Roughness effects of oyster reefs and blue mussel beds in the German Wadden Sea – the BIVA-WATT project

Jan Hitzegrad, L. Brohmann, K. Pfennings, T. Hoffmann, A. Wehrmann, M. Paul, N. Goseberg, T. Schlurmann
Agenda

1. Motivation
2. Objectives
3. Preliminary analysis
4. Conclusion & Outlook
Motivation

Pacific oyster as invasive species

- Formerly native blue mussel beds
  *(Mytilus edulis)* accounted for 5 – 6 % of the area in the Wadden Sea

- Since 1998 populated by the introduced Pacific oyster *(Crassostrea gigas)*

Oyster reef Nordland, Oct. 2019
Pacific oyster as invasive species in Lower Saxony

Motivation

Pacific oyster as invasive species

- Lower Saxon Wadden Sea
  - 2005: 6 t – 1 000 ha
  - 2013: 202 000 t – 1 800 ha

- Current status:
  - Oyster reefs in Lower Saxony
  - Oyster reefs, mixed beds and mussels beds in Schleswig Holstein
Motivation

Characteristics of Pacific oysters

- Large roughness heights $k > 30$ cm
- Formation of rigid structures inducing scour
- Often located in spatial proximity to morphodynamic active tidal channels
- Resilient to waves and ice drift
State of knowledge

- Few laboratory and numerical studies regarding life blue mussels in currents
- One field study investigating wave forcing over an blue mussel bed including few storm events by Donkers et al. (2012)

→ Little to no investigations regarding roughness effects of Pacific oyster reefs in European waters
Knowledge gaps

- Internal **structure** and **morphodynamics** of the mussel beds and oyster reefs
- Interactions of mussel beds and oyster reefs with **waves**
- Interactions of mussel beds and oyster reefs with **tidal currents**
- Interactions of mussel beds and oyster reefs with **combinations of waves and currents**
Agenda

1. Motivation

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Determine roughness effects of oyster reefs and mussel beds in the German Wadden Sea
Objectives

Objective 1
- Parametrization of natural roughnesses of the biogenic structures
- Development of surrogate models of the biogenic structures

Objective 2
- Determination of the roughness length $z_0$ due to currents for both bivalve species
- Determination of wave friction factor $f_w$ for both bivalve species

Objective 3
- Numerical simulation of the near field of around individual bivalves

Objective 4
- Conception and implementation of coupling strategies in morpho-hydroneumrical models
**Objectives**

**Work packages**

- **BIVA_FORM**
  - Measurement of natural roughnesses
  - Development of mussel surrogates

- **BIVA_HYDRO**
  - Experimental investigations
    - Waves and currents

- **BIVA_NUM**
  - Process-based numerical modelling

- **BIVA_CONCEPT**
  - Coupling of morpho-hydroneumeral and ecological models
1. Motivation

2. Objectives and work flow

3. Preliminary analysis

4. Conclusion & Outlook
Preliminary analysis

Field Studies Fall 2019

Nordland
Juist
Kaiserbalje
Butjadingen
Nordstrand
Schleswig-Holstein
Preliminary analysis

Field Studies Fall 2019

Oyster reef Kaiserbalje, Nov. 2019

Mussel bed Nordstrand, Nov. 2019
Population dynamics – Nordland, Juist

12 stations

- bed/reef (100 % internal coverage)
- 0.25 m x 0.25 m
Preliminary analysis

Population dynamics – Nordland, Juist

Abundances - life individuals per m²
Preliminary analysis

Population dynamics – Nordland, Juist

Abundances - total individuals per m²

Abundance [Indiv./m²]

0 500 1000 1500 2000 2500 3000 3500 4000 4500

1 2 3 4 5 6 7 8 9 10 11 12

Preliminary analysis Nordland, Juist

Pacific oyster  Blue mussel
Preliminary analysis

Population dynamics – Nordland, Juist

Relative abundance P. oyster life / dead

Nordland, Juist
Preliminary analysis

Population dynamics – Nordland, Juist

Biomass per m²

Nordland, Juist
Preliminary analysis

Population dynamics – site comparison

Abundances

<table>
<thead>
<tr>
<th>Site</th>
<th>Blue mussel</th>
<th>Pacific oyster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oyster reef, Nordland</td>
<td>708</td>
<td>448</td>
</tr>
<tr>
<td>Oyster reef, Kaiserbalje</td>
<td>1260</td>
<td>884</td>
</tr>
<tr>
<td>Mussel bed, Nordstrand</td>
<td>764</td>
<td>12</td>
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Biomass

