INTERNATIONAL TEMPERATE REEFS SYMPOSIUM

Modelling Mediterranean macroalgal forests – turfs – barrens dynamics under global and local human impacts

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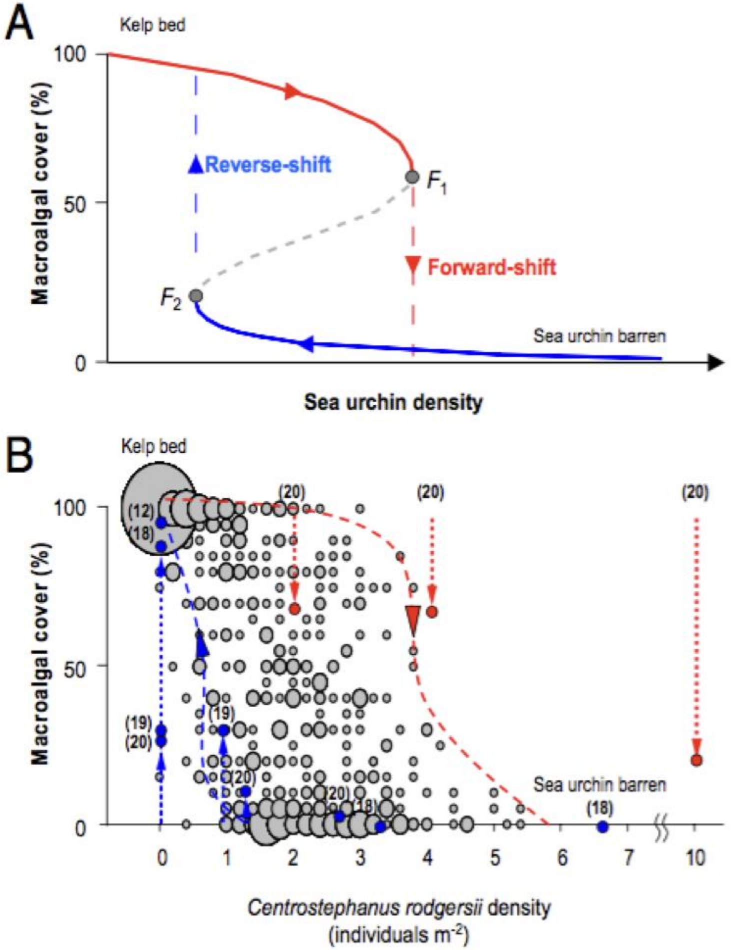
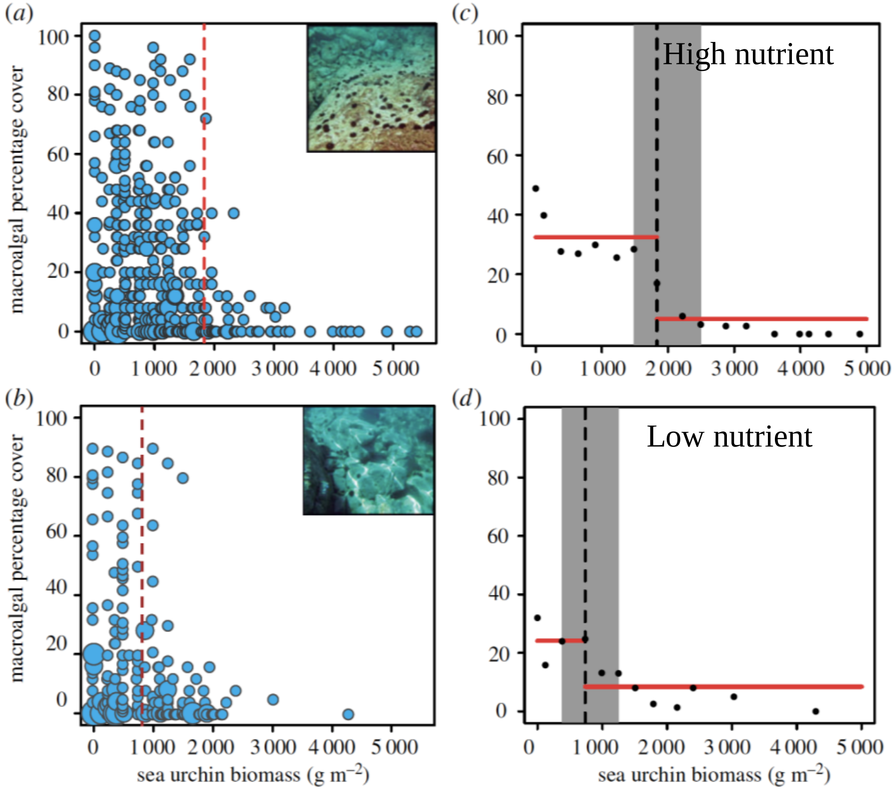
Background



Ling et al., 2015

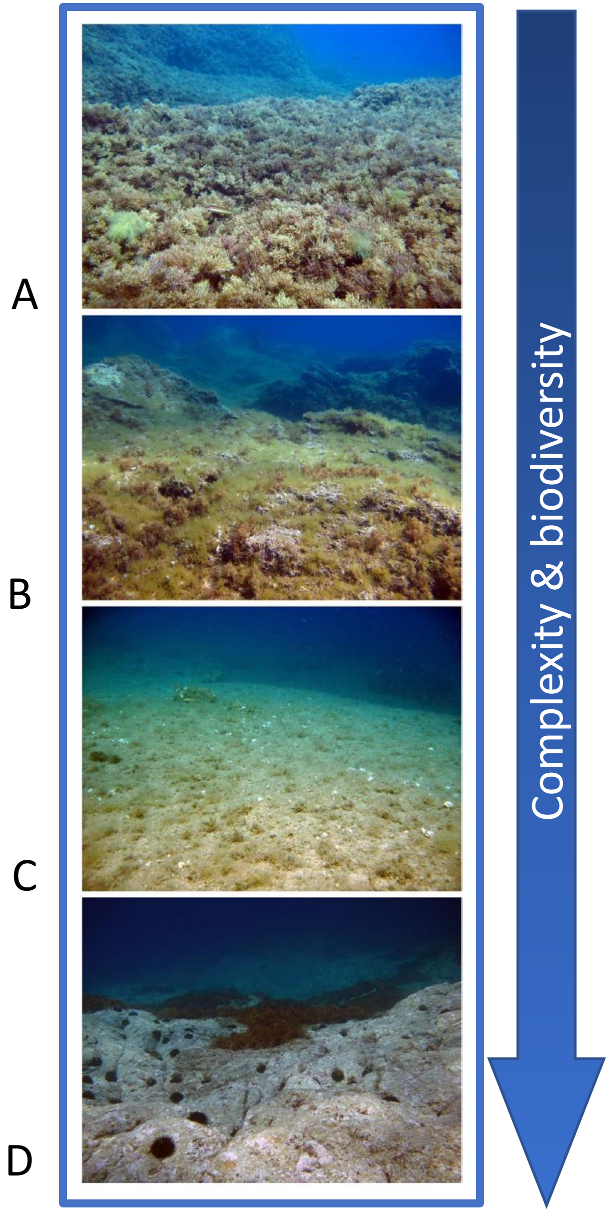
Overgrazing may drive the non-linear transition from kelp forests to sea urchin barrens.

- Hysteresis of the system
- Feedback mechanisms concur to the maintenance of two alternative states



