

Theme Session A
Structure and dynamics of the benthos in ICES waters
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Small-scale heterogeneity in the mobile macro-epifauna associated with mud, sand and coarse habitats

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In recent years, several studies have utilised groundfish surveys as sampling platforms for the broadscale examination of epibenthic fauna. Several fisheries laboratories utilise a 2m steel beam trawl with chain mat for the sampling of epifauna, although only single samples are usually collected at the sampling stations. Hence, although such surveys provide valuable information on the broadscale distribution of epibenthic assemblages, their utility for examining issues relating to species diversity may be restricted by lack of replication. Intensive replicate sampling with 2m beam trawl has now been conducted on specific offshore biotopes around the British Isles, including two mud biotopes (Celtic Deep and north-western Irish Sea), three sand biotopes (outer Bristol Channel and inner and outer Carmarthen Bay), two sand banks (Swarte and Broken Banks in the southern North Sea) and two coarse grounds (a gravel bed in the North Sea and a shell-gravel habitat in the western English Channel). For most sample sites, sampling involved five replicate tows at a central station with single tows taken at eight surrounding grid stations (2 nm and 6 nm NW, NE, SW and SE of the central station). The similarities between catches at these stations and the cumulative number of species observed are described, with the implications for the resource required for monitoring diversity on offshore grounds discussed.

Introduction

In recent years there has been an increased interest in offshore habitats and communities. Traditional benthic studies have focused primarily on the quantitative sampling of macroinfauna, and many such studies have operated on comparatively small spatial scales. There are, however, some benthic studies that sample over broader spatial scales, such as the UK's National Marine Monitoring Programme (Rees et al., 1999) and the North Sea Benthos survey (Rees et al., 2007).

Since the late 1990s, groundfish surveys have served as platforms with which to collect data on the broadscale distribution of epifaunal assemblages, either through sampling the invertebrates collected by the main fishing gear, in the case of beam trawl surveys (e.g. Kaiser et al., 1999; Ellis & Rogers, 2000; Ellis et al., 2000), or by undertaking additional sampling with 2m-beam trawl during otter trawl surveys (e.g. Jennings et al., 1999; Zühlke et al., 2001; Callaway et al., 2002; Ellis et al., 2002). There are obvious cost benefits of sampling epifauna during groundfish surveys, and it also enables a wide spatial area to be surveyed with a standardised gear. Hence, such sampling has resulted in the descriptions of the general epibenthic assemblages occurring around much of the British Isles, including parts of the English Channel, North Sea, Irish Sea and Bristol Channel, and Celtic Sea. Although these studies are suitable for describing the broad assemblage types, and the physical parameters (depth, tidal stress, water temperature etc.) that best correlate with the observed biogeographical patterns in offshore assemblages, most point-source sampling is based on single tows, and most sampling points are widely separated. The absence of replication or examination of small-scale patchiness in the immediate vicinity of sampling stations is therefore an issue that has not been fully addressed. In this paper we examine the catches from 2m-beam trawl sampling undertaken on pre-selected habitats, with respect to replicate sampling and small-scale heterogeneity.

Materials and methods

Field sampling was undertaken during four cruises from 2004–2007 (Figure 1, Table 1), with each cruise targeting specific habitat types. Sampling has examined two mud habitats (NW Irish Sea and Celtic Deep; Figure 2), three sandy habitats in the Bristol Channel (Outer Bristol Channel and Inner and Outer Carmarthen Bay; Figure 3), offshore sand banks (Swarte and Broken Banks in the southern North Sea; Figure 4), a gravel bed (east of Felixstowe; Figure 4) and shell-gravel habitats (western English Channel; Figure 5).

The standard gear used was a steel 2-m beam trawl with chain mat, as described by Jennings et al. (1999). Tows were of 5 minutes duration with a warp:depth ratio of 3:1 used in most cases. Most catches were fully sorted with invertebrates and demersal fish identified to the lowest possible taxonomic level. In the case of large catches, the whole catch would be examined for less abundant species, and then the remaining catch (containing sediment and with an pre-defined range of species) would be sub-sampled, with results subsequently raised to the weight of the total weight of the mixture.

Most sample sites were the locations of trawl stations used in beam and/or otter trawl groundfish surveys (exceptions being the gravel and sand bank habitats in the North Sea). At such

locations, sampling involved replicate sampling ($n=5$) at a central station (i.e. along the 2 nm length of the main trawl tow), with single tows collected at eight sites approximately 2 and 6 nm SE, SW, NE and NW of the centre point of the station. The exceptions from this occurred at the following sites:

- (a) Outer Carmarthen Bay: The grid stations on the NW part of the grid were 1 and 2 nm from the central station, as rough ground was encountered beyond 2 nm (see Figure 3)
- (b) Inner Carmarthen Bay: As the main sampling station was close inshore, the grid extended to the south-west and comprised seven stations (see Figure 3).
- (c) Gravel: Replicate sampling was undertaken in two reference boxes used in previous studies of gravel fauna, with adjacent sites also sampled (see Figure 4).
- (d) Sand banks: Replicate samples were collected on the central part of the bank, four extra samples were collected along the bank and three samples were collected off each the side of the bank (see Figure 4).

During cruises, the weights of all organisms (or sub-samples of) were recorded, to permit future size-spectra analyses. For the present paper, we provide an overview of the sampling, and preliminary analyses of the abundance data (numbers.tow⁻¹) for non-colonial invertebrates and fish. Data for infaunal worms and euphausiids have also been omitted.

Analyses were undertaken using Primer (version 6.1.6). Due to the high abundance of selected taxa (e.g. *Nucula sulcata* on mud, and *Ophiura ophiura* on sand) data were fourth-root transformed.

Results and Discussion

As expected, multivariate analyses for all stations sampled indicated that sites were generally distinct (Figure 6), with some overlap between the sand and sand bank habitats sampled.

