The Impact of Seabed Disturbance on Biogeochemistry, Benthic Diversity and Function in the North Sea

by Ruth Parker[1], Silvana Birchenough[2], Roger Coggan[2], Karema Warr[1], Peter Kershaw[1], Craig Mills[1] and Mark Trimmer[3]

CEFAS The Centre for Environment, Fisheries & Aquaculture Science

Introduction

Coastal marine sediments perform important 'ecosystem functions', including the biogeochemical cycling of carbon and nutrients. These functions can be altered by natural (i.e. storms and tides) or anthropogenic (e.g. fishing, dredge disposal) disturbance. Macrofauna are also capable of influencing biogeochemical processes via bioturbation and bioirrigation mediate carbon burial and sediment redox.

Trawling can impact the seabed and benthic fauna through activities which can have: i) direct effects (e.g. scraping and ploughing of the substrate, sediment resuspension and benthos destruction; and ii) indirect effects (e.g. post-fishing mortality of target and non-target species, and long-term benthic changes)[1].

Predicted ecological changes for fauna upon trawling include; a relative increase in r-strategists (e.g. polychaetes), a decrease in K-strategists (e.g. molluscs and crustaceans), and a decrease in organism size[2,3]. These changes clearly have implications for changes in mode of bioturbation/bioirrigation by the community as well as biodiversity and overall biogeochemical function.

Aim of the study:

To investigate changes in benthic biodiversity and function in relation to sediment biogeochemistry across a gradient of trawling in the Outer Silver Pit (OSP), North Sea. This has been achieved through concurrent measurements of sediment geochemistry and faunal assemblage, including a bioturbation potential index (BPI).

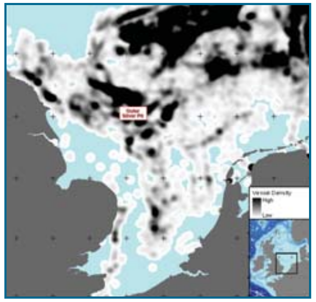


Figure 1: Trawling intensity information for 2002 from satellite monitoring data, showing Outer Silver Pit (OSP) area

Methods

1. Sites:

- 8 sites in Outer Silver Pit selected along gradient of trawling intensity (Figures 1, 2 and 3).
- Sampled October 2001 and July 2002 for sediment characteristics, biogeochemistry and benthic fauna.

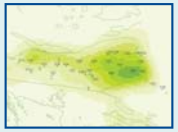


Figure 2: Outer Silver Pit sampling sites (OSP Sn1-7 - this study; Sn S1A-S9C[1], for BPI), bathymetry (50 m) and relative trawling intensity (green shading overflight, 1992-2002)

2. Biogeochemistry:

- Biogeochemical process measurements: Coupled denitrification (D_n), SO_4 reduction, oxygen uptake, nutrient fluxes, sediment oxygen profiles using microelectrodes and pore water profiles.
- Particle size analysis, carbon and porosity.

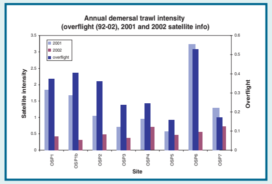


Figure 3: Inter-annual variation in trawling intensity at Outer Silver Pit

3. Faunal-Sediment assemblage:

Epifauna, Infauna and corresponding sediment samples[4].

4. Faunal-Sediment relations:

- Investigation of faunal differences/patterns which may be related to disturbance.
- Abundance data was analysed using standard routines in PRIMER[5] to identify sample clusters and the fauna that typified or discriminated between clusters.
- Environmental variables were tested in relation to faunal spatial patterns.

5. Bioturbation Potential Index (BPI):

Infauna and epifauna were categorised using two criteria:

- Taxa that were highly abundant
- Taxa that were regarded as principal bioturbators (size and biomass) Figure 4.

