ecosure

Tweed River Entrance Sand Bypassing Project
Kirra Reef Biota Monitoring 2016

Final Report

New South Wales Department of Industry

ecology / vegetation / wildlife / aquatic ecology / GIS

Executive summary

New South Wales Department of Industry has commissioned Ecosure Pty Ltd to undertake the 2016 Kirra Reef biota monitoring program, where the project will provide assessment to adequately identify and describe the residing flora and fauna communities of Kirra Reef and three control sites to both compare and build on the existing monitoring program.

Benthic assemblages

Differences in the composition (percent coverage and type of taxon) of benthic assemblages, algal assemblages and faunal assemblages were each compared between horizontal and vertical surfaces among Kirra, Palm Beach, Cook Island and Kingscliff Reefs.

Generally, the composition of the entire benthic assemblages differed at a range of spatial scales, with clear differences evident between surface orientations and among most reefs, except for between vertical surfaces on Kingscliff and Cook Island. The differences were primarily due to differences in the higher coverage of turf algae on horizontal surfaces, which dominated the assemblages. Similar patterns were found for faunal assemblages alone, with assemblages generally having greater diversity on vertical than horizontal surfaces. The least diverse assemblages of benthic fauna were found on Kirra Reef.

Changes made to the monitoring program, particularly the increased number of control locations and identification of benthic taxa to a finer taxonomic scale, have allowed for improved understanding knowledge of the natural variation in coverage of benthic assemblages across a broader spatial scale. Taking this into account, the assemblages on Kirra Reef remain dissimilar to the comparative reefs than would be expected naturally (i.e. among the comparative reefs alone), which is most likely due to the relatively recent burial by sand.

As the extent of reef has stabilised since 2014 it is expected that the composition of benthic assemblages on Kirra Reef would become more similar to those found on near-by comparative reefs (within the degree of natural variability); however, the timeframe for this to happen is likely to be greater than 10 years assuming there is no substantial physical disturbance and adequate recruitment to the reef during that time.

Fish communities

Fish communities were assessed on each reef using a combination of Baited Remote Underwater Video Stations (BRUVS) and Remotely Operated Underwater Vehicle (ROV) transects. Video footage was reviewed to determine the number of species present within each file and their relative abundance using MaxN.

Fish species richness on Kirra Reef was found to be within the range recorded on local comparison reefs, though fish community structure (taxa composition and relative abundance) was shown to be significantly different, with the magnitude of difference being greatest between Kirra Reef and all other comparative reefs.

Key species contributing towards the dissimilarity amongst fish communities at Kirra Reef and other comparative reefs included increased abundances of black rabbitfish (*Siganus fuscescens*, stripped barracuda (*Sphyraena. obtusata*) and black-spotted porcupinefish (*Diodon hystrix*) at Kirra Reef, and a range of species with greater abundances at comparative reefs, most significantly: eastern pomfred (*Schuettea. scalaripinnis*); five-banded sergeant major (*Abudefduf saxatilis*) and various surgeonfishes (*Acanthurus* spp. and *Prionurus microlepidotus*).

The combination of both BRUVS and ROV proved to be a successful approach for identifying resident fish communities, recording comparative (Kirra Reef) and greater species richness (Palm Beach) than previous monitoring episodes. ROV transects were found to identify a greater number of species occurring, however, BRUVS were useful in recording more inconspicuous species such as sharks (Hemiscylliidae, Brachaeluridae) and moray eels (Muraenidae).

Abiotic factors

An assessment of abiotic factors was undertaken using data collected by the Tweed Heads Waverider Buoy. A total of 271,037 wave records recorded from the 01/01/2016 to the 31/05/2016 was used to assess patterns in: (i) wave height (ii) wave direction, and: (iii) sea surface temperature.

The direction of swell within the assessed period occurred most predominately from an east (36.24%) and east-south easterly (33.71%) direction, collectively accounting for 69.95% of all wave records. Prevailing wave heights have generally been from 1 to 2m (40.22%) and below 1m (25.58%). Swell events that were greater than 3 meters have occurred from a north-east to east-south easterly direction and have been more prevalent from an east-north east (51.57%) and easterly direction (40.28%).

Assessment of key patterns in reef exhumation and wave dynamics over the past five years identified that waves of three meters or greater showed a degree of correlation between periods of reef burial and exhumation at Kirra Reef. This included: (i) reef burial where waves heights did not exceed 3 meters over the observation period, (ii) no changes to aerial reef extent during periods of swell events of 3 meters; though no swell events greater than 4 meters, and; (iii) expansion of aerial reef extent coinciding with periods of when waves of greater than 4 meters occurred.

Glossary, acronyms and abbreviations

ANOSIM	Analysis of similarity – a statistical test of the significance of groups
ANOVA	Analysis of variance
Bray-Curtis similarity	a commonly used similarity coefficient for biological community analysis, quantifying the compositional similarity / dissimilarity between two different samples
BRUVS	Baited remote underwater video stations
CPCe	Coral point count with excel extensions
DO	Dissolved oxygen
EC	Electrical conductivity
GIS	Geographical information system
GPS	Global positioning system
Hs	the significant wave height (m), defined as the average of the highest one-third of wave heights in a 26.6-minute wave record
HSE	Health, safety and environment
mg/L	milligrams per litre
nMDS	Non-metric multi-dimensional scaling
NSW	New South Wales
NTU	Nephelometric turbidity unit
p	The *p* value, or calculated probability of a statistically significant difference, where a *p* value < 0.05 is commonly considered a significant, and statistically highly significant difference has a *p* value of < 0.001
PERDISP	Tests the homogeneity of multivariate dispersions within groups, on the basis of any resemblance measure
Pkdir	the direction the peak waves are coming from shown in degrees from true north
R	R scales from +1 to -1. +1 indicates that all the most similar samples are within the same groups. R = 0 occurs if the high and low similarities are perfectly mixed and bear no relationship to the group. A value of -1 indicates that the most similar samples are all outside of the groups.
ROV	Remotely operated underwater vehicle
S. E	Standard error
SIMPER	Similarity percentages – a statistical analysis that quantifies the contribution of each species (or other variable) to the observed similarity (or dissimilarity) between samples
the Department	NSW Department of Industry
TRESBP	Tweed River Entrance Sand Bypassing Project
TRESBCo	Tweed River Entrance Sand Bypassing Company

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1 Introduction

1.1 Background

The Tweed River Entrance Sand Bypassing Project (TRESBP) is a joint initiative of the Queensland and New South Wales Governments, with the purpose of maintaining a navigable entrance to the Tweed River as well as the provision of an ongoing supply of sand to the southern Gold Coast beaches.

The supply of coastal sands to the southern Gold Coast beaches has been anthropogenically influenced since the initial construction of the Tweed River training walls in the 1880s. Following the extension of the Tweed River training walls in 1964 to the commencement of TRESBP in 2001, rectified imagery (Boswood and Murray 1997, cited in FRC 2015) has shown an increase in the areal extent of the rocky outcrops at Kirra Reef, resulting primarily from the reduction in transitional sands along the southern Gold Coast beaches.

Following restoration of the coastal sand supply to southern Gold Coast beaches through the commencement of the TRESBP project in 2001, both the exposed extent and residing flora and fauna communities of Kirra Reef have decreased (FRC 2015). Reef assessments undertaken from 2003 to 2009 (FRC 2015) indicated the spatial extent of Kirra Reef was less than the area of exposed reef recorded prior to the extension of the training walls. Furthermore, since 2011, operational management strategies implemented by TRESBP and natural storm events have resulted in a redistribution of sand and an increase within the area of exposed outcrops at Kirra Reef. Since 2014, the areal extent of Kirra Reef has now stabilised.

To comply with management requirements listed within the TRESBP approval conditions, New South Wales Department of Industry (referred to herein as the Department) on behalf of the two State Governments commissioned Ecosure Pty Ltd to undertake the 2016 Kirra Reef biota monitoring program, to refine the existing monitoring program and adequately identify and describe the residing flora and fauna communities of Kirra Reef relative to three control sites.

1.2 Study objectives

The primary objectives of the 2016 Kirra Reef biota monitoring program were to:

- update the monitoring program design to establish a more scientifically robust long-term baseline dataset that can be used to assess:
  - spatial and temporal (seasonal) variation in the composition of benthic communities on Kirra Reef, relative to three control reefs; and
  - successional stages of recovery in benthic communities following: (i) sand burial and exhumation (following storms), relative to natural seasonality.

- update the monitoring program to incorporate a range of new survey and assessment requirements (listed here within Section 2 Study Design)
- assess spatial and temporal change in the composition of fish, benthic flora and benthic invertebrate communities at Kirra Reef compared with existing control sites on Palm Beach Reef relative to previous monitoring events
- compile a scientifically robust technical report that clearly:
  - describes the updated monitoring design and methods
  - describes field methods and data analysis techniques comprehensively to allow for suitable replication in future monitoring events
  - presents the more scientifically robust results including a comparison with previous monitoring events, using detailed figures, tables and appendices; and
  - provides recommendation to mitigate any recorded or future putative impacts to identified ecological features and functions.

2 Study design

Further to the study objectives, additional requirements within the enhancement of the existing monitoring program are to:

- provide a comparable dataset allowing for temporal comparison with the existing monitoring program
- establish additional control reefs/sites with similar depth/wave exposure characteristics situated both north and south of Kirra Reef
- complete a site specific flora and fauna inventory (inclusive of relative abundances) to the lowest taxonomic level (genus or species level) considering costs and monitoring practicality
- derive biodiversity indices for each site considering variability within horizontal, vertical and direction surfaces
- assess the potential influence of various abiotic factors on reef communities, to identify seasonal / event based changes in reef community structure
- identify and report on the occurrence of any invasive species and/or species of conservation significance; and
- incorporate relevant legislative requirements.

A summary of the monitoring components and assessment techniques used for (i) the previous monitoring program and (ii) updated monitoring program are shown in Table 1.

Table 1 A summary of assessment techniques and supporting monitoring components for (i) the previous monitoring program and (ii) monitoring components incorporated into the updated monitoring program in 2016

	Previous monitoring program components (2001 – 2015)	Additional monitoring components incorporated in 2016
Assessment		
Reef distribution	- Kirra Reef extent mapped annually using spatial imagery	- extent of Palm Beach inner reef, Cook Island Reef and Kingscliff Reef spatially mapped for assessment of broad scale temporal variability - current and historical reef areas presented for comparison to biotic datasets
Abiotic factors	- not included	- assessment of abiotic factors affecting reef communities - in situ water quality profiles for each of the sites assessed to determine whether there are substantial small scale differences among sites and reefs in May 2016 - wave height, wave direction and sea surface temperature data from monitoring buoy analysed for assessment against historical and current trends in reef extent and biotic datasets - recommendations for ongoing abiotic monitoring
Seasonal patterns in benthic assemblages	- patterns in mean (±S.E) % cover of key benthic flora and invertebrate taxonomic groupings - permutational multivariate analysis of variance used to determine difference in the composition (% cover of taxonomic groupings) of benthic assemblages between Kirra and Palm Beach reefs over time	- assessment of genus / species level composition of benthic flora and invertebrate groupings - multivariate analysis of genus / species level data to determine spatial and temporal patterns in community structure for each taxonomic grouping - assessment of key groups contributing to the differences among reefs using SIMPER - calculation and comparison of biodiversity indices for each site and reef surface type
Seasonal patterns in fish communities	- fish species richness and relative abundance considered at reef scale	- provide recommendations and baseline data for multivariate analysis of communities to determine patterns in community composition following seasonal surveys
Community succession	- literature review / descriptive observations	- explicitly determine community succession based on temporal trajectories - assessment of abiotic factors assessing reef communities provide a robust monitoring program design and baseline data from the 2016 event on which future community succession can be analysed statistically
Species of conservation significance and exotic / invasive species	-	- presence of any alien, introduced, invasive, protected or threatened species should be catalogued and acknowledged - appendix listing species of conservation significance and exotic /

	Previous monitoring program components (2001 – 2015)	Additional monitoring components incorporated in 2016
		invasive species likely to occur within the project area and habitat requirements - report section detailing the survey records of species of conservation significance and exotic / invasive species (or noting the absence)
Survey		
Assessment components	- reef flora and benthic invertebrate communities - fish communities	- reef flora and benthic invertebrate communities (lowest taxonomic level) - fish communities (lowest taxonomic level) - abiotic factors (in situ temperature, salinity, pH and turbidity, also wave height, wave direction and sea surface temperature derived from monitoring buoy data) - In situ water quality profiles to assess if small scale differences in abiotic factors exist among sites and reefs
No. sites	where exposed: - 6 Kirra Reef putative impact sites, including 3 outer reef and 3 inner reef (although from 2012 only 3 sites typically assessed) - 3 Palm Beach Reef control sites on inner reef	- 3 sites at each of the following reefs (i) Kirra outer reef; (ii) Palm Beach inner reef, (iii) Cook Island reef, and (iv) Kingscliff Reef - Up to 3 sites on recently exhumed rock at Kirra Reef
Design	per site: reef communities - 15 replicate quadrats on horizontal surfaces (0.25 m^2 / 50 cm x 50 cm) fish communities - underwater visual census of fish communities - baited remote underwater video (BRUVS) techniques (20 minutes) and diver video transects (35 minutes)	reef communities - fixed 25 m transect locations using GPS location of remotely operated underwater vehicle (ROV) and distinct reef structural features for transect positioning - 17 replicate quadrats per transect on vertical surfaces (0.25 m^2 / 50 cm x 50 cm) - 17 replicate quadrats per transect on horizontal surfaces (0.25m^2 / 50 cm x 50 cm) - additional geo-located transects on recently exhumed rock where observed during the May 2016 survey - consistent orientation of transects with respect to wave exposure where reef topography allowed - accurate geo-referenced transects for repeat surveys and temporal analysis of changes fish communities - baited remote underwater video stations (BRUVS) deployed at three sites per reef - visual census using video transects collected using an ROV (using ROV reduces fish behavioural bias caused by diver-fish interactions) - targeted assessment within key micro habitats for species of conservation significance, cryptic and exotic / invasive species using

	Previous monitoring program components (2001 – 2015)	Additional monitoring components incorporated in 2016
		high-resolution imagery collected using an ROV
Taxonomic precision	- species level – fish and macro algae - taxonomic groupings with some species level ID – ascidians - taxonomic groupings – turf algae, sponges, hard coral, soft coral, crinoids	- genus / species level ID of key taxa - some groups such as turf and coralline algae would continue to be a coarse taxonomic grouping
Technique	- diver based assessment and BRUVS	- deployment of ROV and BRUVS

3 Methods

3.1 Literature review

A comprehensive review of literature was undertaken to:

- identify and detail previous survey effort and survey findings
- identify available abiotic datasets
- determine species of conservation significance and their likelihood of occurrence
- identify local occurrences of any exotic / invasive marine species
- review reef fish community assessment techniques and determine most appropriate analytical approach for the current monitoring program.

This included searches and review of:

- previous Kirra Reef biota monitoring reports (FRC 2015, 2014, 2012, 2010, 2005, 2004, 2003, 2001, 1996, 1995a and 1995b)
- NSW Department of Environment and Heritage's threatened species list for marine environments
- Wildlife Online – flora and fauna database managed by Queensland Department of Environment and Heritage Protection
- Protected Matters Search Tool (PMST) – identifies matters of national environmental significance (MNES), managed by Commonwealth Department of Environment (DoE)
- Atlas of Living Australia (www.ala.org.au) website managed by Commonwealth Government
- The National Introduced Marine Pest Information System (NIMPIS) managed by the Commonwealth Government.

3.2 Abiotic factors

An assessment of abiotic factors was undertaken using data collected by the Tweed Heads Datawell 0.9 m GPS Waverider Buoy, positioned in 22 m of water approximately 1,600 m offshore of the Tweed Coast (28°10.910'S, 153°34.555'E). The buoy is jointly operated by the Queensland Department of Science, Information Technology and Innovation (DSITI) and the TRESBP, where data was provided by DSITI.

A total of 271,037 wave records recorded from the 01/01/2000 to the 31/05/2016 was used to assess patterns in:

- significant wave height (Hs)
- wave direction (Pkdir)

- sea surface temperature (°C).

Within excel, data anomalies (i.e. -99 values) were removed and values were binned for both significant wave height (i.e. <1 m, 1 to 2 m etc.) and wave direction (as per ten cardinal directions within Table 2). Pivot tables were then used to derive wave height / wave direction matrices and complete wave rose diagrams displaying the frequency of occurrence for a particular wave category as a percentage of the overall data set (i.e. proportion of records / total number of records for a particular year).

Table 2 cardinal directions used for data binning wave data (Pkdir)

Cardinal direction	Degree direction	Cardinal direction	Degree direction
NNW	326.25 – 348.75	E	78.75 - 101.25
N	348.75 - 11.25	ESE	101.25 - 123.75
NNE	11.25 - 33.75	SE	123.75 - 146.25
NE	33.75 - 56.25	SSE	146.25 - 168.75
ENE	56.25 - 78.75	S	168.75 - 191.25

3.3 Field assessments

Field assessments were completed over a three-day period from the 19th to the 21st of July 2016. Sea conditions were favourable with good water clarity, reduced swell (<1.0 m) and light to moderate (5 to 15 knots) north easterly winds. Conditions started to deteriorate on the final afternoon, with increased north easterly winds resulting in a reduction in water clarity on Kirra Reef.

Work was undertaken from a commercially registered 10.85 m monohull vessel “Cheryl Lee” with a current Australian Maritime Safety Authority issued certificate of survey and operation (open water Class 1C). Vessel operation was undertaken by a Grade 1 coxswain, with all survey works completed in accordance with Ecosure’s Health and Safety Plan developed specifically for this project.

3.3.1 Site selection and establishment of additional control reefs

Transect locations at Kirra Reef were based on those used in previous surveys. A review of previous survey effort (refer to Section 4.1) identified three sites previously used more frequently (KRO3, KRN1 and KRN2), which were subsequently selected as starting points for ROV transects within the current survey event.

Selection of sites on nearshore control reefs were determined through desktop assessment using the following criteria with a descending order of priority:

- similar depth to Kirra Reef
- no variation within reef extent within the area of assessment (based on assessment of available aerial imagery, refer to Section 4.3.2)
- similar exposure to significant swell events (refer to Section 4.2).

3.3.2 Benthic assemblages

Sampling was completed using a vLBV300 HD ROV with the following attachments:

- a custom made lightweight aluminium 50 x 50 cm (0.25 m^2) quadrat with a manoeuvrable mount capable of re-positioning the quadrat into a vertical or horizontal fixed position (Figure 1)
- a Go Pro Hero4 Black camera mounted behind the quadrat and positioned to provide the greatest resolution across the field of view (the quadrat). The camera was programed to collect still imagery every two seconds
- two LED lights positioned facing the quadrat
- a Tritech Micronav ultra-short base line (USBL) tracking system to accurately record co-ordinates at the point of data capture
- a functional grab arm for collection of voucher specimens.

At all reefs, up to 20 photo-quadrats were collected on both horizontal and vertical reef surfaces along three geo-referenced transects (Table 3). Geo-referenced start and end points of the transects were recorded, with a constant heading maintained and noted.

Additionally, 15 geo-referenced photo-quadrats on both horizontal and vertical surfaces (30 in total) of recently exhumed rock on the south western extent of Kirra reef.

Figure 1 ROV with quadrat positioned for horizontal and vertical transects, pilot operating ROV during deployment

Figure 2: Kirra Reef transect locations

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Kirra Reef Monitoring 2016

Transect starting point
Transect end point
Transect line
Reef extent

ecosure

Job number: PR1627
Revision: 0
Author: RSC, DJB
Date: 25/10/2016

0 5 10 20
Metres

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meter

Figure 3: Palm Beach Reef transect locations

Department of Industry

Kirra Reef Monitoring 2016

- Transect starting point
- Transect finishing point
- Transect line
- Reef extent

ecosure

Job number: PR1627
Revision: 0
Author: ALM DJB
Date: 25/10/2016

0 15 30 60 Metres

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meter

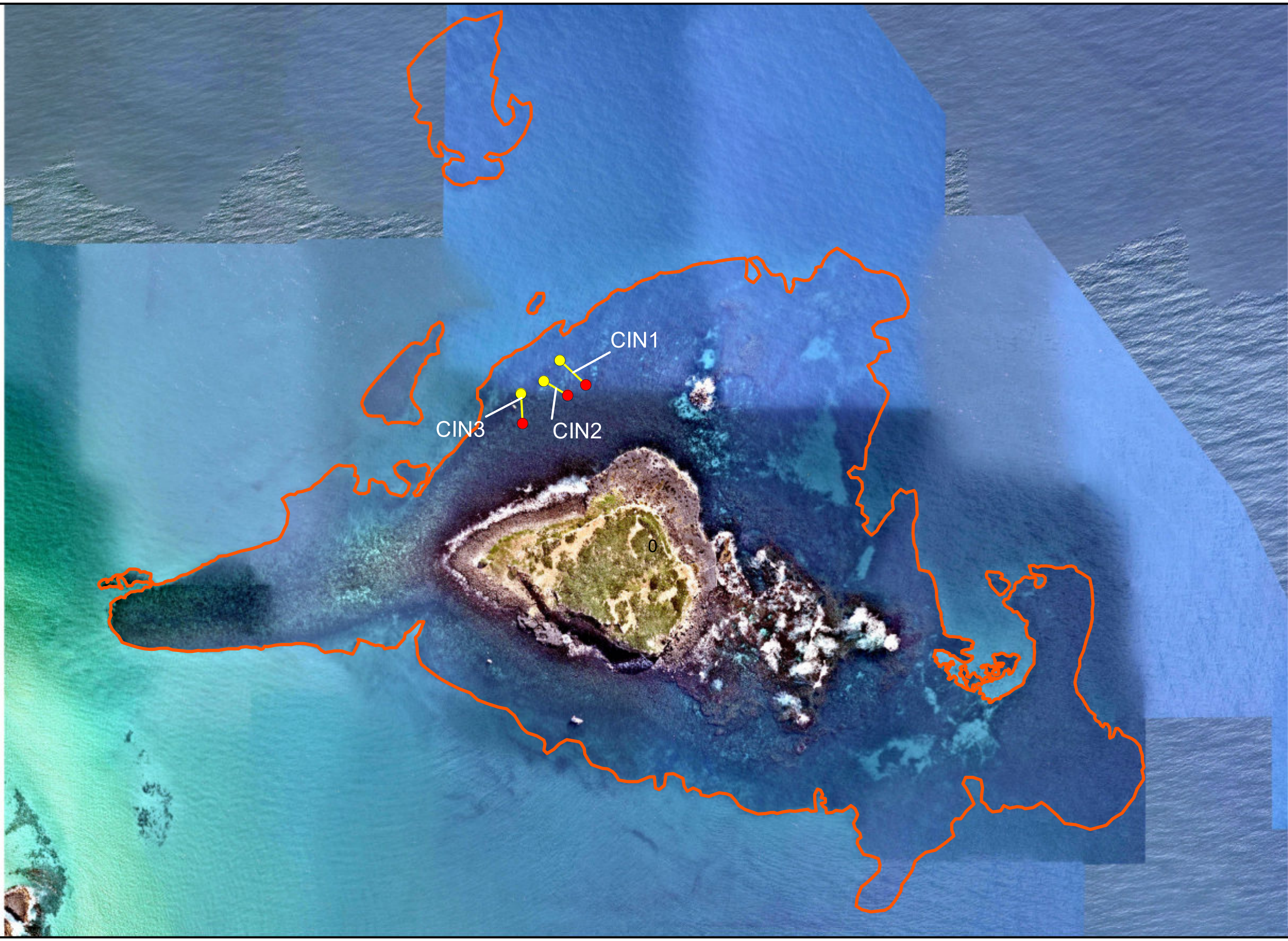

Figure 4: Cook Island transect locations

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Kirra Reef Monitoring 2016

Transect starting point

Transect end point

Transect line

Reef extent

ecosure

Job number: PR1627
Revision: 0
Author: RSC DJB
Date: 25/10/2016

0 25 50 100
Metres

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meter

PR1627_MP4_ReefTransects_CookIsland2016
A4

Figure 5: Kingscliff Reef transect locations

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Kirra Reef Monitoring 2016

Transect starting point
Transect end point
Transect line
Reef extent

ecosure

Job number: PR1627
Revision: 0
Author: ALM DJB
Date: 25/10/2016

0 15 30 60
Metres

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meter

3.3.3 Fish communities

Fish communities were assessed on each reef using a combination of Baited Remote Underwater Video Stations (BRUVS) and ROV transects.

3.3.3.1 Baited remote underwater video stations

A custom designed baited platform with an attached high definition underwater video camera (Go Pro Black) was deployed at three randomly selected sites at each reef (Figure 6). BRUVS were deployed for a period of 90 minutes at each site to collect at least four video files (Go Pro Black segregates video into 17 minute 26 second files). A variety of fresh baits (octopus and pilchards) were placed within a durable plastic meshing and attached to the platform to attract mobile fauna. Where possible, the second, third and fourth video file were selected for fish community analysis to provide a consistent observation period (i.e. not including the period of deployment).

3.3.3.2 Remotely operated underwater vehicle transects

Active searches for fish were completed using an ROV, piloted along each of the geo-referenced transects targeting both open water and specific habitat types (overhangs, caves and in structurally complex habitat like macroalgae). Assessment were undertaken over a 45-minute period collecting ongoing video files approximately 9 minutes in length (± 10 seconds). Four video files were then selected for fish identification and biomass analysis (MaxN), excluding where possible the first video file (first video incorporates deployment period).

3.3.4 Water quality

Physicochemical parameters were measured in situ using a multi-parameter water quality meter (YSI Pro DSS), calibrated prior to the start of each field day. Vertical profiles of the water column were completed from the surface (0.2 m) to the bottom at approximately 1.0 m intervals at each reef. Water quality parameters measured included:

- water temperature (°C)
- electrical conductivity (EC) (µS/cm)
- pH
- dissolved oxygen (DO) (% saturation and mg/L)
- turbidity [nephelometric turbidity units (NTU)].

Figure 6 Image from a BRUVS deployed at Kirra Reef on the 19th of July 2016

Table 3 Co-ordinates for the start and finish points of reef transects undertaken in July 2016 (Datum, WGS 84, grid reference 56J)

Transect	Code	Starting location		Finishing location	
		Easting	Northing	Easting	Northing
Kirra Reef					
Kirra Reef 1	KRN1	552092	6884632	552103	6884662
Kirra Reef 2	KRN2	552119	6884663	552115	6884689
Kirra Reef 3	KRO3	552149	6884693	552126	6884710
Palm Beach Reef					
Palm Beach New 1	PBN1	546744	6890563	546753	6890545
Palm Beach New 2	PBN2	546768	6890539	546789	6890563
Palm Beach New 3	PBN3	546797	6890570	546766	6890586
Cook Island					
Cook Island New 1	CIN1	556681	6881220	556710	6881193
Cook Island New 2	CIN2	556663	6881197	556690	6881181
Cook Island New 3	CIN3	556638	6881183	556640	6881150
Kingscliff Reef					
Kingscliff New 1	KCN1	558105	6874663	558105	6874579
Kingscliff New 2	KCN2	558096	6874599	558045	6874608
Kingscliff New 3	KCN3	558007	6874660	558002	6874593

3.4 Data analysis

3.4.1 Benthic assemblages

The percent cover of benthic assemblages on the four nearshore reefs was assessed using Coral Point Count with Excel extensions (CPCe; Kohler 2006). Up to twenty 50 cm x 50 cm photo quadrats were taken randomly along each of the three horizontal and three vertical transects from each reef. A matrix of 50 randomly distributed points were overlaid on each photo quadrat. Features (including morphospecies for benthic algae and fauna, and substrate type) underlying each of the points were then identified visually by experienced marine ecologists based on previous taxa surveyed in the region. An assessment of voucher specimens collected in the field is still required to confirm the identity of benthic species present on the reefs; however, voucher specimens were not collected in 2016. Summary statistics (including percent coverage of each taxon and substrate type) were calculated and exported from CPCe to Microsoft Excel.

Differences in the composition of benthic assemblages, algal assemblages and faunal assemblages were compared using separate three-factor PERMANOVAs, with orientation (fixed), reef (fixed) and transect (nested in reef; random) as the factors. Results from only 17 quadrats per transect were used to ensure a consistent number of quadrats among transects. Specific differences among orientations, reefs and transects were compared using post-hoc pairwise comparisons (Anderson 2001). PERMANOVA is robust to some of the assumptions of traditional ANOVAs such as non-normality and homogeneity of variance, which is arguably more appropriate when assessing ecological data. Any difference in the degree of multivariate dispersion among reefs and surface orientations was assessed using the PERDISP routine (Anderson 2001). Taxa that contributed to the differences in assemblages among sites were identified using the similarity percentages (SIMPER) routine.

The magnitude of difference between benthic assemblages on Kirra Reef and the three comparative reefs was assessed using pairwise tests following ANOSIM. The average R value for each pairwise test was compared between Kirra Reef and the comparative reefs, and among comparative reefs. Analyses were completed separately for vertical and horizontal surfaces. Differences in the composition of assemblages are greater where R values are closer to 1, with no differences in the composition when R values are equal to 0 (Clarke 1993). We predict that differences in the composition of assemblages on Kirra Reef will become more similar over time to those on nearby comparative reefs and therefore that the average R value would become more similar to that found for differences among comparative reefs. This is measurable to check for an increase over the past few years, and model a prediction

A historical comparison of difference in the composition of benthic assemblages on horizontal surfaces was made with previous survey data from 2010, 2012, 2014 and 2015, and the current survey in 2016. Data from 2016 was aggregated into similar coverage categories as used previously (FRC 2015). The untransformed percent coverage data was converted to a Bray Curtis similarity matrix and differences between Kirra and Palm Beach reefs over time was examined using a three factor PERMANOVA. The factors used in the analysis were Time (fixed); Reef (fixed); transect (nested in Reef and random) or as described previous. Differences in the composition of benthic assemblages between reefs over time were visualised using non-metric Multidimensional (nMDS) Scaling ordinations, using centroids for each reef x time combination.

K-dominance curves were used to examine the diversity (richness and evenness) of benthic faunal assemblages among the different reefs for horizontal and vertical surfaces (Clarke 1990). Average data for each transect was used to generate the K-dominance curves in PRIMER v6 (Clarke and Gorley 2006). These curves are helpful in identifying 'stressed' communities, characterised by having few taxa that contribute a high proportion of the overall abundance (Clarke 1990).

3.4.2 Fish communities

Video footage collected from the BRUVS and ROV were assessed using slow playback mode within Windows Media Player v12. For each video file, the following data was determined for each species present:

- MaxN value – representing the maximum number of individuals of a particular species visible at any single point within the video file (Cappo et al. 2003)
- MaxN time – video time at which MaxN occurred
- Overall abundance ratings based on previous assessment categories (* = <5 individuals, ** = 6 – 20 individuals, *** = 21 – 100 individuals, **** > 100 individuals).

Fish that could not be identified to species were noted and reassessed following the completion of all video assessments. These taxa were identified to the highest taxonomic level (i.e. genus / family) if a positive species level identification was still not possible.

Species richness was calculated for each replicate sample (video file), assessment technique (ROV and BRUV) and compared amongst reefs. Species richness was aggregated among sites and collection methods for Kirra Reef and Palm Beach Reef for comparison against historic values.

Multivariate analysis was undertaken to determine differences in the composition of fish communities among reef systems between putative impact (Kirra reef) and control sites. Analysis was undertaken on a Bray-Curtis similarity matrix of square root transformed ROV MaxN data. The similarity matrix was then used to produce the following:

- non-metric multidimensional scaling (nMDS) ordination of community structure that provide a two-dimensional representation of the similarity among samples
- a one-way analysis of similarity (ANOSIM) was performed to test for a statistically significant difference between ROV video replicates amongst reefs
- similarity percentage (SIMPER) analysis was used to identify the key taxa contributing towards to dissimilarity amongst reefs.

Multivariate statistical analysis was performed using PRIMER v 6.1.14 software.

3.5 Limitations

- ROV position accuracy using the USBL tracking system was reduced when the ROV was positioned along reef crevice's and/or within shallow water with objects obstructing direct line between ROV and the vessel Subsequently, only geo-reference transect lines were collected (with accurate start and end locations) given the likely inaccuracy of geo-positioned quadrat locations. This was supplemented with heading, depth and time information.
- The quality of available aerial imagery was highly variable between time epochs, for example reflection off the water surface and differences in water clarity at different points in time meant that the areal extent of the reef could not be calculated for many time periods.
- geo-referencing and ortho-rectification of the imagery over the submerged reef areas tend to be of a lower quality due to lack of ground control points in these areas which is exacerbated by the fact that these areas tend to be on the edge of the aerial images (and therefore experience greater spatial distortion). In some images this has resulted in distorted reef shape and area which may cause area-change artefacts.
- Voucher specimens were not collected during the field assessment. Identification to morphospecies has been made to the lowest possible taxonomic level based on previously validated image library and an understanding of commonly occurring species on subtidal reefs in the area. The total number of morphospecies may underestimate the true number of species found on the reefs. Confirmation of the identification morphospecies is required using voucher specimens collected from the field (particularly for encrusting species).

4 Literature review

4.1 Previous survey effort

A summary of monitoring sites used within previous assessments is provided within Table 4. Due to historic variability in exposed reef extent at Kirra Reef, up to nine monitoring sites have previously been assessed; however, of these, three sites on the outer western reef section (KRO3, KRN1 and KRN2) have been consistently assessed in the past four survey events. These sites were selected for use within the updated monitoring program.

On Palm Beach Reef, three sites have been consistently used over time (PB1, PB2 and PB3). However, the location of these sites has varied between surveys (FRC 2015, FRC 2014). Locations for Palm Beach reef control sites within the current program have been selected based on best comparable attributes to those found at Kirra Reef.

Table 4 Previous sampling effort undertaken as part of the Kirra Reef Monitoring Program

Reef	Site name	Code	Apr 1995	Jun 1995	Feb 1996	Jan 2001	May 2003	Mar 2004	Feb 2005	Feb 2010	Jul 2012	Apr 2014	Mar 2015
Kirra Reef	Kirra Reef outer 1	KRO1	✓	✓	✓	✓				✓			
	Kirra Reef outer 2	KRO2	✓	✓	✓	✓							
	Kirra Reef outer 3	KRO3	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Kirra Reef inner 1	KRI1	✓	✓	✓	✓							
	Kirra Reef inner 2	KRI2	✓	✓	✓	✓	✓			✓			
	Kirra Reef inner 3	KRI3	✓	✓	✓	✓	✓						
	Kirra Reef new 1	KRN1						✓	✓	✓	✓	✓	✓
	Kirra Reef new 2	KRN2						✓	✓	✓	✓	✓	✓
	Kirra Reef new 3	KRN3							✓				
Palm Beach Reef	Palm Beach 1	PB1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Palm Beach 2	PB2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Palm Beach 3	PB3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

4.2 Abiotic factors

4.2.1 Temporal patterns in wave height and direction

Analysis of significant wave height (Hs) and wave direction (Pkdir) data recorded offshore of Tweed Heads (waverider buoy, 271,037 records from 01/01/2000 to 31/05/2016) is presented within a wave rose diagram (Figure 10) and frequency occurrence charts for both wave height groupings (Figure 11) and wave direction groupings (Figure 12).

Data presented indicates the following patterns in wave conditions occurring along the Tweed coast:

- the direction of swell ranges from the NNW to SSE, where 99.68% of all records are recoded from a NNE to SE direction
- most predominately, swell occurs from the E (36.24%) and ESE (33.71%) directions, collectively accounting for 69.95% of all wave records assessed. Of these records, prevailing wave heights are generally from 1 to 2 m (40.22%) and below 1 m (25.58%)
- wave height is commonly below 2 m (93.45%), with wave heights of 2 to 3 m occurring considerably less frequently (5.67%)
- large swell and/or storm events with wave height of more than 3 m account for a very small proportion (0.87%) of all wave records, representing approximately 101 days of occurrence over the 16-year period.

Patterns in the direction and frequency of large swell (>3 m) is shown within a wave rose diagram (Figure 16) and frequency occurrence charts of wave height groupings (Figure 17) and wave direction groupings (Figure 18). This refined dataset (2428 records equating to 101 days) identifies the following patterns in large swell events:

- swell greater than 3 m occurs from a NE to ESE direction and are more prevalent from a ENE (51.57%) and E direction (40.28%)
- previously noted predominant ESE swell (<3m) is not represented within swells greater than 3, where large ESE swell attributes only 1.94% of records (waves >3 m)
- no large swells have been recorded occurring from a SE, SSE or S direction, or conversely from a NNE and N direction
- swell greater than 6 meters have occurred only from ENE and NE direction.

Seasonal patterns in significant wave height are shown as wave rose diagrams in Figure 19 and indicted the following key patterns occurring:

- ENE swell is more prevalent in summer (20.97%) and autumn (20.18%) than within winter (10.88%) and spring (13.18%), conversely, ESE swell is more prevalent in winter (42.70%) and spring (36.27%) than summer (26.06%) and autumn (30.18%).

