Outils pour comprendre, prédire et gérer les effets de la pêche et du climat sur les récifs tempérés sud-est australiens

Martin P. Marzloff

Collaborators: Craig Johnson, Jeff Dambacher, Rich Little, Stewart Frusher, Scott Ling, J.-C. Soulié, Gretta Pecl, Jess Melbourne-Thomas, Eriko Hoshino, Sarah Jennings, Katell Hamon, Ingrid van Putten, Lucy Robinson, Eric Oliver, Neil Holbrook, Julien Freyer, Neville Barrett, Lainey James, Margaux Daniel

Australian Government
Australian Research Council

UNIVERSITY of TASMANIA

IMAS
INSTITUTE FOR MARINE & ANTARCTIC STUDIES

Structure de ma présentation

1. Effets de la pêche et climat sur les communautés benthiques associées aux laminaires (profondeur < 30m)

2. Communautés benthiques profondes (profondeur: 30-100 m) et changement climatique

Structure de ma présentation

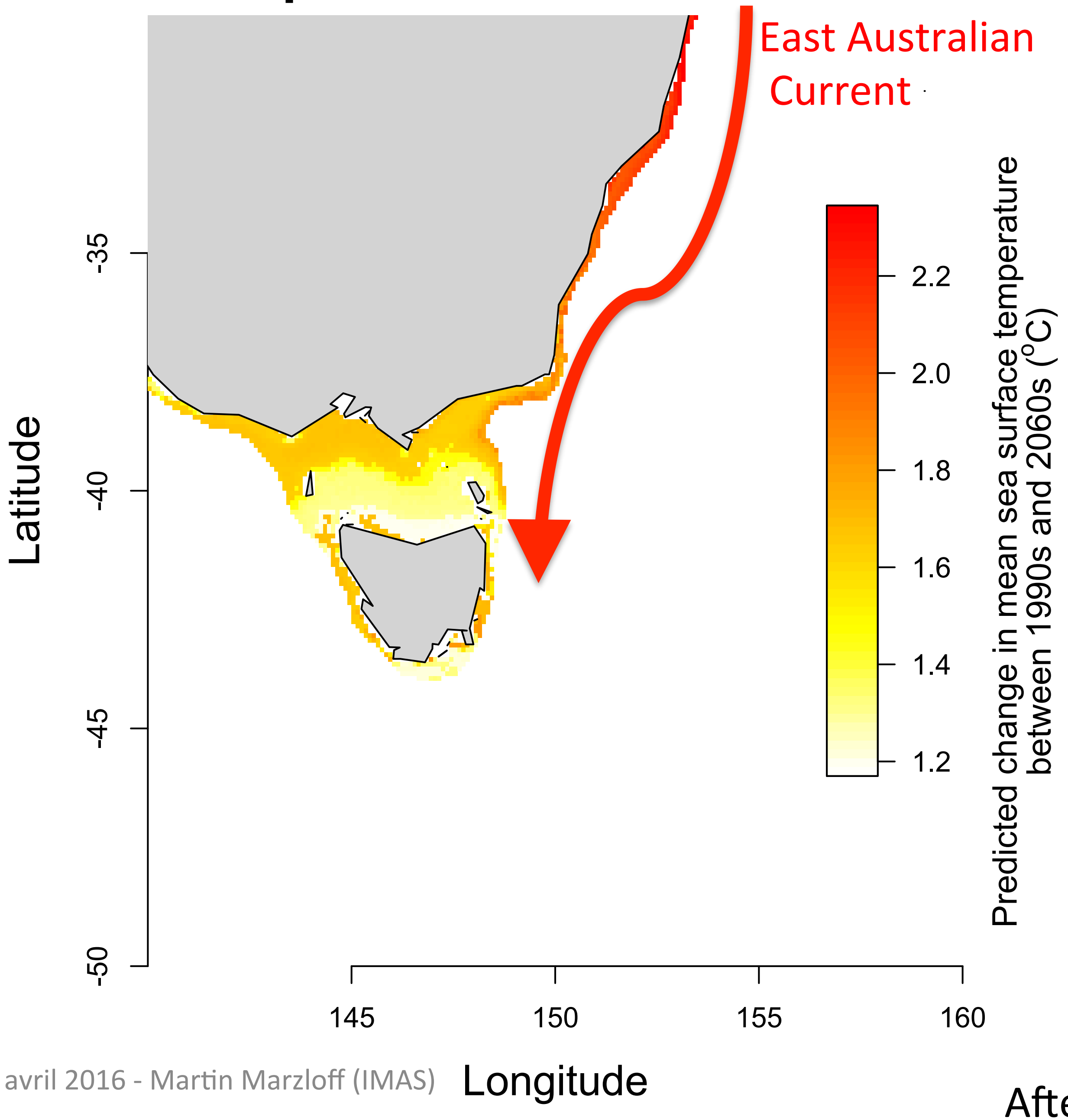
1. Effets de la pêche et climat sur les communautés benthiques associées aux laminaires (profondeur < 30m)

(i) Climate Change and sea urchin barrens in Tasmania

(ii) Future model development (ongoing and in progress)

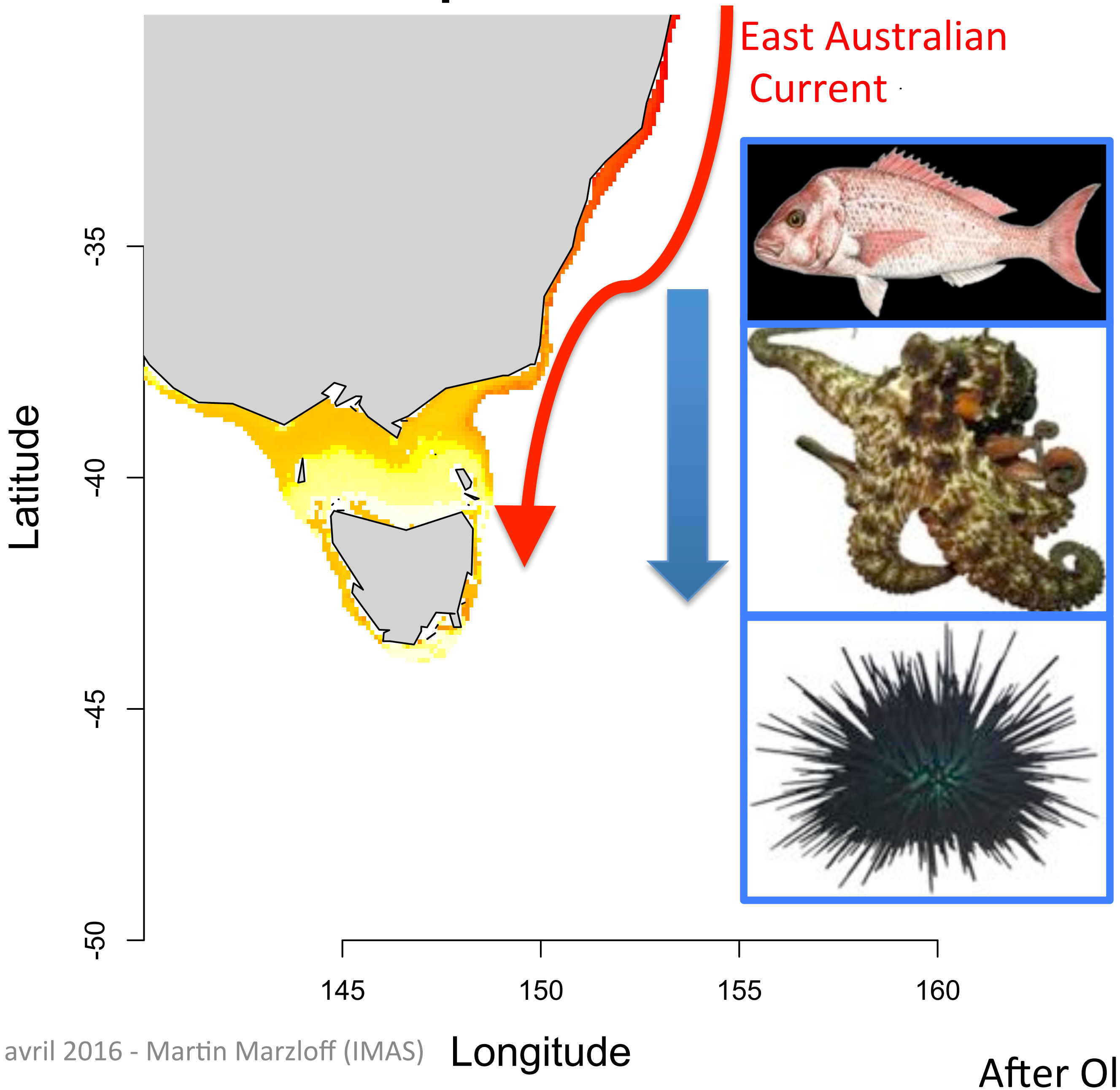
(iii) Species on the move: ecological impacts of range shifts

Global hotspot for ocean warming (Hobday & Pecl, 2014)



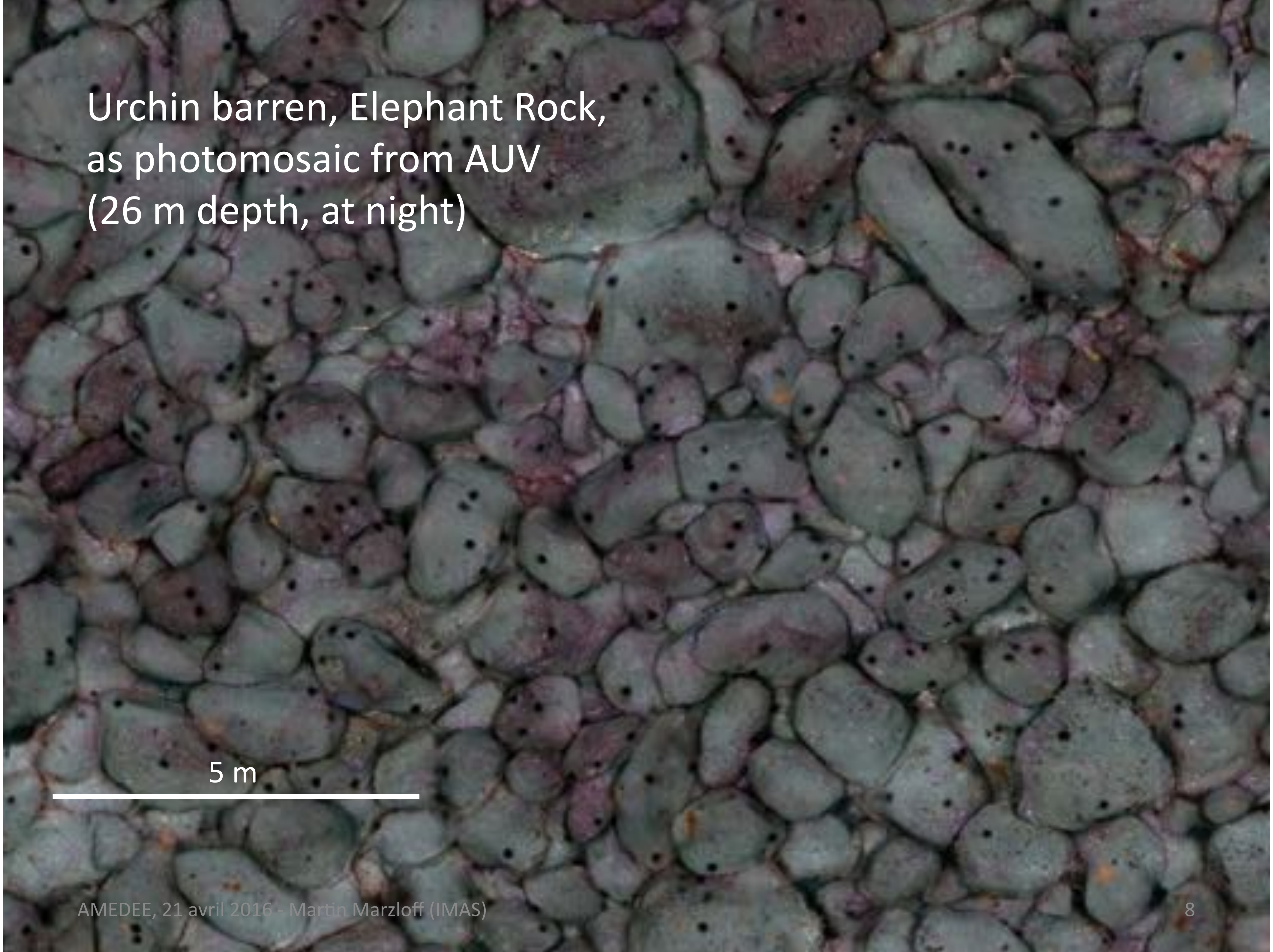
After Oliver & Holbrook, 2014

Global hotspot for ocean warming



After Oliver & Holbrook, 2014

Regional research & management currently focus on the range-extending long-spined sea urchin

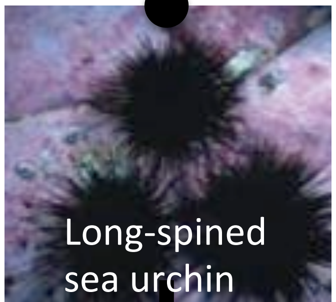

Urchin barren, Elephant Rock,
as photomosaic from AUV
(26 m depth, at night)
5 m

Ongoing research & regional management focus on the range-extending long-spined sea urchin…

Field experiments

Ling et al., 2009 (PNAS)

Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift



Tracey et al., 2015 (Bio. Inv.)

Systematic culling controls a climate driven, habitat modifying invader

Flukes et al., 2012 (MEPS)

Forming sea urchin barrens from the inside out: an alternative pattern of overgrazing

Ongoing research & regional management focus on the range-extending long-spined sea urchin…

Field experiments

Ling et al., 2009 (PNAS)

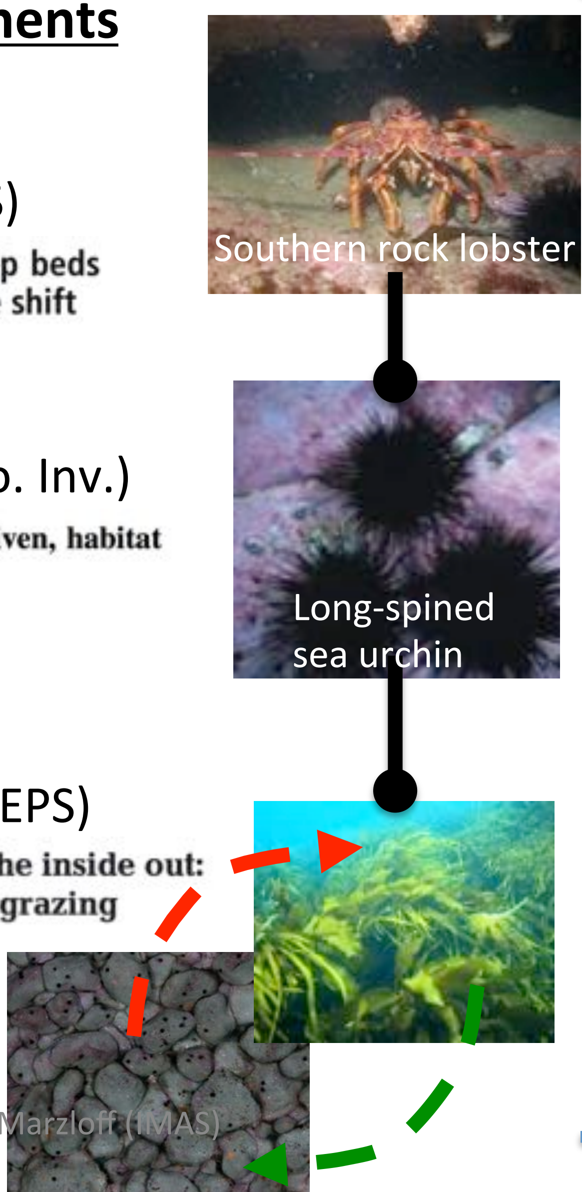
Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift

Tracey et al., 2015 (Bio. Inv.)

Systematic culling controls a climate driven, habitat modifying invader

Flukes et al., 2012 (MEPS)

Forming sea urchin barrens from the inside out: an alternative pattern of overgrazing



Ecosystem modelling

Marzloff et al., 2011 (Eco. Mod.)

Exploring alternative states in ecological systems with a qualitative analysis of community feedback

Marzloff et al., 2013 (Eco. Mod.)

Sensitivity analysis and pattern-oriented validation of TRITON, a model with alternative community states: Insights on temperate rocky reefs dynamics

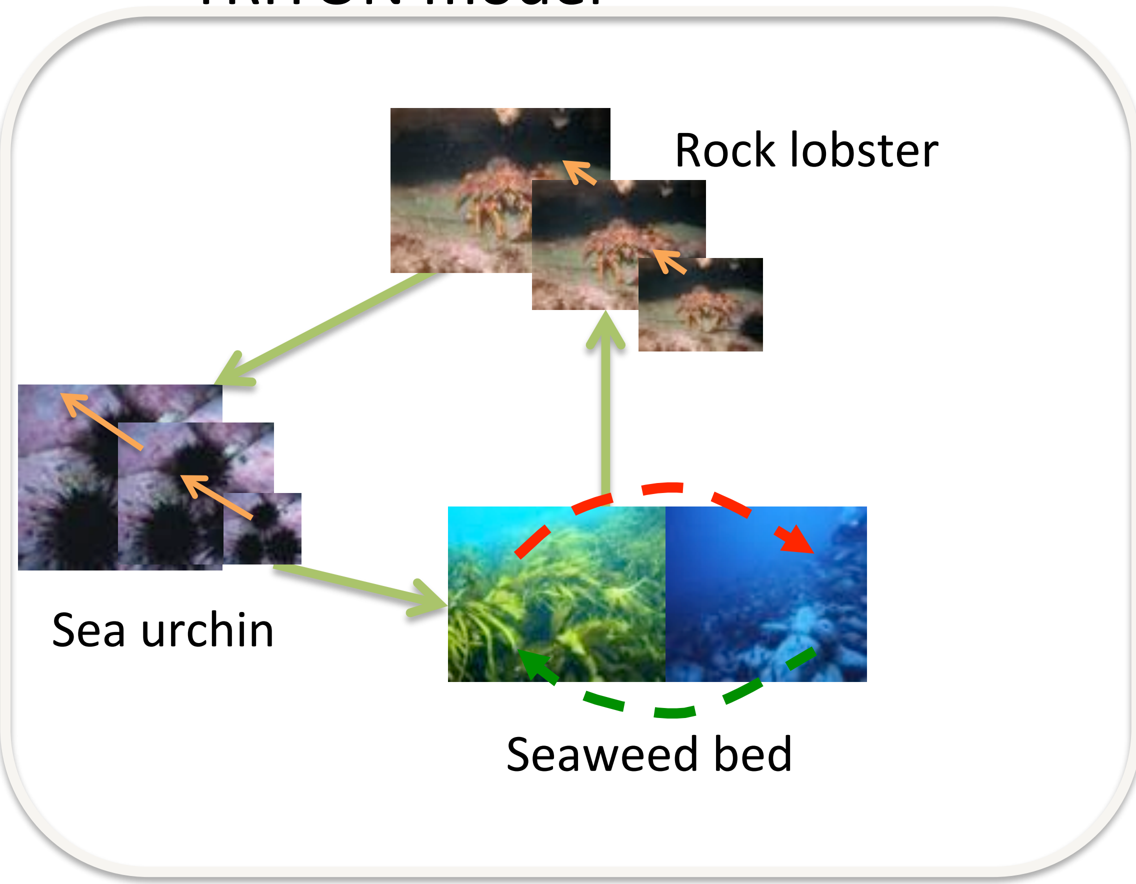
Marzloff et al., 2015 (Ecosystems)

Building Resilience Against Climate-Driven Shifts in a Temperate Reef System: Staying Away from Context-Dependent Ecological Thresholds

Ongoing research & regional management focus on the range-extending long-spined sea urchin…

<u>**Ecosystem modelling:**</u> local dynamics of individual reefs

TRITON model

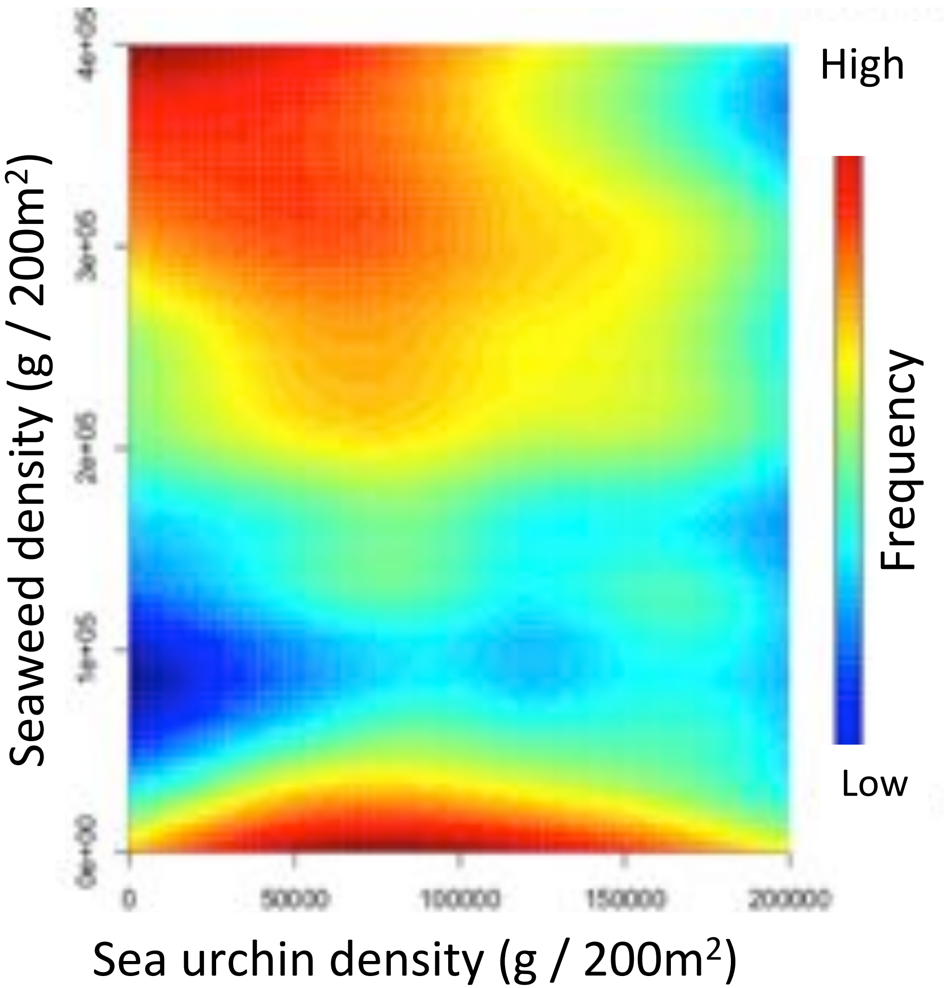


- Deterministic
- Stochastic
- Size-structured
- Building on > 20 years of observations and field experiments

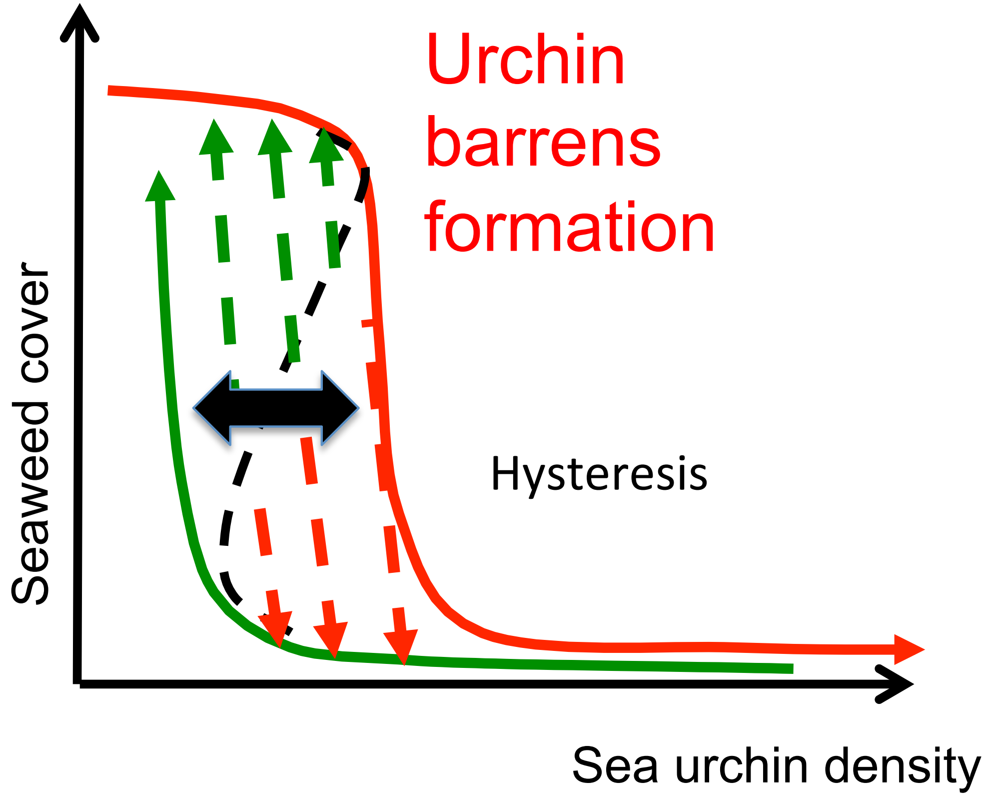
Scenarios, based on > 10,000 Monte-Carlo simulations, which account for both spatial heterogeneity (depth, reef exposure) and parameter uncertainty

Marzloff *et al.*, 2013. <u>Ecological Modelling</u>. 222, 2651-2662.

