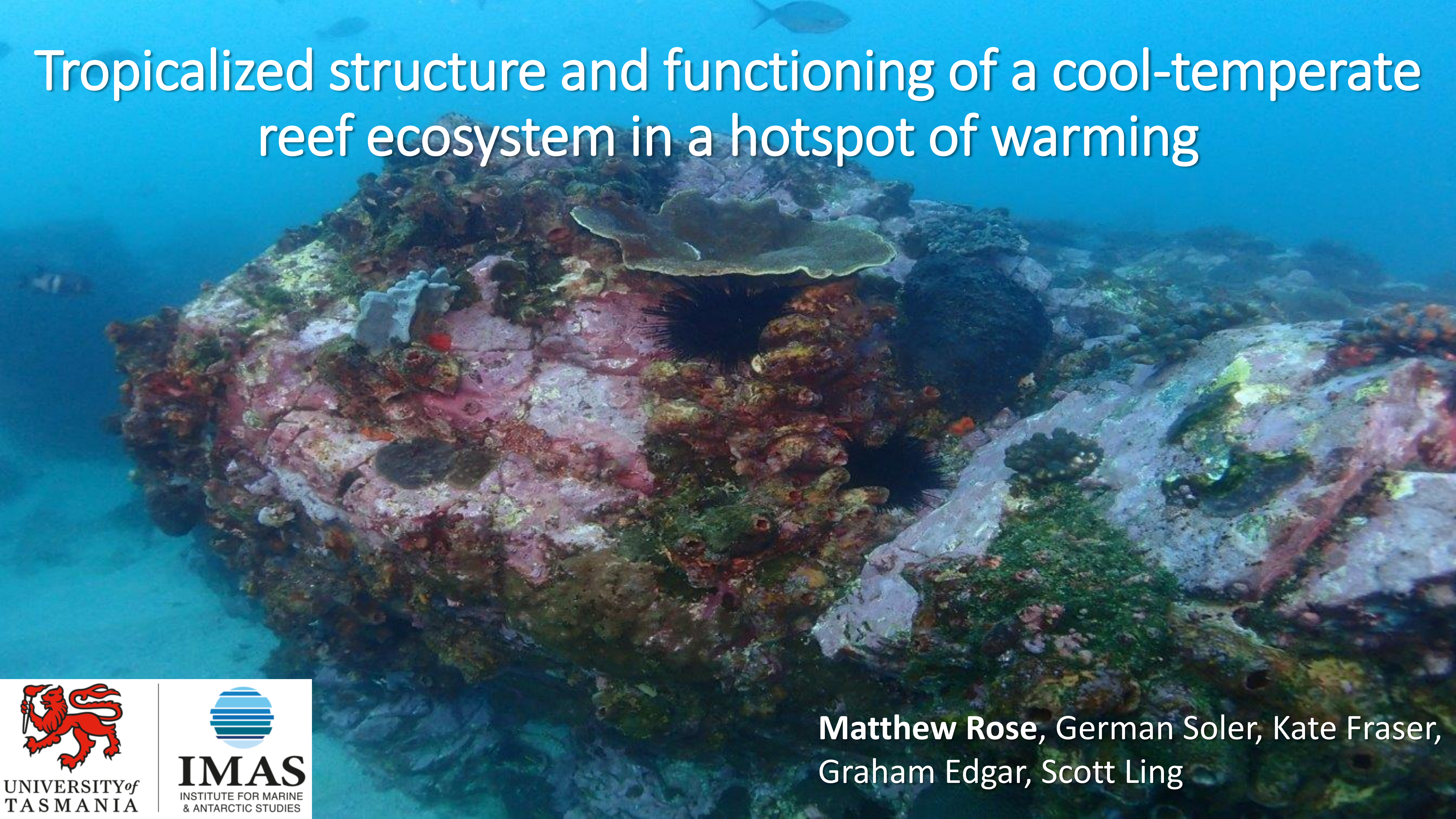
Tropicalized structure and functioning of a cool-temperate reef ecosystem in a hotspot of warming

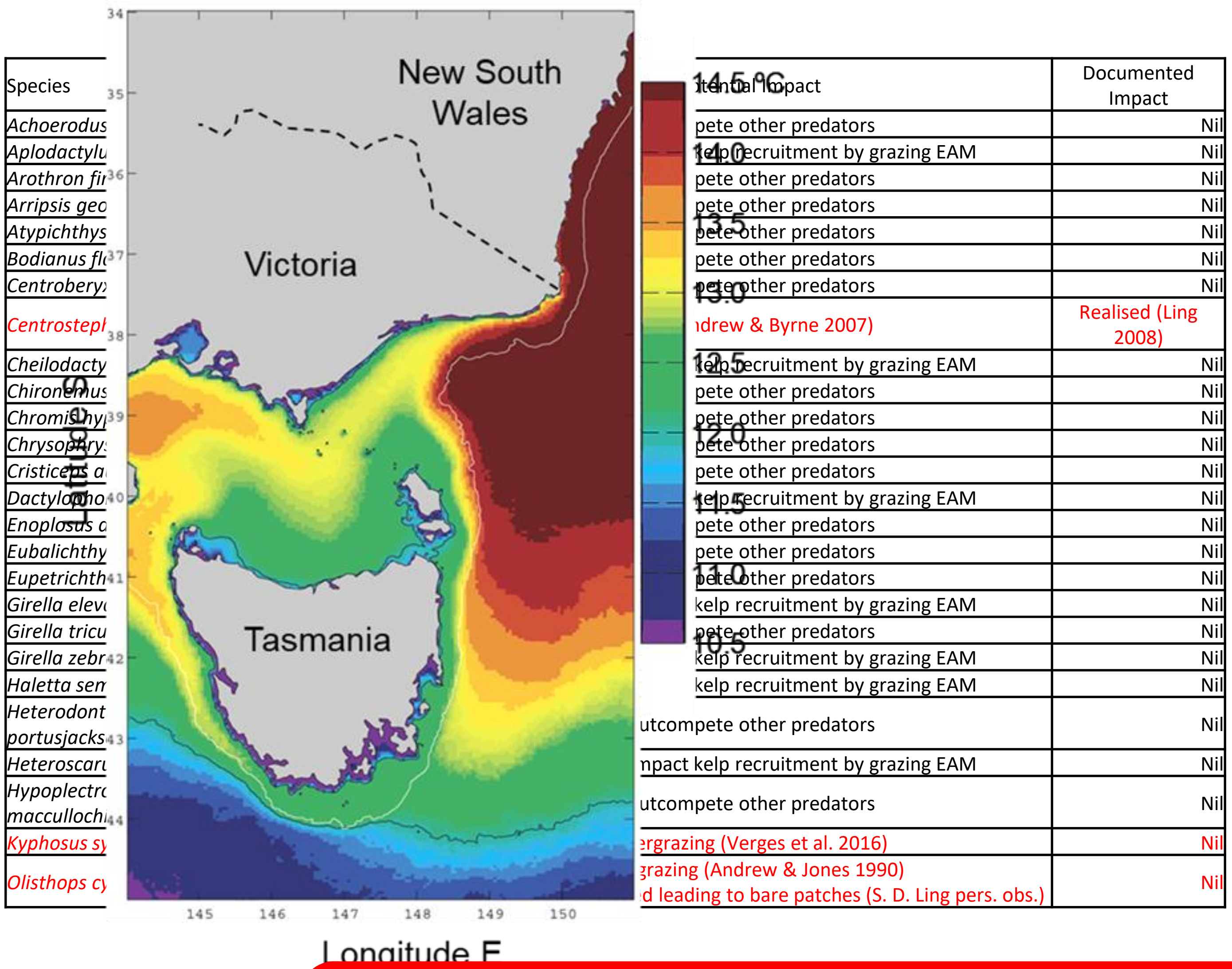


Matthew Rose, German Soler, Kate Fraser, Graham Edgar, Scott Ling

UNIVERSITY of TASMANIA

IMAS INSTITUTE FOR MARINE & ANTARCTIC STUDIES

Introduction



Tropicalization at a high latitude?

- Warming rates 3-4x faster than global averages
- Approximately 45 reef-associated range-extending species observed
- Which species have the greatest influence?

Are tropicalizing Northeastern Tasmanian reefs now structurally and functionally equivalent to NSW?

