SUPPLEMENTARY MATERIAL

Impacts of bottom fishing on the sediment infaunal community and biogeochemistry of cohesive and non-cohesive sediments

Marija Sciberras[1], Ruth Parker[2], Claire Powell[2], Craig Robertson[1], Silke Kröger[2], Stefan Bolam[2], Jan Geert Hiddink[1]

[1]School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, LL59 5AB, United Kingdom, +44 (0)1248 388150

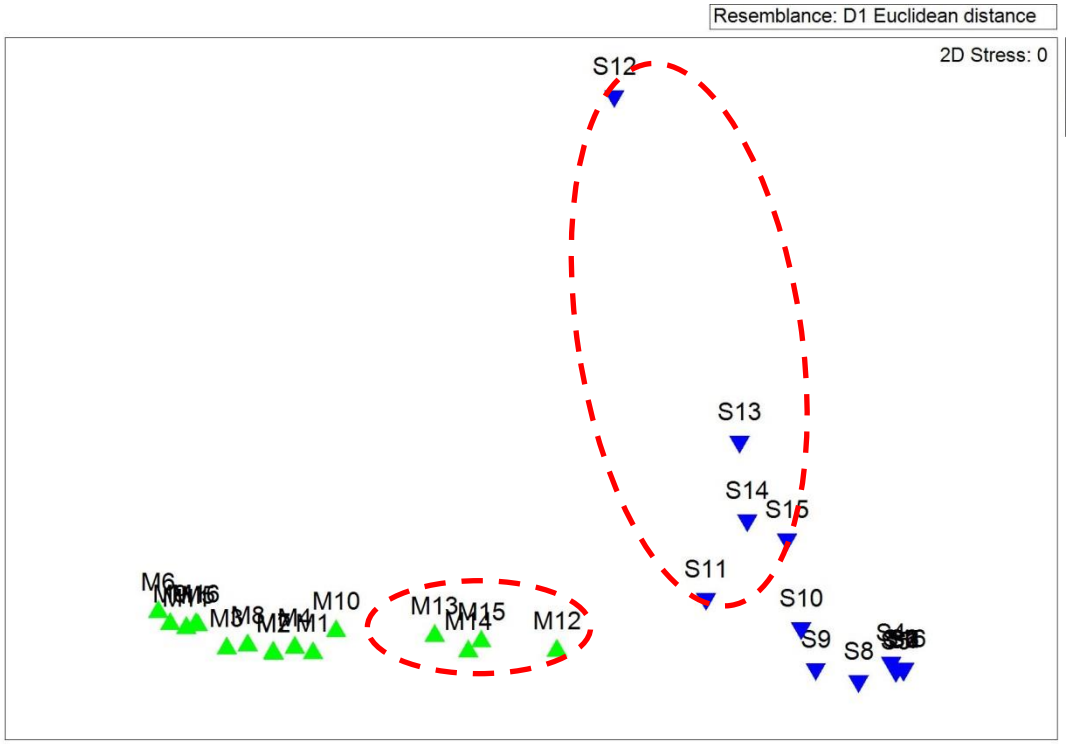
[2]Centre for Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, Suffolk, NR33 0HT, United Kingdom

Corresponding author
email: m.sciberras@bangor.ac.uk
T: (0044) 01248388150

SM 1. Summary of the abiotic habitat characteristics and fishing frequency at each sampling site within the two study locations, Isle of Man fishing ground (sandy sediment) and *Nephrops* fishing ground (muddy sediment). Fishing frequency is expressed as the number of times an area is fished with bottom fishing gear in a year.