Functional attributes (mobility and habit) allocated with a scoring system[6] based on literature[7] and expert knowledge. Formula for the BPI calculation is;

Bioturbation potential Index (f) = biomass *(Activity* Habit)

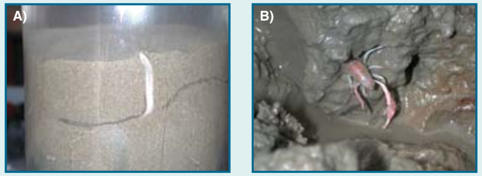


Figure 4: A) Nepthys sp. present in sandy sediment cores, B) Callianassa sp. present in muddy sediments

Results

1. Sediment characteristics and biogeochemistry:

Increased trawling intensity:

- Increases % fines and sorting (Figure 5)
- Increases oxygen penetration (Figure 6)
- Increases sulphate reduction (Figure 7)
- Decreases coupled denitrification (seasonally mediated)
- Does not affect nutrient fluxes or oxygen uptake.

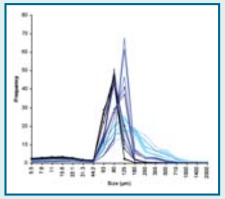


Figure 5: Variation in grain-size spectra (mm) at Outer Silver Pit: increased fines and sorting correspond with increased trawling (intensity increases with darker blue).

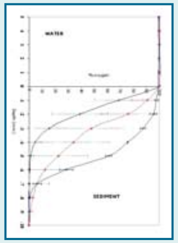


Figure 6: Average sediment oxygen profiles from low (black) and highly (red) impacted (trawling intensity) sites. For comparison, profiles in blue are from low impacted sites where large bioturbators (e.g. Echinocardium) were observed within the cores

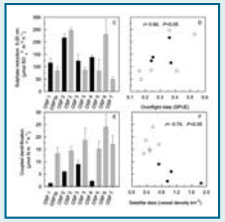


Figure 7: Sulphate reduction and coupled denitrification measurements at Outer Silver Pit, in relation to long term (overflight, 1992-2002) and annual (satellite) trawling intensities

2. Faunal results

- Epifaunal assemblages were more abundant and diverse at low impact sites (Figure 8).
- Species composition varied in a pattern that was closely matched by trawling intensity (Figure 9, correlation = 0.84).
- Infaunal communities also differed between high and low impact sites (Figure 9).
- There was no corresponding difference in abundance and diversity.

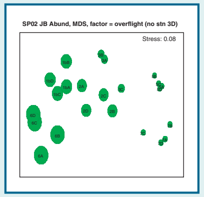


Figure 8: MDS ordination for epifaunal samples, with bubbles showing relative fishing intensity (overflight data)

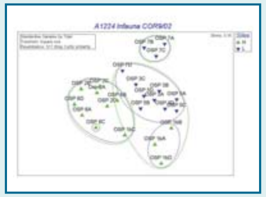
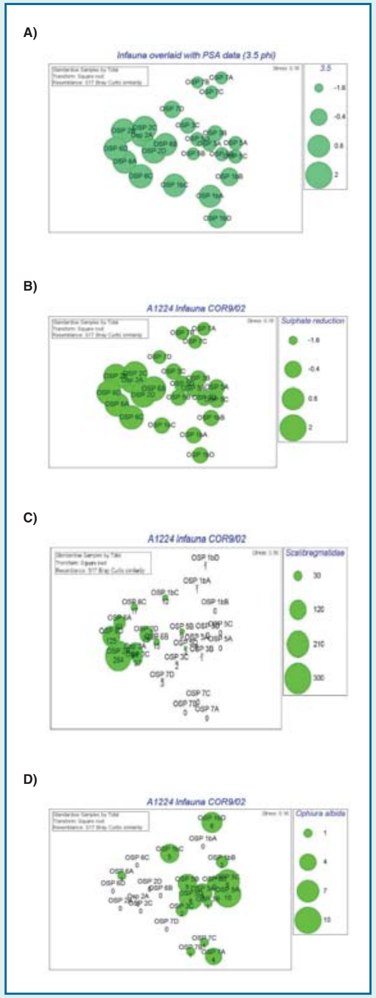


Figure 9: MDS ordination for infauna, with 42% and 50% similarity contours.

3. Faunal function and biogeochemistry:

- The proportion of fine sands (125 and 90 µm) best 'explained' the infaunal biotic pattern.
- The finer grains were more prevalent at the more heavily impacted sites (Figures 5 and 10).
- Sulphate reduction levels were higher at two of the high impact sites.
- The pattern of sulphate reduction closely mirrored the 125µm grain size (Figure 10).
- Of all the infaunal taxa, Scalibregmatidae (a family of burrowing worms) contributed most to the dissimilarity between high and low impact stations.
- Their relative abundance appears to mirror sulphate reduction levels.
- The brittle star *Ophiura albida* was characteristic of low impact, low sulphate reduction sites (Figure 10).