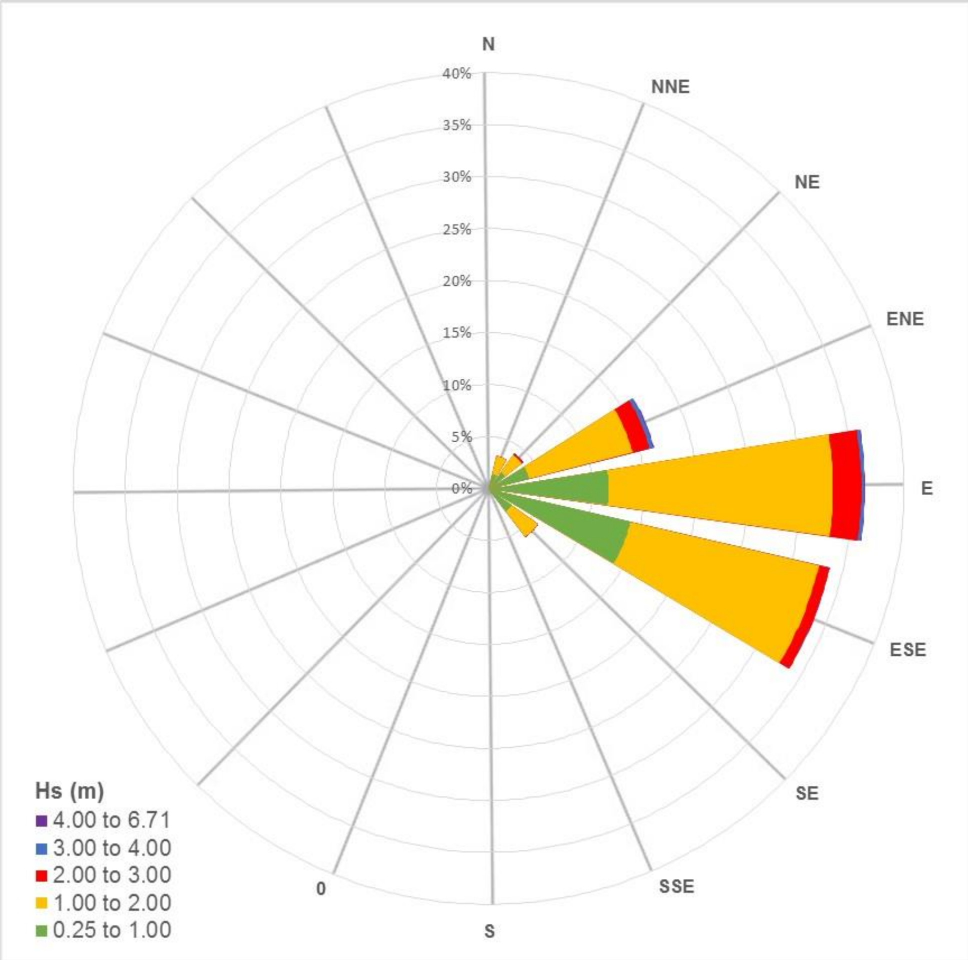


Figure 7 Significant wave height (Hs in m) and wave direction (Pkdir) determined from the Tweed Heads waverider buoy data -01/01/2000 to 31/05/2016

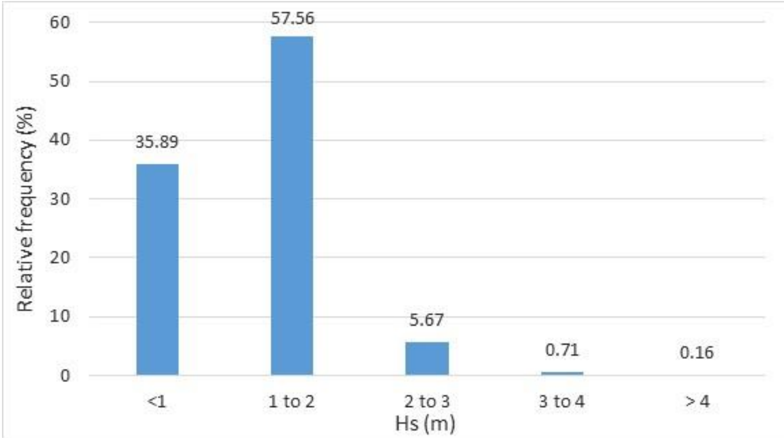


Figure 8 Relative frequency of significant wave heights (Hs) determined from the Tweed Heads waverider buoy hourly interval data -01/01/2000 to 31/05/2016

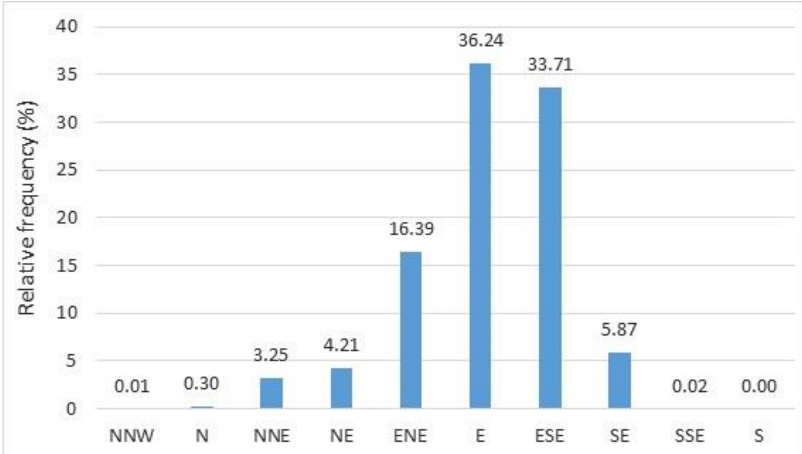


Figure 9 Relative frequency of wave direction (Pkdir) determined from the Tweed Heads waverider buoy hourly interval data -01/01/2000 to 31/05/2016

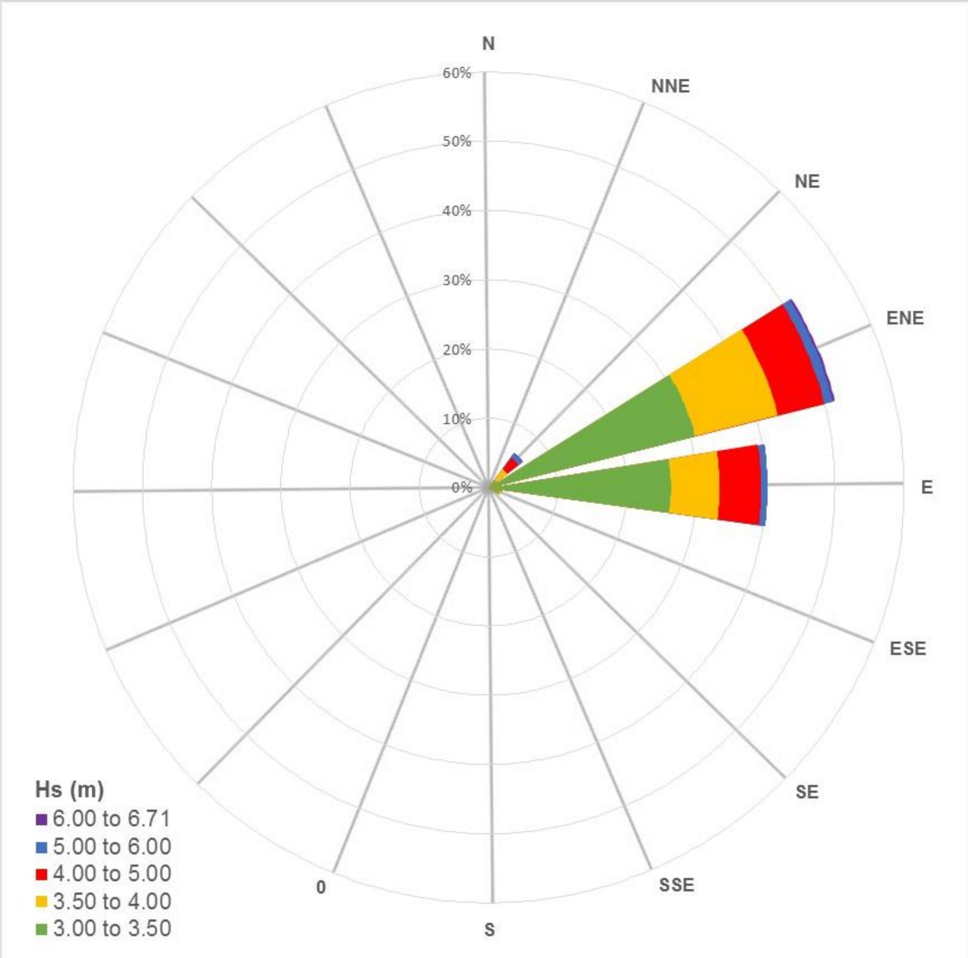


Figure 10 Significant wave height of >3m (Hs) and wave direction (Pkdir) determined from the Tweed Heads waverider buoy data -0.87% of records from 01/01/2000 to 31/05/2016

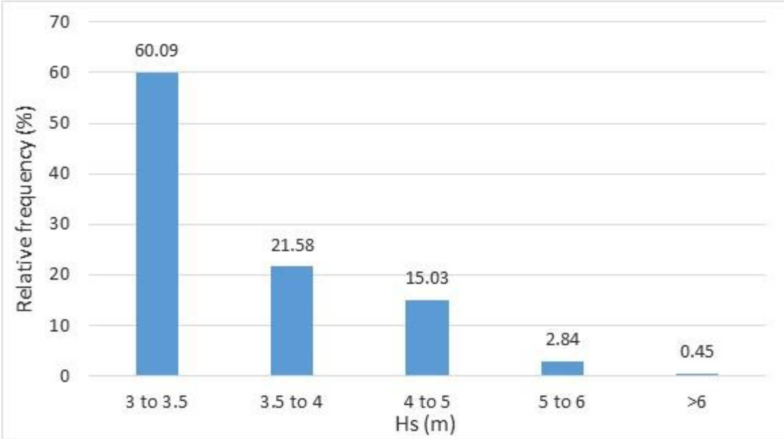


Figure 11 Relative frequency of significant wave heights (Hs) greater than 3m

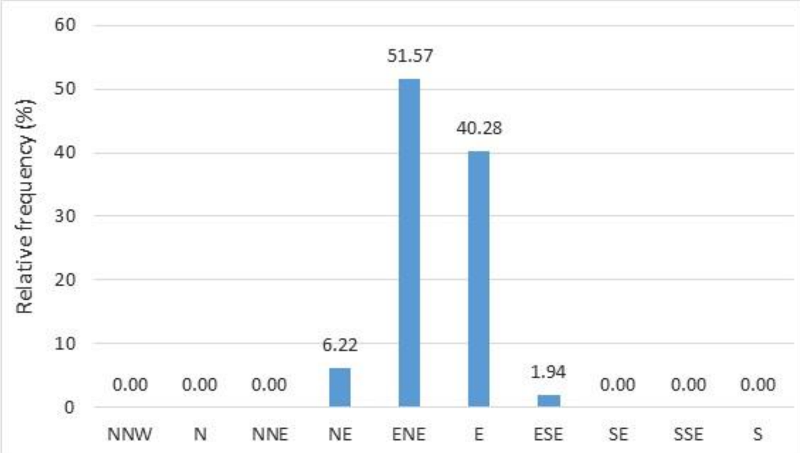


Figure 12 Relative frequency of wave direction (Pkdir) for wave heights greater than 3m

- conditions are typically calmer (≤2 m) within spring (97.52%) opposed to other seasons (90.55 to 93.55%)
- larger swell events (>3 m) occur more frequently within autumn (1.39%) than within other seasons (summer = 0.97%, winter = 0.91% and spring = 0.19%).

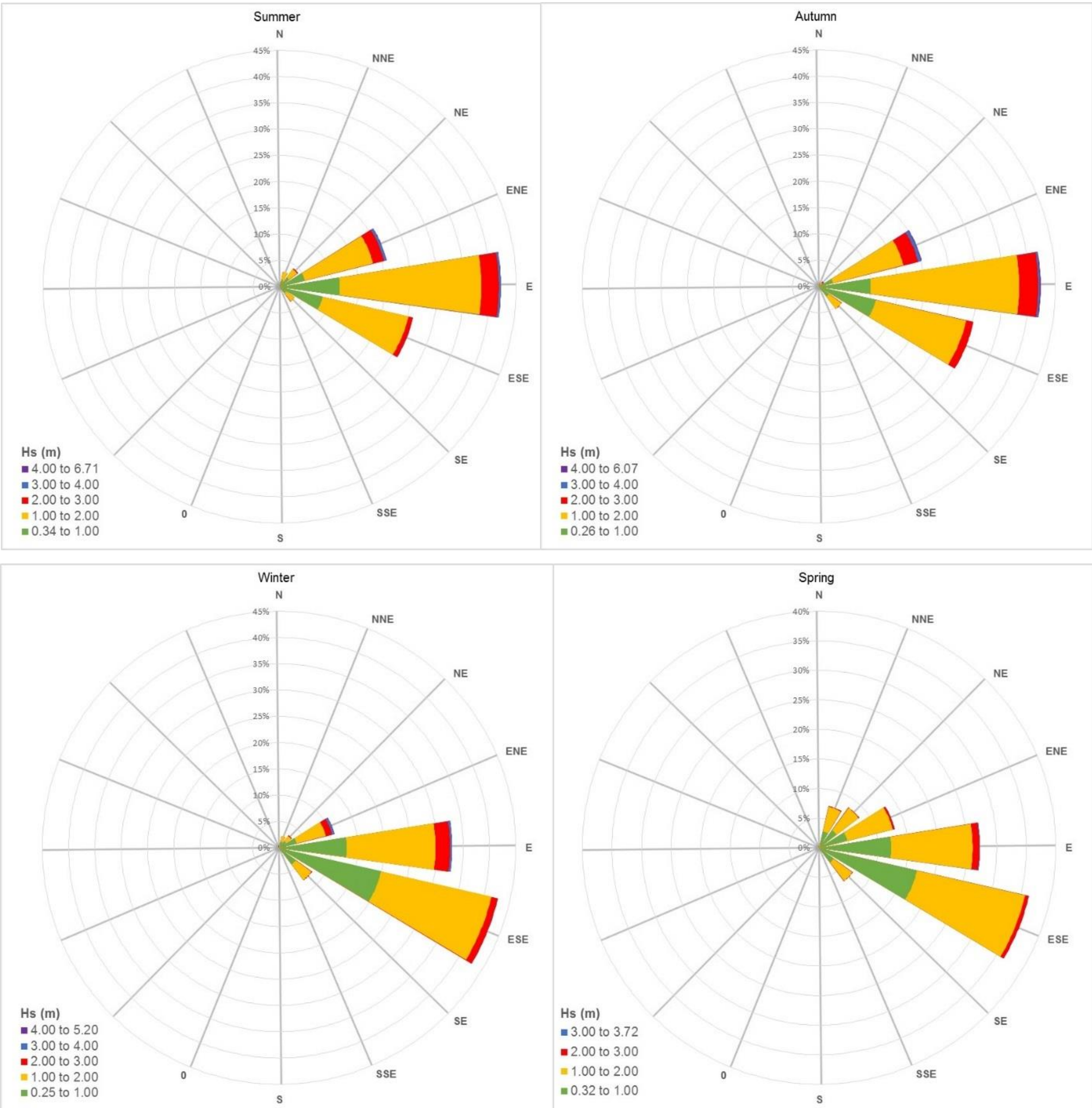


Figure 19 Seasonal patterns in significant wave height (Hs in m) and wave direction (Pkdir) determined from the Tweed Heads waverider buoy data -01/01/2000 to 31/05/2016

4.2.2 Significant swell events

Annual patterns in large swell occurrence (i.e. >3 m) is shown within wave rose diagrams within Figure 20 and Figure 21 and can be summarised as:

- prolonged periods of swell >5 m occurred during 2004, 2009 and 2013, with 2009 having the longest recorded duration of swell
- during 2000, 2001, 2005, 2006, 2012 and 2015 large swell event of 4 to 5 m height occurred for an extended duration
- little to no large swell events occurred during 2002, 2003, 2010, 2011 and 2014.

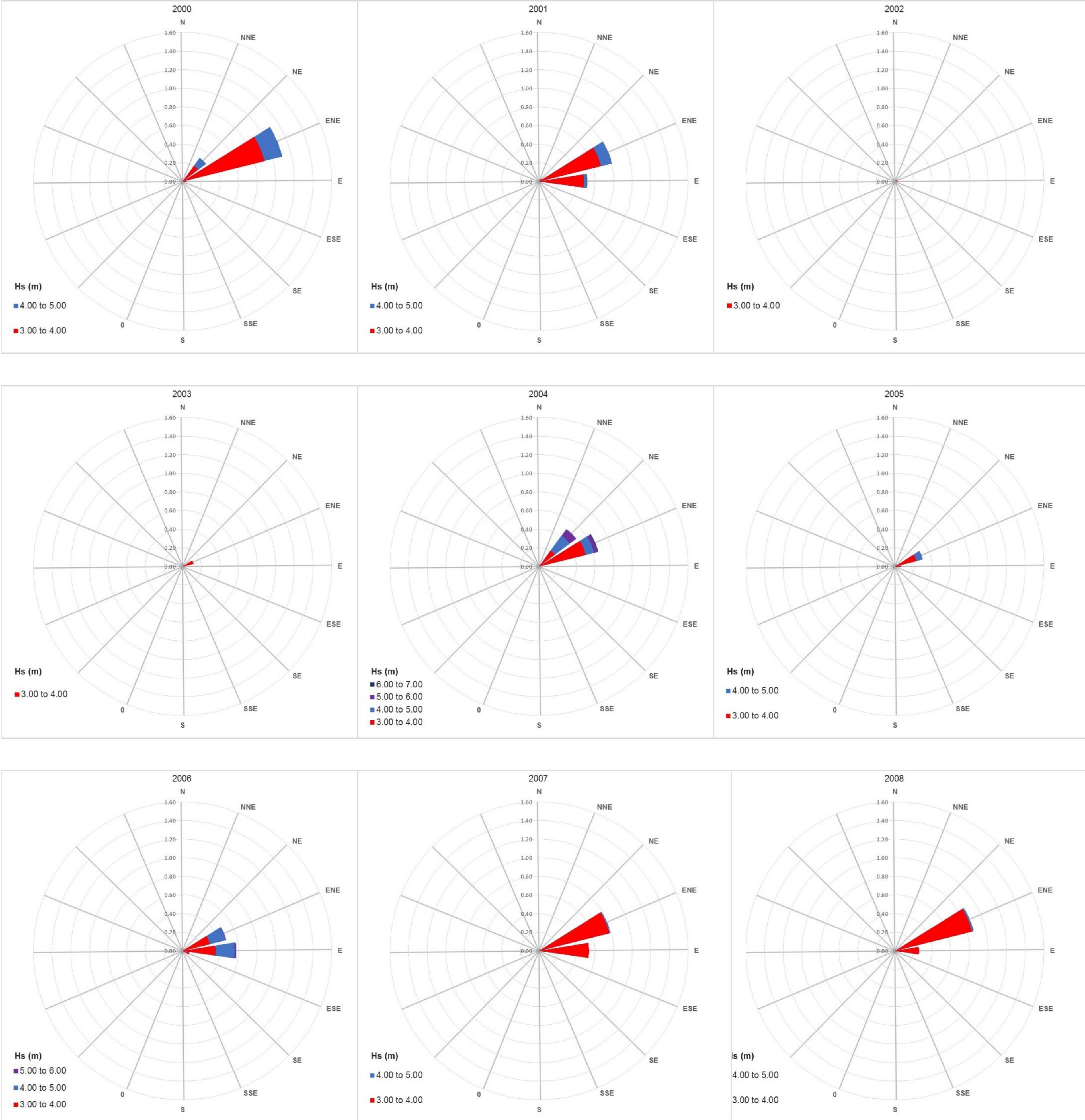


Figure 20 Annual patterns in significant wave heights (Hs in m) of >2 m and wave direction (Pkdir) determined from the Tweed Heads waverider buoy data

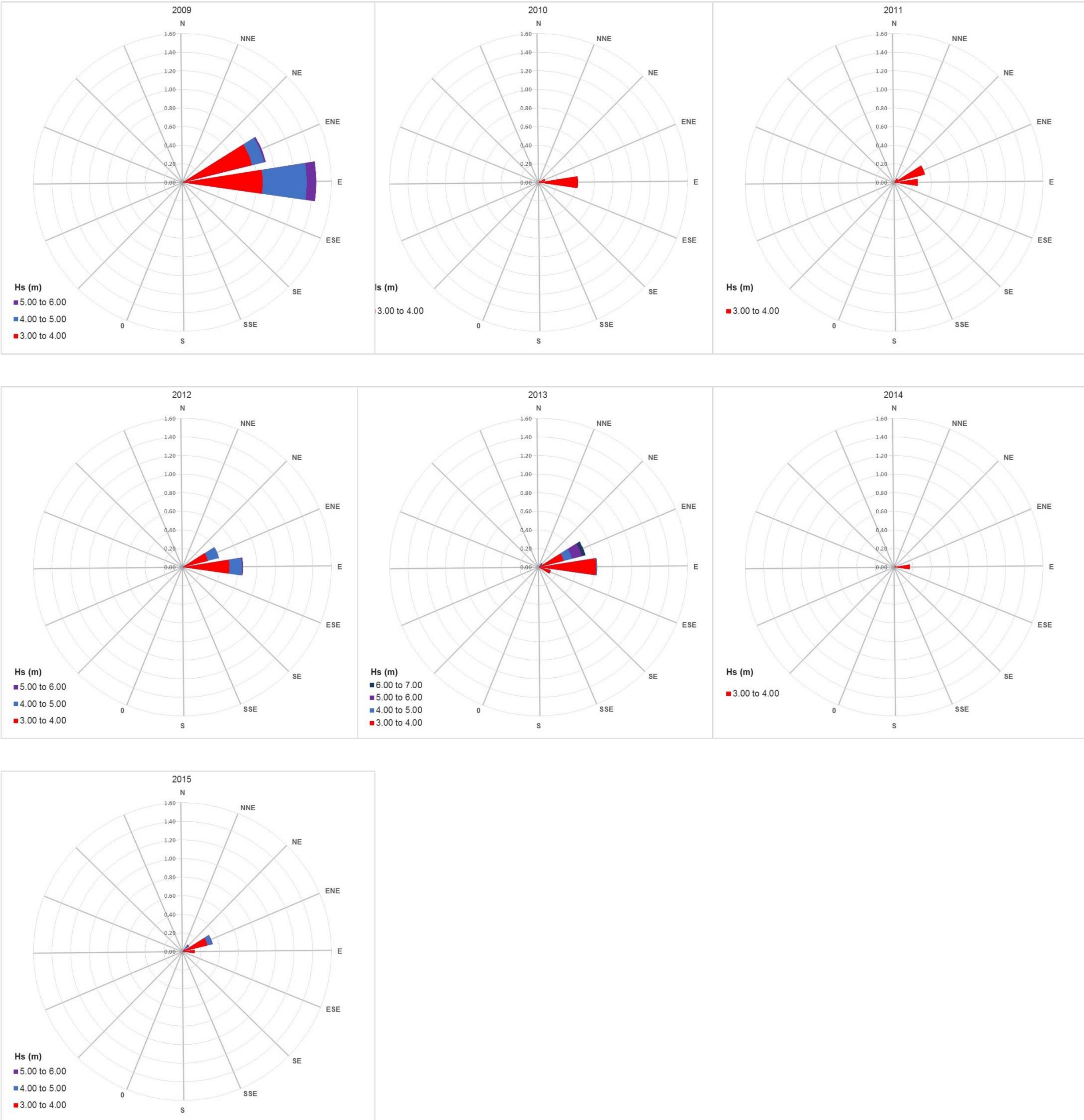


Figure 21 Annual patterns in significant wave heights (Hs in m) of >2 m and wave direction (Pkdir) determined from the Tweed Heads waverider buoy data continued

4.2.3 Temporal patterns in sea surface temperature

Percentile statistics (20th and 80th percentiles) of sea surface temperatures recorded within waters approximately 1,600 m offshore of the Tweed Coast (Tweed Heads waverider buoy data) were determined annually (Figure 22) and monthly (Figure 23) to investigate temporal patterns.

Sea surface temperatures recorded during the study ranged from 12.25°C to 28.20°C. Long term data considered on an annual basis (Figure 22) show some anomalies, including:

- data recorded during 2013 has consistently lower temperatures than all other years. This is likely to be an instrument error, where data shows an immediate drop in temperature on the 8th February 2013 (5.70°C) extending consistently lower temperatures extending for 347 days until an immediate rise in temperature (9.8°C) on the 21st of January 2014
- in 2010, warmer conditions were recorded in mid to late early spring compared to the lower temperatures recorded from other years
- typically, sea surface temperature ranged from 19.45°C (20th percentile value excluding 2013) to 25.70°C (80th percentile value excluding 2013 data).

Monthly data (Figure 23) excluding the 2013/2014 data anomalies listed above, depicts seasonal patterns in sea surface conditions with the warmest average (50th percentile) temperatures recorded during February to March and the coolest from July through till September. The range of temperatures recorded is greatest within the summer months when low sea temperatures can occasionally occur.

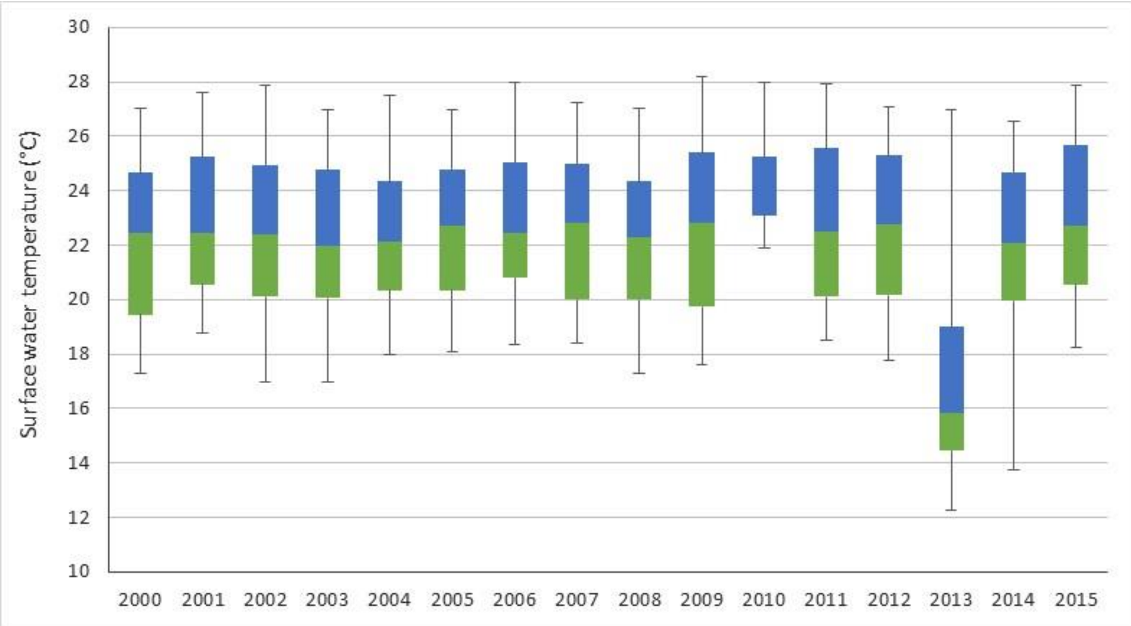


Figure 22 Box plots (20th & 80th percentiles) displaying annual sea surface temperatures for surface waters measured 1,600 m offshore of the Tweed Coast (Tweed Heads waverider buoy data)

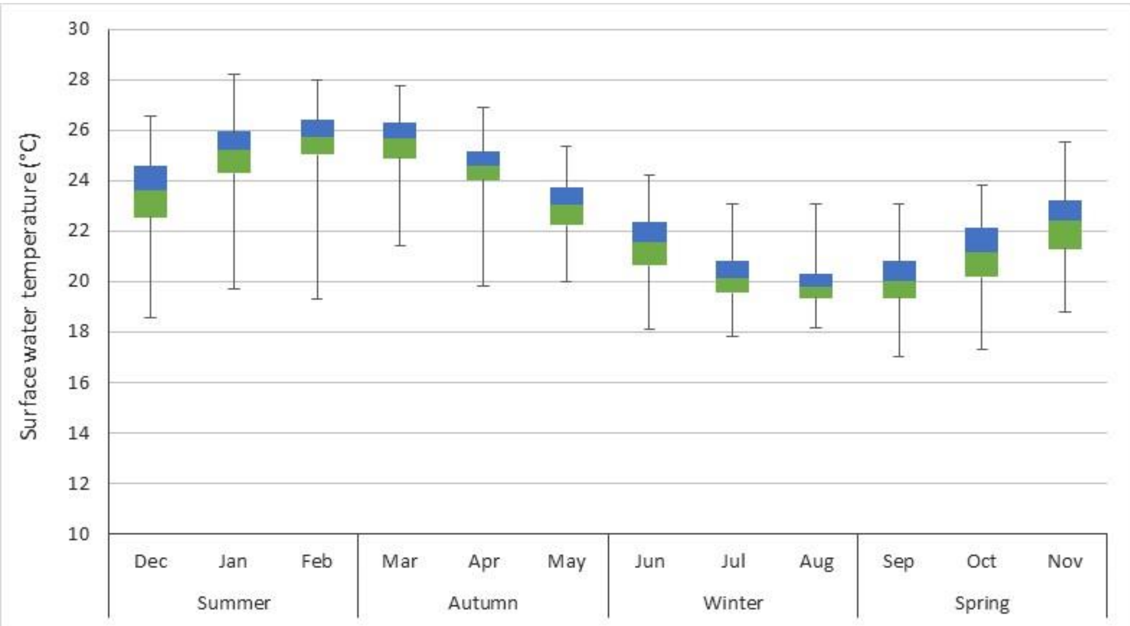


Figure 23 Box plots (20th & 80th percentiles) displaying monthly sea surface temperatures for surface waters measured 1,600 m offshore of the Tweed Coast Tweed Heads waverider buoy data)

4.3 Temporal changes in exposed reef extent

4.3.1 Kirra Reef

Historic changes in exposed reef extent at Kirra Reef has been documented previously (FRC 2015), with approximate areas of exposed reef summarised below within Table 5. Additional to identifying recent changes within reef exhumation, the following section focuses on comparing key patterns in reef exhumation since November 2011 with prevailing wave dynamics (significant wave heights (Hs in m) and wave direction (Pkdir)).

From March 2015 to May 2016 (Figure 25) the overall exposed area of reef at Kirra has increased by approximately 538m^2 incorporating both areas of recent reef exhumation and reef burial, including:

- burial of a small outcrop (116 m^2) on the eastern section of the reef, being exhumed in 2015 following six years of burial
- increases within reef exposure within the northern section of the reef (654 m^2) linking three isolated outcrops to the main section of the reef.

Additional to these recent changes in reef exposure, key patterns in the aerial extent of Kirra Reef since November 2011 include:

- 11th November 2009 to 9th November 2011 – minimal change in reef extent (+35 m^2)
- 9th November 2011 to 5th August 2012 – considerable increase in the aerial extent of the northern section (+2,656 m^2)
- 5th August 2012 to 17th May 2013 – the northern section of reef covered by sand, southern and eastern section of reef further exposed resulting in a slight reduction in overall reef area (-161 m^2)
- 17th May 2013 to 15th June 2013 – reduction in reef extent with the NE edge of the northern reef covered (-738 m^2)
- 15th June 2013 to 9th April 2015 minimal change in reef extent (-13 m^2).

Patterns in exhumations and burial were assessed for any correlation with wave height and direction. There was no evident correlation between prevailing wave characteristics and the aerial extent of Kirra Reef considering predominate wave height / direction (i.e. all data). However, through the gradual elimination of smaller wave categories, it was identified that waves of three meters and greater showed a strong degree of correlation between periods of burial and exhumation (Figure 24), with the following notable observations:[1]

- between May 2013 and June 2013, a reduction in reef extent of 738 m^{2}occured during this period when wave heights did not exceed 3 m

[1] Notably, observations do not account for any variability within sand pumping

- within two periods extending from November 2009 to November 2011 and June 2013 to April 2015 there was no considerable variation in reef extent at Kirra. During these periods, swell events of 3 to 4 m did occur from an easterly direction, though no swell events of greater than 4 m occurred
- periods of expansion in reef extent (i.e. the aerial extent increased due to exhumation increased due to exhumation) coincided with three periods of where swell events of greater than 4 m occurred (November 2011 to August 2012; August 2012 to May 2013; March 2015 to May 2016).

4.3.2 Control reefs

Spatial variation within reef extent was explored using available imagery to determine:

- suitable locations for ongoing monitoring
- natural temporal variability within nearshore reef located north and south of Kirra Reef.

Patterns in reef exposure for nearshore areas of the three determined control sites include:

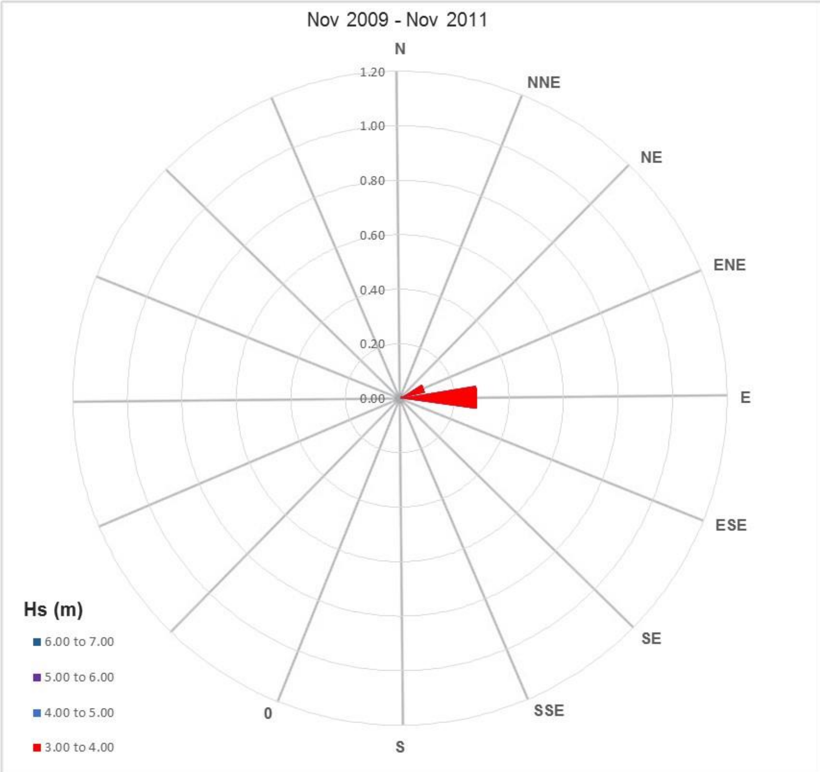
- Palm Beach Reef (Figure 26) – increase in reef exposure within central eastern section of the reef between July 2010 and May 2014 (+2,563 m^2). Other sections of the reef show notable change in exposure. Minimal change in reef exposure between May 2014 and May 2016 (+187 m^2)
- Cook Island Reef (Figure 27) – main section of reef consistent in exposure from 2013 to 2016, some variation within reef exposure on inner north-eastern corner of the reef and an out crop north of the main reef section (+2,223 m^2)
- Kingscliff Reef (Figure 28) – reduction in northern, southern eastern margins of main inshore reef system from June 2013 to May 2016 (-24,216 m^2). Central nearshore section of the reef shows minimal change.

Table 5 Historic approximations of exposed reef extent (area in m^2) for Kirra Reef, Palm Beach Reef, Cook Island Reef and Kingscliff Reef

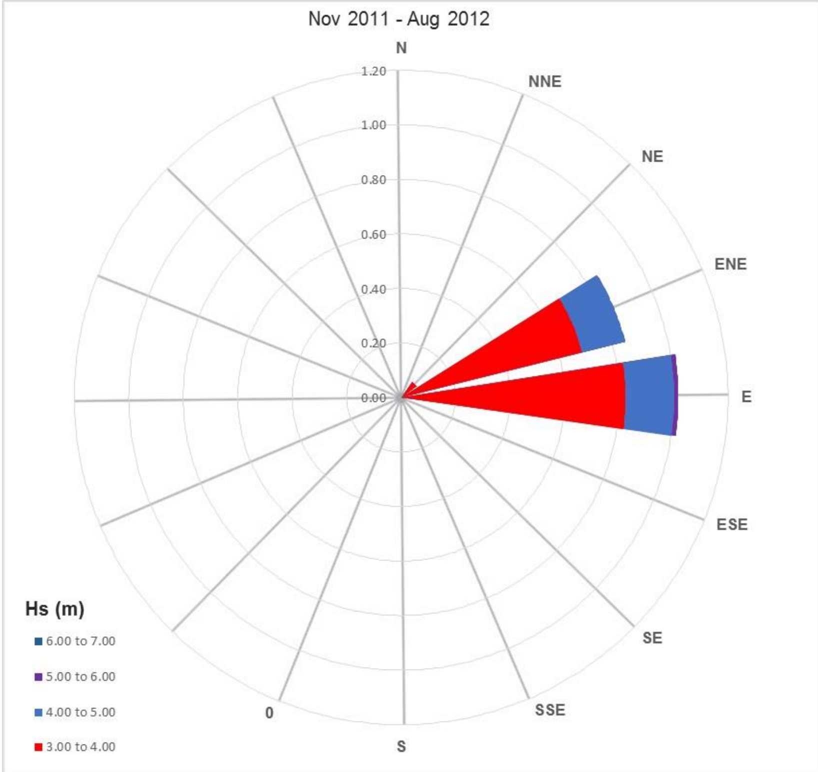
Date	Kirra Reef	Palm Beach Reef	Cook Island	Kingscliff Reef	Imagery source
May 2016	3,326	118,146	388,072	240,942	Nearmap
Mar 2015	2,788	-[2]	-	-	NSW DTI[3]
June 2014	-	-	383,495	268,071	Nearmap
Apr 2014	2,920	117,960	-	-	Nearmap[3]
Jun 2013	2,801	-	385,849	265,162	Nearmap[3]
May 2013	3,539	-	-	-	Nearmap[3]
Aug 2012	3,700	-	-	-	Nearmap[3]
Nov 2011	1,044				NSW DPI[3]
July 2010		115,397			Nearmap
May 2010	965				Nearmap[3]
Nov 2009	1,009				Nearmap[3]
Apr 2004	1,851				NSW DLWC[3]
Nov 2003	3,369				NSW DLWC[3]
Aug 2002	8,515				NSW DIPNR[3]
Feb 2001	20,398				NSW DIPNR[3]

[2] Nearmap imagery does not provide suitable clarity to determine aerial extent of reef exposure (-)

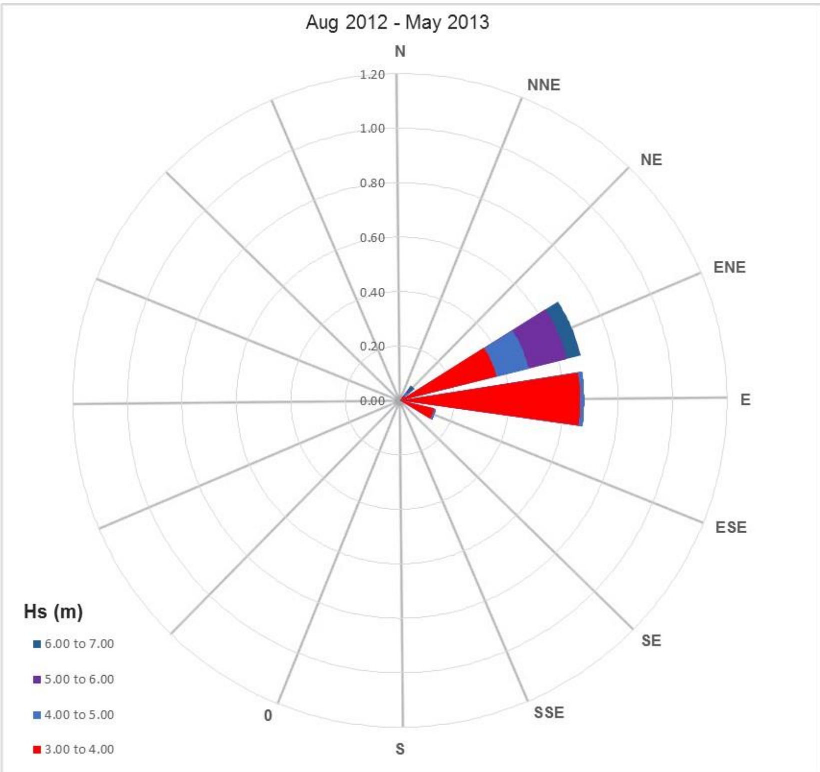
[3] Analysis of Kira Reef extent undertaken by FRC Environmental (FRC 2015)



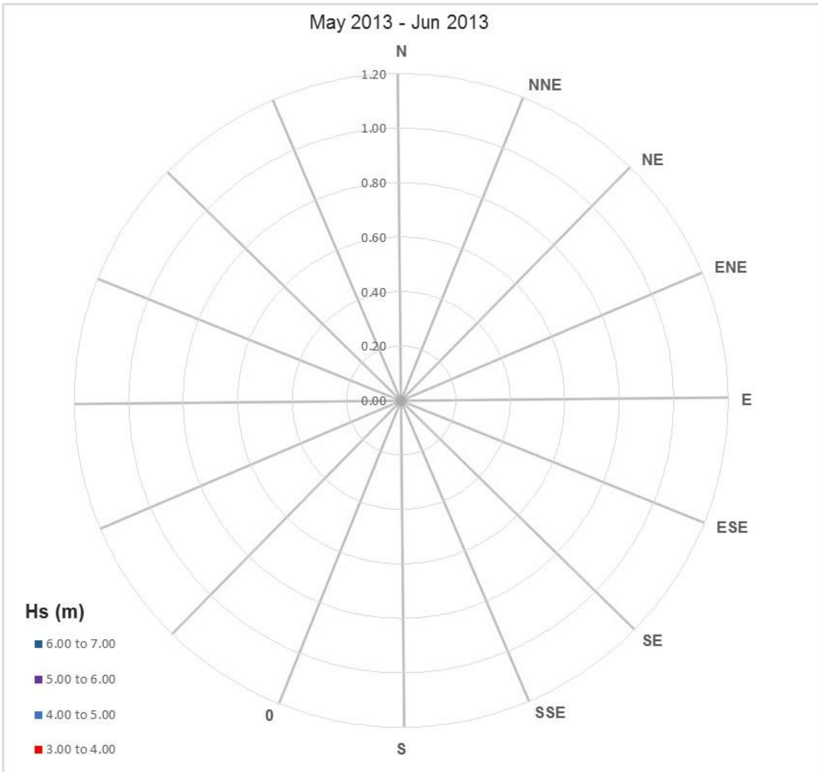
- minimal change in reef extent (+35m^2)



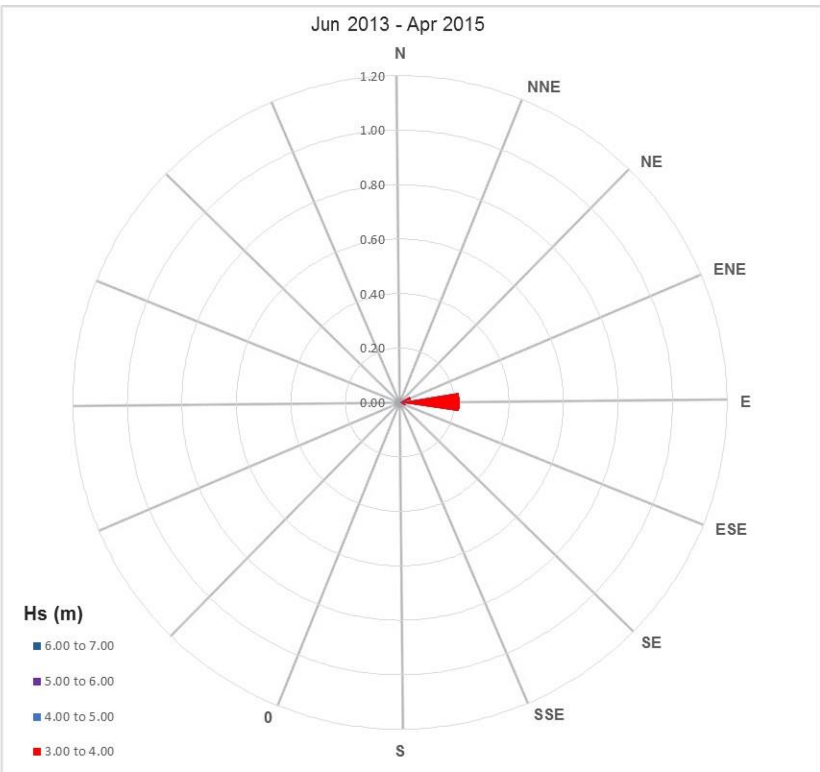
- considerable increase in exposure to outer northern reef extent (+2,656m^2)



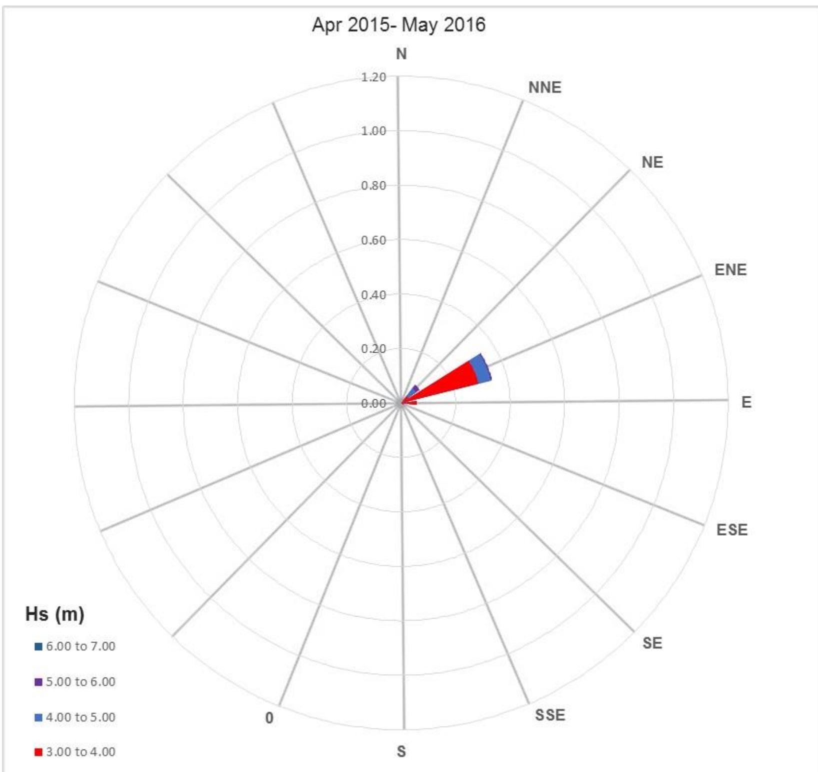
- northern section of reef covered, southern and eastern section of reef further exposed resulting in a slight overall reduction in reef exposure (-161m^2)