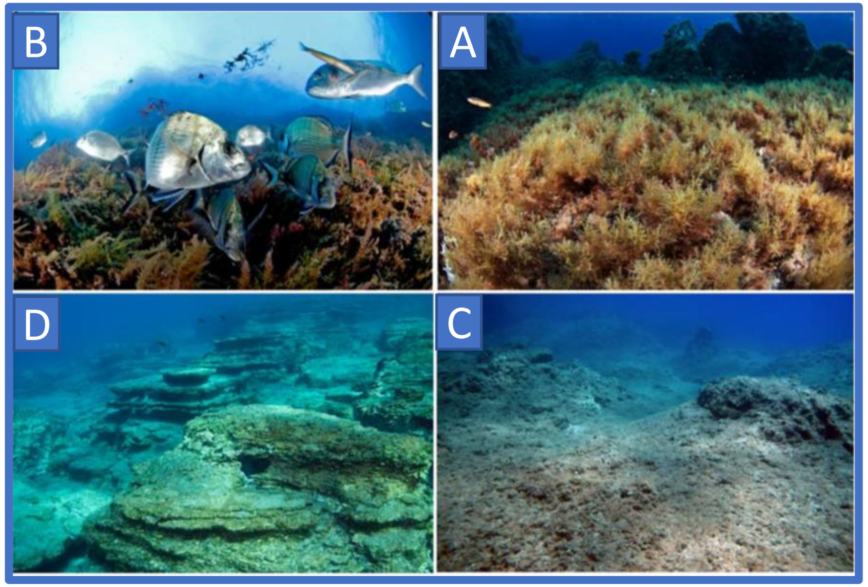
Boada et al., 2017

Background



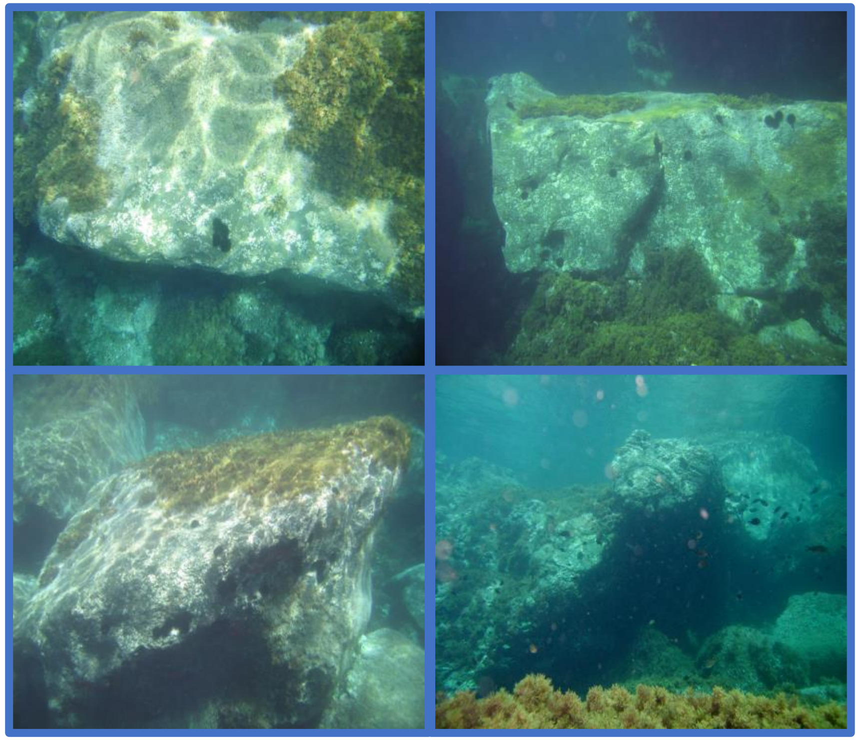
Thiriet et al., 2016

In the Mediterranean Sea,
four alternative states have been identified



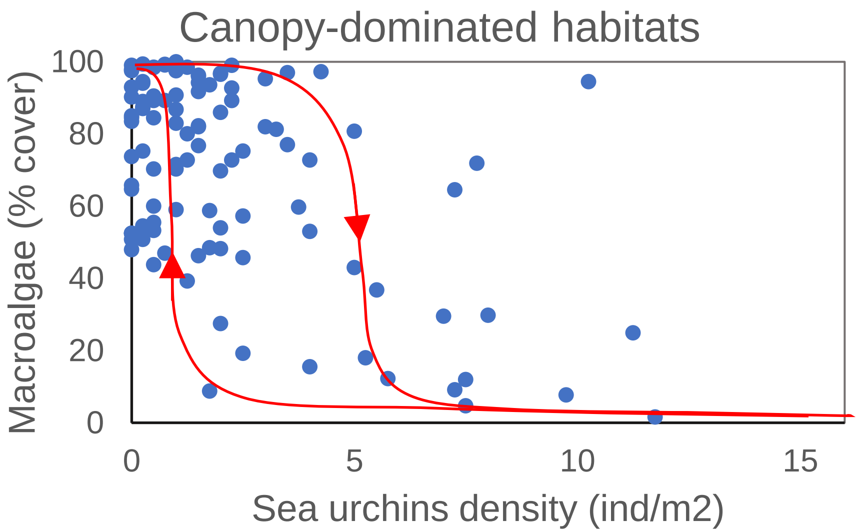
Sala et al., 2012

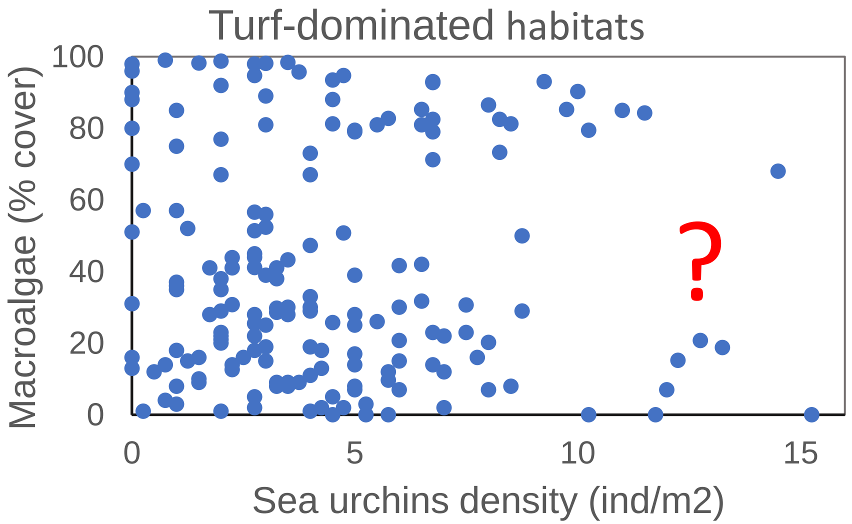
Often, different community types
coexist in mosaics of patches

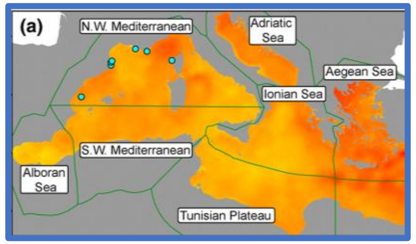


Aim of the work

- Investigate the dynamics of transitions among community types in canopy-dominated and turf-dominated habitats by applying Qualitative Network Models (QPress)
- Predict changes in community type under climate changes and other anthropogenic impacts