Mud habitats: Although both the mud sites were characterised by high numbers of *Nephrops norvegicus*, *Nucula sulcata* and *Crangon allmanni* (Table 2), the two habitats were slightly different (Figure 7, mean dissimilarity = 63.4%). The subtle biogeographic differences between the sites were exemplified by *Dichelopandalus bonnierii* and *Pontophilus spinosus*, which were both more abundant in the Celtic Deep, and *Polinices fusca*, which was absent from the NW Irish Sea. Replicates at the central stations of the two muddy sites were 68–70% similar (Table 3), with the mean similarity across all samples 45% on the slightly more heterogeneous NW Irish

Sea site, and 62% in the Celtic Deep. More taxa (excluding colonial forms etc.) were recorded in the NW Irish Sea (79 taxa) than in the Celtic Deep (56 taxa, Table 4).

Sand habitats: The three sand habitats sampled in the Bristol Channel were in different depth zones, with the Inner Carmarthen Bay site 14–30 m in depth, the Outer Carmarthen Bay 22–41 m in depth and the Outer Bristol Channel site 69–77 m in depth. Replicate samples in the two shallower sites were relatively similar (mean similarity = 65–67%), although the Outer Bristol Channel site was more variable (mean similarity = 40%). The mean similarities across all stations at the three sites (12–14 stations) were 51% (Inner Carmarthen Bay), 46% (Outer Carmarthen Bay) and 39% (Outer Bristol Channel). The offshore site was more dissimilar to the other sites (Figure 8), with both the inner and outer Carmarthen Bay sites characterised by *Pagurus bernhardus*, *Liocarcinus holsatus*, *Astropecten irregularis*, *Ophiura ophiura* and *Buglossidium luteum*.

Sandbank habitats: Two sandbanks in the North Sea were sampled. These were the least diverse of the habitats examined, with only 30 taxa recorded from the crests of the banks, and 46 taxa off the sides of the banks. Both banks had a similar fauna, and the fauna associated with the crests was dominated by *Echiichthys vipera*, *Buglossidium luteum* and *Crangon crangon*. The mean similarity of the five replicate samples were ca. 71% on both banks. There were also differences in the fauna occurring on the crest of the bank in comparison to that occurring on the sides of the banks (Figure 9).

Gravel and shell-gravel habitats: The gravel bed sampled was in a small area of the southern North Sea, and so although the similarity of stations sampled was relatively high (71–75% for replicate hauls, 61% for all stations sampled), this should be viewed in the context of being the smallest spatial grid sampled and also that the southern North Sea is not especially diverse. The dominant motile taxa at this site included *Psammechinus miliaris*, *Asterias rubens* and *Pandalus montagui*. In contrast, the shell-gravel habitat in the western English Channel was very different (Figure 10) and also the most diverse site encountered in the surveys (107 used taxa in the present analysis, in addition to the plethora of sessile taxa that were also observed). The mean similarity of replicate hauls was low (45%).

Summary

Although single 2m-beam trawl samples provide a useful indication of the broad type of epibenthic assemblage occurring in areas, single tows would only collect 24–42% of the motile taxa that of the fauna that may be expected from the overall area, with five tows collecting about

70%. Hence, if 2m-beam trawl studies are to examine issues such as temporal changes in offshore environments or monitor species diversity, then appropriate levels of replication will be required.

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Figure 1: Location of epibenthic sampling stations (2004–2007)

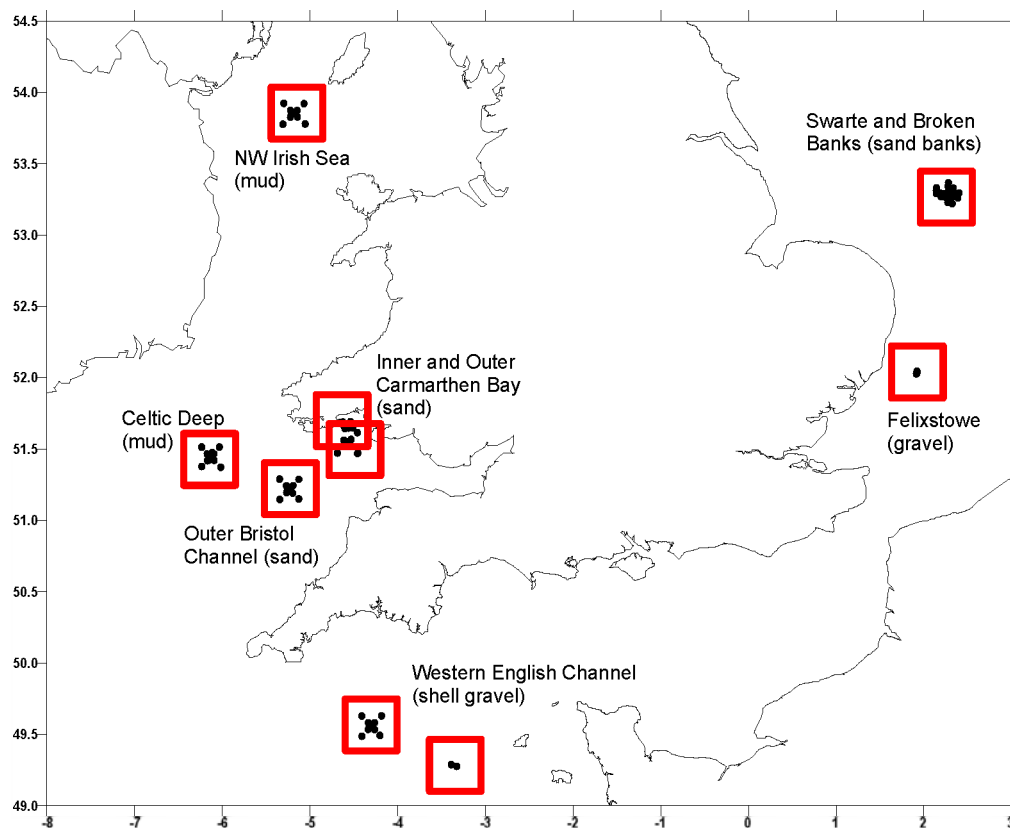


Figure 2: Sampling sites for mud grounds in the NW Irish Sea and Celtic Deep (July 2004)