TRITON ecological model: pattern-oriented validation

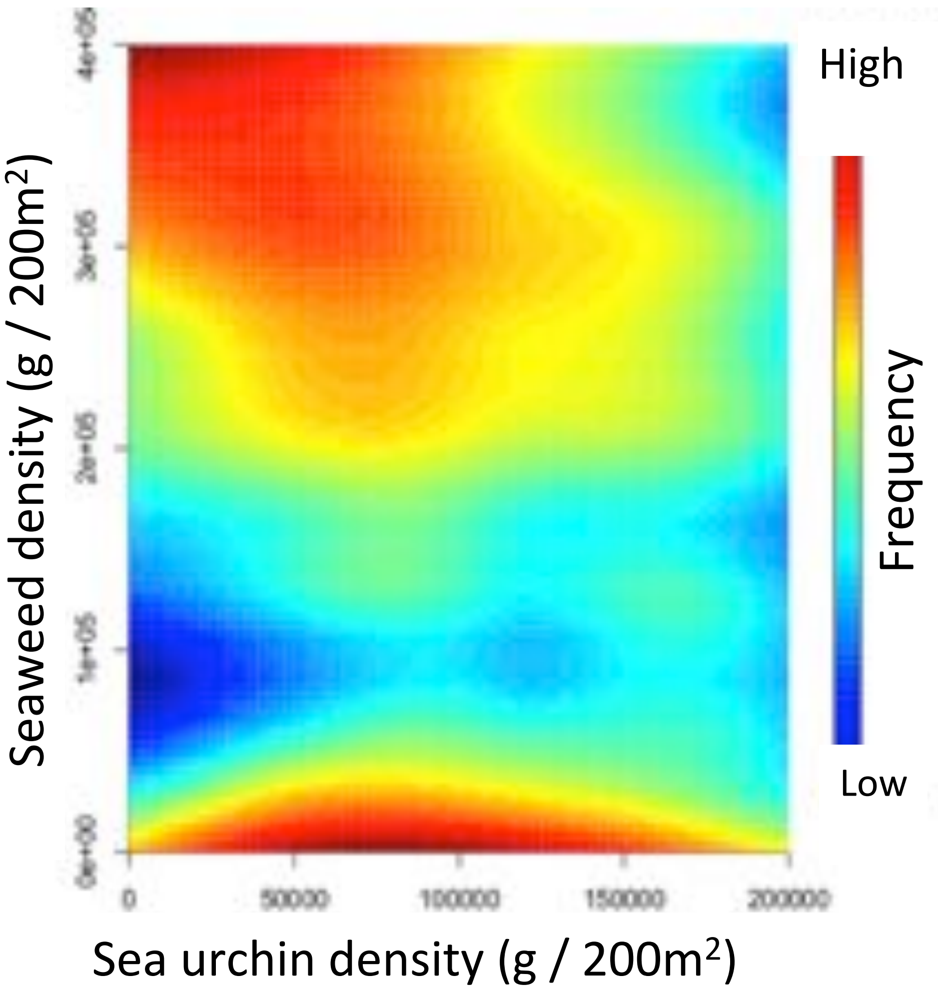


Observations (2002-2011)

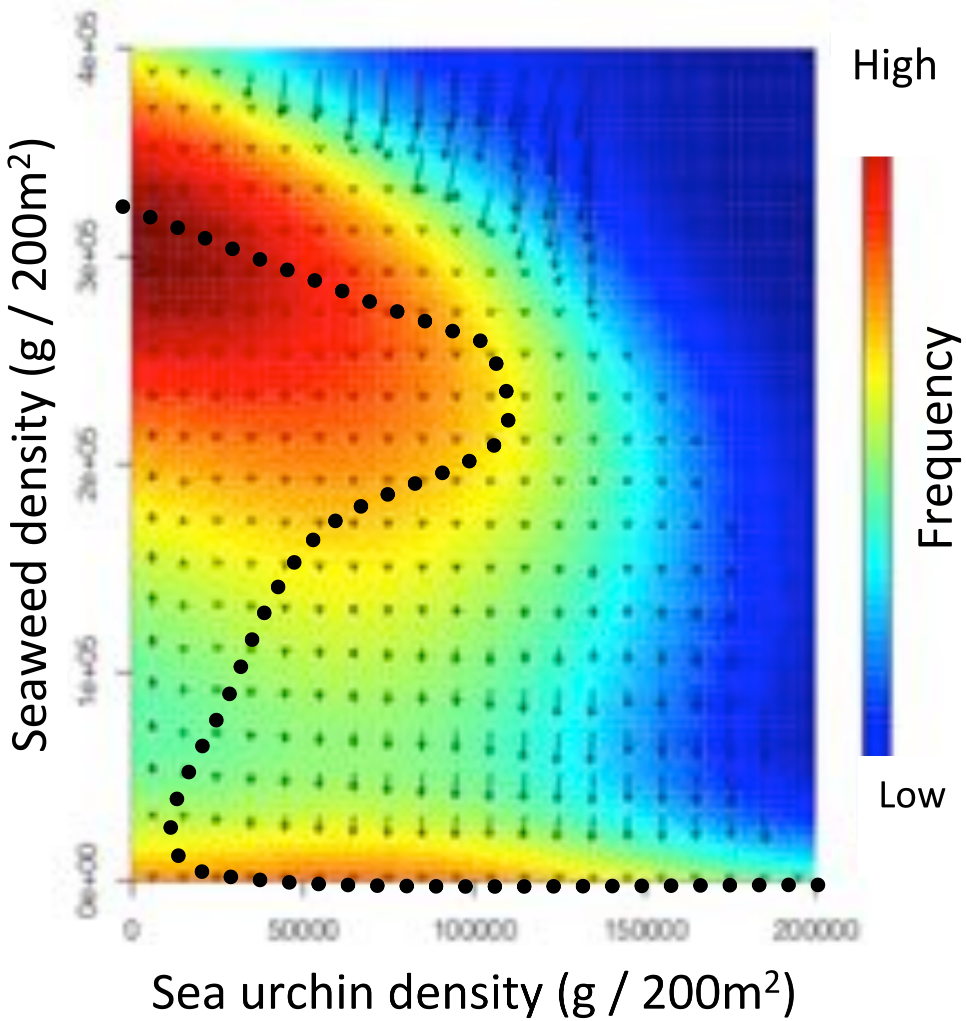


Marzloff *et al.*, 2013. Ecological Modelling. 222, 2651-2662.

TRITON ecological model: pattern-oriented validation



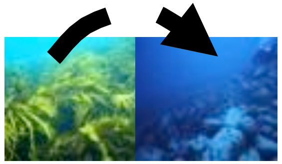
Observations (2002-2011)

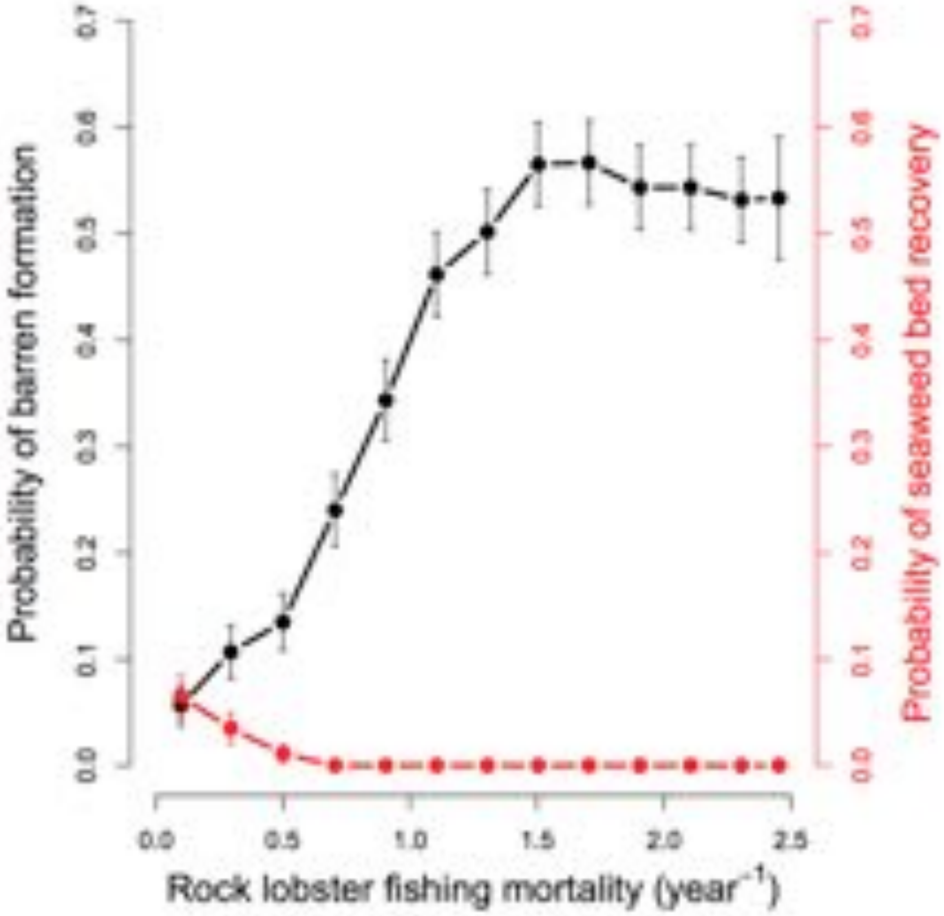


Simulations

Marzloff *et al.*, 2013. Ecological Modelling. 222, 2651-2662.

Ecological thresholds and management strategies





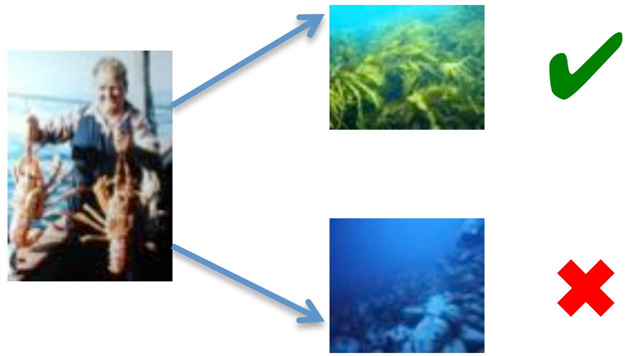
- **Ecosystem modelling**

Marzloff et al., 2015 (Ecosystems)

Building Resilience Against Climate-Driven Shifts in a Temperate Reef System: Staying Away from Context-Dependent Ecological Thresholds

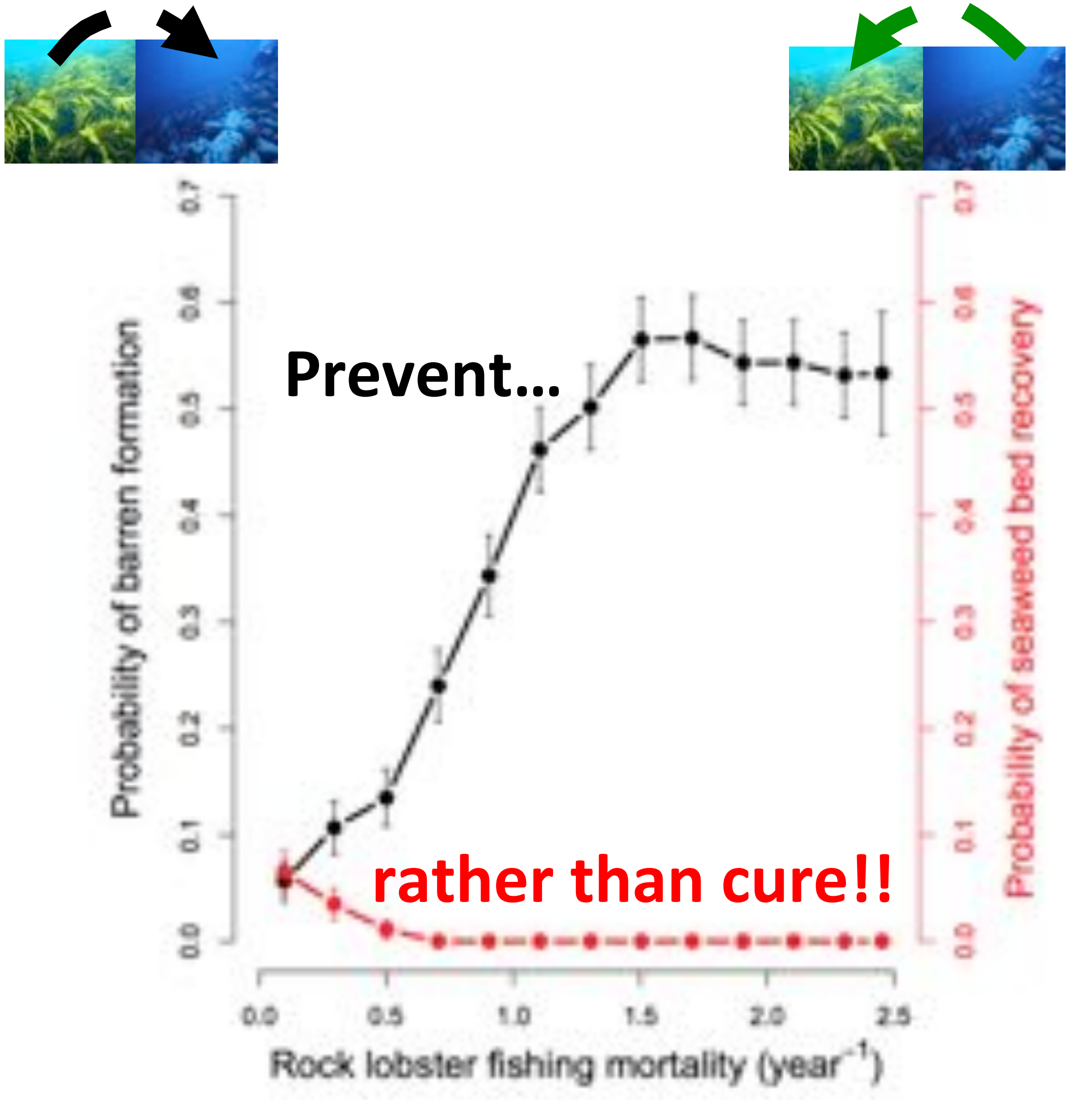
- **Lobster translocation experiment**

Johnson et al., 2014 (FRDC report)



Johnson, Marzloff *et al.* (Submitted to Restoration Ecology)
“Knowing when (not) to attempt ecological restoration”

Ecological thresholds and management strategies



- **Ecosystem modelling**

Marzloff et al., 2015 (Ecosystems)

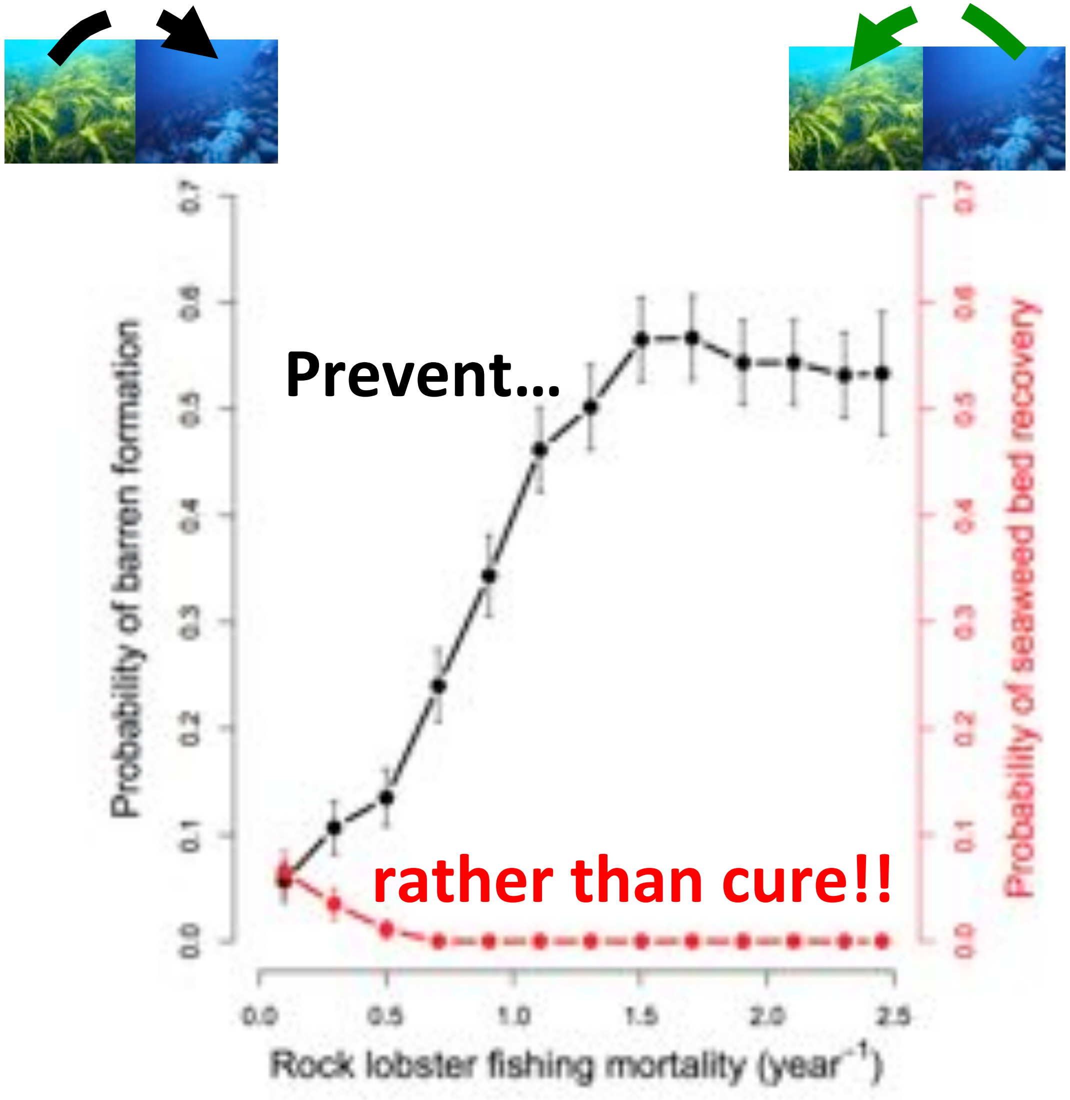
Building Resilience Against Climate-Driven Shifts in a Temperate Reef System: Staying Away from Context-Dependent Ecological Thresholds

- **Lobster translocation experiment**

Johnson et al., 2014 (FRDC report)

2005 2015

Ecological thresholds and management strategies



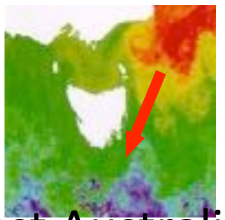
- **Ecosystem modelling**
- **Lobster translocation experiment**

Since 2013:
Spatial ecosystem-based management of Tasmanian lobster fishery

Participatory Structured-Decision-Making process to inform management strategy for the socio-ecosystem

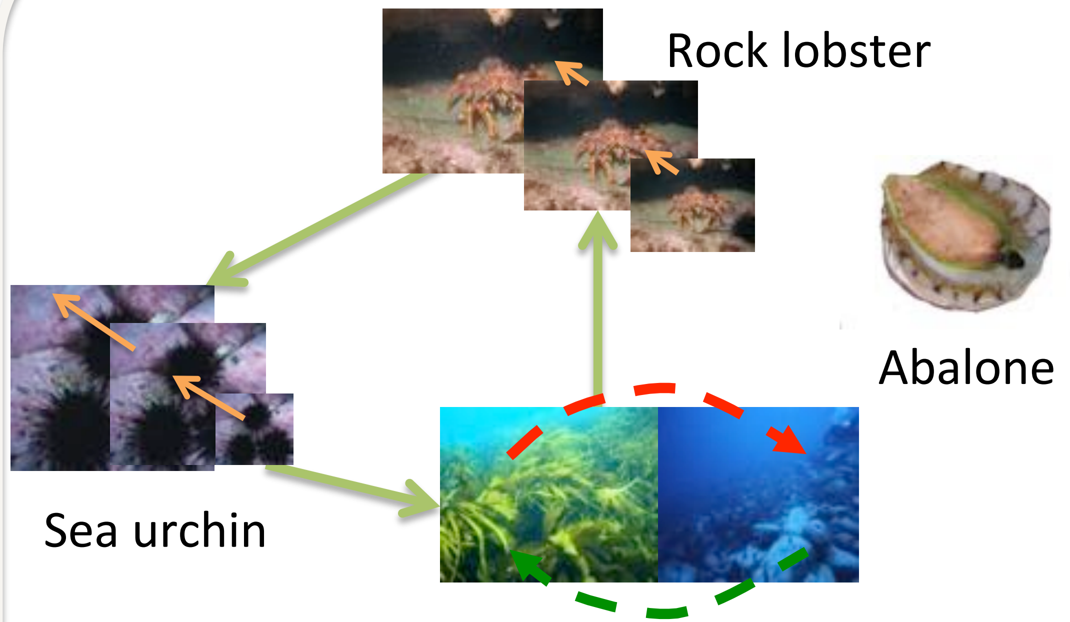
- 1 workshop, 2 sets of interviews with 12 stakeholders
- TRITON model to test scenarios + cost-benefit & feasibility analyses

Physical factor

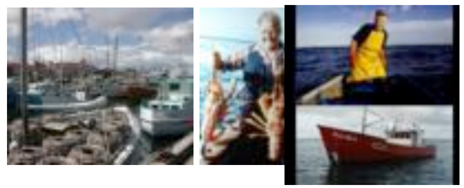


East Australian Current

Biological factors



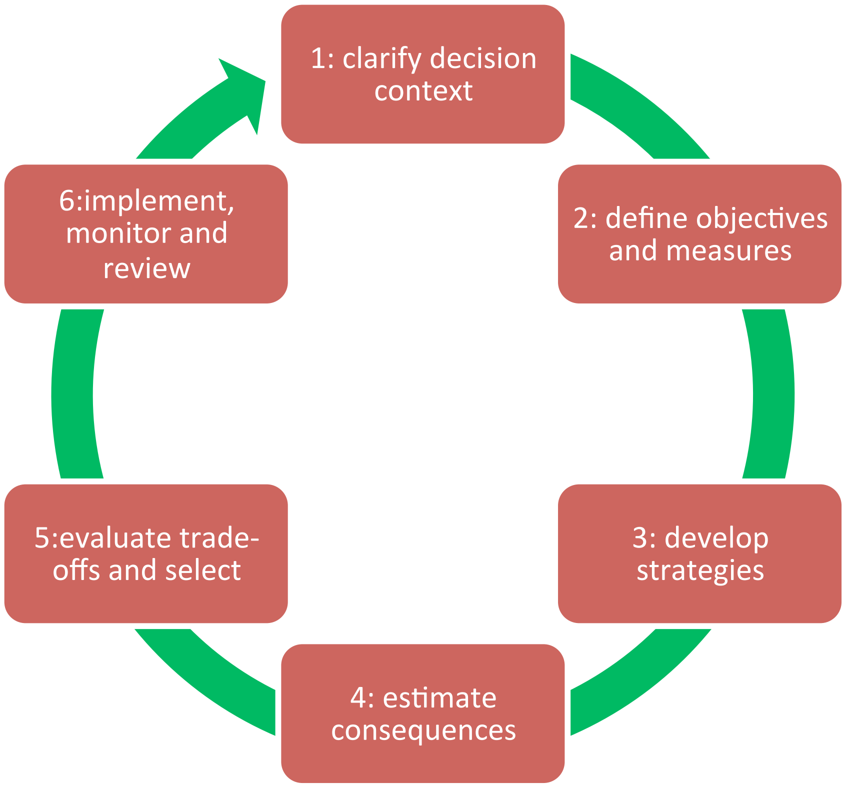
Human factors



Urchin harvesters
Commercial lobster fishers
Recreational lobster fishers
Commercial abalone fishers
Recreational abalone fishers
Lobster fishery managers
Abalone fishery managers
Urchin fishery managers
Conservationists / NGOs

Participatory Structured-Decision-Making process around the TRITON model

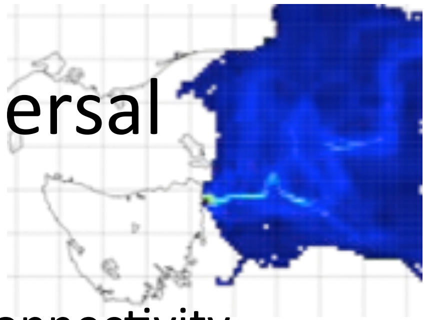
- 1 workshop, 2 sets of interviews with 12 stakeholders
- TRITON model to test scenarios + cost-benefit & feasibility analyses



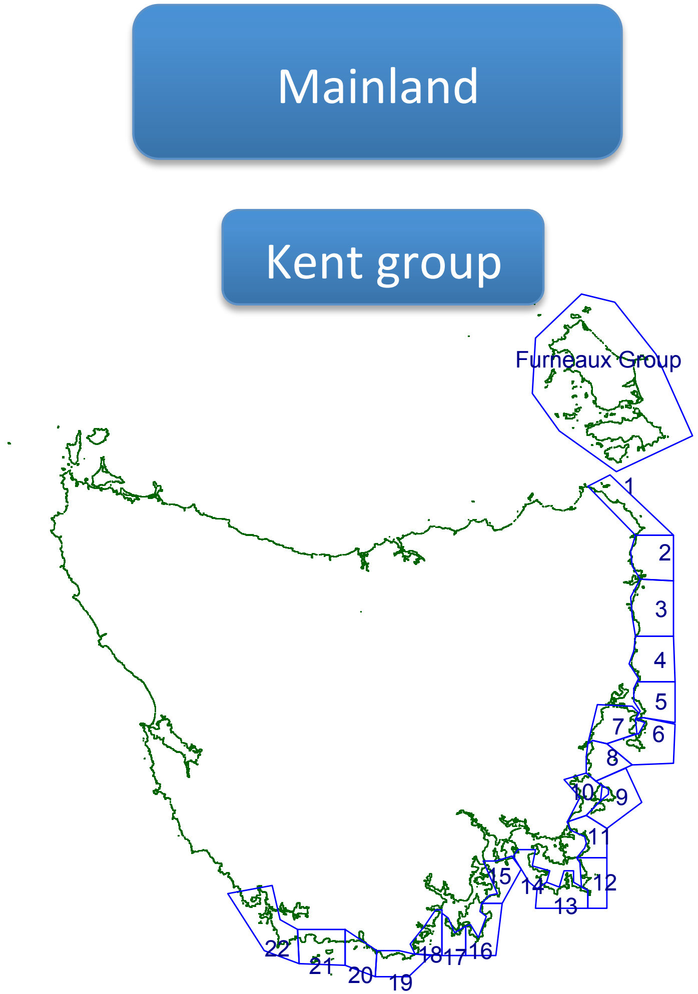
Structured Decision Making follows the process we all go through when facing a complex problem

Marzloff, Robinson *et al.* (in prep.) + Oral paper at MODSIM 2015 & MSEAS conference in Brest (May-June 2016)

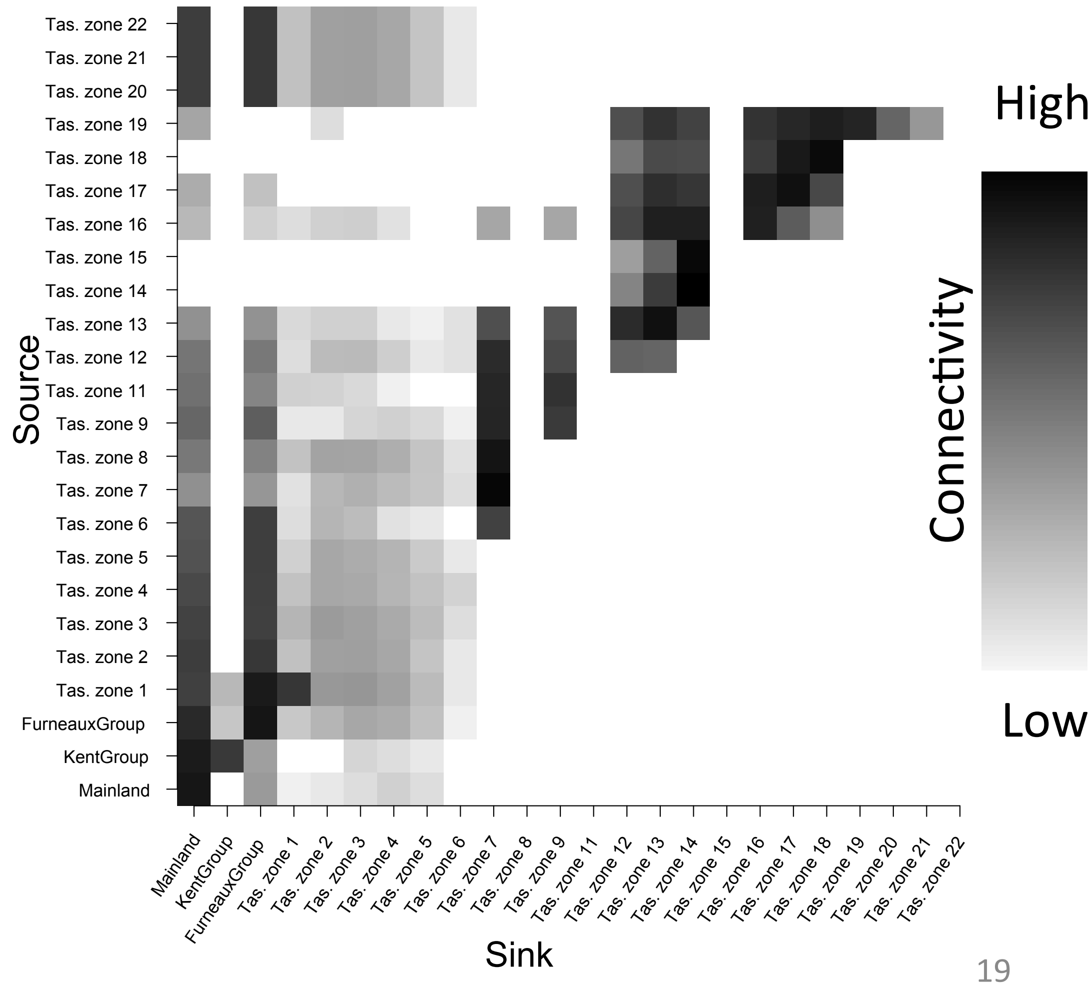
Hydrodynamic modelling of sea urchin larval dispersal



