance peaked in the 20-50 m depth range (noting that sampling was not undertaken at depths shallower than 20 m). Jackass Morwong increased in abundance at depths of greater than 40 m while numbers of Striped Trumpeter and Reef Ocean Perch increased at depths of greater than about 50 m. The prevalence of Southern Calamari at depths of over 60 m at The Friars indicates that this species occupies a wider habitat range than previously suggested.

The Butlers Reef study site was surveyed on two occasions, approximately six months apart, and although there were significant differences in abundance for about one third of the species, the overall community composition was relatively stable. This implies that a snapshot survey is likely to be representative of the key elements of the reef fish community. Of those species with seasonal differences, average abundances were significantly higher for Southern Calamari during autumn, presumably reflecting the influx of new recruits following the peak in spawning activity during late spring/summer.

Several species identified as having extended their distributional ranges southwards into Tasmanian waters and/or increased in abundance as a response to climate change were recorded in this study; not unexpectedly, most of these sightings were restricted to Butlers Reef. Amongst this group there were some species of potential interest to commercial and recreational fishers, namely Grey Morwong (*Nemadactylus douglasii*), Blue Morwong (*N. valenciennesi*), Magpie Perch (*Cheilodactylus nigripes*) and Snapper (*Chrysophrys auratus*).

By comparing the underwater video sampling methods (BRUVs and ROV), it was apparent each was subject to some level of sample bias. For instance, BRUVs over or under represented species depending on the extent that fish-bait acted as an attractant, whereas the greater spatial coverage of the ROV transect was more likely to encounter rarer, cryptic and mobile species that were not bait attracted. Despite such differences, the overall patterns in community composition were similar for both methods, indicating that either method provides a reasonable representation of the fish community present.

The intent of the gillnetting component was to provide validation against a method known to sample species such as Banded Morwong, Blue Warehou and Bastard Trumpeter effectively. However, the nets used proved to fish particularly inefficiently and this method was discontinued after an initial survey. This was almost certainly due to the robust construction of the nets that was required for deployment in deep water. While this design issue would need to be accounted for in future deep reef surveys using this method, the results did indicate that it was capable of detecting Bastard Trumpeter and Blue Warehou, species that were rarely recorded using either of the underwater video methods.

Implications

Overall, this study has expanded our knowledge of the reef fish communities associated with Tasmania's coastal deep reefs, including the associations between habitat characteristics and individual species distribution and abundance. For species of importance to fisheries, we have a revised understanding of depth range for Banded Morwong, with individuals occurring to depths of over 70 m, as well as patterns in the abundance for Bluethroat Wrasse, Purple Wrasse, Jackass Morwong, Striped Trumpeter, and Reef Ocean Perch. Furthermore, size structuring with depth was investigated for Bluethroat Wrasse, Jackass Morwong, Banded Morwong and Striped Trumpeter. By linking known life history and fishery (i.e. size limits) information and it was possible to make some observations about population structure, including the occurrence of juvenile and adults of each species, sexual transitioning in Bluethroat Wrasse, and impact of slot size management for Banded Morwong. This knowledge could be improved on by drawing on data available from other completed BRUV surveys in the Tasmanian region (e.g. Tasman Fracture and Flinders CMRs, Governor Island MPA, Tasman Peninsula) and also as more surveys are undertaken.

Finally, the collation of spatially explicit biological and reef structure data has also opened up the possibility of developing predictive species distribution models, a potential way to enhance stock assessments based on spatial information such as the mapped extent of preferred habitat. Although data were limited for many of the species of interest, modelling was justifiable for Reef Ocean Perch and Bluethroat Wrasse (at The Friars) along with a number of other ecologically important species. For other species that are also attracted to bait, such as Jackass Morwong, Striped Trumpeter, this approach will become increasingly useful as a greater range of habitats and depths are sampled using BRUVs through related projects. For the less bait-attracted species, the ROV approach could offer promise as suggested based on pilot comparisons between methods undertaken as part of the current project.

Keywords

Temperate reefs; Reef habitat classification; Reef fish assemblages; Reef fish fisheries; Baited remote underwater video (BRUV); Remotely operated vehicle (ROV); Gillnets; Bayesian Ordination and Regression Analysis, Relative abundance (*maxN*); Species distribution modelling.

Introduction

Over the past 20 years, detailed surveys have gradually documented the spatial distribution of marine habitat and associated fish assemblages that are present in southeastern Australian coastal waters. These studies have included estuaries, inshore soft sediments and seagrass beds (e.g. Jordan *et al.* 1998), inshore rocky reefs (e.g. Edgar et al. 1997), shelf soft sediments (e.g. Williams and Bax 2001) and shelf reef systems (Bax and Williams 2000). For Tasmanian waters, the fish assemblages associated with habitats between shallow inshore waters and the shelf break, particularly rocky reefs in depths greater than about 20 m, are still poorly understood. Previous reef community monitoring studies have been largely restricted to depths of less than 10 m (Edgar and Barrett 1999, Buxton *et al*, 2006) and the SeaMap Tasmania habitat mapping project was limited to a maximum depth of 40 m (Lucieer *et al.* 2009). Relatively little is known about the structure and extent of shelf reef habitat off Tasmania beyond these depths other than from recent research undertaken as part of Commonwealth Environmental Research Funding (CERF) and the National Environmental Research Program (NERP) Marine Biodiversity Hubs (https://www.nespmarine.edu.au). Research within the Hubs has involved developing and testing new methods of mapping benthic habitats and their associated biodiversity. This work has included the use of high resolution multibeam sonar for mapping the deeper reefs; autonomous underwater vehicles for photographing seabed benthic habitats and their associated sessile biota (e.g. Monk *et al*. 2016a); and baited underwater video for describing related deep shelf fish assemblages (e.g. Nichol et al. 2009, Brooke *et al*. 2010, Barrett *et al*. 2012, Lucieer *et al*. 2013, Hill *et al.* 2014a, Monk et al. 2016b). These studies have demonstrated the utility of these methods, generated practical knowledge of their application and utility and provided datasets such as high-resolution seabed maps in locations of special interest. The groundwork provided by the Hubs has provided the opportunity to apply these methods cost-effectively to fill a critical information gap that exists with respect to commercially and recreationally targeted species that occupy such deeper reef habitats.

Reefs represent important habitats for a number of exploited fish species in Tasmania, including Banded Morwong (*Cheilodactylus spectabilis*), Bluethroat Wrasse (*Notolabrus tetricus*), Purple Wrasse (*N. fucicola*), Striped Trumpeter (*Latris lineata*) and Bastard Trumpeter *(Latridopsis forsteri*) (Emery *et al*. 2017). Banded Morwong are the focus of a commercial gillnet fishery that supplies live-fish to mainland markets. In order to reduce the impacts of barotrauma on the survival of the fish, fishing has traditionally occurred over relatively shallow inshore reefs (< 25 m depth), despite the species occurring in depths to at least 50 m (Gomon *et al*. 2008). Although the proportion of the population resident in the deeper reefs areas remains an uncertainty in the Banded Morwong stock assessment, these fish are likely to be afforded some degree of protection from the fishery (Ziegler *et al*. 2006). Virtually nothing is known about the size/age structure or relative abundance of Banded Morwong associated with these areas of deeper reef. Similarly, Bluethroat Wrasse and Purple Wrasse are targeted commercially in Tasmania for the live-fish markets, with fishing effort focussed on the shallow reefs (< 20 m depth), even though both species occur over a much wider depth range (Gomon *et al*. 2008). A minimum size limit is in place for both species, with the breeding part of the Purple Wrasse population adequately protected by this limit (Emery *et al.* 2017). In contrast, Bluethroat Wrasse change sex such that mature females become males, typically at sizes after they have entered the fishery (Smith *et al.* 2003). As a result, the fishery is biased towards the capture of males and thus, in extreme cases, localised heavy fishing pressure has the potential to result in ‘sperm shortage’. Because the characteristics of the segment of the population occurring in deeper waters is unknown, it remains unclear whether stocks of Bluethroat Wrasse are protected in a sustainable way. Preliminary trials using stereo underwater video survey methods indicate that the technique may be able to inform on abundance and size distribution patterns at depth for each of these species (Seiler 2013, Walsh *et al*. 2017).

Juvenile Striped Trumpeter and Bastard Trumpeter tend to be associated with inshore reefs, where they are targeted by commercial and recreational gillnet fisheries (Murphy and Lyle 1999). In 2015, the minimum size limit for Striped Trumpeter in Tasmania was raised to 550 mm total length, rendering most individuals found inshore sub-legal. Offshore deep reefs are considered the core habitat for mature Striped Trumpeter where they are targeted by line fishing methods (Tracey and Lyle 2005; Tracey *et al*. 2007). In practice, relatively little is known about the distribution and population structuring of this species, yet this may be addressed readily via baited underwater video surveys as preliminary trials suggested that this species was particularly attracted to the baits (Hill *et al.* 2014a). Mature Bastard Trumpeter have rarely been examined and are apparently absent from inshore waters (Murphy and Lyle 1999), either because of high levels of fishing mortality or because individuals move offshore as they mature. Marked recruitment variability represents a feature of both trumpeter species (Murphy and Lyle 1999), with no evidence of strong recruitment for over a decade (Tracey and Lyle 2005). While the relative influence of fishing and/or environmental factors on recent recruitment patterns are unknown, an understanding of habitat linkages and population structuring will be useful in providing protection for critical life history stages and contribute to developing and refining stock assessments. Furthermore, there has been a long-term decline in Bastard Trumpeter catches which, coupled with the paucity of information about the life history of the species, has resulted in significant concern regarding the population status. In 2016, the species was classified as overfished (Emery *et al.* 2017), highlighting a need to develop fishery independent methods to assess the stock.

A range of other commercially important species, including Longsnout Boarfish (*Pentaceropsis recurvirostris*), Jackass Morwong (*Nemadactylus macropterus*) and Reef Ocean Perch (*Helicolenus percoides*), also spend much of their life associated with reef systems on the continental shelf. In addition, there are a range of non-commercial species, for instance sea perches (family Serranidae) and leatherjackets (family Monocanthidae), that are particularly abundant and likely to be critical to the functioning of the reef ecosystem (e.g. Walsh *et al.* 2017).

The structure, composition and functioning of shallow-reefs (< 20 m) and their associated fish communities have been studied quite extensively in Tasmania (Edgar et al. 1997, Edgar and Barrett 1999, Barrett and Wilcox 2001, Barrett *et al.* 2007). The ecological importance of deeper reef ecosystems has not been investigated apart from recent baseline studies of offshore marine protected areas, including the Flinders and the Tasman Fracture Commonwealth Marine Reserves (Hill *et al.* 2014a, Lawrence *et al.* 2015, Monk *et al.* 2016b). Linkages and associations between fish communities from shallow to deep reef areas remain a distinct knowledge gap. Furthermore, Tasmania's coastal reef systems are subject to increasing ecological pressures. These include the impacts of fishing (mainly affecting fish and invertebrate communities), changes in the distribution and abundance of the dominant macroalgal species (Edyvane 2003), range extensions (e.g. *Centrostephanus* and barren formation, Johnson et al. 2005), and ultimately the broader consequences of climate change (e.g. Stuart-Smith *et al.* 2010, 2015; Barrett *et al,* 2014, Sunday *et al*. 2015).

The fish communities associated with coastal reef habitats and the significance of these habitats for fisheries production in Tasmania provide the focus for the present study. Two candidate reef systems, Butlers Reef off the east coast and The Friars off the south coast of Tasmania, were identified for this study (Figure 1). Both reef systems extend offshore from the coast into relatively deep water and support important commercial and recreational fisheries. These study sites do, however, differ markedly in reef structure (bathymetry and geomorphology) and are subject to quite different oceanographic conditions (e.g. exposure and water mass characteristics), providing an opportunity to examine how such factors influence community and individual species population structure.

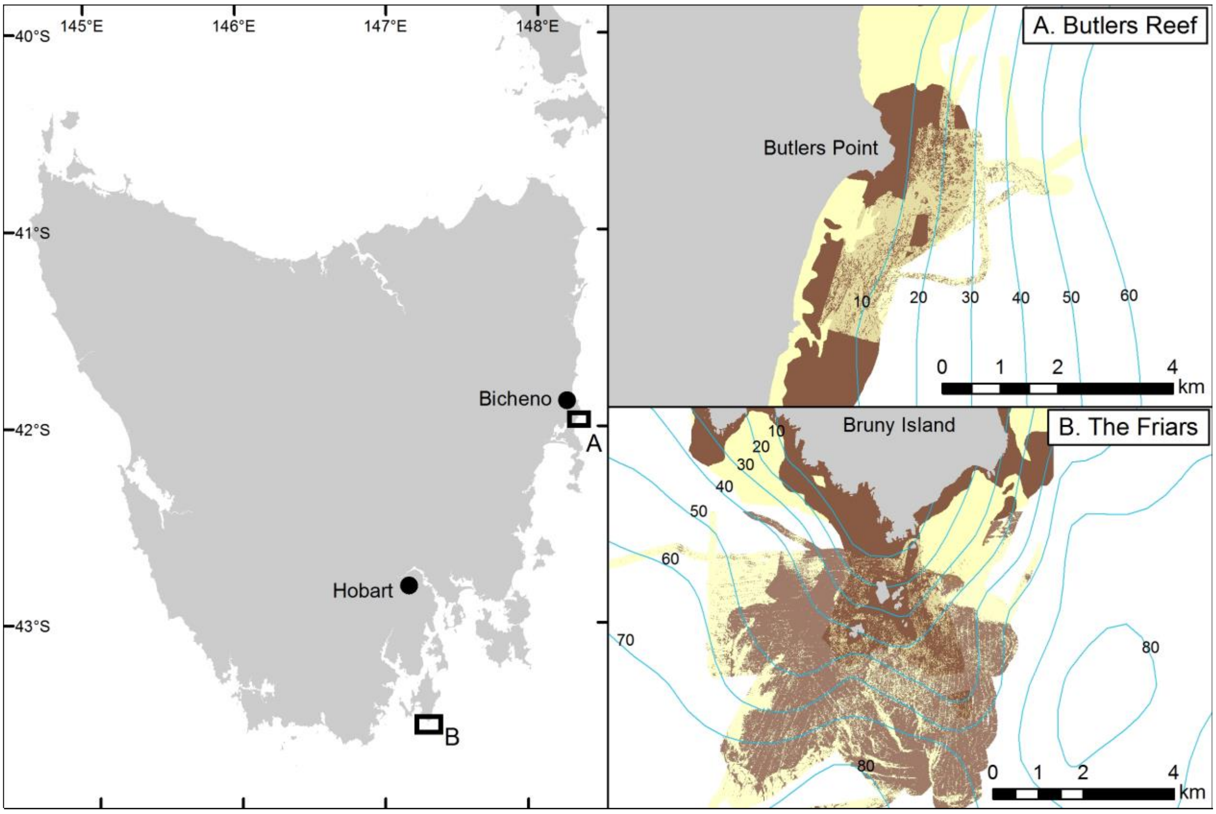


Figure 1. Map of Tasmania showing the two study locations and extent of reef habitat (reef = brown, sand = yellow) from the SeaMap Tasmania habitat database overlaid with multibeam acoustic survey data acquired by the Marine Biodiversity Hub.

Objectives

Specific objectives of this study include:

1. Characterise reef fish communities on the east and south-east coasts of Tasmania by depth and habitat structure
2. Describe habitat associations for the key reef fish species and their links to life-history characteristics
3. Assess the potential to use habitat characteristics to describe and predict fish community structure
4. Assess the significance of reef habitats for fisheries production and fishery assessments

Methods

This study comprised four main components: (1) habitat characterisation and classification; (2) field sampling of fish communities; (3) description of key species population characteristics; and (4) analysis of fish assemblage composition and relationships with reef characteristics.

Habitat Mapping and Classification

In this section, we describe the acquisition and processing of acoustic data to create spatial variables to describe reef habitat structure for the study sites. Available acoustic multibeam data collected through the CERF and NERP Marine Biodiversity Hubs (Nichol et al. 2009, Brooke *et al*. 2010, Barrett *et al*. 2012, Lucieer *et al*. 2013) were analysed for this project. These existing data sets provided an opportunity to cost-effectively assess these environments and to develop methodologies required to fill the critical information gap that exists with respect to commercially targeted species that occupy such shelf habitats in Tasmania.

Habitat mapping and spatial analysis

Depth (bathymetry) and shape (geomorphology) of the seafloor provide the critical framework that underpin seafloor maps. High-resolution bathymetric data derived from multibeam sonar can reveal previously unknown topological features in unprecedented detail. Spatial variables (such as depth, slope, roughness, habitat and hill shaded visualisation) have provided new insights into the structure and complexity of the seafloor; factors that are important in determining the presence of fish and invertebrate species and the composition of reef communities (Moore *et al*. 2010, Hill *et al*. 2014b).

Reef habitat classification is based on parameters derived from physical attributes (such as complexity) and biological attributes (such as dominant epifauna) using established models. Variables that were calculated to characterise the reef structure in both locations are shown in Table 1.

Table 1. Spatial variables processed from the multibeam acoustic data with their associated geological and ecological relevance.

Spatial variable	Variable name	Analysis Window (scale *n* x *n raster cells*)	Details	Geological relevance	Ecological relevance
Slope	Slope	n=3x3 (6 m)shelf n=3x3 (150 m)slope ArcGIS 10.1	Computes the slope angle in the direction of the steepest slope	Stability of sediments (grain size). Local acceleration of currents (erosion, movement of sediments, creation of bedforms)	Stability of sediments (ability to live on sediments). Local acceleration of currents (food supply, exposure etc.).
	Hillshade	n= 3 and 20	Computes hillshade values for a raster surface by considering the illumination angle and shadows.	Hillshading is a method of representing relief on a map by depicting the shadows that would be cast by high ground if light were shining from a certain direction. It is able to show the details in the reef systems and fine scale structuring of the sand.	
Habitat classification	Level 1 of seabed mapping hierarchy: Reef or Sand	Native cell resolution	In the first analysis the seabed is merely classified into reef and sand. Characteristics of the reef such as continuous, patchy, cobble or boulder will be characterised in subsequent analysis	Distribution of consolidated habitat in respect to depth and coastal features of significance e.g. headlands, embayments.	Primary habitat selection for fish communities.
Terrain variation	Rugosity: This method effectively captures variability in slope and aspect into a single measure.	n=3x3 (9m)shelf n=3x3 (60m)slope Terrain Ruggedness (VRM)	These indices provide a measure of how much the seabed terrain varies, and how rugged it is. 0 (no terrain variation) to 1 (complete terrain variation).	Terrain variability and structures reflect dominant geomorphic processes	Index of degree of habitat structure, shelter from exposure/predators (link to life stages). Structural diversity linked to biodiversity.
	Northness	n=3x3 (6 m)shelf	Computes the deviation of the cell from north. Aspect (slope orientation) northness (north–south component, calculated as the sine of the aspect)	Indicates the aspect of the seafloor. It can be used as a proxy for the exposure of the seafloor to prevailing tidal motion at the seafloor and can make the site either exposed or sheltered depending on the location.	Index of degree of shelter from prevailing weather conditions depending on depth.
	Eastness	n=3x3 (6 m)shelf	Computes the deviation of the cell from east. Aspect (slope orientation) eastness (east–west component, calculated as the cosine of the aspect)	Indicates the aspect of the seafloor. It can be used as a proxy for the exposure of the seafloor to prevailing tidal motion at the seafloor and can make the site either exposed or sheltered depending on the location.	Index of degree of shelter from prevailing weather conditions depending on depth.

Field Sampling

General

In addition to traditional sampling techniques, non-extractive, video-based methods have proven to be effective in surveying fish communities (e.g. Watson *et al*. 2009, Moore *et al*. 2010, Langlois *et al*. 2012, Zintzen *et al*. 2012). Baited remote underwater video (BRUV) stations and video surveys using remotely operated vehicles (ROV) can cost-effectively complement data derived from fishing gear, such as gillnets. While each sampling method is subject to bias a multi-method approach provides the ability to more comprehensively describe fish communities and their associations with habitat.

Field sampling using BRUV, ROV and gillnet methods was undertaken at two quite different areas of coastal reef, Butlers Reef off the east coast and The Friars off the south coast of Tasmania. Sampling was conducted between March and December 2015. The Butlers Reef study region is located on the central east coast of Tasmania (Figure 1) and, while protected from the prevailing southwesterly oceanic swell, its oceanography is strongly influenced by the seasonal southward extension of the East Australian Current (EAC) (Ridgway 2007). Overall, the reef extends from the coastline more than 2 kilometres offshore and into depths of about 60 m. By contrast, The Friars study region is exposed to high wave action and is mostly influenced by the Subtropical Convergence and the seasonal incursion of the Zeehan Current (ZC) from the west (Ridgway 2007). This extensive reef system runs to the south of the major promontories on Bruny Island, extending more than 5 kilometres offshore into depths of about 80 m.

The allocation of sampling sites was based on a balanced acceptance sampling approach (Robertson *et al.* 2013), stratified by depth and limited to reef habitat identified in the classification above. Combining stratification with spatial balance enables the flexibility to address the multiple, related questions in this project around habitat use and predictive habitat modelling as well as questions surrounding fish population structure and life history stage (size composition). A minimum target of 60 sites for each reef locality was adopted, corresponding to at least 10 sites per 10-m depth stratum for depths ≥ 20 m. Due to differences in depths at the two reefs, maximum depth of 55 m at Butlers Reef and 80 m at The Friars, up to 18 sites per 10-m depth stratum were selected at Butlers Reef.

BRUV and multi-mesh gillnet deployments and fixed length ROV transects were replicated at individual sites within each stratum. However, recognising logistic limitations of sampling from relatively small vessels with different types of gear, a sampling hierarchy based on gear type was established. Approximately 25% of sites were sampled with all three gear types, half with gillnet and BRUV, and all sites were sampled by BRUV[1]. Sampling was undertaken at both localities in autumn 2015 and repeated at the Butlers Reef early the following summer. This sampling design was established to enable comparisons of fish community structure at regional and seasonal scales, as well as to compare sampling methods.

Baited Remote Underwater Video (BRUV)

Stereo-BRUV units were based on a standard design used in other Australian studies (e.g. Watson *et al.* 2005; Moore *et al*. 2009; Harvey *et al*. 2012). Each unit consisted of two Canon video cameras, either HFM52 with a Raynox HD6600Pro (43mm) wide angle or HRG25, that were mounted 70 cm apart on a base bar inwardly converged at 8 degrees to gain an optimized field of view with visibility of ~7 m distance. Each system was equipped with a synchronizing diode that was visible in the fields of view of both video cameras. The diode was used to check synchronization of the video footage; ensuring measurements were made at the same time in both cameras. The diode emitted minimal light and was standard across all BRUV drops.

[1] Note: sampling of an individual site using the different survey methods was undertaken on different days.

Five BRUV units were deployed at any one time (one per site) and left to film on the seafloor for at least one hour before being retrieved. Each unit was baited with ~800 grams of crushed Australian Sardine (*Sardinops sagax*) in a closed plastic-coated wire mesh basket, suspended 1.2 m in front of the cameras. Adjacent concurrent drops made on a given day were separated by at least 250 m to avoid overlap of bait plumes and reduce the likelihood of fish moving between sites within the one-hour sampling period. All drops were deployed between 08:00 and 18:00 to minimize the effects of diurnal changes in fish behaviour.

Footage from each BRUV deployment was scored using the program EventMeasure (SeaGIS Pty Ltd; www.seagis.com.au) to record species and numbers of individuals present. For each species observed, the maximum number of individuals (*maxN*) present in the field of view in any one frame during the one-hour deployment was recorded. This measure is recognised to be a conservative estimate of abundance and avoids concerns about counting individuals multiple times as they move into and out of the field of view (Harvey *et al*. 2007; Birt *et al*. 2012).

Length measurements were also made for selected key species using EventMeasure. In order to avoid repeated measurements of the same individual, length measurements were made of the time of *maxN* for the species of interest. Measurements were made from the tip of the snout to the medial caudal ray (i.e. total length for species with rounded caudal fin or fork length for fish with a forked caudal fin). To ensure accurate measurement each stereo-BRUV unit was calibrated using a 1 m calibration cube in a swimming pool and the resulting footage analysed using the program CAL (SeaGIS Pty Ltd; www.seagis.com.au).

Remotely Operated Vehicle (ROV)

A SEABOTIX LBV-300-6 ROV was used for video surveys. Video footage was recorded with both the ROV video feed and a GoPro (Hero 3) underwater video camera mounted facing forward and looking slightly down on the ROV. The position of the ROV during surveys was determined acoustically using Tritech MicronNav USBL Tracking system (http://www.tritech.co.uk/product/usbl-tracking-system-micronnav).

At each site, footage was recorded whilst the ROV was driven over three 50 m transects in an equilateral triangle configuration (150 m transect), generally within 2 m of the substrate. Strong currents necessitated the submersion of the ROV umbilical with a tethered clump weight to within 5 m from the seafloor. The effective field of view (transect width) was influenced by the water visibility but generally ranged between 3-5 m.

Video footage was scored using SeaGIS EventMeasure software and the species and total number of fish observed within the field of view was scored for each of the three transects at each site. Fish only were counted if they entered the video frame from ahead of the ROV; fish entering the video footage from behind or overtaking the ROV were not counted. This reduced the likelihood of counting individual fish multiple times.

Gillnet

Four heavy-duty multi-mesh gillnets were constructed for the project. The design of the nets represented a compromise between the ability to sample a range of species of varying sizes, be fished in deep water, often in strong currents, yet be deployed and retrieved from a small research vessel.

Each net was configured as a 125 m multi-mesh panel gillnet, specifications are provided in Table 2. Three mesh sizes, 89, 115 and 150 mm were selected to represent the range of mesh sizes used commercially in Tasmania, the smallest mesh size corresponding to the small mesh classification, the intermediate corresponding to a standard graball and the largest the shark net mesh classification.

Table 2. Specifications of the gillnets used in this study
* multi-monofilament; # monofilament

Mesh (mm)	Gauge (mm)	Length (m)	Height (m)	Hanging ratio	Hanging coeff.	Weight (kg)		Buoyancy (kg)	
						/m	/panel	/m	/panel
89*	0.81	20	2.8	0.5	0.87	0.42	8.4	0.13	2.5
115#	0.9	50	2.8	0.5	0.87	0.42	21.0	0.13	6.3
150#	0.9	50	2.8	0.5	0.87	0.42	21.0	0.13	6.3

Data Analysis

Fish Assemblage Composition and Structure

Overview

Quantitative analyses were based primarily on the BRUV data due to the greater number of replicate deployments and number and diversity of fish observed. More descriptive analyses incorporate information from gillnet and ROV deployments. The key metrics used in the community analyses were species presence, number of sites that the species was recorded/captured, and abundance (numbers) at each site (*maxN* for BRUVs, total numbers captured per gillnet deployment or total numbers observed per 150 m ROV transect).

The BRUVs data were used to examine several features of the structure and composition of fish communities at the study regions. These included:

1) patterns in the composition and structure of fish communities and their relationship with depth and other reef characteristics analysed separately for each study region;
2) comparison of community patterns between regions;
3) seasonal comparison of the fish community composition at Butlers Reef; and
4) comparison of community composition obtained using different sampling methods, namely BRUVs and ROV.

As the focus of this study is the reef fish community, all observations of pelagic species, whilst documented for completeness when scoring the video data, have been excluded from subsequent analyses. Species in this category included Silver Trevally (*Pseudocaranx georgianus*), Jack Mackerel (*Trachurus declivis*), Barracouta (*Thyrsites atun*), tunas (including Southern Bluefin Tuna, *Thunnus maccoyii*) and Gould's Squid (*Nototodarus gouldi*,). In addition, benthic crustaceans (including Southern Rock Lobster, *Jasus edwardsii*) were omitted from the analyses.

Furthermore, for the community analyses data for Butterfly Perch (*Caesioperca lepidoptera*) and Barber Perch (*C. razor*) were combined as *Caesioperca* spp. This was considered necessary as it was not always possible to separate these closely related fish to species. In situations where individual species were readily identifiable and individual species based *maxN* counts were available, these counts have been combined. For sites where individual species as well as a combined species count was available, *maxN* for analysis was determined as either the sum of the individual species counts or the combined species count, which ever was the greater value.

General analyses

Commonalities and differences in assemblages occurring between regions, seasons or gear types were initially explored using Venn diagrams. These diagrams depict the number of species shared between the two categories (region, etc.) and unique to each. The identity of species shared and unique to each category was then tabulated as well as total *maxN* and prevalence (number of sites) for each species.

To visualise patterns in assemblage structure, and to quantify the effect of environmental variables (i.e. reef habitat characteristics) on the composition of assemblages, the technique Bayesian Ordination and Regression Analysis (BORAL) was used (Hui 2016a). BORAL is a model-based analysis that models multivariate abundance data directly, in contrast to distance-based methods that use dissimilarities calculated between pairs of samples as the basis for ordination (e.g. Multi-Dimensional Scaling (MDS)) or regression (e.g. Distance-based linear models (DISTlm); Legendre and Anderson 1999, McArdle and Anderson 2001). Model-based methods for analysing community data offer several advantages over distance-based metrics including the ability to check model assumptions, the ability to directly interpret model outputs, and the ability to account for and describe interactions between species (Warton *et al*. 2015a, Warton *et al.* 2015b). The basic idea of BORAL is to simultaneously fit generalised linear regression models for each species in the data set, with species abundance as the dependent variable. The independent variables are the environmental variables and a number of latent (unmeasured) variables that account for residual correlations between species. Residual correlations could be due to species interactions or due to important covariates that were not measured and can be useful for generating additional hypotheses on how communities are structured. Importantly in our context, the latent variables can be treated as ordination axes.

In the first instance to visualise community patterns, unconstrained ordinations of the composition of species at sites were generated by running BORAL models with two latent variables and no environmental variables. These can be thought of as similar to MDS plots within the distance-based analysis framework. Values of environmental variables for each site were overlaid on plots and the ten most important species (based on the species' coefficients with the latent variables) in the ordination were also plotted to aid interpretation.

The influence of depth and reef characteristics on the structure and composition of assemblages at Butlers Reef and The Friars (separately and combined) was tested more formally by including these factors in BORAL models, akin to a multivariate regression analysis. Rather than using the data to decide which environmental variables to fit using information criteria or other variable selection techniques, all reef characteristics were included in the BORAL models. The influence of each of the reef characteristics was then examined through the significance of the coefficients for each species. Significance was concluded when the 0.95 highest posterior density (HPD) interval (the Bayesian analogue of examining model coefficients and their 95% confidence intervals for inference in a Maximum likelihood framework) did not include zero. Based on the examination of model residuals, a negative binomial distribution was used to model abundance in all BORAL models.

All community composition analyses were conducted in R (R Core Team) and BORAL models were fit using BORAL 1.1.1 (Hui, 2016b).

Community composition

For each region, separate BORAL models based on BRUVs data were fitted. Only species that occurred at three or more sites were included in analyses. Initially models with two latent variables and no environmental variables were fitted in order to plot ordinations and visualise patterns as described above. The influence of reef characteristics on community composition in each region was examined by including: depth, depth^2, slope, rugosity, northness and eastness as explanatory variables in BORAL analyses. These were chosen *a priori* as they were the variables expected to affect at least some of the species. A quadratic term for depth was included to allow for the possibility that maximum abundance for a species was seen at intermediate depths.

The BORAL model partitions the co-occurrence/correlation between species into that which can be explained by the environmental factors that were included in the mode and unmeasured factors. To represent this two plots that summarise the correlation between species were produced. One plot summarised the correlation between species' response to the environmental variables and represents species that share a similar measured environmental niche (positive correlation) or dissimilar niche (negative correlation). The second plot summarised the residual correlations between species, which can be interpreted as correlations due to either unmeasured environmental factors or biological interactions. Significant residual correlations can be indicative of species' interactions, such as competition, or missing environmental predictors.

Regional comparison

Sites surveyed by BRUVs at Butlers Reef and The Friars in autumn were used to examine regional differences in the composition of reef fish communities. For the BORAL models, species occurring at less than three sites were excluded from analyses. Similar to the above analyses, models were fitted with the reef characteristics: depth, depth^2, slope, rugosity, northness and eastness as explanatory variables but also included a term for the region (Butlers vs Friars).

The influence of region and reef characteristics on species richness (the number of species) observed at sites was examined using marginal plots and linear regression.

Seasonal comparison

The effect of season on the composition of the fish community was examined using BRUVs surveys conducted in autumn and the following summer at Butlers Reef. The same sites were sampled in both seasons, resulting a paired design.

BORAL models are unable to account for a paired structure in the latent variables (representing the correlation between species due to sampling the same site) and other model-based community modelling methods only accommodate presence-absence data (Ovaskainen *et al.* 2016). An unconstrained BORAL ordination was used to examine naive patterns in the community composition (i.e. not accounting for the correlation between paired sites). To understand if there were differences in the abundance (*maxN*) of species between autumn and summer, while accounting for the paired nature of the design, a negative binomial generalised linear model (GLM) with a log link was used. The autumn and summer *maxN* for a species at a site was considered as the pair and we tested for seasonal differences within the pairs, while allowing differences to be species dependent. The terms in this model were the pair (site and species), species and species x season interaction.

A significant species by season interaction indicates differences in the community composition between seasons and can be examined on a species-by-species basis by looking at the significance of the levels of this interaction term. This involves multiple comparisons (as many comparison as there are species) for which it should be noted there is a 5% chance of a type I error (incorrectly concluding significance), but this approach was preferred to using multiple test corrections which are often over conservative. Species occurring in less than five samples were excluded from analyses, and models were run using the MASS package (Venables and Ripley 2002) in R.

Sampling method comparison

Fourteen sites at Butlers were sampled with both BRUVs and ROV during autumn and again the following in summer. The fish community observed with the two sampling methods was compared using a similar approach to the seasonal comparison, as sites were re-sampled in a paired design. Only the data for the autumn sampling event were analysed.

ROV data were the total abundance of each species observed in the three 50 m transects at a site. An unconstrained, ordination was run using BORAL to examine naive patterns in composition of the communities. Generalised linear models were also conducted to test for an interaction between species and sampling gear and implemented in the same way as the seasonal comparison. Differences between *maxN* observed using BRUVS and total abundance observed using ROV at a site and species pair were compared using a negative binomial model with a log link. To test for proportional differences in abundance at sites due to the different sampling gears, a binomial model with a logit link was used where ‘successes’ were the abundance of the species of interest at a site and ‘failures’ were the abundance of all other species at a site combined.

Distribution and abundance

Estimation of relative abundance

Based on autumn BRUVs survey data, the Horvitz-Thompson ratio estimator was used to estimate mean *maxN*, a proxy for relative abundance (i.e. number of individuals per site). The total.est function in R function, spsurvey (Kincaid and Olsen, 2015) was used to estimate mean and variance estimates. Mean and standard errors (SE) were calculated for each depth stratum separately and then used to produce an overall mean estimate for each region. In calculating regional estimates, data for each stratum was weighted in accordance to the proportion of the overall habitat area that was represented by the stratum. For this analysis, depths shallower than 20 m have been excluded and only areas of reef habitat defined by the habitat mapping and spatial analyses have been included when determining area.

Predicted distribution and abundance

The collation of spatially explicit biological and reef structure data allows not only the testing of hypotheses on the habitat and environmental factors that influence the distribution and abundance of species and the structuring of fish assemblages, but also opens up the possibility of developing predictive models, often termed species distribution models (SDM) (Elith and Leathwick 2009, Robinson *et al*. 2011). Such models can be used to produce full-coverage maps predicting the distribution of key species or assemblages, thus making efficient use of sparse and difficult to obtain biological data (e.g. Pittman and Brown 2011, Reiss *et al.* 2011). Central to the development of SDMs is data on environmental variables likely to affect the distribution and abundance of species and communities. In addition to depth and habitat type, variables derived from high-resolution acoustic data that characterise the geomorphology of the seafloor can be influential in the fine- to medium-scale patterns of fish distribution. Such maps have the potential to highlight areas of importance for particular species and fisheries that can aid their spatial management.

A GLM with negative binomial distribution was fitted to predict *maxN* for key species across both regions. Depth, slope, region, northness and eastness were included as predictors. To account for the curvilinear relationships between depth and *maxN*, a generalised additive model (GAM) was used for the depth term. Spearman correlations were calculated between observed and predicted *maxN* values for each region. If the correlations were greater than 0.6, predicted abundances were plotted taking account of the relationships with reef characteristics for each of the study reefs.

