stazione zoologica anton dohrn

Meccanismi di risposta di *Posidonia oceanica* alle variazioni ambientali indotte dai cambiamenti climatici

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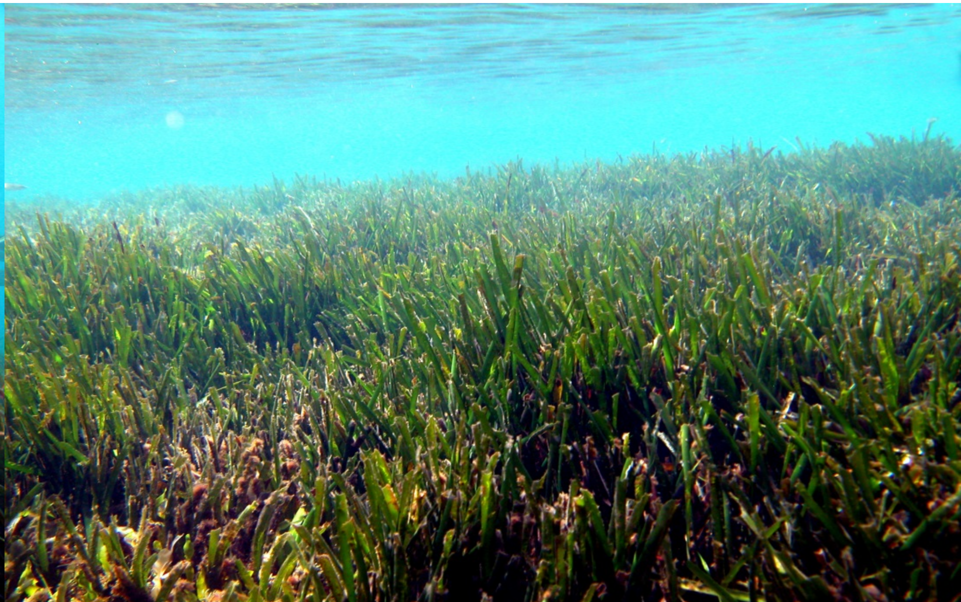
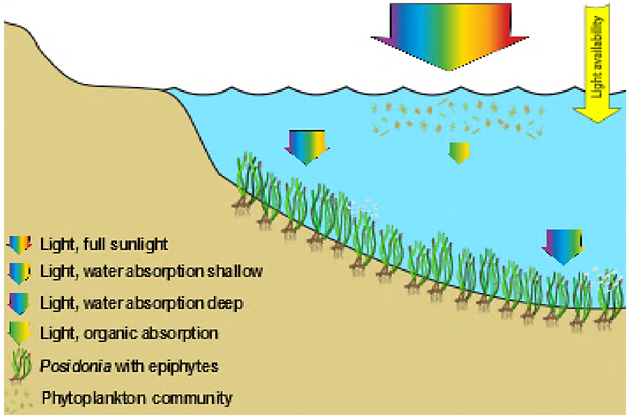
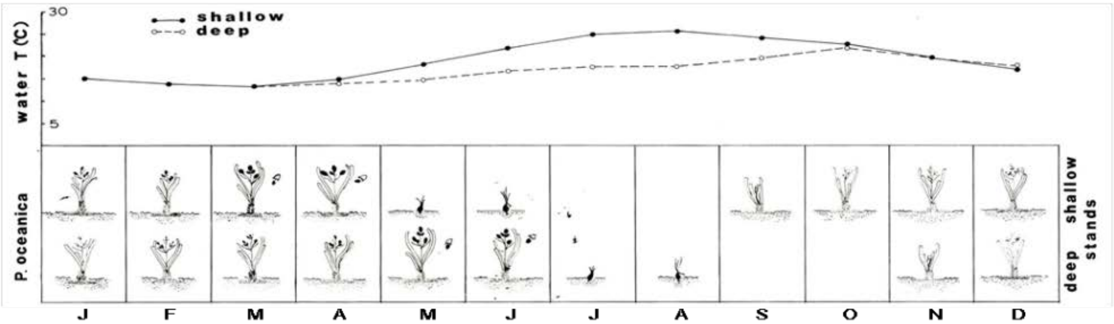


Meadows grow from the surface to 35 m depth



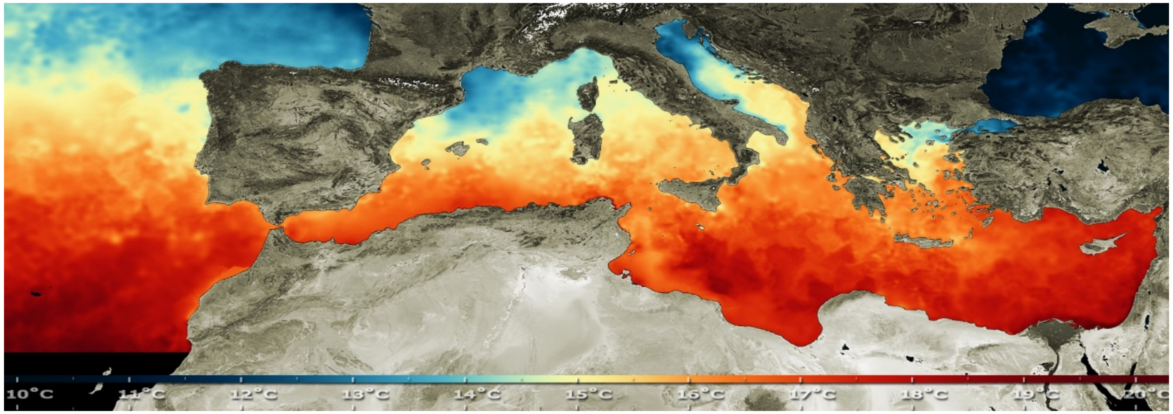
- Meadows experience **different light quantity and quality** along their distribution.
- The **same genotype** can experience differences in light from 50 to 1000 uE.
- Plants also experience **strong differences in temperature** when thermocline is stable



from Buia e Mazzella, 1991

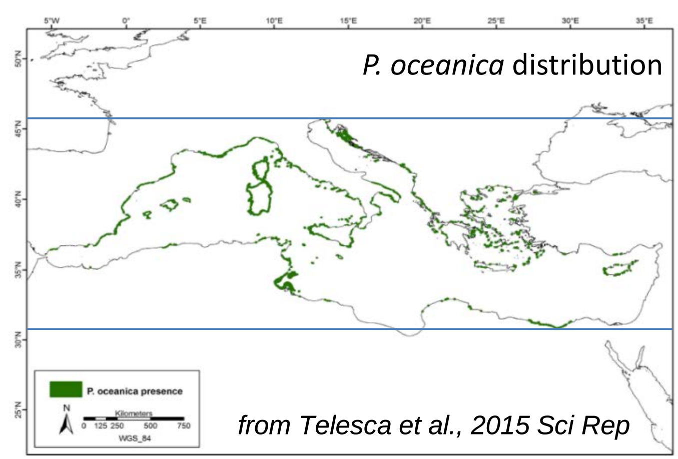
Plants growing at different depth show phenological differences

Meadows grow from from southern to northern Mediterranean coasts



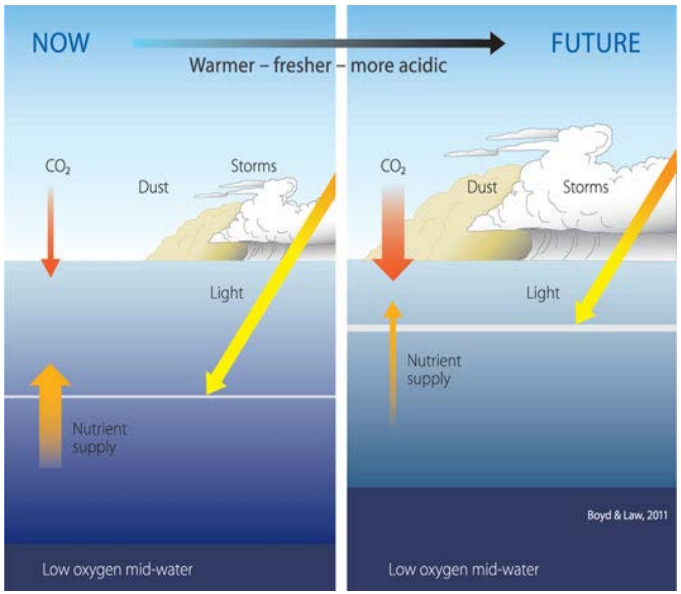
https://www.esa.int/spaceinimages/Images/2008/10/Mediterranean_sea_surface_temperature

- Meadows experience **different light quantity** along their distribution.
- Plants experience **strong differences in temperature** associated to strong differences in SST



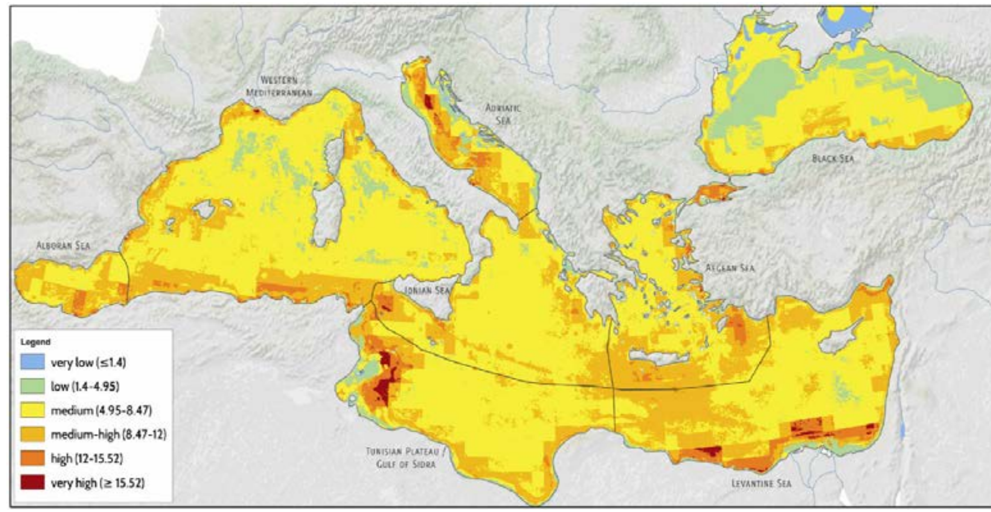
The marine biota is threatened by global climate change and direct human pressures

