Ecologically significant effects of bottom trawling revealed by functional trait analysis of macrobenthic communities

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Background to Project

UK statutory obligations (Marine Benthic Habitats)

- MSFD
- Habitats Directive
- OSPAR
- Marine Coastal Access Act
- The Marine Act (Northern Ireland)
- Marine (Scotland) Act

MSFD and OSPAR:- European and regional sea level legislation that both call for assessment of human activities within marine environment

UK Marine Biodiversity Monitoring R&D Programme leads for all SNCBs and is hopes to deliver status and trend based information on UK marine systems (>87million Hectres)

Abrasion and physical damage ranked as one of the priority pressures affecting UK benthic habitats due to the contribution of demersal fishing activity

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Background to Project

Using Vessel Monitoring System (VMS) data as a proxy for fishing activity

Needs to be underpinned by a full understanding of the pressure-state relationship to allow pressure levels to infer a given habitats condition

Integrated partnership to help deliver government value for money and to bring experts together

Cefas' experience and practical expertise in marine monitoring and research and development projects, JNCC UK lead on conservational advice to govt

Demonstrate that both partners can gather benthic biodiversity data that are valuable to both organisations

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Aims and Objectives

Test the suitability of current aggregated VMS layers for use in designing monitoring surveys using currently available data layer methodologies.

Alternative ways of spatially expressing VMS data were then tested, and assessed against benthic community variability.

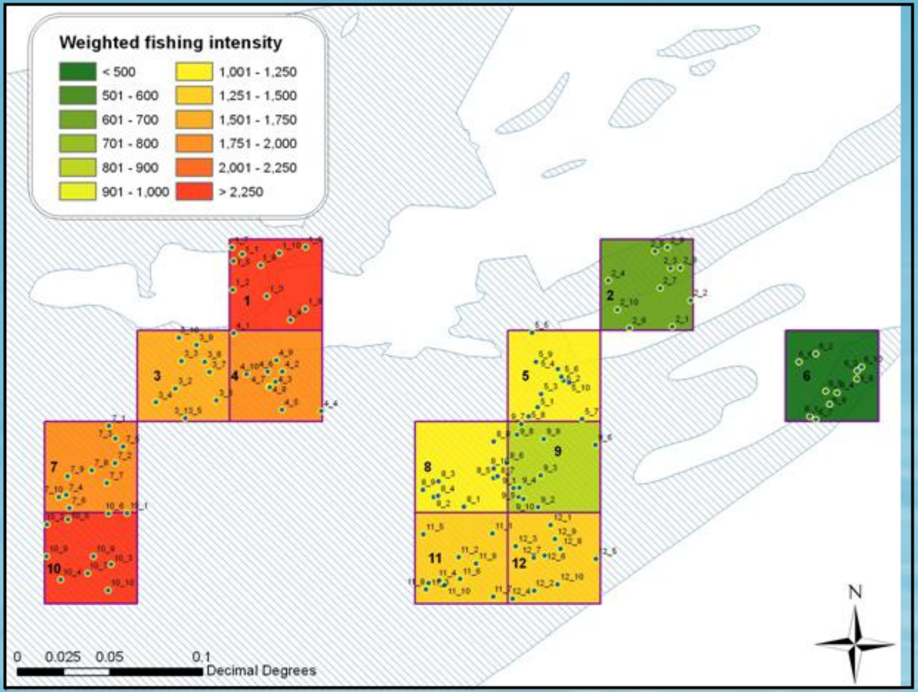
The relationship between pressures associated with fishing activity and benthic response parameters was investigated to identify possible response variables.

It was not the specific purpose of this work to identity thresholds at which demersal fishing begins to have an impact on benthic habitats, nor was it designed to identify benthic indicators of disturbance.

Planning and Methodologies

Survey Planning:-

- ➢Regression
- ➢VMS Processing
- ➢Site Selection
- ➢Habitat selection
- ➢Sample collection
  - ✓PSA
  - ✓Epifauna (Trawl/video)
  - ✓Infauna (Hamon Grab)
  - ✓Power analysis



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Planning and Methodologies

VMS Processing

Aggregated 18months of up to date pings (UK Fleet)

Non-UK vessel effort:

- Not as up to date (6months missing)
- Used primary gear listings from EU registration database

Pings were ‘cleaned’ as per Lee *et al.* (2010)

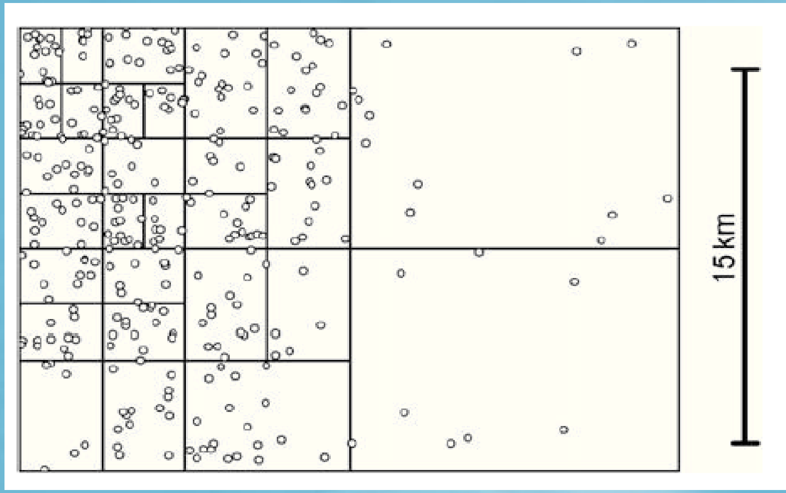
Gear types were weighted based on their relative spatial footprints