Site code	Fishing frequency (yr^{-1})	Water depth (m)	Mean tide stress (Nm^{-2})	Mean wave stress (Nm^{-2})	Grain size distribution (%)		
					Gravel	Sand	Mud
***Nephrops* fishing ground, off Cumbria, England (Mud)**							
M1	2.95	30.3	0.21	0.92	0.0	33.3	66.7
M2	3.87	35.0	0.17	0.69	0.0	29.0	71.0
M3	4.60	33.1	0.18	0.81	0.0	23.6	76.4
M4	4.99	31.5	0.22	0.68	0.0	31.3	68.7
M5	5.41	40.9	0.22	0.52	0.0	20.3	79.7
M6	5.67	34.4	0.21	0.64	0.0	15.8	84.2
M7	5.92	35.7	0.16	0.52	0.0	28.9	71.1
M8	6.09	43.0	0.22	0.42	0.0	26.4	73.6
M9	6.99	33.7	0.19	0.61	0.0	17.2	82.8
M10	7.98	38.1	0.19	0.59	0.0	36.2	63.8
M11	8.51	34.4	0.18	0.72	0.0	19.0	81.0
Isle of Man fishing ground (Sand)							
S1	0.00	26.3	0.20	0.76	0.3	99.7	0.0
S2	0.05	27.1	0.23	0.79	0.1	99.9	0.0
S3	0.11	19.6	0.14	1.43	0.0	100	0.0
S4	0.25	23.9	0.17	1.00	2.4	97.6	0.0
S5	0.35	27.0	0.25	0.70	1.3	98.7	0.0
S6	0.51	23.7	0.17	1.14	0.1	99.9	0.0
S7	1.16	29.4	0.20	0.74	0.2	99.8	0.0
S8	1.63	33.0	0.11	0.73	0.4	95.0	4.6

SM 2. MDS plot of the sediment parameters of the 32 sampling sites. Dotted red lines indicate outlier sites in terms of their environmental variables (% sand, % mud, water depth, tide stress and wave stress) – these sites were excluded from the statistical analyses. M represents muddy sites, S represents sandy sites.



Results of the Pearson's correlation analysis between fishing frequency and environmental parameters (water depth, tide and wave bed stress, percentage sand composition) for the muddy and sandy sites retained for the statistical analyses.

	Muddy study sites	**Sandy study sites**
Water depth (m)	r = 0.35, p = 0.28	r = 0.65, p = 0.08
Mean tide bed stress ($Nm^{-2)}$	r = 0.17, p = 0.61	r = 0.46, p = 0.25
Mean wave bed stress (Nm^{-2})	r = 0.46, p = 0.15	r = 0.35, p = 0.39
% sand composition	r = 0.28, p = 0.41	r = 0.65, p = 0.08

SM 3. Description of traits and modalities used in the biological trait analysis (adapted from Bolam et al. 2014b).

Trait	Modality	Trait Definition	Functional significance and/or vulnerability to fishing
Feeding group	Suspension	The removal of particulate food taken from the water column, generally via filter-feeding	Feeding mode has important implications for the potential for transfer of carbon between the sediment and water and within the sediment matrix. Feeding mode also has important repercussions for many biogeochemical processes (Rosenberg, 1995). Furthermore, whilst scavengers may benefit from higher food availability as a result of carrion, suspension feeders may suffer damage to their filtering devices due to high concentration of suspended sediment following the fishing disturbance event.
	Surface deposit	Active removal of detrital material from the sediment surface. This class includes species which scrape and/or graze algal matter from surfaces	
	Subsurface deposit	Removal of detrital material from within the sediment matrix	
	Scavenger / opportunist	Species which feed upon dead animals	
	Predator	Species which actively predate upon animals (including the predation on smaller zooplankton)	
	Parasite	Species which have a parasitic mode of life on other invertebrate species	
Mobility	Sessile	Species in which the adults have no, or very limited, mobility either because they are attached or are limited to a (semi-) permanent tube or burrow	Adults of faster moving species are more likely to evade capture by trawl gear than slow-moving or sessile individuals. Mobility also affects the ability for adult recolonization of disturbed areas.
	Burrower	Infaunal species in which adults are capable of active movement within the sediment	
	Crawl/creep/climb	Capable of some, generally limited, movement along the sediment surface or rocky substrata	

	Swim	Species in which the adults actively swim in the water column (many usually return to the bed when not feeding)	
Bioturbation mode	Diffusive mixing	Vertical and/or horizontal movement of sediment and/or particulates	Describes the ability of the organism to rework the sediments. Can either be upward, downward, onto the sediment or mixing of the sedimentary matrix. Bioturbation mode has important implications for sediment-water exchange and sediment biogeochemical properties.
	Surface deposition	Deposition of particles at the sediment surface resulting from e.g. defecation or egestion (pseudofaeces) by, for example, filter and surface deposit feeding organisms	
	Upward conveyor	Translocation of sediment and/or particulates from depth within the sediment to the surface during subsurface deposit feeding or burrow excavation	
	Downward conveyor	The subduction of particles from the surface to some depth by feeding or defecation	
	None	Do not perform any of the above and/or not considered as contributing to any bioturbatory capacity	

