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Assessment of offshore habitats in the Cardigan Bay SAC (June 2010 survey)

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Introduction

The scallop fishery for *Pecten maximus* in the Irish Sea is open from 01 November for a period of six months. During the closed season in 2009, complaints were made to the European Commission regarding the amount of scallop dredging activity that had occurred in the previous two seasons. The concerns of the complainants related to the possible effects of the increased levels of fishing activity on the seabed and cetacean features for which the Cardigan Bay SAC was designated (namely bottlenose dolphins, cobble reefs and sand banks). Given the lack of scientific information that would enable an appropriate assessment of the risk of damage to the features of the SAC, the Welsh Assembly Government extended to closed season until 01 March 2010 to allow sufficient time to gather and process additional scientific information in relation to the features of the SAC.

In December 2009 the School of Ocean Sciences conducted an extensive habitat survey of the offshore areas of Cardigan Bay to inform Welsh governmental bodies about the characteristics and status of offshore benthic habitats. Due to the extent of the SAC and limited time available for the survey an area of 225 km^2 was initally surveyed. The survey primarily concentrated on an area, that was highlighted by the fishing industry as an important part of their fishing grounds (Hinz et al. 2010). The results of this survey showed that the seabed in studied area was mainly dominated by sand and gravel. The occurrence of large field of sand waves suggested that the area represented a highly dynamic environment. This indication was further supported by the low species numbers and low abundance of benthic biota. Benthic organisms that are typically found in established reef communities such as hydroids, soft corals, anemones, bryozoans and tunicates were rare even within cobble and boulder habitats and in particular when compared with other established reefs (see Hinz et al 2010 for more detail). As a result of the findings of the first survey the Welsh Assembly Government decided to reopened a proportion of the Cardigan Bay SAC to scallop dredging between March and May 2010 (see Fig 1).

The School of Ocean Sciences was commissioned with a second survey in June 2010 with the aim to survey the western part of the SAC from the 1.5 nm limit to its perimeter, previously not surveyed. Additionally, a subset of stations previously surveyed in December 2009 was resurveyed to investigate temporal changes in habitat and faunal composition. Stations were located both within and outside the area reopened to the 3 month scallop dredging season (March – May 2010), hence allowing comparisons in benthic community structure with respect to changes in fishing effort (fished versus unfished areas). The present report summarizes the findings of this second survey conducted in June 2010.

Background

The king or great scallop *Pecten maximus* is a high value commercial species prosecuted by fishing vessels that used toothed dredges. Experimental and large-scale comparative studies that have quantified the effects of towed bottom-fishing gears have clearly identified that scallop dredges cause direct mortality to benthic biota leading to a reduction in diversity, abundance, biomass and production (Collie et al. 1997; Kaiser et al. 2006; Hiddink et al. 2006). The magnitude of these effects will vary among different types of habitat according to the species assemblage associated with that habitat. Thus reefs composed of long-lived reef-building organisms will be affected most severely by scallop dredging due to the degradation of the habitat, the slow growth rates and infrequent recruitment of the reef-building fauna. The recovery time for such habitats and associated species will be measured in periods of between 5 – 20 years or may not occur at all. At the other extreme, habitats that are subjected to frequent, seasonal and periods of intense natural disturbance are associated with species that are tolerant of these environmental conditions. Examples of large-scale disturbances would include wave erosion at the seabed from winter storms (greater exposure is associated with a higher magnitude of disturbance) that would lead to the resuspension of seabed sediment and its associated fauna, resuspension of sediment by tidal currents leading to the scouring of the seabed fauna, movement of sediments by currents leading to periodic smothering and death of fauna. The species that live in these habitats tend to be opportunistic species that have high growth rates, high reproductive output and recruit frequently following disturbance events. These habitats typically have low species diversity and are dominated by small-bodied fauna and ephemeral epifauna that tend to be high mobile and are scavengers (e.g. crabs, whelks, starfish). Thus while scallop dredging will have a negative impact on such species, the recovery rate of these habitats and their fauna is measured in periods of less than one year (Kaiser 1998; Kaiser et al. 2002; Kaiser et al. 2006).

Definition of 'stony reef'

The Joint Nature Conservation Committee (JNCC) held a workshop in 2008 to defined 'stony reefs' from a conservation and management point of view (Irving 2009). While various views existed about what constituted to a stony reef a consensus was reached. A 'stony reef' was defined as an area of sea bed containing more than 10% of stones above 64 mm (cobbles) with an elevation greater than 64 mm. The extent of the reef has to be above 25 m^2 and it should be dominated by epifaunal species as opposed to infaunal species (Table 1). The extent of resemblance to being a stony reef was further graded into low, medium and high (see Table 1). It was concluded that if a low score in reef resemblance was apparent in any of the four characteristics (composition, elevation, extent and biota) a strong justification would be needed for the area to be considered as an Annex I 'stony reef' and thus to contribute to the Marine Natura site network (Irving 2009).