Planning and Methodologies

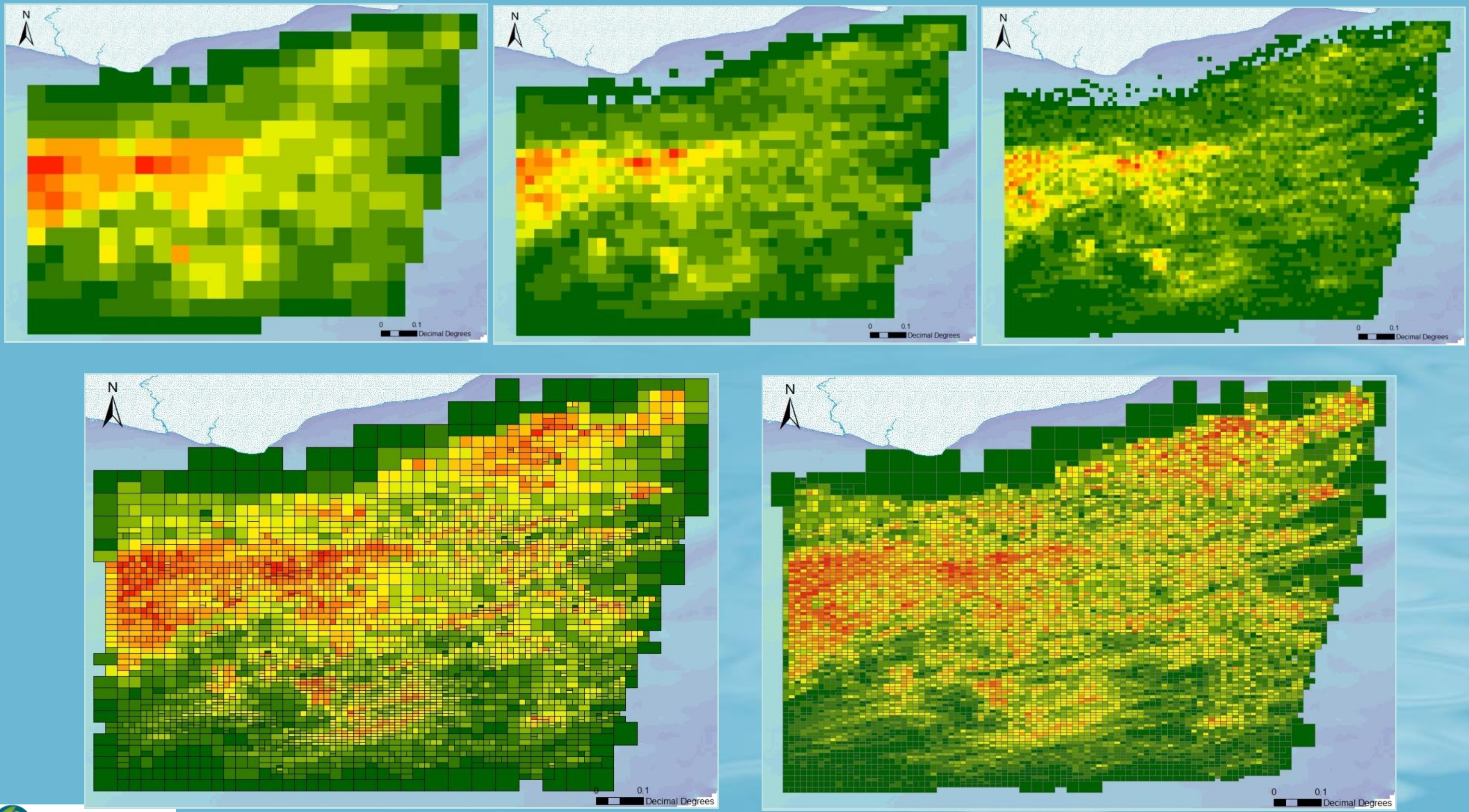
VMS Processing (Cont.)

