

# Analyse de sensibilité, validation et perspective d'estimation intégrée des paramètres pour un modèle avec des états alternatifs de la dynamique de récifs tempérés

Martin Marzloff

Craig Johnson

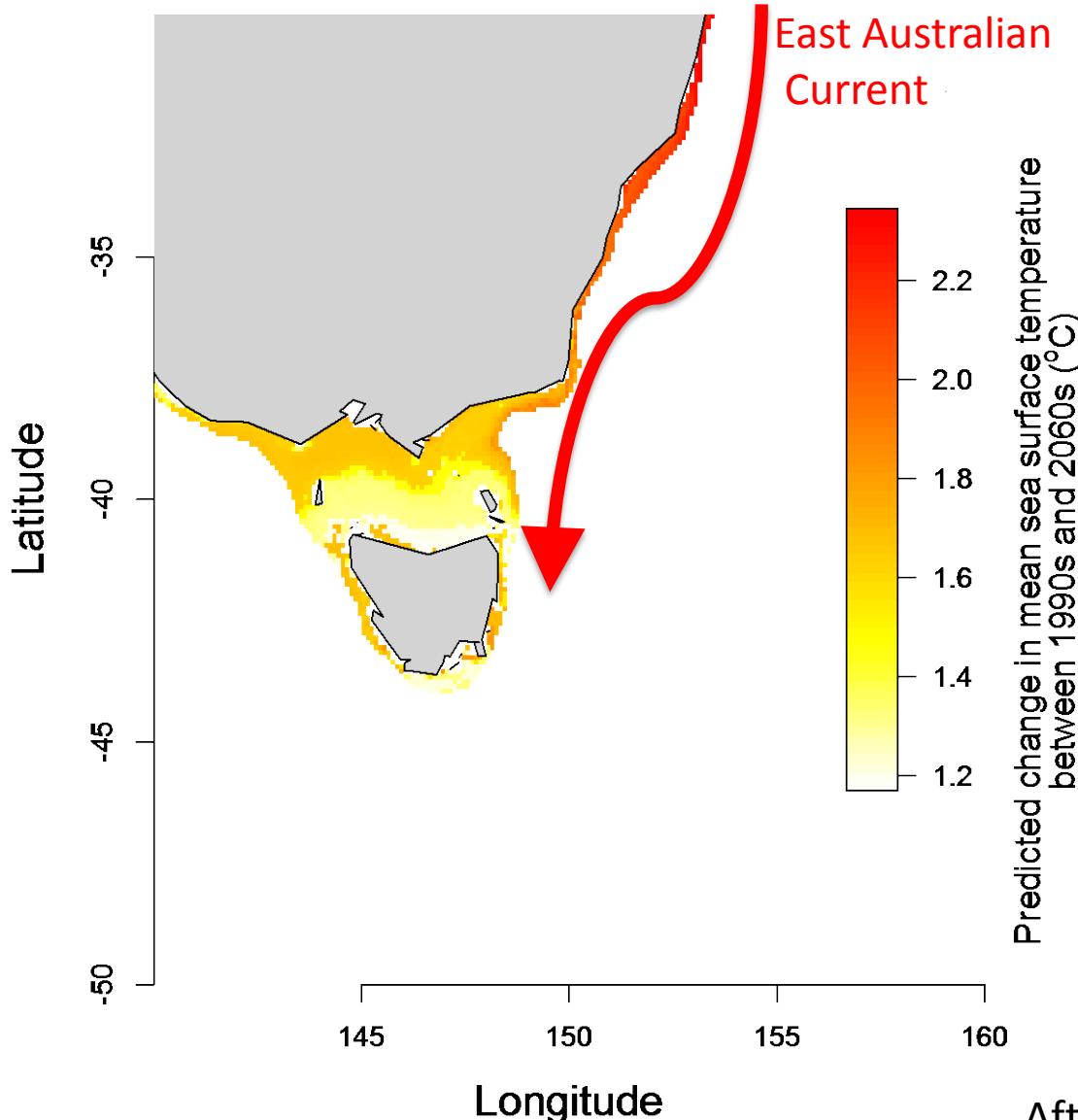
Rich Little

Jean-Christophe Soulié

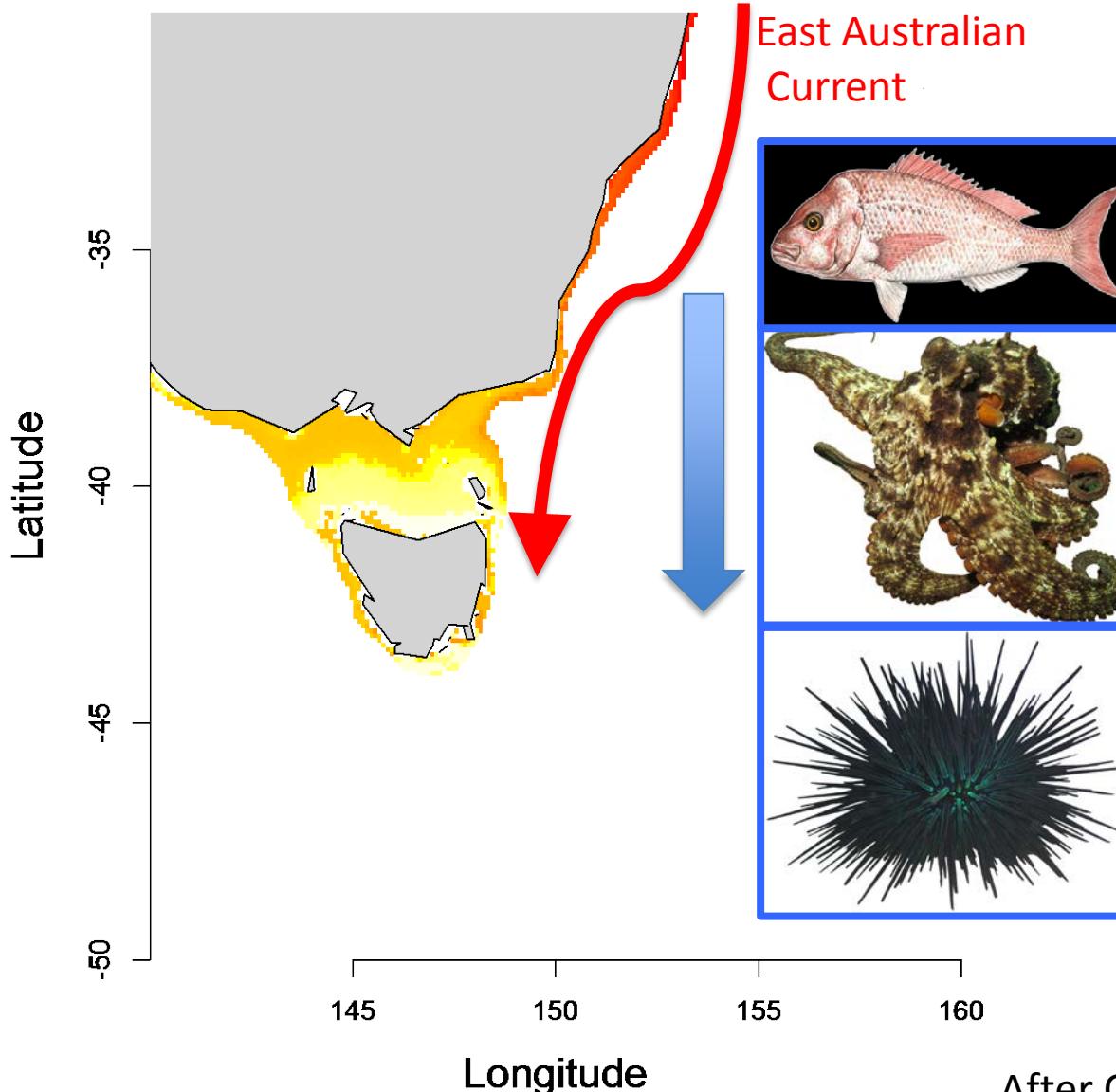
Jarno Vanhatalo



# Global hotspot for ocean warming

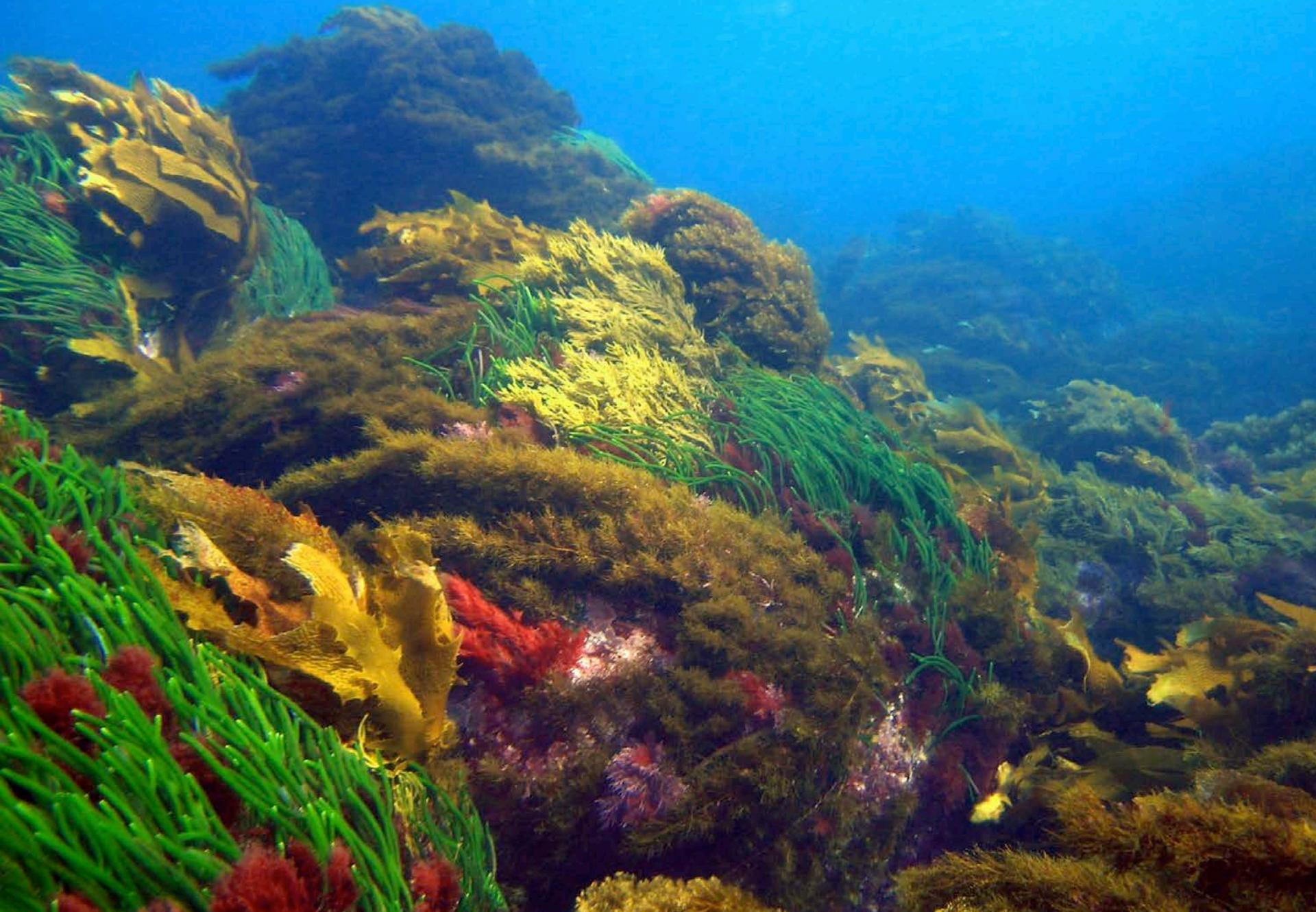


# Global hotspot for ocean warming



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)