Table 1. Summary of the main characterising features of a stony reef as outlined by the JNCC report (Irving 2009).

Characteristic	Not a 'stony reef'	'Resemblance' to being a 'stony reef'		
		Low[2]	Medium	High
Composition:	<10%	10-40% Matrix supported	**40-95%**	**>95% Clast supported**
Notes: Diameter of cobbles / boulders being greater than 64mm. Percentage cover relates to a minimum area of 25m². This 'composition' characteristic also includes 'patchiness'.				
Elevation:	**Flat seabed**	<64mm	**64mm-5m**	**>5m**
Notes: Minimum height (64mm) relates to minimum size of constituent cobbles. This characteristic could also include 'distinctness' from the surrounding seabed. Note that two units (mm and m) are used here.				
Extent:	**<25m²**	← **>25m²** →		
Biota:	**Dominated by infaunal species**			**>80% of species present composed of epifaunal species**

Methods

Survey design

The second survey concentrated on the most western part of the SAC following the request by the Welsh Assembly Government (Fig. 1). Neighbouring sampling stations were separated by approximately 2 km. The final survey area encompassed an area of 230 km^2, 24% of total area of the SAC (960 m^2). Together with the initial survey 53 percent (504 km^2) of the total SAC have to date been surveyed.

Besides sampling of the new area we resampled thirteen stations of the initial survey using the same underwater camera system to reassess the status of benthic habitats and fauna (Fig 1). Six of the resurveyed stations were located in areas that remained closed to fishing while seven stations were within the area reopened to scallop dredging for the period of three month between March to May 2010. The data attained was used to assess if scalloping effort within the reopened area had a significant effect on the abundance, diversity and species composition of benthic fauna.