<table>
<thead>
<tr>
<th>Site</th>
<th>Blue mussel</th>
<th>Pacific oyster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oyster reef, Nordland</td>
<td>2.8</td>
<td>4.8</td>
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<tr>
<td>Oyster reef, Kaiserbalje</td>
<td>21.5</td>
<td>26.4</td>
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<tr>
<td>Mussel bed, Nordstrand</td>
<td>2.4</td>
<td>0.2</td>
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</tbody>
</table>
Preliminary analysis

Digital terrain models – Entire reef model

- Entire reef
- ~ 2000 m x 2000 m
- Drone photogrammetry

DTM, Oyster reef Nordland
Digital terrain models – Detailed sections

- Detailed model in hydro-morphodynamic interesting section
- ~ 100 m x 100 m
- 3D Laser Scan

Point cloud, Oyster reef Nordland
Preliminary analysis

Digital terrain models – Structure types

- ~ 1.0 m x 1.0 m
- Photogrammetry
- 3D Laser Scan
Preliminary analysis

Development of surrogate models
Development of surrogate models

- Evaluation regarding hydraulic parameters

Relative Roughness \( k/D \)
Porosity \( \phi \)
Tortuosity \( \tau \)

...
Preliminary analysis

Structure types

1. Reef
2. Patch I
3. Patch II
4. Transitional zone
5. Garland
6. Cluster I
7. Cluster II
Preliminary analysis

Preliminary laboratory 2D experiments

- Berliner Rinne – LWI TU BS
Preliminary analysis

Preliminary laboratory 2D experiments

- Simplified reef model
- Regular pyramid structure
- $k = 14 \text{ mm}$

→ Scaling factor 1:10 – 1:20
## Preliminary laboratory 2D experiments

### Test programme

<table>
<thead>
<tr>
<th>Water Depth d [m]</th>
<th>Period T [s]</th>
<th>Wave Height H [m]</th>
<th>Wave length L [m]</th>
<th>Reef model</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.13</td>
<td>1.01</td>
<td>~ 0.040</td>
<td>1.18</td>
<td>with/without</td>
</tr>
<tr>
<td>0.18</td>
<td>1.01</td>
<td>~ 0.050</td>
<td>1.34</td>
<td>with/without</td>
</tr>
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<td>1.01</td>
<td>~ 0.058</td>
<td>1.44</td>
<td>with/without</td>
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<td>1.01</td>
<td>~ 0.065</td>
<td>1.91</td>
<td>with/without</td>
</tr>
</tbody>
</table>
Preliminary analysis

Preliminary laboratory 2D experiments
Preliminary Analysis

Surface level elevations

- Transmission coefficient $K_t$
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Velocity measurements

- Velocity profile of the maximal horizontal orbital velocities $u_x$ without structure
Preliminary Analysis

Velocity measurements

- Velocity profile of the maximal horizontal orbital velocities $u_x$ with structure
Preliminary Analysis

Wave friction factor $f_w$

- Determination according to Nielsen (1992)

$$f_w = \exp \left( 5.5 \left( \frac{A_b}{k} \right)^{-0.2} - 6.3 \right)$$

where: $k = 14$ mm

→ Similar results as studies with coral reefs
Agenda

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Conclusion and Outlook

Objective

- Determine roughness effects of oyster reefs and blue mussel beds

Preliminary investigations

- Population dynamics for the three tested sites for fall 2019
- Development of digital terrain models at full-reef scale, detailed section and structure-type scale
- Preliminary laboratory investigations of a simplified reef model subjected to waves
Next steps:

→ Field studies in half-yearly rhythm to monitor spatio-temporal developments

→ Detailed laboratory studies to investigate interactions of both bivalve species with waves, currents by using parameterized surrogate models

→ Development of a numerical model using laboratory experiments as validation
Thank you for your kind attention!

Jan Hitzegrad | The BIVA-WATT project | FZK Kolloquium | 05.03.2020