Consequences of Global Climate Change



from Reusch and Boyd 2012. Evolution

Map of cumulative impact



from Micheli et al 2013. Plos One

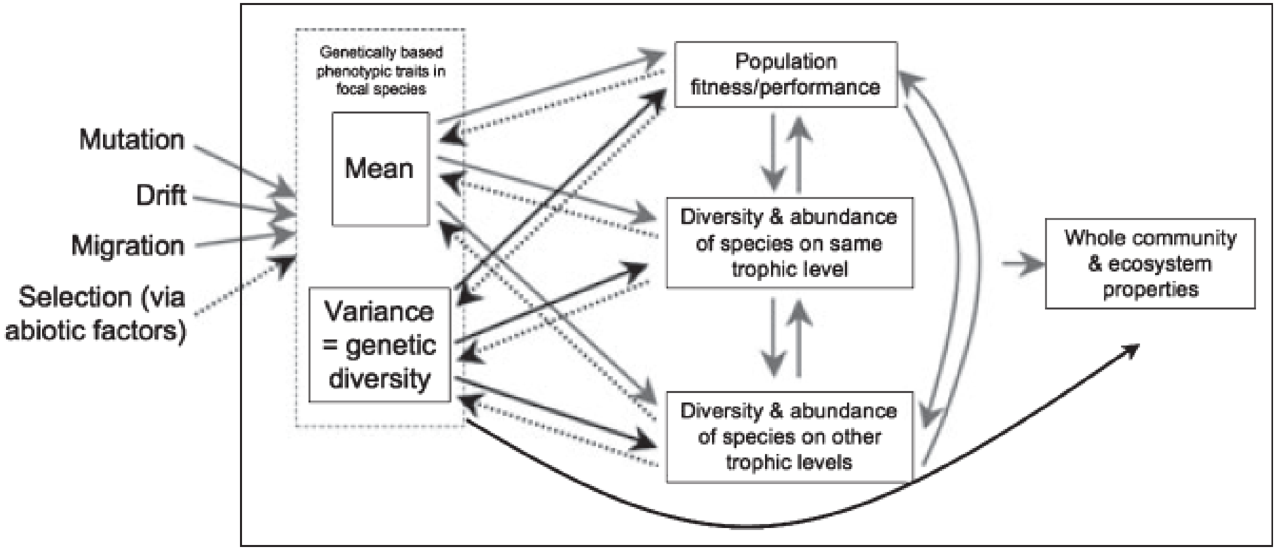
Seagrass ecosystems are declinig worldwide due global changes and to direct human pressures (e.g. urbanisation, discharges, harbour development, boating activities, tourism facilities)

Indicators of changes and state

Genetic approaches to seagrass conservation

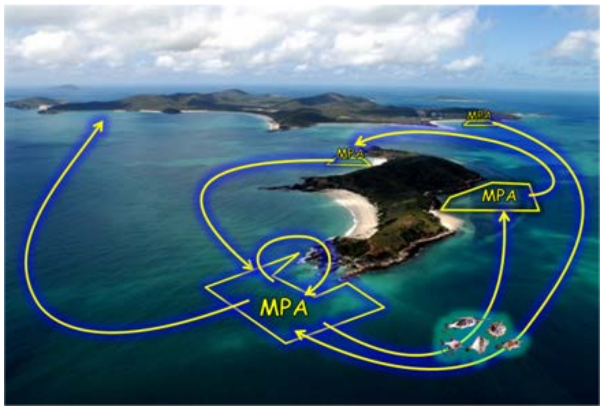
Ecosystem state
indicators

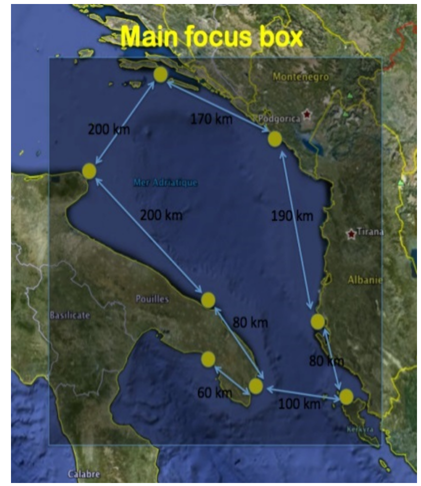
Analysis of genetic diversity to understand ecosystem state (seagrass potential for resistance and resilience)

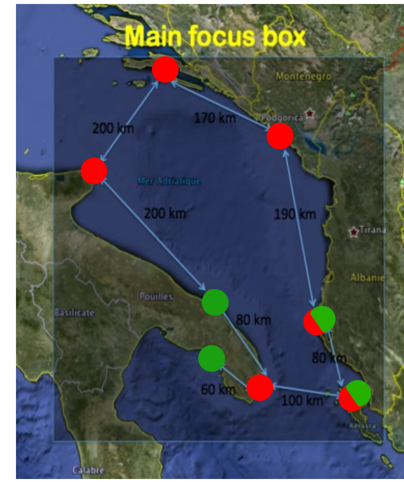


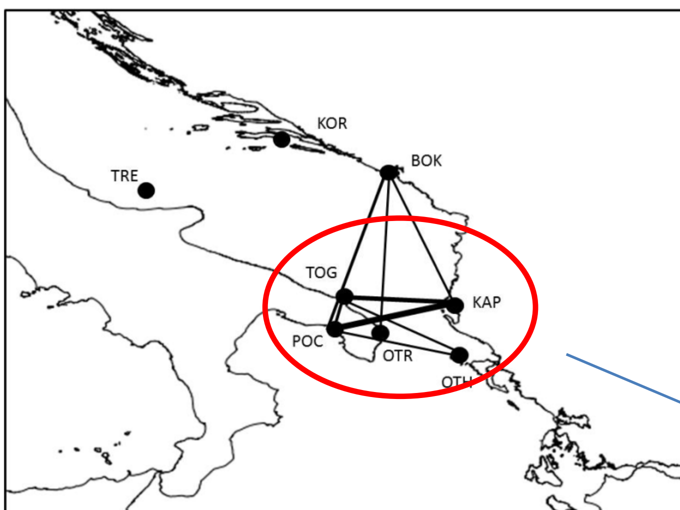
from Hughes et al 2008 Ecol. Lett.

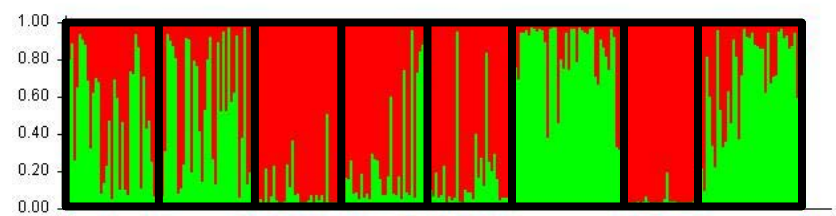
Assessment of connectivity for establishinig network of MPAs







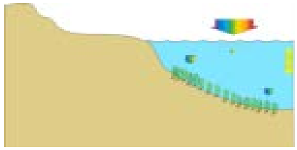


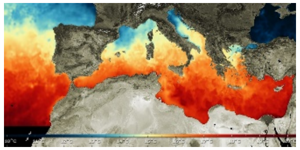


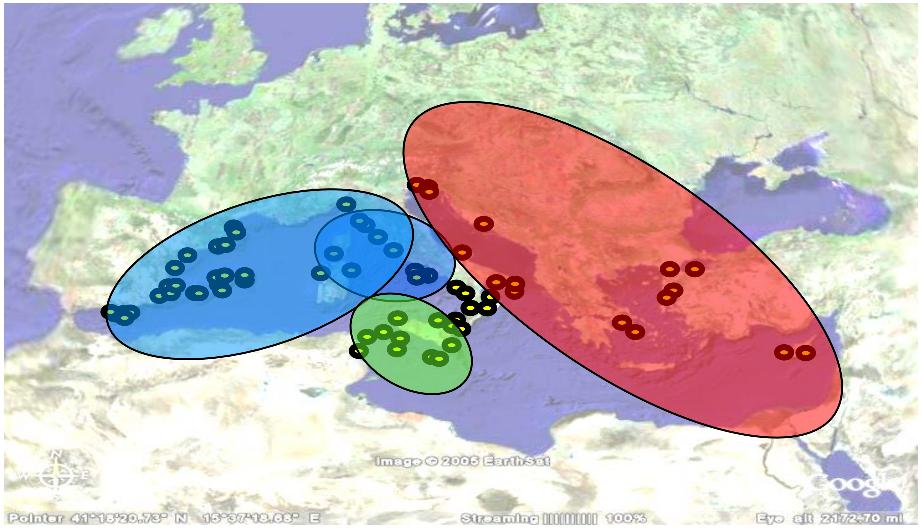
Minimum MPAs network system

Jahnke et al., 2017 Div Distr

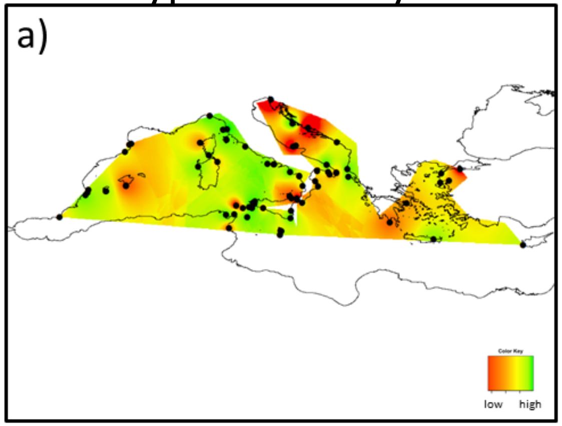
Genetic diversity along geographic and depth gradients