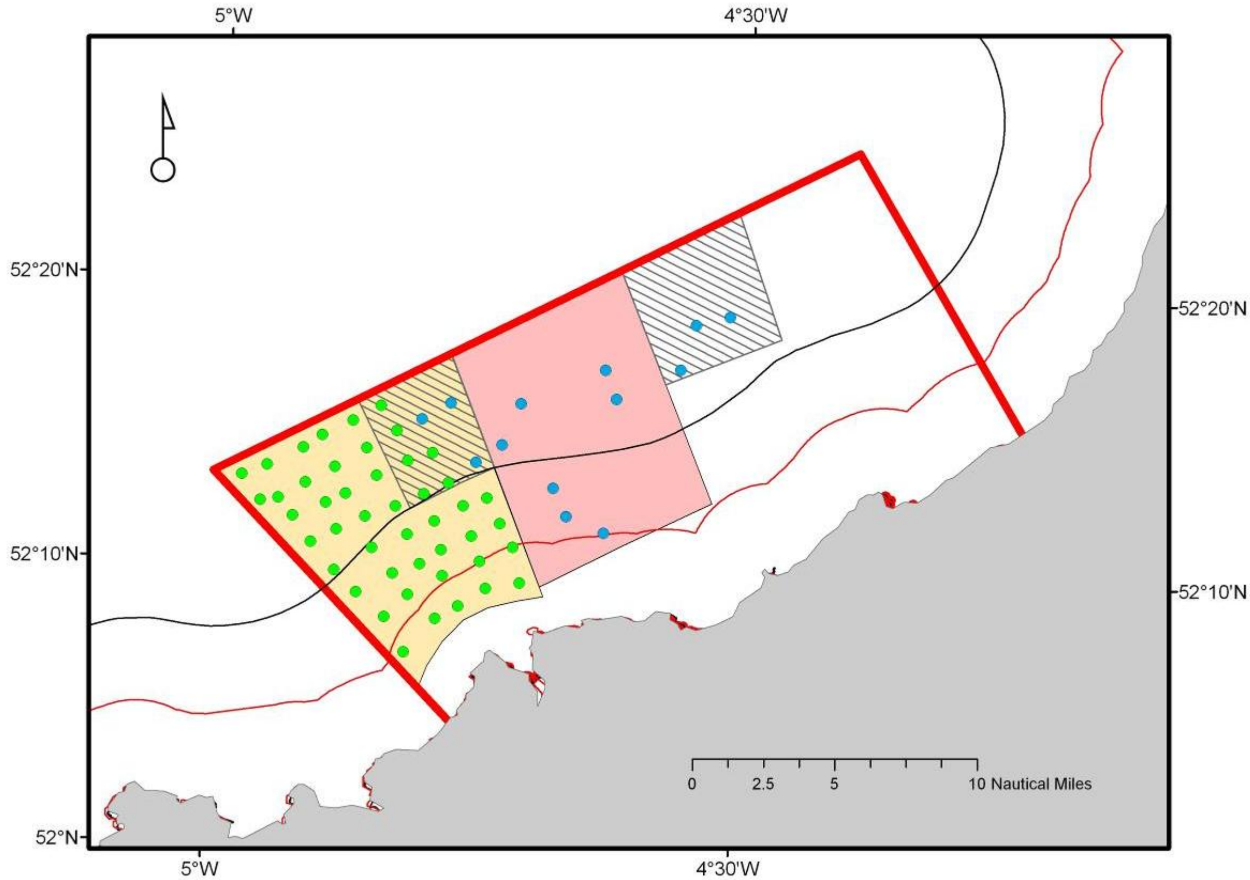

Fig. 1. Location of underwater camera sampling stations. Green points signify new survey sites while blue stations represent resurveyed stations. The area in red was open to fishing for three months between March to May in 2010. Hashed areas and yellow areas remained closed to fishing throughout this period.

Hamon grab samples

A single 0.2m^2 Hamon grab samples were taken at all 52 sites encompassing the 46 new sites and 6 stations previously not sampled during the December 2009 survey. Sediment samples were partly processed on board. After carefully running off any excess sea water each sample was photographed and subsequently weighed. A sub-sample of approximate 500 g of the finer sediment was taken from the total sample and weighed. The remaining sample was sieved onboard over 5 and 64 mm sieves. Each fraction was subsequently weighed. For a preliminary analysis the percentage weight of cobbles (sediment over a grain size of 64 mm) was calculated per station. The sub-sample will be used to determine the grain size distribution of the finer sediment fraction.

Video and stills camera tows

A sledge mounted video and stills camera system was deployed at each sampling station and towed at a speed of approx. 0.5 knots for a period of 10 minutes. Start and end positions of each tow were recorded from the point the sledge had visibly reached the sea floor to the point when the sledge lifted off the ground during hauling. While the video system delivered a continuos live picture which was recorded on DVD the digital stills camera took a high resolution image every 10 seconds. The field of view of the video camera covered an area of approximately $0.12m^2$ (width 0.41m x depth 0.30m). Each still image covered an area of $0.13m^2$ (0.44m x 0.30m).

Habitat description

Habitat types were determined from the still camera images. From this information the percentage of a particular habitat type per tow was calculated. Three main habitats were determined within the new area: a) sand b) gravel and c) cobble and boulder habitats. To allocate images to either habitat category more than 50% of the image's surface area had to be covered by the respective sediment type. To aid distinguishing between gravel and cobble habitats a grid of 64 mm was overlaid over each image during analysis using the software package ImageJ.

Benthic fauna

The abundance of benthic organisms as well as species numbers were determined from stills images. Organisms were identified to the lowest taxonomic level possible. While abundances were standardized to m^2 the number of species were recorded per tow. The number of images varied slightly between tows due to some images being of poor quality making them unusable for the analysis (average number of images analysed 51 $\pm$8 S.D.).

Side scan sonar survey

The side scan survey was conducted over a 3 day period from 22th to 24th June 2010 using the fishing vessel MFV Mercurius. The side scan sonar system was a Cmax CM2 system using a 300m tow cable on a 24v battery powered winch. A sonar range of 100m (total swath width 200m and sonar frequency 325kHz) was employed throughout, with the tow-fish altitude above the seabed kept between 5 to 10m. All survey lines were run perpendicular to the coast as these were found to give the clearest images with the more distinct shadows in the December 2009 survey (Hinz et al 2010). Seven side scan sonar lines were run from the 1.5 nautical mile limit up to the boarder of the SAC within the new survey area (Fig. 2). Three side scan sonar lines within the area reopened to scallop dredging, first surveyed in December 2009, were resurveyed to assess potential temporal changes in seabed morphology (Fig. 2). Furthermore, four additional survey lines were run in the north eastern part of the SAC for which only underwater camera footage and grab samples existed but no side scan sonar data (Fig. 2). Besides assessing bedforms the side scan sonar data was also used to look for fishing activity in form of dredge marks.