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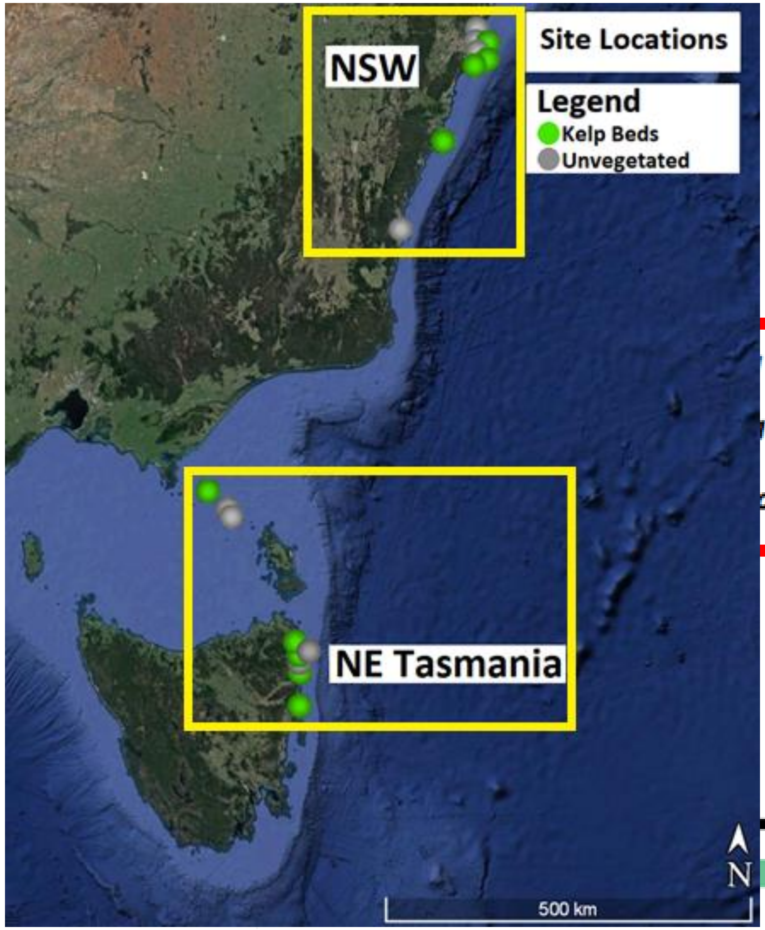
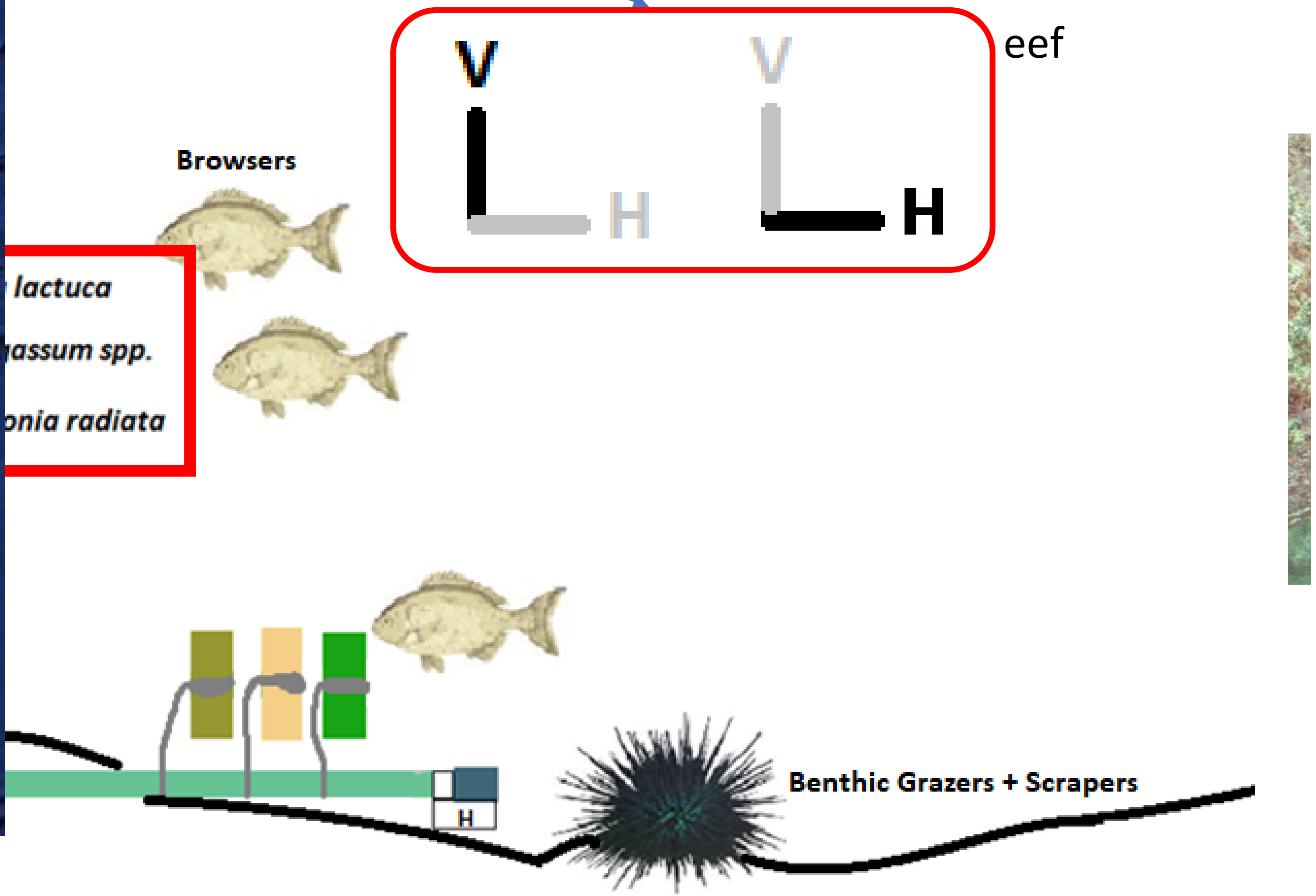
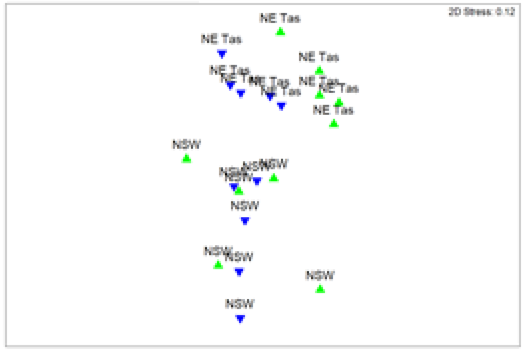
Experimental Design

Location*Habitat*Orientation*Algal Species

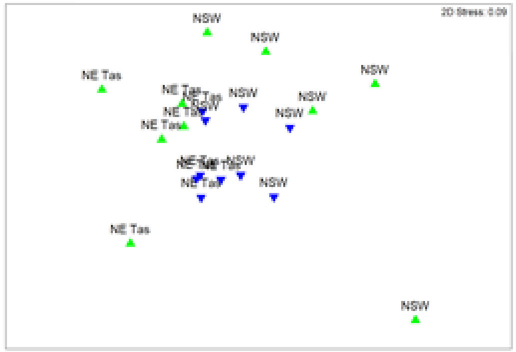




Fish Biomass

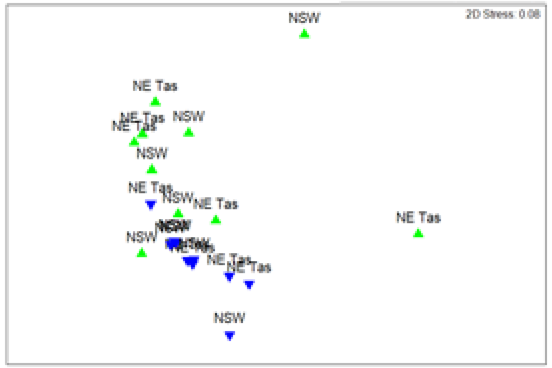


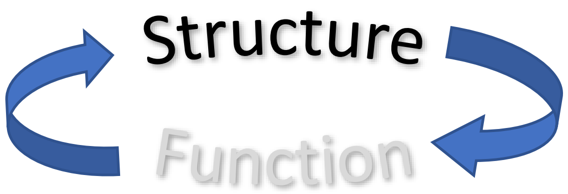
Benthic Biomass



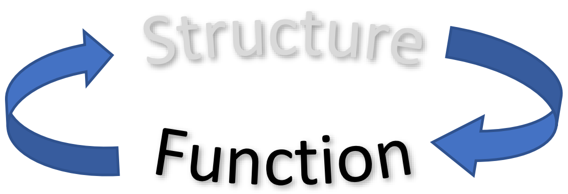
Fish Functional Biomass

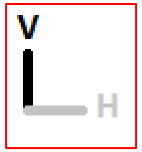
Benthic Functional Biomass

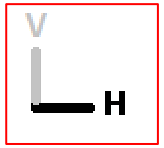




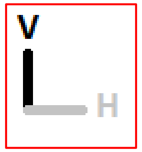
Results

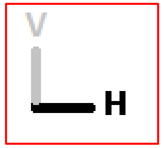






Taxonomic Biomass	Latitudinal Equivalence
Fish	
Kelp Bed	NO
Unvegetated	NO
Benthic	
Kelp Bed	NO
Unvegetated	YES





Functional Group Biomass	Latitudinal Equivalence
Fish	
Kelp Bed	**YES**
Unvegetated	**YES**
Benthic	
Kelp Bed	**YES**
Unvegetated	**YES**

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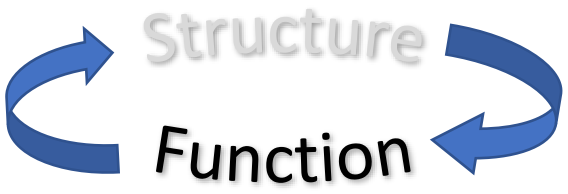
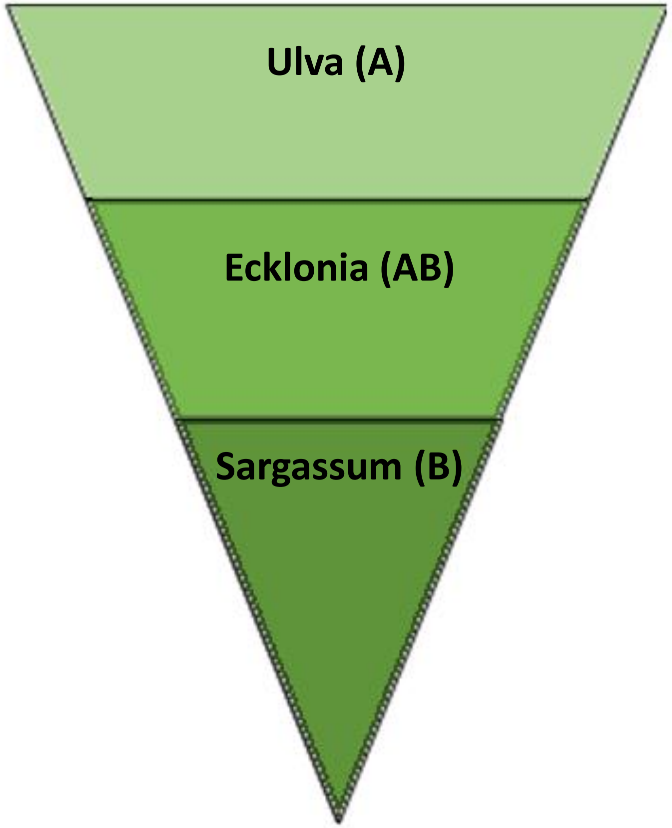
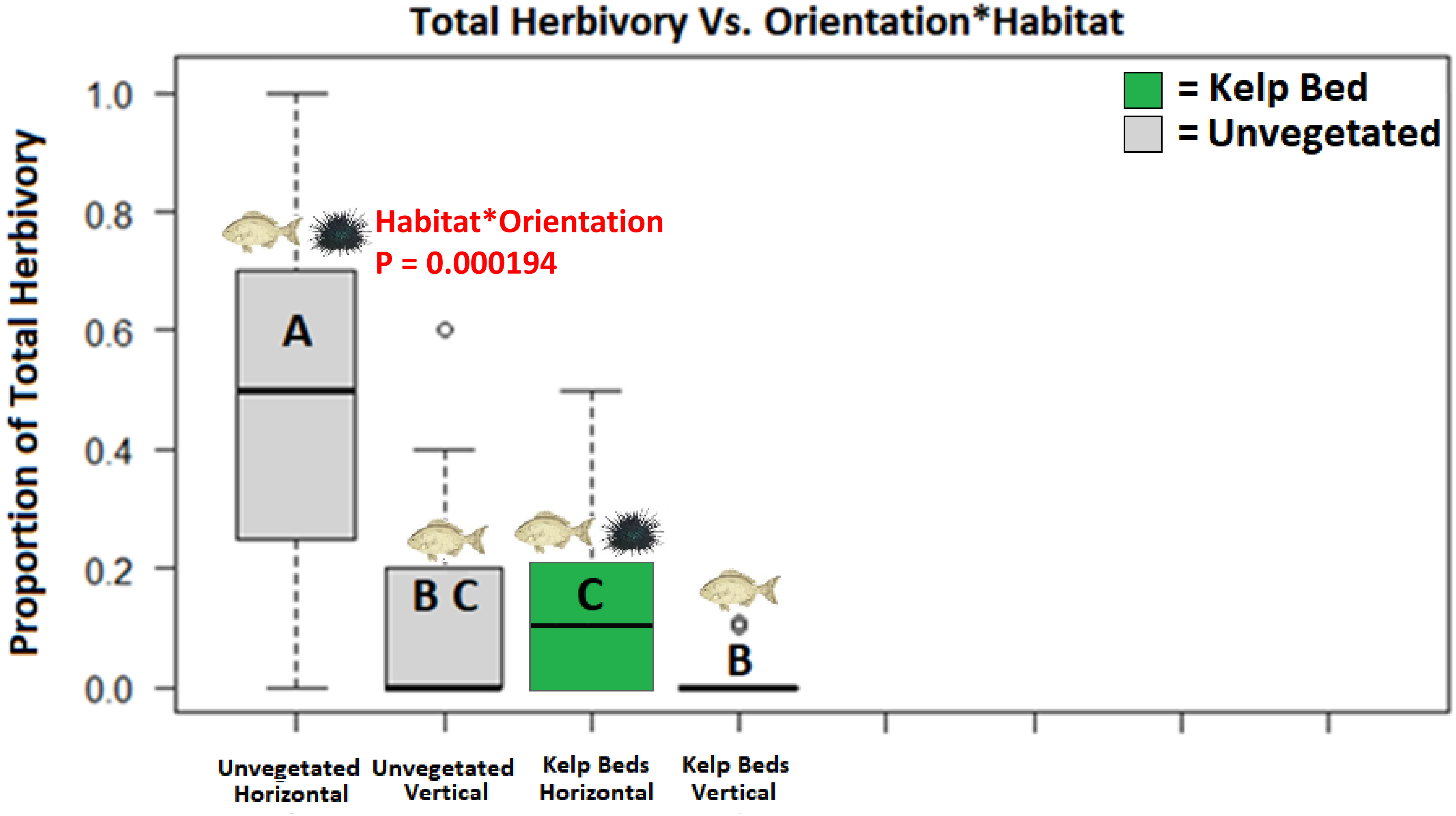


