Theme 2 – Shallow reefs

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Environmental drivers shaping the Ningaloo shallow water fish communities

Mick Haywood, Damian Thomson, Cindy Bessey, Anna Cresswell & Melanie Trapon

Ningaloo Outlook – A partnership between BHP Billiton and CSIRO

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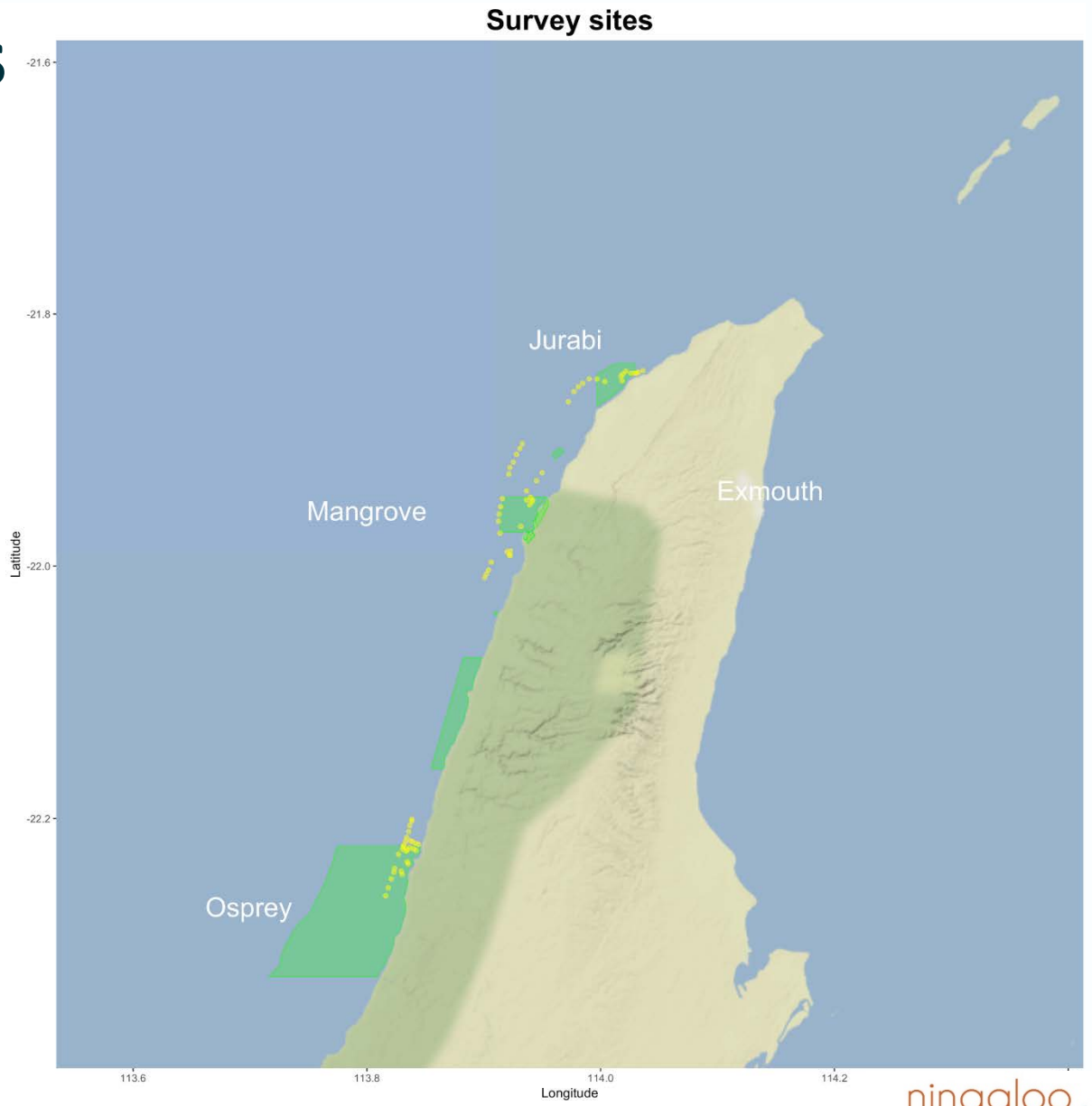
Ningaloo Outlook is a BHP Billiton-CSIRO Industry-Science Marine Research Partnership investing A$5.4 million over five years to gather new knowledge on the Ningaloo reef and its important ecological values

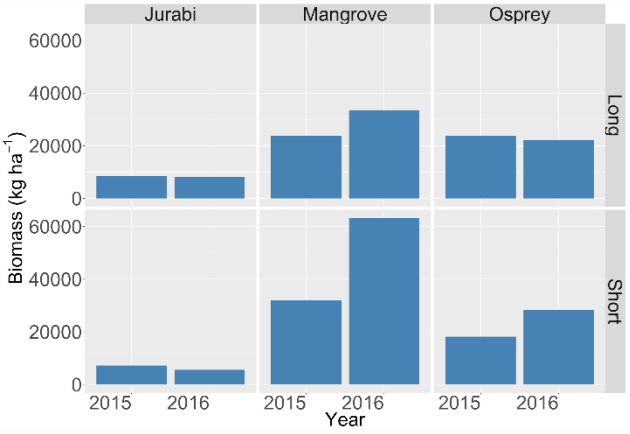
Reef fish surveys

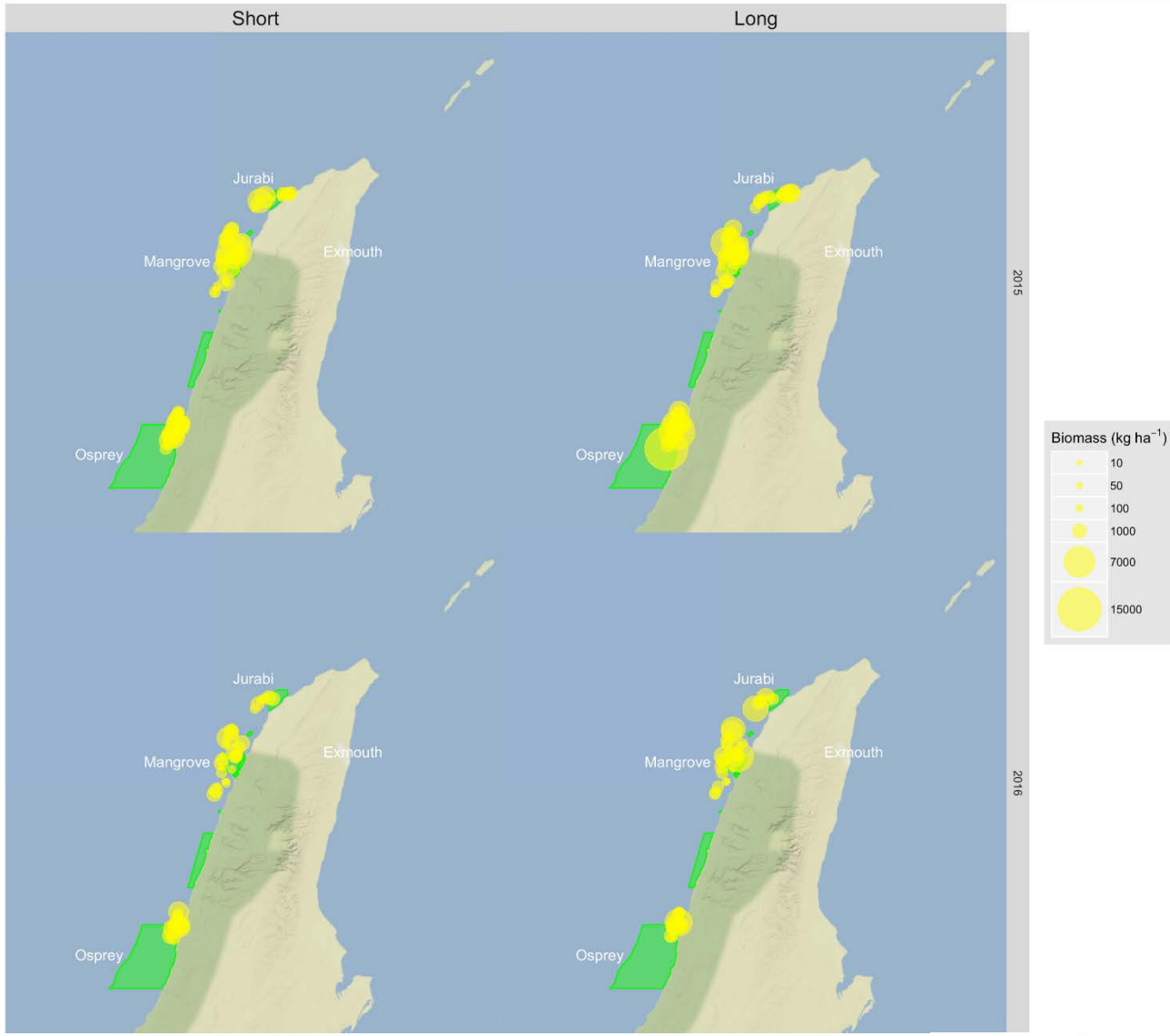
- 72 sites
- Underwater Visual Census (UVC)
- 25 & 100 m transects



Biomass

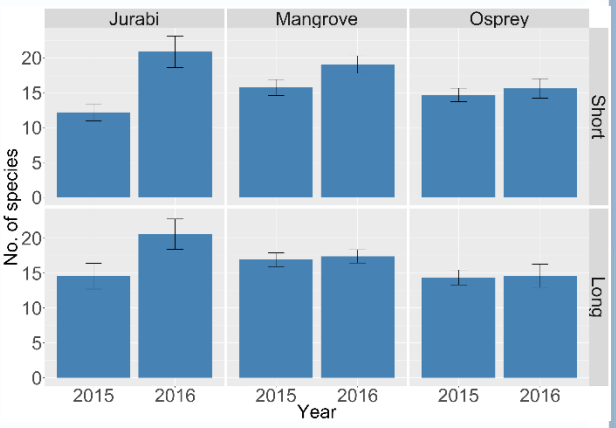
- 2015: 23,969 fish recorded
- 2016: 22,373 fish recorded

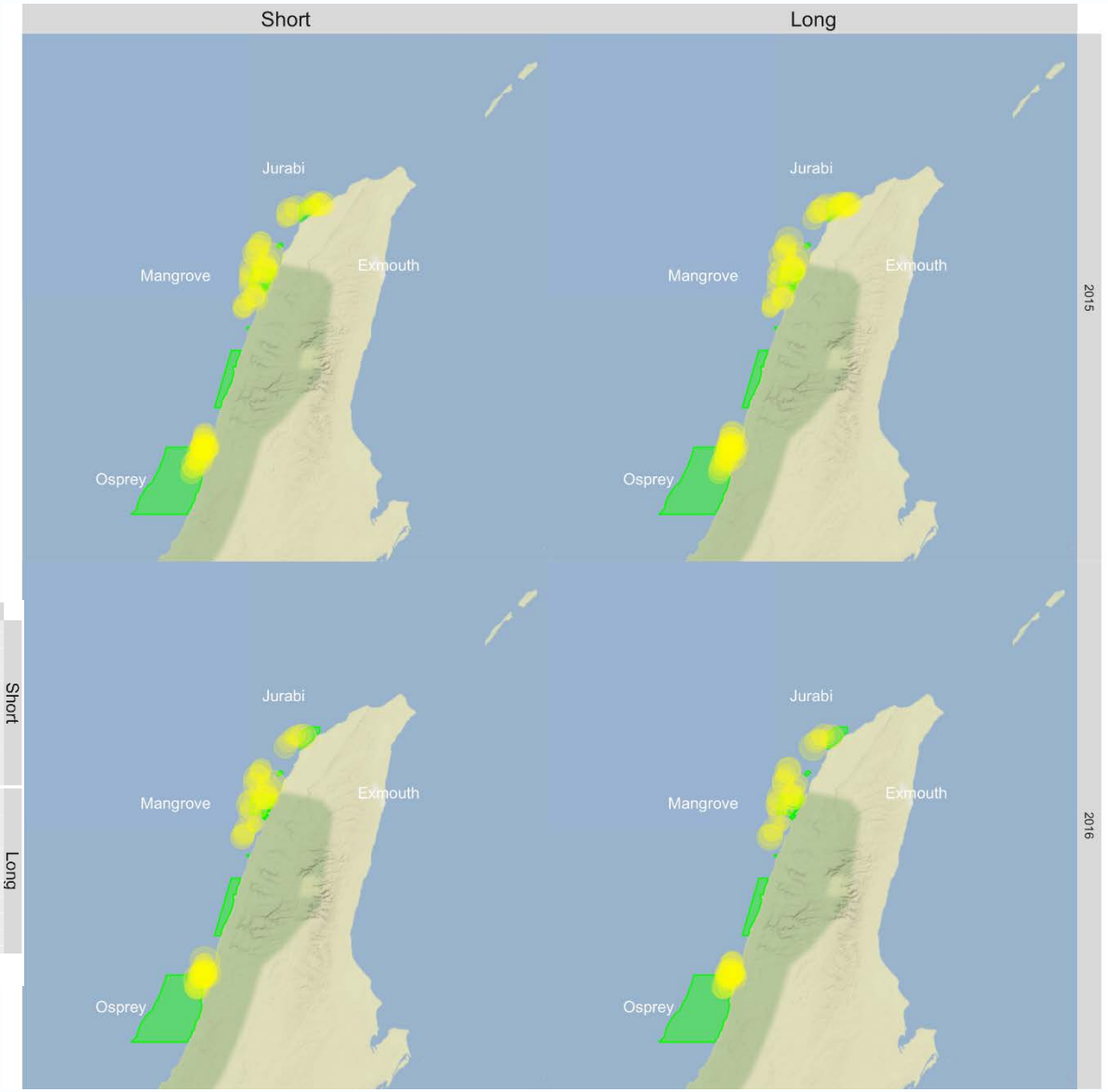




Species richness

- 268 species from 45 families





Effect of habitat on species richness (GAM; mgcv)

Parametric coefficients

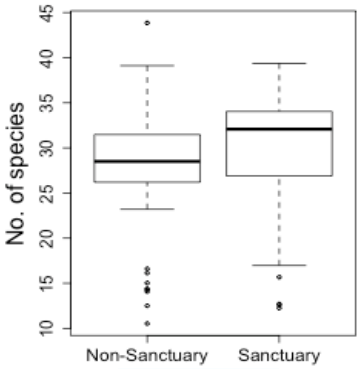
Variable	Estimate	SE	z	Pr(>|z|)
Intercept	3.319	0.034	96.84	<0.0001***
Soft coral	-0.019	0.007	-2.82	0.004**
Management Status	0.157	0.049	3.21	0.013**

Smooth terms

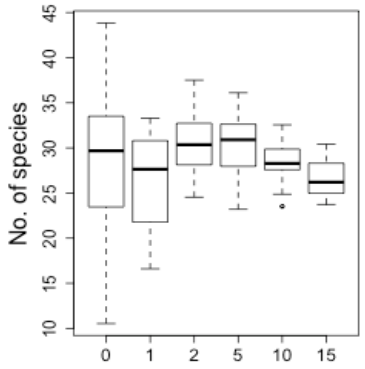
Variable	edf	Ref.df	Chi.sq	P-value
S(Rugosity)	2.50	3.031	13.85	0.003**
S(Bottom velocity)	3.53	4.356	23.66	0.0001***
S(Hard coral)	7.33	8.220	93.62	<0.00010***