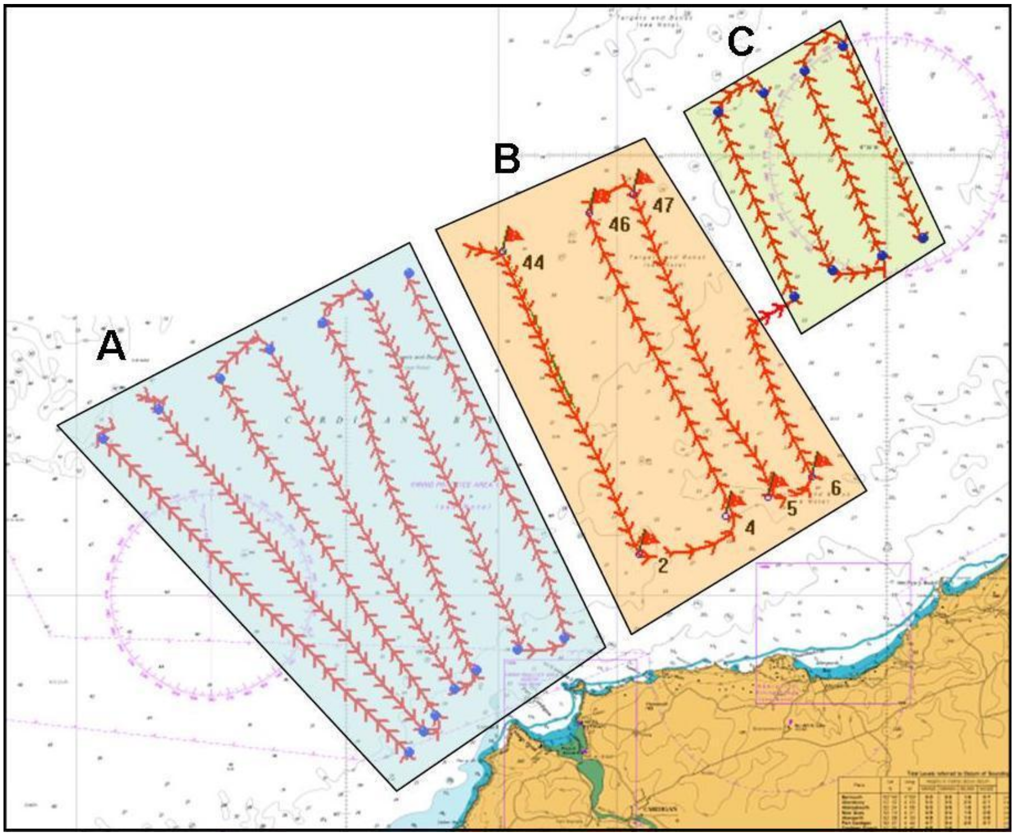

Fig. 2. Side scan survey lines A) new area B) repeat survey C) area previously not surveyed in December 2009.

Analysis of benthic community data from stills images for the newly surveyed area

Species number, total abundance of benthic fauna, as well as indicator species of reef structures were visualized within a GIS. In general, sessile attached benthic fauna such as hydroids, soft corals, anemones, bryozoans and tunicates were classified as species associated with rocky reefs. Abundances of the King scallop *Pecten maximus* were also presented within the GIS.

Benthic community composition as identified from the still photographic images was analysed using multivariate statistics PRIMER v6 (Clarke & Gorley 2006). Prior to analysis the data was standardised due to differences in the tow length and hence number of stills images per tow. The abundance of species recorded was standardised to numbers/m² to make the abundance data comparable. This standardisation is not applicable to the number of species recorded, hence the number of species represents the total number observed per tow. A square root transformation was applied to the data to down-weight the influence of extreme abundance records that occurred in a relatively small number of stations. A similarity matrix of the standardised community data was calculated using the Bray-Curtis index of similarity for each pair-wise combination of sampled sites. A cluster analysis was then performed to generate a dendrogram to indicate potentially significantly different groups of sites based on their community composition. Significantly different clusters were ascertained using the SIMPROF randomisation permutation procedure. A multidimensional scaling ordination plot was then generated to visualise the relationship among sites and groups identified by the SIMPROF procedure. A SIMPER analysis was undertaken to identify those species (indicator species) that accounted for most of the similarity and dissimilarity among the station groups identified by the SIMPROF.

Analysis of the resurveyed stations located in fished and unfished areas

Abundance, species numbers and community composition of benthic fauna recorded at resurveyed sites were compared with the original data collected in December 2006. The resampled sites fell within an area that was subsequently reopened to fishing (n = 7) that were compared with the areas that remained closed to fishing (n = 6) see Fig 3. Thus temporal as well as fishing related changes on abundance, diversity and community composition could be investigated. A 2-way ANOVA was used to test for temporal and fishing induced changes in the abundance and diversity of the benthic community. Factors: **Season,** two levels December/June, **Protection,** two levels Open/Closed. Furthermore a PERMANOVA, multivariate test, was used to investigate changes in community structure with respect to Season and Protection.