SM 4A. The macroinfaunal species that contributed to more than 85% of total abundance in sand and mud habitats. R_i and M_i are the reworking and mobility traits, respectively, and Ft_i is the corresponding sediment reworking functional types. M_i scores: 1 for organisms that live in fixed tubes; 2 indicates limited movement; 3 indicates slow, free movement through the sediment matrix; 4 indicates free movement, that is, via burrow system. R_i scores: 1 for epifauna; 2 for surficial modifiers; 3 for upward and downward conveyors; 4 for biodiffusors; and 5 for regenerators. Reworking types (Ft_i): "S" for surficial modifiers; "B" for biodiffusors; "UC" and "DC" for upward and downward conveyors; "R" for regenerators; and "E" for epifauna.

Class	**Species name**	**Abundance (%)**	**R_i**	**M_i**	**Ft_i**	**Class**	**Species name**	**Abundance (%)**	**R_i**	**M_i**	**Ft_i**
Echinoidea	*Echinocardium* spp.	18.8	4	3	B	Phoronida	*Phoronis* sp.	34.0	2	1	S
Polychaeta	*Lagis koreni*	9.8	3	1	UC	Polychaeta	*Nepthys incisa*	17.4	4	3	B
Bivalvia	*Ensis* sp. *(juvenile)*	9.8	2	2	S	Polychaeta	*Nepthys* sp.	8.4	4	3	B
Polychaeta	*Poecilochaetus serpens*	5.9	2	2	S	Bivalvia	*Saxicavella jeffreysi*	6.4	1	2	E
Polychaeta	*Phoronis* sp.	5.9	2	1	S	Polychaeta	*Minuspio (Prionospio)* sp.	3.0	3	2	UC/DC
Bivalvia	*Phaxas pellucidus*	5.8	2	2	S	Enteropneusta	*Enteropneusta* sp.	2.9	5	4	R
Bivalvia	*Parvicardium* spp.	5.7	2	2	S	Malacsotraca	*Callianassa subterranea*	2.7	4	4	B
Polychaeta	*Owenia fusiformis*	4.11	2	1	S	Bivalvia	*Abra alba*	2.1	2	2	S
Bivalvia	*Mya arenaria*	2.4	2	2	S	Polychaeta	*Polydora* sp.	1.8	3	1	UC/DC
Polychaeta	*Sthenelais limicola*	2.3	4	3	B	Echiura	*Maxmuelleria lankesteri*	1.8	5	4	R
Bivalvia	*Thracia phaseolina*	2.0	3	2	DC	Polychaeta	*Tharyx killariensis*	1.7	2	2	S
Polychaeta	*Spiophanes bombyx*	1.5	3	1	UC/DC	Polychaeta	*Glycera* sp.	1.6	4	3	B
Malacostraca	*Pseudocuma longicornis*	1.5	2	3	S	Polychaeta	*Glyphohesione klatti*	1.5	4	3	B
Polychaeta	*Scoloplos armiger*	1.2	4	3	B						
Malacostraca	*Argissa hamatipes*	1.0	2	3	S						