- reduction in reef extent, north eastern edge of reef covered by sand (-738m^2)



- minimal change in reef extent (-13m^2)



- some increase within the central section of northern reef, burial of small exposed eastern section of the reef (538m^2)

Figure 24 Significant wave heights (Hs in m) of >3m and wave direction (Pkdir) determined from the Tweed Heads waverider buoy data in relation to key changes in reef exposure at Kirra Reef (considered as an overall percentage of ewave records within a particualr time period)

Figure 19: Spatial extent of Kirra Reef in May 2016

Reef extent (3326 m^2)

Department of Industry

Kirra Reef Monitoring 2016

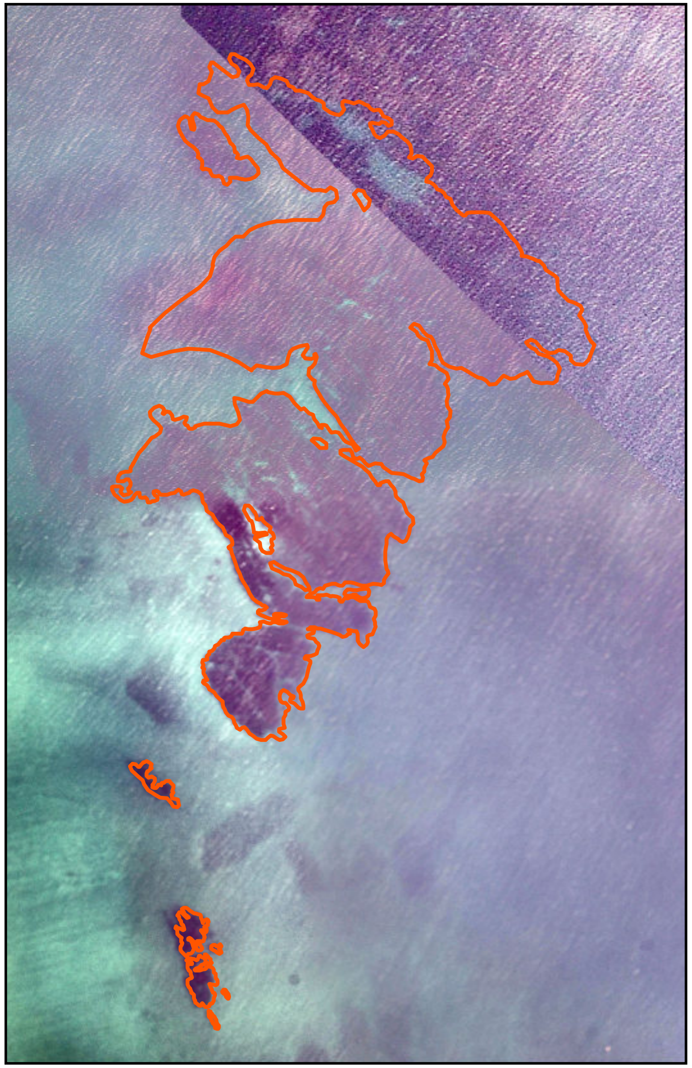
ecosure

Job number: PR1627
Revision: 1
Author: RSC DJB
Date: 25/10/2016

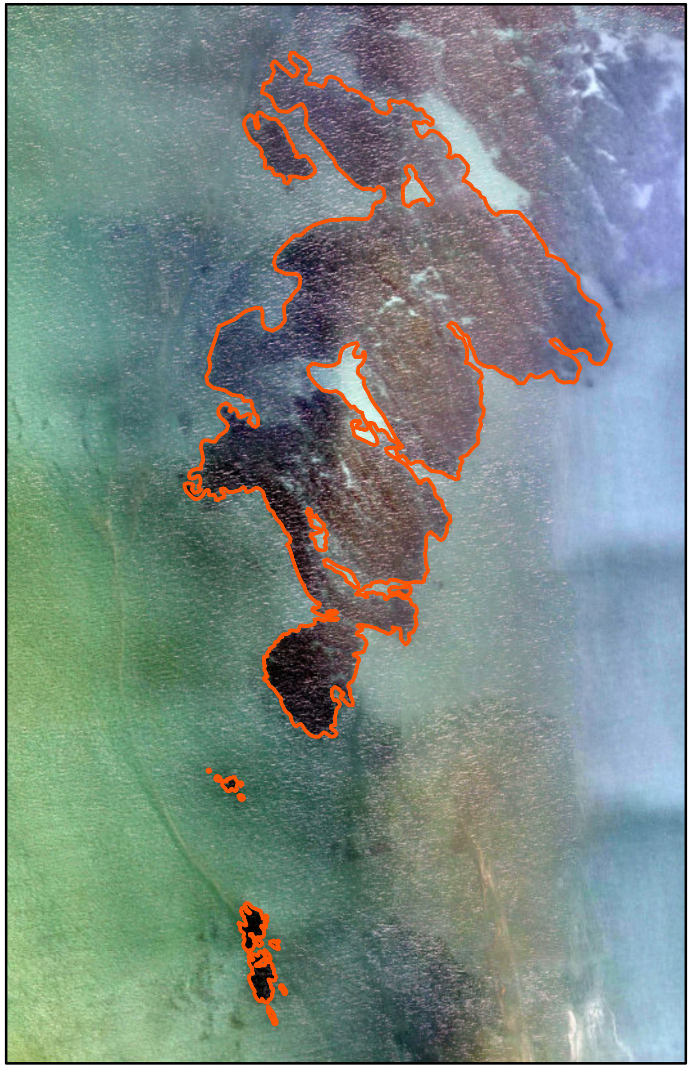
0 5 10 20
Metres

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meter

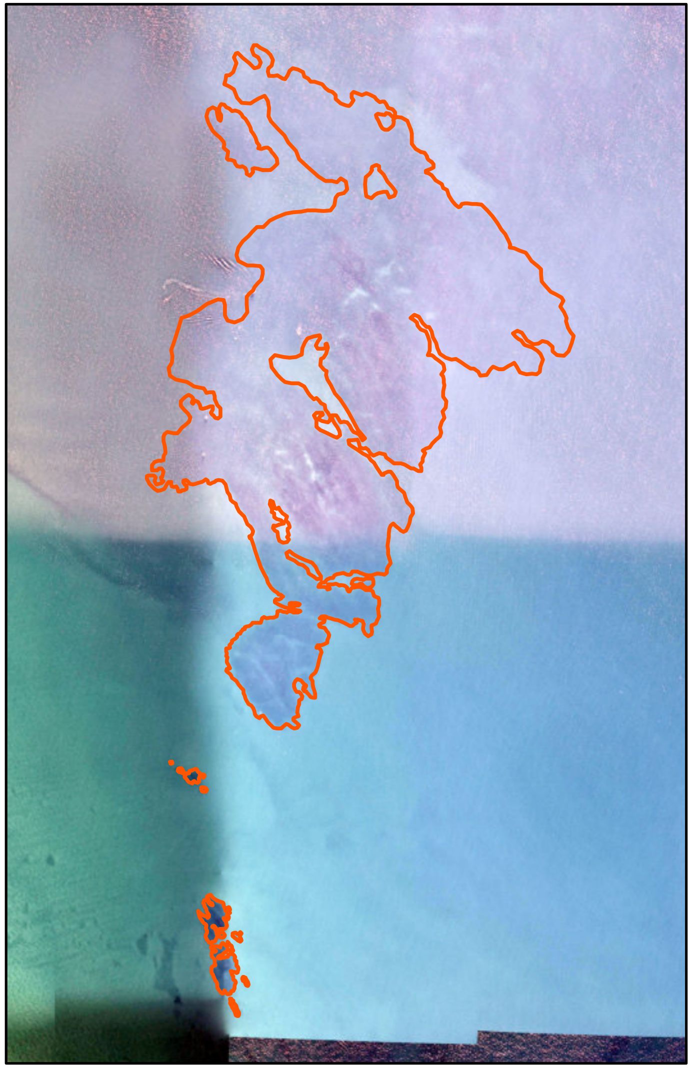
PR1627_MP19_Kirra_Reef_05_2016
A4



July 2010 - 115396 m^2



May 2014 - 117959 m^2



May 2016 - 118146.35 m^2

Figure 20: Spatial extent of Palm Beach Reef extent in 2010, 2014 and 2016

Extent of reef

Department of Industry

Kirra Reef Monitoring 2016

Job number: PR1627
Revision: 0
Author: RSC DJB
Date: 25/10/2016

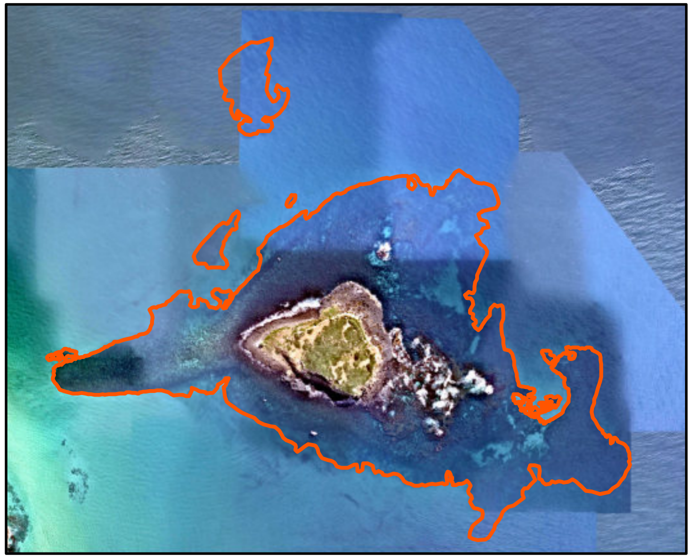
0 25 50 100
Metres

GCS GDA 1994
Datum: GDA 1994
Units: Degree

Data Sources: © Ecosure Pty Ltd, 2016; Image Nearmap 2016

June 2013 - 385849 m^2

June 2014- 383495 m^2



May 2016 - 388072 m^2

Figure 21: Spatial extent of Cook Island Reef extent in 2013, 2014 and 2016

Reef extent

Department of Industry

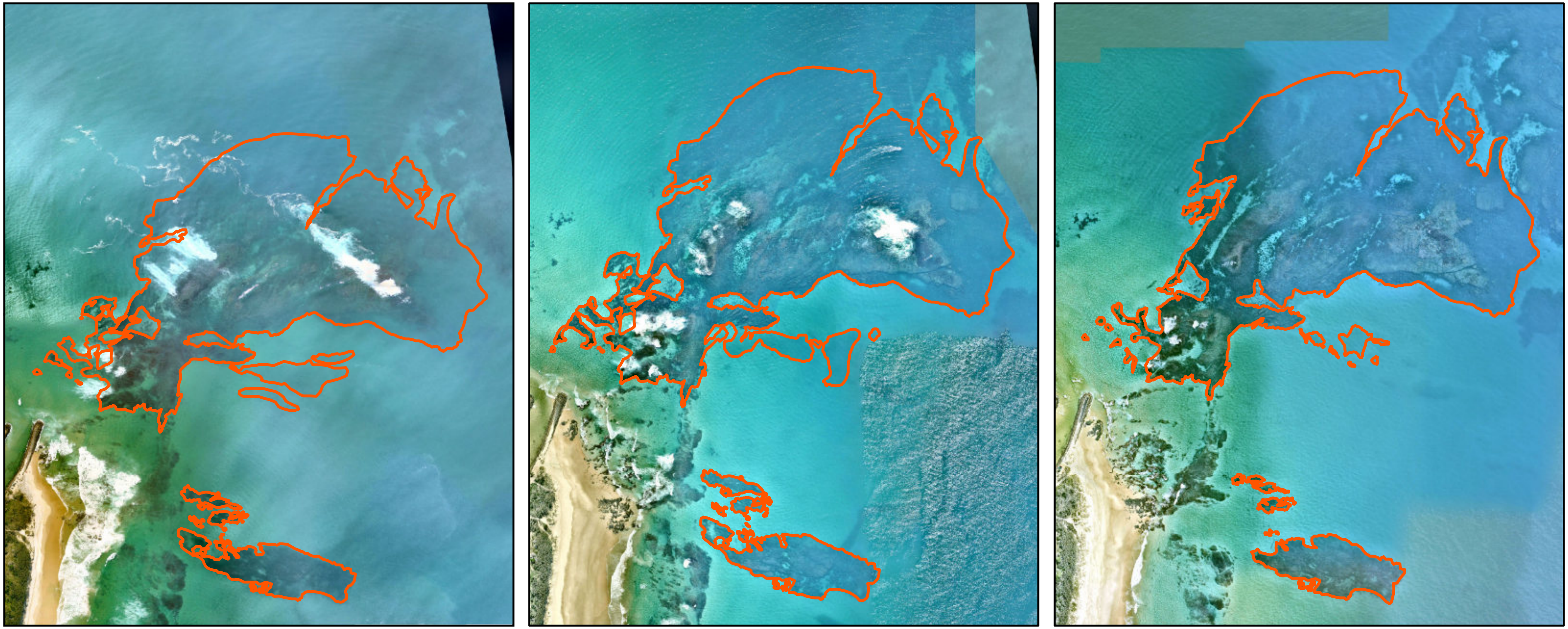
Kirra Reef Monitoring 2016

ecosure

Job number: PR1627
Revision: 0
Author: RSC DJB
Date: 25/10/2016

0 75 150 300
Metres

GCS GDA 1994
Datum: GDA 1994
Units: Degree



June 2013 - 265161 m^2 | June 2014 - 268071 m^2 | May 2016 - 240942 m^2

Figure 22: Spatial extent of Kingscliff Reef in 2013, 2014 and 2016

Department of Industry

Kirra Reef Monitoring 2016

Reef extent

ecosure

Job number: PR1627
Revision: 0
Author: RSC DJB
Date: 25/10/2016

0 75 150 300
Metres

GCS GDA 1994
Datum: GDA 1994
Units: Degree

4.4 Fauna and flora communities

4.4.1 Species of conservation significance

Database and legislative searches of the Commonwealth DoE EPBC Protected Matters Search Tool, Wildlife Online and NSW Bionet, listed 68 marine fauna species of conservation significance with potential to occur in the study area. This included 17 mammals, 11 reptiles, and 40 fish species (Appendix 1).

Of the species listed, several species of conservation significance are known or likely to frequent the study area based on current survey findings and available literature, including:

- humpback whale (*Megaptera novaeangliae*)
- southern right whale (*Eubalaena australis*)
- common dolphin (*Delphinus delphis*)
- Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)
- Indo-Pacific humpback dolphin (*Sousa chinensis*)
- loggerhead turtle (*Caretta caretta*)
- green turtle (*Chelonia mydas*)
- leatherback turtle (*Dermochelys coriacea*)
- flatback turtle (*Natator depressus*)
- black rockcod (*Epinephelus daemelii*).

4.4.2 Exotic / invasive species

Records from the National Introduced Marine Pest Information System (NIMPIS) indicated three pest species have previously been recorded within the Gold Coast / Northern NSW region, and include:

- *Halecium delicatulum* (hydroid) (Figure 29) recorded at Currumbin (1959), occurs in sub-tidal areas on wood, vessels, and concrete (NIMPIS 2016a)
- *Obelia dichotoma* (hydroid) (Figure 30) recorded at Currumbin (1959), found in sub-tidal areas on wood, vessels, and concrete (NIMPIS 2016b)
- *Ulva fasciata* (sea lettuce) (Figure 31) recorded at Byron Bay (1999), occurs in tidal areas on bedrock and reef (NIMPIS 2016c).

Kirra Reef may represent marginal habitat for *Ulva fasciata*, however it is unlikely that either hydroid species would occur as suitable habitat and substrates are not present.

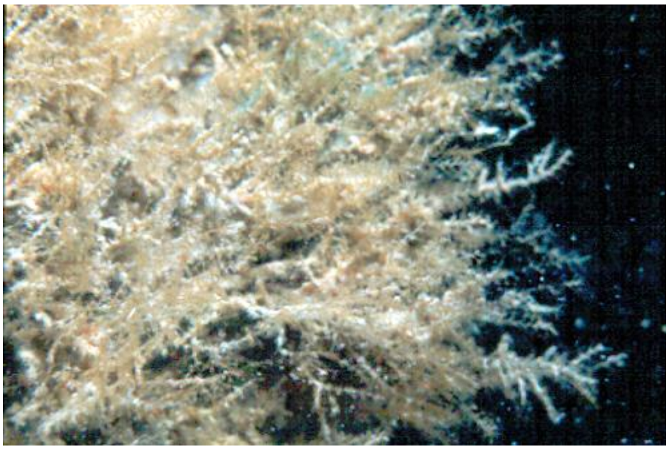


Figure 29 *Halecium delicatulum* (source: NIMPIS 2016a)

Figure 30 *Obelia dichotoma* (source NIMPIS 2016b)

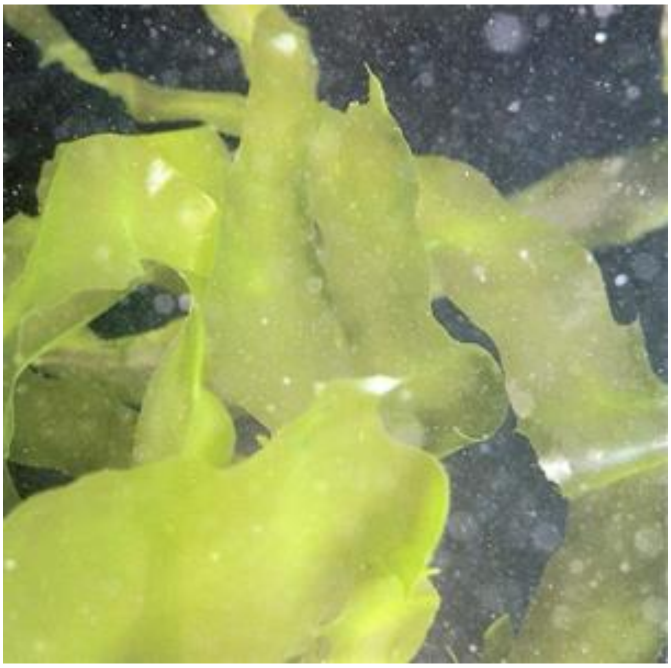


Figure 31 *Ulva fasciata* (source NIMPIS 2016c)

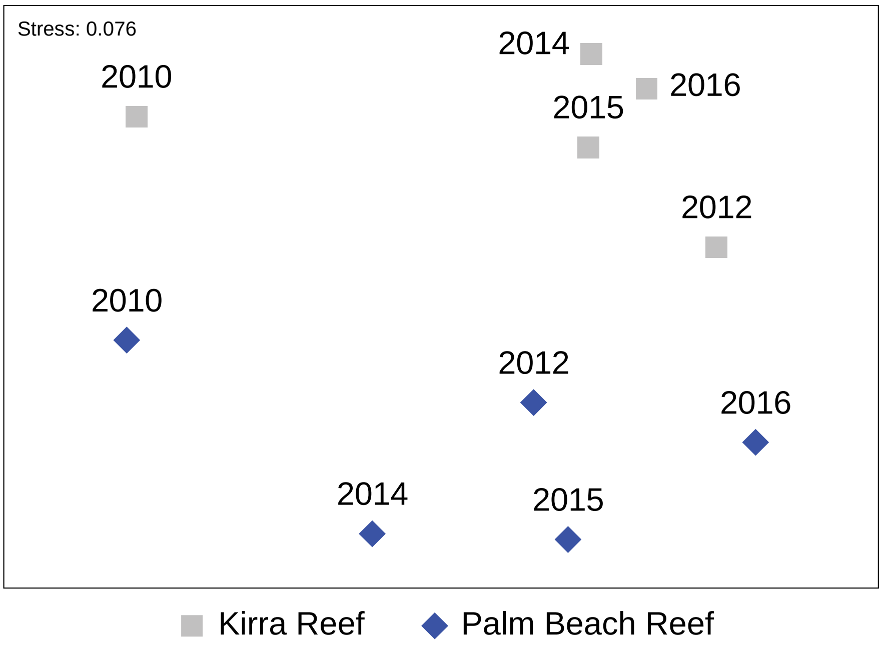
4.4.3 Historical community structure

The composition of benthic assemblages identified at a broad taxonomic level differed consistently between Kirra and Palm Beach Reefs over time; however, the composition at Kirra Reef has not differed in the past three years (Figure 32; PERMANOVA Time x Reef Interaction Pseudo-$F_{4,16}$ = 3.52, p = 0.001; pairwise comparisons Appendix 2). In contrast, the assemblages on Palm Beach Reef have differed consistently over time (Figure 32; PERMANOVA pairwise comparisons, Appendix 2).

The greatest difference in composition on Kirra Reef occurred between the 2010 and 2012 survey periods (PERMANOVA pairwise comparisons, Appendix 2), which was due to an average increase in the coverage of turf algae of 50% and decline in bare surface[4] (Table 6; SIMPER Appendix 2). Combined, these two factors accounted for 72% of the difference between the groups (SIMPER Appendix 2).

The coverage of benthic fauna has changed over time on Kirra Reef. In particular, the coverage of ascidians has increased to a high of 20% in 2014, although only covered 7% of horizontal surfaces in 2016 (Table 6). Sponges have remained relatively low in cover over time, peaking in coverage in 2015. The coverage of soft and hard corals on horizontal surfaces has remained low on Kirra Reef relative to Palm Beach Reef (Table 6). Differences between 2015 and 2016 may be due to modification of the methods incorporating the use of geo-referenced transects, point intercept methods to assess % coverage of different faunal categories on photo-quadrats and also a greater differentiation in assessing the composition of benthic assemblages on vertical and horizontal surfaces.

Figure 32 An nMDS ordination of the difference in the composition of benthic assemblages on horizontal surfaces between Kirra and Palm Beach Reefs between 2010 and 2016



[4] This may be due to variation in the degree of identification completed among the different surveys.

Table 6 Change in the percent coverage of benthic categories over time at (a) Kirra and (b) Palm Beach Reefs.

Benthic Cover Category	Kirra Reef					Palm Beach Reef				
	'10	'12	'14	'15	'16	'10	'12	'14	'15	'16
% Soft Coral	0.0	0.0	0.1	0.0	0.0	7.6	14.4	15.1	19.6	2.6
% Hard Coral	0.1	0.0	0.0	0.0	0.0	5.2	3.5	17.4	10.7	5.4
% Sponge	0.5	2.7	4.4	7.9	3.0	11.7	7.7	7.0	8.1	9.7
% Ascidians	7.4	0.0	20.2	13.1	7.0	9.5	7.8	8.8	2.8	3.3
% Barnacle	8.2	0.0	1.2	0.0	0.0	0.2	3.1	9.7	0.0	0.7
% Anemone	0.0	0.0	1.9	1.0	0.7	0.8	0.0	1.9	5.3	0.3
% Turf Algae	17.4	67.3	36.0	39.7	41.4	18.4	50.2	32.7	48.9	67.4
% Macroalgae	12.7	17.8	24.9	25.8	33.6	1.6	2.5	1.1	0.0	0.7
% Coralline Algae	0.0	0.0	7.1	8.8	7.4	0.0	0.0	0.0	0.0	8.5
% Bare Surface	53.7	12.2	4.4	4.8	2.6	45.1	10.8	6.3	4.7	0.2

5 Results

5.1 Benthic assemblages

5.1.1 Assemblage diversity and composition

Overall, the composition of the entire benthic assemblages differed at a range of spatial scales, with clear differences evident between surface orientations and among reefs (Figure 33a). The benthic assemblages on vertical surfaces at each of the reefs were typically more diverse than horizontal surfaces, and were dominated by turf algae and macroalgae (approximately 60% mean cover), with some ascidians (approximately 14% mean cover) and sponges (approximately 12% mean cover). Other taxa such as hard and soft corals, anemones and echinoderms covered less area (<5% mean cover) (See Appendix 2 for full list of taxa recorded). Benthic assemblages on horizontal surfaces were also dominated by turf algae and foliose macroalgae (approximately 73% mean cover) at each of the reefs, and the coverage of sessile fauna was much lower than on vertical surfaces.

The composition (type of taxa and coverage) of entire benthic assemblages differed between horizontal and vertical surfaces on each of the reefs, except at Palm Beach, where there was no difference between horizontal and vertical surfaces (Figure 33a; PERMANOVA Orientation vs Reef interaction, pseudo-$F_{1,8}$ = 3.54, p = 0.001, Appendix 2 post hoc pairwise comparisons). The difference in composition among the surface orientations was generally due to higher coverage of macroalgae (including turf algae, *Sargassum* spp., *Padina gymnospora, Jania adhaerens,* and coralline algae) on horizontal than vertical surfaces, particularly on Kirra Reef (see Section 5.1.2 for detailed discussion).

On horizontal surfaces the composition of benthic assemblages differed consistently among the reefs (Figure 33a; Appendix 2 Table 17, Table 18, Table 19, PERMANOVA[5] pairwise comparisons). There was a much greater difference in the composition of assemblages between Kirra Reef and the comparative reefs (average ANOSIM R-value = 0.787), than among the comparative reefs alone (Figure 34; average ANOSIM R Value = 0.477[6]).

A similar pattern was found among reefs for assemblages on vertical surfaces, except that there was no difference in the composition between Cook Island and Kingscliff Reefs, which clustered close together on the nMDS ordination below (Figure 33a; Appendix 2 Table 19 PERMANOVA pairwise comparisons). Again, there was a much greater difference in the composition of assemblages between Kirra Reef and the comparative reefs, than among the comparative reefs alone (Figure 34). There was a high coverage of benthic fauna on vertical surfaces at Kirra Reef; however, the benthic assemblages were often dominated by benthic macroalgae (including turf algae and *Sargassum* spp.) which contributed up to 52% of the difference between reefs (SIMPER, Appendix 2).

[5] PERMANOVA Orientation x Reef $MS_{3,8}$ = 9765, Pseudo-F = 3.54, p=0.001)

[6] ANOSIM Global R = 0.532, p=0.001; Average pariwise comparisons)

The differences in the composition of benthic assemblages could be due to a range of site-specific factors including differences in the disturbance regime and degree of sand burial (i.e. Kirra Reef was almost completely buried between 2009 and 2011; FRC Environmental 2015), abiotic factors, settlement and recruitment of sessile species, water quality and / or variation in the abundance of herbivorous fauna between reefs.

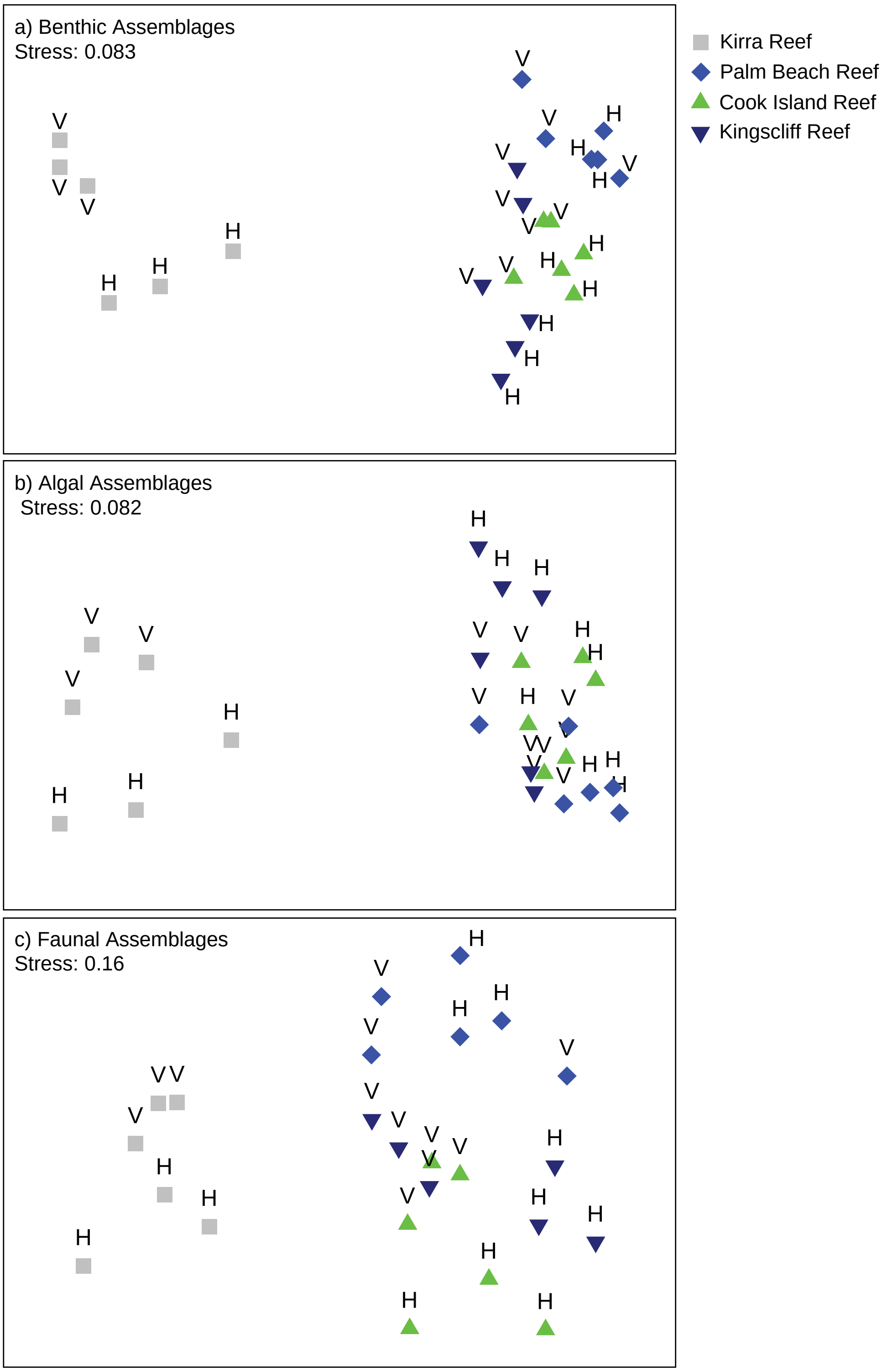


Figure 33 nMDS ordination showing difference in the composition of benthic assemblages between surface orientations and reefs for (a) all benthic organisms, (b) algal assemblages, and (c) faunal assemblages

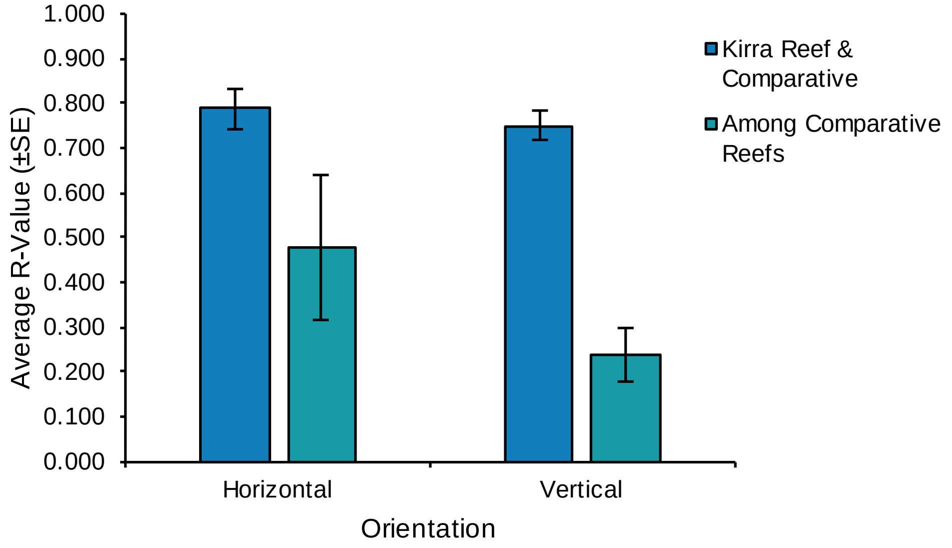


Figure 34 Average ANOSIM R-values (± SE) for differences between Kirra Reef and Comparative Reefs, and among Comparative Reefs

5.1.2 Algal assemblages

The algal assemblages were dominated by turf algae, foliose macroalgae such as *Sargassum* spp., *Padina gymnospora* and coralline algae including *Jania adhaerens*. The composition of algal assemblages differed at a range of spatial scales, with clear differences in the coverage of algae between reefs for each surface orientation, except on vertical surfaces between Cook Island and Kingscliff reefs which did not differ (Appendix 2 PERMANOVA Table 17, pairwise comparisons Table 18 & Table 19).

The average coverage of turf algae was lower on Kirra Reef than at the comparative reefs (approximately 42% on horizontal surfaces and 34% on vertical surfaces at Kirra compared with more than 45% at all other reefs). This difference in coverage contributed up to 50% of the difference between reef groups (SIMPER; Appendix 2 Table 23 & Table 24). On Kirra Reef *Sargassum* spp. on average covered 29% of horizontal surfaces and 12% of vertical surfaces. *Sargassum* spp. was absent at all the comparative reefs. This difference in the coverage of *Sargassum* spp. accounted for up to 38% of the difference in algal assemblages on horizontal surfaces between Kirra Reef and the comparative reefs, and up to 20% of the difference on vertical surfaces (SIMPER; Appendix 2 Table 23 & Table 24).

Fleshy macroalgae such as *Sargassum* can colonise bare substrata before other taxa such as sessile invertebrates, and can cause physical damage to recently settled fauna preventing them from re-establishing on coral reefs (Diaz-Pulido & McCook 2002). The high coverage of *Sargassum* is indicative of the more recent disturbance history at Kirra Reef and may have been timed with a recruitment pulse enabling a high proportion of the area to be colonised by macroalgae (McCook et al. 2001), or could reflect a reduced abundance of herbivorous fish and invertebrates, which can be important in controlling fleshy macroalgae on reefs (McCook 1997; McCook et al. 2001). The exact mechanism for why the algal assemblages differ between reefs has not been specifically tested.

There were also some small-scale differences in the composition of assemblages among transects within reefs; however, the differences were not consistent among reefs. (PERMANOVA Appendix 2, Table 17). The greatest degree of difference among transects occurred at Kirra Reef, which is most likely related to the more recent history of disturbance from sand burial that has occurred on that reef relative to the comparative reefs.

5.1.3 Faunal assemblages

Differences in the composition of benthic faunal assemblages among reefs were consistent with that found for the entire benthic assemblage, with the composition of benthic invertebrates differing among the reefs on both horizontal and vertical surfaces, except on vertical surfaces between Cook Island and Kingscliff reefs which did not differ (Figure 33c; PERMANOVA Orientation x Reef interaction, pseudo-$F_{3,8} = 2.41$, $p = 0.001$, pairwise comparisons Appendix 2). Differences in the composition of benthic fauna among reefs were due to the presence of a variety of different taxa, with no one taxon contributing more than 13% of the difference between pairs of reefs (SIMPER, Appendix 2 Table 25 & Table 26). Similar to algal assemblages, there were also differences in the composition of faunal assemblages at small-scales between transects within reefs, with the greatest degree of small-scale variability occurring on vertical surfaces (Table 17 & Table 18 PERMANOVA Appendix 2).

The faunal assemblages typically had a greater total number of taxa across all quadrats and higher average biodiversity indices (including taxonomic richness, evenness, Shannon's and Simpson's indices) on vertical than on horizontal surfaces at all reefs (Figure 36) (Table 27, Table 28 & Table 29, PERMANOVA pairwise comparisons, $p<0.05$). The most diverse assemblages in terms of total taxonomic richness and K-dominance curves were recorded at Palm Beach Reef, with the least diverse assemblages occurring at Kirra Reef (Figure 36 & Figure 37). The total number of taxa recorded in assemblages on horizontal and vertical surfaces was most similar at Kirra Reef than at the comparative sites. On the vertical surfaces at Kirra Reef, the first 4 ranked taxa accounted for greater than 60% of the cumulative dominance on the reef, while more than double this number of taxa accounted for more than 60% dominance at the comparative reefs (Figure 37). This is likely to reflect the abiotic conditions at Kirra Reef (e.g. sand burial and uncovering; effects of wave action) as K-dominance curves allow the identification of stressed assemblages as they are normally dominated by a few commonly occurring taxa relative to more diverse assemblages dominated by a broader group of taxa (Clarke 1990).

Benthic assemblages are often more diverse on vertical than horizontal surfaces due to a variety of factors such as the degree of competition or disturbance, availability of light, larval settlement preference and habitat complexity (Irving & Connell 2002; Walker & Schlacher 2014 and references cited within). The increased diversity of benthic assemblages on vertical surfaces may be due to a reduction in the degree of burial from sediment, as vertical surfaces are less prone to burial from sediment than horizontal surfaces and a reduced coverage of foliose macroalgae that can cause physical damage to recently settled larvae.