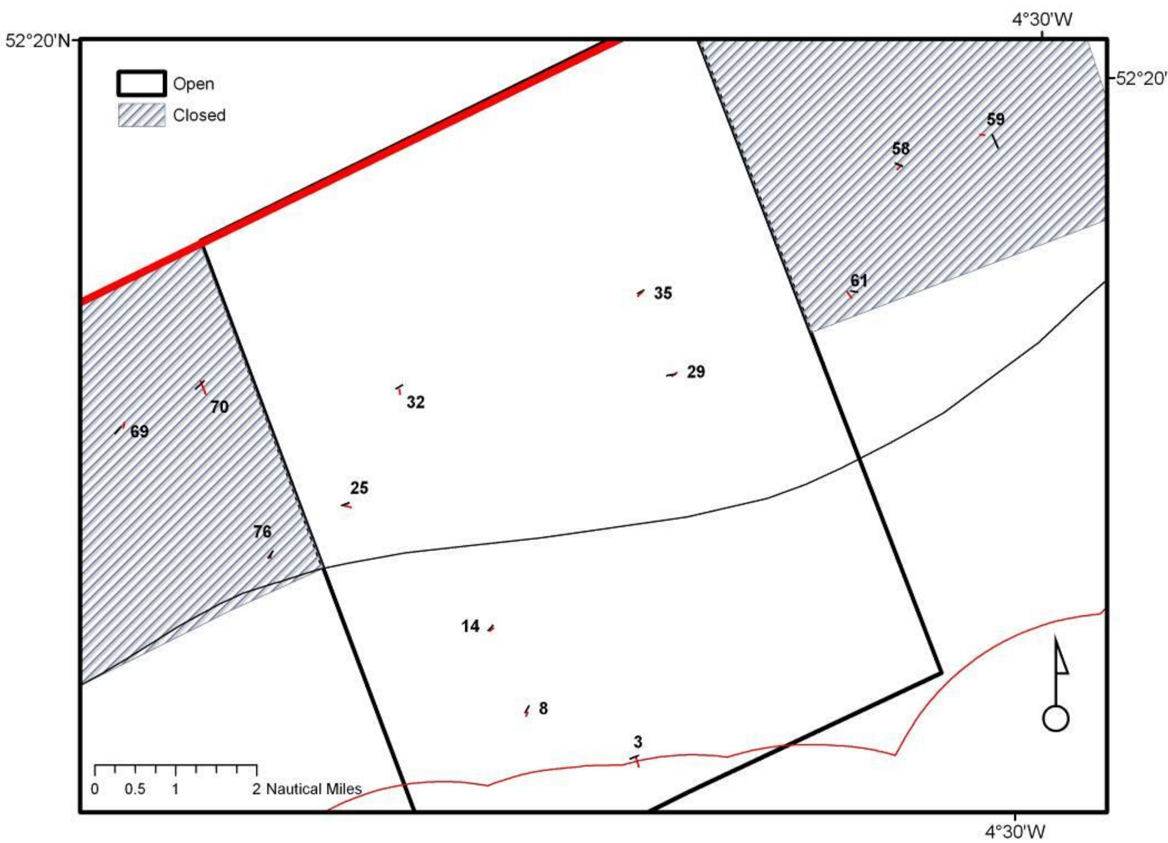

Fig. 3. Location of underwater camera tows of the two surveys conducted in December 2009 (black lines) and in June 2010 (red lines)

Results

Habitat classification from camera tows and grab samples for the new area

The average tow length of the 46 camera tows conducted was 229 m (S.D. $\pm$108m). On average an area of 6.69 m^2 per tow (S.D. $\pm$1.1) was surveyed with the stills camera (average number of still images 51 S.D. $\pm$8). Due to malfunctioning of the stills camera images were not available for station 34. For this station the video footage was consulted to assign habitat types to this station. Still images showed that cobble and boulder habitats were relatively rare and mainly restricted to the southern parts of the survey area (Fig. 4), in particular station 38, 39, 40 and 46 had a high percentage coverage of cobbles and boulder habitats (>50%). Most stations were dominated by gravel and to a lesser degree by sand. Overall the stations had a higher percentage of gravel in comparison to those surveyed in December 2009 (see Hinz et al. 2010).

