ECO-Offshore Miljøovervåking: Towards increasing the ecological relevance of offshore sediment monitoring

DEPT. of CLIMATE & ENVIRONMENT

Summary

One key effect of the aquaculture and petroleum industry on the seafloor ecosystem is the input of organic matter of different biodegradability. This is often not traceable with current monitoring practices.

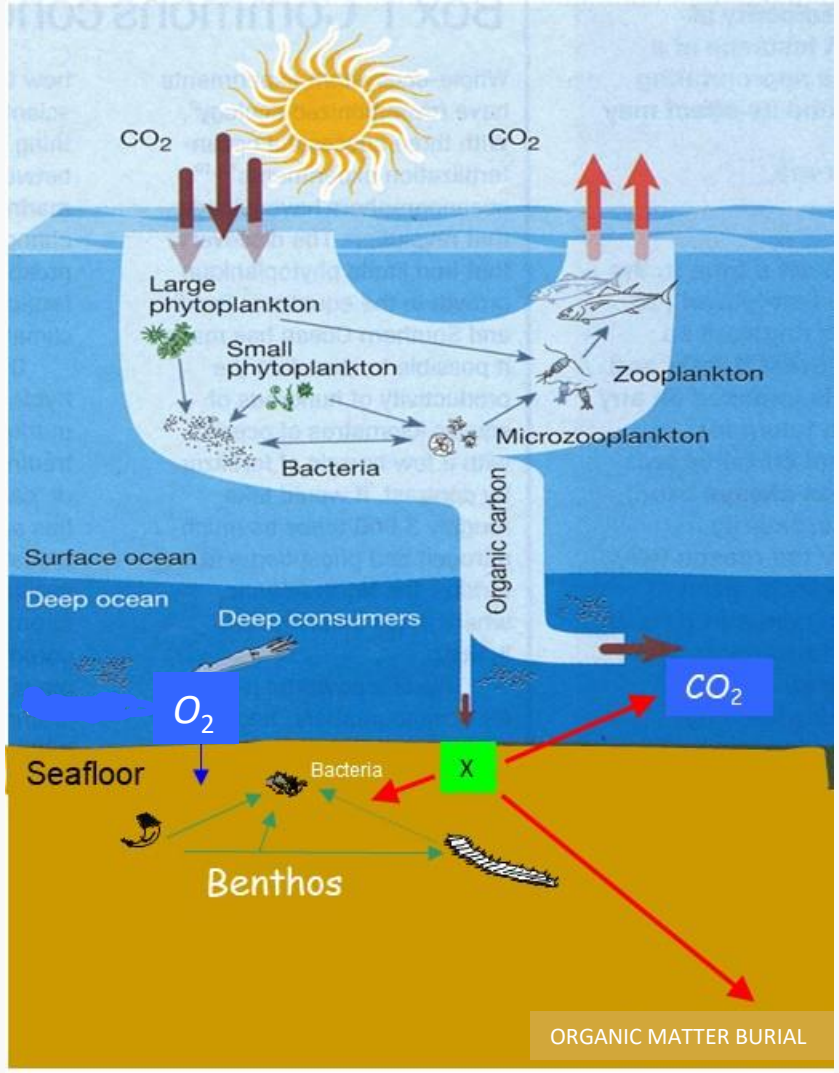
We present new tools to monitor the input and impact of this altered input and discuss its ecological relevance

What is it all about?
SUSTAINABLE development

Universal agreement for the urgency of sustainable development in anthropogenic activity i.e. human-nature interactions are conducted in ecologcial balance with the environment.

Offshore sediment monitoring plays an important role in safe-guarding the environment and is mandatory for the petroleum and aquaculture industries.

With minor expansion and refinement of the current methods, the sensitivity and ecological relevance of these routine sediment monitoring can be importantly increased.



Seafloor life fueled by material X sinking down through the water column

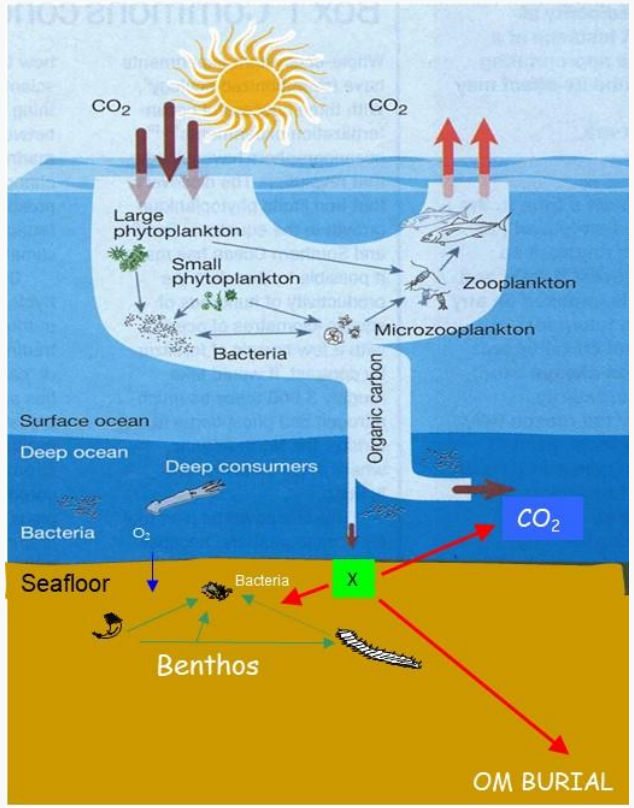
A key ecological process is the recycling of organic matter

Biomass formation = food webs = BIODIVERSITY

reminerlization (respiration) of organic matter

Understanding and modelling oceanic carbon cycle remains a key focus of marine science but relies on data on carbon stocks and respiration rates and modulating factors

Off shore monitoring efforts can fill this gap of information simultaneousy in its attempt to elucidate the resilience of seafloor functioning to anthropogenic pressure.



Changes in X can have negative effects on seafloor community structure and functioning

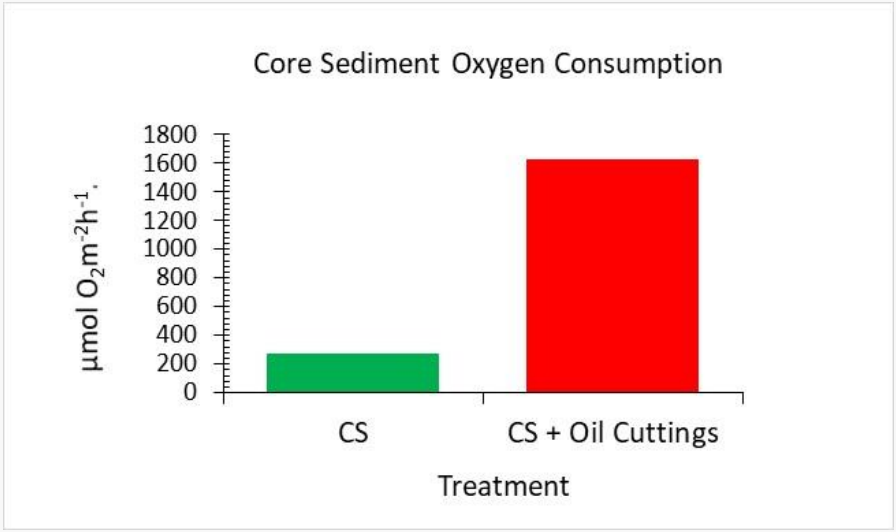
Within the petroleum industry, drill cutting discharge represent a change in X reaching the sea floor