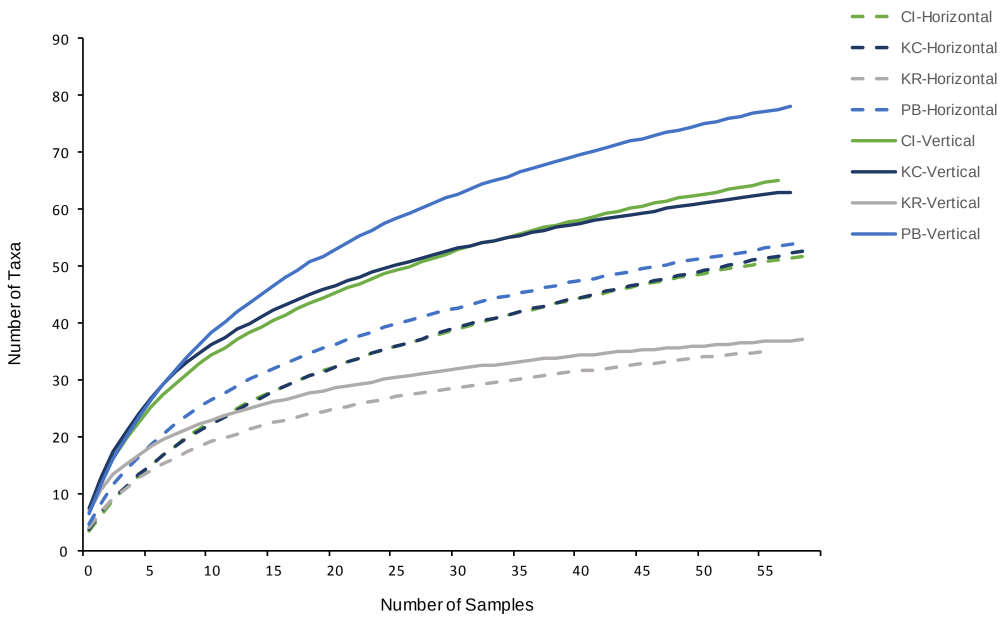


Figure 35 Taxonomic accumulation curves for faunal assemblages for each reef x surface orientation combination

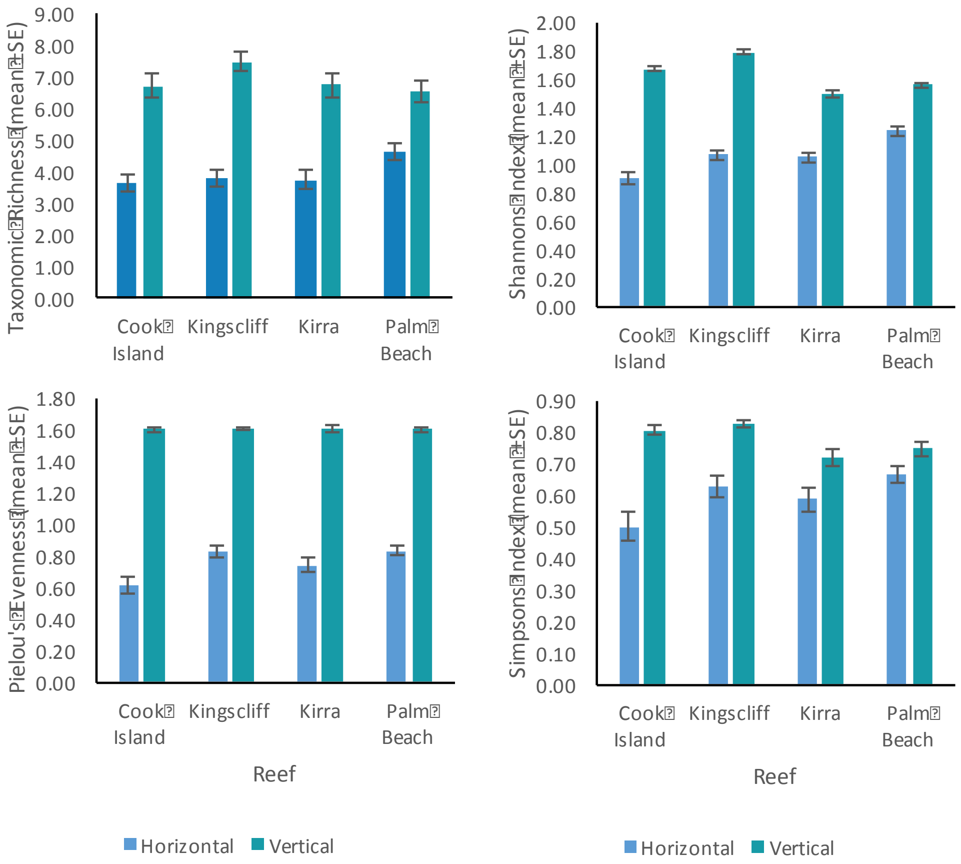


Figure 36 Average (±SE) biodiversity indices for faunal assemblages for each reef x surface orientation combination

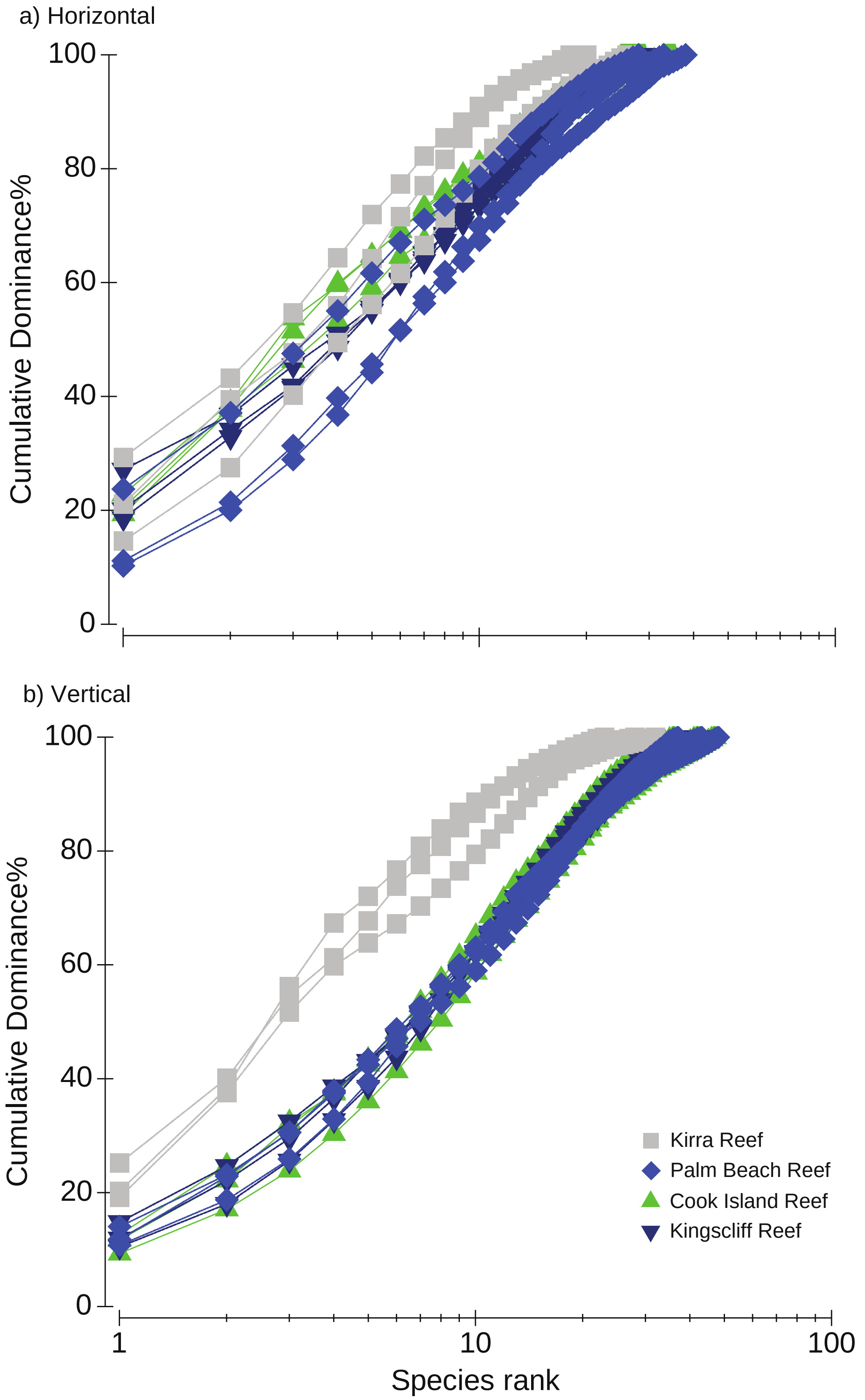


Figure 37 K-Dominance curves for faunal assemblages on (a) horizontal and (b) vertical surfaces, for each reef. Species rank is plotted on a log scale.

5.2 Fish communities

5.2.1 Univariate patterns

A total of 87 bony and cartilaginous fishes, representative of 55 Families were recorded from BRUVS and ROV imagery in 2016 (refer to Appendix 3 for raw data). Of these, the Family Pomacentridae (damselfishes) and Labridae (wrasses) were the most represented with 17 and 14 species respectively.

Species richness varied among reef systems and between survey techniques (i.e. BRUVS vs ROV). Overall, the greatest number of species was recorded at Palm Beach Reef (58 species), while the lowest overall number of species was recorded at Kingscliff Reef (42 species). Kirra Reef and Cook Island reef recorded 45 and 53 species respectively (Figure 38).

Total MaxN values derived from ROV imagery suggest a lower abundance of fish occurring on Kirra Reef (summed MaxN of 744 individuals) relative to comparative reefs (summed MaxN values 1215 to 1844 individuals).

5.2.1.1 Comparison of survey techniques

A consistent difference in species richness was evident between survey techniques. Video transects using ROV consistently recorded a greater number of species, identifying between 84.5 to 92.5% of the total number of species recorded for each reef system (Figure 38). Furthermore, 38.1 to 66.7% of the total number of species recorded on a particular reef were identified from ROV imagery only.

Alternatively, BRUVS imagery recorded between 33.3 to 61.9% of the total number of species identified for each reef system. This included between 7.6 to 15.6% of the total number of species that were not recorded using ROV techniques. Species exclusively recorded using BRUVS included various sharks (Hemiscylliidae, Brachaeluridae), moray eels (Muraenidae), and an array of damselfishes, wrasse and other common species typically identified elsewhere within the study using ROV imagery (i.e. other reef systems).

5.2.1.2 Fish community differences amongst reefs

Abundant and frequently occurring species also varied between reef systems (Table 7). The yellow-tail scad (*Trachurus novaezelandiae*) was both frequently recorded and abundant at all reefs. At Kingscliff Reef and Cook Island the eastern pomfred (*Schuettea scalaripinnis*) was recorded frequently in high numbers, though was observed with less numbers and frequency at both Palm Beach Reef and Kirra Reef.

The omnivorous (with strong herbivorous tendencies) girdled parma (*Parma unifasciata*) and the herbivorous saw-tail surgeon (*Prionurus microlepidotus*) that were frequently recorded at control reefs were only occasionally noted or not recorded at Kirra Reef. Additionally, the herbivorous black rabbitfish (*Siganus fuscescens*) occurred frequently and abundantly at both Kirra Reef and Palm Beach Reef, though was absent from Cook Island Reef and in low frequency / abundance at Kingscliff Reef.

Fish assemblages were aggregated based on feeding group behaviour, and considered in terms of the percentage of species recorded (Figure 39) and fish abundance using MaxN values (Figure 40).

Overall, assemblages were relatively consistent when considered by the composition of feeding groups among reefs, being dominated by carnivorous species (46.7 to 50.1% of species present), herbivores / omnivores with herbivorous tendencies (23.8 to 31.1% of species present) and omnivores (7.7 to 11.9% of species present). In contrast, the composition of fish communities considered by abundance (MaxN values) were dominated by planktivores, comprising 482 (Kirra Reef) to 1369 (Kingscliff Reef) individuals, with numbers predominantly attributed to the occurrence yellow-tail scad and eastern pomfred.

At Kirra Reef, the occurrence of coral consuming species recorded was less than elsewhere (2.2% opposed to 5.7 to 7.1% of species recorded). Furthermore, while Kirra Reef had the greatest percentage frequency of occurrence of species considered herbivorous and omnivores with herbivorous tendencies (31.1% compared to 22.8 to 30.8% of species recorded), their relative abundance was lower (collective MaxN of 85) than at other reefs: Cook Island (collective MaxN of 142); Kingscliff Reef (collective MaxN of 256) and Palm Beach Reef (collective MaxN of 491).

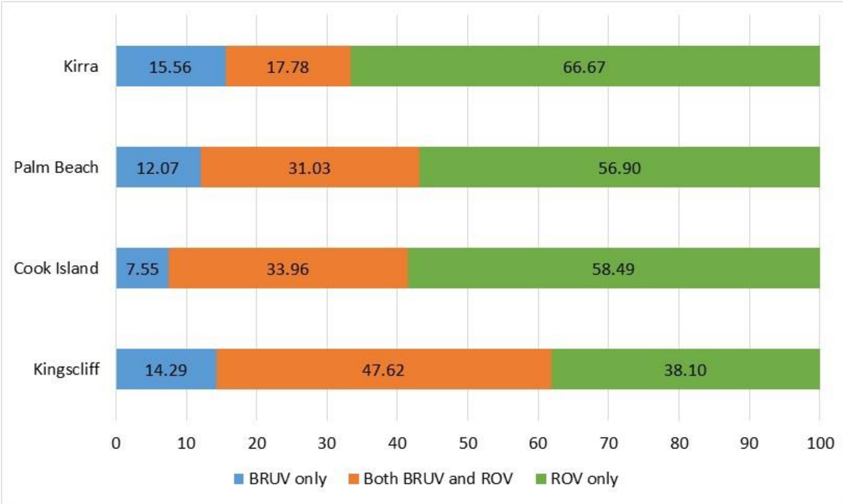
This noted relative reduction in herbivorous fish numbers at Kirra Reef is attributed a greater occurrence of: (i) Acanthuridae (surgeonfishes) and numerous Pomacentridae (damselfishes) at all other reefs; (ii) northern drummer (*Kyphosus gibsoni*) at Cook Island and Kingscliff Reefs, and: (iii) black rabbitfish at Palm Beach Reef.

Table 7 frequency occurring and abundant fish species recorded during the study

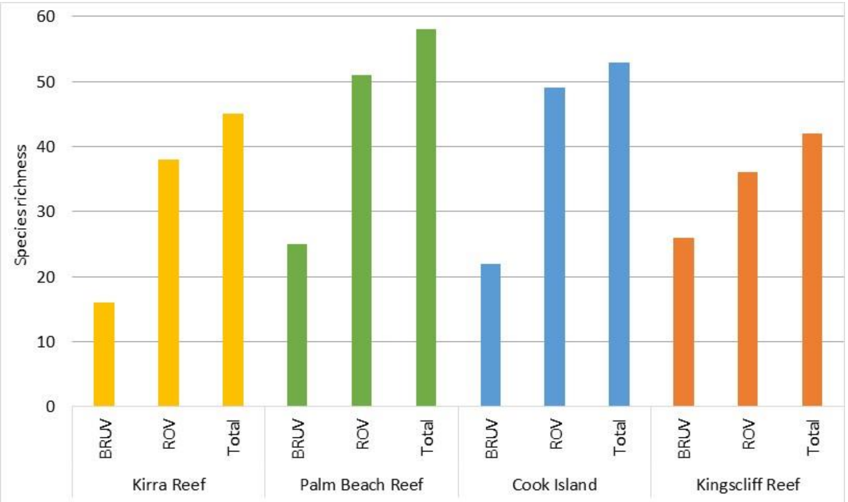
Feeding behaviour	Species	Common name	Kirra	Palm Beach	Cook Island	Kings-cliff
planktivore	*Trachurus novaezelandiae*	yellowtail scad	100%, xxxx	100%, xxxx	100%, xxxx	100%, xxxx
planktivore	*Schuettea scalaripinnis*	eastern pomfred	29%, x	43%, xx	100%, xxxx	100%, xxxx
carnivore	*Acanthopagrus australis*	yellow fin bream	100%, xx	86%, xx	100%, x	100%, xxx
carnivore	*Pseudolabrus guentheri*	Gunther's wrasse	100%, xx	57%, xx	86%, xx	100%, x
omnivore	*Atypichthys strigatus*	Australian mado	100%, xxx	57%, xx	86%, x	100%, xx
omnivore	*Abudefduf saxatilis*	five-banded sergeant major	14%, x	100%, xxx	71%, xxx	0
carnivore	*Thalassoma lutescens*	yellow moon wrasse	43%, x	86%, xx	100%, xx	29%, x
omnivore - HT	*Parma oligolepis*	large-scale parma	43%, xx	71%, xxx	100%, xx	86%, xx
omnivore - HT	*Parma unifasciata*	girdled parma	14%, x	43%, x	86%, xx	100%, xx
planktivore	*Scorpis lineolatus*	silver sweep	100%, xxx	86%, xx	43%, xx	100%, x
herbivore	*Siganus fuscescens*	black rabbitfish	57%, xxx	100%, xxxx	0	14%, x
herbivore	*Prionurus microlepidotus*	sawtail surgeon	0	43%, xx	43%, xx	71%, xxxx
omnivore	*Monodactylus argenteus*	silver batfish	0	0	0	100%, xx

Note: frequency of occurrence is representative of the number of ROV and BRUVS video files each species was identified from, abundance is representative of the maximum abundance at each reef system, where x = < 5 individuals; xx = 6 – 20 individuals; xxx = 21 – 100 individuals, and; xxxx = >100 individuals. 100% occurrence and/or high abundance (> 100 individuals) is highlight in green.

(A)



(B)



(C)

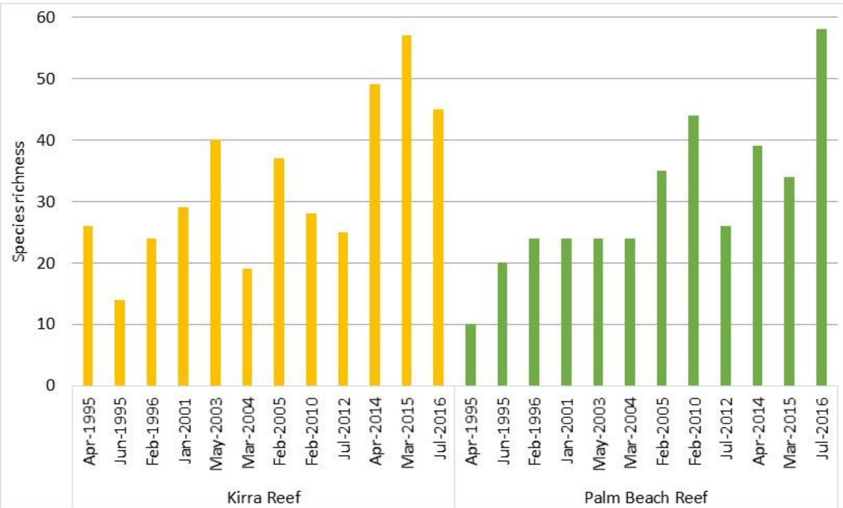


Figure 38 Species richness considering:(A) percentage of species recorded for each method type in 2016; (B) total species richness per reef and method in 2016, and (C) historic total species richness for Kirra Reef and Palm Beach Reef

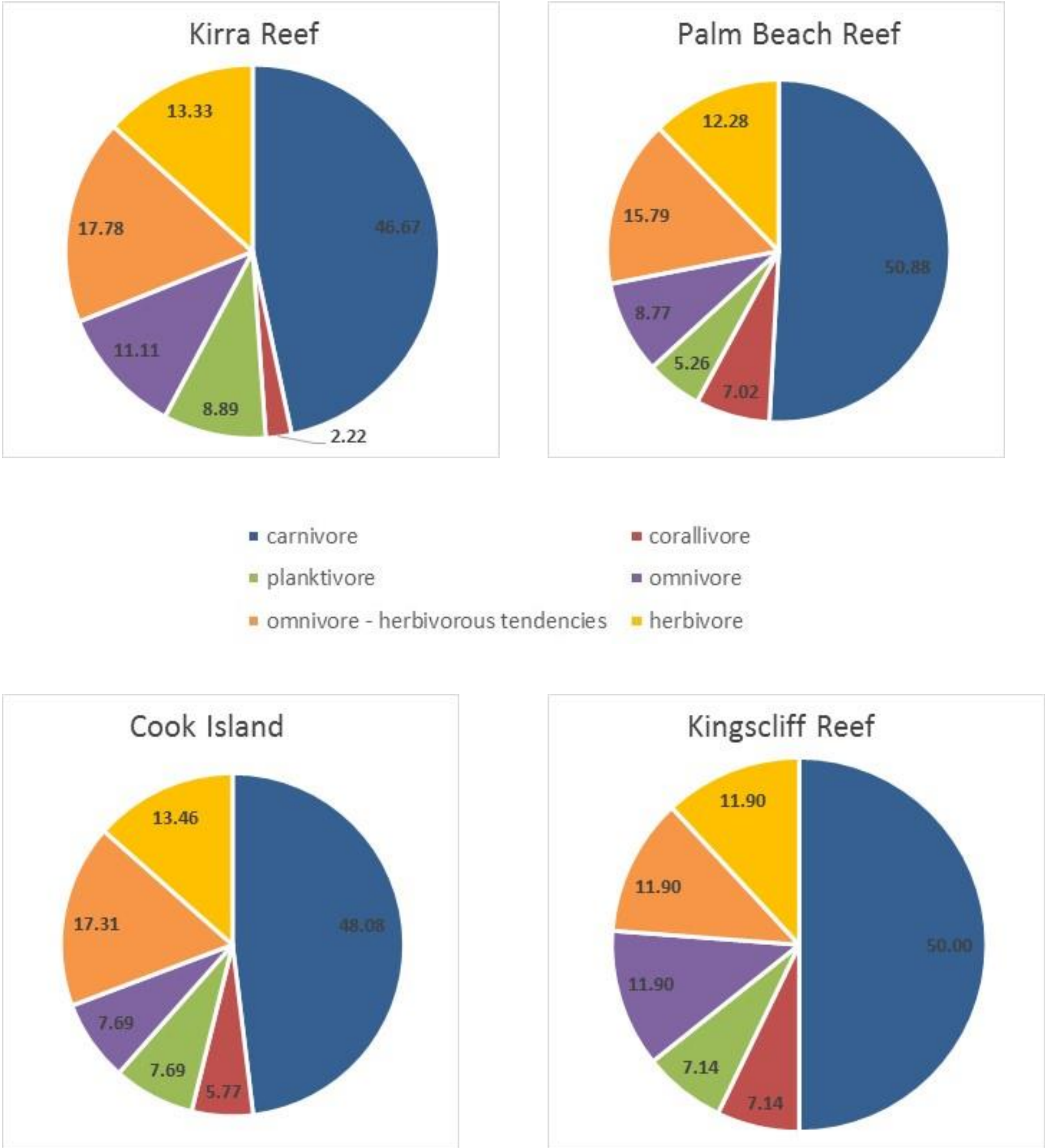


Figure 39 Composition of fish communities (number of species) recorded at each reef system in relation to feeding behaviours

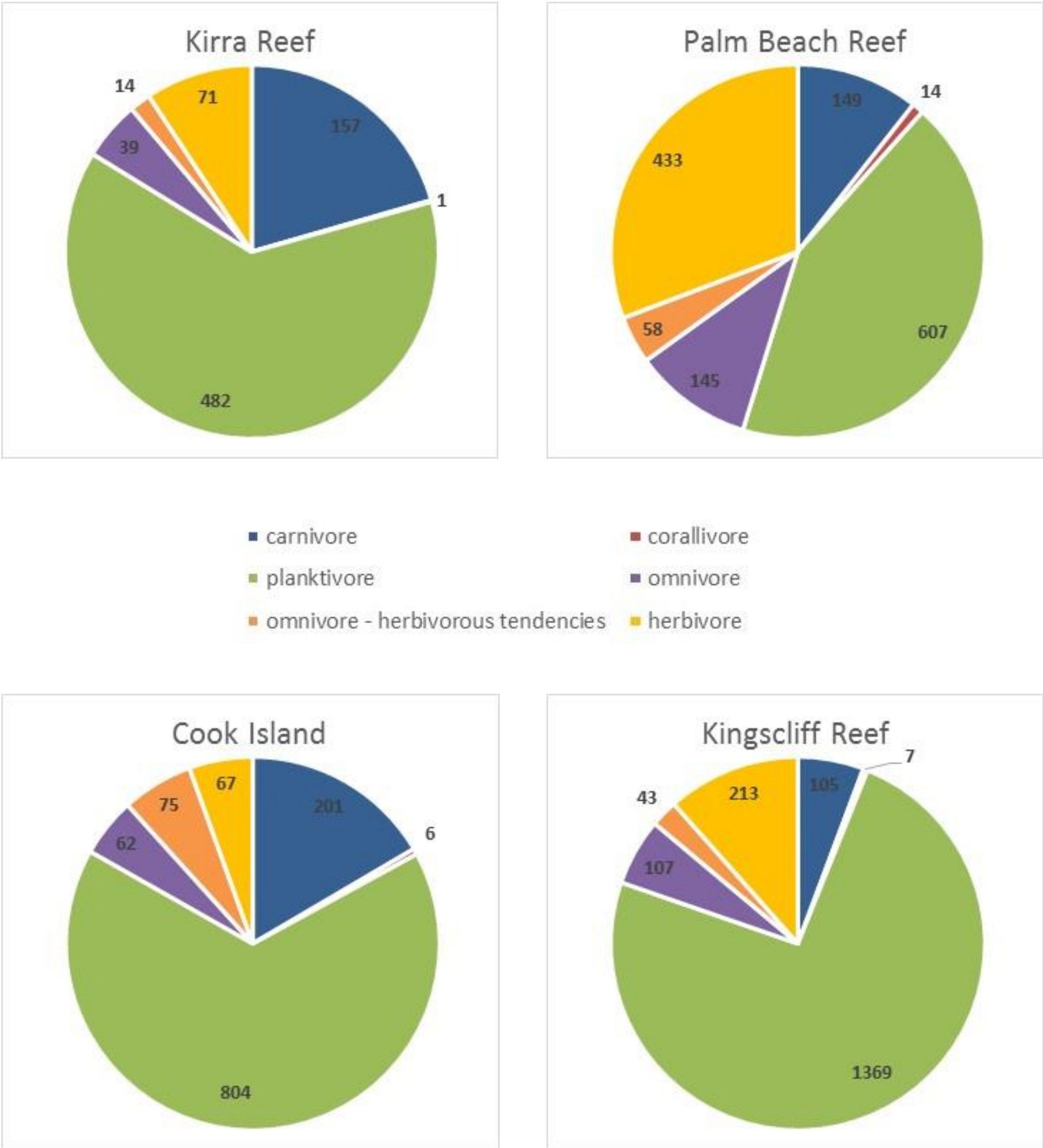


Figure 40 Composition of fish communities (abundance using summed MaxN values) recorded at each reef system in relation to feeding behaviours

5.2.2 Statistical differences in fish community composition among reefs

A two-dimensional n-MDS ordination depicting multivariate patterns in similarity within fish communities observed within ROV imagery replicates collected at each reef is shown in Figure 34. Samples that are situated closer together are considered to be of similar community structure (taxa composition and relative abundance) than samples that are distributed further apart.

Fish assemblages recorded on Kirra Reef were dissimilar to those recorded at other reefs, where a significant difference in the composition of fish communities among different reefs was determined (ANOSIM, p = 0.001, Global R = 0.888, Table 8). Assemblages were less dissimilar amongst comparative reefs, although were still significantly different (ANOSIM pairwise comparisons, Table 8). The magnitude of difference (ANOSIM *R-value*) was greatest between Kirra Reef and the comparative reefs (ANOSIM pairwise comparisons). Notably, the number of possible permutations for each pairwise test was low (35) indicating a low power derived *p*-value, so results have been interpreted with caution.

A variety of species contributed towards the difference in composition between Kirra Reef and other comparative reefs (SIMPER dissimilarities,Table 9). This consistently included increased abundances of black rabbitfish, stripped barracuda (*Sphyraena obtusata*) and black-spotted porcupinefish (*Diodon hystrix*) recorded at Kirra Reef (with the exception of increased abundances of black rabbitfish on Palm Beach Reef) collectively accounting for between 9.17 to 16.71% of dissimilarity between Kirra Reef and the comparative sites. Conversely, a range of different species were found at higher abundances at comparative reefs with key species being:

- eastern pomfred at all three comparative reefs, accounting for 2.93 to 16.07% of dissimilarity and representative of the key dissimilarity between Kirra Reef and comparative reefs at Cook Island and Kingscliff
- five-banded sergeant major (*Abudefduf saxatilis*) at Palm Beach Reef and Cook Island Reef accounting for 9.56% and 3.86% of dissimilarity respectively. This species attributed the most dissimilarity between fish communities recorded at Kirra and Palm Beach reefs
- various surgeonfishes (*Acanthurus* spp. and *Prionurus microlepidotus*) accounting for between 2.83% and 12.81% of the dissimilarity between Kirra Reef at all three comparative reefs
- yellowtail scad and neon damsel (*Pomacentrus coelestisi*) accounting for 4.36% and 3.93% of dissimilarity between Kirra Reef and Palm Beach reef respectively
- black-tipped bulls eye (*Pempheris affinis*) and neon damsel accounting for 5.22% and 3.94% of dissimilarity between Kirra Reef and Cook Island reef respectively
- yellowtail scad, silver batfish (*Monodactylus argenteus*) and girdled parma (*Parma unifasciata*) accounting for 5.12%, 3.56% and 3.13% of dissimilarity between Kirra Reef and Kingscliff reef respectively.

Figure 41 A two-dimensional n-MDS ordination showing spatial patterns in taxonomic composition of fish communities at reef systems using ROV replicate imagery collected within July 2016

Table 8 One-way analysis of similarities (ANOSIM) to determine the difference in fish communities amongst reef systems using ROV replicate imagery collected within July 2016

Test	Test statistic (*R*)	Significance (*p*)	Possible permutations
Global test			
difference between reef systems	0.888	0.001	2627625
Pairwise tests			
Kirra Reef & Palm Beach Reef	0.979	0.029	35
Kirra Reef & Cook Island	1.000	0.029	35
Kirra Reef & Kingscliff Reef	1.000	0.029	35
Palm Beach Reef & Cook Island	0.500	0.029	35
Palm Beach Reef & Kingscliff Reef	0.979	0.029	35
Cook Island & Kingscliff Reef	0.698	0.029	35

Table 9 Similarity percentage analysis (SIMPER) of dissimilarity amongst fish communities occurring at Kirra Reef and other control reef considered separately (data derived from ROV imagery collected in July 2016)

Feeding behaviour	Species	Common name	Kirra Reef Av. abundance	Control Reef Av. abundance	Contrib. %[7]
Kirra vs Palm Beach Reef, average dissimilarity = 54.85%					
omnivore	*Abudefduf saxatilis*	five-banded sergeant major	0.25	5.19	9.56
herbivore	*Siganus fuscescens*	black rabbitfish	3.63	4.69	6.74
carnivore	*Sphyraena obtusata*	stripped barracuda	3.02	0.00	5.99
planktivore	*Trachurus novaezelandiae*	yellowtail scad	7.77	10.04	4.36
omnivore - HT[8]	*Pomacentrus coelestis*	neon damsel	0.35	2.38	3.93
carnivore	*Diodon hystrix*	black-spotted porcupinefish	2.18	0.68	3.18
herbivore	*Acanthurus xanthopterus*	yellowfin surgeon	0.43	1.75	2.99
planktivore	*Schuettea scalaripinnis*	eastern pomfred	0.25	1.53	2.93
Kirra vs Cook Island Reef, average dissimilarity = 62.99%					
planktivore	*Schuettea scalaripinnis*	eastern pomfred	0.25	6.24	10.78
herbivore	*Siganus fuscescens*	black rabbitfish	3.63	0.00	6.47
carnivore	*Sphyraena obtusata*	stripped barracuda	3.02	0.00	5.46
carnivore	*Pempheris affinis*	black-tipped bulls eye	0.00	2.75	5.22
omnivore - HT	*Pomacentrus coelestis*	neon damsel	0.35	2.44	3.94
omnivore	*Abudefduf saxatilis*	five-banded sergeant major	0.25	2.41	3.86
carnivore	*Diodon hystrix*	black-spotted porcupinefish	2.18	0.50	3.03
herbivore	*Acanthurus grammoptilus*	ring-tailed surgeon	0.25	1.86	2.83
Kirra vs Kingscliff Reef, average dissimilarity = 58.74%					
planktivore	*Schuettea scalaripinnis*	eastern pomfred	0.25	8.48	16.07
herbivore	*Prionurus microlepidotus*	saw-tail surgeon	0.00	6.52	12.81
herbivore	*Siganus fuscescens*	black rabbitfish	3.63	0.25	6.54
carnivore	*Sphyraena obtusata*	stripped barracuda	3.02	0.00	5.94
planktivore	*Trachurus novaezelandiae*	yellowtail scad	7.77	10.37	5.12
carnivore	*Diodon hystrix*	black-spotted porcupinefish	2.18	0.00	4.23
omnivore	*Monodactylus argenteus*	silver batfish	0.00	1.87	3.56
omnivore - HT	*Parma unifasciata*	girdled parma	0.00	1.62	3.13

[7] Derived from square root transformed MaxN values

[8] HT indicates species with herbivorous tendencies, being classified as omnivore though most their diet comprises of plant matter

5.3 Physicochemical water quality properties

To assess small scale variability between water quality conditions occurring among reefs physicochemical parameters were profiled throughout the water column (Table 10).

The conductivity, pH, dissolved oxygen and turbidity did not differ with depth or among the reefs (Table 10). Temperature was also typically consistent with depth and only varied by less than 0.2°C with increasing depth. The surface temperature recorded (20.2 to 20.7°C) was between the 50^{th} and 80^{th} percentile values for sea surface temperature recorded in July at the Tweed Head wave buoy (refer to section 4.2.3).

5.4 Species of conservation significance

Three species of conservation significance were observed during the survey within proximity to Kirra Reef (i.e.<2km) during survey and included:

- humpback whale (*M. novaeangliae*)
- Indo-Pacific humpback dolphin (*S chinensis*)
- green turtle (*C. mydas*).

No fish species of conservation significance were recorded.

5.5 Exotic / invasive species

No exotic or invasive species were recorded during surveys or during the analysis of photo-quadrats.

Table 10 Depth profiles of physicochemical parameters collected at each reef system during July 2016.

Reef / date / time	Depth	Temperature	Conductivity	pH	Dissolved oxygen		Turbidity
	(m)	°C	µS/cm	pH unit	% saturation	mg/L	NTU
Kirra Reef 19/07/2016 13:40	0.2	20.7	53,890	8.1	99.0	7.2	0.1
	1	20.7	53,891	8.1	99.0	7.2	0.1
	2	20.7	53,891	8.1	99.0	7.2	0.1
	3	20.6	53,890	8.1	98.9	7.2	0.1
	4	20.6	53,890	8.1	98.9	7.2	0.1
	5	20.6	53,890	8.1	98.9	7.2	0.1
Palm Beach Reef 20/07/2016 11:00	0.2	20.3	53,836	8.1	95.4	7.0	0.1
	1	20.3	53,839	8.1	94.9	7.0	0.1
	2	20.3	53,839	8.1	94.7	6.9	0.1
	3	20.2	53,841	8.1	94.6	6.9	0.1
	4	20.2	53,840	8.1	94.6	6.9	0.1
	5	20.2	53,839	8.1	94.5	6.9	0.1
Cook Island 20/07/2016 12:15	0.2	20.4	53,811	8.1	96.5	7.1	0.1
	1	20.4	53,818	8.1	96.7	7.1	0.1
	2	20.3	53,828	8.1	96.6	7.1	0.1
	3	20.3	53,847	8.1	96.6	7.1	0.1
	4	20.3	53,864	8.1	97.1	7.1	0.1
	5	20.3	53,869	8.1	98.6	7.2	0.1
Kingscliff Reef 21/07/2016 08:20	0.2	20.2	53,832	8.1	96.1	7.1	0.1
	1	20.2	53,836	8.1	96.1	7.1	0.1
	2	20.2	53,846	8.1	95.3	7.0	0.1
	3	20.2	53,855	8.1	94.0	6.9	0.1
	4	20.2	53,856	8.1	92.9	6.8	0.1
	5	20.2	53,861	8.1	92.5	6.8	0.1

6 Discussion

6.1 Impacts of the sand bypassing system on Kirra Reef

6.1.1 Benthic Assemblages

The composition of benthic assemblages may change following seasonal disturbances such as storms, and also following seasonal burial and uncovering due to normal movement of sand bars offshore. Sessile organisms are highly susceptible to physical disturbance from sand burial, storms and associated wave action (Kay & Keough 1981; Walker et al. 2008). The benthic assemblage on Kirra Reef is less diverse than other comparative reefs in the area. This is most likely due to the disturbance history from sand burial during peak operation of the sand bypass in the early 2000s.

Since the quantity of sand bypassed has been reduced, there has been a steady increase in the overall extent of the reef available and a consequent change in the composition of benthic assemblages, with a greater proportion of sessile fauna occupying the reefs. However, it is important to note that there are a variety of other coastal processes that may influence the composition of benthic assemblages on Kirra Reef over time, including the proximity to source populations for larval recruits, interspecies interactions (such as predation, herbivory and interspecific competition), changes in water quality, direction and strength of currents and wave action and the degree of physical disturbance, which can all influence the ultimate composition of benthic assemblages (Walker et al. 2007; Walker & Schlacher 2014).

In July 2016, the extent of Kirra Reef was slightly greater than in the previous year, although the extent of reef appears to have stabilised. Kirra Reef remains a relatively small rocky outcrop surrounded by mobile sand, which moves naturally in response to wave and storm action. As such, movement of sand and significant wave action will continue to be dominant physical forces shaping the composition of benthic assemblages on Kirra Reef.

Reductions in biodiversity caused by physical disturbance have the potential to impact negatively on the productivity of reef ecosystems (Walker et al. 2008). Maintaining biodiverse assemblages (e.g. a variety of sponges, cnidarians, bryozoans and ascidians) can ensure communities that are resilient to future disturbances. Many of these species also contribute a range of ecosystem services, including: nutrient cycling (Scheffers et al. 2004), trophic interactions and food webs (Lesser 2006; Pawlik et al. 2007), bio-erosion of reef substrata (Lopez-Victoria et al. 2006), and stabilizing mobile sediment such as sand (Diaz & Rutzler 2001; Wulff 2001).

If sand delivery to Kirra Reef and associated burial of the reef remains at a similar level to the current situation and remains stable over time than it has done historically, it is expected that this difference in composition between Kirra and the comparative reefs will decrease over time as a greater proportion of sessile fauna become established.

6.1.2 Community Succession

Studies of changes in the benthic composition of reefs in the region have found that reefs in an early state of succession are dominated by a relatively low number of dominant species, while those in a later state of succession are dominated by a greater proportion of species such as hard and soft corals (Walker & Schlacher 2014 and references cited within). In 2016, assemblages at Kirra Reef were dominated by fewer taxa than at the other reefs. This is likely to reflect a community in early succession. Sessile assemblages on temperate and tropical reefs can take a long time to reach equilibrium (more than 13 years) (Butler and Connolly 1999; Burt et al. 2011; Walker & Schlacher 2014)

Interactions between sessile benthic organisms are known to be complex (Sousa 1979), and this observational study cannot determine the exact mechanisms operating at various spatial scales. However, the high coverage of turf algae combined with physical disturbance from wave action may delay the colonisation of some species such as foliose macroalgae, as turf algae can grow rapidly and outcompete other species for space (Kennelly 1987; Benedetti-Cecchi et al. 2001), especially in high light environments such as on horizontal surfaces (Irving & Connell 2002). Furthermore, the moderate coverage of foliose macroalgae (*Sargassum* spp.) recorded on Kirra Reef (particularly on horizontal surfaces) may cause an additional source of competitive disturbance (fronds sweeping the hard rock surface), preventing or delaying the recruitment of sessile invertebrates to some areas on that reef through physical disturbance.

In 2016, several small juvenile corals were noted on the vertical surfaces of Kirra Reef (Figure 42). On Kirra Reef, assuming there is sufficient larval supply and in the absence of substantial physical disturbance, we would expect the coverage of hard and soft corals and other invertebrates will increase over time.

Figure 42 Juvenile *Turbinaria* coral recently settled on vertical surface of Kirra Reef.

6.1.3 Fish communities

Species richness and abundance of reef fish communities has been associated with a range of physical habitat attributes, including: habitat diversity and structural or topographical complexity (Bellwood and Hughes 2001; Friedlander et al. 2003, Gratwicke and Speight 2004); coral species richness (Komyakova et al. 2013) wave disturbance (Friedlander et al. 2003) and the quality and aerial extent of habitat (Gratwicke and Speight 2004).

Considering the relatively small aerial extent and differences in complexity and composition of benthic reef communities at Kirra Reef in comparison to other local nearshore reefs, it was anticipated that residing fish communities would be less diverse and have lower overall abundances than elsewhere. However, in 2016, fish species richness on Kirra Reef was within the range recorded on local comparative reefs, though fish community structure (taxa composition and relative abundance) was shown to be significantly different, with the magnitude of difference being greatest between Kirra Reef and all other comparative reefs.

Key species contributing to the dissimilarity amongst fish communities at Kirra Reef and other comparative reefs included increased abundances of black rabbitfish (*S. fuscescens*, stripped barracuda (*S. obtusata*) and black-spotted porcupinefish (*D. hystrix*) at Kirra Reef. A range of other species had greater abundances at comparative reefs than at Kirra Reef, most significantly: eastern pomfred (*S. scalaripinnis*); five-banded sergeant major (*Abudefduf saxatilis*) and various surgeonfishes (*Acanthurus* spp. and *Prionurus microlepidotus*). Notably, the current dataset provides only a snap shot assessment of the composition of fish assemblages, where ongoing monitoring (particularly seasonal) will provide a more in-depth understanding of community dynamics both within and amongst reefs.

A key structural habitat characteristic of Kirra Reef in comparison to other reefs is the occurrence of fleshy macroalgae (*Sargassum* spp.) (refer to Section 5.1.2), where previous monitoring reports (FRC 2015, FRC 2010) have recorded an enduring cover of *Sargassum* at Kirra Reef that varies considerably in extent over time. While the exact mechanism(s) for the occurrence and variability of macroalgae is undetermined, a possible contributing factor includes the fluctuations within the community structure of residing herbivorous fish (composition and abundance).

The current study recorded a greater overall composition of herbivorous fish (including omnivores with strong herbivorous tendencies), though the abundance was lower on Kirra Reef compared with other reefs. While many studies have identified a negative relationship between herbivorous fish grazing intensity and macroalgae cover (i.e. the cover of macroalgae decreases with increasing abundance of herbivorous fish) (Green & Bellwood 2009), previous studies largely focus on the role of herbivorous fish in coral reef dynamics (e.g. coral to algae phase shifts), including the importance of varying function feeding modes (i.e. herbivorous scarpers, herbivorous browsers) (Green & Bellwood 2009).

Although phase shifts from coral to macroalgae dominated communities following disturbance is not uncommon (Green & Bellwood 2009), there have been few document cases of reversal back to a coral dominated community (Bellwood et al. 2006). Furthermore, assessments undertaken on recovering reef systems, have found the removal of *Sargassum* was not the result of herbivorous species responsible for consuming algae on adjacent coral dominated reefs (Chong-Seng et al. 2014) or the occurrence of residing recorded herbivorous fish (Bellwood et al. 2006), rather phase shifts were driven unexpectedly through algae consumption by a single species previously regarded as an invertebrate feeder.

Therefore, it would be imprudent to assume: (i) that functional herbivorous groups traditionally shown to prevent phase shifts from coral to macroalgae algae communities could be responsible for successional change of benthic communities at Kirra Reef, and: (ii) any variation in the abundance and diversity of herbivorous fish recorded amongst or within (temporal comparisons) reefs systems necessarily correlates with the coverage of *Sargassum* on Kirra Reef.

6.2 Review of monitoring program changes

6.2.1 Suitability of control sites

The addition of two control reefs (compared with historical monitoring, where there was only one control reef) provided a greater understanding of the natural degree of variation within and among reefs that are not exposed to the same degree of disturbance as Kirra Reef. The three control reefs (Palm Beach, Kingscliff and Cook Island reefs) used in this assessment provide a good comparison of the variety of benthic assemblages that occur on rocky subtidal reefs in the Region. As such, we recommend that the additional control reefs be included in future monitoring.

The assemblages typically differ in the composition on both horizontal and vertical surfaces (with the exception of vertical surfaces on Cook Island and Kingscliff Reefs), so ensuring that the assessment of surface orientation is consistent is essential for any future comparisons. Assessing the magnitude of change in composition of benthic assemblages on horizontal and vertical surfaces may provide information to better understand the impacts of sediment burial within reefs, but the degree of sediment accumulation would also need to be assessed.

6.2.2 Seasonal variation within and between benthic reef communities

Deliberate seasonal surveys to assess the effects of seasonal variation on the benthic communities have not been completed. As such, seasonal variation has not been specifically assessed to date. Further detailed assessments of the change in coverage of benthic fauna and algae over time (e.g. two survey events per year) identified to morphospecies would be required to determine the effects of seasonality on these communities. Ideally these would be matched with measures of physical attributes of the ambient environment such as water quality, wave disturbance and sand/sediment accumulation.

An understanding of seasonal variation would be useful to assess the importance of other factors (not related to, or that may interact with, sand delivery from the bypass system). However, an understanding of the seasonal variation in communities is not essential to understand the effects of the sand bypass system on the benthic communities at Kirra Reef, where the timing of annual surveys remains consistent.