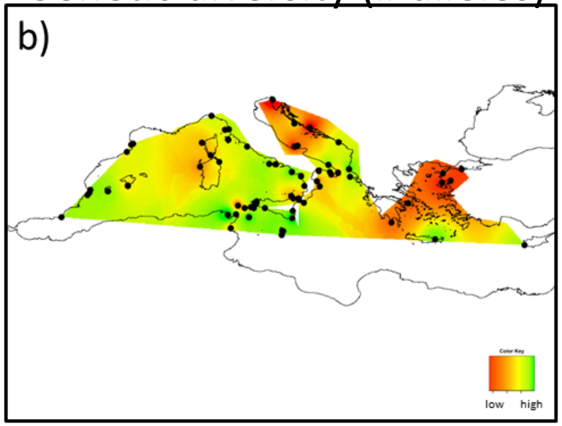




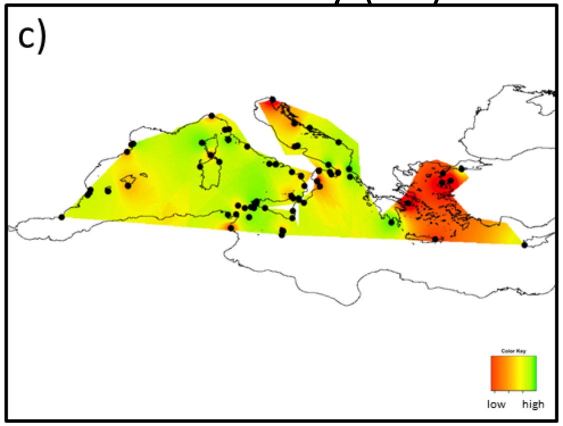
Genotypic diversity



Genetic diversity (# alleles)



Genetic diversity (Ho)

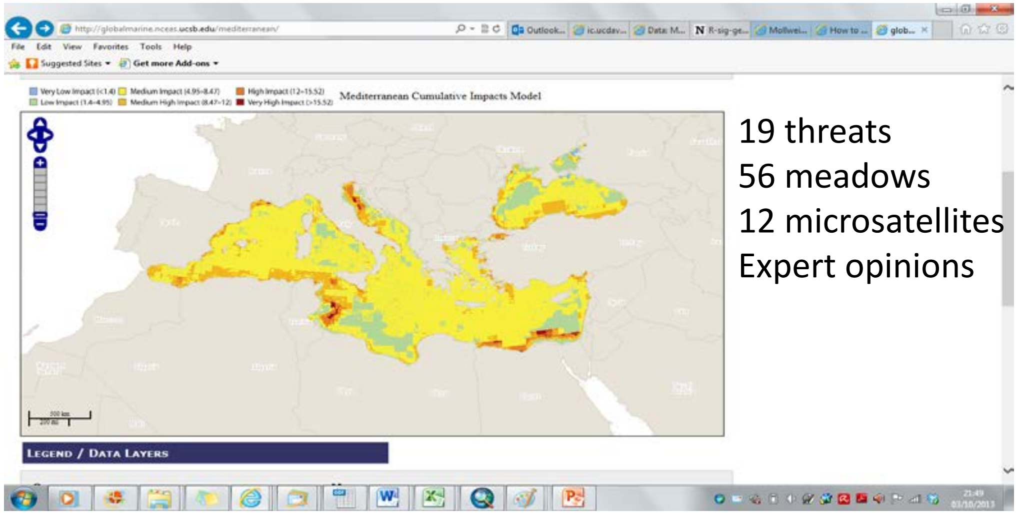


QGIS (Quantum GIS Development Team 2013)

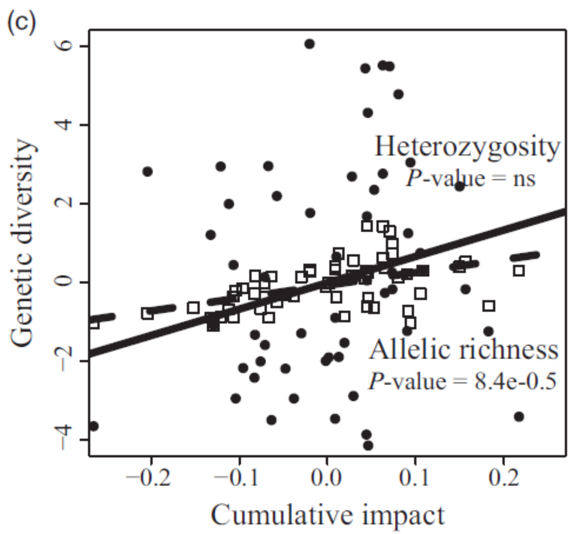
Arnaud-Haond et al. 2007 J Biogeogr; Serra et al., 2010 Mol Ecol; Jahnke et al., 2015 Mol Ecol

Role of genetic variation

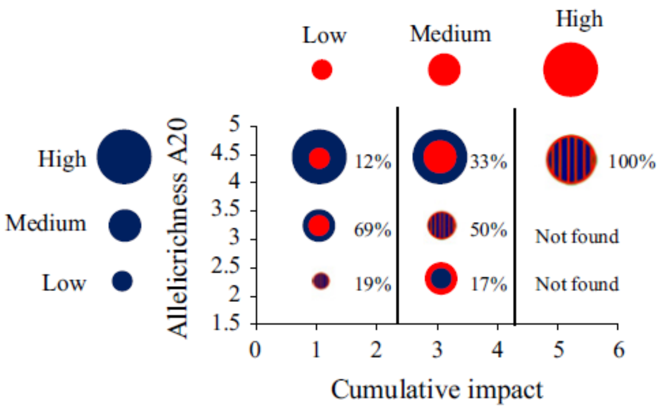
Disturbance and Diversity



19 threats
56 meadows
12 microsatellites
Expert opinions



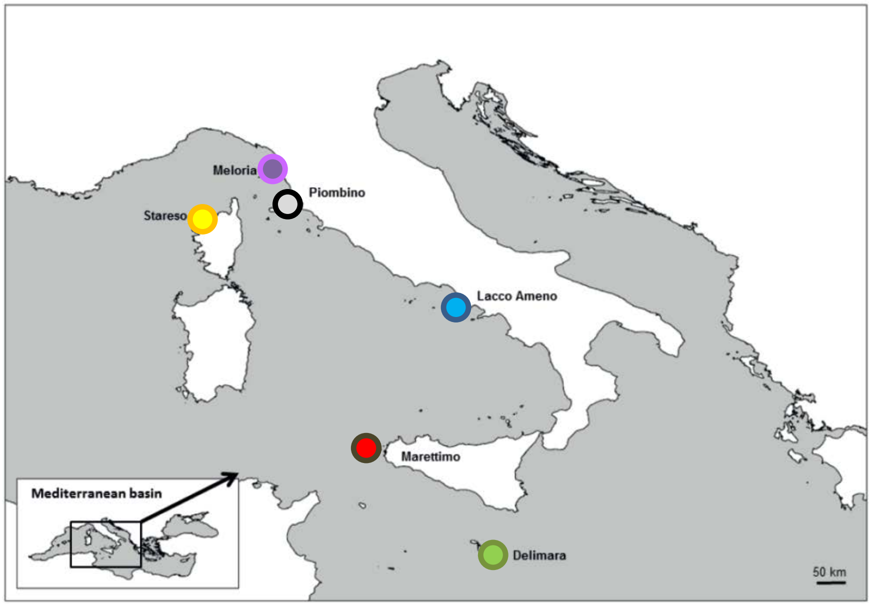
No populations were found with low allelic richness and high cumulative impact, suggesting that these were not able to cope with high impact

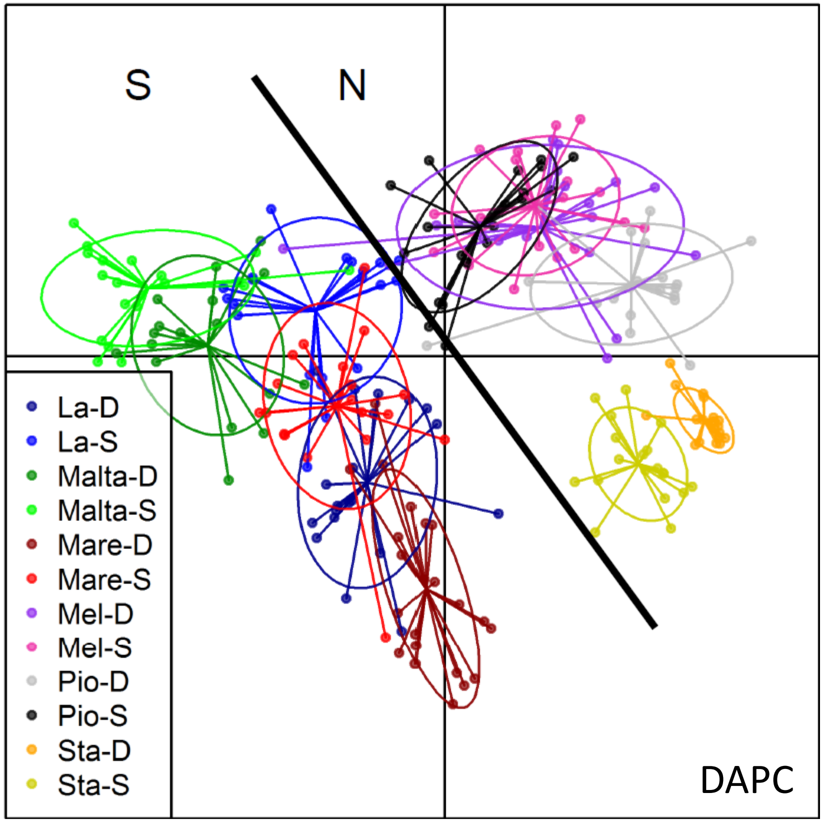


Jahnke et al., 2015 Mol Ecol

Role of genetic variation and structure

Analysis conducted with 24 microsatellite loci. Four outliers loci related to depth and two outlier loci related to latitude were identified.