Different composition and behaviour in the water column

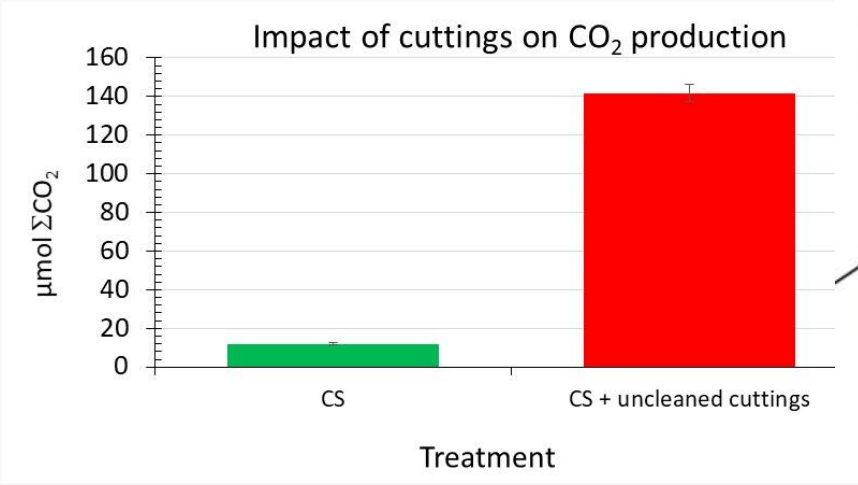
Demonstrating particle sinking behaviour
In short tubes with seawater

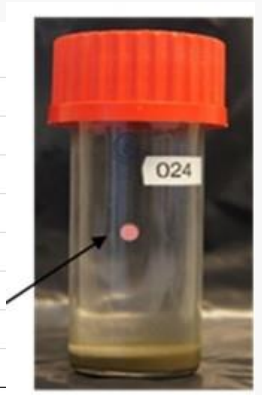
Impact of Un-cleaned drill cuttings with OBM rapidly sinking to the seafloor

Application of benthic mesocosms



Drastic increase in sediment community respiration! Input of organic matter (FOOD) utilized by biota!





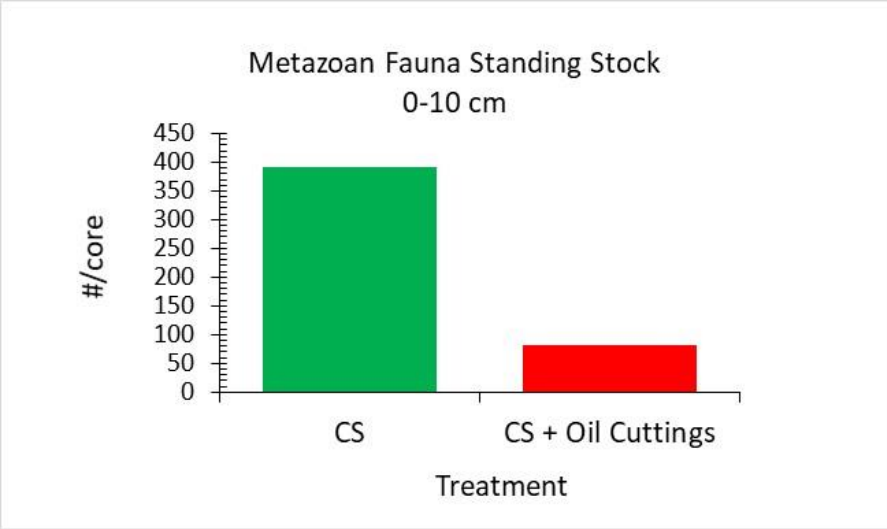
Bottle slurry incubations: test material (20 %) added to control sediment

This input of degradable organic matter also traceable by ΣCO_2 production in simple bottle slurry incubations

Sediment community oxygen consumption measurements and CO_2 production rates show cutting material is a source of organic matter readily utilized by sediment organisms

Impact of Un-cleaned oil drill cuttings rapidly sinking to the seafloor

Biotic utilization of oil drill cutting organics:
Macrofauna standing stock and biodiversity is the biota component in the monitoring program



Mass mortality of fauna! This highlights resilience of key players - bacteria

These cuttings were a supply of large amounts of degradable organic matter that led to anoxic conditions resulting in collapse of food web!

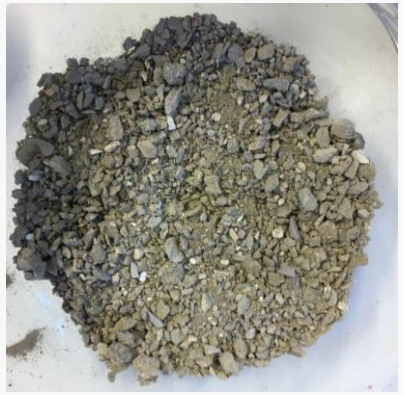
Consequently, offshore discharge of uncleaned oil drill cuttings was prohibited since the early 90's and transported to land for removal of oil. But more efficient if cleaned and returned offshore to the seafloor

Drill cuttings with OBM transported to land for removal of oil but more efficient if cleaned and returned off shore to the ocean.

NORCE

Untreated OBM

Freeze-dried OBM

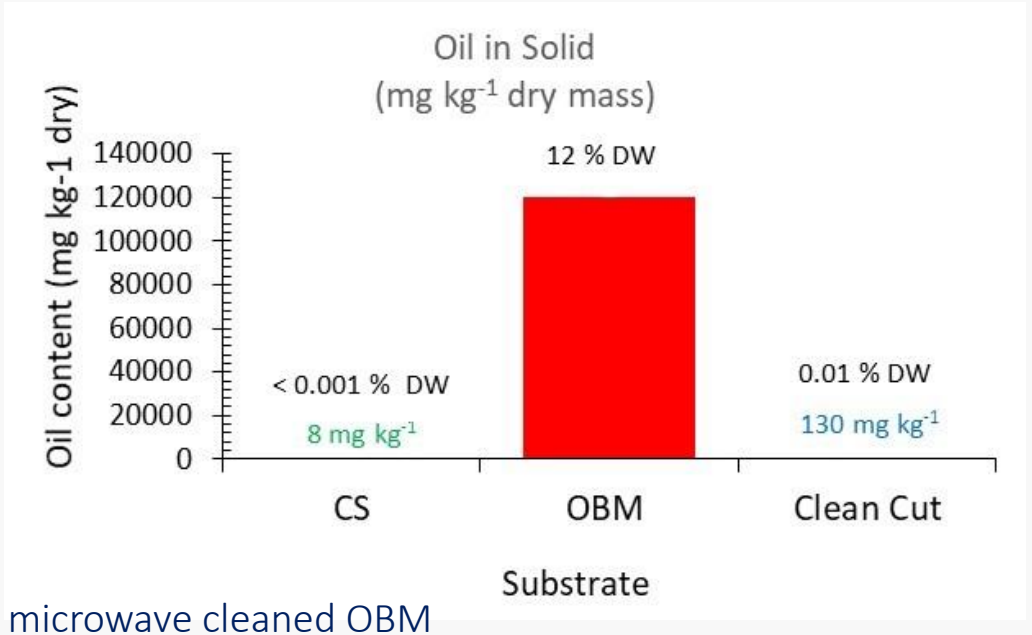


Clean Cut OBM

PROJECT CLEAN CUT: Funded by RFFvest. Examned the efficency of an energy efficient modified microwave method to remove oil from cuttings

