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Theme 1 – Deep reefs

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Classifying and Mapping Ningaloo Deepwater Habitats

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Ningaloo Outlook – A partnership between BHP Billiton and CSIRO

WESTERN COASTAL/OCEAN & ATMOSPHERE
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Ningaloo Outlook is a BHP Billiton-CSIRO Industry-Science Marine Research Partnership investing A$5.4 million over five years to gather new knowledge on the Ningaloo reef and its important ecological values

Ningaloo Marine Park and World Heritage Area

- Australia and Worlds longest continuous fringing coral reef
- State and Commonwealth Marine Parks
- UNESCO World Heritage area
- Growing tourism and recreational fishing pressure
- Adjacent to active oil and gas production fields

From Google Maps

Introduction

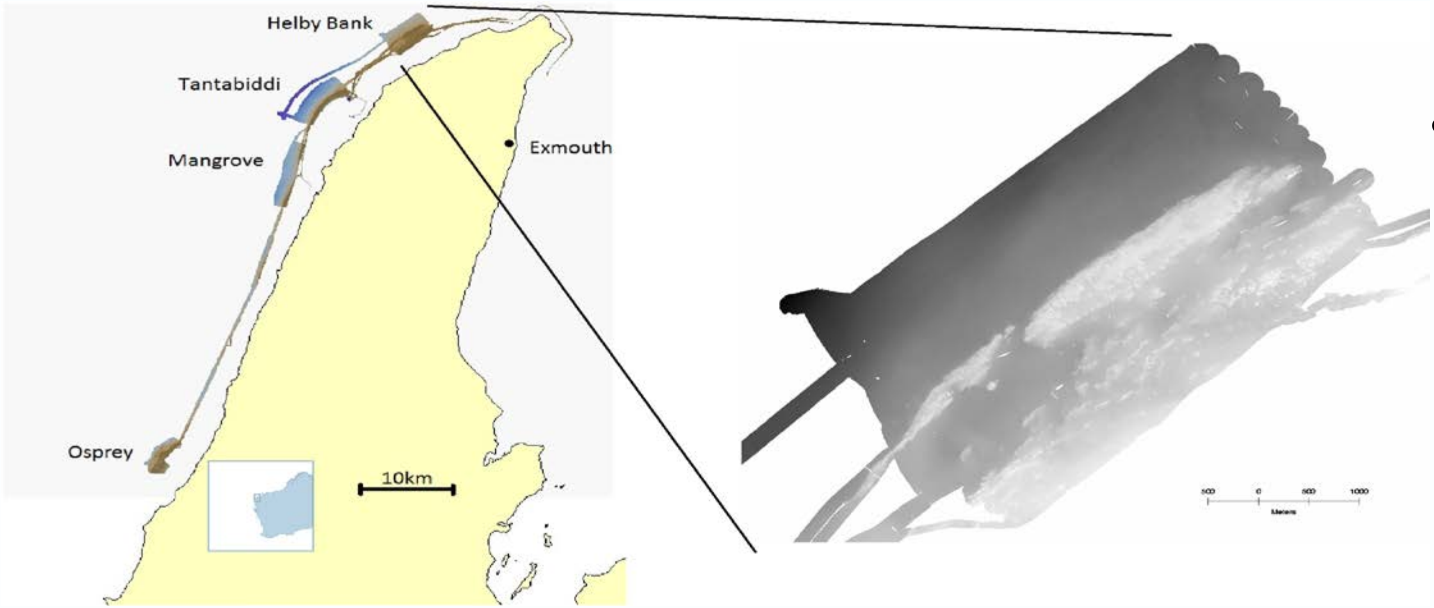
- The deep water (~15m-60m) reefs and other habitats of Ningaloo have seen less scientific scrutiny than their shallow counterparts, due to their relative inaccessibility

- Information on abundance and taxonomic composition of the deepwater habitats and their ecological processes is essential for long-term management of Ningaloo Marine Park - but is a recognised knowledge-gap

- Identifying the substrata that are present in the Ningaloo Reef environment is important step for classifying its benthic habitats, and for targeting areas for Ningaloo Outlook deep reef studies

Reef surveys

- Multibeam Echosounder surveys of Ningaloo Deep reefs took place in June 2015



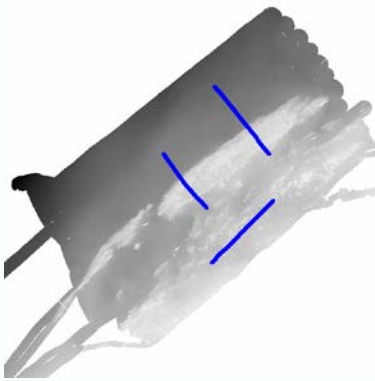
- RV Linnaeus with Kongsberg EM2040c @300kHz

- Bathymetry is the primary purpose of the survey, but an important additional product is the backscatter, or sonic reflectivity

Aim

To characterise and describe seafloor substrata over the extent of the surveyed areas by combining multibeam backscatter, depth and rugosity with ground truth from towed video transects

Towed video



- A subset of the echosounder swaths were repeated with a towed video camera providing ground truth

- The towed video allows us to correlate our observations of the backscatter data with the various substrata identified on the seafloor

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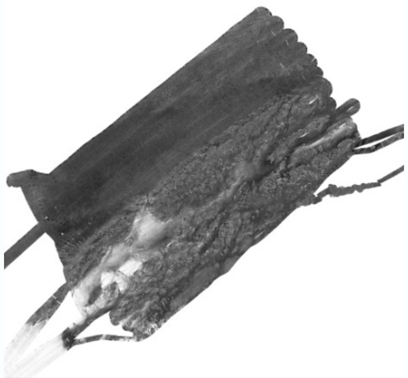
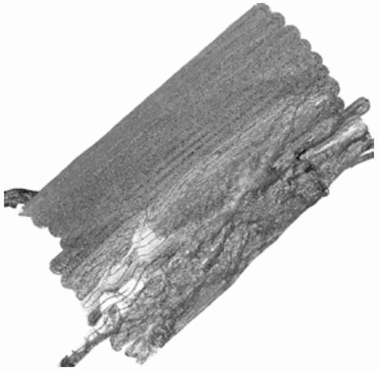
Backscatter

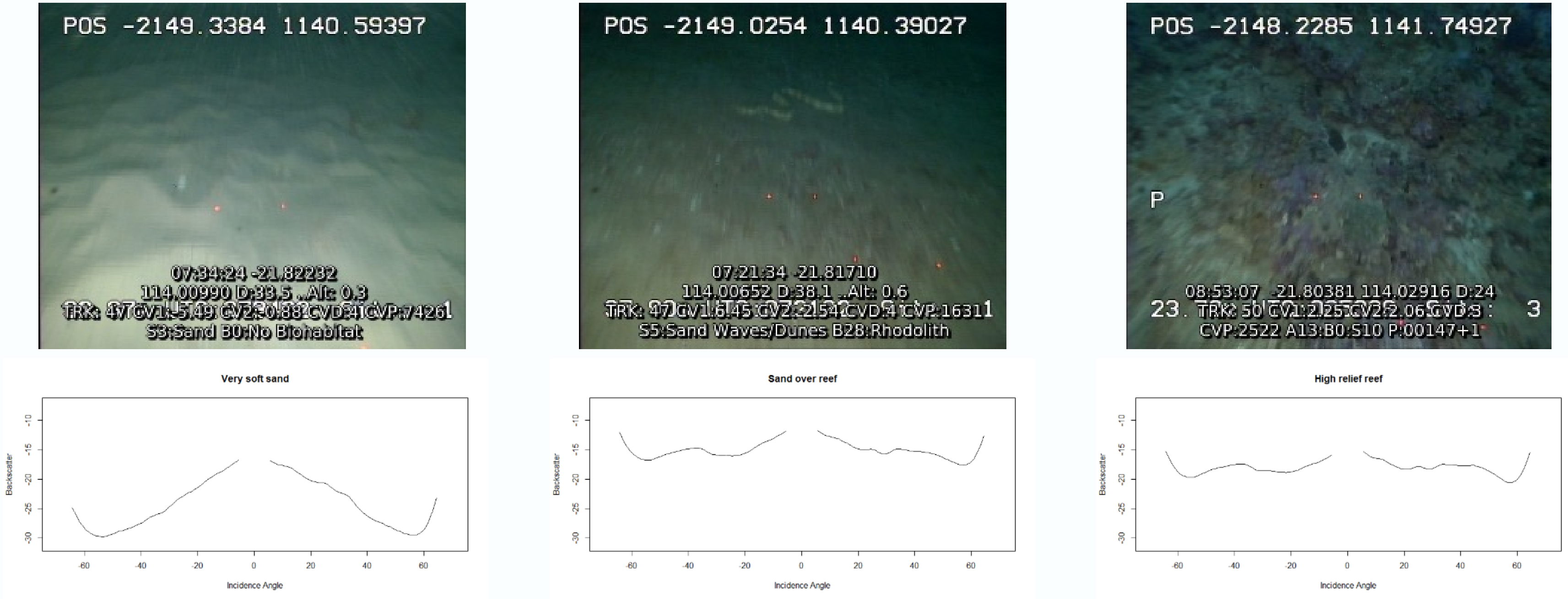


- “Flattened” Backscatter
  - Nice picture
  - Easy for humans to interpret
  - Some information has been removed



- Raw Backscatter
  - Obvious “artefacts” across the swath.
  - Not so nice to look at
  - Contains information about the substrate in the angular response curves

Angular response curves



- The total measured backscatter depends on the overall hardness of the seafloor
- There is additional information embedded in the shape of the backscatter response when plotted against incidence angle

Rugosity

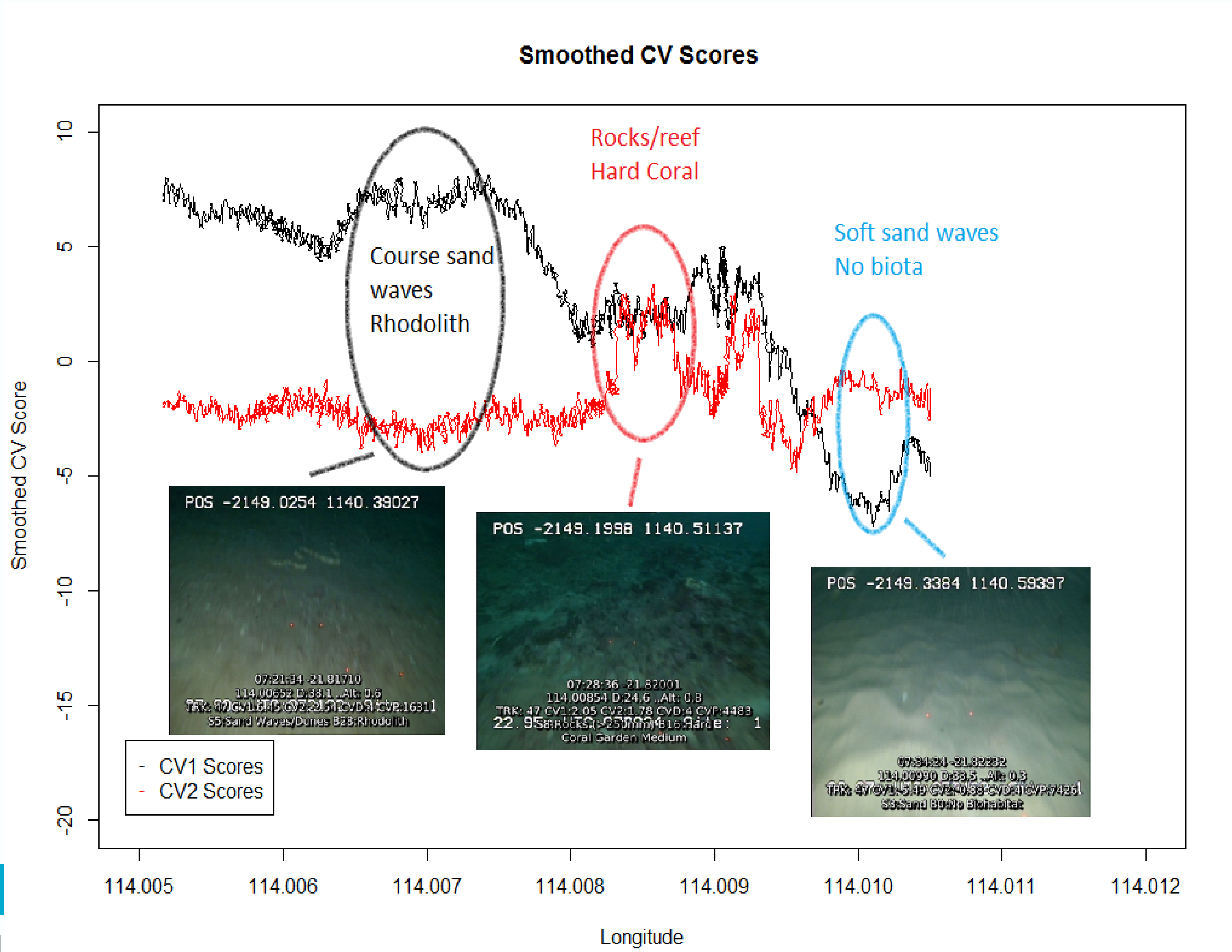
- The rugosity is a depth texture, or roughness, which improves the discrimination between substrata
- Calculated from the depth, it is the ratio of the surface area to the horizontal area (=1 for a flat region, >1 otherwise)

Canonical Variate Analysis (CVA)