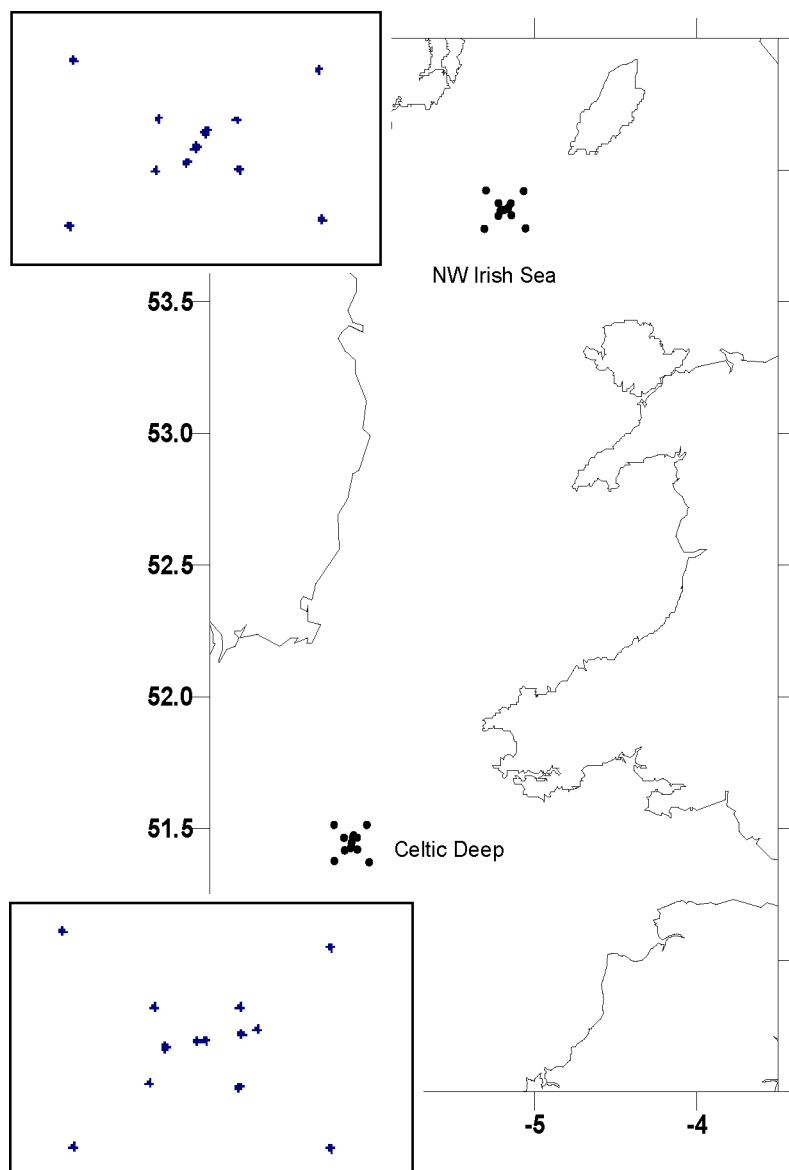


Figure 3: Sampling sites for sand habitats in the Bristol Channel (July 2005)

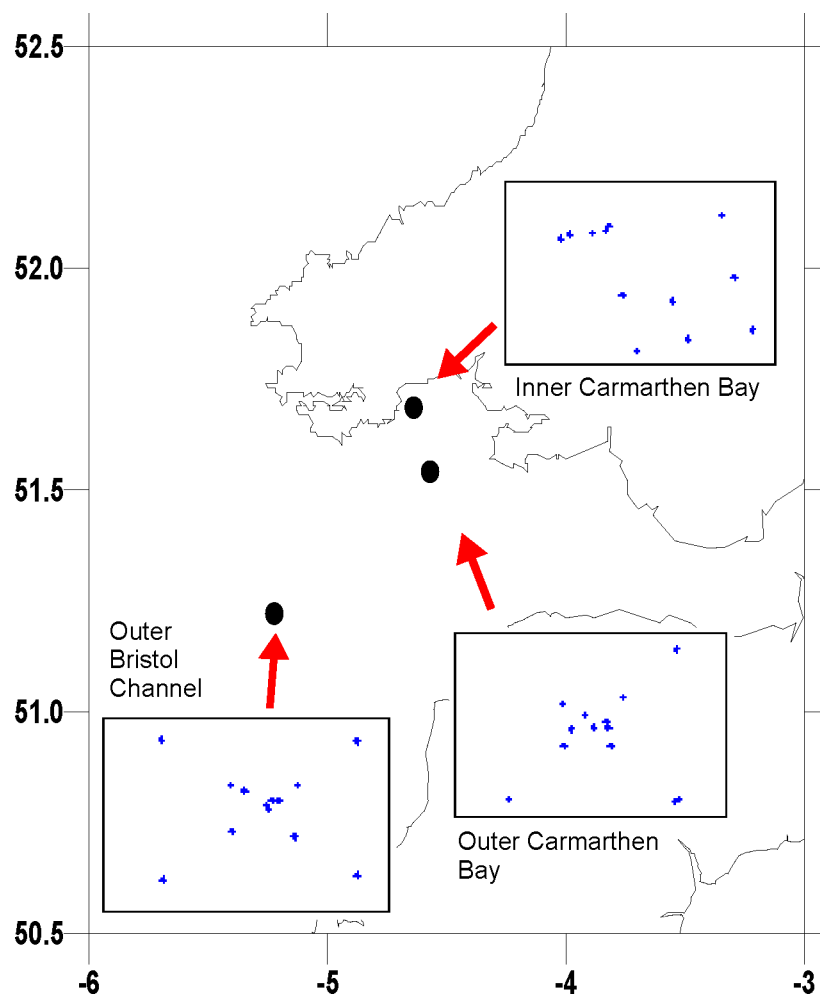


Figure 4: Sampling sites for gravel habitat and offshore sand banks (Swarte and Broken Banks) (April 2006).