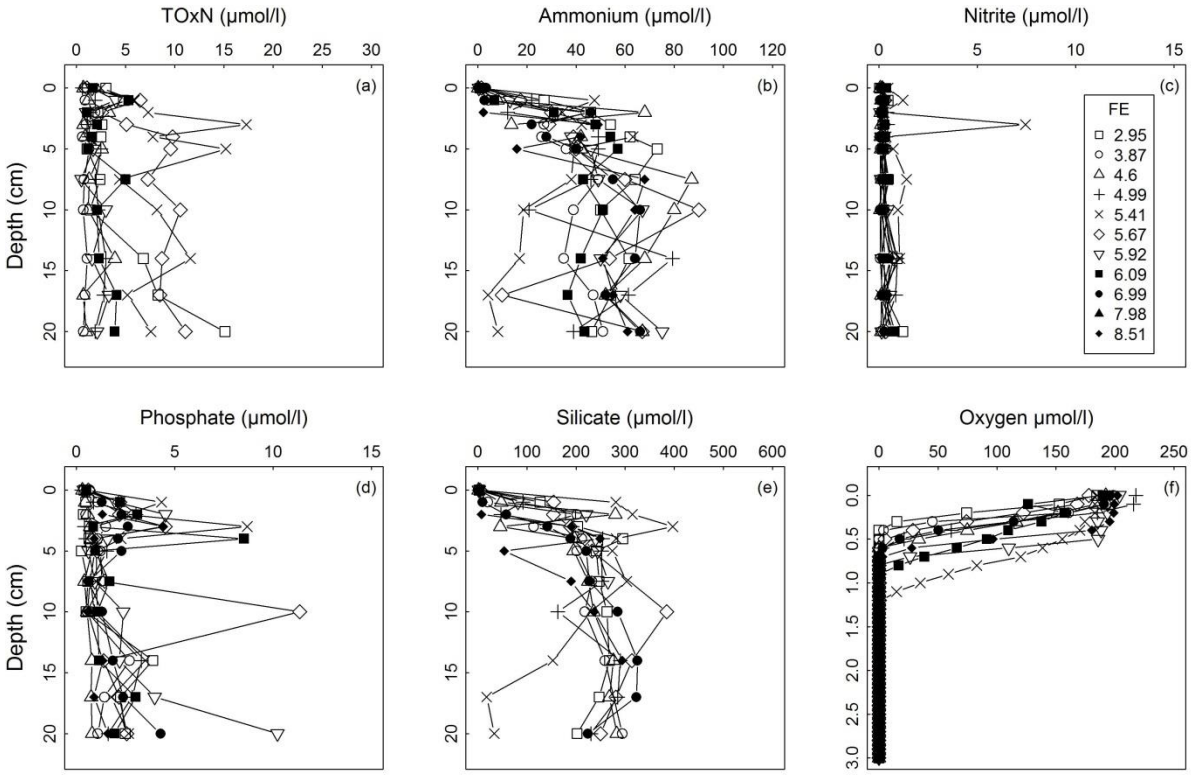
Bivalvia	*Moerella pygmaea*	1.0	2	2	S						
Polychaeta	*Magelona filiformis*	1.0	2	2	S						
Ophiuroidea	*Ophiuroidea juvenile*	1.0	2	2	S						
Bivalvia	*Spisula elliptica*	0.9	2	2	S						
Polychaeta	*Scalibregma inflatum*	0.8	4	4	B						
Polychaeta	*Spio* sp.	0.8	3	2	UC/DC						
Bivalvia	*Abra prismatica*	0.8	2	2	S						
Polychaeta	*Aricidea cerruti*	0.8	2	3	S						
Malacostraca	*Bathyporeia gracilis*	0.7	2	3	S						
Polychaeta	*Magelona johnstoni*	0.7	2	2	S						
Bivalvia	*Ensis ensis*	0.7	2	2	S						
Palaeonemertea	*Tubulanus polymorphus*	0.6	-	-	-						
Polychaeta	*Glycera oxycephala*	0.6	4	3	B						
Polychaeta	*Orbinia sertulata*	0.6	4	3	B						
Holothuroidea	*Thyone* sp.	0.6	2	3	S						

SM 4B. The macroinfaunal species that contributed to more than 85% of total biomass in sand and mud habitats. R_i and M_i are the reworking and mobility traits, respectively, and Ft_i is the corresponding sediment reworking functional types. M_i scores: 1 for organisms that live in fixed tubes; 2 indicates limited movement; 3 indicates slow, free movement through the sediment matrix; 4 indicates free movement, that is, via burrow system. R_i scores: 1 for epifauna; 2 for surficial modifiers; 3 for upward and downward conveyors; 4 for biodiffusors; and 5 for regenerators. Reworking types (Ft_i): "S" for surficial modifiers; "B" for biodiffusors; "UC" and "DC" for upward and downward conveyors; "R" for regenerators; and "E" for epifauna.