Northern and southern and shallow and deep meadow stands appear to be genetically distinct

Jahnke et al. 2019 Heredity

Genetic structure at a meadow scale

Microsatellites based analysis identified clear genetic distinction between plants growing above and below the summer thermocline (~ -15m)

Genetic d … ustering

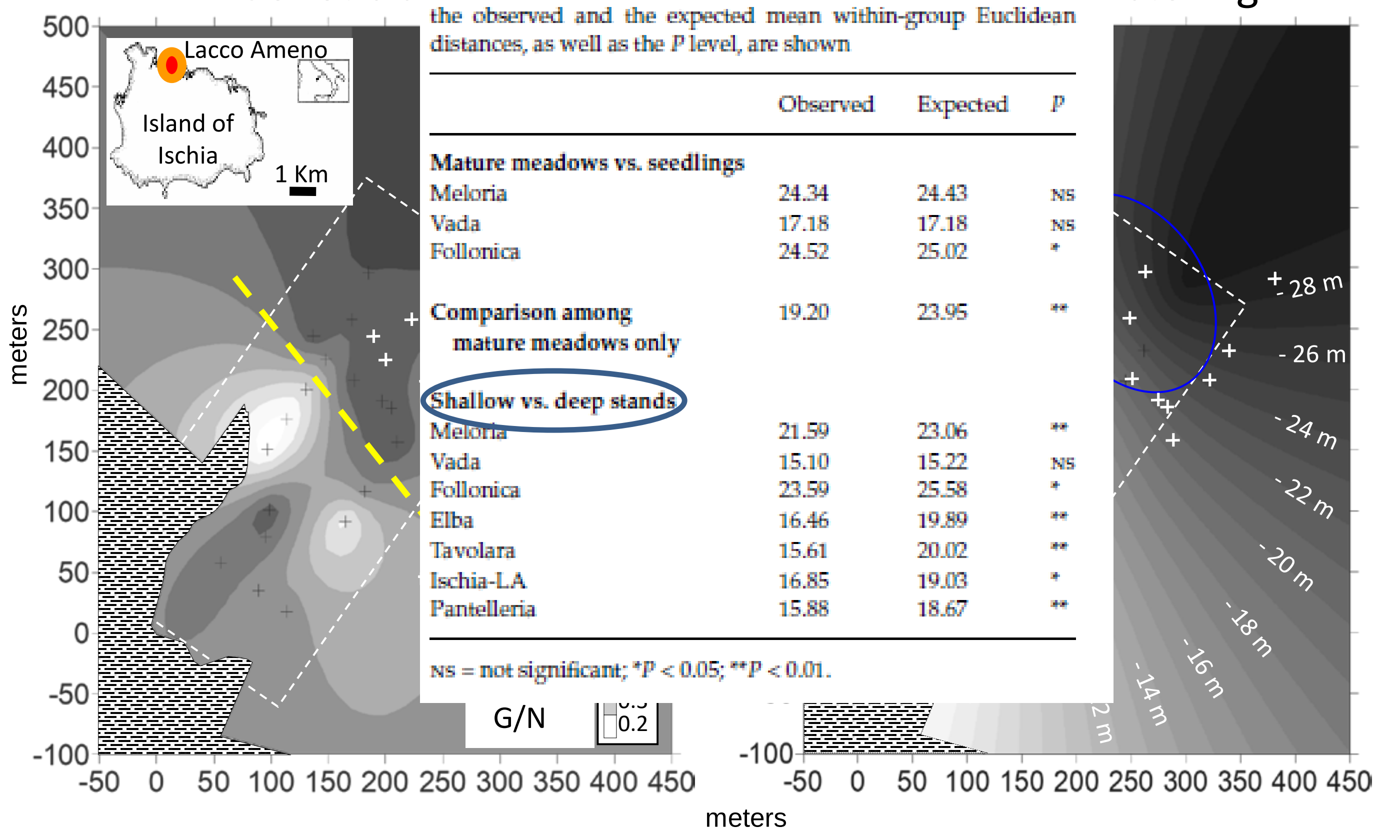


Table 2 MRPP test for identity of a priori defined groups. Both the observed and the expected mean within-group Euclidean distances, as well as the *P* level, are shown

	Observed	Expected	*P*
Mature meadows vs. seedlings			
Meloria	24.34	24.43	NS
Vada	17.18	17.18	NS
Follonica	24.52	25.02	*
Comparison among mature meadows only	19.20	23.95	**
Shallow vs. deep stands			
Meloria	21.59	23.06	**
Vada	15.10	15.22	NS
Follonica	23.59	25.58	*
Elba	16.46	19.89	**
Tavolara	15.61	20.02	**
Ischia-LA	16.85	19.03	*
Pantelleria	15.88	18.67	**

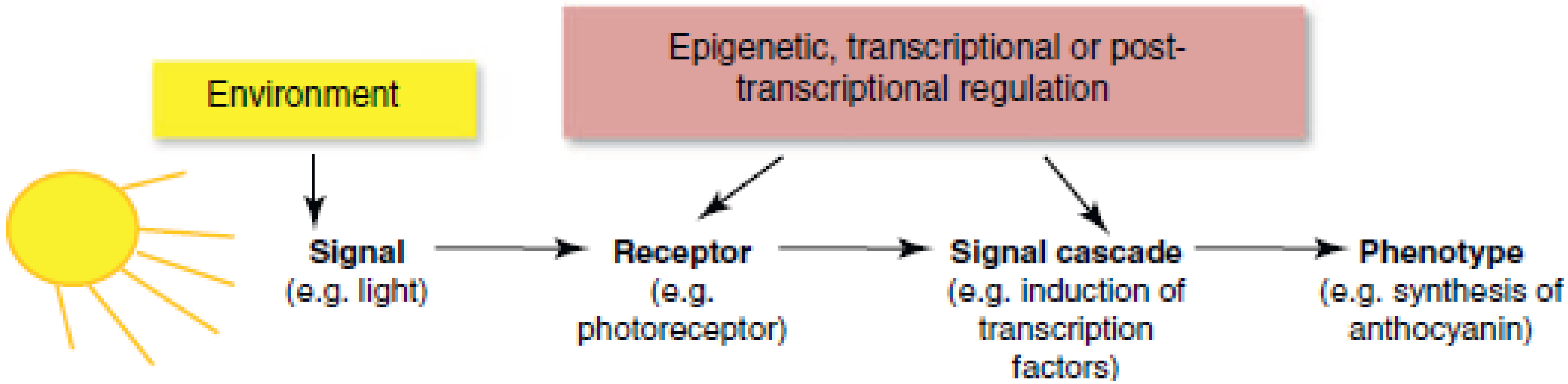
NS = not significant; $*P < 0.05$; $**P < 0.01$.

Procaccini et al 2001 Mol Ecol; Migliaccio et al. 2005 MEPS

Genetic approaches to seagrass conservation

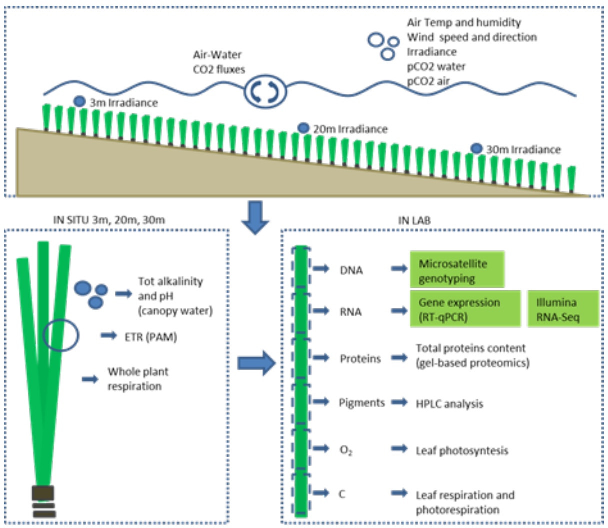
Indicators for detecting **response to changes in drivers**

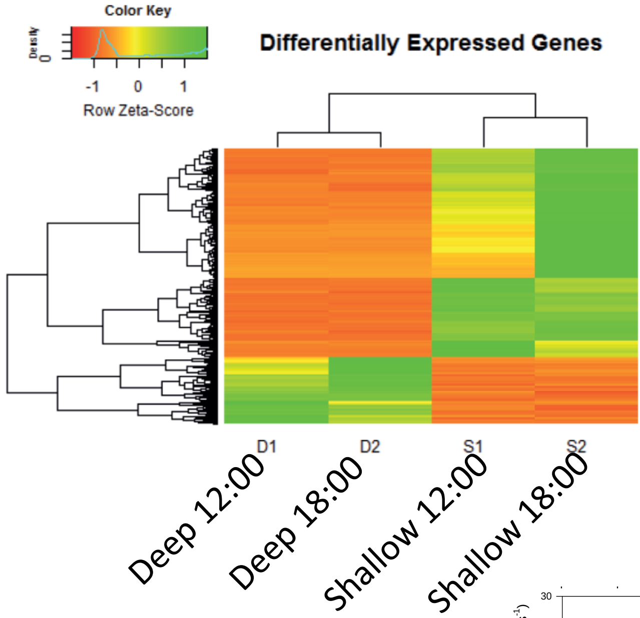
Analysis of gene expression for selecting early warning indicators

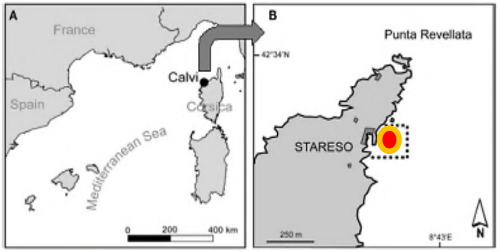


P. oceanica differential response along gradients

Difference in gene expression along depth

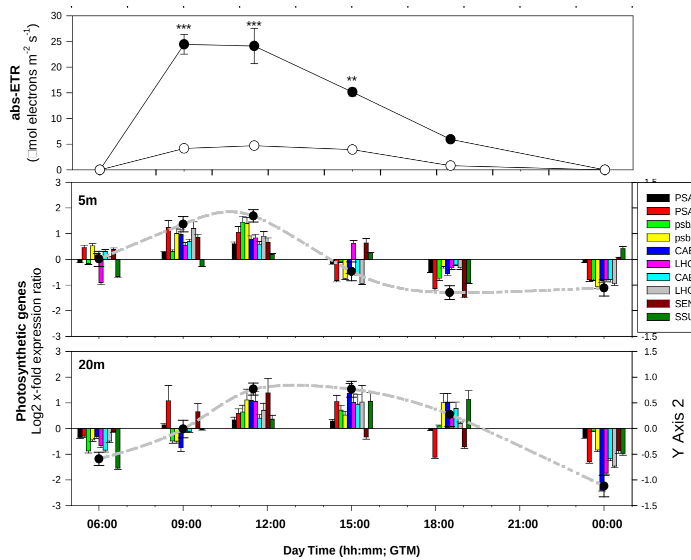






Shallow and deep plants are **locally adapted** to the existing environmental conditions and segregate according to depth