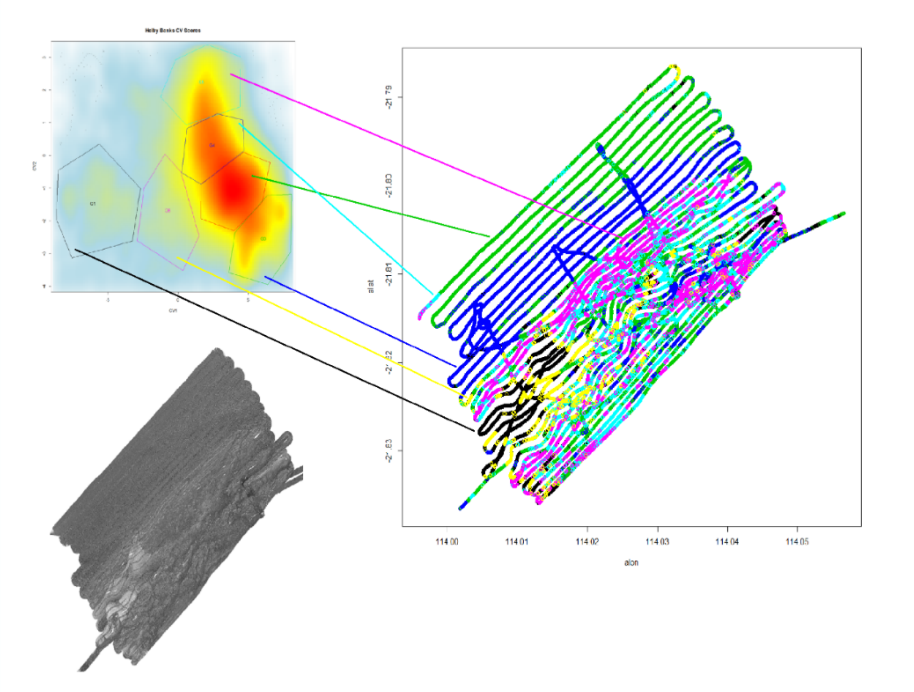
- CVA is a data reduction technique that is used to reduce the angular response data to a few dimensions so that its behaviour can be examined for substrata of interest

- CV scores are calculated for each sonar ping, by projecting the whole-ping AR curve onto the first and second canonical vectors. For the swaths that are coincident with the towed video, this gives CV trace plots

Canonical Variate Analysis (CVA)



Canonical Variate Analysis (CVA)



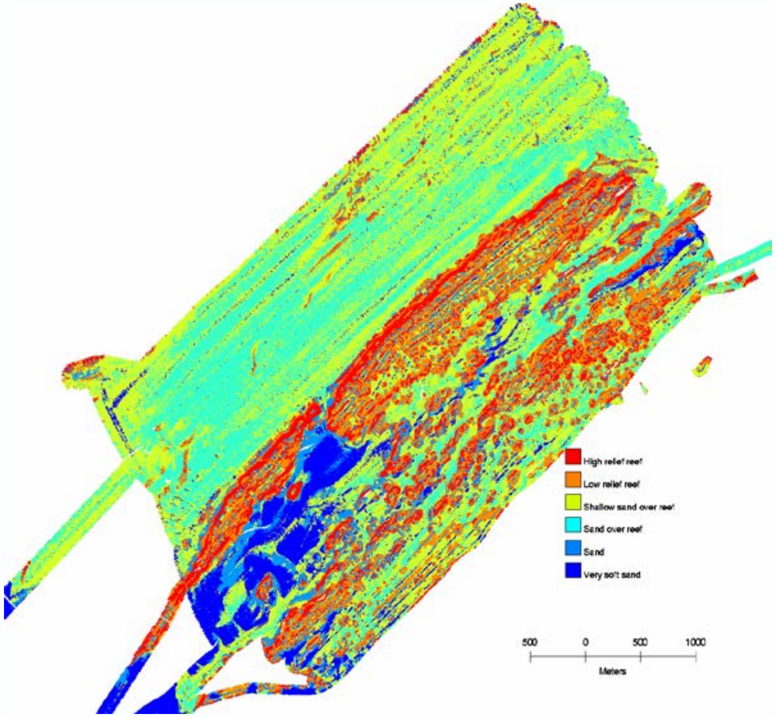
- Coherent areas of the reef correspond with regions of the CV1-CV2 plot

- This indicates that using the CV trace to select homogeneous regions is a suitable approach for training a maximum likelihood classifier

Maximum likelihood classification (MLC)

- Once homogeneous pings have been identified using the video and CV traces, these training pings are extracted and labelled as one of 6 substratum types: Soft Sand; Sand; Sand over Reef; Shallow Sand over Reef; Low Relief Reef and High Relief Reef

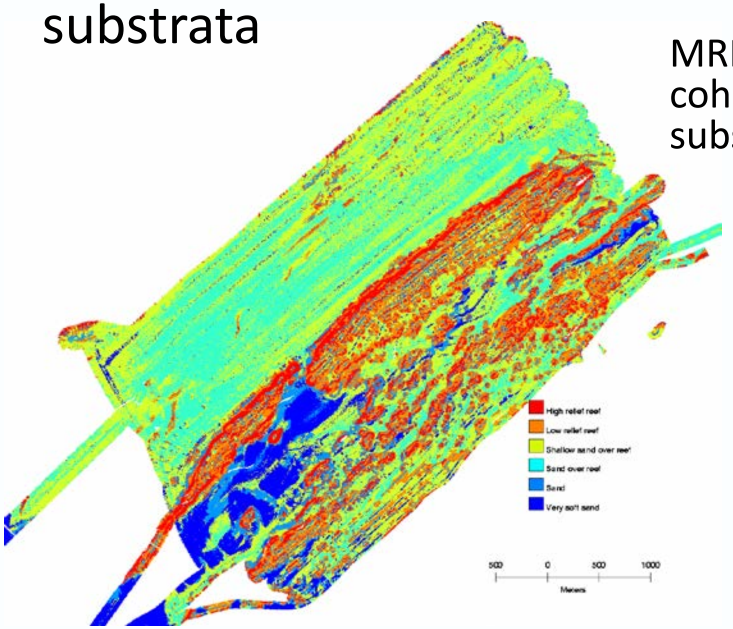
- Using the training pings and the rugosity, MLC is applied to each of the points on the backscatter curves
- The points are treated like vectors by considering a moving window (W=5) around each point, and adding in the average rugosity of the window



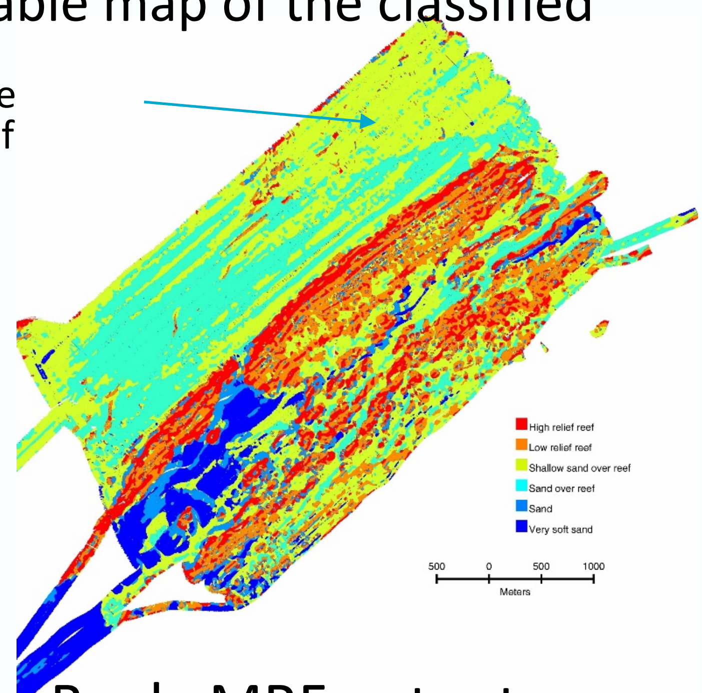
Markov Random Field Updating (MRF)

- To improve the coherence of the classified map and remove some of the local variability, MRF updating is applied
- Updates the likelihoods assigned by MLC with local prior probabilities based on the number of neighbouring pixels that have the same label.
- Gives a smoother, more visually interpretable map of the classified substrata

MRF output has more cohesive groupings of substratum type



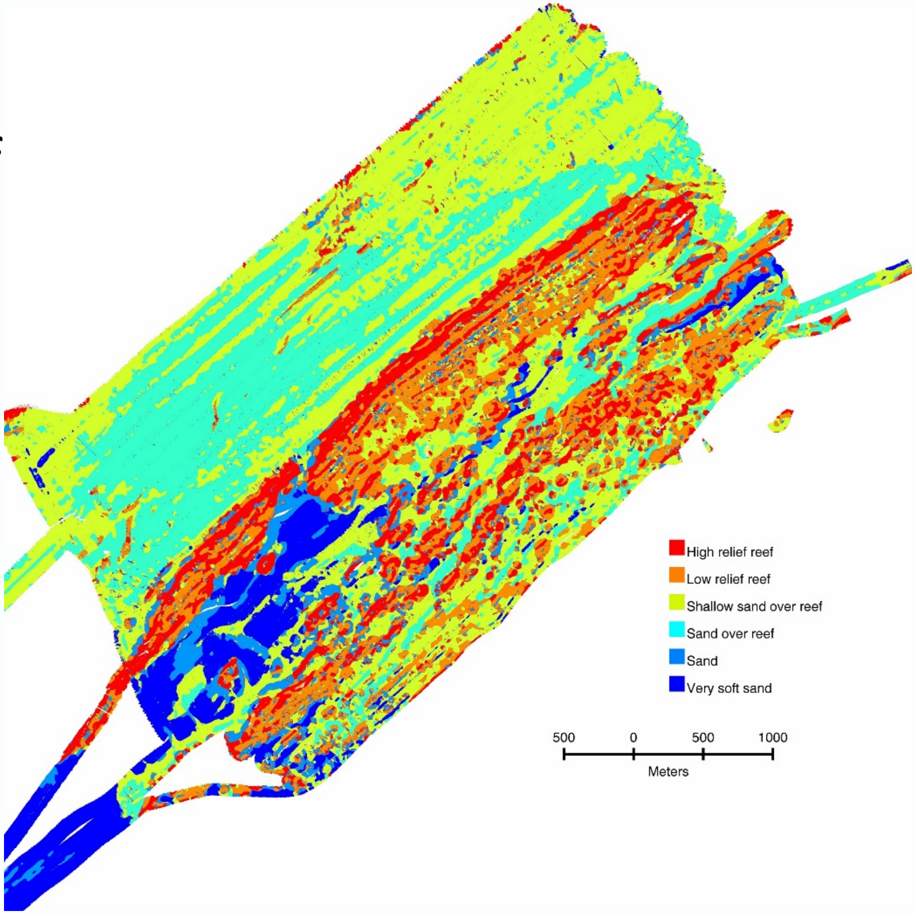
Helby Bank, raw MLC output



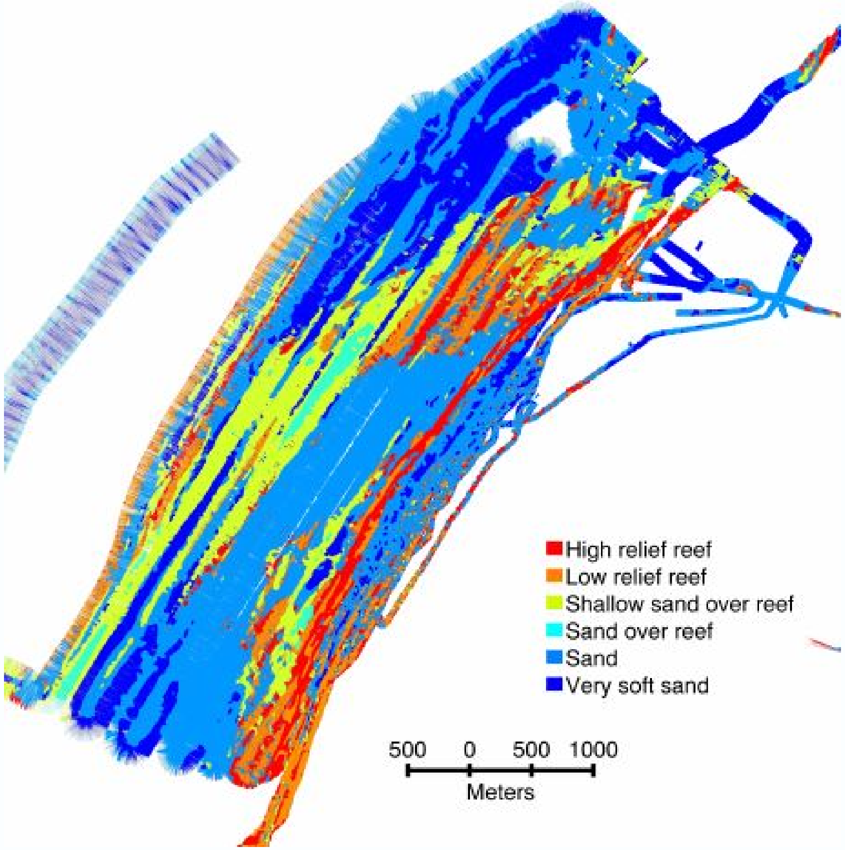
Helby Bank, MRF output

Helby Bank

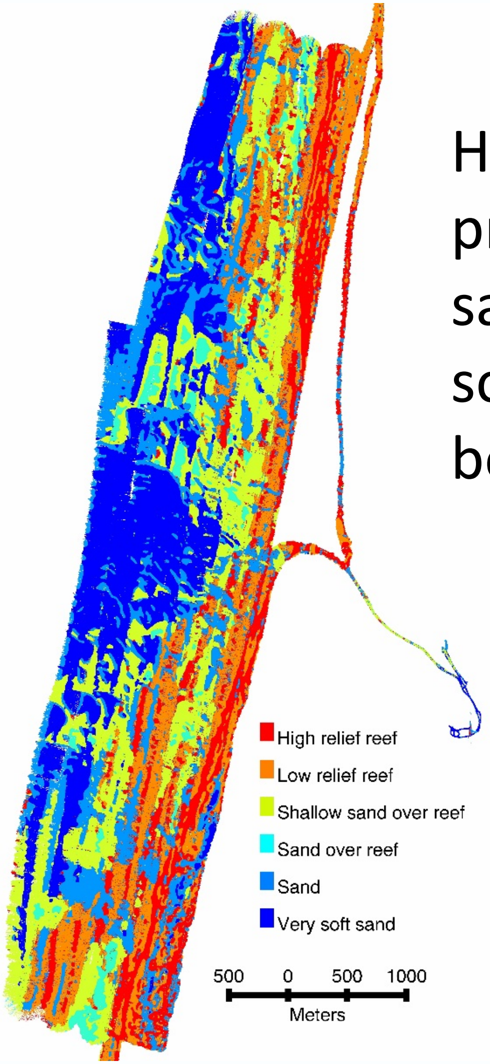
- Most significant area of detached submerged reef in northern Ningaloo
- High proportion of sand covered reef