Deviance explained = 57.1%

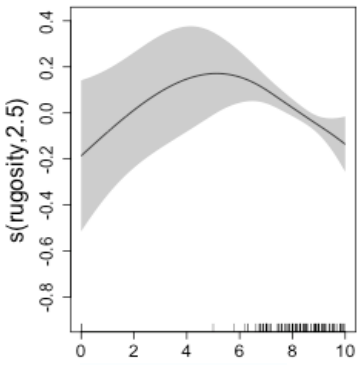
AIC = 861.4



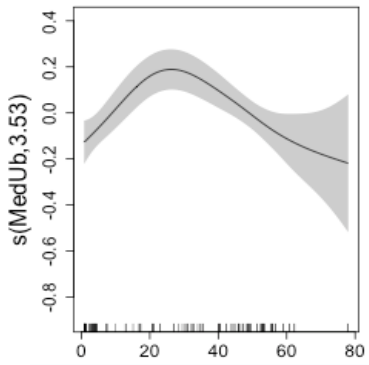
Status



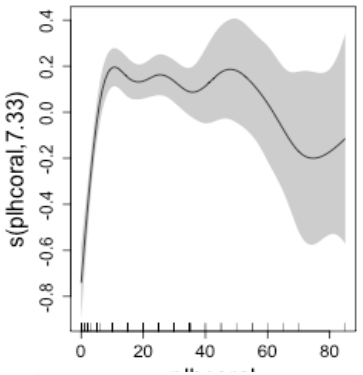
Soft coral cover



Rugosity

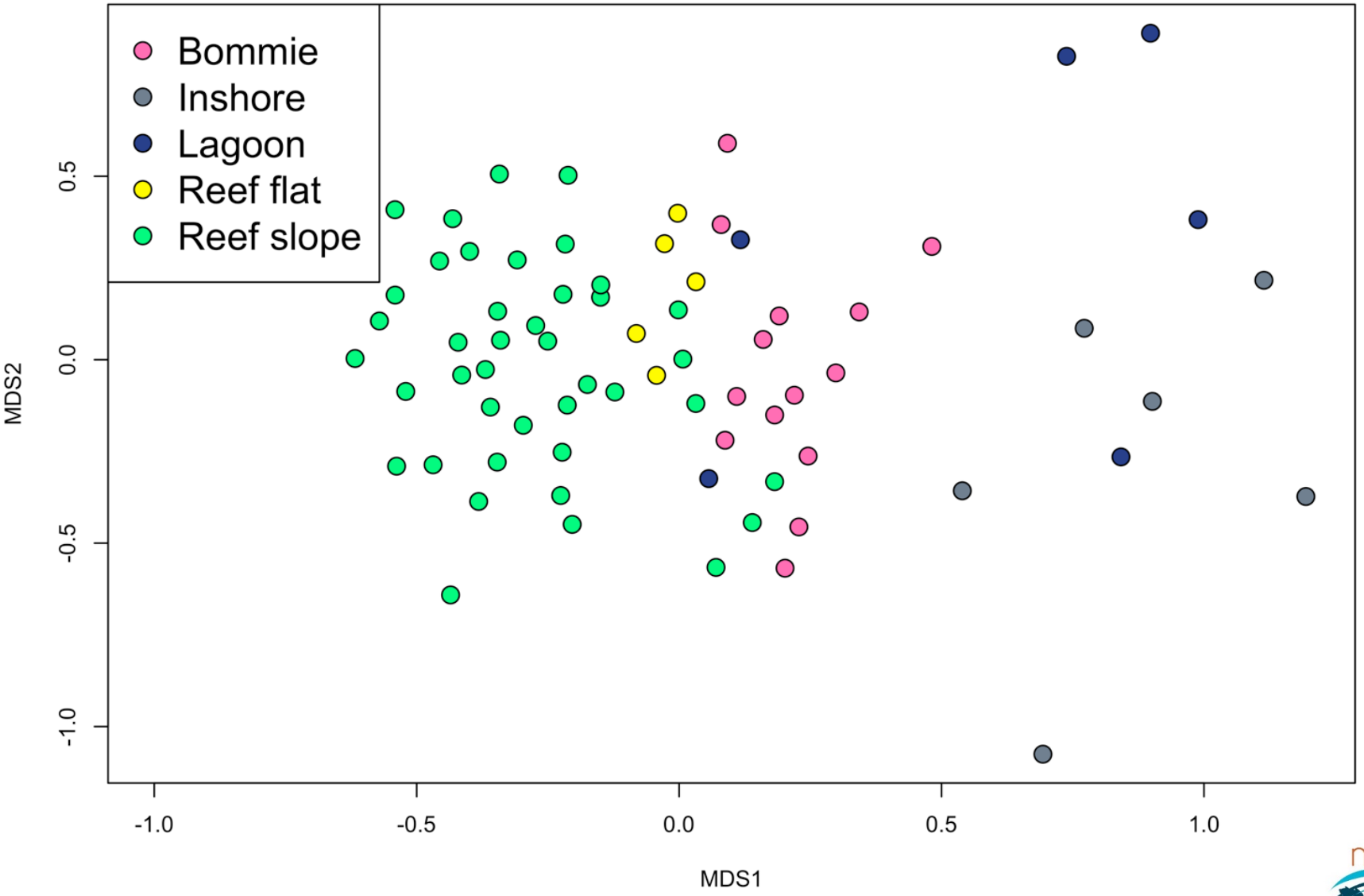


Bottom velocity

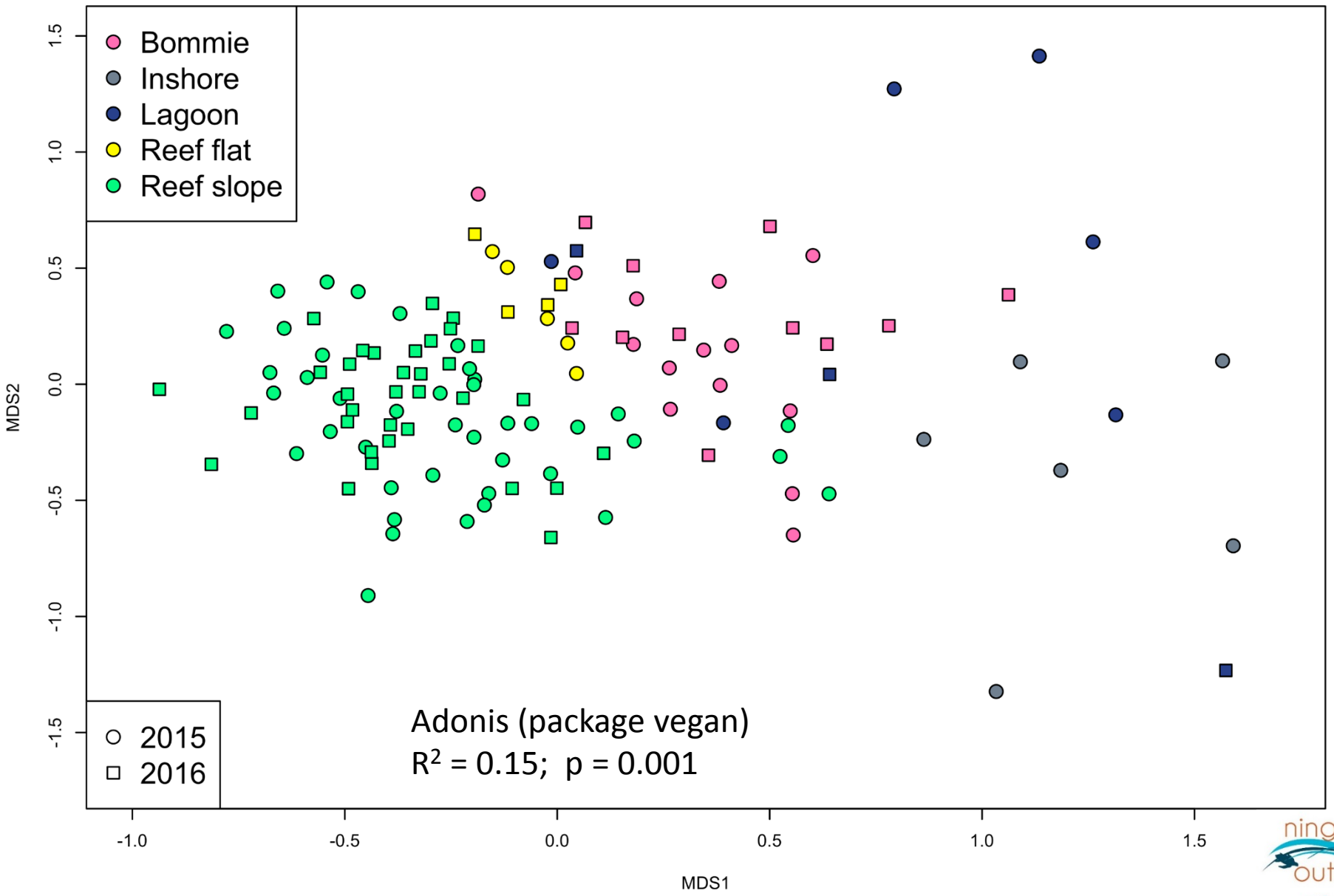


Hard coral cover

Fish community: 2015 100 m transects



Fish community: 2015 & 2016 100 m transects



Species responsible for differences (SIMPER)

	Average biomass (kg ha^{-1})	
	Reef Slope	Reef Flat
Ctenochaetus striatus	6.35	1.03
Acanthurus dussumieri	6.22	2.85
Naso unicornis	5.52	4.32
Scarus rubroviolaceus	4.93	0.56
Chlorurus microrhinos	4.29	0
Chlorurus sordidus	4.14	9.30
Scarus rivulatus	0.60	6.75
Acanthurus triostegus	3.28	6.70
Scarus frenatus	3.49	4.62
Scarus schlegeli	2.87	5.26


Chlorurus sordidus (Gaia Guide)

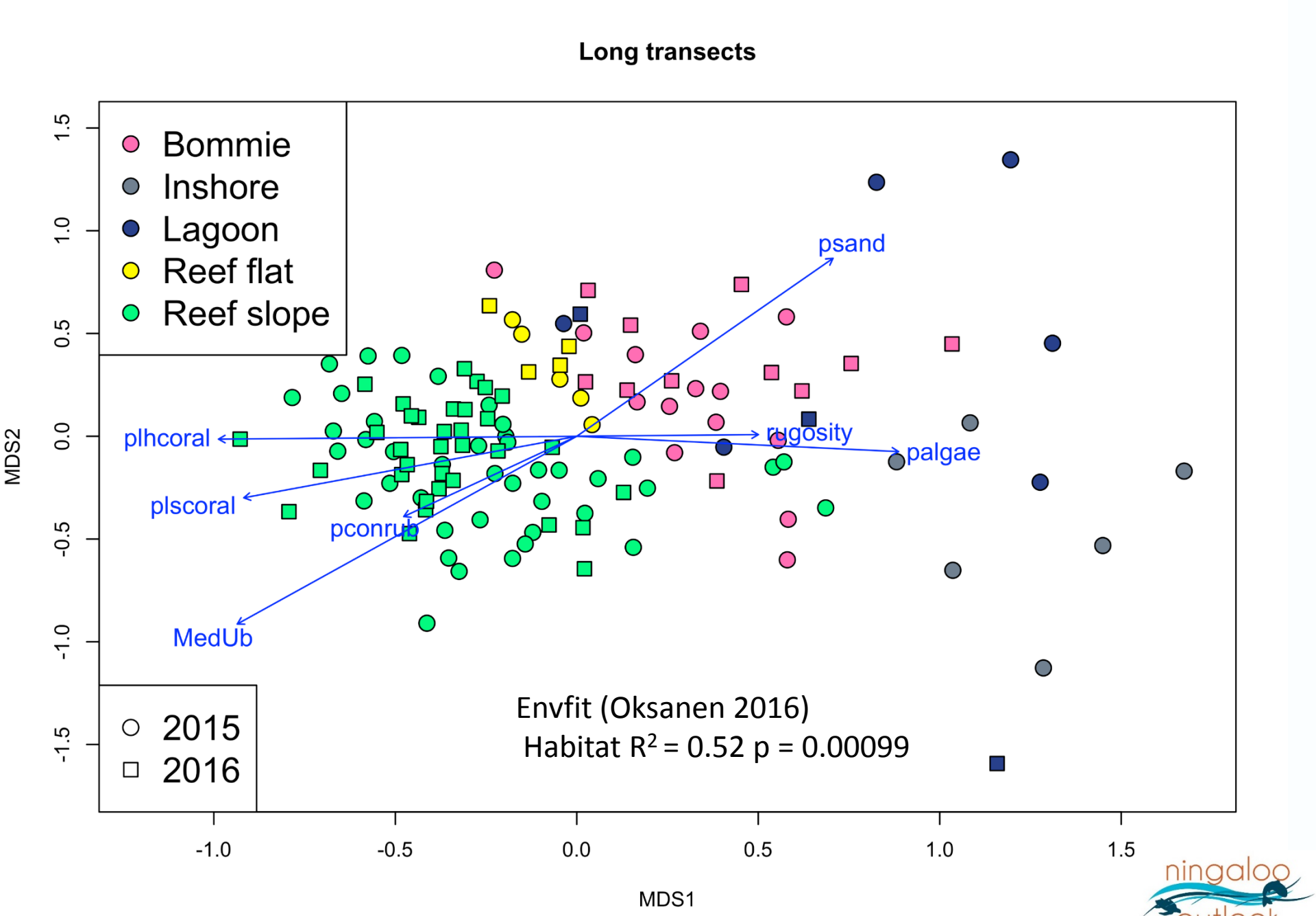

Scarus rivulatus

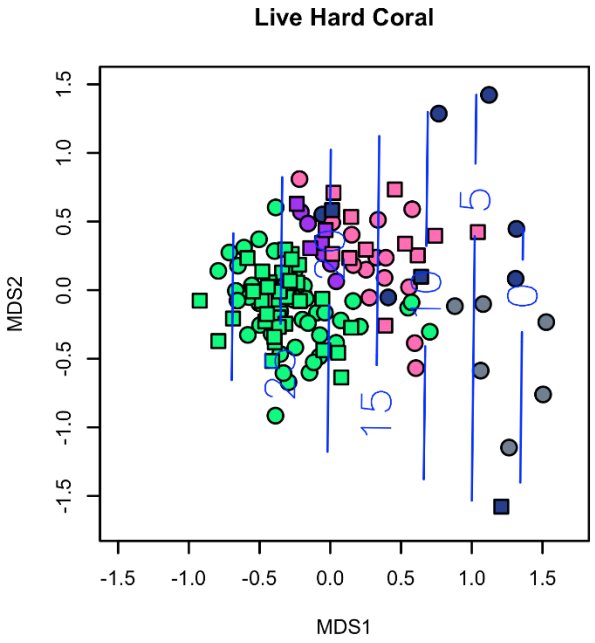

Acanthurus triostegus

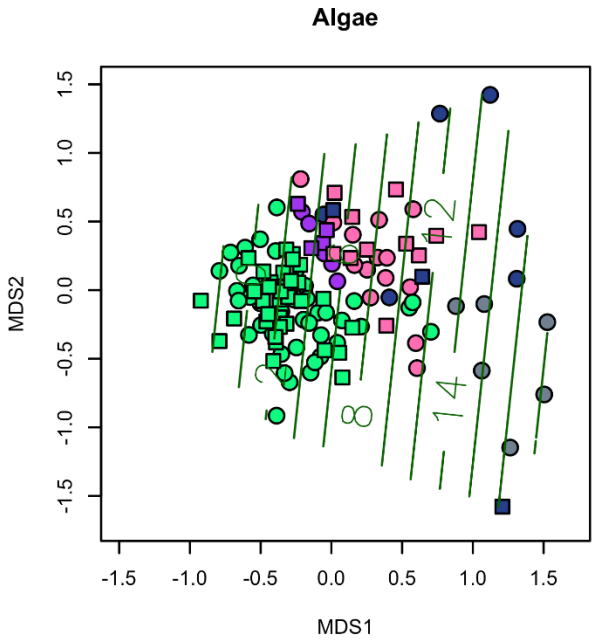

Ctenochaetus striatus (Gaia Guide)

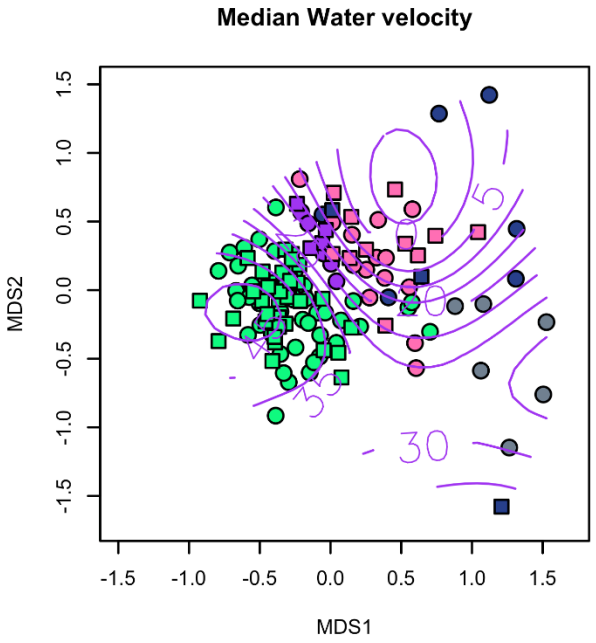
Correlation between environment & fish community (envfit; 100 m transects)

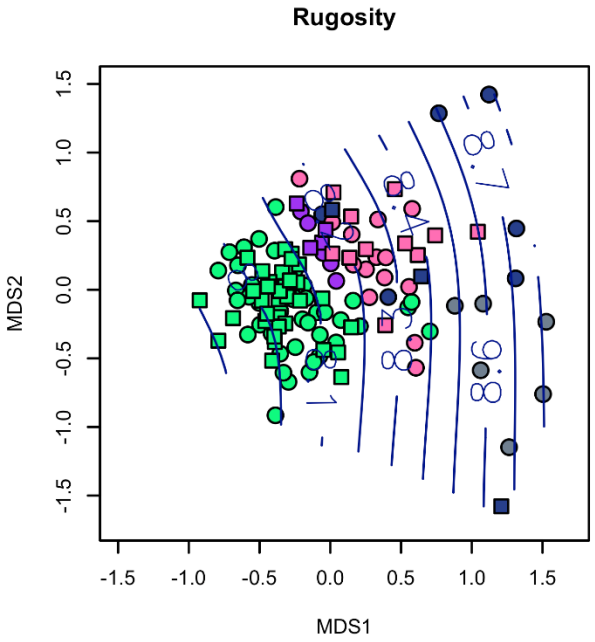
Variable	R^2	P
Predicted bottom velocity	0.45	<0.001***
Sand	0.32	<0.001***
Live hard coral	0.25	<0.001***
Soft coral	0.24	<0.001***
Algae	0.20	<0.001***
Status	0.11	<0.001***
Consolidated rubble	0.09	0.005**
Rugosity	0.06	0.014*
Dead hard coral	0.04	0.040*
Urchins	0.00	0.929
Rubble	0.03	0.126
Bommies	0.03	0.109

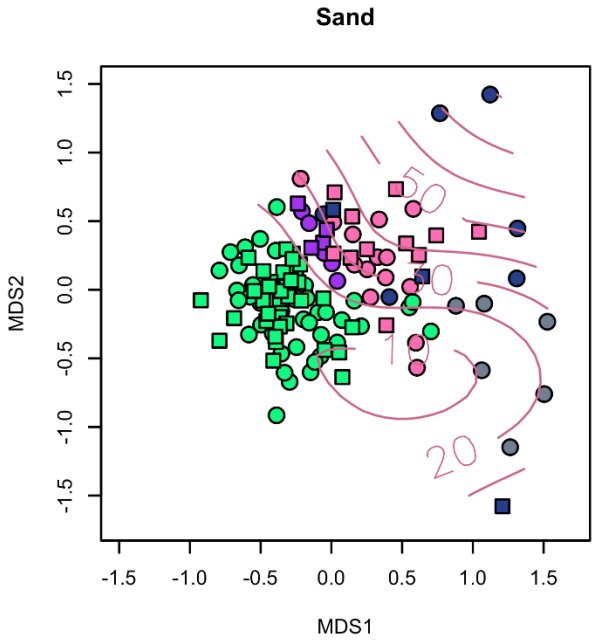

Long transcripts
Bommie
Inshore
Lagoon
Reef flat
Reef slope
2015
2016
psand
plhcoral
rugosity
palgae
plscoral
pconrub
MedUb
Envfit (Oksanen 2016)
Habitat R2 = 0.52 p = 0.00099
MDS1
MDS2
-1.0
-0.5
0.0
0.5
1.0
1.5