Data was spatially aggregated using ArcGIS10.1 using 3 grid sizes 0.05, 0.025, 0.0125

Re-aggregated following approach proposed by Gerritsen *et al.* (2013) using nested regridding (20 and 100 pings)



Distribution and presentation of fishing effort



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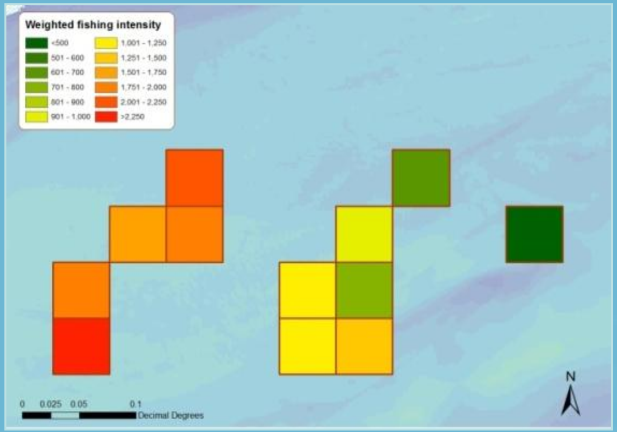
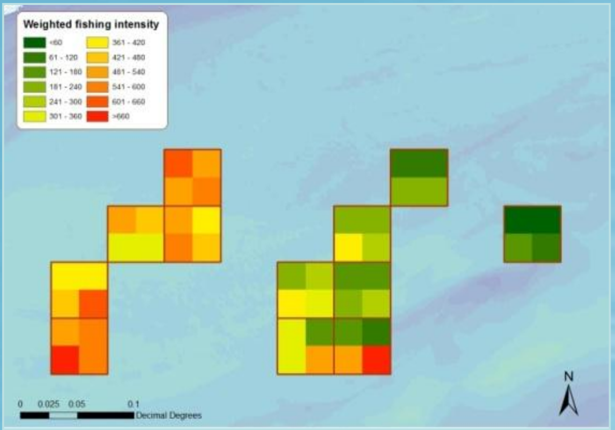
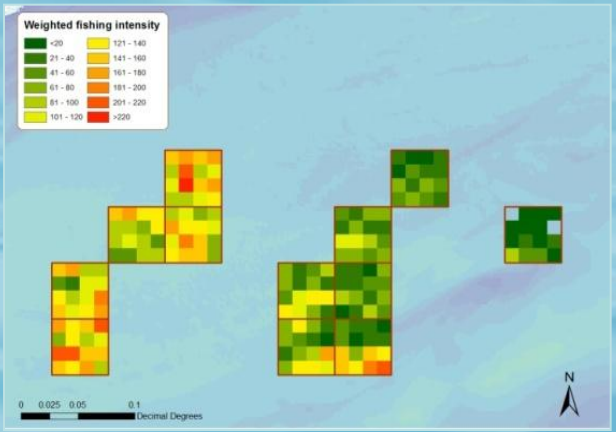
Distribution and presentation of fishing effort

Variability in relative distribution of fishing effort from original 0.05dd grid cells







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Distribution and presentation of fishing effort

Distribution of fishing activity can look very different depending on technique used. Selection of a ‘fit for purpose’ resolution is critical.

At the smallest cell size there is a risk that the spatial footprint of abrasive fishing pressure is underestimated

At the largest grid size there is a risk that the spatial footprint is overestimated

Distribution of abrasive fishing pressure within a raster grid cell. Due to the nature of aggregating the point data into a grid, an assumption has to be made that the fishing effort is distributed evenly over the cell

Differences in VMS presentation vary with region and potentially fishing type

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Relating biological variability to fishing pressure

1. **Univariate biodiversity indices**

Trend	p-value	Observed S
Biomass - VMS05	0.06	+ve
Biomass – VMS025	0.004	+ve
Biomass – VMS0125	0.001	+ve
Richness - VMS05	0.006	+ve
Richness – VMS025	<0.001	+ve
Richness – VMS0125	<0.001	+ve
Abundance - VMS05	0.019	+ve
Abundance – VMS025	<0.001	+ve
Abundance – VMS0125	<0.001	+ve

the magnitude of the trends were very small, indicated by small associated R^2 values (coefficient of determination).This suggests that fishing pressure was having a small, but significant, positive effect on biodiversity indices.

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Relating biological variability to fishing pressure

1. **Univariate biodiversity indices**

A small, but significant, increase in abundance, richness and diversity indices was found consistently, regardless of fishing pressure method

Despite the similar habitats at both sites, there was relatively little agreement in the best predictors of biodiversity indices.

It is apparent that community composition and diversity are best described by the environmental conditions within which they exist rather than by the anthropogenic impact to which they are exposed.

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Relating biological variability to fishing pressure