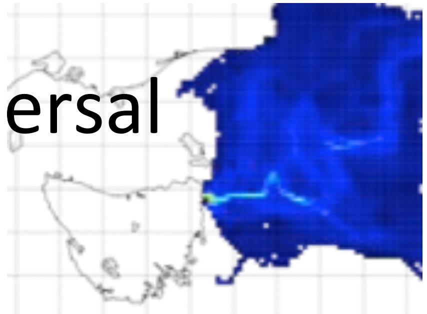
Coastal zones defined for modelling



Regional reef-to-reef connectivity



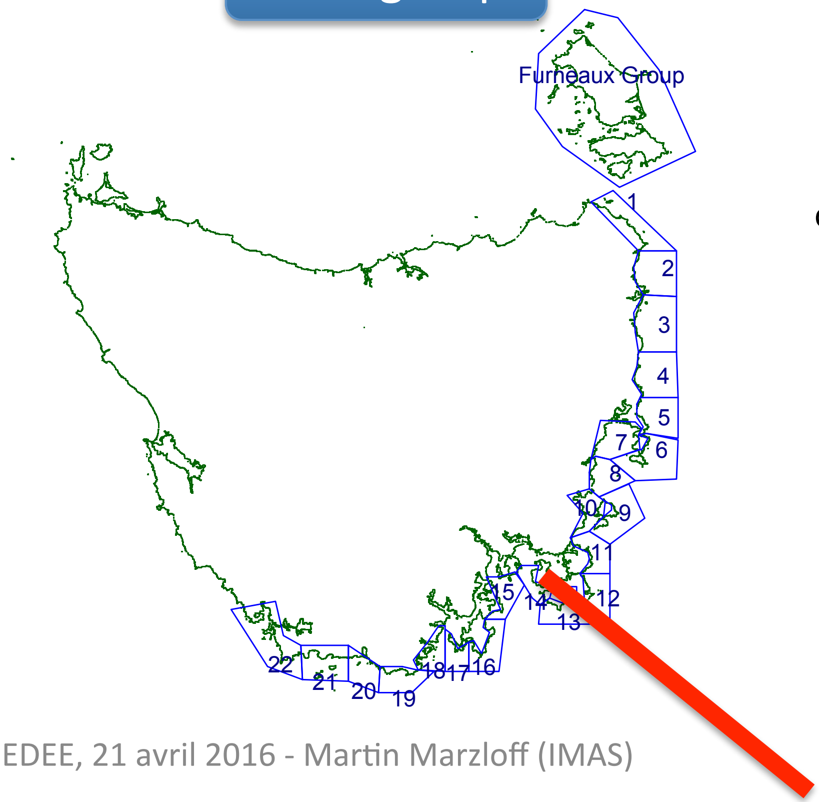
Hydrodynamic modelling of sea urchin larval dispersal



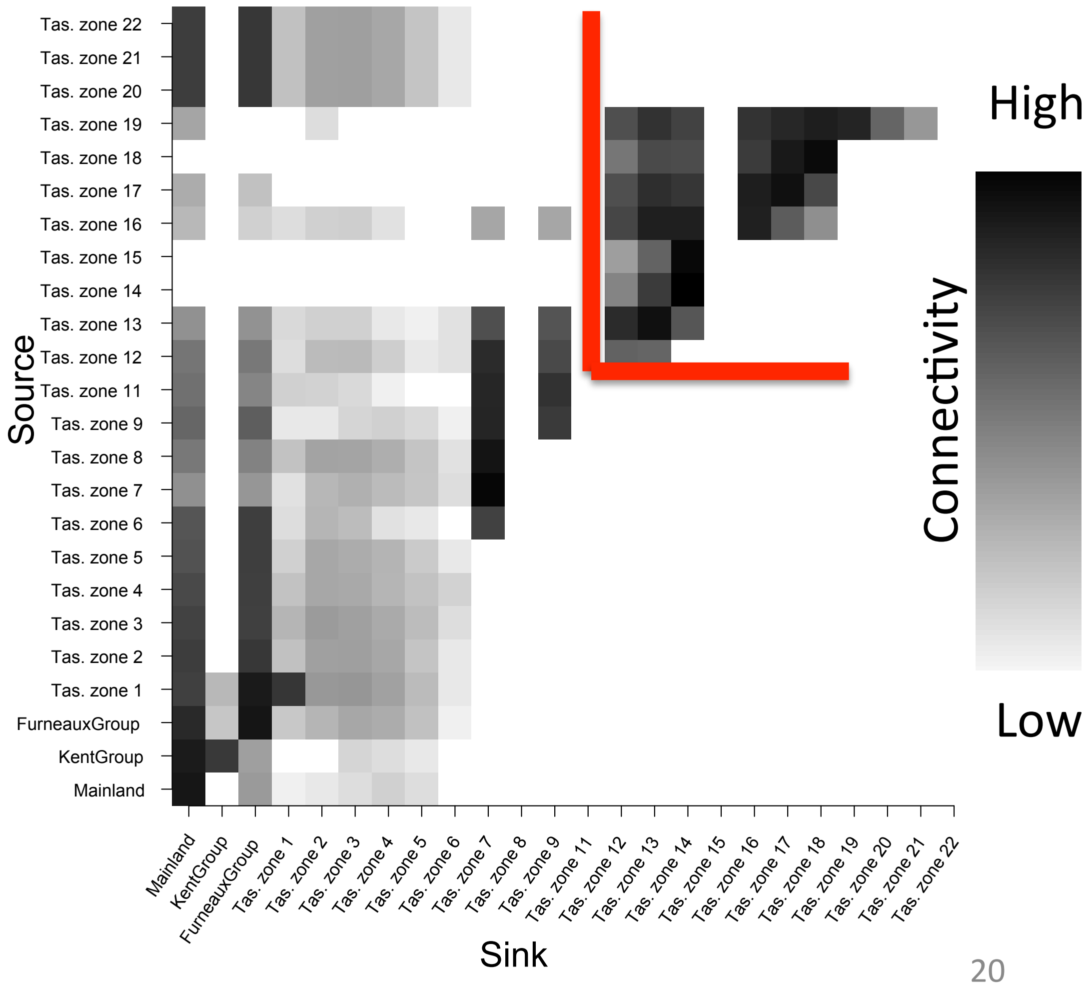
Coastal zones defined for modelling

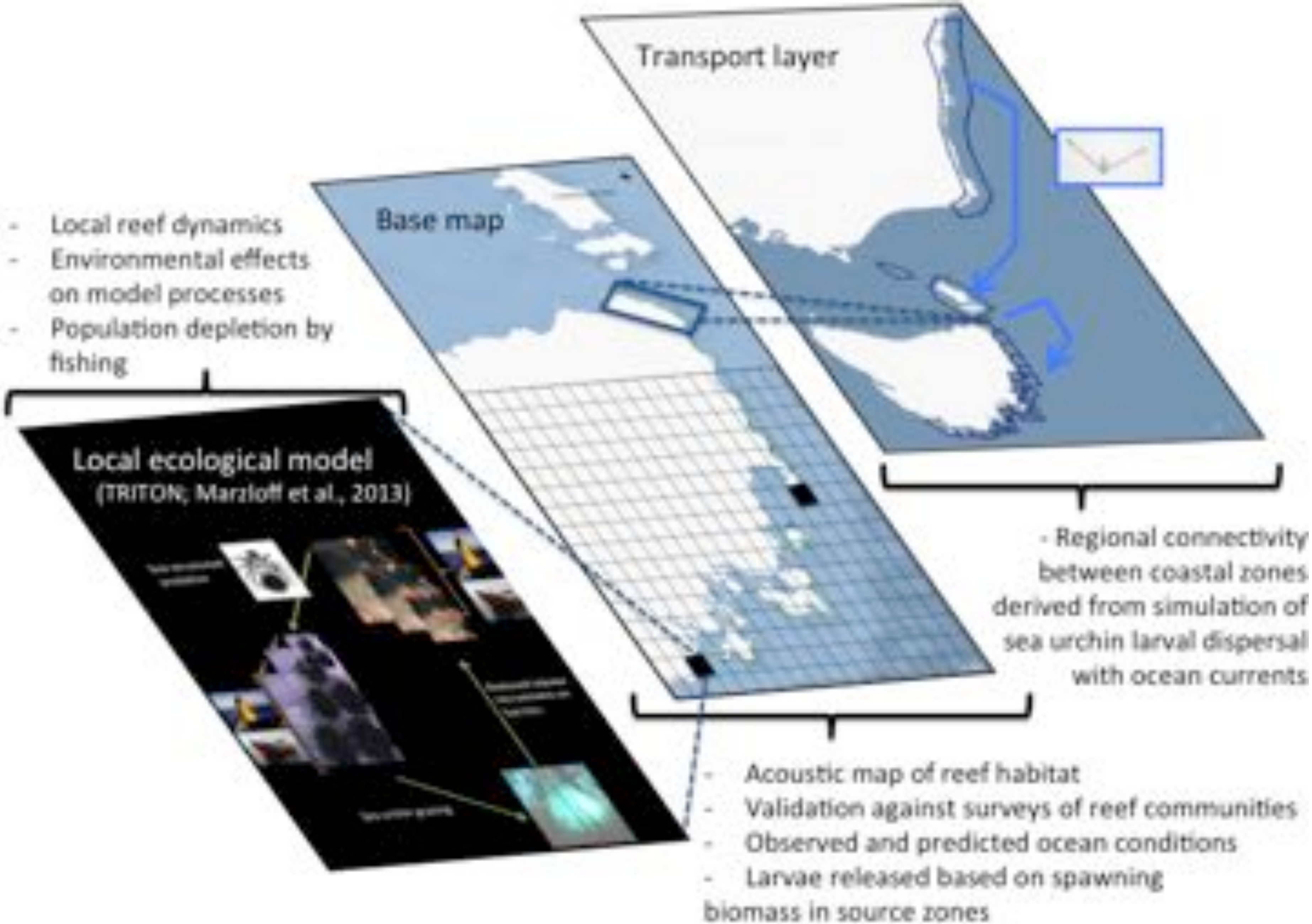
Mainland

Kent group



Regional reef-to-reef connectivity





ARC Discovery Project grant proposal (Johnson & Marzloff)

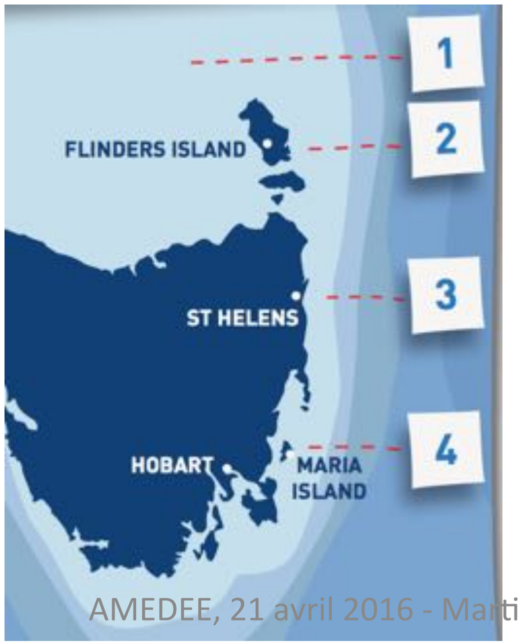
But… How about other range-shifters!?

- 20-80% of marine species within regional ecosystems are shifting polewards <u>concurrently</u> (Sunday *et al.*, 2012 - NCC)
- SE Australia / Tasmania is no exception

But… How about other range-shifters!?

- 20-80% of marine species within regional ecosystems are shifting polewards <u>concurrently </u>(Sunday *et al.*, 2012 - NCC)
- SE Australian / Tasmanian reefs are no exception…

redmap
SPOT. LOG. MAP.

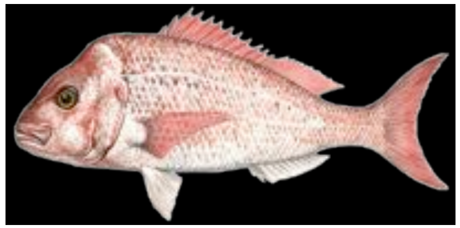


<u>Range shifts: broad functional groups:</u>

Octopus

Sea urchin

Eastern rock lobster



Reef fishes

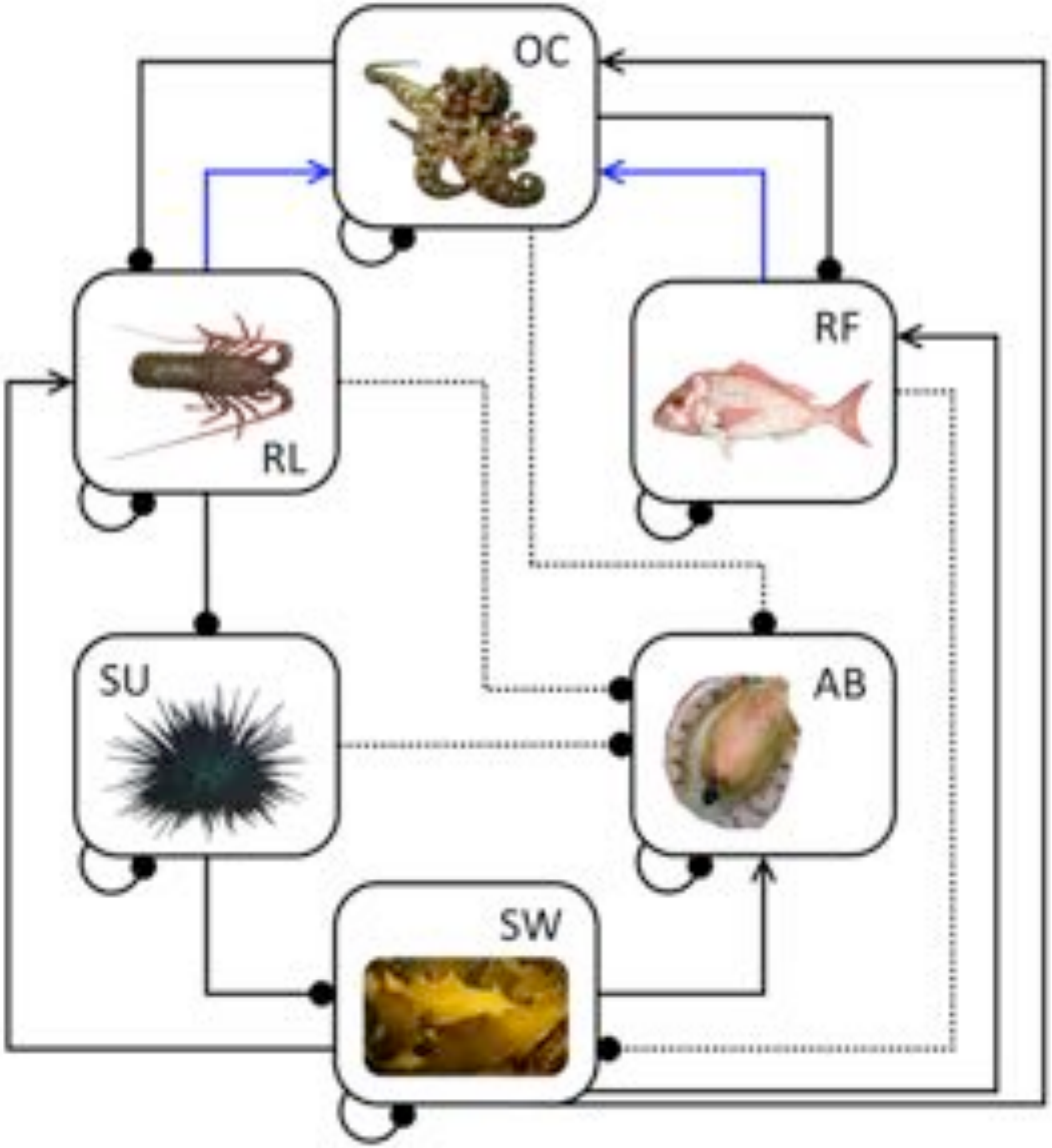
But… How about other range-shifters!?

- 20-80% of marine species within regional ecosystems are shifting polewards concurrently (Sunday *et al.*, 2012 - NCC)
- SE Australia / Tasmania is no exception

- Challenges for research & management in the long term:
  1. Simultaneous climate-driven redistribution of a vast proportion of species within region ecosystems; and
  2. Ecological impacts of multiple range-shifters on regional ecosystem structure & functioning

→ Qualitative modelling of the effects of range-shifting species

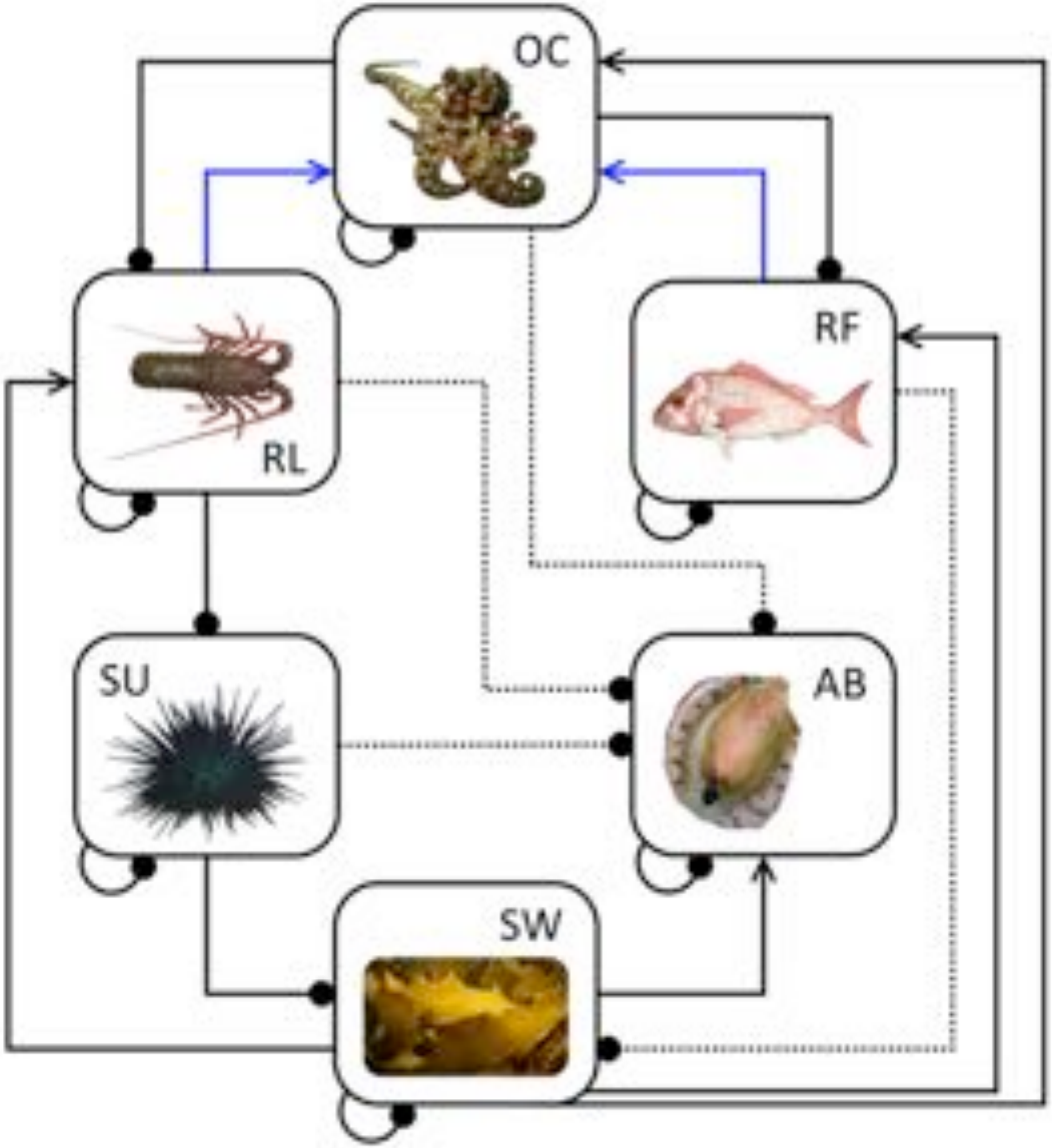
Qualitative Modelling of Tasmanian reef communities



Model groups:
OC: octopus
RL: rock lobster
RF: reef fishes
SU: sea urchin
AB: abalone
SW: seaweed bed

Marzloff *et al.* (in press., GCB)

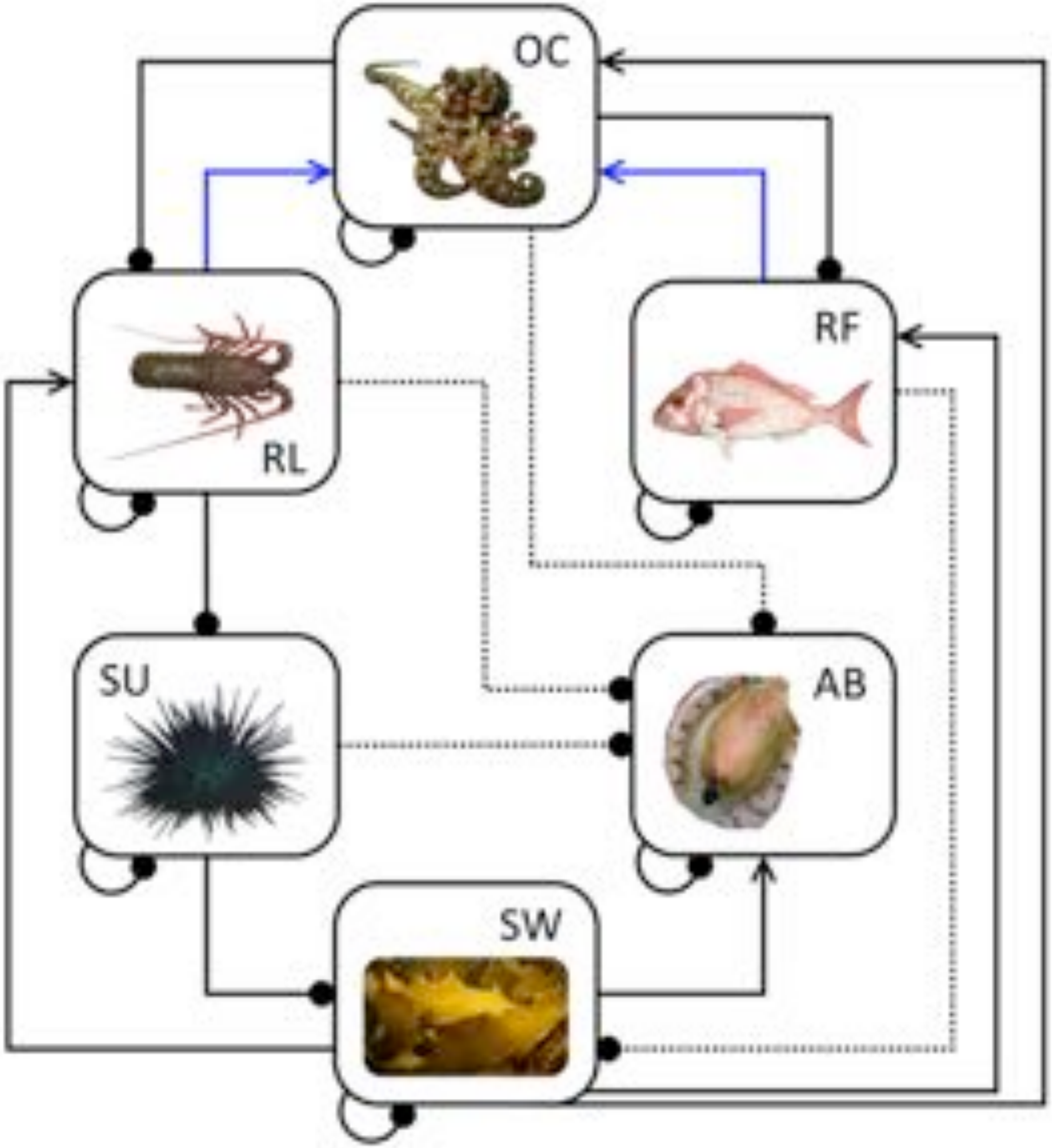
Qualitative Modelling of Tasmanian reef communities



Model groups:
OC: octopus
RL: rock lobster
RF: reef fishes
SU: sea urchin
AB: abalone
SW: seaweed bed

Interactions:
Positive
Negative

Marzloff *et al.* (in press., GCB)