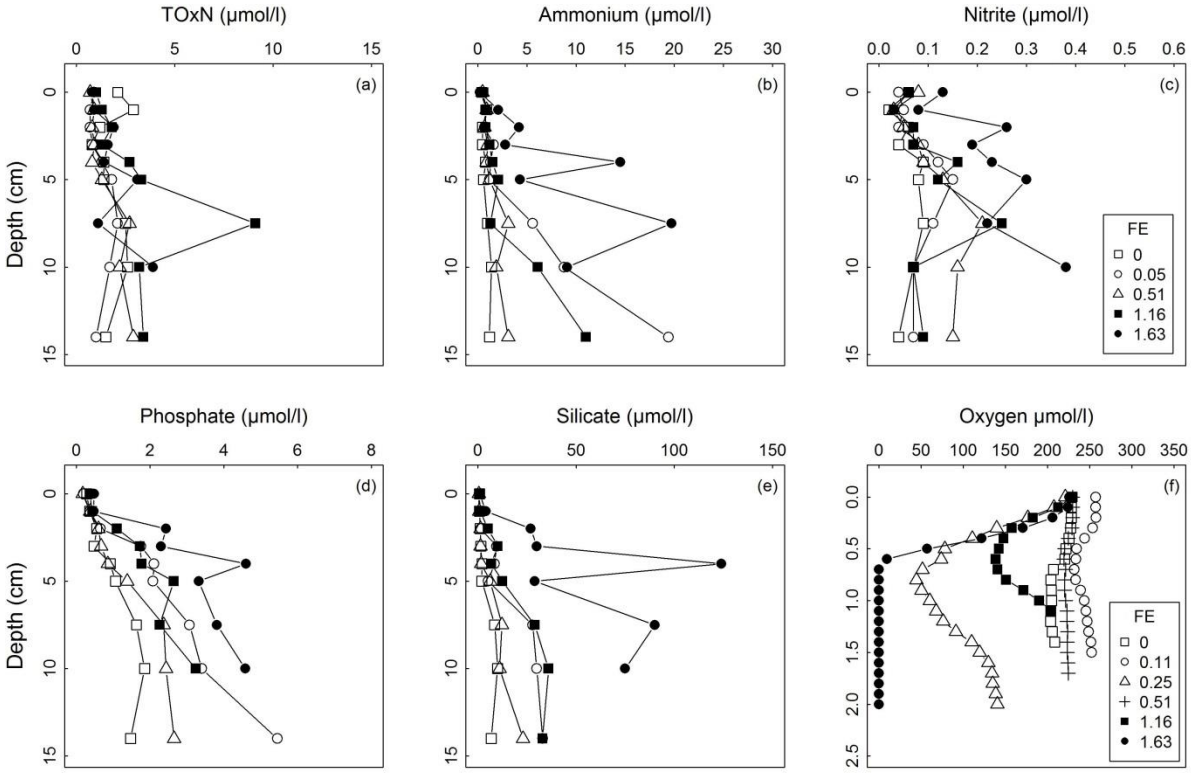
Class	**Species name**	**Biomass (%)**	**R_i**	**M_i**	**Ft_i**	**Class**	**Species name**	**Biomass (%)**	**R_i**	**M_i**	**Ft_i**
Polychaeta	Polychaeta biomass	10	-	-	-	Echiura	*Maxmuelleria lankesteri*	71.0	5	4	R
Holothuroidea	*Labidoplax sp.*	8.5	2	3	S	Malacsotraca	*Callianassa subterranea*	8.2	4	4	B
Anthozoa	*Cerianthus sp.*	8.3	2	1	S	Polychaeta	*Nepthys incisa*	4.7	4	3	B
Bivalvia	*Ensis ensis (juvenile)*	7.8	2	2	S	polychaeta	*Notomastus* sp.	1.9	3	2	UC
Bivalvia	*Bivalvia biomass*	5.2	-	-	-	Polychaeta	*Spio* sp.	1.5	3	2	UC/DC
Bivalvia	*Lucinoma borealis*	4.7	2	2	S	Polychaeta	*Nepthys* sp.	1.3	4	3	B
Asteroidea	*Astropecten irregularis*	3.2	2	3	S	Polychaeta	*Glycera unicornis*	1.2	4	3	B
Phoronida	*Phoronis sp.*	2.9	2	1	S						
Polychaeta	*Clymenella torquata*	2.4	3	1	UC						
Polychaeta	*Clymenella cincta*	2.3	3	1	UC						
Bivalvia	*Thracia phaseolina*	2.3	3	2	DC						
Bivalvia	*Abra prismatica*	2.3	2	2	S						
Polychaeta	*Lagis koreni*	2.3	3	1	UC						
Anopla	*Cerebratulus sp.*	1.9	4	3	B						
Echinoidea	*Echinocardium spp.*	1.9	4	3	B						
Polychaeta	Maldanidae biomass	1.6	-	-	-						