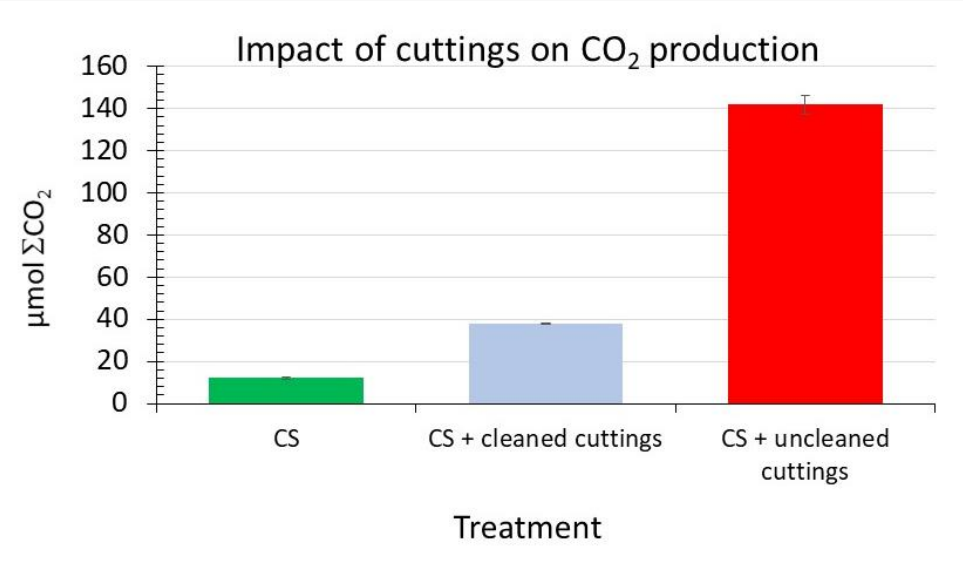
norwegian technology

REGIONALE FORSKINGSFOND VESTLAND



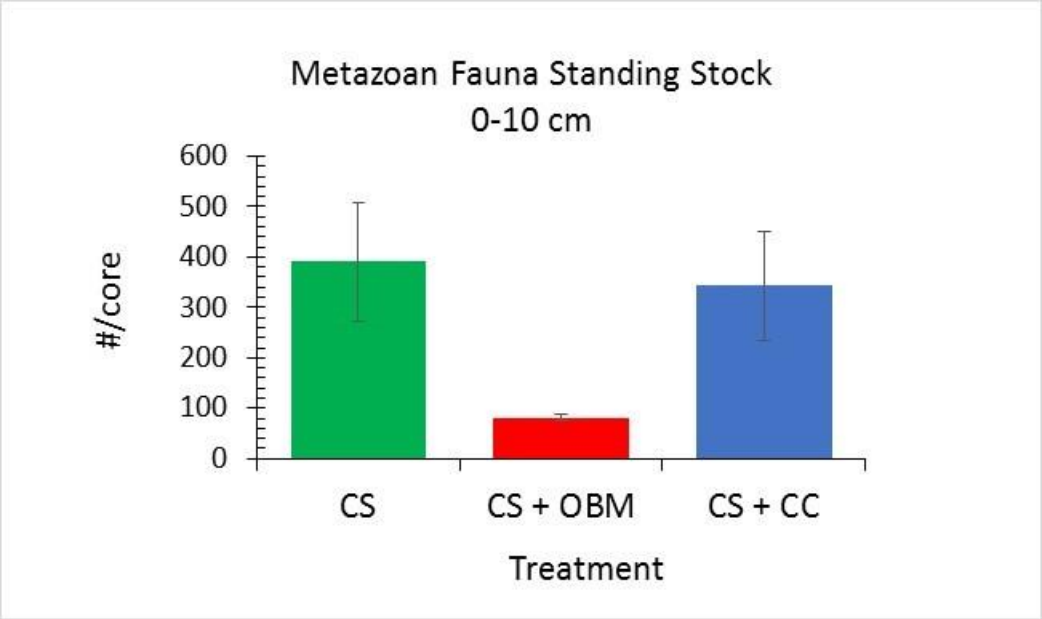
CS = fjord control sediment
OBM = Untreated Oil base Mud material
Clean-Cut: Norwegian Technology modified microwave cleaned OBM

Effciency of modified microwave cleaning of cuttings



Removal of oil led to significant reduction in the amount of degradable carbon available

And prevented the collapse of the food web



CS = control sediment material
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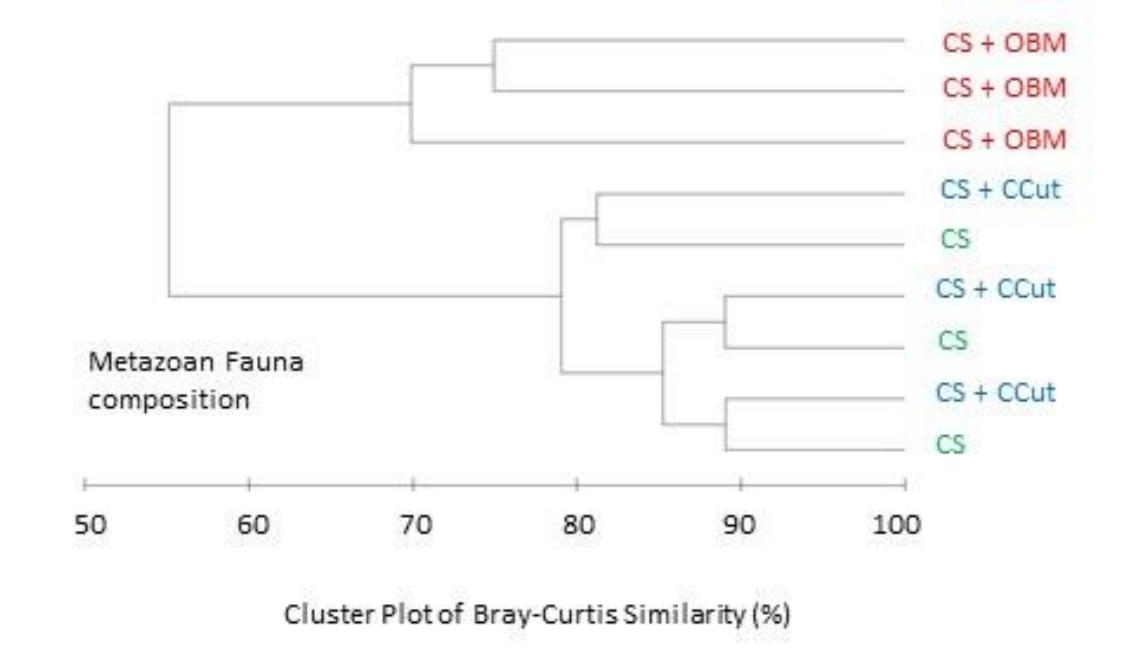
Impact on sediment macrofauna community structure



