Effects of global warming and ocean acidification on benthic communities in the German Wadden Sea
- examined with mesocosm experiments -

Andreas Pansch¹, Harald Asmus¹, Ragnhild Asmus¹, Birte Mensch², Vera Winde³, Martin Wahl⁴

¹Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Wadden Sea Station Sylt
²Christian-Albrechts-University Kiel
³IOW, Leibnitz Institute for Baltic Research Warnemünde
⁴GEOMAR, Helmholtz Centre for Ocean Research Kiel
Why mesocosm studies?

- Close the gap between small scale lab experiments and field studies
- Experiments with communities instead of single species under controlled conditions
- Investigation of species interactions and community structure under climate change
AWI Wadden Sea Station

www.google.de/maps
Mesocosms facilities - Sylt

- Constructed by 4H-Jena Engineering
- Finished in August 2013
- 12 mesocosms → 12 independent experimental units
- Non filtered seawater from the Wadden Sea Station
- Connected with the CO$_2$-gas mixing facility of the institute

→ Made for climate change experiments at the ecosystem level
Single mesocosm

- 170 cm in diameter x 80 cm height
- 1800 l volume
- Insulated wall construction
- Translucent lid
- Temperature regulation
- Multiparameter measurement system
- Flow through
- Tide simulation
- Software
Tide simulation
Tide simulation

low tide
Tide simulation

high tide
Temperature regulation

Aqua medic®
Titanium heater
3 x 500 W

Aqua medic®
Titan 2000 cooler
550 W

Software:
- yearly max/min
- daily max/min
- adjusted by measured temperatures in the field
Temperature regulation

+5 °C
CO$_2$-gas mixing facility

Seawater in each mesocosm is directly aerated with pre-mixed gas.
Seawater acidification

380 ppm
1000 ppm
Multi-parameter measurements

One system for two mesocosms: Hydrolab DS5X

- Parameters measured at the moment
  - temperature
  - pH
  - oxygen (Clark cell)
  - conductivity

- Possible adjustments in the future
  - chlorophyll
  - turbidity
  - Ammonium etc.
Software
First experiments

autumn 2013 + spring 2014

- Macro algal community 
  \((Fucus vesiculosus)\)

- 3 month

- \(\text{CO}_2 \times \text{temperature}\)

- 4 treatments (3 replicates)
  - Ambient
  - Warm \(\rightarrow\) Ambient + 5 °C
  - Acid \(\rightarrow\) 1000 ppm
  - Warm + Acid \(\rightarrow\) + 5 °C, 1000 ppm
Warming inhibited *Fucus* growth
Elevated pCO$_2$ increased Biomass
Stress combination acted antagonistically

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**Fucus vesiculosus**

**Autumn 2013**

- Ambient
- Warm
- Acid
- Warm+Acid

**Spring 2014**

- Ambient
- Warm
- Acid
- Warm+Acid

- p = 0.007 **
- p = 0.092
Warming increased the number of *Gammarus* offspring

- Abundance
  - Ambient: 500
  - Warm: 1000
  - Acid: 1500
  - Warm+Acid: 2000

- Dry weight per Individual
  - Ambient: 0.004
  - Warm: 0.006
  - Acid: 0.008
  - Warm+Acid: 0.010

*p = 0.073*

*p = 0.288*
Warming increased the number of *Gammarus* offspring.
• Warming and acidification as well as the combination of both increased the abundance of *Corophium* sp.
• Warming and acidification as well as the combination of both increased the abundance and growth of *Hydrobia ulvae*
Warming and acidification as well as the combination of both increased the abundance of *Littorina littorea* offspring. Warming increased the growth of juvenile *Littorina littorea*. 

- Warming and acidification as well as the combination of both increased the abundance of *L. littorea* offspring.
- Warming increased the growth of juvenile *L. littorea*. 
adult *Littorina littorea*

Abundance

• No change in abundance

Dry weight per Individual

- Warming reduced the biomass of adult *L. littorea*

Spring 2014

\[ p = 0.370 \]
• Warming and acidification as well as the combination of both increased the abundance of *L. mariae*.
• Growth increased under the combination of warming and high pCO$_2$. 

Spring 2014
• Warming decreased the abundance of *M. edulis* offspring and growth of *M. edulis adults*
• Elevated CO$_2$ increased the abundance of offspring
Crassostrea gigas

Abundance

- No settled oysters were found

- Elevated CO$_2$ decreased growth of *C. gigas*
- The combination of warming and elevated CO$_2$ led to control growth
### Summary

<table>
<thead>
<tr>
<th>Species</th>
<th>Warm</th>
<th>Acid</th>
<th>Warm+Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Fucus vesiculosus</em></td>
<td>![thumbs down]</td>
<td>![thumbs up]</td>
<td>![thumbs down]</td>
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<tr>
<td><em>Gammarus sp.</em></td>
<td>![thumbs up]</td>
<td>![thumbs down]</td>
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<tr>
<td><em>Corophium sp.</em></td>
<td>![thumbs down]</td>
<td>![thumbs up]</td>
<td>![thumbs up]</td>
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<tr>
<td><em>Hydrobia ulvae</em></td>
<td>![thumbs up]</td>
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<tr>
<td>Juv. <em>L. littorea</em></td>
<td>![thumbs up]</td>
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<tr>
<td>Adult <em>L. littorea</em></td>
<td>![thumbs up]</td>
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<tr>
<td><em>Littorina mariae</em></td>
<td>![thumbs up]</td>
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<tr>
<td><em>Mytilus edulis</em></td>
<td>![thumbs down]</td>
<td>![thumbs up]</td>
<td>![thumbs up]</td>
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<tr>
<td><em>Crassostrea gigas</em></td>
<td>![thumbs up]</td>
<td>![thumbs up]</td>
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</tr>
</tbody>
</table>
Conclusions

- No obvious negative effects at elevated pCO$_2$
- Warming impacted *Fucus* and *Mytilus* negatively
- Combination of warming and acidification acted antagonistically → Importance of multiple stressor experiments
- Important to differentiate between direct and indirect effects
- First results show higher impact of acidification on Wadden Sea community than on Baltic Sea communities

Although single species effects were shown widely in the literature, two of the main predicted future threats, warming and acidification, do not negatively impact benthic Wadden Sea assemblages.
Future plans

Summer 2014 (still running)

- *Fucus vesiculosus* community
  
  \((\text{CO}_2 \times \text{temperature}) \times \text{eutrophication}\)

- Test with Ecological Network Analysis

- Experiments on *Seagrass* communities

- Test of more stressors, stress combinations, species, life stages and communities
  - fish larvae, small fish
  - turbidity, deoxygenation, hyposalinity, sedimentation, micro plastics
Thanks for your attention