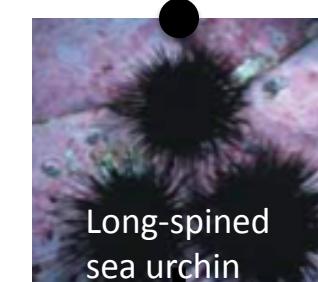
5 m

# 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)

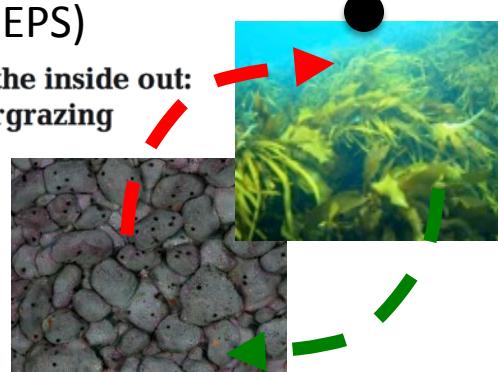
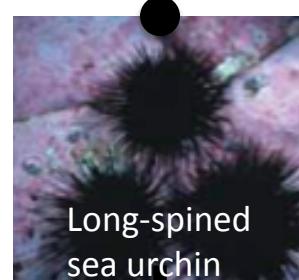
Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift

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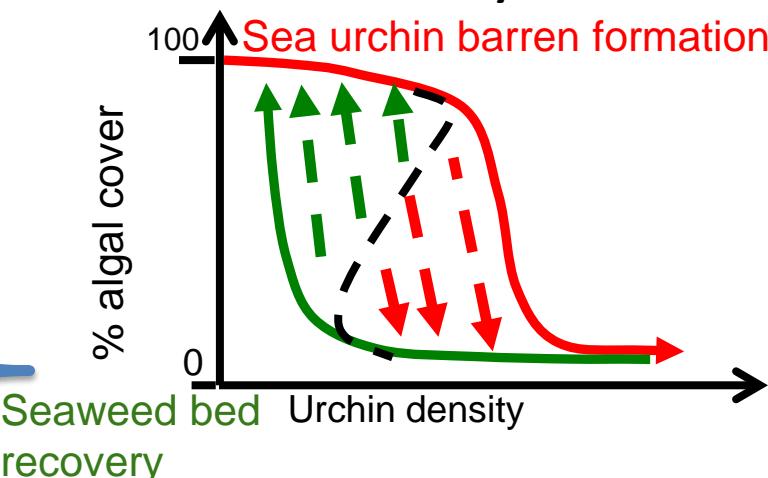
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## Ecosystem modelling

To understand reef dynamics



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

## Field experiments

Ling et al., 2009 (PNAS)

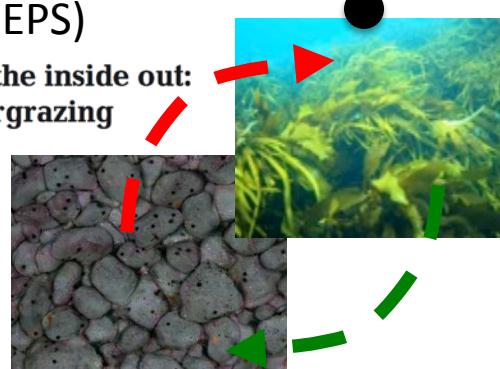
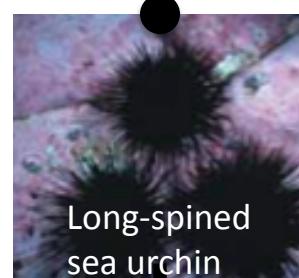
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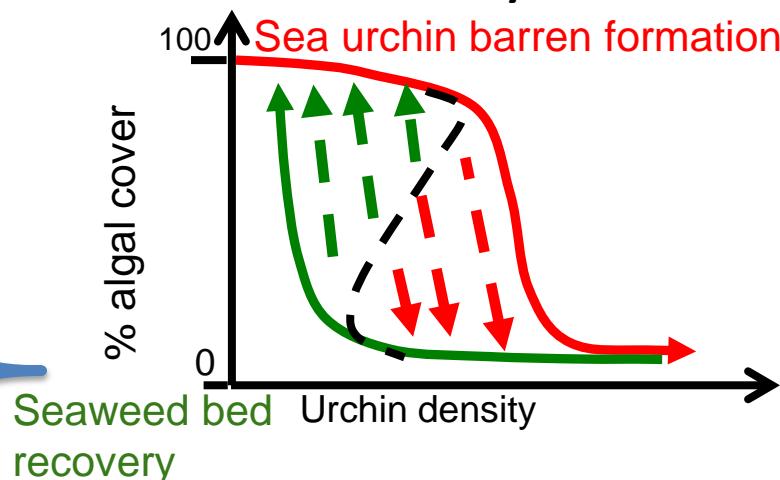
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Forming sea urchin barrens from the inside out:  
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## Ecosystem modelling

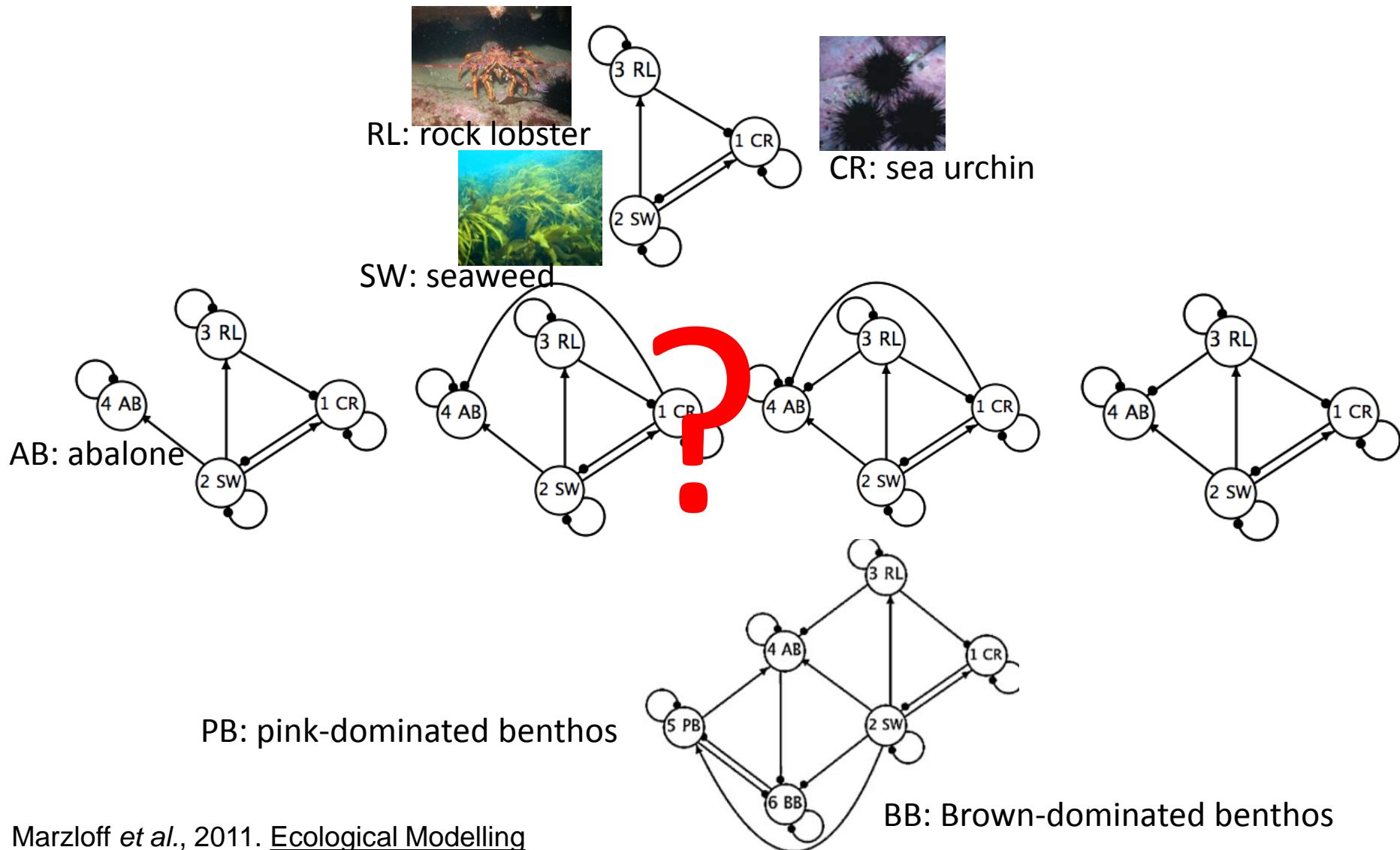
To understand reef dynamics



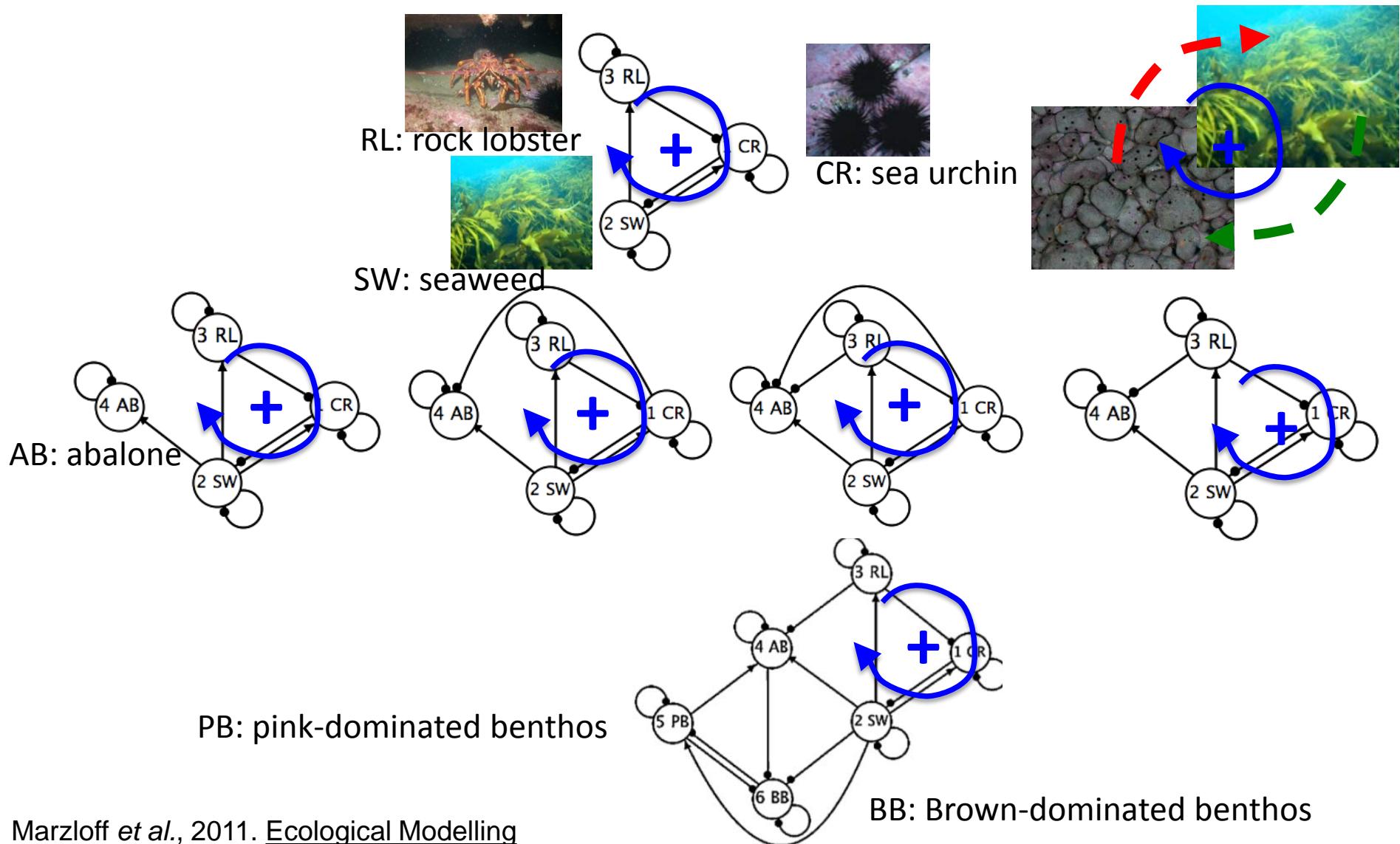
To test management strategies

- Culling or harvesting sea urchin
- Restoring natural predators
  - Reduction in fishing
  - Marine reserves
  - Translocation experiments