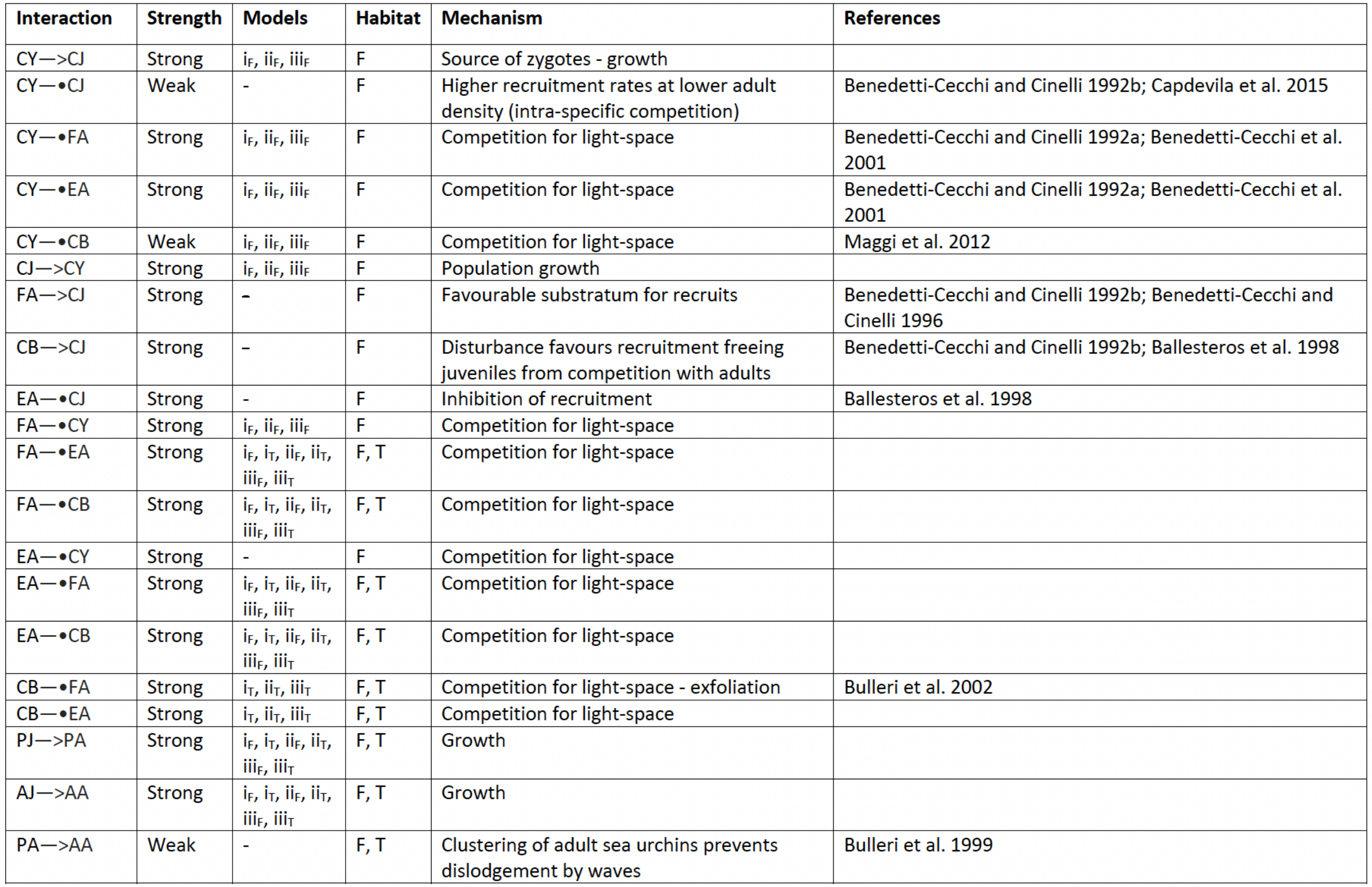






Building the Qualitative Network Model. Step 1

- Literature review: 82 articles



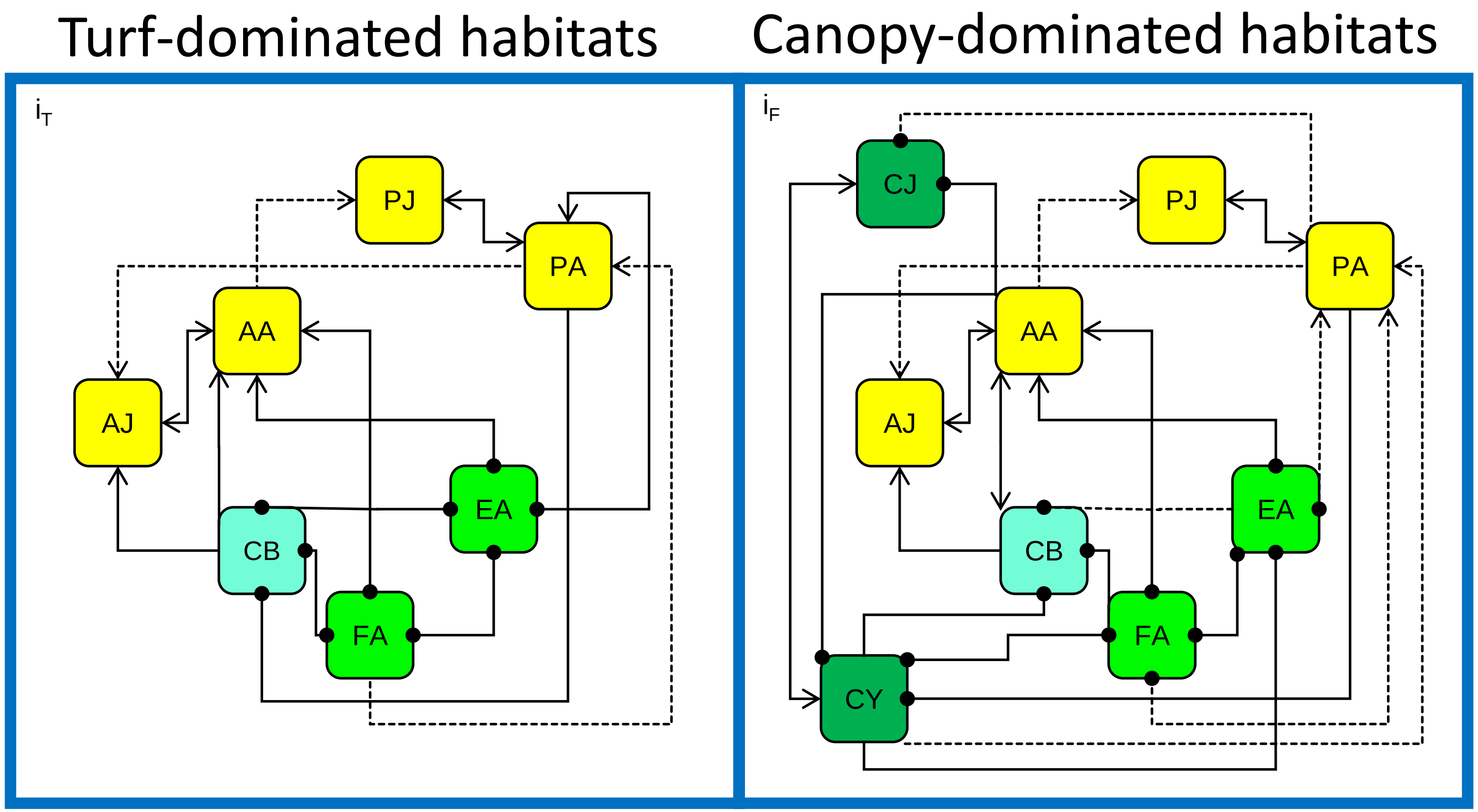
Interaction	Strength	Models	Habitat	Mechanism	References
CY—>CJ	Strong	i_F, ii_F, iii_F	F	Source of zygotes - growth	
CY—•CJ	Weak	-	F	Higher recruitment rates at lower adult density (intra-specific competition)	Benedetti-Cecchi and Cinelli 1992b; Capdevila et al. 2015
CY—•FA	Strong	i_F, ii_F, iii_F	F	Competition for light-space	Benedetti-Cecchi and Cinelli 1992a; Benedetti-Cecchi et al. 2001
CY—•EA	Strong	i_F, ii_F, iii_F	F	Competition for light-space	Benedetti-Cecchi and Cinelli 1992a; Benedetti-Cecchi et al. 2001
CY—•CB	Weak	i_F, ii_F, iii_F	F	Competition for light-space	Maggi et al. 2012
CJ—>CY	Strong	i_F, ii_F, iii_F	F	Population growth	
FA—>CJ	Strong	–	F	Favourable substratum for recruits	Benedetti-Cecchi and Cinelli 1992b; Benedetti-Cecchi and Cinelli 1996
CB—>CJ	Strong	–	F	Disturbance favours recruitment freeing juveniles from competition with adults	Benedetti-Cecchi and Cinelli 1992b; Ballesteros et al. 1998
EA—•CJ	Strong	-	F	Inhibition of recruitment	Ballesteros et al. 1998
FA—•CY	Strong	i_F, ii_F, iii_F	F	Competition for light-space	
FA—•EA	Strong	i_F, i_T, ii_F, ii_T, iii_F, iii_T	F, T	Competition for light-space	
FA—•CB	Strong	i_F, i_T, ii_F, ii_T, iii_F, iii_T	F, T	Competition for light-space	
EA—•CY	Strong	-	F	Competition for light-space	
EA—•FA	Strong	i_F, i_T, ii_F, ii_T, iii_F, iii_T	F, T	Competition for light-space	
EA—•CB	Strong	i_F, i_T, ii_F, ii_T, iii_F, iii_T	F, T	Competition for light-space	
CB—•FA	Strong	i_T, ii_T, iii_T	F, T	Competition for light-space - exfoliation	Bulleri et al. 2002
CB—•EA	Strong	i_T, ii_T, iii_T	F, T	Competition for light-space	
PJ—>PA	Strong	i_F, i_T, ii_F, ii_T, iii_F, iii_T	F, T	Growth	
AJ—>AA	Strong	i_F, i_T, ii_F, ii_T, iii_F, iii_T	F, T	Growth	
PA—>AA	Weak	-	F, T	Clustering of adult sea urchins prevents dislodgement by waves	Bulleri et al. 1999

- 21 nodes included in the model: 5 algal groups, 4 herbivores (species and life stages), 5 predator species, 7 human stressors (processes)

- 2 different models (canopy habitats /turf-dominated habitats)

- 122 interactions classified as positive, negative, uncertain/weak
(e.g., competition, facilitation, grazing, predation, habitat preference, recruitment preferences, effects of stressors)

Building the QNM. Step 2 core models



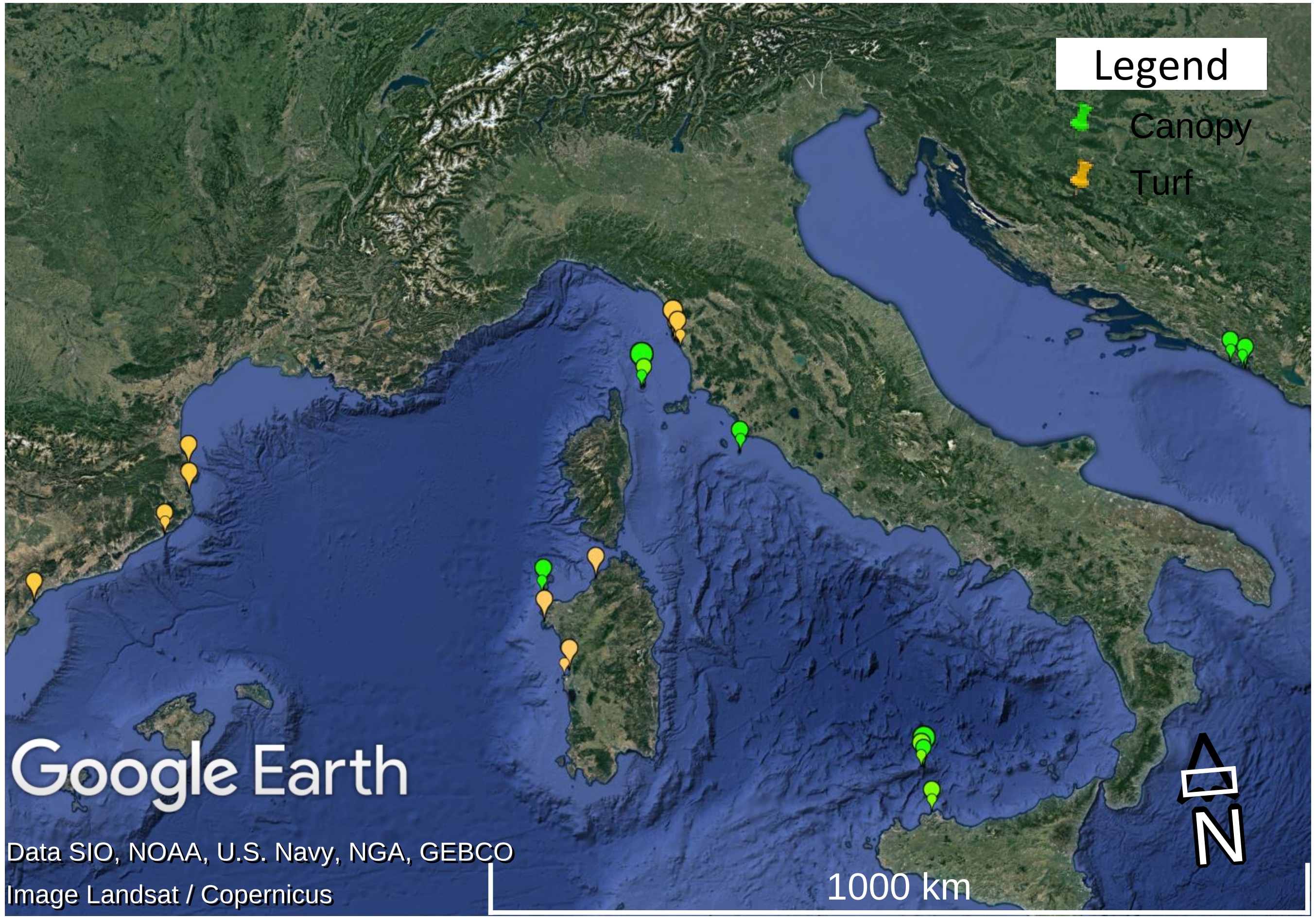
→ positive interaction

—● negative interaction

- - -● weak interaction

AA	*Arbacia lixula* adults
PA	*Paracentrotus lividus* adults
PJ	*P. lividus* juveniles
AJ	*A. lixula* juveniles
EA	Erect macroalgae
FA	Filamentous algae
CB	Coralline barrens
CY	*Cystoseira s.l.* adults
CJ	*Cystoseira s.l.* germlings