2. Biological traits analysis

Trait	Modality	Description
Size Range (mm)	<10 (VS) 10-20 (S) 21-100 (SM) 101-200 (M) 201-501 (ML) >501 (L)	These reflect the maximum size the individual can reach in any dimension (either in height or width/breadth). For colonials such as bryozoans and hydroids, the size of colony is given, not the size of the individual cell.
Morphology	Fragile	Fragile or shell/structure
	No Protection	Body covered by a protective outer tissue made up of, for example, cellulose, e.g., tunicates
	Protected	Body covered or encased in either tough skin or exoskeleton
	Robust	Hard shell/ability to regenerate
Longevity	<1 year 1-3 years 3-10 years >10 years	The maximum lifespan of the adult stage
Larval Development Location	Pelagic – Planktotrophic	Larvae feed and grow in water column, generally spend a few weeks there enabling great dispersal potential
	Pelagic - Lecithotrophic	Larvae enter water column but are reliant on yolk reserves; typically pelagic for <1wk. Limits dispersal potential
	Benthic (direct)	Larval stage missing (eggs develop into juvenile forms) or larvae are limited to the bed
Egg Development Location	Asexual / budding	Species can reproduce asexually, either by fragmentation, budding, epitoky, etc. Often this is in addition to some form of sexual reproduction
	Sexual – shed eggs (pelagic)	Eggs are released into the water column
	Sexual – shed eggs (benthic)	Eggs are released onto/into the bed, either free or maintained on bed by mucous or other means
	Sexual – brood eggs	Eggs are maintained by adult for protection, either within parental tube or within body cavity
Living Habit	Tube-dwelling	Organism lives within a permanent structure within the sediment. Tube may be lined with sand, mucus or calcium carbonate and thus afford some kind of physical protection
	Burrow-dwelling	Lives within a permanent or temporary burrow, organism capable of fabricating new burrows quickly.
	Free-living	Species in which adult is not limited to any restrictive structure at any time. Able to move freely within sediments
	Crevice/hole/ under stones	Adults are typically cryptic, predominantly found inhabiting spaces made available by coarse/rock substrate and/or tubes made by biogenic species or algal holdfasts
	Epi/endo zoic/phytic	Organisms which are found directly attached to other organisms. May be found attached to external shells of animals or fronds of macroalgae. Includes those found within cavities of animals (e.g. mantle cavity of gastropods)
	In shell/tube of other animal	Organisms that primarily inhabit shell/tube of other animal
	Attached to substratum	Organisms actively attached to larger substrata or rock

Trait	Modality	Description
Sediment Position	Surface	Species which are found on or just above the seabed. These do not cross the sediment/water interface whilst undertaking biological activities (feeding, locomotion).
	Shallow infauna (0-5cm)	Species whose bodies are found almost exclusively below sediment surface between 0 and 5cm sediment depth. Such species may have connection (either permanent or temporary) with overlying water column for feeding.
	Mid-depth infauna (5-10cm depth)	Species whose bodies are partly or exclusively found below sediment surface at a depth generally between 5 and 10 cm sediment depth. The species may also be capable of occupying other sediment depth classes. Such species may have connection (either permanent or temporary) with overlying water column for feeding.
	Deep-infauna (>10cm)	Species whose bodies are partly or exclusively found below sediment surface at a depth greater than 10 cm sediment depth. The species may also be capable of occupying other sediment depth classes. Such species may have connection with overlying water column for feeding.
Feeding mode	Suspension	The removal of particulate food taken from the water column, generally via filter-feeding
	Surface deposit	Active removal of detrital material from the sediment surface, either via palps or 'hoovering', using an inhalant siphon. This class includes species which scrape and/or graze algal matter from surfaces.
	Sub-surface deposit	Removal of detrital material from within the sediment matrix. Generally involves non-selective ingestion of sediment and active egestion of sediment
	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. An uncommon trait, found in eulimid gastropods and RHIZOCEPHALA crustaceans
Mobility	None	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
	Low	Species in which adults are capable of some limited movement along the sediment surface or rocky substrata
	High	Species in which the adults are capable of movement along the sediment surface, rocky substrata and burrowing
Bioturbation	Diffusive mixing	Vertical and/or horizontal movement of sediment and/or particulates resulting from the activities of, for example, some free-living polychaetes, subsurface deposit feeders and carnivores, and burrow excavating species
	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.

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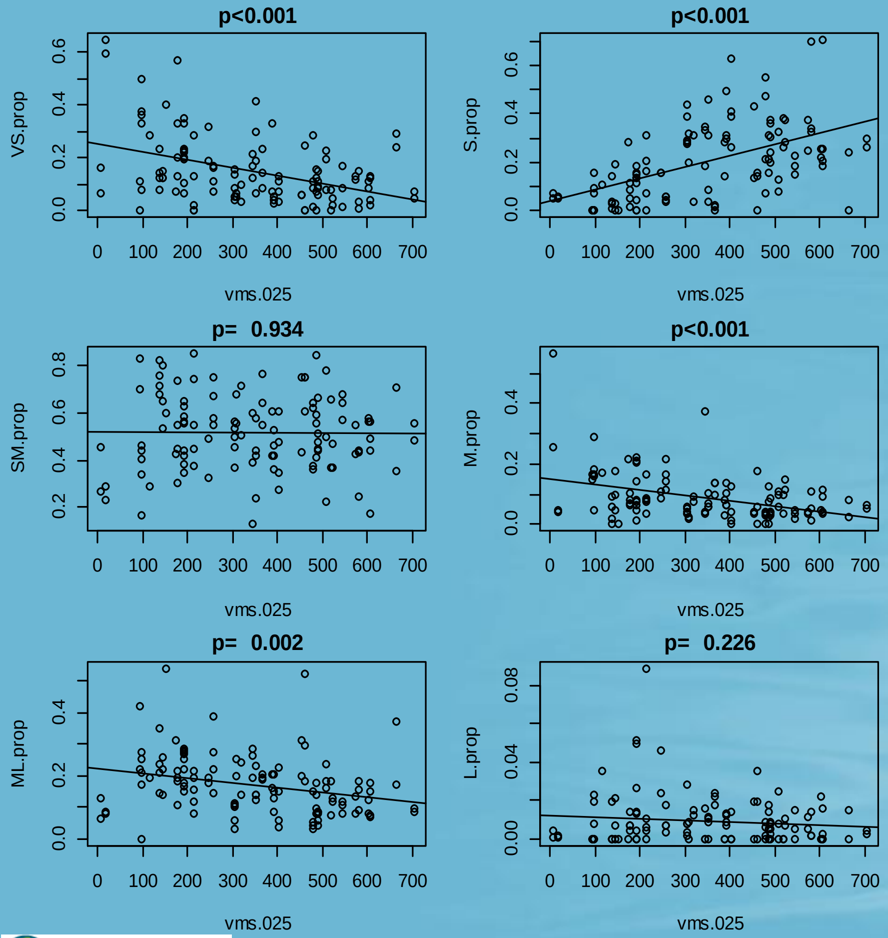
Relating biological variability to fishing pressure

