# Tolerance to climate change of early life-stage *Fucus vesiculosus* varies among sibling groups

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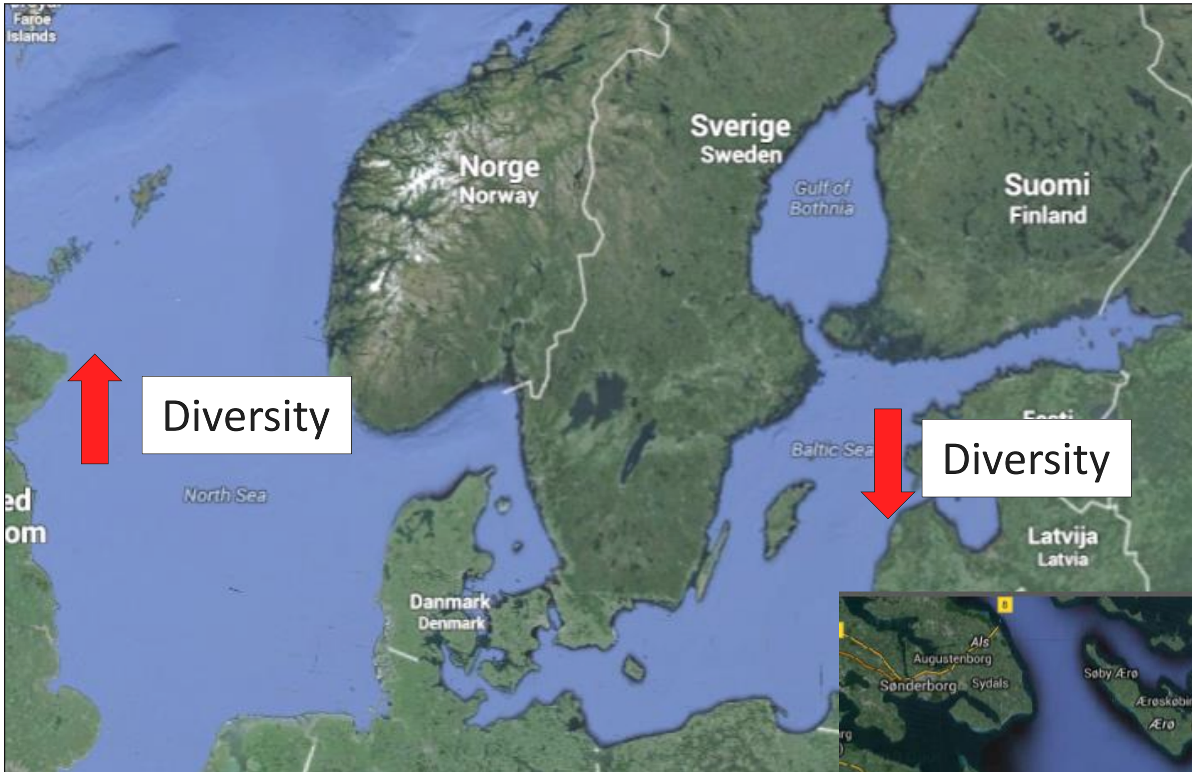
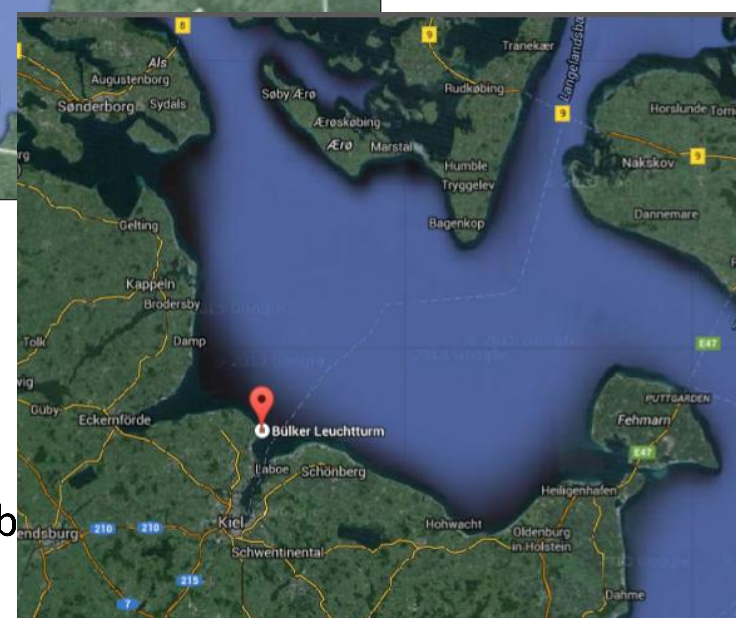
# Genetic diversity of *Fucus vesiculosus*




Confers potential for adaptation through selection

Allows for resilience and ecosystem services

**Hypothesis:** Populations of high genetic diversity perform b

# *Fucus vesiculosus* – Bülk Population

Genotyping of 42 adult *Fucus vesiculosus*

-> their physiological responses at the Benthocosms experiment (T x CO2) were analysed Angelika Graiff

9 microsatellite markers were used to describe the genetic diversity:

