Sublittoral mussel reefs in the Dutch Wadden Sea: ephemeral hotspots for biodiversity options for restoration and exploitation

Aad Smaal, IMARES & Wageningen University

Yerseke, NL

Restoration of reefs, march 2013
Background of the presentation

- Dynamics of sublittoral mussel beds and associated flora and fauna are not well known
- There are ideas about what they look like, and the Natura 2000 policy aim is to have more of them
- It was questioned what impact mussel seed fishery has on bed development
- A research project (PRODUS) about the impact of mussel seed fishery on the natural values of the sublittoral western Wadden Sea, was carried out in the period 2006 – 2012, commissioned by the government and the mussel industry
- Focus on * natural values, and *impact
- Final report is *in prep
Research framework

- Traditional mussel culture depends on mussel seed fished on wild beds
- Mussel seed is collected by fishery on wild sublittoral beds by bottom dredging
- This may disrupt benthic habitats including their natural values
- It may also restrict new mussel recruitment in fished areas
- Court case on N2000 permit 2008: not enough knowledge on impacts
Mussel seed stock dynamics

- Bed area varies from 500 – 5000 ha
- Dynamics in mussel stock size (prior to fishery), based on surveys in spring: 10 – 110 mln kg in autumn: 5 – 80 mln kg
- Average annual seed harvest = 50 % of stock transplanted to culture plots: 4000 ha
Research approach

- Synoptic mapping: comparison of biodiversity of wild mussel beds / mussel culture plots / other sublittoral habitats in the western Wadden Sea
- Analysis of mussel – oyster associated species
- Impact study BACI approach:
  - selection of 40 plots, open and closed for fishery
  - spread over the seed mussel bed areas
  - to be sampled before and after fishery, up to several years (time series: BACI+)
- Comparison with data from additionally closed areas
Comparison community 1981/82 versus 2008
all sublitt habitats: 397 stations Western Wadden Sea

- Since 1982 invasions of new species: Marenzelleria, Oyster, Ensis
- invasive filter feeders now dominant
Sampling stations: wild beds / culture plots

Additional survey on wild mussel beds, oyster beds, and mussel culture plots; 159 stations in 3 yrs

shellfish beds = biodiversity hot spots
<table>
<thead>
<tr>
<th>Species</th>
<th>Phylum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allisuc</td>
<td>Annelida</td>
</tr>
<tr>
<td>Carmae</td>
<td>Arthropoda</td>
</tr>
<tr>
<td>Conret</td>
<td>Bryozoa</td>
</tr>
<tr>
<td>Alcyonidioles mytili</td>
<td>Arthropoda</td>
</tr>
<tr>
<td>Balanus crenatus</td>
<td>Arthropoda</td>
</tr>
<tr>
<td>Mertidium senile</td>
<td>Cnidaria</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>Annelida</td>
</tr>
<tr>
<td>Polychaeta cornuta</td>
<td>Annelida</td>
</tr>
<tr>
<td>Crepidula fornicate</td>
<td>Mollusca</td>
</tr>
<tr>
<td>Harmothoe impar</td>
<td>Annelida</td>
</tr>
<tr>
<td>Alitta virens</td>
<td>Annelida</td>
</tr>
<tr>
<td>Streblosia benedicti</td>
<td>Annelida</td>
</tr>
<tr>
<td>Asterias rubens</td>
<td>Echinodermata</td>
</tr>
<tr>
<td>Harmothoe imbricata</td>
<td>Annelida</td>
</tr>
<tr>
<td>Eunida sanguinea</td>
<td>Annelida</td>
</tr>
<tr>
<td>Obelia longissima</td>
<td>Cnidaria</td>
</tr>
<tr>
<td>Molgula socialis</td>
<td>Chordata</td>
</tr>
<tr>
<td>Crassostrea gigas</td>
<td>Mollusca</td>
</tr>
<tr>
<td>Eunida sanguinea</td>
<td>Annelida</td>
</tr>
<tr>
<td>Hemigrapsus takanoi</td>
<td>Arthropoda</td>
</tr>
<tr>
<td>Melita palmata</td>
<td>Arthropoda</td>
</tr>
<tr>
<td>Polydora ciliata</td>
<td>Annelida</td>
</tr>
<tr>
<td>Mysta picta</td>
<td>Annelida</td>
</tr>
<tr>
<td>Monocorophium acherusicum</td>
<td>Arthropoda</td>
</tr>
<tr>
<td>Eualalia viridis</td>
<td>Annelida</td>
</tr>
<tr>
<td>Clytia hemisphaerica</td>
<td>Cnidaria</td>
</tr>
<tr>
<td>Phyllocoelus mucosa</td>
<td>Annelida</td>
</tr>
<tr>
<td>Petricolus pholadiformis</td>
<td>Mollusca</td>
</tr>
<tr>
<td>Pholoe minuta</td>
<td>Annelida</td>
</tr>
<tr>
<td>Pedicellina cernua</td>
<td>Entoprocta</td>
</tr>
<tr>
<td>Pinnothecus pisum</td>
<td>Arthropoda</td>
</tr>
<tr>
<td>Lepidopus squamatus</td>
<td>Annelida</td>
</tr>
<tr>
<td>Mytilicola orientalis</td>
<td>Arthropoda</td>
</tr>
<tr>
<td>Styela clava</td>
<td>Chordata</td>
</tr>
</tbody>
</table>
ASSOCIATED SPECIES BY GROUP