Tantabiddi

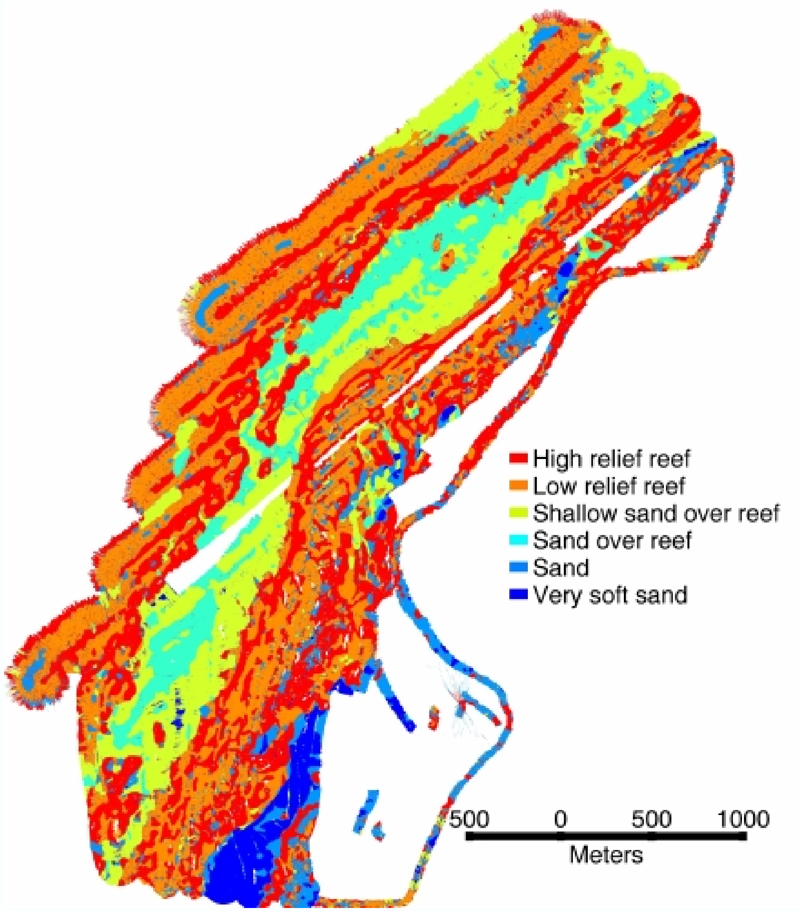


Mangrove



High proportions of sand and very soft sand at both areas

Osprey



Higher proportion of hard substrata than other locations

Summary of validation results

Area	Video No	Accuracy (%)	Mean Accuracy ± SD for Area (%)
Helby Banks	**1**	**82.5**	**73.8 ± 8.8**
	2	67.5	
	3	80	
	4	65	
Tantabiddi	**6**	**85**	**76.9 ± 8.0**
	7	70	
	8	70	
	9	82.5	
Osprey	**16 & 17**	**80**	**70.0 ± 10.0**
	18	60	
	20	70	

Conclusion

- Exploiting the backscatter curve over the full range of angular responses along with rugosity allows accurate classification of benthic substrata in the deep-water reefs of the Ningaloo Marine Park
- Bottom composition is a key indicator of benthic habitat, so these maps will feed into a secondary process of benthic habitat mapping (overlaying biology on the substratum types)
- Some artefacts remain in the processed maps, and removing these is a goal of future work
- Substantial variation in substratum types among the sites surveyed, vital information representing biodiversity for future planning and management

Acknowledgements

- **BHP Billiton-CSIRO Ningaloo Outlook Marine Research Partnership**
- **Data 61**

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AUV surveys of deepwater corals at Ningaloo Reef

Russ Babcock, Karl Forcey, Joe Turner, Melanie Trapon, Andreas Marouchos & Mick Haywood

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Ningaloo Outlook Deepwater findings

Substrate maps

- Backscatter provides a highly useful method of rapid substratum classification
- Substantial variation among sites – not simply a zonal progression of habitat types

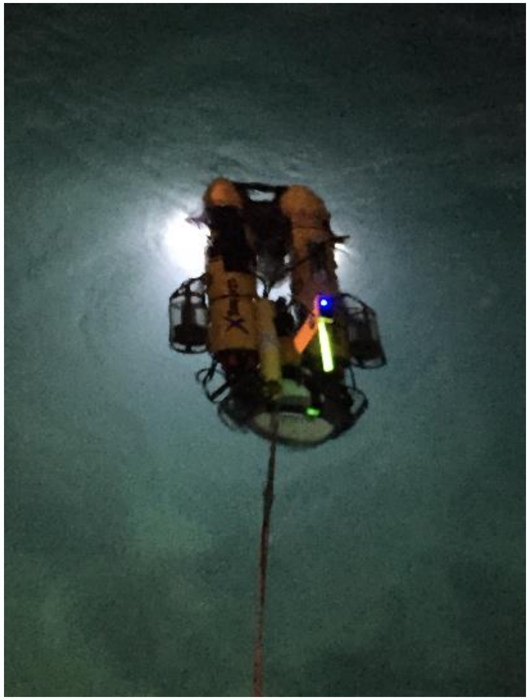
Benthic assemblages

- Distinct assemblages at shallow and deep reef sites, and at off reef sites
- New habitat types described in deepwater areas (*Diaseris*)

Generally these areas are poorly known, especially their dynamics

Starbug-X Background

Starbug X Operational Specifications



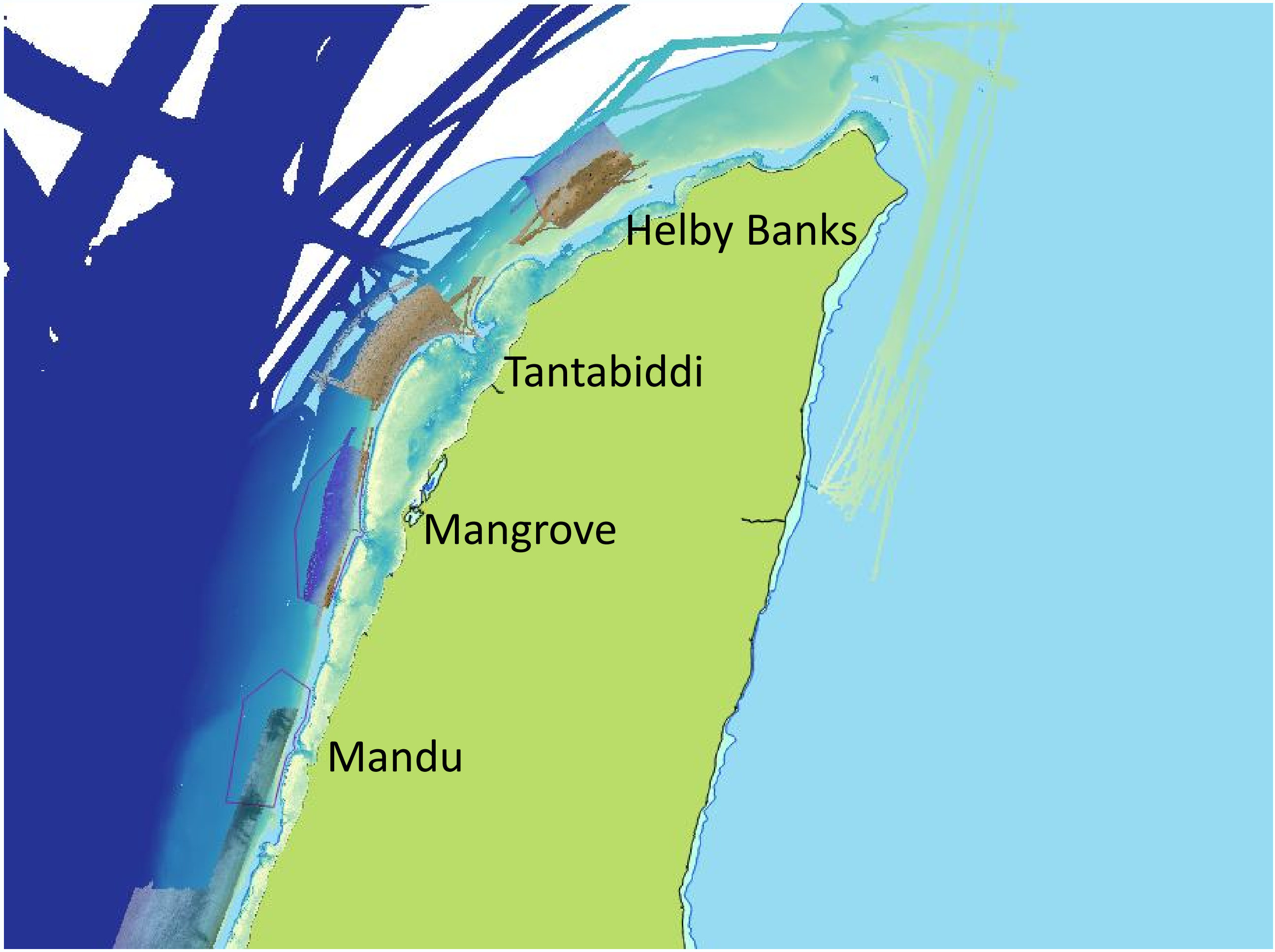
- Endurance - 8 hours (@ survey speed)
- Survey Speed – 0.3 – 0.6 m/s
- Max Speed – 1.5 m/s
- Max Current – 0.75 knots
- Survey Altitude – 0.5 - 2m typical
- Max Operational Depth – 100m
- Mass – 32 Kg
- Surface GPS
- Downward–looking altimeter
- Forward looking altimeter: obstacle avoidance
- USBL beacon – position tracking and post-hoc course data
- Lights

SBX Sensor Payload

Science Systems

- CTD (Seabird)
- Wetlabs EcoTriplet (down)
  - Backscatter (700nm)
  - Chl-A
  - CDOM
- Licor PAR (up and down)
- Aanderraa Oxygen Optode
- Additional science port
- Downward facing cameras

Target areas



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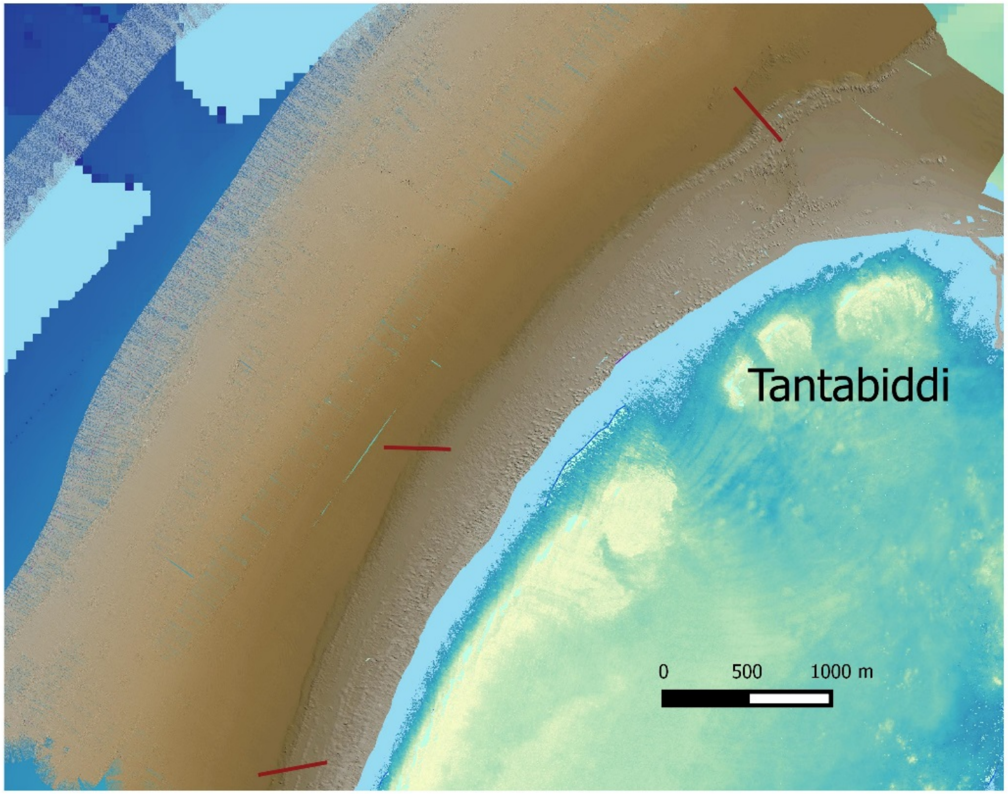
Deep Reef Ecology