# Sensitivity To Model Structure Uncertainty

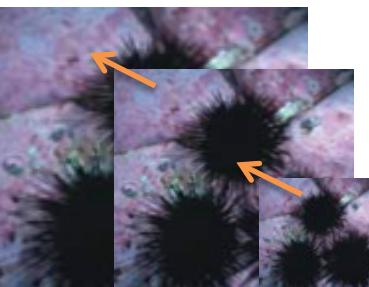
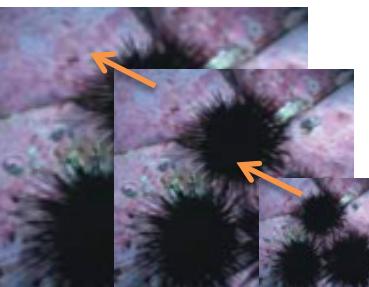


# Sensitivity To Model Structure Uncertainty

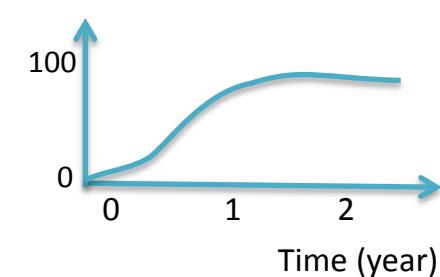


# TRITON model (Temperate Reefs In Tasmania with lObsters and urchiNs)

Size-structured predation  
with density-dependence



Reduced lobster  
recruitment as barrens  
form  
Seaweed cover (%)



Coupling Python - R



Grazing



# Parameterisation

Parameter	Estimate	Standard error	Confidence interval	Data source
<b>Seaweed bed logistic dynamics</b>				
$\alpha_{SW}$	<b>4.43</b>	1.65	1.72 – 7.14	
$K_{SW}$	<b><math>3.4 \times 10^5</math></b>	$3.6 \times 10^4$	$2.8 \times 10^5 – 4 \times 10^5$	
$\mu_{SW}$	<b>5000</b>		2500 – 10000	Ling, 2008

with  $\alpha$ , intrinsic growth rate;  $K$ , carrying capacity;  $\mu$ , mean annual recruitment rate.

### Sea urchin size-structured population dynamics parameters

Individual growth is described by an inverse logistic growth function (Ling and Johnson, 2009), with  $\beta$  annual natural mortality rate and  $\mu$ , mean annual recruitment rate:

$M_{CR}$	<b>0.11</b>	0.1 – 0.15	
$\mu_{CR}$	<b>4100</b>	2500 – 10000	Ling et al., 2009b

The annual stochastic recruitment function follows a binomial with a 0.4 probability of success, which is combined with a lognormal with a standard deviation of 0.5.

### Lobster size-structured population dynamics parameters

Polynomial growth functions from the stock assessment model describes individual growth (after Punt et al., 1997; McGarvey and Feenstra, 2001) with  $\beta$ , annual natural mortality rate and  $\mu$ , mean annual recruitment rate:

$M_{RL}$	<b>0.23</b>	0.20 – 0.26	
$\mu_{RL}$	<b>350</b>	200 – 800	Barrett et al., 2009

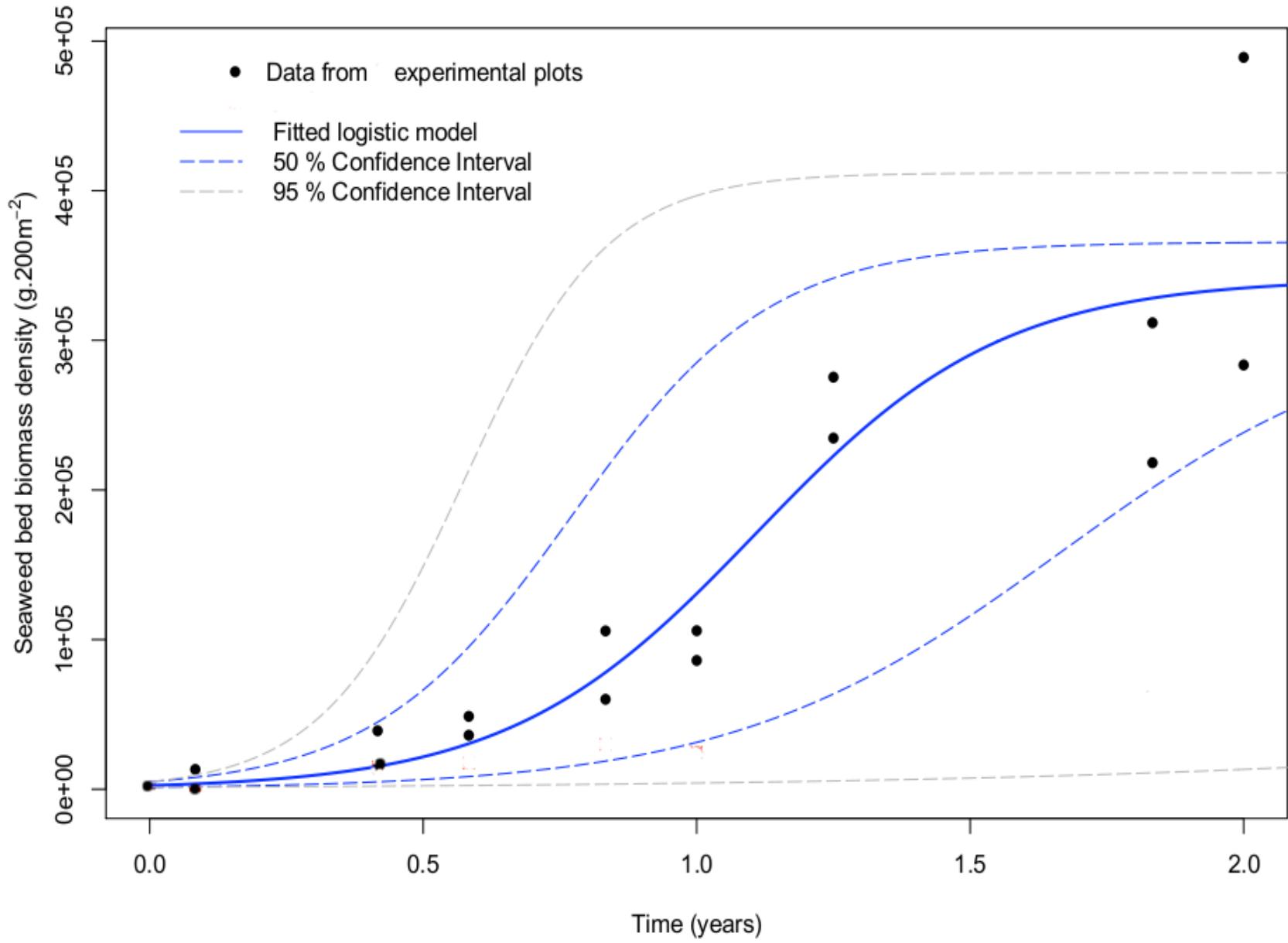
The annual stochastic recruitment function follows a lognormal with a standard deviation of 0.6.

### Lobster dependency on the state of the seaweed bed

Lobster recruitment is scaled by:  $(1 - \beta_{RL,SW}) \times (1 - \frac{B_{SW}}{K_{SW}})$   
with  $B_{SW}$ , seaweed bed biomass density;  $K_{SW}$ , seaweed bed carrying capacity.

$\beta_{RL,SW}$	<b>0.64</b>	0.11	0.46 – 0.83	Johnson, unpublished data
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# Parameterisation



# Parameterisation

Parameter	Estimate	Standard error	90% conf. int.	Data source
<b>Urchin grazing rate</b>				
$\beta_{SW,CR}$	<b>5.94</b>	1.10	4.13 – 7.75	Hill et al., 2003
<b>Functional responses of lobster predation on urchin</b>				
	(Ling et al., 2009a; Johnson, unpublished data)			
	With $B_{CR}$ , urchin biomass density (g. 200m <sup>-2</sup> ):			
	Holling type I as $\beta_{CR,RL} = \min(\beta B_{CR}, \beta')$			
$\beta$	<b>6.68 × 10<sup>-4</sup></b>	$2.27 \times 10^{-5}$	$6.31 \times 10^{-4}$ - $7.05 \times 10^{-4}$	
$\beta'$	<b>9.40</b>	3.00	4.46 - 14.33	
	Holling type II as $\beta_{CR,RL} = \frac{\beta(B_{CR})}{1+\beta'(B_{CR})}$			
$\beta$	<b>11.09 × 10<sup>-4</sup></b>	$1.68 \times 10^{-4}$	$8.34 \times 10^{-4}$ - $13.85 \times 10^{-4}$	
$\beta'$	<b>1.10 × 10<sup>-4</sup></b>	$0.20 \times 10^{-4}$	$7.76 \times 10^{-5}$ - $14.19 \times 10^{-5}$	
	Holling type III as $\beta_{CR,RL} = \frac{\beta(B_{CR})^2}{1+\beta'(B_{CR})^2}$			
$\beta$	<b>2.35 × 10<sup>-7</sup></b>	$0.55 \times 10^{-7}$	$1.46 \times 10^{-7}$ - $3.25 \times 10^{-7}$	
$\beta'$	<b>2.50 × 10<sup>-8</sup></b>	$0.60 \times 10^{-8}$	$1.47 \times 10^{-8}$ - $3.60 \times 10^{-8}$	

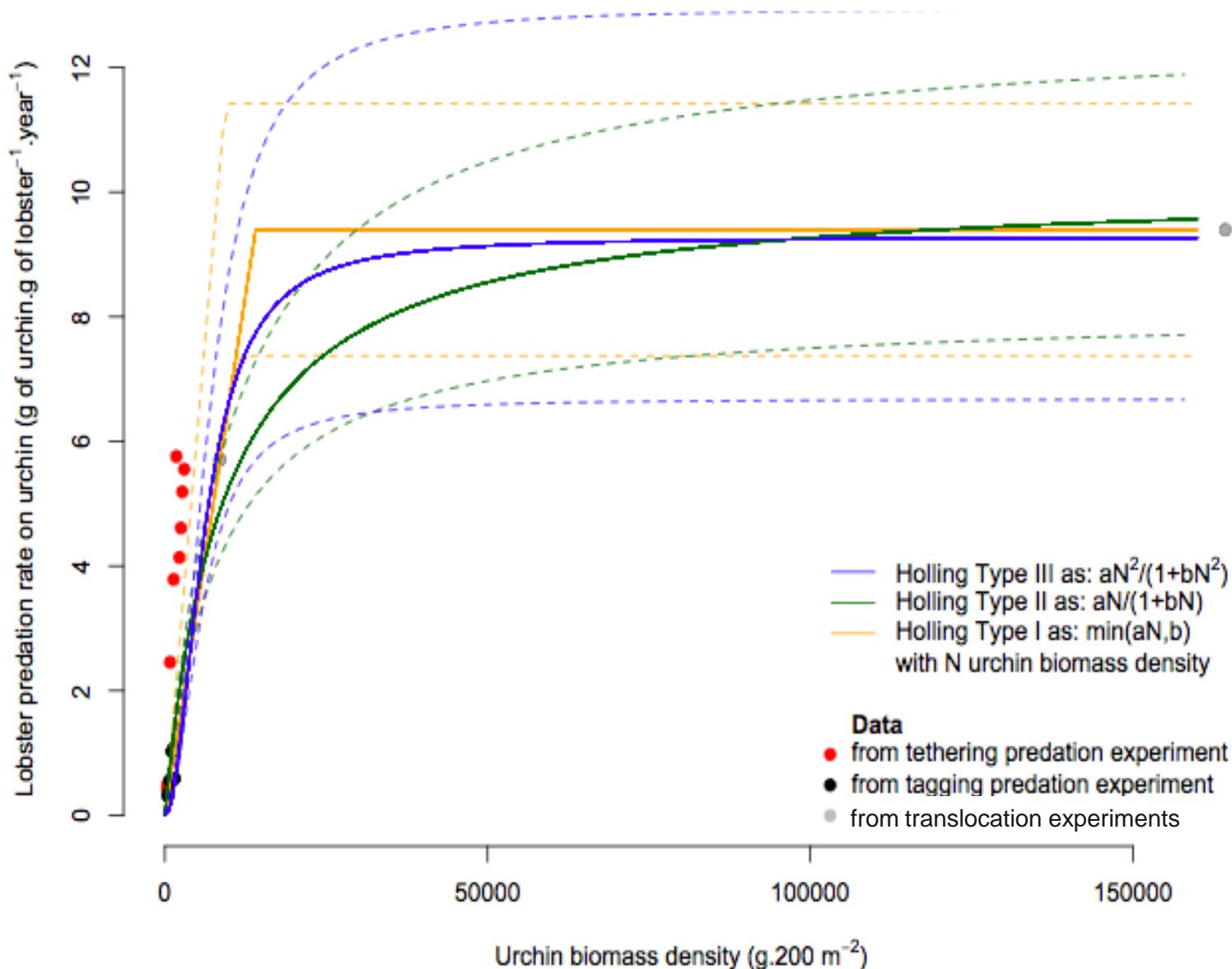
Allometric and other size-based relationships

**Length-weight relationship for the long-spined sea urchin** (Ling, unpublished data)  
 $B = 0.00267 \times TD^{2.534}$ ,  
with B, urchin individual weight (g); TD, urchin test diameter (mm).