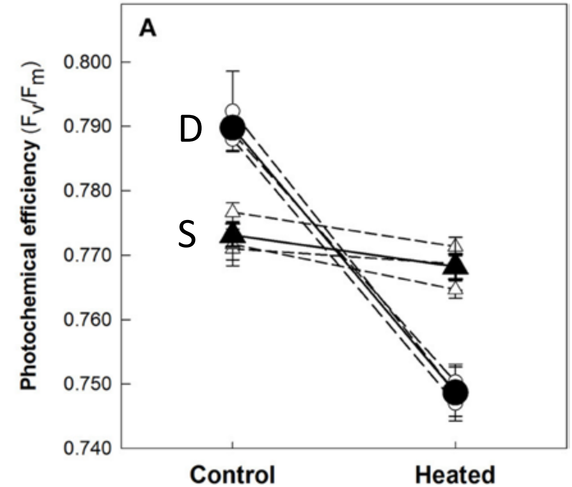
Photosynthesis

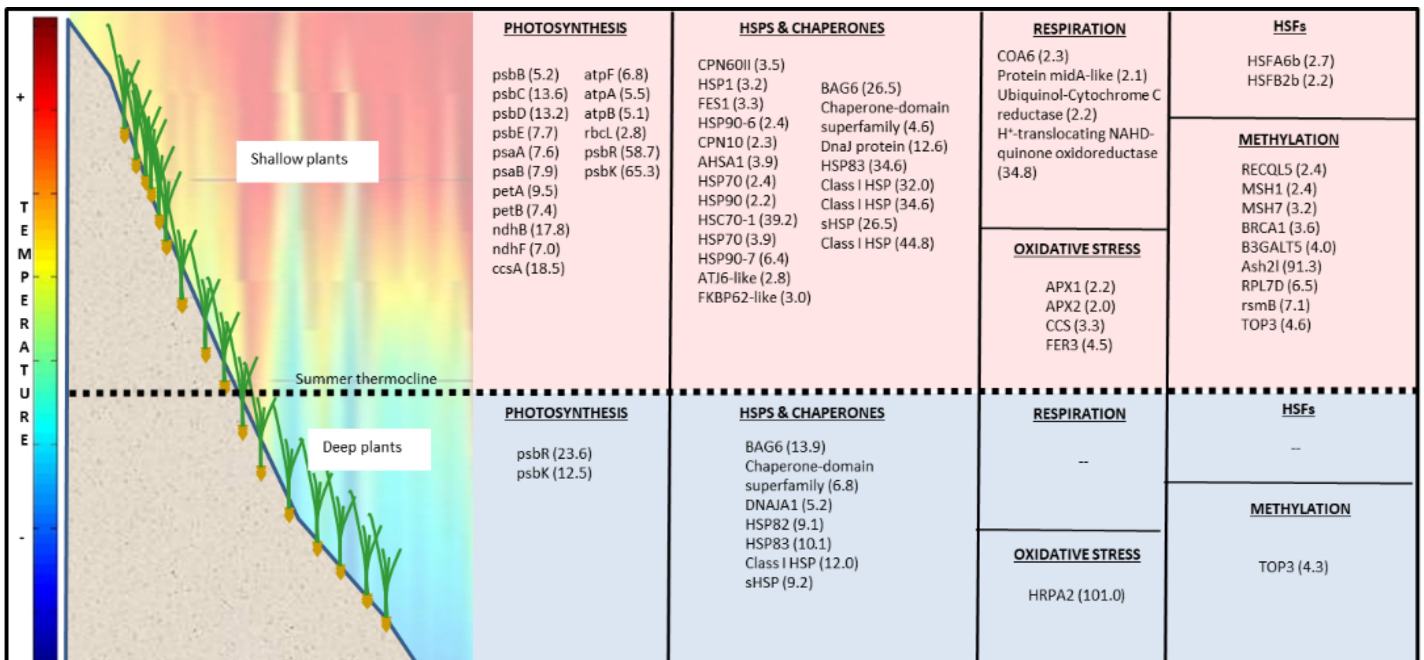


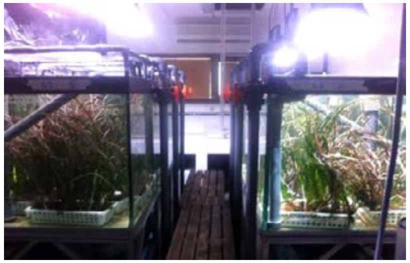
Procaccini et al. 2017 Sci Rep; Marin Guirao et al., 2017 Fr Plant Sci

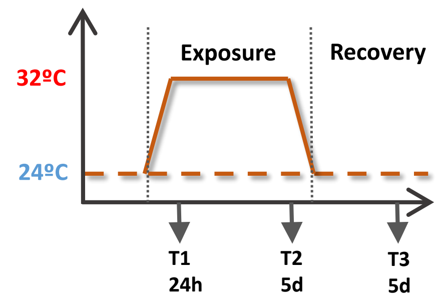
Difference in gene expression along depth

Shallow and deep plants have a different capability to respond to a simulated temperature increase (heat wave)





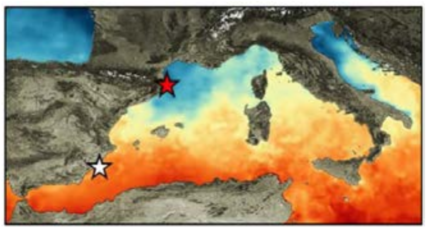


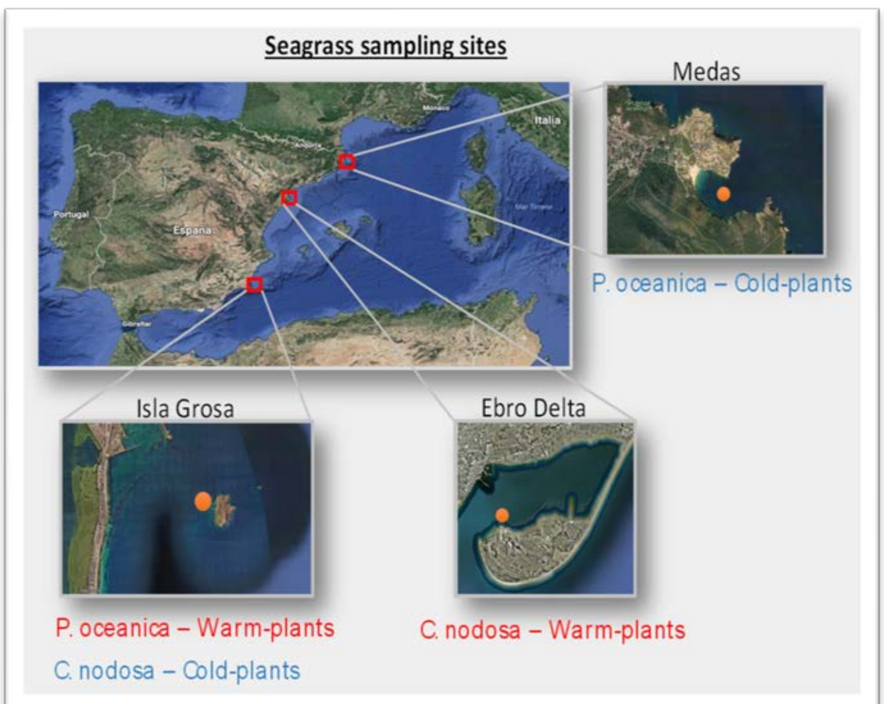


Procaccini et al. 2017 Sci Rep; Marin Guirao et al., 2017 Fr Plant Sci

P. oceanica differential response along gradients

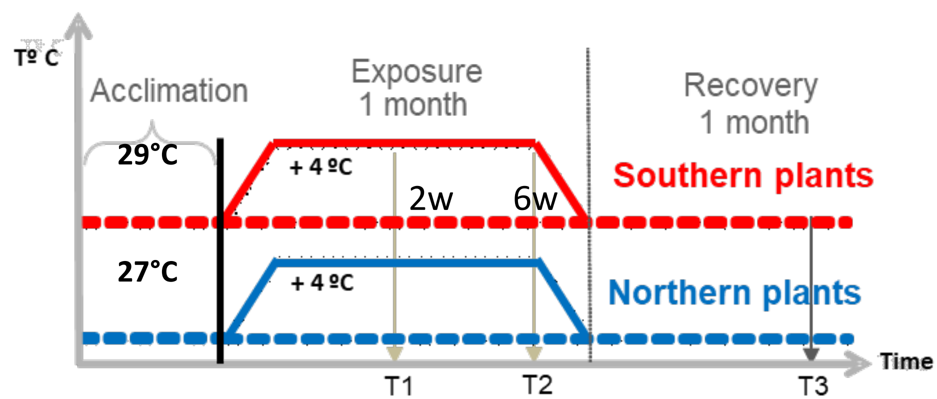
Long term exposure to heat stress of plants from a latitudinal gradient (24 libraries – Ion Torrent) *P. oceanica* – *C. nodosa*