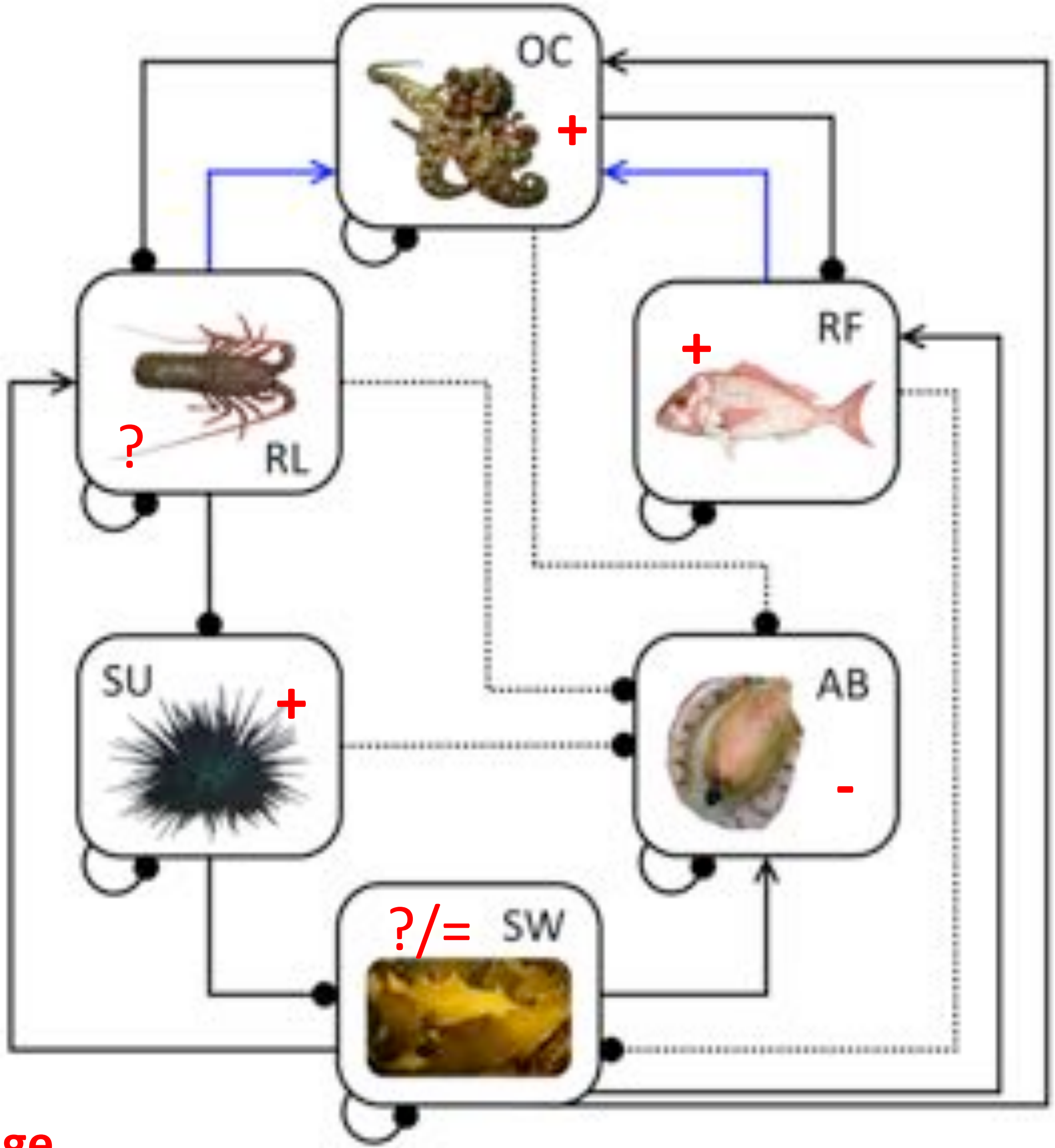


Model groups:
OC: octopus
RL: rock lobster
RF: reef fishes
SU: sea urchin
AB: abalone
SW: seaweed bed

Interactions:
Positive
Negative

Alternative models
Model i
Model ii
Model iii

Marzloff *et al.* (in press., GCB)



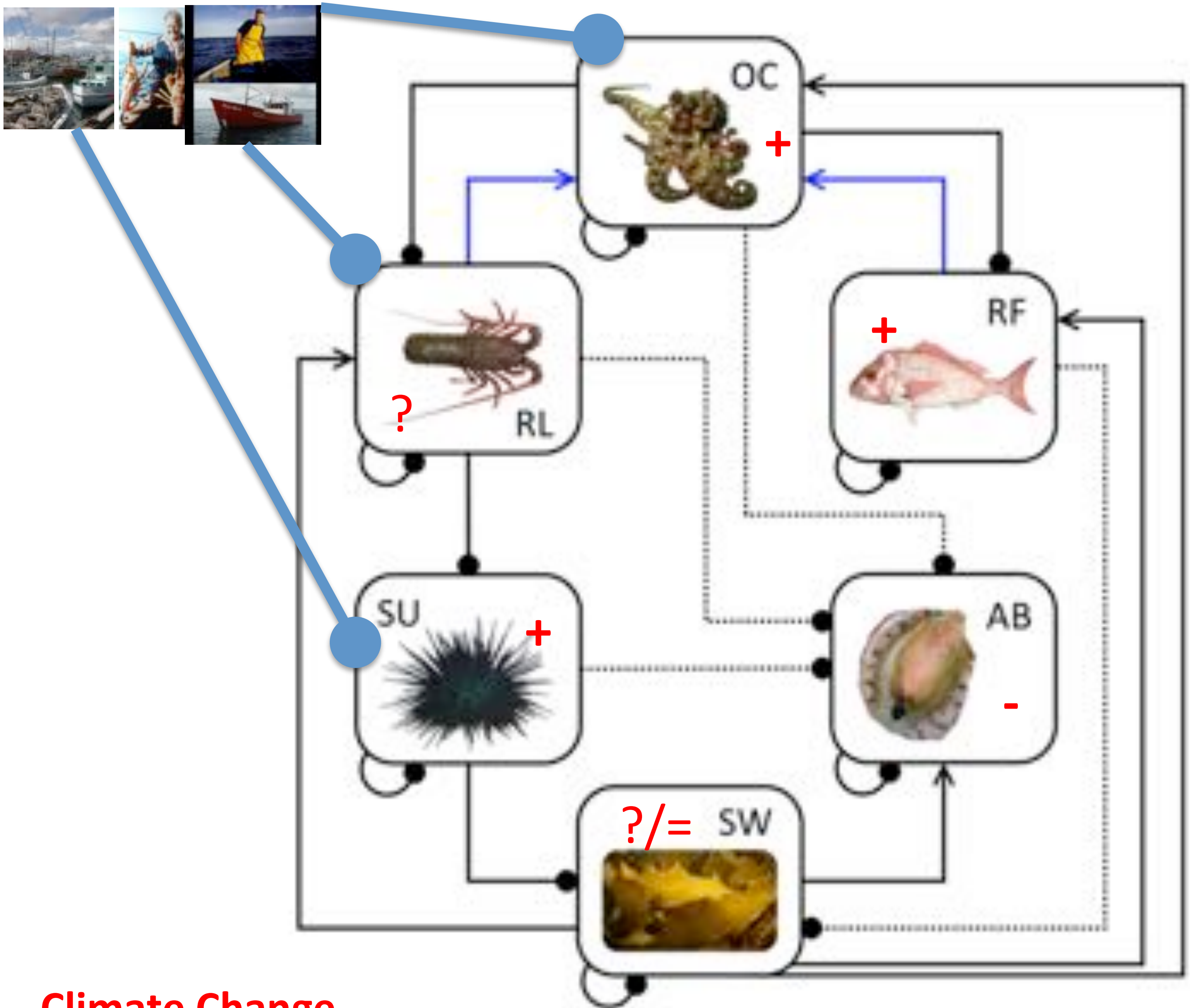
Model groups:
OC: octopus
RL: rock lobster
RF: reef fishes
SU: sea urchin
AB: abalone
SW: seaweed bed

Interactions:
Positive
Negative

Alternative models
Model i
Model ii
Model iii

Climate Change

Marzloff *et al.* (in press., GCB)



Model groups:
OC: octopus
RL: rock lobster
RF: reef fishes
SU: sea urchin
AB: abalone
SW: seaweed bed

Interactions:
Positive
Negative

Alternative models
Model i
Model ii
Model iii

Climate Change

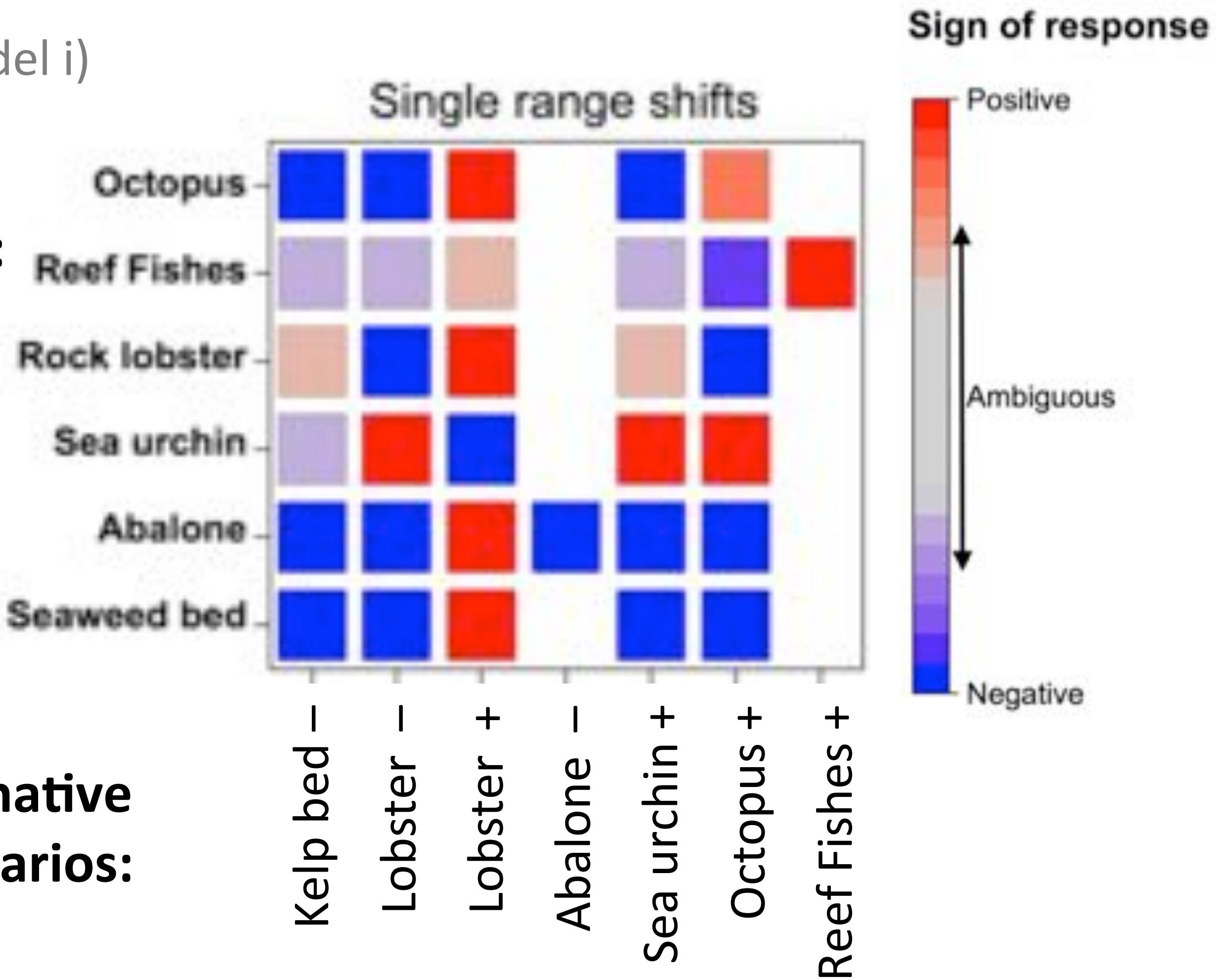
Marzloff *et al.* (in press., GCB)

Qualitative predictions: effects of range-shifting species

(Model i)

Response of:

To alternative scenarios:



Range shifts modelled as a long-term change in abundance:

+ : increase (range extension)

- : decrease (range contraction)

? : rock lobster =

 + 

eastern southern

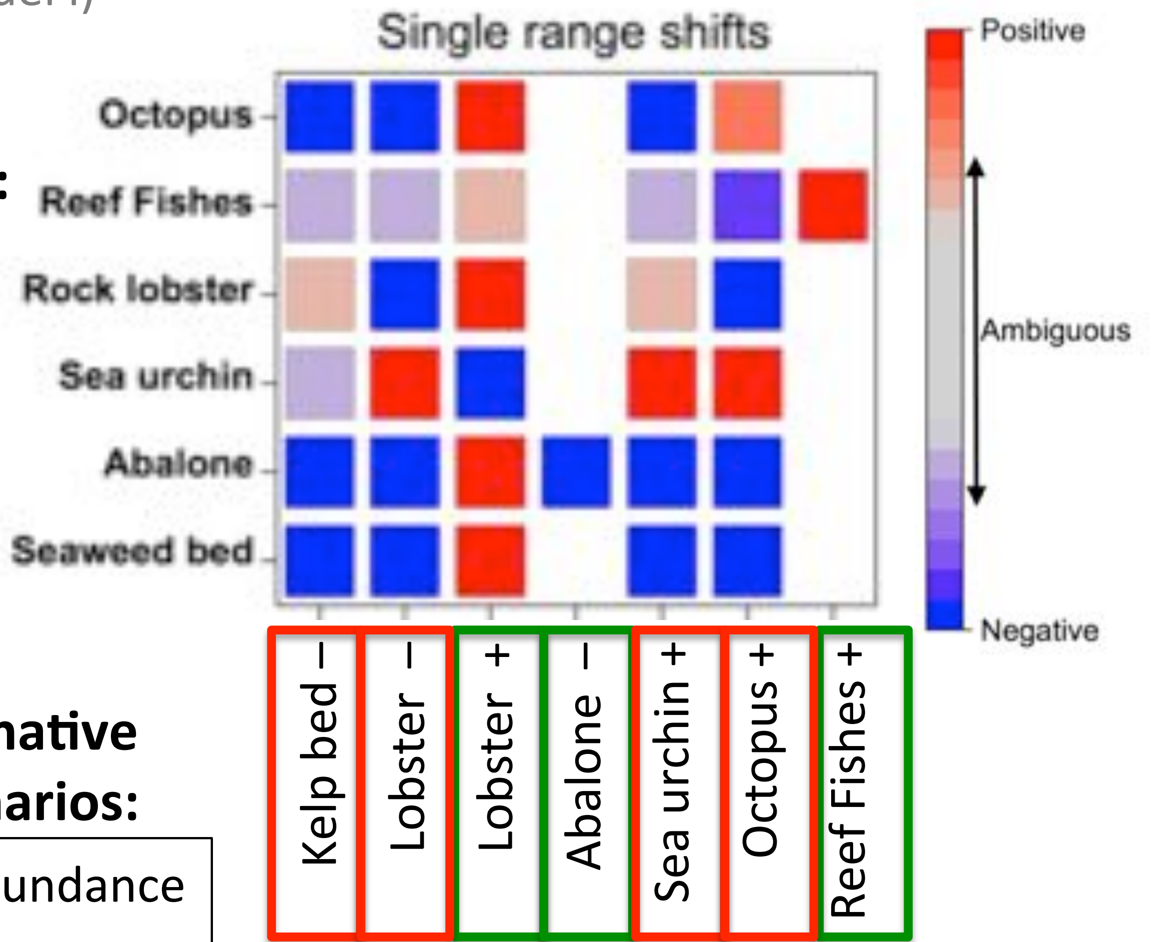
Marzloff *et al.* (in press., GCB)

Qualitative predictions: effects of range-shifting species

(Model i)

Response of:

Sign of response

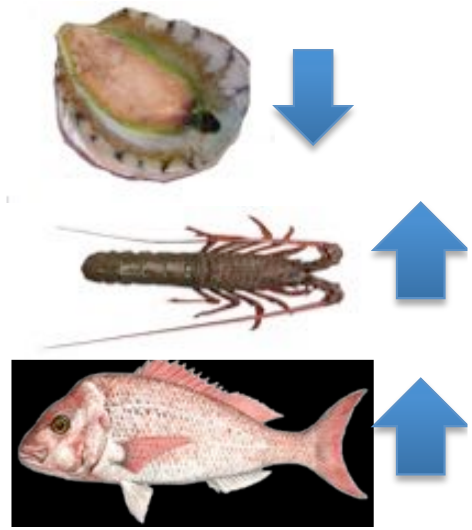


To alternative scenarios:

Change in abundance
+ : increase
- : decrease

Identification of:

(1) Range-shifters of lesser ecological concerns

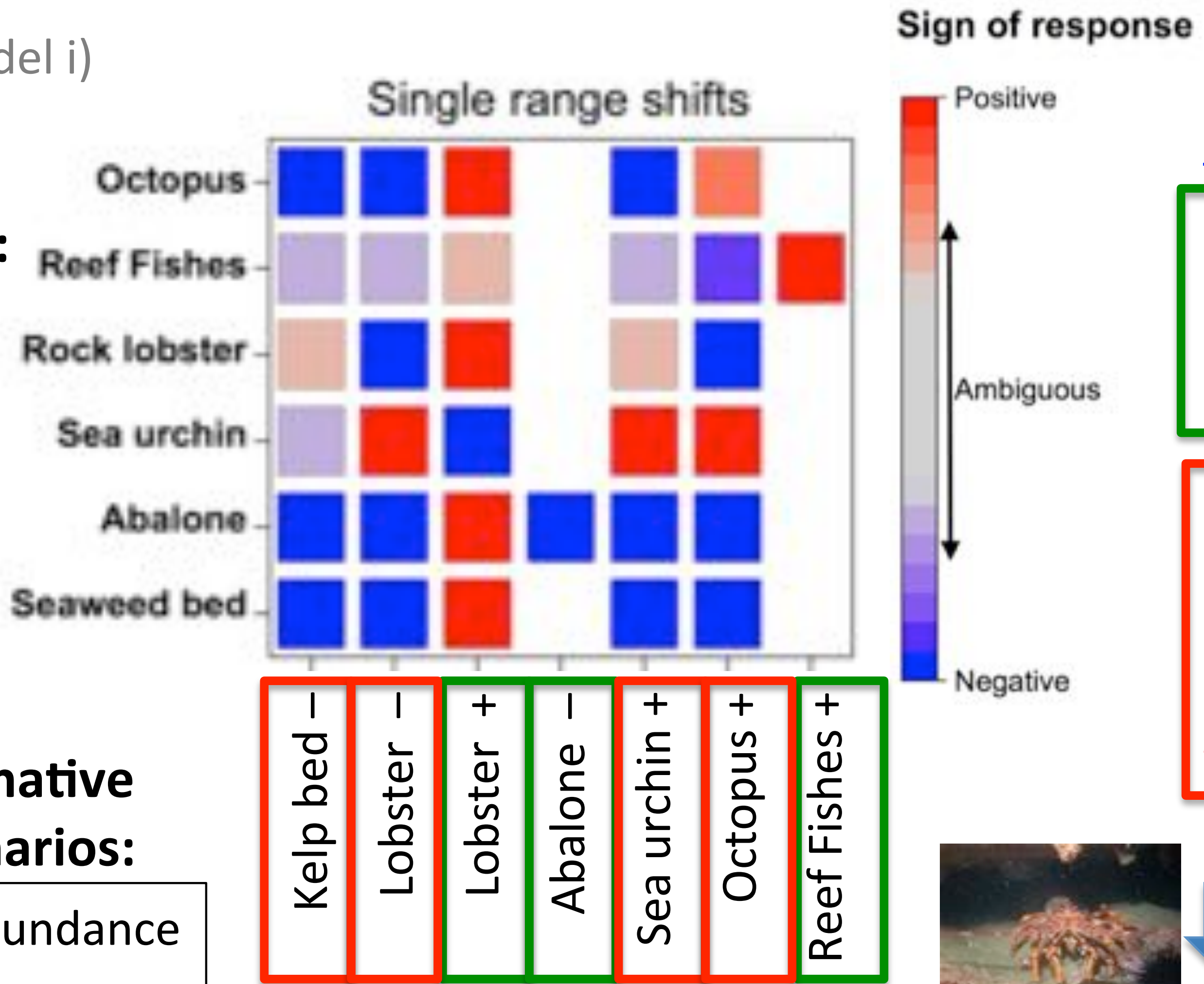


Marzloff *et al.* (in press., GCB)

Qualitative predictions: effects of range-shifting species

(Model i)

Response of:



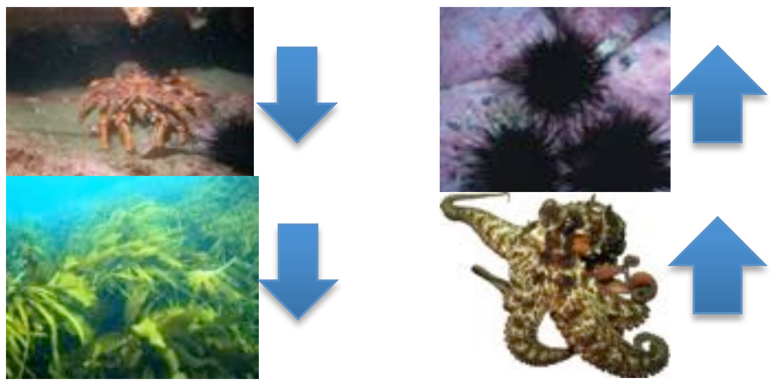
To alternative scenarios:

Change in abundance
+ : increase
- : decrease

Identification of:

(1) Range-shifters of lesser ecological concerns

(2) Range-shifters that can induce community-wide effects & affect ecosystem structure and functioning

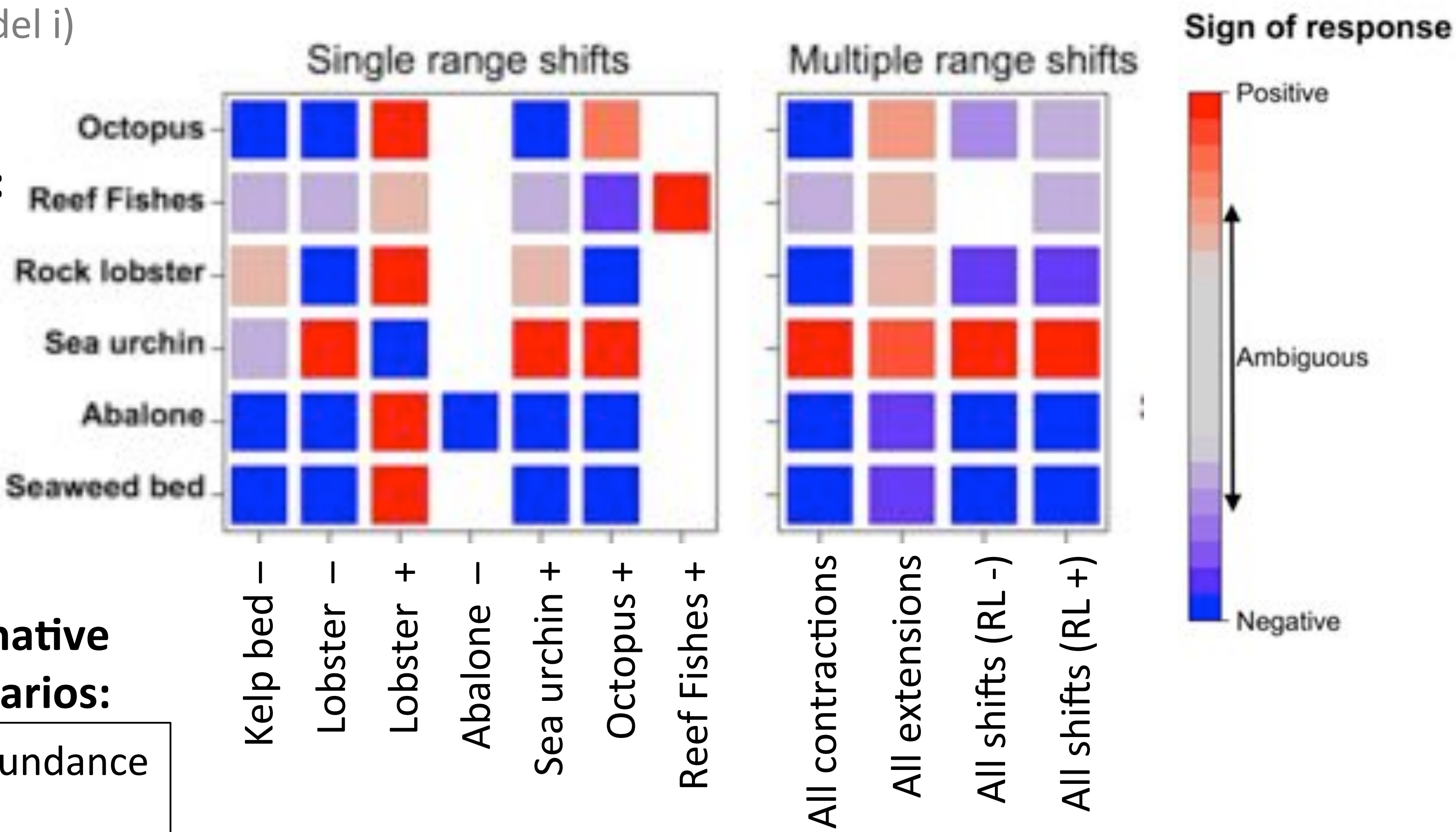


Marzloff *et al.* (in press., GCB)

Qualitative predictions: effects of range-shifting species

(Model i)

Response of:



To alternative scenarios:

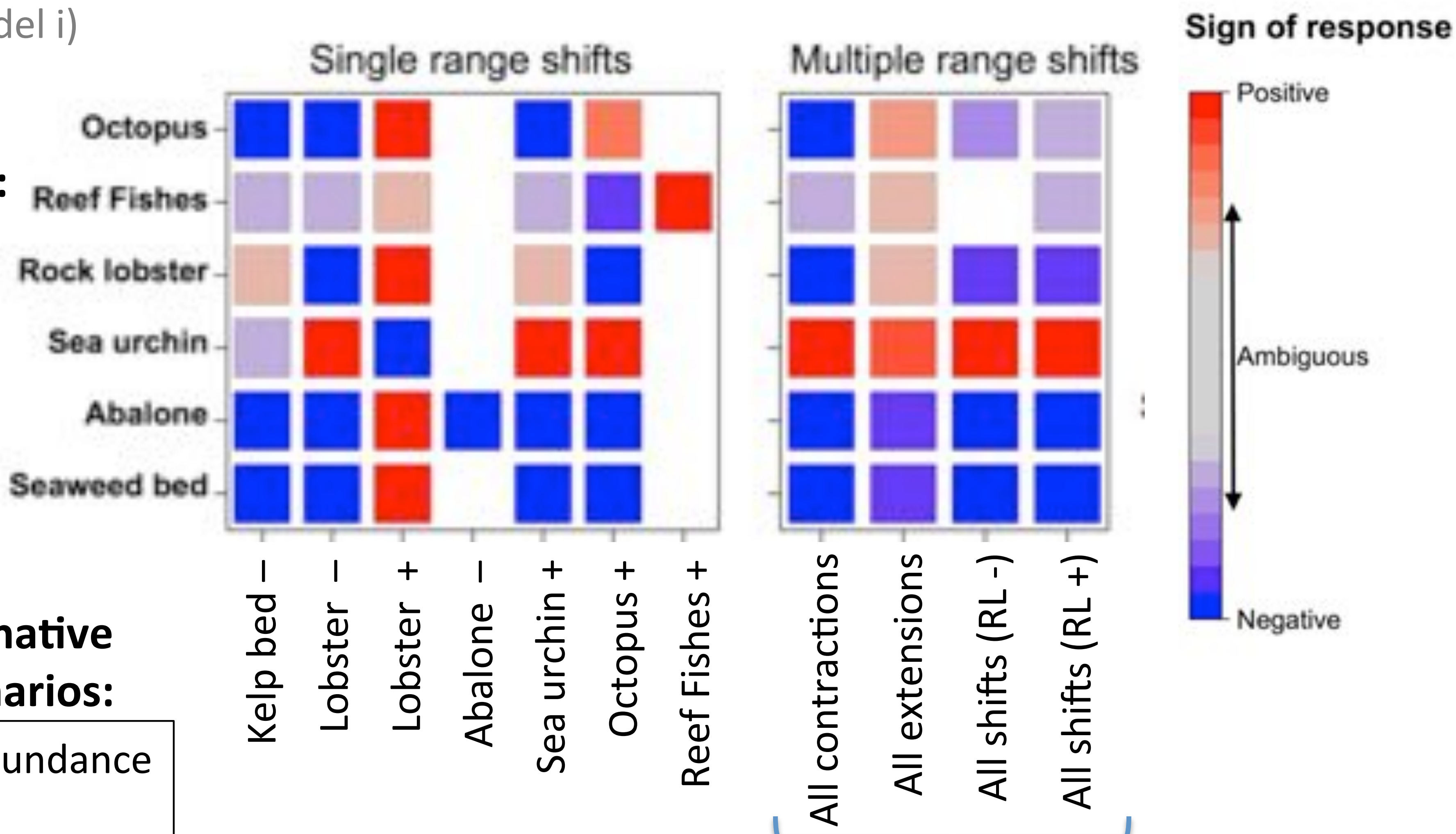
Change in abundance
+ : increase
- : decrease