**Length-weight relationship for the southern rock lobster** (Punt and Kennedy, 1997)  
 $B = 0.000271 \times CL^{3.135}$ ,  
with B, lobster individual weight (g); CL, lobster carapace length (mm).

**Size-Structured predation of lobster on urchin** (Ling et al., 2009a)  
 $CL_{min} = 43.5 \times \log(TD) - \beta$ , with  $\beta \in [48.91 : 71.01]$   
with CL, lobster carapace length (mm); TD, urchin test diameter (mm).

# Parameterisation



# Simulation characteristics

% algal cover



100



0



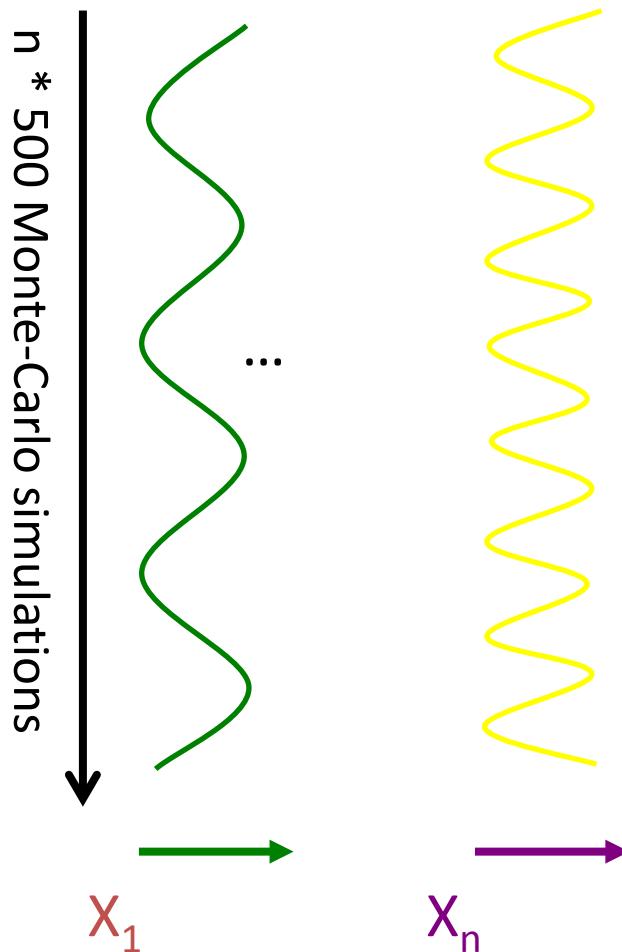
Monthly outputs of seaweed, sea urchin and rock lobster

Mean biomass densities over the last 10 years as 'final state' of the simulation

Time (year)

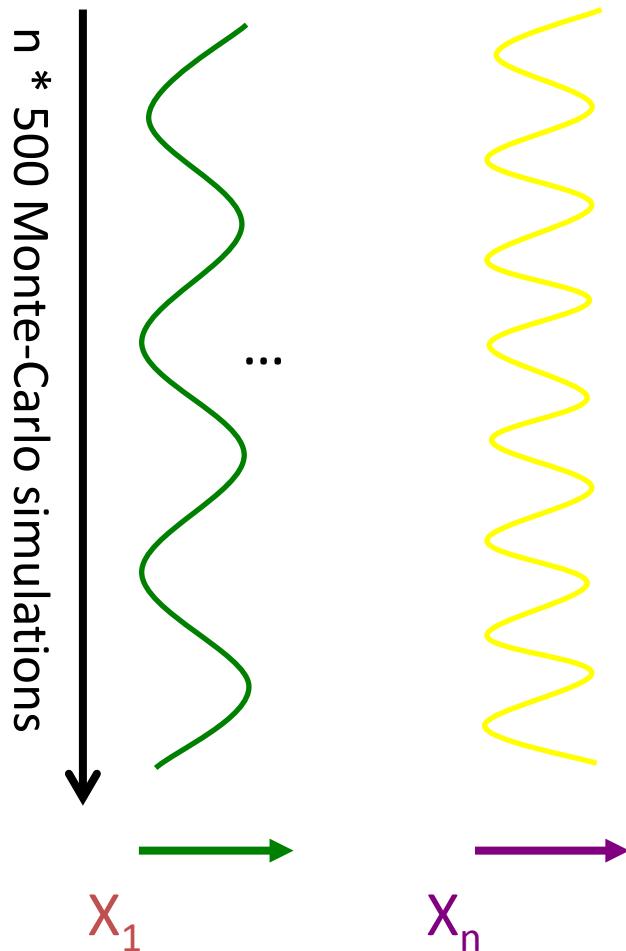
# Extended FAST (Saltelli et al., 1999)