Function - Herbivory

Assay Species P = 0.011320





Location P = 0.027182

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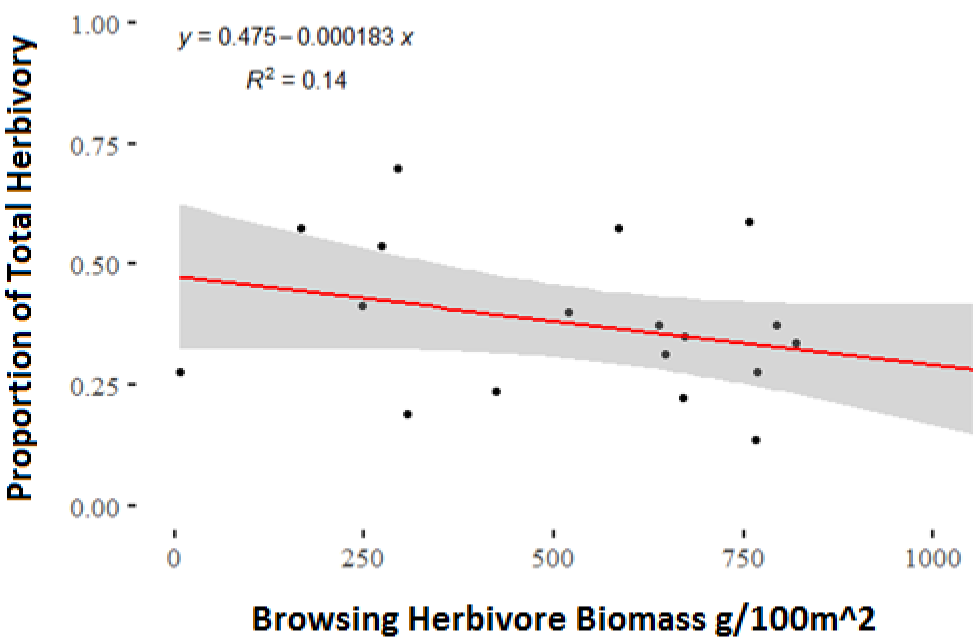
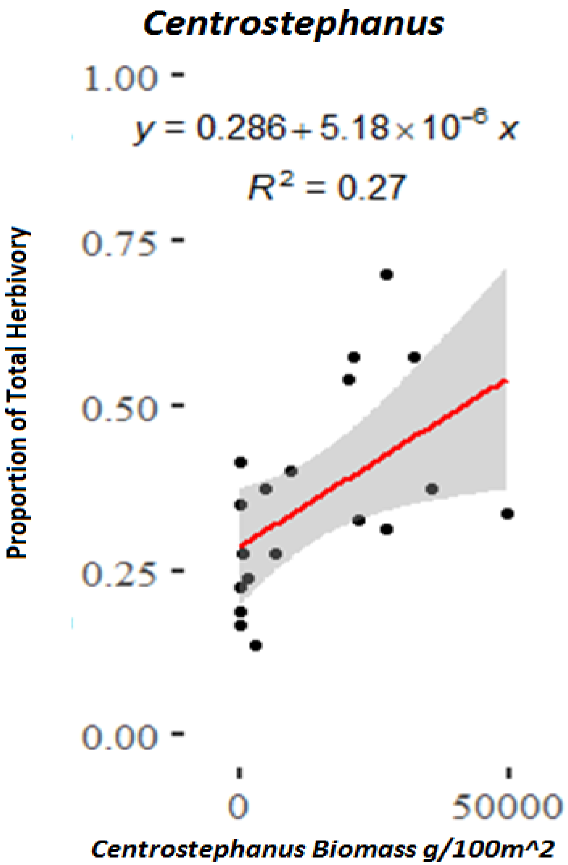
Predicting Function From Structure

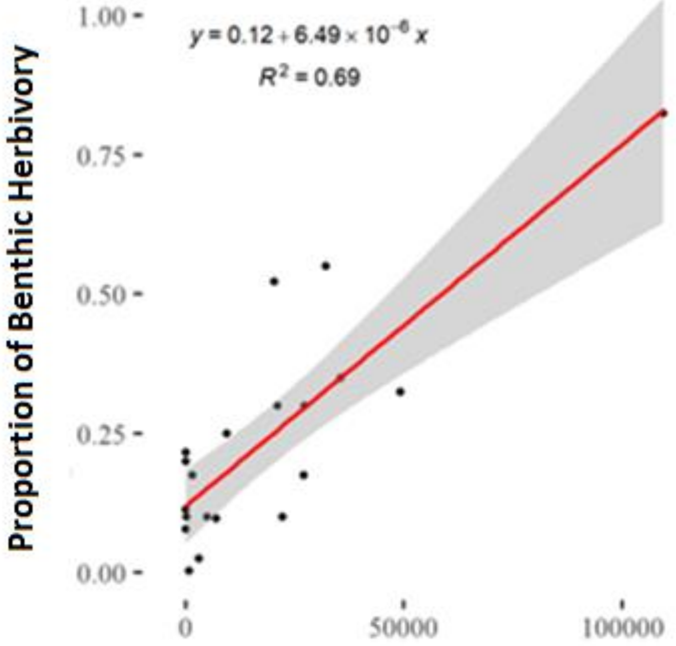
Browsing Herbivores



- Browsing herbivorous fish biomass showed no evidence of predicting herbivory



Centrostephanus



- Urchins are primary driver of herbivory
- Bioindicator

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Concluding Points

- Equivalence in community structure, functional community structure and measured patterns of herbivory on unvegetated reefs b/w NE Tas and NSW

- Therefore tropicalised unvegetated Tasmanian reefs are structurally and functionally equivalent to NSW reefs

- Coastwide resurvey of eastern Tas reefs showed an increase from 3% to 15% unvegetated, tropicalised reef-scape in the past 15 years (Ling & Keane 2018)

- *Centrostephanus* is the primary driver of ecosystem function, should therefore be utilised as a bioindicator in Tas and NSW

Acknowledgements

ARC Discovery Project 2017 “Human impacts on marine herbivores that contribute to degradation of reef ecosystems”; G. Edgar, S. Ling, A. Hoey, E. Duffy

Reef Life Survey

Redmap

Divers:
Scott Ling
John Turnbull
Kate Fraser
John Keane
Gabby Walley
German Soler
Lizzi Oh
Martin Puchert
Louise de Beuzeville

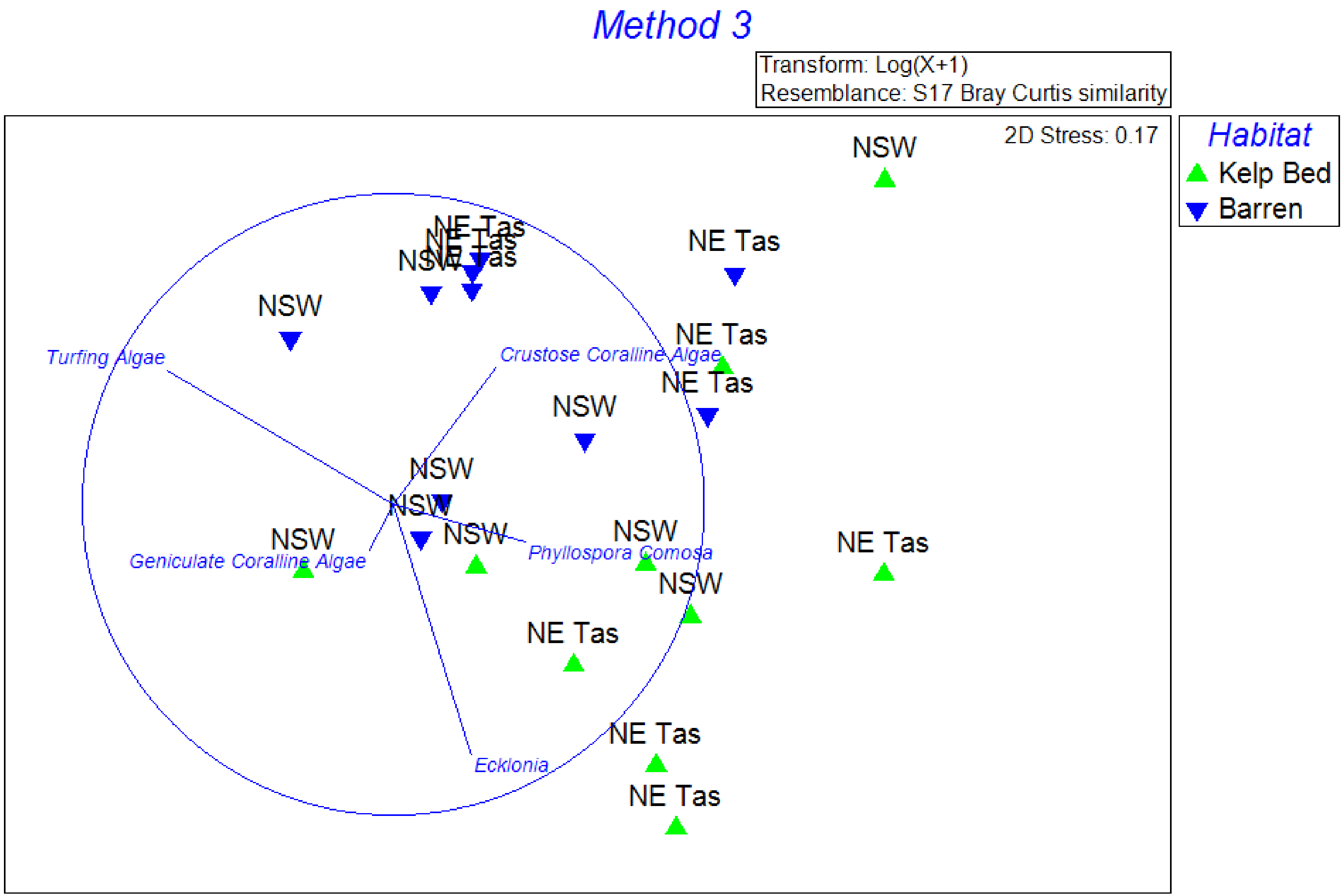
Discussions
Rick Stuart-Smith and Freddie Heather

Questions?