**Parameters**:

$H_O$ Observed Heterozygosity

$H_E$ Expected Heterozygosity

$F_{IS}$ Inbreeding factor

# Genetic diversity of *Fucus vesiculosus*

## Microsatellite analysis of 42 adult *F. vesiculosus*

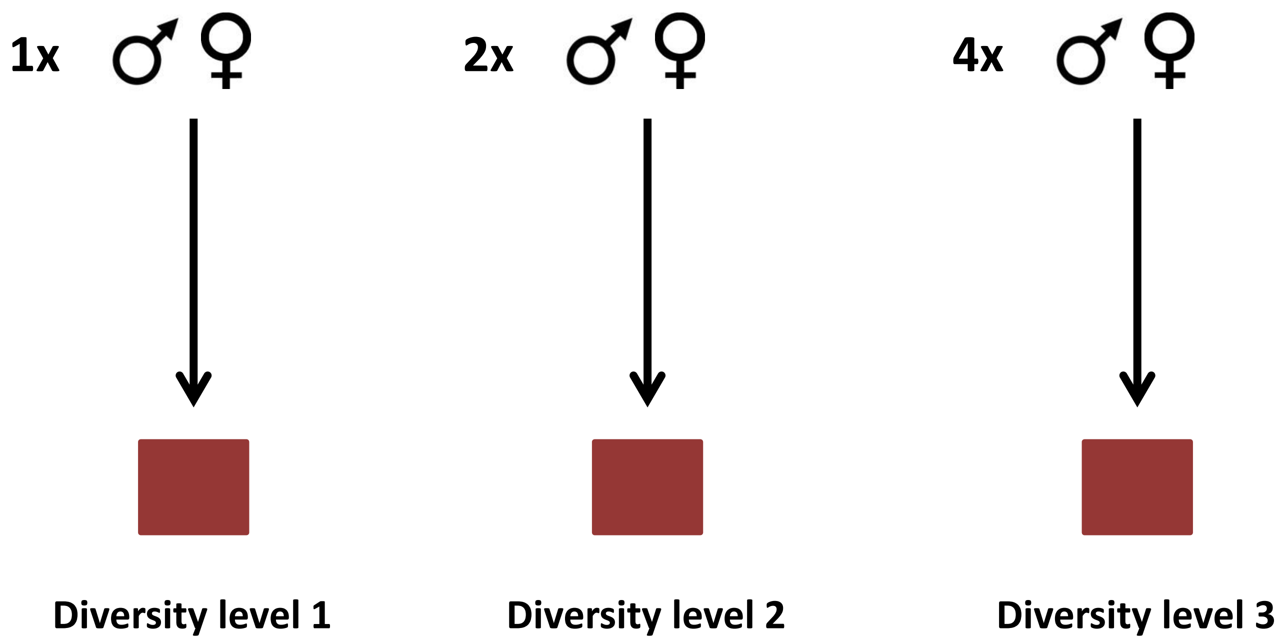
| Locus | $N_A$ | Size range (bp) | $H_O$ | $H_E$ | $F_{IS}$ |
|---|---|---|---|---|---|
| **L85** | 8 | 112 - 126 | 0,7105 | 0,6274 | - 0,135 |
| **L94** | 5 | 151 - 184 | 0,9000 | 0,6038 | -0,500 |
| **Fsp1** | 11 | 122 - 160 | 0,8158 | 0,8242 | 0,010 |
| **Fsp2** | 17 | 115 - 195 | 0,5000 | 0,9069 | 0,452 |
| **F9** | 10 | 184 - 212 | 0,6579 | 0,8182 | 0,198 |
| **F19** | 10 | 162 - 192 | 0,5714 | 0,6779 | 0,159 |
| **F34** | 8 | 186 - 220 | 0,9750 | 0,6655 | -0,474 |
| **F36** | 3 | 216 - 224 | 0,9231 | 0,5891 | -0,579 |
| **F60** | 3 | 188 - 194 | 0,3000 | 0,4165 | 0,282 |
| **Total** | **x = 8.33** | | 0,7060 | 0,6810 | Estimation multilocus: - 0,0370 |

# Settlement of germlings

Collection of **fertile adult** *Fucus vesiculosus*


Induction of **gamete release**

**Settling of germlings** on limestones cubes: edge length 2 cm.



# Three diversity levels of *Fucus vesiculosus* gemlings

**Diversity level**

**offspring of 1 parental pair each**

**Low** 1 2 3 4 5 6 7 8

***versus***

**offspring of 2 parental pairs each**

**Medium** 1, 2 3, 4 5, 6 7, 8

***versus***

**offspring of 4 parental pairs each**

**High** 1, 2, 3, 4 5, 6, 7 , 8

# Climate change scenario: Kiel Benthocosms

Investigation of **species interactions** and **community structure** under climate change