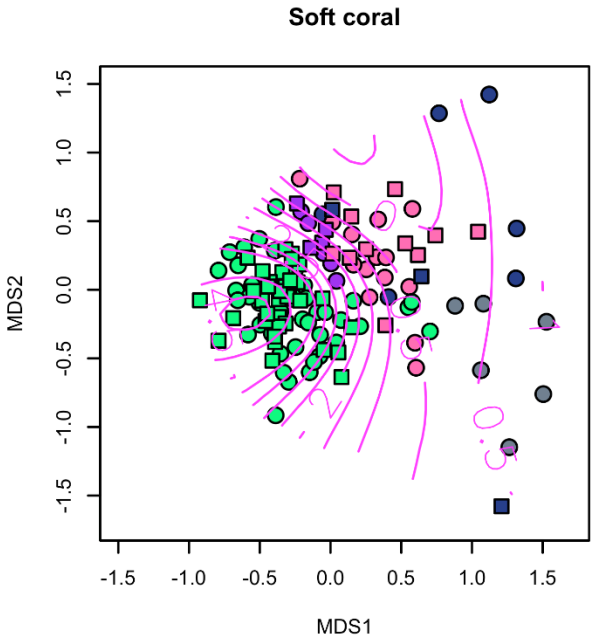

Live Hard Coral
MDS2
MDS1
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
5
10
15
20


Algae
MDS2
MDS1
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
8
12
14


Median Water velocity
MDS2
MDS1
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
30

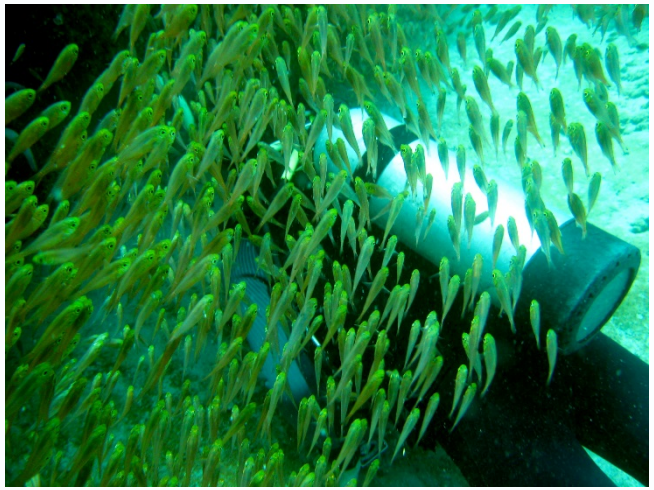

Rugosity
MDS2
MDS1
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5


Sand
MDS2
MDS1
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
20


Soft coral
MDS2
MDS1
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

Future work

- Continue multivariate analyses on short transects
- Investigate univariate relationships of family biomass with environment



Acknowledgements

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- **Pete Barnes & Jamie Small**

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Urchin Distributions Along the Slope and Inner Habitats of the Ningaloo Reef

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What Are Urchins and Why Study Them

- Sea Hedgehogs – small marine invertebrates
  - Phylum: Echinodermata, Class: Echinoidea, ~1000 extant species (World Echinoidea Database)

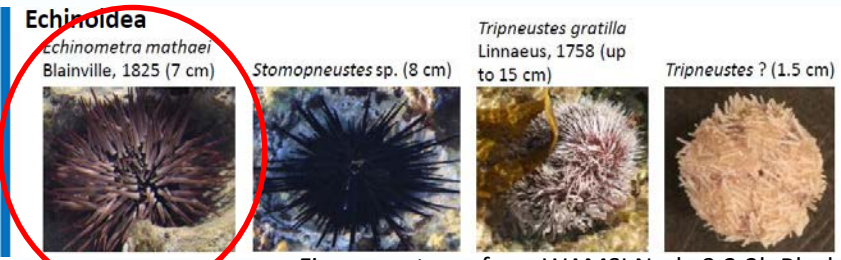
- Integral role in coral reef ecosystems
  - herbivores that mediate competition for space between corals and algae
  - modify the reef substratum; bio-erosion
  - food source for some species of fish
  - used as indicators of coral reef health

- Fill potential knowledge gaps (Fisher et al. 2011)
  - analysis of 4098 coral reef ecosystem papers over 1957-2009
  - increased focus of research on fish and corals

    30.6% on fish, 24.3% on corals, 2.8% on urchins

Class - Common names	CR
Actinopterygii- Ray-finned fishes	1256
Anthozoa - Anemones, corals (various)	994
Liliopsida - Seagrasses	45
Malacostraca - Crabs, lobsters, shrimp, krill, amphipods, isopods	233
Magnoliopsida - Mangroves	34
Phaeophyceae - Brown algae (including kelp)	145
Gastropoda - Snails, slugs	102
Echinoidea - Sea urchins, sand dollars	115
Demospongiae - Sponges	159
Bivalvia - Bivalves	86
Florideophyceae - Red algae	124
Polychaeta - Segmented worms	68
Hydrozoa - Hydrozoans	109
Bryopsidophyceae - Green algae (various)	57
Asteroidea - Starfish	78
Ulvophyceae - Green algae (sea lettuce)	46
Gymnolaemata - Moss animals	77
Maxillopoda - Barnacles, copepods	40
Mammalia - Mammals	15
Ascidiacea - Sea squirts	30
Insecta - Insects	0
Holothuroidea - Sea cucumbers	20
Aves - Birds	4

Figure capture from Fisher et al. 2011



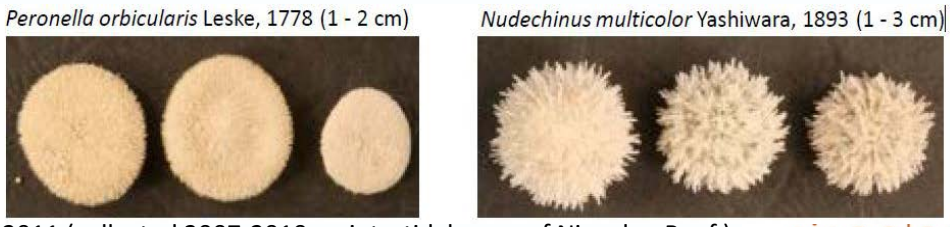


Figure captures from WAMSI Node 3.2.2b Black et al. 2011 (collected 2007-2010 on intertidal areas of Ningaloo Reef)

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The Overlooked But Abundant Mole Urchin

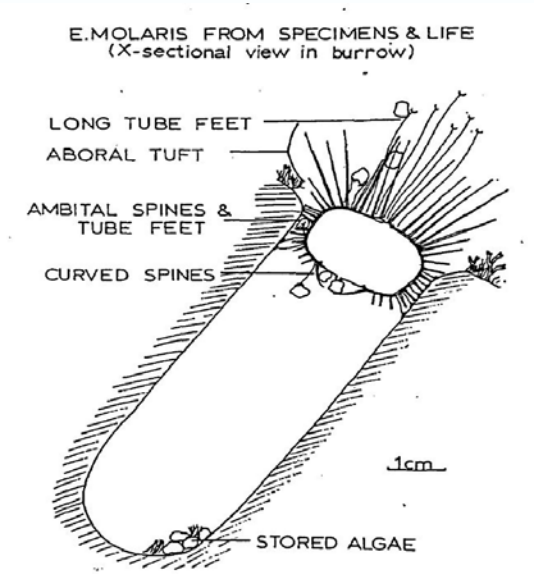
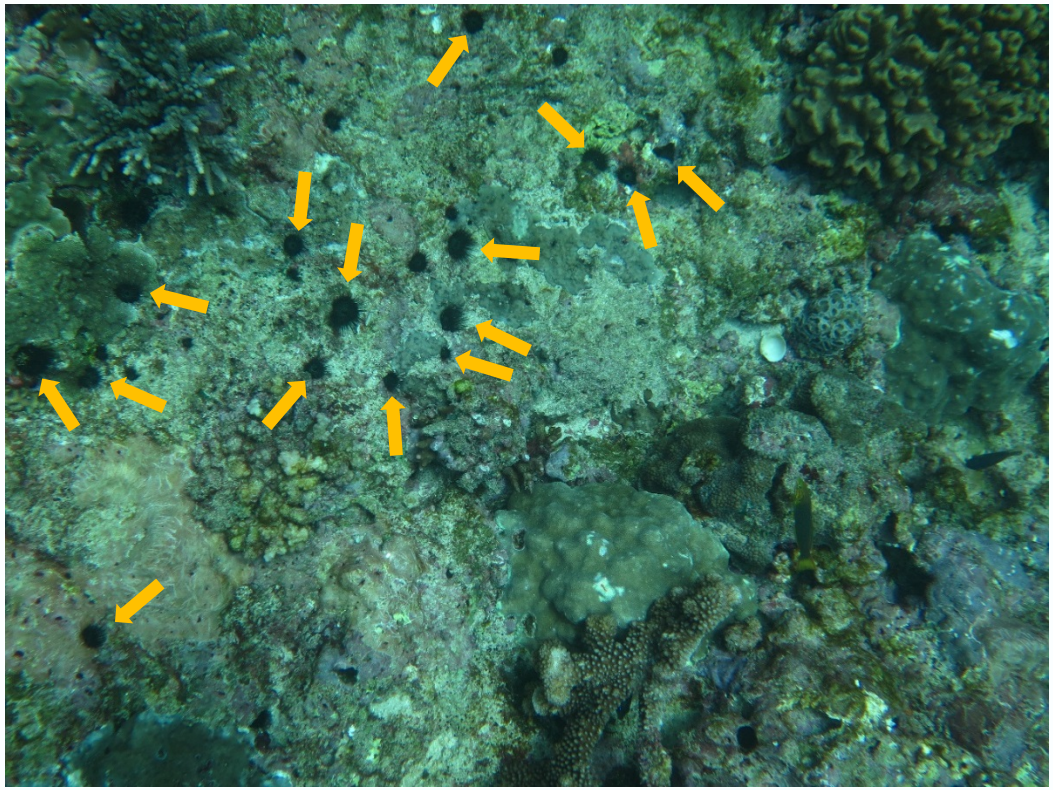


Figure capture from Campbell et al. 1973

Figure capture from Tokeshi & Tanaka 2010

Class: Echinoidea
Family: Echinometridae
Echinostrephus molaris
(Blainville, 1825)



Site 69747: Mangrove Slope, May 2016

Methods to Determine Relative Abundance

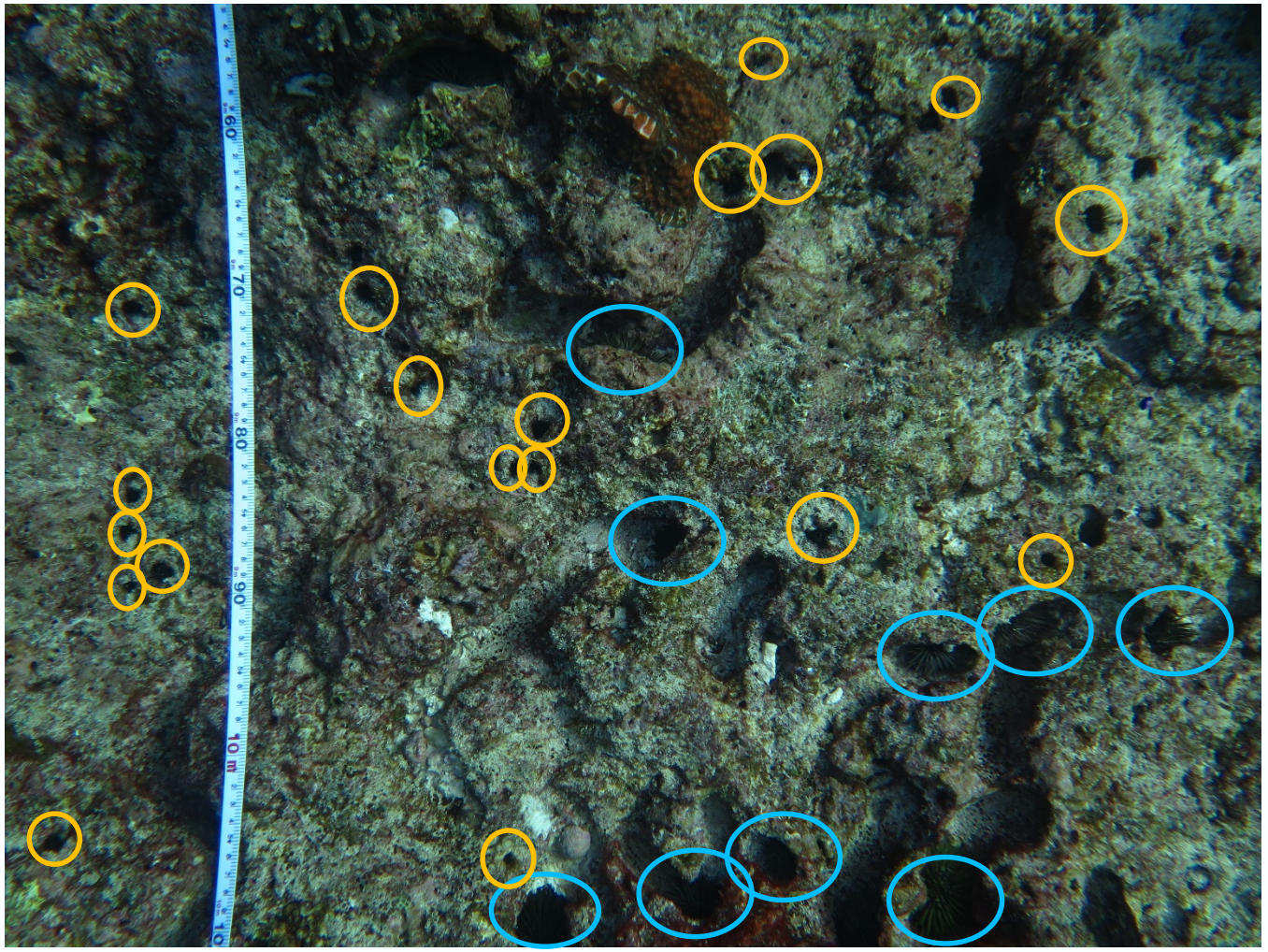
- Benthic photos taken every 50cm along a 25m transect
- Estimate area of picture
- Estimate area for transect

  -Area: ~10.5m^2
- Quantified most abundant urchins

  -*Echinometra mathaei*

  -*Echinostrephus molaris*

  -zoom in; observe criteria



Site 69427: Mangrove Slope, May 2016

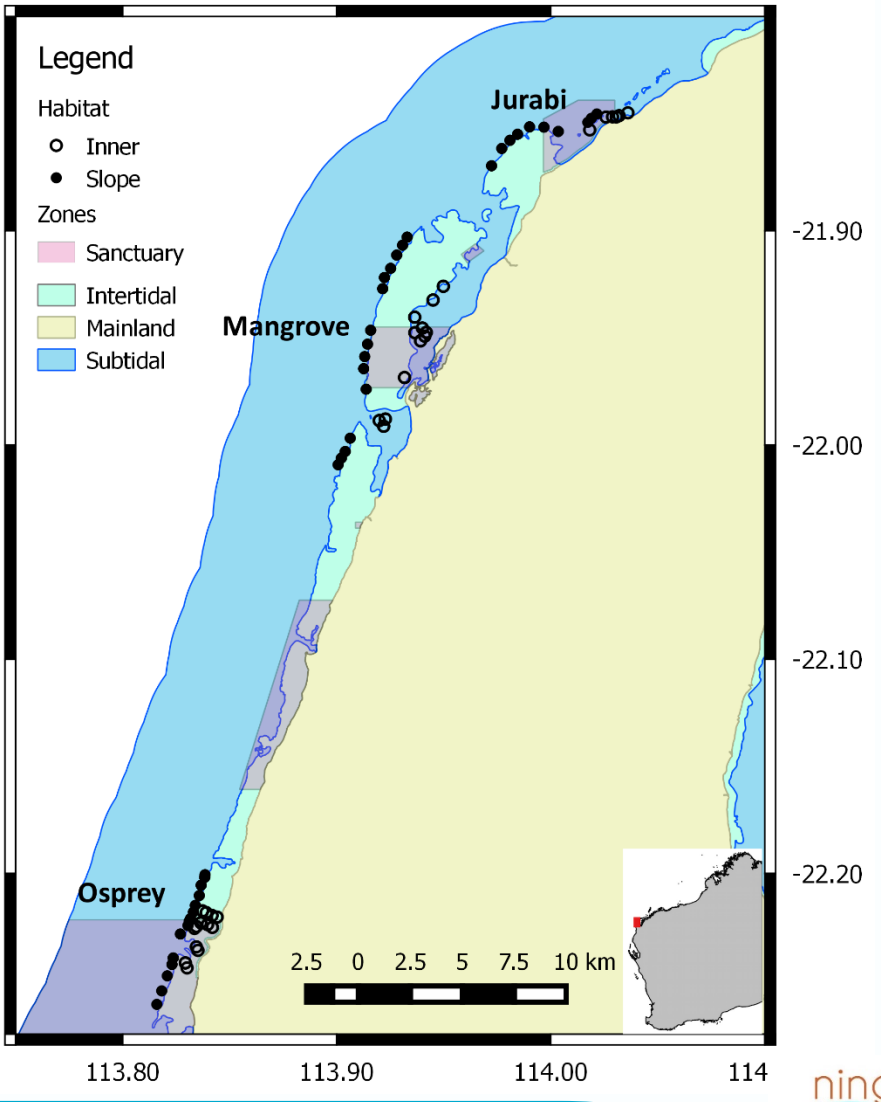
Urchin Survey Sites and Predictor Variables

- Benthic surveys (n=126, 3780 photos)
  - May 2015 (71) & May 2016 (55)
- Three main regions
  - Jurabi (n=23)
  - Mangrove (n=54)
  - Osprey (n=49)
- Reef Habitat

  – Outer (slope, n=74) vs. Inner habitat (n=52)

  - Inner incl. bommie, lagoon, flat, inshore
- Management Zone
  - Sanctuary (n=49), Non-Sanctuary (n=77)

- Rugosity – index of structural complexity
- % Algal Cover – index of food availability
- % Hard Coral Cover – index of competition for space with corals
- Water Velocity (Model Prediction) – index of bottom water movement



Analysis of Urchin Data

- GAM with negative binomial distribution and log link function; fit full subset of predictors with penalization for a total of 74 models (Fisher pers. comm.)