Results and Discussion

Habitat Mapping and Classification

Butlers Reef

In the SeaMap Tasmania report for this region (Lucieer *et al*, 2007) the total algal cover between Butlers Point and Bicheno remained above 75% until 30 m depth, where it rapidly decreased to less than 10% by 40 m (Figure 2). The algal canopy structure in this section was characterised by *Phyllospora comosa* in shallow water and *Ecklonia radiata* in the deeper water. The former was the dominant algal species at depths of less than 10 m, with lesser amounts of *E. radiata* and *Durvillaea potatorum* also present. *Phyllospora comosa* and *E. radiata* were present in roughly equal portions between 10 and 20 m. Below 20 m the amount of *P. comosa* decreased with *E. radiata* becoming the dominant algae to 35 m depth. Red algae were present from 5 to 35 m with a peak between 25 and 35 m. Likewise coralline algae were present from 0 to 35 m with higher abundances between 15 and 30 m. Very little *Caulerpa* was seen in this section, with only small amounts observed in the 20 to 25 m and 35 to 40 m depth ranges. Sponge habitat dominated in depths below 35 m.

The extent of multibeam acoustic data collected at high resolution (2 m) and available for the Butlers Reef area is presented in Figures 3-7. The maps provide visual representations of bathymetry (Figure 3), habitat type (Figure 4), seafloor slope (Figure 5), rugosity (Figure 6) and hillshade (Figure 7). The highest rugosity occurs at depths of less than about 35 m, beyond which the reef profile is relatively low and increasingly comprised of mixed areas of sand and reef as it extends offshore into deeper water.

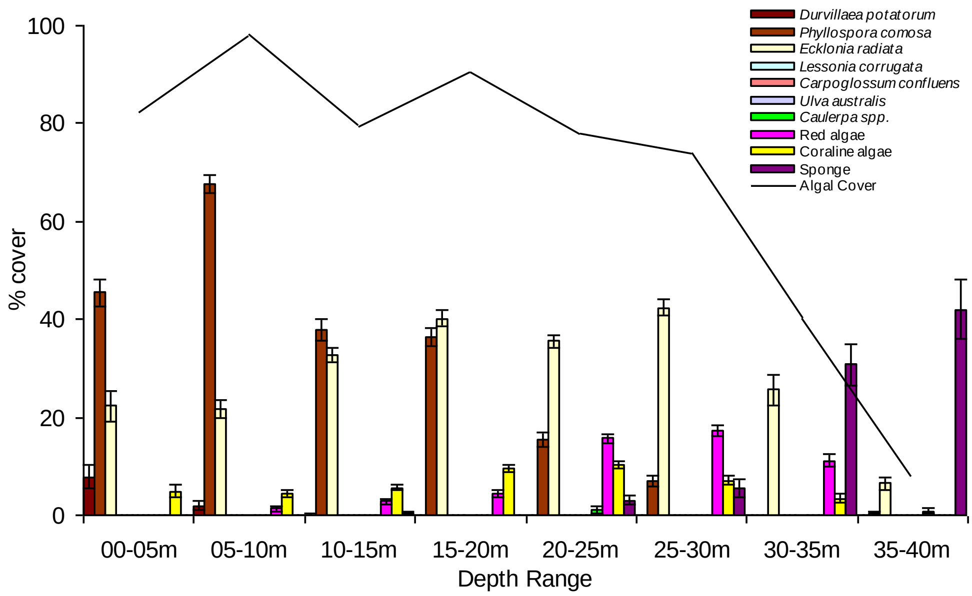


Figure 2. Mean Percentage cover (± SE) for dominant canopy macroalgae and understorey algae associated with reef habitats in 5 m depth strata between Butlers Point and Bicheno (Lucieer *et al*. 2007).

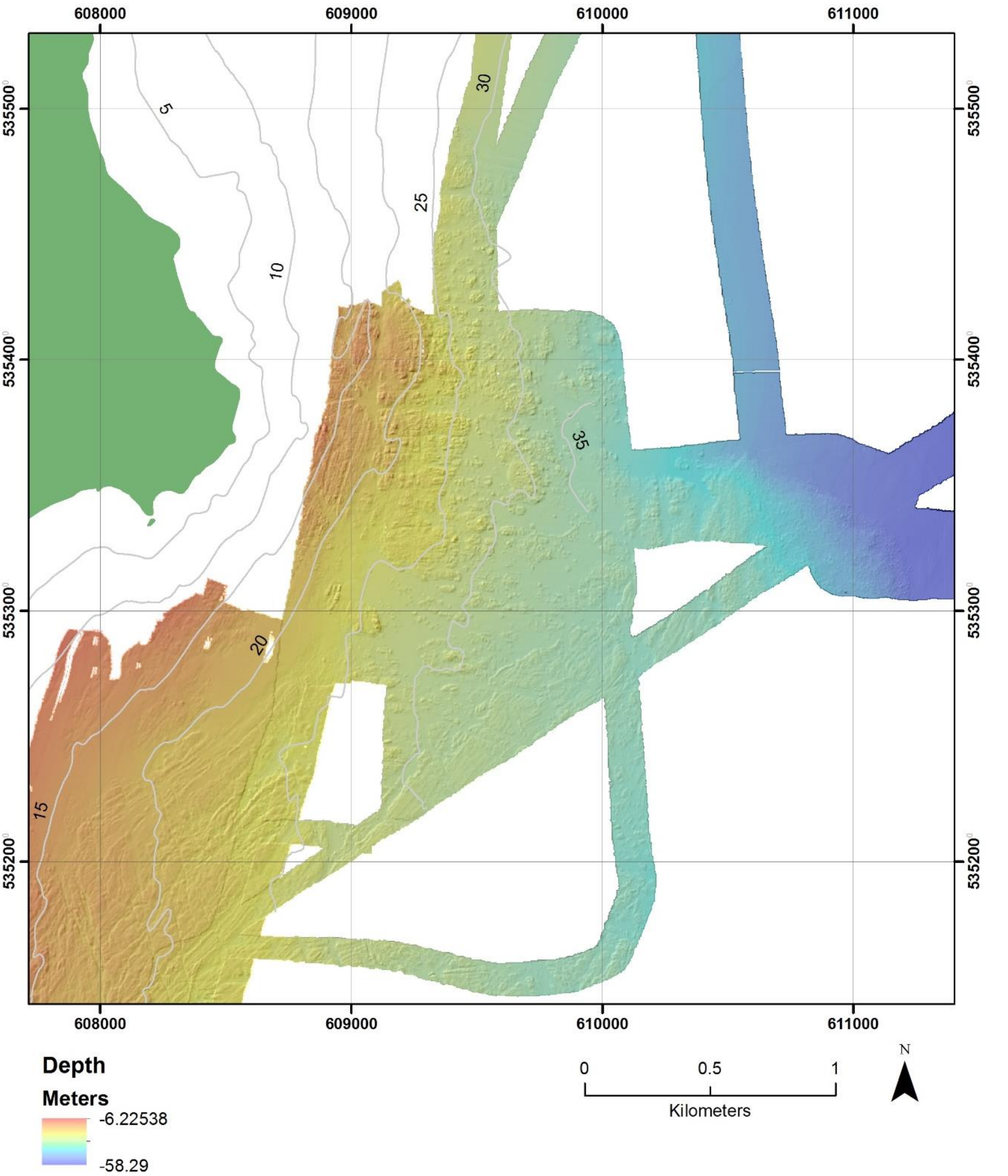


Figure 3. Depth distribution of Butlers Reef site.

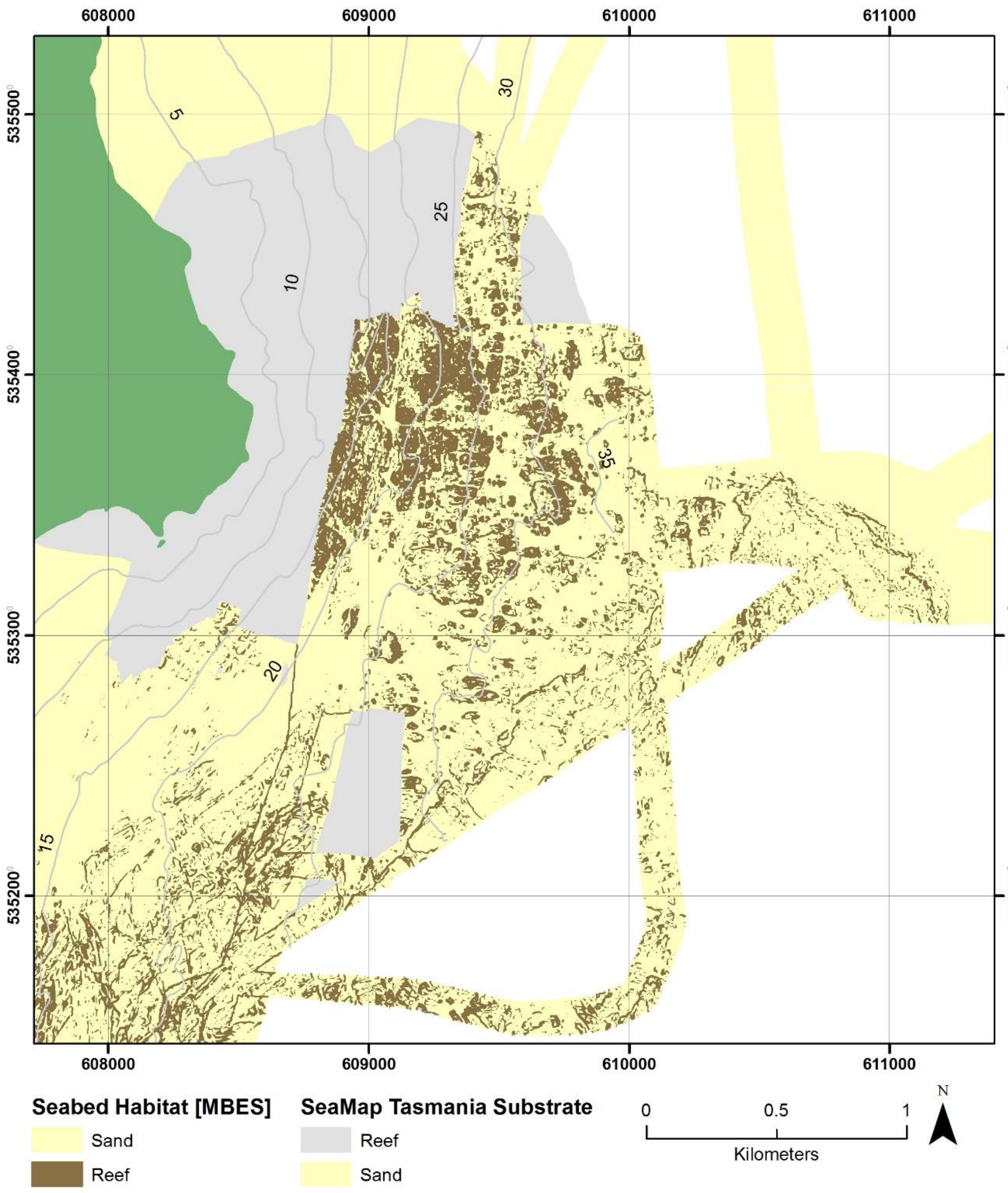


Figure 4. Primary biotope habitats- sand and reef distribution at Butlers Reef site.

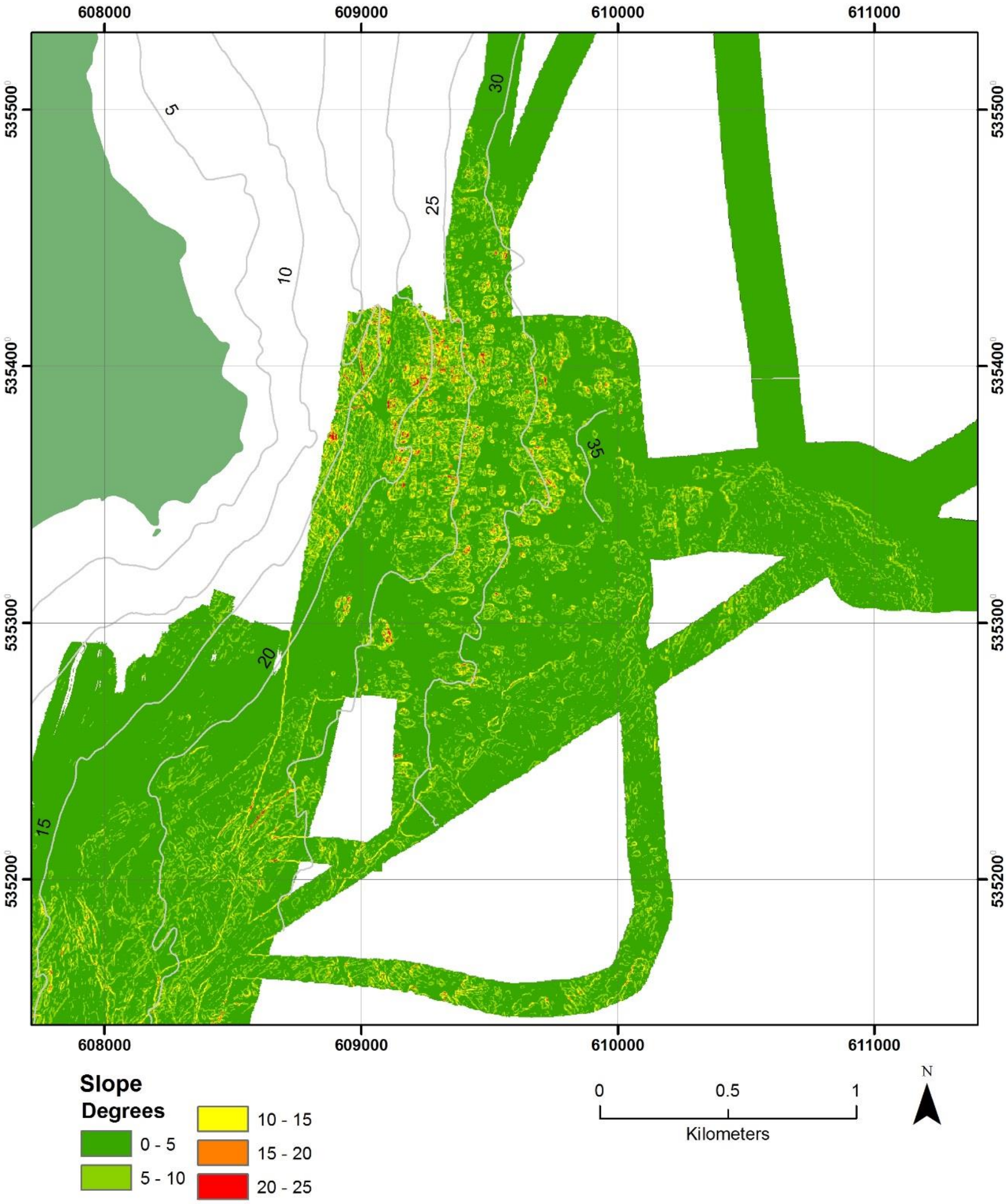


Figure 5. Characteristics of seafloor slope at Butlers Reef site.

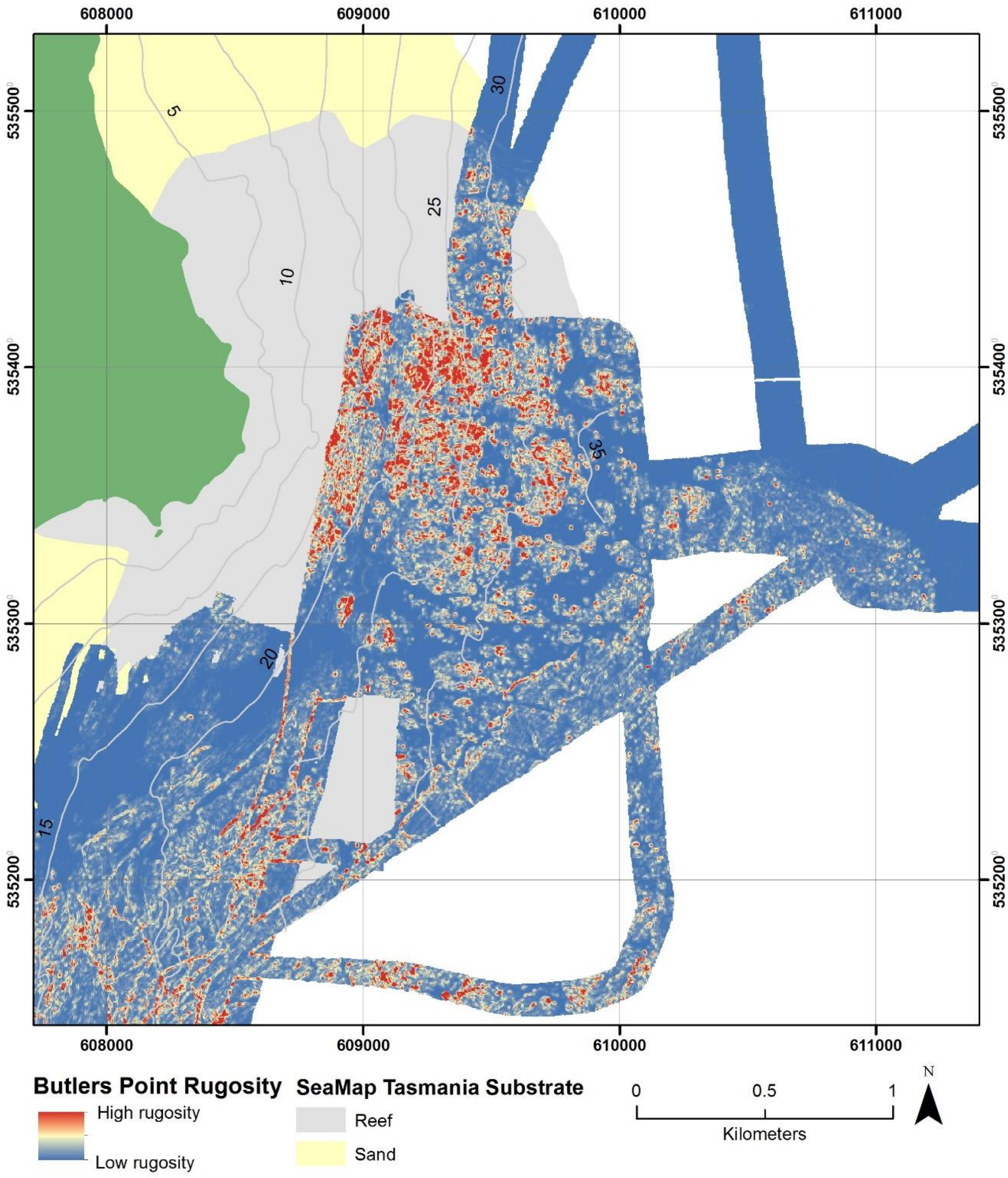


Figure 6. Characteristics of seafloor rugosity at Butlers Reef site.

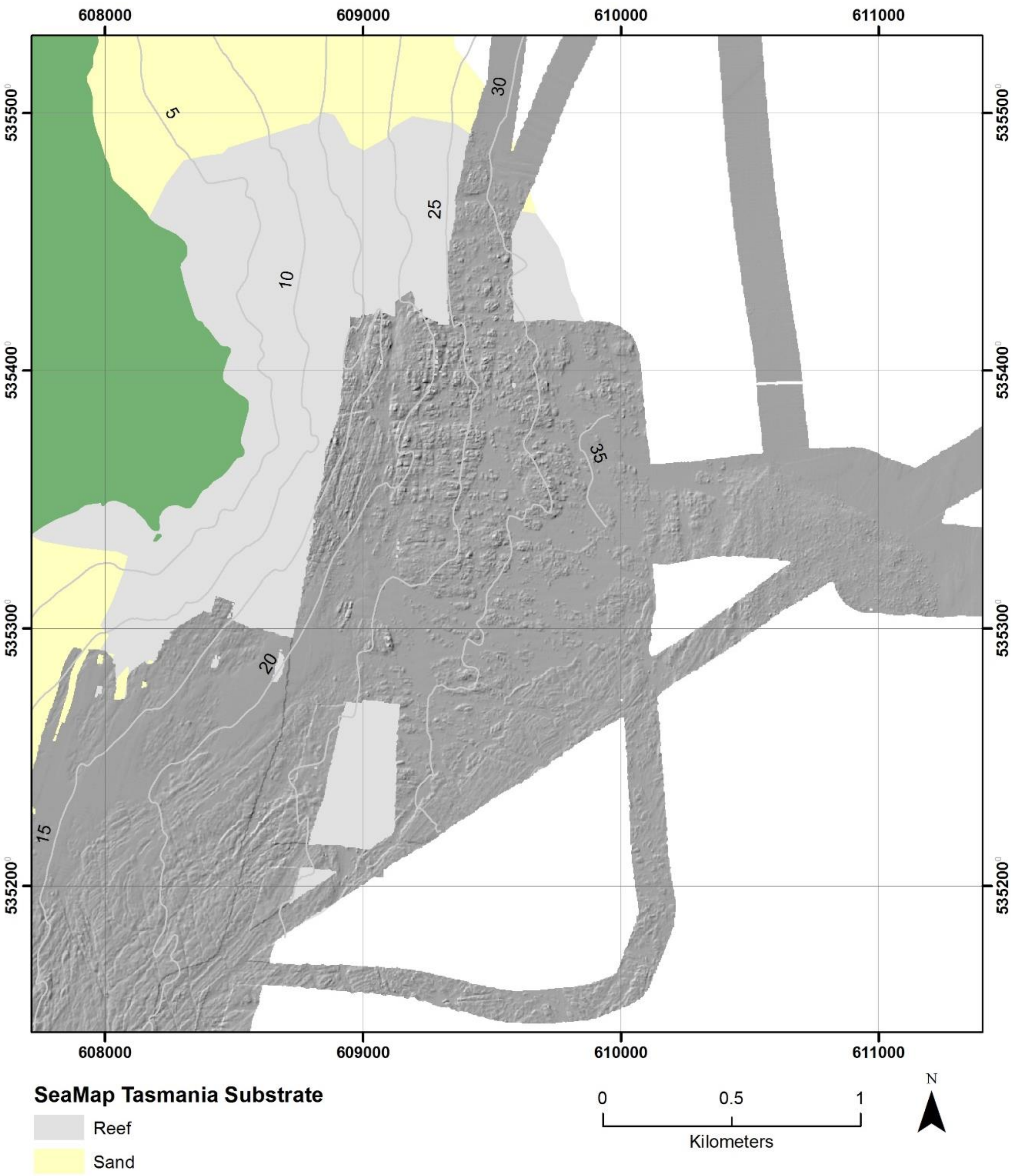


Figure 7. Characteristics of bathymetric hillshade at Butlers Reef site.

The Friars

There are no significant sheltered water communities in this section of coastline, and those present are typical of those expected on a highly exposed coast. The geology is dominated by dolerite coast, reefs and offshore islands, and the coastline is dominated by steeply sloping to cliff top shores. The macroalgal communities on reef are dominated by *Durvillaea potatorum* to 10 m, with *Phyllospora comosa* extending from 5 to 15 m and *Ecklonia radiata* from 10 to 30 m (Barrett *et al*. 2001). Sponges and other invertebrates dominate the benthic community below 30 m. Cover of the larger brown algae is not high in many areas, presumably due to the very high exposure to wave action, however, a higher cover of red algae and encrusting corallines is evident. South and westerly aspects had the least cover of the larger brown algae. In deeper areas subject to currents (particularly off headlands), profuse sponge, seawhip and gorgonian fan communities are found (Barrett *et al*. 2001). The sedimentary substrates are composed entirely of exposed sand, which extend from the shoreline in Cloudy Bay (Bruny Island).

The multibeam acoustic data collected for The Friars is at a native 2 m resolution and the map series in Figures 8-12 demonstrate the characteristics of the depth distribution, habitat characterisation (reef and sand), slope, rugosity and hillshade. The reef is relatively high profile (high rugosity) across much of the depth range and the perimeters are characterised by areas of patchy reef, intermingled with a gravelly substrate. The sand substrate is typified by having topography with sand banks, shelves and steps, visualised in the hillshaded bathymetry product (Figure 12).

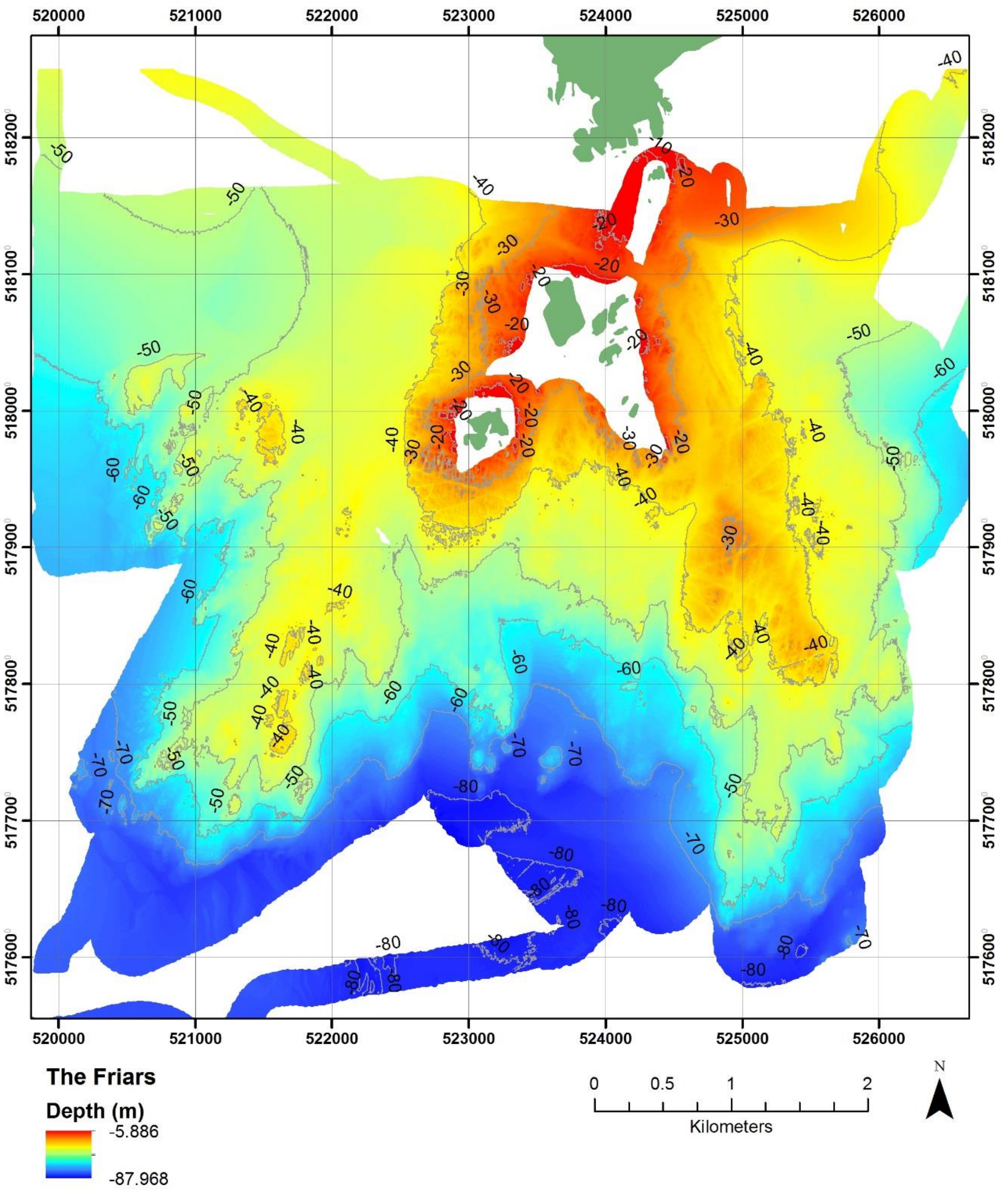


Figure 8. Depth distribution of The Friars study site showing depths ranging from 6 m to 88 m.

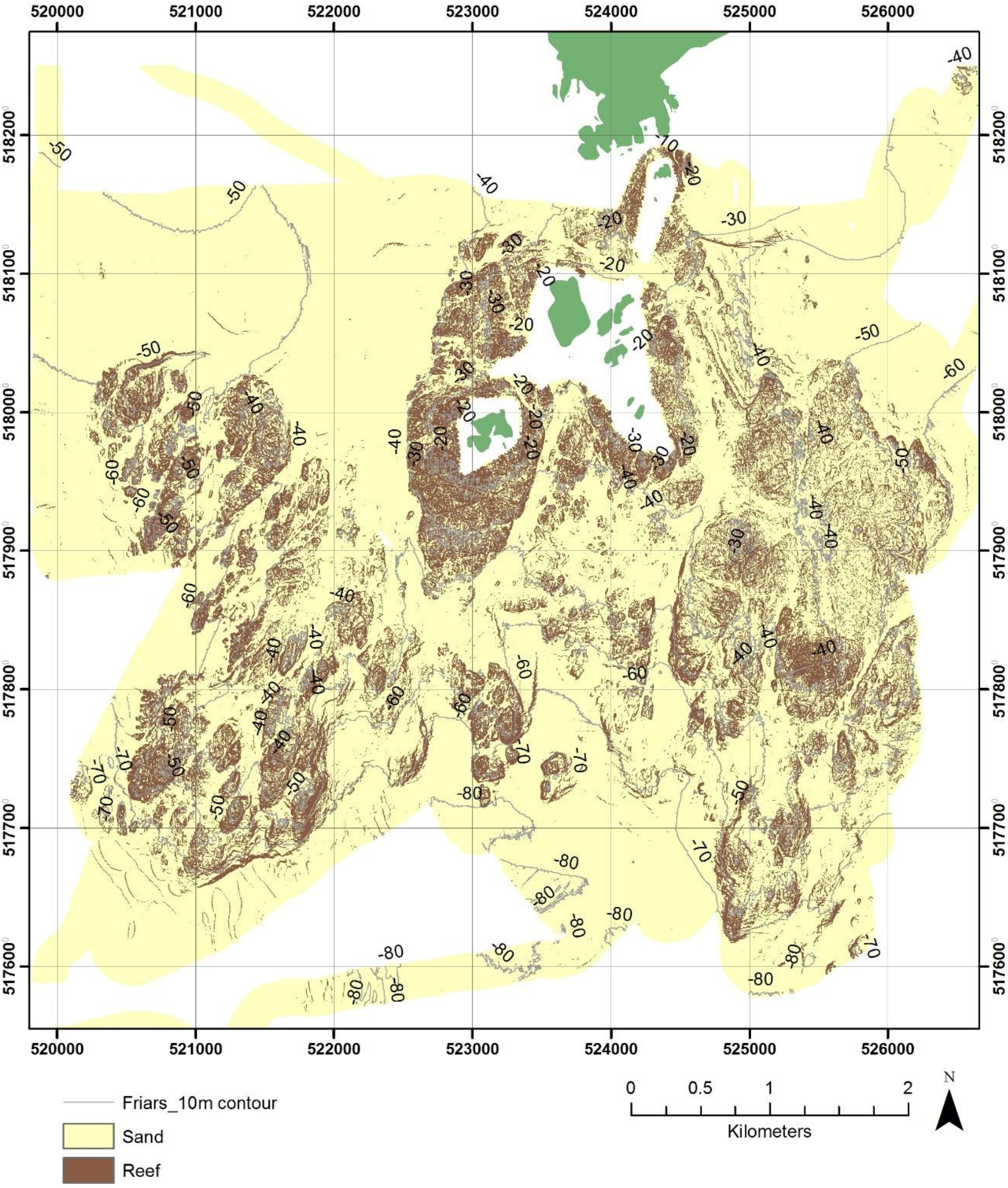


Figure 9. Primary biotope habitats- sand and reef distribution within the Friars study site.

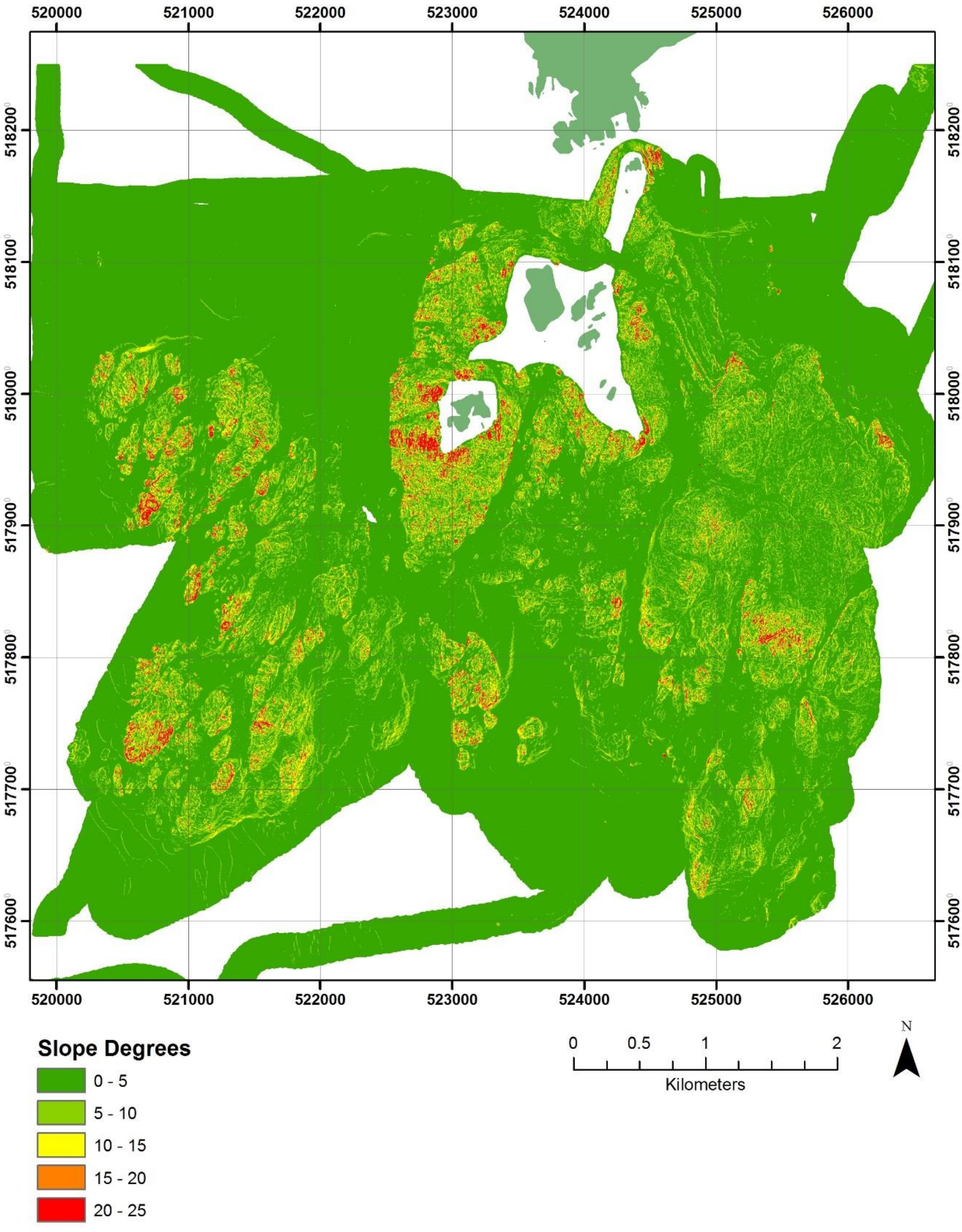


Figure 10. Characteristics of seafloor slope within the Friars study site.