n Input parameters

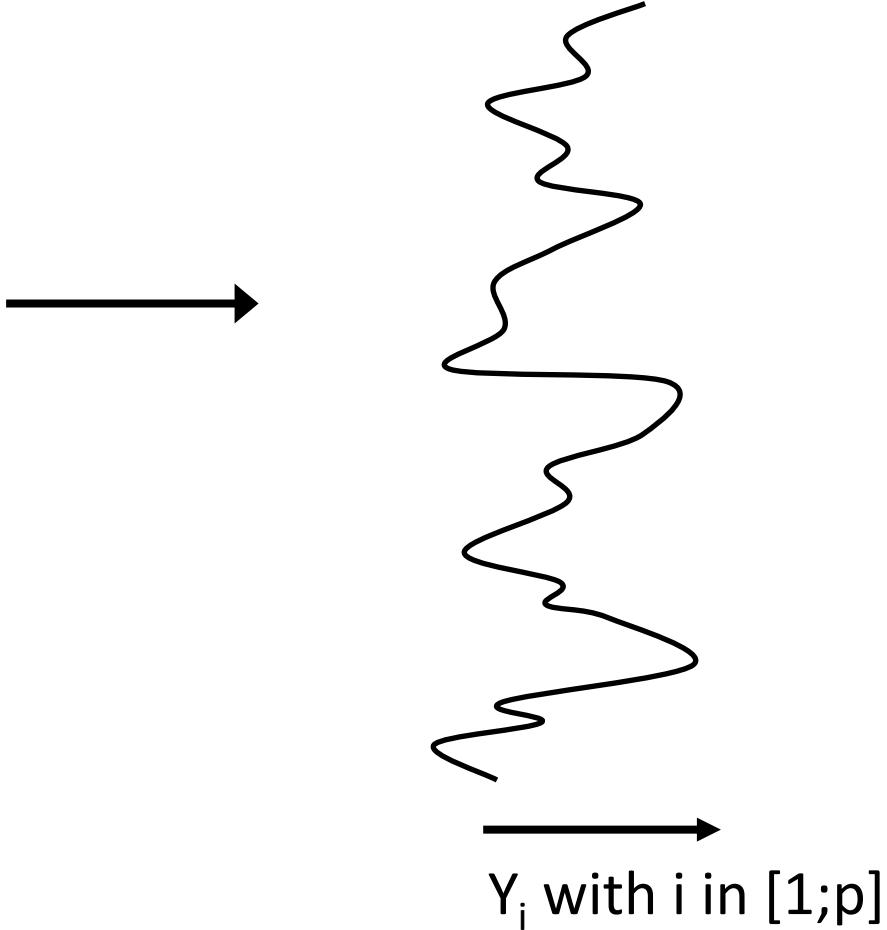


# Extended FAST (Saltelli et al., 1999)

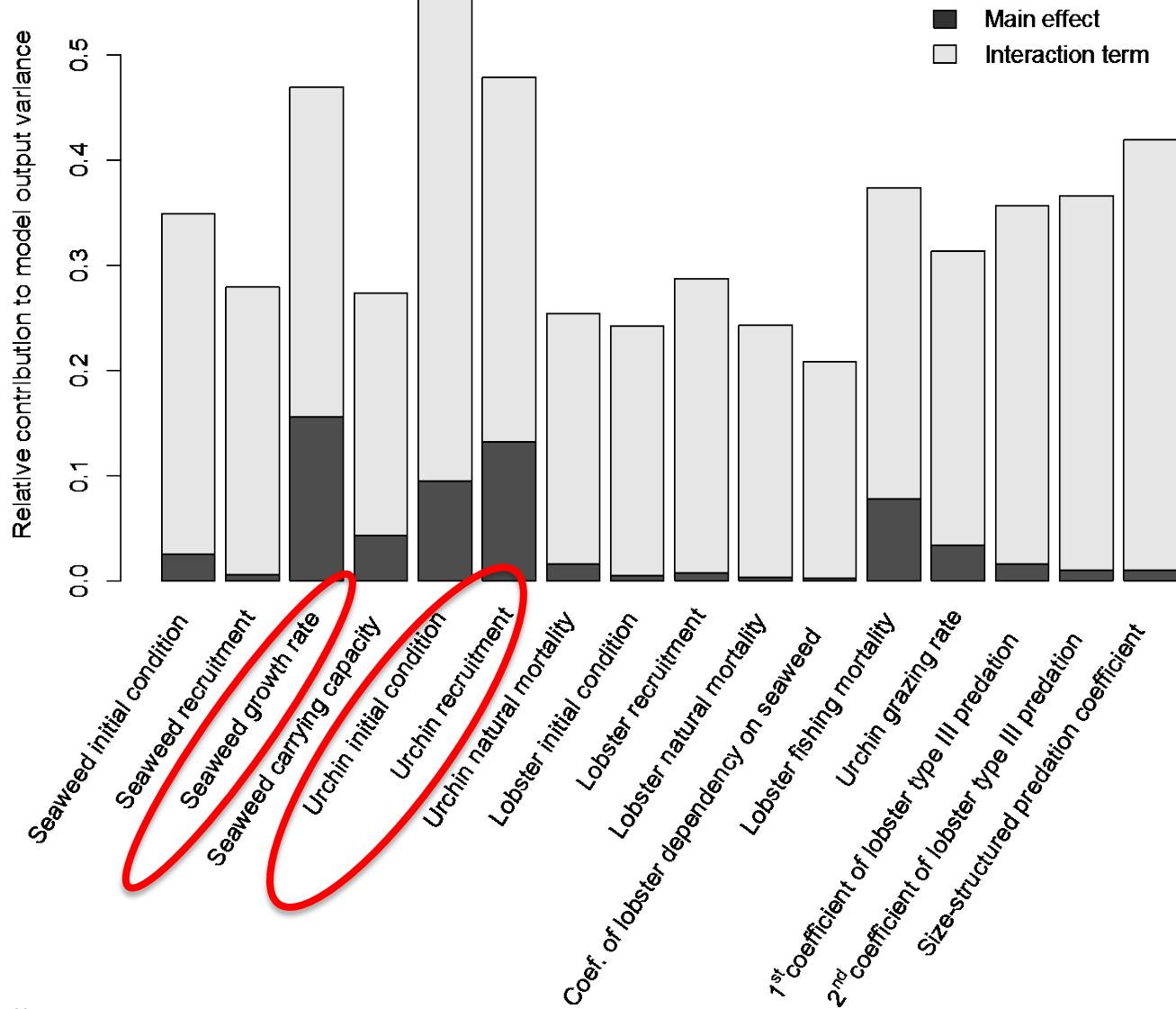
n Input parameters



p Model outputs

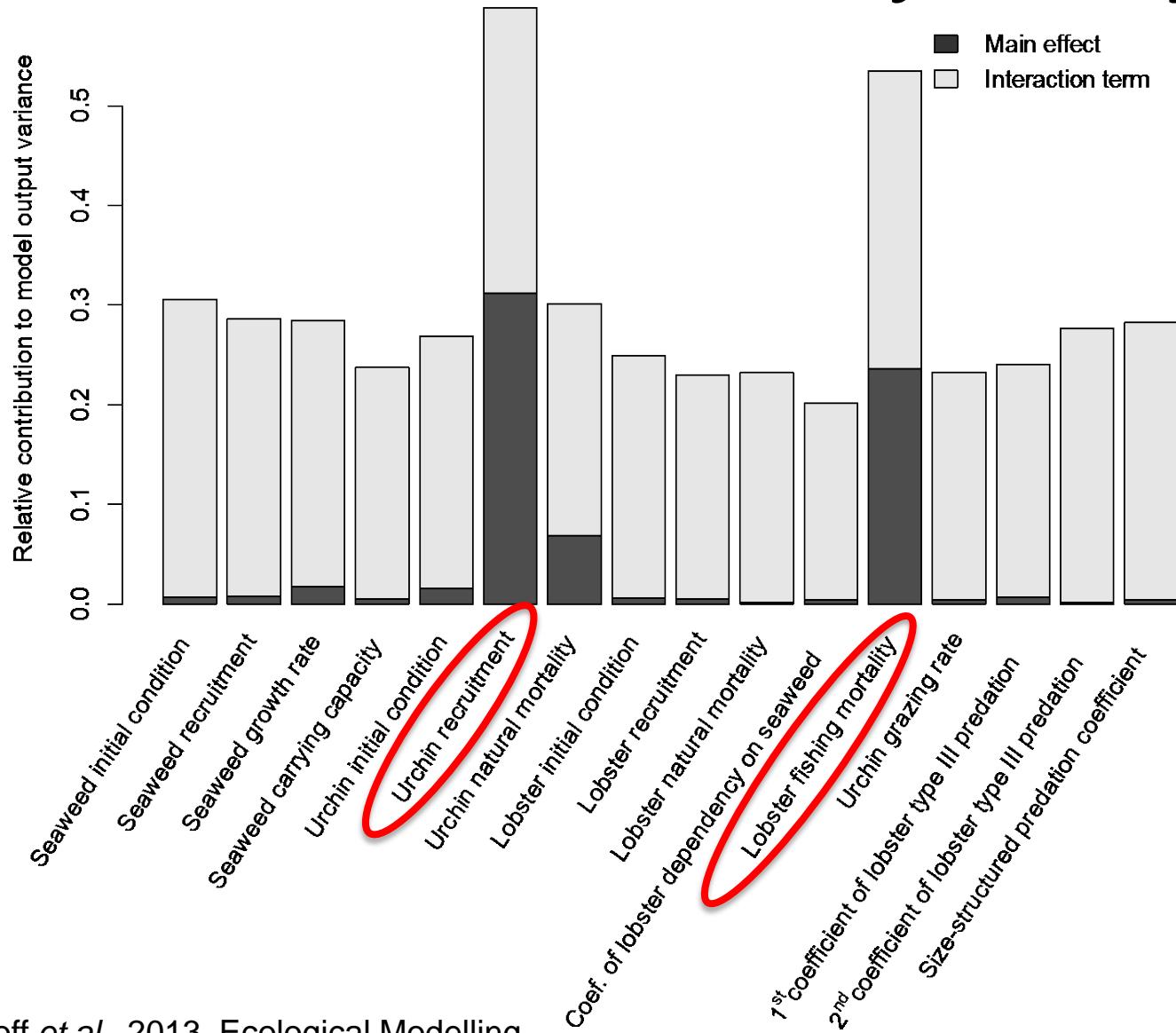


# Global sensitivity analysis



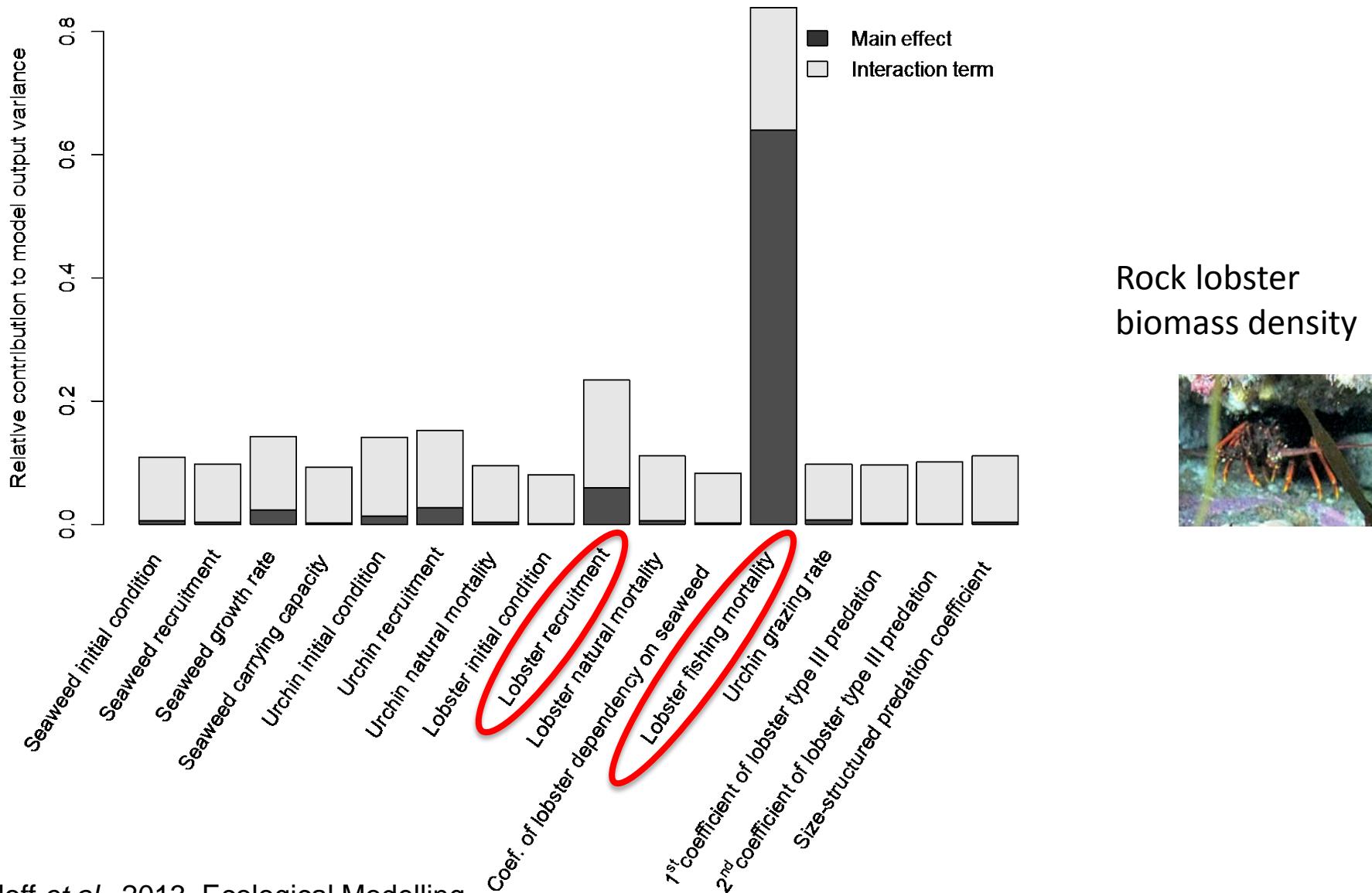
Seaweed bed  
biomass density

# Global sensitivity analysis

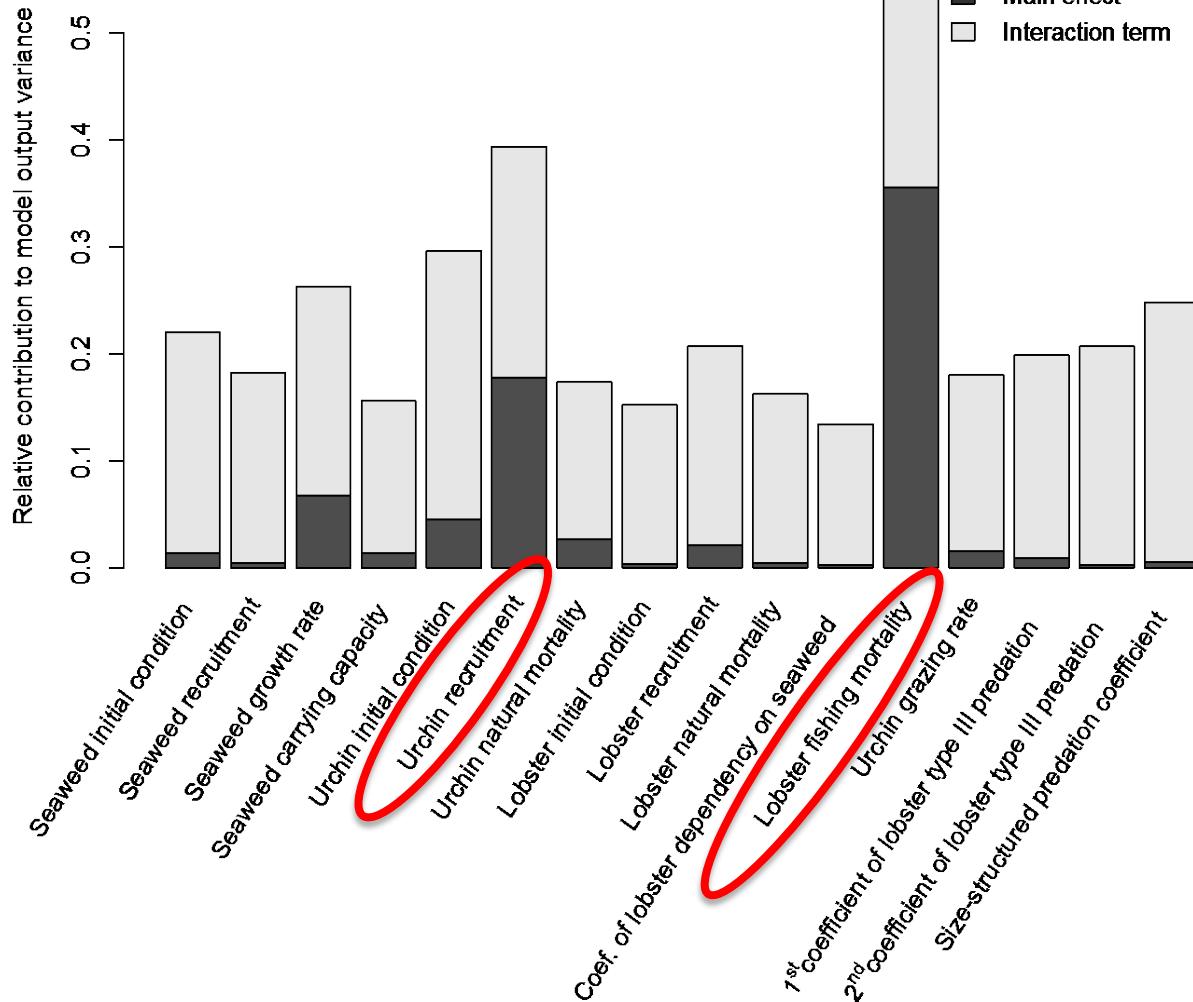


Sea urchin  