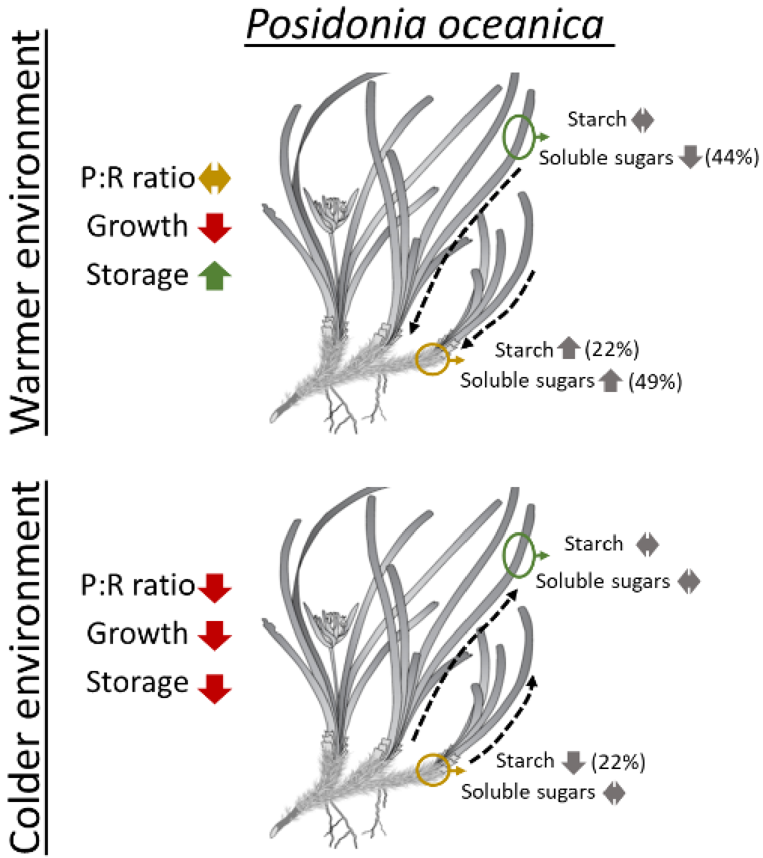
SAMPLING:

- PAM: weekly
- Mortality: weekly
- Antioxidant activity: T2 & T3
- Carbohydrates: T2 & T3
- Photosynthesis & Respiration: T2 & T3
- Pigments: T2 & T3
- Growth: T2 & T3
- Morphology: T2 & T3



Marin Guirao et al., 2018 Mar Poll Bull

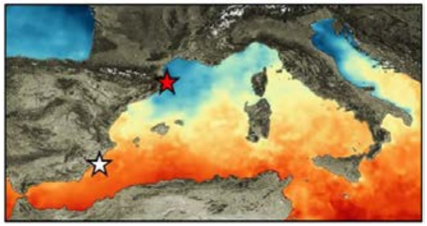
P. oceanica differential response along gradients

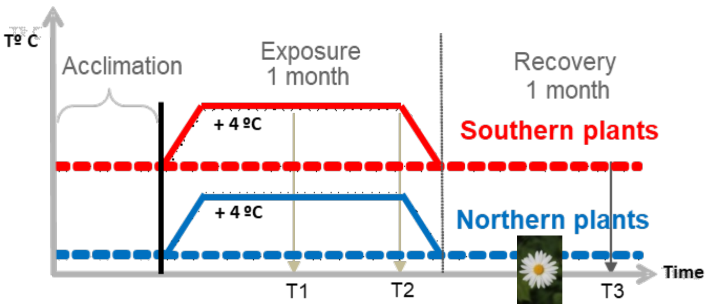


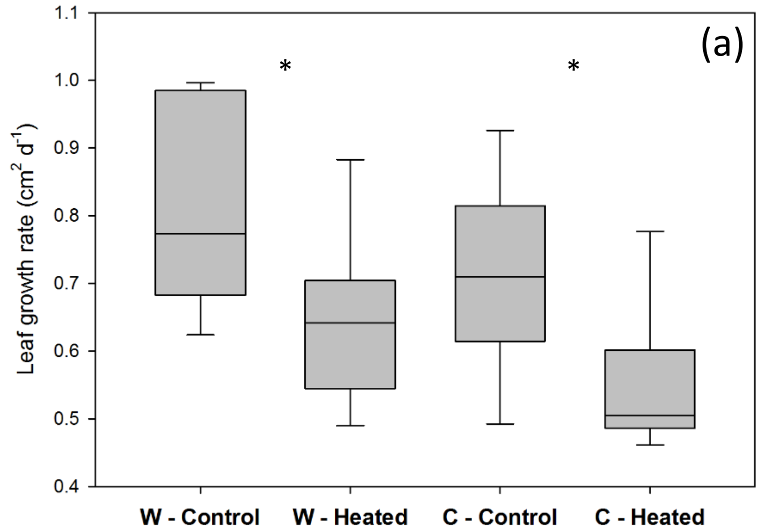
Plants from colder environments are more affected by warming.

Marin Guirao et al., 2018 Mar Poll Bull

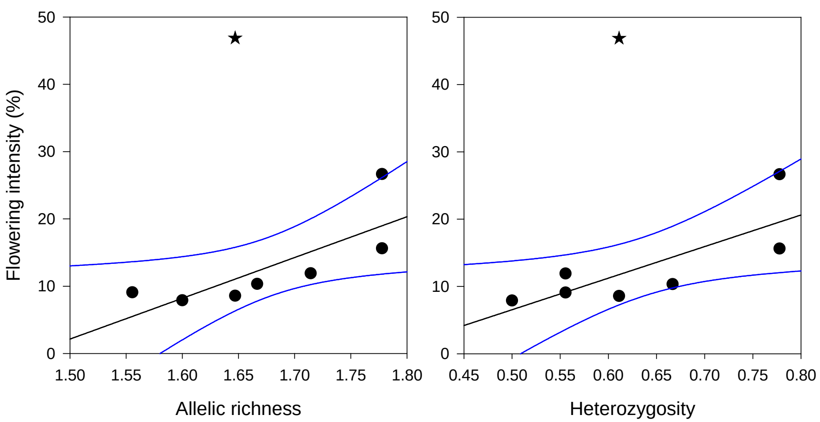
Stress response to warming

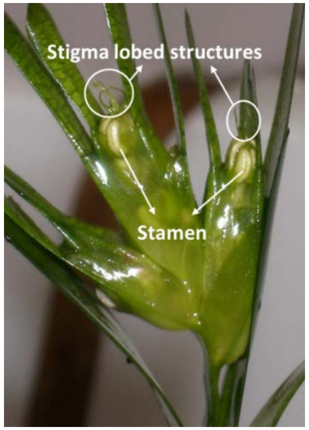






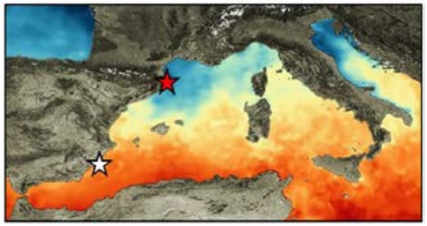
Genetic diversity of flowering plants correlate with flowering intensity