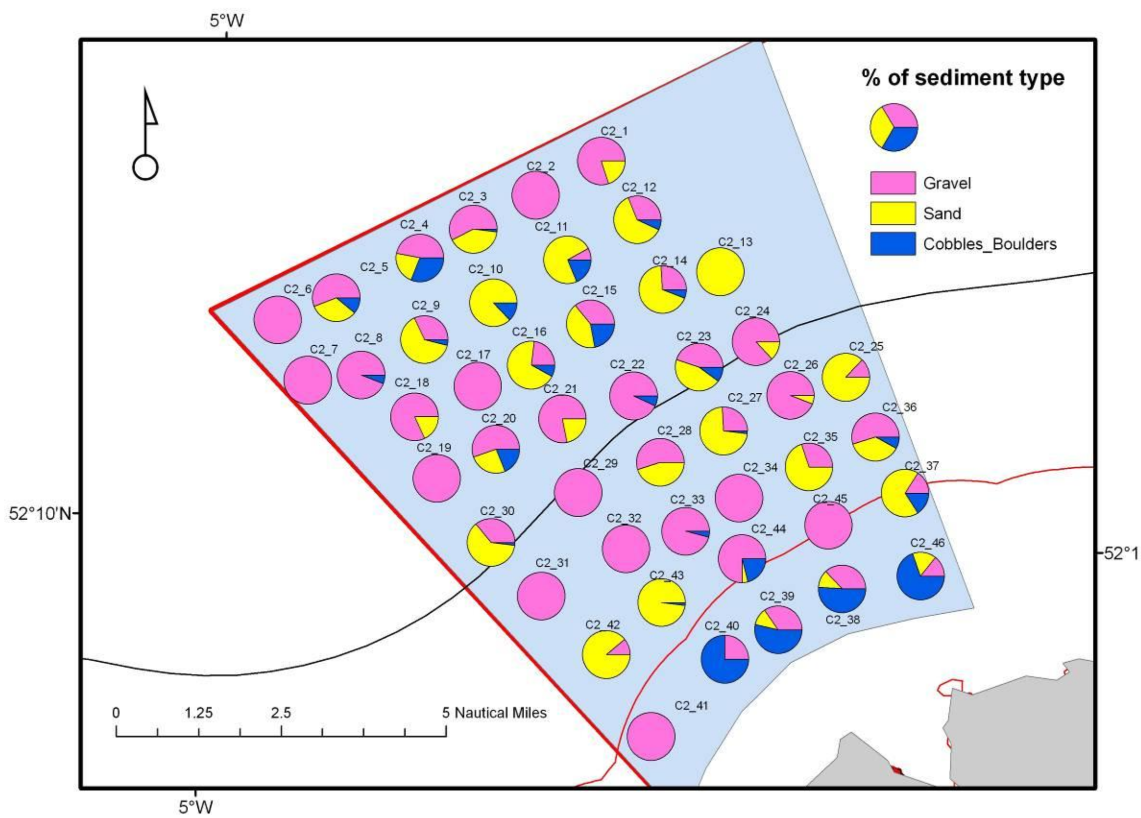

Fig. 4. Percentage contribution of sediment types (Sand, Gravel, Cobbles and Boulders) identified from the still images obtained for the newly surveyed area.

The preliminary analysis of sediment samples taken by the Hamon grab showed that cobbles, sediment above 64mm, were recorded at 9 stations (Fig 5.). The percentage weight of cobbles with respect to the total sample's wet weighed was found to be higher compared to the previously surveyed area to the East (see Hinz et al 2010). The average percentage of cobbles at sites where cobbles occurred was 22%. Station 46 showed 70% cobbles as only cobbles were retrieved with very little fine sediment. The grab failed to work at six stations and an assessment of these sites was therefore not possible. The grab tends to fail on very hard grounds such as compact sand and very coarse substrates (boulders and bedrock). However, failure to retrieve a sediment sample should not be interpreted as an indication of rocky habitats.