Nov 2016, most recent mission

- 3 days
- >4km of transects
- 12-49m depth
- >16,000 images



Water Column Characterization

- 11MB sensor data

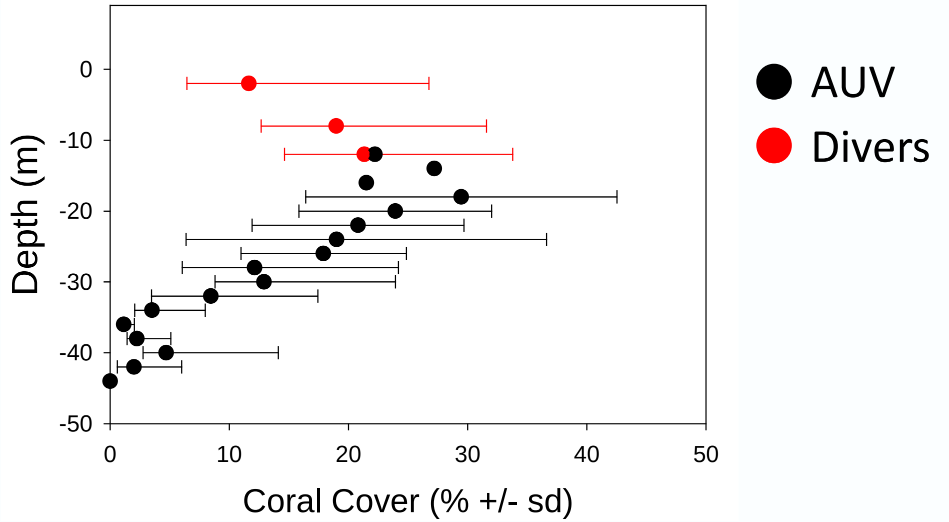
Ningaloo

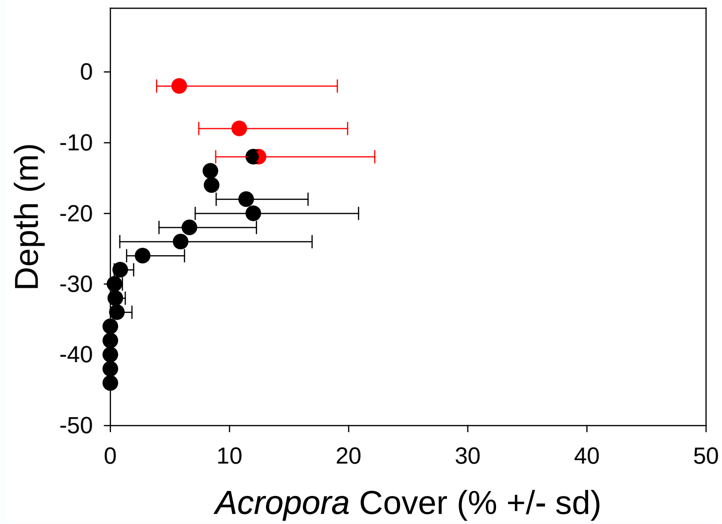
Deep Reef Ecology

Results

Coral Distribution

- Depth Extent
- Composition
- Peak in cover @ 20m





Ningaloo

Deep Reef Ecology

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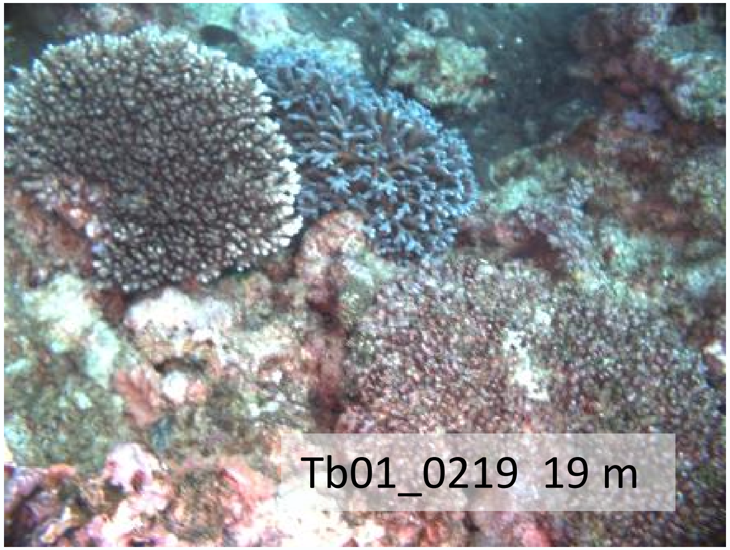

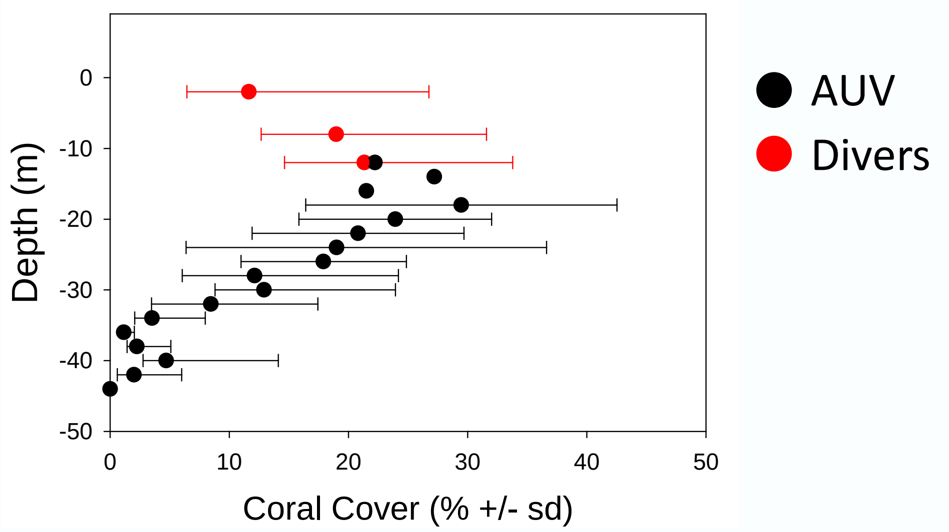

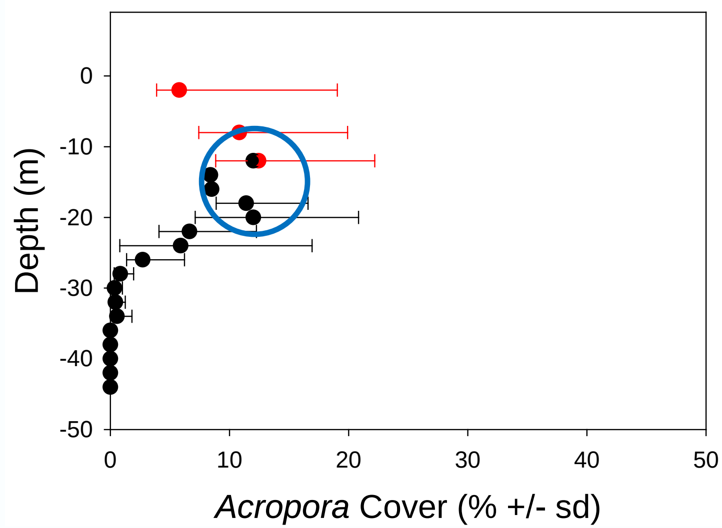

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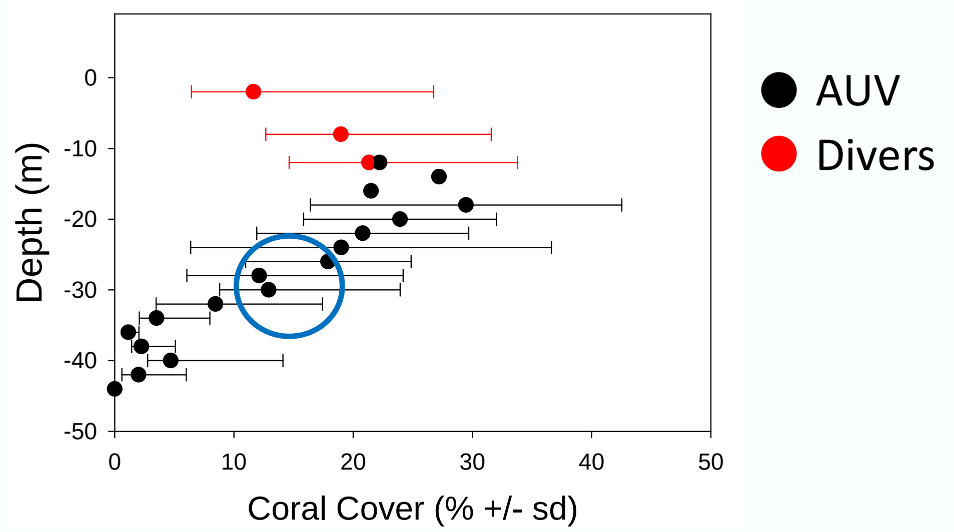

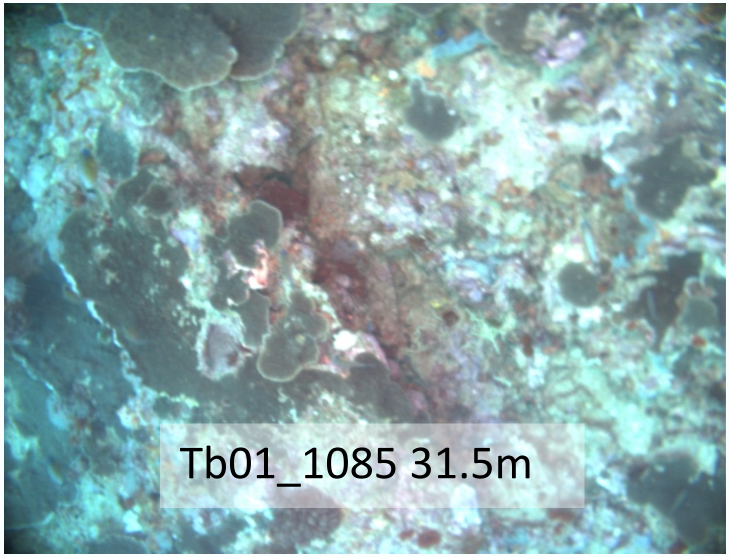

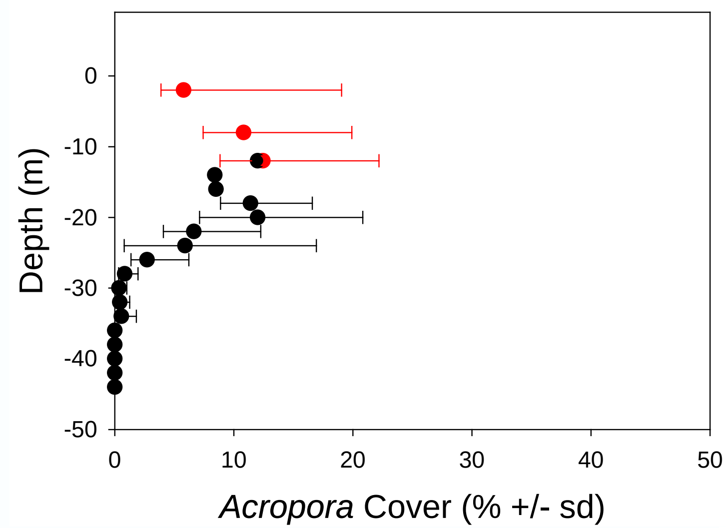

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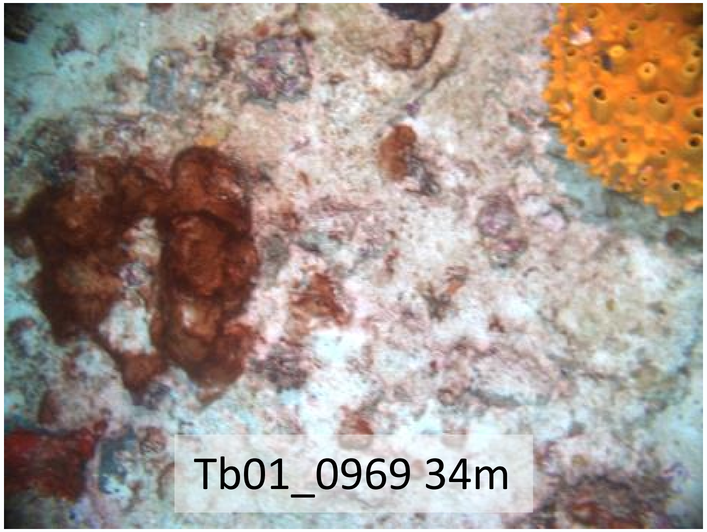
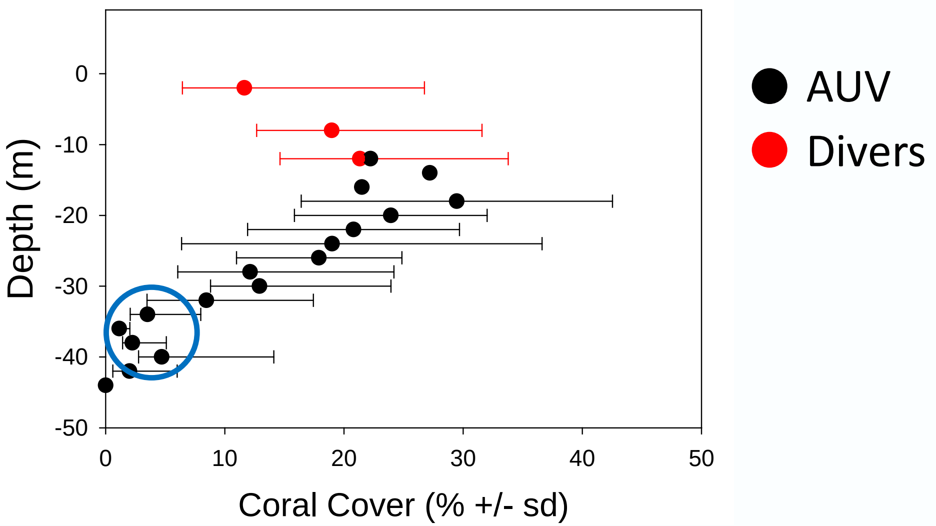
Deep Reef Ecology