6.2.3 Community succession

Continuation of the current monitoring program design (using analysis of photo-quadrats taken along geo-referenced transects) would provide an indication of community succession at Kirra Reef. We predict that the composition of benthic assemblages would become more similar to that found on the comparative reefs, or at least the magnitude of dissimilarity would be within that found among the comparative reefs. These results would be indicative of a trajectory of succession at Kirra Reef that is more similar to the communities of rocky reefs in the region.

To assess differences in the spatial and temporal patterns of potential settlement and recruitment of sessile fauna and algae, settlement plates could be deployed at Kirra and comparative reefs. A series of replicated plates could be retrieved at regular intervals and the coverage of sessile taxa quantified.

6.2.4 Fish communities

The combination of both BRUVS and ROV proved to be a successful approach for identifying resident fish communities, recording comparative (Kirra Reef) and greater species richness (Palm Beach) than previous monitoring episodes. ROV transects were found to identify a greater number of species occurring, however, BRUVS were useful in recording more inconspicuous species such as sharks (Hemiscylliidae, Brachaeluridae) and moray eels (Muraenidae).

Deriving species specific MaxN values provides a more robust assessment of fish community structure (particularly abundance). However, given the distinction between assemblages recorded between survey techniques it was not appropriate to combine datasets within multivariate analysis. Additionally, four ROV video samples did not provide suitable statistical power (possible permutations) where it is recommended that future monitoring episodes include an additional replicate (i.e. five replicates to allow for 126 possible permutations) ROV videos to provide a more statistically robust dataset.

6.2.5 Assessment of abiotic data

Analysis of significant wave height (Hs) and wave direction (Pkdir) data was useful in identifying long term trends within prevailing wave conditions occurring on the Tweed Coast and Southern Gold Coast. Assessment of key patterns in reef exhumation and wave dynamics over the past five years identified that waves of three meters or greater were positively correlated with periods of reef burial and exhumation at Kirra Reef.

It is recommended that future monitoring includes ongoing assessment of the relationship between larger swell occurrence (i.e. >3 m) and in reef burial or exhumation for Kirra Reef and comparative reefs where suitable imagery is available (i.e. x number of suitable Nearmap images available since the current study).

6.2.6 Other Recommendations

Where possible, increasing the number of transects on each reef to capture small-scale spatial variability in the coverage of sessile fauna would be desirable. However, due to the small size of Kirra Reef, this may not be achievable without having transects that overlap spatially with a consequential loss of data independence.

7 Conclusions and recommendations

The current extent of Kirra Reef is similar to the size predicted in the EIS. The maintenance bypassing of sand appears to more closely match the natural northwards transport of sand due to long-shore drift, wave action and tidal currents, allowing the extent of reef area to stabilise. Over time there has been substantial changes in the composition of benthic assemblages at Kirra Reef, largely due to the colonisation and growth of macroalgae and sessile invertebrates following exhumation of the reef in 2012.

In 2016, the composition of benthic assemblages on Kirra Reef remains dissimilar to that on comparative reefs, due largely to the high coverage of macroalgae and turf algae on Kirra Reef. We expect that, if sand delivery remains stable and environmental conditions relatively benign, that the difference in composition between Kirra and the comparative reefs will decrease over time as more species such as hard and soft corals recruit to the benthic assemblage.

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Appendix 1 Species of Conservation Significance

Table 11 Marine mammal species of conservation significance (those confirmed or likely to occur are in bold)

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Whales							
Balaenoptera edeni	Bryde's whale	Listed	Not listed	Not listed	Migratory, heading towards warmer tropical waters during the winter. Found between 40° S and 40° N, primarily in temperatures exceeding 16.3 °C. [2]	The inshore form appears to be resident in waters containing suitable prey stocks of pelagic shoaling fishes. [2]	Potential
Balaenoptera musculus	Blue whale	Endangered	Not listed	Endangered	Migratory, much of the Australian continental shelf and coastal waters have no particular significance to the whales and are used only for migration and opportunistic feeding [2]	All marine open waters, the only known areas of significance to Blue Whales are feeding areas around the southern continental shelf, none within Queensland. [2]	Unlikely
Balaenoptera physalus	Fin whale	Vulnerable	Not listed	Not listed	Occurs globally in polar to tropical waters.[2]	Rarely in inshore waters, often found in areas of complex and steep bathymetry, such as deep ravines.[2]	Unlikely
Eubalaena australis	**Southern right whale**	**Endangered**	**Not listed**	**Endangered**	**Australian coast between about May and November.[2]**	**Migratory, all marine open waters.[2]**	**Confirmed-congregation or aggregation known to occur within area**
Megaptera novaeangliae	**Humpback whale**	**Vulnerable**	**Vulnerable**	**Vulnerable**	**Australian coast between about May and November.[2]**	**Mostly remain within 10 km of the coastline in that area during the northward migration.[2]**	**Confirmed - congregation or aggregation known to occur within area**

[9] Sources include: (1) the Australian museum, http://australianmuseum.net.au/; (2) EPBC's SPRAT database, http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl; and (3) FishBase, http://www.fishbase.org/search.php.

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Orcinus orca	Killer whale	Listed	Not listed	Not listed	Migratory, widespread globaly.[2]	All marine open waters - following humpback whale winter migration.	Potential
Physeter macrocephalus	Sperm Whale	Listed	Not listed	Vulnerable	Recorded offshore from all Australian states.[2]	Inhabit offshore areas with a water depth of 600 m or more, and are uncommon in waters less than 300 m deep.[2]	Unlikely
Dolphins							
Delphinus delphis	**Common dolphin**	**Listed**	**Not listed**	Not listed	**Found in tropical, subtropical and temperate waters of the Atlantic, Pacific and Indian Oceans.** [2]	**Occurring in both shallow and deep offshore waters.** [2]	**Likely**
Grampus griseus	Risso's dolphin	Listed	Not listed	Not listed	Inhabits tropical, subtropical, temperate and subantarctic waters. [2]	Occur mainly on steep sections of the upper continental slope, usually in waters deeper than 1000 m.[2]	Unlikely
Lagenorhynchus obscurus	Dusky dolphin	Listed	Not listed	Not listed	Migratory, occur throughout the Southern hemisphere, mostly in temperate and sub-Antarctic zones.[2]	Primarily inhabit inshore waters but may also be pelagic at times.[2]	Unlikely
Orcaella heinsohni (previously O. brevirostris)	Irrawaddy dolphin	Listed	Vulnerable	Not listed	Migratory, occur only in waters off the northern half of Australia, from approximately Broome to the Brisbane River.[2]	Primarily found in shallow waters less than 20 m deep, close to the coast, close to river and creek mouths and in the proximity of seagrass beds. [2]	Potential
Sousa chinensis	**Indo-pacific humpback dolphin**	**Listed**	**Not listed**	**Not listed**	**Indo-Pacific.**[2]	**Inhabit shallow coastal, estuarine, and occasionally riverine habitats, in tropical and subtropical regions.**[2]	**Likely**

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Sousa sahulensis	**Australian humpback dolphin**	**Listed**	**Vulnerable**	**Not listed**	**in Queensland occurs on the Great Barrier Reef Marine Park; Moreton Bay; the lower reaches of the Brisbane River, and adjacent offshore waters.[2]**	**Inhabit shallow coastal, estuarine, and occasionally riverine habitats, in tropical and subtropical regions.[2]**	**Likely**
Stenella attenuata	Spotted dolphin	Listed	Not listed	Not listed	Occur in tropical zone within the Pacific, Atlantic and Indian oceans.[2]	Inhabit both near-shore and oceanic habitats.[2]	Unlikely
Tursiops aduncus	**Indo-Pacific bottlenose dolphin**	**Listed**	**Not listed**	**Not listed**	**Migratory, found in tropical and sub-tropical habitats of the Indian Ocean, Indo-Pacific Region and the western Pacific Ocean.[2]**	**Inshore areas such as bays and estuaries, nearshore waters, open coast environments, and shallow offshore waters.[2]**	**Likely**
Tursiops truncatus	Bottlenose dolphin	Listed	Not listed	Not listed	Temperate and tropical waters around the world.[2]	Australia populations generally tend to inhabit offshore waters.[2]	Unlikely
Dugong							
Dugong dugon	Dugong	Listed	Vulnerable	Endangered	Tropical and subtropical coastal waters from east Africa to Vanuatu.[2]	Predominately coastal and estuarine waters where seagrass occurs.[2]	Potential

Table 12 Marine reptile species of conservation significance (those confirmed or likely to occur are in bold)

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Turtles							
Caretta caretta	**Loggerhead turtle**	**Endangered**	**Endangered**	**Endangered**	**Migratory, throughout tropical, sub-tropical and temperate waters.[2]**	**Open ocean and coastal waters with both hard and soft substrates including rocky and coral reefs, muddy bays, sandflats, estuaries and seagrass meadows. Nesting occurs on open, sandy beaches.[2]**	**Confirmed - Breeding known to occur within area (DoE 2016)**
Chelonia mydas	**Green turtle**	**Vulnerable**	**Vulnerable**	**Vulnerable**	**Migratory, found in tropical and subtropical waters throughout the world.[2]**	**Spend their first five to ten years drifting on ocean currents. Settle in shallow benthic foraging habitats such as tropical tidal and sub-tidal coral and rocky reef habitat or inshore seagrass beds.[2]**	**Confirmed - Foraging, feeding or related behaviour known to occur within area (DoE 2016)**
Dermochelys coriacea	**Leatherback turtle**	**Endangered**	**Endangered**	**Endangered**	**Migratory, global tropical and temperate distribution.[2]**	**Pelagic species residing in a variety of ocean and coastal habitats, venturing close to shore mainly during the nesting season.[2]**	**Likely**
Eretmochelys imbricata	Hawksbill turtle	Vulnerable	Vulnerable	Not listed	Migratory, found in tropical, subtropical and temperate waters in all the oceans of the world.[2]	Spend their first five to ten years drifting on ocean currents, settle and forage in tropical tidal and sub-tidal coral and rocky reef habitat. Also found less frequently within	Potential

[10] Sources include; (2) EPBC's SPRAT database, http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
						seagrass habitats of coastal waters.[2]	
Lepidochelys olivacea	Olive ridley turtle	Endangered	Endangered	Not listed	Migratory with a circumtropical distribution.[2]	Forage over shallow benthic habitats, have not been recorded in coral reef habitat or shallow inshore seagrass flats (Limpus 2008).	Unlikely
Natator depressus	**Flatback turtle**	**Vulnerable**	**Vulnerable**	**Not listed**	**Migratory, occurs along the Australian continental shelf, to the coastal waters of eastern Indonesia.[2]**	**Inhabit soft bottom habitat over the continental shelf of northern Australia.[2]**	**Confirmed - Foraging, feeding or related behaviour known to occur within the area (DoE 2016)**
Sea snakes							
Aipysurus laevis	Olive sea snake	Listed	Endangered	Not listed	Tropical and subtropical coastal and coral reef waters in northern Australia and the south west Pacific Ocean.[2]	Larger, sheltered reefs and rarely on highly exposed reefs.[2]	Unlikely
Astrotia stokesii	Stoke's sea snake	Listed	Endangered	Not listed	Tropical coastal areas from the Arabian Sea, to the Taiwan Strait and the north coast of Australia.[2]	Associated with inner reef drop-offs at water depths of 7–10 m, also occuring on muddy substrates at depths of 10 m and in coastal tidal pools.[2]	Unlikely
Hydrophis elegans	Elegant sea snake	Listed	Endangered	Not listed	Widespread in tropical Australia. [2]	Variety of marine and estuarine habitats, including sandy substrates in less than two metres of water to depths of approximately 80 m.[2]	Potential
Laticauda laticaudata	Sea krait	Listed	Not listed	Not listed	Widely distributed in the west and south west Pacific.[2]	Inhabits coral and rocky reefs, found to intensively use the beach rocks situated within the intertidal area.[2]	Potential

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Pelamis platurus	Yellow-bellied sea snake	Listed	Not listed	Not listed	Indian and Pacific oceans.[2]	Usually found within a few kilometers of the coast and prefers shallow inshore waters. Though also occurs in open waters well away from coasts and reefs.[2]	Potential

Table 13 Fish species of conservation significance (those confirmed to occur are in bold)

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Sharks and rays							
Carcharias taurus (east coast population)	Grey nurse shark	Critically Endangered	Endangered	Not listed	Occurs in tropical and temperate waters in the Atlantic, Indian and western Pacific Oceans.[1]	Shallow coastal waters from the surf zone down to 60 m, although it has been recorded from water as deep as 190 m. usually found in the vicinity of dropoffs, caves and ledges. [1]	Potential - Key aggregation habitats located north and south of study area.
Carcharodon carcharias	Great white shark	Vulnerable	Not listed	Not listed	Migratory, found worldwide in temperate, coastal waters.[1]	Temperate, coastal waters.[1]	Potential
Lamna nasus	Mackerel shark	Listed	Not listed	Not listed	Has an antitropical distribution.[1]	Occurs widely in inshore and oceanic temperate marine waters.[1]	Potential
Rhincodon typus	Whale shark	Vulnerable	Not listed	Not listed	Migratory, found in tropical and warm temperate waters.[1]	Occurs in continental shelf and offshore waters in both tropical and warm temperate waters of all oceans.[1]	Unlikely
Manta alfredi	Reef Manta Ray	Listed	Not listed	Not listed	Recorded from central Western Australia, around the tropical north of the country and south to the southern coast of New South Wales.[1]	Open water	Potential
Manta birostris	Giant Manta Ray	Listed	Not listed	Not listed	Recorded from south-western Western Australia, around the tropical north of the country and south to the southern coast of New South Wales.[1]	Open water	Potential

[11] Sources include: (1) the Australian museum, http://australianmuseum.net.au/; (2) EPBC's SPRAT database, http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl; and (3) FishBase, http://www.fishbase.org/search.php.

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Fishes							
Epinephelus daemelii	**Black rock cod**	**Vulnerable**	**Not listed**	**Not listed**	**From southern Queensland to eastern Victoria.** [1]	**Known from coastal and offshore reefs.**[1]	**Likely**
Epinephelus lanceolatus	Queensland grouper	Not listed	Not listed (protected under the *Fisheries Act 1994*)	Not listed	Indo-Pacific.[3]	Found on coral reefs, common in shallow waters. Found in caves or wrecks, also in estuaries.[3]	Potential
Pristis zijsron	Green sawfish	Vulnerable	Not listed	Not listed	Once widely distributed in the northern Indian Ocean, available catch records suggest that the northern Australia may be the last region where significant populations exist.[2]	Inhabits muddy bottom habitats and enters estuaries. It has been recorded in inshore marine waters, estuaries, river mouths, embankments and along sandy and muddy beaches.[2]	Unlikely
Acentronura tentaculata	Shortpouch pygmy pipehorse	Listed	Not listed	Not listed	Occurs in the West Pacific.[2]	Found on tropical inshore reefs, also occurs in temperate waters associated with shallow sandflats in protected and somewhat silty coastal areas among sparse low plant growth and in algae on rocks, coral, sponge gardens, vertical rock walls, wrecks and sand.[2]	Potential
Campichthys tryoni	Tryon's pipefish	Listed	Least Concern	Not listed	Western Central Pacific: endemic to Australia.[3]	No available data on habitat or depth of capture.[3]	Unknown
Corythoichthys amplexus	Fijian banded pipefish	Listed	Not listed	Not listed	Reported to occur throughout the Indo-West Pacific.[2]	Prefers protected coral habitats in depths of 0-31 m.[2]	Unlikely

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Corythoichthys ocellatus	Orange-spotted Pipefish	Listed	Not listed	Not listed	Western Central Pacific: Celebes and Philippines to Palau, the Solomon Islands, and Australia.[3]	Inhabits rubble patches of shallow sheltered reefs. Found to a depth of 12 m.[3]	Unlikely
Festucalex cinctus	Girdled pipefish	Listed	Least Concern	Not listed	Occurring in inshore waters of the Northern Territory, Queensland and New South Wales.[1]	Usually found in sheltered coastal bays, often on patches of rubble, sand or in sparse algal growth in depths of 10 m to 20 m.[1]	Unlikely
Filicampus tigris	Tiger pipefish	Listed	Least Concern	Not listed	Occurs from southern Queensland to central New South Wales and from the central to north-western coasts of Western Australia.[1]	Usually seen in estuaries on rubbly, sandy or weedy bottoms.[1]	Unlikely
Halicampus grayi	Mud pipefish	Listed	Not listed	Not listed	Indo-West Pacific.[3]	Adults live in muddy habitats, often covered with silt and extremely well-camouflaged.[3]	Unlikely
Hippichthys cyanospilos	Blue-specked pipefish	Listed	Not listed	Not listed	Indo-Pacific.[3]	Adults occur in estuaries, lower reaches of coastal rivers and streams and mangroves.[3]	Unlikely
Hippichthys heptagonus	Madura pipefish	Listed	Not listed	Not listed	Africa, Asia and Oceania.[3]	Common in the lower reaches of rivers and streams, and in estuarine habitats.[3]	Unlikely
Hippichthys penicillus	Beady pipefish	Listed	Not listed	Not listed	Indo-West Pacific.[3]	Adults inhabit lower reaches of streams and rivers, also seagrass beds in estuaries and other shallow inshore habitats.[3]	Potential
Hippocampus kelloggi	Kellogg's seahorse	Listed	Not listed	Not listed	Indo-West Pacific.[3]	Deep water species, associated with corals.[3]	Unlikely

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Hippocampus kuda	Spotted seahorse	Listed	Not listed	Not listed	Indo-Pacific.[3]	Inhabit seagrass and marine algae areas of estuaries and seaward reefs; also on steep mud slopes. Found in open water and attached to drifting Sargassum.[3]	Potential
Hippocampus planifrons	Flat-faced seahorse	Listed	Least Concern	Not listed	Northern Australia.[2]	Data unavailable.	Unknown
Hippocampus trimaculatus	Three-spot Seahorse	Listed	Not listed	Not listed	Indo-Pacific: southern India to Japan, Australia and Tahiti.[3]	Inhabits gravel or sand bottoms around shallow reefs; muddy estuaries and near mangroves, tolerating brackish waters.[3]	Potential
Hippocampus whitei	White's seahorse	Listed	Least Concern	Not listed	Occurs in depths down to about 25 m in temperate marine waters along the south-eastern and south-western coasts of Australia. It is common in Sydney Harbour.[1]	Found in shallow protected waters in seagrass, algae beds and under wharves.[1]	Unlikely
Lissocampus runa	Javelin pipefish	Listed	Least Concern	Not listed	Occurring in temperate inshore waters from northern New South Wales, around the south of the country to south-western Western Australia.[1]	Usually encountered in algal beds and rubbly substrates near rocky reefs.[1]	Potential
Maroubra perserrata	Sawtooth pipefish	Listed	Least Concern	Not listed	From northern New South Wales, around the south of the country including Tasmania, to south-western Western Australia.[1]	Found on coastal rocky reefs and estuaries in temperate marine waters.[1]	Potential
Micrognathus andersonii	Anderson's pipefish	Listed	Not listed	Not listed	Indo-Pacific.[3]	Inhabits tide pools, reef flats, and shallow sand flats among algae or seagrasses to a depth of 5 m or more.[3]	Unlikely
Micrognathus brevirostris	Thorntail pipefish	Listed	Not listed	Not listed	Western indian Ocean and along the eastern Australian seaboard.[3]	Found among algae.[3]	Potential

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
Microphis manadensis	Manado pipefish	Listed	Not listed	Not listed	Asia and Oceania: Reports from Australia requires verification by additional collections.[3]	Mostly found in streams or rivers, some as far as 30 km upstream from the mouth.[3]	Unlikely
Solegnathus dunckeri	Duncker's pipehorse	Listed	Least Concern	Not listed	occurring from southern Queensland to the central New South Wales coast and Lord Howe Island.[1]	Marine waters at depths between 30 m and 140 m.[1]	Unlikely
Solegnathus hardwickii	Pallid pipehorse	Listed	Not listed	Not listed	Western Indian Ocean and Western Pacific.[3]	Found in the continental shelf.[3]	Unlikely
Solegnathus spinosissimus	Spiny pipehorse	Listed	Not listed	Not listed	known to occur from New South Wales, Victoria, Tasmania and New Zealand.1	In temperate marine waters from 30 m - 230 m depth, over muddy bottoms.1	Unlikely
Solenostomus cyanopterus	Robust ghostpipefis h	Listed	Not listed	Not listed	found in coastal bays and estuaries from Shark Bay, Western Australia, around the tropical north and south to Sydney Harbour.1	Usually seen in pairs near algae or seagrass beds. When disturbed it will move into the vegetation.1	Potential
Solenostomus paegnius	Rough-snout ghost pipefish	Listed	Not listed	Not listed	Indo-Pacific.[3]	Found in algal/rubble reefs and sandy bottoms, often at depths below 10 m.[3]	Potential
Solenostomus paradoxus	Ornate ghost pipefish	Listed	Not listed	Not listed	widespread distribution in tropical waters of the Indian and western Pacific Oceans.[1]	Found in protected coastal waters, especially near coral and rocky dropoffs.[1]	Unlikely
Stigmatopora nigra	Widebody pipefish	Listed	Not listed	Not listed	Temperate marine waters from southern Queensland, around the south of the country and north to the central coast of Western Australia.[1]	Occurs in estuaries where it is common in seagrass beds or in weedy areas on rocky reefs.[1]	Potential
Syngnathoides biaculeatus	Double-end pipefish	Listed	Not listed	Not listed	Occurs in tropical waters of the Indo-west and Central Pacific.[1]	Occur in protected coastal shallows over or among algae, seagrasses, or floating weeds.[3]	Potential
Trachyrhamph us bicoarctatus	Bentstick pipefish	Listed	Not listed	Not listed	Occurs in marine waters throughout much of the Indo-West	Lives in bays and estuaries on sand or mud, from the	Unlikely

Scientific name	Common name	EPBC Act	QLD NC Act	NSW TSC Act	Distribution	Key habitat requirements	Likelihood of occurrence
					Pacific.[1]	shallows to at least 40 m depth.[1]	
Urocampus carinirostris	Hairy pipefish	Listed	Not listed	Not listed	Western Pacific: Australia and Papua New Guinea.[3]	Found mostly in algal or Zostera beds, rarely at depths of more than a few meters.[3]	Unlikely
Vanacampus margaritifer	Mother-of-pearl pipefish	Listed	Least Concern	Not listed	Occurs from southern Queensland, down the New South Wales coast and around the south of the country to eastern South Australia.[1]	Coastal and estuarine waters usually in algal beds and rubbly or muddy areas.[1]	Potential

Appendix 2 Results of Reef Statistical Analysis

Table 14 PERMANOVA results for the historical comparison between Kirra and Palm Beach Reefs

Factor	Df	Historical Comparison of Benthic Assemblages	
		MS	Pseudo-F/sig.
Time	4	51197	13.35***
Reef	1	70767	19.22**
Transect (Reef)	6	4947	5.08***
Time x Reef	4	12456	3.25***
Time x Transect (Reef)	16	3836	3.94***
Residual	448	974	

Significance level: **p < 0.01; ***p = 0.001.

Table 15 Post-hoc pairwise t-values for difference in benthic assemblages between survey years at (a) Kirra and (b) Palm Beach Reefs, and (c) between the reefs over time, following PERMANOVA

Pairwise Comparison	(a) Kirra Reef	(b) Palm Beach Reef	Pairwise Comparison	(c) Kirra vs Palm Beach Reef
	t –value/sig.	t –value/sig.		t –value/sig.
2010 vs 2012	4.66**	3.06**	2010	1.96*
2012 vs 2014	3.04*	1.16 ns	2012	2.11*
2014 vs 2015	0.90 ns	1.53 ns	2014	2.66**
2015 vs 2016	1.02 ns	4.70***	2015	5.39***
			2016	4.32***

Significance level (Monte Carlo P values): ns = not significant; *p < 0.05; **p < 0.01; ***p = 0.001.

Table 16 SIMPER results for the difference in coverage of taxonomic groups between surveys on Kirra Reef

Taxonomic Group	Average Abundance		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
	Reef				
a)	**2010**	**2012**	**65.85**		
% Turf Algae	17.4	67.3	26.2	2.2	40
% Bare	53.7	12.2	21.5	1.9	33
% Macroalgae	12.7	17.8	8.8	1.1	13
% Barnacles	8.2	0.0	4.1	1.1	6
b)	**2012**	**2014**	**53.18**		
% Turf Algae	67.3	36.0	18.9	1.7	35
% Macroalgae	17.8	24.9	10.2	1.5	19
% Ascidians	0.0	20.2	10.1	1.3	19
% Bare	12.2	4.4	5.9	1.1	11
% Coralline Algae	0.0	7.1	3.6	0.8	7

Table 17 PERMANOVA results for differences in the compostion of assemblages between orientations among reefs

Factor	Df	Benthic Assemblages		Algal Assemblages		Faunal Assemblages	
		MS	Pseudo-F/sig.	MS	Pseudo-F/sig.	MS	Pseudo-F/sig.
Orientation	1	32052	11.64**	13103	13.95***	42072	7.51***
Reef	3	60338	11.92***	42806	15.79***	49944	5.90***
Transect (Reef)	8	5063	4.11***	2712	6.85***	8472	2.33***
Orientation x Reef	3	9765	3.54***	5281	5.62***	13495	2.41***
Orientation x Transect (Reef)	8	2755	2.24***	939	2.37***	5602	1.54***
Residual	396	1233		396		3632	

Significance level: ** $p < 0.01$; *** $p < 0.001$.

Table 18 Post-hoc pairwise t-values for difference in benthic assemblages from vertical and horizontal orientations in each reef following PERMANOVA

Reef	Benthic Assemblages	Algal Assemblages	Faunal Assemblages
Kirra	2.70***	2.51*	2.17**
Cook Island	2.25**	1.51 ns	2.24***
Palm Beach	1.38 ns	1.51 ns	1.40*
Kingscliff	3.14***	3.95**	2.01**

Significance level: ^{ns} = not significant; *p < 0.05; **p < 0.01; ***p < 0.001.

Table 19 Post-hoc pairwise t-values for difference in assemblages in horizontal (H) and vertical (V) surface orientations among reefs following PERMANOVA

	Benthic Assemblages		Algal Assemblages		Faunal Assemblages	
Pairwise Comparisons	H	V	H	V	H	V
Kirra vs Cook Island	2.89***	4.22***	3.22**	4.10***	1.95**	3.34***
Kirra vs Kingscliff	3.42***	3.33***	3.81***	3.45***	2.41***	2.67***
Kirra vs Palm Beach	3.56***	3.44***	4.13**	4.22***	2.47***	2.69***
Cook Island vs Kingscliff	2.04***	1.32 ^{ns}	2.46**	1.03 ^{ns}	1.51**	1.31 ^{ns}
Cook Island vs Palm Beach	2.76***	2.08***	3.34**	3.17***	1.68***	1.65***
Kingscliff vs Palm Beach	4.58***	1.73**	8.26***	2.20*	2.14***	1.53**

Significance level: ^{ns} = not significant; *p < 0.05; **p < 0.01; ***p < 0.001.

Table 20 Average percent coverage of taxa recorded at each reef on horizontal (H) and vertical (V) surfaces in 2016

Phyla	Major Group	Taxonomic Group	Cook Island		Kingscliff		Kirra		Palm Beach	
			H	V	H	V	H	V	H	V
Annelida	Polychaeta	Onuphidae	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Annelida	Polychaeta	*Spirobranchus* sp.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Arthropoda	Maxillopoda	*Amphibalanus* sp.	0.2	0.0	0.0	0.0	0.0	0.1	0.6	1.8
Chordata	Ascidiacea	*Aplidium* sp.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Chordata	Ascidiacea	*Botrylloides leachi*	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Chordata	Ascidiacea	*Botrylloides* sp.1	0.0	0.1	0.0	0.3	0.0	1.0	0.0	0.5
Chordata	Ascidiacea	*Clavelina australis*	0.0	0.8	0.0	0.6	0.0	0.0	0.1	0.8
Chordata	Ascidiacea	*Cnemidocarpa stolonifera*	0.3	0.0	0.0	0.1	1.1	1.2	0.1	0.1

Phyla	Major Group	Taxonomic Group	Cook Island		Kingscliff		Kirra		Palm Beach	
			H	V	H	V	H	V	H	V
Chordata	Ascidiacea	*Didemnum membraneaceum*	0.0	0.1	0.0	0.5	0.0	1.0	0.0	0.3
Chordata	Ascidiacea	*Didemnum* sp.1	0.0	0.9	0.1	1.2	0.3	0.1	0.1	1.1
Chordata	Ascidiacea	*Didemnum* sp.2	0.0	0.7	0.4	0.8	0.1	0.2	0.0	0.1
Chordata	Ascidiacea	*Didemnum* sp.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Chordata	Ascidiacea	*Didemnum* sp.4	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0
Chordata	Ascidiacea	*Didemnum* sp.5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Chordata	Ascidiacea	*Distaplia* sp.1	0.0	0.4	0.0	0.3	0.0	0.0	0.0	0.1
Chordata	Ascidiacea	*Ecteinascidia nexa*	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Chordata	Ascidiacea	*Herdmania momus*	0.2	1.6	0.2	1.8	0.4	6.0	0.0	0.0
Chordata	Ascidiacea	*Leptoclinides* sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Chordata	Ascidiacea	*Leptoclinides* sp.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Chordata	Ascidiacea	*Lissoclinum* sp.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Chordata	Ascidiacea	*Microcosmus exasperatus*	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chordata	Ascidiacea	*Pallusia julinea*	0.0	0.4	0.0	0.4	0.0	0.9	0.1	1.4
Chordata	Ascidiacea	*Polycarpa procera*	0.4	1.7	0.4	1.4	2.8	7.6	0.0	0.7
Chordata	Ascidiacea	*Polycarpa* sp.1	0.2	0.1	0.0	0.1	0.8	1.2	0.1	0.1
Chordata	Ascidiacea	*Pyura stolonifera*	1.7	1.9	1.5	3.5	1.7	5.4	2.5	2.6
Chordata	Ascidiacea	*Symplegma brakenhielmi*	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Chordata	Ascidiacea	*Symplegma reptans*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Cnidaria	Actinaria	*Actinaria* sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cnidaria	Actinaria	*Entacmaea quadricolor*	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Cnidaria	Actinaria	*Heteractis* sp.1	1.2	0.1	0.1	0.0	0.6	0.6	0.2	0.4
Cnidaria	Alcyonacea	*Cladiella australis*	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Cnidaria	Alcyonacea	*Cladiella* sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2
Cnidaria	Alcyonacea	*Cladiella* sp.2	0.2	0.0	0.2	0.0	0.0	0.0	0.2	0.2
Cnidaria	Alcyonacea	*Cladiella* sp.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Cnidaria	Alcyonacea	*Dendronephthya* sp.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Cnidaria	Alcyonacea	*Dendronephthya* sp.2	1.9	1.3	0.7	0.0	0.0	0.0	0.6	0.7
Cnidaria	Alcyonacea	*Lobophyton* sp.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Cnidaria	Alcyonacea	*Lobophyton* sp.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Cnidaria	Alcyonacea	*Sarcophyton* sp.1	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.3
Cnidaria	Alcyonacea	*Sarcophyton* sp.2	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Cnidaria	Alcyonacea	*Sarcophyton* sp.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Cnidaria	Alcyonacea	*Tubipora* sp.1	0.0	0.2	0.0	0.3	0.0	0.0	0.0	0.0
Cnidaria	Alcyonacea	*Xenia* sp.1	0.5	0.0	0.4	0.0	0.0	0.0	0.0	0.2
Cnidaria	Hydrozoa	*Macrorhynchia* sp.1	0.0	0.0	0.1	0.1	1.0	1.8	0.0	0.0
Cnidaria	Hydrozoa	*Macrorhynchia* sp.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Cnidaria	Scleractinia	*Acanthastrea lordhowensis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cnidaria	Scleractinia	*Acropora digitifera*	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0

Phyla	Major Group	Taxonomic Group	Cook Island		Kingsclif f		Kirra		Palm Beach	
			H	V	H	V	H	V	H	V
Cnidaria	Scleractinia	*Acropora solitaryensis*	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Cnidaria	Scleractinia	*Acropora* sp.1	0.9	0.1	0.0	0.0	0.0	0.0	1.0	0.1
Cnidaria	Scleractinia	*Acropora* sp.2	0.7	0.0	0.2	0.0	0.0	0.0	0.1	0.2
Cnidaria	Scleractinia	*Favia speciosa*	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6
Cnidaria	Scleractinia	*Favites flexuosa*	1.0	0.4	0.2	0.0	0.0	0.0	0.0	0.3
Cnidaria	Scleractinia	*Goniastrea australensis*	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.6
Cnidaria	Scleractinia	*Goniopora* sp.1	0.1	0.3	0.4	0.1	0.0	0.0	0.0	0.3
Cnidaria	Scleractinia	*Platygyra lamellina*	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.1
Cnidaria	Scleractinia	*Pocillopora damicornis*	0.0	0.1	0.0	0.0	0.0	0.0	2.6	1.1
Cnidaria	Scleractinia	*Porites lutea*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Cnidaria	Scleractinia	*Porites* sp.1	0.0	0.0	0.2	0.0	0.0	0.0	0.9	1.0
Cnidaria	Scleractinia	*Tubastrea faulkneri*	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Cnidaria	Scleractinia	*Turbinaria mesenterina*	4.0	0.0	0.4	0.0	0.0	0.0	0.1	0.3
Cnidaria	Zoantharia	*Discosoma rhodostoma*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Cnidaria	Zoantharia	*Discosoma* sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Cnidaria	Zoantharia	*Palythoa caesia*	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Cnidaria	Zoantharia	*Protopalythoa* sp.1	0.1	0.1	0.6	0.3	0.0	0.0	0.5	0.4
Echino-dermata	Asteroidea	*Echinaster luzonicus*	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Echino-dermata	Crinoidea	*Cenolia glebosis*	0.1	0.0	0.0	0.0	2.3	7.4	0.0	0.0
Echino-dermata	Crinoidea	*Cenolia* sp.1	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.0
Echino-dermata	Echinoidea	*Diadema* spp.	0.1	0.3	0.0	0.1	0.0	0.0	0.1	0.3
Echino-dermata	Echinoidea	*Echinometra mathaei*	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Echino-dermata	Echinoidea	*Phyllacanthus parvispinus*	0.1	0.2	0.3	0.3	0.0	0.0	0.2	0.1
Echino-dermata	Echinoidea	*Tripneustes gratilla*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mollusca	Bivalvia	*Pinctata maculata*	0.0	0.0	0.0	0.0	0.1	0.0	0.3	1.2
Mollusca	Bivalvia	*Pinctata* sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Porifera	Demospongiae	*Acanthella* sp.1	0.0	1.1	0.0	1.4	0.0	0.0	0.0	0.7
Porifera	Demospongiae	*Acanthella* sp.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.4
Porifera	Demospongiae	*Agelas* sp.1	0.7	0.8	0.1	0.6	0.0	0.0	1.1	0.7
Porifera	Demospongiae	*Aplysilla* sp.2	0.1	0.2	0.0	0.4	0.1	0.3	0.4	0.1
Porifera	Demospongiae	*Aplysilla* sp.3	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1
Porifera	Demospongiae	*Aplysilla sulfurea*	0.0	0.3	0.2	0.2	0.0	0.3	0.0	0.0
Porifera	Demospongiae	*Batzella* sp.1	0.0	0.1	0.0	0.3	0.0	0.0	0.2	0.1
Porifera	Demospongiae	*Batzella* sp.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Porifera	Demospongiae	*Callyspongia (Cladochalina) manus*	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0

Phyla	Major Group	Taxonomic Group	Cook Island		Kingscliff		Kirra		Palm Beach	
			H	V	H	V	H	V	H	V
Porifera	Demospongiae	*Callyspongia* sp.1	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.0
Porifera	Demospongiae	*Callyspongia* sp.2	0.0	0.0	0.0	0.0	0.0	1.4	0.1	0.7
Porifera	Demospongiae	*Chondrilla* sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Porifera	Demospongiae	*Chondropsis* sp.2	0.0	0.2	0.2	1.0	0.0	0.1	1.1	1.6
Porifera	Demospongiae	*Clathria* sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Porifera	Demospongiae	*Cliona* sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Porifera	Demospongiae	*Cliona* sp.2	0.0	0.7	0.0	0.7	0.0	0.1	0.0	0.1
Porifera	Demospongiae	*Cribrochalina* sp.1	0.0	0.0	0.1	0.3	0.0	0.2	0.0	0.0
Porifera	Demospongiae	*Cribrochalina* sp.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Porifera	Demospongiae	*Cribrochalina* sp.3	0.0	0.0	0.0	0.0	1.2	1.3	0.0	0.3
Porifera	Demospongiae	*Desmapsamma* sp.1	0.0	0.0	0.0	0.1	0.6	0.9	0.3	0.0
Porifera	Demospongiae	*Dysidea* sp.1	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0
Porifera	Demospongiae	*Dysidea* sp.2	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.3
Porifera	Demospongiae	*Dysidea* sp.3	0.1	0.1	0.1	1.2	0.0	0.7	2.7	0.8
Porifera	Demospongiae	*Dysidea* sp.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Porifera	Demospongiae	*Dysidea* sp.5	0.2	0.5	1.1	1.3	0.0	0.0	0.0	0.0
Porifera	Demospongiae	encrusting porifera sp.1	0.3	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Porifera	Demospongiae	encrusting porifera sp.2	1.6	1.4	4.0	1.2	0.0	0.0	0.0	1.0
Porifera	Demospongiae	encrusting porifera sp.3	0.4	1.2	0.2	0.6	0.0	0.0	0.0	0.1
Porifera	Demospongiae	encrusting porifera sp.4	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0
Porifera	Demospongiae	encrusting porifera sp.5	0.0	0.1	0.3	1.7	0.1	0.1	0.4	0.8
Porifera	Demospongiae	*Haliclona* sp.1	0.0	0.0	0.0	0.0	0.2	0.8	0.0	0.0
Porifera	Demospongiae	*Haliclona* sp.2	0.0	0.0	0.0	0.1	0.2	0.9	0.0	0.1
Porifera	Demospongiae	*Hyattella* sp.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1
Porifera	Demospongiae	*Hyattella* sp.2	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.1
Porifera	Demospongiae	*Iotrochota* sp.1	1.0	1.4	0.4	0.6	0.1	0.0	0.8	0.7
Porifera	Demospongiae	*Mycale* sp.1	0.2	0.2	0.2	0.1	0.0	0.0	0.2	0.0
Porifera	Demospongiae	*Rhabdastrella globostellata*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.7
Porifera	Demospongiae	*Rhabdastrella* sp.1	0.0	0.1	0.5	1.1	0.0	0.0	0.1	0.0
Porifera	Demospongiae	*Spheciospongia confoederata*	0.5	0.9	1.0	0.3	0.0	0.2	1.1	3.1
Porifera	Demospongiae	*Spheciospongia montiformis*	0.0	0.3	0.0	0.5	0.0	0.0	0.0	0.0
Porifera	Demospongiae	*Spheciospongia* sp.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Porifera	Demospongiae	*Stelletta* sp.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Chlorophyta	Bryopsidophyceae	*Caulerpa peltata*	0.3	1.0	0.3	0.5	0.0	0.0	0.0	0.0
Chlorophyta	Bryopsidophyceae	*Caulerpa lentillifera*	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Chlorophyta	Bryopsidophyceae	*Halimeda discoidea*	0.3	0.1	0.2	0.0	0.0	0.4	0.0	0.0
Chlorophyta	Chlorophyceae	*Chlorodesmis major*	0.8	0.0	0.0	0.2	0.0	0.0	0.7	0.1
Chlorophyta	Ulvophyceae	*Ulva lactuca*	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0

Phyla	Major Group	Taxonomic Group	Cook Island		Kingscliff		Kirra		Palm Beach	
			H	V	H	V	H	V	H	V
Phaeophyta	Phaeophyceae	*Dictyopteris* sp.1	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Phaeophyta	Phaeophyceae	*Dictyota* spp.	3.1	1.0	5.8	2.5	1.0	0.4	0.1	0.0
Phaeophyta	Phaeophyceae	*Ecklonia radiata*	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Phaeophyta	Phaeophyceae	*Padina gymnospora*	5.1	3.3	8.9	1.1	0.8	0.0	0.0	0.0
Phaeophyta	Phaeophyceae	*Sargassum spp*	0.0	0.0	0.0	0.0	28.8	12.6	0.0	0.0
Rhodophyta	Florideophyceae	*Halipliton roseum*	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0
Rhodophyta	Rhodophytaceae	*Galaxaura* sp.1	6.6	4.9	6.9	2.5	1.6	1.2	0.0	0.0
Rhodophyta	Rhodophytaceae	*Jania adhaerens*	0.0	0.4	4.6	1.9	6.1	6.5	0.0	0.0
Rhodophyta	Rhodophytaceae	*Laurencia brogniartii*	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Rhodophyta	Rhodophytaceae	*Laurencia* spp.	0.2	0.1	0.8	0.9	0.0	0.0	0.0	0.0
Rhodophyta	Rhodophytaceae	unknown macroalgae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhodophyta	-	encrusting coralline algae	4.5	3.0	8.5	2.9	1.3	1.4	8.1	8.4
-	-	turf algae	56.8	59.6	46.7	58.1	41.8	33.7	68.5	55.8

Table 21 SIMPER results for the benthic categories contributing to the difference between reefs on horizontal surfaces