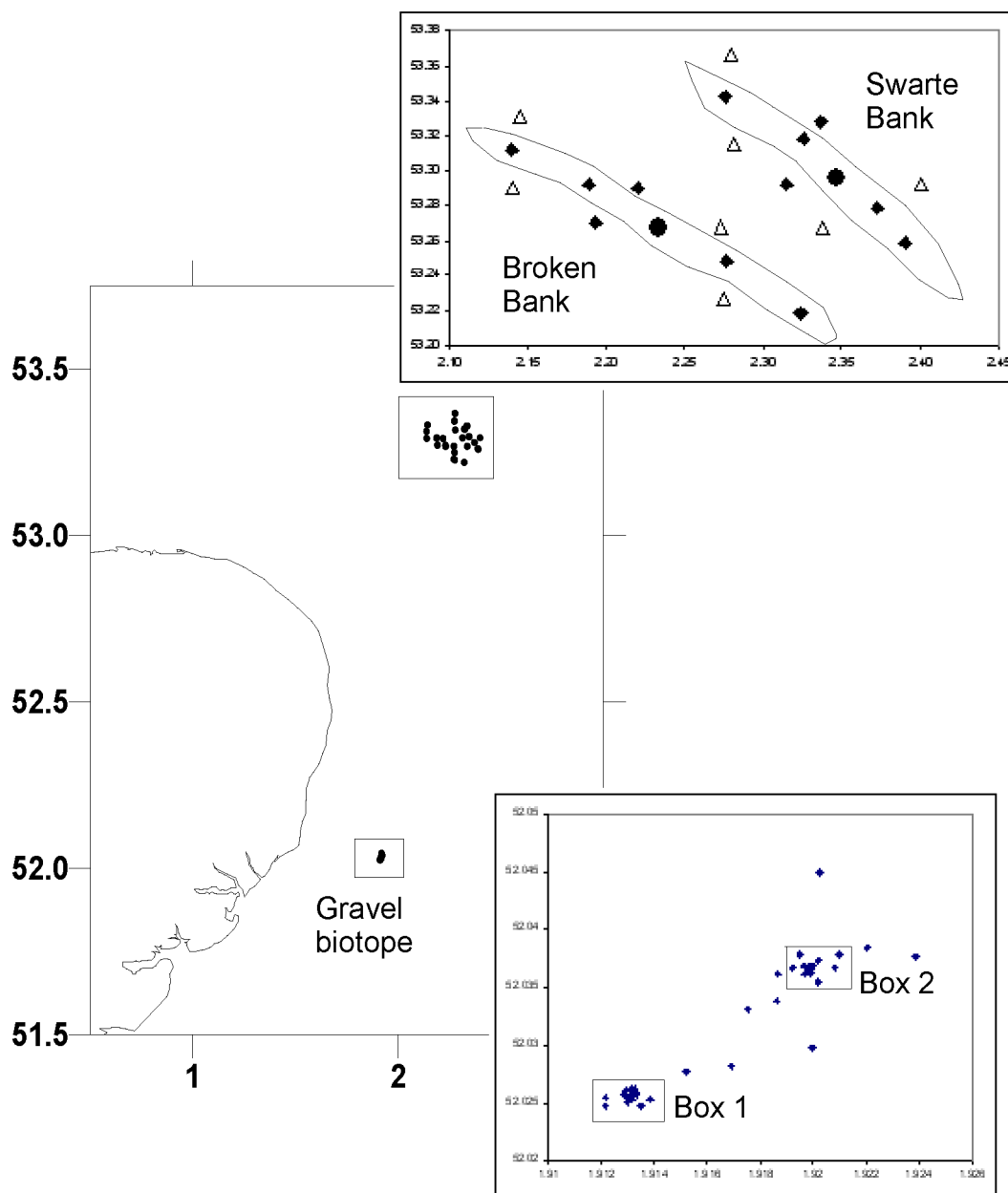


Figure 5: Sampling site for shell-gravel habitat in the western English Channel and Banc des Langoustieres (April 2007).

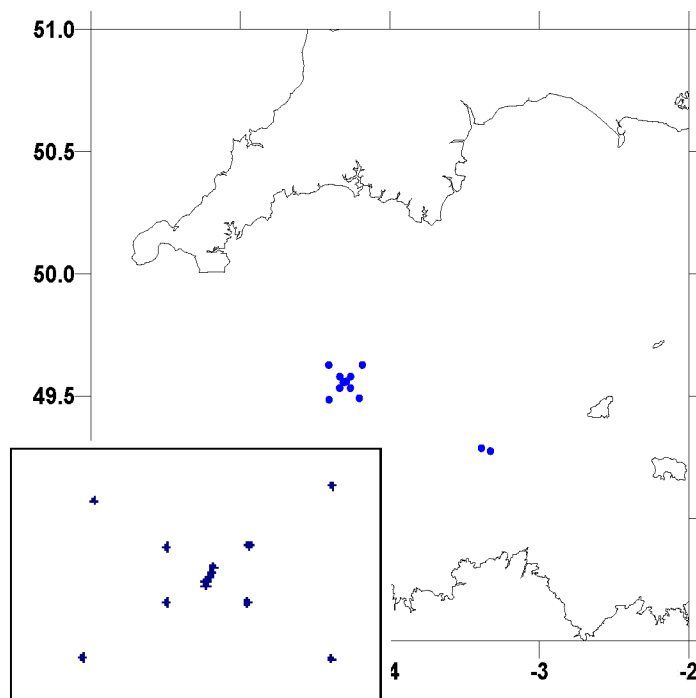


Figure 6: MDS plot of 2m beam trawl catches (numbers per 5 minute tow, fourth-root transformed)