2. Biological traits analysis (Size)



X variable	VS	S	SM	M	ML
None	9.8	13.1	15.6	5.7	7.2
Vms.05	9.3	11.1	16.0	5.3	7.0
Vms.025	9.4	11.0	16.0	5.3	6.8
Vms.0125	9.5	12.0	15.8	5.5	6.9
Vms.20	10.0	12.0	15.9	5.6	7.3
Vms.100	9.6	11.5	16.0	5.6	7.3
Silt	10.2	13.3	15.4	5.5	7.4
Gravel	9.5	12.2	15.6	5.4	6.3
Depth	10.2	12.9	15.9	5.6	7.4
Dist	10.1	13.5	15.6	5.4	7.5
Carbon	10.1	13.0	15.8	5.7	6.8
Nitrogen	10.2	13.3	15.6	5.6	7.3
Group	9.5	10.7	15.8	5.2	6.1
Mode	9.6	12.4	16.0	5.4	7.1

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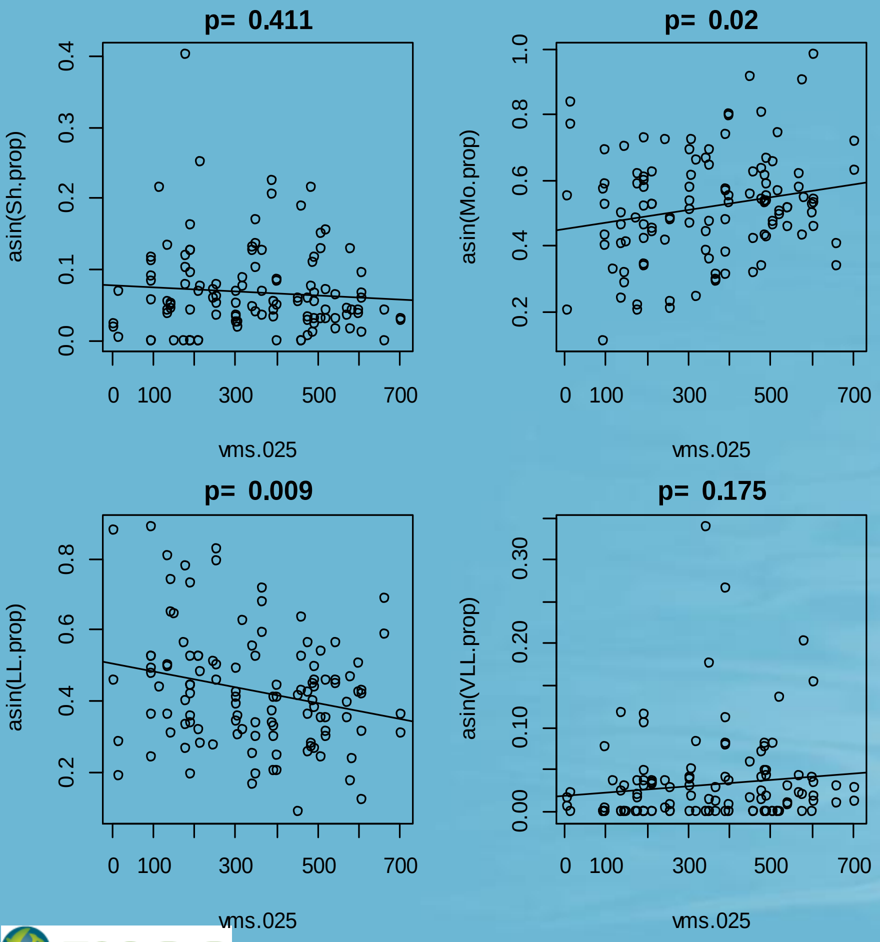
Relating biological variability to fishing pressure