**Upscaling** of: Multiple **factors**, Multi-**species** communities, Multi-**seasonal** approach

**Flow-through system** allows a near natural scenario

Closing the gap **between laboratory and field** experiments

Wahl et al. 2015 *Limnology and Oceanography: Methods*

# Warming and acidification: Kiel Benthocosms

**Seasonal variation - 2013**

**Temperature:** + 5 °C

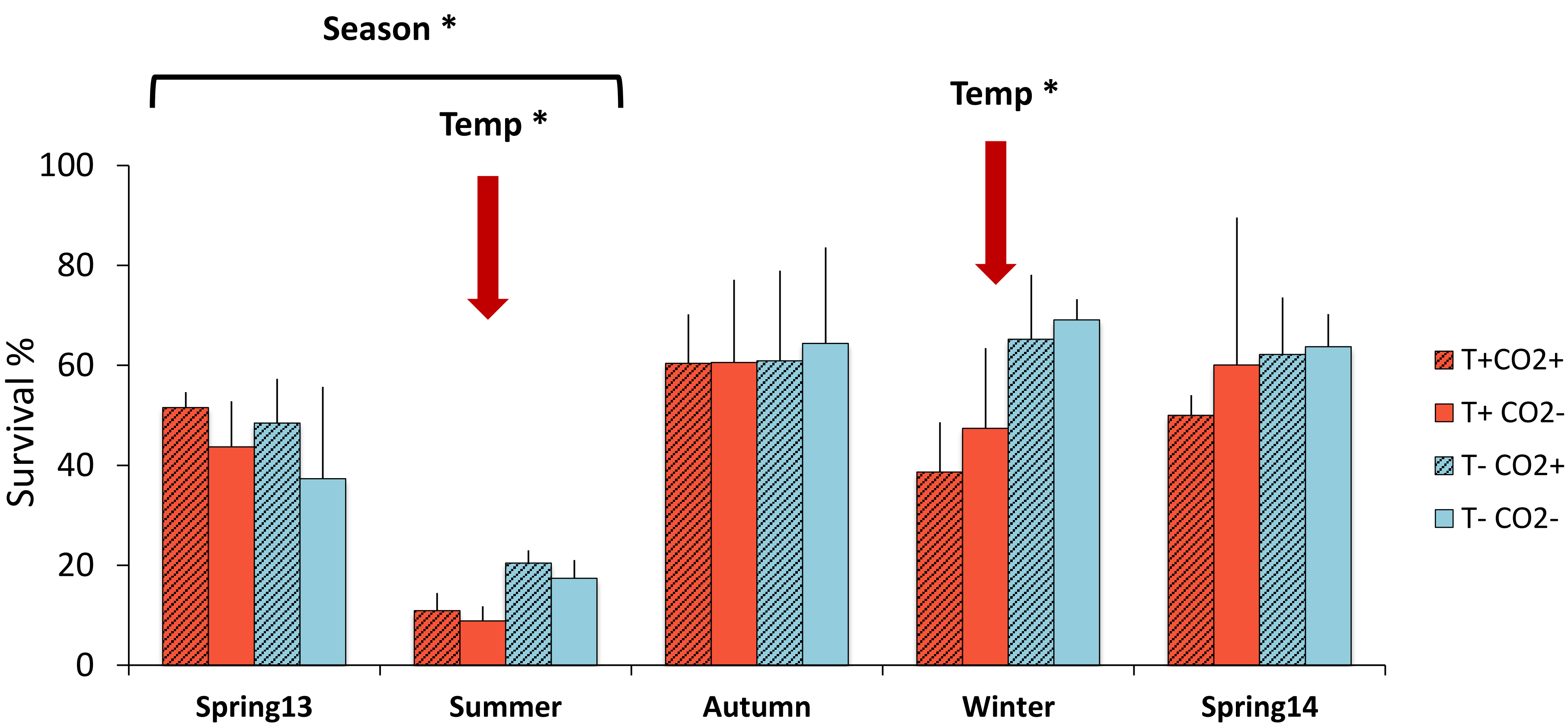
**4 treatment levels**

High Temperature + $pCO_2$
High Temperature
High $pCO_2$
Ambient (Fjord conditions)