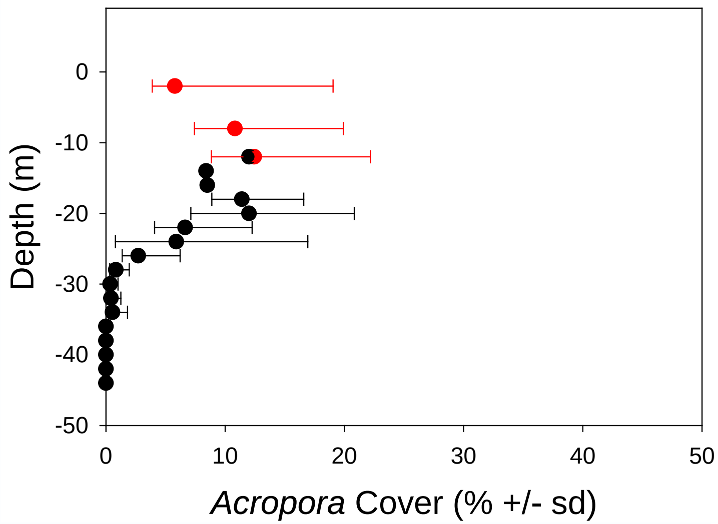
Results

Coral Distribution

- Depth Extent
- Composition
- Peak in cover @ 20m







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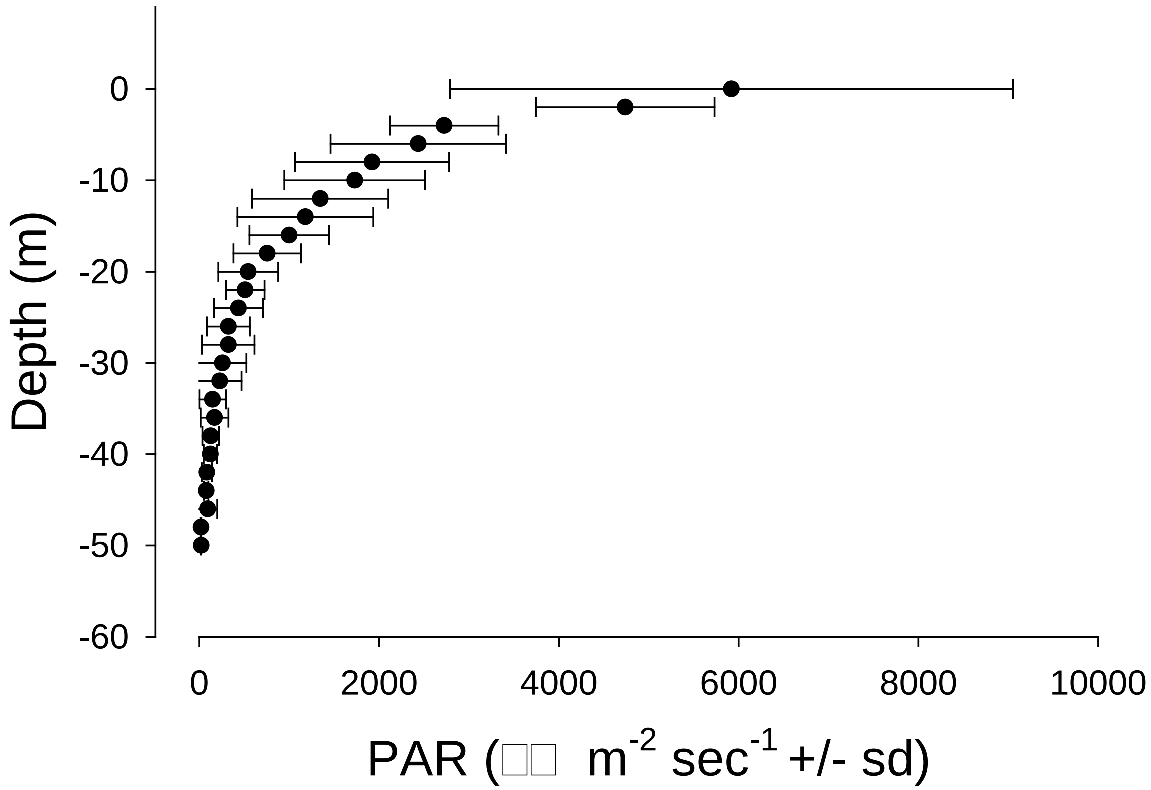
Deep Reef Ecology

Results

Water Column Characterization

- Light vs Depth profile (PAR)



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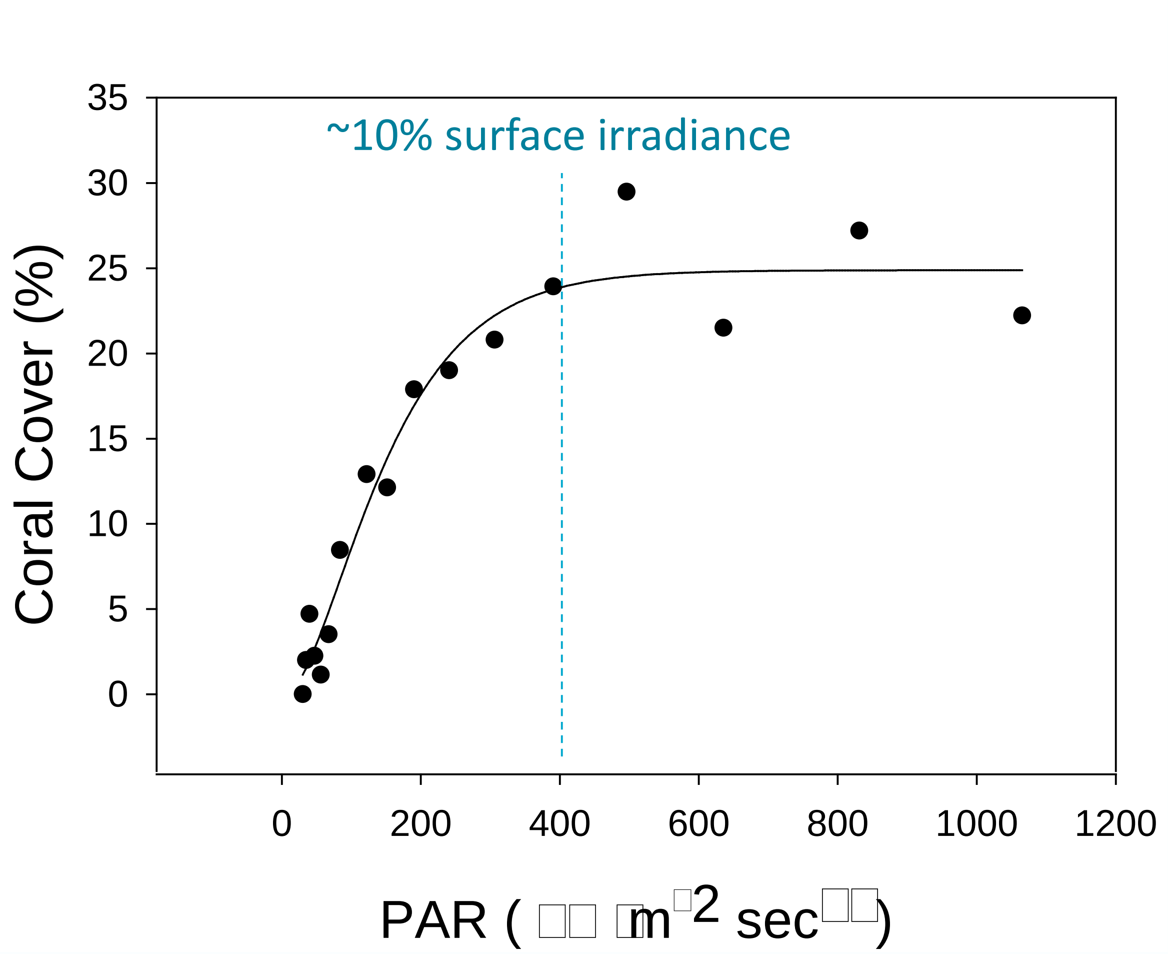
Deep Reef Ecology

Coral Distribution

- Cover declines as light reduced below 10%



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Deep Reef Ecology

Coral Distribution

- Global light limits

Location	Species	Depth	% PAR	Source
Hawaii	*Leptoseris hawaiiensis*	153	0.07	Kahng and Maragos (2006) and Kahng and Kelley (2007)
Red Sea, Gulf of Aqaba	*Leptoseris fragilis*	145	0.11	Schlichter et al. (1986) and Fricke et al. (1987)
Bahamas, San Salvador	*Agaricia* sp.	119	0.15	Reed (1985)
Puerto Rico	either *Agaricia* or *M. cavernosa*	90	0.29	Garcia-Sais et al. (2007)
West Florida Shelf	*Agaricia* sp., *Madracis decactis*	80	1.00	Phillips et al. (1990), and Jarrett et al. (2005)
Curacao	*Montastraea cavernosa, Agaricia*	80	0.65	Van den Hoek et al. (1978) and Vermeij and Bak (2002)
Okinawa	*Pachyseris speciosa, Favia speciosa*	>70		Yamazato (1972)
Chagos Islands	Unspecificed	>60		Sheppard (1980) and Sheppard (1981)
East Florida Shelf	*Oculina vericosa* (zooxanthellate)	40	5.84	Reed (1980)
Ningaloo	Scleractinia	42	1.4	Current study

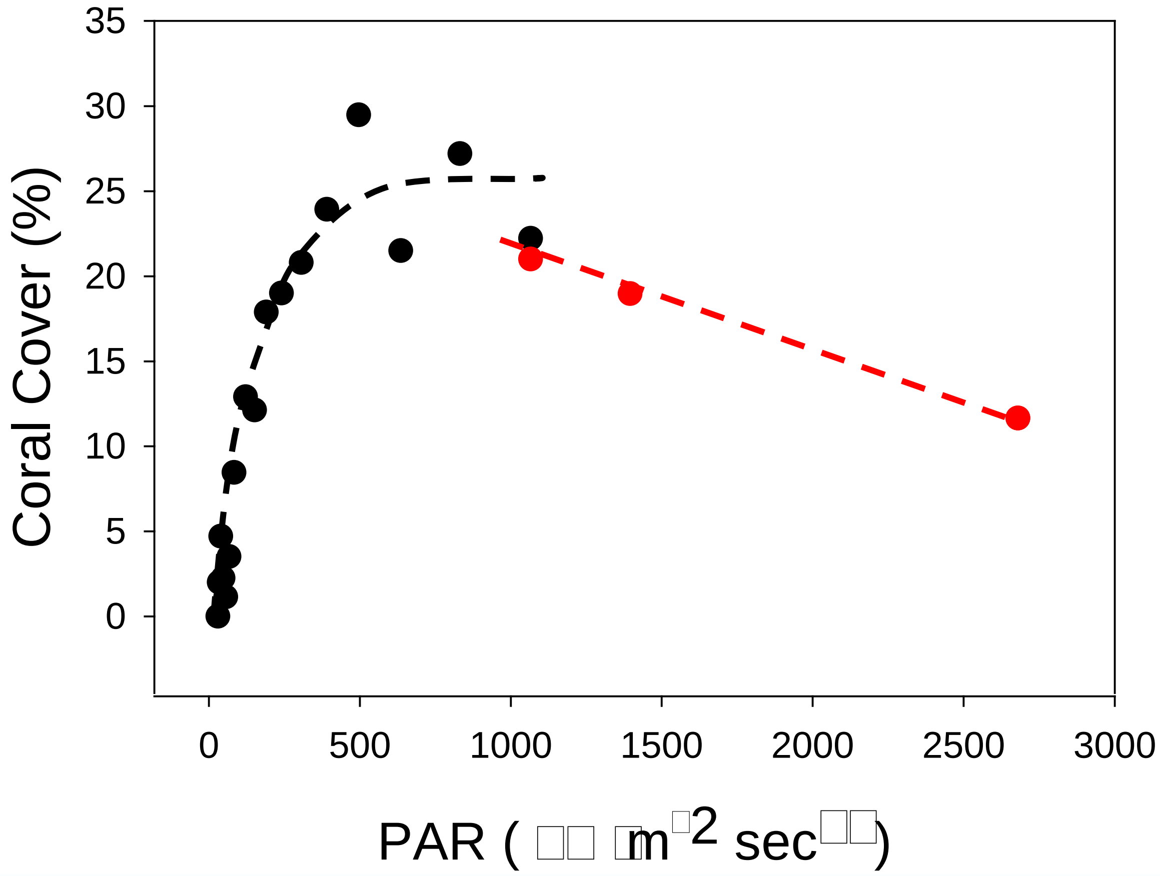
From Kahng et al. 2010

Ningaloo

Deep Reef Ecology

Coral Distribution

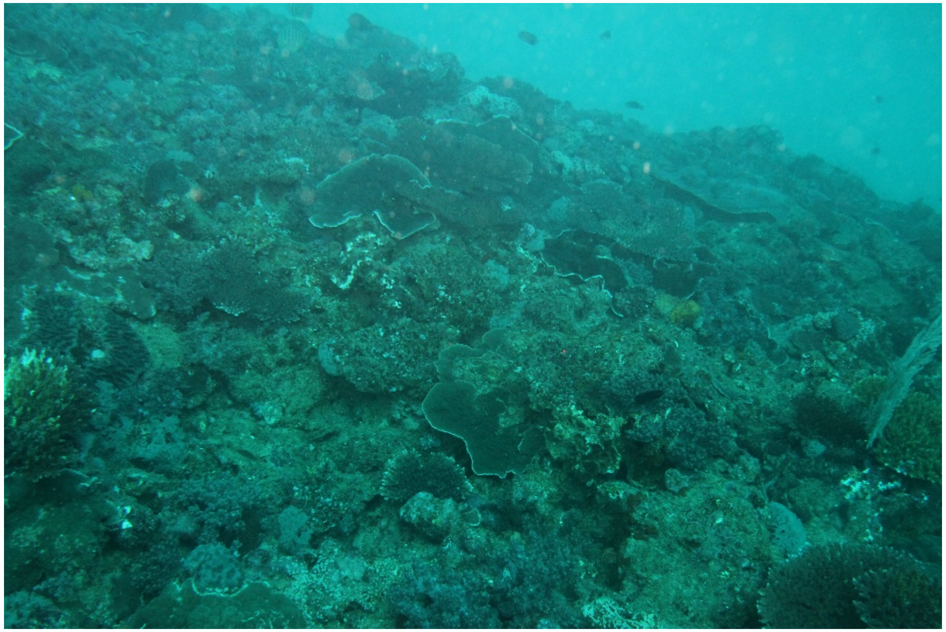
- Are different processes limiting coral cover in deep and shallow reefs?