Figures 10A to D: The MDS from Figure 9 overlain with bubble plots for A) 90µm grain size, B) sulphate reduction levels and abundance of C) Scalibregmatidae and D) Ophiura albida

4. Bioturbation Potential Index (BPI):

- High BPI values were found at high impact areas (stations 2 and 6, Figure 11).
- Moderate BPI values found at the low impact stations (stations 3 and 5, Figure 11).
- Low BPI values found at stations 1 and 7.
- BPI values are not radically different between high and low impacted stations for the 2002 cruises.

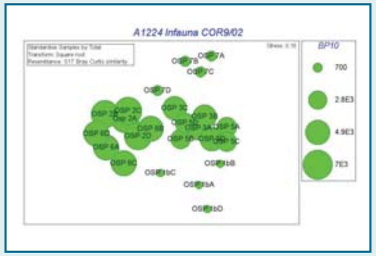


Figure 11: The MDS from Figure 9 overlain with bubble plots for BPI values

Conclusions and Future developments

- Variations in sediment type, geochemistry and benthic fauna correspond with gradients in trawling impact, estimated from overflight (1992-2002) and satellite data (2001-02).
- The coincidence of fishing effort, particle size distributions (inverse) and various faunal and geochemical observations need to be related with the evolving sedimentary environment, residual sediment transport pathways and processes (including trawling) driving sediment changes through the pit.
- Results showed that the faunal assemblages appear to respond to PSA changes and/or the associated changes in SO4 reduction. It is not yet clear which environmental factors (impact level, sediment composition, chemistry) are the main drivers for the observed biotic patterns. Such causal relationships may only be established through targeted experiments.
- BPI values showed a slight change between high and low impacted stations. Low BPI values were found at stations 1 and 7. This is coincident with low biomass values of species recorded at these two sites. Further work is required to validate the role (habit, activity) of bioturbating species and therefore their function at different sites as defined by the BPI.
- Additional biogeochemical variables (denitrification, pore-water nitrate, redox) need to be tested with the BPI and assemblage data. This will provide further insight into the functional role of benthic fauna and whether the biogeochemical changes observed with trawling are physically driven (C burial, resuspension) or mediated by changes in faunal diversity and assemblage.

References

1. Jones, J.B. (1992) Environmental impact of trawling on the seabed: a review. *New Zealand Journal of Marine and Freshwater Research* **26**: 59-67.
2. Jennings, S., Dinmore, T., Duplisea, D., Warr, K. and J. Lancaster, 2001. Trawling disturbance can modify benthic production process. *Journal of Animal Ecology*, **70**: 459-475
3. Jennings, S. and Kaiser, M.J. (1998). The effects of fishing on marine ecosystems. *Advances in Marine Biology* **34**: 203-352.
4. Boyd, S. E. (2002). Guidelines for the conduct of benthic studies at aggregate dredgings sites. Lowestoft, Department for Transport, Local Government and the Regions. CEFAS: 117.
5. Clarke, K. R. and R. N. Gorley (2001). Primer. Version 5. Primer-E, Plymouth UK.
6. Swift, D. J. (1993). "The macrobenthic infauna off Sellafield (North Eastern Irish Sea) with special reference to bioturbation." *Journal of Marine Biological Association of the UK* **73**: 143-162.
7. Bremner, J., S. I. Rogers, Frid, C.L.J. (2003). "Assessing functional diversity in marine benthic ecosystems comparison of approaches." *Marine Ecology Progress Series* **254**: 11-25.

Acknowledgements

This work was funded by the Department for Environment, Food and Rural Affairs (Project code AE1224).

[1] The Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK. http://www.cefas.co.uk e.r.parker@cefas.co.uk
[2] The Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Burnham laboratory, Remembrance Avenue, Burnham on Crouch, Essex CM 0HA, UK. [3] School of Biological Sciences, Queen Mary, University of London, Mile End Road, E1 4NS, UK.