Structure → Inferred → Measured

		Total: Model explained 69.92%			Vertical: Model Insignificant			Horizontal: Model explained 81.80%			Benthic: Model Explained 82.47%		
Functional Group	**Species**	**Img**	**Predicted**	**Observed**	**Img**	**Predicted**	**Observed**	**Img**	**Predicted**	**Observed**	**Img**	**Predicted**	**Observed**
	C. rodgersii	0.42	60.38%	89.34%	0.00	0.00%	0.00%	0.39	48.44%	89.34%	0.47	56.72%	89.34%
Benthic Grazing	***H. erythrogramma***	0.00	**0.00%**	**7.38%**	0.00	0.00%	0.00%	0.00	**0.00%**	**7.38%**	0.00	**0.00%**	**7.38%**
and Scraping Herbivores	***Amblypneustes spp.***	0.02	**3.33%**	**0.00%**	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
(2/5 Predicted; 2/5 Observed)	***P. parvispinus***	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.07	**8.31%**	**0.00%**	0.13	**16.09%**	**0.00%**
	T. alexandri	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.02	**3.02%**	**0.00%**	0.02	**2.82%**	**0.00%**
	T. undulatus	0.06	**9.41%**	**0.00%**	0.00	0.00%	0.00%	0.06	**7.88%**	**0.00%**	0.06	**7.78%**	**0.00%**
Benthic Grazing Herbivores	*T. torquatus*	0.00	0.00%	0.82%	0.00	0.00%	0.00%	0.01	1.01%	0.00%	0.00	0.00%	0.82%
(2/5 Predicted; 2/5 Observed)	*A. dactylomela*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.07	8.93%	0.00%
	H. rubra	0.00	0.00%	2.46%	0.00	0.00%	0.00%	0.04	5.18%	2.46%	0.07	8.13%	2.46%
	D. auricularia	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Benthic Deposit Feeding Omnivores	*A. tentoriiforme*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Feeding Omnivore (0/2 Predicted; 0/2 Observed)	*Pagurid spp.*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Benthic Predatory	*N. tuberculosus*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
and Grazing Omnivorew (0/2 Predicted, 0/2 Observed)	*H. elatus*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Grazing Herbivores (1/1 Predicted; 0/1 Observed)	***M. immaculatus***	0.19	**28.22%**	**0.00%**	0.00	0.00%	0.00%	0.16	**20.23%**	**0.00%**	0.00	0.00%	0.00%
	P. microlepis	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Browsing Herbivores	*A. lophodon*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
(0/5 Predicted; 0/5 Observed)	***O. cyanomelas***	**0.00**	**0.00%**	**0.00%**	**0.00**	**0.00%**	**0.00%**	**0.00**	**0.00%**	**0.00%**	**0.00**	**0.00%**	**0.00%**
	A. vittiger	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
	M. trachylepis	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Predatory and	*C. truncatus*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Browsing Omnivore	*Z. cornutus*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
(0/3 Predicted; 0/3 Observed)	*H. australis*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%

(green)	Predicited to have a significant contribution to explained model variation (P<0.05).
(yellow)	Contributed to model variation explained but weren't observed in field, or were observed in field but weren't predicted for in regresion model.



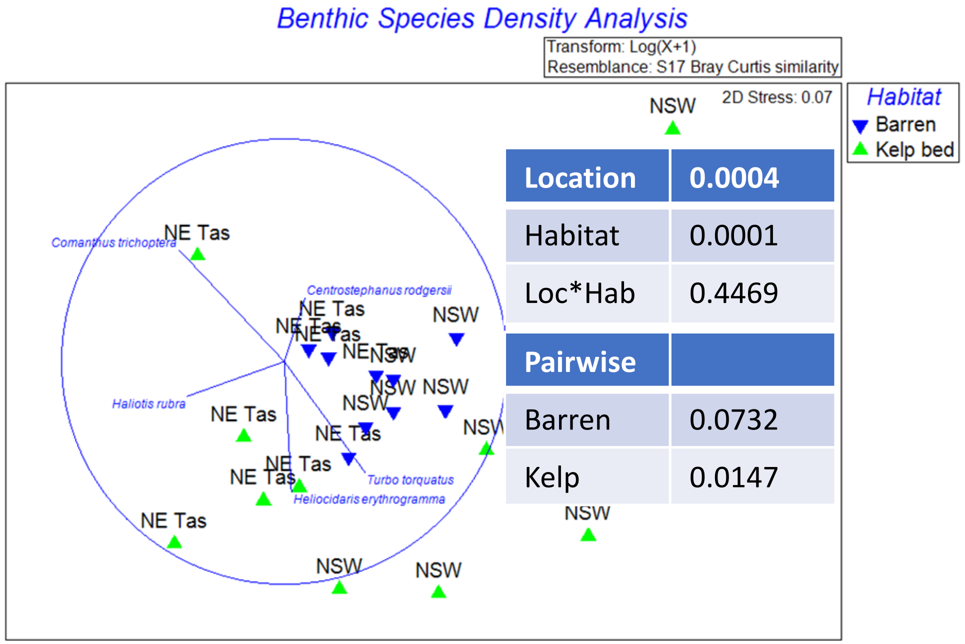
- Photo-quadrats
- Habitat structure (macroalgage/ sponges/CCA).
- Kelp beds same across location…therefore good logic to compare them
- Differences in barrens, > turfing algae in NSW barrens, > CCA in Tas. Perhaps driven by mesograzers. But same in regards to lack of macroalgae cover, therefore good logic to compare.

Structure

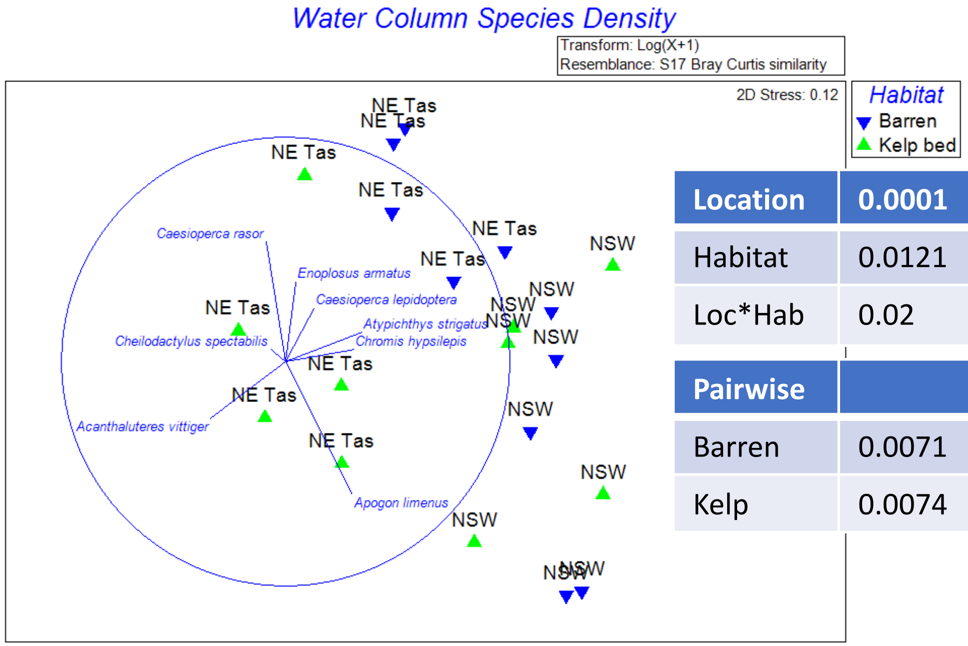
Analyses

Multivariate + Univariate on Species:
Abundance
Density
Biomass

Patterns
Consistent across each 3 multivariate analyses



Location	0.0004
Habitat	0.0001
Loc*Hab	0.4469
Pairwise	
Barren	0.0732
Kelp	0.0147



Location	0.0001
Habitat	0.0121
Loc*Hab	0.02
Pairwise	
Barren	0.0071
Kelp	0.0074

Univariate:

- > biomass centros on barrens (same across locations)
- > biomass helios in kelp beds (same across locations)
- > Olisthops cyanomelas biomass in Tas, in kelp beds (range-extender)
- > Parma microlepis biomass on barrens, associating with coral reef-like habitat structure.

Inferred Function

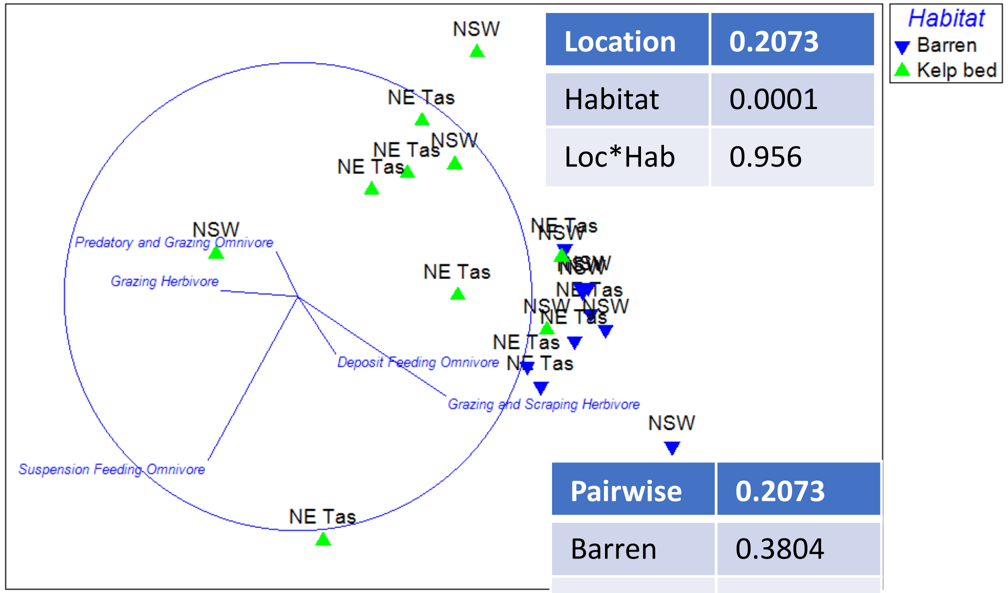
Analyses

Multivariate on Functional Groups:
Abundance
Density
Biomass

Patterns
Benthic – same patterns for biomass but suspension feeders not as important