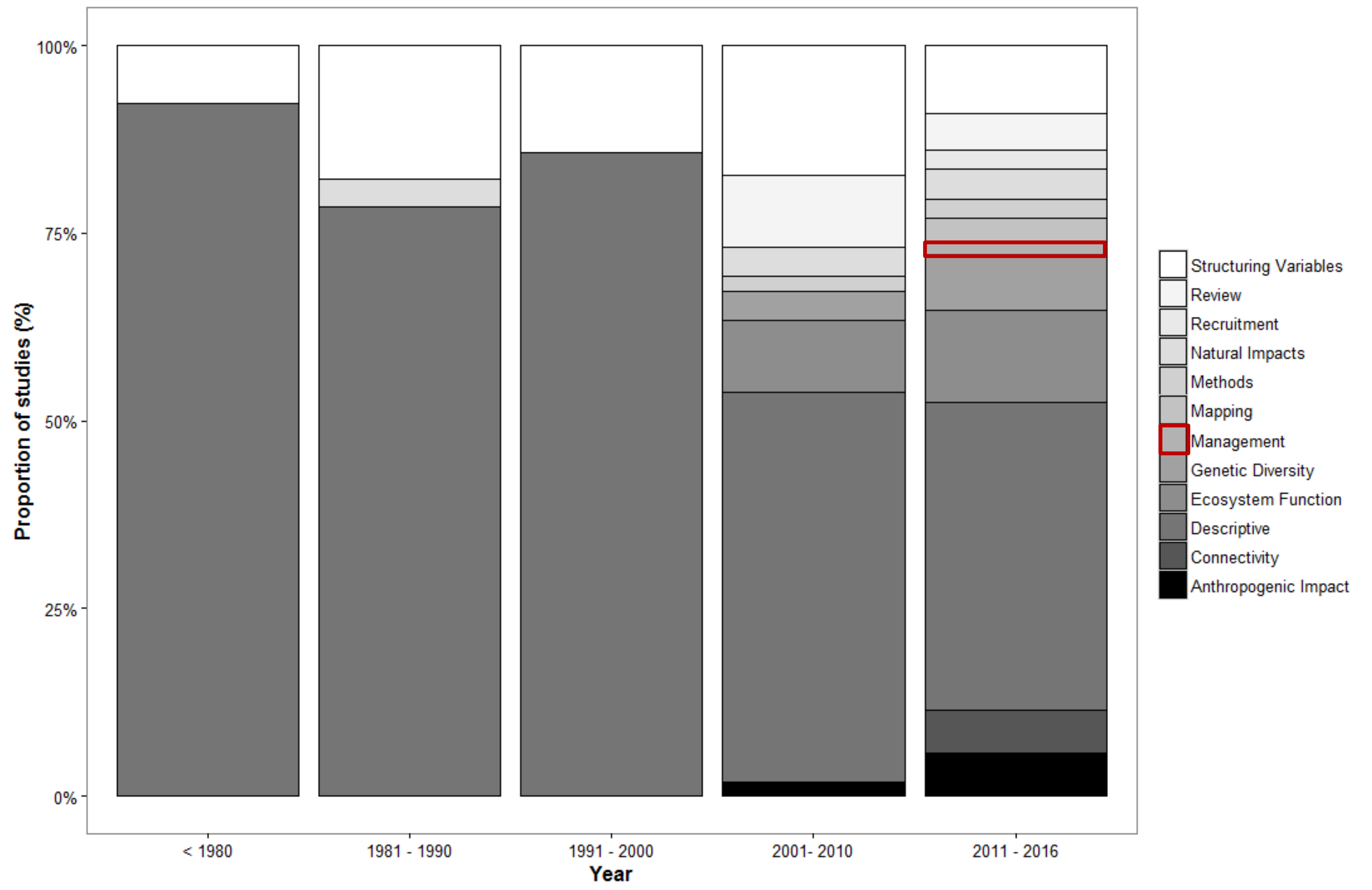
Deep reef research for management

Future research

- New information for the long term protection of deep water habitats
- Repeated observations to detect important variations and trends
- Target 20m stratum for increased ability to detect change
- Compare and contrast shallow and deep reef dynamics and factors limiting coral cover (light vs disturbance)



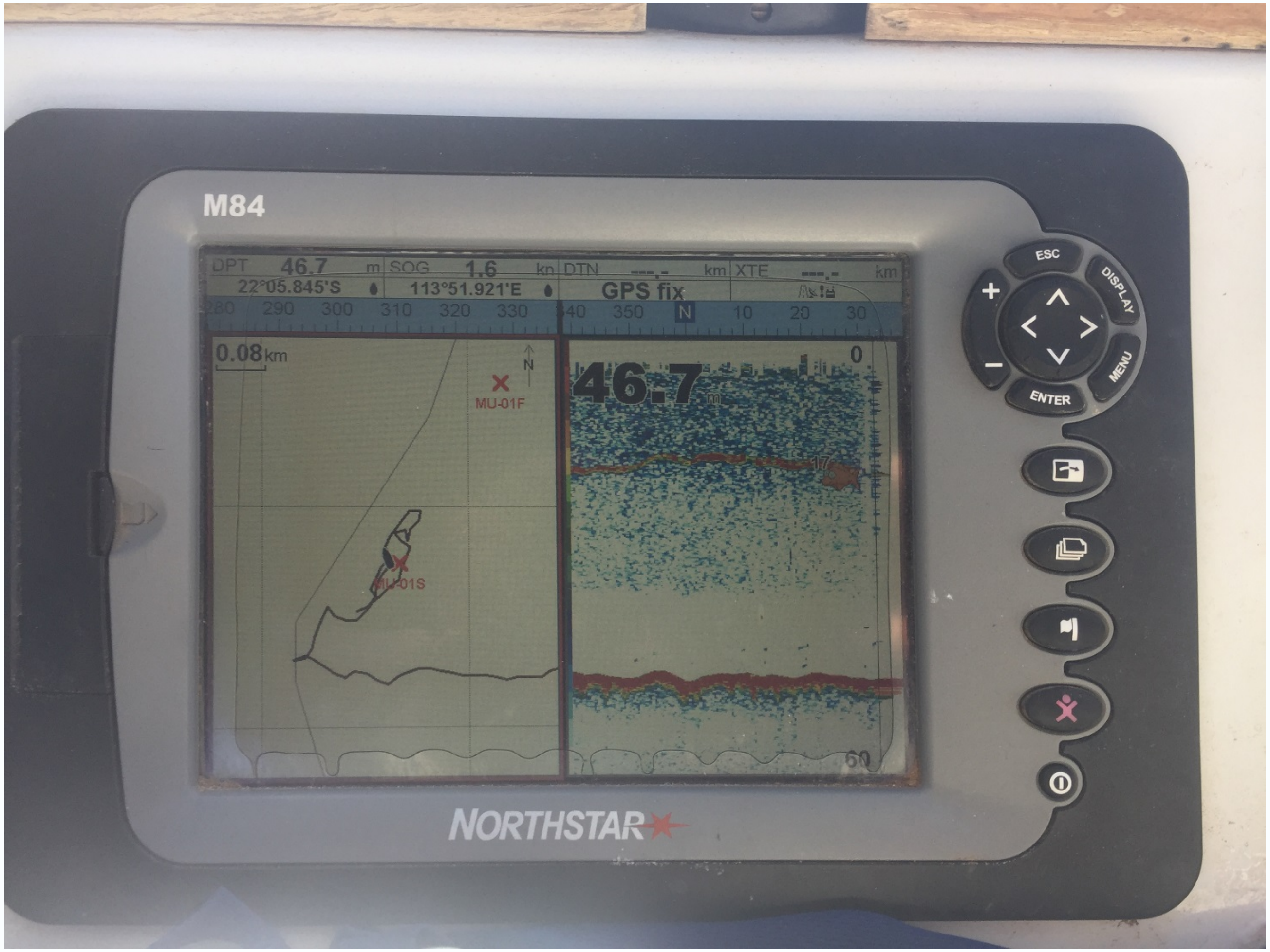
Deep reef research for management



(Turner et al. Review)

Other observations and discoveries

water column structure and biology



Other observations and discoveries

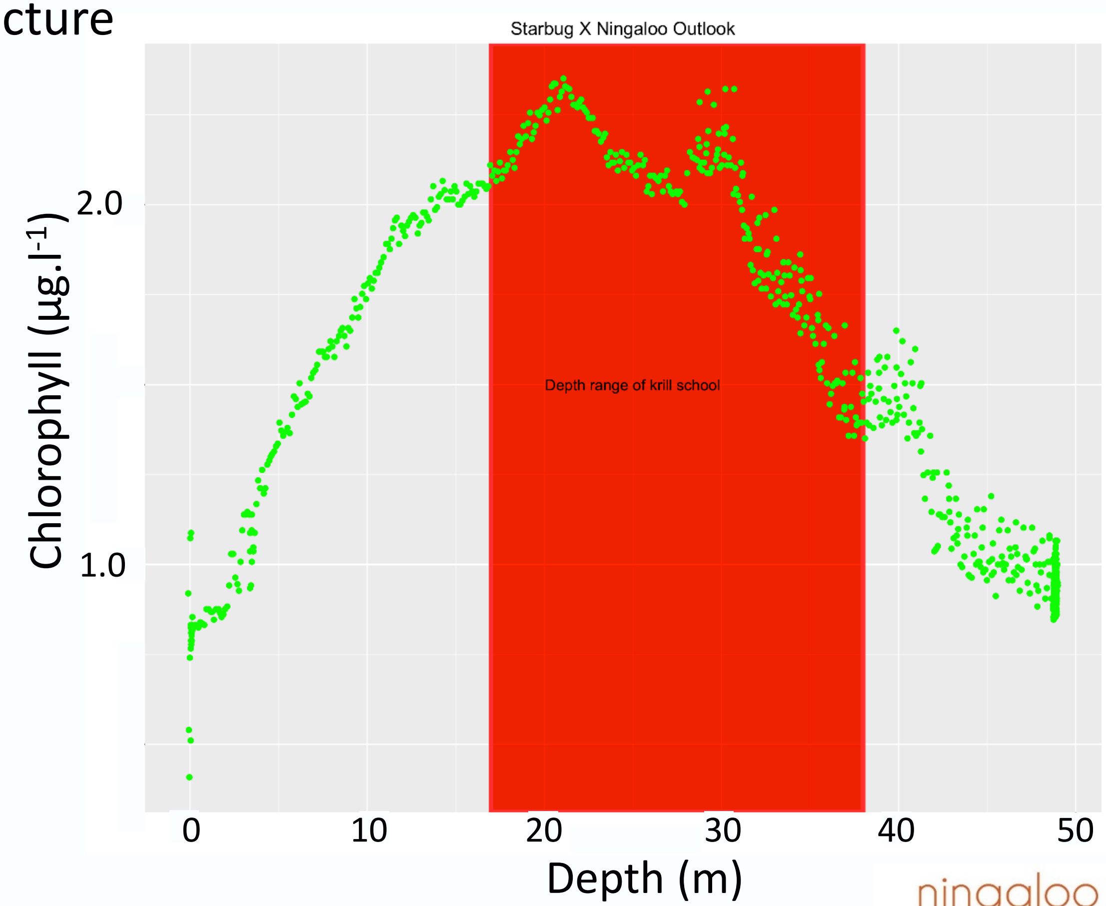
water column structure and biology

Water Column Characterization

- Example of water column structure and biology

krill

Mu01_0165 32m

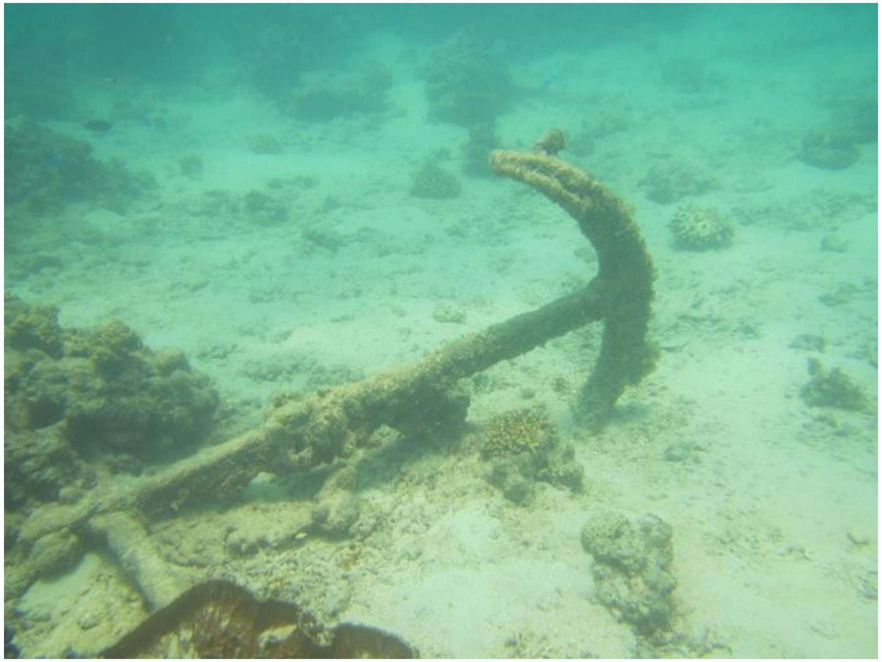


Other observations and discoveries

Opportunistic Discovery

19th Century anchor

- Detected on reviewing video
- Located using SBX track
- Details provided to WA Maritime Museum



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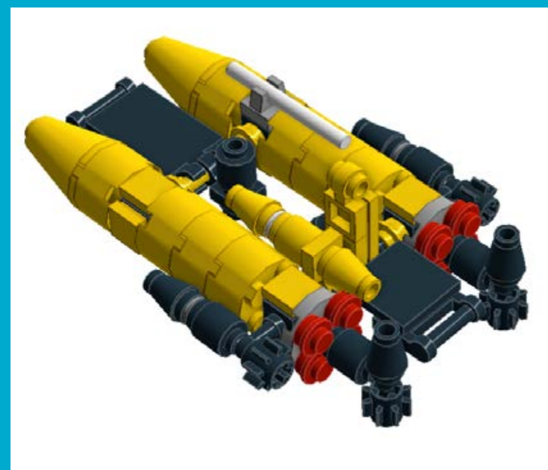

https://www.etsy.com/au/shop/L360ofOcean $19.99

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Global studies of Mesophotic Coral Ecosystems (MCEs) – Ningaloo in context