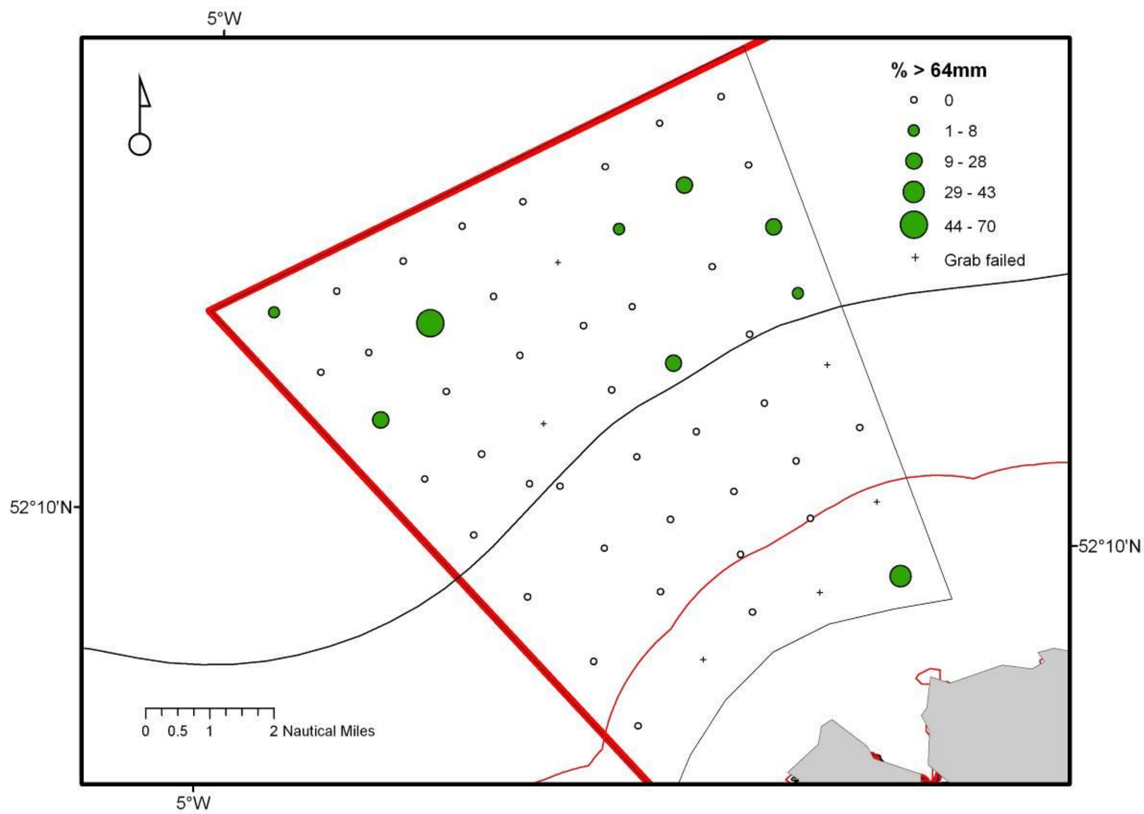

Fig. 5. Percentage of cobbles and boulders (>64 mm) in grab samples. Data displayed underestimates the percentages of cobbles and boulders in sediment samples as they refer to the total wet weight of the sample as opposed to the dry weight

Habitat classification from side scan sonar survey for the new area

The general background area appears to be composed of relatively coarse substrate (Fig 6), confirmed by the still images to be mainly gravel (see examples on pages 12-15), with some areas showing individual boulders that cast acoustic shadows in the side-scan sonar images (Fig. 6). Characteristic of the entire area were fields of mobile sand which showed distinct bedforms (sand waves). These sand waves were generally oriented perpendicular to the prevailing current and varied in size in different locations (Fig. 7). Most of the features shown by the data were consistent with those found during the December 2009 survey i.e. there were still areas of boulders, rougher gravely patches and sand fields (ribbons) present. The area to the North East which was newly surveyed by the side scan showed significantly more fields of sands compared to the newly surveyed area to the West (Fig. 7).

A noticeable difference from the December 2009 survey were the scallop dredging marks that were found in the area that was open to scallop dredging. Dredge marks were also found in the newly surveyed area to the East where scallop dredging was restricted (Fig 8, for a detailed discussion see below). These dredge mark features are clearly visible on the sonar records as two sets of parallel dark and light bands which cut across natural bedforms (sand waves).