Water Column – opposite for biomass, equivalence shown

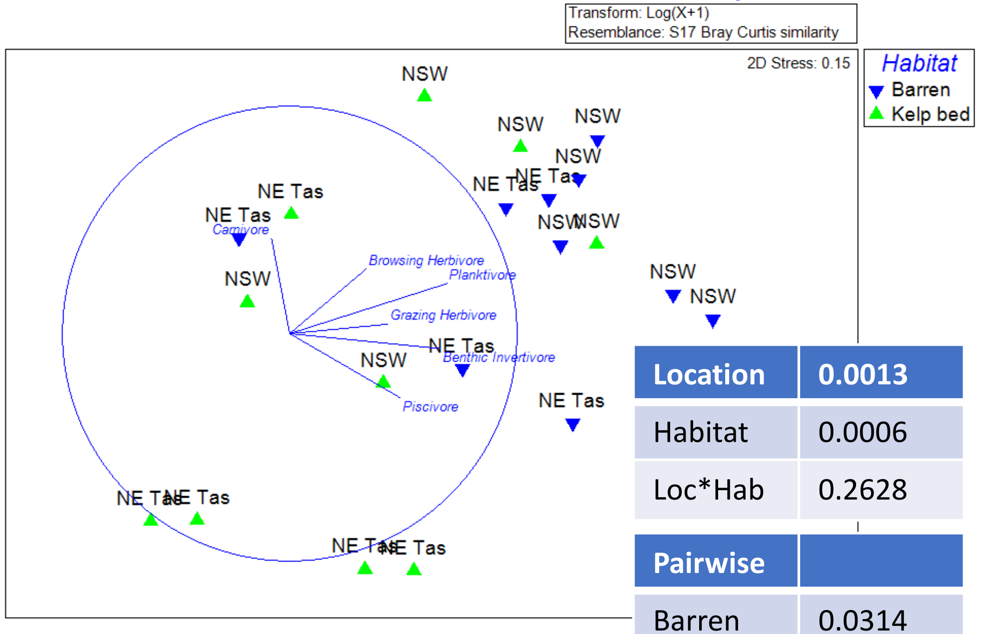
Benthic Functional Entities Density



Location	0.2073
Habitat	0.0001
Loc*Hab	0.956

Pairwise	0.2073
Barren	0.3804
Kelp	0.65

Water Column Functional Entities Density



Location	0.0013
Habitat	0.0006
Loc*Hab	0.2628

Pairwise	
Barren	0.0314
Kelp	0.024

Univariate:

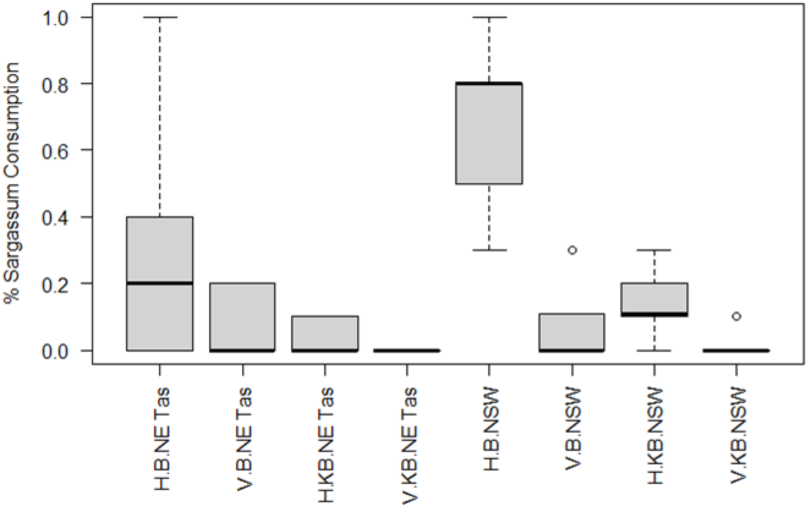
- Benthic Grazing and Scraping Herbivores Biomass > Barrens, same across locations.
- Planktivore biomass > in Tas, concentrated on barrens