CS = control sediment material
OBM = Untreated Oil base Mud material
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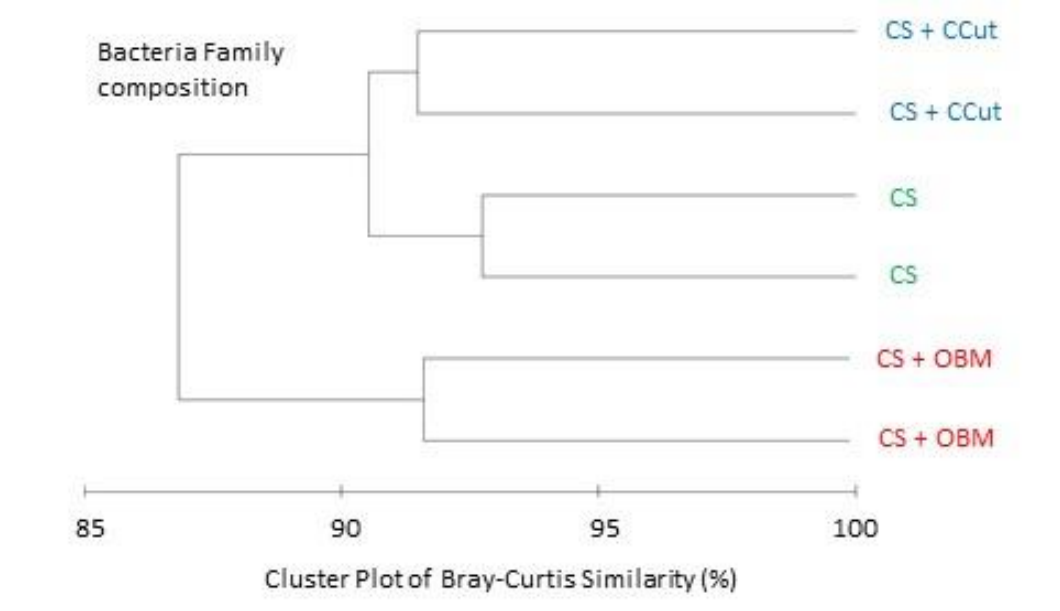
Un-cleaned oil cuttings caused mass mortality of fauna and change in community structure

Unlike Oil based mud cuttings, microwave cleaned cuttings had no adverse impact on macrofauna community size and structure

Macrofauna indeed a valuable monitoring tool.
INCREASE ECOLOGICAL RELEVANCE:
1. Convert macrofauna densities to carbon biomass from blotted weight of the different species.

2. Microbes are key ecological players but not a monitoring parameter. Strong drop in costs of DNA sequencing may change this.

Impact on bacteria community structure based on DNA metagenomics



CS = control fjord sediment OBM = Untreated Oil base Mud material
CC = Clean-Cut: Microwave cleaned OBM

Increase sediment respiration with un-cleaned oil cuttings indicated high bacteria resilience, but clearly a change in bacteria community structure

Bacteria a very sensitive tool to monitor oil in sediment, rapid shift in bacteria communities with strong dominance of hydrocarbon degraders in oil rich cuttings.

INCREASE ECOLOGICAL RELEVANCE:

1. Include this key player and carbon biomass is readily calculated from bacteria counts.

Drill cutting specific characteristics as additional monitors:

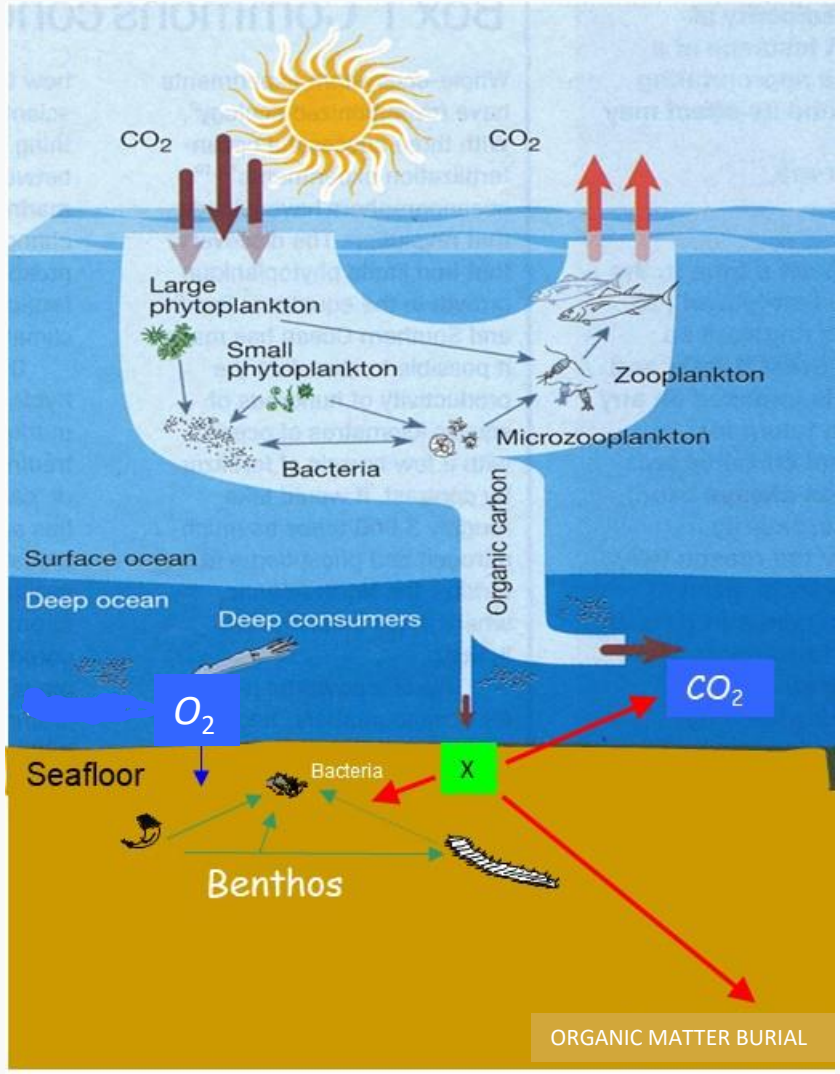
	mol C/N	δ^{13}C-TOC (‰)
CS	9.07	-22.00
UN-CLEANED CUTTINGS	54.9	-27.68
CLEANED CUTTINGS	50.56	-26.86

These parameters can be obtained in a single measurement, no extra costs than standard TOC measurements