Polychaeta	*Orbinia sertulata*	1.6	4	3	B						
Bivalvia	*Nucula hanleyi*	1.6	2	3	S						
Polychaeta	*Aglaophamus rubella*	1.5	4	3	B						
Malacostraca	*Bathyporeia gracilis*	1.4	2	3	S						
Polychaeta	*Anaitides groenlandica*	1.3	4	3	B						
Ophiuroidea	*Ophiura albida*	1.2	2	2	S						
Polychaeta	*Lepidasthenia argus*	1.2	-	-	-						
Gastropoda	*Euspira nitida*	1.2	2	3	S						
Bivalvia	*Mya arenaria*	1.2	2	2	S						
Polychaeta	*Owenia fusiformis*	1.1	2	1	S						
Polychaeta	*Nepthys cirrosa*	1.1	4	3	B						
Bivalvia	*Ensis sp. (juvenile)*	1.0	2	2	S						
Anthozoa	*Actinaria sp.*	0.9	-	-	-						

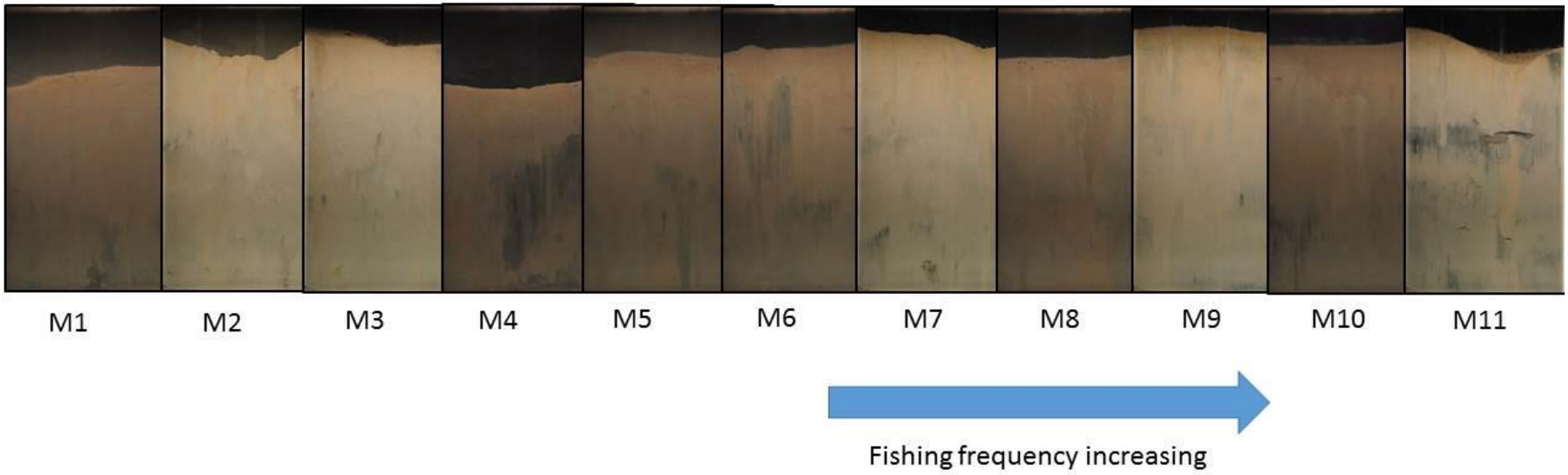
SM 5A. Concentration (µmols/l) profiles at the **muddy sites** for total inorganic nitrogen (TOxN), ammonium (NH_4^+), nitrite (NO_2^-), phosphate (PO_4^{3-}), silicate (SiO_4^-) and oxygen. Different symbols represent different fishing frequency (shown in the legend FE).



SM 5B. Concentration (µmols/l) profile at the **sandy sites** for total inorganic nitrogen (TOxN), ammonium (NH_4^+), nitrite (NO_2^-), phosphate (PO_4^{3-}), silicate (SiO_4^-) and oxygen. Different symbols represent different fishing frequency (shown in the legend FE).