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
a)	**Cook Island**	**Kingscliff**	**43.42**		
turf algae	56.8	46.7	8.0	1.4	18.6
Padina gymnospora	5.1	8.9	4.3	1.1	9.9
coralline algae	4.5	8.5	3.2	1.3	7.3
Dictyota spp.	3.1	5.8	3.1	1.1	7.3
Galaxaura sp.	6.6	7.0	3.1	1.2	7.2
encrusting porifera sp. 2	1.6	4.0	2.4	0.7	5.5
Jania adhaerensadhaerens	0.0	4.6	2.3	0.7	5.3
Turbinaria mesenterina	4.0	0.4	2.2	0.4	5.0
Dendronephthya sp. 2	1.9	0.7	1.2	0.4	2.8
Pyura stolonifera	1.7	1.5	1.2	0.7	2.8
Spheciospongia confoederata	0.5	1.0	0.7	0.3	1.7
Iotrochota sp. 1	1.0	0.4	0.7	0.3	1.5
Heteractis sp. 1	1.2	0.1	0.6	0.6	1.4
Dysidea sp. 5	0.2	1.1	0.6	0.7	1.4
Favites flexuosa	1.0	0.2	0.6	0.3	1.4
Laurencia spp.	0.2	0.8	0.5	0.5	1.1
Acropora sp. 2	0.8	0.2	0.5	0.2	1.1

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Acropora sp. 1	0.9	0.0	0.5	0.2	1.1
Chlorodesmis major	0.8	0.0	0.4	0.3	1.0
Xenia sp.1	0.5	0.4	0.4	0.4	0.9
Agelas sp.1	0.8	0.1	0.4	0.6	0.9
Polycarpa procera	0.4	0.4	0.4	0.4	0.9
Protopalythoa sp. 1	0.1	0.6	0.3	0.5	0.8
encrusting porifera sp. 3	0.4	0.2	0.3	0.3	0.7
Caulerpa peltata	0.3	0.3	0.3	0.4	0.7
Rhabdastrella sp. 1	0.0	0.5	0.3	0.4	0.6
Goniopora sp.1	0.1	0.4	0.2	0.5	0.6
Dictyopteris sp.1	0.5	0.0	0.2	0.3	0.6
Halimeda discoidea	0.3	0.2	0.2	0.4	0.5
b)	**Cook Island**	**Kirra**	**56.30**		
Sargassum spp.	0.0	28.9	14.7	1.6	26.0
turf algae	56.8	41.8	10.0	1.4	17.7
Jania adhaerensadhaerens	0.0	6.1	3.1	0.6	5.5
Galaxaura sp.	6.6	1.6	3.0	1.3	5.4
Padina gymnospora	5.1	0.8	2.7	0.8	4.8
coralline algae	4.5	1.3	2.1	1.0	3.7
Turbinaria mesenterina	4.0	0.0	2.0	0.3	3.6
Dictyota spp.	3.1	1.0	1.8	0.7	3.1
Polycarpa procera	0.4	2.8	1.5	0.7	2.6
Pyura stolonifera	1.7	1.7	1.3	0.8	2.4
Cenolia sp.1	0.1	2.3	1.2	0.7	2.0
Dendronephthya sp. 2	1.9	0.0	1.0	0.3	1.8
encrusting porifera sp. 2	1.6	0.0	0.8	0.4	1.4
Heteractis sp.1	1.2	0.6	0.8	0.7	1.4
Cribrochalina sp. 3	0.0	1.2	0.6	0.5	1.1
Cnemidocarpa stolonifera	0.3	1.1	0.6	0.6	1.1
Iotrochota sp. 1sp. 1	1.0	0.1	0.6	0.2	1.0
Macrorhynchia sp. 1	0.0	1.0	0.5	0.3	0.9
Favites flexuosa	1.0	0.0	0.5	0.3	0.9
Acropora sp. 1	0.9	0.0	0.5	0.2	0.8
Polycarpa sp. 1	0.2	0.8	0.4	0.7	0.8
Chlorodesmis major	0.8	0.0	0.4	0.2	0.7
Agelas sp.1	0.8	0.0	0.4	0.6	0.7
Acropora sp. 2	0.8	0.0	0.4	0.2	0.7
c)	**Kingscliff**	**Kirra**	**56.36**		
Sargassum spp.	0.0	28.9	14.7	1.6	26.1

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
turf algae	46.7	41.8	7.2	1.3	12.8
Padina gymnospora	8.9	0.8	4.4	1.1	7.8
Jania adhaerensadhaerens	4.6	6.1	4.0	0.9	7.0
coralline algae	8.5	1.3	3.8	1.5	6.7
Galaxaura sp.	7.0	1.6	3.2	1.1	5.7
Dictyota spp.	5.8	1.0	2.7	1.0	4.8
encrusting porifera sp. 2	4.0	0.0	2.0	0.6	3.6
Polycarpa procera	0.4	2.8	1.5	0.7	2.6
Pyura stolonifera	1.5	1.7	1.2	0.8	2.1
Cenolia sp.	0.0	2.3	1.1	0.7	2.0
Cribrochalina sp. 3	0.0	1.2	0.6	0.5	1.1
Dysidea sp. 5	1.1	0.0	0.6	0.7	1.0
Cnemidocarpa stolonifera	0.0	1.1	0.6	0.6	1.0
Macrorhynchia sp. 1	0.1	1.0	0.5	0.3	1.0
Spheciospongia confoederata	1.0	0.0	0.5	0.2	0.9
Laurencia sp.1	0.8	0.0	0.4	0.4	0.8
Polycarpa sp. 1	0.0	0.8	0.4	0.6	0.7
Heteractis sp. 1	0.1	0.6	0.4	0.4	0.7
Onuphidae	0.0	0.7	0.4	0.2	0.6
Dendronephthya sp. 2	0.7	0.0	0.4	0.4	0.6
Protopalythoa sp. 1sp. 1	0.6	0.0	0.3	0.4	0.5
d)	**Cook Island**	**Palm Beach**	**41.58**		
turf algae	56.8	68.5	9.2	1.4	22.0
Galaxaura sp.	6.6	0.0	3.3	1.3	8.0
coralline algae	4.5	8.1	3.1	1.4	7.3
Padina gymnospora	5.1	0.0	2.6	0.7	6.2
Turbinaria mesenterina	4.0	0.1	2.0	0.3	4.9
Dictyota spp.	3.1	0.1	1.6	0.6	3.8
Pyura stolonifera	1.7	2.5	1.5	0.9	3.7
Dysidea sp. 3	0.1	2.7	1.4	0.3	3.2
Pocillopora damicornis	0.0	2.6	1.3	0.4	3.1
Dendronephthya sp. 2	1.9	0.6	1.2	0.4	2.8
Acropora sp. 1	0.9	1.0	0.9	0.3	2.2
Iotrochota sp. 1sp. 1	1.0	0.8	0.8	0.3	2.0
encrusting porifera sp. 2	1.6	0.0	0.8	0.4	1.9
Spheciospongia confoederata	0.5	1.1	0.7	0.4	1.8
Agelas sp.1	0.8	1.1	0.7	0.7	1.8
Chlorodesmis major	0.8	0.7	0.7	0.4	1.7
Heteractis sp.1	1.2	0.2	0.7	0.6	1.6

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Chondropsis sp. 2	0.0	1.1	0.6	0.6	1.3
Favites flexuosa	1.0	0.0	0.5	0.3	1.2
Porites sp. 1	0.0	1.0	0.5	0.2	1.1
Acropora sp. 2	0.8	0.1	0.4	0.2	1.0
Dendronephthya sp. 2	0.0	0.8	0.4	0.4	1.0
Amphibalanus sp.	0.2	0.6	0.4	0.6	0.9
Acropora solitaryensis	0.0	0.7	0.3	0.2	0.8
Protopalythoa sp. 1sp. 1	0.1	0.5	0.3	0.4	0.7
Aplysilla sp. 2	0.1	0.4	0.3	0.4	0.6
Xenia sp.1	0.5	0.0	0.2	0.3	0.6
Dictyopteris sp.1	0.5	0.0	0.2	0.3	0.6
Sarcophyton sp. 1	0.3	0.2	0.2	0.3	0.6
encrusting porifera sp. 5	0.0	0.4	0.2	0.5	0.5
Polycarpa procera	0.4	0.0	0.2	0.3	0.5
Platygyra lamellina	0.3	0.2	0.2	0.2	0.5
Mycale sp.1	0.2	0.2	0.2	0.4	0.5
e)	**Kingscliff**	**Palm Beach**	**47.54**		
turf algae	46.7	68.5	12.2	1.8	25.7
Padina gymnospora	8.9	0.0	4.5	1.1	9.4
Galaxaura sp.	7.0	0.0	3.5	1.1	7.3
Dictyota spp.	5.8	0.1	2.9	1.0	6.1
coralline algae	8.5	8.1	2.8	1.3	5.9
Jania adhaerensadhaerens	4.6	0.0	2.3	0.7	4.9
encrusting porifera sp. 2	4.0	0.0	2.0	0.6	4.2
Pyura stolonifera	1.5	2.5	1.4	1.0	2.9
Dysidea sp. 3	0.1	2.7	1.4	0.3	2.9
Pocillopora damicornis	0.0	2.6	1.3	0.4	2.7
Spheciospongia confoederata	1.0	1.1	1.0	0.4	2.0
Dendronephthya sp. 2	0.7	0.6	0.6	0.5	1.3
Chondropsis sp. 2	0.2	1.1	0.6	0.6	1.2
Dysidea sp. 5	1.1	0.0	0.6	0.7	1.2
Agelas sp. 1	0.1	1.1	0.6	0.5	1.2
Porites sp. 1	0.2	1.0	0.5	0.2	1.1
Iotrochota sp. 1sp. 1	0.4	0.8	0.5	0.7	1.1
Acropora sp. 1	0.0	1.0	0.5	0.2	1.0
Protopalythoa sp. 1sp. 1	0.6	0.5	0.5	0.6	1.0
Laurencia sp.	0.8	0.0	0.4	0.4	0.9
Dendronephthya sp. 2	0.0	0.8	0.4	0.4	0.9
Chlorodesmis major	0.0	0.7	0.4	0.4	0.8

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
encrusting porifera sp. 5	0.3	0.4	0.3	0.5	0.7
Acropora solitaryensis	0.0	0.7	0.3	0.2	0.7
Amphibalanus sp.	0.0	0.6	0.3	0.5	0.7
Rhabdastrella sp. 1	0.5	0.1	0.3	0.4	0.6
Aplysilla sp. 2	0.0	0.4	0.2	0.4	0.5
Sarcophyton sp. 2	0.4	0.0	0.2	0.1	0.5
Goniopora sp. 1sp. 1	0.4	0.0	0.2	0.4	0.5
Turbinaria mesenterina	0.4	0.1	0.2	0.2	0.5
f)	**Kirra Reef**	**Palm Beach**	**56.57**		
Sargassum spp.	28.9	0.0	14.6	1.6	25.9
turf algae	41.8	68.5	14.6	1.7	25.7
coralline algae	1.3	8.1	3.6	1.5	6.4
Jania adhaerensadhaerens	6.1	0.0	3.1	0.6	5.5
Pyura stolonifera	1.7	2.5	1.5	1.0	2.7
Polycarpa procera	2.8	0.0	1.4	0.6	2.5
Dysidea sp. 3	0.0	2.7	1.4	0.3	2.4
Pocillopora damicornis	0.0	2.6	1.3	0.4	2.3
Cenolia sp.	2.3	0.0	1.1	0.7	2.0
Galaxaura sp.	1.6	0.0	0.8	0.6	1.4
Cribrochalina sp. 3	1.2	0.0	0.6	0.5	1.1
Cnemidocarpa stolonifera	1.1	0.1	0.6	0.6	1.0
Dictyota spp.	1.0	0.1	0.6	0.7	1.0
Spheciospongia confoederata	0.0	1.1	0.6	0.3	1.0
Chondropsis sp. 2	0.0	1.1	0.5	0.6	1.0
Agelas sp.1	0.0	1.1	0.5	0.5	1.0
Macrorhynchia sp. 1	1.0	0.0	0.5	0.3	0.9
Acropora sp. 1	0.0	1.0	0.5	0.2	0.9
Porites sp. 1	0.0	1.0	0.5	0.2	0.8
Padina gymnospora	0.8	0.0	0.4	0.3	0.8
Polycarpa sp. 1	0.8	0.1	0.4	0.7	0.7
Iotrochota sp. 1sp. 1	0.1	0.8	0.4	0.6	0.7
Dendronephthya sp. 2	0.0	0.8	0.4	0.4	0.7
Heteractis sp. 1	0.6	0.2	0.4	0.5	0.7
Desmapsamma sp. 1	0.6	0.3	0.4	0.5	0.7
Onuphidae	0.7	0.0	0.4	0.2	0.6

Table 22 SIMPER results for the benthic categories contributing to the difference between reefs on vertical surfaces

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
a)	**Cook Island**	**Kingscliff**	**93.21**		
encrusting porifera sp.2	1.57	4.01	12.26	0.73	13.15
Pyura stolonifera	1.73	1.45	8.00	0.67	8.58
Turbinaria mesenterina	4	0.35	7.71	0.4	8.27
Dendronephthya sp. 2	1.93	0.71	5.57	0.52	5.98
Heteractis sp. 1	1.18	0.12	4.39	0.45	4.71
Dysidea sp. 5	0.24	1.14	4.09	0.63	4.38
Spheciospongia confoederata	0.51	0.98	3.60	0.33	3.86
Iotrochota sp. 1sp. 1	1.02	0.35	3.46	0.32	3.71
Agelas sp. 1	0.75	0.08	2.71	0.44	2.91
Favites flexuosa	0.98	0.24	2.46	0.31	2.64
Protopalythoa sp. 1sp. 1	0.12	0.59	2.39	0.38	2.56
Xenia sp. 1	0.47	0.4	2.31	0.39	2.48
Polycarpa procera	0.39	0.39	2.28	0.39	2.45
Acropora sp. 1	0.9	0	2.13	0.23	2.28
Rhabdastrella sp. 1	0	0.51	1.88	0.32	2.02
Acropora sp. 2	0.75	0.2	1.7	0.23	1.83
Goniopora sp. 1sp. 1	0.08	0.43	1.66	0.32	1.78
Mycale sp. 1sp. 1	0.2	0.2	1.52	0.24	1.63
encrusting porifera sp. 3	0.39	0.2	1.27	0.27	1.36
encrusting porifera sp. 5	0	0.31	1.21	0.23	1.29
Phyllacanthus parvispinus	0.08	0.27	1.12	0.32	1.20
Cladiella sp. 3	0.16	0.2	1.07	0.23	1.15
Lobophyton sp. 1	0	0.35	1.01	0.13	1.08
Cnemidocarpa stolonifera	0.27	0.04	1.01	0.32	1.08
Chondropsis sp. 2	0.04	0.2	0.95	0.30	1.02
Echinaster luzonicus	0.27	0	0.95	0.34	1.02
Didemnum sp. 2	0	0.35	0.95	0.13	1.02
Polycarpa sp. 1	0.24	0.04	0.89	0.33	0.96
Herdmania momus	0.2	0.16	0.87	0.39	0.93
Aplysilla sulfurea	0	0.2	0.72	0.23	0.78
Dysidea sp. 3	0.08	0.12	0.72	0.24	0.77
Sarcophyton sp. 1	0.27	0	0.69	0.19	0.74
Sarcophyton sp. 2	0	0.43	0.57	0.14	0.61
b)	**Cook Island**	**Kirra**	**95.40**		
Pyura stolonifera	1.73	1.7	8.45	0.64	8.86

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Polycarpa procera	0.39	2.79	7.98	0.62	8.36
Turbinaria mesenterina	4	0	7.16	0.37	7.51
Cenolia sp.	0.08	2.26	6.31	0.61	6.62
Heteractis sp. 1	1.18	0.63	5.29	0.51	5.54
Dendronephthya sp. 2	1.93	0	4.28	0.41	4.49
Cnemidocarpa stolonifera	0.27	1.12	3.81	0.57	4
Cribrochalina sp. 3	0.04	1.23	3.79	0.46	3.97
encrusting porifera sp.2	1.57	0	3.47	0.37	3.64
Polycarpa sp. 1	0.24	0.79	3.19	0.57	3.35
Iotrochota sp. 1sp. 1	1.02	0.08	2.96	0.26	3.1
Macrorhynchia sp. 1	0.04	1.02	2.86	0.31	3
Agelas sp. 1	0.75	0	2.68	0.37	2.81
Onuphidae	0	0.71	2.43	0.23	2.55
Acropora sp. 1	0.9	0	2.15	0.23	2.26
Favites flexuosa	0.98	0	2.05	0.28	2.15
Spheciospongia confoederata	0.51	0	1.57	0.26	1.65
Desmapsamma sp. 1	0	0.55	1.57	0.33	1.64
Acropora sp. 2	0.75	0	1.47	0.2	1.54
Xenia sp. 1	0.47	0	1.34	0.31	1.4
Herdmania momus	0.2	0.36	1.32	0.31	1.38
Didemnum sp. 1	0	0.27	1.12	0.19	1.17
Entacmaea quadricolor	0	0.27	1.11	0.2	1.16
Echinaster luzonicus	0.27	0	0.98	0.32	1.03
Cenolia sp.1	0.08	0.25	0.97	0.25	1.02
Dysidea sp. 1	0.04	0.32	0.97	0.4	1.02
encrusting porifera sp. 3	0.39	0	0.91	0.24	0.95
Mycale sp. 1sp. 1	0.2	0	0.89	0.14	0.93
Haliclona sp. 2	0	0.24	0.83	0.25	0.87
Dysidea sp. 5	0.24	0	0.7	0.28	0.74
Sarcophyton sp. 1	0.27	0	0.7	0.19	0.73
Aplidium sp.1	0.08	0	0.61	0.11	0.64
c)	**Kingscliff**	**Kirra**	**95.97**		
encrusting porifera sp.2	4.01	0	11.08	0.65	11.54
Polycarpa procera	0.39	2.79	8.41	0.66	8.77
Pyura stolonifera	1.45	1.7	7.55	0.82	7.87
Cenolia sp.	0	2.26	6.57	0.64	6.85
Dysidea sp. 5	1.14	0	4.15	0.6	4.32
Cribrochalina sp. 3	0.04	1.23	4.04	0.49	4.21
Cnemidocarpa stolonifera	0.04	1.12	3.76	0.52	3.92

Taxonomic Group	Average Abundance		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
	Habitat Category				
Polycarpa sp. 1	0.04	0.79	3.08	0.56	3.2
Macrorhynchia sp. 1	0.08	1.02	3.07	0.33	3.2
Heteractis sp. 1	0.12	0.63	2.68	0.33	2.79
Onuphidae	0	0.71	2.55	0.24	2.66
Spheciospongia confoederata	0.98	0	2.37	0.23	2.46
Protopalythoa sp. 1sp. 1	0.59	0	2.35	0.35	2.45
Rhabdastrella sp. 1	0.51	0	2.02	0.32	2.11
Dendronephthya sp. 2	0.71	0	2	0.37	2.09
Desmapsamma sp. 1	0	0.55	1.65	0.34	1.72
Goniopora sp. 1sp. 1	0.43	0	1.58	0.29	1.65
encrusting porifera sp. 5	0.31	0.08	1.57	0.28	1.63
Didemnum sp. 1	0.12	0.27	1.48	0.25	1.55
Herdmania momus	0.16	0.36	1.36	0.3	1.41
Iotrochota sp. 1sp. 1	0.35	0.08	1.35	0.28	1.41
Didemnum sp. 2	0.35	0.08	1.29	0.17	1.34
Xenia sp. 1	0.4	0	1.2	0.25	1.25
Entacmaea quadricolor	0	0.27	1.15	0.21	1.2
Dysidea sp. 1	0.04	0.32	1.12	0.39	1.17
Lobophyton sp. 1	0.35	0	1.08	0.14	1.12
Dysidea sp. 2	0.12	0.2	0.95	0.34	0.99
Haliclona sp. 2	0.04	0.24	0.94	0.28	0.98
Chondropsis sp. 2	0.2	0	0.91	0.28	0.95
Phyllacanthus parvispinus	0.27	0	0.91	0.27	0.94
Turbinaria mesenterina	0.35	0	0.79	0.18	0.82
Mycale sp. 1sp. 1	0.2	0	0.79	0.21	0.82
Aplysilla sulfurea	0.2	0	0.78	0.23	0.81
d)	**Cook Island**	**Palm Beach**	**93.21**		
Pyura stolonifera	1.73	2.54	9.11	0.78	9.78
Turbinaria mesenterina	4	0.08	6.62	0.37	7.11
Dysidea sp. 3	0.08	2.65	5.52	0.44	5.92
Pocillopora damicornis	0.04	2.56	5.11	0.39	5.48
Dendronephthya sp. 2	1.93	0.63	4.82	0.5	5.17
Agelas sp.1	0.75	1.07	4.57	0.53	4.91
Iotrochota sp. 1sp. 1	1.02	0.79	3.83	0.44	4.11
Acropora sp. 1	0.9	0.99	3.73	0.33	4
Chondropsis sp. 2	0.04	1.07	3.69	0.45	3.96
Spheciospongia confoederata	0.51	1.09	3.63	0.43	3.89
Heteractis sp. 1	1.18	0.24	3.6	0.51	3.86

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
encrusting porifera sp.2	1.57	0	3.06	0.37	3.28
Dendronephthya sp. 2	0	0.82	2.06	0.33	2.21
Favites flexuosa	0.98	0	1.83	0.27	1.96
Protopalythoa sp. 1sp. 1	0.12	0.51	1.81	0.37	1.94
Acropora sp. 2	0.75	0.12	1.61	0.23	1.72
encrusting porifera sp. 5	0	0.43	1.54	0.39	1.65
Aplysilla sp. 2	0.08	0.44	1.51	0.39	1.62
Mycale sp. 1sp. 1	0.2	0.24	1.34	0.29	1.44
Porites sp. 1	0	0.95	1.32	0.21	1.42
Acropora solitaryensis	0	0.67	1.26	0.16	1.35
Rhabdastrella globostellata	0	0.4	1.25	0.19	1.34
Xenia sp. 1	0.47	0	1.14	0.31	1.22
Sarcophyton sp. 1	0.27	0.2	1.06	0.27	1.14
Cnemidocarpa stolonifera	0.27	0.12	1.01	0.38	1.09
Polycarpa procera	0.39	0.04	1.01	0.24	1.08
Polycarpa sp. 1	0.24	0.12	0.94	0.38	1.01
Cladiella sp. 3	0.16	0.24	0.94	0.25	1.01
Desmapsamma sp. 1	0	0.27	0.83	0.32	0.89
Pinctata maculata	0	0.27	0.82	0.28	0.88
encrusting porifera sp. 3	0.39	0	0.79	0.24	0.85
Echinaster luzonicus	0.27	0	0.79	0.35	0.85
Platygyra lamellina	0.27	0.16	0.71	0.24	0.76
Batzella sp. 1	0.04	0.16	0.63	0.25	0.67
Phyllacanthus parvispinus	0.08	0.16	0.6	0.27	0.64
e)	**Kingscliff**	**Palm Beach**	**93.42**		
encrusting porifera sp.2	4.01	0	9.38	0.66	10.04
Pyura stolonifera	1.45	2.54	8.62	0.86	9.22
Dysidea sp. 3	0.12	2.65	5.89	0.45	6.3
Pocillopora damicornis	0	2.56	5.33	0.39	5.7
Spheciospongia confoederata	0.98	1.09	4.53	0.4	4.84
Chondropsis sp. 2	0.2	1.07	4.05	0.51	4.34
Agelas sp. 1	0.08	1.07	3.71	0.44	3.97
Dysidea sp. 5	1.14	0	3.33	0.65	3.56
Protopalythoa sp. 1sp. 1	0.59	0.51	3.11	0.51	3.33
Dendronephthya Dendronephthya sp. 2	0.71	0.63	2.99	0.52	3.2
Iotrochota sp. 1sp. 1	0.35	0.79	2.9	0.56	3.1
encrusting porifera sp. 5	0.31	0.43	2.36	0.47	2.52
Dendronephthya Dendronephthya	0	0.82	2.17	0.34	2.33

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
sp. 2					
Acropora sp. 1	0	0.99	2.08	0.23	2.23
Rhabdastrella sp. 1	0.51	0.08	1.82	0.37	1.95
Porites sp. 1	0.16	0.95	1.62	0.24	1.73
Aplysilla sp. 2	0.04	0.44	1.57	0.39	1.68
Mycale sp.1	0.2	0.24	1.34	0.38	1.44
Acropora solitaryensis	0	0.67	1.33	0.16	1.42
Rhabdastrella globostellata	0	0.4	1.32	0.19	1.41
Goniopora sp.1	0.43	0	1.26	0.33	1.35
Polycarpa procera	0.39	0.04	1.26	0.39	1.35
Cladiella sp. 3	0.2	0.24	1.1	0.29	1.17
Phyllacanthus parvispinus	0.27	0.16	1.08	0.34	1.16
Heteractis sp.1	0.12	0.24	1.07	0.27	1.14
Xenia sp.1	0.4	0	1	0.25	1.07
Lobophyton sp. 1	0.35	0	0.92	0.14	0.99
Turbinaria mesenterina	0.35	0.08	0.91	0.22	0.97
Didemnum sp. 2	0.35	0	0.87	0.14	0.93
Desmapsamma sp. 1	0	0.27	0.87	0.34	0.93
Pinctata maculata	0	0.27	0.85	0.3	0.91
Aplysilla sulfurea	0.2	0	0.63	0.24	0.67
Cnemidocarpa stolonifera	0.04	0.12	0.61	0.24	0.65
Cladiella sp. 2	0	0.27	0.6	0.14	0.64
Batzella sp. 1	0.04	0.16	0.58	0.27	0.62
Acropora sp. 2	0.2	0.12	0.56	0.19	0.6
Sarcophyton sp. 2	0.43	0	0.55	0.14	0.59
f)	**Kirra**	**Palm Beach**	**95.28**		
Pyura stolonifera	1.7	2.54	9.2	0.83	9.66
Polycarpa procera	2.79	0.04	6.79	0.61	7.13
Dysidea sp. 3	0.04	2.65	5.76	0.44	6.04
Cenolia sp.	2.26	0	5.64	0.64	5.92
Pocillopora damicornis	0	2.56	5.35	0.39	5.62
Chondropsis sp. 2	0	1.07	3.91	0.45	4.1
Agelas sp. 1	0	1.07	3.67	0.4	3.85
Cribrochalina sp. 3	1.23	0.04	3.4	0.49	3.56
Cnemidocarpa stolonifera	1.12	0.12	3.28	0.56	3.44
Spheciospongia confoederata	0	1.09	2.76	0.35	2.9
Polycarpa sp. 1	0.79	0.12	2.63	0.6	2.77
Macrorhynchia sp. 1	1.02	0	2.53	0.31	2.66
Iotrochota sp. 1sp. 1	0.08	0.79	2.43	0.53	2.55

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Dendronephthya sp. 2	0	0.82	2.19	0.34	2.3
Heteractis sp. 1	0.63	0.24	2.16	0.42	2.27
Onuphidae	0.71	0	2.13	0.24	2.24
Acropora sp. 1	0	0.99	2.09	0.23	2.2
Desmapsamma sp. 1	0.55	0.27	2.09	0.47	2.19
encrusting porifera sp. 5	0.08	0.43	1.8	0.42	1.89
Protopalythoa sp. 1sp. 1	0	0.51	1.73	0.34	1.82
Aplysilla sp. 2	0.08	0.44	1.62	0.39	1.7
Dendronephthya sp. 2	0	0.63	1.6	0.35	1.68
Porites sp. 1	0	0.95	1.38	0.21	1.45
Acropora solitaryensis	0	0.67	1.33	0.16	1.4
Rhabdastrella globostellata	0	0.4	1.33	0.19	1.4
Didemnum sp. 1	0.27	0.08	1.06	0.26	1.11
Pinctata maculata	0.08	0.27	1.03	0.32	1.08
Entacmaea quadricolor	0.27	0	0.94	0.21	0.99
Dysidea sp. 1	0.32	0.04	0.89	0.42	0.93
Haliclona sp. 2	0.24	0.04	0.87	0.29	0.91
Herdmania momus	0.36	0	0.83	0.22	0.87
Mycale sp. 1sp. 1	0	0.24	0.81	0.31	0.85
Callyspongia sp. 1	0.16	0.08	0.74	0.23	0.77

Table 23 SIMPER results for the algal categories contributing to differences between reefs on horizontal surfaces

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
a)	**Cook Island**	**Kingscliff**	**31.89**		
turf algae	56.84	46.7	10	1.38	31.36
Padina gymnospora	5.14	8.91	5.25	1.14	16.45
coralline algae	4.47	8.48	3.94	1.29	12.35
Galaxaura sp.	6.59	6.95	3.85	1.21	12.07
Dictyota spp.	3.1	5.77	3.81	1.1	11.96
Jania adhaerens	0.04	4.59	2.8	0.71	8.78
b)	**Cook Island**	**Kirra**	**46.82**		
Sargassum spp.	0	28.85	17.96	1.57	38.35
turf algae	56.84	41.82	12.2	1.43	26.06
Jania adhaerens	0.04	6.14	3.76	0.63	8.04
Galaxaura sp.	6.59	1.55	3.66	1.27	7.82

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Padina gymnospora	5.14	0.83	3.16	0.78	6.75
coralline algae	4.47	1.27	2.54	1.06	5.43
c)	**Kingscliff**	**Kirra**	**48.40**		
Sargassum spp.	0	28.85	17.39	1.59	35.94
turf algae	46.7	41.82	8.69	1.31	17.95
Padina gymnospora	8.91	0.83	5.15	1.14	10.64
Jania adhaerens	4.59	6.14	4.66	0.88	9.63
coralline algae	8.48	1.27	4.52	1.48	9.34
Galaxaura sp.	6.95	1.55	3.81	1.12	7.88
d)	**Cook Island**	**Palm Beach**	**27.15**		
turf algae	56.84	68.53	12.12	1.28	44.65
Galaxaura sp.	6.59	0	4.17	1.29	15.38
coralline algae	4.47	8.11	3.97	1.36	14.62
Padina gymnospora	5.14	0	3.13	0.73	11.54
Dictyota spp.	3.1	0.12	1.9	0.57	6.99
e)	**Kingscliff**	**Palm Beach**	**36.18**		
turf algae	46.7	68.53	15.17	1.74	41.92
Padina gymnospora	8.91	0	5.46	1.14	15.1
Galaxaura sp.	6.95	0	4.36	1.15	12.05
Dictyota spp.	5.77	0.12	3.54	1.02	9.79
coralline algae	8.48	8.11	3.46	1.32	9.56
Jania adhaerens	4.59	0	2.82	0.71	7.79
f)	**Kirra**	**Palm Beach**	**36.18**		
Sargassum spp.	28.85	0	18.02	1.58	38.47
turf algae	41.82	68.53	17.74	1.82	37.86
coralline algae	1.27	8.11	4.5	1.55	9.62
Jania adhaerens	6.14	0	3.77	0.63	8.05

Table 24 SIMPER results for the algal categories contributing to differences between reefs on vertical surfaces

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
a)	**Cook Island**	**Kingscliff**	**24.36**		
turf algae	59.58	58.09	9.77	1.32	40.09
Galaxaura sp.	4.88	2.52	3.75	0.79	15.39
Padina gymnospora	3.34	1.08	2.57	0.64	10.56
coralline algae	3.02	2.89	2.25	1.14	9.23
Dictyota spp.	0.97	2.49	2.11	0.41	8.65
Jania adhaerens	0.44	1.9	1.43	0.48	5.88
Caulerpa peltata	0.97	0.53	0.94	0.48	3.87
b)	**Cook Island**	**Kirra**	**48.49**		
turf algae	59.58	33.71	23.27	1.43	47.99
Sargassum spp.	0	12.56	8.85	1.06	18.25
Jania adhaerens	0.44	6.52	4.65	0.87	9.59
Galaxaura sp.	4.88	1.19	3.88	0.68	8
Padina gymnospora	3.34	0	2.49	0.58	5.14
coralline algae	3.02	1.37	2.46	0.93	5.08
c)	**Kingscliff**	**Kirra**	**46.90**		
turf algae	58.09	33.71	23.51	1.47	50.13
Sargassum spp.	0	12.56	9.03	1.06	19.25
Jania adhaerens	1.9	6.52	5.04	0.92	10.74
Galaxaura sp.	2.52	1.19	2.39	0.69	5.1
coralline algae	2.89	1.37	2.21	1.18	4.71
Dictyota spp.	2.49	0.41	2.06	0.36	4.38
d)	**Cook Island**	**Palm Beach**	**26.96**		
turf algae	59.58	55.82	13.29	1.17	49.3
coralline algae	3.02	8.44	5.39	1.06	19.99
Galaxaura sp.	4.88	0	3.4	0.63	12.6
Padina gymnospora	3.34	0	2.32	0.58	8.59
e)	**Kingscliff**	**Palm Beach**	**24.88**		
turf algae	58.09	55.82	12.58	1.1	50.55
coralline algae	2.89	8.44	5.22	1.02	20.97
Galaxaura sp.	2.52	0	1.82	0.59	7.3
Dictyota spp.	2.49	0.04	1.76	0.33	7.06
Jania adhaerens	1.9	0	1.33	0.42	5.33
f)	**Kirra**	**Palm Beach**	**46.55**		
turf algae	33.71	55.82	23.34	1.43	50.14

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Sargassum spp.	12.56	0	9.61	1.05	20.64
coralline algae	1.37	8.44	6.69	0.99	14.38
Jania adhaerens	6.52	0	5.03	0.85	10.8

Table 25 SIMPER results for the faunal categories contributing to differences between reefs on horizontal surfaces

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
a)	**Cook Island**	**Kingscliff**	**93.21**		
encrusting porifera sp.2	1.57	4.01	12.26	0.73	13.15
Pyura stolonifera	1.73	1.45	8	0.67	8.58
Turbinaria mesenterina	4	0.35	7.71	0.4	8.27
Dendronephthya sp. 2	1.93	0.71	5.57	0.52	5.98
Heteractis sp. 1	1.18	0.12	4.39	0.45	4.71
Dysidea sp. 5	0.24	1.14	4.09	0.63	4.38
Spheciospongia confoederata	0.51	0.98	3.6	0.33	3.86
Iotrochota sp. 1	1.02	0.35	3.46	0.32	3.71
Agelas sp. 1	0.75	0.08	2.71	0.44	2.91
Favites flexuosa	0.98	0.24	2.46	0.31	2.64
Protopalythoa sp. 1sp. 1	0.12	0.59	2.39	0.38	2.56
Xenia sp. 1	0.47	0.4	2.31	0.39	2.48
Polycarpa procera	0.39	0.39	2.28	0.39	2.45
Acropora sp. 1	0.9	0	2.13	0.23	2.28
Rhabdastrella sp. 1	0	0.51	1.88	0.32	2.02
Acropora sp. 2	0.75	0.2	1.7	0.23	1.83
Goniopora sp. 1sp. 1	0.08	0.43	1.66	0.32	1.78
Mycale sp. 1sp. 1	0.2	0.2	1.52	0.24	1.63
encrusting porifera sp. 3	0.39	0.2	1.27	0.27	1.36
encrusting porifera sp. 5	0	0.31	1.21	0.23	1.29
Phyllacanthus parvispinus	0.08	0.27	1.12	0.32	1.20
Cladiella sp. 3	0.16	0.2	1.07	0.23	1.15
Lobophyton sp. 1	0	0.35	1.01	0.13	1.08
Cnemidocarpa stolonifera	0.27	0.04	1.01	0.32	1.08
Chondropsis sp. 2	0.04	0.2	0.95	0.30	1.02
Echinaster luzonicus	0.27	0	0.95	0.34	1.02
Didemnum sp. 2	0	0.35	0.95	0.13	1.02

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Polycarpa sp. 1	0.24	0.04	0.89	0.33	0.96
Herdmania momus	0.2	0.16	0.87	0.39	0.93
Aplysilla sulfurea	0	0.2	0.72	0.23	0.78
Dysidea sp. 3	0.08	0.12	0.72	0.24	0.77
Sarcophyton sp. 1	0.27	0	0.69	0.19	0.74
Sarcophyton sp. 2	0	0.43	0.57	0.14	0.61
b)	**Cook Island**	**Kirra**	**95.40**		
Pyura stolonifera	1.73	1.7	8.45	0.64	8.86
Polycarpa procera	0.39	2.79	7.98	0.62	8.36
Turbinaria mesenterina	4	0	7.16	0.37	7.51
Cenolia sp.	0.08	2.26	6.31	0.61	6.62
Heteractis sp. 1	1.18	0.63	5.29	0.51	5.54
Dendronephthya sp. 2	1.93	0	4.28	0.41	4.49
Cnemidocarpa stolonifera	0.27	1.12	3.81	0.57	4
Cribrochalina sp. 3	0.04	1.23	3.79	0.46	3.97
encrusting porifera sp.2	1.57	0	3.47	0.37	3.64
Polycarpa sp. 1	0.24	0.79	3.19	0.57	3.35
Iotrochota sp. 1	1.02	0.08	2.96	0.26	3.1
Macrorhynchia sp. 1	0.04	1.02	2.86	0.31	3
Agelas sp. 1	0.75	0	2.68	0.37	2.81
Onuphidae	0	0.71	2.43	0.23	2.55
Acropora sp. 1	0.9	0	2.15	0.23	2.26
Favites flexuosa	0.98	0	2.05	0.28	2.15
Spheciospongia confoederata	0.51	0	1.57	0.26	1.65
Desmapsamma sp. 1	0	0.55	1.57	0.33	1.64
Acropora sp. 2	0.75	0	1.47	0.2	1.54
Xenia sp. 1	0.47	0	1.34	0.31	1.4
Herdmania momus	0.2	0.36	1.32	0.31	1.38
Didemnum sp. 1	0	0.27	1.12	0.19	1.17
Entacmaea quadricolor	0	0.27	1.11	0.2	1.16
Echinaster luzonicus	0.27	0	0.98	0.32	1.03
Cenolia sp.1	0.08	0.25	0.97	0.25	1.02
Dysidea sp. 1	0.04	0.32	0.97	0.4	1.02
encrusting porifera sp. 3	0.39	0	0.91	0.24	0.95
Mycale sp. 1sp. 1	0.2	0	0.89	0.14	0.93
Haliclona sp. 2	0	0.24	0.83	0.25	0.87
Dysidea sp. 5	0.24	0	0.7	0.28	0.74
Sarcophyton sp. 1	0.27	0	0.7	0.19	0.73
Aplidium sp.1	0.08	0	0.61	0.11	0.64

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
c)	**Kingscliff**	**Kirra**	**95.97**		
encrusting porifera sp.2	4.01	0	11.08	0.65	11.54
Polycarpa procera	0.39	2.79	8.41	0.66	8.77
Pyura stolonifera	1.45	1.7	7.55	0.82	7.87
Cenolia sp.	0	2.26	6.57	0.64	6.85
Dysidea sp. 5	1.14	0	4.15	0.6	4.32
Cribrochalina sp. 3	0.04	1.23	4.04	0.49	4.21
Cnemidocarpa stolonifera	0.04	1.12	3.76	0.52	3.92
Polycarpa sp. 1	0.04	0.79	3.08	0.56	3.2
Macrorhynchia sp. 1	0.08	1.02	3.07	0.33	3.2
Heteractis sp. 1	0.12	0.63	2.68	0.33	2.79
Onuphidae	0	0.71	2.55	0.24	2.66
Spheciospongia confoederata	0.98	0	2.37	0.23	2.46
Protopalythoa sp. 1sp. 1	0.59	0	2.35	0.35	2.45
Rhabdastrella sp. 1	0.51	0	2.02	0.32	2.11
Dendronephthya sp. 2	0.71	0	2	0.37	2.09
Desmapsamma sp. 1	0	0.55	1.65	0.34	1.72
Goniopora sp. 1sp. 1	0.43	0	1.58	0.29	1.65
encrusting porifera sp. 5	0.31	0.08	1.57	0.28	1.63
Didemnum sp. 1	0.12	0.27	1.48	0.25	1.55
Herdmania momus	0.16	0.36	1.36	0.3	1.41
Iotrochota sp. 1	0.35	0.08	1.35	0.28	1.41
Didemnum sp. 2	0.35	0.08	1.29	0.17	1.34
Xenia sp. 1	0.4	0	1.2	0.25	1.25
Entacmaea quadricolor	0	0.27	1.15	0.21	1.2
Dysidea sp. 1	0.04	0.32	1.12	0.39	1.17
Lobophyton sp. 1	0.35	0	1.08	0.14	1.12
Dysidea sp. 2	0.12	0.2	0.95	0.34	0.99
Haliclona sp. 2	0.04	0.24	0.94	0.28	0.98
Chondropsis sp. 2	0.2	0	0.91	0.28	0.95
Phyllacanthus parvispinus	0.27	0	0.91	0.27	0.94
Turbinaria mesenterina	0.35	0	0.79	0.18	0.82
Mycale sp. 1sp. 1	0.2	0	0.79	0.21	0.82
Aplysilla sulfurea	0.2	0	0.78	0.23	0.81
d)	**Cook Island**	**Palm Beach**	**93.21**		
Pyura stolonifera	1.73	2.54	9.11	0.78	9.78
Turbinaria mesenterina	4	0.08	6.62	0.37	7.11
Dysidea sp. 3	0.08	2.65	5.52	0.44	5.92
Pocillopora damicornis	0.04	2.56	5.11	0.39	5.48