biomass density

# Global sensitivity analysis

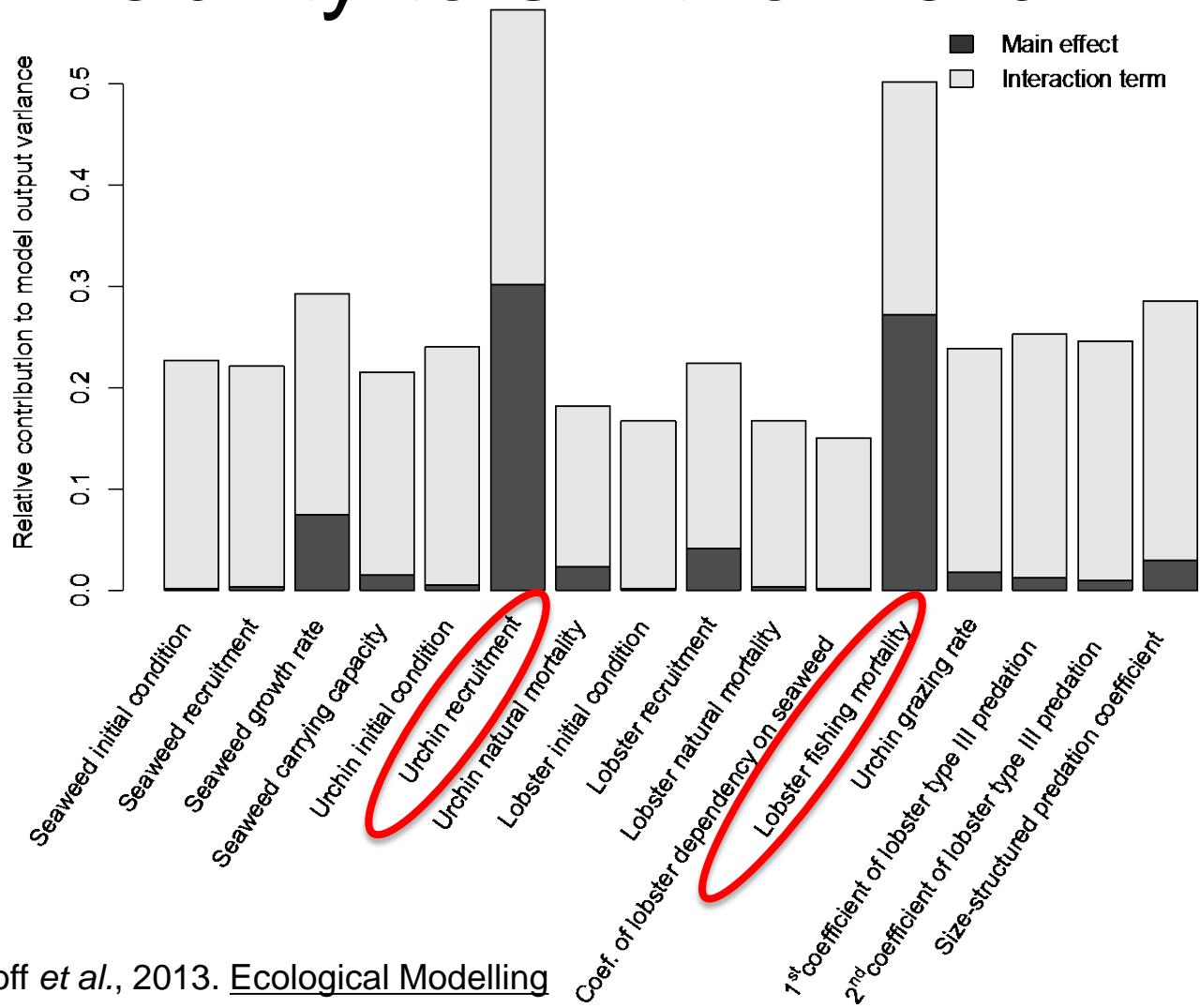
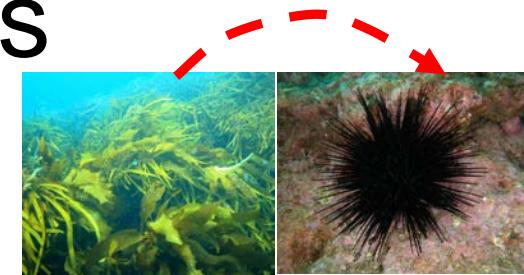


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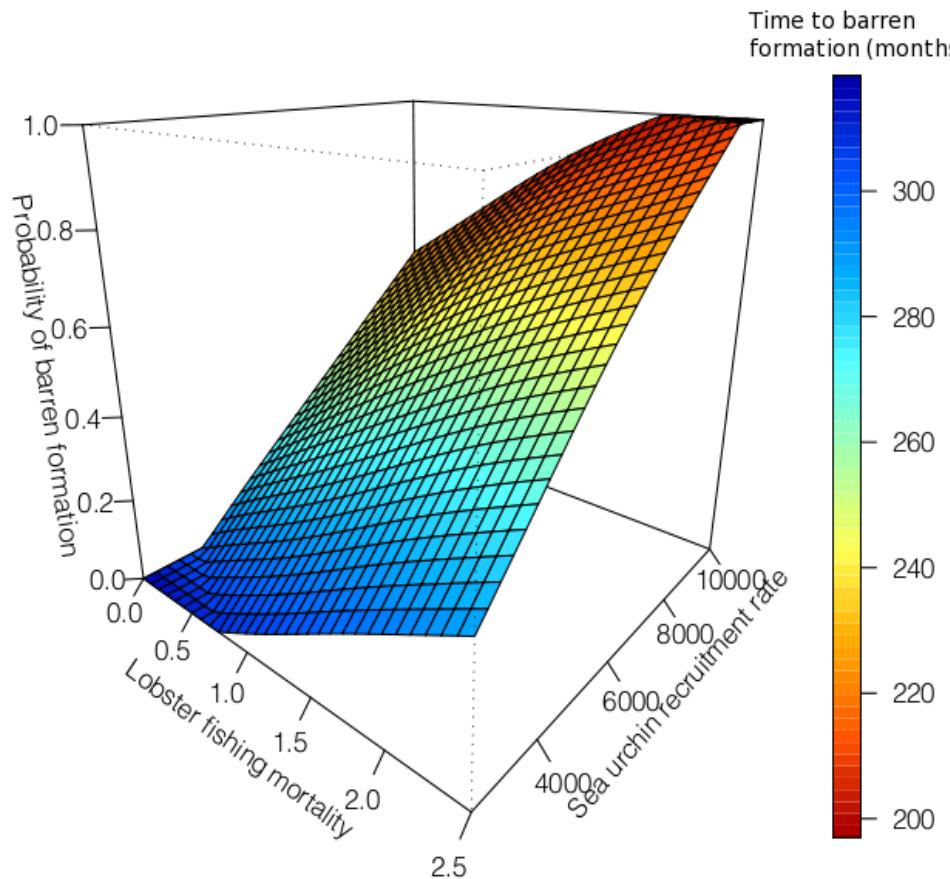
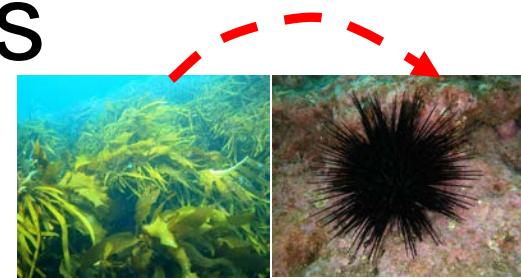


1 axis of PCA  
on simulated  
biomasses

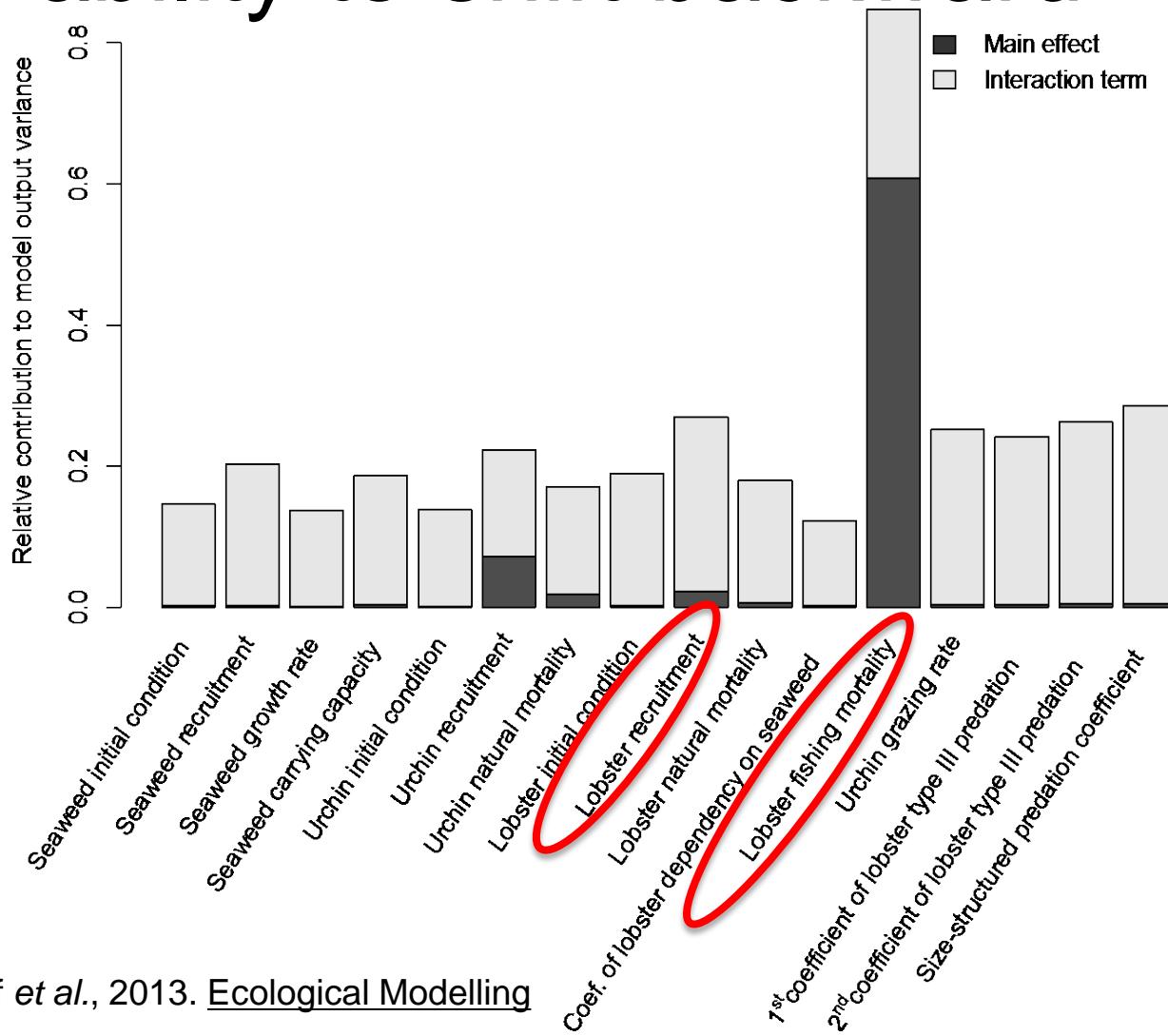
# Sensitivity analysis of model's ability to shift forward