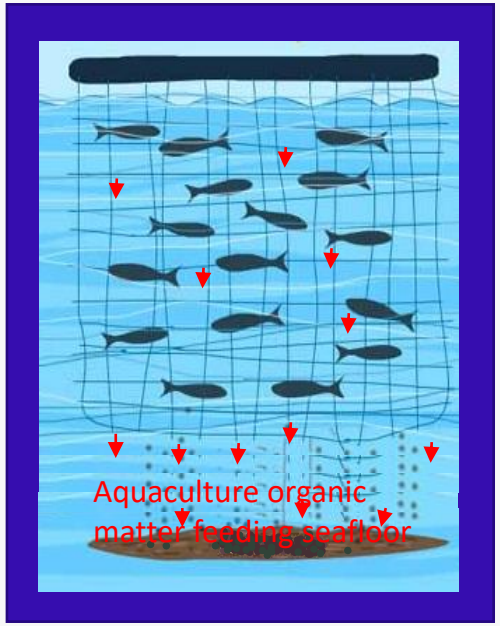
	Offshore Miljøovervåking	Eco-Offshore Miljøovervåking
Sediment TOC*	% TOC (% Dry mass sediment 0-1 cm)	+ % TOC + gTOC m^{-2} per sediment depth
Sediment TON*	-	+ % TON + g TON m^{-2} per sediment depth
Sediment mol C/N ratio*	-	+ mol C/N ratio
Sediment δ^{13}C-TOC & δ^{15}N-TON*	-	+ ‰
Macrofauna Biomass	-	+ gram organic carbon and total nitrogen* per species for a selected # of stations Species Conversion Table: Blotted wet weight to Carbon & Nitrogen content for all other stations and future studies.
Sediment TOC degradation rates: **Measured through sediment oxygen consumption (SOC) and CO_2 production rates. Both in intact cores or small bottle slurry measurements.**	-	+ gC respired/m2/day + Half-life of TOC

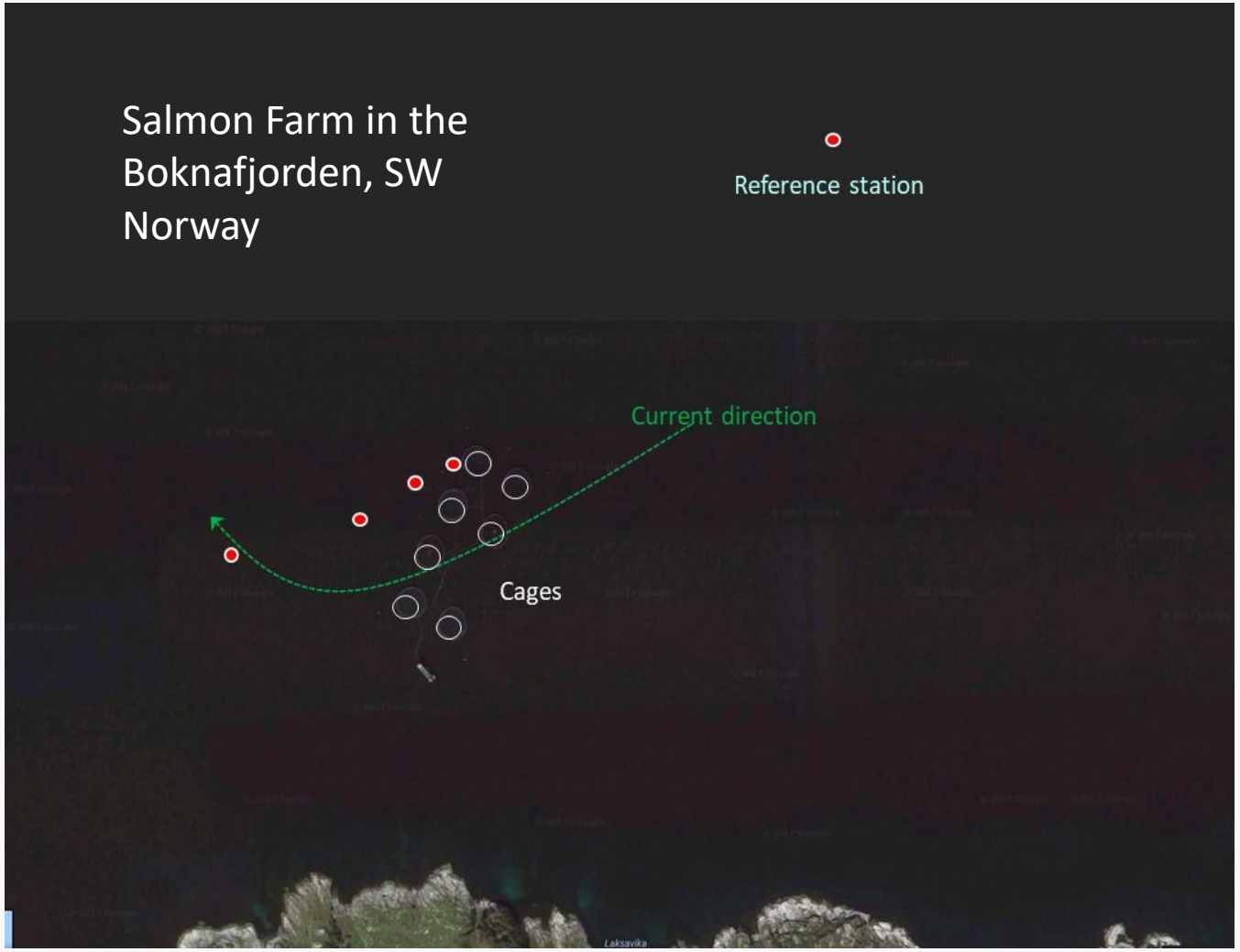
*Obtained in a single measurement

Towards increasing the sensitivity & ecological relevance of offshore sediment monitoring



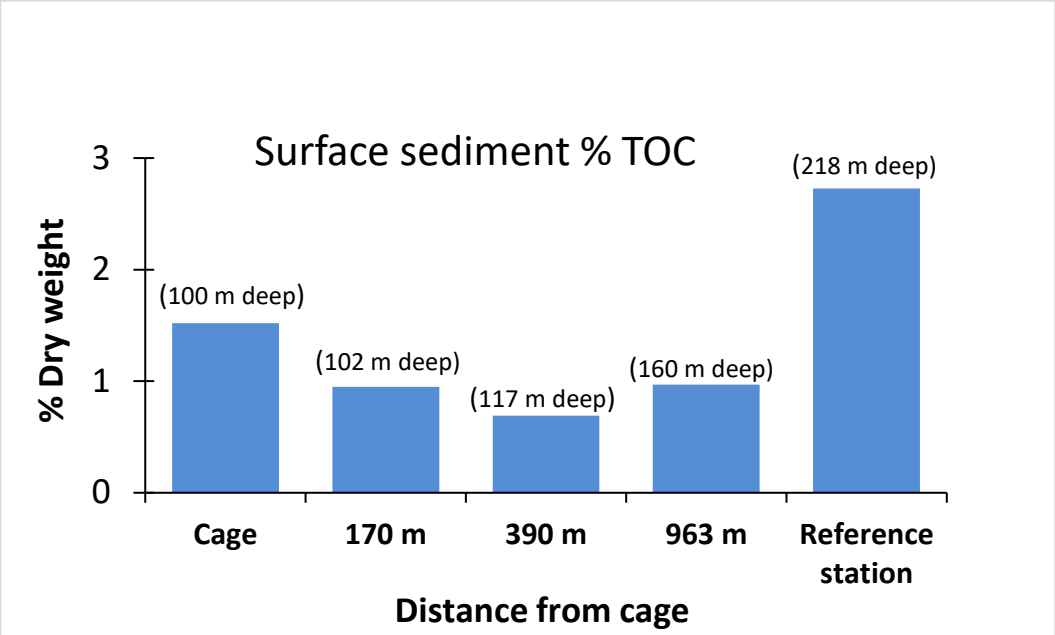
Within the aquaculture industry, fish faeces and excess feed are a new source of organic matter reaching the seafloor.