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Dendronephthya sp. 2	1.93	0.63	4.82	0.5	5.17
Agelas sp. 1	0.75	1.07	4.57	0.53	4.91
Iotrochota sp. 1	1.02	0.79	3.83	0.44	4.11
Acropora sp. 1	0.9	0.99	3.73	0.33	4
Chondropsis sp. 2	0.04	1.07	3.69	0.45	3.96
Spheciospongia confoederata	0.51	1.09	3.63	0.43	3.89
Heteractis sp. 1	1.18	0.24	3.6	0.51	3.86
encrusting porifera sp.2	1.57	0	3.06	0.37	3.28
Dendronephthya sp. 2	0	0.82	2.06	0.33	2.21
Favites flexuosa	0.98	0	1.83	0.27	1.96
Protopalythoa sp. 1sp. 1	0.12	0.51	1.81	0.37	1.94
Acropora sp. 2	0.75	0.12	1.61	0.23	1.72
encrusting porifera sp. 5	0	0.43	1.54	0.39	1.65
Aplysilla sp. 2	0.08	0.44	1.51	0.39	1.62
Mycale sp. 1sp. 1	0.2	0.24	1.34	0.29	1.44
Porites sp. 1	0	0.95	1.32	0.21	1.42
Acropora solitaryensis	0	0.67	1.26	0.16	1.35
Rhabdastrella globostellata	0	0.4	1.25	0.19	1.34
Xenia sp. 1	0.47	0	1.14	0.31	1.22
Sarcophyton sp. 1	0.27	0.2	1.06	0.27	1.14
Cnemidocarpa stolonifera	0.27	0.12	1.01	0.38	1.09
Polycarpa procera	0.39	0.04	1.01	0.24	1.08
Polycarpa sp. 1	0.24	0.12	0.94	0.38	1.01
Cladiella sp. 3	0.16	0.24	0.94	0.25	1.01
Desmapsamma sp. 1	0	0.27	0.83	0.32	0.89
Pinctata maculata	0	0.27	0.82	0.28	0.88
encrusting porifera sp. 3	0.39	0	0.79	0.24	0.85
Echinaster luzonicus	0.27	0	0.79	0.35	0.85
Platygyra lamellina	0.27	0.16	0.71	0.24	0.76
Batzella sp. 1	0.04	0.16	0.63	0.25	0.67
Phyllacanthus parvispinus	0.08	0.16	0.6	0.27	0.64
e)	**Kingscliff**	**Palm Beach**	**93.42**		
encrusting porifera sp.2	4.01	0	9.38	0.66	10.04
Pyura stolonifera	1.45	2.54	8.62	0.86	9.22
Dysidea sp. 3	0.12	2.65	5.89	0.45	6.3
Pocillopora damicornis	0	2.56	5.33	0.39	5.7
Spheciospongia confoederata	0.98	1.09	4.53	0.4	4.84
Chondropsis sp. 2	0.2	1.07	4.05	0.51	4.34
Agelas sp. 1	0.08	1.07	3.71	0.44	3.97

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Dysidea sp. 5	1.14	0	3.33	0.65	3.56
Protopalythoa sp. 1sp. 1	0.59	0.51	3.11	0.51	3.33
Dendronephthya sp. 2	0.71	0.63	2.99	0.52	3.2
Iotrochota sp. 1	0.35	0.79	2.9	0.56	3.1
encrusting porifera sp. 5	0.31	0.43	2.36	0.47	2.52
Dendronephthya sp. 2	0	0.82	2.17	0.34	2.33
Acropora sp. 1	0	0.99	2.08	0.23	2.23
Rhabdastrella sp. 1	0.51	0.08	1.82	0.37	1.95
Porites sp. 1	0.16	0.95	1.62	0.24	1.73
Aplysilla sp. 2	0.04	0.44	1.57	0.39	1.68
Mycale sp. 1sp. 1	0.2	0.24	1.34	0.38	1.44
Acropora solitaryensis	0	0.67	1.33	0.16	1.42
Rhabdastrella globostellata	0	0.4	1.32	0.19	1.41
Goniopora sp. 1sp. 1	0.43	0	1.26	0.33	1.35
Polycarpa procera	0.39	0.04	1.26	0.39	1.35
Cladiella sp. 3	0.2	0.24	1.1	0.29	1.17
Phyllacanthus parvispinus	0.27	0.16	1.08	0.34	1.16
Heteractis sp. 1	0.12	0.24	1.07	0.27	1.14
Xenia sp. 1	0.4	0	1	0.25	1.07
Lobophyton sp. 1	0.35	0	0.92	0.14	0.99
Turbinaria mesenterina	0.35	0.08	0.91	0.22	0.97
Didemnum sp. 2	0.35	0	0.87	0.14	0.93
Desmapsamma sp. 1	0	0.27	0.87	0.34	0.93
Pinctata maculata	0	0.27	0.85	0.3	0.91
Aplysilla sulfurea	0.2	0	0.63	0.24	0.67
Cnemidocarpa stolonifera	0.04	0.12	0.61	0.24	0.65
Cladiella sp. 2	0	0.27	0.6	0.14	0.64
Batzella sp. 1	0.04	0.16	0.58	0.27	0.62
Acropora sp. 2	0.2	0.12	0.56	0.19	0.6
Sarcophyton sp. 2	0.43	0	0.55	0.14	0.59
f)	**Kirra**	**Palm Beach**	**95.28**		
Pyura stolonifera	1.7	2.54	9.2	0.83	9.66
Polycarpa procera	2.79	0.04	6.79	0.61	7.13
Dysidea sp. 3	0.04	2.65	5.76	0.44	6.04
Cenolia sp.	2.26	0	5.64	0.64	5.92
Pocillopora damicornis	0	2.56	5.35	0.39	5.62
Chondropsis sp. 2	0	1.07	3.91	0.45	4.1
Agelas sp. 1	0	1.07	3.67	0.4	3.85
Cribrochalina sp. 3	1.23	0.04	3.4	0.49	3.56

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Cnemidocarpa stolonifera	1.12	0.12	3.28	0.56	3.44
Speciospongia confoederata	0	1.09	2.76	0.35	2.9
Polycarpa sp. 1	0.79	0.12	2.63	0.6	2.77
Macrorhynchia sp. 1	1.02	0	2.53	0.31	2.66
Iotrochota sp	0.08	0.79	2.43	0.53	2.55
Dendronephthya sp. 2	0	0.82	2.19	0.34	2.3
Heteractis sp. 1	0.63	0.24	2.16	0.42	2.27
Onuphidae	0.71	0	2.13	0.24	2.24
Acropora sp. 1	0	0.99	2.09	0.23	2.2
Desmapsamma sp. 1	0.55	0.27	2.09	0.47	2.19
encrusting porifera sp. 5	0.08	0.43	1.8	0.42	1.89
Protopalythoa sp. 1sp. 1	0	0.51	1.73	0.34	1.82
Aplysilla sp. 2	0.08	0.44	1.62	0.39	1.7
Dendronephthya sp. 2	0	0.63	1.6	0.35	1.68
Porites sp. 1	0	0.95	1.38	0.21	1.45
Acropora solitaryensis	0	0.67	1.33	0.16	1.4
Rhabdastrella globostellata	0	0.4	1.33	0.19	1.4
Didemnum sp. 1	0.27	0.08	1.06	0.26	1.11
Pinctata maculata	0.08	0.27	1.03	0.32	1.08
Entacmaea quadricolor	0.27	0	0.94	0.21	0.99
Dysidea sp. 1	0.32	0.04	0.89	0.42	0.93
Haliclona sp. 2	0.24	0.04	0.87	0.29	0.91
Herdmania momus	0.36	0	0.83	0.22	0.87
Mycale sp. 1sp. 1	0	0.24	0.81	0.31	0.85
Callyspongia sp. 1	0.16	0.08	0.74	0.23	0.77

Table 26 SIMPER results for the faunal categories contributing to differences between reefs on vertical surfaces

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
a)	**Cook Island**	**Kingscliff**	**86.23**		
Pyura stolonifera	1.87	3.45	6.85	0.98	7.94
Herdmania momus	1.58	1.81	4.75	0.81	5.51
Polycarpa procera	1.71	1.42	4.49	0.49	5.21
encrusting porifera sp.2	1.38	1.24	4.12	0.67	4.78
Acanthella sp. 1	1.07	1.44	3.8	0.78	4.41
encrusting porifera sp. 5	0.08	1.69	3.36	0.44	3.9

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Didemnum sp. 1	0.91	1.16	3.2	0.69	3.71
Iotrochota sp. 1	1.36	0.6	3.07	0.7	3.56
Dysidea sp. 5	0.52	1.31	2.96	0.73	3.43
encrusting porifera sp. 3	1.25	0.6	2.76	0.64	3.2
Didemnum sp. 2	0.68	0.79	2.45	0.55	2.84
Hyattella sp. 2	0.71	0.71	2.41	0.53	2.8
Clavelina australis	0.8	0.61	2.29	0.64	2.66
Agelas sp. 1	0.79	0.56	2.28	0.63	2.65
Rhabdastrella sp. 1	0.15	1.05	2.21	0.5	2.56
Cliona sp. 3	0.71	0.67	2.15	0.61	2.5
Dysidea sp. 3	0.08	1.19	2.15	0.33	2.49
Chondropsis sp. 2	0.22	1.02	2.05	0.62	2.38
Spheciospongia confoederata	0.93	0.26	1.92	0.34	2.23
Dendronephthya sp. 2	1.27	0.04	1.9	0.32	2.2
Spheciospongia montiformis	0.3	0.48	1.53	0.24	1.77
Pallusia julinea	0.45	0.45	1.47	0.56	1.71
Distaplia sp. 1	0.39	0.3	1.28	0.42	1.48
Aplysilla sp. 2	0.15	0.41	1.1	0.45	1.28
encrusting porifera sp. 1	0.04	0.5	1.05	0.29	1.22
Macrorhynchia sp. 2	0.6	0	1.05	0.22	1.22
Phyllacanthus parvispinus	0.22	0.34	1.04	0.38	1.21
Didemnum membranaceum	0.11	0.49	1.02	0.41	1.19
Aplysilla sulfurea	0.3	0.22	0.95	0.35	1.1
Goniopora sp.1	0.34	0.11	0.9	0.38	1.04
Symplegma brakenhielmi	0.42	0	0.85	0.35	0.99
Diadema spp.	0.34	0.08	0.78	0.33	0.9
Tubipora sp.1	0.15	0.26	0.74	0.29	0.86
Favites flexuosa	0.44	0	0.72	0.16	0.84
Tubastrea faulkneri	0.04	0.3	0.7	0.25	0.81
Batzella sp. 1	0.07	0.26	0.67	0.4	0.77
Botrylloides sp. 1	0.07	0.27	0.66	0.4	0.77
b)	**Cook Island**	**Kirra**	**91.75**		
Polycarpa procera	1.71	7.6	11.2	0.87	12.22
Cenolia sp.	0.04	7.37	10.03	0.84	10.94
Herdmania momus	1.58	6.04	8.59	0.84	9.37

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Pyura stolonifera	1.87	5.38	7.36	0.94	8.03
Callyspongia sp. 2	0	1.37	2.38	0.41	2.59
encrusting porifera sp. 2	1.38	0	2.3	0.49	2.51
Iotrochota sp. 1	1.36	0	2.29	0.51	2.49
Polycarpa sp. 1	0.11	1.22	2.2	0.74	2.4
Cribrochalina sp. 3	0	1.3	2.13	0.52	2.32
Cnemidocarpa stolonifera	0	1.22	1.94	0.71	2.11
Macrorhynchia sp. 1	0	1.78	1.93	0.37	2.11
encrusting porifera sp. 3	1.25	0	1.92	0.49	2.1
Acanthella sp. 1	1.07	0	1.76	0.48	1.92
Didemnum sp. 1	0.91	0.11	1.71	0.63	1.86
Pallusia julinea	0.45	0.93	1.69	0.74	1.84
Didemnum membranaceum	0.11	1	1.66	0.36	1.81
Dendronephthya sp. 2	1.27	0	1.65	0.3	1.8
Spheciospongia confoederata	0.93	0.22	1.61	0.3	1.76
Botrylloides sp. 1	0.07	1	1.48	0.5	1.61
Agelas sp. 1	0.79	0	1.46	0.58	1.59
Didemnum sp. 2	0.68	0.22	1.4	0.53	1.53
Desmapsamma sp. 1	0	0.89	1.39	0.33	1.51
Clavelina australis	0.8	0	1.39	0.46	1.51
Callyspongia sp. 3	0.04	0.78	1.36	0.27	1.48
Haliclona sp. 2	0	0.89	1.32	0.23	1.44
Hyattella sp. 2	0.71	0	1.29	0.34	1.4
Cliona sp. 3	0.71	0.07	1.17	0.44	1.27
Heteractis sp. 1	0.08	0.63	1.03	0.38	1.12
Macrorhynchia sp. 2	0.6	0	0.94	0.21	1.02
Dysidea sp. 3	0.08	0.71	0.87	0.21	0.95
Aplysilla sulfurea	0.3	0.26	0.86	0.36	0.93
Dysidea sp. 5	0.52	0	0.82	0.39	0.89
Symplegma brakenhielmi	0.42	0	0.76	0.32	0.83
Aplysilla sp. 2	0.15	0.33	0.7	0.2	0.76
c)	**Kingscliff**	**Kirra**	**88.77**		
Polycarpa procera	1.42	7.6	9.77	0.91	11
Cenolia sp.	0.04	7.37	9.31	0.84	10.49
Herdmania momus	1.81	6.04	7.99	0.85	9.01
Pyura stolonifera	3.45	5.38	7.35	0.99	8.28

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
encrusting porifera sp. 5	1.69	0.11	2.69	0.43	3.03
Dysidea sp. 3	1.19	0.71	2.29	0.35	2.58
Acanthella sp. 1	1.44	0	2.29	0.58	2.58
Callyspongia sp. 2	0.04	1.37	2.18	0.43	2.46
Dysidea sp. 5	1.31	0	2.12	0.62	2.39
Polycarpa sp. 1	0.07	1.22	1.98	0.77	2.23
Cribrochalina sp. 3	0.04	1.3	1.95	0.54	2.19
encrusting porifera sp. 2	1.24	0	1.94	0.42	2.19
Macrorhynchia sp. 1	0.08	1.78	1.91	0.39	2.15
Didemnum membranaceum	0.49	1	1.91	0.45	2.15
Didemnum sp. 1	1.16	0.11	1.88	0.47	2.12
Cnemidocarpa stolonifera	0.11	1.22	1.84	0.74	2.07
Rhabdastrella sp. 1	1.05	0	1.65	0.45	1.86
Pallusia julinea	0.45	0.93	1.56	0.74	1.75
Chondropsis sp. 2	1.02	0.07	1.53	0.54	1.72
Botrylloides sp. 1	0.27	1	1.47	0.56	1.66
Desmapsamma sp. 1	0.11	0.89	1.4	0.36	1.58
Didemnum sp. 2	0.79	0.22	1.38	0.37	1.56
Haliclona sp. 2	0.07	0.89	1.31	0.25	1.47
Callyspongia sp. 3	0	0.78	1.16	0.28	1.3
Hyattella sp. 2	0.71	0	1.09	0.4	1.22
Aplysilla sp. 2	0.41	0.33	1.08	0.32	1.22
Cliona sp. 3	0.67	0.07	1.07	0.42	1.2
Iotrochota sp. 1	0.6	0	1.02	0.53	1.15
Clavelina australis	0.61	0	0.94	0.39	1.06
encrusting porifera sp. 3	0.6	0	0.91	0.4	1.02
Agelas sp. 1	0.56	0	0.88	0.31	0.99
Heteractis sp. 1	0	0.63	0.85	0.37	0.96
encrusting porifera sp. 1	0.5	0	0.79	0.26	0.89
Spheciospongia montiformis	0.48	0	0.77	0.19	0.86
d)	**Cook Island**	**Palm Beach**	**91.36**		
Spheciospongia confoederata	0.93	3.13	5.84	0.56	6.4
Pyura stolonifera	1.87	2.55	5.4	0.88	5.91
encrusting porifera sp. 2	1.38	0.97	3.69	0.56	4.04
Iotrochota sp. 1	1.36	0.75	3.21	0.7	3.51
Polycarpa procera	1.71	0.67	3.17	0.37	3.47

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Didemnum sp. 1	0.91	1.11	3.05	0.45	3.34
Dendronephthya sp. 2	1.27	0.73	2.94	0.42	3.22
Acanthella sp. 1	1.07	0.72	2.94	0.57	3.22
Chondropsis sp. 2	0.22	1.63	2.86	0.61	3.13
Herdmania momus	1.58	0	2.77	0.58	3.04
Pallusia julinea	0.45	1.38	2.7	0.73	2.96
Clavelina australis	0.8	0.83	2.63	0.56	2.88
Agelas sp. 1	0.79	0.75	2.4	0.67	2.62
encrusting porifera sp. 3	1.25	0.08	2.13	0.53	2.33
Pocillopora damicornis	0.07	1.11	2.11	0.31	2.31
Pinctata maculata	0	1.23	2.03	0.34	2.22
encrusting porifera sp. 5	0.08	0.82	1.62	0.45	1.78
Hyattella sp. 2	0.71	0.15	1.58	0.4	1.73
Porites sp. 1	0	0.96	1.5	0.25	1.65
Dysidea sp. 3	0.08	0.81	1.43	0.29	1.57
Didemnum sp. 2	0.68	0.08	1.36	0.54	1.49
Rhabdastrella globostellata	0	0.7	1.3	0.25	1.42
Cliona sp. 3	0.71	0.07	1.29	0.47	1.41
Callyspongia sp. 2	0	0.71	1.26	0.43	1.38
Discosoma rhodostoma	0	1.19	1.22	0.14	1.34
Favites flexuosa	0.44	0.33	1.19	0.25	1.3
Goniastrea australensis	0.08	0.63	1.13	0.22	1.24
Macrorhynchia sp. 2	0.6	0.04	1.08	0.23	1.19
Botrylloides sp. 1	0.07	0.48	1.06	0.46	1.16
Goniopora sp. 1sp. 1	0.34	0.3	1.03	0.32	1.13
Diadema sp.	0.34	0.3	1.03	0.37	1.12
Heteractis sp. 1	0.08	0.44	0.97	0.29	1.07
Dysidea sp. 5	0.52	0	0.89	0.41	0.97
Favia sp. 2	0	0.59	0.85	0.25	0.93
Distaplia sp. 1	0.39	0.07	0.84	0.34	0.92
Protopalythoa sp. 1	0.08	0.37	0.82	0.36	0.9
Porites lutea	0	0.44	0.82	0.13	0.9
Symplegma brakenhielmi	0.42	0	0.82	0.34	0.9
Cliona sp. 1	0.11	0.41	0.79	0.31	0.86
Didemnum membranaceum	0.11	0.33	0.75	0.38	0.82
Cladiella sp. 3	0	0.26	0.63	0.13	0.69

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Aplysilla sulfurea	0.3	0	0.6	0.29	0.65
Phyllacanthus parvispinus	0.22	0.11	0.59	0.31	0.64
Spheciospongia montiformis	0.3	0	0.58	0.13	0.64
Dysidea sp. 2	0	0.3	0.53	0.18	0.58
Discosoma sp. 1	0	0.3	0.53	0.17	0.58
Acropora sp. 2	0	0.19	0.5	0.13	0.55
Turbinaria mesenterina	0	0.33	0.49	0.14	0.53
Cribrochalina sp. 3	0	0.26	0.46	0.22	0.51
Chondrilla sp.	0.04	0.19	0.46	0.27	0.5
Polycarpa sp. 1	0.11	0.11	0.44	0.31	0.48
e)	**Kingscliff**	**Palm Beach**	**90.24**		
Pyura stolonifera	3.45	2.55	6.37	0.99	7.06
Spheciospongia confoederata	0.26	3.13	4.7	0.52	5.21
encrusting porifera sp. 5	1.69	0.82	3.64	0.56	4.03
Chondropsis sp. 2	1.02	1.63	3.29	0.77	3.64
encrusting porifera sp. 2	1.24	0.97	3.28	0.53	3.63
Acanthella sp. 1	1.44	0.72	3.23	0.68	3.58
Didemnum sp. 1	1.16	1.11	3.16	0.45	3.51
Herdmania momus	1.81	0	3.08	0.63	3.41
Polycarpa procera	1.42	0.67	2.87	0.57	3.18
Dysidea sp. 3	1.19	0.81	2.84	0.41	3.14
Pallusia julinea	0.45	1.38	2.42	0.78	2.68
Dysidea sp. 5	1.31	0	2.3	0.65	2.55
Clavelina australis	0.61	0.83	2.16	0.52	2.4
Agelas sp. 1	0.56	0.75	2.04	0.52	2.26
Iotrochota sp. 1	0.6	0.75	1.87	0.72	2.07
Pinctata maculata	0	1.23	1.85	0.35	2.05
Pocillopora damicornis	0	1.11	1.83	0.3	2.03
Rhabdastrella sp. 1	1.05	0.04	1.81	0.47	2.01
Porites sp. 1	0	0.96	1.37	0.24	1.52
Hyattella sp. 2	0.71	0.15	1.35	0.46	1.5
Didemnum sp. 2	0.79	0.08	1.34	0.35	1.48
Dendronephthya sp. 2	0.04	0.73	1.29	0.29	1.43
Callyspongia sp. 2	0.04	0.71	1.19	0.45	1.32
Cliona sp. 3	0.67	0.07	1.19	0.45	1.31
Didemnum membranaceum	0.49	0.33	1.18	0.47	1.3

Taxonomic Group	Average Abundance Habitat Category		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
Discosoma rhodostoma	0	1.19	1.16	0.14	1.29
Rhabdastrella globostellata	0	0.7	1.16	0.26	1.28
Botrylloides sp. 1	0.27	0.48	1.12	0.56	1.24
encrusting porifera sp. 3	0.6	0.08	1.05	0.44	1.17
Protopalythoa sp. 1	0.27	0.37	0.99	0.44	1.1
Goniastrea australensis	0	0.63	0.91	0.19	1.01
encrusting porifera sp. 1	0.5	0	0.86	0.27	0.95
Spheciospongia montiformis	0.48	0	0.83	0.2	0.92
Aplysilla sp. 2	0.41	0.08	0.83	0.44	0.92
Favia sp. 2	0	0.59	0.79	0.25	0.88
Heteractis sp. 1	0	0.44	0.77	0.27	0.85
Porites lutea	0	0.44	0.75	0.14	0.83
Phyllacanthus parvispinus	0.34	0.11	0.75	0.35	0.83
Distaplia sp. 1	0.3	0.07	0.71	0.31	0.78
Tubastrea faulkneri	0.3	0.04	0.61	0.25	0.68
Batzella sp. 1	0.26	0.07	0.58	0.41	0.64
Dysidea sp. 2	0.07	0.3	0.58	0.22	0.64
Diadema sp.	0.08	0.3	0.57	0.31	0.64
Cladiella sp. 3	0	0.26	0.55	0.13	0.61
Cliona sp. 1	0	0.41	0.55	0.25	0.61
Hyattella sp. 1	0.23	0.12	0.53	0.34	0.59
Goniopora sp. 1	0.11	0.3	0.51	0.2	0.57
Discosoma sp. 1	0	0.3	0.48	0.17	0.53
Favites flexuosa	0	0.33	0.48	0.22	0.53
Cribrochalina sp. 3	0.04	0.26	0.47	0.24	0.52
Cribrochalina sp. 1	0.3	0	0.46	0.22	0.51
Cnemidocarpa stolonifera	0.11	0.11	0.46	0.32	0.51
Turbinaria mesenterina	0	0.33	0.45	0.14	0.5
f)	**Kirra**	**Palm Beach**	**93.03**		
Polycarpa procera	7.6	0.67	9.43	0.87	10.13
Cenolia sp.	7.37	0.04	9.01	0.83	9.69
Herdmania momus	6.04	0	7.53	0.77	8.09
Pyura stolonifera	5.38	2.55	6.84	0.94	7.35
Spheciospongia confoederata	0.22	3.13	4.16	0.49	4.47
Callyspongia sp. 2	1.37	0.71	2.65	0.53	2.85

Taxonomic Group	Average Abundance		Average Dissimilarity	Dissimilarity / SD	Contribution (%)
	Habitat Category				
Chondropsis sp. 2	0.07	1.63	2.22	0.55	2.39
Pallusia julinea	0.93	1.38	2.19	0.74	2.36
Cribrochalina sp. 3	1.3	0.26	2.07	0.55	2.23
Polycarpa sp. 1	1.22	0.11	1.92	0.75	2.06
Macrorhynchia sp. 1	1.78	0.04	1.82	0.38	1.96
Cnemidocarpa stolonifera	1.22	0.11	1.76	0.74	1.89
Dysidea sp. 3	0.71	0.81	1.72	0.32	1.85
Didemnum membranaceum	1	0.33	1.69	0.42	1.82
Pinctata maculata	0	1.23	1.65	0.33	1.78
Botrylloides sp. 1	1	0.48	1.65	0.6	1.77
Pocillopora damicornis	0	1.11	1.63	0.28	1.75
Didemnum sp. 1	0.11	1.11	1.54	0.26	1.65
encrusting porifera sp. 2	0	0.97	1.48	0.31	1.59
Heteractis sp. 1	0.63	0.44	1.4	0.43	1.5
Clavelina australis	0	0.83	1.33	0.36	1.43
Iotrochota sp. 1	0	0.75	1.32	0.48	1.42
encrusting porifera sp. 5	0.11	0.82	1.31	0.44	1.41
Desmapsamma sp. 1	0.89	0.04	1.27	0.33	1.37
Haliclona sp. 2	0.89	0.07	1.26	0.25	1.36
Porites sp. 1	0	0.96	1.23	0.23	1.32
Agelas sp. 1	0	0.75	1.22	0.4	1.31
Acanthella sp. 1	0	0.72	1.17	0.31	1.26
Callyspongia sp. 3	0.78	0	1.12	0.27	1.21
Dendronephthya sp. 2	0	0.73	1.1	0.27	1.18
Discosoma rhodostoma	0	1.19	1.06	0.13	1.14
Rhabdastrella globostellata	0	0.7	1.04	0.24	1.12
Goniastrea australensis	0	0.63	0.82	0.19	0.88
Favia sp. 2	0	0.59	0.71	0.24	0.76
Porites lutea	0	0.44	0.66	0.13	0.71
Protopalythoa sp. 1	0	0.37	0.56	0.3	0.61
Aplysilla sp. 2	0.33	0.08	0.5	0.17	0.54
Cliona sp. 1	0	0.41	0.49	0.24	0.53
Cladiella sp. 3	0	0.26	0.49	0.13	0.53
Dysidea sp. 2	0	0.3	0.43	0.18	0.46
Discosoma sp. 1	0	0.3	0.43	0.16	0.46

Table 27 PERMANOVA results for differences in the diversity indices of faunal assemblages between orientations, and among reefs

Factor	Df	Taxonomic Richness		Evenness		Shannons		Simpsons	
		MS	Pseudo-F/sig.	MS	Pseudo-F/sig.	MS	Pseudo-F/sig.	MS	Pseudo-F/sig.
Orientation	**1**	**894.7**	**70.16****	1.47	15.86**	33.27	47.17***	3.31	29.96***
Reef	3	5.3	0.53	0.25	4.83	0.63*	1.69	0.15	2.79
Transect (Reef)	8	10.0	1.98	0.05	1.00	0.37	1.57	0.05	1.20
Orientation x Reef	3	14.4	1.13	0.38	4.11*	1.16	1.65	0.25	2.24
Orientation x Transect (Reef)	8	12.8	2.53*	0.09	1.80	0.71	3.01**	0.11	2.55**
Residual	396	5.0		0.05		0.23		0.04	

Significance level: *p<0.05; **p < 0.01; ***p < 0.001.

Table 28 PERMANOVA pairwise comparisons for differences in the diversity indices of faunal assemblages among reefs for horizontal (H), and vertical (V) orientations.

Reef	Taxonomic Richness	Evenness	Shannons	Simpsons
Kirra	10.68**	19.64**	8.15*	7.88*
Cook Island	4.05 ^{ns}	2.95 ^{ns}	3.77 ^{ns}	3.32 ^{ns}
Palm Beach	1.98 ^{ns}	0.47 ^{ns}	1.33 ^{ns}	0.89 ^{ns}
Kingscliff	6.16*	2.96 ^{ns}	9.58*	24.29***

Significance level: ^{ns} = not significant; *p < 0.05; **p < 0.01; ***p < 0.001.

Table 29 PERMANOVA pairwise comparisons for differences in the diversity indices of faunal assemblages among reefs for horizontal (H), and vertical (V) orientations.

Pairwise Comparisons	Taxonomic Richness		Evenness		Shannons		Simpsons	
	H	V	H	V	H	V	H	V
Kirra vs Cook Island	0.19	1.31	2.35	0.39	0.99	1.68	1.67	1.07
Kirra vs Kingscliff	0.12	0.07	1.44	5.03**	0.82	2.13	1.11	3.87
Kirra vs Palm Beach	0.94	0.49	2.12	3.18*	1.27	1.78	1.56	2.67*
Cook Island vs Kingscliff	0.14	1.06	3.25*	6.09**	0.35	3.32*	2.22	6.40**

Pairwise Comparisons	Taxonomic Richness		Evenness		Shannons		Simpsons	
	H	V	H	V	H	V	H	V
Cook Island vs Palm Beach	1.03	1.65	0.10	4.01*	0.82	3.19*	0.49	4.77**
Kingscliff vs Palm Beach	1.04	0.42	1.62	2.74	0.89	0.71	1.05	1.19

Significance level: ^{ns} = not significant; *p < 0.05; **p < 0.01; ***p < 0.001.

Appendix 3 Fish data

Table 30 Max N values for BRUVS and ROV imagery replicate samples collected at Kirra Reef (July 2016)

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Acanthuridae								
Acanthurus grammoptilus	ring-tailed surgeon	0	0	0	1	0	0	0
Acanthurus mata	Pale surgeon	0	0	0	0	0	0	0
Acanthurus xanthopterus	yellowfin surgeon	0	0	0	0	0	3	0
Acanthurus sp.		0	0	0	0	1	0	0
Prionurus microlepidotus	sawtail surgeon	0	0	0	0	0	0	0
Acanthurus olivaceus	orange-band surgeon	0	0	0	0	0	0	0
Naso sp.	unicornfish	0	0	0	0	0	0	0
Apogonidae								
Apogon cookii	cook's cardinal fish	0	0	0	0	0	0	0
Apogon doederleini	four lined cardinal fish	0	0	0	0	0	0	0
Aracanidae								
Strophiurichthys robustus	freckled boxfish	0	0	0	0	0	0	0
Arripididae								
Arripis georgiana	tommy rough	0	0	0	0	0	0	0
Balastidae								
Balistoides conspicillum	clown triggerfish	0	0	0	0	0	0	0
Sufflamen chrysopterus	half-moon triggerfish	0	0	0	0	0	0	0
Sufflamen fraenatus	bridled triggerfish	0	0	0	0	0	0	0
Blennidae								
Plagiotremus tapeinosoma	hit and run blenny	0	0	0	0	0	0	0
Brachaeluridae								
Brachaelurus waddi	blindshark	0	0	0	0	0	0	0
Caesionidae								
Diagramma labiosum	painted sweetlip	0	0	0	0	0	0	0
Diagramma pictum	painted sweetlip	0	0	0	1	1	2	1
Carangidae								
Caranax sp.	trevally	0	0	0	0	0	0	0
Gnathanodon speciosus	golden trevally	0	0	0	0	0	0	0
Pseudocaranx dentex	silver trevally	0	0	0	0	0	1	0
Scomberoides lysan	queenfish	0	0	0	0	0	0	0
Tracinotus blochii	dart	0	0	0	0	0	0	0
Trachurus novaezelandie	yellow-tail scad	60	102	55	70	80	50	45
Chaetodontidae								
Chaetodon auriga	threadfin butterfly fish	0	0	0	0	0	1	0
Chaetodon citrinellus	citron butterfly fish	0	0	0	0	0	0	0
Chaetodon flavirostris	dusky butterfly fish	0	0	0	0	0	0	0
Chaetodon lineolatus	lined butterfly fish	0	0	0	0	0	0	0
Heinochus sp.	banner fish	0	0	0	0	0	0	0
Chaetodon guentheri	gunther's butterflyfish	0	0	0	0	0	0	0
Chaetodon kleinii	brown butterflyfish	0	0	0	0	0	0	0
Cheilodactylidae								
Cheilodactylus fuscus	red morwong	0	0	0	0	0	1	0
Cheilodactylus vestitus	crested morwong	0	0	0	0	0	0	0
Chironemidae								
Chironemus marmoratus	kelp fish	0	0	0	0	0	0	0
Cirrhitidae								
Cirrhitichthys sp.	hawkfish	0	0	0	0	0	0	0
Dasyatidae								
Dasyatis kuhlii	blue-spotted mask ray	0	0	0	0	0	0	0
Pastinachus atrus	cowtail stingray	0	0	0	0	0	0	0
Diodontidae								
Dicotylichthys punctulatus	three-bar porcupine fish	0	0	0	0	0	0	0
Diodon holacanthus	freckled porcupine fish	0	0	0	0	0	0	0

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Diodon hystrix	black-spotted porcupine fish	0	0	0	7	4	7	2
Ephippidae								
Platax orbicularis	round batfish	0	0	0	0	0	0	0
Enoplosidae								
Enoplosus armatus	old wife	0	0	0	0	0	0	0
Fistularidae								
Fistularia commersonii	smooth flutemouth	0	0	0	0	0	0	0
Fistularia petimba	rough flutemouth	0	0	0	0	0	0	0
Gerridae								
Gerres subfasciatus	silver biddy	0	0	0	0	2	2	1
Haemulidae								
Plectorhyncus flavomaculatus	gold-spotted sweetlip	0	0	0	0	0	0	0
Hemiscylliidae								
Chiloscyllium sp.	cat shark	0	0	1	0	0	0	0
Labridae								
Achoerodus gouldi	blue groper	0	0	0	0	0	0	0
Anampses meleagrides	spotted wrasse	0	0	0	0	0	0	0
Bodianus axillaris	Coral hogfish	0	0	0	0	0	0	0
Choerodon graphicus	graphic tuskfish	0	0	0	0	0	0	0
Coris picta	comb wrasse	0	0	0	0	0	0	0
Diproctacanthus xanthurus	yellowtail tubelip	0	0	0	0	0	0	0
Halichoeres sp.	striped wrasse	0	0	0	0	0	0	0
Labroides dimidiatus	cleaner wrasse	1	0	0	0	1	2	1
Labridae sp.	unknown wrasse	1	0	0	0	0	0	0
Notolabrus gymnogensis	crimson-banded wrasse	0	0	0	2	1	4	1
Notolabrus sp.	wrasse	0	0	0	0	0	0	0
Pseudolabrus guentheri	Gunthers Wrasse	4	3	2	3	2	3	2
Thalasoma jansenii	Jansen's wrasse	1	0	0	1	0	0	0
Thalassoma lunare	moon wrasse	0	0	0	0	0	0	0
Thalassoma lutescens	yellow moon wrasse	0	0	0	0	1	1	1
Lutjanidae								
Lutjanus sp.		0	0	0	0	0	0	0
Lutjanus fluviflamma	black-spot snapper	0	0	0	0	0	0	0
Lutjanus russelli	moses perch	0	0	0	1	1	0	0
Microcanthidae								
Atpichthys strigatus	Australian mado	9	5	3	3	2	2	4
Microcanthus strigatus	stripey	0	0	0	0	0	1	1
Monocanthidae								
Meuschenia trachylepis	yellow-tailed leatherjacket	0	0	0	1	1	1	1
Monocanthus chinensis	fan-bellied leatherjacket	0	0	0	0	0	0	0
Oxymonacanthus longirostris	orange spotted filefish	0	0	0	0	0	0	0
Monodactylidae								
Monodactylus argenteus	silver batfish	0	0	0	0	0	0	0
Schuettea scalaripinnis	eastern pomfred	0	0	1	0	0	0	1
Mullidae								
Mulloidichthys vanicolensis	yellowfin goatfish	0	0	0	0	0	0	0
Parupeneus barberinoides	half-and-half goatfish	0	0	0	0	0	0	0
Parupeneus ciliatus	diamond-scaled goat fish	0	0	0	0	0	0	0
Parupeneus signatus	black spot goat fish	0	0	0	0	8	0	0
Parupeneus sp.		0	0	0	0	0	0	0
Muraenidae								
Gymnothorax aurostus	white-speckled moray	0	0	1	0	0	0	0
Gymnothorax favagineus	tessellate moray	0	0	0	0	0	0	0
Gynothorax prasineus	green moray	0	0	0	0	0	0	0
Gynothorax sp.	moray eel	0	0	0	0	0	0	0
Siderea thyrsoidea	white-eyed moray	0	0	0	0	0	0	0
Myliobatididae								
Aetobatus narinari	white-spotted eagle ray	0	0	0	0	0	0	3

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Orectolobidae								
Orectolobus ornatus	ornate wobbegong	0	0	0	0	0	0	1
Ostraciidae								
Ostracion cubicus		0	0	0	0	0	0	0
Pempheridae								
Pempheris affinis	black-tipped bulls eye	0	0	0	0	0	0	0
Pempheris multiradiata	bullseye	0	0	0	0	0	0	0
Pempheris oualensis	black-finned bullseye	0	0	0	0	0	0	0
Pentacerotidae								
Paristiopterus labiosus	giant boarfish	0	0	0	0	0	0	0
Pinguipedidae								
Parapercis queenslandiae	queensland grubfish	0	0	0	0	0	0	0
Platycephalidae								
Platycephalus fuscus	dusky flathead	0	0	0	0	0	0	0
Plesiopidae								
Trachinops taeniatus	eastern hulafish	0	0	0	0	0	0	0
Plotosidae								
Cnidoglanis macrocephala	estuary catfish	0	0	0	0	0	0	0
Polynemidae								
Polydactylus ngipinnis	black-finned threadfin	0	0	0	0	0	0	0
Pomacanthidae								
Centropyge tibicen	keyhole angelfish	0	0	0	0	2	0	0
Pomacanthus semicirculatus	blue angelfish	0	0	0	0	0	0	0
Centropyge vrolikii	pearly-scaled angelfish	0	0	0	0	0	0	0
Pomacentridae								
Abudefduf bengalensis	Bengal sergeant major	0	0	0	0	0	0	0
Abudefduf vaigiensis	sergeant major	0	0	0	0	0	0	0
Abudefduf saxatilis	five-banded sergeant major	0	0	0	0	1	0	0
Abudefduf sexfasciatus	scissor-tail sergeant	0	0	0	0	0	0	0
Abudefduf whitleyi	Whitley's sergeant	0	0	0	0	0	0	0
Amphiprion akindynos	Barrier reef anemone fish	0	0	0	0	0	0	0
Amphiprion sp.	clown fish	0	0	0	0	0	0	0
Chromis chrysura	robust puller	0	0	0	0	1	1	0
Chromis nitida	barrier reef chromis	0	0	0	0	0	0	0
Chrysiptera sp.	Demoiselle	0	0	0	0	1	0	0
Dascyllus trimaculatus	domino puller	0	0	0	0	0	0	0
Parma microlepis	white ear puller	0	0	0	0	0	0	0
Parma oligolepis	large-scaled parma	0	0	0	1	1	1	0
Parma polylepis	banded parma	1	0	1	0	0	0	0
Parma unifasciata	Girdled parma	1	0	0	0	0	0	0
Plectroglyphidodon leucozonus	whiteband damsel	0	0	0	0	1	0	0
Pomacentrus australis	Australian damsel	0	0	0	0	0	0	0
Pomacentrus bankanensis	fire damsel	0	0	0	0	0	0	0
Pomacentrus coelestis	neon damsel	0	0	0	0	0	0	2
Pomacentrus sp.		0	0	0	0	0	0	0
Pomacentridae sp.		0	0	0	0	0	2	0
Stegastes gascoynei	coral sea gregory	1	0	1	0	0	0	0
Stegastes sp.	damsel	0	0	0	0	0	0	0
Pomatomidae								
Pomatomus saltatrix	tailor	0	0	0	0	0	0	0
Rhinobatidae								
Aptychotrema sp.	shovelnose ray	0	0	0	0	0	0	0
Glaucostegus typus	giant shovelnose ray	0	0	0	0	0	0	0
Scorpaendiae								
Centropogon australis	fortescue	0	0	1	0	0	0	0
Pterois volotans	red firefish	0	0	0	0	0	0	0
Scorpaena cardinalis	red scorpionfish	0	0	0	0	0	0	0

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Synancia horrida	estuarine stonefish	0	0	0	0	0	0	0
Dendrochirus zebra	zebra lionfish	0	0	0	0	0	0	0
Scombridae								
Cybiosarda elegans	leaping bonito	0	0	0	0	0	0	0
Scomberomorus commerson	spanish mackerel	0	0	0	0	0	0	0
Scorpididae								
Scorpis lineolatus	silver sweep	5	1	5	1	1	2	1
Kyphosus gibsoni	northern silver drummer	0	0	0	3	0	0	0
Serranidae								
Anthias sp.	anthias	0	0	0	0	0	0	0
Epinephelus fasciatus	black-tipped cod	0	0	0	0	0	0	0
Diploprion bifasciatum	barred soapfish	0	0	0	0	0	0	0
Plectropomus maculatus	coral trout	0	0	0	0	0	0	0
Siganidae								
Siganus fuscescens	rabbit fish	0	0	0	15	2	30	14
Sillaginidae								
Sillago analis	gold-lined whiting	0	0	0	0	0	0	0
Sparidae								
Acanthopagrus australis	yellow fin bream	2	3	4	4	5	3	2
Rhabdosargus sarba	tarwhine	0	0	0	0	0	0	0
Sphyraenidae								
Sphyraena argentea	barracuda	0	0	0	0	0	0	0
Sphyraena obtusata	striped sea pike	0	0	0	7	1	10	28
Syngnathidae								
Sp. 1	pipefish	0	0	0	0	0	0	0
Stegestomatidae								
Stegostoma fasciatum	leopard shark	0	0	0	0	0	0	0
Tetraodontidae								
Arothron hispidus	stars and stripes pufferfish	0	0	0	0	0	0	0
Arthron immaculatus	immaculate pufferfish	0	0	0	0	0	0	0
Arothron manillensis	narrow lined toadfish	0	0	0	0	0	0	0
Arothron stellatus	starry toadfish	1	0	0	1	1	1	0
Canthigaster valentini	black-saddled toby	0	0	0	0	0	0	0
Lagocephalus sp.	toadfish	0	0	0	0	0	0	0
Torquigener pleurogramma	toadfish	0	0	0	0	0	0	0
Urolophidae								
Urolophus sp.	stingaree	0	0	0	0	1	0	0
Zanclidae								
Zanclus cornutus	moorish idol	0	0	0	0	0	0	0