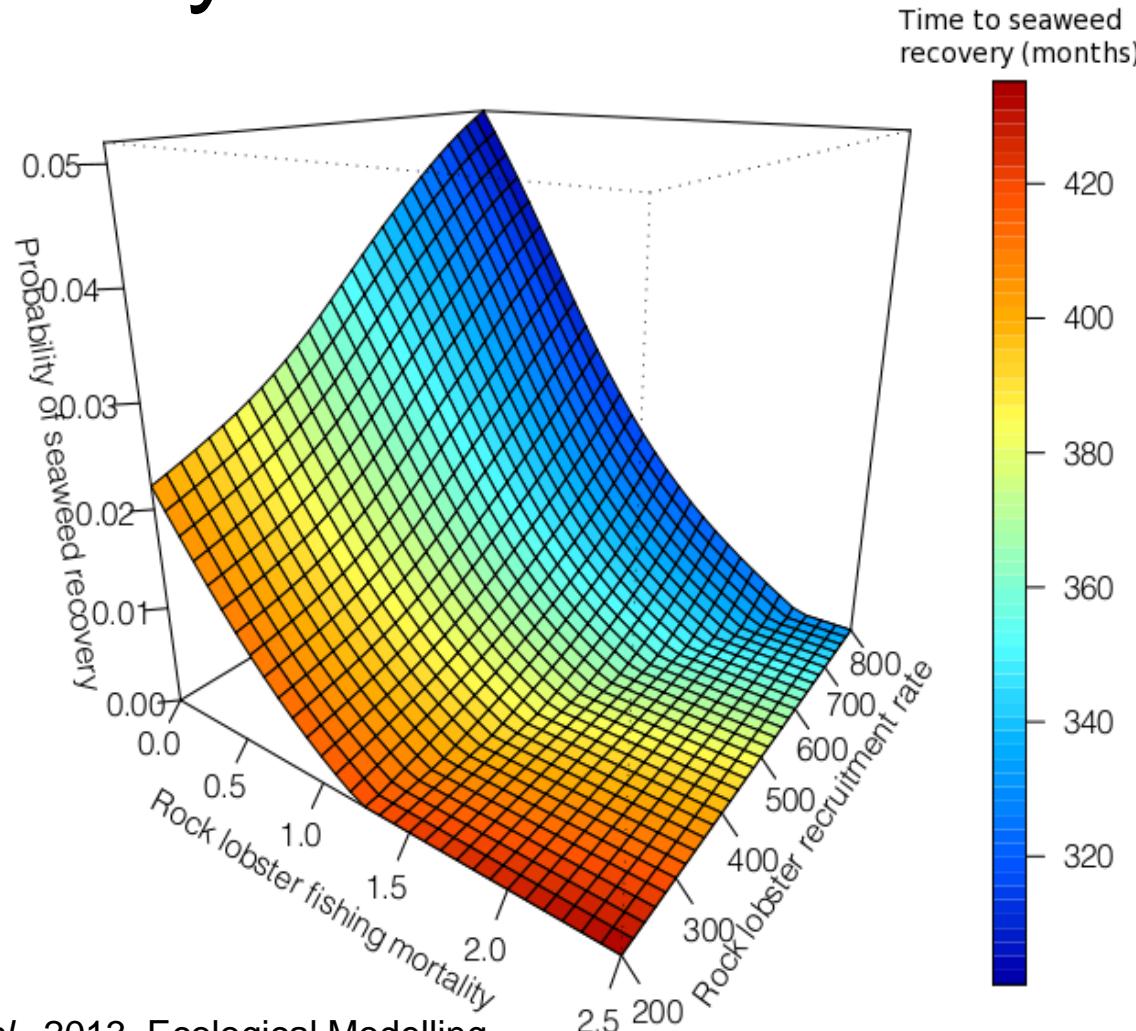
# Sensitivity analysis of model's ability to shift forward



# Sensitivity analysis of model's ability to shift backward

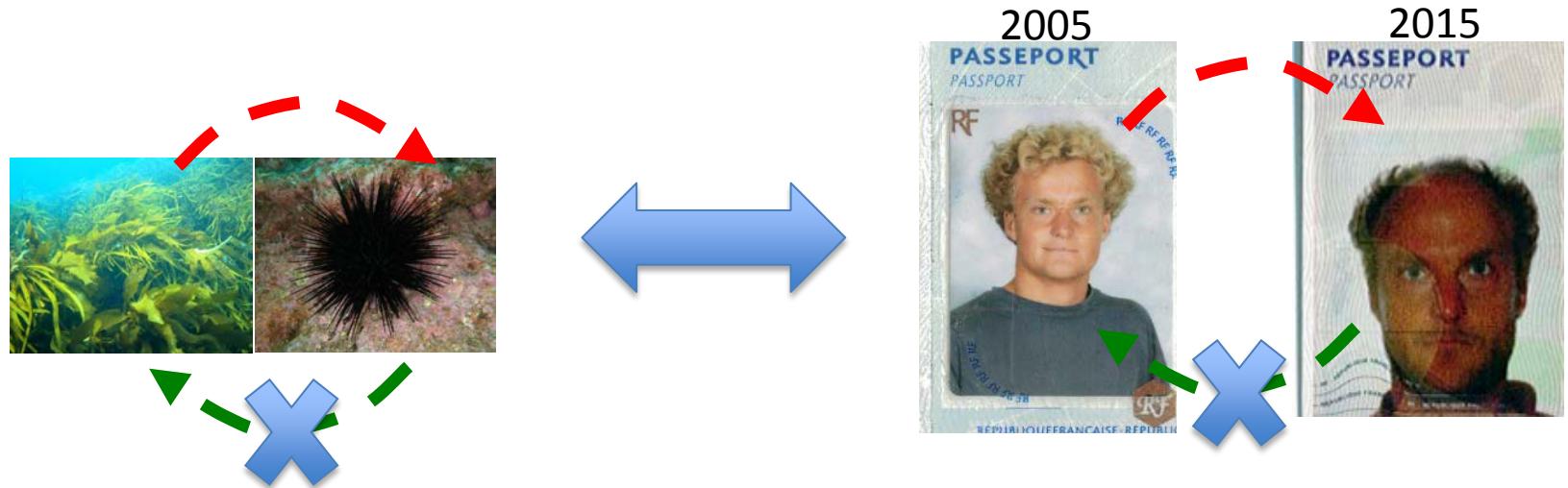


# Sensitivity analysis of model's ability to shift backward



# Sensitivity analysis of model's ability to shift

Prevent rather than cure canopy loss!

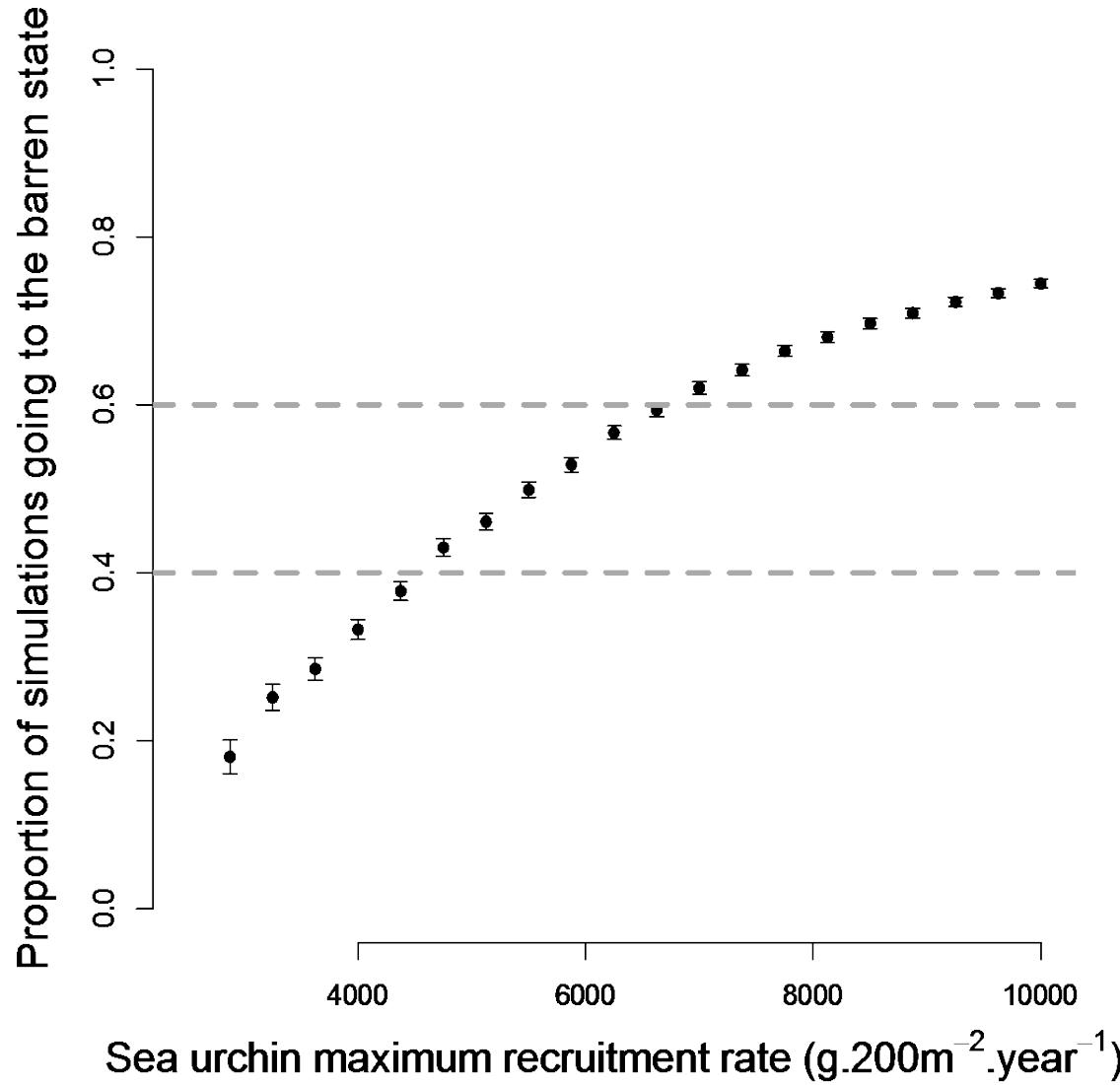


# Model calibration



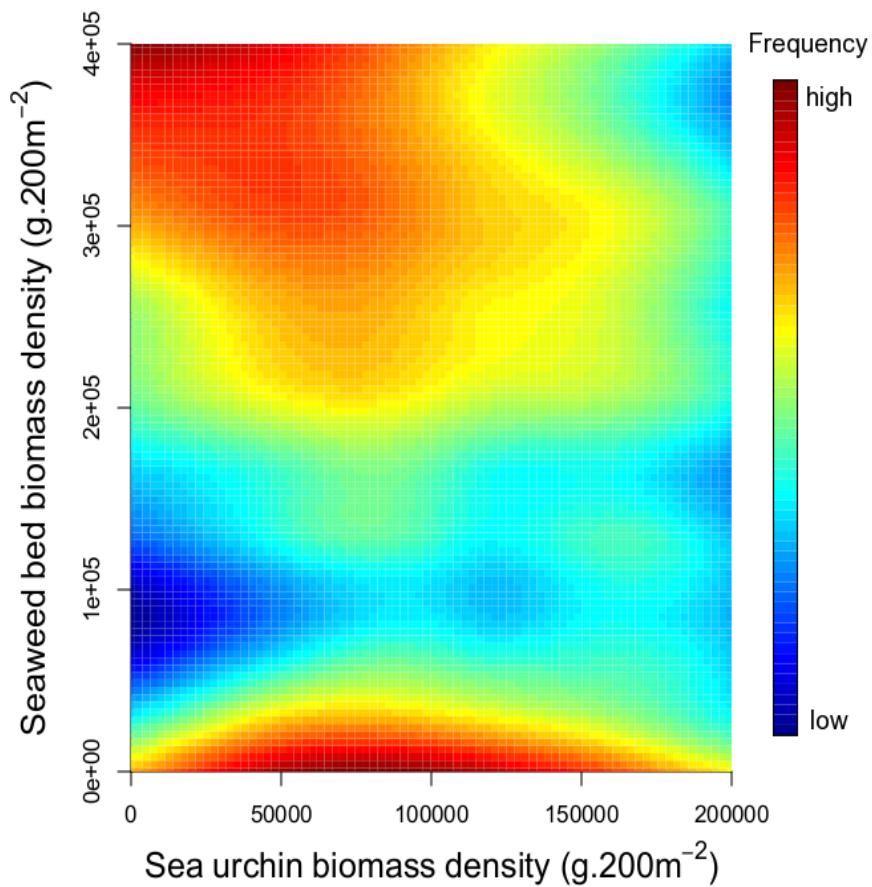
- Model's ability to shift from seaweed bed to urchin barren under historical fishing conditions (i.e. long-term depletion of sea urchin predator)
  - 50% of inshore reef habitat exposed to the long-spined sea urchin turn into urchin barren in the long-term (e.g. NSW; Kent Island group in Bass Strait; Northeast Tas.)