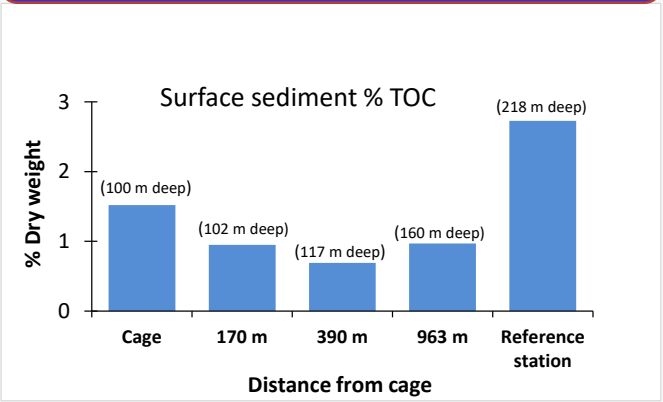
We examined surface sediment along a transect in a salmon farm in the Boknafjorden. The reference station is a deep basin with fine grained sediment.

Organic enrichment may not be evident when measured as % TOC



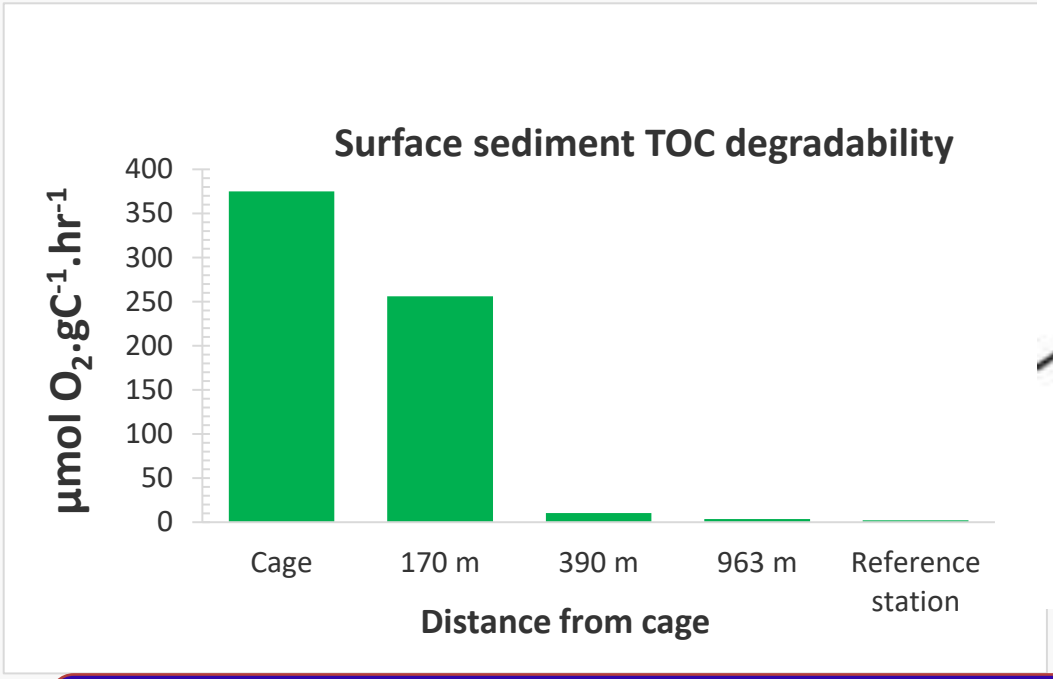
Looked closer at other characterisctics of organic matter: degradability and stable carbon isotope signatures.

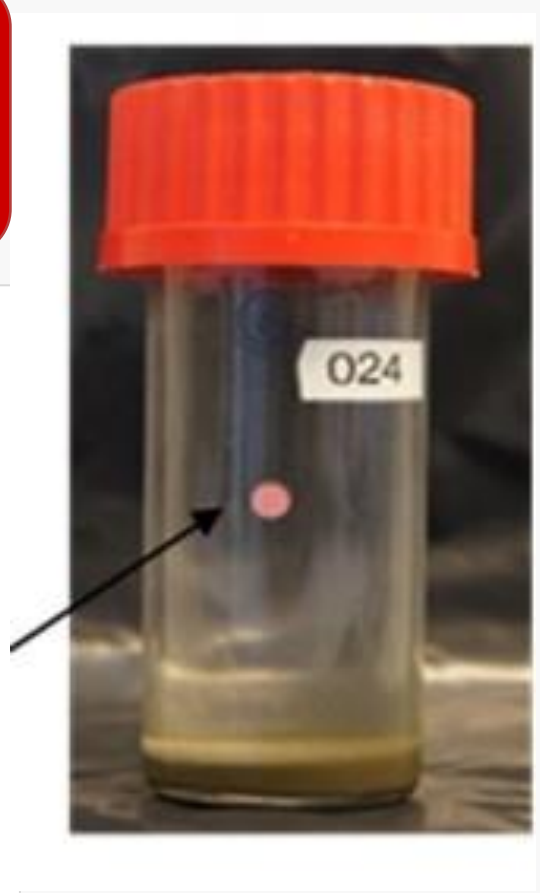
Organic enrichment may not be evident when measured as % DW



Utility of organic matter degradability as indicator of impact?

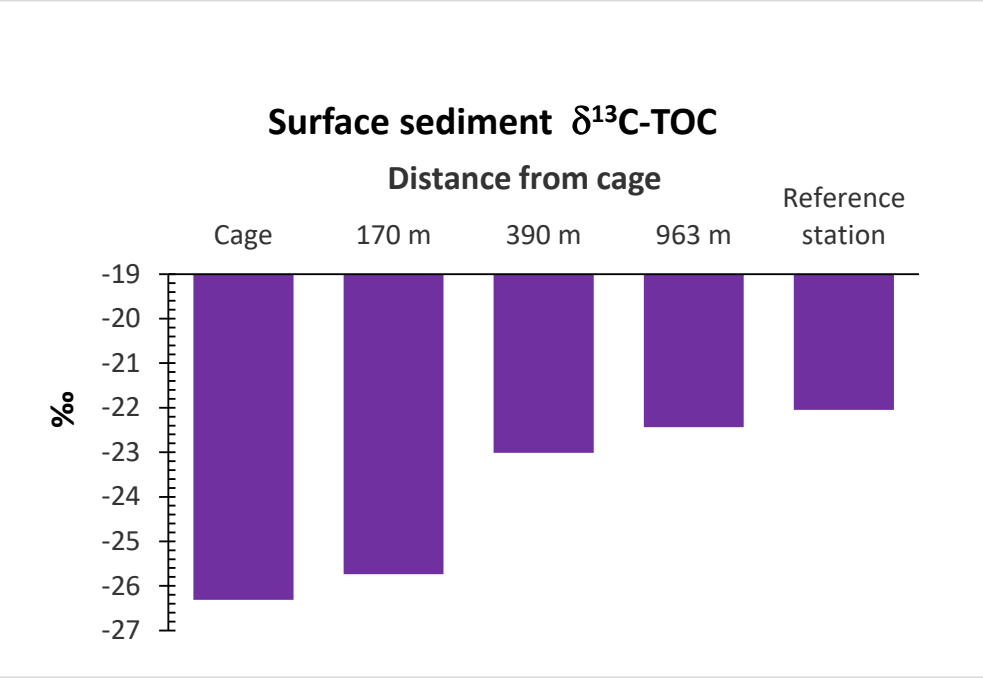
MICRO-RESPIROMETER. Small Bottle sediment-water slurry incubations: non-invasive O_2 consumption measurements.