**$pCO_2$:** 1100 µatm

**n = 3**

# Warming and acidification in a seasonal environment

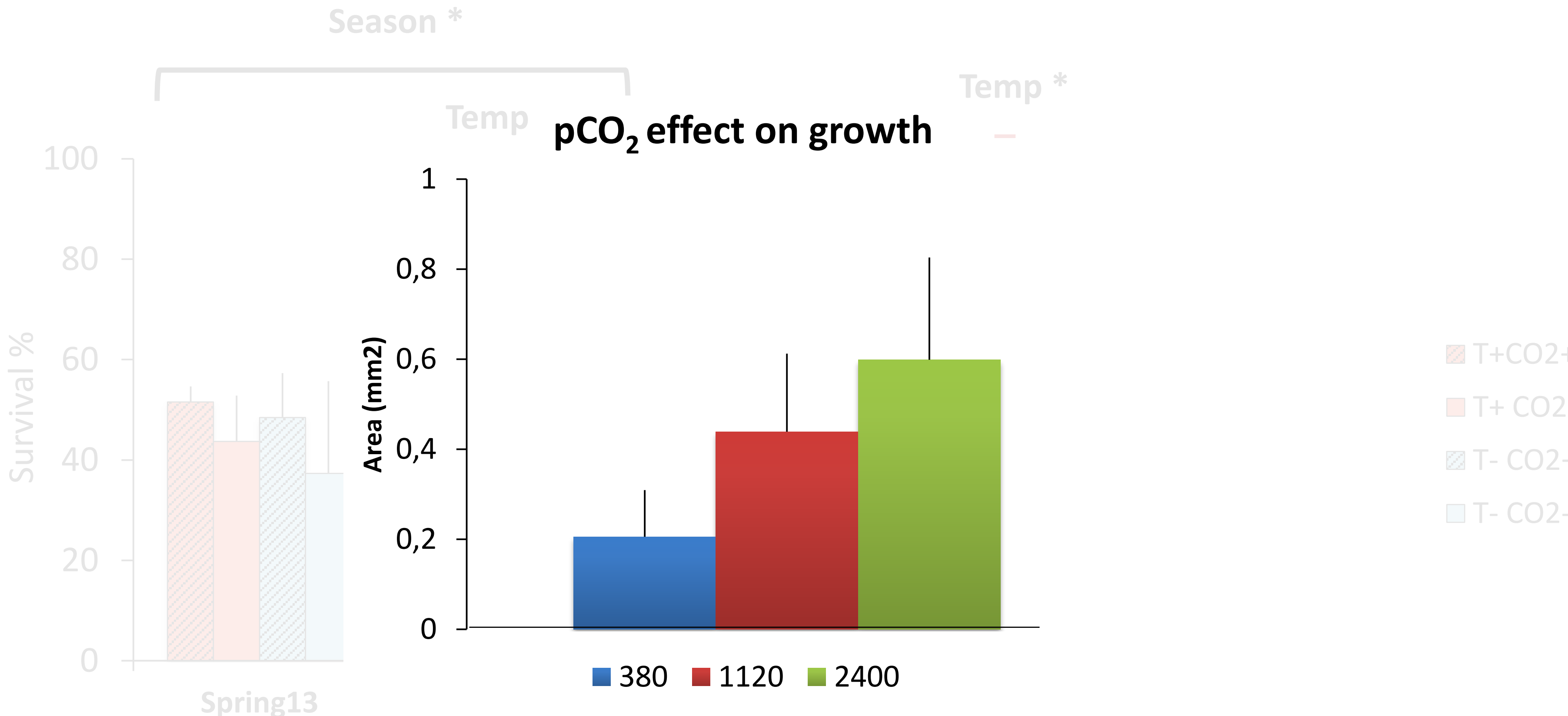



**Seasonal differences** between spring and summer (p-value < 0.05)

**Means +SD**
**n=3**

**Warming** decreases survival in **summer** and also in **winter** (p-value < 0.05)

# Acidification effect on growth – Laboratory approach



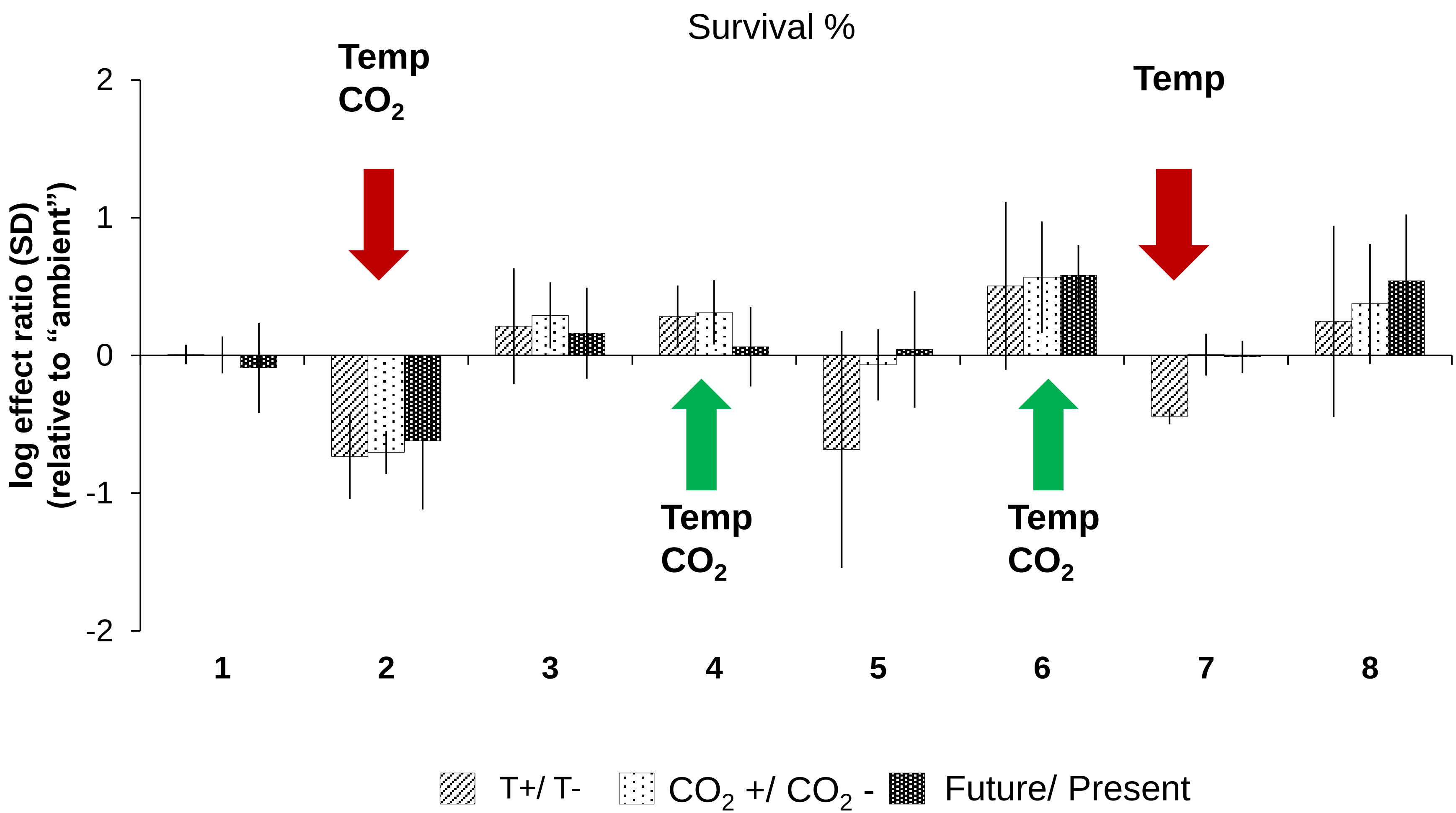

High pCO$_2$ levels increase growth of *Fucus* germlings (p-value < 0.05) = **fertilisation effect**