Echinometra mathaei

Model	AICc	d.AICc	*wi* AICc	r^2
Algae + Zone + Rugosity	587.93	0	0.23	0.36
Region + Region x Water Velocity	588.69	0.76	0.16	0.42
Region + Rugosity + Water Velocity x Region	589.66	1.74	0.10	0.42
Rugosity + Zone + Algae x Zone	589.85	1.93	0.09	0.36
Algae + Zone + Rugosity x Zone	590.03	2.10	0.08	0.36

Echinostrephus molaris

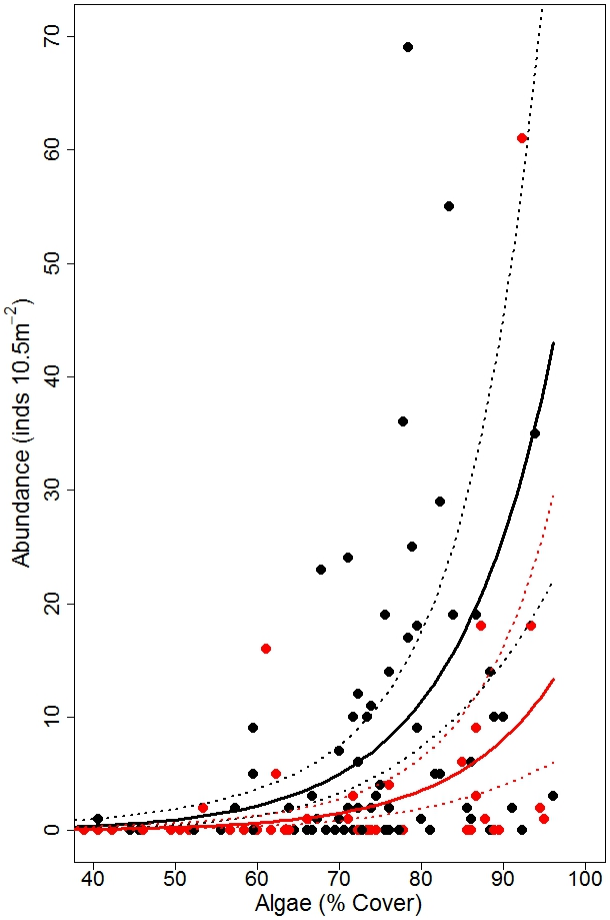
Model	AICc	d.AICc	*wi* AICc	r^2
Habitat + Region + Rugosity x Region	646.56	0	0.49	0.67
Habitat + Hard Coral + Rugosity x Habitat	649.53	2.97	0.11	0.65
Habitat + Rugosity + Region	650.02	3.46	0.09	0.64
Habitat + Region + Rugosity x Habitat	650.15	3.60	0.08	0.65
Habitat + Rugosity x Habitat + Hard Coral x Habitat	650.85	4.29	0.06	0.65

Algae
Management Zone
Rugosity

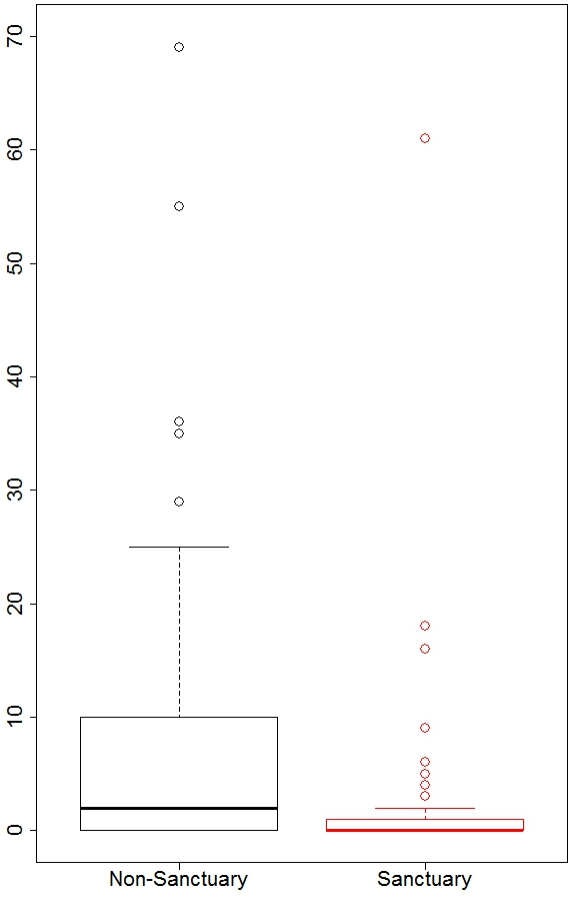
Habitat
Region
Rugosity x Region

Urchin Distributions at Ningaloo Reef

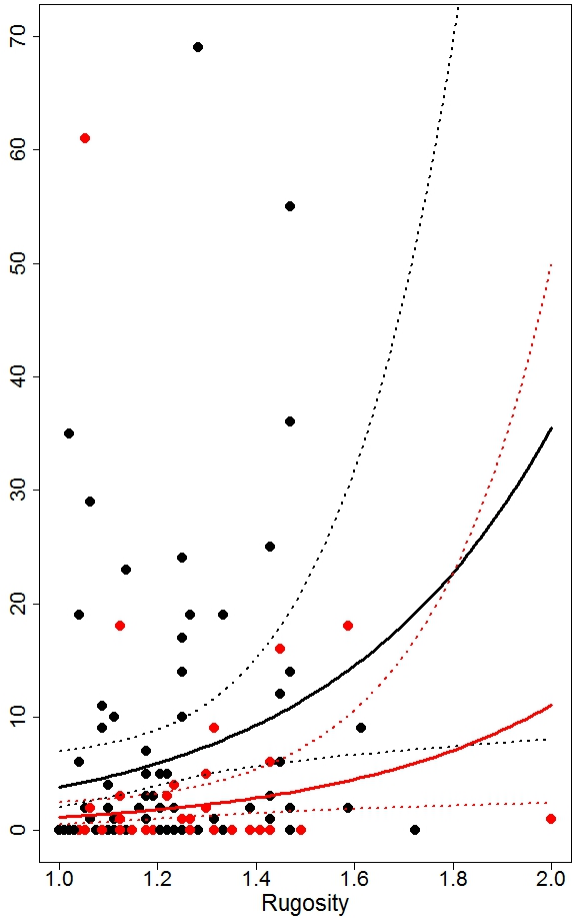
Echinometra mathaei



Algal Cover



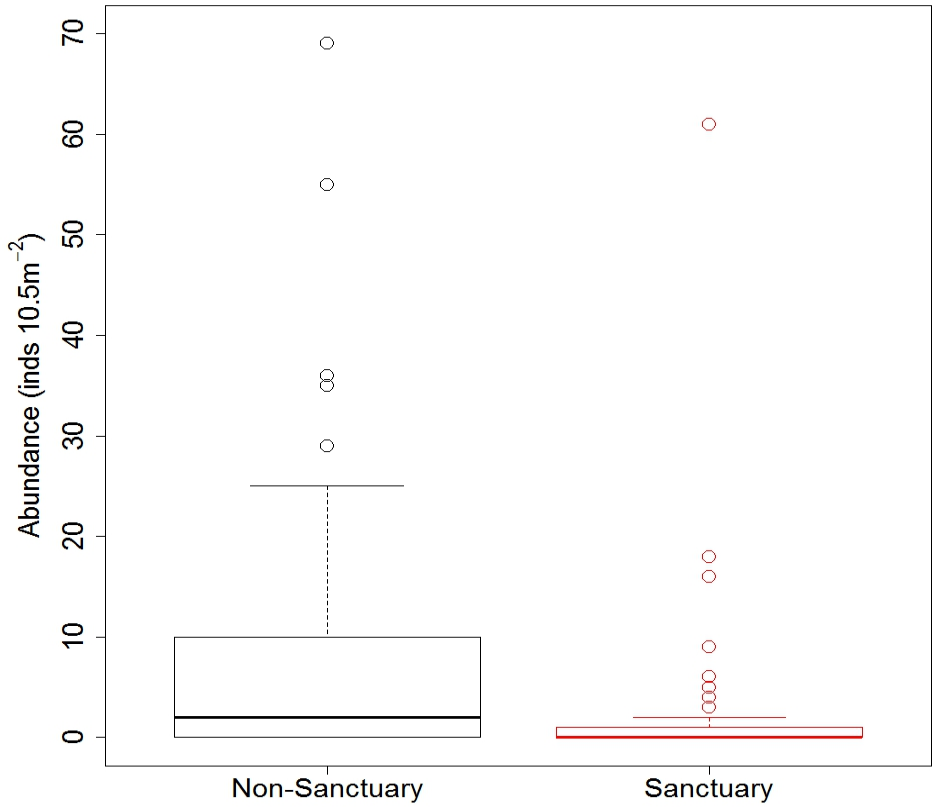
Management Zone



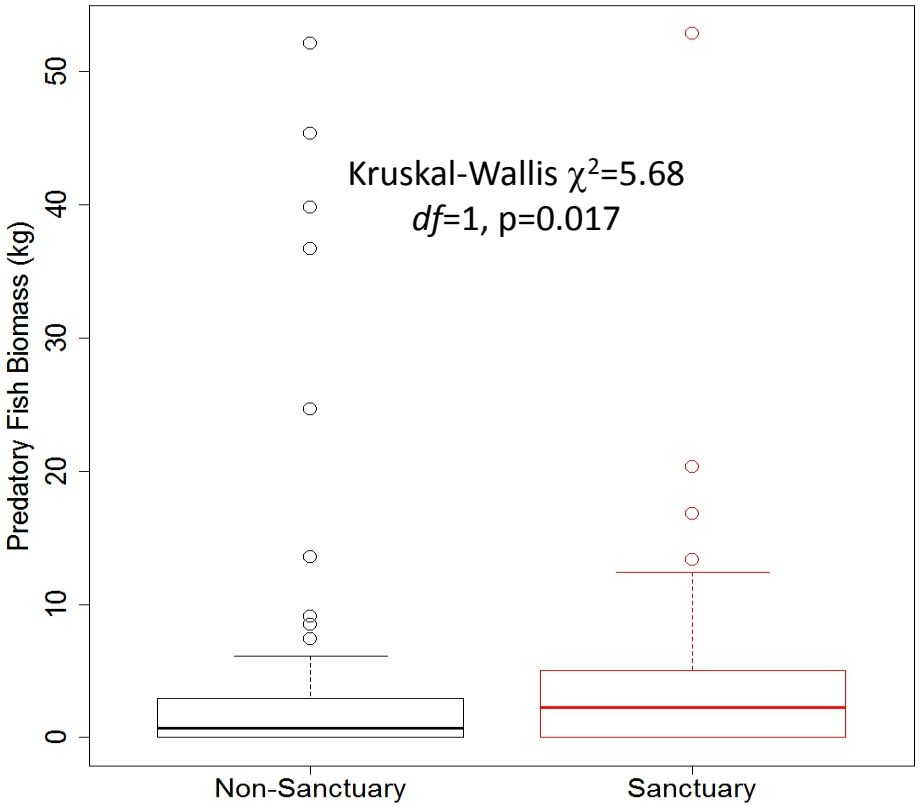
Rugosity

Urchin Distributions at Ningaloo Reef

Echinometra mathaei



22 Potential Urchin Predators



Predators Inc. (≥35cm):
Tetradontidae(n=6), Balistidae(n=4)
Labridae(n=6), Lethrinidae(n=6)

Figure captions from www.fishesofaustralia.net.au

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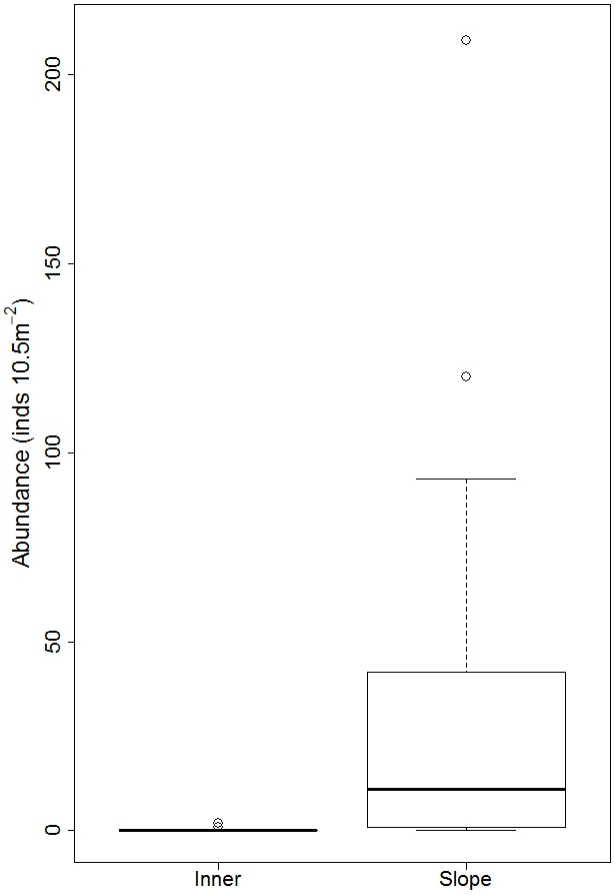
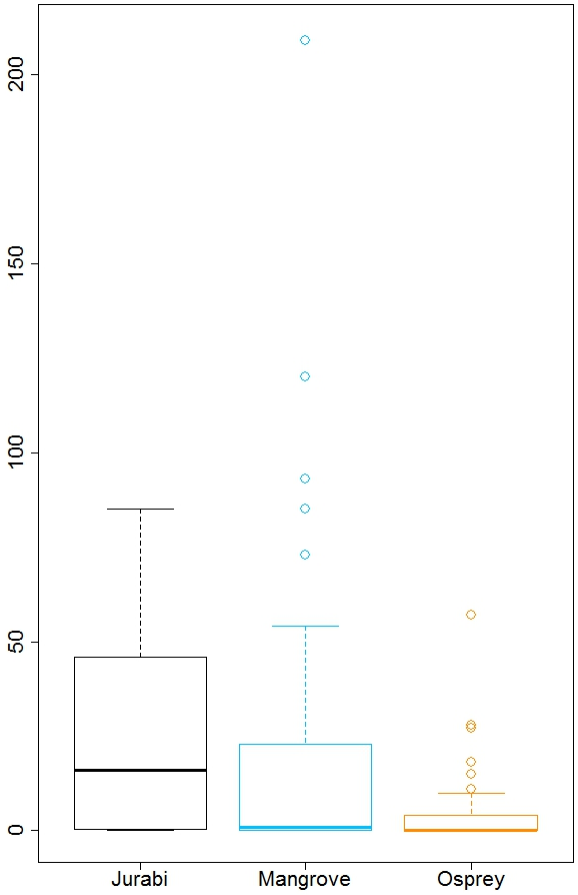
Urchin Distributions at Ningaloo Reef

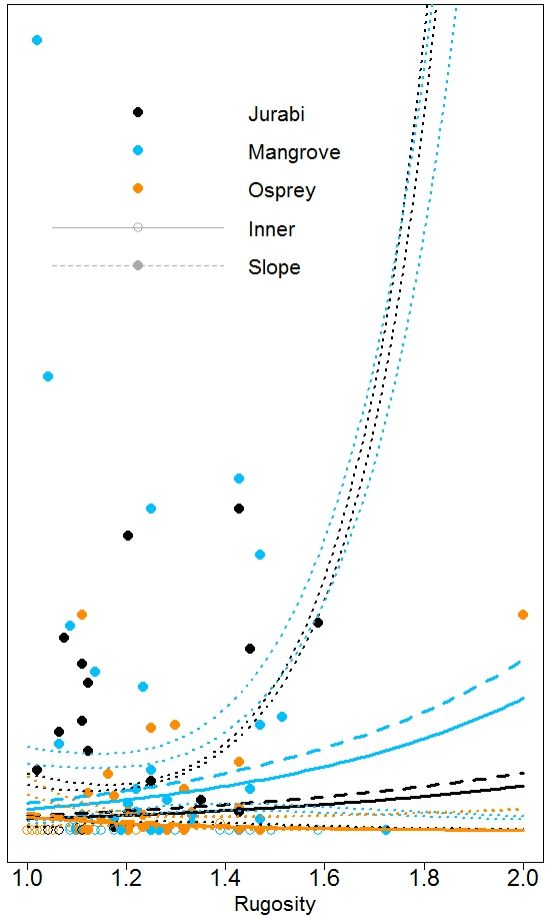
Echinostrephus molaris



Habitat

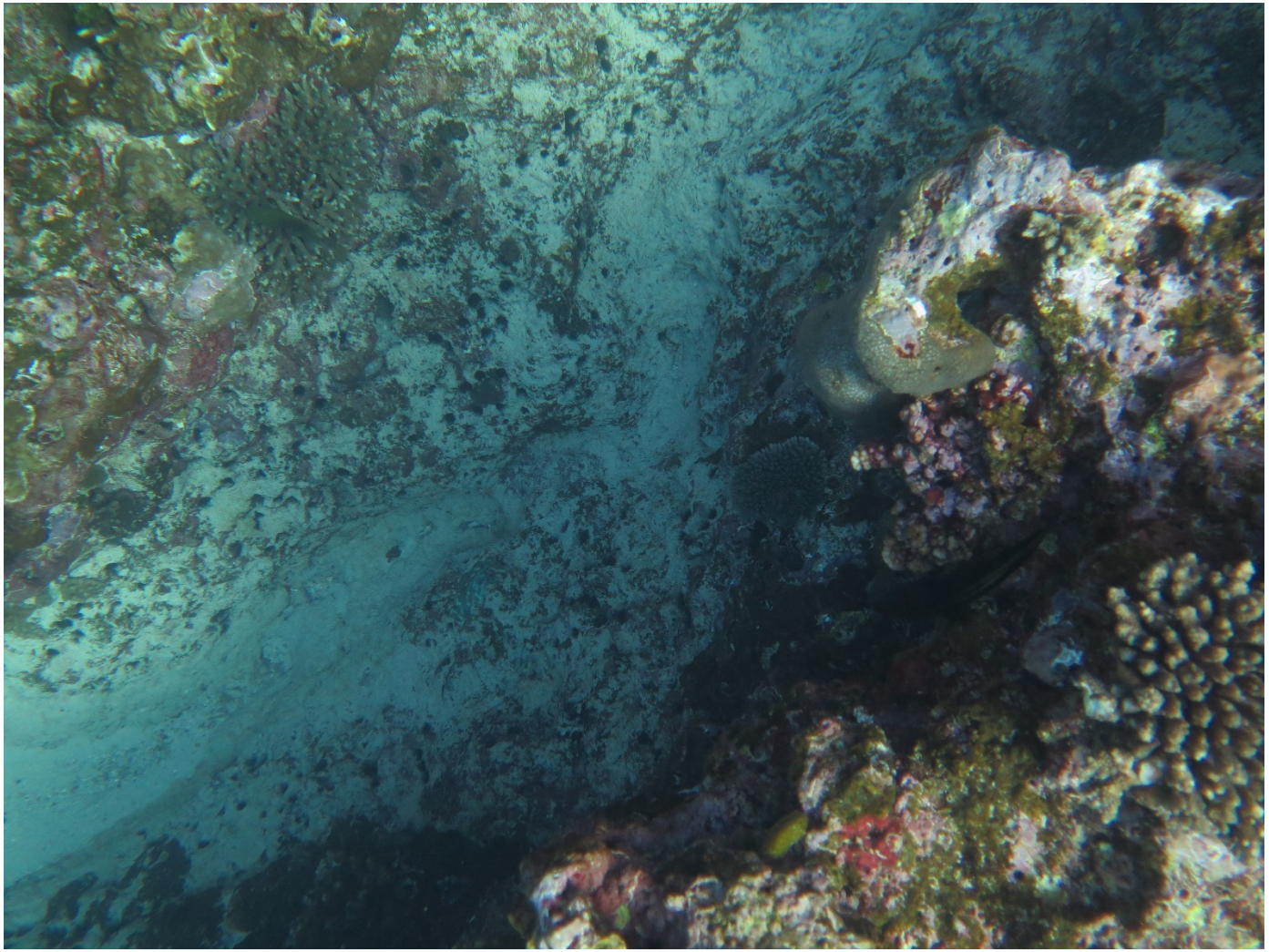


Region



Rugosity x Region

Direction of Further Studies



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Acute Climatic Disturbances: Inertial and Elastic Resilience