Marzloff *et al.* (in press., GCB)

Qualitative predictions: effects of range-shifting species

(Model i)

Response of:



To alternative scenarios:

Change in abundance
+ : increase
- : decrease

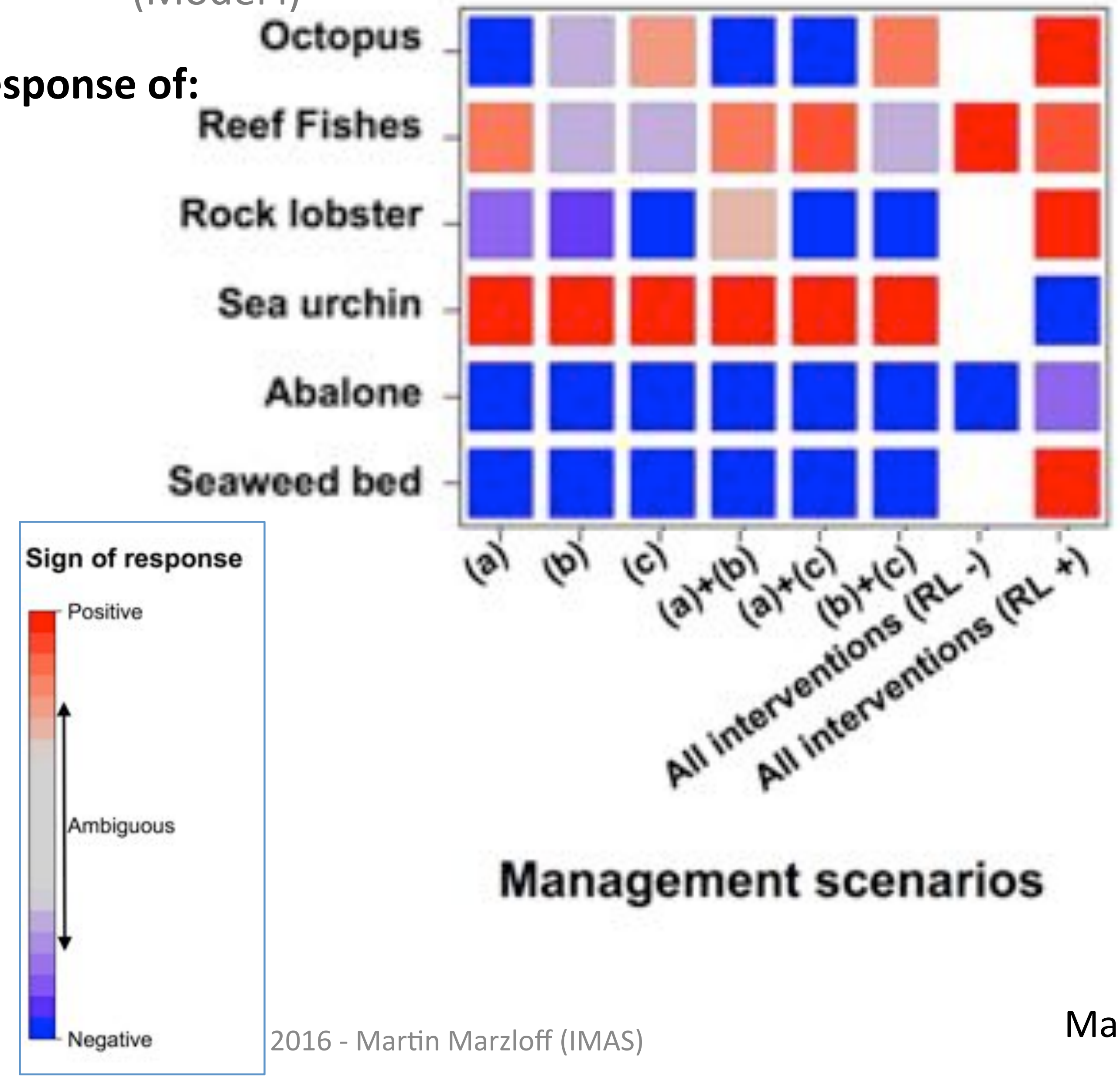
Negative community effects of multiple range-shifters are likely to add up!

Marzloff *et al.* (in press., GCB)

Qualitative predictions: effects of management interventions

(Model i)

Response of:



Management interventions:

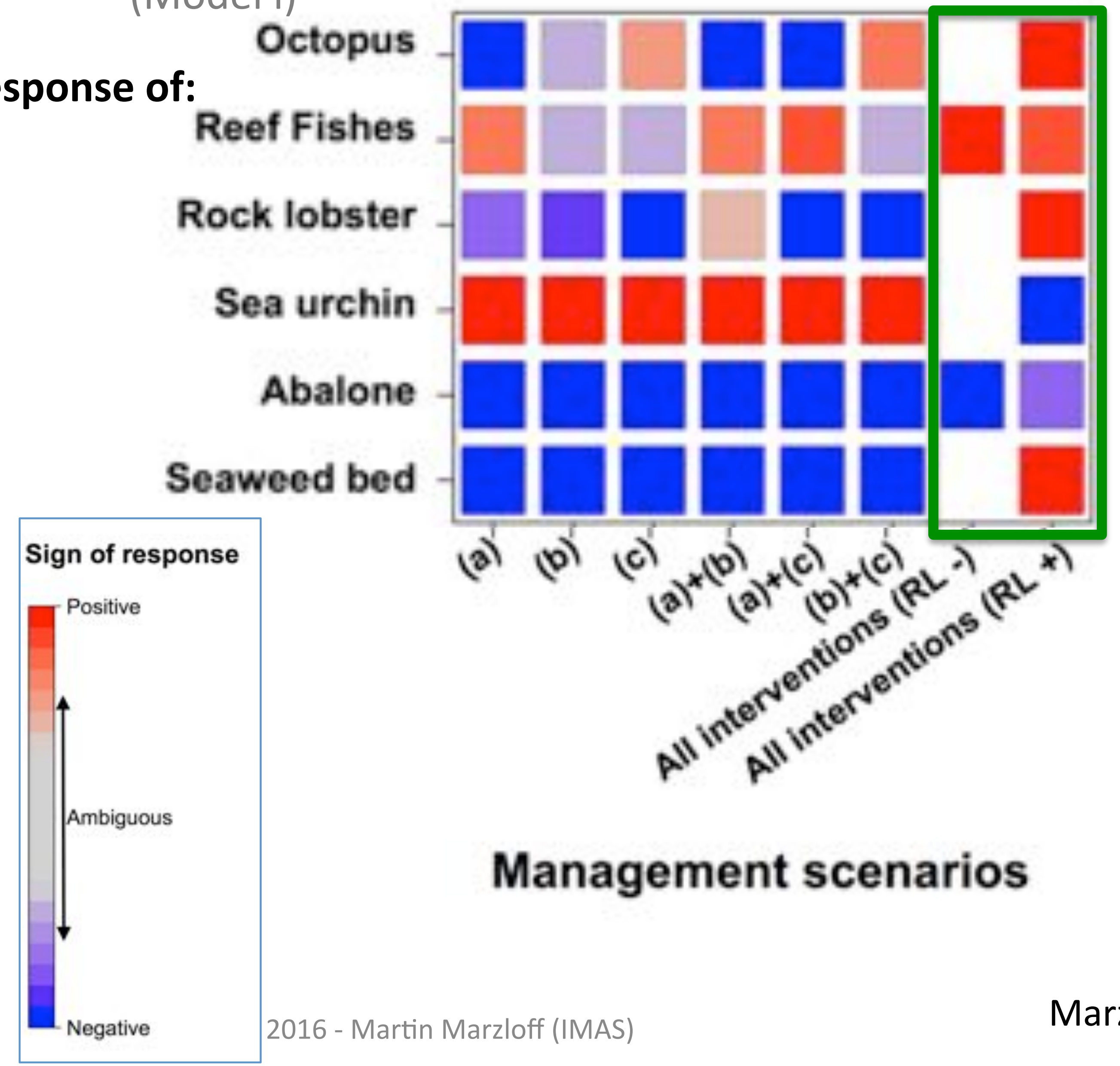
a: octopus harvesting
b: lobster stock rebuilding
c: sea urchin culling / harvesting

Marzloff *et al.* (in press., GCB)

Qualitative predictions: effects of management interventions

(Model i)

Response of:



Management interventions:

a: octopus harvesting
b: lobster stock rebuilding
c: sea urchin culling / harvesting

Combining available management interventions is key to effectively mitigate the negative ecosystem impacts of range-shifters regionally.

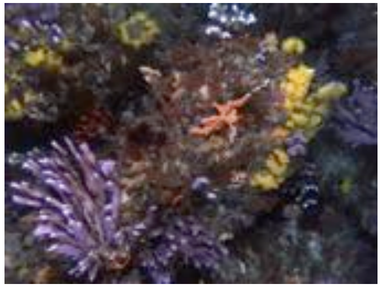
Marzloff *et al.* (in press., GCB)

Take-home messages (Part 1)…

- Focus on sea urchin barrens in eastern Tasmania is justified in the medium term
- In the long-term, qualitative modelling based on limited information (Marzloff et al., in press – GCB) can help:
  1. Identify range-shifters of ecological concerns, which requires dedicated monitoring, research and management;
  2. Assess the combined ecological impacts of multiple range-shifters;
  3. Guide management strategies to prevent undesirable and hard-to-reverse consequences of climate-driven range shifts
- Quantitative modelling of ecological impacts of range-shifts is a sensible next step, but hard and costly to implement in practise…

Structure de ma présentation

1. Effets de la pêche et climat sur les communautés benthiques associées aux laminaires (profondeur < 30m)



2. Communautés benthiques profondes (profondeur: 30-100 m) et changement climatique

Habitat formers & reef ecosystems

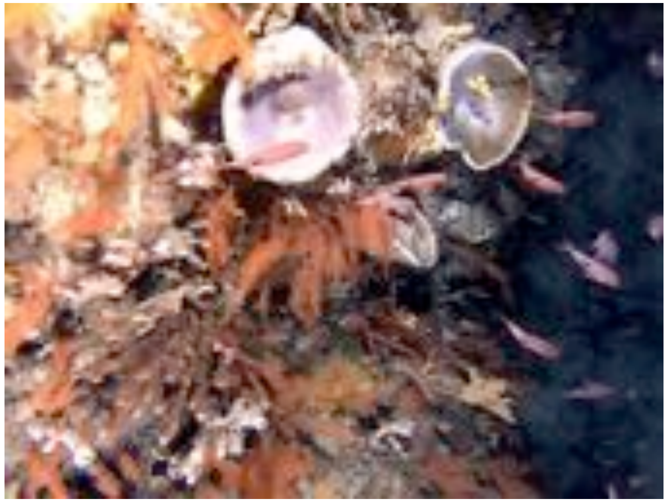
Corals

Seaweed beds

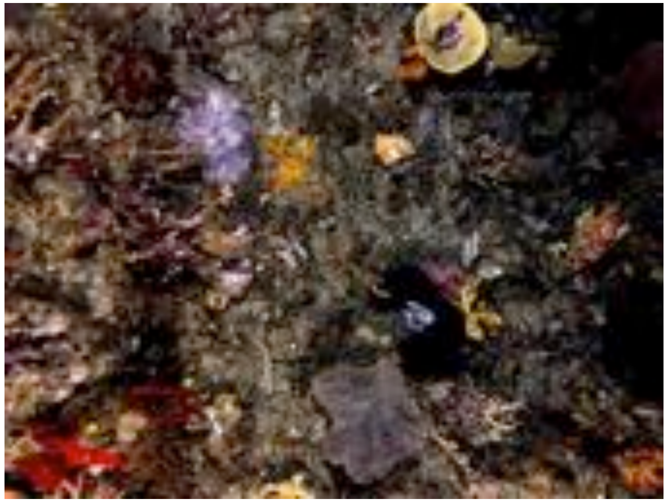
- Complex 3D structure
- Shelter from predation
- Diversity
- Food source
- Nutrient recycling

Habitat formers & reef ecosystems

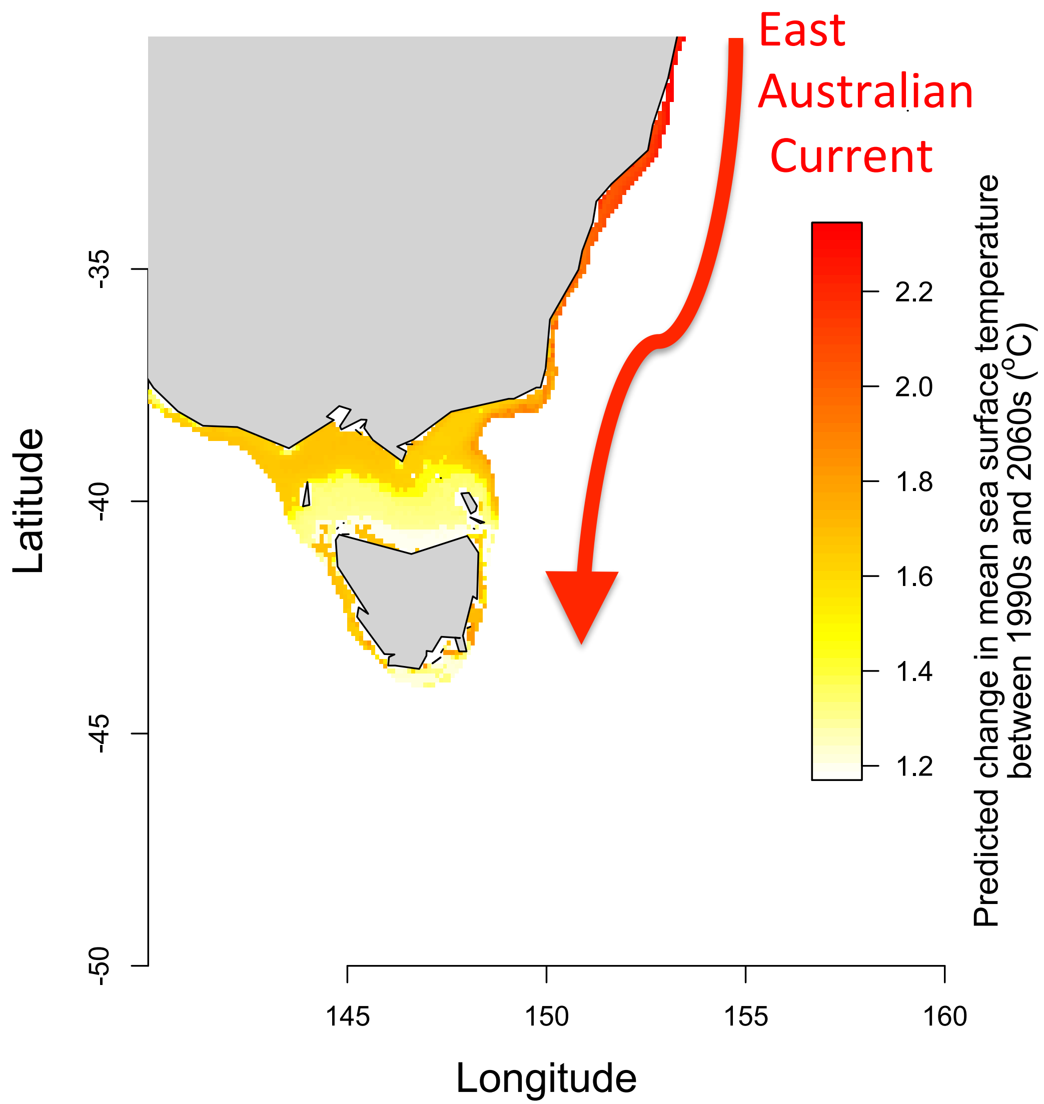
Corals



Seaweed beds



Climate-driven changes in eastern Australia



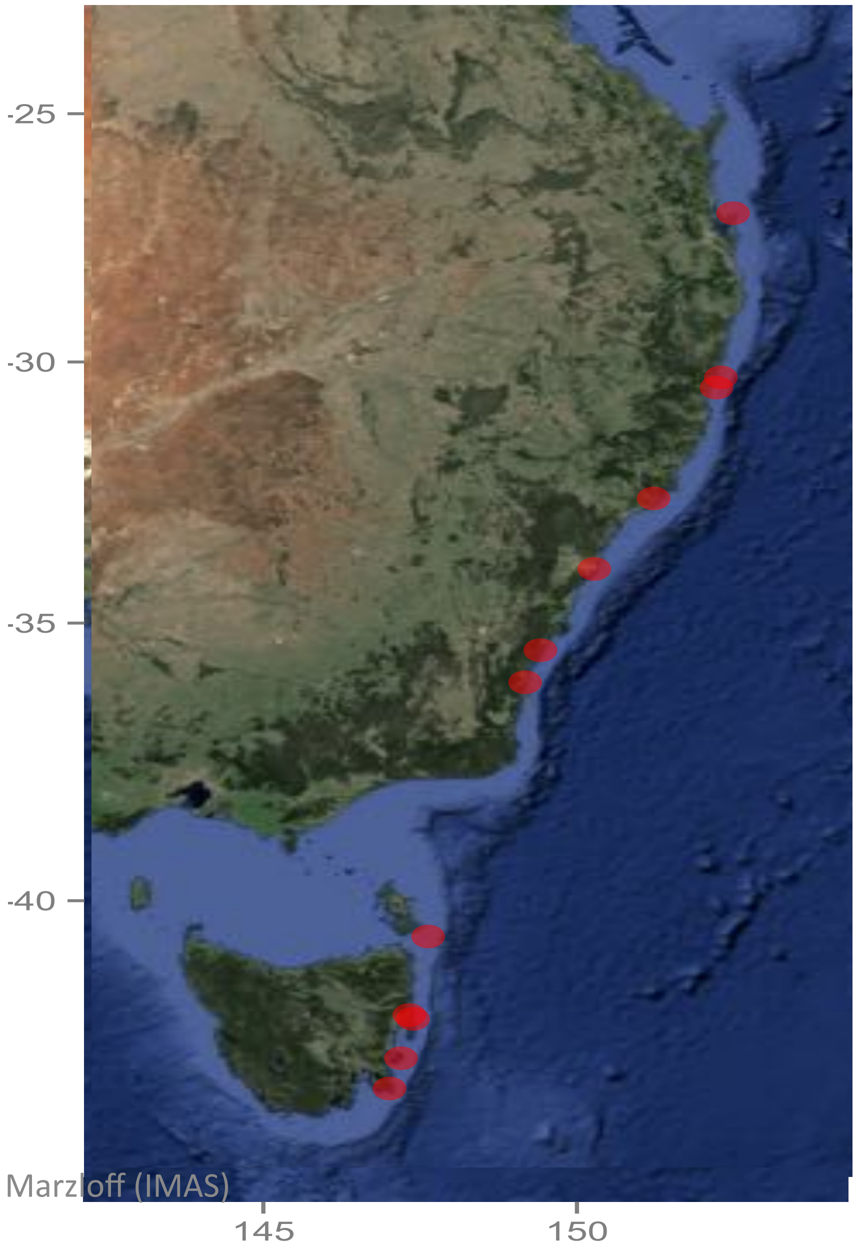
- Climate-driven effects on habitat formers
  - Coral bleaching
  - Decay of the giant kelp
  - Shift from kelp beds to 'barrens' due to range-shifting herbivores

- Limited information about deeper (> 30m) sessile invertebrates

Biotic data from AUV imagery

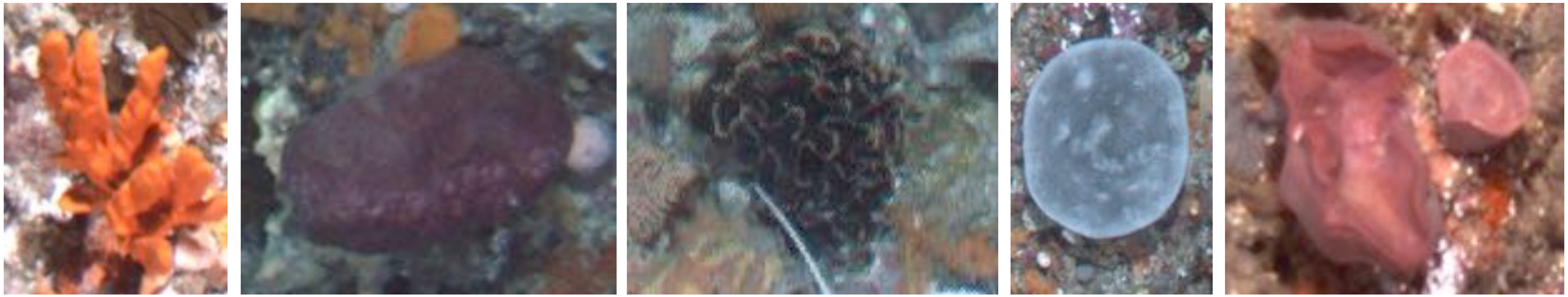
IMOS Autonomous Underwater Vehicle 'Sirius'

Biotic data from AUV imagery

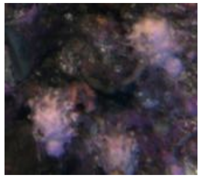
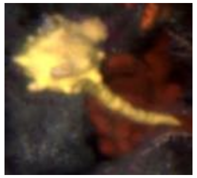
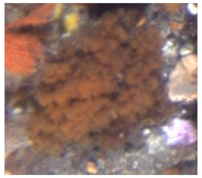
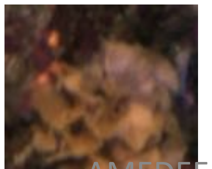


Biotic data from AUV imagery

- Lainey James' MSc project
- Image scoring = time-consuming challenge
  - Selection of ~50 morphospecies based on detectability features (i.e. size/colour/shape)

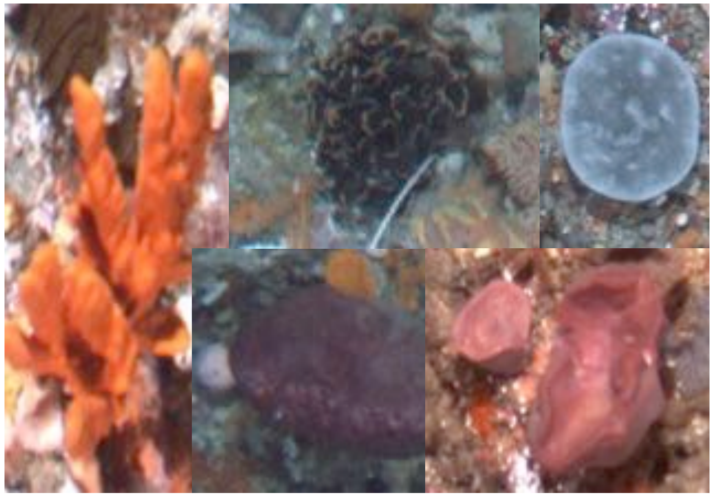


  - > 1,800 images scored across all sites

	Broad group	Specifier	Shape	Colour	Morph. Level	Sub-Group Level	CATAMI Level
	Ascidian	Solitary	Stalked	Purple	ASSP	Stalked Solitary Ascidian	ASS
	Ascidian	Solitary	Stalked	Yellow	ASSY		
	Bryozoan	N/A	Soft	Orange	BRYSO	Soft bryozoan	BRY
	Bryozoan	N/A	Soft	Brown	BRYSB		
	Bryozoan	Foliaceous	Soft	Black	BRYSFB		
	Bryozoan	Fenestrate	Hard	White	BRYHFW	Hard bryozoan	

<u>3 Levels</u> of classification:

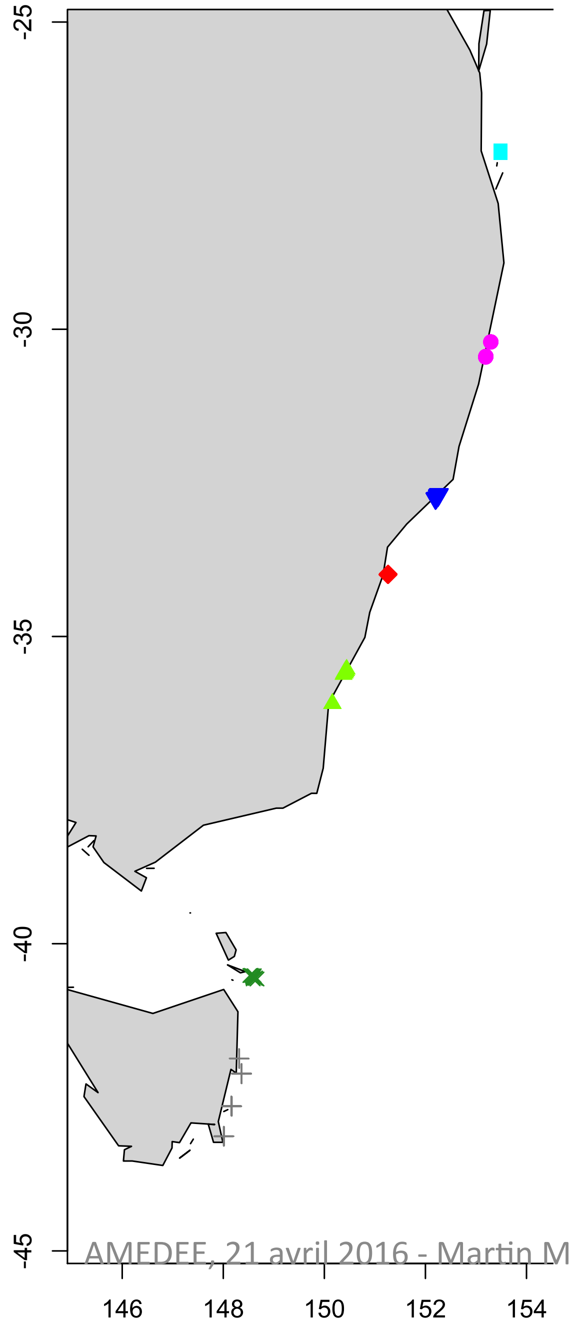
- CATAMI
- Group
- Morphospecies (colour + shape)