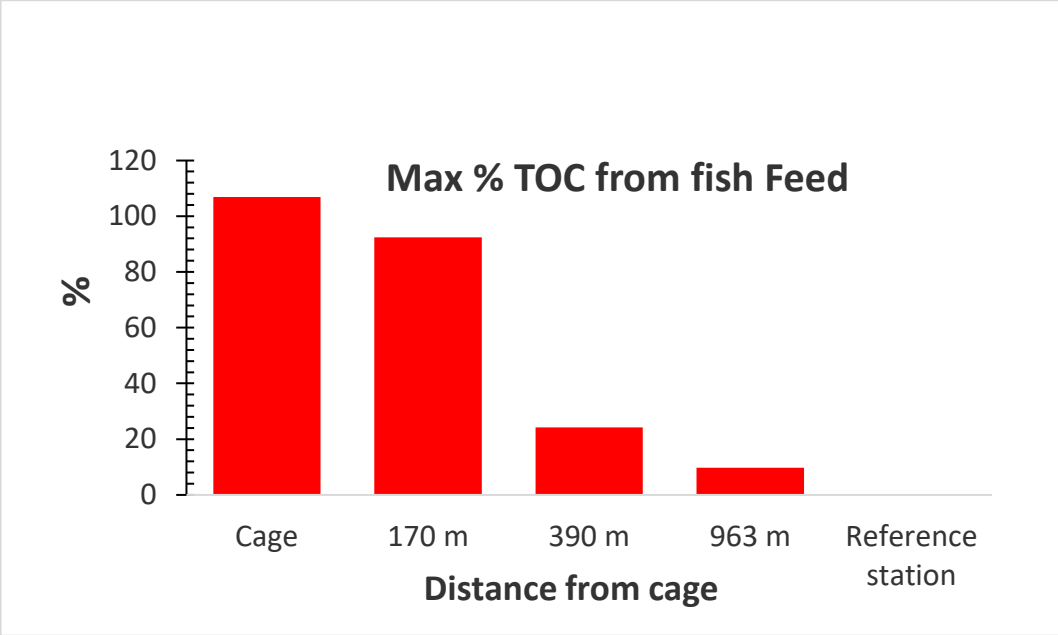
Enrichment is restricted to close to cages and not at reference station!

Stable carbon isotope signatures support that impact is limited to close to cages

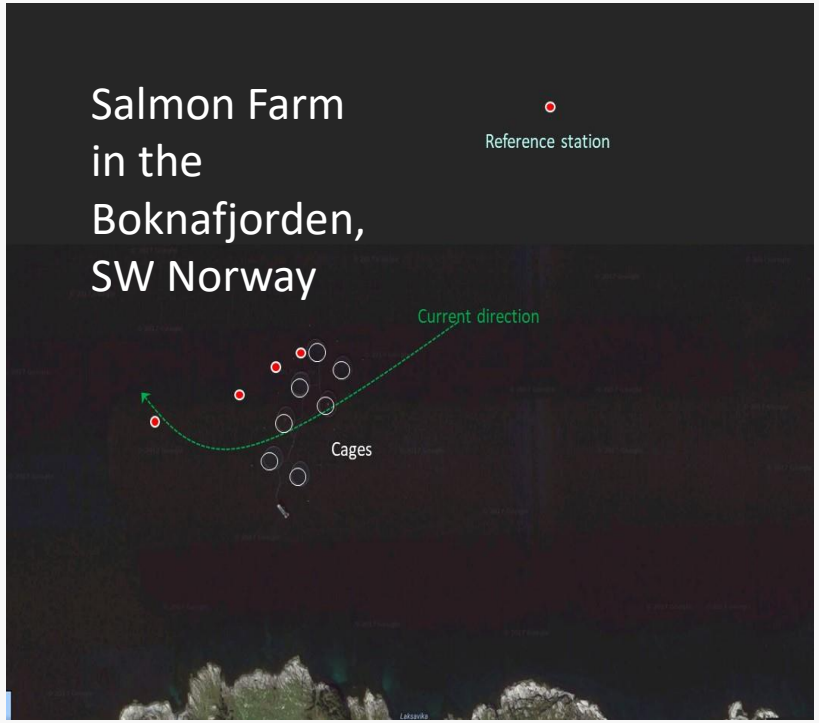


Reference station has a typical marine TOC signature, clearly different from fish feed signatures under cages.

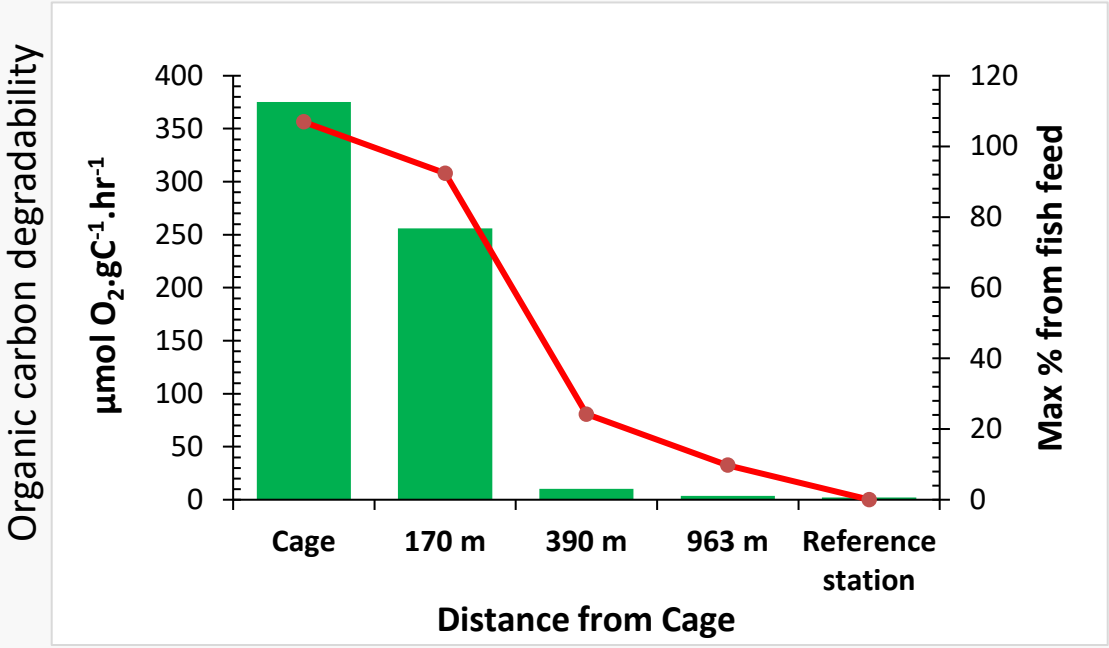
Using carbon source isotope mixing model to estimate maximun contribution from fish feed