Anna Cresswell PhD Scholar

Supervisors: Damian Thomson (CSIRO), Michael Renton (UWA), Tim Langlois (UWA), Mick Haywood (CSIRO), Gary Kendrick(UWA)

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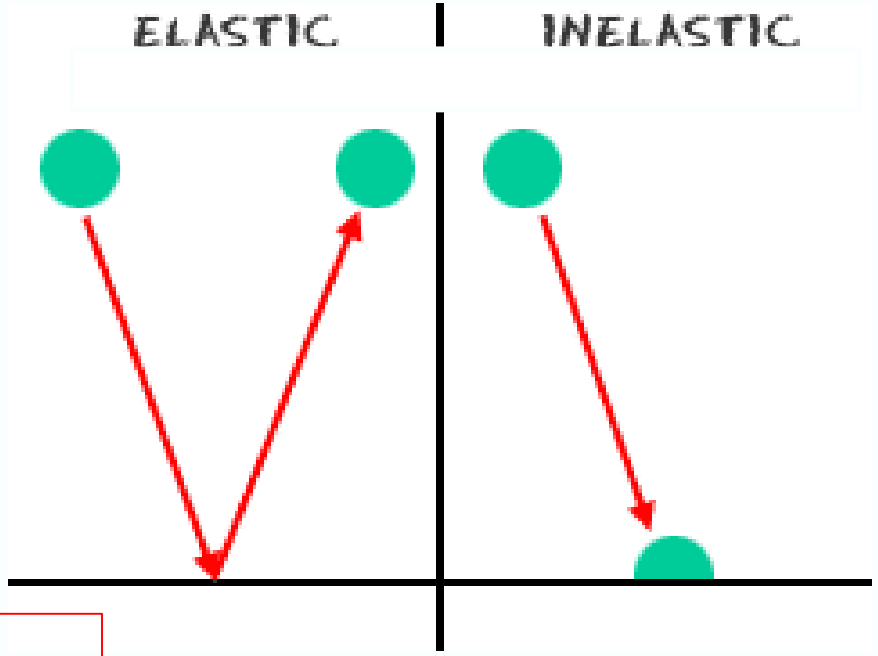
Vulnerability?
Elasticity?
Recovery?
Resilience?
Resistance?
Inertia?
Adaptation?

Inertial and Elastic Resilience

Inertia: *Tendency to remain unchanged*

Elasticity: *Capacity of an object to return to its original state following disturbance*



Inertia + Elasticity = Resilience

1. Meta-analysis

How does the resilience of key **marine habitat formers** differ for different acute climatic disturbances?

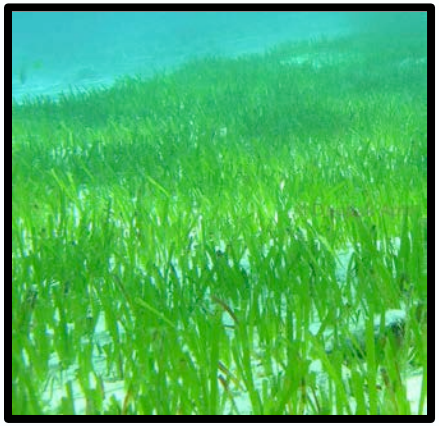
Covariates

- Fishing level
- History of disturbance
- Isolation from other reefs
- Human pressure
- Reef type and zone
- Intensity, scale and duration of disturbance

Coral

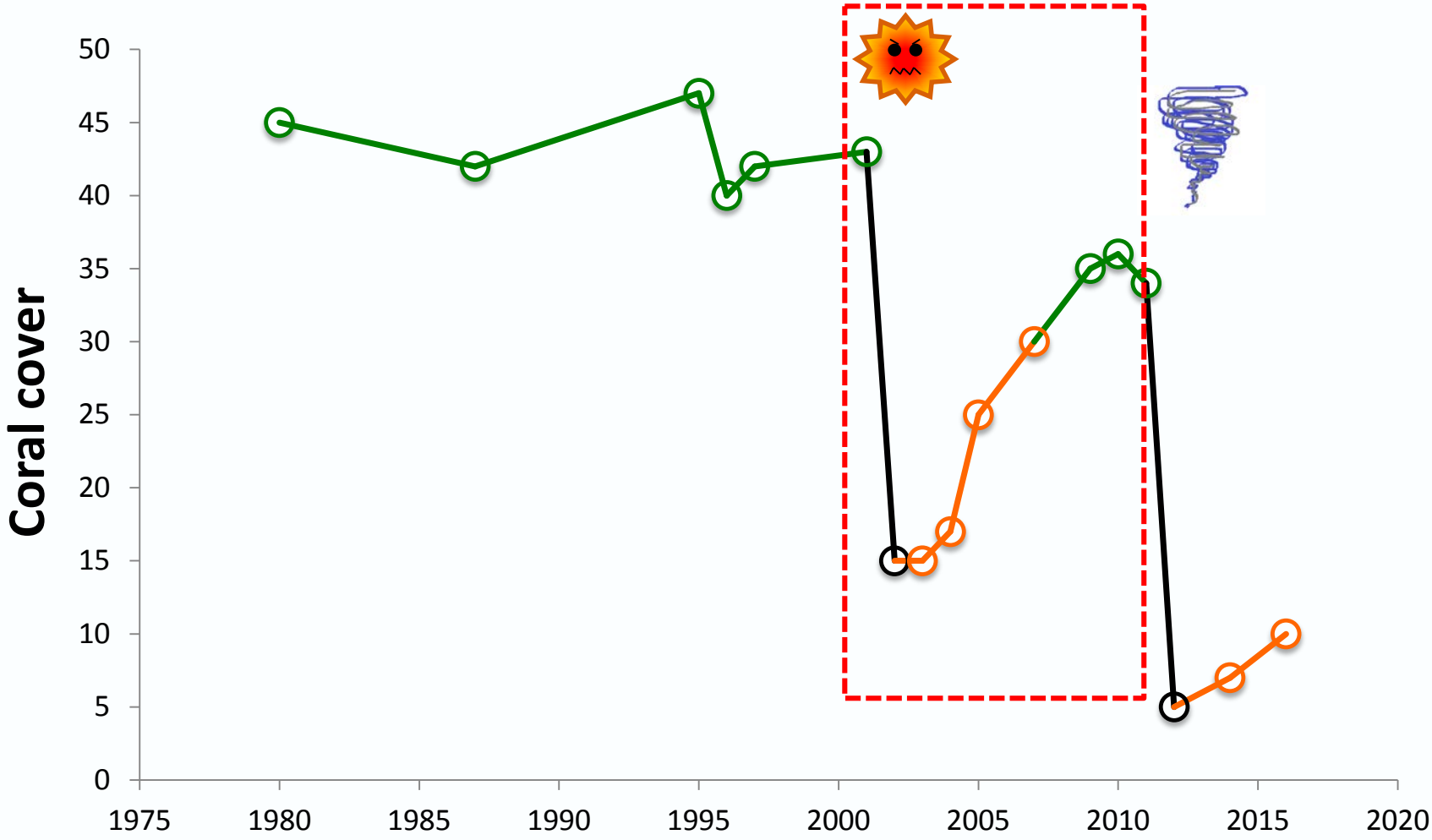
Kelp

Seagrass



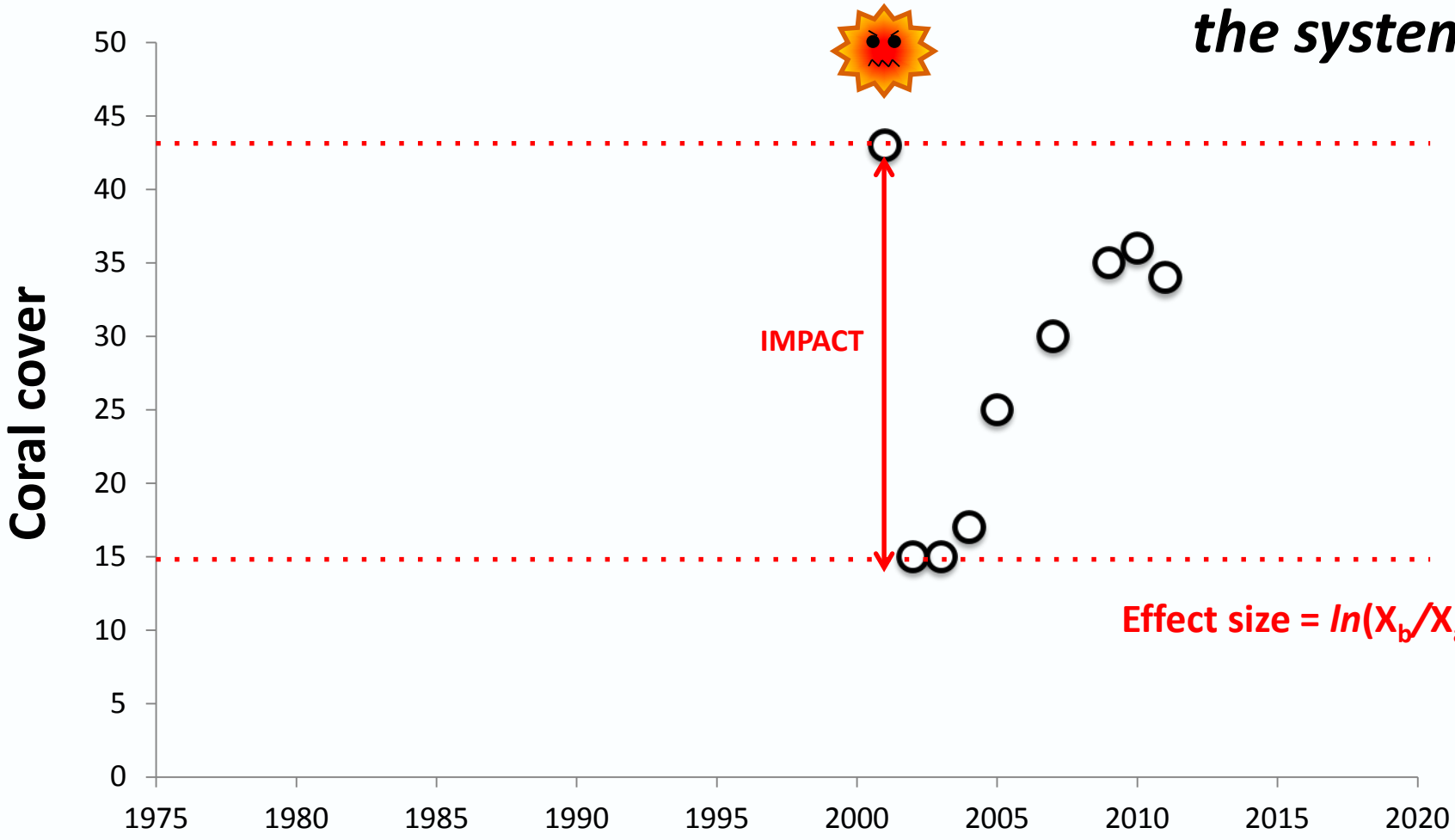
Mangroves

Meta-analysis for disturbance impact and recovery



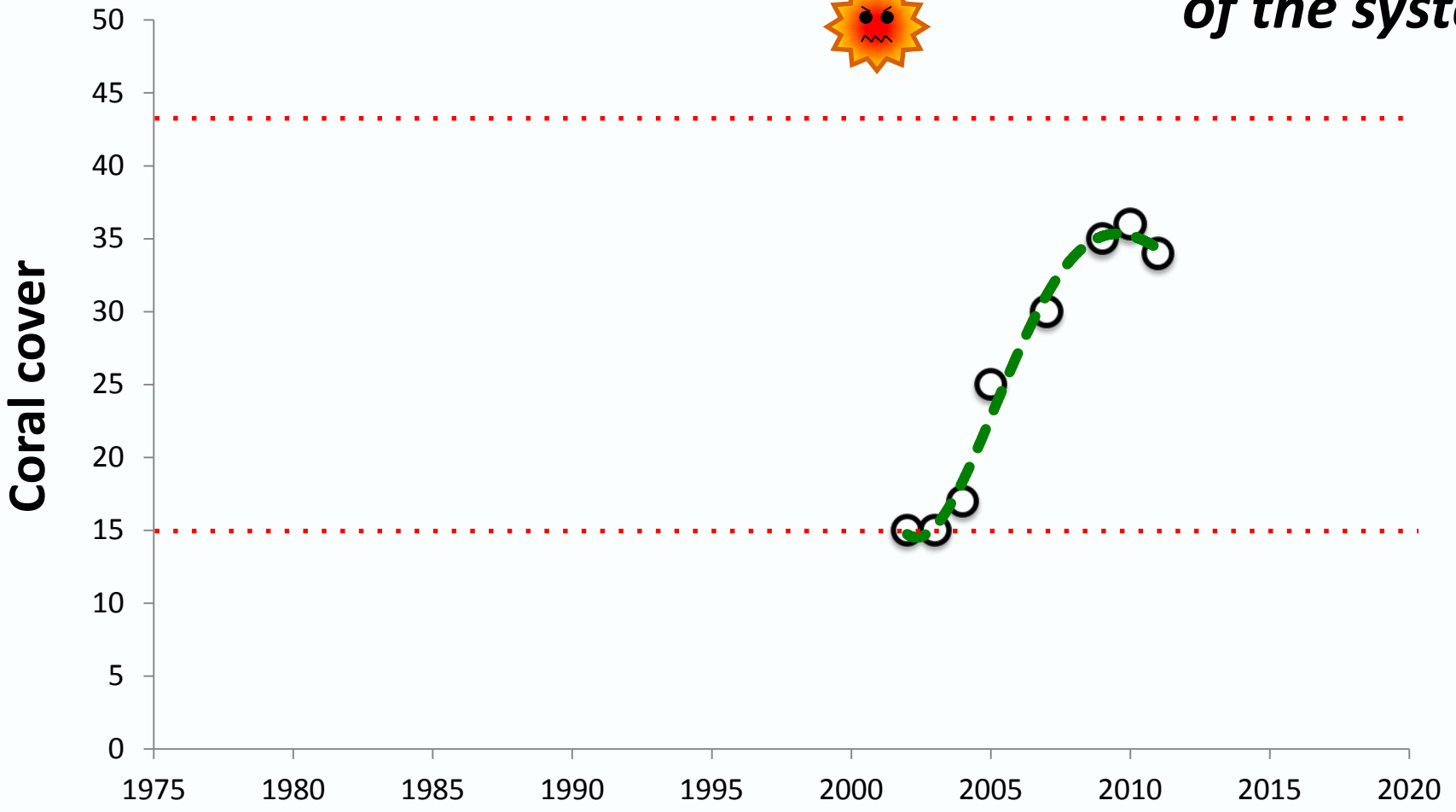
Meta-analysis for disturbance impact and recovery