**Means +SD**
**n=3**

**Warming** decreases survival in **summer** and also in **winter** (p-value < 0.05)

**Means +SD**
**n=3**

# Siblings vary in tolerance to warming and acidification



# Warming, acidification and nutrient enrichment

**Temperature:** + 5 °C

**$pCO_2$:** 1100 µatm

↑ **[Temperature + $pCO_2$] x** ↑ **Nutrients**

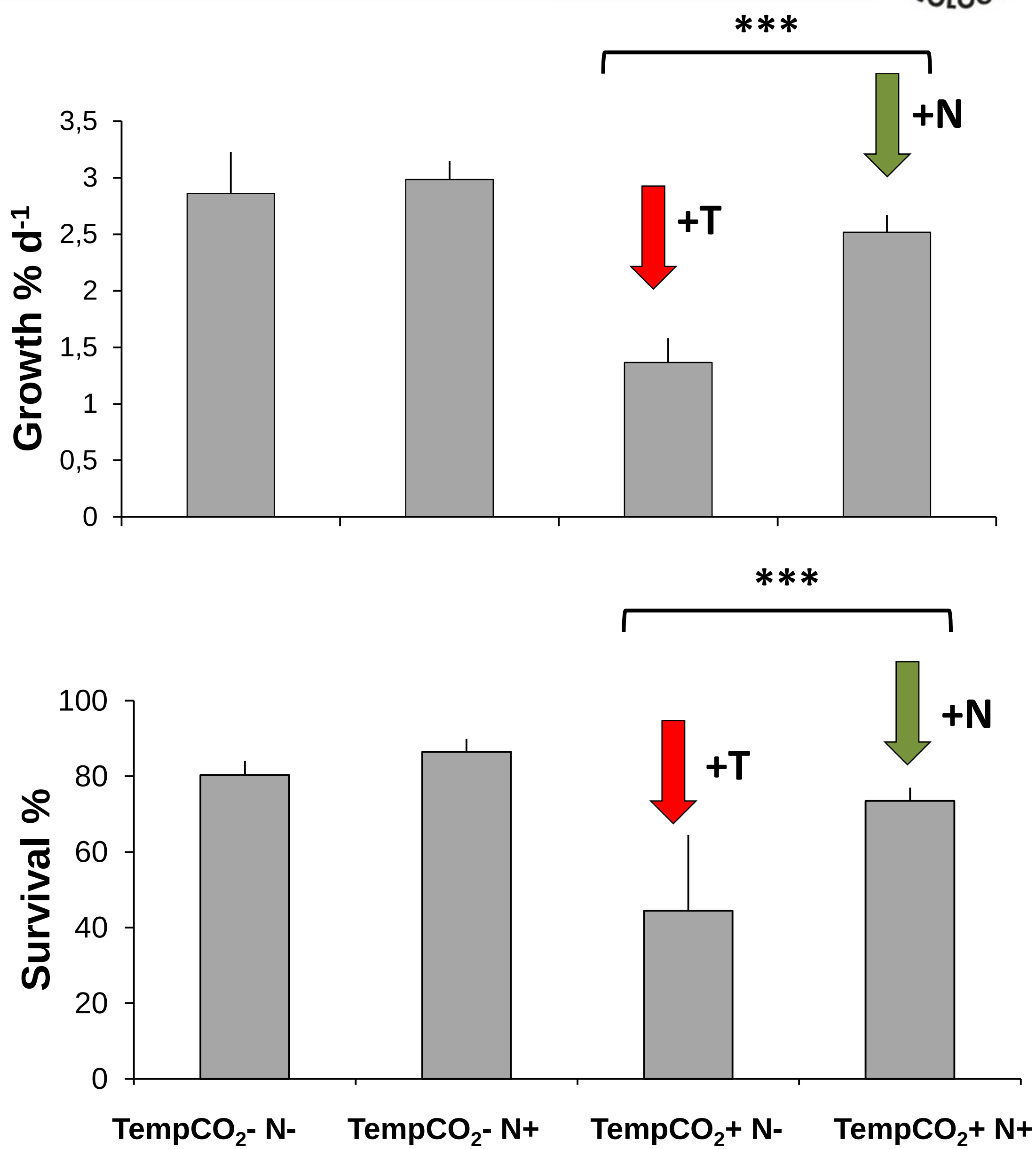
[$NO_2$ $NO_3$ $PO_4$]

# Nutrient enrichment mitigates heat wave stress

Warming during a heat wave decreased survival and growth significantly ($p < 0.0001$)

**Nutrient** enrichment **attenuates** the high mortality and growth reduction ($p < 0.0001$)

**Warming+Acidification interacts** with the factor **nutrients** ($p < 0.0001$)



# Local Upwelling event

[Temperature + $pCO_2$] x Nutrients

[$NO_2$ $NO_3$ $PO_4$]