2. Biological traits analysis (Longevity)



X variable	Sh	Mo	LL	VLL
None	4.6	12.7	12.6	3.47
Vms.05	4.6	12.6	12.5	3.41
Vms.025	4.6	12.7	12.5	3.40
Vms.0125	4.7	12.6	12.4	3.39
Vms.20	4.6	12.8	12.5	3.45
Vms.100	4.6	12.8	12.3	3.41
Silt	4.6	12.8	12.6	3.36
Gravel	4.4	12.6	12.6	3.38
Depth	4.6	12.6	12.3	3.44
Dist	4.5	12.9	12.7	3.41
Carbon	4.4	12.7	12.6	3.42
Nitrogen	4.6	12.7	12.8	3.41
Group	4.6	12.3	12.4	3.45
Mode	4.5	12.8	12.8	3.38

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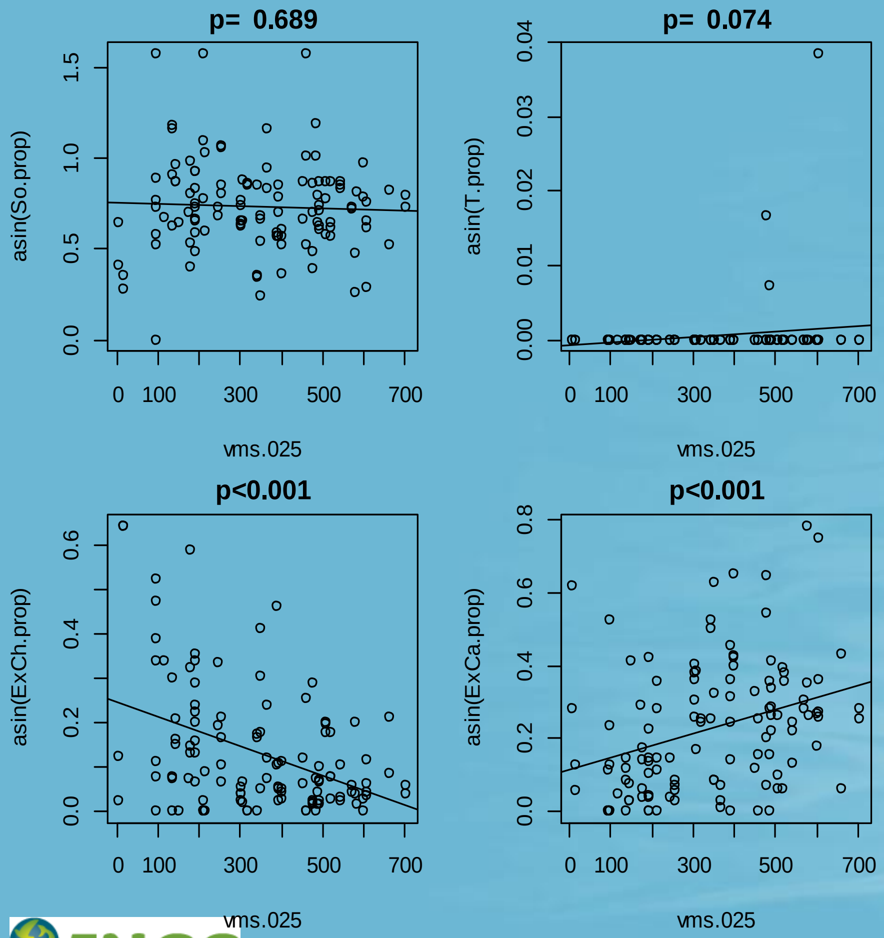
2. Biological traits analysis (Morphology)



X variable	So	ExCh	ExCa
None	18.3	10.8	14.4
Vms.05	18.6	10.1	13.5
Vms.025	18.7	10.0	13.4
Vms.0125	18.7	10.3	13.0
Vms.20	18.7	10.8	13.9
Vms.100	18.7	10.5	13.8
Silt	18.4	11.1	14.6
Gravel	18.6	9.7	13.1
Depth	18.5	11.0	14.7
Dist	18.6	10.9	14.8
Carbon	18.6	10.7	14.3
Nitrogen	18.2	11.1	14.4
Group	19.2	8.6	12.0
Mode	18.7	9.5	13.7