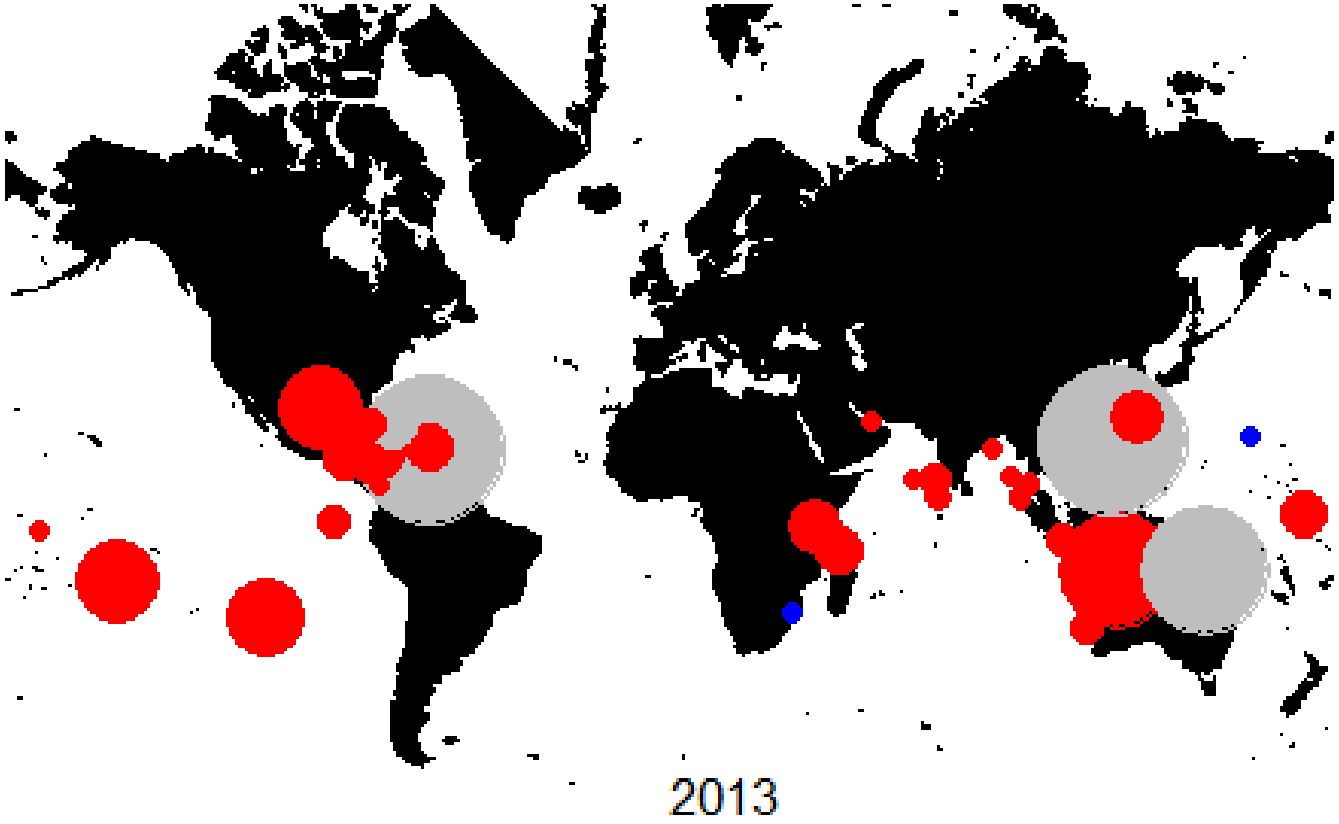
Measure of the inertia of the system



Meta-analysis for disturbance impact and recovery

Measure of the elasticity of the system





Disturbance type

Cyclone

Flood

Elevated sea temperature

Number of survey years

n = 25

n = 9

n = 2

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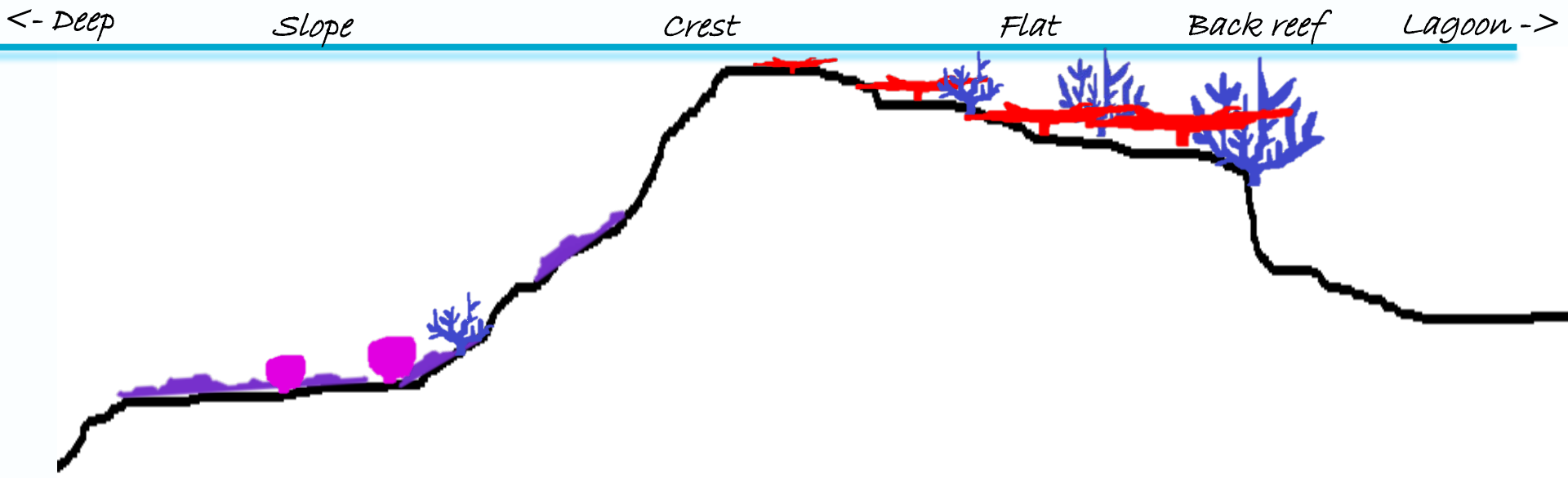
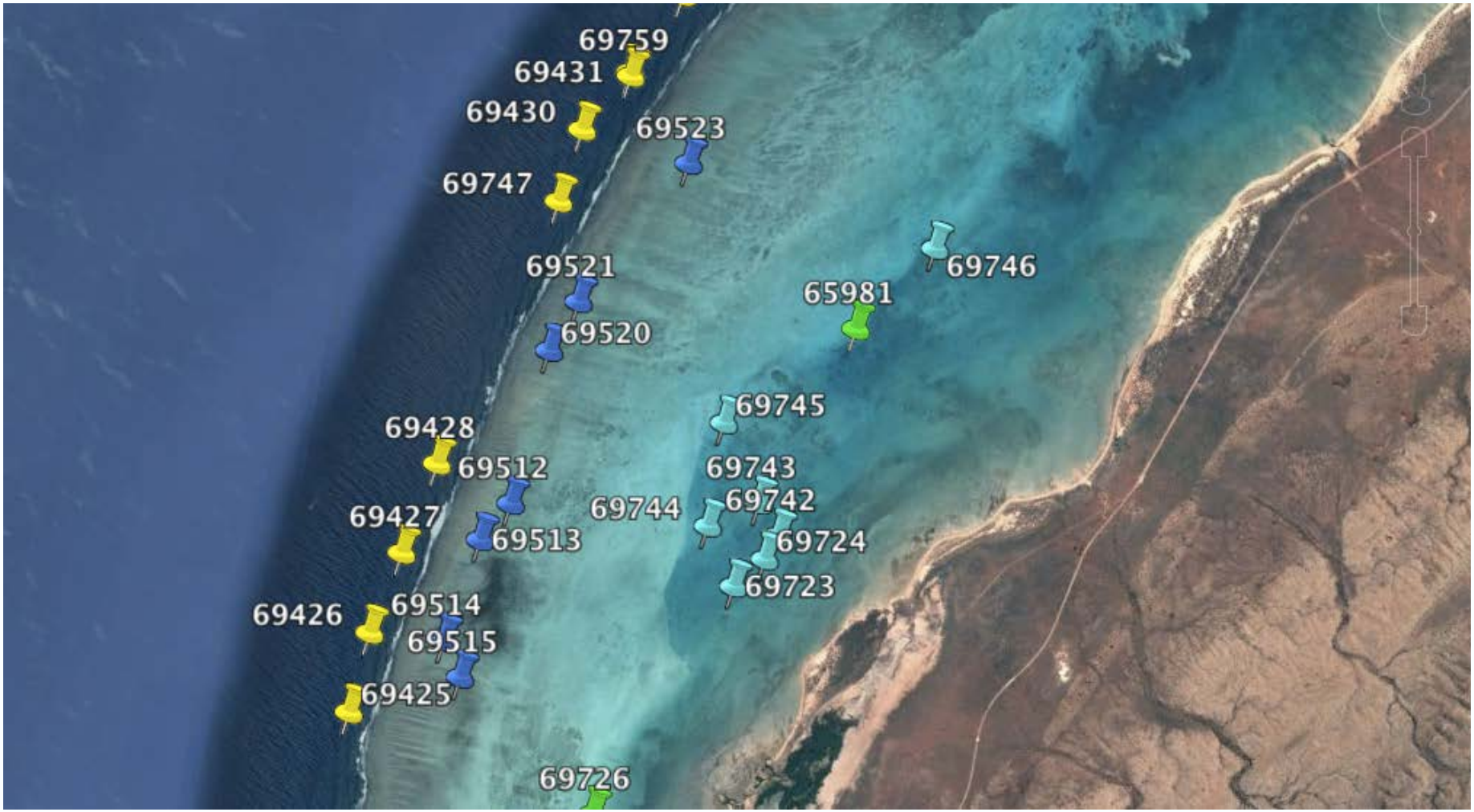
2. Inertia and elasticity of coral morphologies to hydrodynamic disturbances

High hydrodynamic stress

Low hydrodynamic stress



Ningaloo Reef morphology profile



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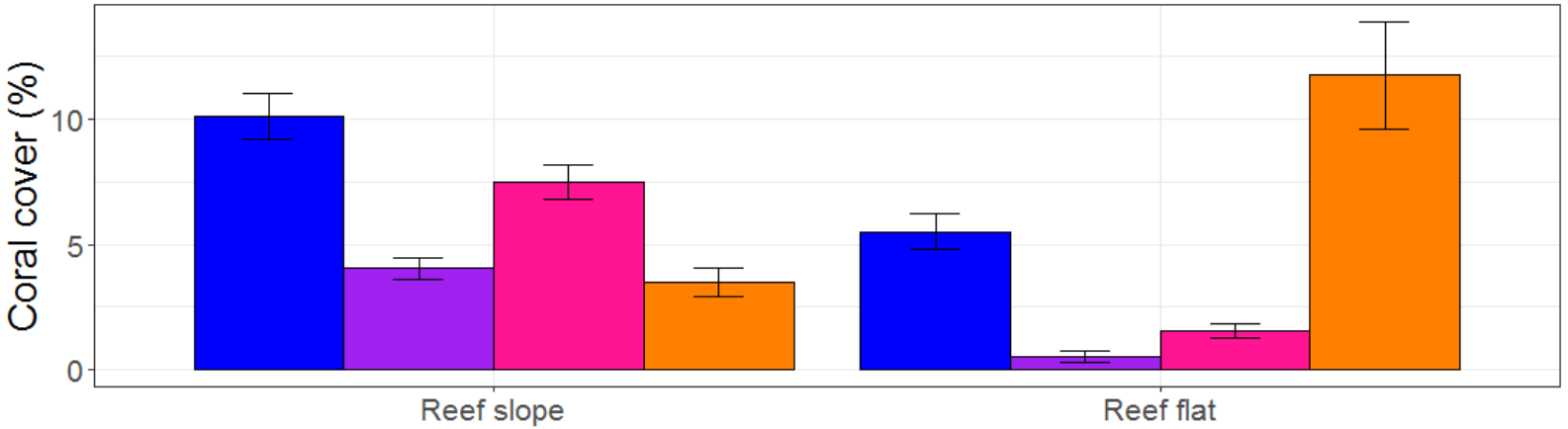
Hydrodynamic driven morphology?

Complex coral

Encrusting coral

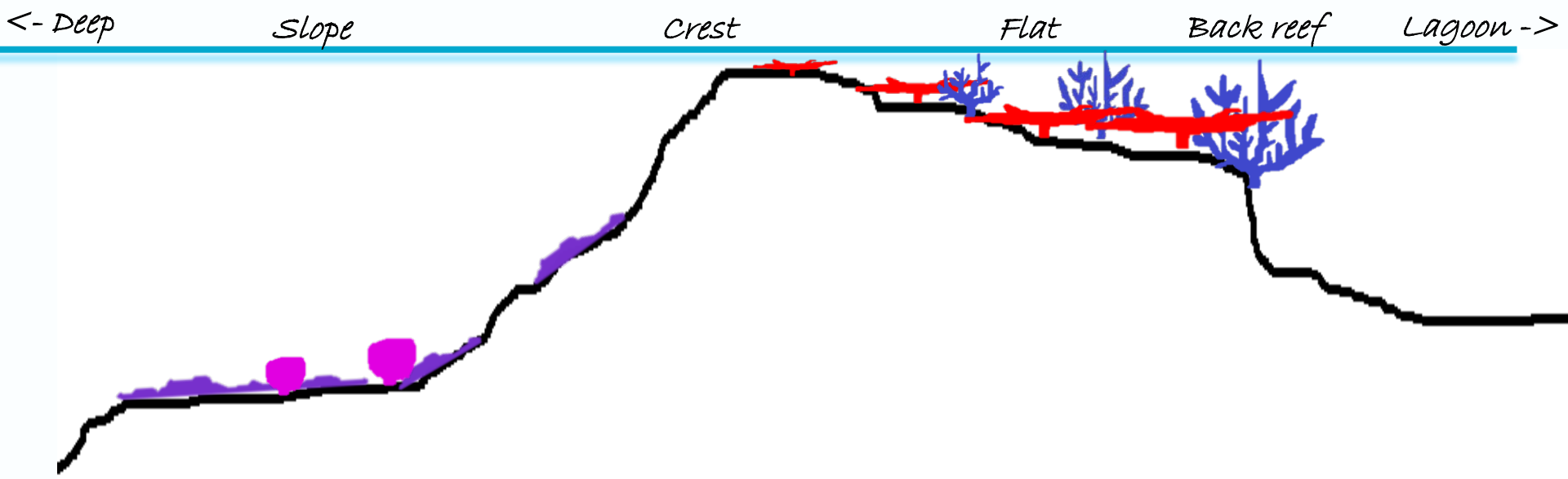
Massive coral

Tabular coral



Morphological trade-offs in a changing climate

Growth versus fragility



Morphological trade-offs in a changing climate

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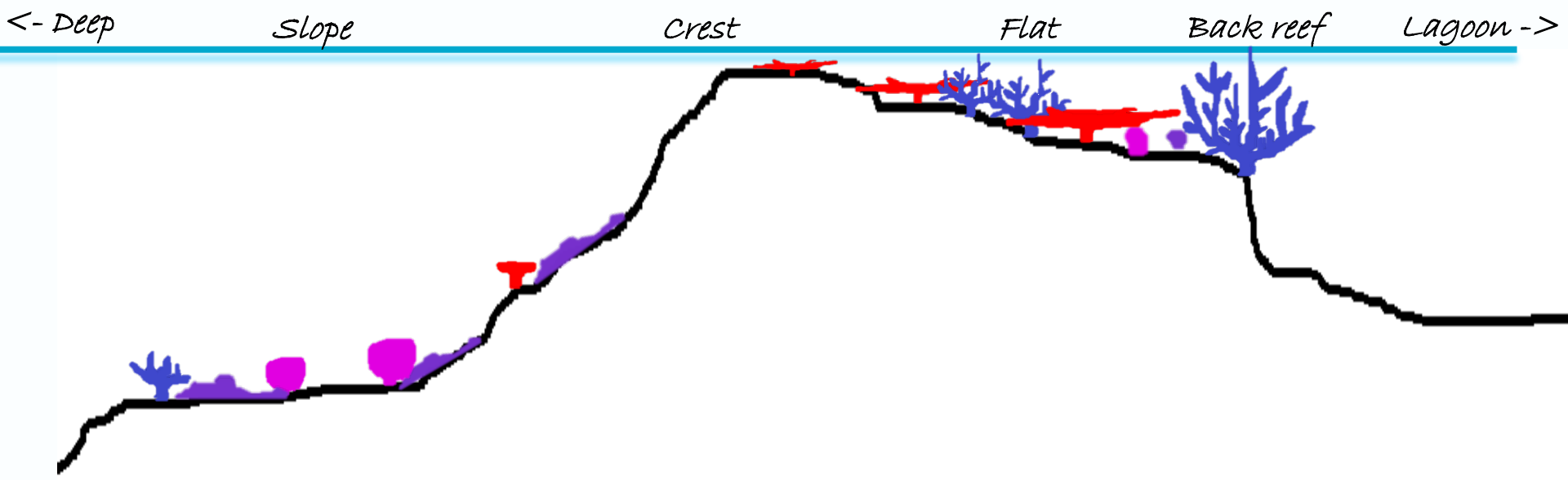
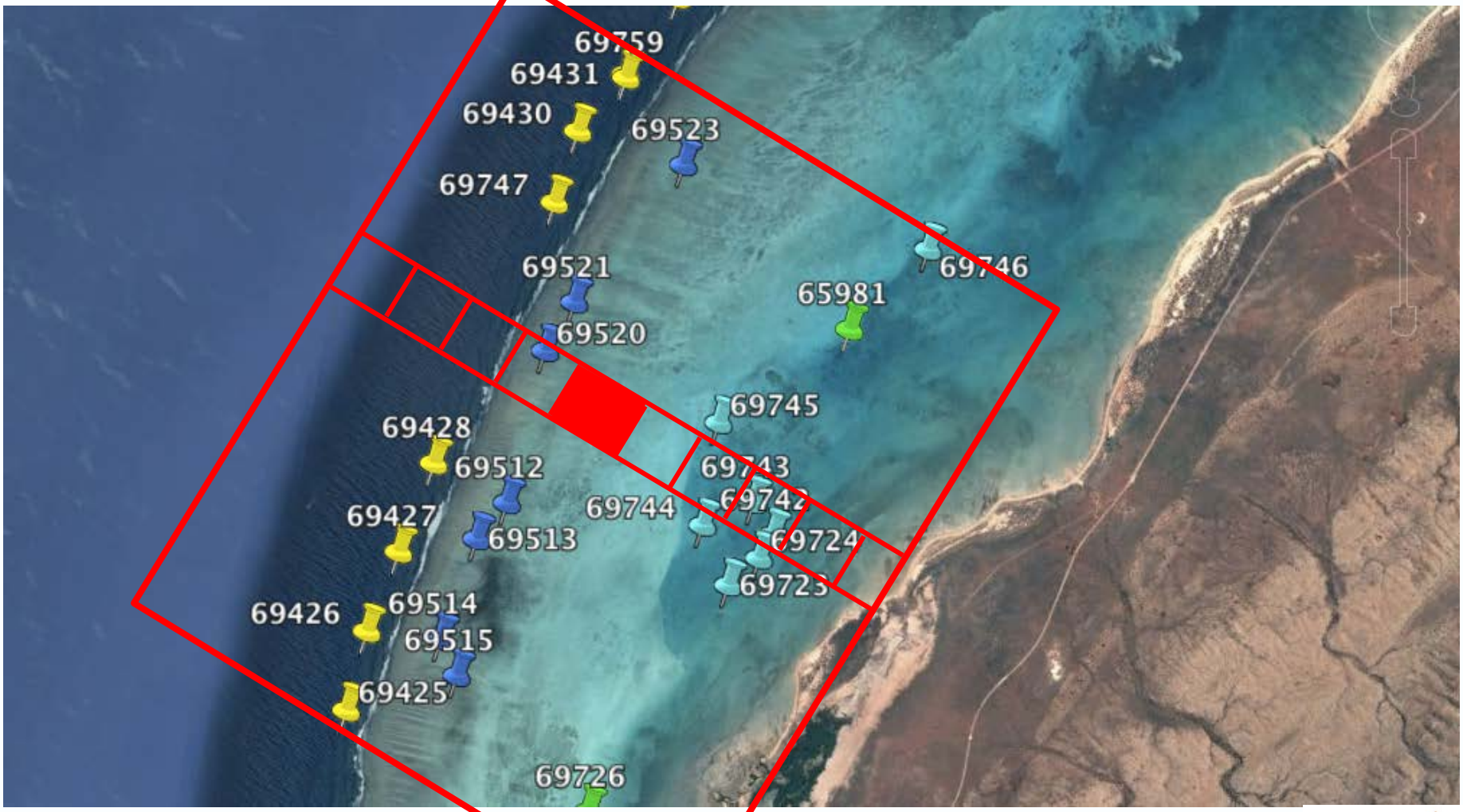
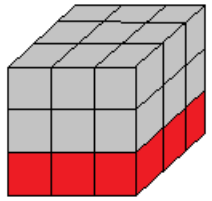
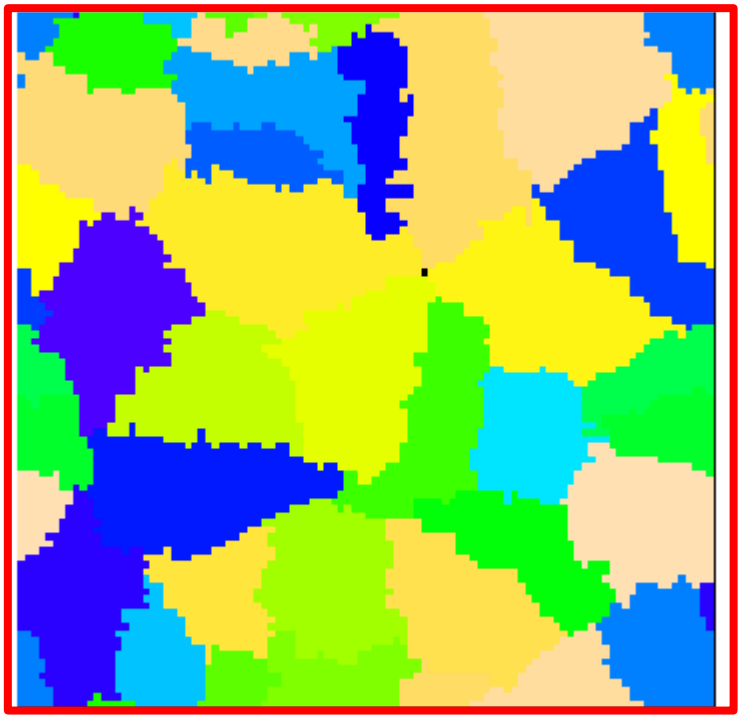