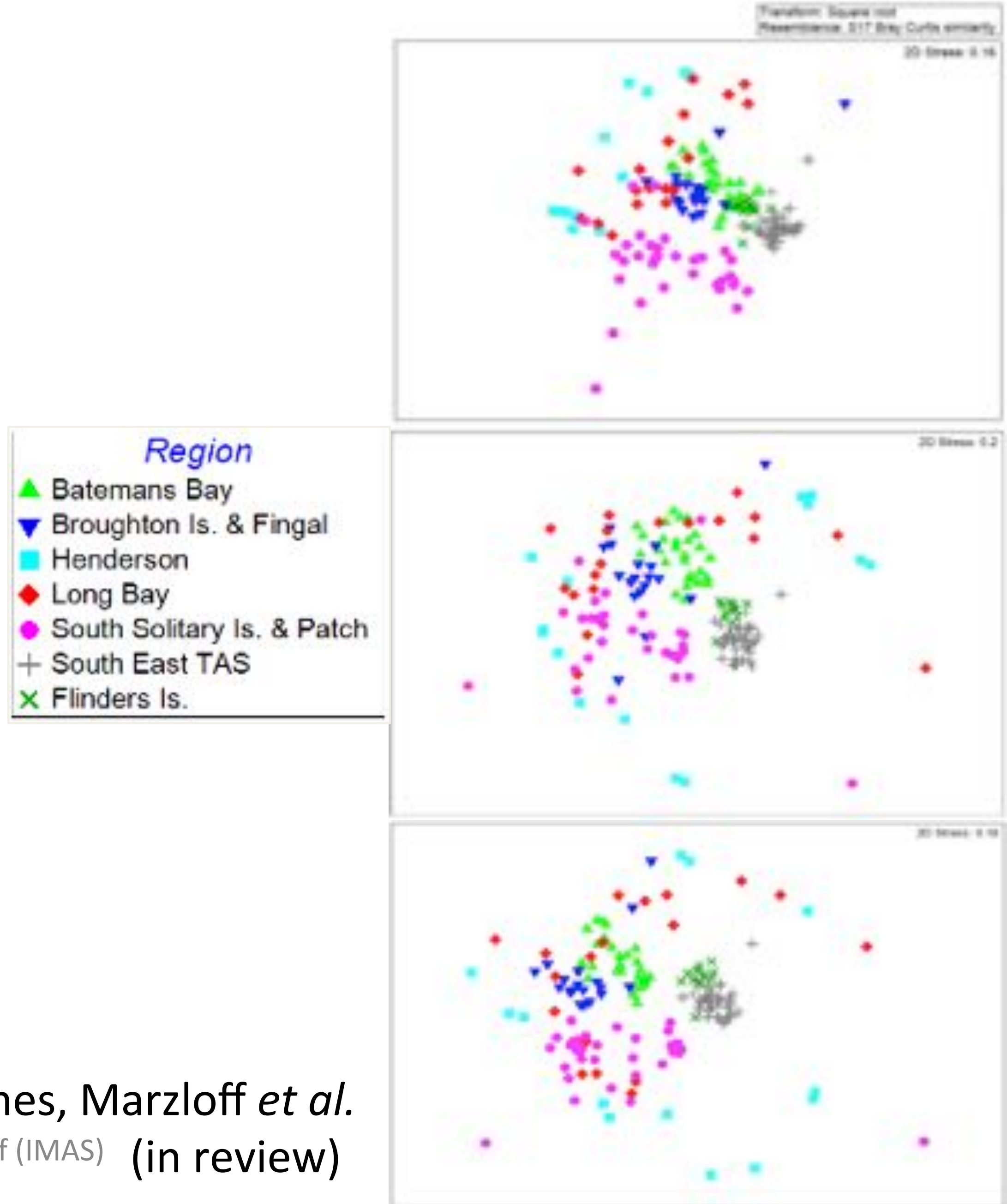


Environmental covariates & methods

- Environmental covariates
    - Depth
    - Substrate profile, Seafloor slope & aspect
    - Temperature
    - Primary productivity
    - Ocean biogeochemistry (e.g. salinity, nitrate concentration)
    - Shear stress near the seafloor
- Community-based analysis (MDS, CAP, distLM)
- Single group/species distribution models
    - Alternative methods: GLMs, GAMs, Random Forests
    - Cross validation
    - Model averaging for predictions ('Bagged' or bootstrapped aggregated)

Latitudinal gradient in deep reef community





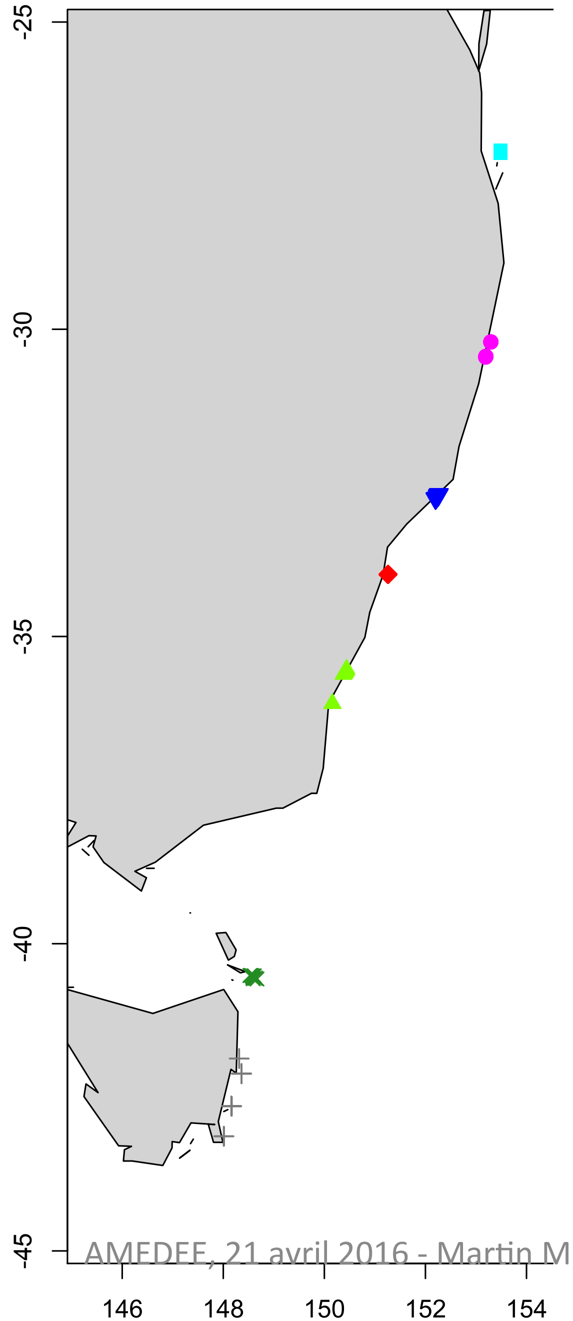
Classification
(i) CATAMI

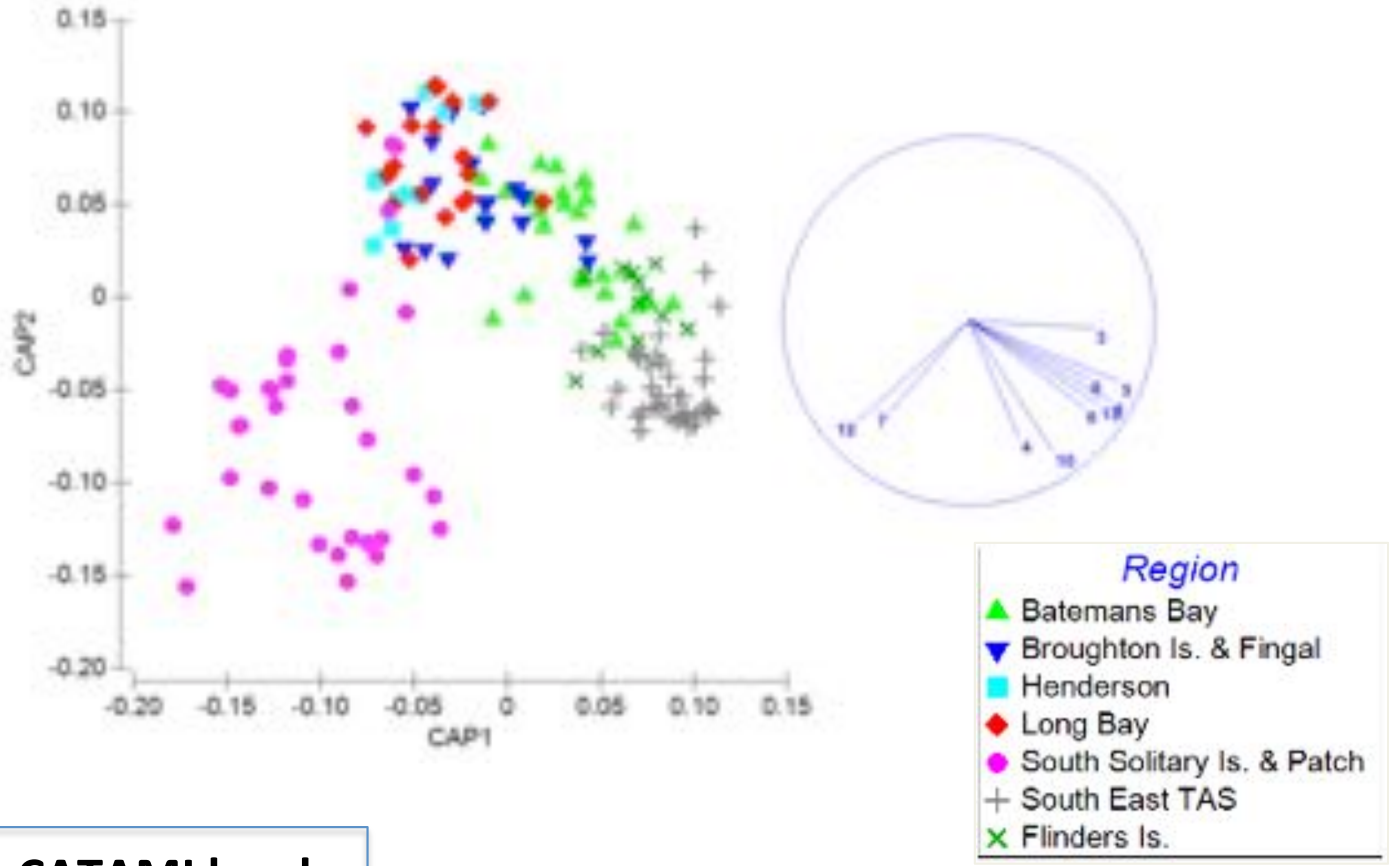
(ii) GROUP

(iii) MORPH.

James, Marzloff *et al.* (in review)

Latitudinal gradient in deep reef community



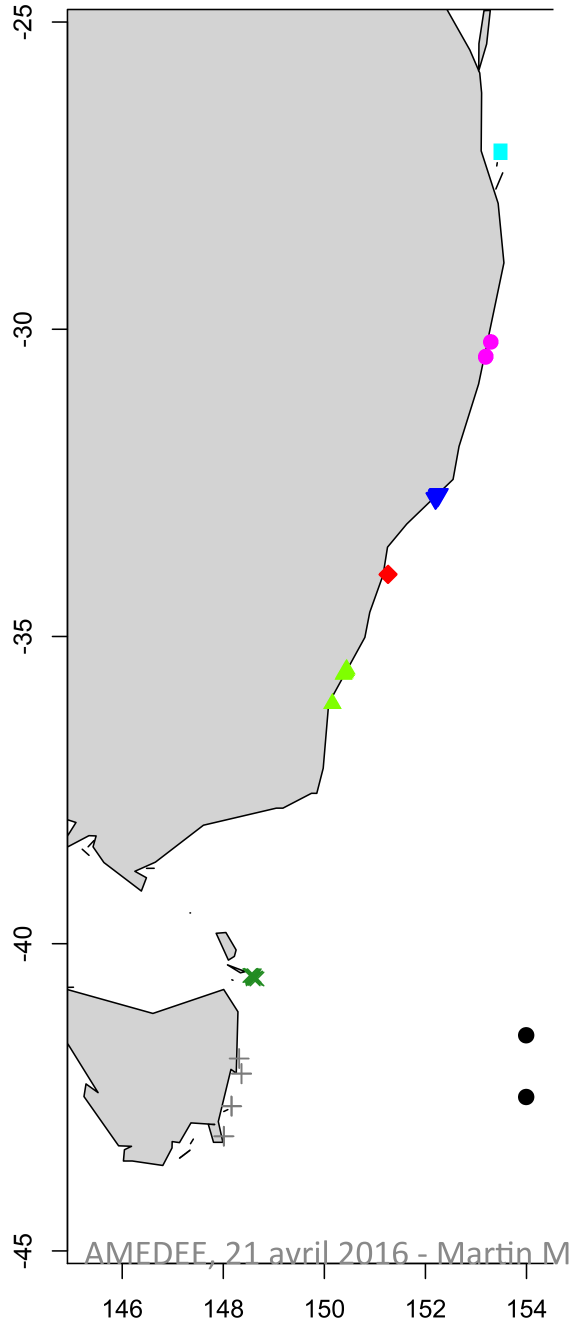


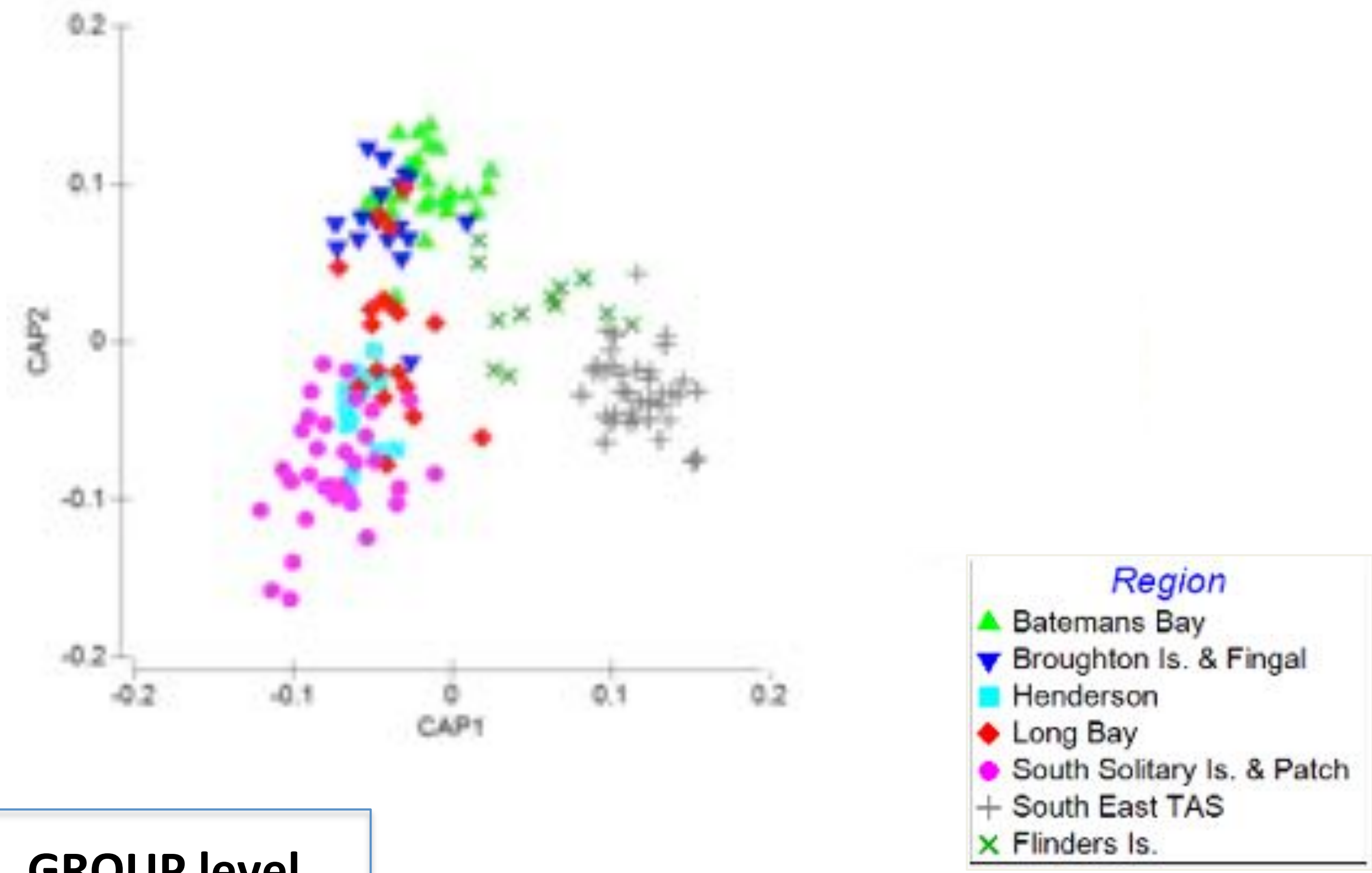
CATAMI level

- **2** = Sponges: Massive forms: Simple
- **3** = Bryozoa
- **4** = Sponges: Hollows forms: Cups & alike
- **5** = Sponges: Erect forms: Branching
- **6** = Sponges: Erect forms: Laminar
- **7** = Cnidaria: Corals: Black & Octocorals: Fan (2D): Rigid
- **8** = Sponges: Erect forms: Palmate
- **10** = Cnidaria: Corals: Black & Octocorals: Fan (2D): Fern-frond: Complex
- **12** = Cnidaria: Corals: Black & Octocorals: Branching (3D): Non-fleshy: Arborescent
- **13** = Sponges: Massive forms: Radially organised

James, Marzloff *et al.* (in review)

Latitudinal gradient in deep reef community



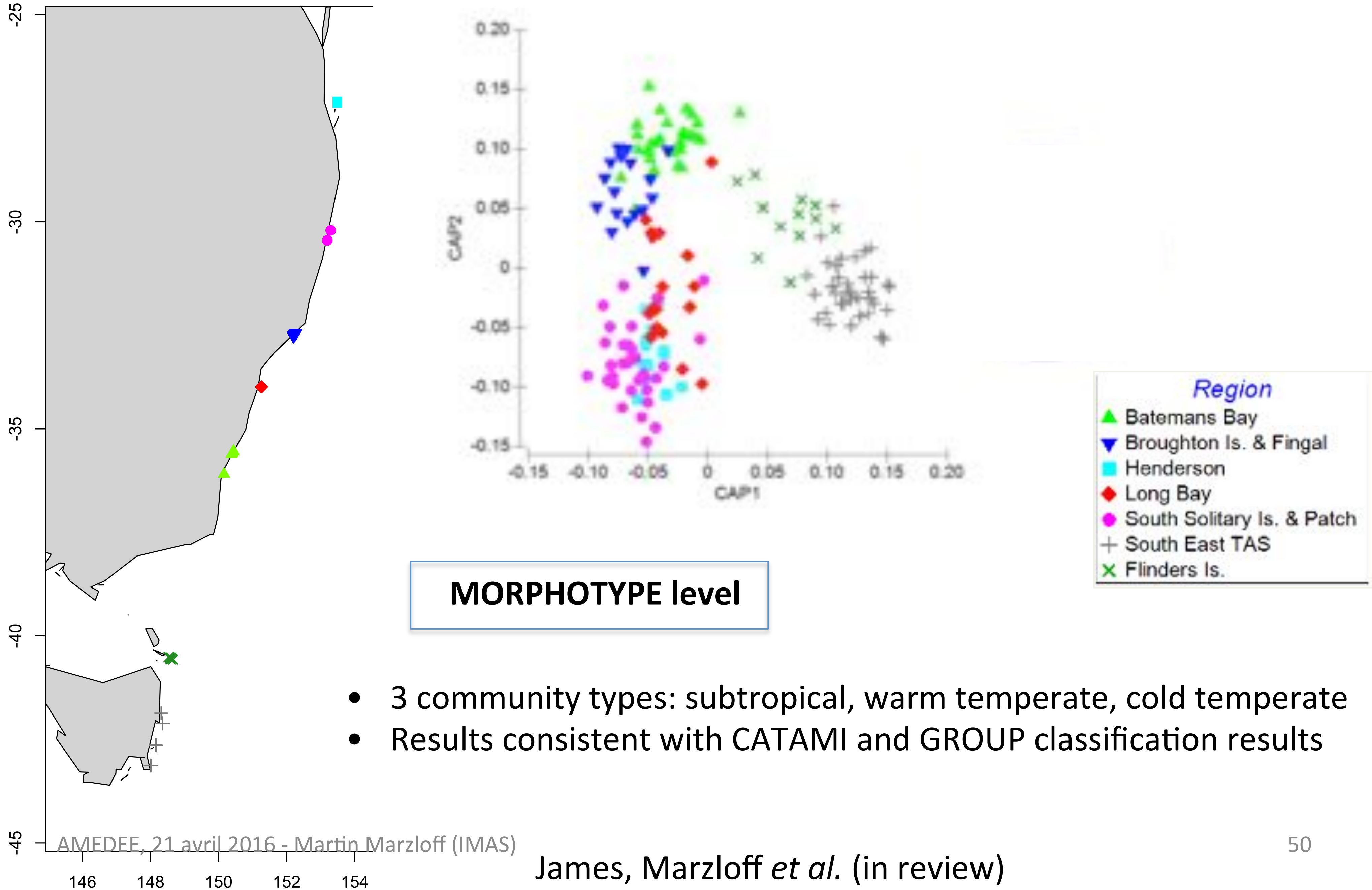


GROUP level

- 3 community types: subtropical, warm temperate, cold temperate
- Results consistent with CATAMI classification results

James, Marzloff *et al.* (in review)

Latitudinal gradient in deep reef community



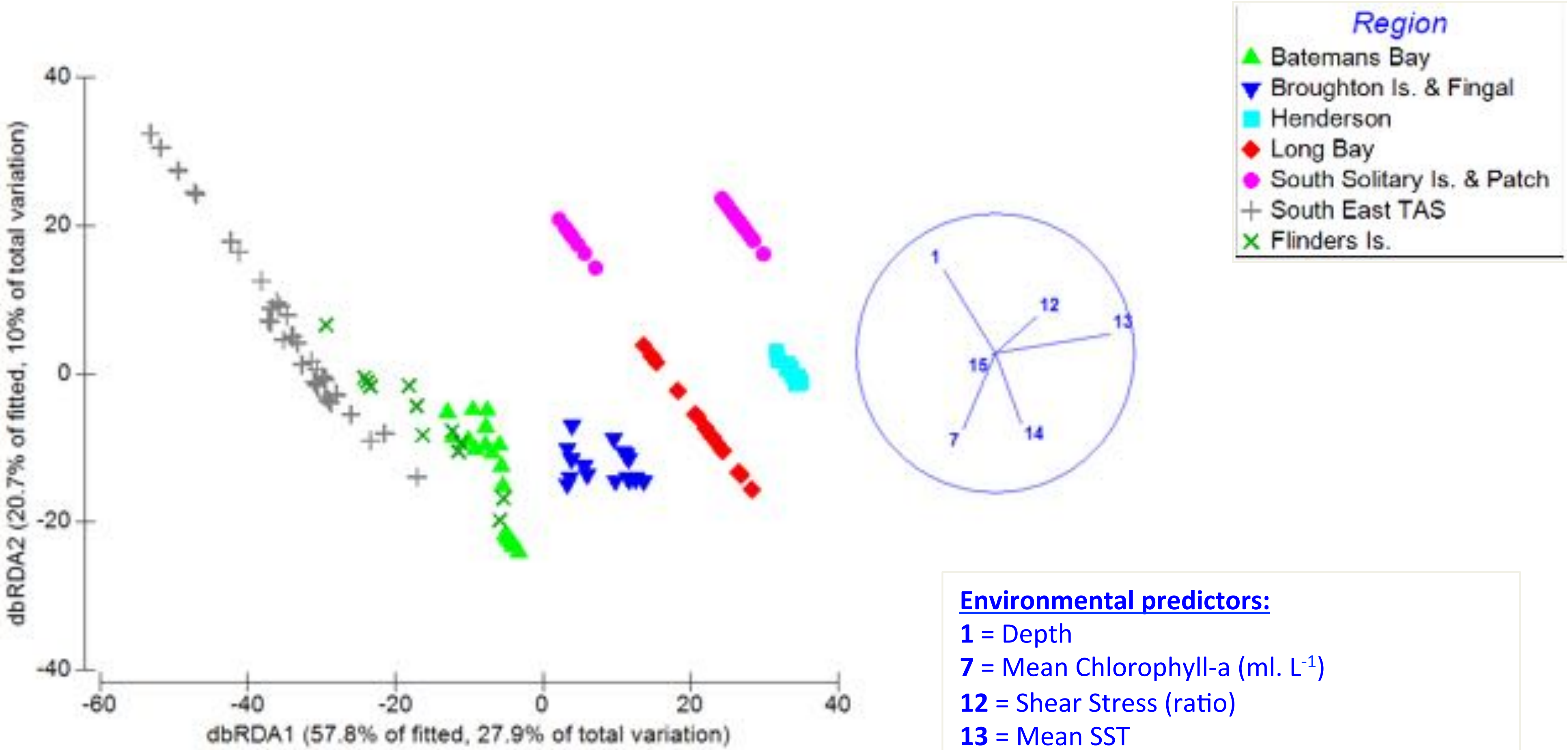
MORPHOTYPE level

- 3 community types: subtropical, warm temperate, cold temperate
- Results consistent with CATAMI and GROUP classification results

James, Marzloff *et al.* (in review)

Relation with environmental gradient

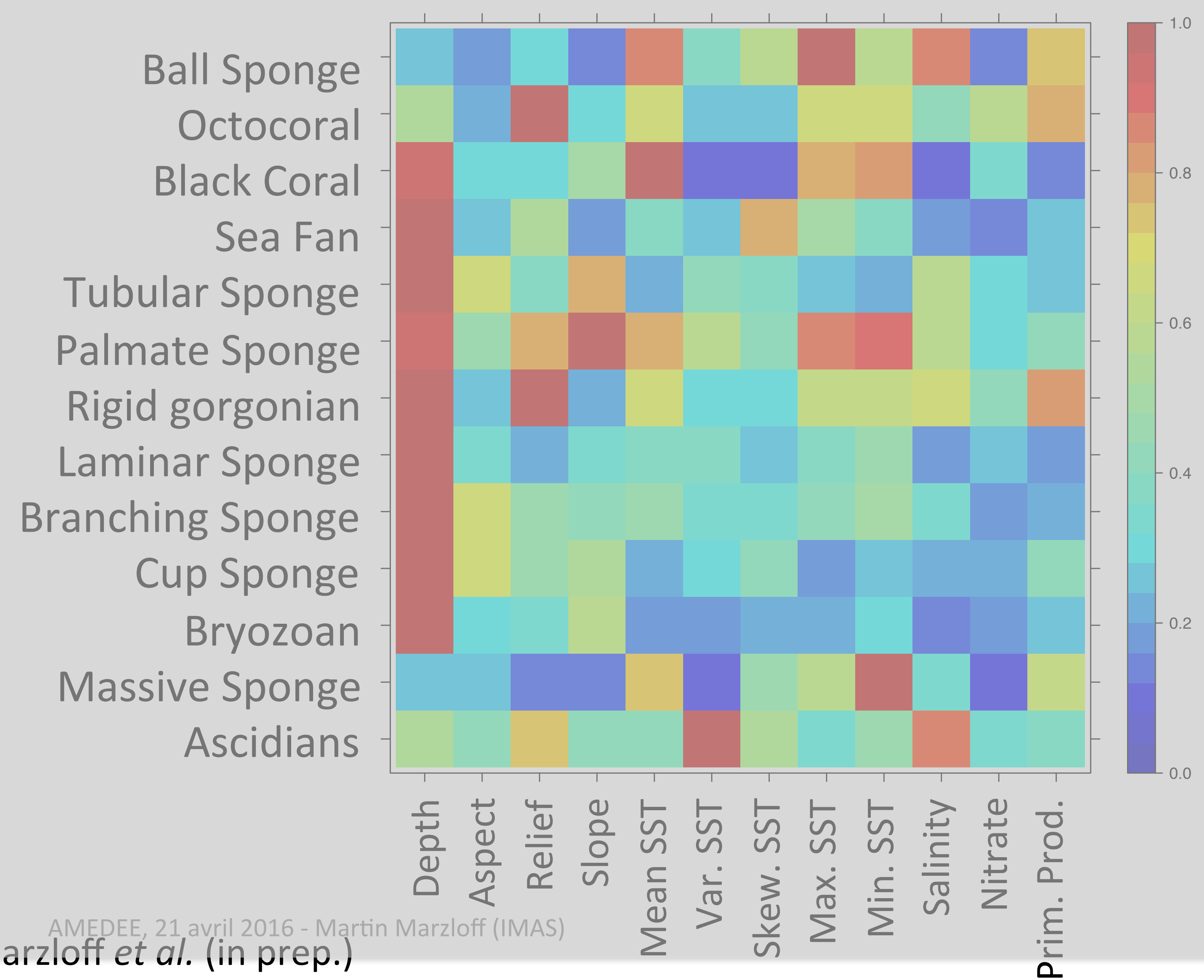
DistLM relating variability in community composition
with variability in environmental conditions



Environmental predictors:
1 = Depth
7 = Mean Chlorophyll-a (ml. L^{-1})
12 = Shear Stress (ratio)
13 = Mean SST
14 = Seasonal amplitude in SST
15 = s.d. of SST (seasonal cycle filtered out)

James, Marzloff *et al.* (in review)

Environmental covariates selected in RFs

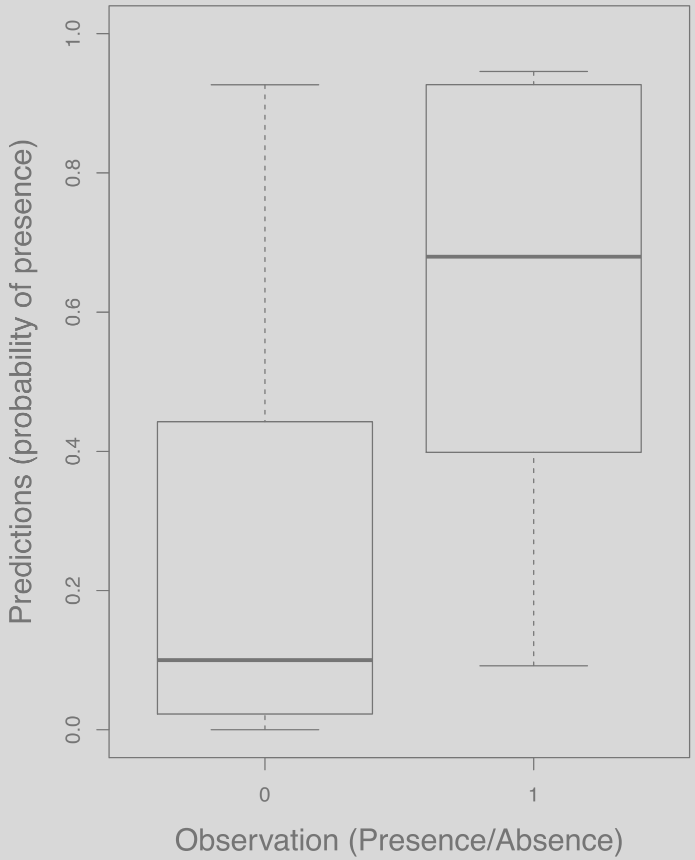


Marzloff *et al.* (in prep.)