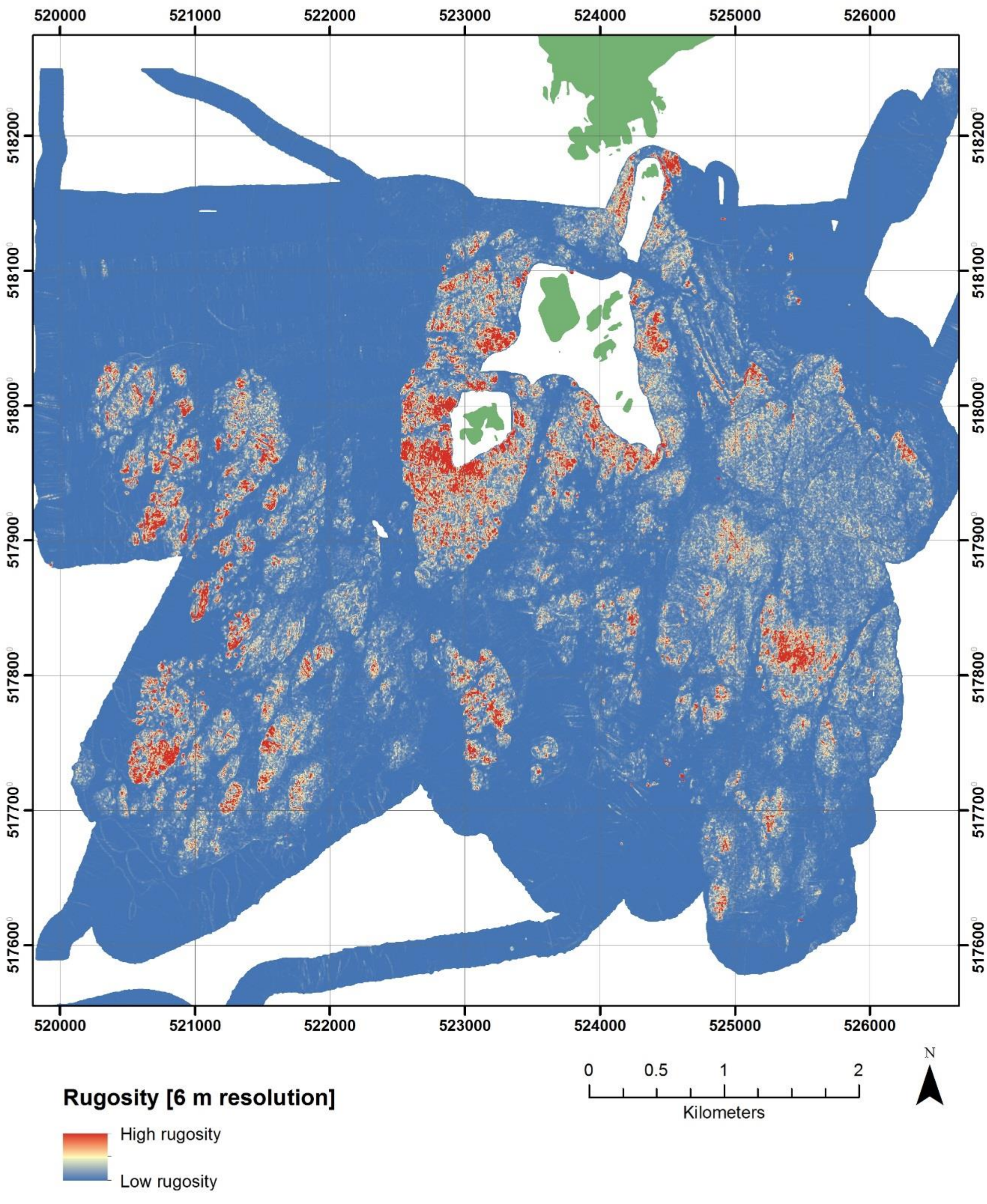


Figure 11. Characteristics of seafloor rugosity within the Friars study site.

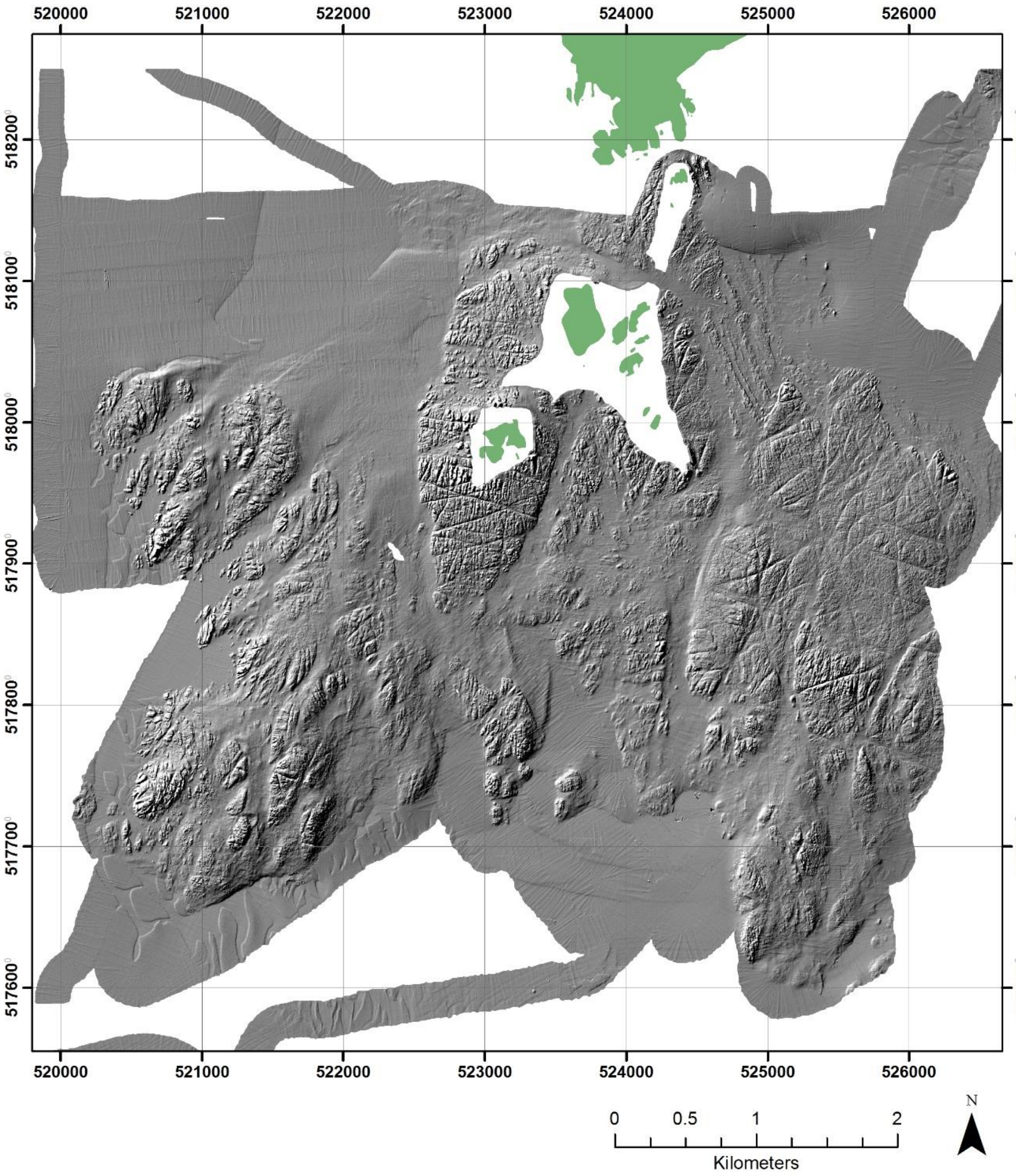


Figure 12. Characteristics of bathymetric hillshade within the Friars study site. This metric is particularly useful to visualise the soft sediment steps to the south east of the main reef system.

Fish Assemblage Composition and Structure

Overview

The spatial characteristics derived from the multibeam acoustic data for each region provided the foundation analysis for site selection to identify discrete regions for fish community characterisation at Butlers Reef and The Friars. Sixty-three sites were allocated at Butlers Reef and 60 sites at The Friars (Figure 13), the characteristics of these sites are summarised in Figure 14. The most conspicuous difference between localities was the greater depth range of the sites at The Friars and the obvious difference in the orientation of the two locations; The Friars with a predominant southern orientation and Butlers Reef with a predominantly northern and eastern orientation. With the exception of some outliers at The Friars, both localities were characterised by similar slope and rugosity distributions.

In accordance with the sampling hierarchy, about 25% of the sites at Butlers Reef were sampled by ROV, approximately half with gillnet and all sites were sampled using BRUVs. Logistical factors, notably swell and strong currents at The Friars precluded the deployment of the ROV at that location, otherwise approximated half of the sites were sampled by gillnet and all sites were sampled using the BRUVs. Both areas were sampled during autumn (field sampling was conducted between March and May 2015) to facilitate regional comparisons of fish assemblages. Butlers Reef was re-sampled using BRUVs and ROV in early summer (December 2015) to enable seasonal comparisons. In total 186 BRUVs drops, 58 gillnet deployments and 28 ROV transects were completed during the study (Table 3).

Overall, the various sampling gear (Table 4) recorded 80 species of finfish and elasmobranchs along with five species of cephalopods. Species of commercial and recreational importance such as Banded Morwong (*Cheilodactylus spectabilis*), Jackass Morwong (*Nemadactylus macropterus*), Bluethroat Wrasse (*Notolabrus tetricus*), Striped Trumpeter (*Latris lineata*) and Longsnout Boarfish (*Pentaceropsis recurvirostris*) were recorded at both localities and by each of the sampling methods, albeit often in very low numbers (refer Appendix Tables S1-3). Purple Wrasse (*Notolabrus fucicola*) and Southern Calamari (*Sepioteuthis australis*) were only recorded by BRUVs while Blue Warehou (*Seriolella brama*) were captured by gillnet at both localities but only observed by BRUVs at Butlers Reef during autumn. Toothbrush Leatherjacket (*Acanthaluteres vittiger*), Common Gurnard Perch (*Neosebastes scorpaenoides*), Reef Ocean Perch (*Helicolenus percoides*) and Butterfly Perch (*Caesioperca lepidoptera*) were also recorded in most gear, locality and season combinations.

A number species identified as having extended their distributional ranges southwards into Tasmanian waters and/or increased in abundance as a response to climate change were also recorded in this study. For instance, according to Last *et al*. (2011) species that have recently extended their range into Tasmanian waters and were observed during this study included Grey Morwong (*Nemadactylus douglasii*), Blue Morwong (*N. valenciennesi*) and Southern Maori Wrasse (*Ophthalmolepis lineolata*). Species reported to have increased in abundance and recorded in this study included Snapper (*Chrysophrys auratus*), Magpie Perch (*Cheilodactylus nigripes*), Silver Spot (*Chironemus maculosus*), Old Wife (*Enoplosus armatus*), Castelnau’s Wrasse (*Dotalabrus aurantiacus*), Mosaic Leatherjacket (*Eubalichthys mosaicus*), Herring Cale (*Olisthops cyanomelas*), White-ear (*Parma microlepis*), Port Jackson Shark (*Heterodontus portusjacksoni*) and Sparsely-spotted Stingaree (*Urolophus paucimaculatus*). The majority (8 out of 13) of these so-called climate change affected species were only observed at Butlers Reef while two, including Blue Morwong, were only sighted at The Friars. Of these species, the morwongs and Snapper are of interest to commercial and recreational fishers, although commercial landings remain very low (Emery *et al*. 2017). There is, however, a developing recreational fishery for Snapper that is taking advantage of the increased abundance of this species in Tasmanian waters.

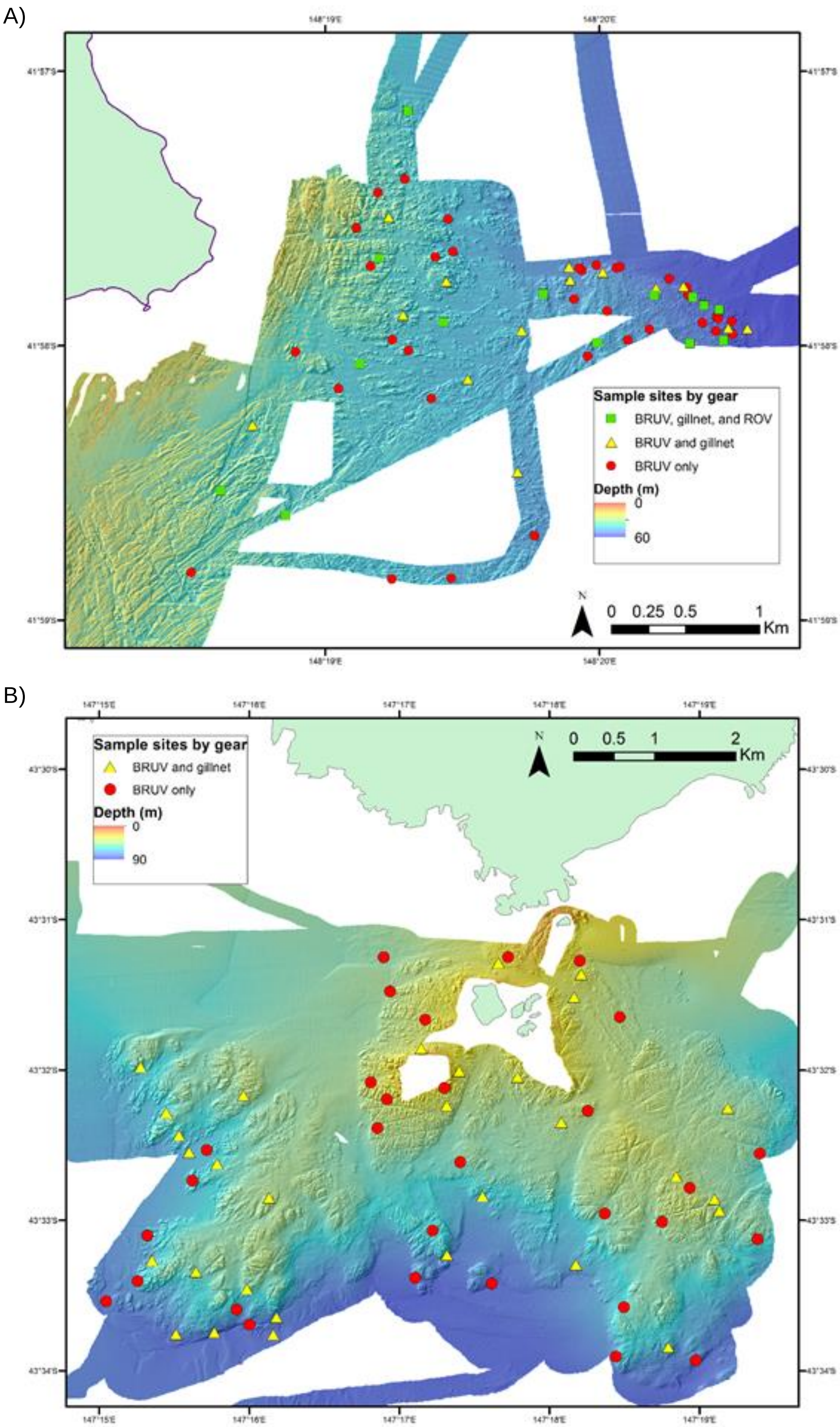


Figure 13. Maps of A) Butlers Reef and B) The Friars indicating the location of sampling sites and sampling methods.

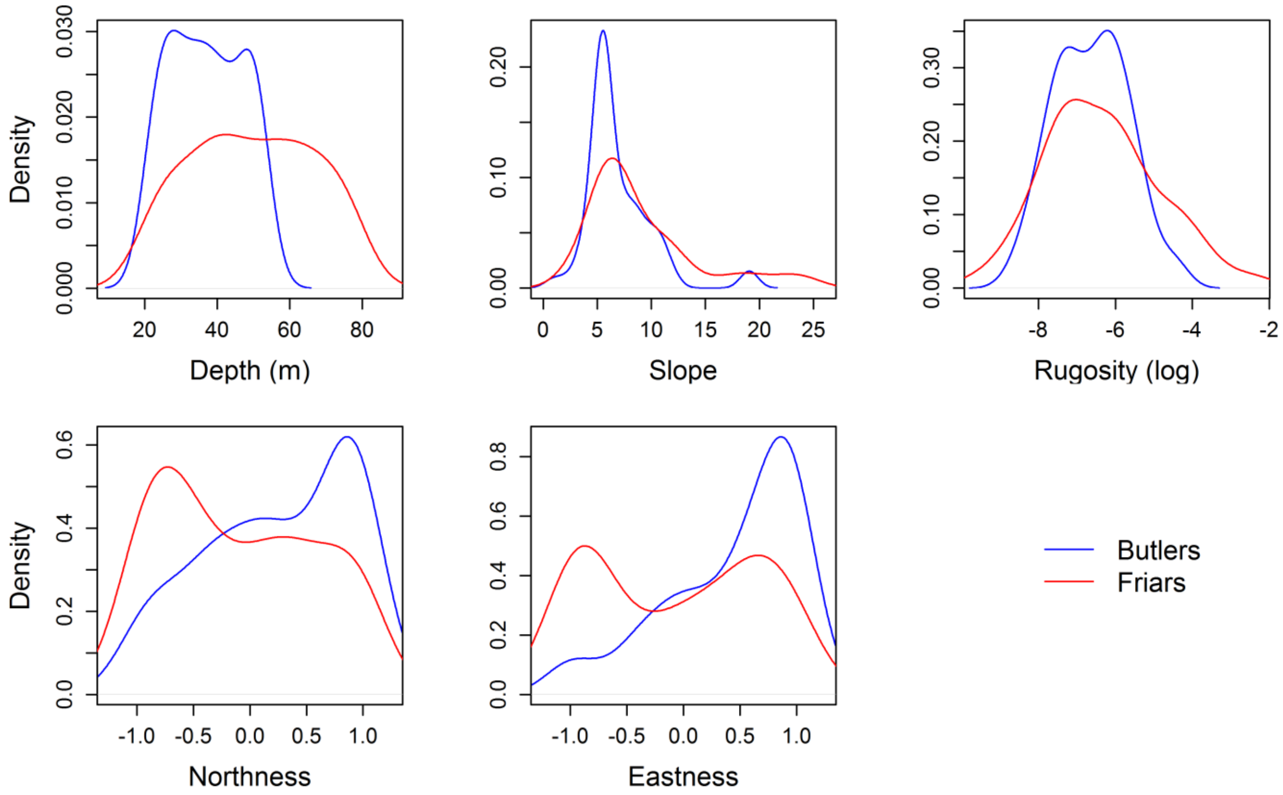


Figure 14. Density distribution of reef characteristics at sampling sites at Butlers Reef and The Friars.

Table 3. Summary of sampling details by season and method

Reef /Season	Details	BRUVS	Gillnet	ROV
Butlers / Autumn	Month sampled	March 2015	March 2015	May 2015
	No. sites	63	28	14
Friars / Autumn	Month sampled	March/April 2015	April 2015	
	No. sites	60	30	-
Butlers / Summer	Month sampled	December 2015		December 2015
	No. sites	63	-	14
	Total sites	186	58	28

Table 4. Species presence (+) based on sampling method, region and season.

			The Friars		Butlers Reef				
			Autumn		Autumn			Summer	
Family	Standard fish name	Species	BRUV	Gillnet	BRUV	Gillnet	ROV	BRUV	ROV
Aplodactylidae	Marblefish	*Aplodactylus arctidens*	+	+		+	+	+	
Berycidae	Swallowtail	*Centroberyx affinis*			+			+	
Callanthiidae	Splendid Perch	*Callanthias australis*	+		+		+	+	+
Carangidae	Silver Trevally	*Pseudocaranx georgianus*	+						
	Common Jack Mackerel	*Trachurus declivis*	+		+			+	+
Centrolophidae	Blue Warehou	*Seriolella brama*		+	+	+			
Cheilodactylidae	Magpie Perch	*Cheilodactylus nigripes*	+	+	+		+	+	
	Banded Morwong	*Cheilodactylus spectabilis*	+	+	+	+	+	+	+
	Grey Morwong	*Nemadactylus douglasii*			+			+	
	Jackass Morwong	*Nemadactylus macropterus*	+	+	+	+	+	+	+
	Blue Morwong	*Nemadactylus valenciennesi*	+						
Chironemidae	Silver Spot	*Chironemus maculosus*	+						
Clinidae	Johnston's Weedfish	*Heteroclinus johnstoni*	+						
Congridae	Southern Conger	*Conger verreauxi*	+		+			+	
Cyttidae	Silver Dory	*Cyttus australis*	+	+	+			+	+
Dasyatidae	Smooth Stingray	*Dasyatis brevicaudata*	+		+				
Dinolestidae	Longfin Pike	*Dinolestes lewini*	+		+		+	+	+
Diodontidae	Globefish	*Diodon nicthemerus*	+		+		+	+	
Enoplosidae	Old Wife	*Enoplosus armatus*			+		+	+	+
Gempylidae	Barracouta	*Thyrsites atun*	+		+			+	
Gerreidae	Silverbelly	*Parequula melbournensis*	+		+		+	+	+
Heterodontidae	Port Jackson Shark	*Heterodontus portusjacksoni*			+	+			
Hexanchidae	Broadnose Shark	*Notorynchus cepedianus*	+		+			+	
Labridae	Castelnau's Wrasse	*Dotalabrus aurantiacus*						+	+
	Purple Wrasse	*Notolabrus fucicola*	+		+			+	
	Bluethroat Wrasse	*Notolabrus tetricus*	+	+	+	+	+	+	+
	Southern Maori Wrasse	*Ophthalmolepis lineolata*			+		+	+	+
	Senator Wrasse	*Pictilabrus laticlavius*	+		+		+	+	+
	Rosy Wrasse	*Pseudolabrus rubicundus*	+		+		+	+	+
	Crimson Cleaner Wrasse	*Suezichthys aylingi*	+					+	
Latridae	Bastard Trumpeter	*Latridopsis forsteri*	+	+					
	Striped Trumpeter	*Latris lineata*	+	+	+	+		+	+
Monacanthidae	Toothbrush Leatherjacket	*Acanthaluteres vittiger*	+	+	+	+	+	+	+
	Black Reef Leatherjacket	*Eubalichthys bucephalus*						+	
	Gunn's Leatherjacket	*Eubalichthys gunnii*	+		+		+	+	+
	Mosaic Leatherjacket	*Eubalichthys mosaicus*	+	+	+	+		+	
	Leatherjacket (unident)	*Meuschenia* sp.			+				
	Brownstriped Leatherjacket	*Meuschenia australis*	+		+		+	+	+
	Sixspine Leatherjacket	*Meuschenia freycineti*	+		+		+	+	+
	Velvet Leatherjacket	*Meuschenia scaber*	+		+		+	+	+
	Stars-and-stripes Leatherjacket	*Meuschenia venusta*	+		+			+	
	Ocean Jacket	*Nelusetta ayraud*			+		+		
	Bluefin Leatherjacket	*Thamnaconus degeni*	+		+	+		+	

Table 4. Continued

			The Friars		Butlers Reef				
			Autumn		Autumn			Summer	
Family	**Standard fish name**	**Species**	**BRUV**	**Gillnet**	**BRUV**	**Gillnet**	**ROV**	**BRUV**	**ROV**
Moridae	Largetooth Beardie	*Lotella rhacina*	+		+		+	+	+
	Red Cod	*Pseudophycis bachus*	+	+	+	+		+	
	Bearded Rock Cod	*Pseudophycis barbata*	+		+		+	+	+
Mullidae	Bluespotted Goatfish	*Upeneichthys vlamingii*	+		+		+	+	+
Myliobatidae	Southern Eagle Ray	*Myliobatis australis*	+		+				
Neosebastidae	Common Gurnard Perch	*Neosebastes scorpaenoides*	+	+	+	+	+	+	+
Odacidae	Herring Cale	*Olisthops cyanomelas*			+	+	+	+	+
Ostraciidae	Shaw's Cowfish	*Aracana aurita*	+		+			+	+
Parascylliidae	Rusty Carpetshark	*Parascyllium ferrugineum*						+	
Pempherididae	Bigscale Bullseye	*Pempheris multiradiata*			+		+	+	+
Pentacerotidae	Longsnout Boarfish	*Pentaceropsis recurvirostris*	+	+	+	+	+	+	+
Pinguipedidae	Barred Grubfish	*Parapercis allporti*			+		+	+	
Platycephalidae	Southern Sand Flathead	*Platycephalus bassensis*	+					+	
Pomacentridae	White-ear	*Parma microlepis*			+		+	+	+
Pristiophoridae	Southern Sawshark	*Pristiophorus nudipinnis*			+	+			
Rajidae	Melbourne Skate	*Spiniraja whitleyi*	+	+	+			+	
Rhinobatidae	Southern Fiddler Ray	*Trygonorrhina dumerilii*						+	
	Eastern Fiddler Ray	*Trygonorrhina fasciata*	+						
Scombridae	Southern Bluefin Tuna	*Thunnus maccoyii*	+						
Scorpaenidae	Southern Red Scorpionfish	*Scorpaena papillosa*	+					+	
Scyliorhinidae	Orange Spotted Catshark	*Asymbolus rubiginosus*	+					+	
	Catshark (unident)	*Atelomycterus* sp.	+						
	Draughtboard Shark	*Cephaloscyllium laticeps*	+	+	+	+		+	+
Sebastidae	Reef Ocean Perch	*Helicolenus percoides*	+		+	+	+	+	+
Serranidae	Butterfly Perch	*Caesioperca lepidoptera*	+	+	+		+	+	+
	Barber Perch	*Caesioperca rasor*	+		+		+	+	+
	Halfbanded Seaperch	*Hypoplectrodes maccullochi*			+			+	+
Sparidae	Snapper	*Chrysophrys auratus*			+				
Sphyraenidae	Snook	*Sphyraena novaehollandiae*			+				
Tetraodontidae	Ringed Toadfish	*Omegophora armilla*	+						
Trachichthyidae	Sandpaper Fish	*Paratrachichthys macleayi*	+		+		+	+	+
Triakidae	Gummy Shark	*Mustelus antarcticus*	+		+				
Urolophidae	Stingaree (unident)	Stingaree	+						
	Banded Stingaree	*Urolophus cruciatus*			+			+	+
	Sparsely-spotted Stingaree	*Urolophus paucimaculatus*	+		+				
Sepiidae	Giant Cuttlefish	*Sepia apama*			+				
Loliginidae	Southern Calamari	*Sepioteuthis australis*	+		+			+	
Octopodidae	Octopus (unident)	Octopus	+						
	Maori Octopus	*Pinnoctopus cordiformis*	+					+	
Ommastrephidae	Gould's Squid	*Nototodarus gouldi*	+						
Paguridae	Hermit crab	Hermit crab	+						
Diogenidae	Hermit crab	Hermit crab	+						
Palinuridae	Southern Rocklobster	*Jasus edwardsii*	+		+			+	

BRUVs data

The BRUVs recorded the greatest diversity of species, including a wide range of reef associated species as well as a number of pelagic species that tended to be sighted occasionally (Appendix Table S1). Three families of fish were particularly prominent: Serranidae, which include Butterfly Perch and Barber Perch (*Caesioperca rasor*); Labridae, which include Rosy Wrasse (*Pseudolabrus rubicundus*) and Bluethroat Wrasse; and Monocanthidae, which include Velvet Leatherjacket (*Meuschenia scaber*), Brownstripe Leatherjacket (*Meuschenia australis),* Toothbrush Leatherjacket (*Acanthaluteres vittiger*) and Bluefin Leatherjacket (*Thamnaconus degeni*). Collectively, these families accounted for 82% of the total number (sum of *maxN*) of reef-associated fish recorded by BRUVs at Butlers Reef and 91% of total numbers recorded at The Friars.

In relation to species of commercial or recreational importance, only Jackass Morwong and Bluethroat Wrasse were common (> 65% sites), occasionally present in schools of more than five individuals. Of the other species, Reef Ocean Perch and Banded Morwong were occasionally recorded (>10% sites). while the remaining species were rarely observed (< 10% sites), or only common at one of the reefs, e.g. Striped Trumpeter (>25% of Butlers Reef sites) and Southern Calamari (50% of Friars sites).

Gillnet data

Poor gillnet catch rates were experienced in the autumn surveys (only 106 fish captured in 58 deployments), influenced in part by operational factors dictated by working from a relatively small research vessel (short net lengths and short soak times). In addition, the heavy gauge mesh and high floatation headlines designed to minimise the effects of currents may have reduced capture effectiveness. Consequently, this method was considered unlikely to yield sufficient data to justify its use in the summer surveys and therefore the decision was taken to discontinue the use of this gear.

A total of 22 species were captured by gillnet (Appendix Table S2), some of which were rarely observed in the BRUVs footage; these included Blue Warehou, Bastard Trumpeter (*Latridopsis forsteri*) and Marblefish (*Aplodactylus arctidens*), species that are rarely targeted by line fishing (and hence unlikely to be attracted to bait). The main commercial and recreational species of interest were represented in the catches, albeit in low numbers.

ROV data

Over 40 species of fish were observed on the ROV transects, and while the total number of fish counted was large despite only 14 transects in both seasons, a single species, Butterfly Perch, accounted for around 90% of the total fish numbers (Appendix Table S3). Amongst the species of commercial and recreational significance, Bluethroat Wrasse was the most common and was observed on most transects. Banded Morwong, Jackass Morwong and Longsnout Boarfish and Striped Trumpeter were far less common.

Butlers Reef

Sixty-three BRUVs drops were completed during the autumn survey of Butlers Reef, with 59 species of fish (teleosts and elasmobranchs) and cephalopods (excluding pelagic species) identified, 42 of which were represented at three or more sites[2] (Appendix Table S1).

Unconstrained ordination plots indicate that there are patterns in community composition mainly related to depth (Figure 15). Species such as Barred Grubfish (*Parapercis allporti*) and Splendid

[2] For this purpose *Caesioperca lepidoptera* and *C. razor* have been combined as *Caesioperca* spp.

Perch (*Callanthias australis*) appeared to be indicative of the deeper depths, Purple Wrasse (*Notolabrus fucicola*) and Herring Cale (*Olisthops cyanomelas*) indicative of the shallower depths.

These patterns were tested more formally by including environmental variables in the multivariate regression analysis. A BORAL model was implemented that included depth, depth squared, slope, rugosity, northness and eastness. From this analysis, information on how individual species responded to each of the environmental variables was extracted; species with significant responses to reef characteristics other than depth in the model are presented in Figure 16. Apart from depth, there were few statistically significant relationships, in part due to the low abundance of many species[3]. Of these, Purple Wrasse showed a negative relationship with slope, whereas two other species responded to aspect (northness and eastness), presumably as this is a surrogate for exposure. Rugosity was not a significant factor for any species. The most marked response was with depth, with more than half of the species examined (i.e. 23 out of 42 species) showing significant (linear or quadratic[4]) responses to depth. Figure 17 shows the predicted relationship between depth and species abundance for these species via topological colours. These analyses clearly demonstrate the transition from shallow water (20-30 m) preferred species, e.g. Draughtboard Shark (*Cephaloscyllium laticeps*), Purple Wrasse and Herring Cale, to species that prefer intermediate depths (40-60 m), e.g. Barred Grubfish, Common Gurnard Perch (*Neosebastes scorpaenoides*), Sandpaper Fish (*Paratrachichthys macleayi*) and Splendid Perch. Peak abundances of the commercially and recreational important Jackass Morwong (*Nemadactylus macropterus*) and Striped Trumpeter (*Latris lineata*) occurred at depths of greater than about 40 m. Other commercial species of interest, such as Banded Morwong (*Cheilodactylus spectabilis*) were either insufficiently abundant for depth related patterns to be detected by the model, or were more or less evenly distributed over the depth range examined here. Thus, the main pattern in the composition of the fish assemblage at Butlers Reef was related to depth, a finding that was also clearly illustrated by the shallow/deep distinction in the ordination plots (Figure 15).

Figure 18 examines the correlations between individual species and their abundances based on their similar/opposite responses to reef characteristics. Thirty-five of the 42 species showed a significant correlation to at least one other species. Not surprisingly, many of these relationships appeared to be driven by depth preferences. Shallow water species, Old Wife (*Enoplosus armatus*), Purple Wrasse, Senator Wrasse (*Pictilabrus laticlavius*) and Draughtboard Shark tended to respond the opposite (negative correlations) to reef characteristics to the majority of the other (deeper dwelling) species. There were exceptions, notably Longsnout Boarfish (*Pentaceropsis recurvirostris*) which showed similar responses to these four species, despite being categorized as having a deeper water distribution (Figure 18).

Figure 19 examines the relationship between species that interact or respond similarly/differently to unmeasured reef characteristics. For example, a negative correlation between Longfin Pike (*Dinolestes lewini*) and Halfbanded Seaperch (*Hypoplectrodes maccullochi*) or Bearded Rock Cod (*Pseudophycis barbata*), implies that these species are less likely to be present together, even after reef characteristics are taken into account. Conversely, a number of the monocanthids including Toothbrush Leatherjacket (*Acanthaluteres vitteger*), Brownstriped Leatherjacket (*Meuschenia australis*), Velvet Leatherjacket (*M. scaber*) and Gunn’s Leatherjacket (*Eubalichthys gunnii*) were positively correlated, indicating that these species were more likely to be present together than could be explained by the reef characteristics. The ecological significance of these relationships for this latter group of related species is unclear but may warrant further investigation since the data on which these correlations are based appears to be quite robust (number of sites).

[3] In order to reduce this problem, analyses were limited to include species that occurred in three or more sites. Species that are relatively rare will inevitably contain less information.

[4] Non-linear relationships with depth are evident where abundances peak (indicated by warm colours) at intermediate depths and decline (cool colours) either side of the peak abundance depth range.

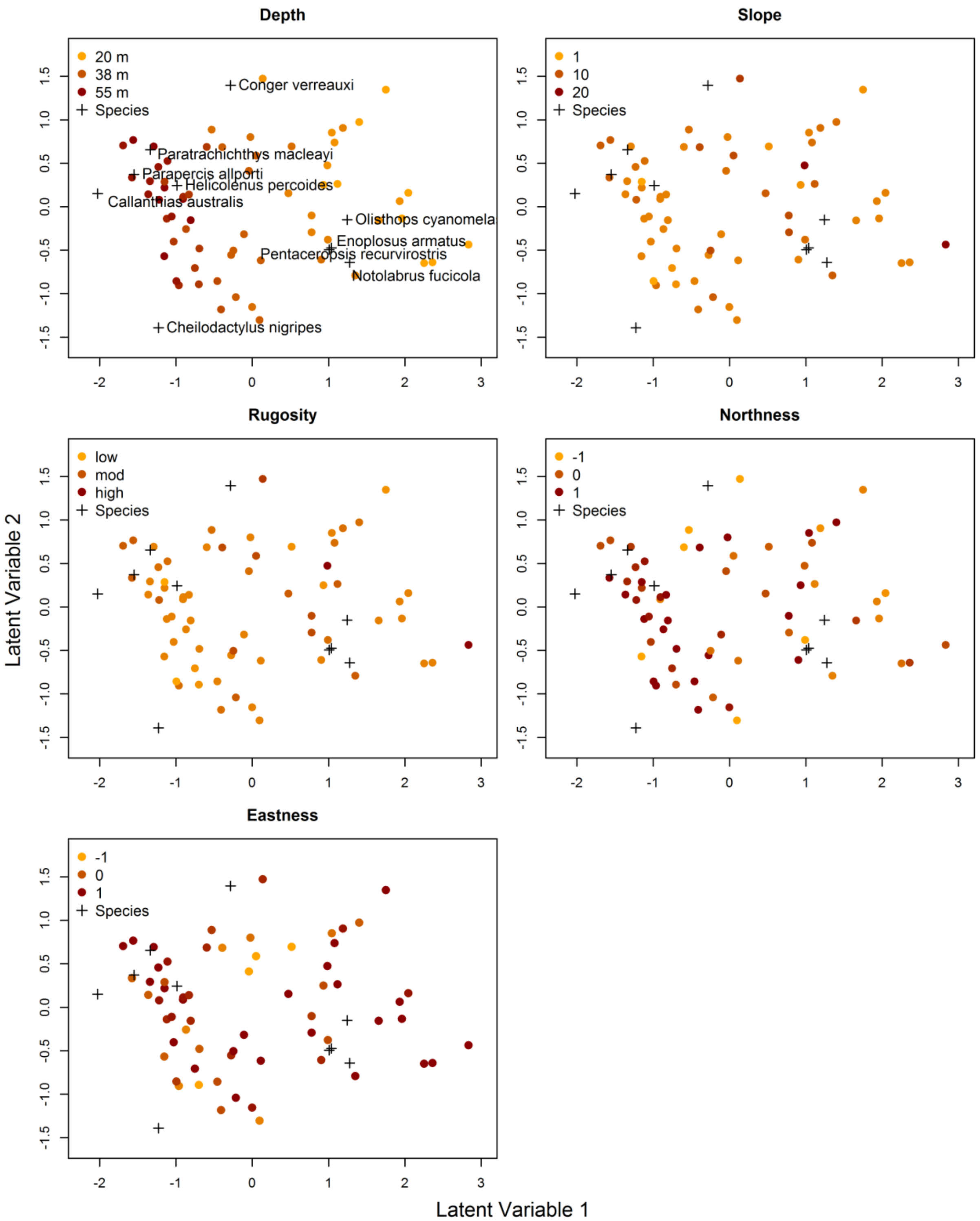


Figure 15. Unconstrained, model-based ordination of the species composition of sites at the Butlers sampled in autumn. Each circle represents a BRUVs site and the values of environmental variables are overlaid on sites. The location of the ten most important species are also plotted.