Validating the QNM. Step 3



Data collection in the field

2002, 2013-2015

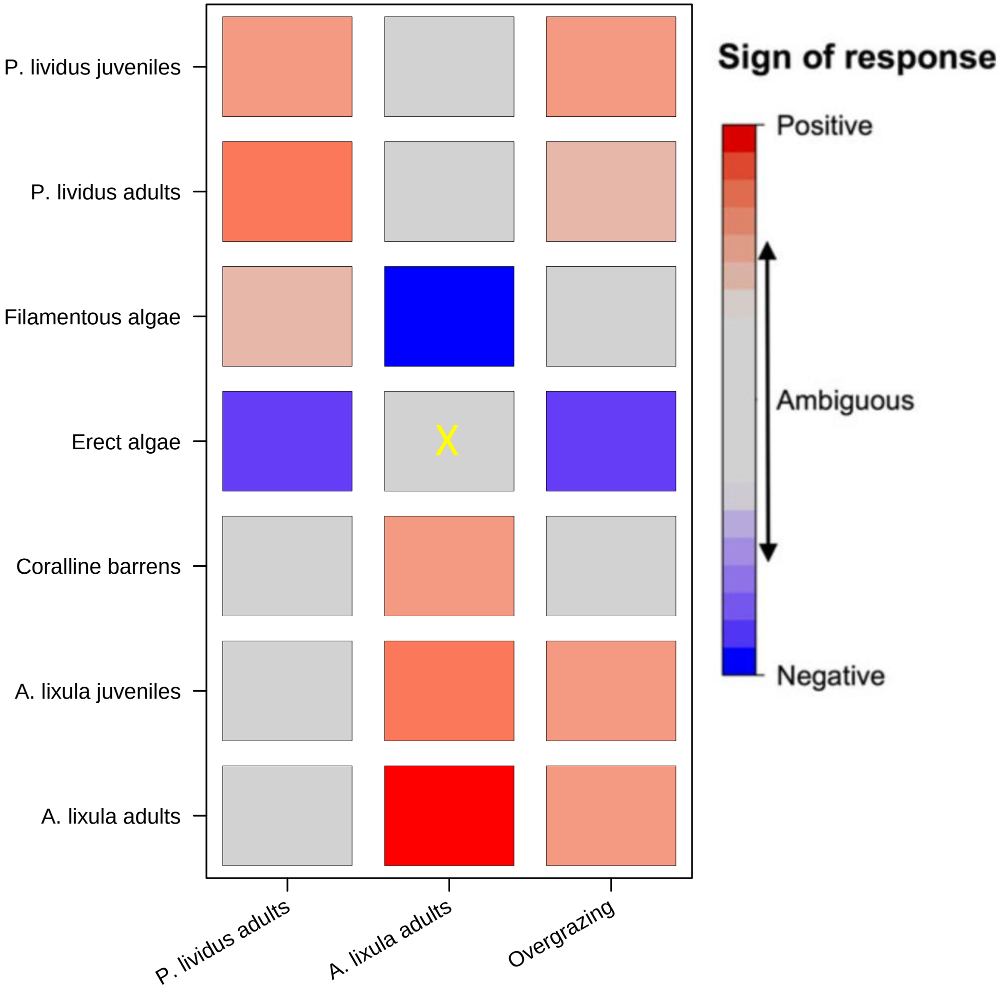
21 sites dominated by ● canopy,
16 dominated by ● turf

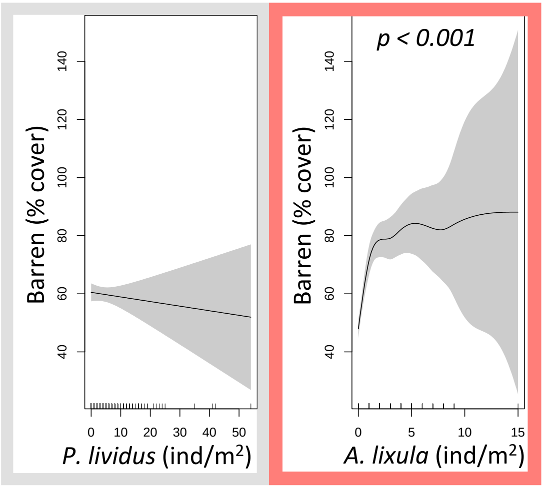
overall 1362 quadrats 1x1 m

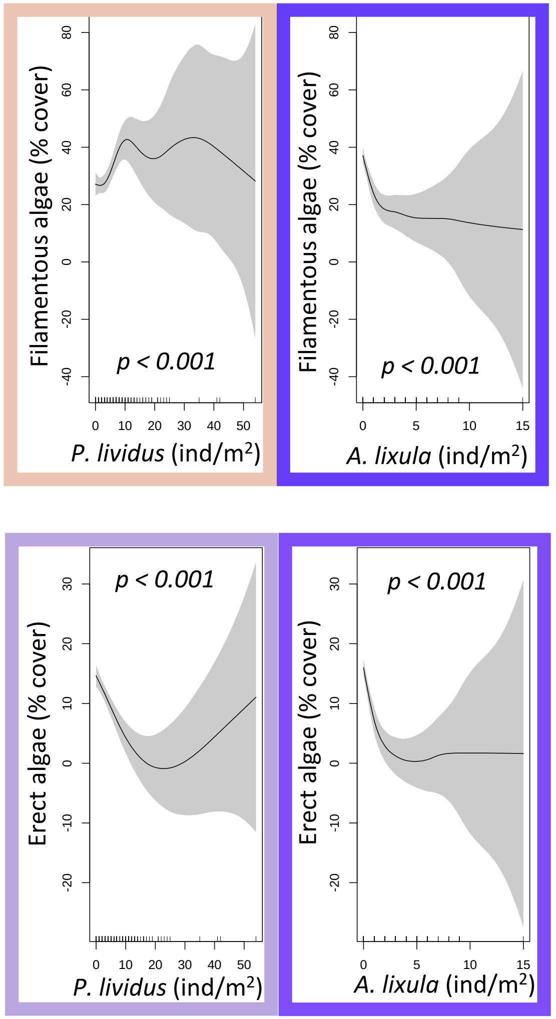
% cover of macroalgae (classified as *Cystoseira s.l.*, erect macroalgae, filamentous algae, coralline barren)

N° *P. lividus* and *A. lixula* (<3 cm classified as juveniles)

Validating the QNM. Turf-dominated habitats

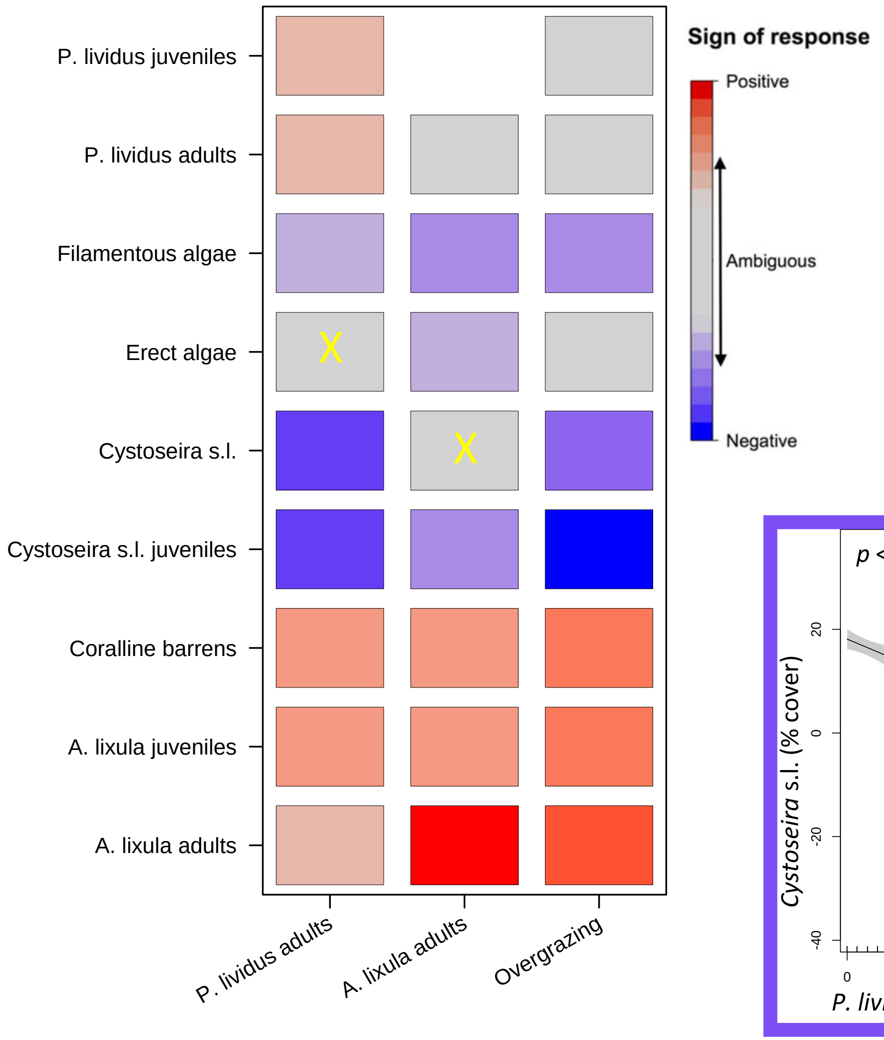




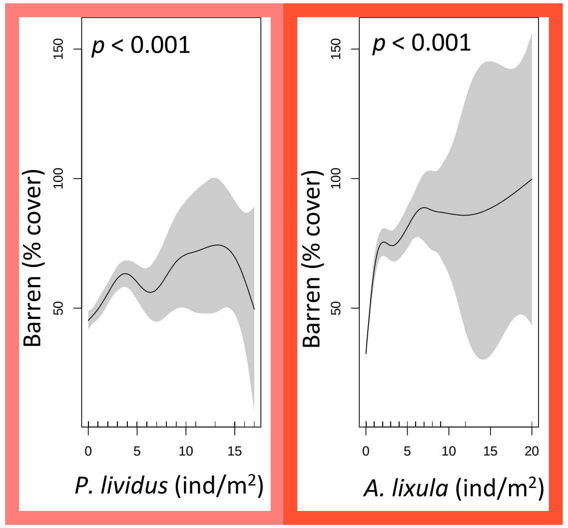


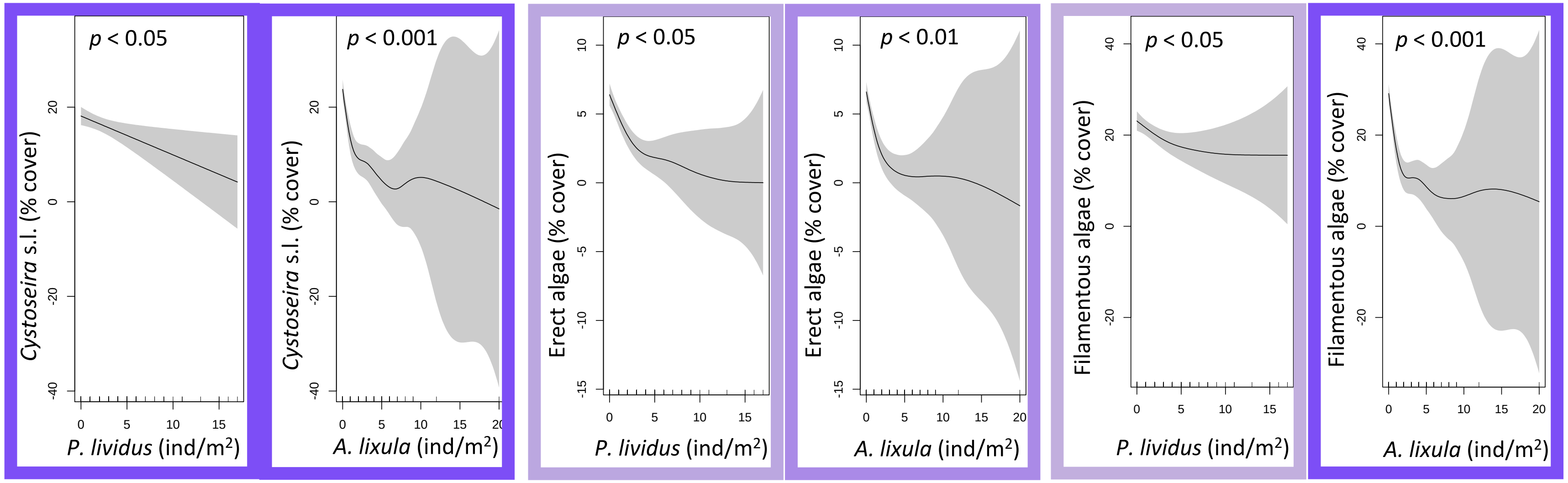
Algal groups	**GAM**	
	DEV (%)	AIC
Filamentous algae	11.8	6791.39
Erect macroalgae	18.0	5880.20
Coralline barrens	17.8	6919.07