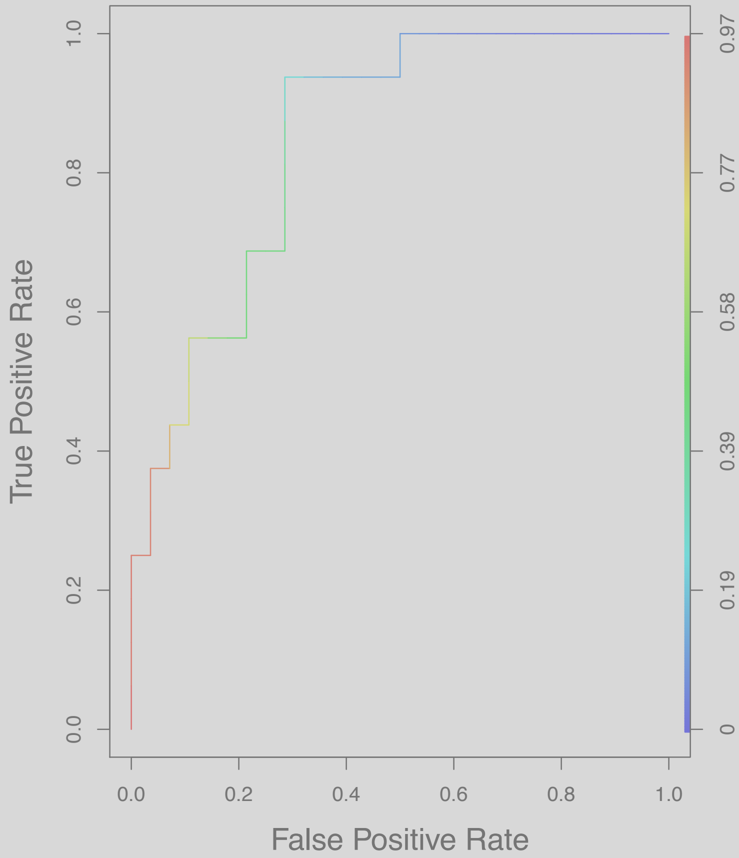
Predictions for individual groups (RFs)

Stalked Solitary Ascidians

Predictions Vs Observations



ROC curve (error rates)

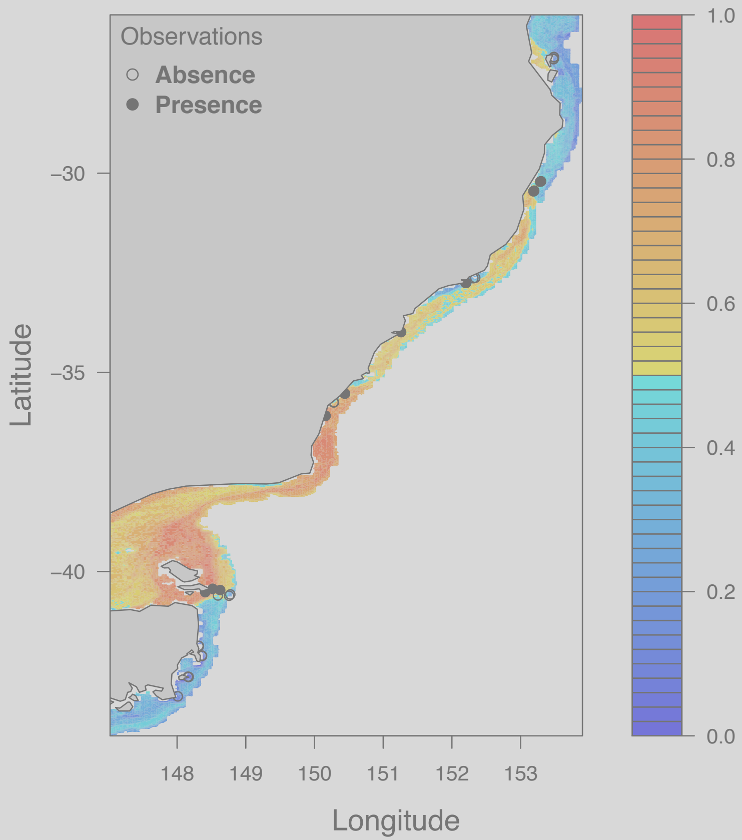


Marzloff *et al.* (in prep.)

Predictions for individual groups

Stalked Solitary Ascidians

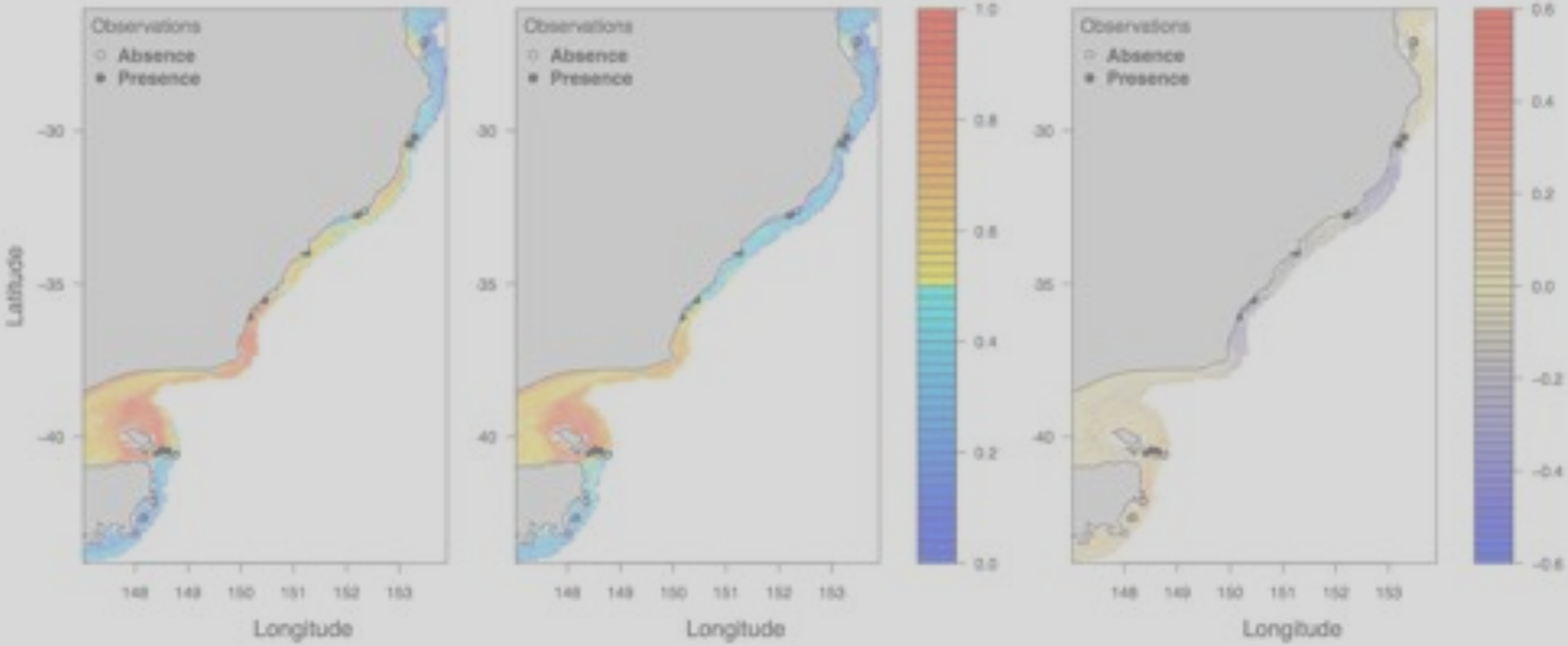
Predicted probability of presence (NOW)



Marzloff *et al.* (in prep.)

Predictions for individual groups

NOW 2060s CHANGE

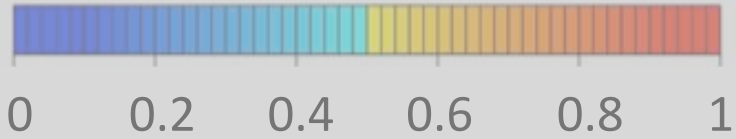


Stalked Solitary Ascidians

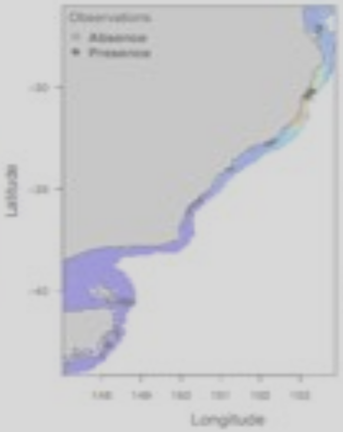
Marzloff *et al.* (in prep.)

NOW

PROBABILITY OF PRESENCE



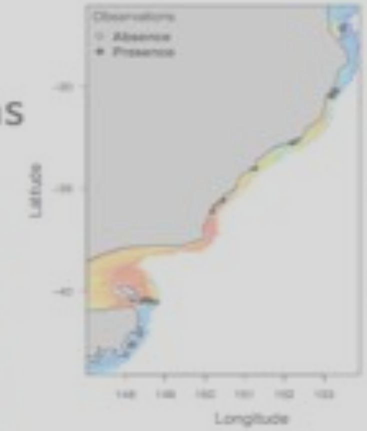
Octocorals



Subtropical distribution

(Queensland; Northern New-South-Wales)

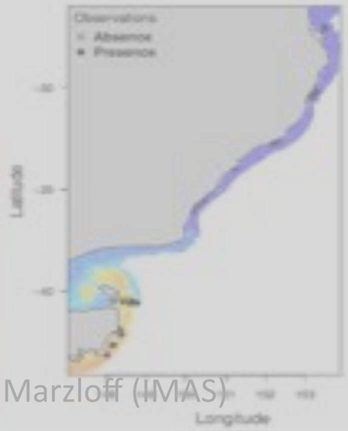
Stalked Ascidians



Warm temperate distribution

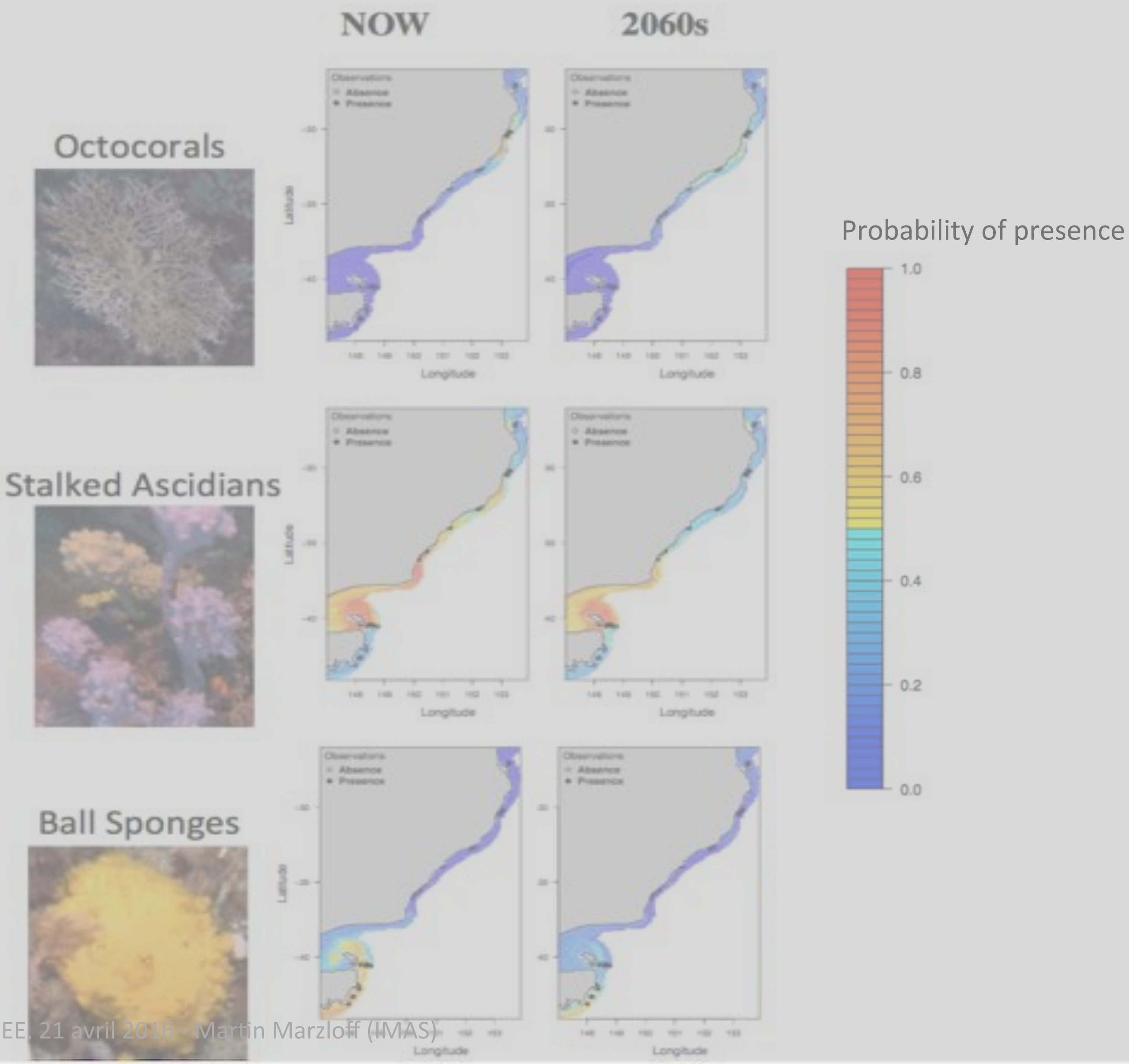
(New-South-Wales)

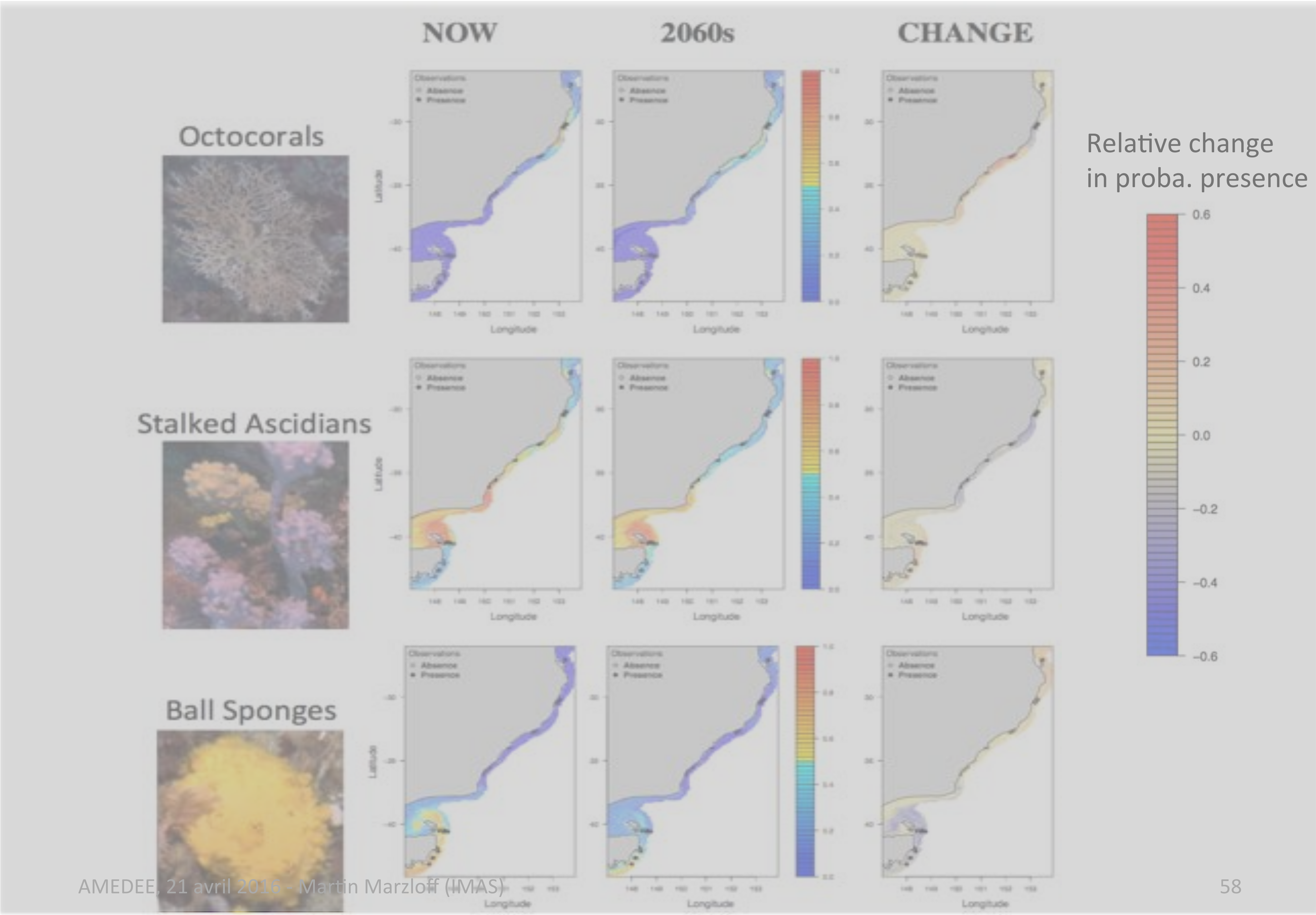
Ball Sponges



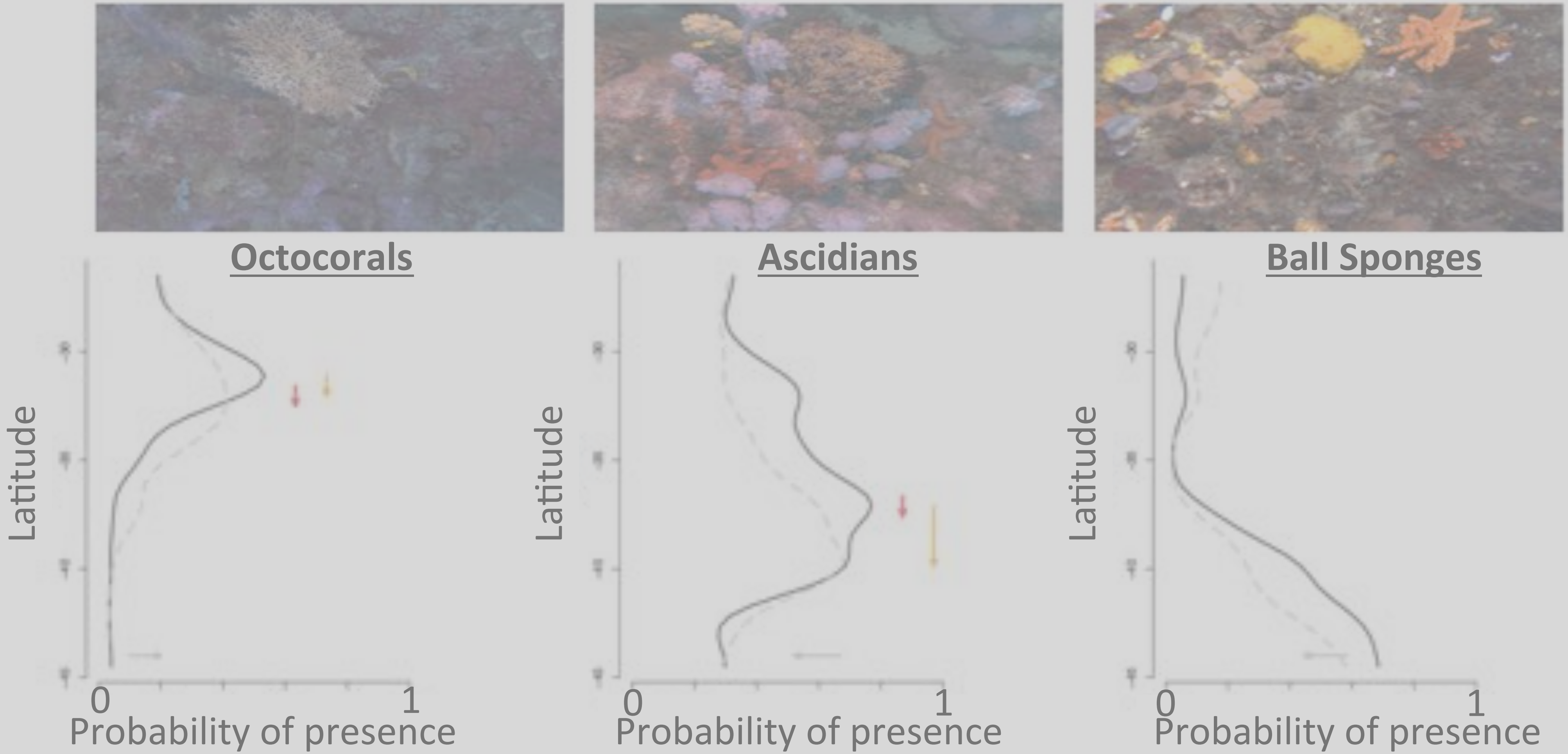
Cold temperate distribution

(Tasmania)


NOW
2060s
Octocorals
Stalked Ascidians
Ball Sponges
Longitude
Probability of presence
1.0
0.8
0.6
0.4
0.2
0.0


NOW
2060s
CHANGE
Octocorals
Stalked Ascidians
Ball Sponges
Relative change
in proba. presence
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
Longitude

Change in latitudinal distributions



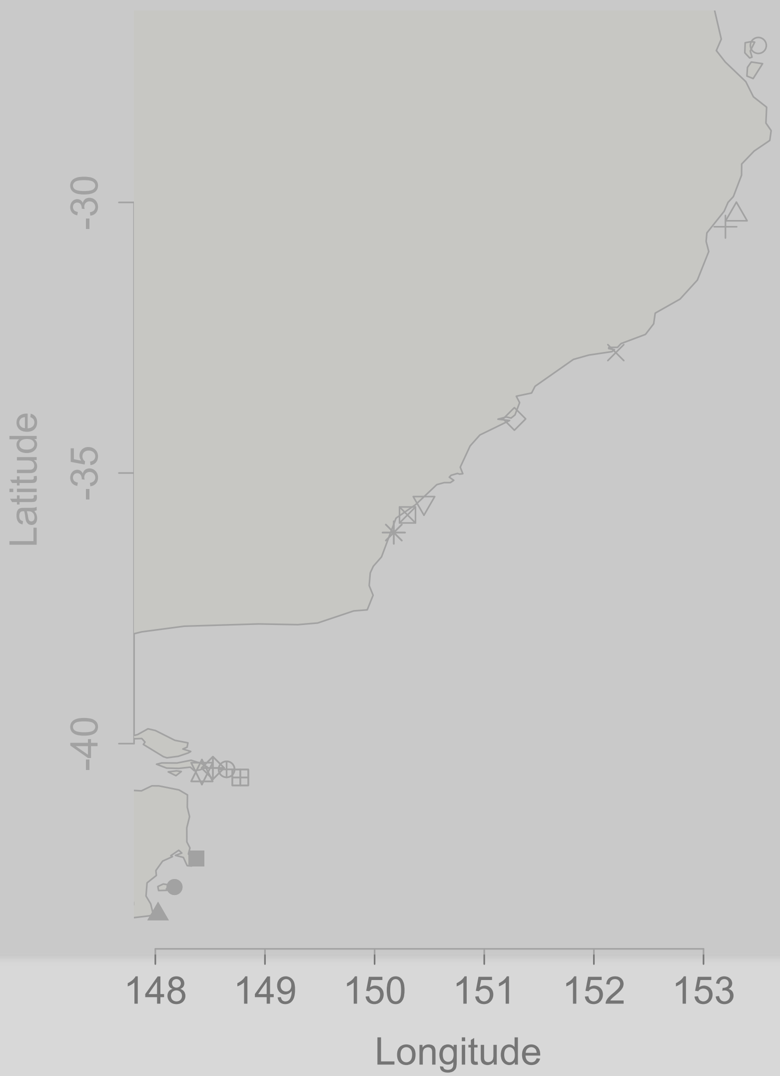
NOW
2060s
Relative change in regional probability of presence