ASSOCIATION WITH MUSSELS & OYSTERS
Comparison wild beds – culture plots

• Total 108 species in 159 box cores
• 84 species on natural beds (5 unique)
• 102 on mussel culture plots (23 unique)
• *Per box* core more species in wild beds, 
  wild: soft substrate species
  culture: hardsub
• 16 species were invasive
  and were all found in both habitats
## DOMINANT SPECIES WILD / CULTURE PLOTS

<table>
<thead>
<tr>
<th>Genus</th>
<th>Species</th>
<th>substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alitta</td>
<td>virens</td>
<td>1</td>
</tr>
<tr>
<td>Carcinus</td>
<td>maenas</td>
<td>1</td>
</tr>
<tr>
<td>Conopeum</td>
<td>reticulum</td>
<td>4</td>
</tr>
<tr>
<td>Harmothoe</td>
<td>impar</td>
<td>3</td>
</tr>
<tr>
<td>Lanice</td>
<td>conchilega</td>
<td>1</td>
</tr>
<tr>
<td>Alcyonidioides</td>
<td>mytili</td>
<td>4</td>
</tr>
<tr>
<td>Asterias</td>
<td>rubens</td>
<td>3</td>
</tr>
<tr>
<td>Harmothoe</td>
<td>imbricata</td>
<td>3</td>
</tr>
<tr>
<td>Melita</td>
<td>palmata</td>
<td>3</td>
</tr>
<tr>
<td>Sagartia</td>
<td>troglodytes</td>
<td>2</td>
</tr>
<tr>
<td>Hemigrapsus</td>
<td>takanoi</td>
<td>3</td>
</tr>
<tr>
<td>Obelia</td>
<td>longissima</td>
<td>4</td>
</tr>
<tr>
<td>&lt;NA&gt;</td>
<td>&lt;NA&gt;</td>
<td>1</td>
</tr>
<tr>
<td>Alitta</td>
<td>succinea</td>
<td>2</td>
</tr>
<tr>
<td>Balanus</td>
<td>crenatus</td>
<td>4</td>
</tr>
<tr>
<td>Streblopio</td>
<td>benedicti</td>
<td>1</td>
</tr>
<tr>
<td>Polydora</td>
<td>cornuta</td>
<td>2</td>
</tr>
<tr>
<td>Metridium</td>
<td>senile</td>
<td>4</td>
</tr>
<tr>
<td>Clytia</td>
<td>hemisphaerica</td>
<td>4</td>
</tr>
<tr>
<td>Crepidula</td>
<td>fornicata</td>
<td>3</td>
</tr>
</tbody>
</table>

1 = SOFT SEDIMENT  
2 = HETEROGENEOUS SEDIMENT  
3 = HARD SUBSTRATE MOBILE  
4 = HARD SUBSTRATE SESSILE

**CULTURE**

**WILD**
Comparison wild beds – culture plots

More mussel biomass = more species
Culture plot mussel biomass > wild beds, hence more species
But also differences in salinity: wild beds in lower salinity zones
ROLE OF PEBBLES

NO EFFECT OF STONES ON NR OF SPECIES IN COMPARISON TO MUSSELS
ROLE OF CULTURE PLOTS FOR BIRDS

Decrease in Eider duck nrs in the Wadden Sea
Not on culture plots
Impact study: baci+

- Mussel biomass
- Benthos
- New spatfall
- Fish
- Sediment
- Habitat structure
- Fishery effort
- Edge effects
Sampling stations plots

western wadden sea:
40 * 2 * 4 ha plots

Sampling inner 100*100 m

Mussel spatfall driven distribution

Sampling period 2006 - 2011
Mussel seed fishery

- Mussel culture is basically the transplantation of mussels from seed beds to culture plots.
- Fishery is done in autumn on beds in relatively unstable areas = areas vulnerable for starfish predation and storm damage green/yellow areas.
- In spring fishery occurs also in the more stable areas: red/orange areas.
Mussel densities per plot: $t_0 - t_1$