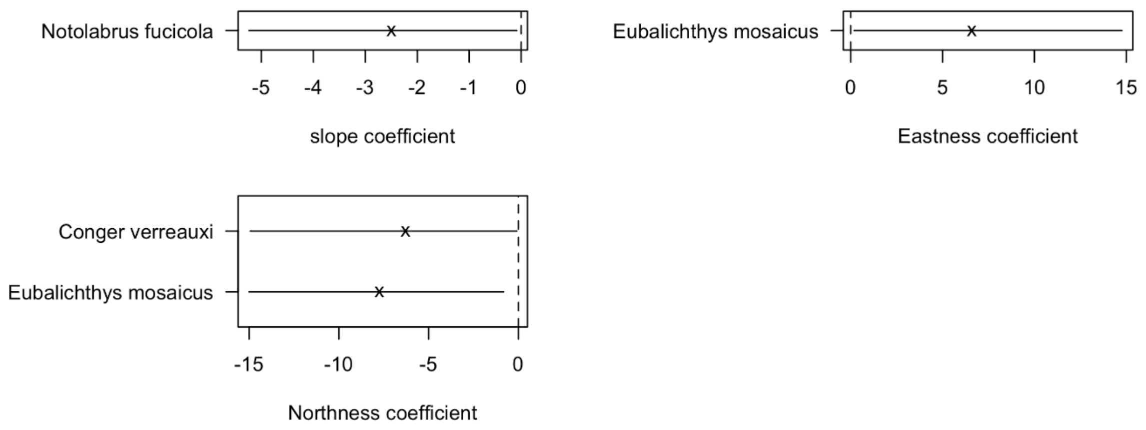


Figure 16. Caterpillar plots, showing the response of each species to reef characteristics at Butlers Reef, via the regression coefficients (indicated by an x) and their 0.95 HPD intervals (indicated by a line). Only species with significant responses are shown.
Positive coefficients indicate a significantly higher abundance of that species at higher levels of the reef characteristic.

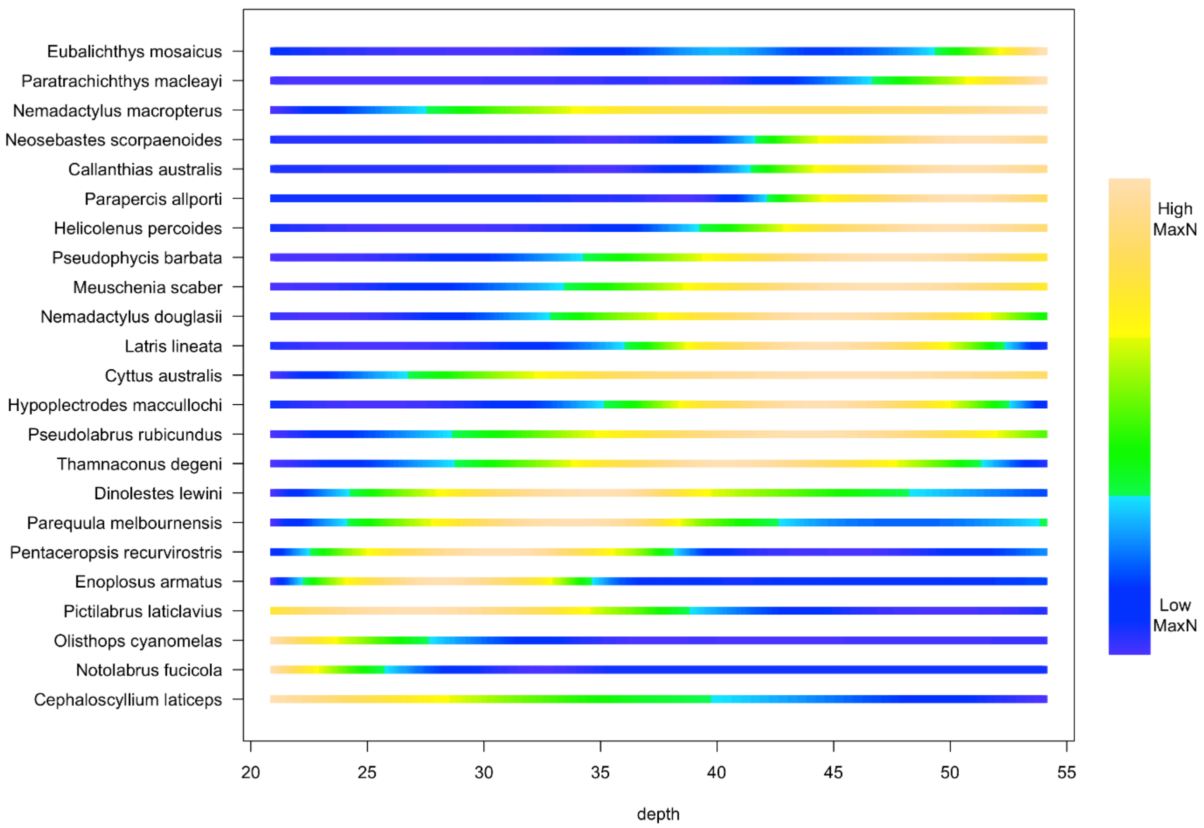


Figure 17. Relationships of species abundance with depth at Butlers Reef. The predicted species abundances from the BORAL model are plotted using topological colours, where higher/medium/lower abundances are indicated by orange/green/blue colours.
Only species with significant relationships with depth are plotted. Species are ordered according to the depth where maximum abundance is predicted to occur.

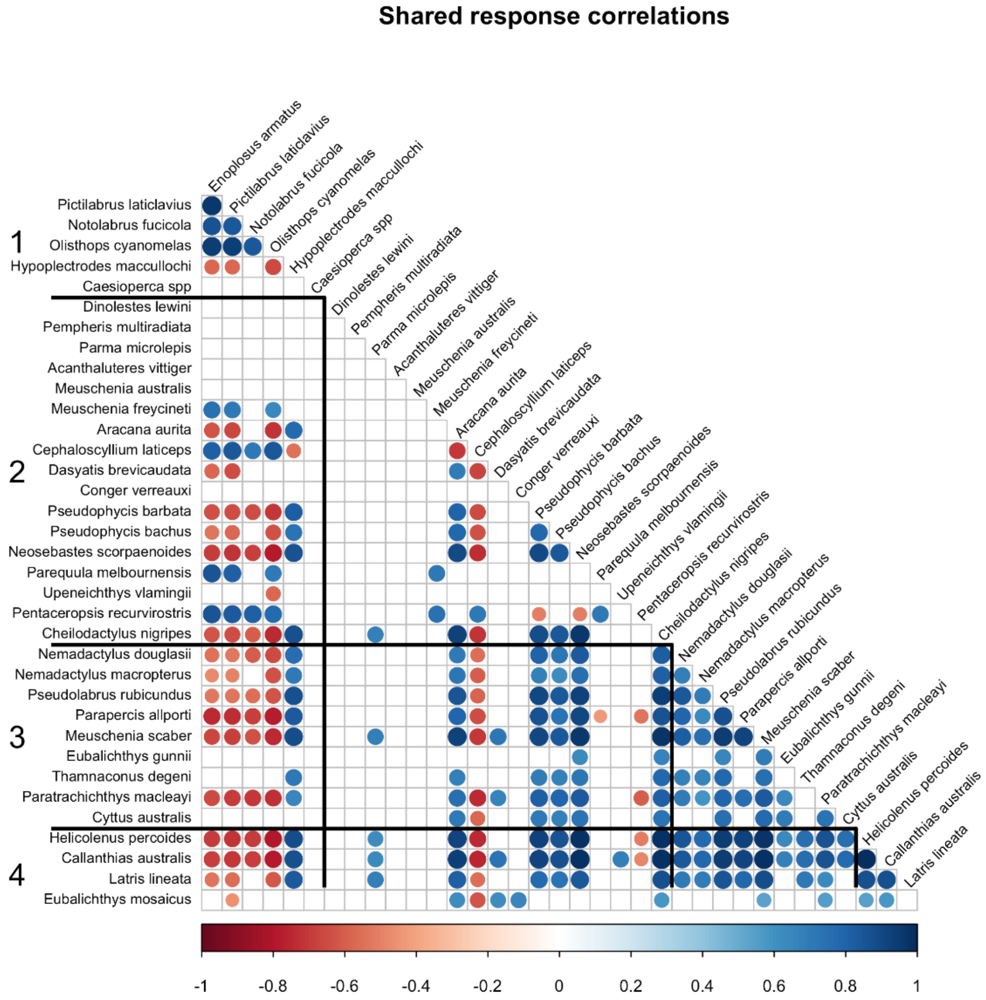


Figure 18. Correlations showing shared responses between species at Butlers Reef.
Blue/red dots indicate pairs of species that have positive/negative correlation, indicating that they respond in the same/opposite way to reef characteristics. Only significant correlations are shown; the larger with darker colours have stronger correlations. Species are ordered into 4 groups[5]; (1) shallow water species (0-20 m), (2) typically shallow species but may be found over entire depth range here, (3) typically found over whole depth range here and (4) deeper reef affinity (40+ m).

5 Groupings are qualitatively based on depth abundance profiles depicted in Figures 17and 22 and are provided to assist with the interpretation of correlations between species.

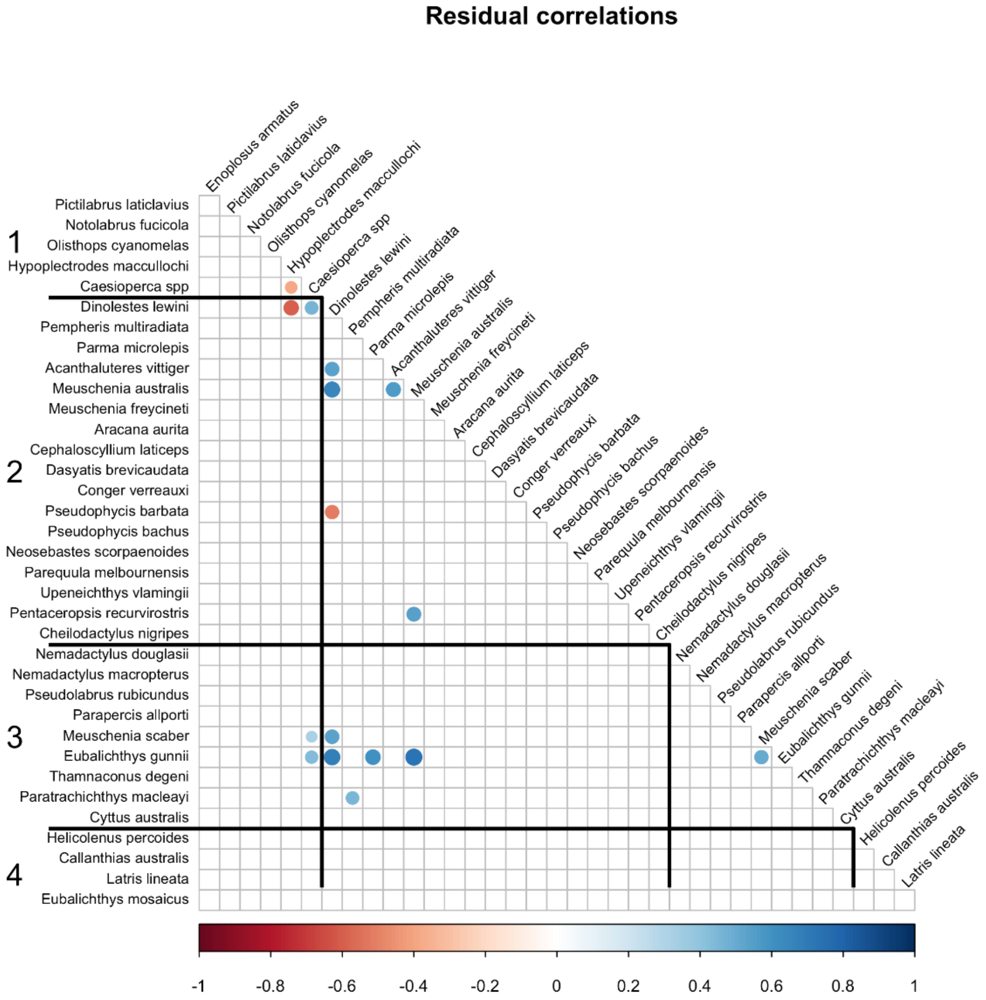


Figure 19. Residual correlations between species, after adjusting for reef characteristics at Butlers Reef. Refer Figure 18 for explanation.

The Friars

Sixty BRUVs drops were completed during the autumn survey of The Friars, with 59 species of fish and cephalopods (excluding pelagic species) identified, 30 of which were represented at three or more sites[6] (Appendix Table S1).

As noted for Butlers Reef, unconstrained ordination plots indicate that observed patterns in community composition are mainly related to depth (Figure 20), with this analysis also suggesting that Splendid Perch (*Callanthias australis*) are indicative of the deeper depths and Purple Wrasse (*Notolabrus fucicola*) indicative of the shallower depths.

These patterns were formally tested by including environmental variables in the multivariate regression analysis, BORAL. Slope and northness were significant for very few species (Figure 21). Banded Morwong (*Cheilodactylus spectabilis*), Bluefin Leatherjacket (*Thamnaconus degeni*) and Gummy Shark (*Mustelus antarcticus*) preferred areas of less steep reef while Splendid Perch (*C. australis*) preferred areas of more northerly (less exposed) aspect and Southern Red Scorpionfish (*Scorpaena papillosa*) more southerly (exposed) aspect. When compared with Butlers Reef there was,

[6] For this purpose *Caesioperca lepidoptera* and *C. razor* have been combined as *Caesioperca* spp.

however, no consistency in the relationships between reef characteristics of slope, northness, eastness or rugosity for individual species (refer Figure 16).

Depth was an influential variable for many species, with 18 species showing significant (linear or quadratic) responses to depth (Figure 22). Eleven of these species were also found to have significant relationships with depth at Butlers Reef (refer Figure 17) and, with two possible exceptions, the modelled relationships were consistent in terms of depths at which abundances were greatest. Striped Trumpeter (*Latris lineata*) and Silverbelly (*Parequula melbournensis*) were exceptions. The former was most abundant at depths greater than 70 m (albeit based on a small sample size), compared with 40-50 m at Butlers Reef. The latter species was most abundant in the 50-70 m depth range at The Friars, which was substantially deeper than at Butlers Reef. These differences may be more influenced by the limited depth range available at Butlers Reef coupled with small sample sizes rather than being biologically meaningful. The prevalence of Southern Calamari (*Sepioteuthis australis*) at depths of over 60 m at The Friars indicates that this species occupies a wider habitat range than previously suggested, noting that the fishery for this species is largely restricted to relatively sheltered, shallow inshore waters, often associated with areas of seagrass (Emery *et al*. 2017).

Twenty-four of the 30 reef species present at The Friars showed a significant correlation to at least one other species in their response to the reef characteristics (Figure 23). Most of the correlations between species were positive. The shallow water species, Senator Wrasse (*Pictilabrus laticlavius*), Purple Wrasse and Bluethroat Wrasse (*Notolabrus tetricus*), were, however, exceptions and each tended to be negatively correlated in their responses to reef characteristics to the deeper water species. After accounting for reef characteristics, none of the species were seen to have negative species interactions at The Friars, (Figure 24). Overall, the strong negative correlations between shallow and deeper water species to reef characteristics observed at The Friars was consistent with the pattern observed at Butlers Reef (Figure18), highlighting the importance of depth in defining the preferred niche for many of the temperate reef species.

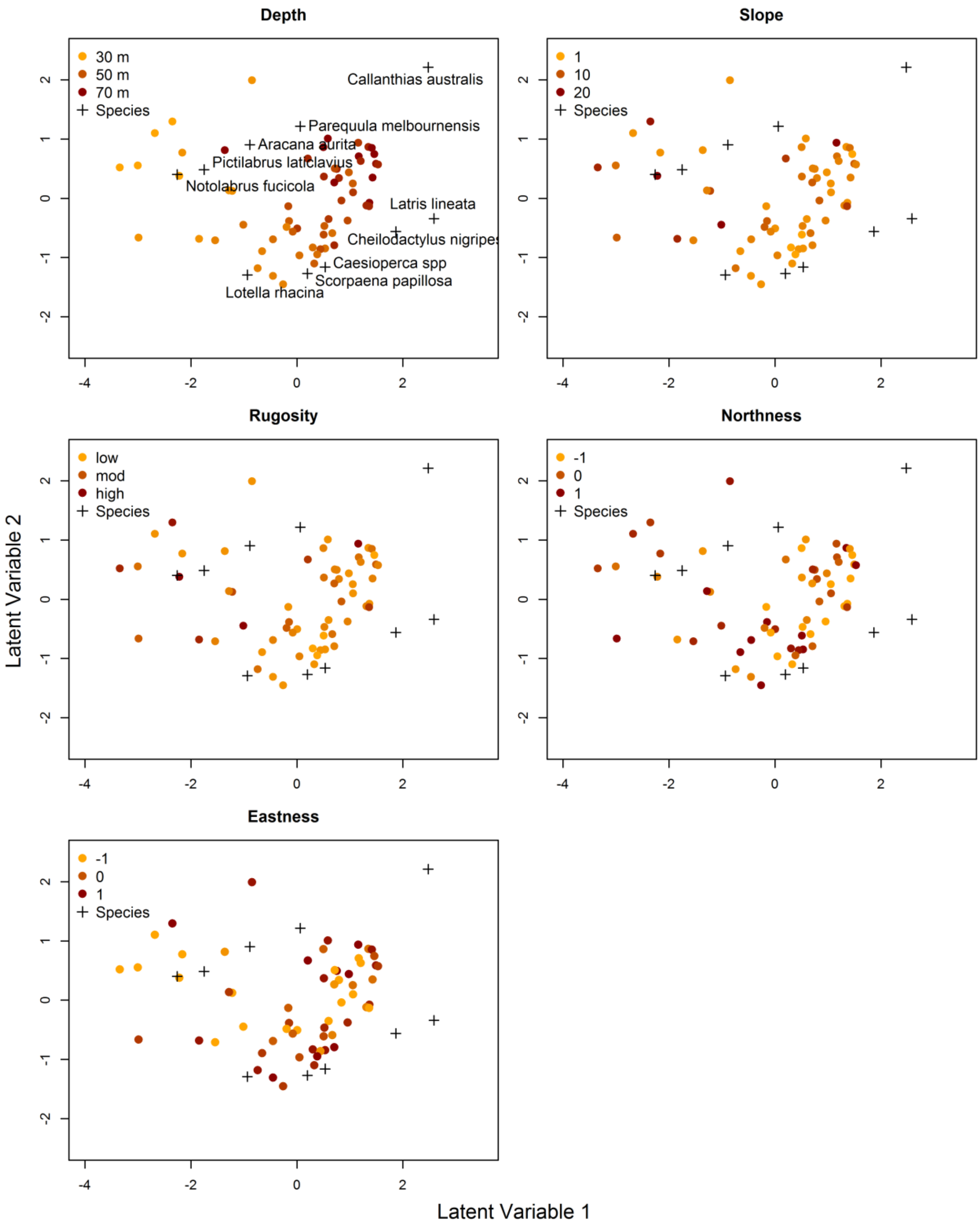


Figure 20. Unconstrained, model-based ordination of the species composition of sites at The Friars sampled in autumn. Each circle represents a BRUVs site and the values of environmental variables are overlaid on sites. The location of the ten most important species are also plotted.

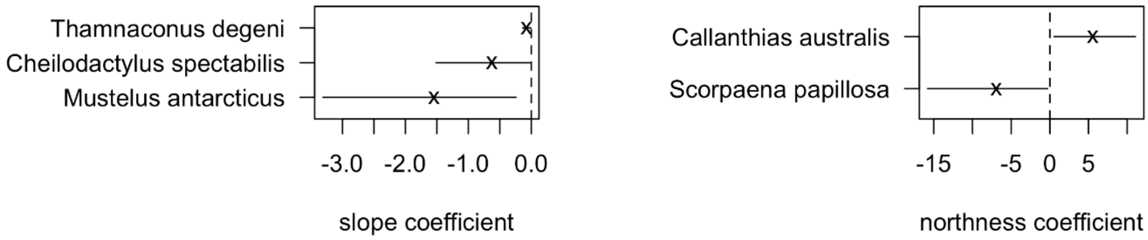


Figure 21. Caterpillar plots, showing the response of each species to reef characteristics at The Friars, via the regression coefficients (indicated by an x) and their 0.95 HPD intervals indicated by a line).
Only species with significant responses are shown. (Rugosity and eastness are not shown as there were no significant coefficients).Those coefficients with positive coefficients indicate a significantly higher abundance of that species at higher levels of the reef characteristic. Species are ordered according to the coefficients.

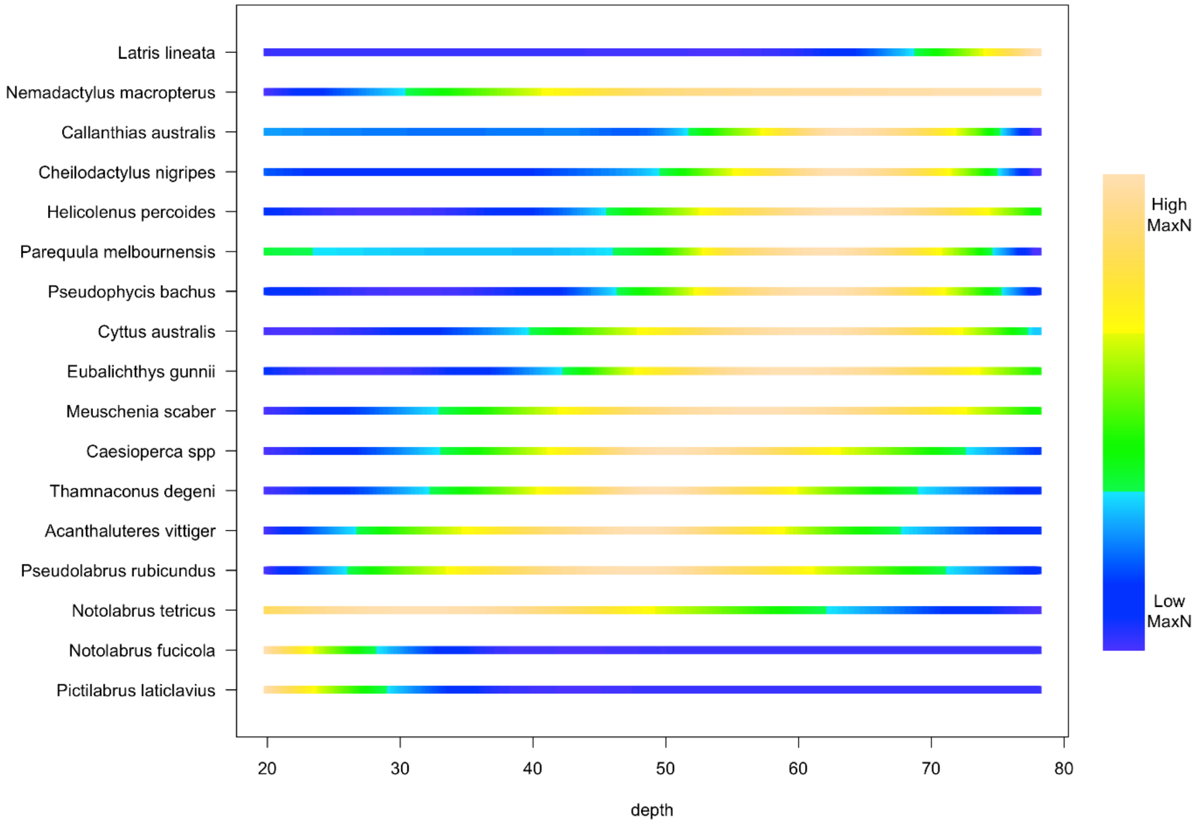


Figure 22. Relationships of species abundance with depth at The Friars. The predicted species abundances from the BORAL model are plotted using topological colours, where orange/green/blue colours indicate higher/medium/lower abundances.
Only species with significant relationships with depth are plotted. Species are ordered according to the depth where maximum abundance is predicted to occur.

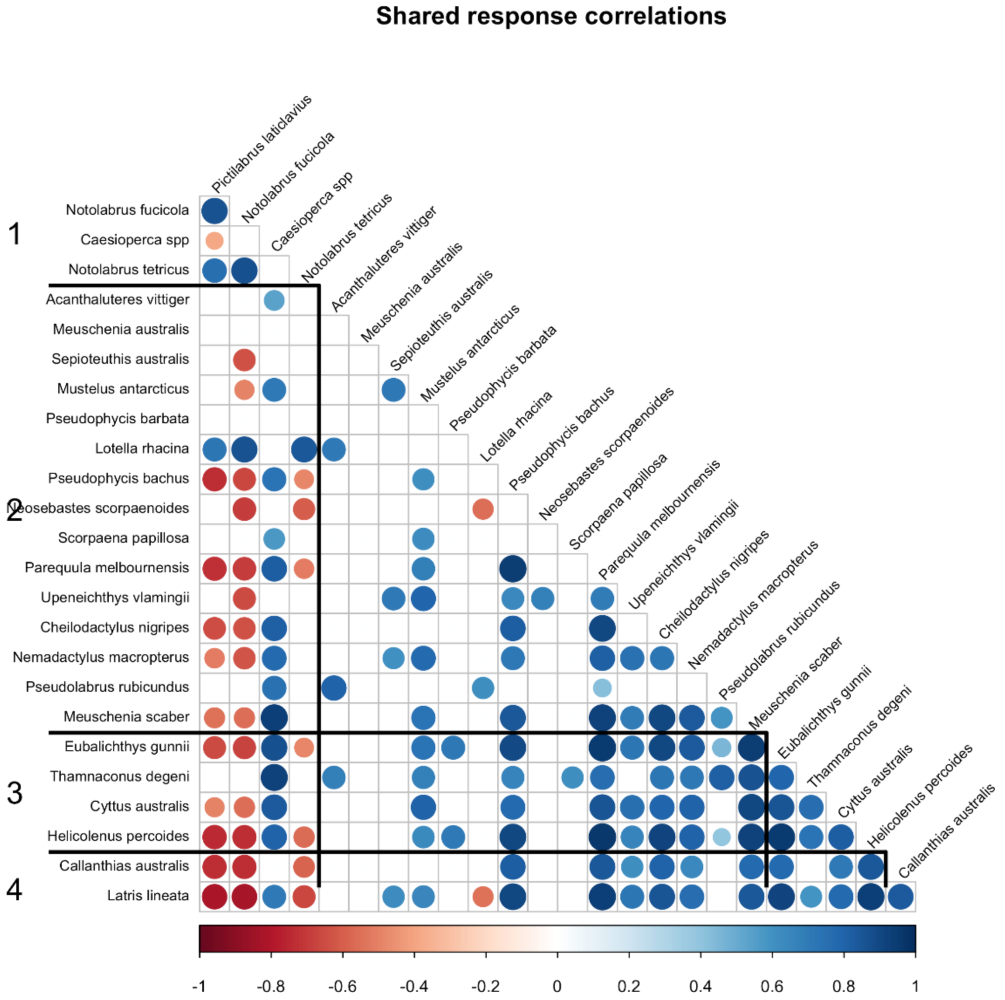


Figure 23. Correlations showing shared responses between species at The Friars.
Refer Figure 18 for explanation.

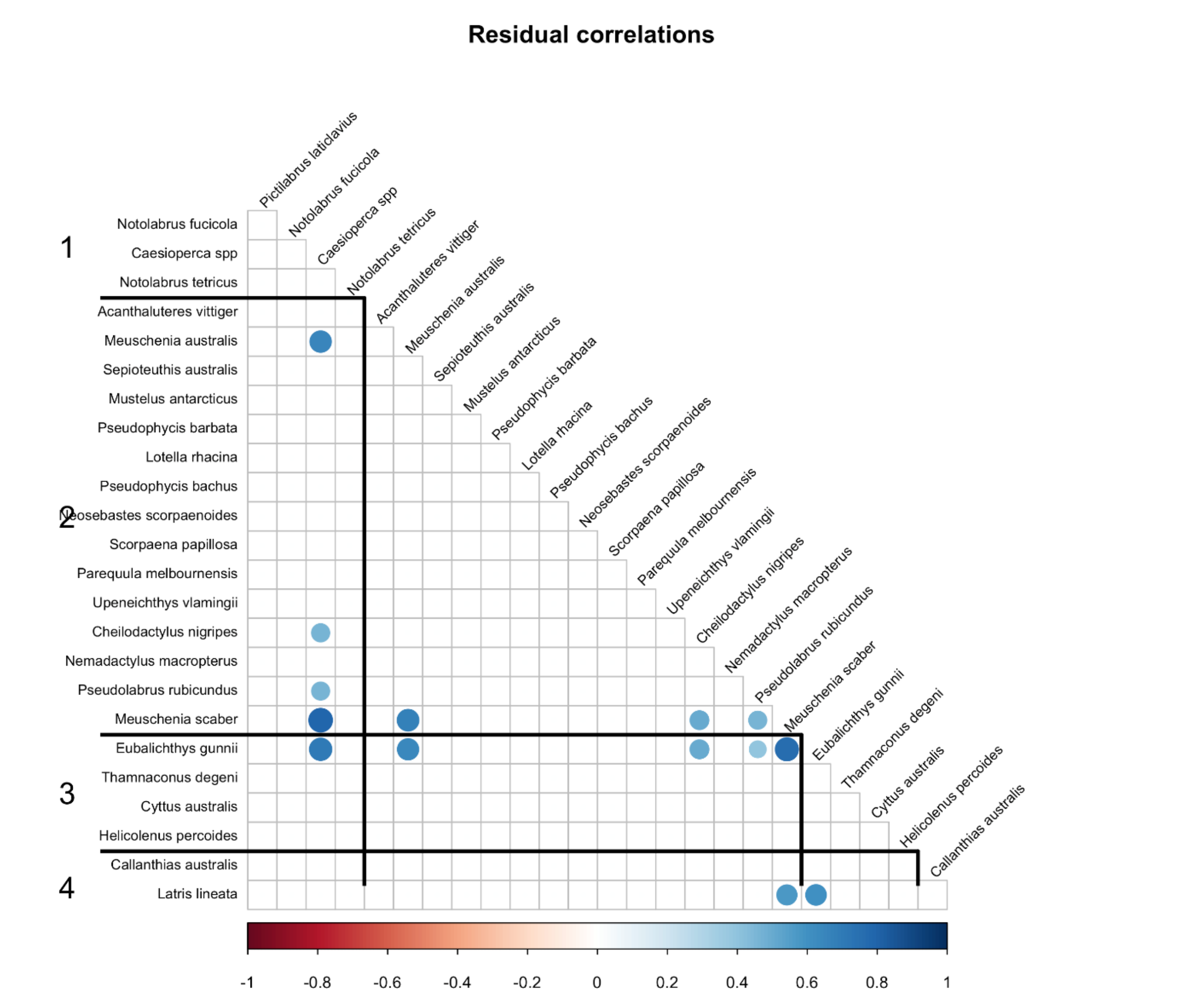


Figure 24. Residual correlations between species, after adjusting for reef characteristics at The Friars. Refer Figure 18 for explanation.

Regional comparison

With the pelagic species excluded, 75 fish and cephalopod species were recorded by BRUVs during autumn surveys conducted at the two reef localities, 40 being common to both and 18 unique to Butlers Reef and 17 to The Friars (Figure 25, Table 5). Half of the species unique to Butlers Reef and virtually all of the species only observed at The Friars were recorded at just one or two sites and in low numbers. Species that were relatively common (≥ 9 sites) and unique to Butlers Reef included Halfbanded Seaperch (*Hypoplectrodes maccullochi*), Grey Morwong (*Nemadactylus douglasii*), White-ear (*Parma microlepis)* and Herring Cale (*Olisthops cyanomelas*); the only species recorded at more than three sites and unique to The Friars was Southern Red Scorpionfish (*Scorpaena papillosa*).

For regional assemblage comparison, species that were recorded at fewer than three sites (out of 123 in the combined dataset) have been excluded, resulting in 46 species considered in the analyses. The majority (36 species) occurred at both locations, with nine unique to Butlers Reef and a single species unique to The Friars.

Unconstrained ordination plots indicate that there are patterns in community composition that are mainly related to locality and depth (Figure 26). Herring Cale, Old Wife (*Enoplosus armatus*) and

Bigscale Bullseye (*Pempheris multiradiata*) were more common at Butlers Reef, while Gummy Shark (*Mustelus antarcticus*), Southern Red Scorpionfish and Bluefin Leatherjacket (*Thamnaconus degeni*) more common at The Friars. Species such as Barred Grubfish (*Parapercis allporti*) and Splendid Perch (*Callanthias australis*) appeared to be indicative of deeper depths while Purple Wrasse (*Notolabrus fucicola*) was indicative of shallower depths. These patterns were formally tested by including region and environmental variables in the BORAL analysis.

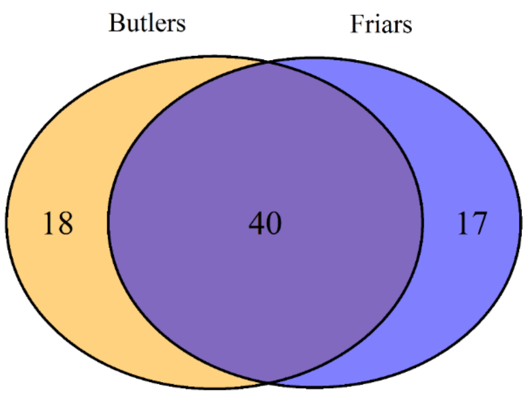


Figure 25. Venn diagram showing the number of species unique to each location and common to both based on autumn BRUVs surveys.

Table 5. List of species unique to each location and common to both. Numbers in brackets indicate the total *maxN* across all sites followed by the number of sites (out of 123 across both regions) in which the species was recorded.