# Model calibration



# Pattern-oriented model validation

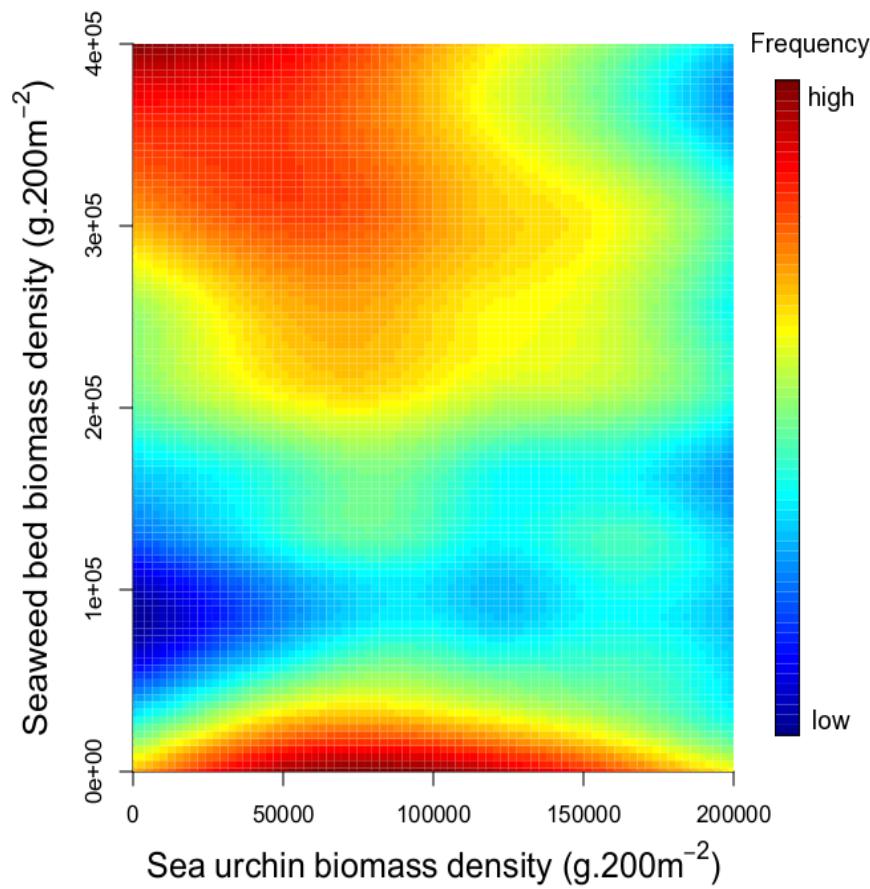
Frequency of community states



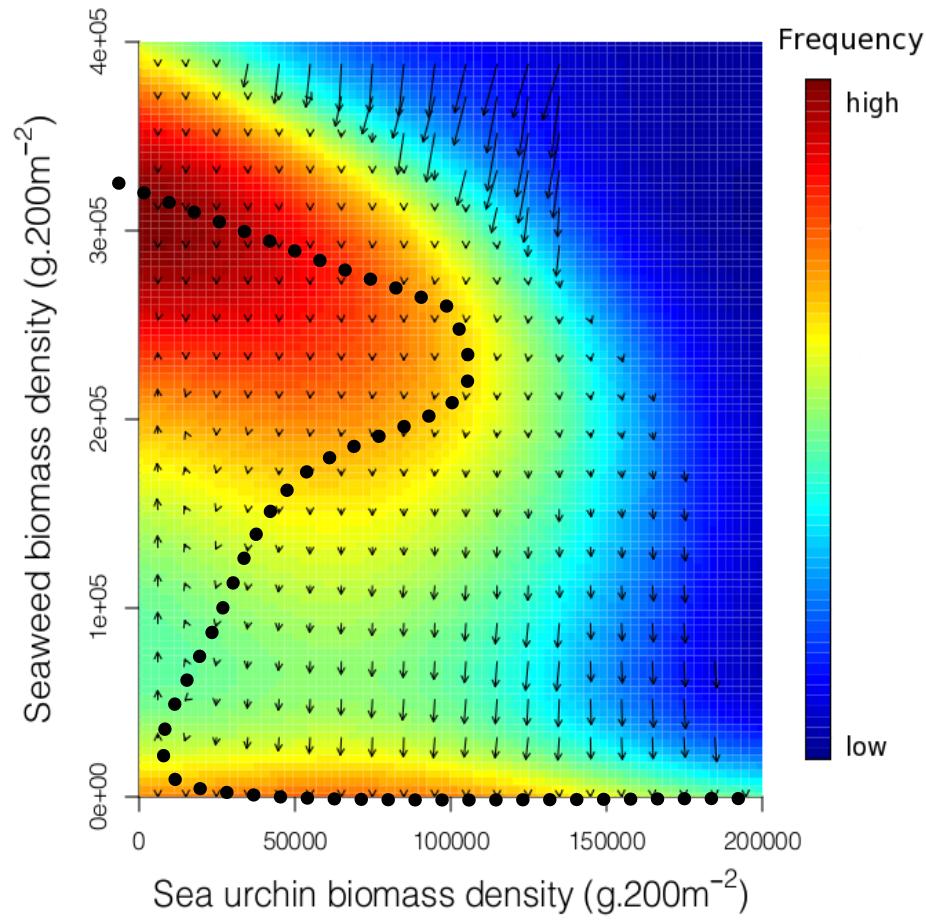
Observations (2002-2011 Surveys)

# Pattern-oriented model validation

Frequency of community states



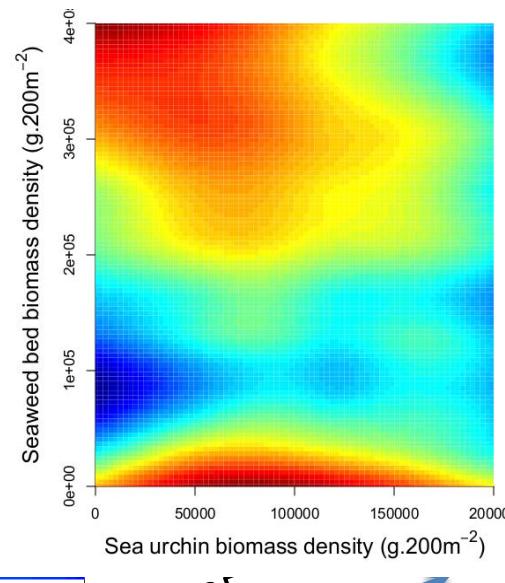
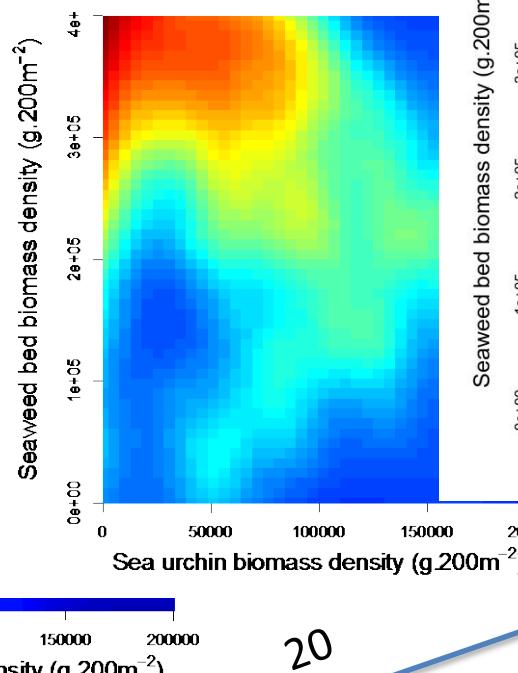
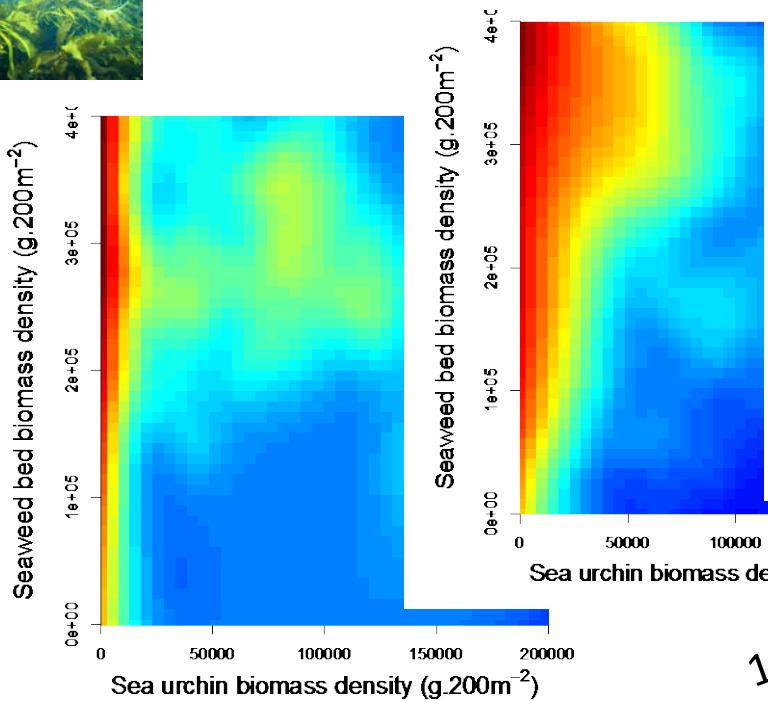
Observations (2002-2011 Surveys)



Simulations

# Back-estimating parameter space?

Optimising parameter space based on simulated Vs. Observed reef states  
as sea urchin population builds up



95 percentile of urchin age distribution  
(in years)

10

15

20

25

# Merci de votre attention

Marzloff, M.P., Dambacher, J.M., Johnson, C.R., Little, L.R. and Frusher, S.D., 2011. Exploring alternative states in ecosystem systems with a qualitative analysis of community feedback. *Ecological Modelling*, **222**:2651-2662.

Marzloff MP, Johnson CR, Little LR, Soulié J-C, Ling SD, Frusher SD (2013) Sensitivity analysis and pattern-oriented validation of TRIM with alternative community states: Insights on temperate rocky reefs dynamics. *Ecological Modelling*, **258**, 16-32.

Marzloff MP, Little LR, Johnson CR (2015) Building Resilience Against Climate-Driven Shifts in a Temperate Reef System: Staying Afloat Using Context-Dependent Ecological Thresholds. *Ecosystems*, **19**, 1-15.

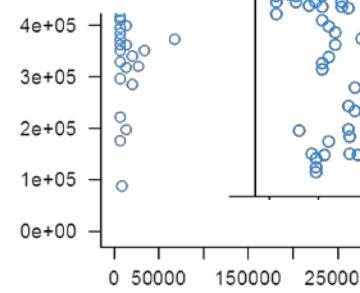
Saltelli A, Tarantola S, Chan KPS (1999) A quantitative model-independent method for global sensitivity analysis of model output. *Technometrics*, **41**, 39-56.



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# Back-estimating parameter space?

Observed evolution of reef states as sea urchin settles in



95 percentile of urchin age distribution  
(in years)