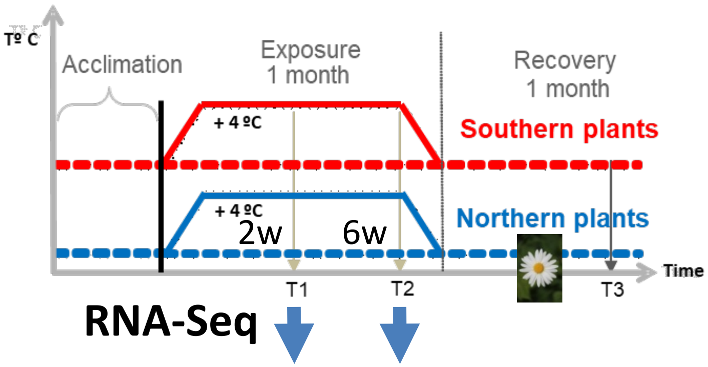


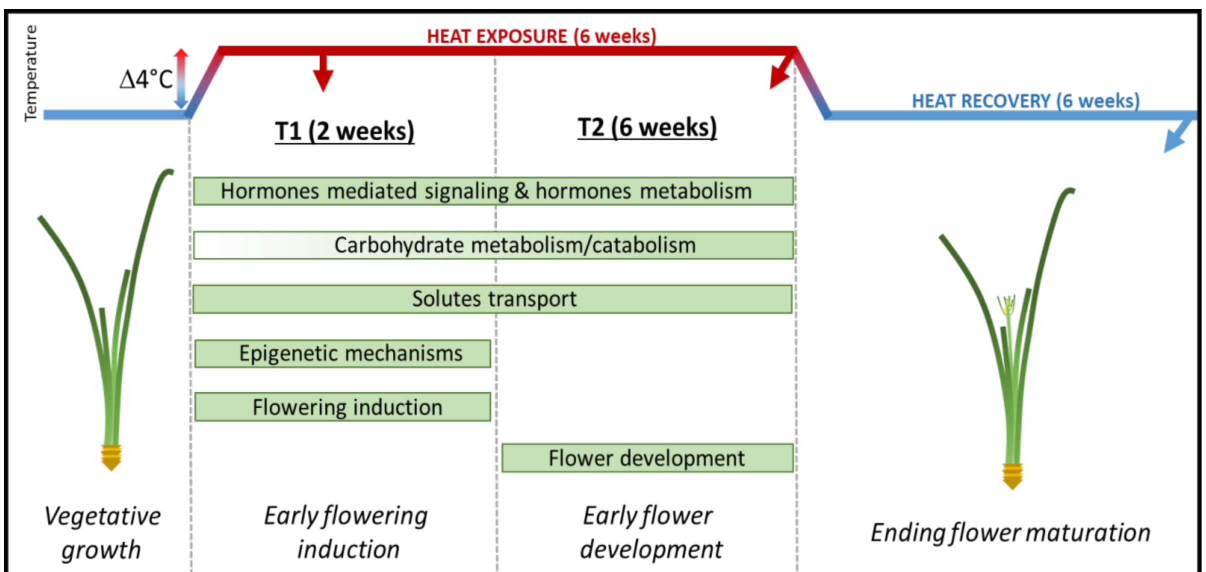


Ruiz et al 2017 Mar Poll Bull; Marin Guirao et al., 2018 Mar Poll Bull

Stress response to warming







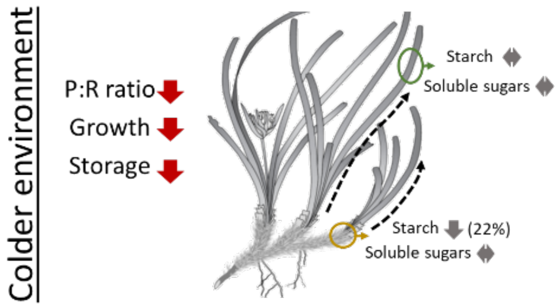
Marin Guirao et al., 2019 Mol Ecol

Flowering induction starts already after two weeks of warming

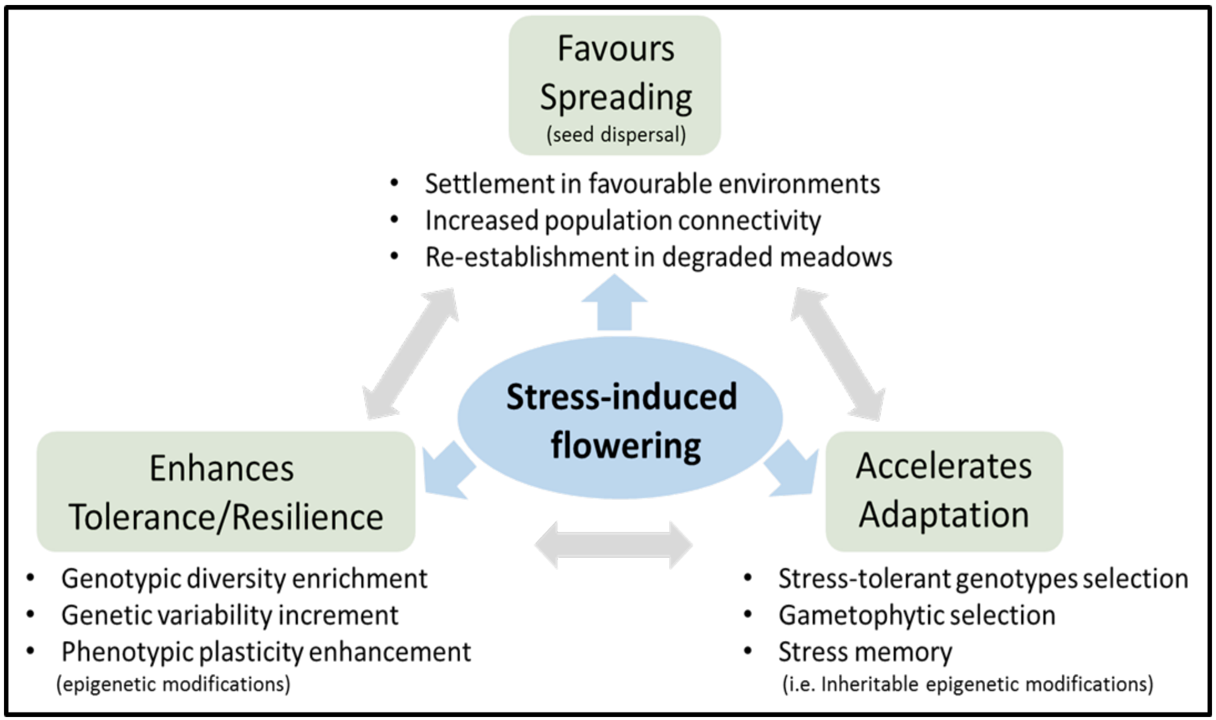
Flower development genes are expressed when flowers are still not visible

Stress response to warming

Altered expression levels of several transcriptional factors, photoperiodic-genes and gene familes, which **regulates flowering time by modulating the photoperiod pathway**



Plants invest energy in the response to stress

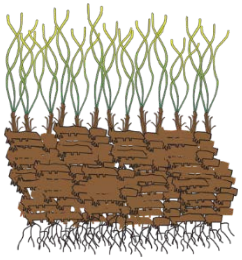


Marin Guirao et al., 2019 Mol Ecol

Mutiple stressors and early warning indicators

SPECIES

Posidonia oceanica

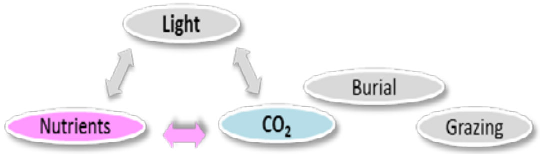


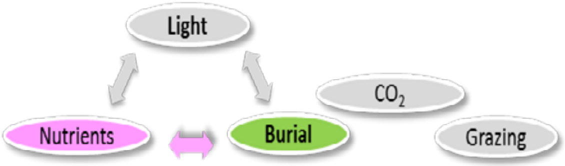
FACTORS

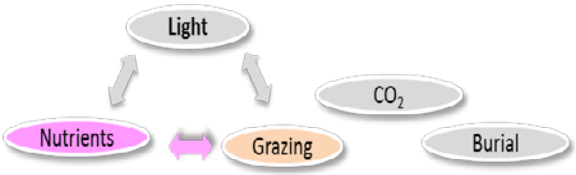
EXPERIMENTAL DESIGN

APPROACH

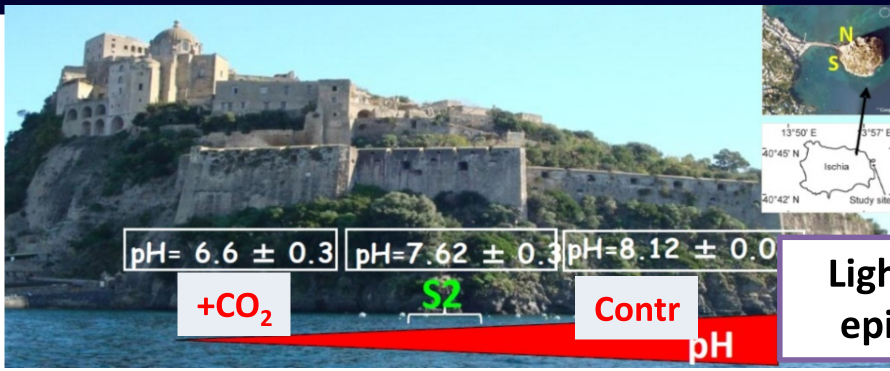
FACTORS	EXPERIMENTAL DESIGN	APPROACH
CO_2 and NUTRIENTS	Two levels of CO_2 and three levels of nutrients. At volcanic vents - Ischia.	RT-qPCR
NUTRIENTS and BURIAL	Two levels (medium and high) of nutrients and burial. In the field	RT-qPCR
NUTRIENTS and GRAZING	Two levels of intensity (high and control) and temporal variance (pulse and press) of nutrients and grazing activities (natural and overgrazing). In the field	RT-qPCR