Again, main impact is close to cages

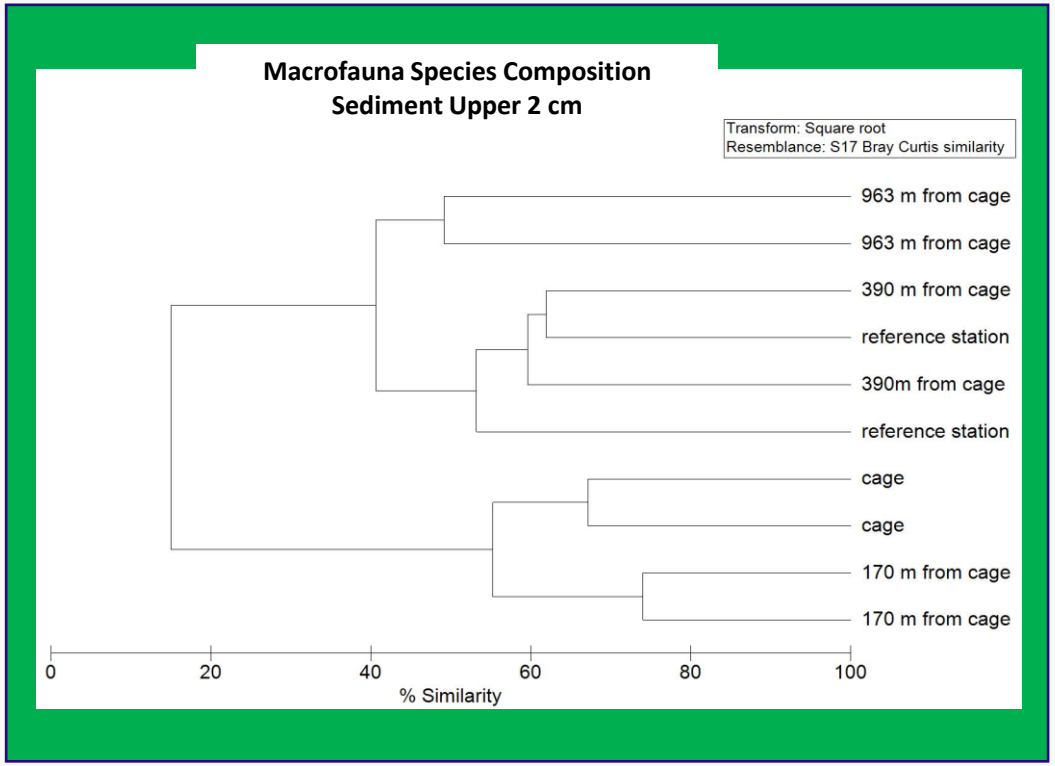


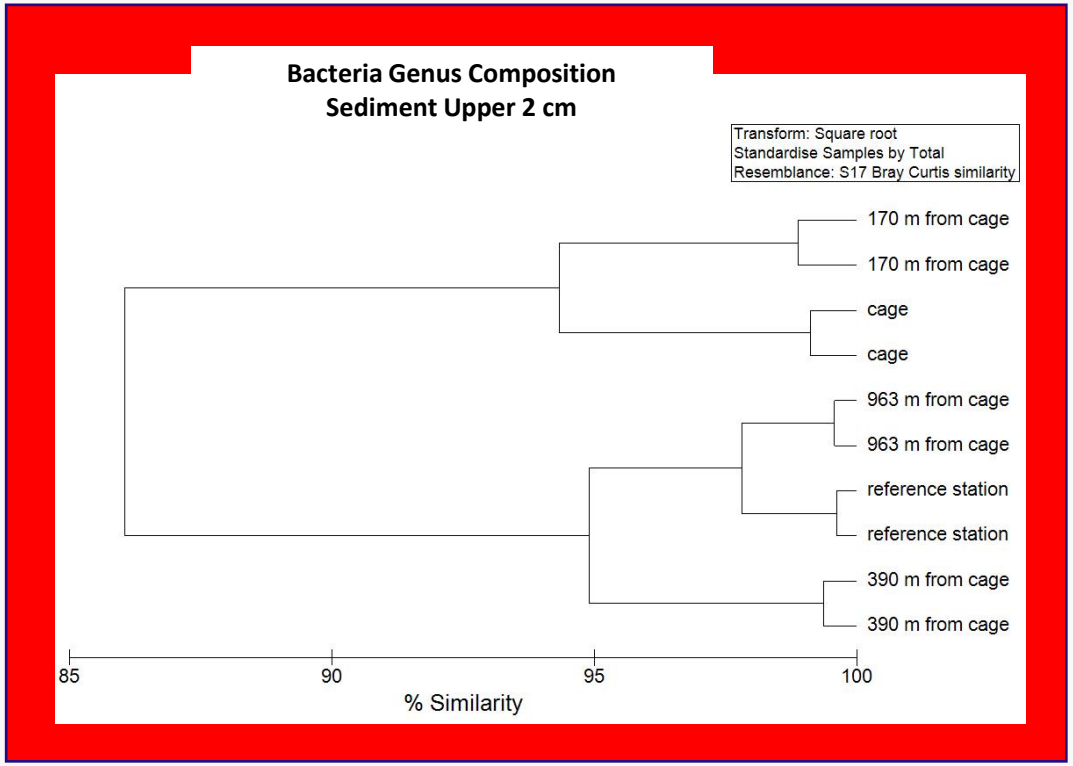
Direct measure of sediment organic matter degradability and stable carbon isotope signatures are very sensitive tools to monitor impact.



MICRO-RESPIROMETER. Small Bottle organic matter degradability and isotope signatures can also be done with Suspended Particulate Matter from different water depths to document spreading of organic matter.

Trends observed with the direct measure of organic reactivity and stable isotope signatures are supported by macrofauna and bacteria composition patterns.





Main impact is close to cages

Fjord sediment as hotspots for carbon burial

Surface sediment TOC content (1 cm thick layer)

	Boknafjorden surface sediment		**Other coastal subtidal areas surface sediment**	**Organic Rich sediment**	
	Aquaculture impacted	Outside influence of Aquaculture	S. North Sea and Eastern Arabian Sea	Oxygen minimum zone E. Arabian sea	Ancient sediment deposit (sapropel, E. Mediterranean Sea)
mol TOC.m^{-2}	11-16	6-10	5-7	12-14	11-16
	High degradability organic matter	Low degradability organic matter		Low degradability organic matter	

Aquaculture is also moving offshore: together with consortium partners NORCE was succcesfull in obtaining a KSP project around sustainable offshore aqualculture within NFR-Green Platform program.

Missing baseline information NCS offshore sediment: mol TOC.m-2 and biota carbon biomass: Eco-Offshore miljøovervåking!

Acknowledgements

Data presented was generated in projects financed by RFFVest and EU

With contributions from several colleagues including: Thorleifur Agustsson, Henk Bolhuis, Peter van Breugel, Alessio Gomeiro, Fiona Provan and Steinar Sanni.

Special thanks to equinor for providing test material and supporting the elaboration of NORCE mesocosm facilities.

Tusen takk!

Thank you for your attention!