Joe Turner PhD Scholar

Supervisors: Gary Kendrick, Renae Hovey, Russ Babcock

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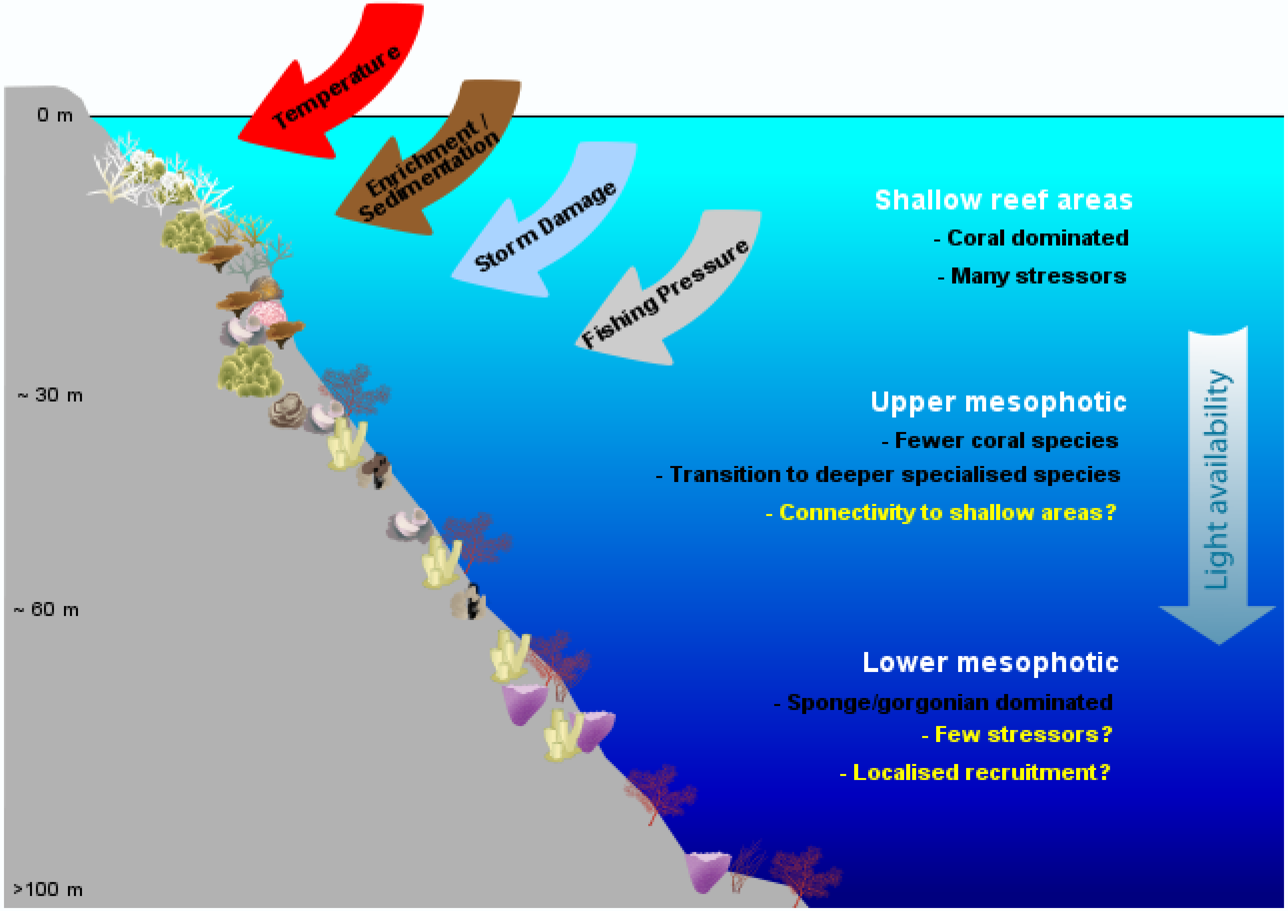
Deepwater (mesophotic) reefs

- What are mesophotic reefs?



Global mesophotic reefs

Aim:

Identify the current extent of knowledge on mesophotic coral ecosystems (MCEs) in terms of:

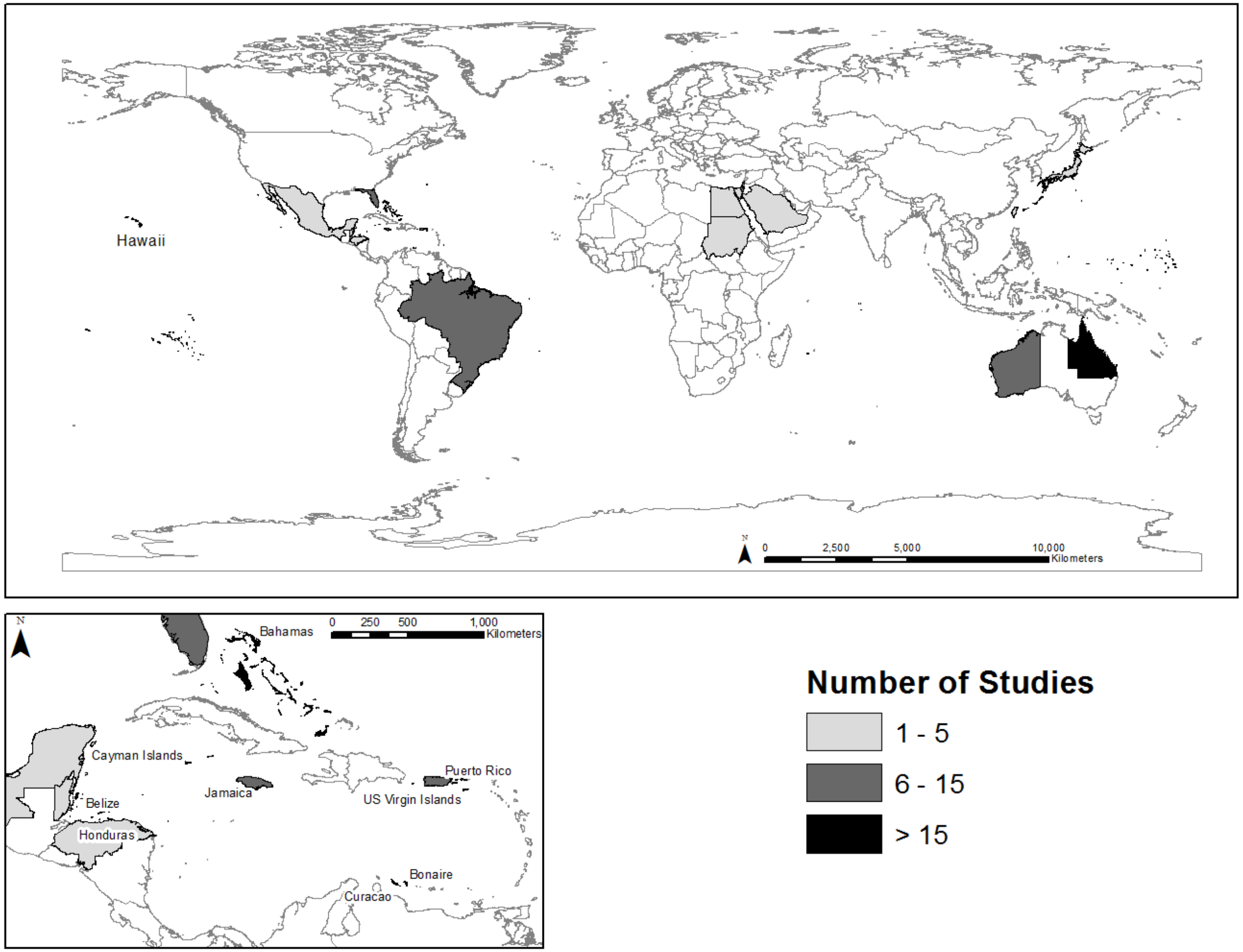
- **Where are MCEs located? And where are studies being conducted?**
- **The trends in MCE research**
- **The methods use to research MCEs**
- **The broad differences in the biological assemblages**

Global mesophotic reefs

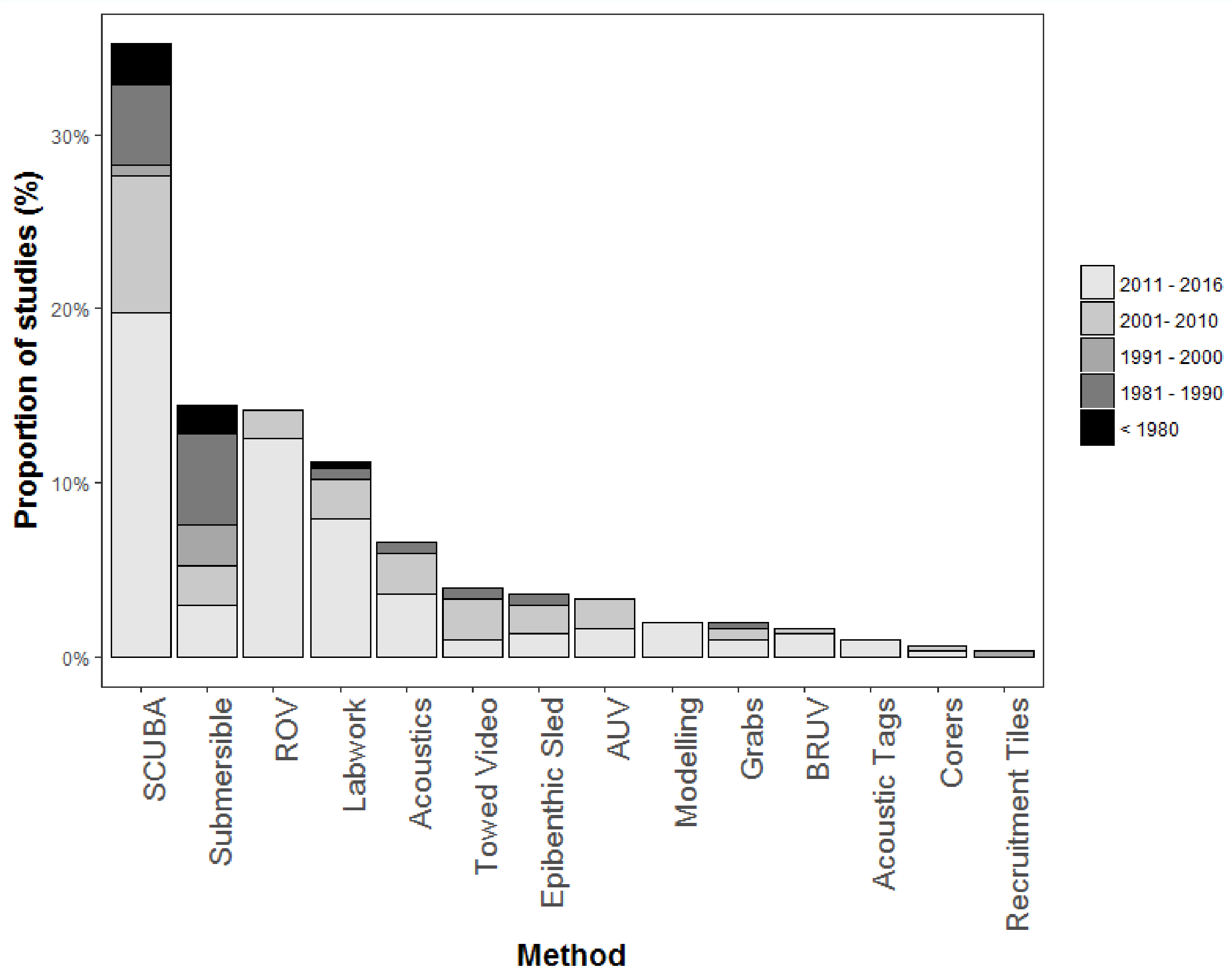
- Methods:
  - Thorough search of databases (Google Scholar, Scopus, Web of Science)

  - Information on each paper will be entered into a database, including:
    - Basic information (authors, year, title, journal and number of citations)
    - Geographic location (split into region, country and specific study area)
    - Date
    - Primary focus
    - Methods used
    - Depth range investigated and
    - When possible, ecological aspects such as species diversity, deepest records and the transition depth between communities were noted