Butlers Reef	Common		The Friars
Centroberyx affinis (1/1)	*Acanthaluteres vittiger (79/53)*	*Meuschenia venusta (2/2)*	*Aplodactylus arctidens (2/2)*
Chrysophrys auratus (1/1)	*Aracana aurita (15/15)*	*Mustelus antarcticus (9/7)*	*Asymbolus rubiginosus (1/1)*
Enoplosus armatus (7/5)	*Caesioperca spp (5425/114)*	*Myliobatis australis (2/2)*	*Atelomycterus spp (1/1)*
Heterodontus portusjacksoni (1/1)	*Callanthias australis (195/24)*	*Nemadactylus macropterus (174/88)*	*Chironemus maculosus (2/1)*
Hypoplectrodes maccullochi (19/17)	*Cephaloscyllium laticeps (69/53)*	*Neosebastes scorpaenoides (24/21)*	*Heteroclinus johnstoni (1/1)*
Meuschenia spp (2/1)	*Cheilodactylus nigripes (14/10)*	*Notolabrus fucicola (22/13)*	*Latridopsis forsteri (2/2)*
Nelusetta ayraud (1/1)	*Cheilodactylus spectabilis (42/37)*	*Notolabrus tetricus (245/112)*	Leatherjacket spp *(1/1)*
Nemadactylus douglasii (18/15)	*Conger verreauxi (11/10)*	*Notorynchus cepedianus (2/2)*	*Nemadactylus valenciennesi (1/1)*
Olisthops cyanomelas (12/9)	*Cyttus australis (46/38)*	*Paratrachichthys macleayi (73/15)*	Octopus spp *(1/1)*
Ophthalmolepis lineolata (7/7)	*Dasyatis brevicaudata (4/4)*	*Parequula melbournensis (12/10)*	*Omegophora armilla (1/1)*
Parapercis allporti (7/4)	*Dinolestes lewini (374/51)*	*Pentaceropsis recurvirostris (7/7)*	*Pinnoctopus cordiformis (1/1)*
Parma microlepis (12/12)	*Diodon nicthemerus (4/3)*	*Pictilabrus laticlavius (49/38)*	*Platycephalus bassensis (2/2)*
Pempheris multiradiata (10/6)	*Eubalichthys gunnii (70/55)*	*Pseudolabrus rubicundus (2285/122)*	*Pseudocaranx georgianus (1/1)*
Pristiophorus nudipinnis (2/2)	*Eubalichthys mosaicus (7/7)*	*Pseudophycis bachus (66/28)*	*Scorpaena papillosa (4/4)*
Sepia apama (1/1)	*Helicolenus percoides (170/60)*	*Pseudophycis barbata (56/36)*	*Suezichthys aylingi (1/1)*
Seriolella brama (23/1)	*Latris lineata (53/21)*	*Sepioteuthis australis (78/39)*	*Trygonorrhina fasciata (1/1)*
Sphyraena novaehollandiae (2/2)	*Lotella rhacina (21/19)*	*Spiniraja whitleyi (3/3)*	Urolophidae spp *(1/1)*
Urolophus cruciatus (3/3)	*Meuschenia australis (122/88)*	*Thamnaconus degeni (769/71)*	
	Meuschenia freycineti (99/55)	*Upeneichthys vlamingii (46/33)*	
	Meuschenia scaber (1154/106)	*Urolophus paucimaculatus (2/2)*	

Twenty-five out of the 46 species (54%) had a significant response to region (Figure 27), indicating that assemblages were quite different between regions. Many of the responses were negative, indicating lower abundance and occurrence of many species at The Friars. Some of the species, including Old Wife, Halfbanded Seaperch, Grey Morwong, White-ear, Bigscale Bullseye and Banded Stingaree (*Urolophus cruciatus)* were only found at Butlers Reef. Others, such as Longfin Pike (*Dinolestes lewini*), Sixspine Leatherjacket (*Meuschenia freycineti),* Senator Wrasse (*Pictilabrus laticlavius*) and Splendid Perch were more commonly recorded and abundant at Butlers Reef. Only Bluefin Leatherjacket, Southern Calamari (*Sepioteuthis australis*) and Rosy Wrasse (*Pseudolabrus rubicundus*) were more abundant at The Friars. Of the commercially and recreationally significant fish species, Striped Trumpeter (*Latris lineata*) and Bluethroat Wrasse (*Notolabrus tetricus*) were significantly more abundant at Butlers Reef.

Generally, species that were significantly more abundant at Butlers Reef tended to have distributional ranges that extended into the warmer waters of mainland Australia. In fact several of these species, including Old Wife, White-ear, Grey Morwong, Southern Maori Wrasse (*Ophthalmolepis lineolata*), Herring Cale and Halfbanded Seaperch, are considered to have expanded their distributional ranges southwards or increased in abundances as a response to ocean warming in Tasmanian waters (Last *et al*. 2011).

Reflecting the importance of depth in influencing the patterns in community composition at the scale of the individual reef, depth was also highly influential in the combined dataset. Twenty-seven species (59%) showed significant (linear or quadratic) responses to depth (Figure 28). Interestingly, however, species such as Southern Calamari, Silverbelly (*Parequula melbournensis),* Toothbrush Leatherjacket (*Acanthaluteres vittiger*), Grey Morwong, Longfin Pike, and Longsnout Boarfish (*Pentaceropsis recurvirostris*) for which significant relationships were evident at the individual reef scale were not included in this group (refer Figures 17 and 22). While artefacts due to sampling cannot be discounted, noting that some sample sizes are small, these results suggest that the association between depth and abundance is likely to be complex and mediated by a range of environmental and biological factors unique to each locality. Conversely, for a small number of species, namely Globe fish (*Diodon nicthemerus*), Bluespotted Goatfish (*Upeneichthys vlamingii*) and Largetooth Beardie (*Lotella rhacina*), it was only in the combined dataset that significant responses to depth became evident.

The transition from shallow water (20-30 m) preferred species, e.g. Draughtboard Shark (*Cephaloscyllium laticeps*), Purple Wrasse and Herring Cale, to intermediate depths (40-60 m), e.g. Butterfly/Barber Perch (*Caesioperca* spp), Halfbanded Seaperch, Barred Grubfish, to the deeper water (> 60 m) species, e.g. Common Gurnard Perch (*Neosebastes scorpaenoides*), Globefish and Red Cod (*Pseudophycis bachus*) is clearly evident in Figure 28. In regard to species of significance to fisheries, peak abundances of Purple Wrasse occurred at depths of less than 30 m, Bluethroat Wrasse in the 20-50 m depth range, Jackass Morwong (*Nemdactylus macropterus*) at depths greater than about 40 m and Striped Trumpeter between 45-60 m. The latter species, however, is known to be abundant at much greater depths that suggested here (Tracey and Lyle 2005, Seiler 2013), the present result being influenced by the limited depth range available at Butlers Reef and low numbers sighted at The Friars. Of note, is that even in the combined dataset, Banded Morwong (*Cheilodactylus spectabilis*) was not shown to have a clear depth related trend in this analysis, and hence the depth relationship for this key commercial species is not shown in Figure 28.

Although slope, northness, eastness and rugosity were included in the model, they were significant only for a few species, confirming that region and depth are the most important factors structuring these communities (Figure 27). Most species that responded to slope preferred less steep reef, e.g. Barber and Butterfly Perch (*Caesioperca* spp.), Globefish, Gummy Shark (*Mustelus antarcticus*) and Bluefin Leatherjacket, whereas only Sandpaper Fish (*Paratrachichthys macleayi*) preferred more steeply sloping reef habitat. Sandpaper Fish and Bigscale Bullseye preferred reefs with a more easterly aspect, presumably linked to the fact that they were more abundant at Butlers Reef, whereas Bluefin Leatherjacket, which was more abundant at The Friars, showed a preference for southerly aspect reef.

Although not a common species (refer Appendix Table S1), Mosaic Leatherjacket (*Eubalichthys mosaicus*) appeared to prefer reef with a more easterly and southerly aspect. None of the species showed a significant response to rugosity, a finding consistent with the individual reef analyses.

Species richness, the number of species recorded at a site, was consistently and significantly higher at Butlers Reef compared with The Friars (Figure 29, Table 6). In both regions, species richness increased with depth and decreased with slope, but was unrelated to rugosity, northness or eastness. A similar depth-related trend in species richness was noted by Walsh *et al*. (2017) in BRUV studies conducted off eastern Tasmania over a 5-50 m depth range. This pattern was partly attributed to the obscuring influence of algae at shallower depths (< 20 m), although this remains to be validated by approaches that can account for the algal effect. Our study, which largely excluded depths where macroalgae cover is thickest, suggests that increasing species richness, at least over the depth range examined, is a real phenomenon of cool temperate reef fish communities. Interestingly, the observation of no clear relationship with reef complexity (rugosity) at the species richness level is in contrast with patterns observed in coral reef systems (e.g. Gratwicke and Speight 2005), where there tends to be a strong positive correlation between the two. This may be a real pattern reflecting tropical and temperate contrasts in habitat specialisation of reef fishes, or may simply reflect methodological differences between the studies, with ours using remotely sensed rugosity values from multibeam sonar, and theirs using direct measurement. Further comparisons will be required, utilising similar methodology, to resolve the strength of these relationships in the temperate zone.

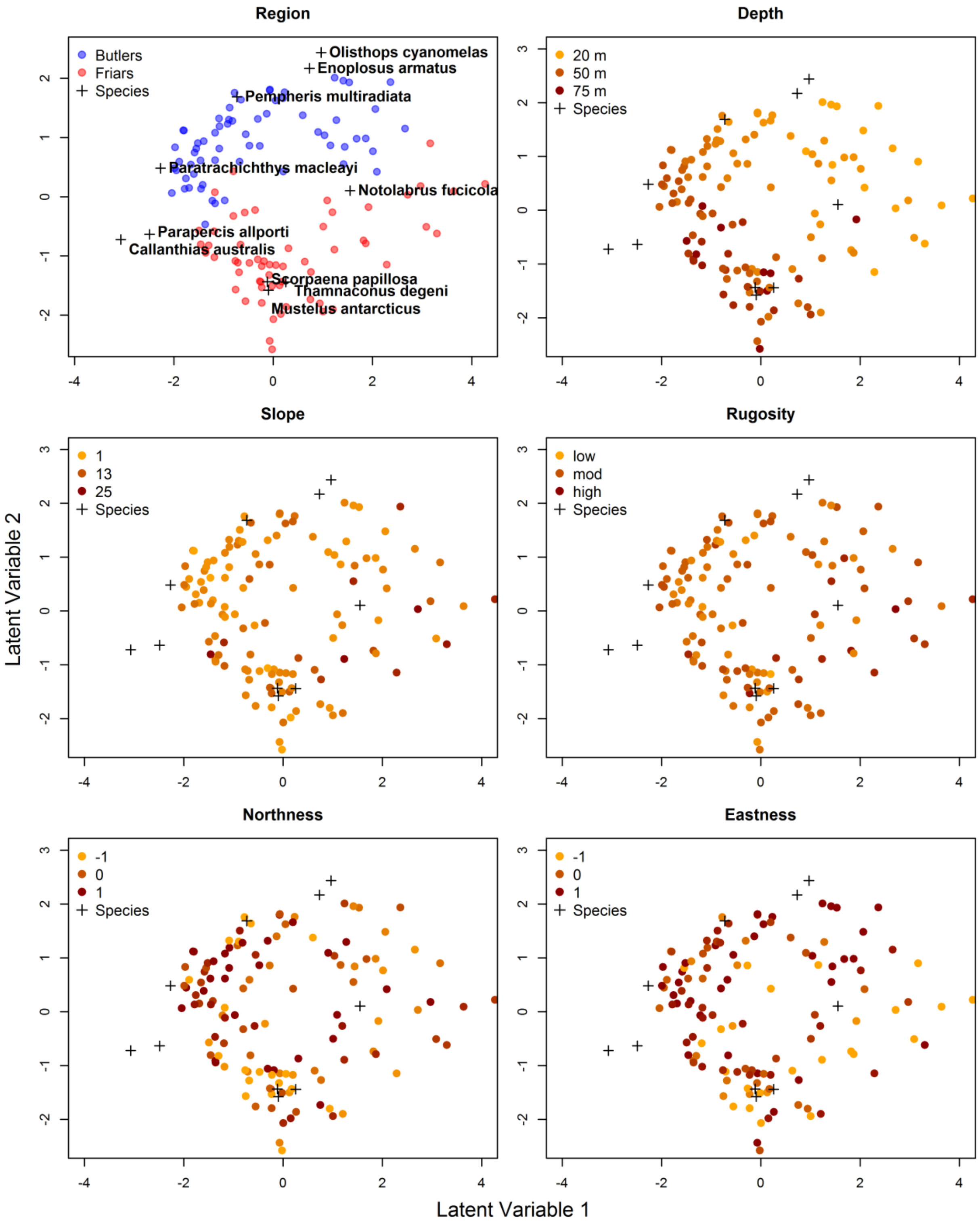


Figure 26. Unconstrained, model-based ordination of the species composition of sites at Butlers and Friars sampled in autumn. Each circle represents a BRUVs site and the region or values of environmental factors are overlaid on sites. The location of the ten most important species are also plotted.

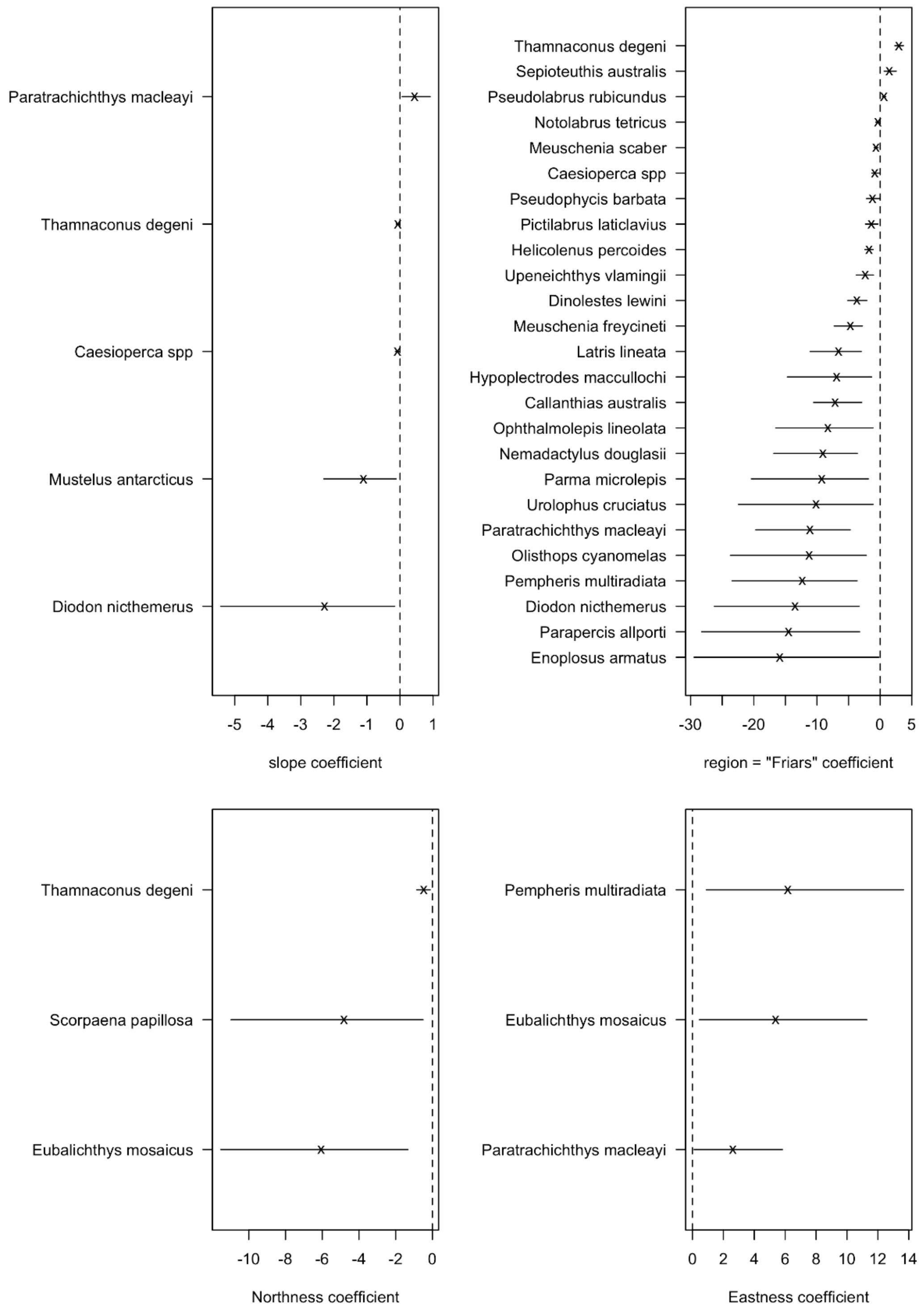


Figure 27. Caterpillar plots, showing the response of each species to reef characteristics, via the regression coefficients (indicated by an x) and their 0.95 HPD intervals indicated by a line.

Only species with significant responses are shown. (Rugosity is not shown as there were no significant coefficients). Positive coefficients indicate a significantly higher abundance of that species at higher levels of the reef characteristic (or at Friars region relative to Butlers region). Species are ordered according to the coefficients.

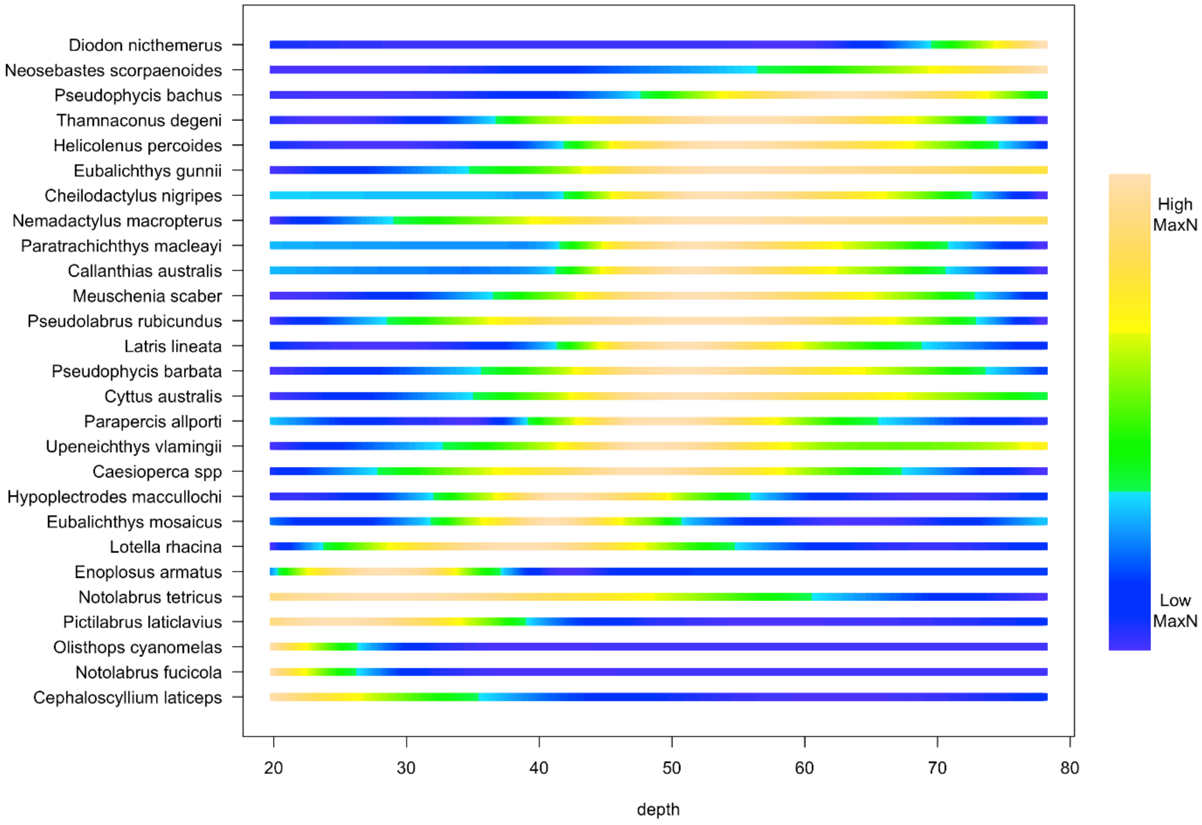


Figure 28. Relationships of species abundance with depth. The predicted species abundances from the BORAL model are plotted using topological colours, where high/medium/low abundances are indicated by orange/green/blue colours, respectively.

Only species with significant relationships with depth are plotted. Species are ordered according to the depth where maximum abundance is predicted to occur.

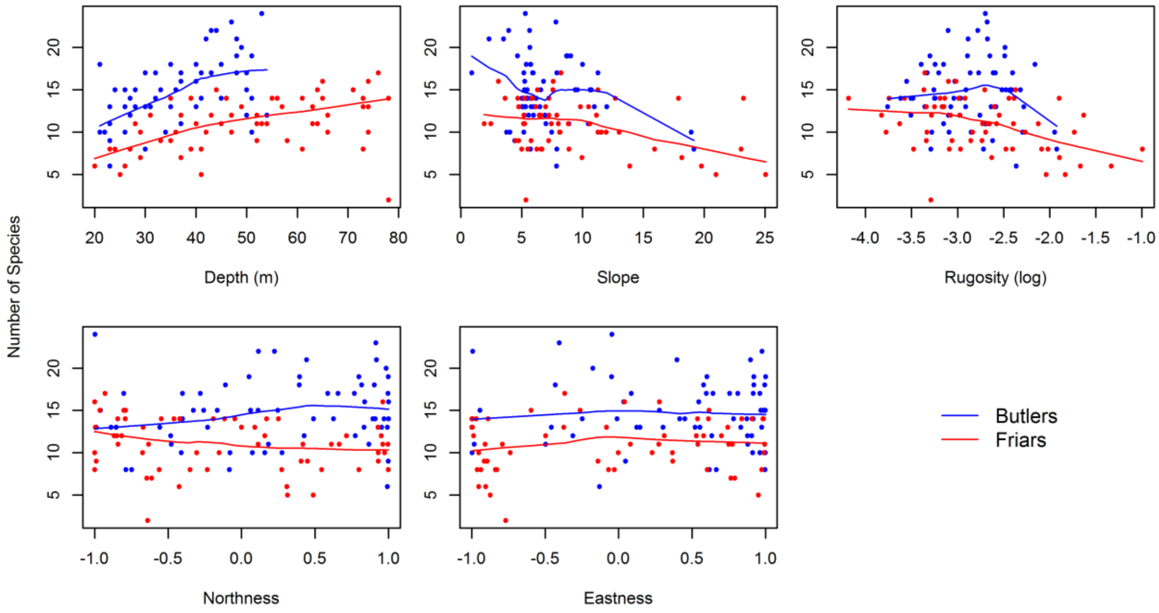


Figure 29. The relationship between species richness (number of species) at Butlers Reef and The Friars sites and their corresponding reef characteristics. Locally weighted Scatterplot Smoothing (LOWESS) lines are plotted for each region to indicate the nature of the relationships.

Table 6. Results of linear model relating species richness to region and reef characteristics.

Term	Estimate	Std. Error	t-value	P- value
(Intercept)	13.851	2.433	5.693	**<0.001**
Region: Friars	-4.797	0.713	-6.727	**<0.001**
Depth	0.121	0.023	5.252	**<0.001**
Slope	-0.200	0.086	-2.331	**0.022**
log(Rugosity)	0.829	0.727	1.140	0.257
Northness	0.187	0.440	0.425	0.671
Eastness	0.324	0.438	0.740	0.461

Seasonal comparison

A same number of species (58) were recorded in the autumn and summer surveys at Butlers Reef, most (46) of which were present in both seasons (Figure 30). Of the species unique to one season, the majority were recorded in low numbers and/or at fewer than three sites (Table 7). Exceptions included Southern Calamari (*Sepioteuthis australis*) and Smooth Stingray (*Dasyatis brevicaudata*) during autumn, and Castelnau's Wrasse (*Dotalabrus aurantiacus*) and Orange Spotted Catshark *(Asymbolus rubiginosus*) during summer. While an incidental observation, a moderately sized school of Blue Warehou (*Seriolella brama*) was observed at one site during autumn, the presence of which corresponds to what has traditionally been the main season for commercial catches of this species.

The naive, unconstrained ordination of sites in both seasons does not account for the paired nature of the design where the same sites were visited in both seasons. However, it does show that there is overlap in the composition of assemblages between seasons, with some site pairs occurring close together in ordination space, while others appear more separated (Figure 31).

The average abundance (*maxN*) of many species was similar across both seasons, whilst some species were found in greater abundance in autumn and fewer were found in greater abundance in summer (Figure 32). Species recorded in at least nine sites (out of 126 across both seasons) were included in the GLM for the interaction between species and season, after accounting for the paired nature of the sampling design (Table 8). This analysis revealed no significant seasonal effect on abundance for the majority (68%) of species. Of those species with seasonal differences, average abundances were higher for Butterfly and Barber Perch (*Caesioperca* spp), Silver Dory (*Cyttus australis*), Longfin Pike (*Dinolestes lewini)*, Grey Morwong (*Nemadactylus douglasii*), Sandpaper Fish (*Paratrachichthys macleayi*), Rosy Wrasse (*Pseudolabrus rubicundus*), Southern Calamari (*Sepioteuthis australis*) and Bluespotted Goatfish (*Upeneichthys vlamingii*) during autumn (Table 8). By contrast, Toothbrush Leatherjacket (*Acanthaluteres vittiger*), Splendid Perch (*Callanthias australis*), Common Gurnard Perch (*Neosebastes scorpaenoides*) and Red Cod (*Pseudophycis bachus*) were more abundant during the summer survey. The ecological significance of such seasonal variability is unclear, with several of the species tending to exhibit strong site attachment (e.g. Rosy Wrasse, Toothbrush Leatherjacket; Barrett 1995a,b) while others are suspected of being long-term residents on home reefs (e.g. Butterfly and Barber Perch and Red Cod; Barrett, pers. obs.). Several of the other species are considered to be relatively mobile (e.g. Longfin Pike, Southern Calamari, Silver Dory and Grey Morwong) and hence are more likely to be variable within a seasonal time scale. The higher abundances of Southern Calamari during autumn may reflect the influx of new recruits following the peak in spawning activity during late spring/summer (Moltschaniwskyj and Pecl 2003). It is also noteworthy that Southern Calamari were also common at this time of year at The Friars. Notwithstanding seasonal variability in the abundance of some species, it is clear that the community composition was relatively stable and that a snapshot survey is likely to be representative of the key elements of the reef fish community. This is likely to be a realistic assumption as shallow-water (<20 m) eastern Tasmanian reef fish assemblages have been shown to be relatively stable over decadal time scales (Barrett *et al.* 2007, Stuart-Smith *et al.* 2010).

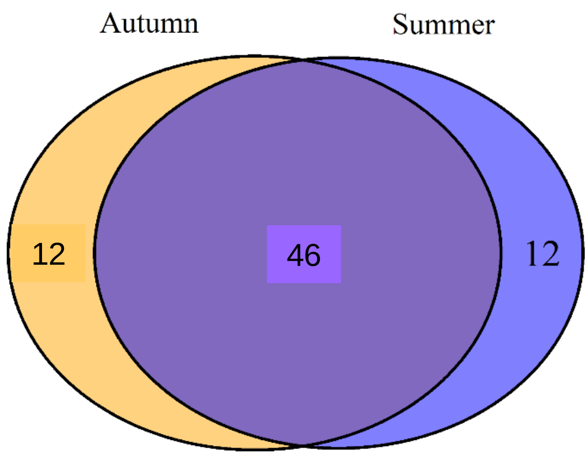


Figure 30. Venn diagram showing the number of species unique to each season and common to both seasons at Butlers.

Table 7. List of species unique to each season and common to both seasons at Butlers. Numbers in brackets indicate the total *maxN* across all sites followed by the number of sites (out of 126 across both seasons) where the species was recorded.

Autumn	Common		Summer
Chrysophrys auratus (1/1)	*Acanthaluteres vittiger (110/77)*	*Nemadactylus douglasii (20/17)*	*Aplodactylus arctidens (1/1)*
Dasyatis brevicaudata (3/3)	*Aracana aurita (8/8)*	*Nemadactylus macropterus (164/94)*	*Asymbolus rubiginosus (3/3)*
Heterodontus portusjacksoni (1/1)	*Caesioperca spp (6462/126)*	*Neosebastes scorpaenoides (32/27)*	*Dotalabrus aurantiacus (9/4)*
Meuschenia spp. (2/1)	*Callanthias australis (483/38)*	*Notolabrus fucicola (8/8)*	*Eubalichthys bucephalus (2/2)*
Mustelus antarcticus (1/1)	*Centroberyx affinis (8/4)*	*Notolabrus tetricus (321/126)*	*Odacidae spp. (1/1)*
Myliobatis australis (1/1)	*Cephaloscyllium laticeps (86/68)*	*Notorynchus cepedianus (2/2)*	*Parascyllium ferrugineum (1/1)*
Nelusetta ayraud (1/1)	*Cheilodactylus nigripes (14/10)*	*Olisthops cyanomelas (25/22)*	*Pinnoctopus cordiformis (2/2)*
Pristiophorus nudipinnis (2/2)	*Cheilodactylus spectabilis (53/48)*	*Ophthalmolepis lineolata (13/13)*	*Platycephalus bassensis (2/2)*
Sepia apama (1/1)	*Conger verreauxi (4/4)*	*Parapercis allporti (8/5)*	*Pseudocaranx spp. (3/1)*
Seriolella brama (23/1)	*Cyttus australis (41/35)*	*Paratrachichthys macleayi (110/24)*	*Scorpaena papillosa (1/1)*
Sphyraena novaehollandiae (2/2)	*Dinolestes lewini (494/77)*	*Parequula melbournensis (15/14)*	*Suezichthys aylingi (1/1)*
Urolophus paucimaculatus (1/1)	*Diodon nicthemerus (4/3)*	*Parma microlepis (26/26)*	*Trygonorrhina dumerilii (1/1)*
	Enoplosus armatus (13/10)	*Pempheris multiradiata (17/11)*	
	Eubalichthys gunnii (89/69)	*Pentaceropsis recurvirostris (13/11)*	
	Eubalichthys mosaicus (17/17)	*Pictilabrus laticlavius (84/61)*	
	Helicolenus percoides (238/62)	*Pseudolabrus rubicundus (1472/126)*	
	Hypoplectrodes maccullochi (34/32)	*Pseudophycis bachus (39/26)*	
	Latris lineata (72/35)	*Pseudophycis barbata (73/41)*	
	Lotella rhacina (41/36)	*Spiniraja whitleyi (2/2)*	
	Meuschenia australis (114/91)	*Thamnaconus degeni (40/29)*	
	Meuschenia freycineti (217/110)	*Upeneichthys vlamingii (60/44)*	
	Meuschenia scaber (1246/115)	*Urolophus cruciatus (4/4)*	
	Meuschenia venusta (4/4)	*Sepioteuthis australis (10/10)*	

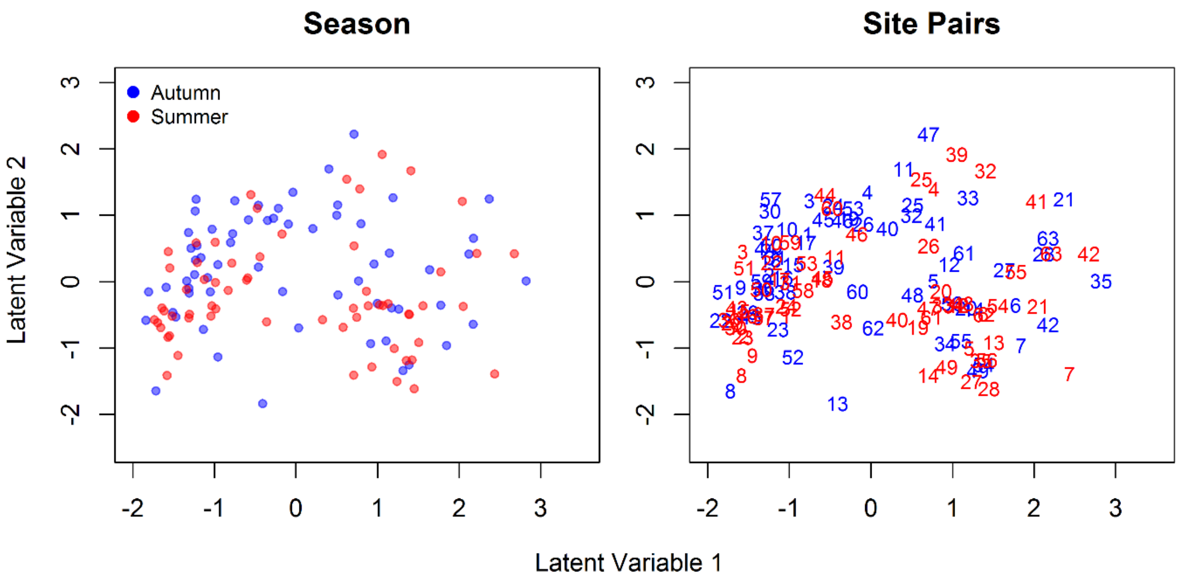


Figure 31. Unconstrained naive ordination of assemblages at BRUV sites sampled at Butlers in autumn and summer. The ordination does not take into account correlation between sites that were visited in both seasons. Site pairs are indicated by the same number in the right-hand plot.

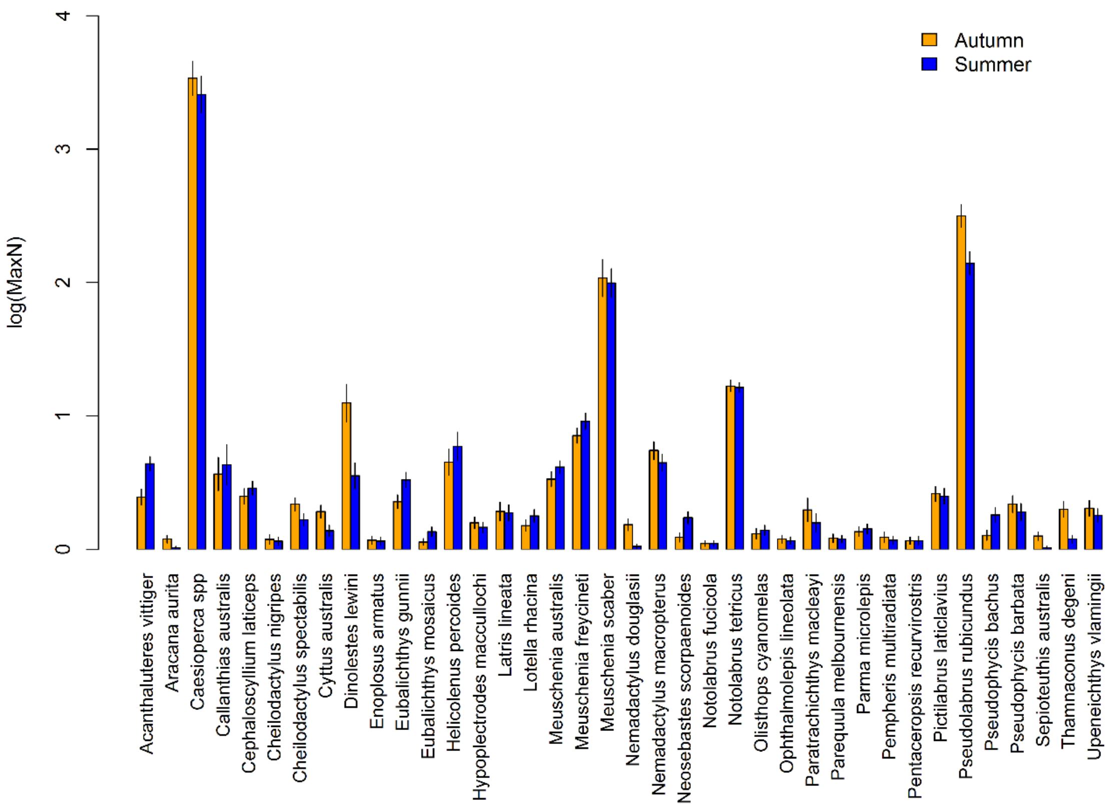


Figure 32. Abundance of each species in each season across all sampling sites at Butlers Reef. Values are the log of the average *maxN* and the error bars are standard errors.

Table 8. Results of the GLM for the interaction between species and season. The interaction is relative to autumn, with positive estimates indicating a higher abundance in summer and negative estimates indicating a higher abundance in autumn.