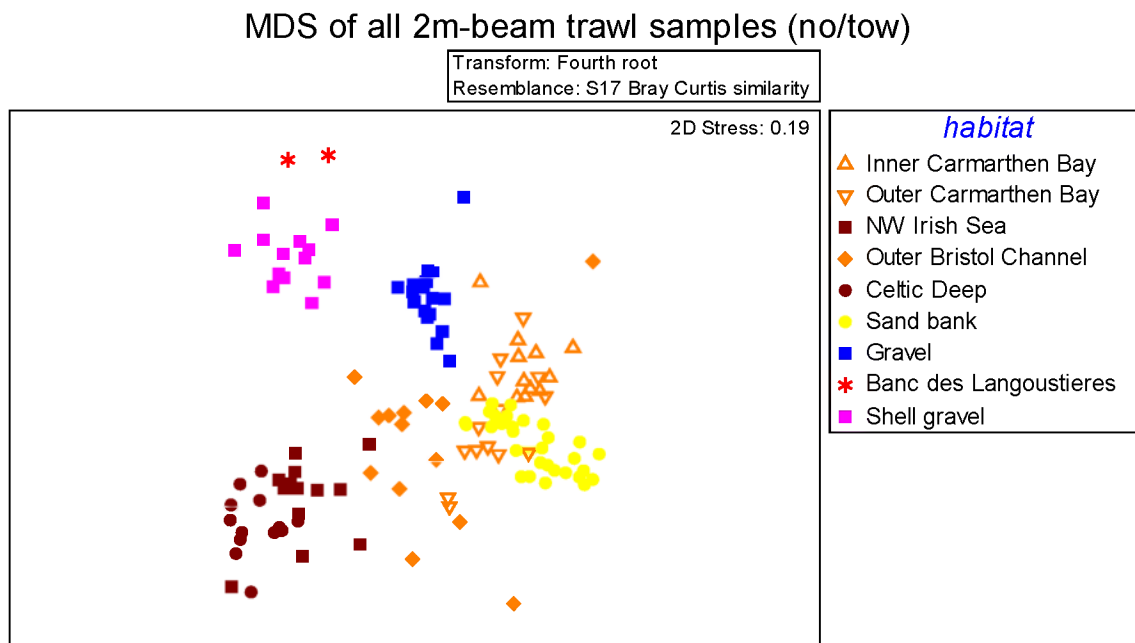


Figure 7: Analyses of 2m-beam trawl catches on mud habitats in the North-western Irish Sea (IS) and Celtic Deep (CD), including (top) MDS plot of catches at centre, and inner and outer grid stations; and (bottom) the cumulative number of species at all stations for both sites.

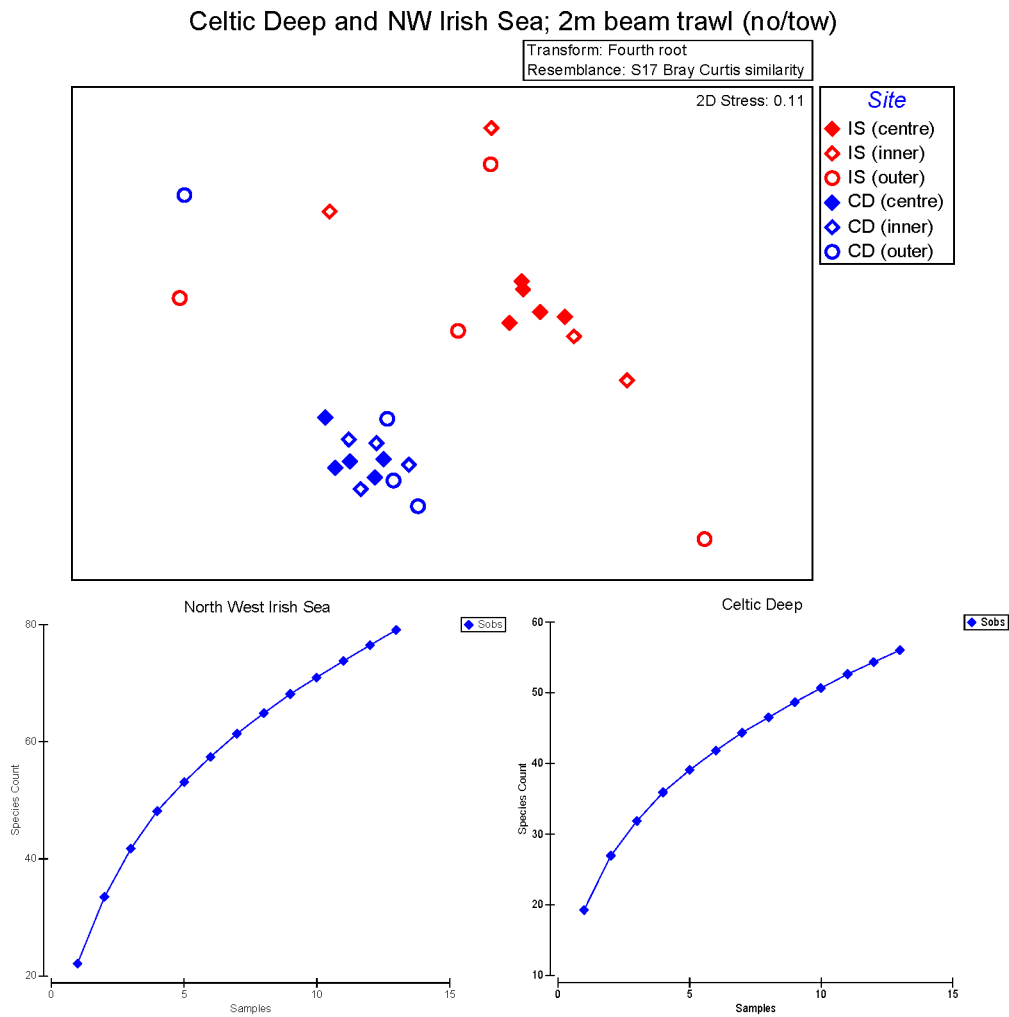


Figure 8: Analyses of 2m-beam trawl catches on sand habitats in the Outer Bristol Channel (OBC), Outer Carmarthen Bay (OCB) and Inner Carmarthen Bay (ICB), including (top) MDS plot of catches at centre, and inner and outer grid stations; and (bottom) the cumulative number of species at all stations for the three sites.