4-way ANOVA Testing Herbivory

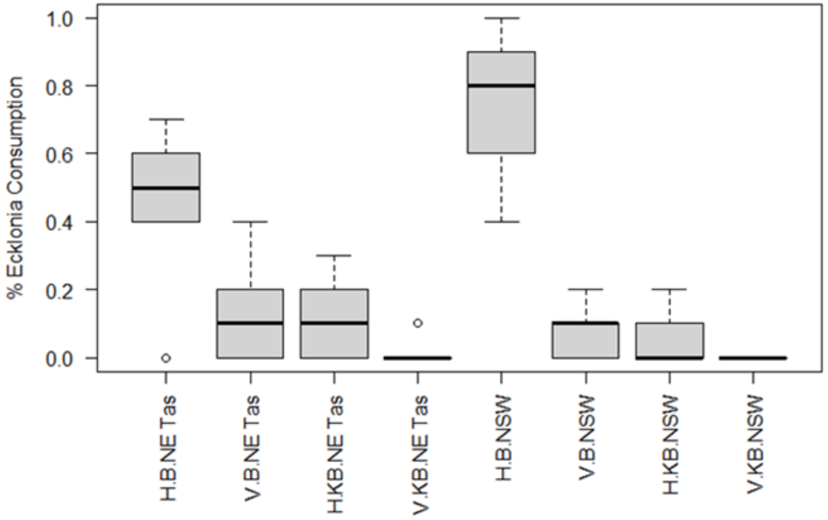
```
                                         Df Sum Sq Mean Sq F value   Pr(>F)    
Location                                  1  0.420   0.420   5.032 0.027182 *  
Habitat                                   1  3.583   3.583  42.980 2.77e-09 ***
Orientation                               1  5.665   5.665  67.949 8.67e-13 ***
AssaySpecies2                             2  0.783   0.392   4.697 0.011320 *  
Location:Habitat                          1  0.042   0.042   0.506 0.478695    
Location:Orientation                      1  0.294   0.294   3.525 0.063476 .  
Habitat:Orientation                       1  1.253   1.253  15.023 0.000194 ***
Location:AssaySpecies2                    2  0.106   0.053   0.638 0.530529    
Habitat:AssaySpecies2                     2  0.222   0.111   1.332 0.268666    
Orientation:AssaySpecies2                 2  0.057   0.029   0.344 0.709761    
Location:Habitat:Orientation              1  0.195   0.195   2.337 0.129650    
Location:Habitat:AssaySpecies2            2  0.220   0.110   1.321 0.271584    
Location:Orientation:AssaySpecies2        2  0.092   0.046   0.553 0.577098    
Habitat:Orientation:AssaySpecies2         2  0.005   0.003   0.030 0.970141    
Location:Habitat:Orientation:AssaySpecies2 2  0.073   0.036   0.437 0.647040    
Residuals                                96  8.004   0.083                     
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Measured Function – each marcoalgae species Tested against **Location*Habitat*Orientation**

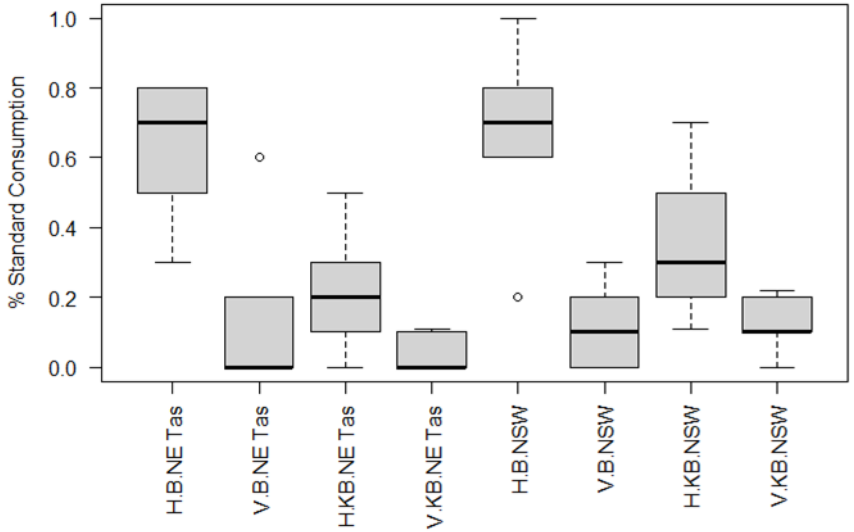
B
Sargassum



AB
Ecklonia



A
Ulva - Standard



Location = 0.043
Habitat = 0.005
Orientation = 0.0004

Habitat*Orientation = 0.011

Habitat*Orientation = 0.042

INCREASING PALLETABILITY

Introduction

Tropicalisation

- Poleward range-extensions of thermal range niches (Parmesan, C. & Yohe, G., 2003 Pecl et al., 2017; Stuart-Smith et al., 2017)

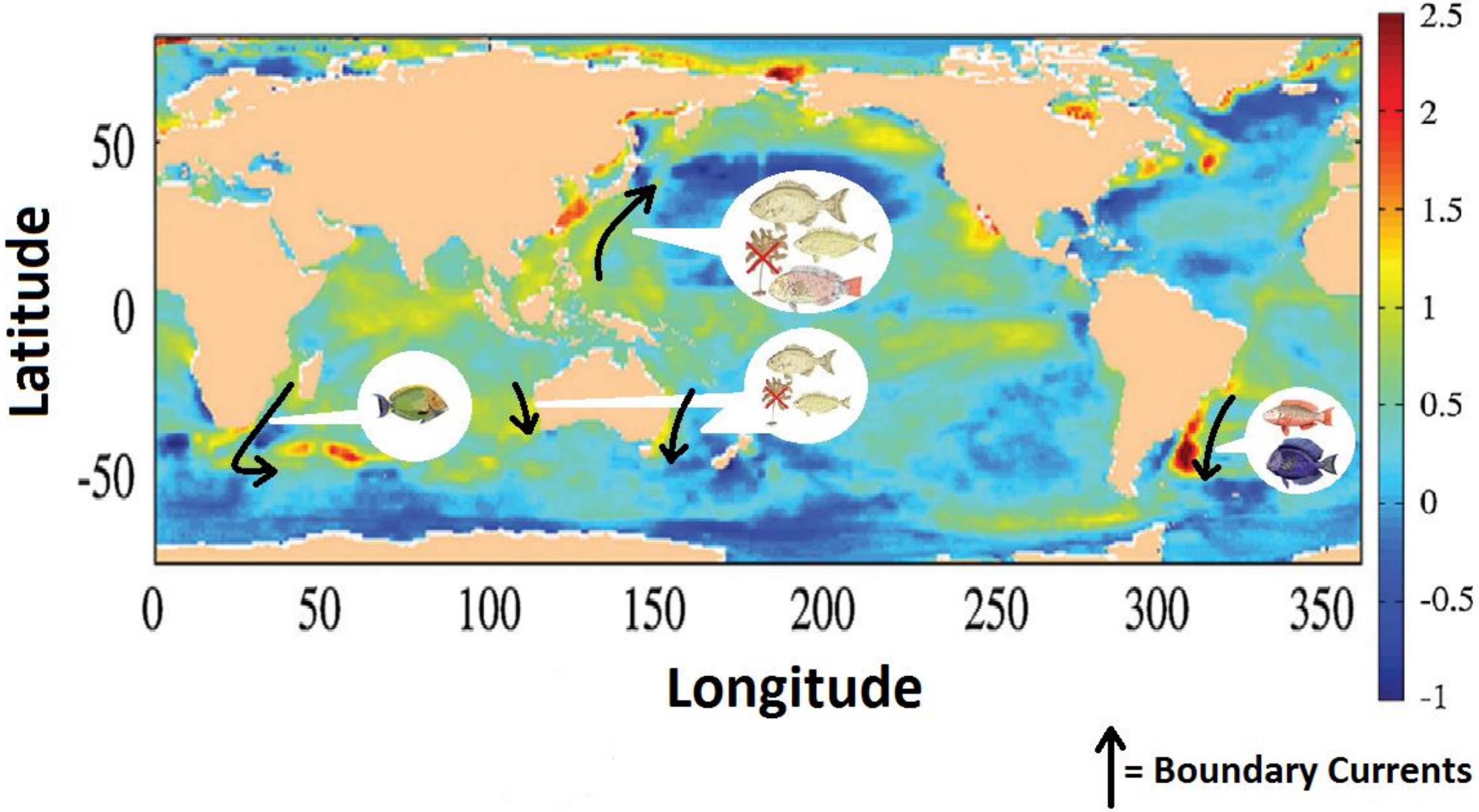
- Reef community structure

- Change in ecosystem function

Introduction

Tropicalisation around the globe

- Occurring globally
- Rabbitfish
- Drummer
- Overlaps with hotspots
- Tropicalisation at high latitudes?

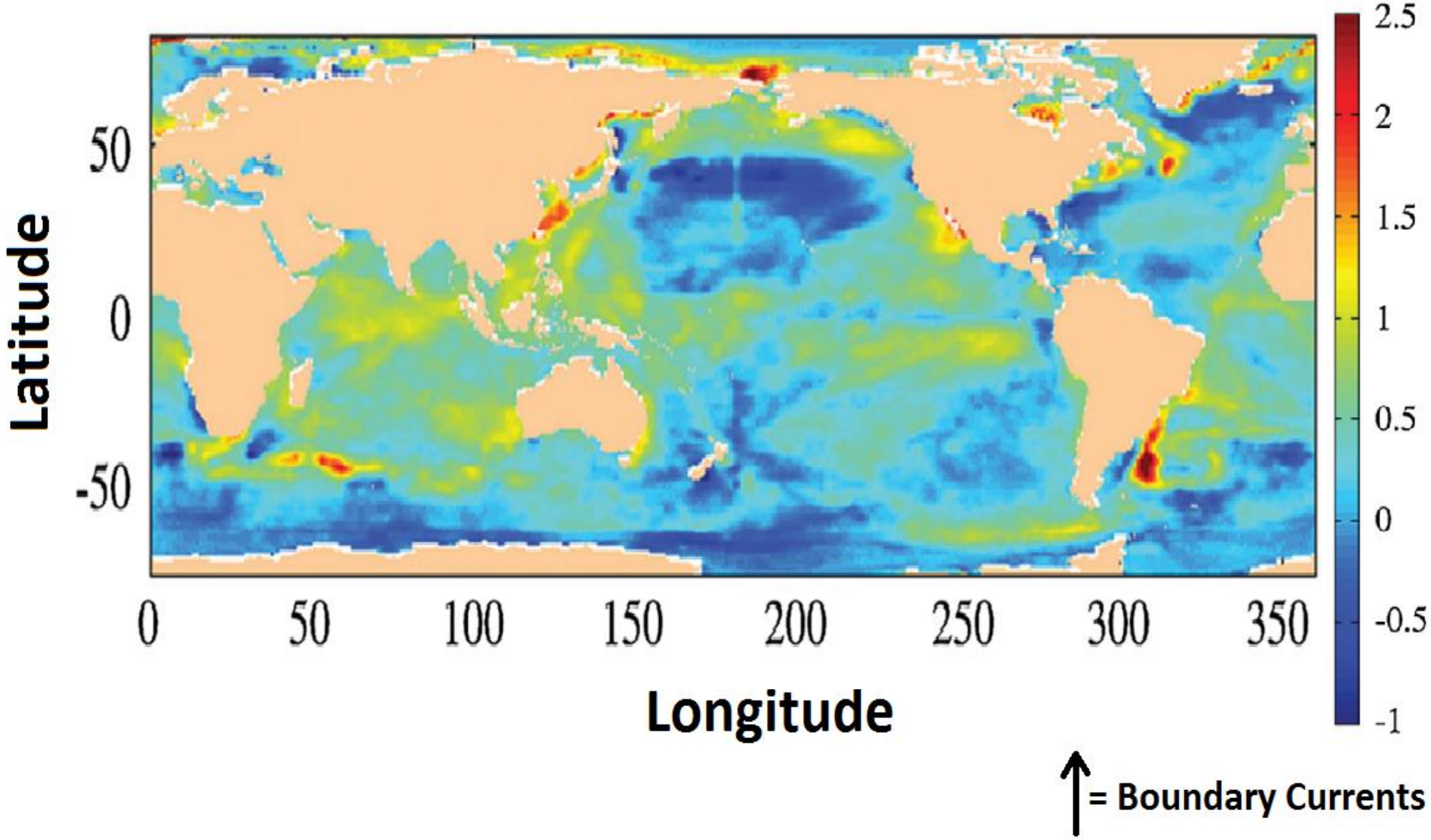


(Re-drawn from Hobday and Pecl, 2014)

Introduction

Oceans as a heat sink

- Temperature
- Changing ocean currents
- Hotspots
- Novel species interactions

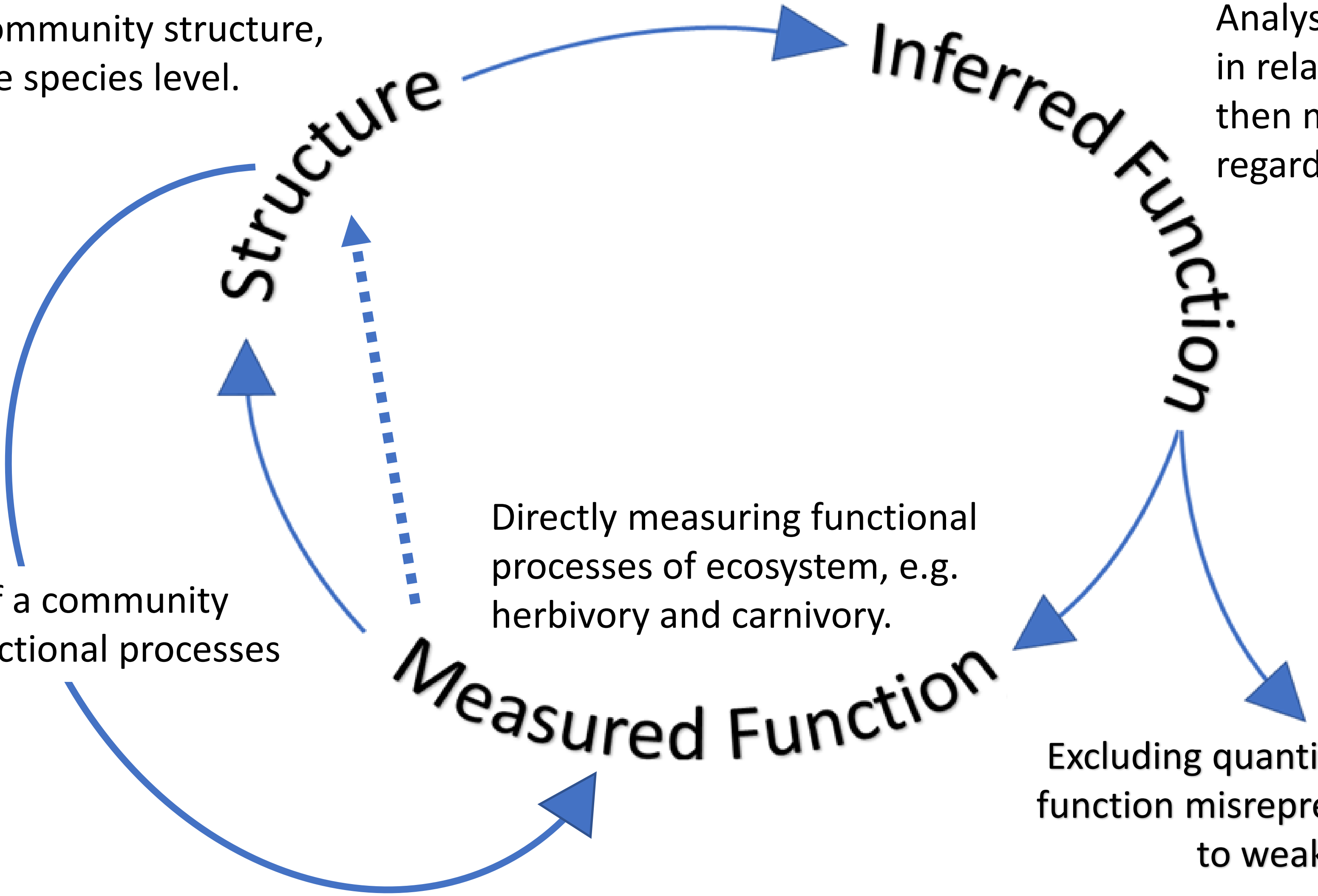


(Re-drawn from Hobday and Pecl, 2014)

Introduction

Analysing community structure, ideally at the species level.

Analysing community structure in relation to functional traits, then making inferences regarding ecosystem function.

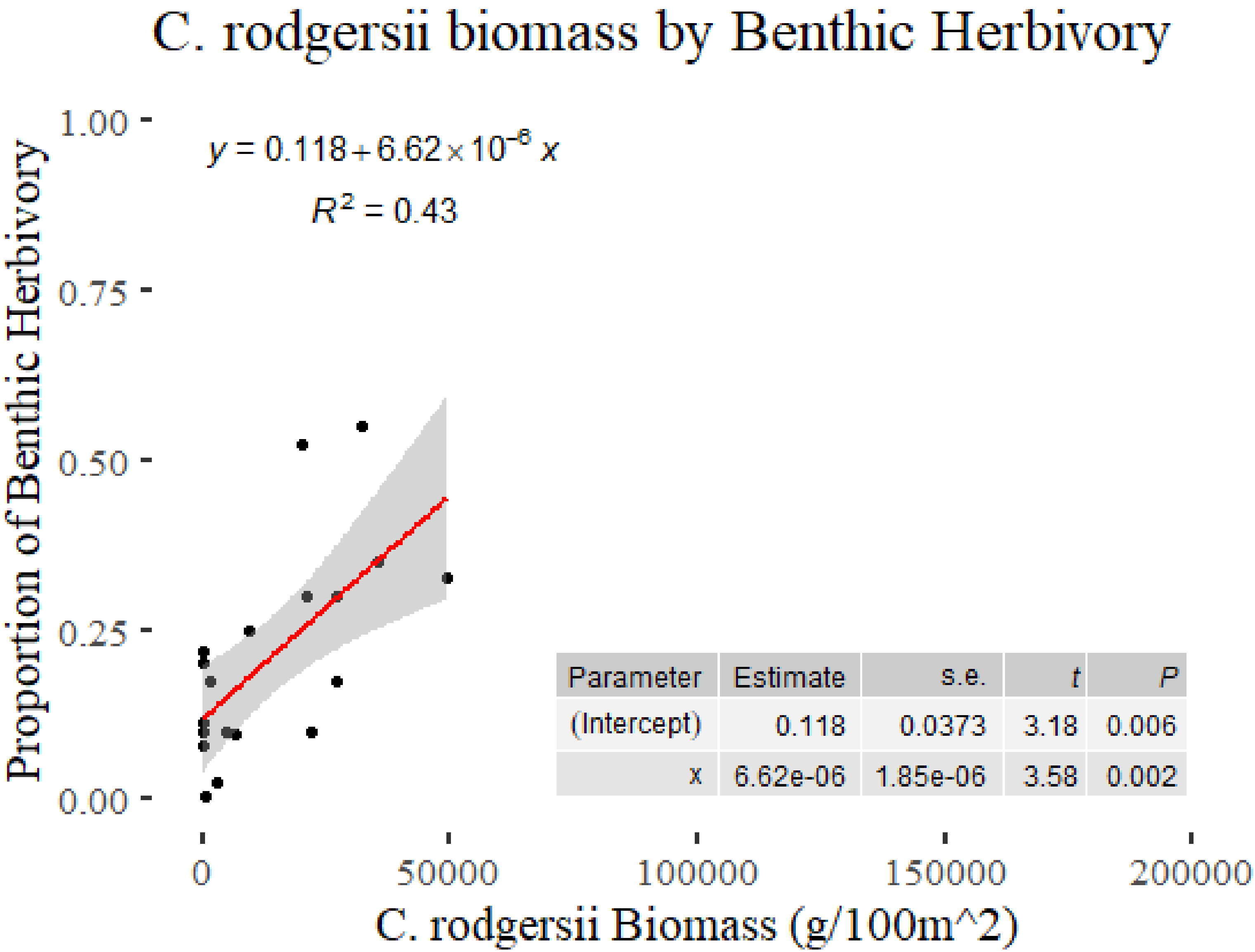


Directly measuring functional processes of ecosystem, e.g. herbivory and carnivory.