Species	Estimate	Std. Error	z-value	P- value
Acanthaluteres vittiger	0.496	0.212	2.335	**0.020**
Aracana aurita	-1.949	1.085	-1.797	0.072
Caesioperca spp	-0.162	0.071	-2.275	**0.023**
Callanthias australis	0.381	0.162	2.349	**0.019**
Cephaloscyllium laticeps	0.112	0.231	0.484	0.628
Cheilodactylus nigripes	-0.268	0.568	-0.472	0.637
Cheilodactylus spectabilis	-0.432	0.294	-1.469	0.142
Cyttus australis	-0.679	0.344	-1.975	**0.048**
Dinolestes lewini	-1.194	0.158	-7.575	**0.000**
Enoplosus armatus	-0.141	0.581	-0.243	0.808
Eubalichthys gunnii	0.442	0.232	1.908	0.056
Eubalichthys mosaicus	0.889	0.550	1.616	0.106
Helicolenus percoides	0.255	0.164	1.553	0.120
Hypoplectrodes maccullochi	-0.232	0.363	-0.640	0.522
Latris lineata	-0.153	0.268	-0.570	0.569
Lotella rhacina	0.352	0.332	1.059	0.289
Meuschenia australis	0.153	0.201	0.758	0.449
Meuschenia freycineti	0.187	0.153	1.219	0.223
Meuschenia scaber	-0.164	0.093	-1.764	0.078
Nemadactylus douglasii	-2.203	0.758	-2.905	**0.004**
Nemadactylus macropterus	-0.188	0.176	-1.069	0.285
Neosebastes scorpaenoides	0.970	0.413	2.352	**0.019**
Notolabrus fucicola	0.000	0.740	0.000	1.000
Notolabrus tetricus	-0.031	0.130	-0.239	0.811
Olisthops cyanomelas	0.112	0.423	0.264	0.791
Ophthalmolepis lineolata	-0.159	0.582	-0.273	0.785
Paratrachichthys macleayi	-0.676	0.273	-2.475	**0.013**
Parequula melbournensis	-0.122	0.542	-0.226	0.821
Parma microlepis	0.159	0.411	0.386	0.700
Pempheris multiradiata	-0.353	0.533	-0.662	0.508
Pentaceropsis recurvirostris	0.108	0.581	0.186	0.853
Pictilabrus laticlavius	-0.016	0.237	-0.066	0.947
Pseudolabrus rubicundus	-0.384	0.087	-4.409	**0.000**
Pseudophycis bachus	0.946	0.375	2.522	**0.012**
Pseudophycis barbata	-0.141	0.257	-0.547	0.585
Sepioteuthis australis	-2.200	1.067	-2.062	**0.039**
Thamnaconus degeni	-1.549	0.433	-3.577	**0.000**
Upeneichthys vlamingii	-0.290	0.282	-1.026	0.305

Comparison of video sampling methods

Fourteen Butlers Reef sites were sampled with both BRUVs and ROV in autumn and again in summer, with the BRUVs drops consistently recording more species compared to the ROV transects (Figure 33). However, most of the species that were recorded exclusively by one method tended to be observed at just one or two sites (i.e. 20 of the 23 and 14 of the 17 species recorded in autumn and summer surveys, respectively, refer Table 9 and Appendix Table S4). During autumn, Draughtboard Shark (*Cephaloscyllium laticeps*), Silver Dory (*Cyttus australis*), Bluefin Leatherjacket (*Thamnaconus degeni)* and Striped Trumpeter (*Latris lineata)* were the only species recorded exclusively at more than two sites by BRUVs. Species unique to the ROV included Marblefish (*Aplodactylus arctidens*) in autumn and Castelnau’s Wrasse (*Dotalabrus aurantiacus*) in summer, the former being herbivorous and thus unlikely to be attracted to the bait station.

The naive unconstrained ordination of autumn samples, showed distinct differences between the community compositions (based on abundance) sampled with BRUV and ROV (Figure 34). Because BRUVs use *maxN* as the measure of abundance, which is recognised as being a conservative estimate of abundance, we may expect that for many species this difference may be driven by the ROV recording higher total abundances. Interestingly, for many species this was not the case (Figure 35). GLM results, that take into account the paired nature of the design indicate that for just under half of the species there was no difference in abundance estimates between methods (Table 10). Several species in this category are not necessarily attracted to bait but tended to be observed more or less incidentally by both methods, examples include Banded Morwong (*Cheilodactylus spectabilis*), Longsnout Boarfish (*Pentaceropsis recurvirostris)* and Bigscale Bullseye (*Pempheris multiradiata*). Not unexpectedly, estimates of abundance for a number of species that are actively attracted to fish bait were greater in the BRUV samples; these include Longfin Pike (*Dinolestes lewini*), Reef Ocean Perch (*Helicolenus percoides*), Brownstriped Leatherjacket (*Meuschenia australis*), Sixspine Leatherjacket (*M. freycineti*), Velvet Leatherjacket (*M. scaber*), and Jackass Morwong (*Nemadactylus macropterus*). Species such as Toothbrush Leatherjacket (*Acanthaluteres vittiger*), Butterfly and Barber Perch (*Caesioperca* spp), Splendid Perch (*Callanthias australis*), Bluethroat Wrasse (*Notolabrus tetricus*) and Rosy Wrasse (*Pseudolabrus rubicundus*) however, were consistently recorded in higher abundances in ROV samples (Table 10). When considering relative composition, i.e. the proportion of individuals of each species recorded by each gear, there were significant differences for all but two species, Toothbrush Leatherjacket and Southern Maori Wrasse (*Ophthalmolepis lineolata*) (Table 10). These differences in proportional representation between methods are strongly influenced by the disproportionately large number of *Caesioperca* spp. recorded in the ROV samples (Figures 35 - 36).

Of particular note was that no Bastard Trumpeter (*Latridopsis forsteri*) were encountered by either the ROV or BRUVs during this comparison (or for that matter over the full sampling program involving BRUVS at Butlers Reef). While this species is not bait-attracted, and hence might not be expected to be sighted routinely by BRUVs, it is normally a commonly encountered species on east coast reef systems (Barrett, pers. obs.) and would have normally been expected to be sighted by either the ROV, or as an incidental background sighting by the BRUVS. While this lack of sightings may relate to a current decline in the abundance of this species in Tasmanian waters (Emery *et al.* 2017), or biases associated with the sampling techniques, resolution of effective sampling of this species at depth is required, potentially through further targeted studies in areas known to host moderate populations of this species.

At the level of describing species diversity, the two sampling methods provided a consistent representation of the more common and abundant species within the reef fish community. There were, however, some notable differences in the relative abundance of species, which can be related, in part at least, to biases associated with each sampling method. For instance, piscivorous species were seen in relatively higher abundances compared with the ROV while the ROV was more likely to encounter rarer, cryptic and mobile species that were not bait attracted, including planktivores and herbivores. An additional point of difference between methods relates to spatial and temporal coverage, with the

ROV covering a 150 m transect whereas the BRUVs record fish activity at a defined site over a period of one-hour. Further work is needed to fully explore the cost effectiveness of each method for describing overall fish assemblages; in particular recognising the logistic considerations related to conducting standardised transects at depth using the ROV set against higher post processing costs for BRUV deployments. While not a focus of this study, the time taken to process BRUV video was approximately 4 hours for each drop (one hour recording) compared with approximately half an hour of processing for each ROV deployment.

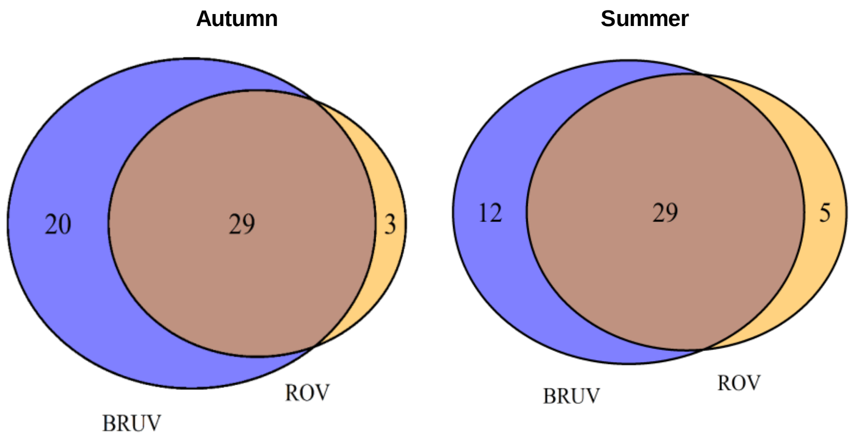


Figure 33. Venn diagrams showing the number of species unique to each and common to both ROV and BRUVs at 14 sites sampled by both gears at Butlers Reef in autumn and summer.

Table 9. List of species unique to ROV and BRUVs and common to both gear types at fourteen sites sampled by both gears at Butlers in autumn. Numbers in brackets indicate the number of sites where the species was recorded; for species common to both methods, the first number represents the number of BRUV samples and the second number the number of ROV sites.

BRUV	Common		ROV
Aracana aurita (1)	*Acanthaluteres vittiger (6/6)*	*Neosebastes scorpaenoides (2/1)*	*Aplodactylus arctidens (2)*
Centroberyx affinis (1)	*Caesioperca spp (14/14)*	*Notolabrus tetricus (14/14)*	*Diodon nicthemerus (1)*
Cephaloscyllium laticeps (7)	*Callanthias australis (4/7)*	*Olisthops cyanomelas (2/2)*	*Leatherjacket unident (1)*
Conger verreauxi (2)	*Cheilodactylus nigripes (1/1)*	*Ophthalmolepis lineolata (3/3)*	
Cyttus australis (7)	*Cheilodactylus spectabilis (10/7)*	*Parapercis allporti (1/1)*	
Dasyatis brevicaudata (2)	*Dinolestes lewini (12/4)*	*Paratrachichthys macleayi (4/6)*	
Eubalichthys mosaicus (1)	*Enoplosus armatus (2/1)*	*Parequula melbournensis (1/2)*	
Hypoplectrodes maccullochi (3)	*Eubalichthys gunnii (9/4)*	*Parma microlepis (3/1)*	
Latris lineata (4)	*Helicolenus percoides (6/2)*	*Pempheris multiradiata (3/4)*	
Meuschenia venusta (1)	*Lotella rhacina (4/2)*	*Pentaceropsis recurvirostris (3/3)*	
Mustelus antarcticus (1)	*Meuschenia australis (10/2)*	*Pictilabrus laticlavius (5/1)*	
Nemadactylus douglasii (2)	*Meuschenia freycineti (11/3)*	*Pseudolabrus rubicundus (14/14)*	
Pristiophorus nudipinnis (1)	*Meuschenia scaber (12/8)*	*Pseudophycis barbata (5/6)*	
Pseudophycis bachus (2)	*Nelusetta ayraud (1/1)*	*Upeneichthys vlamingii (4/3)*	
Sepia apama (1)	*Nemadactylus macropterus (10/4)*		
Sepioteuthis australis (2)			
Sphyraena novaehollandiae (1)			
Spiniraja whitleyi (1)			
Thamnaconus degeni (5)			
Urolophus cruciatus (1)			

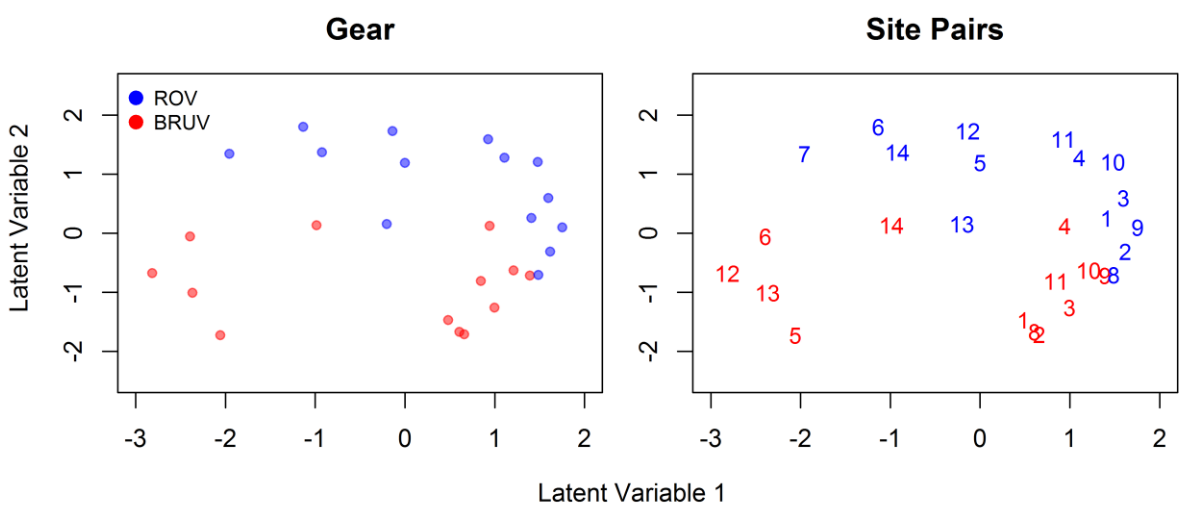


Figure 34. Unconstrained ordination of site sampled with ROV and BRUVs at Butlers in autumn. Blue indicates ROV samples and red indicates BRUV samples, numbers refer to site numbers.

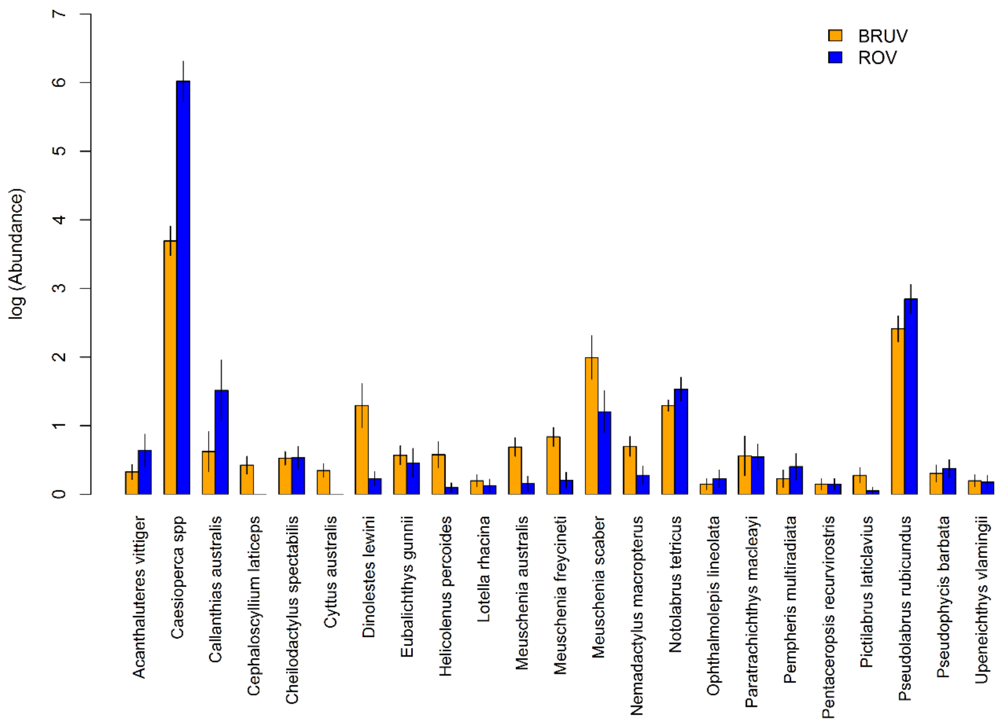


Figure 35. Abundance of each species recorded by each sampling gear across all sampling sites at Butlers Reef in autumn. Values are the log of the average *maxN* for BRUVs and log of total abundance across 3 x 50 m transect for ROV. Error bars are standard errors.

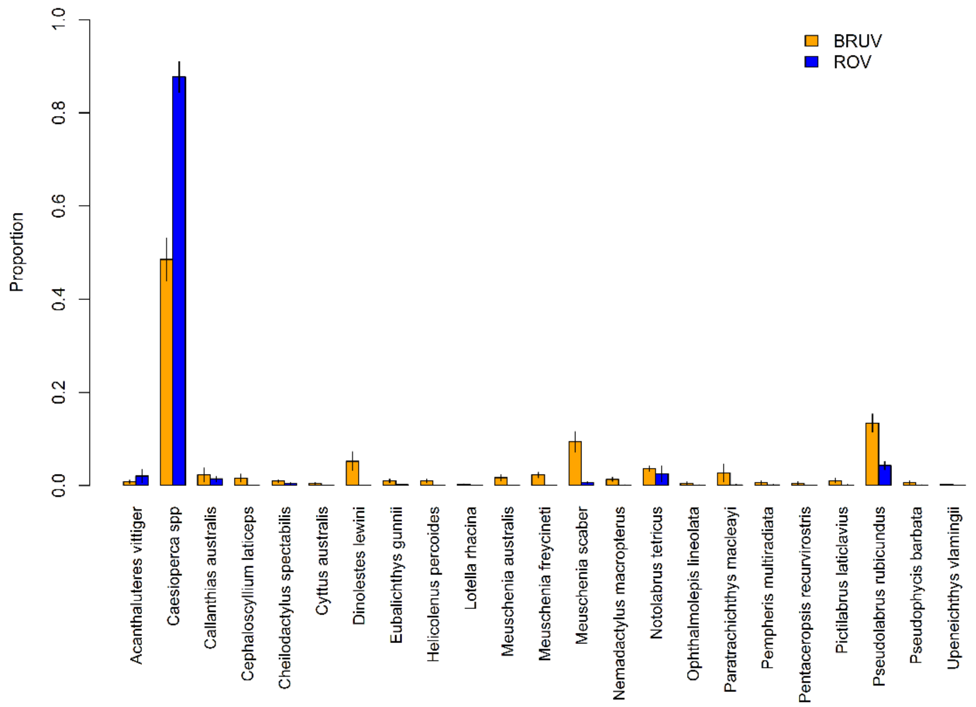


Figure 36. The proportion of individuals of each species recorded by BRUVs and ROV at sampling sites at Butlers Reef in autumn. Values are calculated as the proportion of individuals of each species compared to all individuals recorded at a site for each method (i.e. row standardised). Error bars are standard errors.

Table 10. Results of the GLM for the interaction between species and gear type, after accounting for the paired nature of the sampling design. The interaction is relative to BRUVs, with positive estimates indicating a higher abundance or proportion in the ROV samples and negative estimates indicating a higher abundance or proportion in BRUVS.
* Indicates species that were not recorded in the ROV samples and therefore reliable estimates could not be obtained.

	Count Model				Proportion Model			
Species	**Estimate**	**Std. Error**	**z value**	**P value**	**Estimate**	**Std. Error**	**z value**	**P value**
Acanthaluteres vittiger	1.255	0.444	2.829	**0.005**	0.087	0.452	0.192	0.848
Caesioperca spp	2.401	0.098	24.514	**0.000**	2.428	0.069	35.339	**0.000**
Callanthias australis	1.582	0.231	6.858	**0.000**	-0.475	0.183	-2.597	**0.009**
*Cephaloscyllium laticeps**								
Cheilodactylus spectabilis	0.272	0.409	0.664	0.507	-1.488	0.412	-3.608	**0.000**
*Cyttus australis**								
Dinolestes lewini	-3.154	0.493	-6.395	**0.000**	-4.803	0.460	-10.450	**0.000**
Eubalichthys gunnii	0.174	0.381	0.456	0.648	-1.295	0.366	-3.536	**0.000**
Helicolenus percoides	-2.208	0.760	-2.903	**0.004**	-4.144	0.748	-5.542	**0.000**
Lotella rhacina	-0.306	0.779	-0.393	0.694	-2.151	0.768	-2.798	**0.005**
Meuschenia australis	-1.461	0.567	-2.577	**0.010**	-3.284	0.566	-5.801	**0.000**
Meuschenia freycineti	-1.503	0.509	-2.955	**0.003**	-3.207	0.507	-6.326	**0.000**
Meuschenia scaber	-0.913	0.186	-4.910	**0.000**	-2.824	0.156	-18.069	**0.000**
Nemadactylus macropterus	-0.957	0.459	-2.084	**0.037**	-2.874	0.451	-6.377	**0.000**
Notolabrus tetricus	0.453	0.223	2.031	**0.042**	-1.114	0.215	-5.186	**0.000**
Ophthalmolepis lineolata	0.675	0.726	0.930	0.352	-1.007	0.727	-1.384	0.166
Paratrachichthys macleayi	-0.723	0.337	-2.148	**0.032**	-3.109	0.297	-10.454	**0.000**
Pempheris multiradiata	0.815	0.507	1.608	0.108	-1.126	0.496	-2.270	**0.023**
Pentaceropsis recurvirostris	0	0.827	0.000	1.000	-1.75	0.851	-2.056	**0.040**
Pictilabrus laticlavius	-1.799	1.092	-1.647	0.100	-3.556	1.108	-3.211	**0.001**
Pseudolabrus rubicundus	0.493	0.134	3.679	**0.000**	-1.365	0.102	-13.316	**0.000**
Pseudophycis barbata	0.249	0.519	0.479	0.632	-1.498	0.519	-2.884	**0.004**
Upeneichthys vlamingii	-0.012	0.720	-0.017	0.986	-1.937	0.719	-2.692	**0.007**

Population characteristics – key species

General observations

Key species of commercial and recreational significance, namely Banded Morwong (*Cheilodactylus spectabilis*), Jackass Morwong (*Nemadactylus macropterus*), Striped Trumpeter (*Latris lineata*) and Bluethroat Wrasse (*Notolabrus tetricus*), were generally recorded in low abundances, limiting the range and scope of biological analyses that are possible. Bastard Trumpeter (*Latridopsis forsteri*), another species of interest, was captured in very low numbers by gillnet and only two individuals were recorded by the BRUV surveys. Nonetheless, there are some general observations that can be made about these species based on the present study.

Each of the species, with the exception of Banded Morwong, are reported to occur to depths exceeding 150 m (Gomon *et al*. 2008), indicating that suitable habitats may extend beyond the depths of both studied reef systems, even if their optimal habitat is shallower. Consistent with this, Jackass Morwong, Striped Trumpeter and Bluethroat Wrasse were all recorded by BRUVs to the maximum depths at which the gear was deployed (> 75 m). Banded Morwong, by contrast, are reported to occur to a maximum depth of about 50 m (Gomon *et al*. 2008). Although not actively attracted to the BRUVs, being a benthic micro-invertebrate feeder (McCormick 1998, Metcalf *et al*. 2008), Banded Morwong were observed (generally as solitary individuals) over a wider depth range than previously suggested (Figure 37). The greatest depth at which an individual was recorded was 73 m, and since commercial netting for the species is generally limited to a maximum of 25-30 m depth, these data support the hypothesis that part of the population may experience some degree of protection by way of a depth refuge (Ziegler *et al*. 2006). The significance of such a refuge for the sustainability of the fishery will be determined by rate of movement across depths (mixing) and the proportion of the stock biomass present at the greater depths. While the current study was unable to directly address these considerations, it has confirmed the possibility of a depth refuge benefit for Banded Morwong, albeit one likely to be significantly reduced at depths of 55 m or more (Figures. 37 and 40).

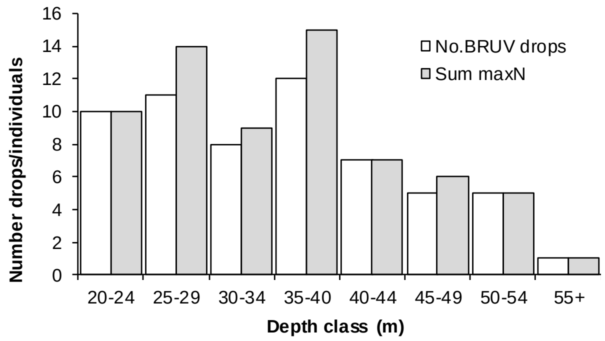


Figure 37. Sum of *maxN* for Banded Morwong and number of BRUV drops by depth class at which the species was recorded (based on the combined BRUV dataset).

Size composition

Size composition data was available for BRUVs and gillnets, although sample sizes for the latter were too small to justify any detailed analyses. Length frequency distributions for Banded Morwong, Jackass Morwong, Striped Trumpeter and Bluethroat Wrasse are presented in Figure 38 and summarised in Table 11.

Recognising that depth is a significant factor in the community analyses, size composition data were separated into shallow (< 40 m) and deep (40 m+) strata to investigate potential size segregation by depth (Table 11). With the exception of Jackass Morwong, mean sizes and length frequency distributions were not significantly different based on the depth, providing no evidence of population structuring by depth (Table 11). Although Jackass Morwong were larger on average in the shallow stratum, the shape of the distributions were not significantly different. In general, mean lengths were similar for BRUV and gillnet samples of each species.

Banded Morwong ranged in size from 31-50 cm fork length (FL), which given that the size at 50% maturity occurs about 32 cm (Ziegler *et al*. 2007) suggests that most individuals were mature (Figure 38). While most individuals fell within the legal size range (a slot size limit of 36 to 46 cm applies in Tasmania), sub-legal fish represented just 15% whereas fish over legal size fish accounted for 26% of the sample. This observation implies that the slot size has afforded some protection to the larger (older) individuals in the population, although differences in growth rates and maximum size between the sexes mean that it is males rather than females that receive greater protection due to this management measure (Ewing *et al*. 2007).

Jackass Morwong measured between 19 and 47 cm FL which, based on size at maturity of 25-27 cm (Jordan 1998), indicates that both immature and mature fish were represented (Figure 38). Population structuring with depth has been reported in this species, with juveniles dominating the inner shelf (0-50 m) and juveniles and adults in mid- (50-100 m) and outer- (100-200 m) shelf waters (Jordan 2001). Our data do not show such as clear pattern of structuring with depth but do confirm that juvenile and adults utilise these deeper coastal reef habitats.

Striped Trumpeter ranged from 41 to 69 cm FL, the majority (76%) being smaller than the size at 50% maturity, i.e. 53-54 cm FL (Tracey *et al*. 2007) (Figure 38). Population structuring by depth has been documented in this species, with juveniles and immature individuals most common at depths of less than about 50 m and adults tending to dominate at greater depths (Tracey and Lyle 2005). The present findings are generally consistent with these observations with most of the fish likely to be sub-adults.

The size composition of Bluethroat Wrasse was characterised by a bimodal length frequency distribution, with peaks at about 30 and 45 cm total length (TL)[7] and size range of 14 to 50 cm TL (Figure 38). Bluethroat Wrasse is a protogynous hermaphrodite, with females changing sex to become males. Since the species exhibits obvious sexual dimorphism in terms of coloration and body shape it was possible to assign sex (or development phase) to each individual observed from the video data (Figure 39). The mode of smaller fish was more or less exclusively female whereas the mode of larger individuals was predominately comprised of males. By examining sex ratios by length class, the transition from female to male was clearly evident, with the transition commencing at about 32 cm (transitional) and effectively completed by about 42 cm. Commercial fishery data suggest that the transition occurs at smaller sizes in Victorian waters, commencing at sizes as small as 25 cm TL and males dominating size classes above 35 cm TL (Smith *et al*. 2003). It is feasible that, in addition to reflecting regional differences in population dynamics, high exploitation rates and a lower minimum size limit in Victoria (28 cm in Victoria compared with 30 cm in Tasmania) may have resulted in females transitioning at smaller sizes to replace males removed by fishing. A long-term study of Bluethroat Wrasse populations in South Australia found that mean female size and sex ratios were influenced by fishing pressure, suggesting that these parameters may be a useful indicator of localised fishing pressure (Shepherd *et al*. 2010). In the absence of time series data it is uncertain whether fishing has had an impact on the size at transition in Tasmanian populations, although Barrett (1995a) found that a heavily fished Tasmanian population (netting bycatch) transitioned as low as 25 cm TL, relative to more remote populations that transitioned at sizes above 32 cm TL.

Table 11. Size composition summaries for species of commercial and recreational significance, based on comparison of mean size (ANOVA) and shape of the distribution (Kolmogorov–Smirnov [KS] test) by depth category for BRUV data.

	BRUVS											Gillnet		
	<40 m			40 m+			ANOVA		KS Test					
Species	**No.**	**Mean**	**SD**	**No.**	**Mean**	**SD**	**F**	**Sign**	**D-stat**	**D-crit**	**Sign**	**No.**	**Mean**	**SD**
Cheilodactylus spectabilis	24	40.8	5.4	10	42.7	3.9	1.061	ns	0.267	0.512	ns	9	43.5	5.5
Nemadactylus macropterus	71	33.0	4.3	144	31.5	4.5	5.752	**0.017**	0.144	0.197	ns	9	34.5	3.5
Latris lineata	7	53.3	7.7	68	50.5	6.2	1.222	ns	0.298	0.540	ns	5	54.5	6.6
Notolabrus tetricus	196	35.3	7.8	181	36.6	7.5	2.610	ns	0.079	0.140	ns	18	35.9	5.0

[7] As the caudal fin in Bluethroat Wrasse is truncate the length measurement is total length.

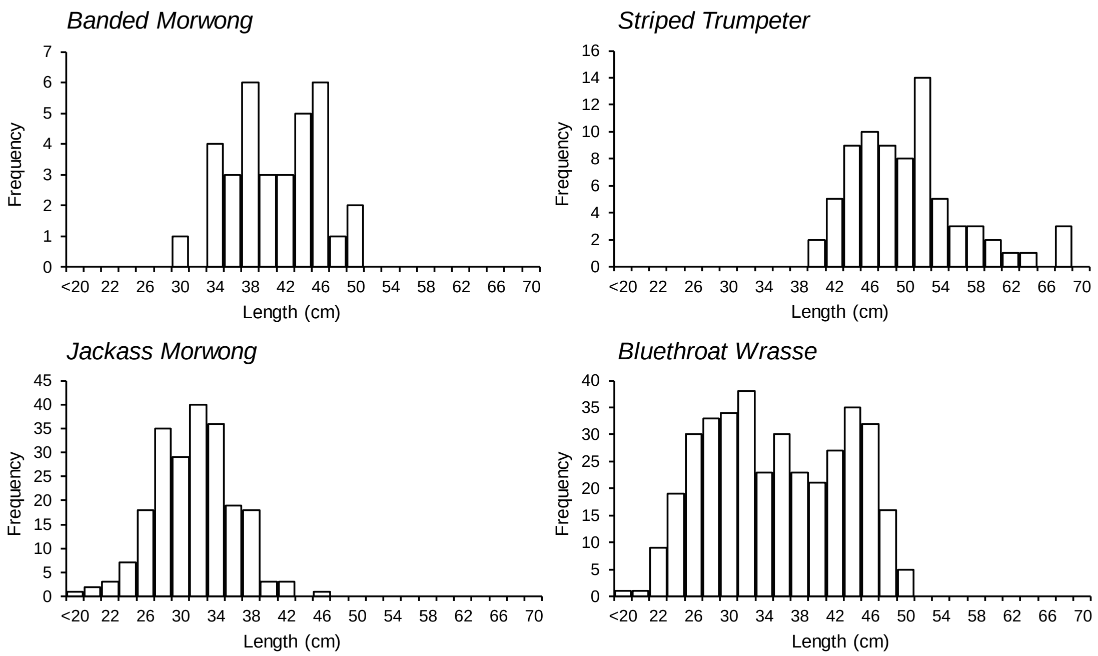


Figure 38. Length frequency distributions Banded Morwong (*Cheilodactylus spectabilis*), Jackass Morwong (*Nemadactylus macropterus*), Striped Trumpeter (*Latris lineata*) and Bluethroat Wrasse (*Notolabrus tetricus*) based on BRUVs data. Data are presented in 2 cm size classes.

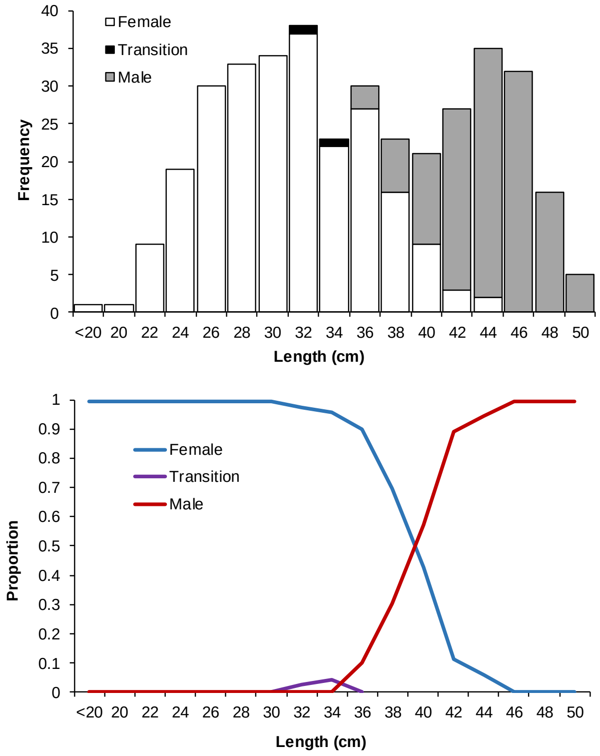


Figure 39. Bluethroat Wrasse length frequency distribution by sex/stage (upper) and proportions of sex/stage by length (lower).

Distribution and abundance

Relative abundance

Mean *maxN*, based on autumn BRUVs surveys, was applied as a proxy for relative abundance for species of commercial and recreational significance along with a range of other ecologically important components of the reef fish community. Species of commercial and recreational significance included Banded Morwong (*Cheilodactylus spectabilis*), Jackass Morwong (*Nemadactylus macropterus*), Striped Trumpeter (*Latris lineata*), Bluethroat Wrasse (*Notolabrus tetricus*) and Reef Ocean Perch (*Helicolenus percoides*). Other species of interest included the dominant monocanthid species - Toothbrush Leatherjacket (*Acanthaluteres vittiger*), Gunn's Leatherjacket (*Eubalichthys gunnii*), Brownstriped Leatherjacket (*Meuschenia australis*), Sixspine Leatherjacket (*M. freycineti*), Velvet Leatherjacket (*M. scaber*) and Bluefin Leatherjacket (*Thamnaconus degeni*) – in addition to Butterfly Perch (*Caesioperca lepidoptera*), Barber Perch (*C. razor*), Longfin Pike (*Dinolestes lewini*), Senator Wrasse (*Pictilabrus laticlavius*), Rosy Wrasse (*Pseudolabrus rubicundus*), Red Cod (*Pseudophycis bachus*), and Bearded Rock Cod (*P. barbata*). Collectively, these species accounted for over 90% of total fish numbers recorded and, with few exceptions, each species was commonly observed (generally at > 40% of BRUVs sites).

Overall and mean relative abundances by region and depth strata are presented in Figure 40 and in Appendix Tables S5 & S6. Despite differences in key reef characteristics, overall weighted mean abundances were similar between the two reef locations for Toothbrush Leatherjacket, Gunn's Leatherjacket, Brownstriped Leatherjacket, Jackass Morwong, Striped Trumpeter, Butterfly Perch and Bearded Rock Cod. Species with significantly higher mean abundances at Butlers Reef included Sixspine Leatherjacket, Bluethroat Wrasse, Senator Wrasse, Banded Morwong, Barber Perch and Longfin Pike whereas Velvet Leatherjacket, Bluefin Leatherjacket, Rosy Wrasse, Reef Ocean Perch and Red Cod were more abundant at The Friars. To some extent, some of these regional differences could be linked to species depth preferences. For example, species with no strong pattern in mean abundance across the range of available depth strata, e.g. Brownstriped Leatherjacket, Jackass Morwong, Butterfly Perch and Bearded Rock Cod, had similar overall regional abundances. By contrast, species that exhibited higher abundances within the shallower depth strata, e.g. Sixspine Leatherjacket, Bluethroat Wrasse, Senator Wrasse, Banded Morwong and Barber Perch, tended to have significantly higher overall mean abundance at Butlers Reef. Conversely, species for which abundance increased with depth, e.g. Velvet Leatherjacket, Reef Ocean Perch and Red Cod; overall mean abundances tended to higher at The Friars. Depth preferences, however, do not fully account for differences between localities, with abundances of some species differing markedly between regions even at similar depths. For instance, mean abundances for Sixspine Leatherjacket, Barber Perch and Longfin Pike at Butlers Reef, and Bluefin Leatherjacket at The Friars were about an order of magnitude higher than at comparable depths in the other region. Ultimately, at the spatial scale of the present study it is clear that interactions between environmental and ecological processes influence the distribution and abundance of individual species, including biogeographical gradients.