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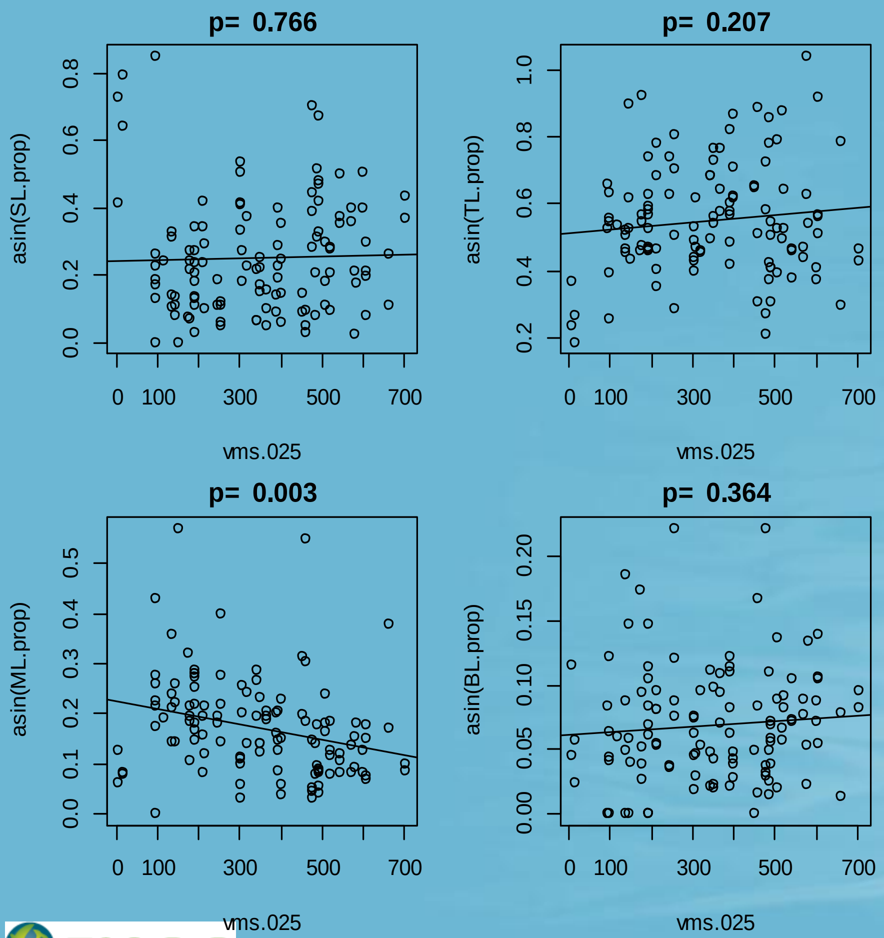
Relating biological variability to fishing pressure

2. Biological traits analysis (Position)



X variable	SL	TL	ML	BL
None	13.7	13.1	7.3	3.5
Vms.05	13.6	13.4	7.0	3.5
Vms.025	13.6	13.5	6.8	3.5
Vms.0125	13.8	13.2	6.9	3.5
Vms.20	13.6	12.9	7.4	3.5
Vms.100	13.7	13.2	7.2	3.5
Silt	13.6	13.3	7.4	3.5
Gravel	11.2	12.7	6.4	3.4
Depth	13.3	12.5	7.4	3.6
Dist	13.1	12.9	7.4	3.6
Carbon	12.6	13.0	6.9	3.5
Nitrogen	13.7	13.4	7.3	3.5
Group	10.4	12.2	6.0	3.4
Mode	12.7	13.0	7.0	3.5

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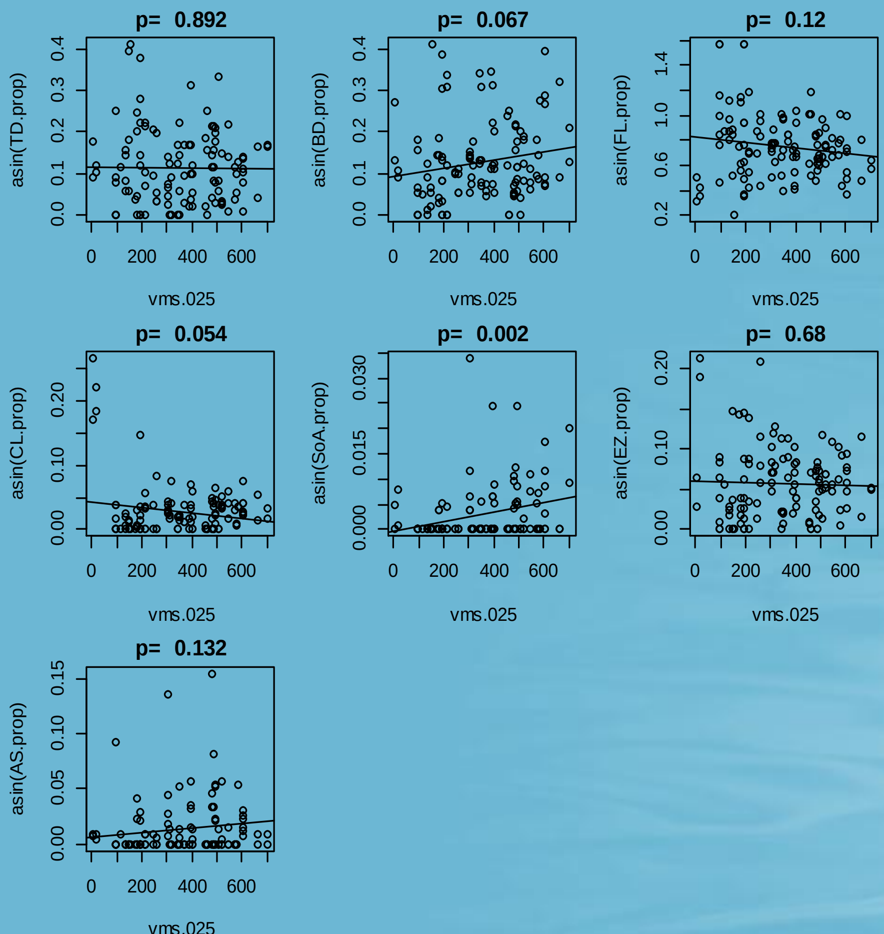
Relating biological variability to fishing pressure