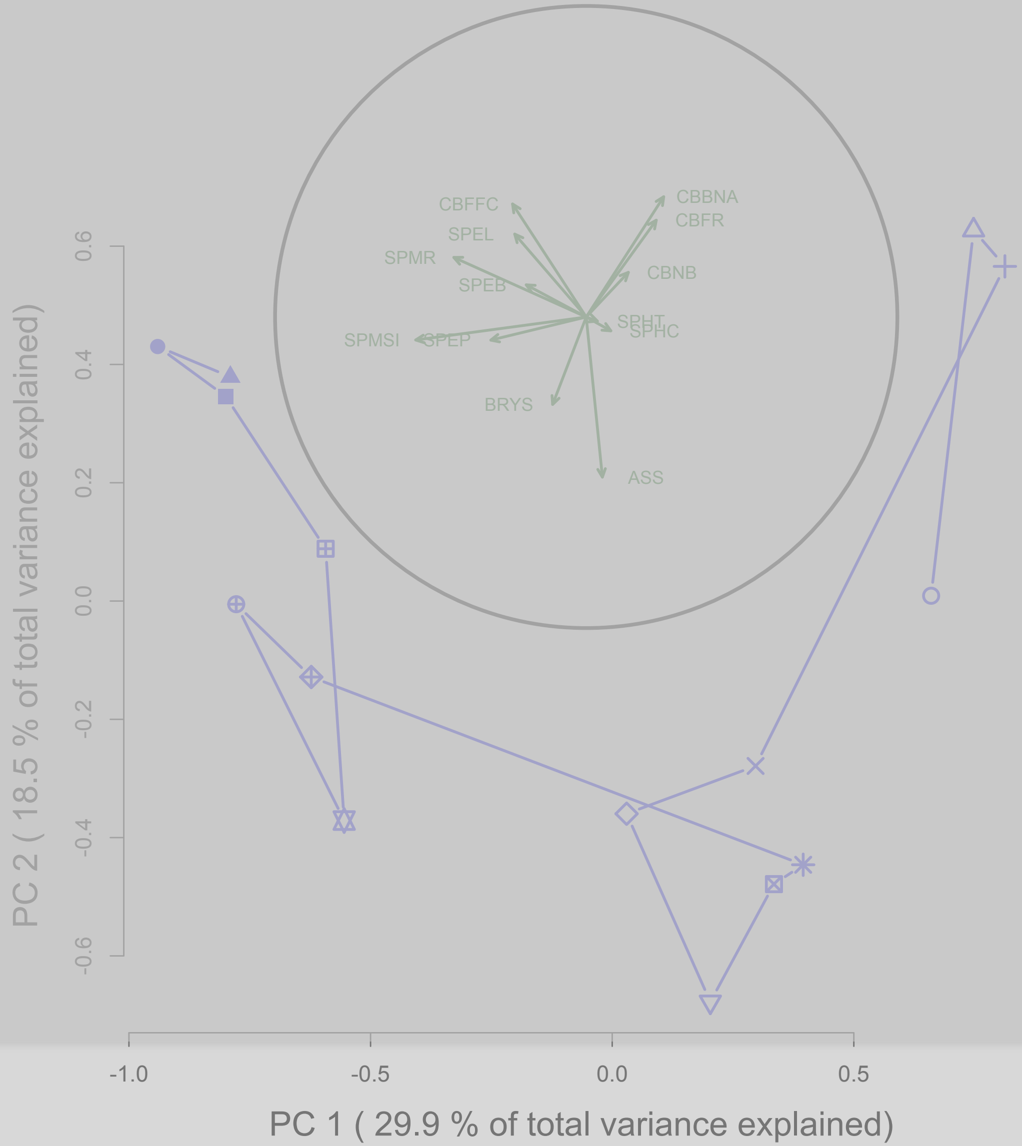
Latitudinal shift in optimal and median of distribution

Marzloff *et al.* (in prep.)

Predicted change in communities

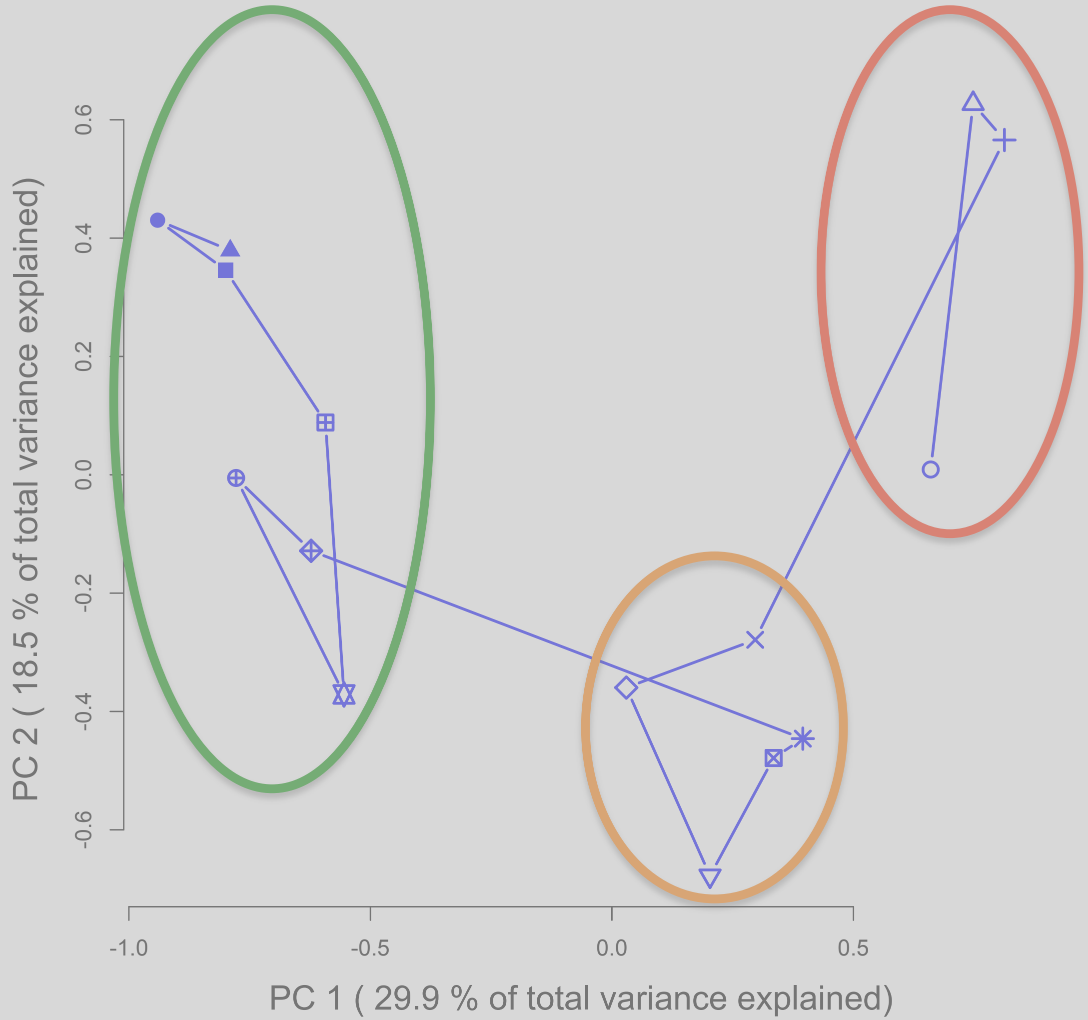
AUV monitoring sites





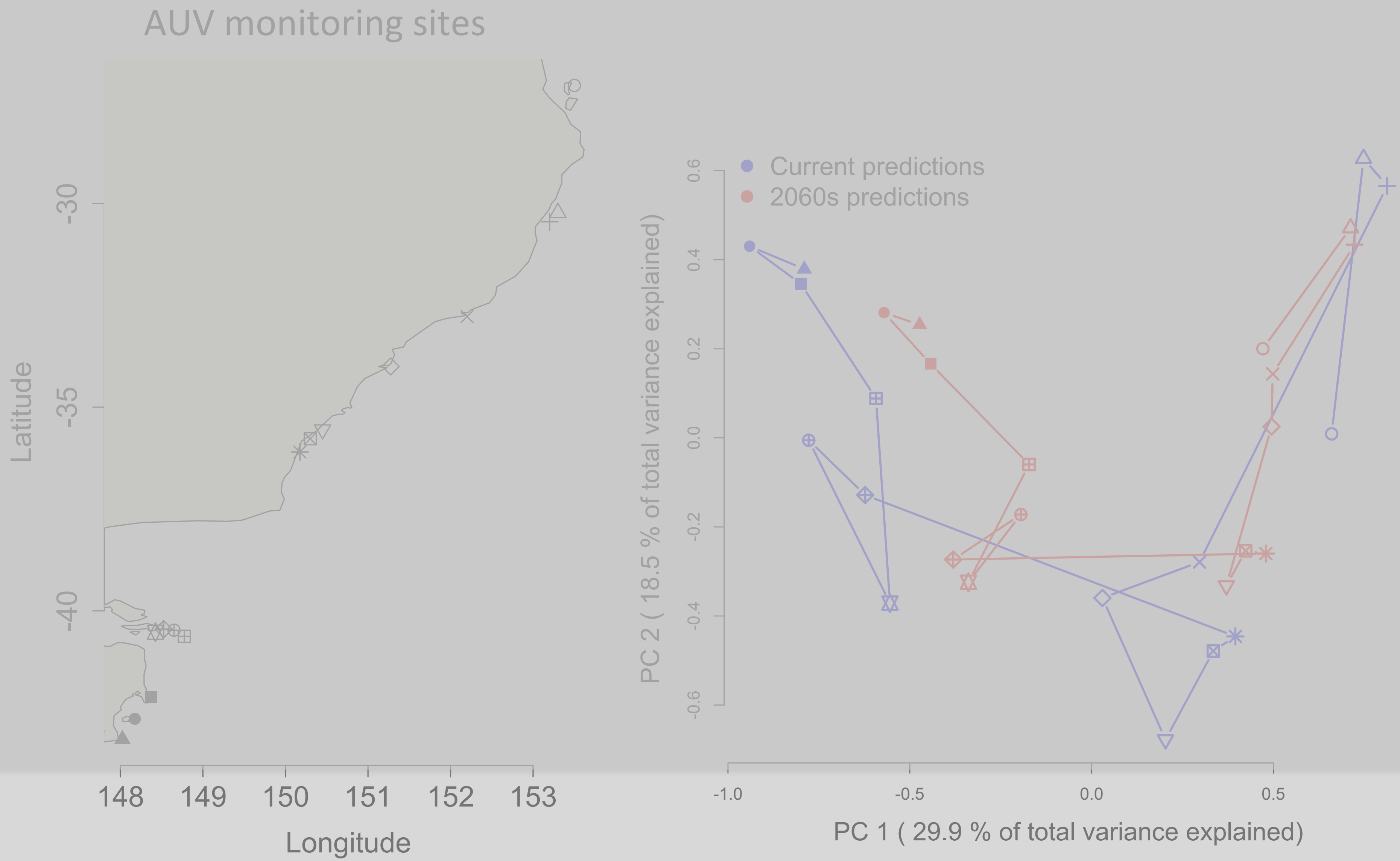
Marzloff *et al.* (in prep.)

Predicted change in communities



Marzloff *et al.* (in prep.)

Predicted change in communities



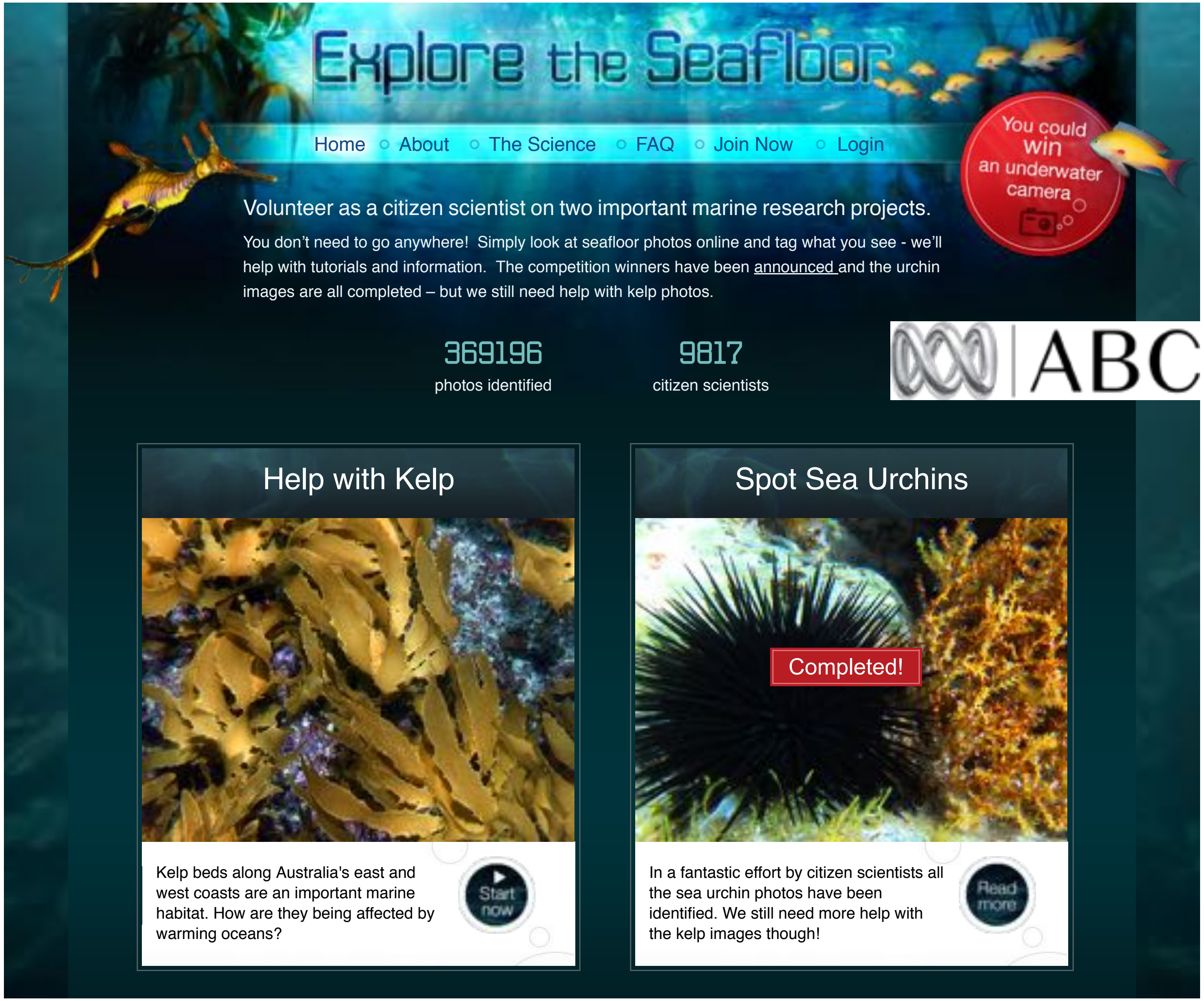
Marzloff *et al.* (in prep.)

Take-home messages (Part 2)…

- 3 main benthic community types across the latitudinal gradient
- Differences in the distribution of individual groups:
  - Truncated Vs. widespread distribution
  - Probability of presence related to large-scale ocean conditions and/or local seafloor features
- Future projections using 2060s ocean forecast
  - Range of responses to ocean changes
  - Non-trivial consequences on deep reef community structure & composition

Marzloff *et al.* (in prep.)

ABC Citizen Science initiative - 'Explore the Seafloor'



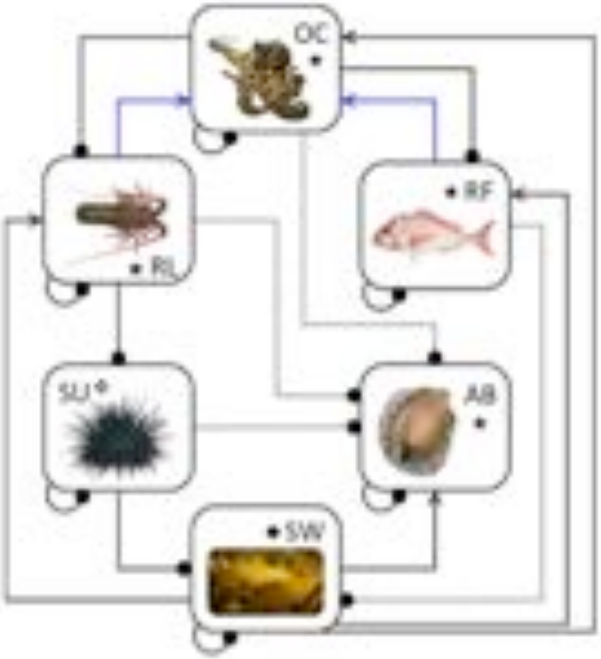
- Validation of a subset against 'expert' data
- Reliable data (correlation > 0.9 with expert data)
- Possibility to increase accuracy based on QC filters
- HUGE increase in number of scored AUV images! (> an order of magnitude)

- **~400,000 photos** scored between National Science Week (Aug. 2013) and Nov. 2014
- **~10,000 'citizen scientists'**

Marzloff et al. (in prep.)

Martin Marzloff: martin.marzloff@utas.edu.au

Merci de votre attention!



Interaction types

- Main effect – included in models (i), (ii), (iii)
- Weak effect – included in models (ii), (iii)
- Uncertain effect – included in model (iii)

Model groups

- SU **long-spined sea urchin** (*Centrostephanus rodgersii*)
- SW **seaweed bed** (*Ecklonia radiata, Phyllospora comosa etc…*)
- AB **abalone** (both blacklip and greenlip species)
- RL **rock lobster** (southern rock lobster and northern counterpart eastern rock lobster)
- OC **octopus** (different species, including *Octopus maorum* and *Octopus tetricus*)
- RF **reef fish** (different species, including several range-shifting species)
- ● commercial species
- ◆ destructive grazer
- ◆ habitat former

Positive input in the abundance of:

Long-term effects on:

	SW	RL	AB	SU	OC	RF
OC	+	+	0	–	–[2]	0
RF	+[3]	+[3]	0	–[3]	–[2]	+[2]
RL	+[1]	+	0	–[1]	–	0
SU	–[1]	–	0	+	+	0
AB	+	+	+[2]	–	–	0
SW	+	+	0	–	–	0

Conditions:

- **Direct effects > indirect effects**

1: $a_{RL,SW}\, a_{OC,OC} > a_{OC,SW}\, a_{RL,OC}$

2: $a_{RF,SW}\, a_{OC,OC} > a_{OC,SW}\, a_{RF,OC}$

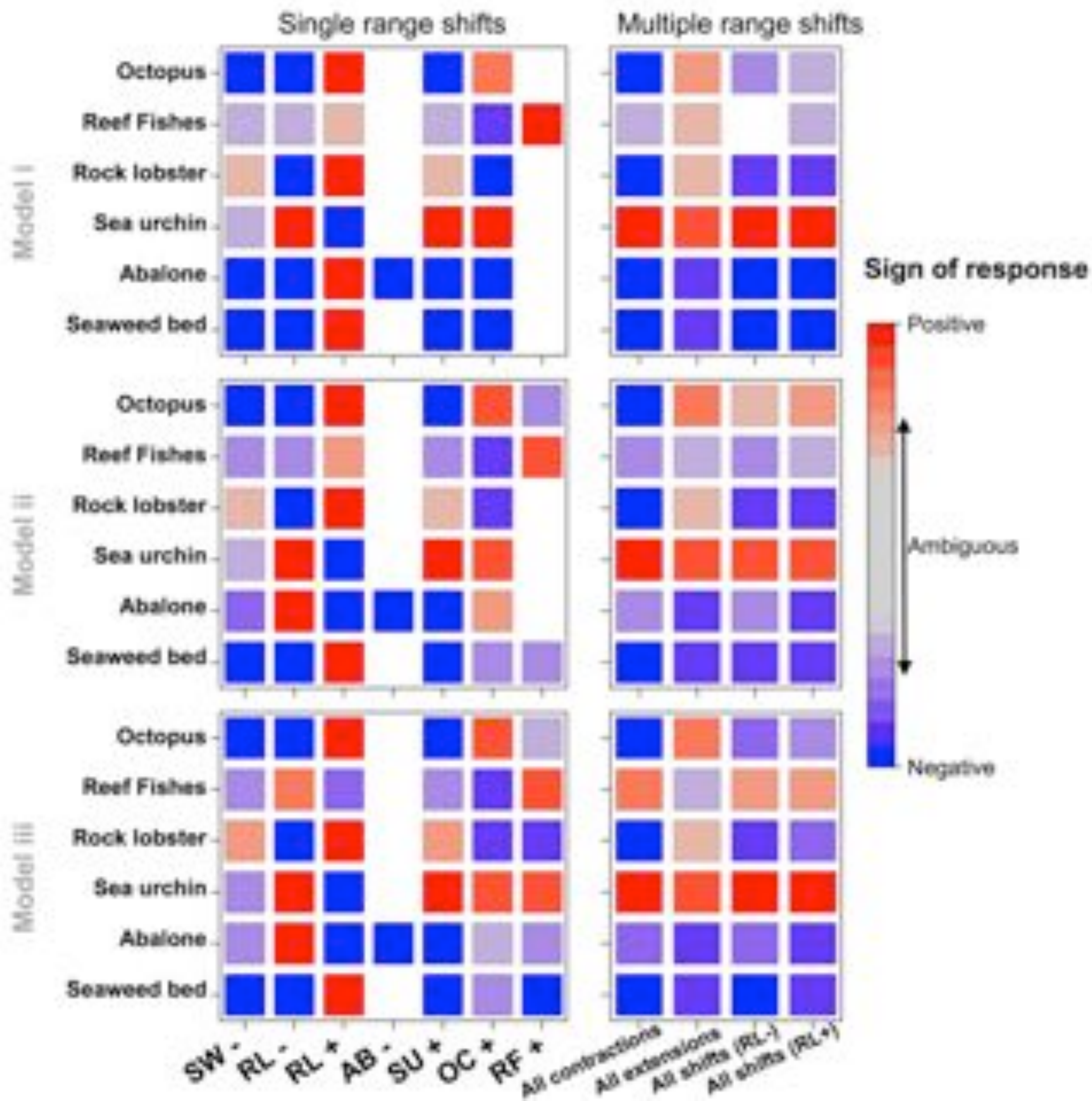
- **Model stability**

(negative feedback > positive feedback)

3: $a_{SU,SU}\, a_{SW,SW}\, a_{RL,RL} > a_{SU,RL}\, a_{RL,SW}\, a_{SW,SU}$

where $a_{i,j}$ is the effect of variable *j* on variable *i*.

Marzloff *et al.* (in review)



Scenarios:

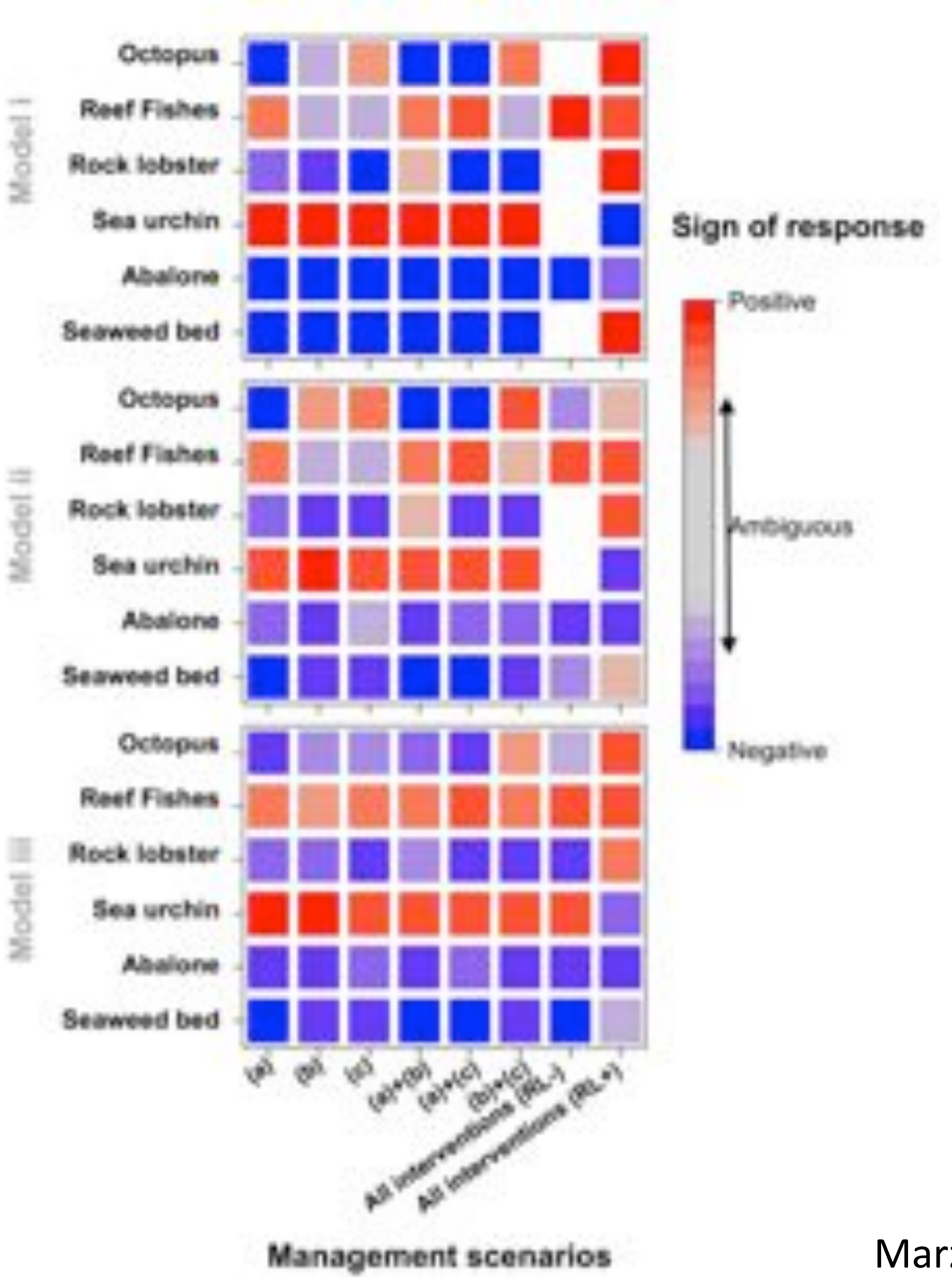
Range contractions
(native species)

Range extensions
(mainland species)

All (worst)
(lobster stock decline)

All (best)
(eastern rock lobster replaces southern rock lobster)

Marzloff *et al.* (in press) GCB



Management interventions:

a: octopus harvesting
b: lobster stock rebuilding
c: sea urchin culling / harvesting

Scenarios:
- 'worst': lobster stock decline
- 'best': eastern rock lobster replaces southern rock lobster

Marzloff *et al.* (in press). GCB