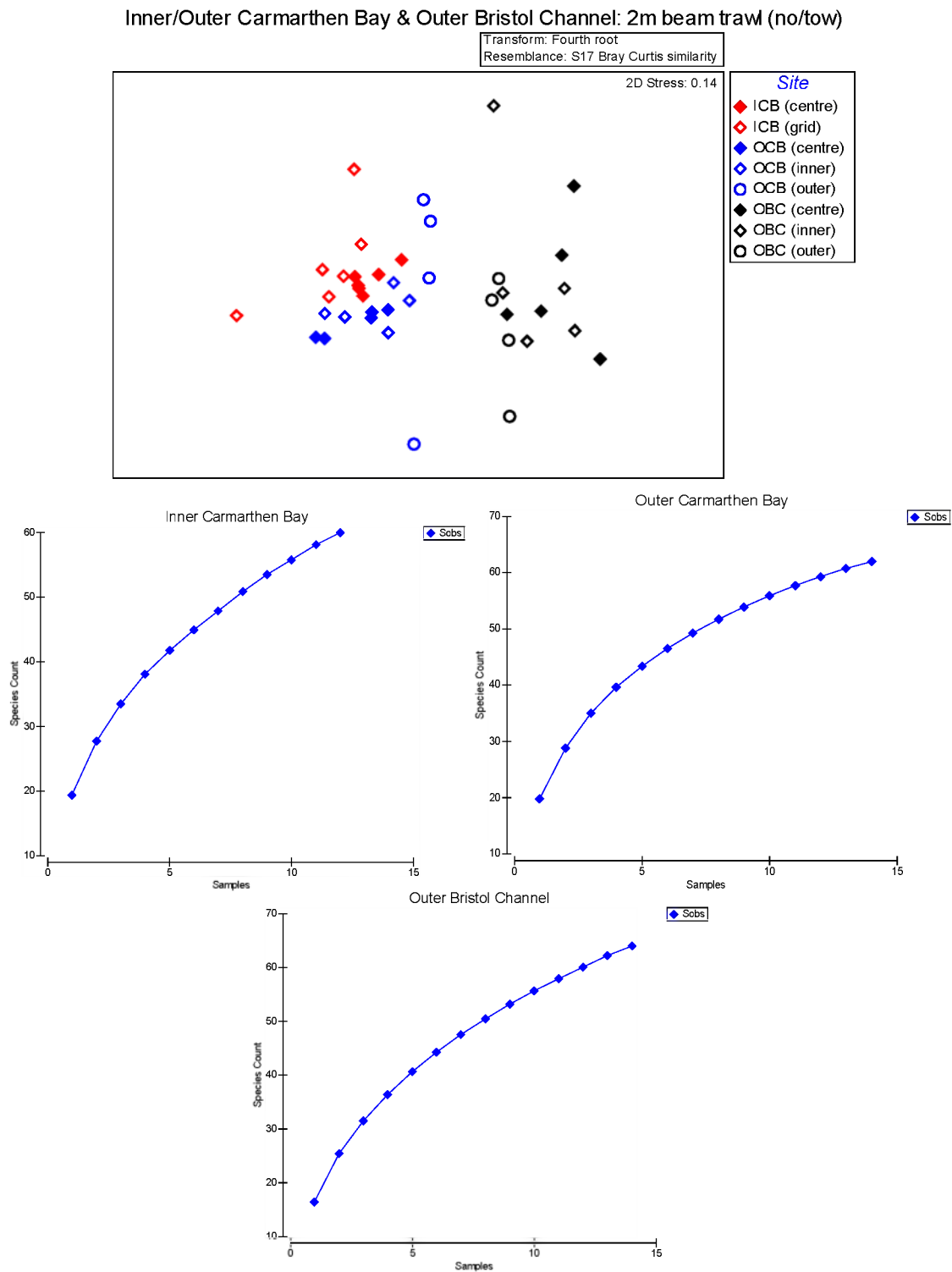


Figure 9: Analyses of 2m-beam trawl catches on the Swarte Bank (SB) and Broken Bank (BB) offshore sand banks in the North Sea, including (a) MDS plot of catches at the replicate stations on the crest, other stations along the crest and stations off the sides of the banks; and (bottom) the cumulative number of species on and around both banks.