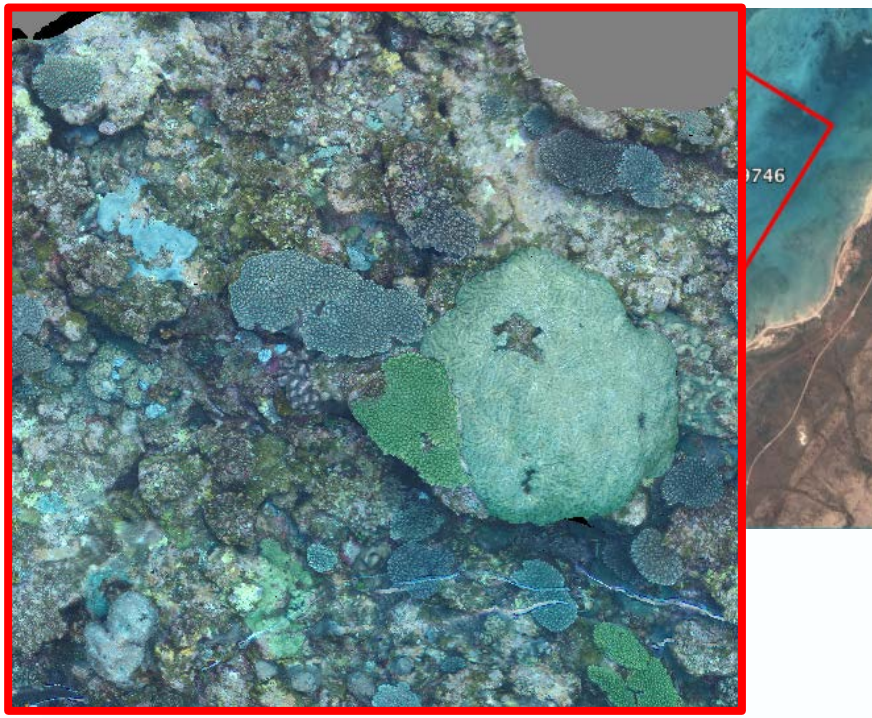
Functional structural coral (FSC) modelling



Preliminary FSC Model development







Month 91

Summary

- Meta-analysis ongoing to put the resilience of Ningaloo Reef in context
- Model development in progress
- Interested in any thoughts/ comments

Acknowledgements

- BHP Billiton-CSIRO Ningaloo Outlook Marine Research Partnership
- UWA School of Biological Sciences
- Dr Joachim Claudet, University of Perpignan, France

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Life on the slope – coral, carbonate and carbonate consumers

Damian Thomson, Mick Haywood, Cindy Bessey, Anna Cresswell & Melanie Trapon

Ningaloo Outlook – A partnership between BHP Billiton and CSIRO

WESTERN COASTAL/OCEAN & ATMOSPHERE
www.csiro.au

CSIRO

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

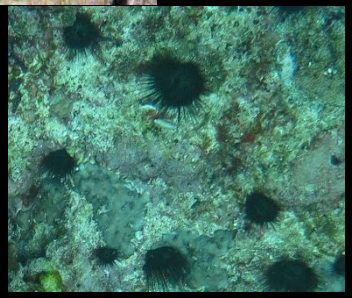
Unique aspects of the program

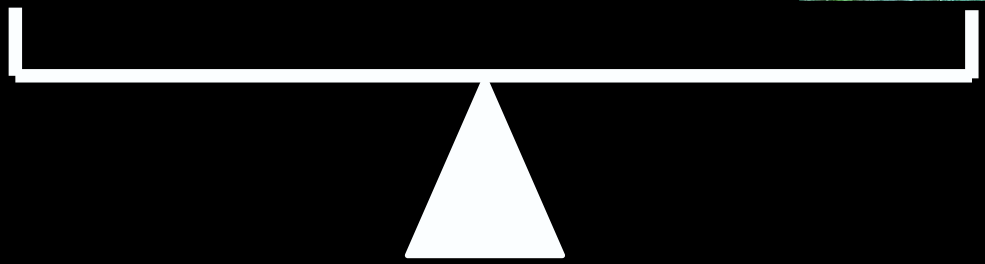
- Extend long term datasets for fish, corals and invertebrates on the reef flat
- Provide critical baseline data for fish, corals and invertebrates on the reef slope
- Integrate physical and biological datasets i.e. fish, benthos, wave model and carbonate budgets

Carbonate budget = balance between production and erosion

Production

Erosion





Why look at carbonate budgets

- Climate change on coral reefs a fundamental research priority
- Positive carbonate budgets essential for structural maintenance of corals reefs
- Prolonged negative budgets linked to declines in coral cover, structural complexity and fish abundance *(Gardner et al. 2006 Nature, Paddack et al. 2009 Cur. Biol., Graham et al. 2012 Coral Reefs)*