### Autumn fishery:
- **Before**
- **After**

### Spring fishery:
- **Before**
- **After**
Mussel biomass per plot over time

after 1 yr  3 yr  5 yr
After springfishery  spring  spring

Ref 7 9
Vis
Biomass (kg/m²)

First fishery  Autumn (instable beds)  Spring (stable beds)

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Fished</th>
<th>Median</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR-w</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NJov</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NJon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VJ1v</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VJ1n</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VJ2v</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VJ3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VJ4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VJ5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VJ6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**T0 - T1**

<table>
<thead>
<tr>
<th></th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.1901</td>
</tr>
</tbody>
</table>

**Stock (Ti)**

<table>
<thead>
<tr>
<th></th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.185</td>
</tr>
</tbody>
</table>

(Wilcoxon Rank Sign Test)
Impact on mussels

- Mussel fishery reduces mussel biomass
- Biomass reduction on control plots as well
  ... Not everywhere..

3 sites with high biomass after 5 years
High biomass on 3 out of 40 plots

WHY?
Starfish predation? NO
Other factors?
Impact macrobenthos > 5 mm

More mussels = More species
Impact on density and species nr of some species at T1;
no difference at T2
Impact macrobenthos > 1 mm

Impact on density at T1:
Significant lower in fished plots

Impact on biodiversity
at Tmid: 2 years:
Significant higher in fished plots

Large natural variability
Comparison with plots in closed areas

Vlieter:
70 ha closed 2009

Breezanddijk
143 ha closed 2010
Comparison with plots in closed areas

Areas show different dynamics, linked to starfish predation
Low mussel biomass : low species nrs
Conclusions natural dynamics

= annual surveys:
  ▪ Sublittoral mussel stocks vary in size and surface area over time

= monitoring closed areas:
  ▪ Starfish predation determining factor

= The synoptic surveys showed
  ▪ Long term changes, invasive species take over
  ▪ Mussels are hot spots for biodiversity
  ▪ Wild beds and culture plots exists under different conditions
  ▪ Both habitats have high biodiversity
Conclusions fishery impacts

= mussel stock

- decrease of mussel biomass in fished and control plots after autumn fishery: instable sites, starfish

- significant difference in spring fishery, fished plots maintain lower biomass for 2 years after fishery

= benthos

- decrease of density in fished plots directly after fishery; species nr lower on fished plots until 2 years after fishery
Restoration options

- New shellfish policy NL since 2004 aims for maintaining mussel culture, without negative environmental impacts
- NATURA 2000 maintenance goals H1110 a: improve mussel bed habitat that includes mussels of different year classes, because of their structural and functional features
- Mussel transition agreement NL: close seed fishery on wild beds and turn to suspended seed collection; midterm eval. 2013
- Does this deliver mature sublittoral mussel beds?
Restoration options

- More mussels = more biodiversity (nr spec & abundance)
- Culture plots are important for benthic biodiversity and birds
- No fishing does not mean more mussels
- Depends on the area: stability map to be validated
- Mussel bed restoration *may be* enhanced by reduction of fishery
- Chance of success may be limited
  - see control plots
  - see the fate of mussels in relatively stable closed areas:
    1 survived, 1 declined
- Additional measures to be considered to achieve maintenance goals
- HOW?..link restoration and exploitation
Thank you

Acknowledgements

Symposium organisers

Co-authors: Jan Drent, Rob Dekker, Marnix van Stralen, Johan Craeymeersch, Sander Glorius, Jeroen Jansen

...and our team:
Margriet van Asch, Rob van Bemmelen, Anneke vd Brink, Bert Brinkman, Jenny Cremer, Norbert Dankers, Rob Dekker, Elze Dijkman, Bruno Ens, Frouke Fey, Sander Glorius, Kees Kersting, Joke Kesteloo, Erik Meester, Anneke Rippen Pepijn de Vries, Carola van Zweeden, college’s of labs and ships.
**INTERTIDAL SHELLFISH BEDS**

**OYSTERS: 1000 HA**

**MUSSELS: 2000 HA**

DO THE OYSTERS TAKE OVER?

OYSTERBEDS AS SUBSTRATE FOR MUSSELS

2006

SCHIERMONNIKOOG

2011

Graphs showing the distribution of oysters, mussels, and both in the West and East regions from 1999 to 2011.
Impact on new spatfall

- Spatfall was divided in large (>150/m²) and small (<150/m²) spatfall.
- Large spatfall not related to existing mussel biomass.
- Small spatfall positively correlated with mussels.
- Not different for open and closed plots.

![Graph showing log spat nrs and log mussel biomass](image)