Benthic production and energy export from man-made structures to natural soft bottoms: repercussions for food provisioning services?

Jennifer Dannheim, Silvana Birchenough, Jan Beermann, Clement Garcia, Joop WP Coolen, Ilse de Mesel, Steven Degraer
background and study aims

- rapid expansion of man-made structures (MMS) → offshore wind farms
- faunal differences – new players: hard substrates ↔ soft sediments
- benthic production (species energy turned into biomass) major food source and relevant ecosystem service

**do the potential discharges from OWF piles affect benthic functioning?**

- how much extra biomass on piles?
- how much energy is potentially exported?
- is production increased in the soft bottom?
general concept

meta analysis: 6 OWF, Southern North Sea

natural vs. OWF habitats

comparison over time

potential export

OWF piles

soft bottom

OWF
methods: meta analysis

- Generalised linear mixed models (GLM) to link production to environmental parameters (OWF as random factor)
- effect size (Cohen’s d with Hegde’s correction\(^2\)) for comparability between different structures & habitats

\[
Cohen's\ d = \frac{\bar{X}_I - \bar{X}_C}{S}
\]

\(\bar{X}_I\) mean of impact group
\(\bar{X}_C\) mean of control group
\(S\) pooled standard deviation

- calculation of potential export (\(B_{L/G}:\) biomass loss/gain)

\[
B_{L/G} [gC\ m^{-2}] = Biomass_{t2} - (Biomass_{t1} + Production_{t1 \rightarrow t2})
\]

- calculation of potentially Production Impacted Area (PIA)

\[
PIA [m^{-2}] = \frac{1}{Detection\ Level} * \left( \frac{Biomass - Export_{L} * Trophic\ Efficiency}{Production_{soft-bottom\ community}} \right)
\]

\(^1\)Brey (2012) Limnology and Oceanography Methods, 10, 581-589
\(^2\)Hedges, Gurevitch, Curtis (1999) Ecology, 80, 1150-1156
\(^3\)Lindeman (1942) Ecology, 23, 399-418

data
~4300 samples from
~540 stations
~ 800 taxa
fouling community & infauna (soft bottom)

UNDINE
parameter
biodiversity, abundance, biomass (B gC m\(^{-2}\))
secondary production, model\(^1\) (P gC m\(^{-2}\) y\(^{-1}\))

www.insitenorthsea.org
energy flow: hard substrate

↓ depth at structure
↑ temperature
no change over age
no change to coast
distance

\[ \chi^2 (1) = 107.85, p < 0.001 \]

\[ \chi^2 (1) = 82.16, p < 0.001 \]

\[ \chi^2 (1) = 2.59, p = 0.11 \]

\[ \chi^2 (1) = 0.45, p = 0.50 \]

\( N = 740 \)
energy flow: soft bottom

- no change over age
- ↑ distance to structure
- ↑ temperature
- ↓ median grain size, projects

a) age ($\chi^2 (1) = 0.01, p = 0.92$)

b) dist ($\chi^2 (1) = 27.32, p < 0.001$)

c) temp ($\chi^2 (1) = 260.60, p < 0.001$)

d) MdGS ($\chi^2 (1) = 11.75, p < 0.001$)

N = 3037
**effect size**

\[ \text{Cohen's } d = \frac{\bar{X}_I - \bar{X}_C}{S} \]

- \( \bar{X}_I \) mean of impact group
- \( \bar{X}_C \) mean of control group
- \( S \) pooled standard deviation

- **large**
- **medium**
- **small**
- **negligible**

Hedges, Gurevitch, Curtis (1999) Ecology, 80, 1150-1156
potential energy export

$B_{L/G} = B_{t2} - (B_{t1} + P_{t1\rightarrow t2})$, $N = 159$

highest variability & highest loss in 0-5 m depth of structure
potential energy export

biomass m\(^{-2}\) y\(^{-1}\)

biomass / windmill (10m!)

biomass / alpha ventus farm

biomass / all German wind farms

---

turbine scale

+ 38%

wind farm scale

+ 5%

regional scale (German EEZ)

+ 0.4%
Detection limit of 20\% increase in production:

- mainly within 200 m around pile

\[ P_{PIA} = \frac{1}{Detection \ Limit} \]

\[ P_{log} = 4 \, gC \, m^{-2} \, y^{-1} \]

\[ P_{log} = 2 \, gC \, m^{-2} \, y^{-1} \]
**summary and ecological relevance**

<table>
<thead>
<tr>
<th>hard substrate</th>
<th>highest production at upper structure parts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>spatial differences: higher production in German/Dutch waters</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>export</th>
<th>high export from structure to surrounding but also recruitment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>highest export from upper structure parts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>soft bottom</th>
<th>higher production in reference areas, however</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>soft bottom changes within natural range</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PIA</th>
<th>Detection limit of 20% ~200 m, local phenomenon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overlapping PIA between turbines (&gt;500 m) at &lt;5%</td>
</tr>
</tbody>
</table>

**Benthic production and energy export: repercussions for food provisioning services?**

ANSWER: **YES and NO**

- **soft bottom**: changes too small to affect benthic invertebrates on larger scales
  - changes within the natural range, local effects of benthic production (wrong scale in monitoring?)

- **Hard-substrate**: food source, direct feeding (megafauna/fish not part of this study)

- further studies needed on (a) large mobile epifauna & demersal fish species (attraction-production hypothesis) and (b) higher number of turbines and long-term changes