Objectives

1. What are the important producers and bioeroders?

2. Spatial arrangement of production and bioerosion

3. Is production a good predictor of bioerosion?

4. Spatial arrangement of net budgets

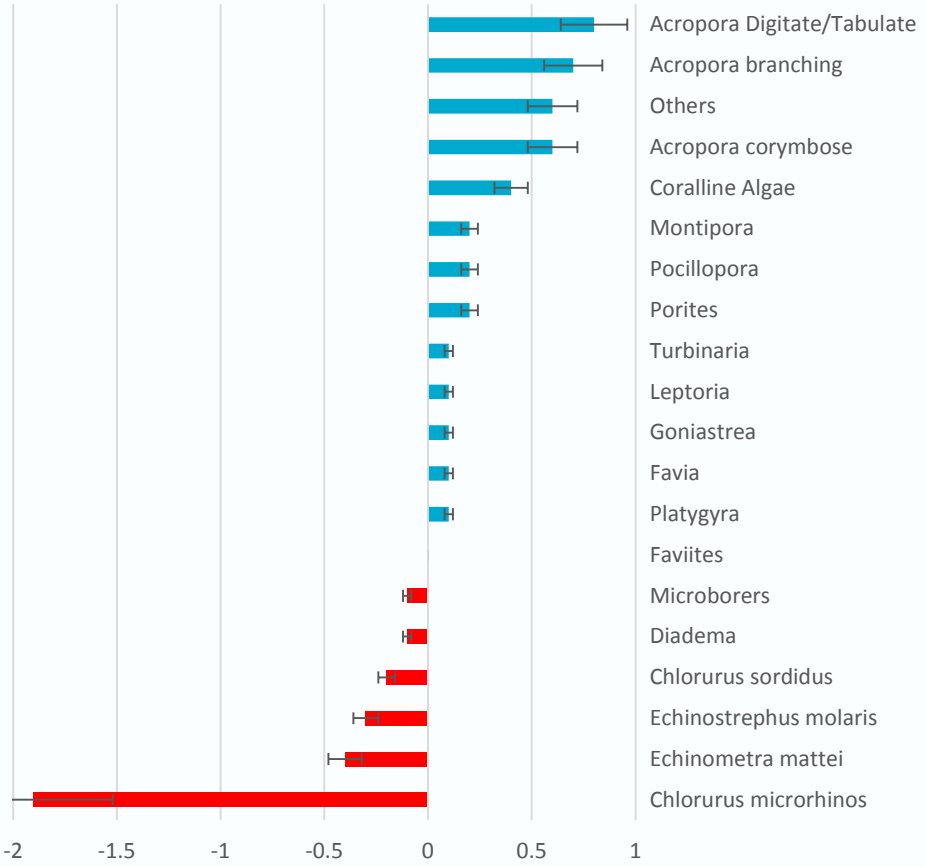
1. Important producers and bioeroders

- Acropora

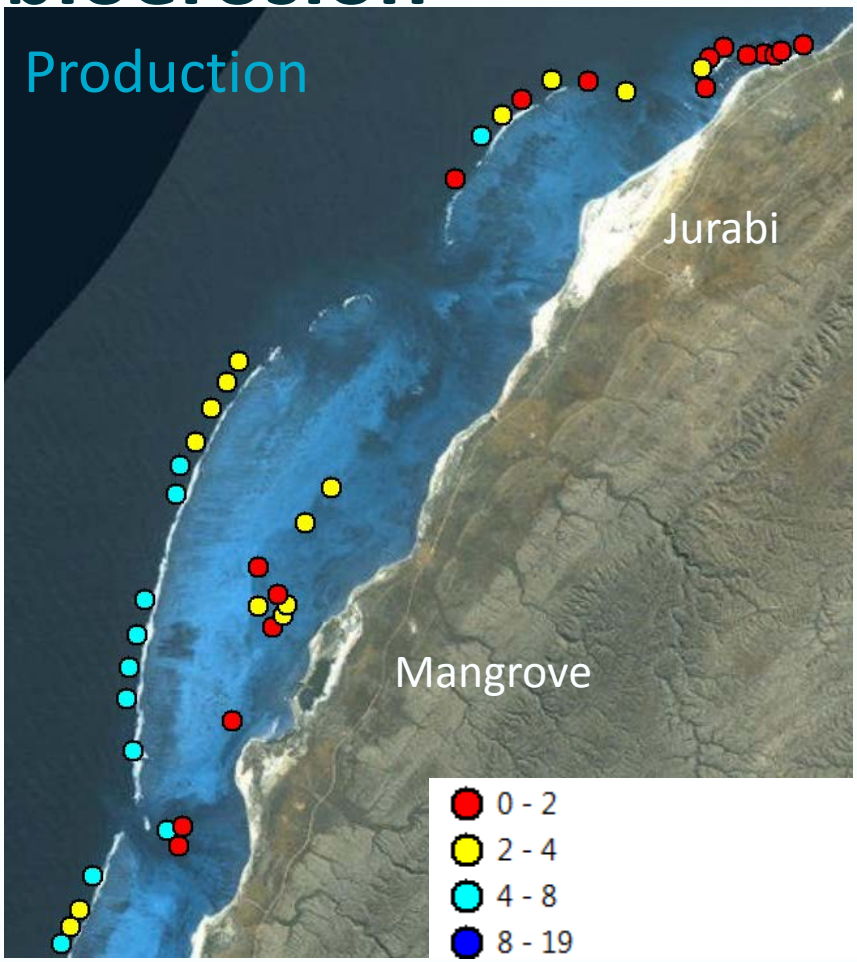
- Parrotfish

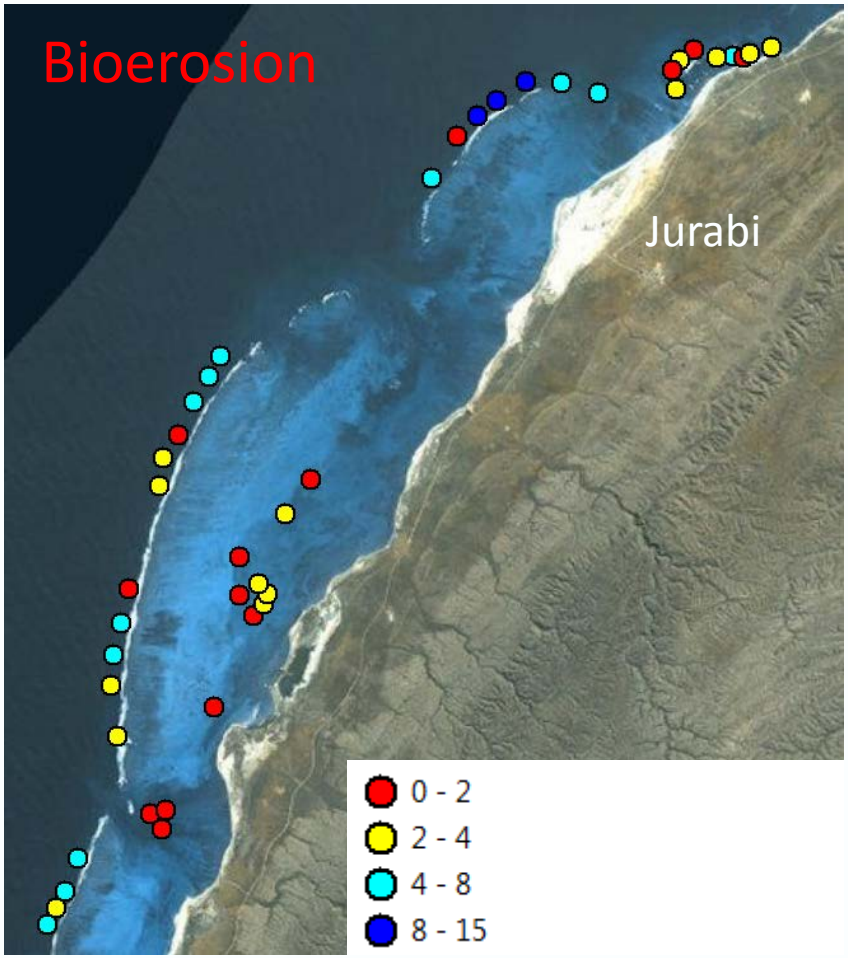
Mean production 3.3 kg/$CaCO^3$/m^2/yr

Mean bioerosion 2.9 kg/$CaCO^3$/m^2/yr

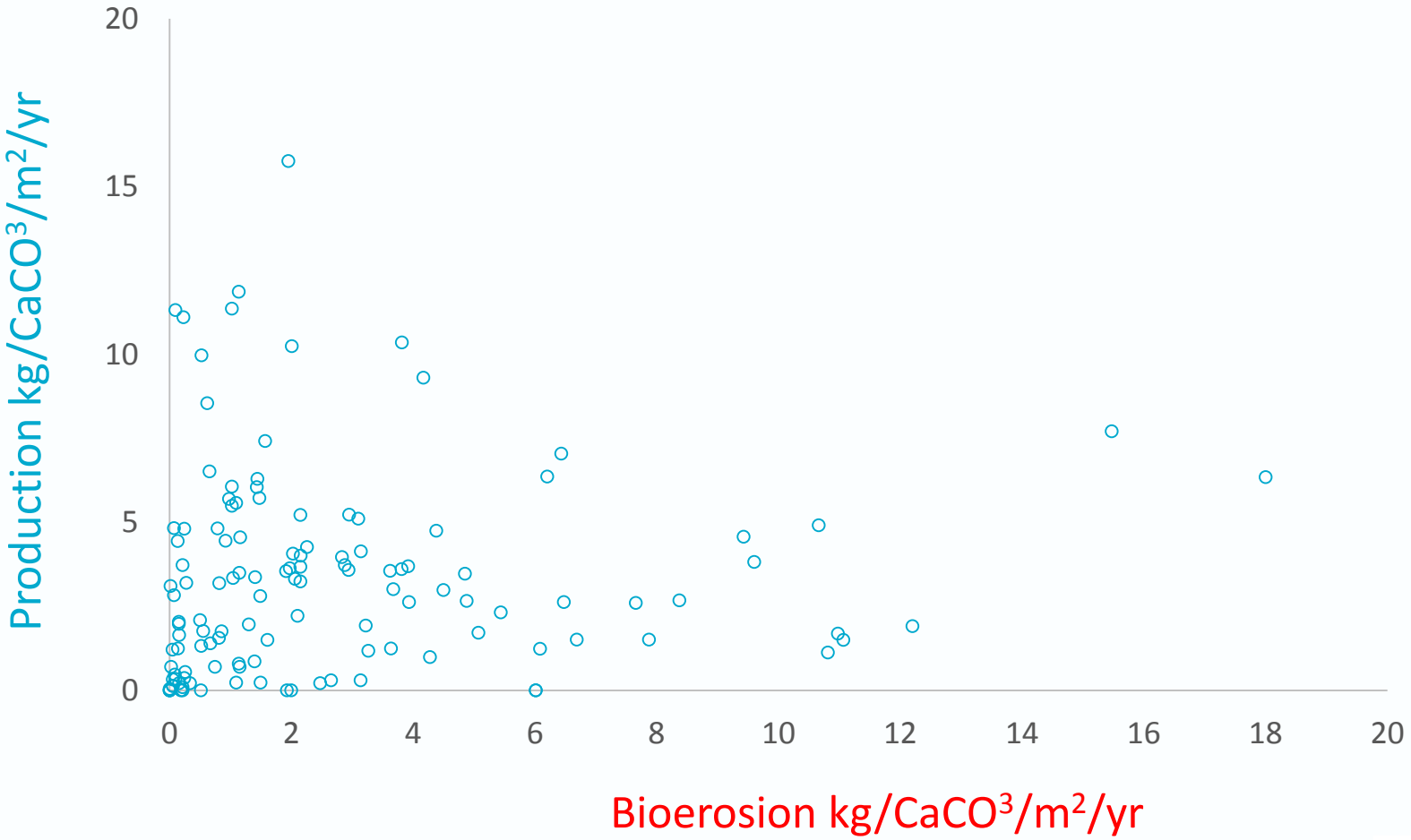


2. Spatial arrangement of production and bioerosion

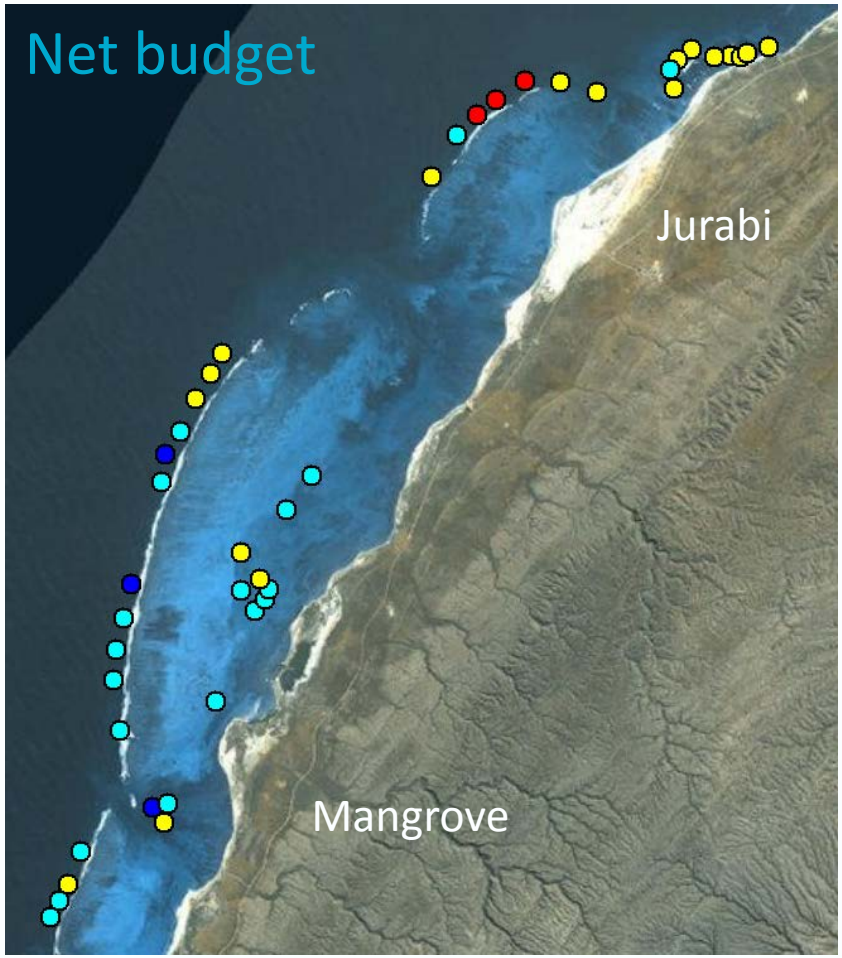


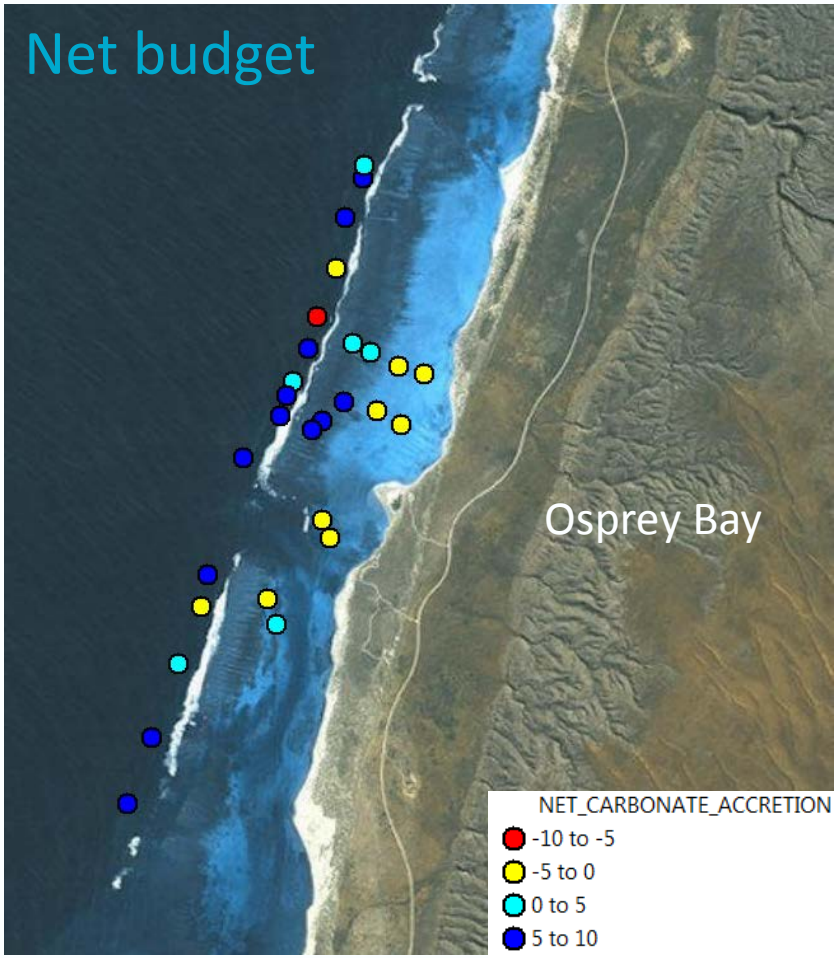


3. Is production a good predictor of bioerosion?



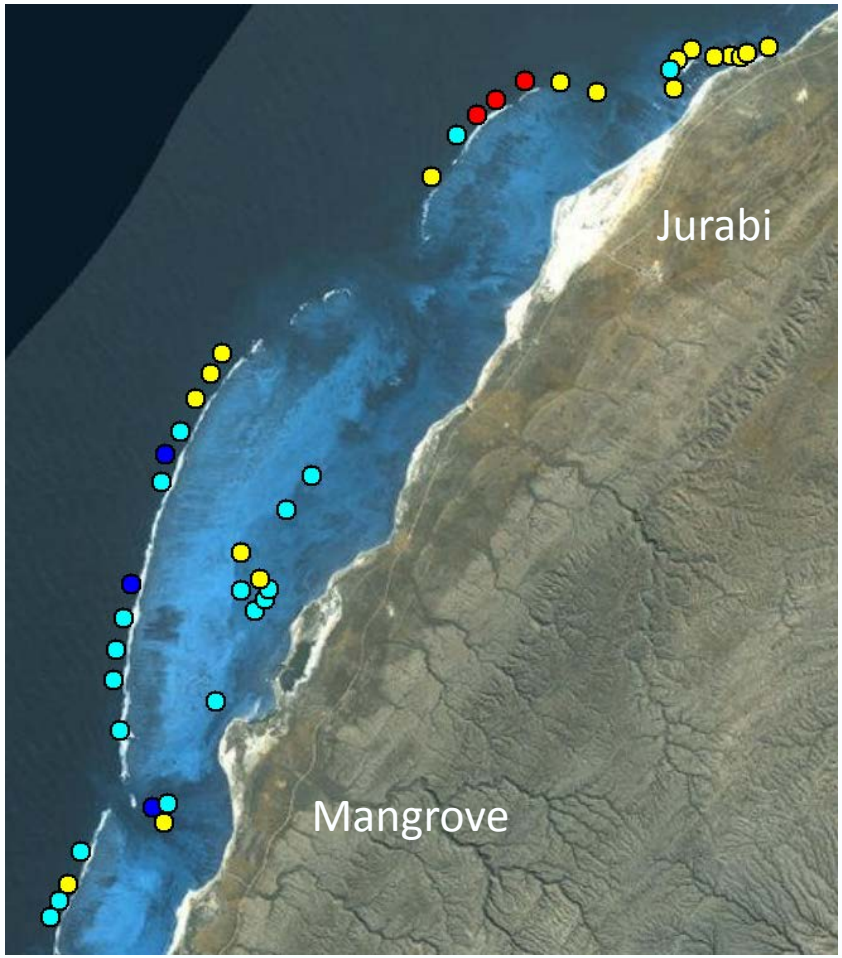
4. Spatial arrangement of net budgets

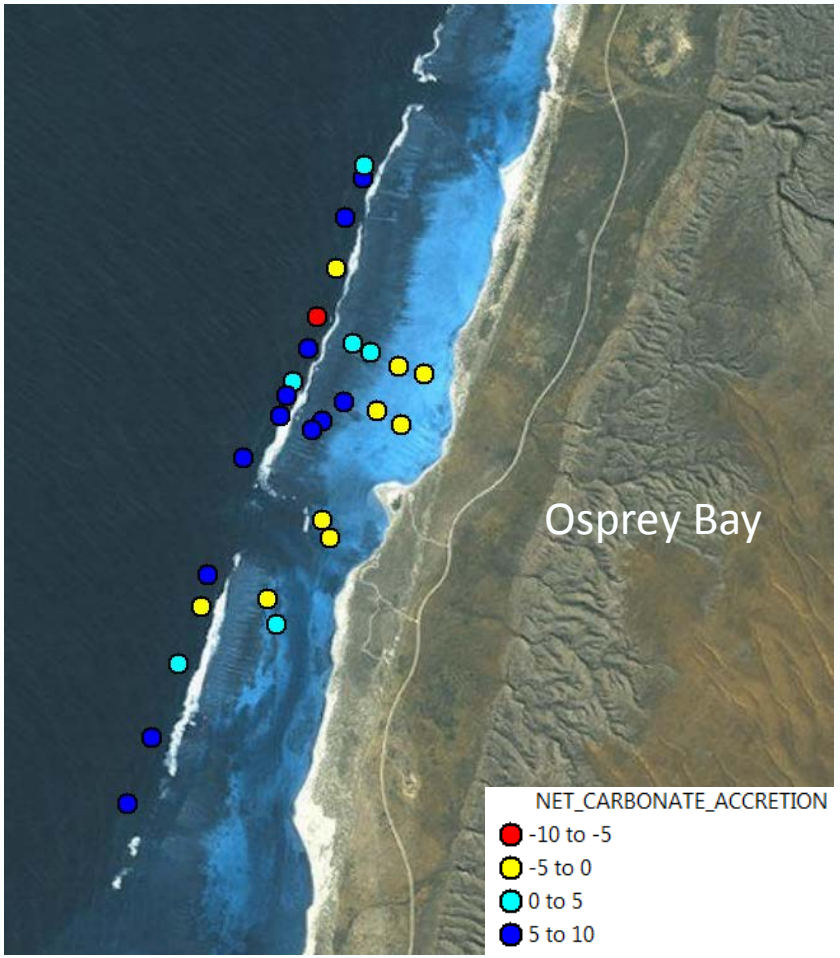




4. Spatial arrangement of net budgets

Linear mixed-effects model with 7 covariates ~ *Year + Depth + Reef + Region + MPA Zone + Reef Complexity + Water Velocity*





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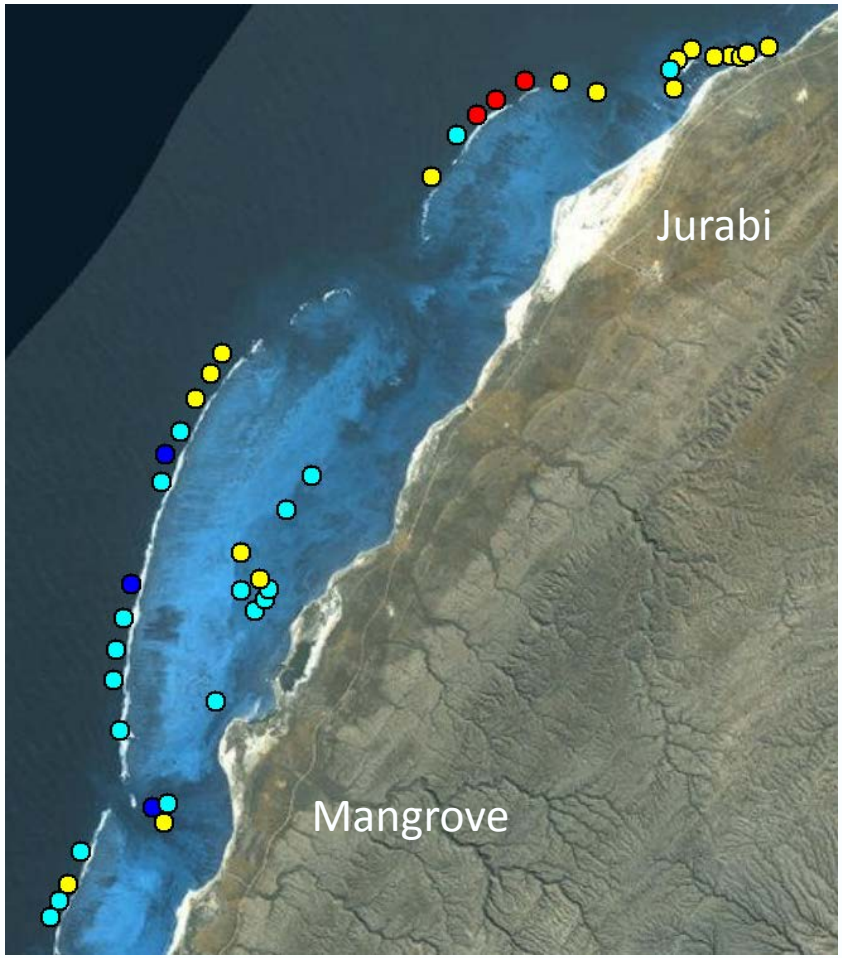

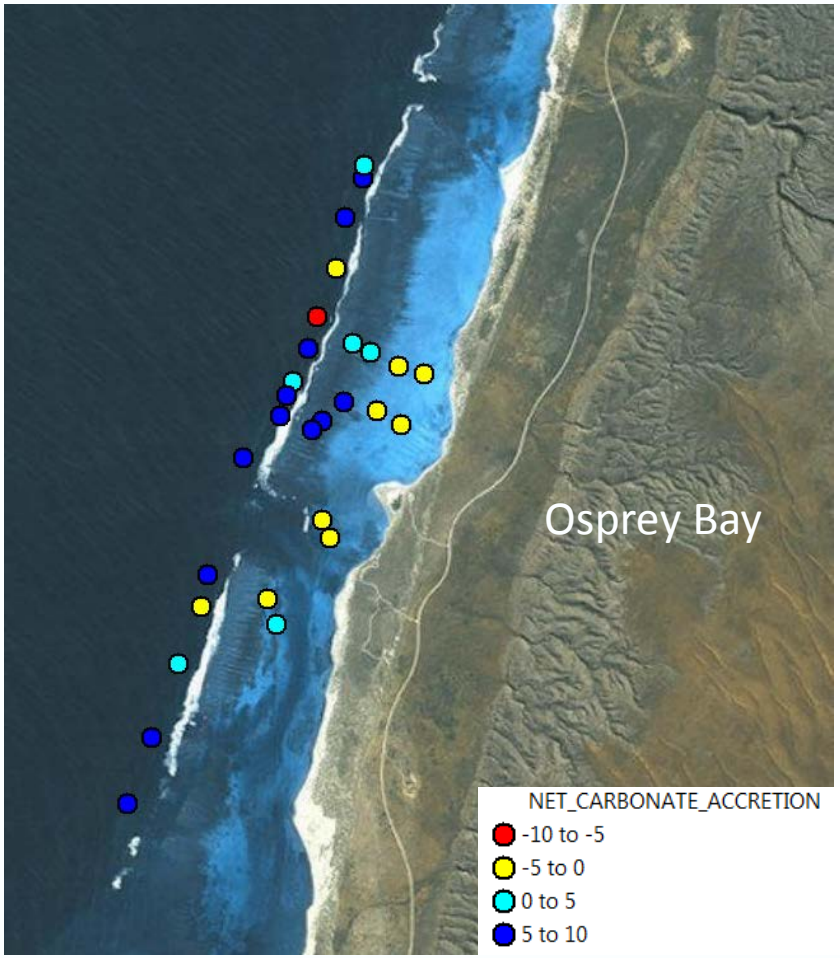

Conclusions

What are the important producers and bioeroders?

Prod = *Acropora*

Bio. = *C.microrhinos, E.mathaei*

Is production a good predictor of bioerosion? No

Spatial arrangement of net budgets

Negatively related with depth

Acknowledgements

- BHP Billiton-CSIRO Ningaloo Outlook Marine Research Partnership
- Reefcheck, Susie Bedford and CCG members
- Emma Lawrence for statistical advice
- C. Perry, S. Wilson and M.0'Leary
- Jo Myers, Jamie Small and the team

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Theme 2 Question Time

Coffee time….

Session 2 starts at 3:40….