Validating the QNM. Canopy-dominated habitats



Algal groups	GAM	
	DEV (%)	AIC
Filamentous algae	21.6	5748.33
Erect macroalgae	15.6	5793.07
Cystoseira s.l.	16.9	5748.5
Coralline barrens	43.5	6269.53

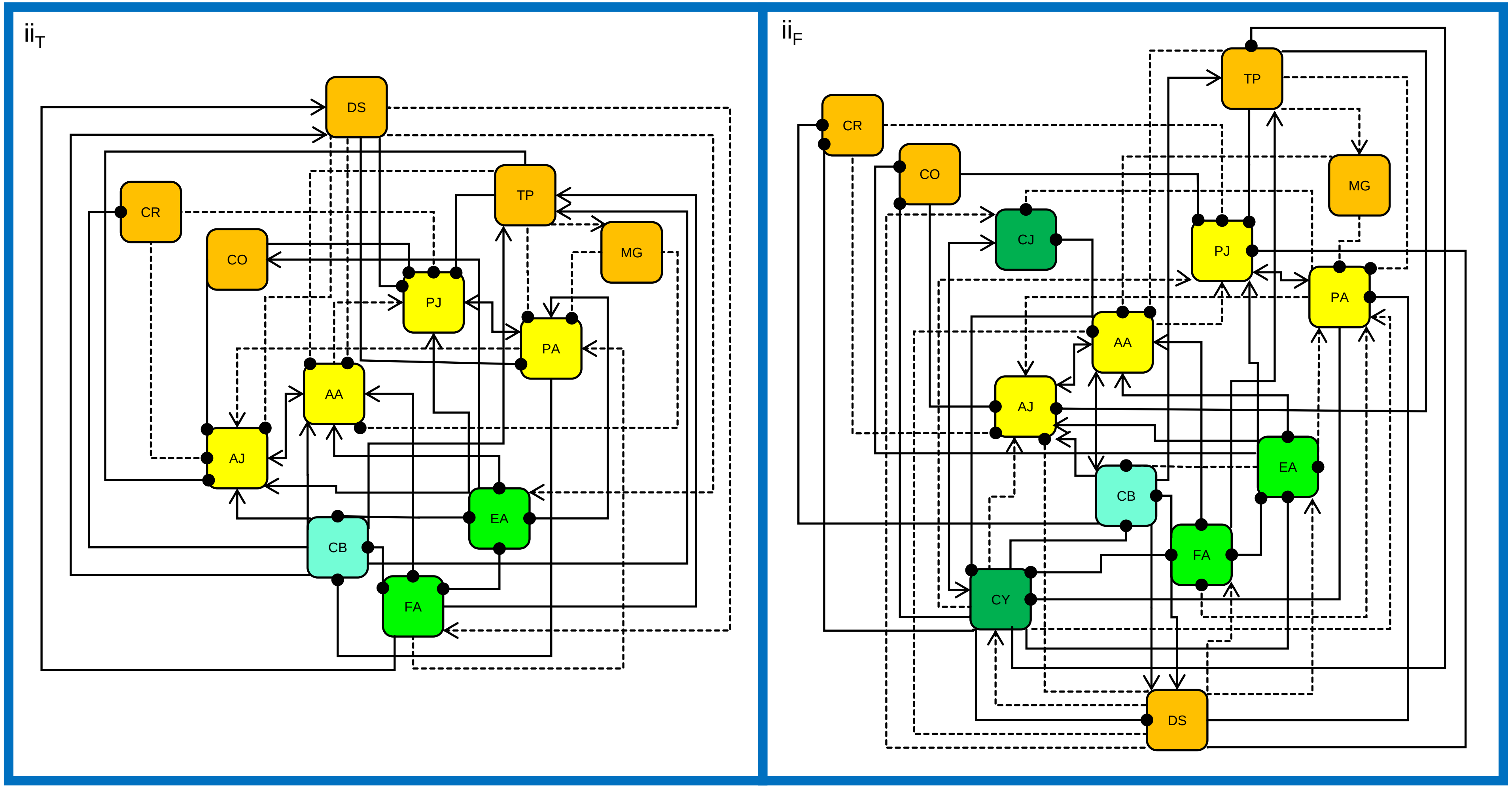




Building the QNM. including predators

Turf-dominated habitats

Canopy-dominated habitats



DS	*Diplodus spp.*
MG	*Marthasterias glacialis*
TP	*Thalassoma pavo*
CO	*Coris julis*
CR	Crustacean predators
AA	*Arbacia lixula* adults
PA	*Paracentrotus lividus* adults
PJ	*P. lividus* juveniles
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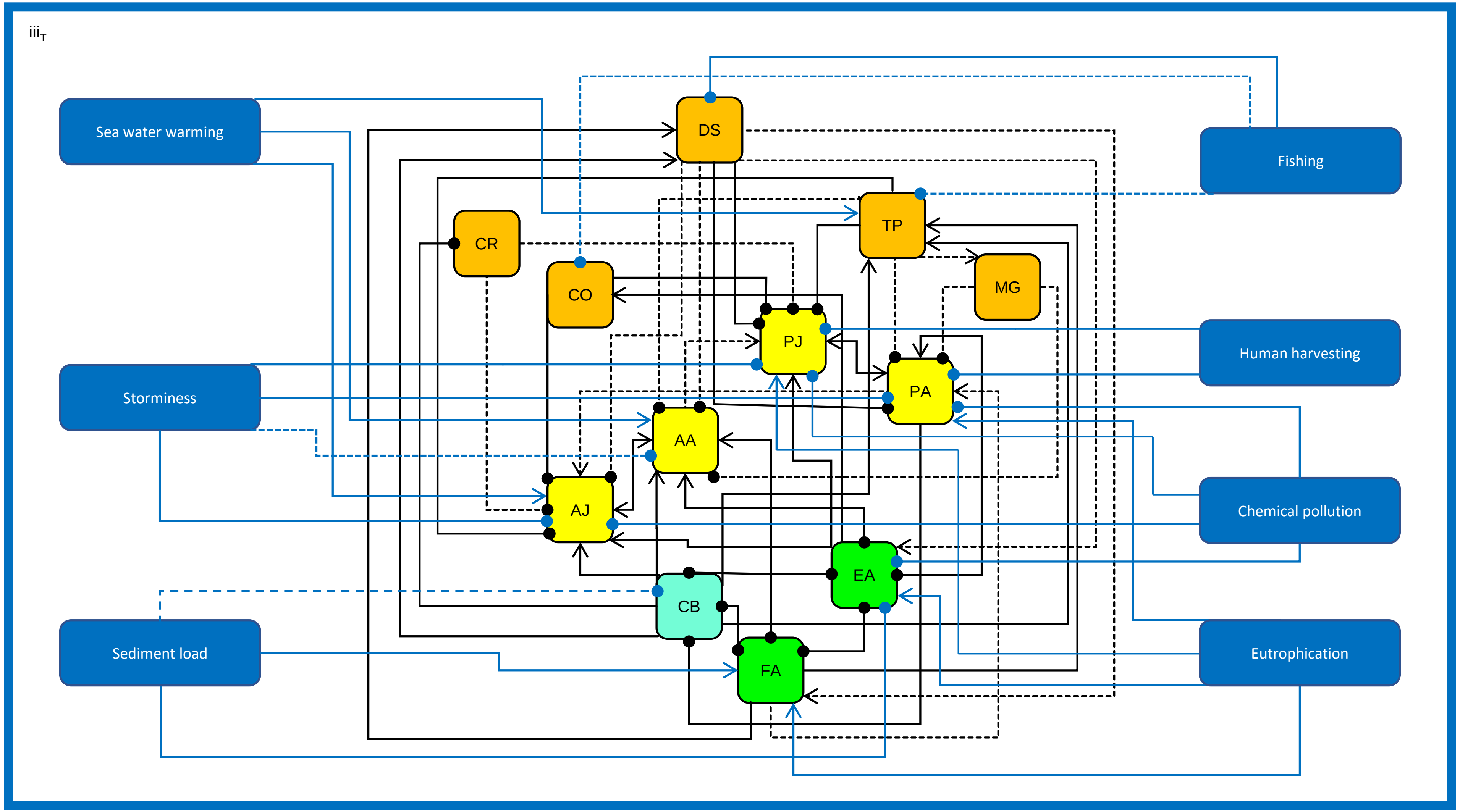
Building the QNM. including anthropogenic stressors