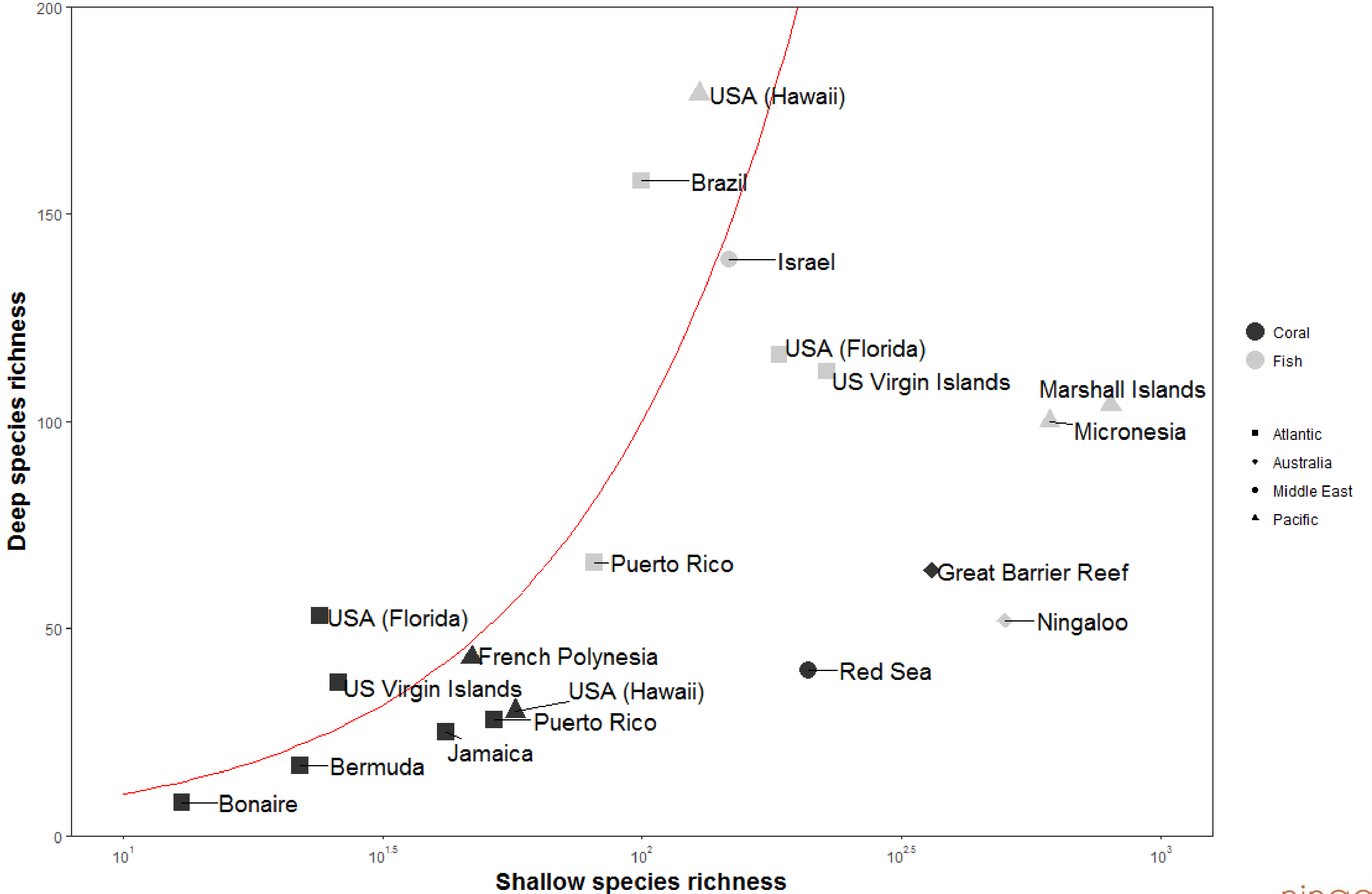
Global mesophotic reefs



Global mesophotic reefs



Global mesophotic reefs



Global mesophotic reefs

Region	Country	Depth (m)	Reference
Atlantic	Bahamas	119	(Reed 1985)
	Barbados	74	(Bak 1975)
	Bermuda	78	(Fricke and Meischner 1985)
	Curacao	91	(Bongaerts et al. 2015)
	Jamaica	> 120	(Goreau and Goreau 1973)
	Puerto Rico	90	(Garcia-Sais et al. 2007)
	USA (Florida)	80	(Reed 1980)
	USA (Gulf of Mexico)	84	(Rezak and Bright 1985)
Australia	Australia (GBR)	125	(Englebert et al. 2014)
	Australia (Ningaloo)	60	(Rees et al. 2004)
Middle East	Israel	201	(Fricke and Knauer 1986)
Pacific	Hawaii	153	(Kahng and Marcos 2006)
	Johnston Atoll	165	(Maragos and Jokiel 1986)
	Marshall Islands	112	(Colin et al. 1986)
	Samoa	110*	(Bare et al. 2010)

Global mesophotic reefs

Conclusions:

- Research highly localised – particularly in the Caribbean
- Research trends are diversifying
- Methods are diversifying
- MCEs can vary between regions
- Early definitions may not be appropriate for all MCEs

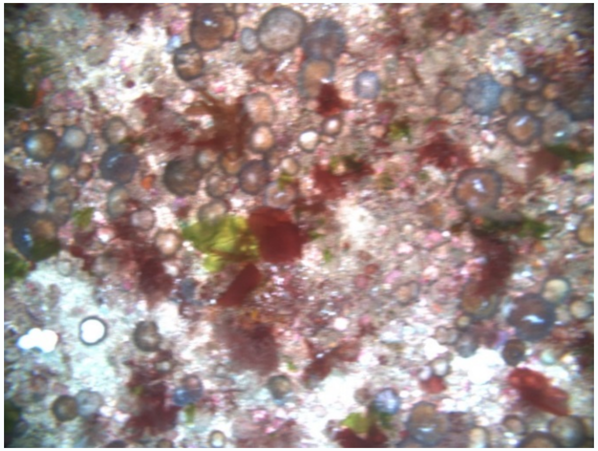
Ningaloo mesophotic communities

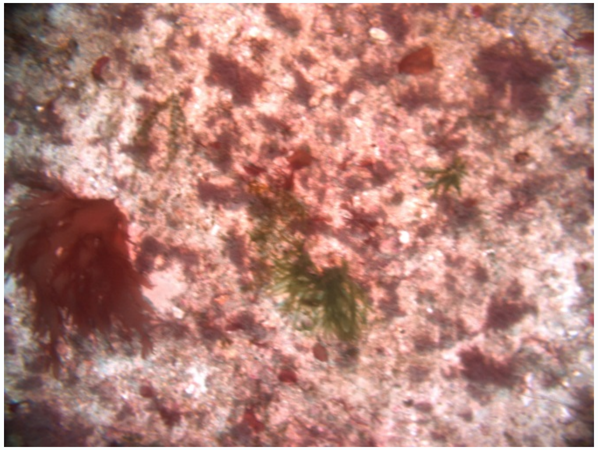
Aim:

Quantitatively determine and describe the communities present at mesophotic depths

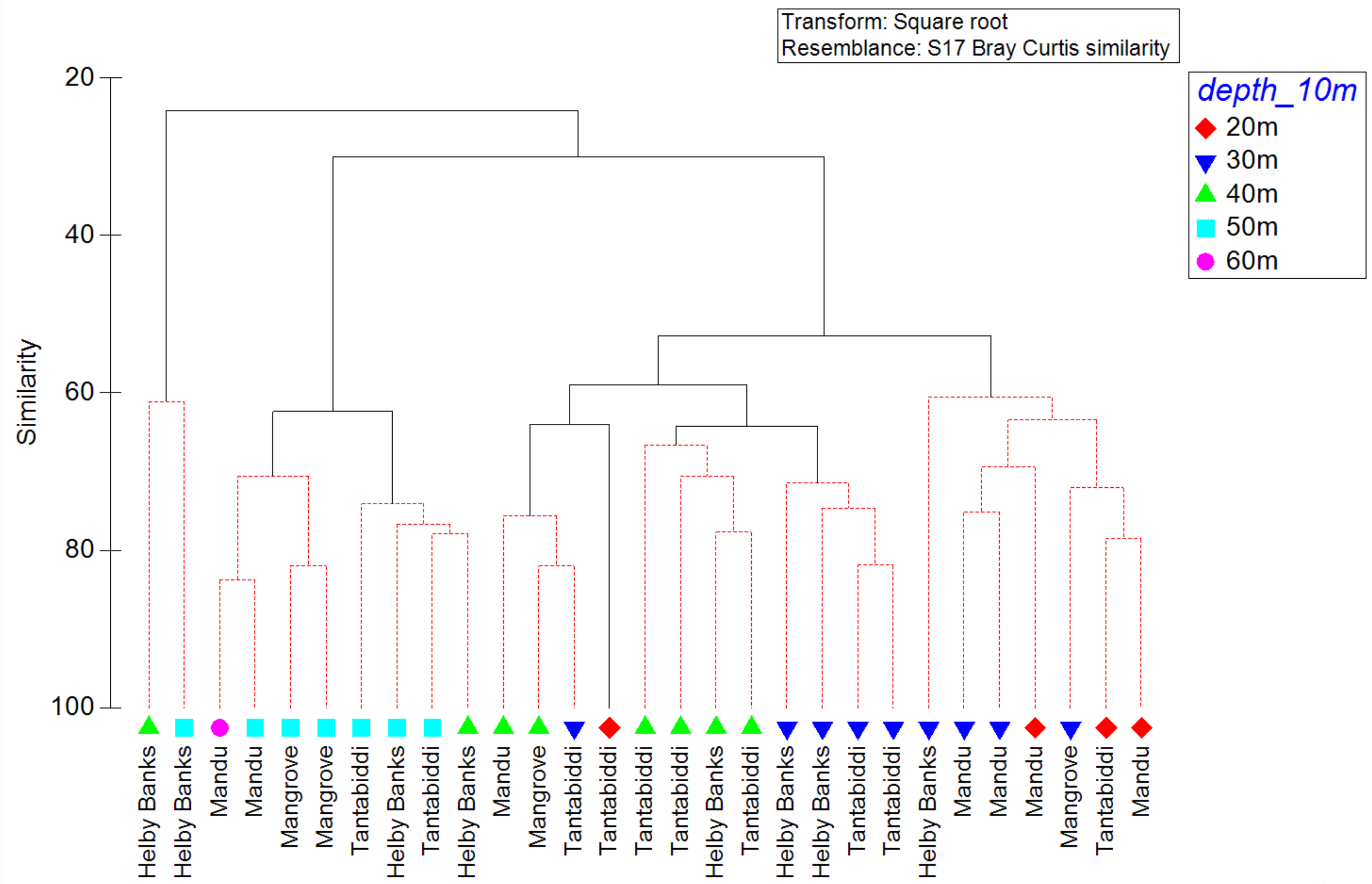
- High coral cover (20 – 50 %) has been observed in northern areas of the park, Mandu, although below 50 m hard corals are rare (Rees et al. 2004)
- Likely due to factors such as increased turbidity, sediment scour, strong currents and substratum limitation
- The deeper areas of Ningaloo are characterised by sponge gardens with many of these species not being found in shallower waters (Rees et al. 2004)
- Randomly selected images from Starbug AUV transects for analysis

Biological Communities

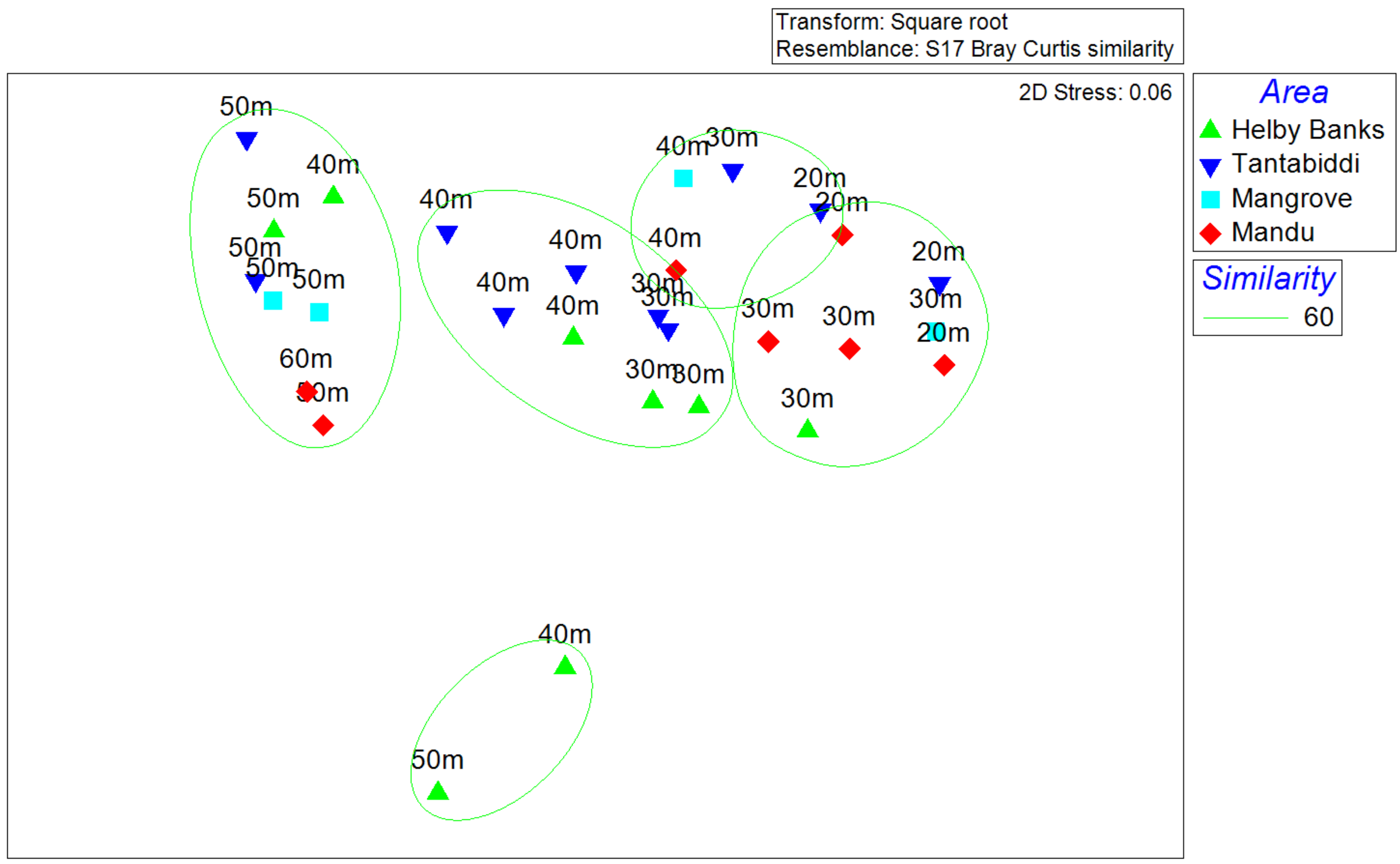




Biological Communities



Biological Communities



Biological Communities

- **BIOENV** results

Variables	Rho correlation	p-value
Depth	0.427	0.001
Depth + Chlorophyll	0.424	0.001
Depth + Chlorophyll + Light Energy	0.424	0.001
Depth + Light Energy	0.399	0.001

- **PERMANOVA** (1-way, Depth category)

All pairwise comparisons significantly different except 50/60m

Table shows average similarity between/within groups

	20m	30m	40m	50m	60m
20m	45.976				
30m	38.342	38.947			
40m	30.093	35.986	40.842		
50m	7.3104	19.659	34.449	51.383	
60m	8.3458	22.505	37.412	56.51	68.859

Initial Conclusions

- The deepest areas (50 – 60m) appear to be significantly different communities.
- Broad transitional zone appears to occur
- Depth shown to be the main driver so far. Geomorphological variables will be added to the models in the future

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Theme 1 Question Time