+ [Temperature + $pCO_2$] + Nutrients

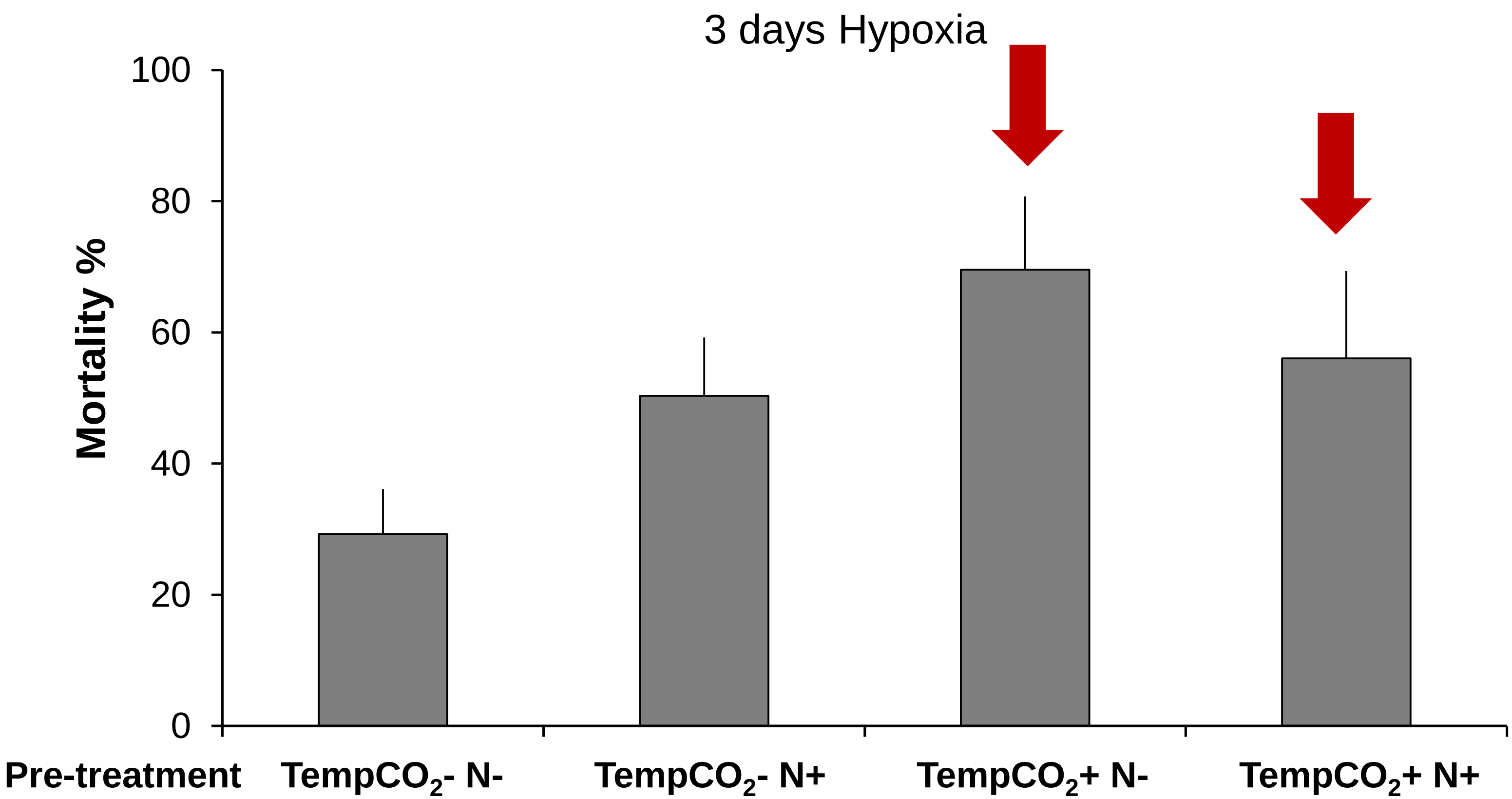
+ [Temperature + $pCO_2$] - Nutrients

- [Temperature + $pCO_2$] + Nutrients

- [Temperature + $pCO_2$] - Nutrients

**3 days Upwelling**

# Sensitivity to hypoxia is enhanced by previous warming




**Mortality** of *F. vesiculosus* germlings is **strongly increased under hypoxia** in all groups of pre-treatments

Previous exposure to **warming and acidification decreased the tolerance** to hypoxia stress ($p < 0.001$)

# Genotypic correlations determine the direction of selection

Populations resistance to multiple factors depend on **trade correlation**

Analysis of **sibling groups sensitivity** towards **multiple stressors** was performed

**Sibling groups sensitivity** to stressor A and stressor B **may correlate**

⟶ **genotypic correlations**

*Vinebrook et al. (2004)*

**Sibling groups were ranked according to the different sensitivities:**

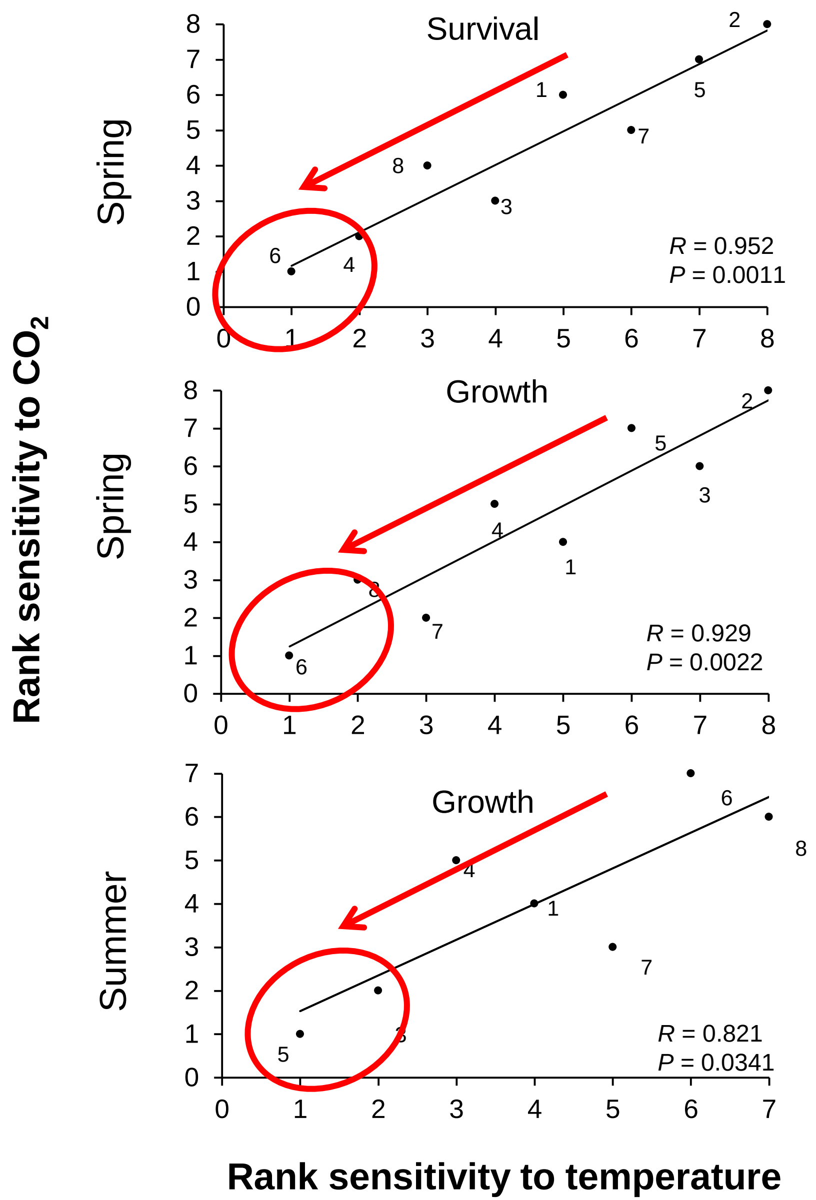
Warming

Acidification

Warming + acidification

Hypoxia

# Siblings correlations of sensitivities to warming and OA




Sensitivity to warming and acidification is **positively correlated** ($p < 0.05$)