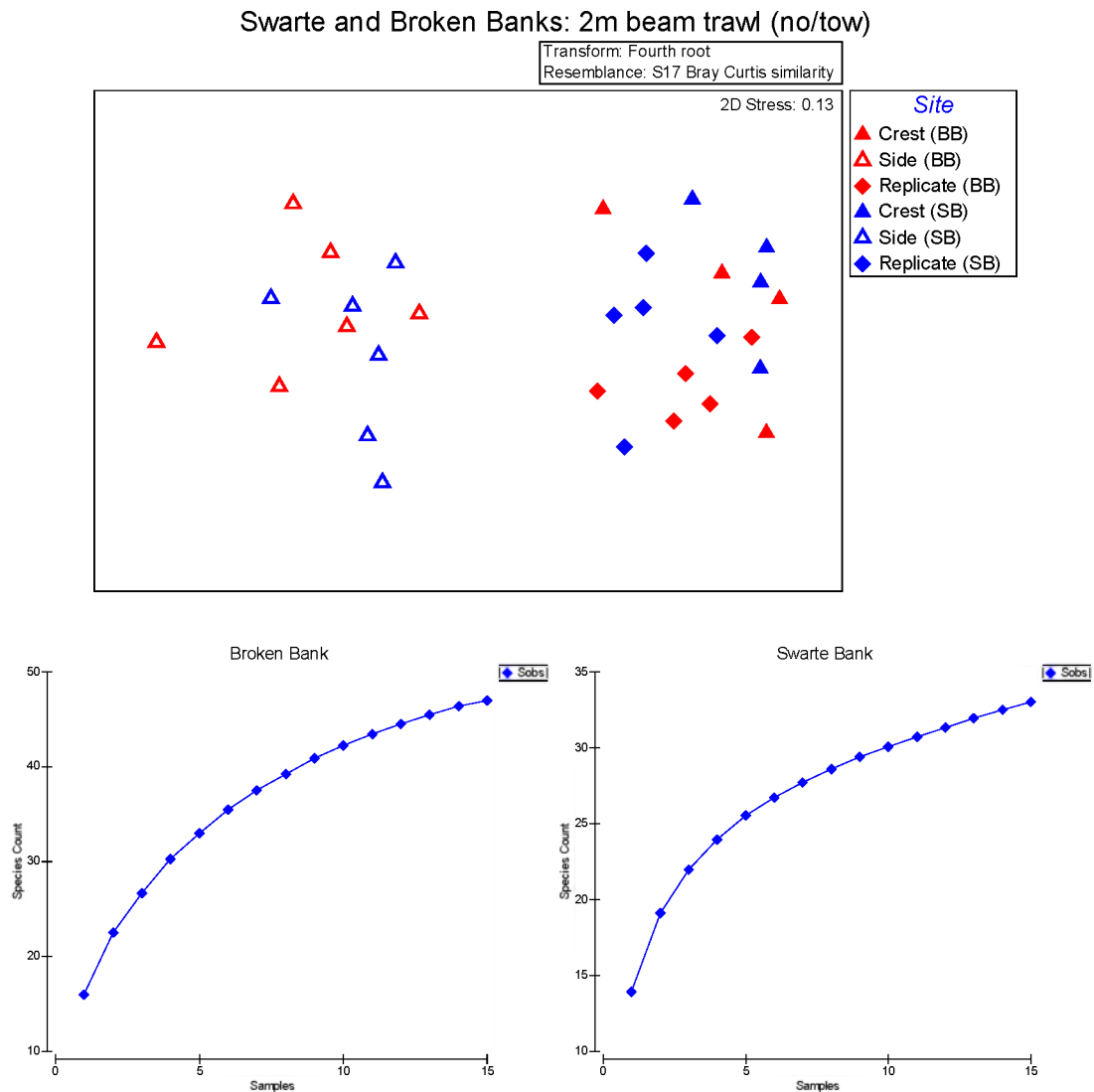


Figure 10: Analyses of 2m-beam trawl catches on gravel (North Sea) and shell-gravel (western English Channel), including (top) MDS plot of catches and (bottom) the cumulative number of species at both sites.

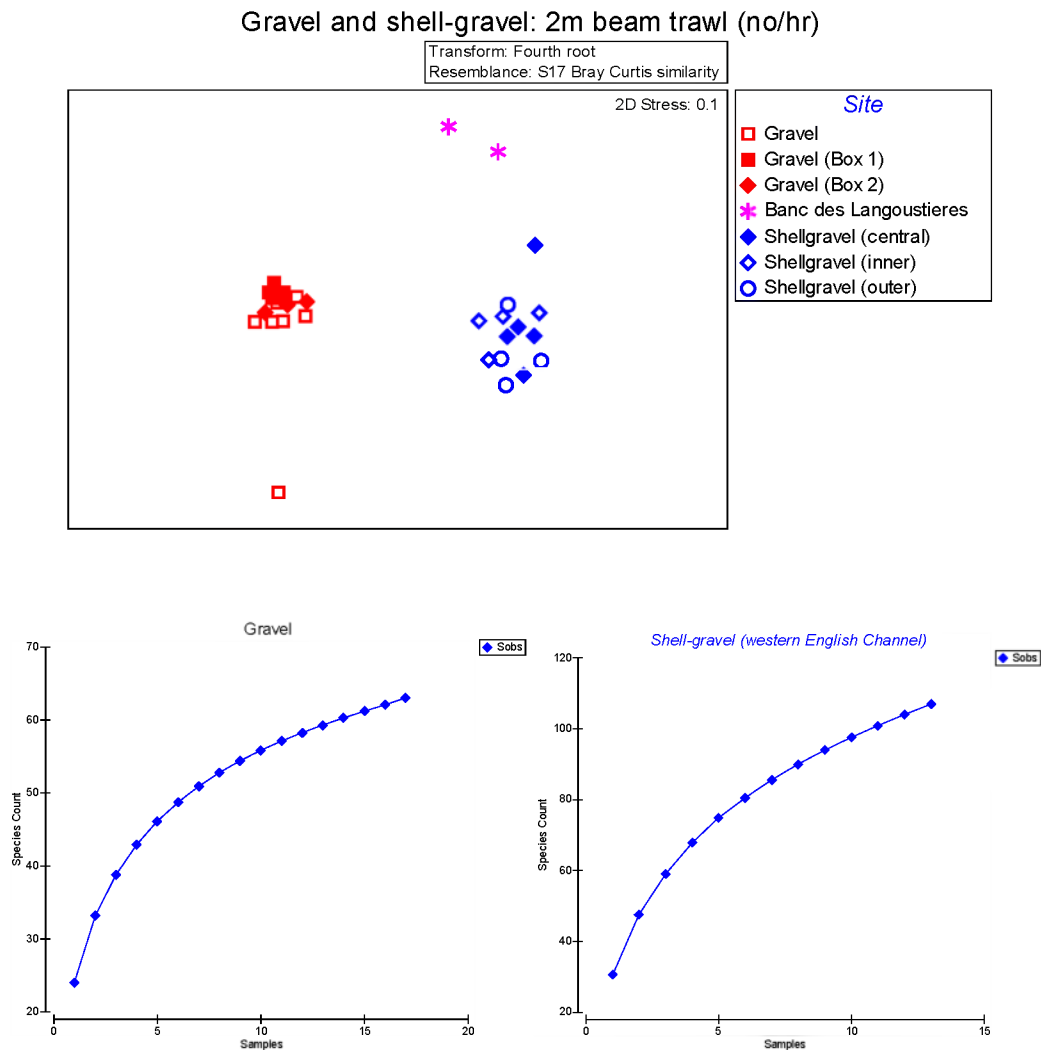


Table 1: Summary of sampling undertaken from 2004–2007 by habitat type giving the number of hauls made, depth ranges and whether the main station is a fixed station (yes/no/occasional) on groundfish surveys. Total number of stations = 128.