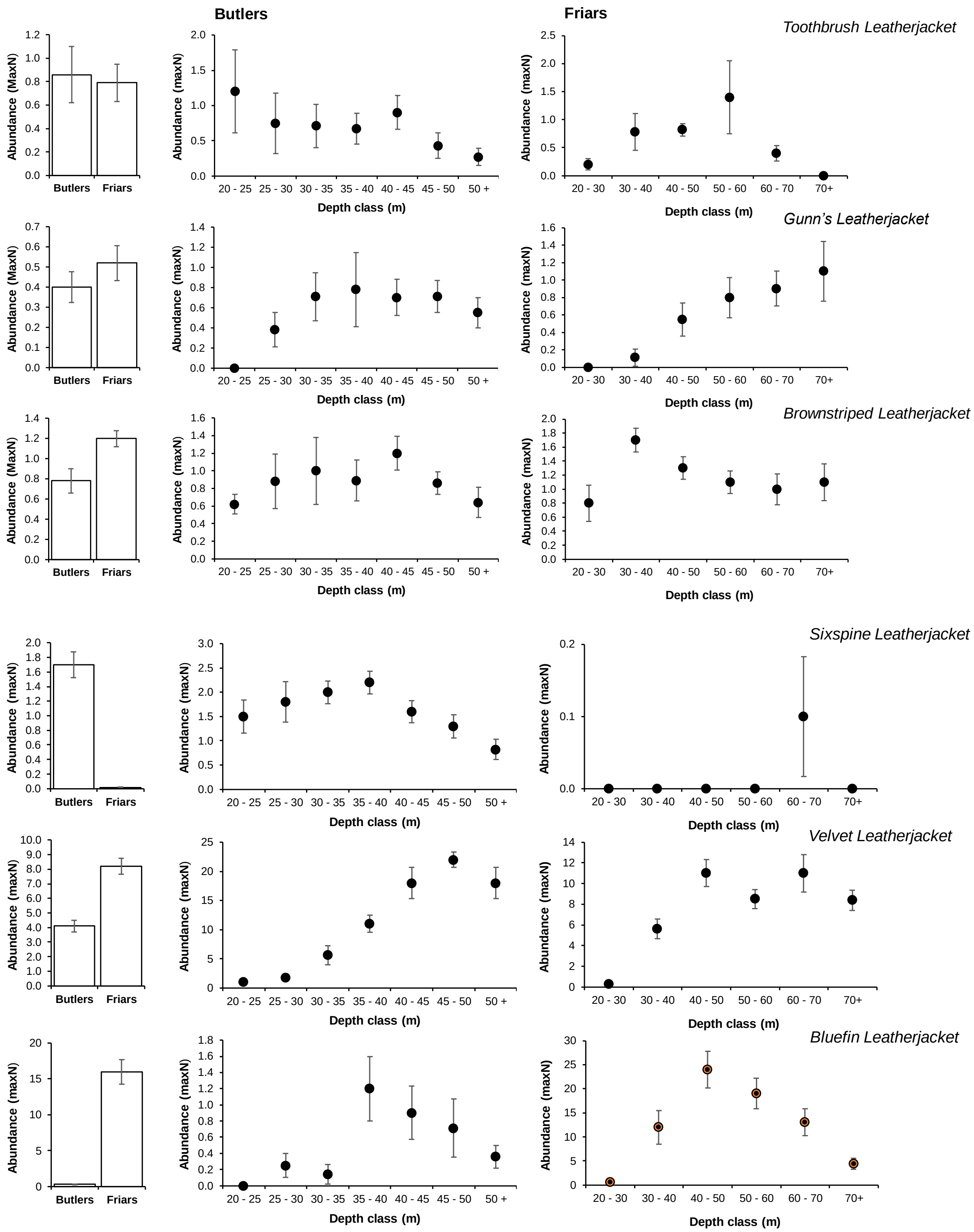


Figure 40. Overall and mean relative abundances by depth (based on BRUV *maxN*) for Butlers Reef and The Friars study regions in autumn. Error bars represent one standard error.

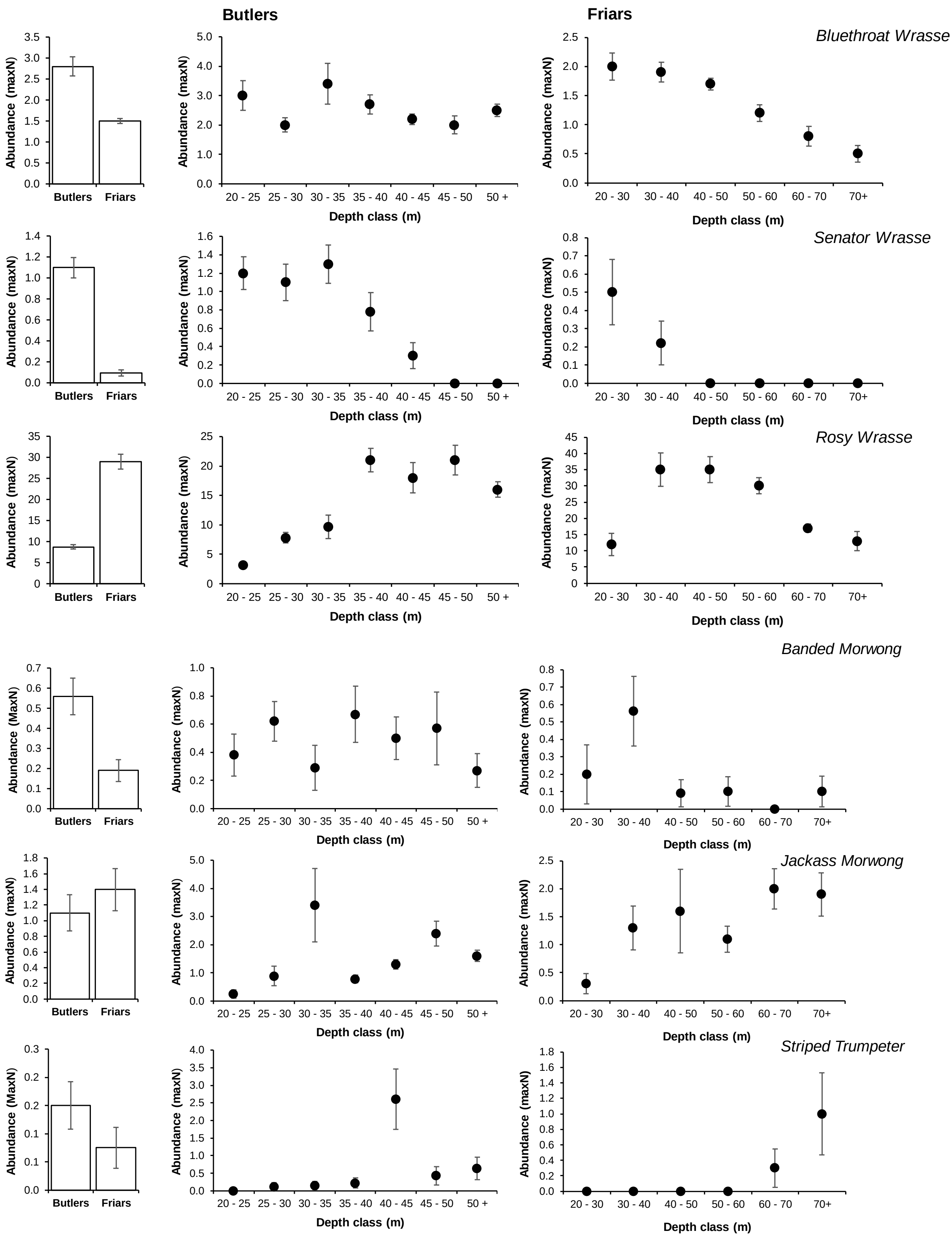


Figure 40. Continued.

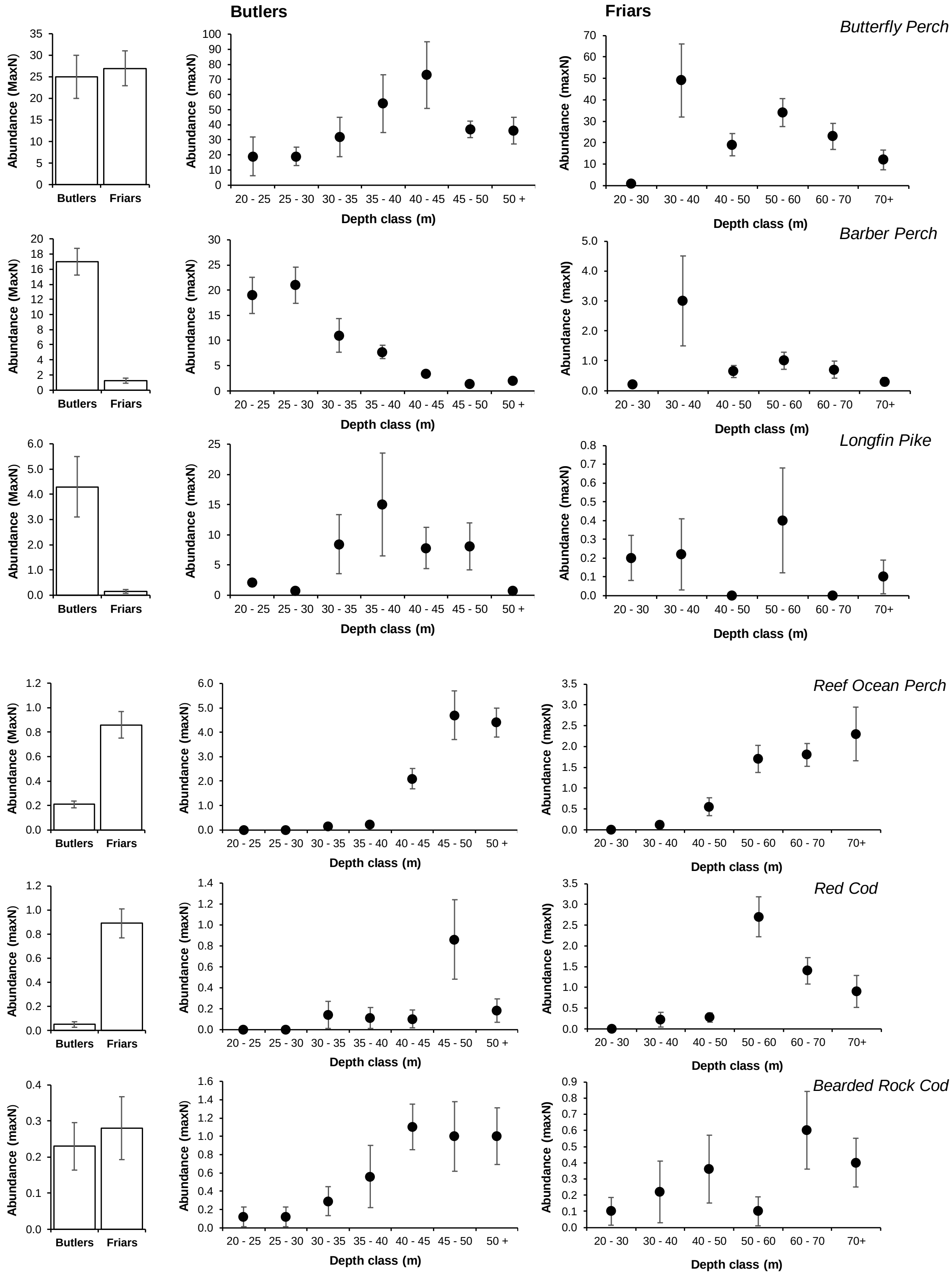


Figure 40. Continued.

Predicted distribution and abundance

The potential to develop predictive habitat distribution models or SDMs was assessed for each of the eighteen key species by establishing relationships between abundance and reef characteristics and then comparing observed and predicted values as a measure of model performance. GLMs were fitted to predict *maxN* with depth, slope, region, northness and eastness included as explanatory variables based on the combined autumn survey data for the two reef locations. A GAM was used for the depth term to account for the non-linear relationships between depth and abundance. Depth was a significant factor for all but five species (Table 12), a finding that is consistent with the combined region BORAL analysis (refer Figure 28). Since reporting a measure of relative explanatory power using the GLM/GAMs for every species modelled and across every environmental covariate would represent too many variables, the overall explanatory power was examined via a permutational multivariate analysis of variance using distance matrices (Anderson 2001) (refer Appendix Table S7). Caterpillar plots presented in Figures 16, 17, 21, 22, 27 and 28 indicate those variables that have significant effects for each species of interest.

Observed and predicted *maxN* values were compared using Spearman's rank-order correlation for each species separately by region (Table 12). Correlations greater than 0.6, the level selected in this study to indicate satisfactory model performance, were achieved for Reef Ocean Perch (*Helicolenus percoides*), Velvet Leatherjacket (*Meuschenia scaber*) and Rosy Wrasse (*Pseudolabrus rubicundus*) in both regions, for Barber Perch (*Caesioperca rasor*) and Senator Wrasse (*Pictilabrus laticlavius*) at Butlers Reef, and for Bluethroat Wrasse (*Notolabrus tetricus*) and Bluefin Leatherjacket (*Thamnaconus degeni*) at The Friars. By taking account of the relationships with reef characteristics, predicted abundances were made across areas of reef deeper than 20 m for each of these species (Figures 41-47).

Of these species, only Bluethroat Wrasse and Reef Ocean Perch are of interest to fisheries. While the SDMs are preliminary, in part due to the limited coverage of available reef habitats around Tasmania, our analyses do establish the potential to quantify the distribution and abundance for a range of species with respect to habitat suitability. Where data such as that derived from BRUV and/or ROV surveys are quantified with respect to abundance and size distribution, and related to habitat characteristics, SDMs have the potential to enhance stock assessments.

As the area of benthic habitat adjacent to Tasmania mapped by multibeam sonar is extended and through further analysis of existing and future BRUV datasets it should be possible to improve the utility of the SDMs for a range of commercially and recreationally important species. Furthermore, as greater information on the species-habitat relationships becomes available there will also be opportunities to explore and compare statistical approaches to modelling these associations, as well as addressing a broad range of questions, including biogeography, conservation biology, climate change in addition to resource management (Guisan and Zimmermann 2000, Robinson *et al*. 2011).

Table 12. Measures of fit for the individual species GAMs of abundance (*maxN*), with Spearman's correlations comparing observed and predicted *maxN* by region. Correlations greater than 0.6 are indicated (bold and italics).

Outputs are for a model that includes depth, slope, northness and eastness, as explained in the text.

Species	R^2	p-value for depth	Deviance explained (%)	Correlation - Butlers	Correlation - Friars
Acanthaluteres vittiger	0.04	0.1846	20	0.35	0.38
Caesioperca lepidoptera	0.08	1.00E-04	20	0.36	0.46
Caesioperca rasor	0.54	0	63	***0.82***	-0.05
Cheilodactylus spectabilis	0.10	0.1603	21	0.07	0.43
Dinolestes lewini	0.09	0.3302	50	0.18	0.16
Eubalichthys gunnii	0.06	0.002	14	0.23	0.48
Helicolenus percoides	0.57	0	71	***0.84***	***0.73***
Latris lineata	0.05	0.0028	48	0.38	0.36
Meuschenia australis	0.06	0.5876	8	0.10	0.34
Meuschenia freycineti	0.58	0.3066	71	0.36	-0.09
Meuschenia scaber	0.54	0	69	***0.82***	***0.72***
Nemadactylus macropterus	0.13	0.0033	29	0.55	0.56
Notolabrus tetricus	0.32	0.0014	38	0.15	***0.64***
Pictilabrus laticlavius	0.53	0.0026	65	***0.71***	0.45
Pseudolabrus rubicundus	0.48	0	50	***0.69***	***0.66***
Pseudophycis bachus	0.32	8.00E-04	45	0.26	0.56
Pseudophycis barbata	0.13	0.0033	20	0.45	0.29
Thamnaconus degeni	0.67	0	75	0.36	***0.81***

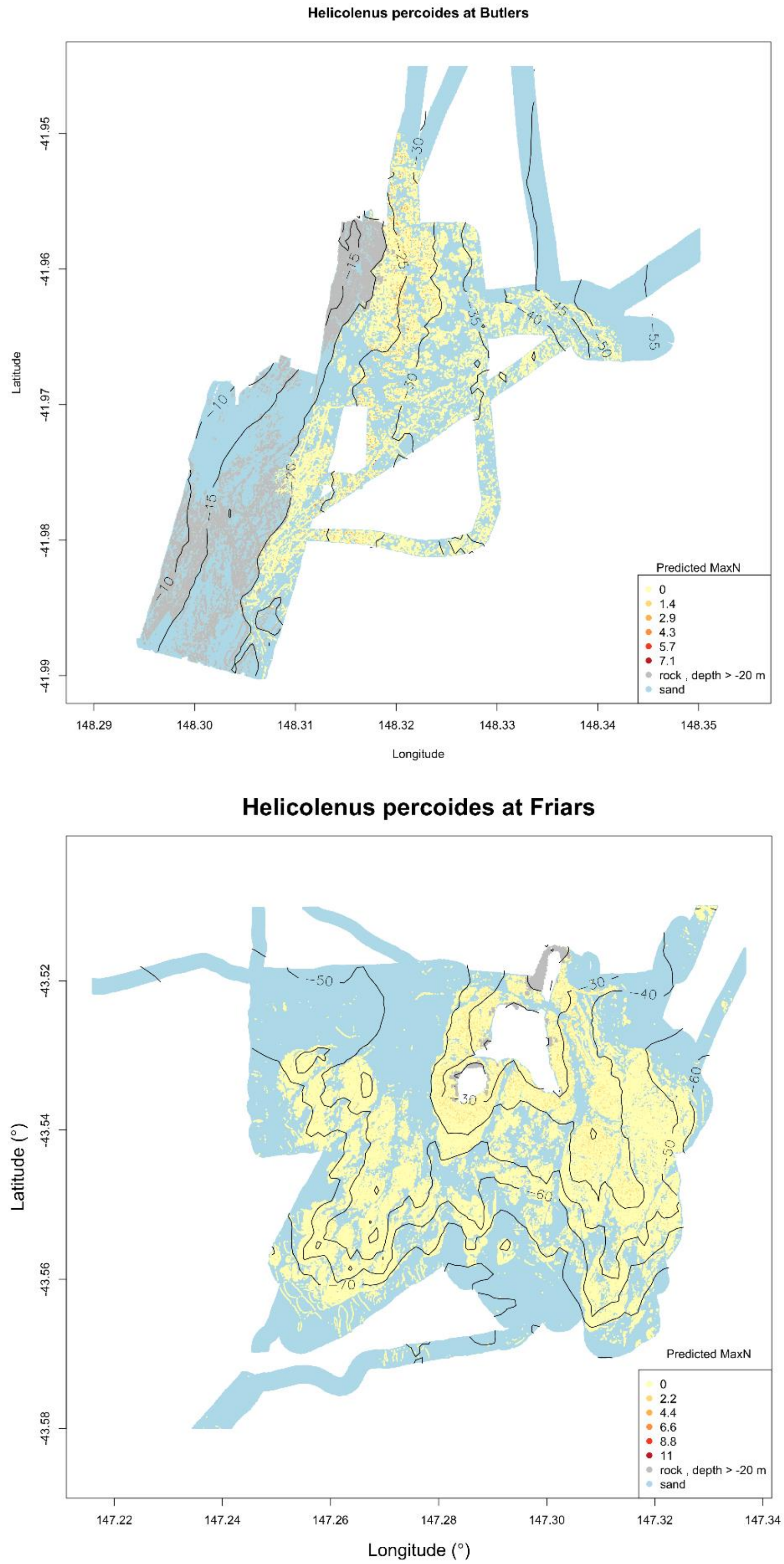


Figure 41. Predicted distribution and abundance (*max N*) of Reef Ocean Perch at Butlers Reef (upper) and The Friars (below).

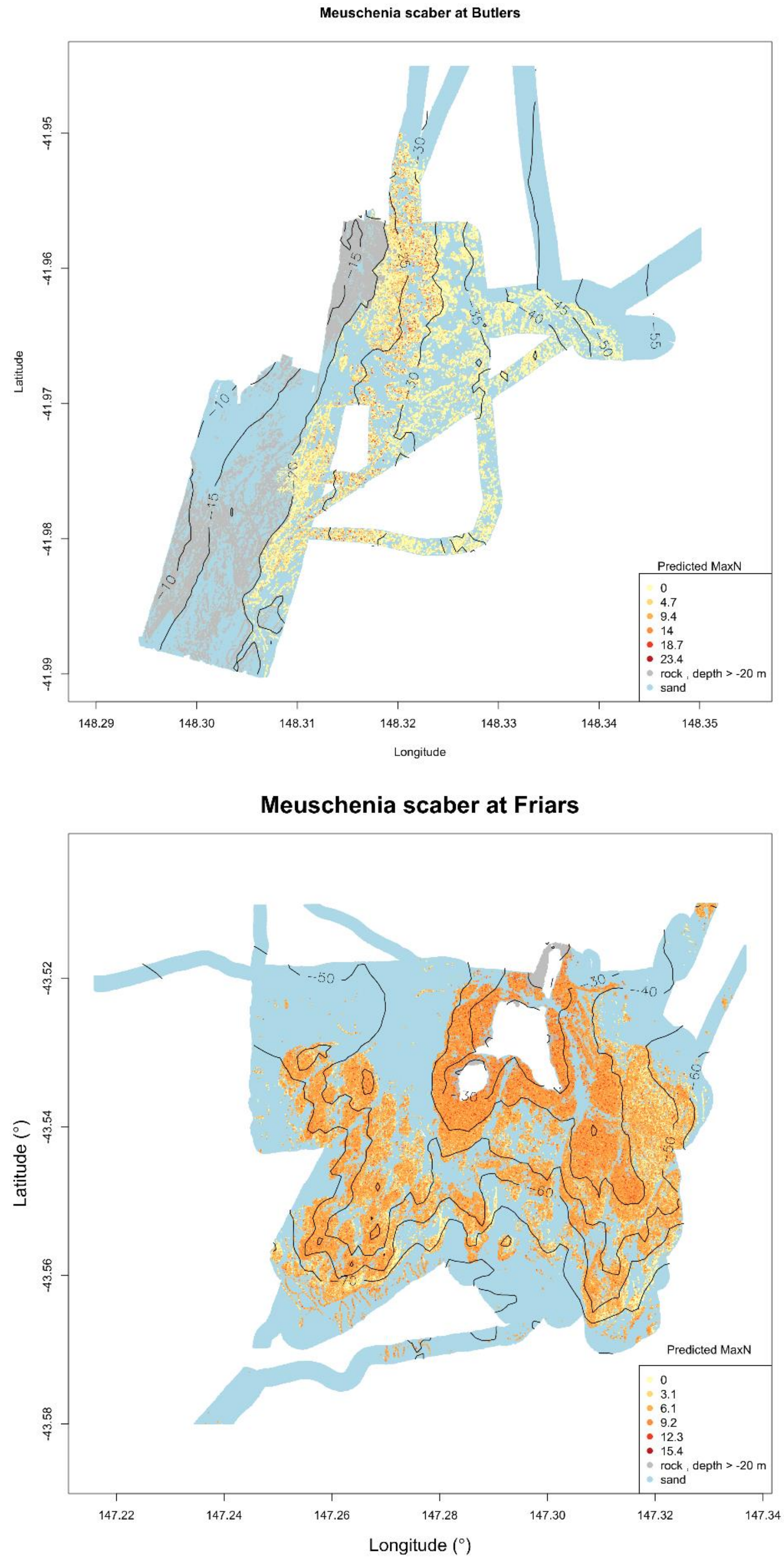
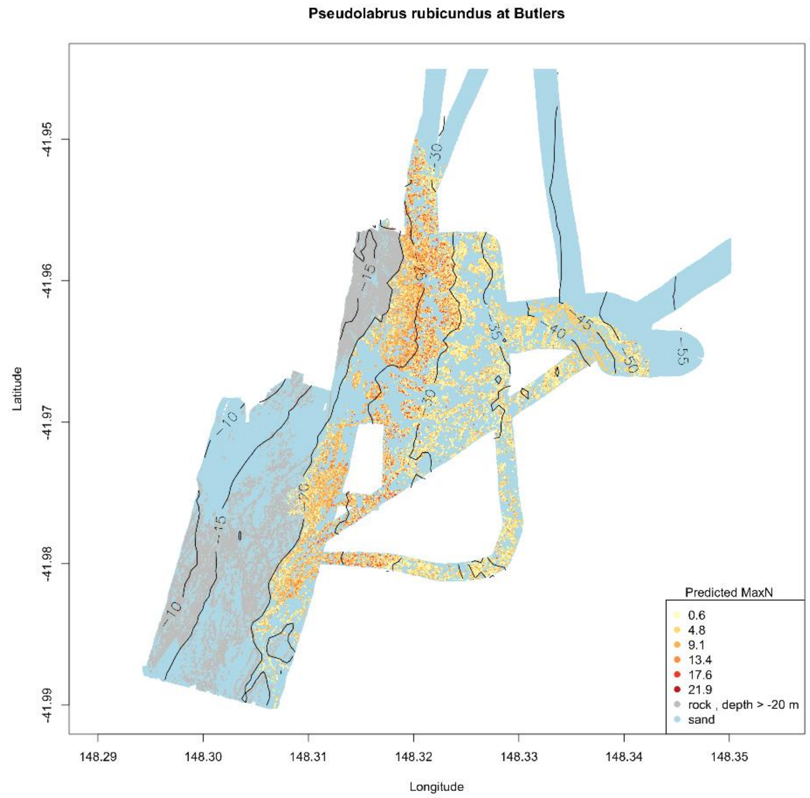


Figure 42. Predicted distribution and abundance (*max N*) of Velvet Leatherjacket at Butlers Reef (upper) and The Friars (lower).



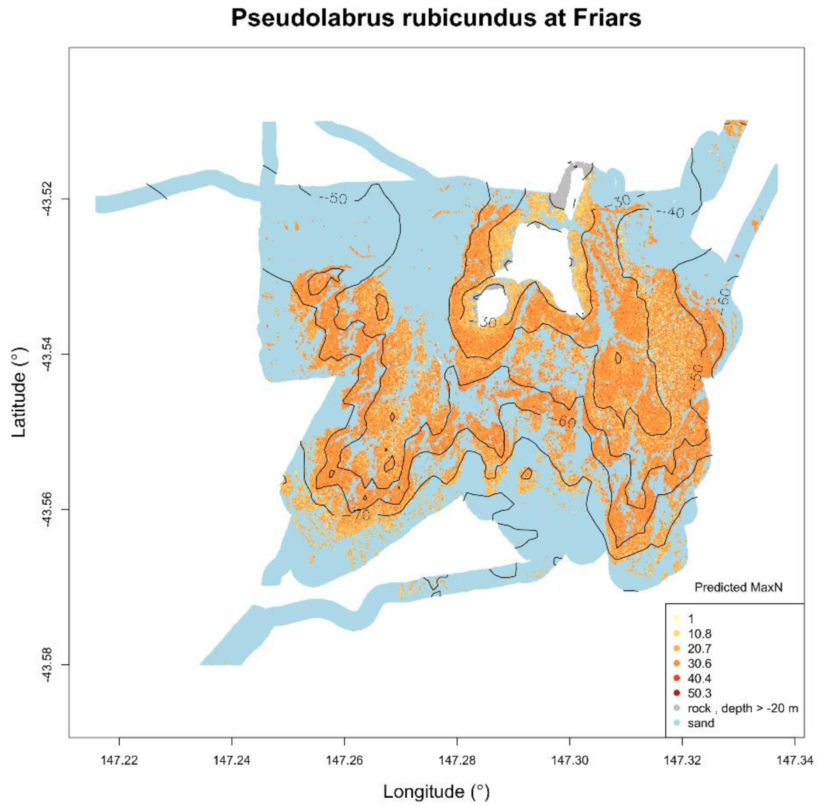


Figure 43. Predicted distribution and abundance (*max N*) of Rosy Wrasse at Butlers Reef (upper) and The Friars (lower).

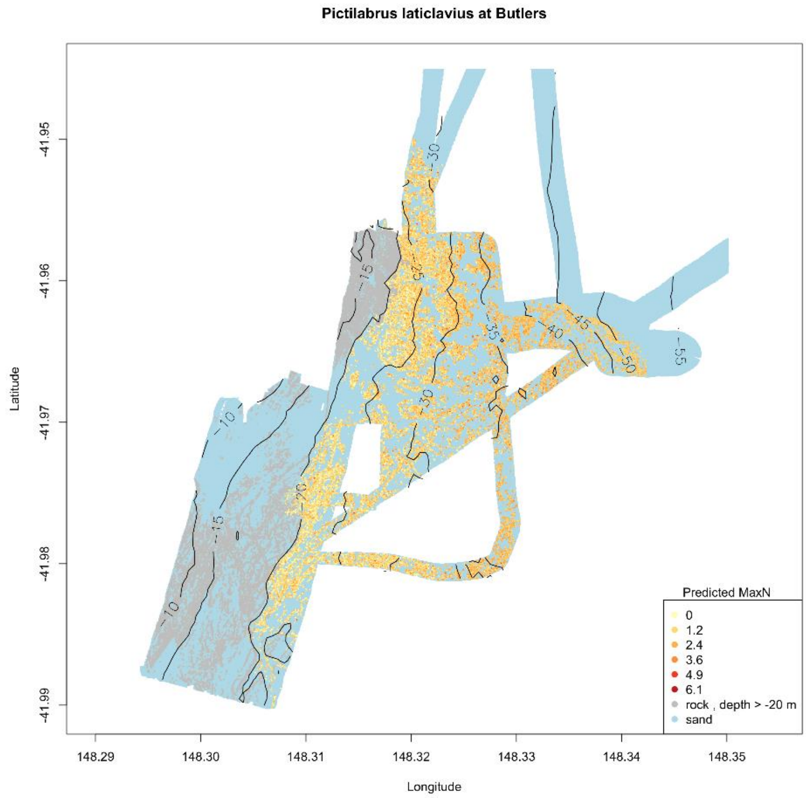


Figure 44. Predicted distribution and abundance (*max N*) of Senator Wrasse at Butlers Reef.

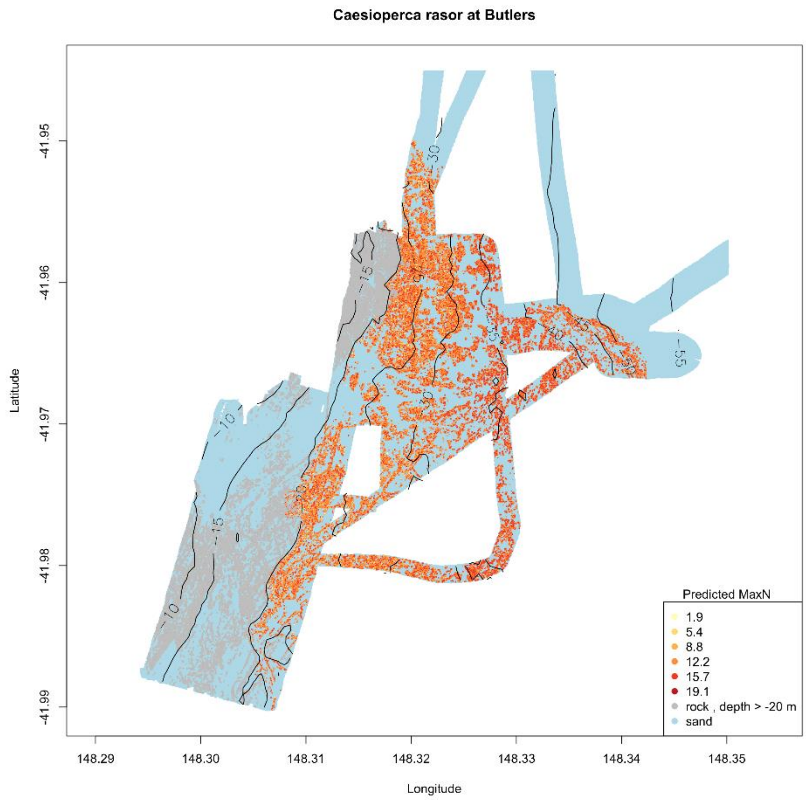


Figure 45. Predicted distribution and abundance (*max N*) of Barber Perch at Butlers Reef.

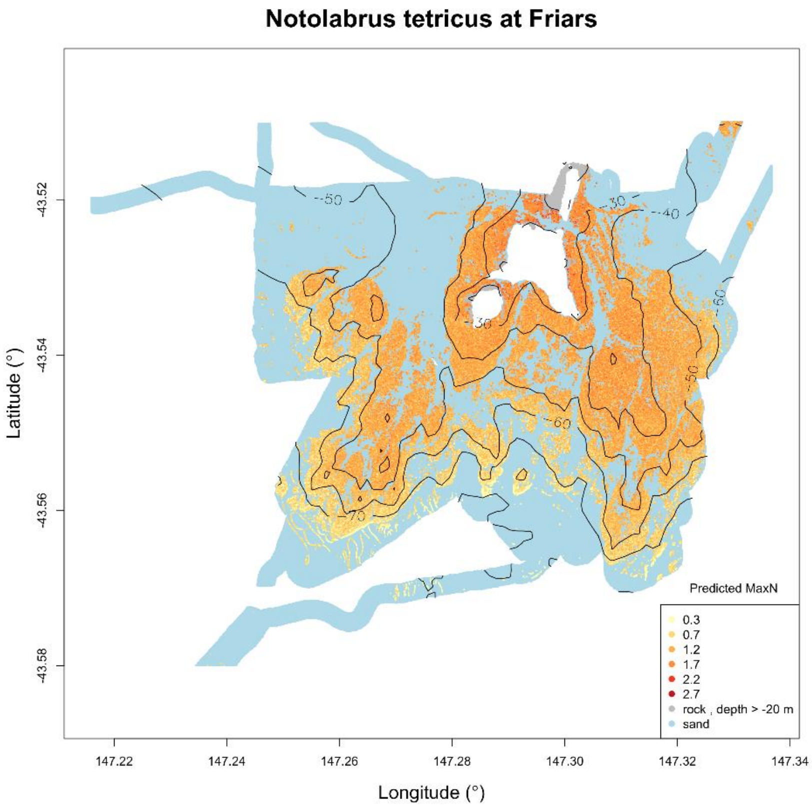


Figure 46. Predicted distribution and abundance (*max N*) of Bluethroat Wrasse at The Friars.

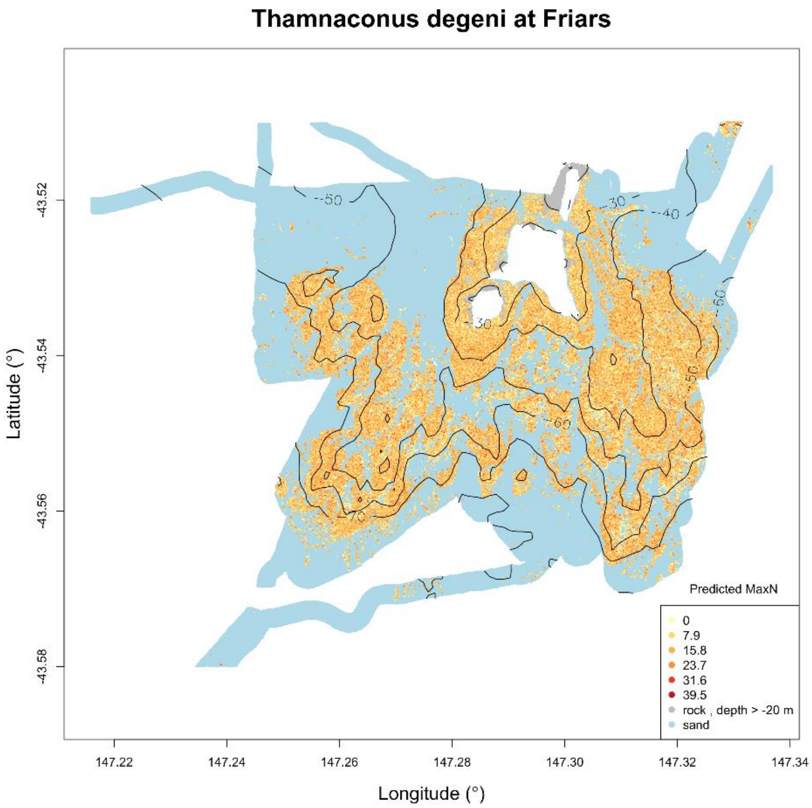


Figure 47. Predicted distribution and abundance (*max N*) of Bluefin Leatherjacket at The Friars.

Conclusion

Tasmania's coastal reef habitats support important commercial and recreational fisheries for a range of invertebrate and fish species. The shallow inshore fish communities are generally well studied, with diver-based visual surveys conducted over several decades. There have been relatively few studies conducted at depths below about 20 m; consequently, these deeper reef fish communities and their associations with habitat characteristics are poorly described. The present study was initiated to address this gap with a focus on commercially and recreationally important reef species.

Two large patches of coastal reef, Butlers Reef off the central east coast and The Friars off the south coast of Tasmania were described using high-resolution multibeam acoustics and the associated fish communities surveyed with underwater video methods, including baited remote underwater video (BRUV) and remotely operated vehicle (ROV), as well as gillnets. BRUV-based sampling was the primary method used in this study, recognising its proven success in other studies undertaken nationally, regionally and locally in Tasmania.

Both reefs extend several kilometres offshore into relatively deep water (> 50 m) while differing in structural complexity, exposure and prevailing oceanographic conditions. Butlers Reef is a relatively low profile reef that is largely sheltered from large oceanic swells, whereas The Friars is structurally more complex and exposed to high wave action. Furthermore, the oceanic environment around Tasmania is dynamic, influenced by two boundary currents, the Eastern Australia Current and Zeehan Current, the former having greater influence on the physical oceanography of the east coast and the latter influencing the south coast marine environment.