The structure of a community dictates the functional processes

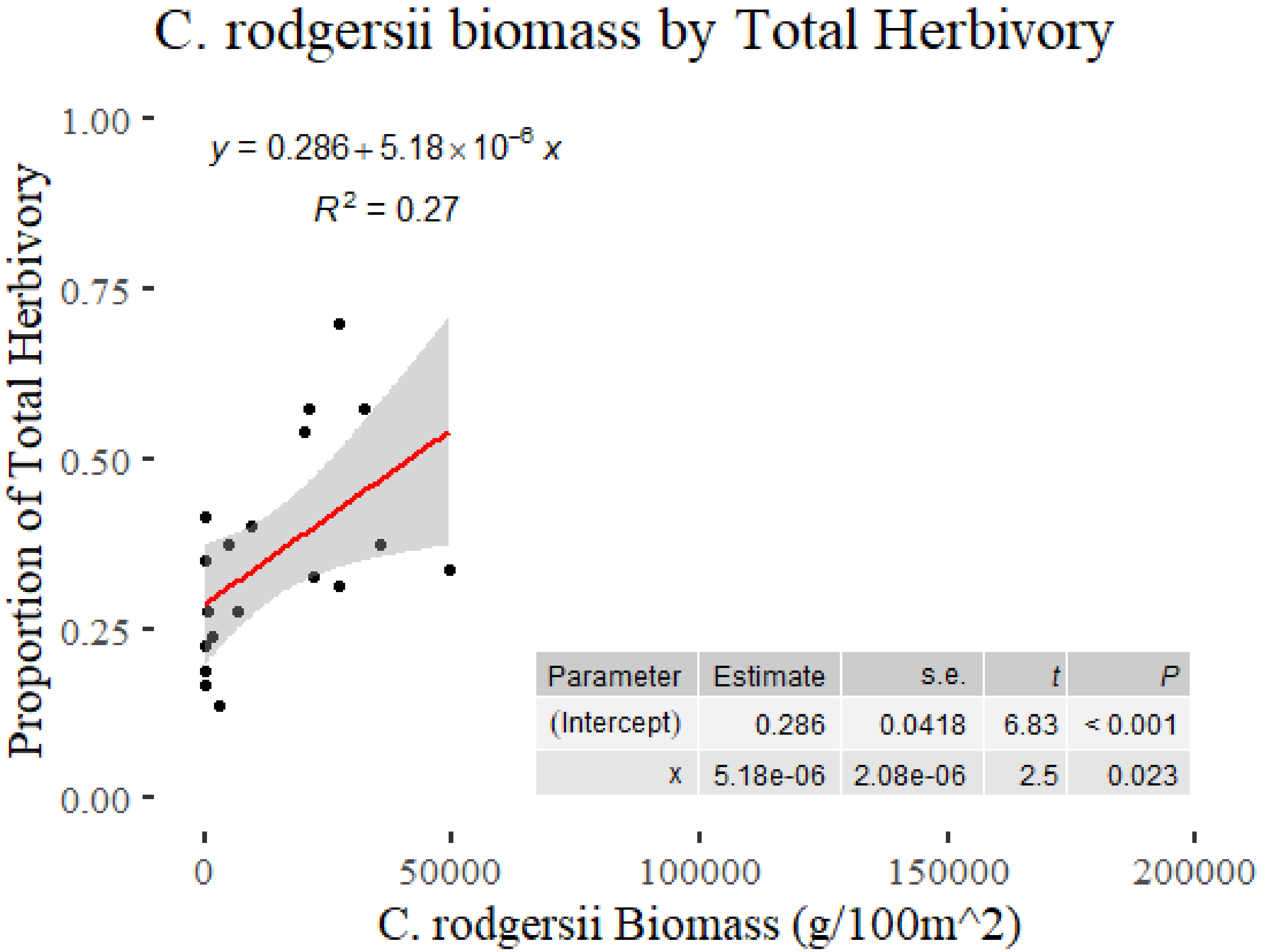
Excluding quantitative measurements of function misrepresents ecosystem leading to weaker conclusions

REMOVING OUTLIERS WORSENS FIT



Parameter	Estimate	s.e.	*t*	*P*
(Intercept)	0.118	0.0373	3.18	0.006
x	6.62e-06	1.85e-06	3.58	0.002

REMOVING OUTLIERS WORSENS FIT



Parameter	Estimate	s.e.	*t*	*P*
(Intercept)	0.286	0.0418	6.83	< 0.001
x	5.18e-06	2.08e-06	2.5	0.023

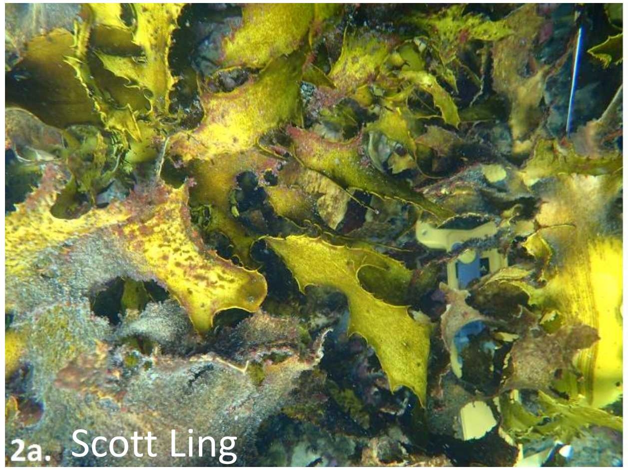
Structure ➔ Inferred ➔ Measured ➔

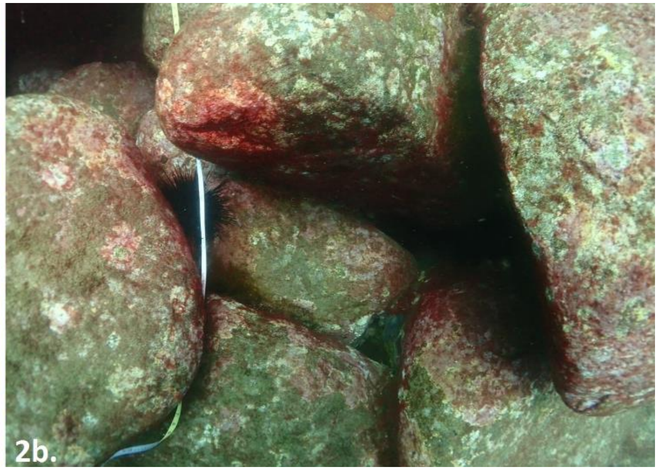
Tell this story using the correlation plots of centro biomass to reduce stuff on screen

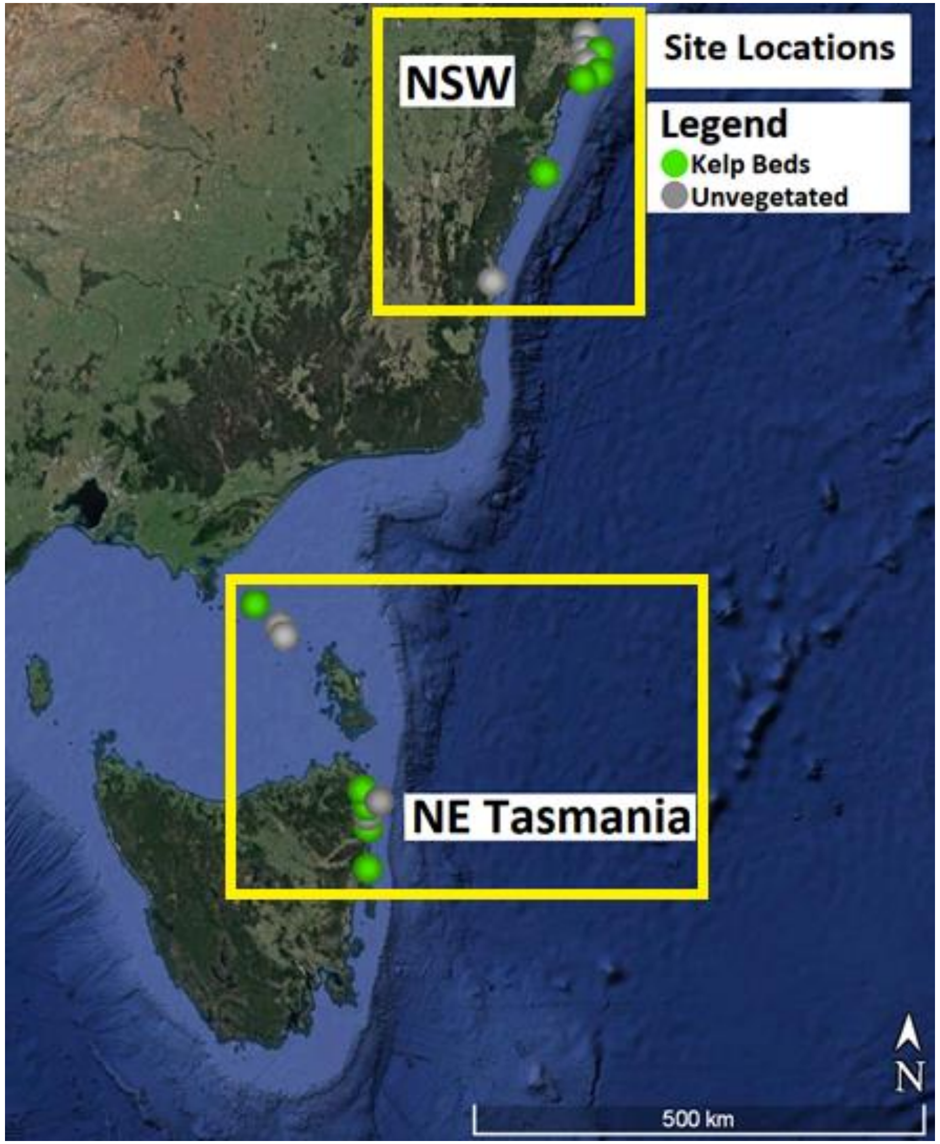
		Total: Model explained 69.92%			Vertical: Model Insignificant			Horizontal: Model explained 81.80%			Benthic: Model Explained 82.47%		
Functional Group	Species	Img	Predicted	Observed	Img	Predicted	Observed	Img	Predicted	Observed	Img	Predicted	Observed
	C. rodgersii	0.42	60.38%	89.34%	0.00	0.00%	0.00%	0.39	48.44%	89.34%	0.47	56.72%	89.34%
Benthic Grazing	***H. erythrogramma***	0.00	**0.00%**	**7.38%**	0.00	0.00%	0.00%	0.00	**0.00%**	**7.38%**	0.00	**0.00%**	**7.38%**
and Scraping Herbivores	***Amblypneustes spp.***	0.02	**3.33%**	**0.00%**	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
(2/5 Predicted; 2/5 Observed)	***P. parvispinus***	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.07	**8.31%**	**0.00%**	0.13	**16.09%**	**0.00%**
	T. alexandri	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.02	**3.02%**	**0.00%**	0.02	**2.82%**	**0.00%**
	T. undulatus	0.06	**9.41%**	**0.00%**	0.00	0.00%	0.00%	0.06	**7.88%**	**0.00%**	0.06	**7.78%**	**0.00%**
Benthic Grazing Herbivores	*T. torquatus*	0.00	0.00%	0.82%	0.00	0.00%	0.00%	0.01	1.01%	0.00%	0.00	0.00%	0.82%
(2/5 Predicted; 2/5 Observed)	*A. dactylomela*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.07	8.93%	0.00%
	H. rubra	0.00	0.00%	2.46%	0.00	0.00%	0.00%	0.04	5.18%	2.46%	0.07	8.13%	2.46%
	D. auricularia	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Benthic Deposit Feeding Omnivores	*A. tentoriiforme*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Feeding Omnivore (0/2 Predicted; 0/2 Observed)	*Pagurid spp.*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Benthic Predatory	*N. tuberculosus*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
and Grazing Omnivorew (0/2 Predicted, 0/2 Observed)	*H. elatus*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Grazing Herbivores (1/1 Predicted; 0/1 Observed)	***M. immaculatus***	0.19	**28.22%**	**0.00%**	0.00	0.00%	0.00%	0.16	**20.23%**	**0.00%**	0.00	0.00%	0.00%
	P. microlepis	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Browsing Herbivores	*A. lophodon*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