Turf-dominated habitats



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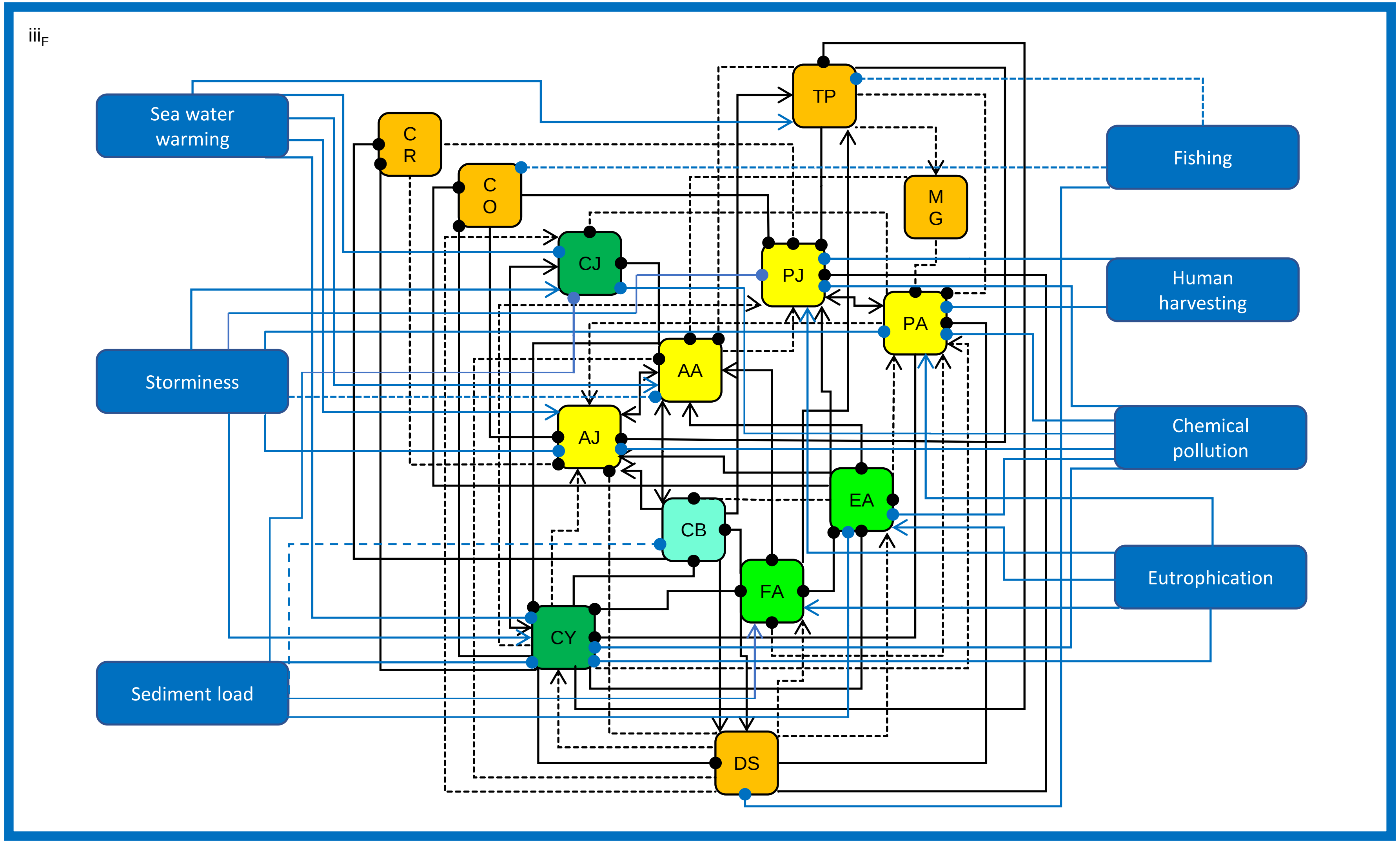
Building the QNM. including anthropogenic stressors

Canopy-dominated habitats



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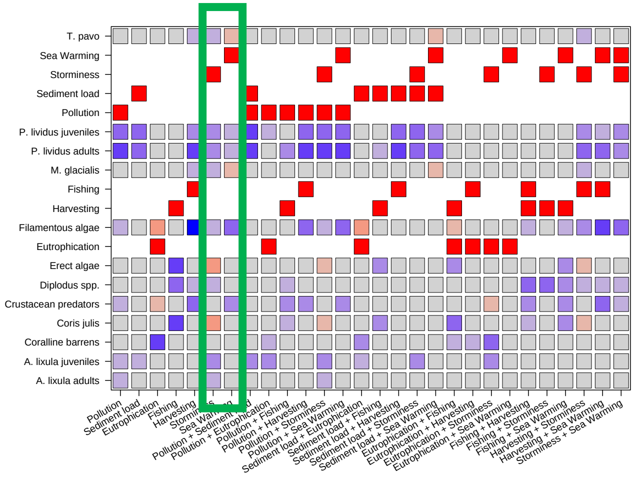
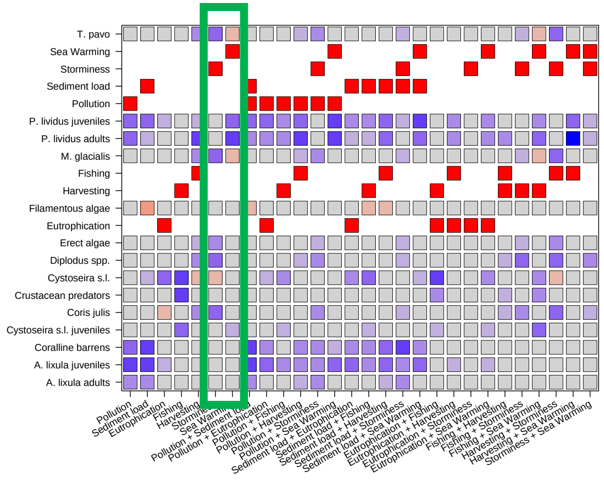
Results