Effects of **CO2 and nutrient supply on** plant performance



Plants were treated with different levels of nutrients High N, Mod N

The experiment lasted 15 months

Light stress for epiphyte loss

LOW pH

Nutrient limitation

Lower seagrass productivity

NUTR^{+}

NUTR^{+++}

NORMAL pH

Normal seagrass productivity

NUTR^{+} NUTR^{+++}

Lower seagrass productivity

Higher antioxidants response

Carbon reserves depletion

Epiphyte overgrowth

Stress responsive genes +++

Cumulative effect of stressors

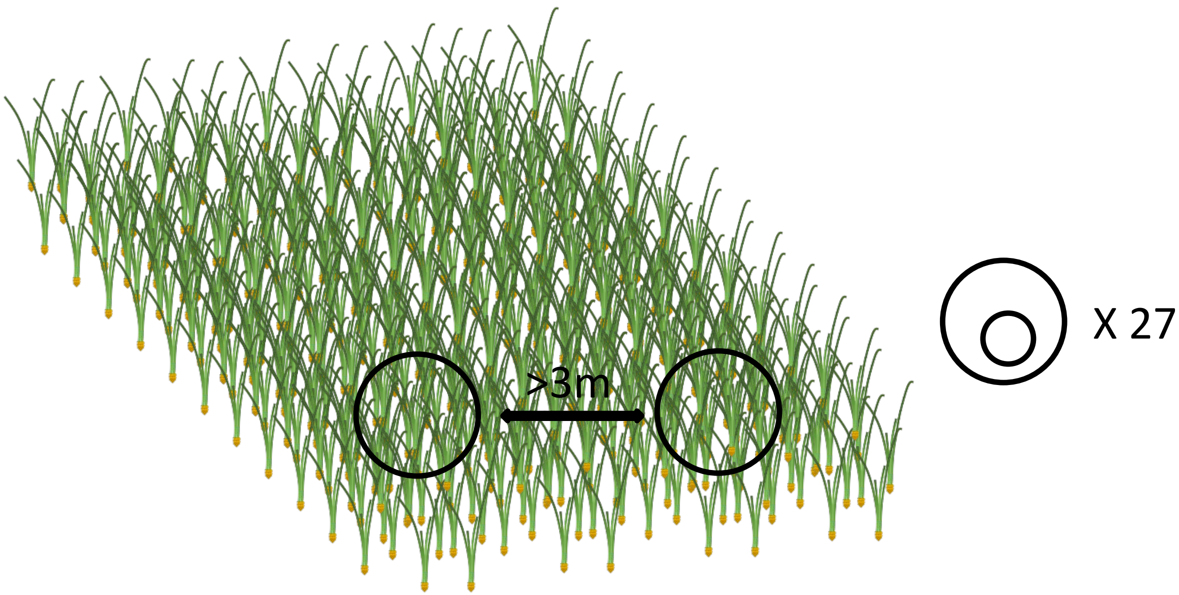
Stress responsive genes ---

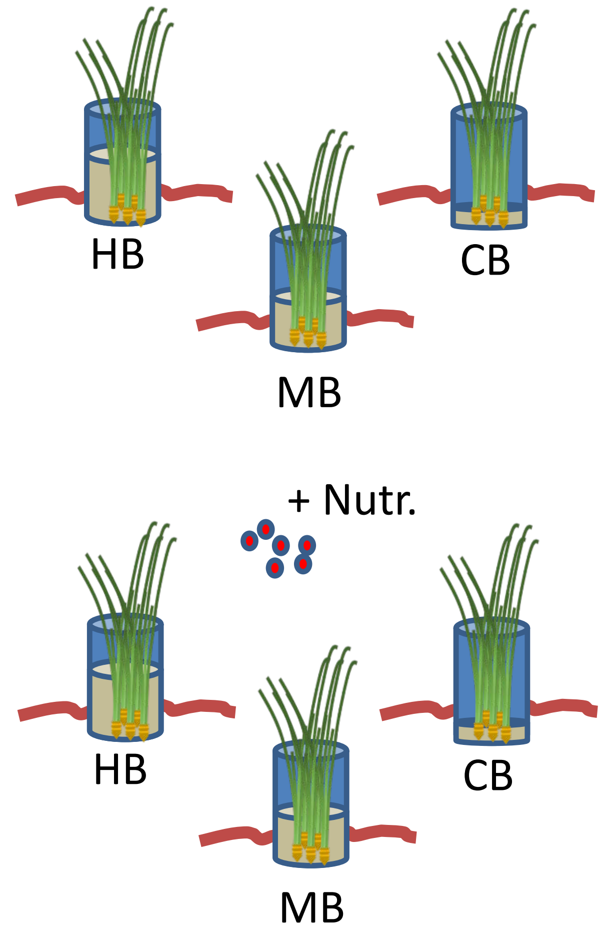
Nitrogen transporters +++

Compensation of C/N balance

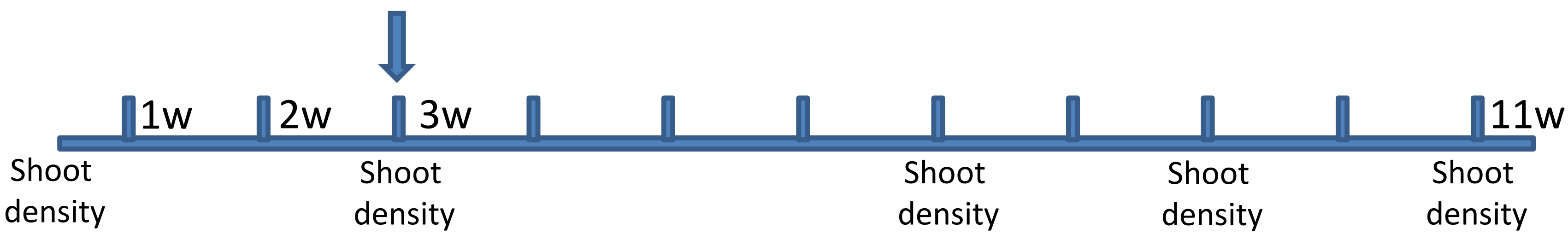
Ravaglioli et al. subm

Mutiple stressors and early warning indicators



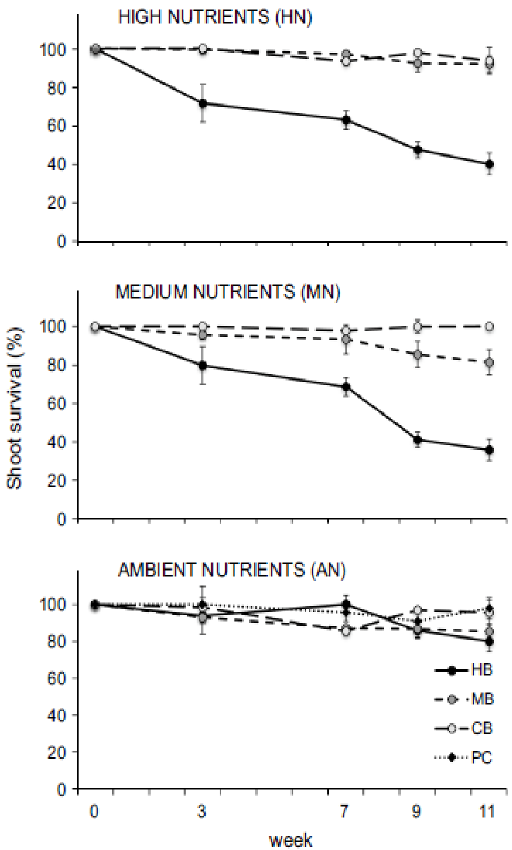


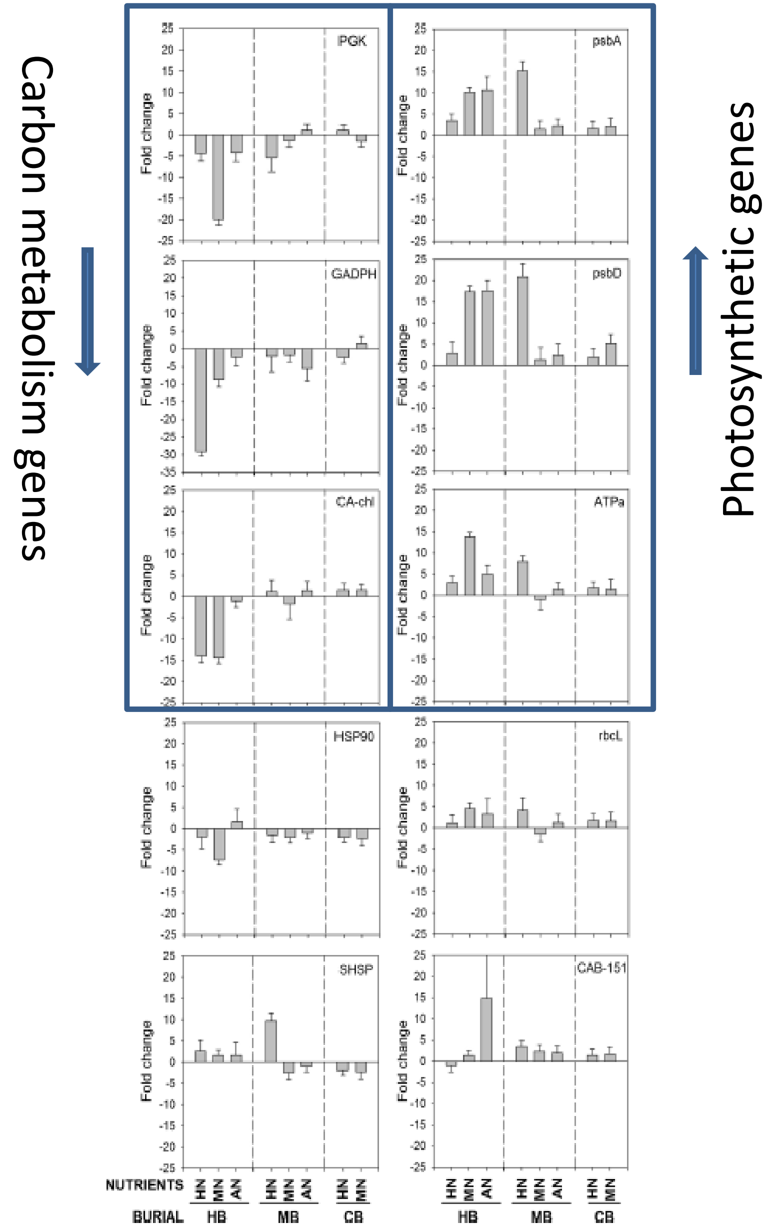
6 - morphological variables
11- physiological biochemical variables
10 – stress related genes



Ceccherelli et al. 2018 Oecologia

Early warning indicators





Ceccherelli et al. 2018 Oecologia

Early warning indicators

The multiple regressions conducted with morphological, antioxidant, isotope, and genetic covariates explained the 27.8%, 36.4, 33.2 and 60.6 (Adjusted *R*2 values) of the variance in shoot survival, respectively

Effect	Estimate	SE	*t* value	*p* value
Morphological/growth				
Epiphyte load	− 0.00365	0.00104	− 3.50	**0.00193**
Shoot biomass	− 0.17576	0.10531	− 1.66	0.10869
Leaf growth	0.06651	0.03766	1.766	0.09066
Adjusted $R^2 = 0.2779$	$F_{3,23} = 4.33$ *p* value 0.0146			
Physiological and biochemical (antioxidant)				
ORAC	− 0.0004	0.00013	− 3.045	**0.00557**
Phenolics	0.0007	0.00021	3.697	**0.00113**
Adjusted $R^2 = 0.3644$	$F_{2,24} = 8.45$ *p* value 0.0016			
Physiological and biochemical (isotopes)				
Leaf N	− 0.4591	0.2735	− 1.678	0.1075
Leaf δ^{15}N	− 0.1782	0.1195	− 1.491	0.1501
Leaf S	− 0.5854	0.4482	− 1.306	0.2050
Leaf δ^{34}S	0.0627	0.0266	2.356	**0.0278**
Adjusted $R^2 = 0.3321$	$F_{2,22} = 4.23$ *p* value 0.0108			
Gene expression				
CA-chl	0.0546	0.00972	5.623	**0.00000**
ATPa	− 0.0216	0.01205	− 1.796	0.08510
Adjusted $R^2 = 0.6056$	$F_{2,24} = 20.96$ *p* value 0.0000			

Variable	Stressor effect	Association to survival
Epiphyte load	↑N ↑B	Very high
Necrosis	↑N ↑B	–
Leaf growth rate	↑N	Low
ORAC	No Ha	Medium
TEAC	↑N	–
Phenolics	↓N ↓B	High
Leaf δ^{34}S	No effect	Medium
GADPH	No Ha	–
HSP90	No Ha	–
PGK	↓B	–
psbA	No Ha	–
CA-chl	↓ B	Very high
ATPa	↑ B	Low

The positive estimate of Ca-chl suggests that overexpression of this gene at week 3 is positively correlated with shoot survival at week 11

The chloroplast carbonic anhydrase (CAchl) catalyzes the conversion of HCO3 into CO2

84% of the variation in shoot mortality explained by the model

Ceccherelli et al. 2018 Oecologia

Overall conclusions

- **Genetic diversity matters in responding to adverse conditions**
- **Seagrass meadows are locally adapted to existing environmental conditions**
- **Reaction norm and response plasticity depend from the environmental conditions plants experience in their distribution areal**
- **Flowering is a stress response allowing plants to escape from adverse conditions**
- **Target genes can be used as early warning indicators**

Thank you for your attention

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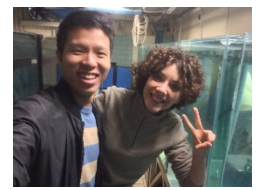

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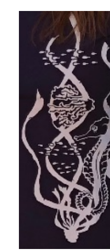

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https://www.researchgate.net/lab/Gabriele-Procaccinis-Group-Molecular-Ecology-of-Seagrasses-Gabriele-Procaccini

https://gpgroupszn.wixsite.com/website