Bottom trawling impacts on the deep-sea benthic communities from the SW Portuguese continental slope (NE Atlantic)

Sofia P. Ramalho¹,², Marina R. Cunha¹, Lidia Lins², Ellen Pape², Eliana Alfaro Cordova², Nikolaos Lampadariou³, Ann Vanreusel²

¹ Universidade de Aveiro & CESAM, Portugal
² Ghent University, Belgium
³ Hellenic Centre for Marine Research, Greece

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Deep-sea and human activities

- Largest single ecosystem on earth
- Supports one high levels of biodiversity (Approx. 5% explored)
- Provide essential goods and services (CO$_2$ sink, mineral and biological resources)

↓

- Trawling is considered to exploit biological resources beyond safe limits, with nearly no global regulations (OSPAR zones), and with major consequences to benthic communities
- Mostly concentrated on the upper continental slope and seamounts

Impact assessment problems (methodologies, remoteness, variety of habitats and large spectrum of functions and services provided)

Ramirez-Llodra et al., 2011
Effects in deep-sea benthic communities

- Most knowledge arises from shallow-waters and common approaches of difficult application → Habitats with **low resilience** (K-selected life history traits)
- Few deep–sea studies showed (seamounts and cold-water corals):
  - losses in faunal **standing stocks and diversity**
  - damage/removal of sessile habitat-forming organisms
  - **sediment resuspension** (changes in biogeochemistry)
  - alteration of sea floor topography (e.g. submarine canyons)

E.g. Koslow et al., 2001; Fosså et al., 2002; Althaus et al., 2009; Clark and Rowden, 2009; Puig et al., 2012
Effects in deep-sea benthic communities

- Mostly based on independent **results** from a faunal group or subsystem (e.g. epibenthic megafauna)

- **Larger fauna seem to be easily removed** leading to communities dominated by small-size fauna (reduction of competition and predation interactions)

<table>
<thead>
<tr>
<th>Group</th>
<th>Lower Size limit</th>
<th>Sampler</th>
<th>Representative taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-</td>
<td>&lt;63 μm</td>
<td>corer</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Meio-</td>
<td>32 - 63 μm</td>
<td>corer</td>
<td>Nematodes, copepods</td>
</tr>
<tr>
<td>Macro-</td>
<td>250-500 μm</td>
<td>corer</td>
<td>Polychaetes, crustaceans</td>
</tr>
<tr>
<td>Mega-</td>
<td>cm</td>
<td>Trawls, Photographs</td>
<td>Fishes, echinoderms</td>
</tr>
</tbody>
</table>

Can we expected size dependent responses to physical disturbance?

Jennings et al., 2001
Effects in the ecosystem functioning

- Positive biodiversity-functioning relationship, where **loss of biodiversity** seems to **affect energy and matter fluxes** (e.g. oxygen production, nutrient cycling, burial of organic matter) and consequently the ecosystem’s **efficiency and stability** (resistance and resilience)

- Macrofaunal key role in the sediment biogeochemistry
  - Promoting bioturbation and bio-irrigation to the anoxic layers

Danovaro et al., 2008; Loreau, 2008
Aim

Investigate **trawling disturbance effects on the different size groups** of the deep-sea benthos **composition and diversity** in relation with **ecosystem functioning** (stock and flux of energy and material) on the continental slope
Portaria n.o 769/2006 de 7 de Agosto, Artigo 8º:
“Fishing with trawl gear may not be exercised within six miles of the coastline…”
Fisheries in the SW Portuguese margin (NE Atlantic)

- Bottom trawling in the SW Portugal target mostly **deep-water crustaceans** of high commercial value at 200 to 800m water depth

- High levels of by-catch and discarding (50-90%)

Norway lobster
*(Nephrops norvegicus)*

Distribution limited to muddy sediments in order to excavate burrows

Restraint of trawling areas

Erzini et al., 2003 and Leocádio et al., 2012
Fisheries in the SW Portuguese margin (NE Atlantic)

Source: https://www.marinetraffic.com
Study area and sampling design

- **June 2013** - ROV survey (2 transects)
  - 500m-200m (“trawled” – “not-trawled”)
  - Video recording for megafauna analysis
Study area and sampling design

Sampling site selection based on ROV observations
Study area and sampling design

Faunal diversity:
- 5 stations (2 trawled, 3 not-trawled; n=3):
  - Environmental parameters (MUC)
  - Microfauna (MUC)
  - Meiofauna (MUC)
  - Macrofauna (Box-corer and MUC)

Pulse-chase experiment:
- Sediment cores (st 4 (T) and st 2 (NT))
- 24h acclimation + $^{13}$C labelled algae (ca. 2.8 mg C)
- T0 (control), T3, T8 cores were processed for:
  - Bacterial biomass/production (PLFAs),
  - Bioturbation ($^{13}$C TOC)
  - Pore-water irrigation (Ammonia)
Results - Megafauna

- Significant differences in composition ($p<0.001$) between high intensity trawled and low trawling intensity areas
- Onuphidae polychaetes were the main responsible
Results - Environmental and Macrofauna

- Grain size main driver for the impact separation:
  - T - mainly muddy sediments
  - NT - Fine-coarse sand

- Inverse pattern between T and NT stations considering the sampling method
- St4 (T) - natural high densities?
Results – Macrofauna

• ANOSIM showed significant differences between trawled and not-trawled stations (Global R: 0.26; p = 0.011) at the family level

Do we have a sampler effect (Box or MUC)?
Do we have lack of taxonomic resolution?
Results - Meiofauna

There were no significant differences in the abundances between impacted and non impacted stations, however community composition showed significant differences (Global R: 0.168; p=0.043)
Results - Pulse-chase experiment

- Absence of a negative effect on bacterial biomass/production → TOC ca. 1.5x at St 4 (T)
- St 2 showed higher bioturbation (8 days)
- Pore-water irrigation seemed to differ significantly, with highest irrigation in St2 (NT).

Highly variable results due to the reduced number of replicates
Summary

- Sediment grain size was the main factor responsible for differences between T and NT areas, related to *Nephrops norvegicus* habitats (muddy sediments).

- In general, **faunal analysis showed inconclusive results between impact levels.** Several factors may be responsible:
  - Lack of good reference stations (similar sediment type)
  - Sampler effect - (MUC - exclude larger fauna, overestimate abundances)
  - Lack of taxonomic resolution
  - Necessary to include faunal functional traits (biomass, feeding type, mobility, etc.)

- Functioning experiment, showed that both bioturbation and bioirrigation were higher in NT stations, although the high variability within the low number of replicates.
More sampling, different results?

- **RV Pelagia - May 2014**
  - 4 new ROV surveys (confirmation of trawled and reference areas)

- **RV Belgica – June 2014**
  - Additional stations (including NT areas with similar grain size)
  - Consistent sampling methods (Macrofauna)
  - Repetition of the experiment more replicates

At each station 3 replicate within a 1nm (N/S) were collected in order to study spatial variability within different trawling intensity area
Acknowledgments

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