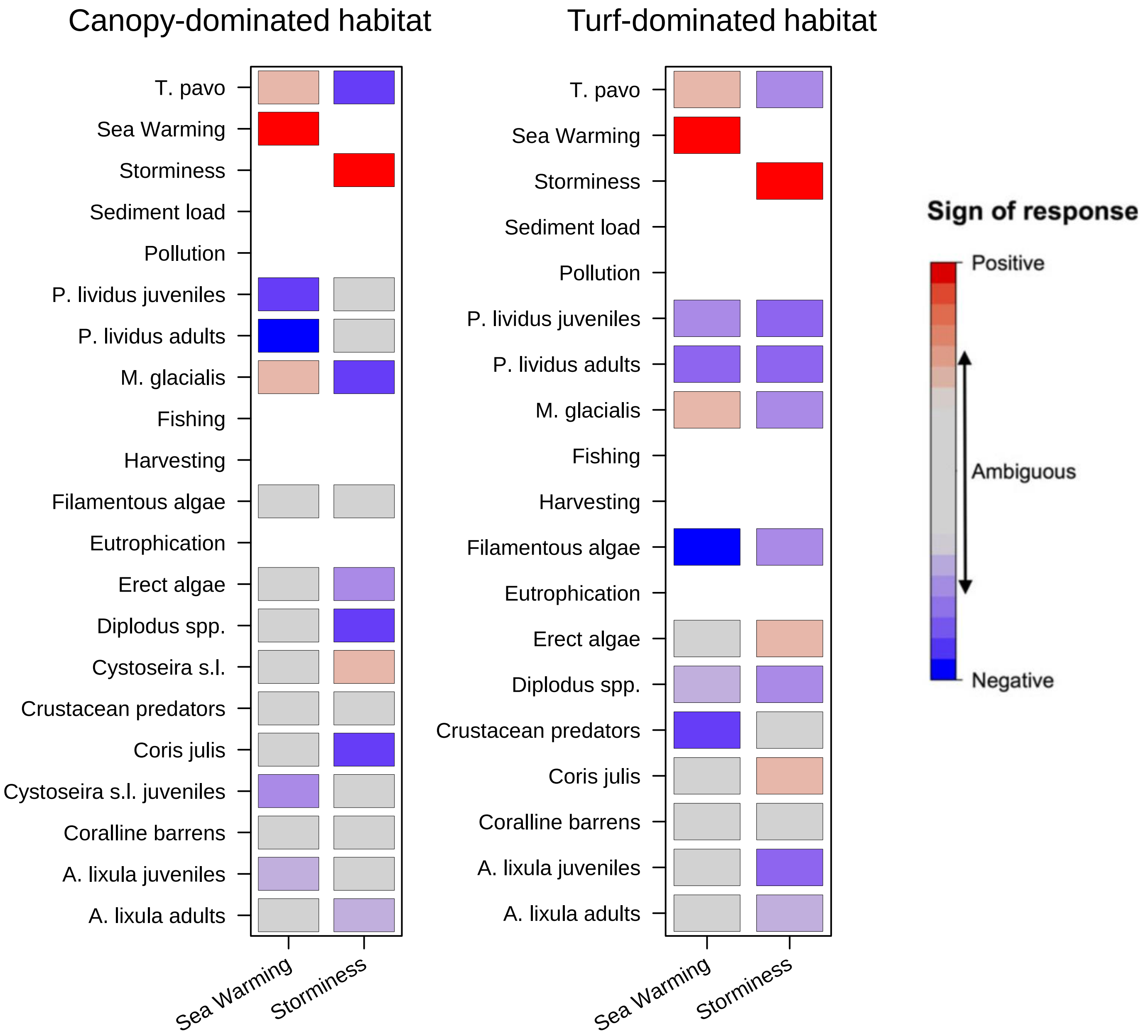
Climate Change



Turf-dominated: combined stressors

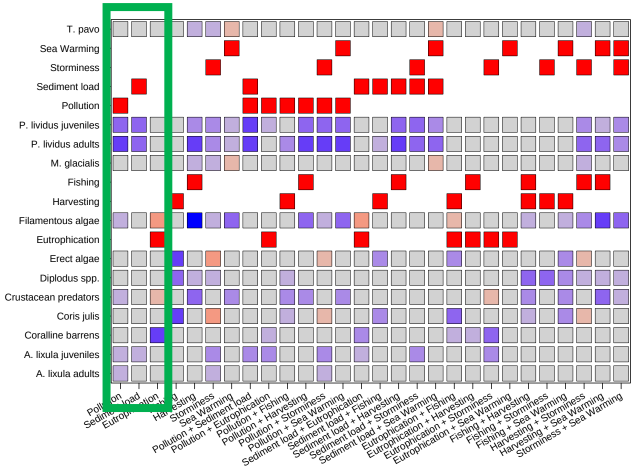


Canopy-dominated: combined stressors

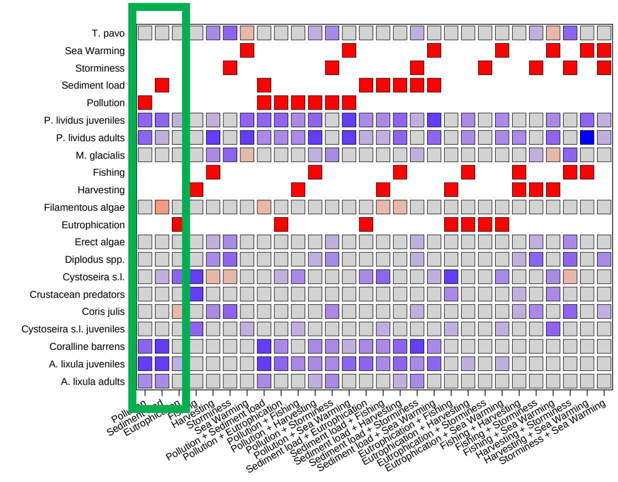

Canopy-dominated habitat

Turf-dominated habitat

Results



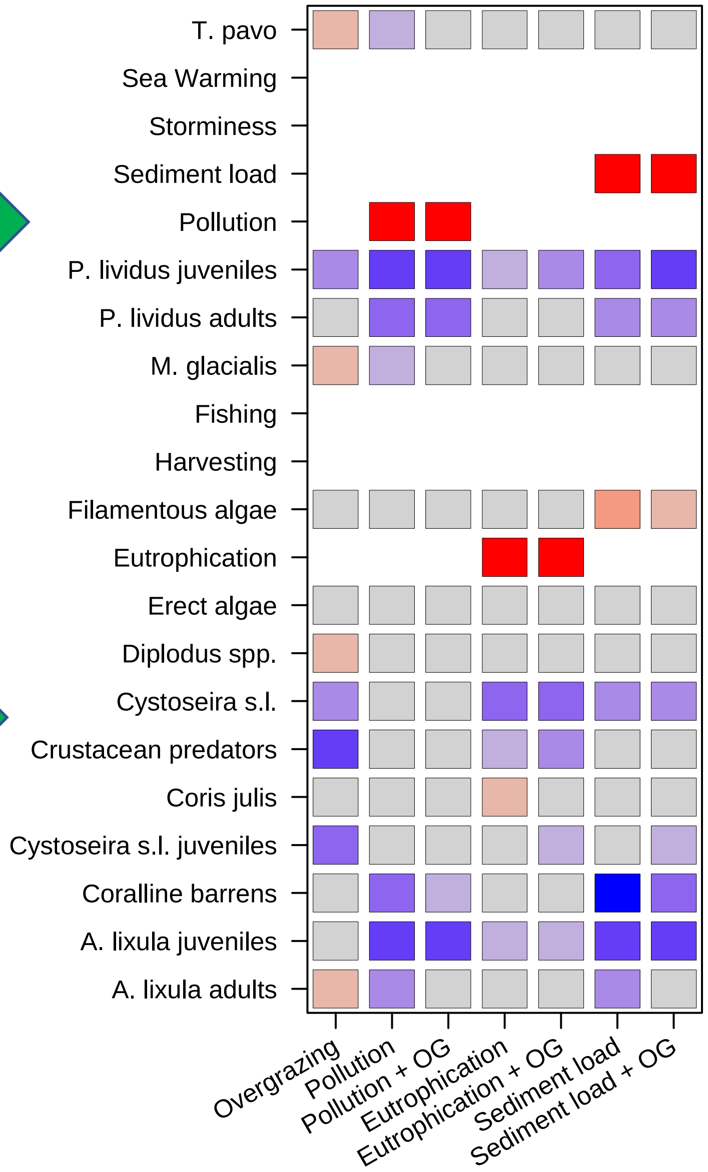
Turf-dominated: combined stressors



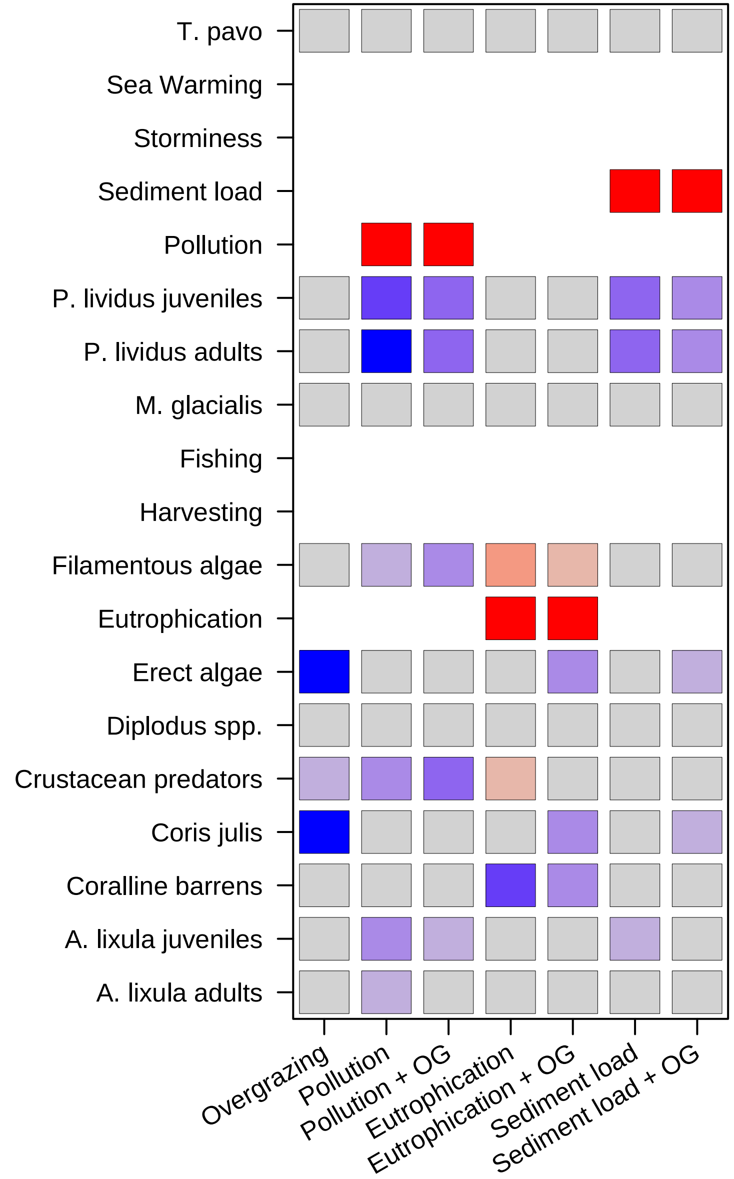
Canopy-dominated: combined stressors

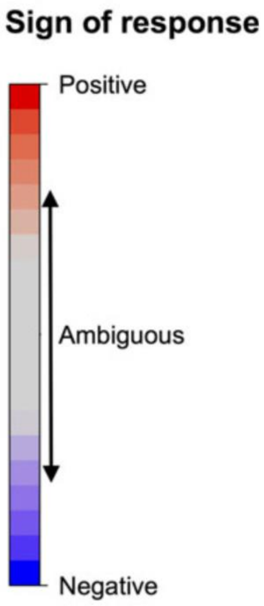
Local stressors

Canopy-dominated habitat



Turf-dominated habitat

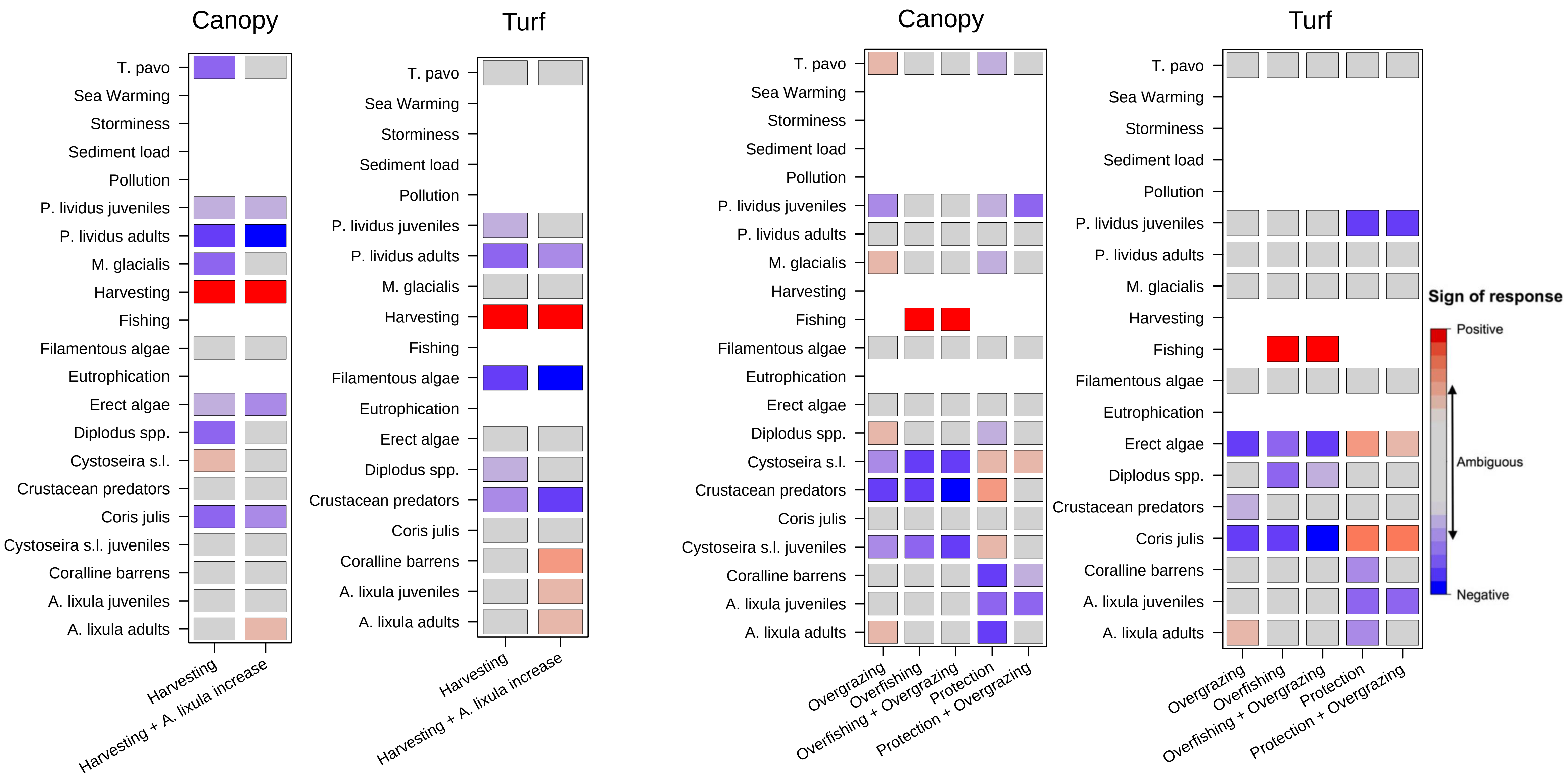




Results

P. lividus harvesting

Overfishing & protection



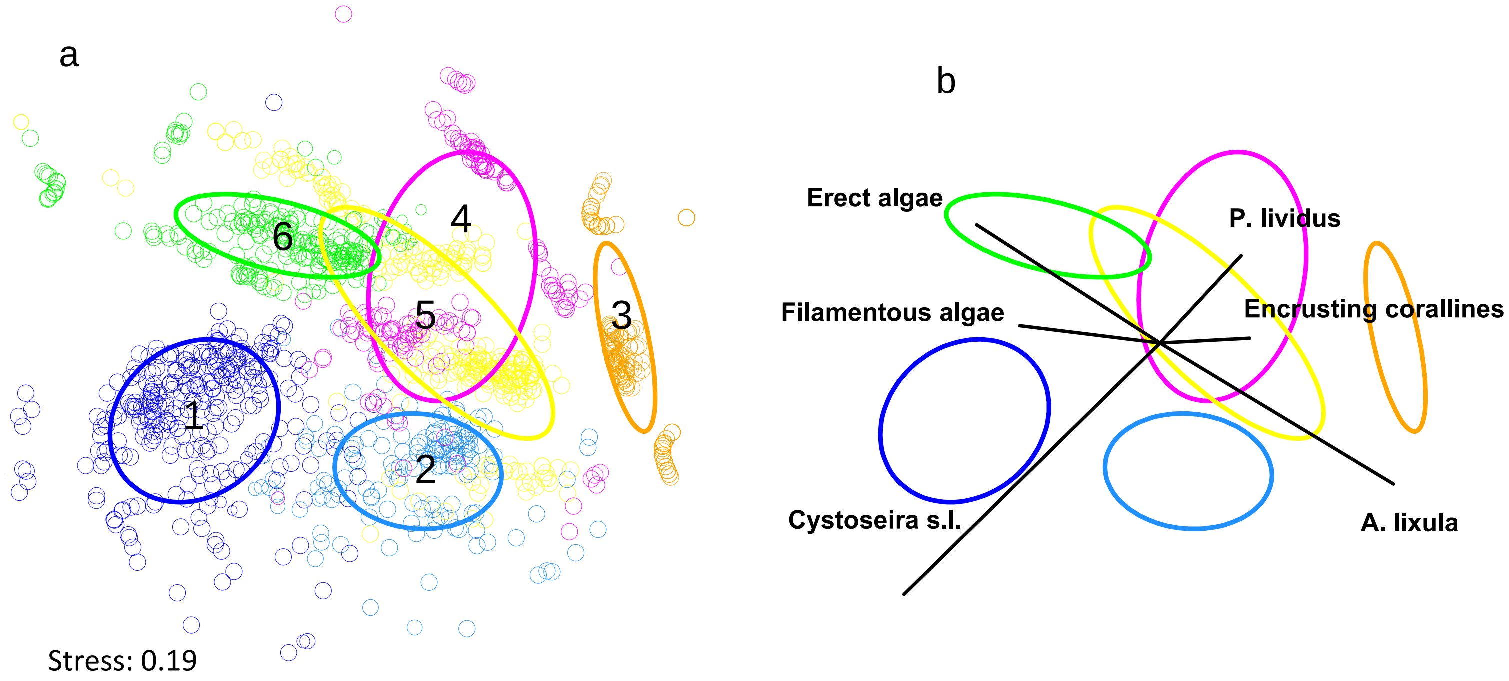
Conclusions

- Human pressures will differently affect forests and turf-dominated habitats.
- Mosaics of the four community types will persist under all human pressures, although local pressures will reduce the extent of barrens and favour filamentous algae in turf- and canopy-dominated habitats.
- Overfishing, eutrophication and sedimentation caused by human activity will degrade fucoids forests. However, management intervention and increase storminess can shift turfs to macroalgal forests.

Thank you for your attention!

Validating the model.

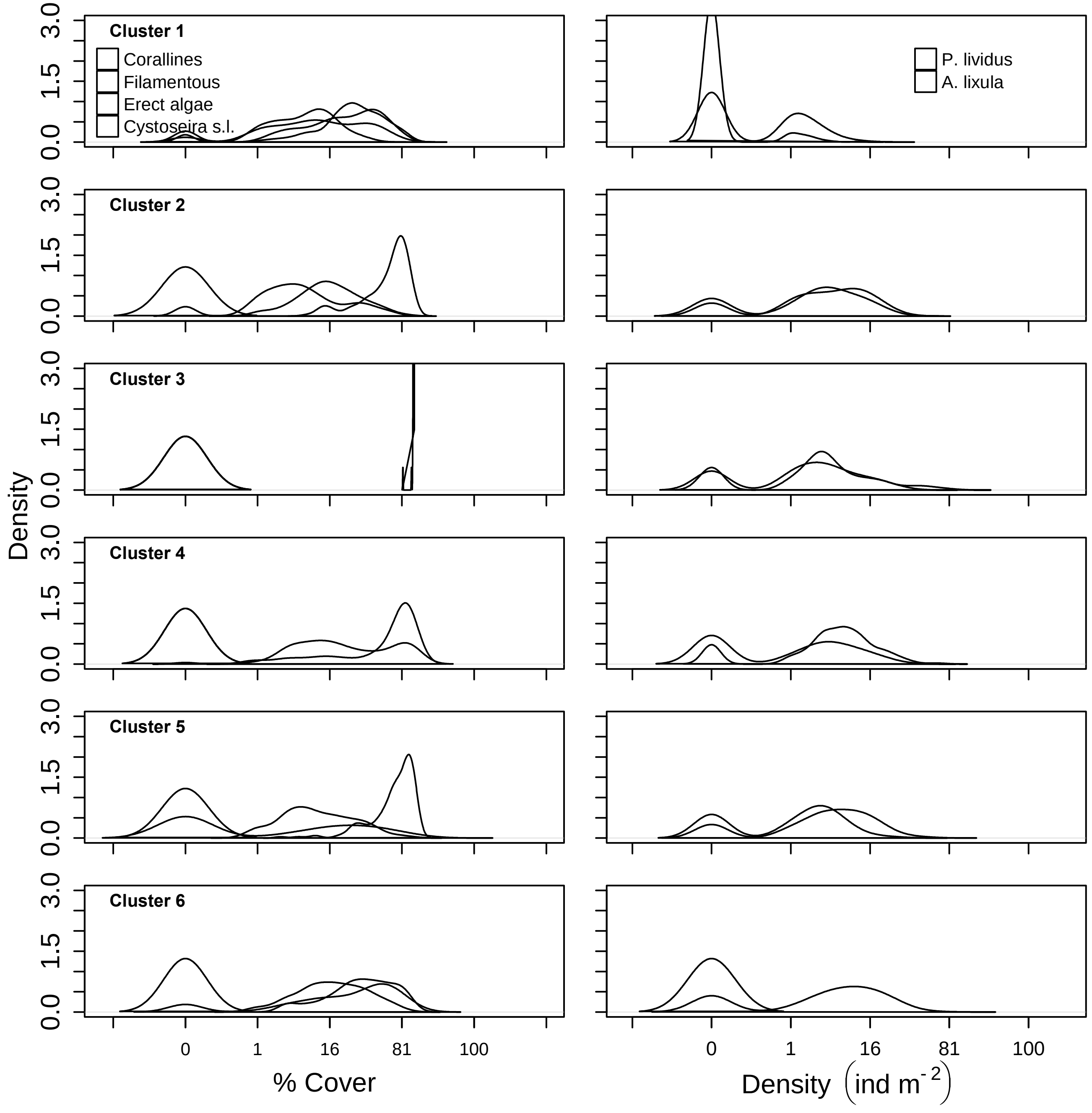
Model-based clustering of data collected in the field



Cluster	Forest / Turf (%)	Community types	Absent groups
1	99.7/ 0.3	Low sea urchin density (< 1.5 ind/m^2), mosaic of canopy (30%), turfs (40%) and barrens (30%)	-