2. Biological traits analysis (Living Habit)



X variable	TD	BD	FL	CL	SoA	EZ	AS
None	7.2	7.8	19.4	2.6	0.40	3.5	1.69
Vms05	7.4	7.5	19.5	2.7	0.38	3.6	1.65
Vms025	7.3	7.4	19.4	2.7	0.36	3.6	1.62
Vms125	7.3	7.5	19.2	2.7	0.37	3.6	1.62
Vms20	7.3	7.6	19.5	2.6	0.40	3.6	1.65
Vms100	7.3	7.4	19.5	2.7	0.40	3.6	1.66
Silt	7.2	7.1	18.0	2.4	0.39	3.6	1.66
Gravel	7.2	7.2	17.8	2.3	0.29	3.6	1.31
Depth	7.0	7.5	19.7	2.5	0.40	3.5	1.67
Dist	7.3	7.5	19.7	2.6	0.37	3.6	1.64
Carbon	7.3	7.6	19.8	2.5	0.31	3.6	1.64
Nitrogen	7.3	7.5	19.7	2.5	0.40	3.6	1.66
Group	7.5	7.0	17.9	2.2	0.27	3.6	1.46
Mode	7.3	7.4	19.3	2.6	0.37	3.6	1.65

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Relating biological variability to fishing pressure

2. Biological traits analysis

The key relationships observed, for infaunal communities, between changes in trait proportionality and fishing activity included a gradual increase in the 11-20mm size group and a decrease in the 21-100, 201-500 and >500 mm size classes

Other observed changes in community traits included an increase in species with exoskeletons (gastropod shells) at the EEC site as fishing activity increased and an increase in subsurface deposit feeders which correlated well with an increase in burrowing species.

Although the above relationships could be attributed to an increase in fishing activity, further consideration must be given to whether infaunal communities are a good indicator of fishing activity

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Relating biological variability to fishing pressure

2. Biological traits analysis (cont.)

Traits themselves are not necessarily mutually exclusive and a suite of relevent traits may be best considered to interpret impact from activity. Development of a trait based index may well describe the interplay between pressure and impact.

Epifaunal Traits

Dominated by free living species and species found within shells and tubes of other species. The dominant feeding type at both sites was predominantly predators and scavengers with no relationship observed with increased levels of fishing activity. Similarly both sites were dominated by species which exhibited low mobility (crawlers) and, again, no relationship with fishing activity was observed.

Relating biological variability to fishing pressure

3. Natural disturbance

In this study, the W-statistic did not significantly relate to any scores of fishing pressure. However, for infauna, the magnitude of the W-statistic at Th may indicate that the site was already disturbed and the trend at EEC was for increasing disturbance with fishing pressure score.

Species/community traits makeup from areas of high levels of natural disturbance are thought to be similar to those species/community traits attributed to benthic communities that are exposed to high levels of fishing activity. The relative impact of such activities on benthic communities is also thought to be partly due to whether the anthropogenic disturbance exceeds background levels of natural disturbance (Jennings & Kaiser 1998).

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Wider Policy Context

1. **Detecting Change**

What this study has shown is that, for this sandy sedimentary habitat, effects of fishing are significant, but small. Any seabed monitoring intended to detect possible impacts of fishing pressure on benthic communities will need to be sufficiently robust and powerful to pick up these subtle changes against a background of natural variability.

The fact that benthic communities exposed to high levels of natural disturbance and high levels of fishing activity tend to express the same functional traits makes it very difficult to define and quantify which of these is having the greatest affect on the benthic communities and thus driving community structure

Wider Policy Context

2. VMS Processing

The ability to detect the impact of fishing on the seabed relies on being able to accurately attribute a known level of fishing intensity to biological samples.

Over estimation of fishing intensity may result in the selection of sample locations that are less likely to represent areas where trawling has taken place. In a low resolution grid, the chances of taking a sample from an area of seabed that has actually been trawled from a cell with few VMS points are small.

Scale, along with associated over or under estimation of fishing intensity, will have a direct effect on which cells best represent this gradient.

Statistical analysis demonstrated that there was little difference in terms of explanatory power between the different VMS processing methods

Wider Policy Context

3. Monitoring Pressures

A risk-based approach to monitoring broadly recommends the identification of habitats and species which are at different levels of risk.

This study suggests that, particularly for this habitat, due to variability around response variables, no natural groupings of this pressure, and the subtle effects fishing pressure has on the benthic communities, a regression approach may be preferable to a categorical one.

It should be noted that the conclusions of this study are only relevant to the habitat on which the study was undertaken and in order to inform future monitoring surveys, studies of this kind are required on other sedimentary habitat types.

Conclusions and Limitations

The assumption that fishing abrasion pressure within each cell was homogeneous. Regridding pressure layers to finer resolutions showed that this was not always the case.

Historical fishing disturbance at the sites meant that the communities were being maintained in an already modified state. As such, short-term changes in fishing pressure had no further effect on community organisation.

Natural variability at both sites have pre-disposed the benthic communities to exist in a dynamic environment which masks any potential community change from anthropogenic impact.

Environmental factors had a stronger to predict community variability than fishing on this habitat.

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