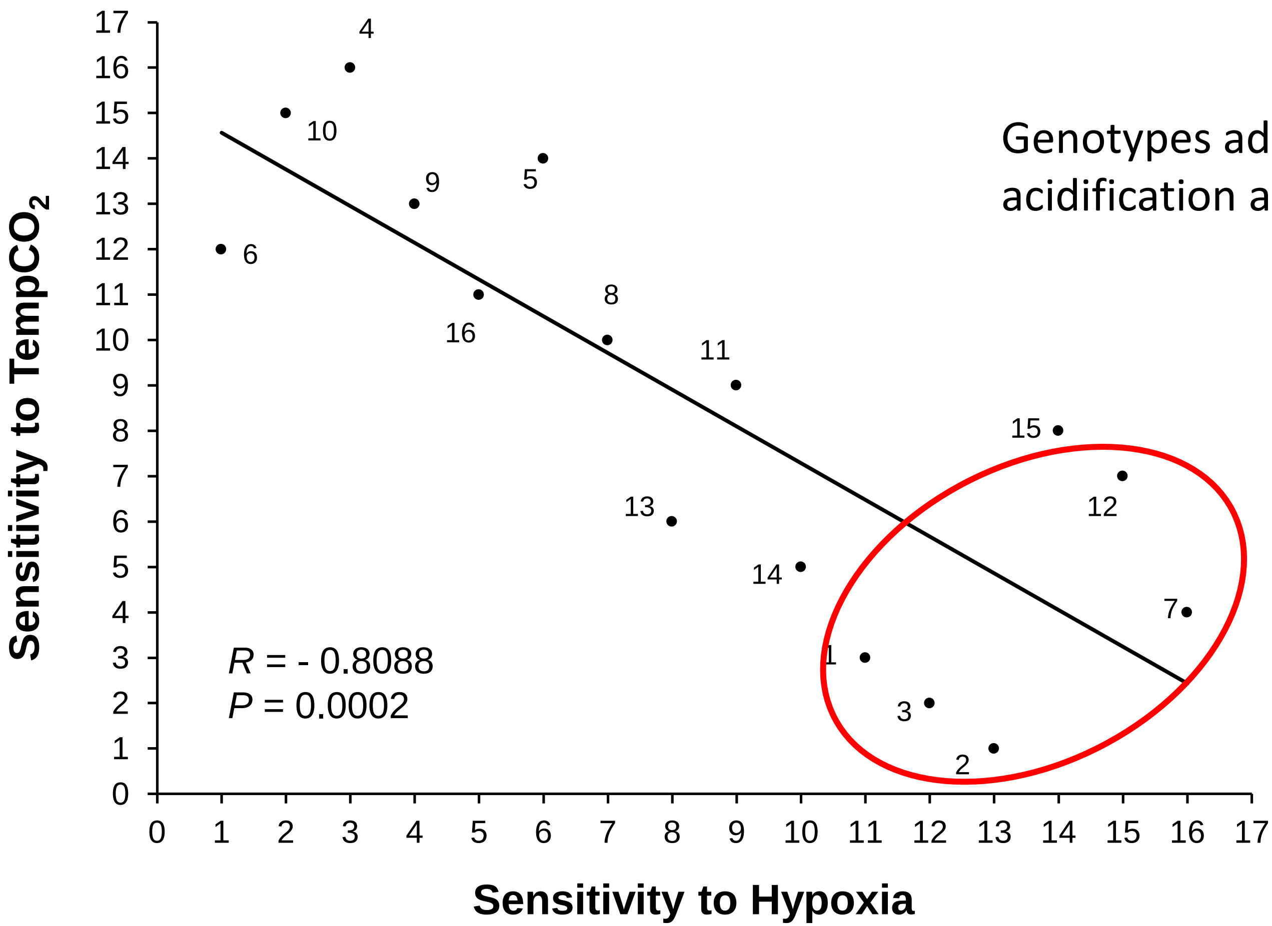
**Direction of selection** goes towards the more tolerant genotypes to warming and acidification

**Positive correlation** will accelerate selection processes towards these genotypes

# Correlations of sensitivities to OAW and hypoxia

Sensitivity towards warming+acidification and hypoxia is **negatively correlated** ($p < 0.001$)

Genotypes adapted to warming and acidification are **most sensitive to hypoxia**

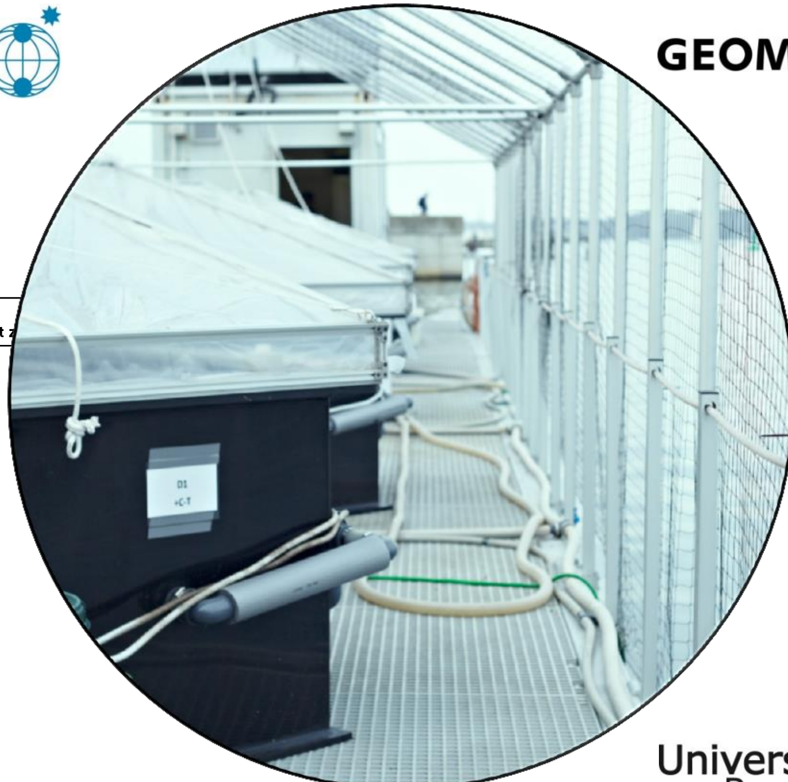


# Conclusions

- **Warming** enhances **growth** in summer, but **reduces survival** in late summer
- **Seasonal variation** determines **climate change effects** on growth and survival
- **Sibling groups vary** in their response to warming and acidification