A wide diversity of fish, elasmobranch and cephalopod species were associated with the deep reef habitats, with three families especially prominent; Serranidae (sea perches; 3 species), Labridae (wrasses; 7 species) and Monocanthidae (leatherjackets; 10 species). Collectively, these families accounted for over 80% the total numbers of reef-associated fish recorded at both reef locations. Species of commercial and recreational importance that were observed associated with the reef habitats included Banded Morwong (*Cheilodactylus spectabilis*), Jackass Morwong (*Nemadactylus macropterus*), Bluethroat Wrasse (*Notolabrus tetricus*), Purple Wrasse (*Notolabrus fucicola*), Striped Trumpeter (*Latris lineata*), Bastard Trumpeter (*Latridopsis forsteri*), Longsnout Boarfish (*Pentaceropsis recurvirostris*), Reef Ocean Perch (*Helicolenus percoides*), Blue Warehou (*Seriolella brama*) and Southern Calamari (*Sepioteuthis australis*). Of these species, however, only Jackass Morwong and Bluethroat Wrasse were commonly observed (> 65% BRUV sites); Reef Ocean Perch and Banded Morwong were occasionally recorded (>10% sites) and the remainder were rarely observed (< 10% sites), or common at only one of the reefs, e.g. Striped Trumpeter (>25% of Butlers Reef sites) and Southern Calamari (50% of Friars sites).

Patterns in community composition were formally tested using multivariate regression analysis for each study area separately and also compared for regional differences. Reef characteristics including depth, slope, rugosity and aspect were included as factors in the models. Depth was a highly influential variable, with over half of the reef-associated species showing significant (linear or quadratic) responses to depth (based on individual reef and combined reef assessments). These depth related patterns varied by species, with some showing gradual changes in abundance with depth (linear relationships, e.g. Bluethroat Wrasse at The Friars) while others showed sharp transitions (quadratic responses, e.g. Butterfly Perch at The Friars). While some of these patterns, including non-linear responses, may have been related to size differentiation with depth, there was generally insufficient size information to adequately quantify such patterns. None of the other reef characteristics emerged as being particularly important. This observation was unexpected, given that diver observations have tended to indicate that many species have definable habitat preferences (e.g. cave associated) (N. Barrett, pers obs.). However, it is likely that the current method used to categorise habitat variability (e.g. aspect, slope, rugosity) were not available at sufficiently fine spatial resolution to allow good fitting of models. It may also be possible that bait-attraction resulted in fish movements away from preferred habitats, breaking down more typically observed patterns. Alternative approaches to observing such relationships, such as ROV-based observations, may be needed to reliably quantify the importance of habitat features other than depth.

The regional comparison also indicated that the assemblages were quite different, with many species present in lower abundances at The Friars compared with Butlers Reef. Some differences between the regions was expected, given that they have significantly different wave exposure regimes (The Friars location is exposed to prevailing regular powerful swells from the SW), and are markedly influenced by differing water bodies (strong EAC influence vs strong Subtropical Convergence influence). These oceanic differences not only determine the influence of warm affinity species (most abundant at the Butlers Point location), but also the extent of cool temperate species, and their interaction with ocean currents for larval transport and recruitment. Both of these factors, exposure, and oceanography, are therefore likely to influence the structure of the assemblage present. Species richness was also consistently and significantly higher at Butlers Reef, increasing with depth at both study reefs. In contrast to some other studies, rugosity, a proxy for reef complexity, did not emerge as a significant factor influencing species richness.

In relation to species of relevance to fisheries, Bluethroat Wrasse, Reef Ocean Perch and Striped Trumpeter were significantly more abundant at Butlers Reef whereas Southern Calamari were more abundant at The Friars. Region was not a significant factor for any of the other species of interest, a finding that was influenced by low numbers recorded for each of the species. Within the depth range of the studied reefs (to almost 80 m), however, depth was significant for Bluethroat Wrasse, Purple Wrasse, Jackass Morwong, Striped Trumpeter, Reef Ocean Perch and Southern Calamari, along with a wide variety of non-commercial species. Highest abundance of Purple Wrasse occurred at depths of less than 30 m whereas Bluethroat Wrasse abundance peaked in the 20-50 m depth range (noting that sampling was not undertaken at depths shallower than 20 m). Jackass Morwong abundance increased at depths of greater than 40 m while numbers of Striped Trumpeter and Reef Ocean Perch increased at depths of greater than about 50 m. The prevalence of Southern Calamari at depths of over 60 m at The Friars indicates that this species occupies a wider habitat range than previously suggested, noting that the fishery for this species is largely restricted to relatively sheltered, shallow inshore waters, often associated with areas of seagrass.

The Butlers Reef study site was surveyed on two occasions, approximately six months apart, and although there were significant differences in abundance for about one third of the species, the overall community composition was relatively stable. This implies that a snapshot survey is likely to be representative of the key elements of the reef fish community. Of those species with seasonal differences, average abundances were significantly higher for Southern Calamari (*Sepioteuthis australis*) during autumn, presumably reflecting the influx of new recruits following the peak in spawning activity during late spring/summer.

Several species identified as having extended their distributional ranges southwards into Tasmanian waters and/or increased in abundance as a response to climate change were recorded in this study. As expected most of these sightings were restricted to the more northern of the two reefs (Butlers Reef). Amongst this group, there were some species of potential interest to commercial and recreational fishers, namely Grey Morwong (*Nemadactylus douglasii*), Blue Morwong (*N. valenciennesi*), Magpie Perch (*Cheilodactylus nigripes*) and Snapper (*Chrysophrys auratus*). The latter species is taken readily by line fishing and is becoming an increasing target for recreational fishers in Tasmania.

By comparing the underwater video sampling methods (BRUVs and ROV), it was apparent each was subject to some level of sampling bias. For instance, BRUVs over or under represented species depending on the extent that fish-bait acted as an attractant, whereas the greater spatial coverage of the ROV transect was more likely to encounter rarer, cryptic and mobile species that were not bait attracted. Despite such differences, the overall patterns in community composition were similar for both methods, indicating that either method provides a reasonable representation of the fish community present. Further research is needed to explore the relative effectiveness of each approach, particularly for providing robust data on species of interest to fisheries. Another consideration is the greater time commitments required to process BRUVs samples set against the technical challenges of undertaking an ROV transect at depth.

The intent of the gillnetting component was to provide validation against a method known to effectively sample species such as Banded Morwong, Blue Warehou and Bastard Trumpeter. However, the nets used fished particularly inefficiently and this method was discontinued after an initial survey. This was almost certainly due to the robust construction of the nets, necessary for deployment in deep water to minimise the influence of currents and the risk of loss or damage. While this design issue would need to be accounted for in future deep reef surveys using this method, the results did indicate that it was capable of detecting Bastard Trumpeter and Blue Warehou, both species that were rarely recorded using either of the underwater video methods.

Overall, this study has expanded our knowledge of the reef fish communities associated with Tasmania's coastal deep reefs, including the associations between habitat characteristics and individual species distribution and abundance. For species of commercial and recreational fishery importance we have a revised understanding of depth range for Banded Morwong, with individuals occurring to depths of over 70 m, as well as describing patterns in the abundance for Bluethroat Wrasse, Purple Wrasse, Jackass Morwong, Striped Trumpeter, and Reef Ocean Perch. Furthermore, size structuring with depth was investigated for Bluethroat Wrasse, Jackass Morwong, Banded Morwong and Striped Trumpeter. Although some of these data were limited, by linking known life history and fishery (i.e. size limits) information and it was possible to make some observations about population structure, including the occurrence of juvenile and adults of each species, sexual transitioning in Bluethroat Wrasse, and impact of slot size management for Banded Morwong. This knowledge could be improved on by drawing on data available from other completed BRUV surveys (e.g. Tasman Fracture and Flinders CMRs, Governor Island MPA, Tasman Peninsula) and also as more BRUV surveys are undertaken.

Finally, the collation of spatially explicit biological and reef structure data has also opened up the possibility of developing predictive species distribution models, a potential way to enhance stock assessments based on spatial information such as the mapped extent of preferred habitat. A moderate amount of data is required to inform this approach and there needs to be a strong correlation/association with one or more habitat characteristic to aid in informing the model. At this stage, such models are most reliably informed by characteristics at the broad scale, such as depth and extent of reef, given that no strong relationships were found here with other habitat characteristics derived from multibeam sonar. Although data were limited for many of the species of interest, modelling was justifiable for Reef Ocean Perch and Bluethroat Wrasse (at The Friars) along with a number of other ecologically important species. For other species that are also bait attracted, such as Jackass Morwong, Striped Trumpeter, it is anticipated that this approach will become increasingly useful as a greater range of habitats and depths are sampled using BRUVs through related projects. For the less bait-attracted species, the ROV approach could offer promise as suggested based on pilot comparisons between methods undertaken as part of the current project. In the future, improvements in our knowledge of species/habitat relationships derived from more closely matched and finer-scale spatial data will enable such models to be revised and refined.

Implications

This study has substantially expanded our knowledge of the reef fish communities associated with Tasmania's coastal deep reefs, including the associations between habitat characteristics and distribution and abundance for individual species. These data also contribute to a broader regional and national understanding that is being developed with a standardised sampling method (BRUVs) and will provide a sound baseline for ongoing reporting and analysis of these fish communities at regional and national scales.

The BRUV sampling method was generally successful in describing overall fish assemblages, regional differences, depth related patterns, and in detecting community-wide attributes including the extent that climate-influenced species are now contributing to these communities. For species of importance to fisheries, we have a revised understanding of patterns of abundance by depth for Banded Morwong (*Cheilodactylus spectabilis*), Bluethroat Wrasse (*Notolabrus tetricus*), Purple Wrasse (*N. fucicola*), Jackass Morwong (*Nemadactylus macropterus*), Striped Trumpeter (*Latris lineata*), and Reef Ocean Perch (*Helicolenus percoides*). For the live-fish fishery species (Banded Morwong and Wrasse), these patterns are particularly relevant, given that fishing is targeted at the relatively shallow reefs (<25 m) to reduce the impacts of barotrauma on fish survival. As a consequence, the deeper water components of the Banded Morwong and Bluethroat Wrasse populations are effectively protected from fishing by a depth refuge. Purple Wrasse on the other hand, have a stronger preference for the shallower areas of reef that fall largely within the target depth range of the fishery. However, a minimum size limit well above the size at maturity for this species provides some level of protection to the adult stock.

In addition to distribution and abundance, information on population structuring was available for a number of species, including Bluethroat Wrasse, Jackass Morwong, Banded Morwong and Striped Trumpeter. Establishing links between life history stage and habitat characteristics were possible for these species, noting that both juveniles and adults of each species utilise the deeper reef habitats. In the case of Bluethroat Wrasse, it was possible to describe the size at sexual transitioning, a process that is likely to be influenced by the effects of localised fishing pressure.

This study described relationships between habitat characteristics and species abundance for several species. The collation of such spatially explicit biological and reef structure data opens up the possibility of developing predictive species distribution models (SDMs), which could enhance stock assessments using spatial information such as the mapped extent of preferred habitat. Although data were limited for many of the species of interest, it is reasonable to expect that BRUVs data will become increasingly useful in mapping distributions for species attracted to bait, such as Bluethroat Wrasse, Purple Wrasse, Jackass Morwong, Striped Trumpeter. For the less bait-attracted species, the ROV approach offers promise as suggested by comparisons between methods undertaken as part of the current project.

Recommendations

Further research is needed to cross-validate the effectiveness of video based verses gillnet based methods for species on deeper reefs and would ideally be focussed on a species by species basis and in core habitats where abundances are known to be at levels where encounters are expected. This could certainly involve similar trials in shallow water reefs where netting approaches are known to be effective, thus providing effective cross validation.

Key species such as Banded Morwong (*Cheilodactylus spectabilis*) and Bastard Trumpeter (*Latridopsis forsteri*) are not attracted to baits and are not as surveyed effectively as other species using BRUVs. Nonetheless, there were sufficient sightings of Banded Morwong to build a meaningful picture of distribution and size composition with depth, albeit one that could be improved with further sampling.

Bastard Trumpeter, on the other hand, were rarely sighted by the BRUVs despite a significant number of deployments and even though several individuals were captured by gillnet (confirming their presence). Given increasing concerns over Bastard Trumpeter stock levels (currently classified as overfished in Tasmania; Emery *et al.* 2017), the development of fishery independent methods to assess the stock status requires further investigation. If BRUVs are not suitable to the task, further development of other approaches such as ROVs is required, although this method also failed to observe the species (albeit with far less sampling effort than the BRUV deployments.

Further development of the capacity to utilise SDMs to support and inform stock assessments of commercially and recreationally exploited species is recommended. A key step to facilitate this requires a concerted focus on mapping of Tasmania's coastal reef systems using multibeam sonar systems, which are becoming more and more cost-effective. In addition, further analyses of data currently available from other BRUV surveys undertaken adjacent to Tasmania (e.g. Tasman Fracture and Flinders CMRs, Governor Island MPA, Tasman Peninsula) is warranted. With the present dataset, these surveys represent a substantial resource that can add to the understanding of exploited species as well as an opportunity to continue to explore the value of SDMs for stock assessments.

Finally, since a standardised approach to BRUV sampling was used in the present study the data can be added to the Global Archive database for Australian BRUV datasets being developed by the University of Western Australia and Australian Ocean Data Network (AODN: https://portal.aodn.org.au/). Not only will the data provide a baseline for future studies in the region, but will also be available for analysis of regional to national (to global) patterns, and reporting into processes such as State of the Environment.

Extension and Adoption

Distribution and biological information relevant to several of the commercial and recreational important species will be incorporated in future Scalefish Fishery Assessment reports. This information will be used mainly to provide biological context for the species.

Several scientific publications are planned from this study, noting that by drawing on data from other studies conducted by the project team (i.e. Tasman Fracture and Flinders CMR, Governor Island MPA and Tasman Peninsula BRUV surveys) a comprehensive regional picture of the importance and role of the temperate reef habitats in supporting fisheries and biodiversity will be feasible.

Project coverage

A media release was issued on 11th September 2014 (Attachment 1) and the PI was interviewed on 936 ABC radio (Hobart and Northern Tasmania) by Joel Rynberger (14:30, 11th September 2014) and by Cate Grant for ABC online - http://www.abc.net.au/news/2014-09-11/research-highlights-the-importance-of-reefs/5736150

An article relating to the project was published in The Mercury on 12 September 2014. The PI delivered key project outcomes as formal presentations to the Recreational Fisheries Advisory Committee on 2nd March 2017 and Scalefish Fishery Advisory Committee on 3rd March 2017.

A compilation of BRUVs video footage showing examples of reef habitat and various fish species has been prepared to promote the current project and IMAS BRUVs research in general. The presentation (13 minute video) contributed to the IMAS exhibition at Agfest (May 2017), a major rural event in Tasmania that attracted almost 60,000 visitors in 2016. The video presentation proved extremely popular, attracting a lot of comment and interest from the general public.

Appendix 1: Project staff

Institute for Marine and Antarctic Studies

Dr Jeremy Lyle
Dr Neville Barrett
Dr Nicole Hill
Dr Vanessa Lucieer
Dr Russell Thomson*
Justin Hulls
Graeme Ewing

*Present address: Centre for Research in Mathematics
School of Computing, Engineering and Mathematics
Western Sydney University

Appendix 2: Intellectual Property

The research relating to this project is for the public domain and the report and any resulting publications are intended for broad dissemination and promotion.

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Appendix 4: Supplementary Tables

Table S1. Summary of BRUV data by region and season.

		The Friars		Butlers Reef			
		Autumn		Autumn		Summer	
Family	**Species**	**Sum *maxN***	**No. sites**	**Sum *maxN***	**No. sites**	**Sum *maxN***	**No. sites**
Aplodactylidae	*Aplodactylus arctidens*	2	2			1	1
Berycidae	*Centroberyx affinis*			1	1	7	3
Callanthiidae	*Callanthias australis*	32	5	163	19	320	19
Carangidae	Trevally (unident)					3	1
	Pseudocaranx georgianus	1	1				
	Trachurus declivis	500	1	1500	9	897	11
Centrolophidae	*Seriolella brama*			23	1		
Cheilodactylidae	*Cheilodactylus nigripes*	6	5	8	5	6	5
	Cheilodactylus spectabilis	10	8	32	29	21	19
	Nemadactylus douglasii			18	15	2	2
	Nemadactylus macropterus	83	39	91	49	73	45
	Nemadactylus valenciennesi	1	1				
Chironemidae	*Chironemus maculosus*	2	1				
Clinidae	*Heteroclinus johnstoni*	1	1				
Congridae	*Conger verreauxi*	8	7	3	3	1	1
Cyttidae	*Cyttus australis*	19	14	27	24	14	11
Dasyatidae	*Dasyatis brevicaudata*	1	1	3	3		
Dinolestidae	*Dinolestes lewini*	9	6	365	45	129	32
Diodontidae	*Diodon nicthemerus*	1	1	3	2	1	1
Enoplosidae	*Enoplosus armatus*			7	5	6	5
Gempylidae	*Thyrsites atun*	59	7	4	3	7	5
Gerreidae	*Parequula melbournensis*	4	3	8	7	7	7
Heterodontidae	*Heterodontus portusjacksoni*			1	1		
Hexanchidae	*Notorynchus cepedianus*	1	1	1	1	1	1
Labridae	*Dotalabrus aurantiacus*					10	5
	Notolabrus fucicola	18	9	4	4	4	4
	Notolabrus tetricus	81	49	164	63	157	63
	Ophthalmolepis lineolata			7	7	6	6
	Pictilabrus laticlavius	7	6	42	32	42	29
	Pseudolabrus rubicundus	1417	59	868	63	604	63
	Suezichthys aylingi	1	1			1	1
Latridae	*Latridopsis forsteri*	2	2				
	Latris lineata	13	4	40	17	32	18
Monacanthidae	Leatherjacket (unident)	1	1				
	Acanthaluteres vittiger	36	24	43	29	67	48
	Eubalichthys bucephalus					2	2
	Eubalichthys gunnii	35	25	35	30	54	39
	Eubalichthys mosaicus	2	2	5	5	12	12
	Meuschenia sp.			2	1		
	Meuschenia australis	69	47	53	41	61	50

Table S1. Continued

Family	Species	The Friars		Butlers Reef			
		Autumn		Autumn		Summer	
		Sum *maxN*	No. sites	Sum *maxN*	No. sites	Sum *maxN*	No. sites
	Meuschenia freycineti	1	1	98	54	119	56
	Meuschenia scaber	453	51	701	55	545	60
	Meuschenia venusta	1	1	1	1	3	3
	Nelusetta ayraud			1	1		
	Thamnaconus degeni	736	49	33	22	7	7
Moridae	*Lotella rhacina*	4	4	17	15	24	21
	Pseudophycis bachus	55	20	11	8	28	18
	Pseudophycis barbata	18	13	38	23	35	18
Mullidae	*Upeneichthys vlamingii*	11	10	35	23	25	21
Myliobatidae	*Myliobatis australis*	1	1	1	1		
Neosebastidae	*Neosebastes scorpaenoides*	15	14	9	7	23	20
Odacidae	Cale (unident)					1	1
	Olisthops cyanomelas			12	9	13	13
Ostraciidae	*Aracana aurita*	8	8	7	7	1	1
Parascylliidae	*Parascyllium ferrugineum*					1	1
Pempherididae	*Pempheris multiradiata*			10	6	7	5
Pentacerotidae	*Pentaceropsis recurvirostris*	1	1	6	6	7	5
Pinguipedidae	*Parapercis allporti*			7	4	1	1
Platycephalidae	*Platycephalus bassensis*	2	2			2	2
Pomacentridae	*Parma microlepis*			12	12	14	14
Pristiophoridae	*Pristiophorus nudipinnis*			2	2		
Rajidae	*Spiniraja whitleyi*	2	2	1	1	1	1
Rhinobatidae	*Trygonorrhina dumerilii*					1	1
	Trygonorrhina fasciata	1	1				
Scombridae	Tuna (unident)	2	1				
	Thunnus maccoyii	1	1				
Scorpaenidae	*Scorpaena papillosa*	4	4			1	1
Scyliorhinidae	*Asymbolus rubiginosus*	1	1			3	3
	Atelomycterus sp.	1	1				
	Cephaloscyllium laticeps	28	23	41	30	45	38
Sebastidae	*Helicolenus percoides*	65	31	105	29	133	33
Serranidae	*Caesioperca* spp.	817	14	611	6		
	Caesioperca lepidoptera	1356	47	2410	59	2676	55
	Caesioperca rasor	56	25	609	61	426	62
	Hypoplectrodes maccullochi			19	17	15	15
Sparidae	*Chrysophrys auratus*			1	1		
Sphyraenidae	*Sphyraena novaehollandiae*			2	2		
Tetraodontidae	*Omegophora armilla*	1	1				
Trachichthyidae	*Paratrachichthys macleayi*	3	2	70	13	40	11
Triakidae	*Mustelus antarcticus*	8	6	1	1		
Urolophidae	Stingaree (unident)	1	1				
	Urolophus cruciatus			3	3	1	1
	Urolophus paucimaculatus	1	1	1	1		
Teleost (unident)	Unidentified fish	50	1				

Table S1. Continued

Family	Species	The Friars		Butlers Reef			
		Autumn		Autumn		Summer	
		Sum *maxN*	No. sites	Sum *maxN*	No. sites	Sum *maxN*	No. sites
Sepiidae	*Sepia apama*			1	1		
Loliginidae	*Sepioteuthis australis*	69	30	9	9	1	1
Octopodidae	Octopus (unident)	1	1				
	Pinnoctopus cordiformis	1	1			2	2
Ommastrephidae	*Nototodarus gouldi*	8	4				
Paguridae	Hermit crab	1	1				
Diogenidae	Hermit crab	1	1				
Palinuridae	*Jasus edwardsii*	104	33	8	8	7	5
Otariidae	*Arctocephalus* sp.	2	2				
	Total	6313	60	8414	63	6756	63

Table S2. Summary of gillnet catches by region for autumn 2015

Family	Species	Butlers	The Friars	Total
Aplodactylidae	*Aplodactylus arctidens*	3	2	5
Centrolophidae	*Seriolella brama*	1	6	7
Cheilodactylidae	*Cheilodactylus nigripes*		2	2
	Cheilodactylus spectabilis	8	1	9
	Nemadactylus macropterus	3	6	9
Cyttidae	*Cyttus australis*		1	1
Heterodontidae	*Heterodontus portusjacksoni*	1		1
Labridae	*Notolabrus tetricus*	9	9	18
Latridae	*Latridopsis forsteri*		6	6
	Latris lineata	4	1	5
Monacanthidae	*Eubalichthys mosaicus*	1	4	5
	Thamnaconus degeni	1		1
	Acanthaluteres vittiger	1	2	3
Moridae	*Pseudophycis bachus*	1	5	6
Neosebastidae	*Neosebastes scorpaenoides*	1	1	2
Odacidae	*Olisthops cyanomelas*	3		3
Pentacerotidae	*Pentaceropsis recurvirostris*	6	1	7
Pristiophoridae	*Pristiophorus nudipinnis*	1		1
Rajidae	*Spiniraja whitleyi*		1	1
Scyliorhinidae	*Cephaloscyllium laticeps*	3	7	10
Sebastidae	*Helicolenus percoides*	3		3
Serranidae	*Caesioperca lepidoptera*		1	1
	Total	50	56	106

Table S3. Summary of ROV data for Butlers Reef surveys by season; total numbers by species and number of transects in which each species was recorded.

		Autumn		Summer	
Family	Species	Total No.	No. transects	Total No.	No. transects
Aplodactylidae	*Aplodactylus arctidens*	2	2		
Callanthiidae	*Callanthias australis*	167	7	62	5
Carangidae	*Trachurus declivis*			1	1
Cheilodactylidae	*Cheilodactylus nigripes*	2	1		
	Cheilodactylus spectabilis	15	7	7	5
	Nemadactylus macropterus	7	4	3	3
Cyttidae	*Cyttus australis*			1	1
Dinolestidae	*Dinolestes lewini*	5	4	35	2
Diodontidae	*Diodon nicthemerus*	1	1		
Enoplosidae	*Enoplosus armatus*	2	1	2	2
Gerreidae	*Parequula melbournensis*	2	2	5	4
Labridae	*Dotalabrus aurantiacus*			2	2
	Notolabrus tetricus	64	14	35	12
	Ophthalmolepis lineolata	6	3	2	1
	Pictilabrus laticlavius	1	1	30	8
	Pseudolabrus rubicundus	292	14	218	14
Latridae	*Latris lineata*			3	1
Monacanthidae	*Acanthaluteres vittiger*	26	6	27	9
	Eubalichthys gunnii	18	4	8	6
	Leatherjacket (unident)	1	1	3	3
	Meuschenia australis	4	2	4	3
	Meuschenia freycineti	5	3	2	2
	Meuschenia scaber	63	8	50	10
	Nelusetta ayraud	1	1		
Moridae	*Lotella rhacina*	3	2	2	2
	Pseudophycis barbata	9	6	5	3
Mullidae	*Upeneichthys vlamingii*	4	3	5	5
Neosebastidae	*Neosebastes scorpaenoides*	1	1	5	3
Odacidae	*Olisthops cyanomelas*	5	2	5	3
Ostraciidae	*Aracana aurita*			2	2
Pempherididae	*Pempheris multiradiata*	14	4	23	5
Pentacerotidae	*Pentaceropsis recurvirostris*	3	3	5	2
Pinguipedidae	*Parapercis allporti*	1	1		
Pomacentridae	*Parma microlepis*	1	1	3	2
Scyliorhinidae	*Cephaloscyllium laticeps*			1	1
Sebastidae	*Helicolenus percoides*	2	2	7	5
Serranidae	*Caesioperca lepidoptera*	7596	13	5948	13
	Caesioperca rasor	241	8	57	8
	Hypoplectrodes maccullochi			2	2
Trachichthyidae	*Paratrachichthys macleayi*	17	6	33	3
Urolophidae	*Urolophus cruciatus*			2	2
	Total	8581	14	6605	14

Table S4. List of species unique to ROV and BRUVs and common to both gear types at fourteen sites sampled by both gears at Butlers in summer. Numbers in brackets indicate the number of sites where the species was recorded; for species common to both methods the first number represents the number of BRUV samples and the second number the number of ROV sites.

BRUV	Common		ROV
Asymbolus rubiginosus (1)	*Acanthaluteres vittiger (10/9)*	*Meuschenia scaber (12/10)*	*Aracana aurita (2)*
Centroberyx affinis (1)	*Caesioperca spp (14/14)*	*Nemadactylus macropterus (11/3)*	*Dotalabrus aurantiacus (2)*
Cheilodactylus nigripes (1)	*Callanthias australis (5/5)*	*Neosebastes scorpaenoides (2/3)*	*Leatherjacket unident (3)*
Conger verreauxi (1)	*Cephaloscyllium laticeps (7/1)*	*Notolabrus tetricus (14/12)*	*Pentaceropsis recurvirostris (2)*
Eubalichthys mosaicus (3)	*Cheilodactylus spectabilis (4/5)*	*Olisthops cyanomelas (2/3)*	*Urolophus cruciatus (2)*
Notolabrus fucicola (1)	*Cyttus australis (1/1)*	*Ophthalmolepis lineolata (2/1)*	
Odacidae unident (1)	*Dinolestes lewini (5/2)*	*Paratrachichthys macleayi (4/3)*	
Platycephalus bassensis (1)	*Enoplosus armatus (2/2)*	*Parequula melbournensis (1/4)*	
Pseudophycis bachus (4)	*Eubalichthys gunnii (8/6)*	*Parma microlepis (3/2)*	
Scorpaena papillosa (1)	*Helicolenus percoides (6/5)*	*Pempheris multiradiata (2/5)*	
Spiniraja whitleyi (1)	*Hypoplectrodes maccullochi (5/2)*	*Pictilabrus laticlavius (7/8)*	
Thamnaconus degeni (1)	*Latris lineata (4/1)*	*Pseudolabrus rubicundus (14/14)*	
	Lotella rhacina (5/2)	*Pseudophycis barbata (4/3)*	
	Meuschenia australis (11/3)	*Upeneichthys vlamingii (2/5)*	
	Meuschenia freycineti (12/2)		

Table S5. Relative abundance (mean *maxN* and standard error (SE) of key species by depth stratum based on autumn BRUV survey of Butlers Reef.

		Depth stratum (m)							
Species	***maxN***	**20 - 25**	**25 - 30**	**30 - 35**	**35 - 40**	**40 - 45**	**45 - 50**	**50+**	**Overall**
Acanthaluteres vittiger	Mean	1.20	0.75	0.71	0.67	0.90	0.43	0.27	0.86
	SE	0.59	0.43	0.31	0.22	0.24	0.18	0.12	0.24
Caesioperca lepidoptera	Mean	19.00	19.00	32.00	54.00	73.00	37.00	36.00	25.00
	SE	13.00	6.30	13.00	19.00	22.00	5.40	8.80	5.00
Caesioperca rasor	Mean	19.00	21.00	11.00	7.70	3.40	1.40	2.00	17.00
	SE	3.60	3.60	3.30	1.30	0.43	0.26	0.64	1.80
Cheilodactylus spectabilis	Mean	0.38	0.62	0.29	0.67	0.50	0.57	0.27	0.56
	SE	0.15	0.14	0.16	0.20	0.15	0.26	0.12	0.09
Dinolestes lewini	Mean	2.10	0.75	8.40	15.00	7.80	8.10	0.73	4.30
	SE	0.63	0.21	4.90	8.50	3.40	3.90	0.20	1.20
Eubalichthys gunnii	Mean	0.00	0.38	0.71	0.78	0.70	0.71	0.55	0.40
	SE	0.00	0.17	0.24	0.37	0.18	0.16	0.15	0.08
Helicolenus percoides	Mean	0.00	0.00	0.14	0.22	2.10	4.70	4.40	0.21
	SE	0.00	0.00	0.11	0.13	0.42	1.00	0.60	0.03
Latris lineata	Mean	0.00	0.12	0.14	0.22	2.60	0.43	0.64	0.15
	SE	0.00	0.11	0.13	0.14	0.86	0.26	0.32	0.04
Meuschenia australis	Mean	0.62	0.88	1.00	0.89	1.20	0.86	0.64	0.78
	SE	0.11	0.31	0.38	0.23	0.19	0.13	0.17	0.12
Meuschenia freycineti	Mean	1.50	1.80	2.00	2.20	1.60	1.30	0.82	1.70
	SE	0.34	0.42	0.23	0.23	0.23	0.24	0.21	0.18
Meuschenia scaber	Mean	1.00	1.80	5.60	11.00	18.00	22.00	18.00	4.10
	SE	0.46	0.58	1.60	1.50	2.70	1.30	2.70	0.40
Nemadactylus macropterus	Mean	0.25	0.88	3.40	0.78	1.30	2.40	1.60	1.10
	SE	0.15	0.35	1.30	0.13	0.17	0.44	0.20	0.23
Notolabrus tetricus	Mean	3.00	2.00	3.40	2.70	2.20	2.00	2.50	2.80
	SE	0.51	0.24	0.70	0.33	0.18	0.30	0.21	0.23
Pictilabrus laticlavius	Mean	1.20	1.10	1.30	0.78	0.30	0.00	0.00	1.10
	SE	0.18	0.20	0.21	0.21	0.14	0.00	0.00	0.10
Pseudolabrus rubicundus	Mean	3.10	7.80	9.60	21.00	18.00	21.00	16.00	8.70
	SE	0.27	0.88	2.00	2.00	2.60	2.50	1.30	0.51
Pseudophycis bachus	Mean	0.00	0.00	0.14	0.11	0.10	0.86	0.18	0.05
	SE	0.00	0.00	0.13	0.10	0.08	0.38	0.11	0.02
Pseudophycis barbata	Mean	0.12	0.12	0.29	0.56	1.10	1.00	1.00	0.23
	SE	0.11	0.11	0.16	0.34	0.25	0.38	0.31	0.07
Thamnaconus degeni	Mean	0.00	0.25	0.14	1.20	0.90	0.71	0.36	0.30
	SE	0.00	0.15	0.12	0.40	0.33	0.36	0.14	0.07

Table S6. Relative abundance (mean *maxN* and standard error (SE) of key species by depth stratum based on autumn BRUV survey of The Friars.

		Depth stratum (m)						
Species	***maxN***	**20 - 30**	**30 - 40**	**40 - 50**	**50 - 60**	**60 - 70**	**70+**	**Overall**
Acanthaluteres vittiger	Mean	0.20	0.78	0.82	1.40	0.40	0.00	0.79
	SE	0.10	0.33	0.11	0.65	0.14	0.00	0.16
Caesioperca lepidoptera	Mean	0.90	49.00	19.00	34.00	23.00	12.00	27.00
	SE	0.49	17.00	5.20	6.60	6.10	4.60	4.10
Caesioperca rasor	Mean	0.20	3.00	0.64	1.00	0.70	0.30	1.20
	SE	0.11	1.50	0.21	0.29	0.29	0.14	0.33
Cheilodactylus spectabilis	Mean	0.20	0.56	0.09	0.10	0.00	0.10	0.19
	SE	0.17	0.20	0.08	0.08	0.00	0.09	0.05
Dinolestes lewini	Mean	0.20	0.22	0.00	0.40	0.00	0.10	0.15
	SE	0.12	0.19	0.00	0.28	0.00	0.09	0.07
Eubalichthys gunnii	Mean	0.00	0.11	0.55	0.80	0.90	1.10	0.52
	SE	0.00	0.10	0.19	0.23	0.20	0.34	0.09
Helicolenus percoides	Mean	0.00	0.11	0.55	1.70	1.80	2.30	0.86
	SE	0.00	0.10	0.21	0.33	0.27	0.64	0.11
Latris lineata	Mean	0.00	0.00	0.00	0.00	0.30	1.00	0.08
	SE	0.00	0.00	0.00	0.00	0.25	0.53	0.04
Meuschenia australis	Mean	0.80	1.70	1.30	1.10	1.00	1.10	1.20
	SE	0.26	0.17	0.16	0.16	0.22	0.26	0.08
Meuschenia freycineti	Mean	0.00	0.00	0.00	0.00	0.10	0.00	0.01
	SE	0.00	0.00	0.00	0.00	0.08	0.00	0.01
Meuschenia scaber	Mean	0.30	5.60	11.00	8.50	11.00	8.40	8.20
	SE	0.19	0.95	1.30	0.93	1.80	0.98	0.56
Nemadactylus macropterus	Mean	0.30	1.30	1.60	1.10	2.00	1.90	1.40
	SE	0.18	0.39	0.75	0.23	0.36	0.39	0.27
Notolabrus tetricus	Mean	2.00	1.90	1.70	1.20	0.80	0.50	1.50
	SE	0.23	0.17	0.10	0.14	0.17	0.14	0.07
Pictilabrus laticlavius	Mean	0.50	0.22	0.00	0.00	0.00	0.00	0.09
	SE	0.18	0.12	0.00	0.00	0.00	0.00	0.03
Pseudolabrus rubicundus	Mean	12.00	35.00	35.00	30.00	17.00	13.00	29.00
	SE	3.40	5.20	4.00	2.50	1.20	2.90	1.80
Pseudophycis bachus	Mean	0.00	0.22	0.27	2.70	1.40	0.90	0.89
	SE	0.00	0.18	0.11	0.48	0.32	0.38	0.12
Pseudophycis barbata	Mean	0.10	0.22	0.36	0.10	0.60	0.40	0.28
	SE	0.09	0.19	0.21	0.09	0.24	0.15	0.09
Thamnaconus degeni	Mean	0.60	12.00	24.00	19.00	13.00	4.40	16.00
	SE	0.23	3.50	3.80	3.20	2.80	1.10	1.70

Table S7: Results of Permutational Multivariate Analysis of Variance Using Distance Matrices, showing the relative explanatory power (R2) of each of the environmental covariates.
Covariates indicated by a * were included in the GLM/GAM prediction models.

	Degrees of freedom	Sums of Squares	F	R^2	p-value
Depth *	1	2.2	15	0.091	<0.001
$depth^2$ *	1	1.8	12	0.074	<0.001
Region *	1	1.8	12	0.074	<0.001
Slope *	1	0.93	6.5	0.039	<0.001
Eastness *	1	0.37	2.6	0.016	0.009
Northness *	1	0.25	1.8	0.011	0.085
$slope^2$	1	0.17	1.2	0.0073	0.29
Log_{10}(rugosity)	1	0.081	0.57	0.0034	0.78
Residuals	110	16		0.68	
Total	120	24		1	