(0/5 Predicted; 0/5 Observed)	***O. cyanomelas***	**0.00**	**0.00%**	**0.00%**	**0.00**	**0.00%**	**0.00%**	**0.00**	**0.00%**	**0.00%**	**0.00**	**0.00%**	**0.00%**
	A. vittiger	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
	M. trachylepis	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Predatory and	*C. truncatus*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Browsing Omnivore	*Z. cornutus*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
(0/3 Predicted; 0/3 Observed)	*H. australis*	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%	0.00	0.00%	0.00%
(green)	Predicited to have a significant contribution to explained model variation (P<0.05).												
(yellow)	Contributed to model variation explained but weren't observed in field, or were observed in field but weren't predicted for in regresion model.												

Methods

- Two geographic regions; spanning mid-latitude temperate to high-latitude cold temperate.
- 5 Kelp bed habitats and 5 unvegetated reef habitats within each location.
- Structure and function within these habitat types was compared between locations.







Methods

- 10 stakes per orientation at each habitat within each location.
- Herbivory: 2 x 7cm pieces, Assayed at 1-hour and 24-hour mark.
- Carnivory tested using dried squid

ns. 2020

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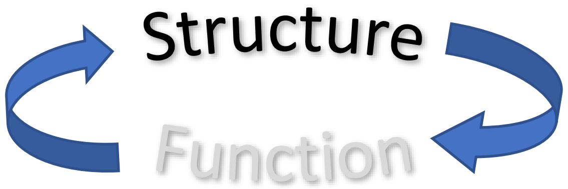
ns. 2020

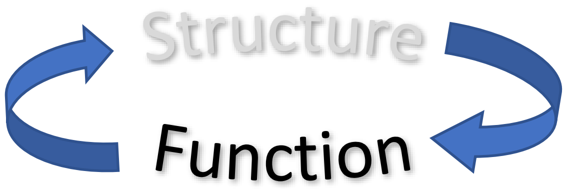
Analytical Methods

Overarching Question

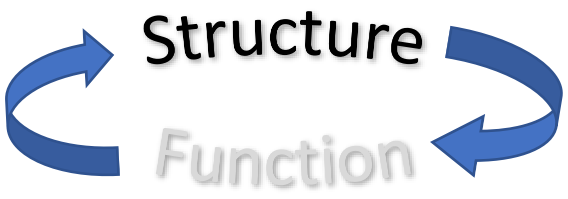
- Are tropicalising North eastern Tasmanian reefs now structurally and functionally equivalent to NSW?



- Compared the community structure in regards to species biomass and biomass of species functional groups.
- Location*Habitat

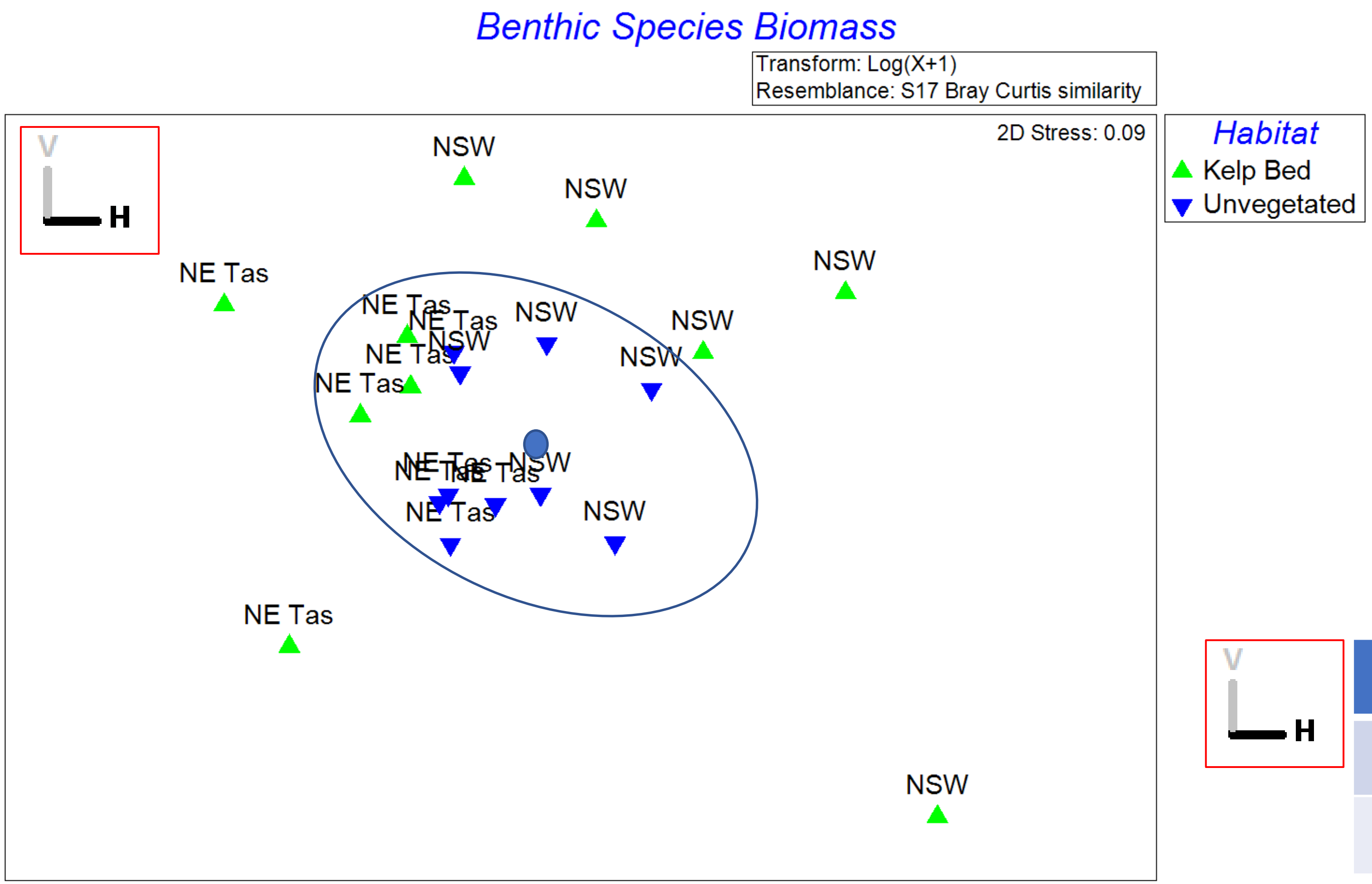


- For herbivory a 4 way ANOVA was used testing Location*Habitat*Orientation*Algal Species
- Multiple regression to investigate if I could then predict function from structure
- Carnivory was tested; no significant variation



Results

MDS + PERMANOVA



P Values

Location = 0.0002

Habitat = 0.0013

Location*Habitat = 0.339

Pairwise

Unvegetated = 0.0834

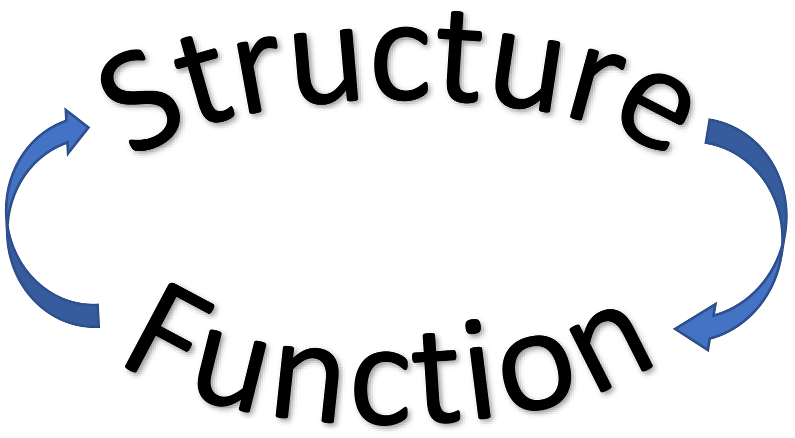
Kelp Bed = 0.008

Latitudinal Equivalence?

Benthic Species Biomass	Equivalence?
Kelp Bed	NO
Unvegetated	**YES**

Aims & Hypotheses

Overarching Aim



Hypotheses

H1 = Taxonomic structure of reef communities between NE Tasmania and NSW are not significantly different.

H2 = Ecological functioning of reef communities between NE Tasmania and NSW are not significantly different.

H3 = Magnitude of herbivory from urchins will be larger, in relation to that of fish herbivory between NE Tasmania and NSW are not significantly different.