Cruise	Habitat	Location	Fishing station No. of tows	Grid (including notes on water depths)
End 9/04	Mud	NW Irish Sea	Yes 13	Central station (five replicate tows, 64 m) with single tows at eight stations across inner (64–73 m) and outer (71–130 m) grids
		Celtic Deep	Yes 13	Central station (five replicate tows, 112 m) with single tows at eight stations across inner (108–113 m) and outer (101–114 m) grids
Cory 1/05	Sand	Outer Bristol Channel	Occ. 14	Central station (five replicate tows, 74 m) with single tows at eight stations across inner (70–75 m) and outer (69–77 m) grids; one additional tow
		Outer Carmarthen Bay	Yes 14	Central station (five replicate tows, 38 m) with single tows at eight stations across inner (33–40 m) and outer (22–41 m) grids; one additional tow
		Inner Carmarthen Bay	Yes 12	Station in NW corner (five replicate tows, 15 m) and surrounding grid (single tows at seven stations, 14–30 m)
End 10A/06	Sand bank	Swarte Bank	No 15	Central station (five replicate tows, 17 m) on the bank, four tows elsewhere along the bank (15–20 m), three tows either side of bank (28–38 m)
		Broken bank	No 15	Central station (five replicate tows, 18 m) on the bank, four tows elsewhere along the bank (18–21 m), three tows either side of bank (33–40 m)
	Gravel	Felixstowe	No 17	Five replicate tows in two reference boxes (33 and 39 m), seven additional tows (34–38 m) in surrounding area
End 6/07	Shell-gravel	Western English Channel	Occ. 13	Central station (five replicate tows, 85 m) with single tows at eight stations across inner (82–86 m) and outer (86–94 m) grids
		Banc des Langoustieres	No 2	Single samples either side of the bank (62–70 m)

Table 2: Most abundant fauna at each of the sites (species accounting for 70% of the cumulative number, fourth-root transformed data).

Common name	Species	NW Irish Sea	Celtic Deep	Outer Bristol Channel	Outer Carmarthen Bay	Inner Carmarthen Bay	Sandbanks	Gravel	Shell gravel
Shrimp	<i>Crangon allmani</i>	*	*	*				*	*
Pink shrimp	<i>Pandalus montagui</i>	*						*	
Norway lobster	<i>Nephrops norvegicus</i>	*	*						
Auger shell	<i>Turritella communis</i>	*							
Nut shell	<i>Nucula sulcata</i>	*	*						
Sand goby	<i>Pomatoschistus</i> sp.	*		*	*		*		
Poor cod	<i>Trisopterus minutus</i>	*							*
Long-rough dab	<i>Hippoglossoides platessoides</i>	*							
	<i>Dichelopandalus bonnieri</i>		*						
	<i>Pontophilus spinosus</i>		*						
Dark necklace shell	<i>Euspira fusca</i>		*						
Witch	<i>Glyptocephalus cynoglossus</i>		*						
Cloak anemone	<i>Adamsia carciniopados</i>			*					*
	<i>Anapagurus laevis</i>			*					*
Common hermit crab	<i>Pagurus bernhardus</i>			*	*	*		*	*
	<i>Pagurus prideaux</i>			*					*
Sandstar	<i>Astropecten irregularis</i>			*	*	*			
Dab	<i>Limanda limanda</i>			*	*		*		
Swimming crab	<i>Liocarcinus holsatus</i>				*	*		*	
	<i>Abra</i> spp.				*				
Common brittlestar	<i>Ophiura ophiura</i>				*	*	*		
Solenette	<i>Buglossidium luteum</i>				*	*	*	*	
Long-legged spider crab	<i>Macropodia rostrata</i>					*			
Common whelk	<i>Buccinum undatum</i>					*		*	
	<i>Philine aperta</i>					*			
Common shrimp	<i>Crangon crangon</i>						*		
Lesser weever fish	<i>Echiichthys vipera</i>						*		
Scaldfish	<i>Arnoglossus laterna</i>						*		
	<i>Pandalina brevirostris</i>							*	
Hairy crab	<i>Pilumnus hirtellus</i>							*	
Queen scallop	<i>Aequipecten opercularis</i>							*	*
Common starfish	<i>Asterias rubens</i>							*	
Green sea urchin	<i>Psammechinus miliaris</i>							*	
Devonshire cup coral	<i>Caryophyllia smithii</i>								*
Squat lobster	<i>Galathea</i> spp.								*
Squat lobster	<i>Munida rugosa</i>								*
Nut crab	<i>Ebalia tuberosa</i>								*
	<i>Macropodia linnaesi</i>								*
	<i>Macropodia tenuirostris</i>								*
Oval venus	<i>Timoclea ovata</i>								*
Jeffrey's goby	<i>Buenia jeffreysi</i>								*

Table 3: Mean similarity of catches at sites

Habitat	Location	Mean similarity (%, 5 replicates)	Total no. of stations	Mean similarity
Mud	NW Irish Sea	70.1	13	45.1
	Celtic Deep	67.9	13	61.6
Sand	Outer Bristol Channel	40.4	14	39.4
	Outer Carmarthen Bay	65.1	14	45.9
	Inner Carmarthen Bay	67.1	12	51.4
Sand	Swarte Bank	70.9	15	57.5
bank	Broken bank	71.3	15	
Gravel	Felixstowe	70.7–74.6	17	61.4
Shell-	Western English Channel	45.2	13	44.4
gravel	Banc des Langoustiers	-	2	-

Table 4: Number of stations fished at each site (N), total number of taxa (excluding sessile/colonial species) recorded (S), the mean number of taxa recorded at a single station (number and as a proportion of the total number of taxa recorded)

Site	N	S	Taxa in one sample		
			Mean	SD	% S mean and range (\pm SD)
Swarte Bank	15	33	13.9	4.0	42.2 (30.0–54.4)
Broken Bank	15	47	16.0	6.3	34.0 (20.6–47.3)
Celtic Deep	13	56	19.3	6.2	34.4 (23.4–45.4)
Inner Carmarthen Bay	12	60	19.3	5.5	32.2 (23.0–41.5)
Outer Carmarthen Bay	14	62	19.7	5.1	31.8 (23.7–40.0)
Gravel	17	63	24.0	5.3	38.1 (29.7–46.6)
Outer Bristol Channel	14	64	16.3	5.6	25.5 (16.8–34.3)
NW Irish Sea	13	79	22.0	8.9	27.9 (16.6–39.2)
Shell-gravel	13	107	30.6	7.4	28.6 (21.7–35.5)