Table 31 Max N values for BRUV and ROV imagery replicate samples collected at Palm Beach Reef (July 2016)

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Acanthuridae								
Acanthurus grammoptilus	ring-tailed surgeon	0	1	1	2	0	0	1
Acanthurus mata	Pale surgeon	0	0	0	0	0	0	1
Acanthurus xanthopterus	yellowfin surgeon	0	0	0	15	0	3	2
Acanthurus sp.		0	2	0	2	1	1	4
Prionurus microlepidotus	sawtail surgeon	0	0	0	0	9	1	1
Acanthurus olivaceus	orange-band surgeon	0	0	0	0	0	0	0
Naso sp.	unicornfish	0	0	0	0	0	0	0
Apogonidae								
Apogon cookii	cook's cardinal fish	0	0	0	0	2	2	0
Apogon doederleini	four lined cardinal fish	0	0	0	0	0	0	0
Aracanidae								
Strophiurichthys robustus	freckled boxfish	0	0	0	0	0	0	0
Arripididae								
Arripis georgiana	tommy rough	25	0	0	0	0	0	10
Balastidae								
Balistoides conspicillum	clown triggerfish	0	0	0	0	0	0	0
Sufflamen chrysopterus	half-moon triggerfish	0	0	0	0	0	0	0
Sufflamen fraenatus	bridled triggerfish	0	0	0	0	0	0	0
Blennidae								
Plagiotremus tapeinosoma	hit and run blenny	0	0	0	0	0	0	0
Brachaeluridae								
Brachaelurus waddi	blindshark	0	0	0	0	0	0	0
Caesionidae								
Diagramma labiosum	painted sweetlip	0	0	0	0	1	0	1
Diagramma pictum	painted sweetlip	0	0	0	0	0	0	0
Carangidae								
Caranax sp.	trevally	0	0	0	0	0	0	0
Gnathanodon speciosus	golden trevally	0	0	0	0	0	0	0
Pseudocaranx dentex	silver trevally	0	0	0	0	0	0	0
Scomberoides lysan	queenfish	0	0	0	0	0	0	0
Tracinotus blochii	dart	0	0	0	0	0	0	0
Trachurus novaezelandie	yellow-tail scad	50	20	100	140	70	90	110
Chaetodontidae								
Chaetodon auriga	threadfin butterfly fish	0	0	0	1	0	0	1
Chaetodon citrinellus	citron butterfly fish	0	0	0	0	0	0	2
Chaetodon flavirostris	dusky butterfly fish	2	1	0	1	0	1	2
Chaetodon lineolatus	lined butterfly fish	0	0	0	0	0	0	0
Heinochus sp.	banner fish	0	0	0	0	0	0	0
Chaetodon guentheri	gunther's butterflyfish	0	0	0	0	0	0	0
Chaetodon kleinii	brown butterflyfish	0	0	0	0	0	0	0
Cheilodactylidae								
Cheilodactylus fuscus	red morwong	0	0	0	0	0	0	0
Cheilodactylus vestitus	crested morwong	0	0	0	0	0	0	1
Chironemidae								
Chironemus marmoratus	kelp fish	0	0	0	0	0	0	0
Cirrhitidae								
Cirrhitichthys sp.	hawkfish	0	0	0	0	0	0	0
Dasyatidae								
Dasyatis kuhlii	blue-spotted mask ray	0	0	0	0	0	0	0
Pastinachus atrus	cowtail stingray	0	0	0	0	0	0	0
Diodontidae								
Dicotylichthys punctulatus	three-bar porcupine fish	0	0	0	0	0	0	1
Diodon holacanthus	freckled porcupine fish	0	0	0	0	0	0	0
Diodon hystrix	black-spotted porcupine fish	0	0	0	1	0	0	3
Ephippidae								
Platax orbicularis	round batfish	0	0	0	0	0	0	0
Enoplosidae								

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Enoplosus armatus	old wife	0	0	0	0	0	0	0
Fistularidae								
Fistularia commersonii	smooth flutemouth	0	0	0	0	0	0	0
Fistularia petimba	rough flutemouth	0	0	0	0	0	0	0
Gerridae								
Gerres subfasciatus	silver biddy	0	0	0	0	0	1	0
Haemulidae								
Plectorhyncus flavomaculatus	gold-spotted sweetlip	0	0	0	0	0	0	0
Hemiscylliidae								
Chiloscyllium sp.	cat shark	0	0	0	0	0	0	0
Labridae								
Achoerodus gouldi	blue groper	0	0	0	2	0	0	0
Anampses meleagrides	spotted wrasse	0	0	0	0	0	0	0
Bodianus axillaris	Coral hogfish	0	0	0	0	0	0	0
Choerodon graphicus	graphic tuskfish	0	0	0	0	0	0	0
Coris picta	comb wrasse	0	0	0	0	3	0	3
Diproctacanthus xanthurus	yellowtail tubelip	0	0	0	0	2	1	0
Halichoeres sp.	striped wrasse	0	0	0	0	0	0	0
Labroides dimidiatus	cleaner wrasse	0	0	0	1	2	1	5
Labridae sp.	unknown wrasse	0	0	0	0	0	0	0
Notolabrus gymnogensis	crimson-banded wrasse	0	0	0	1	0	0	0
Notolabrus sp.	wrasse	1	0	0	0	1	0	0
Pseudolabrus guentheri	Gunthers Wrasse	0	0	0	1	1	3	2
Thalasoma jansenii	Jansen's wrasse	0	0	0	1	1	1	1
Thalassoma lunare	moon wrasse	0	0	0	0	0	0	0
Thalassoma lutescens	yellow moon wrasse	1	1	0	4	3	2	5
Lutjanidae								
Lutjanus sp.		0	0	1	0	0	0	0
Lutjanus fluviflamma	black-spot snapper	2	0	0	0	0	0	0
Lutjanus russelli	moses perch	1	0	0	0	0	1	2
Microcanthidae								
Atpichthys strigatus	Australian mado	3	2	1	0	0	0	4
Microcanthus strigatus	stripey	0	0	1	1	0	1	8
Monocanthidae								
Meuschenia trachylepis	yellow-tailed leatherjacket	0	0	0	0	1	1	1
Monocanthus chinensis	fan-bellied leatherjacket	0	0	0	0	0	0	0
Oxymonacanthus longirostris	orange spotted filefish	0	0	0	0	0	0	0
Monodactylidae								
Monodactylus argenteus	silver batfish	0	0	0	0	0	0	0
Schuettea scalaripinnis	eastern pomfred	0	0	0	3	7	3	0
Mullidae								
Mulloidichthys vanicolensis	yellowfin goatfish	0	1	0	2	0	0	1
Parupeneus barberinoides	half-and-half goatfish	0	0	0	0	0	0	0
Parupeneus ciliatus	diamond-scaled goat fish	0	0	0	0	0	0	0
Parupeneus signatus	black spot goat fish	0	0	0	3	1	0	1
Parupeneus sp.		0	0	0	0	0	0	0
Muraenidae								
Gymnothorax aurostus	white-speckled moray	0	0	0	0	0	0	0
Gymnothorax favagineus	tessellate moray	0	0	0	0	0	0	0
Gynothorax prasineus	green moray	0	0	0	0	0	0	0
Gynothorax sp.	moray eel	0	0	0	0	0	0	0
Siderea thyrsoidea	white-eyed moray	1	0	1	0	0	0	0
Myliobatididae								
Aetobatus narinari	white-spotted eagle ray	0	0	0	0	0	0	0
Orectolobidae								
Orectolobus ornatus	ornate wobbegong	0	0	0	0	0	1	0
Ostraciidae								
Ostracion cubicus		0	0	0	0	0	0	0
Pempheridae								
Pempheris affinis	black-tipped bulls eye	0	0	0	0	0	0	2
Pempheris multiradiata	bullseye	0	0	0	1	0	0	1

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Pempheris oualensis	black-finned bullseye	0	0	0	0	0	0	0
Pentacerotidae								
Paristiopterus labiosus	giant boarfish	0	0	0	0	0	0	1
Pinguipedidae								
Parapercis queenslandiae	queensland grubfish	0	0	0	0	0	0	0
Platycephalidae								
Platycephalus fuscus	dusky flathead	0	0	0	0	0	0	0
Plesiopidae								
Trachinops taeniatus	eastern hulafish	0	0	0	0	0	0	0
Plotosidae								
Cnidoglanis macrocephala	estuary catfish	0	0	0	0	0	0	0
Polynemidae								
Polydactylus ngipinnis	black-finned threadfin	0	0	0	0	0	0	0
Pomacanthidae								
Centropyge tibicen	keyhole angelfish	0	1	0	0	0	1	1
Pomacanthus semicirculatus	blue angelfish	0	0	0	0	0	0	0
Centropyge vrolikii	pearly-scaled angelfish	0	0	0	0	0	0	0
Pomacentridae								
Abudefduf bengalensis	Bengal sergeant major	0	0	0	0	0	0	0
Abudefduf vaigiensis	sergeant major	0	0	0	0	0	0	0
Abudefduf saxatilis	five-banded sergeant major	1	3	1	18	18	30	46
Abudefduf sexfasciatus	scissor-tail sergeant	0	0	0	0	0	0	1
Abudefduf whitleyi	Whitley's sergeant	0	0	0	0	0	0	2
Amphiprion akindynos	Barrier reef anemone fish	0	0	0	0	0	0	0
Amphiprion sp.	clown fish	0	0	0	1	4	0	0
Chromis chrysura	robust puller	0	0	0	0	0	0	0
Chromis nitida	barrier reef chromis	0	0	0	0	0	0	0
Chrysiptera sp.	Demoiselle	0	0	0	0	0	0	0
Dascyllus trimaculatus	domino puller	0	0	0	0	0	0	0
Parma microlepis	white ear puller	2	0	0	0	0	0	0
Parma oligolepis	large-scaled parma	0	0	3	2	3	3	5
Parma polylepis	banded parma	0	0	0	0	0	0	0
Parma unifasciata	Girdled parma	0	0	0	1	0	1	1
Plectroglyphidodon leucozonus	whiteband damsel	0	0	0	0	0	0	0
Pomacentrus australis	Australian damsel	0	0	0	0	0	0	0
Pomacentrus bankanensis	fire damsel	0	0	0	0	0	0	1
Pomacentrus coelestis	neon damsel	0	0	0	13	3	6	3
Pomacentrus sp.		0	0	0	0	0	0	0
Pomacentridae sp.		0	0	0	0	0	0	0
Stegastes gascoynei	coral sea gregory	0	0	0	1	1	1	0
Stegastes sp.	damsel	0	0	0	0	0	0	0
Pomatomidae								
Pomatomus saltatrix	tailor	0	0	0	0	0	0	0
Rhinobatidae								
Aptychotrema sp.	shovelnose ray	0	0	0	0	0	0	0
Glaucostegus typus	giant shovelnose ray	0	0	0	0	0	0	0
Scorpaendiae								
Centropogon australis	fortescue	1	1	0	0	1	0	0
Pterois volotans	red firefish	0	0	0	0	0	0	0
Scorpaena cardinalis	red scorpionfish	0	0	0	0	0	0	0
Synancia horrida	estuarine stonefish	0	0	0	0	0	0	0
Dendrochirus zebra	zebra lionfish	0	0	0	0	0	0	0
Scombridae								
Cybiosarda elegans	leaping bonito	0	0	0	0	0	0	0
Scomberomorus commerson	spanish mackerel	0	0	0	0	0	0	0
Scorpididae								
Scorpis lineolatus	silver sweep	5	2	3	1	0	2	1
Kyphosus gibsoni	northern silver drummer	0	0	0	0	0	0	0
Serranidae								
Anthias sp.	anthias	0	0	0	0	0	0	0

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Epinephelus fasciatus	black-tipped cod	0	0	0	0	0	0	0
Diploprion bifasciatum	barred soapfish	0	0	0	0	0	0	0
Plectropomus maculatus	coral trout	0	0	0	0	0	0	0
Siganidae								
Siganus fuscescens	rabbit fish	29	2	200	120	2	1	29
Sillaginidae								
Sillago analis	gold-lined whiting	0	0	0	0	0	0	0
Sparidae								
Acanthopagrus australis	yellow fin bream	4	5	4	5	0	3	2
Rhabdosargus sarba	tarwhine	0	0	1	0	0	0	0
Sphyraenidae								
Sphyraena argentea	barracuda	0	0	0	0	0	0	0
Sphyraena obtusata	striped sea pike	2	0	1	0	0	0	0
Syngnathidae								
Sp. *1*	pipefish	0	0	0	0	0	0	0
Stegestomatidae								
Stegostoma fasciatum	leopard shark	0	0	0	0	0	0	0
Tetraodontidae								
Arothron hispidus	stars and stripes pufferfish	0	0	0	0	0	0	0
Arthron immaculatus	immaculate pufferfish	0	0	0	0	0	0	0
Arothron manillensis	narrow lined toadfish	0	0	0	0	0	0	0
Arothron stellatus	starry toadfish	0	0	0	0	1	1	2
Canthigaster valentini	black-saddled toby	0	0	0	0	0	0	0
Lagocephalus sp.	toadfish	0	0	0	0	0	0	0
Torquigener pleurogramma	toadfish	0	0	0	0	0	0	0
Urolophidae								
Urolophus sp.	stingaree	0	0	0	0	0	0	0
Zanclidae								
Zanclus cornutus	moorish idol	0	0	0	0	0	0	0

Table 32 Max N values for BRUV and ROV imagery replicate samples collected at Cook Island Reef (July 2016)

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Acanthuridae								
Acanthurus grammoptilus	ring-tailed surgeon	2	0	0	4	4	1	6
Acanthurus mata	Pale surgeon	0	0	0	0	0	1	0
Acanthurus xanthopterus	yellowfin surgeon	0	0	0	0	2	0	2
Acanthurus sp.		3	2	3	2	5	0	8
Prionurus microlepidotus	sawtail surgeon	0	0	0	1	5	2	0
Acanthurus olivaceus	orange-band surgeon	0	0	0	0	0	0	0
Naso sp.	unicornfish	0	0	0	0	0	0	0
Apogonidae								
Apogon cookii	cook's cardinal fish	0	0	0	0	0	0	0
Apogon doederleini	four lined cardinal fish	0	0	0	0	0	0	0
Aracanidae								
Strophiurichthys robustus	freckled boxfish	0	0	0	0	0	0	0
Arripididae								
Arripis georgiana	tommy rough	0	0	0	0	0	0	0
Balastidae								
Balistoides conspicillum	clown triggerfish	0	0	0	0	0	0	1
Sufflamen chrysopterus	half-moon triggerfish	0	0	0	0	0	0	1
Sufflamen fraenatus	bridled triggerfish	0	0	0	0	0	0	0
Blennidae								
Plagiotremus tapeinosoma	hit and run blenny	0	0	0	0	0	0	0
Brachaeluridae								
Brachaelurus waddi	blindshark	0	0	0	0	0	0	0
Caesionidae								
Diagramma labiosum	painted sweetlip	0	0	0	0	0	0	1
Diagramma pictum	painted sweetlip	0	0	0	0	0	0	0
Carangidae								
Caranax sp.	trevally	0	0	0	0	0	0	0
Gnathanodon speciosus	golden trevally	0	0	0	0	0	0	0
Pseudocaranx dentex	silver trevally	0	0	0	0	0	0	0
Scomberoides lysan	queenfish	0	0	0	0	0	0	3
Tracinotus blochii	dart	0	0	0	0	0	0	0
Trachurus novaezelandie	yellow-tail scad	150	140	50	100	50	35	60
Chaetodontidae								
Chaetodon auriga	threadfin butterfly fish	0	0	0	0	0	0	0
Chaetodon citrinellus	citron butterfly fish	0	0	0	0	0	0	1
Chaetodon flavirostris	dusky butterfly fish	0	0	0	0	1	0	2
Chaetodon lineolatus	lined butterfly fish	0	0	0	0	0	0	0
Heinochus sp.	banner fish	0	0	0	0	0	0	0
Chaetodon guentheri	gunther's butterflyfish	0	0	0	0	0	0	0
Chaetodon kleinii	brown butterflyfish	0	0	0	0	0	0	0
Cheilodactylidae								
Cheilodactylus fuscus	red morwong	0	0	0	1	0	0	0
Cheilodactylus vestitus	crested morwong	0	0	0	0	0	0	0
Chironemidae								
Chironemus marmoratus	kelp fish	0	0	0	0	0	0	0
Cirrhitidae								
Cirrhitichthys sp.	hawkfish	0	0	0	0	0	0	0
Dasyatidae								
Dasyatis kuhlii	blue-spotted mask ray	0	0	0	0	0	0	0
Pastinachus atrus	cowtail stingray	0	0	0	0	0	0	0
Diodontidae								
Dicotylichthys punctulatus	three-bar porcupine fish	0	0	0	0	0	0	0
Diodon holacanthus	freckled porcupine fish	0	0	0	0	0	0	0
Diodon hystrix	black-spotted porcupine fish	0	0	0	1	0	0	1
Ephippidae								
Platax orbicularis	round batfish	0	0	0	0	0	0	0
Enoplosidae								

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Enoplosus armatus	old wife	0	0	0	0	0	2	0
Fistularidae								
Fistularia commersonii	smooth flutemouth	0	0	0	0	0	0	0
Fistularia petimba	rough flutemouth	0	0	0	0	0	0	0
Gerridae								
Gerres subfasciatus	silver biddy	0	0	0	0	0	0	0
Haemulidae								
Plectorhyncus flavomaculatus	gold-spotted sweetlip	0	0	0	0	0	0	0
Hemiscylliidae								
Chiloscyllium sp.	cat shark	0	0	0	0	0	0	0
Labridae								
Achoerodus gouldi	blue groper	0	1	0	2	1	1	2
Anampses meleagrides	spotted wrasse	0	0	0	0	0	0	0
Bodianus axillaris	Coral hogfish	0	0	0	0	1	0	0
Choerodon graphicus	graphic tuskfish	1	0	0	0	0	0	0
Coris picta	comb wrasse	0	0	0	0	0	0	0
Diproctacanthus xanthurus	yellowtail tubelip	0	0	0	2	0	0	0
Halichoeres sp.	striped wrasse	0	0	0	1	0	0	0
Labroides dimidiatus	cleaner wrasse	2	0	0	1	5	3	10
Labridae sp.	unknown wrasse	1	0	0	0	0	0	2
Notolabrus gymnogensis	crimson-banded wrasse	0	0	0	1	0	1	0
Notolabrus sp.	wrasse	0	0	0	0	0	0	0
Pseudolabrus guentheri	Gunthers Wrasse	0	2	2	2	2	2	2
Thalasoma jansenii	Jansen's wrasse	3	0	0	1	0	0	1
Thalassoma lunare	moon wrasse	0	0	0	0	0	1	0
Thalassoma lutascens	yellow moon wrasse	2	1	1	3	3	2	2
Lutjanidae								
Lutjanus sp.		0	0	0	0	0	0	0
Lutjanus fluviflamma	black-spot snapper	0	0	0	0	0	0	0
Lutjanus russelli	moses perch	0	0	0	0	1	1	0
Microcanthidae								
Atpichthys strigatus	Australian mado	1	1	2	1	0	1	1
Microcanthus strigatus	stripey	0	0	0	0	3	4	0
Monocanthidae								
Meuschenia trachylepis	yellow-tailed leatherjacket	1	0	0	0	0	0	0
Monocanthus chinensis	fan-bellied leatherjacket	0	0	0	0	0	0	0
Oxymonacanthus longirostris	orange spotted filefish	0	0	0	0	0	0	0
Monodactylidae								
Monodactylus argenteus	silver batfish	0	0	0	0	0	0	0
Schuettea scalaripinnis	eastern pomfred	6	20	20	32	75	38	20
Mullidae								
Mulloidichthys vanicolensis	yellowfin goatfish	0	0	0	0	0	1	0
Parupeneus barberinoides	half-and-half goatfish	0	0	0	0	0	0	0
Parupeneus ciliatus	diamond-scaled goat fish	0	0	0	0	0	0	0
Parupeneus signatus	black spot goat fish	1	0	0	1	0	0	1
Parupeneus sp.		0	0	0	0	0	0	1
Muraenidae								
Gymnothorax aurostus	white-speckled moray	0	0	0	0	0	0	0
Gymnothorax favagineus	tessellate moray	0	0	0	0	0	0	0
Gynothorax prasineus	green moray	0	0	0	0	0	0	0
Gynothorax sp.	moray eel	0	0	0	0	0	0	0
Siderea thyrsoidea	white-eyed moray	0	0	0	0	0	0	0
Myliobatididae								
Aetobatus narinari	white-spotted eagle ray	0	0	0	0	0	0	0
Orectolobidae								
Orectolobus ornatus	ornate wobbegong	0	1	0	0	0	0	1
Ostraciidae								
Ostracion cubicus		0	0	0	0	0	0	0
Pempheridae								
Pempheris affinis	black-tipped bulls eye	0	0	0	0	1	100	0
Pempheris multiradiata	bullseye	0	0	0	0	0	0	0

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Pempheris oualensis	black-finned bullseye	0	0	0	0	0	0	0
Pentacerotidae								
Paristiopterus labiosus	giant boarfish	0	0	0	0	0	0	0
Pinguipedidae								
Parapercis queenslandiae	queensland grubfish	0	0	0	0	0	0	0
Platycephalidae								
Platycephalus fuscus	dusky flathead	0	0	0	0	0	0	0
Plesiopidae								
Trachinops taeniatus	eastern hulafish	0	0	0	0	0	0	0
Plotosidae								
Cnidoglanis macrocephala	estuary catfish	0	0	0	0	0	0	0
Polynemidae								
Polydactylus ngipinnis	black-finned threadfin	0	0	0	0	0	0	0
Pomacanthidae								
Centropyge tibicen	keyhole angelfish	0	0	0	0	1	0	0
Pomacanthus semicirculatus	blue angelfish	0	0	0	0	0	0	0
Centropyge vrolikii	pearly-scaled angelfish	0	0	0	0	0	0	0
Pomacentridae								
Abudefduf bengalensis	Bengal sergeant major	0	0	0	0	0	0	0
Abudefduf vaigiensis	sergeant major	0	0	0	0	0	0	0
Abudefduf saxatilis	five-banded sergeant major	15	0	0	20	10	1	1
Abudefduf sexfasciatus	scissor-tail sergeant	0	0	0	0	0	0	0
Abudefduf whitleyi	Whitley's sergeant	0	0	0	0	0	0	0
Amphiprion akindynos	Barrier reef anemone fish	0	0	0	0	0	1	1
Amphiprion sp.	clown fish	0	0	0	0	0	0	2
Chromis chrysura	robust puller	0	0	0	0	2	0	0
Chromis nitida	barrier reef chromis	0	0	0	0	0	0	0
Chrysiptera sp.	Demoiselle	0	0	0	0	0	0	0
Dascyllus trimaculatus	domino puller	0	0	0	0	0	0	0
Parma microlepis	white ear puller	0	0	0	0	0	0	0
Parma oligolepis	large-scaled parma	1	4	1	3	2	1	3
Parma polylepis	banded parma	1	0	0	0	0	0	0
Parma unifasciata	Girdled parma	3	1	1	2	3	0	2
Plectroglyphidodon leucozonus	whiteband damsel	0	0	0	1	0	0	0
Pomacentrus australis	Australian damsel	0	0	0	0	0	0	0
Pomacentrus bankanensis	fire damsel	0	0	0	0	0	0	0
Pomacentrus coelestis	neon damsel	0	0	0	10	5	0	19
Pomacentrus sp.		0	0	0	0	1	0	1
Pomacentridae sp.		0	0	0	0	0	0	0
Stegastes gascoynei	coral sea gregory	1	0	1	1	1	1	1
Stegastes sp.	damsel	0	0	0	0	0	0	0
Pomatomidae								
Pomatomus saltatrix	tailor	0	0	0	0	0	0	0
Rhinobatidae								
Aptychotrema sp.	shovelnose ray	0	0	0	0	0	0	0
Glaucostegus typus	giant shovelnose ray	0	0	0	0	0	0	0
Scorpaendiae								
Centropogon australis	fortescue	0	0	0	1	0	0	0
Pterois volotans	red firefish	0	0	0	0	0	0	0
Scorpaena cardinalis	red scorpionfish	0	0	0	0	0	0	0
Synancia horrida	estuarine stonefish	0	0	0	0	0	0	0
Dendrochirus zebra	zebra lionfish	0	0	0	0	0	0	0
Scombridae								
Cybiosarda elegans	leaping bonito	0	0	0	0	0	0	0
Scomberomorus commerson	spanish mackerel	0	0	0	0	0	0	0
Scorpididae								
Scorpis lineolatus	silver sweep	1	1	4	0	0	0	0
Kyphosus gibsoni	northern silver drummer	0	0	0	10	0	1	2
Serranidae								
Anthias sp.	anthias	0	0	0	0	0	0	0

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Epinephelus fasciatus	black-tipped cod	0	0	0	0	0	0	0
Diploprion bifasciatum	barred soapfish	0	0	0	0	0	0	0
Plectropomus maculatus	coral trout	0	0	0	0	0	0	0
Siganidae								
Siganus fuscescens	rabbit fish	0	0	0	0	0	0	0
Sillaginidae								
Sillago analis	gold-lined whiting	0	0	0	0	0	0	0
Sparidae								
Acanthopagrus australis	yellow fin bream	4	1	1	1	2	1	2
Rhabdosargus sarba	tarwhine	0	0	0	0	0	0	0
Sphyraenidae								
Sphyraena argentea	barracuda	0	0	0	0	0	0	0
Sphyraena obtusata	striped sea pike	0	0	0	0	0	0	0
Syngnathidae								
Sp. *1*	pipefish	0	0	0	0	0	0	0
Stegestomatidae								
Stegostoma fasciatum	leopard shark	0	0	0	0	0	0	0
Tetraodontidae								
Arothron hispidus	stars and stripes pufferfish	0	0	0	0	0	0	0
Arthron immaculatus	immaculate pufferfish	0	0	0	0	0	0	0
Arothron manillensis	narrow lined toadfish	0	0	0	0	0	0	0
Arothron stellatus	starry toadfish	0	0	0	0	0	0	0
Canthigaster valentini	black-saddled toby	0	0	0	0	0	0	0
Lagocephalus sp.	toadfish	0	0	0	0	0	0	0
Torquigener pleurogramma	toadfish	0	0	0	0	0	0	0
Urolophidae								
Urolophus sp.	stingaree	0	0	0	0	0	0	0
Zanclidae								
Zanclus cornutus	moorish idol	0	0	0	0	0	0	0

Table 33 Max N values for BRUV and ROV imagery replicate samples collected at Kingscliff Reef (July 2016)

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Acanthuridae								
Acanthurus grammoptilus	ring-tailed surgeon	1	0	0	0	2	2	2
Acanthurus mata	Pale surgeon	0	0	0	0	0	0	0
Acanthurus xanthopterus	yellowfin surgeon	0	0	0	0	0	0	0
Acanthurus sp.		1	2	3	0	0	0	0
Prionurus microlepidotus	sawtail surgeon	1	0	0	59	52	11	62
Acanthurus olivaceus	orange-band surgeon	0	0	0	0	0	0	0
Naso sp.	unicornfish	0	0	0	0	0	0	0
Apogonidae								
Apogon cookii	cook’s cardinal fish	0	0	0	0	0	0	0
Apogon doederleini	four lined cardinal fish	0	0	0	0	0	0	0
Aracanidae								
Strophiurichthys robustus	freckled boxfish	0	0	0	0	0	0	0
Arripididae								
Arripis georgiana	tommy rough	0	0	0	0	0	0	0
Balastidae								
Balistoides conspicillum	clown triggerfish	0	0	0	0	0	0	0
Sufflamen chrysopterus	half-moon triggerfish	0	0	0	0	0	0	0
Sufflamen fraenatus	bridled triggerfish	0	0	0	0	0	0	0
Blennidae								
Plagiotremus tapeinosoma	hit and run blenny	0	0	0	0	0	0	0
Brachaeluridae								
Brachaelurus waddi	blindshark	0	1	0	0	0	0	0
Caesionidae								
Diagramma labiosum	painted sweetlip	0	1	0	0	1	0	1
Diagramma pictum	painted sweetlip	0	0	0	0	0	0	0
Carangidae								
Caranax sp.	trevally	0	0	0	0	0	0	0
Gnathanodon speciosus	golden trevally	0	0	0	0	0	0	0
Pseudocaranx dentex	silver trevally	2	3	2	0	0	1	0
Scomberoides lysan	queenfish	0	0	0	0	0	0	0
Tracinotus blochii	dart	0	0	0	0	0	0	0
Trachurus novaezelandie	yellow-tail scad	200	110	235	150	100	100	85
Chaetodontidae								
Chaetodon auriga	threadfin butterfly fish	0	0	0	0	0	0	0
Chaetodon citrinellus	citron butterfly fish	0	0	0	0	3	0	0
Chaetodon flavirostris	dusky butterfly fish	1	0	0	0	2	0	0
Chaetodon lineolatus	lined butterfly fish	0	0	0	0	0	0	0
Heinochus sp.	banner fish	0	0	0	0	1	0	0
Chaetodon guentheri	gunther's butterflyfish	0	0	0	0	0	0	0
Chaetodon kleinii	brown butterflyfish	0	0	0	0	0	0	0
Cheilodactylidae								
Cheilodactylus fuscus	red morwong	0	1	0	0	1	0	0
Cheilodactylus vestitus	crested morwong	0	0	0	0	0	0	0
Chironemidae								
Chironemus marmoratus	kelp fish	0	0	0	0	1	0	0
Cirrhitidae								
Cirrhitichthys sp.	hawkfish	0	0	0	0	0	0	0
Dasyatidae								
Dasyatis kuhlii	blue-spotted mask ray	0	0	0	0	0	0	0
Pastinachus atrus	cowtail stingray	0	0	0	0	0	0	0
Diodontidae								
Dicotylichthys punctulatus	three-bar porcupine fish	0	0	0	0	0	0	0
Diodon holacanthus	freckled porcupine fish	0	0	0	0	0	0	0
Diodon hystrix	black-spotted porcupine fish	0	0	0	0	0	0	0
Ephippidae								
Platax orbicularis	round batfish	0	0	0	0	0	0	0
Enoplosidae								

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Enoplosus armatus	old wife	0	0	0	0	0	0	0
Fistularidae								
Fistularia commersonii	smooth flutemouth	0	0	0	0	0	0	0
Fistularia petimba	rough flutemouth	0	0	0	0	0	0	0
Gerridae								
Gerres subfasciatus	silver biddy	0	0	0	0	0	0	0
Haemulidae								
Plectorhyncus flavomaculatus	gold-spotted sweetlip	0	0	0	0	0	0	0
Hemiscylliidae								
Chiloscyllium sp.	cat shark	0	0	0	0	0	0	0
Labridae								
Achoerodus gouldi	blue groper	0	0	0	0	1	3	1
Anampses meleagrides	spotted wrasse	0	0	0	0	0	0	0
Bodianus axillaris	Coral hogfish	0	0	0	0	0	0	0
Choerodon graphicus	graphic tuskfish	0	0	0	0	1	0	0
Coris picta	comb wrasse	0	0	1	0	0	0	0
Diproctacanthus xanthurus	yellowtail tubelip	0	0	0	0	0	0	0
Halichoeres sp.	striped wrasse	0	0	0	0	0	0	0
Labroides dimidiatus	cleaner wrasse	0	0	0	0	6	6	1
Labridae sp.	unknown wrasse	0	0	0	0	0	0	0
Notolabrus gymnogensis	crimson-banded wrasse	0	0	0	1	0	1	1
Notolabrus sp.	wrasse	1	0	0	0	0	0	0
Pseudolabrus guentheri	Gunthers Wrasse	1	1	1	1	1	2	2
Thalasoma jansenii	Jansen's wrasse	0	0	0	0	0	0	0
Thalassoma lunare	moon wrasse	0	1	0	0	1	0	0
Thalassoma lutascens	yellow moon wrasse	0	0	0	2	0	1	0
Lutjanidae								
Lutjanus sp.		0	0	0	0	0	0	0
Lutjanus fluviflamma	black-spot snapper	0	0	0	0	0	0	0
Lutjanus russelli	moses perch	0	0	0	1	0	0	1
Microcanthidae								
Atpichthys strigatus	Australian mado	27	15	15	4	6	10	3
Microcanthus strigatus	stripey	0	0	0	0	1	0	0
Monocanthidae								
Meuschenia trachylepis	yellow-tailed leatherjacket	0	0	0	0	0	1	0
Monocanthus chinensis	fan-bellied leatherjacket	0	0	0	0	0	0	0
Oxymonacanthus longirostris	orange spotted filefish	0	0	0	0	0	0	0
Monodactylidae								
Monodactylus argenteus	silver batfish	2	1	5	1	8	5	2
Schuettea scalaripinnis	eastern pomfred	28	59	2	60	50	100	83
Mullidae								
Mulloidichthys vanicolensis	yellowfin goatfish	0	0	0	0	0	0	0
Parupeneus barberinoides	half-and-half goatfish	0	0	0	0	0	0	0
Parupeneus ciliatus	diamond-scaled goat fish	0	0	0	0	0	0	0
Parupeneus signatus	black spot goat fish	1	0	0	0	1	1	0
Parupeneus sp.		0	0	0	0	0	0	0
Muraenidae								
Gymnothorax aurostus	white-speckled moray	0	0	0	0	0	0	0
Gymnothorax favagineus	tessellate moray	0	0	0	0	0	0	0
Gynothorax prasineus	green moray	0	0	0	0	0	0	0
Gynothorax sp.	moray eel	0	0	0	0	0	0	0
Siderea thyrsoidea	white-eyed moray	0	0	0	0	0	0	0
Myliobatididae								
Aetobatus narinari	white-spotted eagle ray	0	0	0	0	0	0	0
Orectolobidae								
Orectolobus ornatus	ornate wobbegong	1	0	0	0	1	1	0
Ostraciidae								
Ostracion cubicus		0	0	0	0	0	0	0
Pempheridae								
Pempheris affinis	black-tipped bulls eye	0	0	0	0	0	0	0
Pempheris multiradiata	bullseye	0	0	0	0	0	0	0

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Pempheris oualensis	black-finned bullseye	0	0	0	0	0	0	0
Pentacerotidae								
Paristiopterus labiosus	giant boarfish	0	0	0	0	0	0	0
Pinguipedidae								
Parapercis queenslandiae	queensland grubfish	0	0	0	0	0	0	0
Platycephalidae								
Platycephalus fuscus	dusky flathead	0	0	0	0	0	0	0
Plesiopidae								
Trachinops taeniatus	eastern hulafish	0	0	0	0	0	0	0
Plotosidae								
Cnidoglanis macrocephala	estuary catfish	0	0	0	0	0	0	0
Polynemidae								
Polydactylus ngipinnis	black-finned threadfin	0	0	0	0	0	0	0
Pomacanthidae								
Centropyge tibicen	keyhole angelfish	0	0	0	0	0	0	0
Pomacanthus semicirculatus	blue angelfish	0	0	0	0	0	0	0
Centropyge vrolikii	pearly-scaled angelfish	0	0	0	0	0	0	0
Pomacentridae								
Abudefduf bengalensis	Bengal sergeant major	0	0	0	0	0	0	0
Abudefduf vaigiensis	sergeant major	0	0	0	0	0	0	0
Abudefduf saxatilis	five-banded sergeant major	0	0	0	0	0	0	0
Abudefduf sexfasciatus	scissor-tail sergeant	0	0	0	0	0	0	0
Abudefduf whitleyi	Whitley's sergeant	0	0	0	0	0	0	0
Amphiprion akindynos	Barrier reef anemone fish	0	0	0	0	0	0	0
Amphiprion sp.	clown fish	0	0	0	0	0	0	0
Chromis chrysura	robust puller	0	0	0	0	0	0	0
Chromis nitida	barrier reef chromis	0	0	0	0	0	0	0
Chrysiptera sp.	Demoiselle	0	0	0	0	0	0	0
Dascyllus trimaculatus	domino puller	0	0	0	0	0	0	0
Parma microlepis	white ear puller	0	0	0	0	0	0	0
Parma oligolepis	large-scaled parma	0	3	1	2	1	1	1
Parma polylepis	banded parma	0	0	0	0	0	0	0
Parma unifasciata	Girdled parma	1	1	2	3	3	4	1
Plectroglyphidodon leucozonus	whiteband damsel	0	0	0	0	0	0	0
Pomacentrus australis	Australian damsel	0	0	0	0	0	0	0
Pomacentrus bankanensis	fire damsel	0	0	0	0	0	0	0
Pomacentrus coelestis	neon damsel	0	0	0	0	6	9	0
Pomacentrus sp.		0	0	0	0	0	0	0
Pomacentridae sp.		0	0	1	0	0	0	1
Stegastes gascoynei	coral sea gregory	0	0	0	1	0	1	0
Stegastes sp.	damsel	0	0	0	0	0	0	0
Pomatomidae								
Pomatomus saltatrix	tailor	0	0	0	0	0	0	0
Rhinobatidae								
Aptychotrema sp.	shovelnose ray	0	0	0	0	0	0	0
Glaucostegus typus	giant shovelnose ray	0	0	0	0	0	0	0
Scorpaendiae								
Centropogon australis	fortescue	0	0	0	0	0	0	1
Pterois volotans	red firefish	0	0	0	0	0	0	0
Scorpaena cardinalis	red scorpionfish	0	0	0	0	0	0	0
Synancia horrida	estuarine stonefish	0	0	0	0	0	0	0
Dendrochirus zebra	zebra lionfish	0	0	0	0	0	0	0
Scombridae								
Cybiosarda elegans	leaping bonito	0	0	0	0	0	0	0
Scomberomorus commerson	spanish mackerel	0	0	0	0	0	0	0
Scorpididae								
Scorpis lineolatus	silver sweep	1	1	1	1	1	1	1
Kyphosus gibsoni	northern silver drummer	0	7	0	3	2	0	2
Serranidae								
Anthias sp.	anthias	0	0	0	0	0	0	0

Scientific Name	Common Name	BRUV 1	BRUV 2	BRUV 3	ROV 1	ROV 2	ROV 3	ROV 4
Epinephelus fasciatus	black-tipped cod	0	0	0	0	0	0	0
Diploprion bifasciatum	barred soapfish	0	0	0	0	0	0	0
Plectropomus maculatus	coral trout	0	0	0	0	0	0	0
Siganidae								
Siganus fuscescens	rabbit fish	0	0	0	0	0	0	1
Sillaginidae								
Sillago analis	gold-lined whiting	0	0	0	0	0	0	0
Sparidae								
Acanthopagrus australis	yellow fin bream	14	5	7	2	9	2	2
Rhabdosargus sarba	tarwhine	1	0	0	0	0	0	0
Sphyraenidae								
Sphyraena argentea	barracuda	0	0	0	0	0	0	0
Sphyraena obtusata	striped sea pike	0	0	1	0	0	0	0
Syngnathidae								
Sp. *1*	pipefish	0	0	0	0	0	0	0
Stegestomatidae								
Stegostoma fasciatum	leopard shark	0	0	0	0	0	0	0
Tetraodontidae								
Arothron hispidus	stars and stripes pufferfish	0	0	0	0	0	0	0
Arthron immaculatus	immaculate pufferfish	0	0	0	0	0	0	0
Arothron manillensis	narrow lined toadfish	0	0	0	0	0	0	0
Arothron stellatus	starry toadfish	0	0	0	0	0	1	0
Canthigaster valentini	black-saddled toby	0	0	0	0	0	0	0
Lagocephalus sp.	toadfish	0	0	0	0	0	0	0
Torquigener pleurogramma	toadfish	0	0	0	0	0	0	0
Urolophidae								
Urolophus sp.	stingaree	0	0	0	0	0	0	0
Zanclidae								
Zanclus cornutus	moorish idol	0	0	0	0	0	0	0

Revision history

Revision No.	Revision date	Details	Prepared by	Reviewed by	Approved by
01	16/12/2016	Tweed River Entrance Sand Bypassing Project - Kirra Reef Biota Monitoring 2016 – Draft Report	Dr Simon Walker Principal Ecologist, ESP	Chris Pietsch, Senior Aquatic Ecologist	Dr Alan House, Principal Ecologist
00	31/09/2016	Tweed River Entrance Sand Bypassing Project - Kirra Reef Biota Monitoring 2016 – Draft Report	Chris Pietsch, Senior Aquatic Ecologist, Dr Simon Walker Principal Ecologist, ESP	Dr Simon Walker, Principal Ecologist, ESP Chris Pietsch, Senior Aquatic Ecologist	Dr Alan House, Principal Ecologist

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Report compiled by Ecosure Pty Ltd

admin@ecosure.com.au www.ecosure.com.au

PR1627.RE Kirra Reef Biota Monitoring 2016 - Final report

Adelaide
PO Box 145
Pooraka SA 5095
P 1300 112 021
M 0407 295 766

Brisbane
PO Box 675
Fortitude Valley QLD 4006
P 07 3606 1030

Gold Coast
PO Box 404
West Burleigh QLD 4219
P 07 5508 2046
F 07 5508 2544

Rockhampton
PO Box 235
Rockhampton QLD 4700
P 07 4994 1000
F 07 4994 1012

Sydney
PO Box 880
Surry Hills NSW 2010
P 02 9437 6919