  -> **potential for adaptation**
- **Heat wave stress** is mitigated under **nutrient enrichment** but enhances the **sensitivity to hypoxia**
- **Positive correlation of sensitivities** towards warming and acidification determines the **direction of selection**
- **Populations adapted to warming and acidification** are most sensitive to hypoxic upwelling

# Acknowledgments

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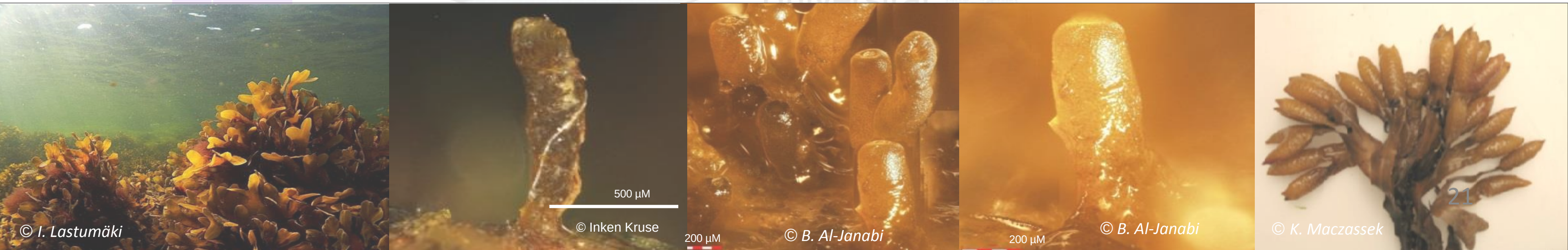
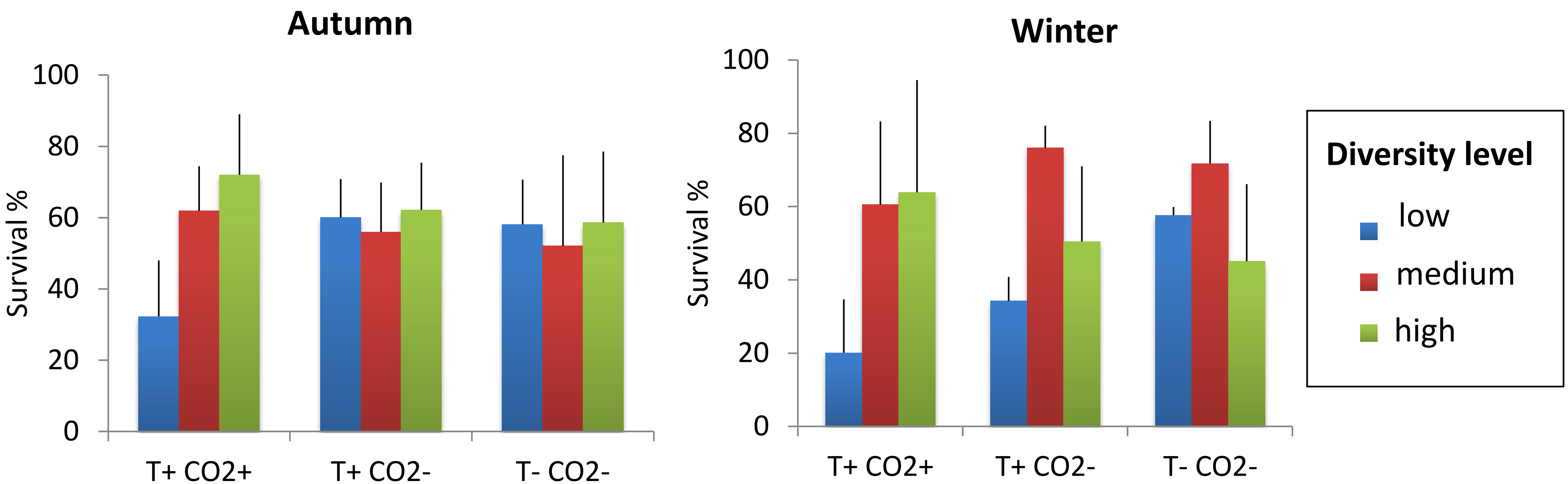


# Higher diversity level survive better under warming




Means +SD
n=3

Survival high diversity level **>** survival low diversity level
at **high temperatures** (p-value < 0.05)

Increased survival for a group of many families indicated **facilitation** processes among different genotypes

# Nutrient treatment



**Table 1** Nutrient concentrations in the present (mean of the last 7 years according to the respective summer months) and future nutrient conditions as doubled amounts of the present nutrient concentrations for $PO_4$, $NO_2$, $NO_3$ in µmol $L^{-1}$.

| | July | | August | | September | |
|---|---|---|---|---|---|---|
| | Present | Future | Present | Future | Present | Future |
| **$PO_4$** | 0.46 | 0.93 | 0.59 | 1.19 | 1.06 | 2.11 |
| **$NO_2$** | 0.53 | 1.05 | 0.77 | 1.54 | 1.27 | 2.54 |
| **$NO_3$** | 0.18 | 0.36 | 0.20 | 0.40 | 0.22 | 0.44 |