2	100 / 0	High urchin density (∼ 12 ind/m^2), mostly *A. lixula,* 64% barrens, with 13% canopy and 18% filamentous turfs	Erect macroalgae
3	54 / 46	High urchin density (∼ 13 ind/m^2), coralline barrens only (99.9%)	*Cystoseira s.l.*, erect and filamentous algae
4	20.8/ 79.2	High urchin density (∼ 13 ind/m^2), mosaic of barrens (63%) and filamentous turfs (36%)	*Cystoseira s.l.*, erect macroalgae
5	5 / 95	High urchin density (∼ 11 ind/m^2), mosaic of barrens (73%), shrublike- (17%) and simplified turfs (16%)	*Cystoseira s.l.*
6	5.6 / 94.4	*P. lividus* (∼ 9 ind/m^2), mosaic of shrublike- (23%) and simplified turfs (42%), barrens (35%)	*A. lixula, Cystoseira s.l.*

Validating the model.

	CLUSTER (mean (SE))					
	1	2	3	4	5	6
P. lividus (ind/m^2)	1.11 (0.11)	5.14 (0.45)	8.04 (0.86)	8.87 (0.57)	7.68 (0.67)	9.06 (0.63)
A. lixula (ind/m^2)	0.21 (0.05)	6.88 (0.56)	5.06 (0.43)	4.30 (0.35)	3.06 (0.32)	0
Corallines (%)	18.47 (1.10)	64.31 (1.91)	99.89 (0.07)	63.02 (2.01)	72.61 (1.92)	34.96 (1.79)
Filamentous (%)	32.72 (1.28)	18.39 (1.34)	0	35.96 (2.00)	15.68 (1.77)	41.54 (1.66)
Erect algae (%)	9.12 (0.52)	0	0	0	16.58 (1.35)	22.71 (1.23)
Cystoseira s.l. (%)	30.40 (1.25)	12.57 (1.24)	0	0	0	0
Habitat (% of total)						
Forest	99.7	100	54	20.8	5	5.6
Turfs	0.3	0	46	79.2	95	94.4
N° of replicates	295	153	239	283	159	233



Kernel density of algae (left) and sea urchins (right) variables for each regime with arrows corresponding to the respective mean values. X-axes are fourth-root transformed to same scaling as used in cluster analysis.