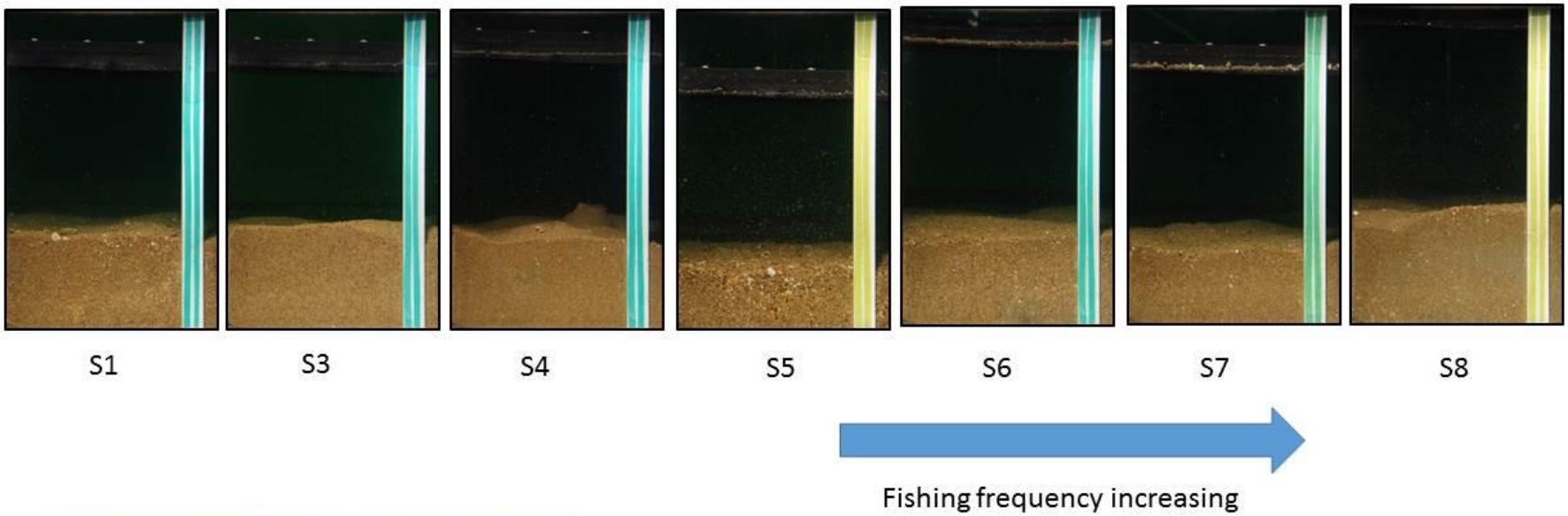


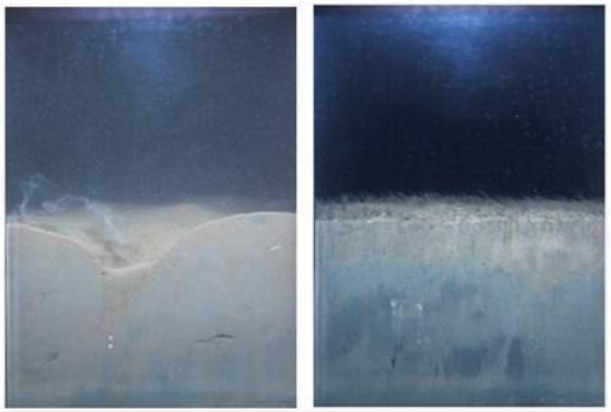
SM 6A. Sediment profile images obtained using the **SPI-camera at the muddy study area** (*Nephrops* fishing ground). The difference in the sediment colour seen between NP 2, 4, 8, 9, 10, 11 (darker colour) and NP 1, 3, 5, 6, 7 (lighter colour) is due to a light artefact produced by the SPI-camera rather than changes associated with the aRPD.



Reference SPI-images of undisturbed soft sediments in the North Sea

SM 6B. Sediment profile images obtained using the **SPI-camera at the sandy study area** (Isle of Man fishing ground).





Reference SPI-images of undisturbed soft sediments in the North Sea