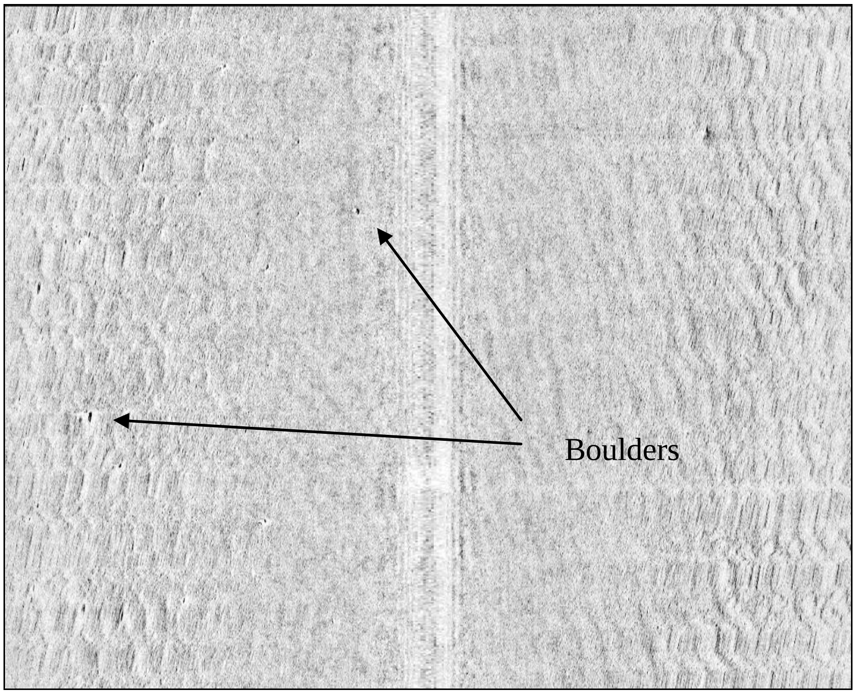

Fig. 6 .Characteristic side scan image of the new survey area to the East showing coarser grounds with individual boulders.

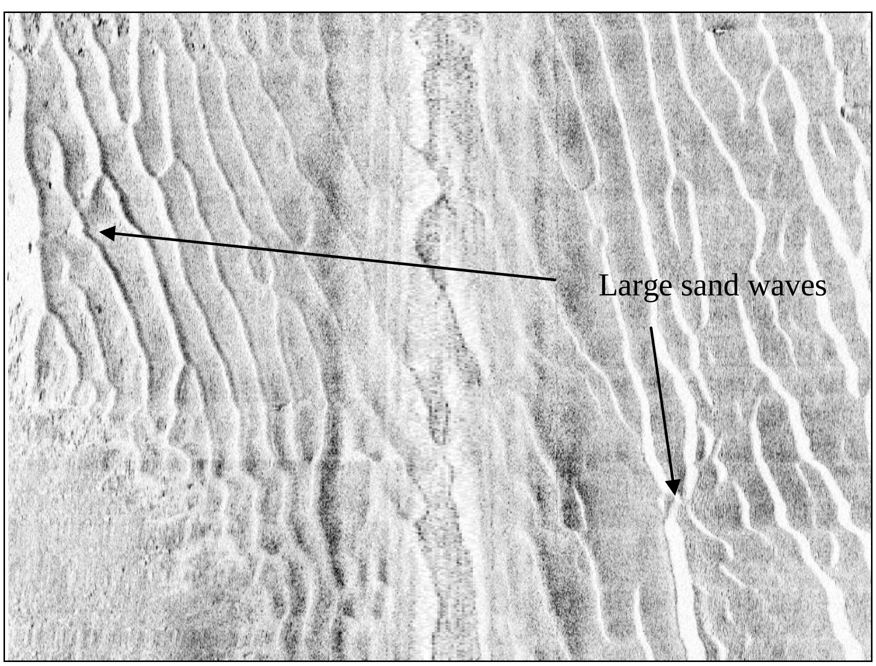

Fig 7 Characteristic side scan image of the new survey area to the East showing large bedforms of sand.

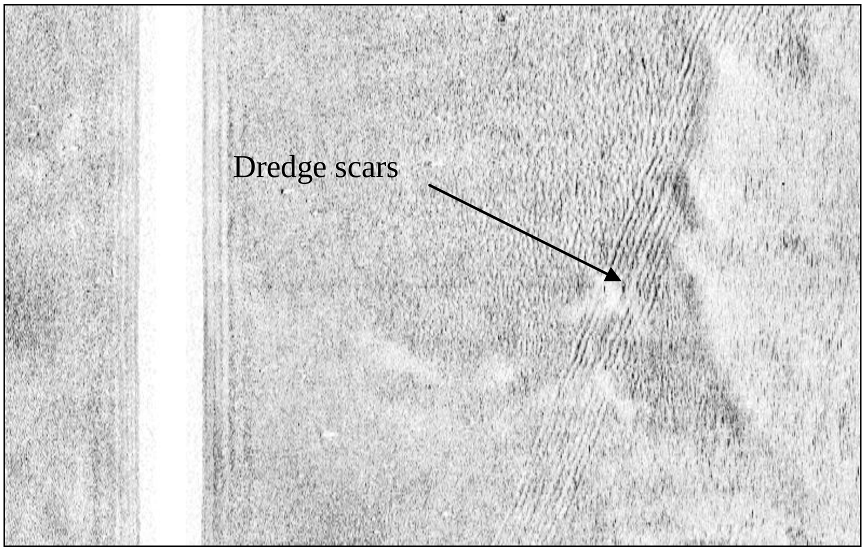

Fig 8. Clear scallop dredge mark of two 4 gang beams within the area to the East that was closed to scallop dredging.

To ground truth side scan sonar images a subset of 8 video tows was selected for the newly surveyed area (Fig 10-13). Video tow positions and side scan sonar lines are shown in Fig. 9.

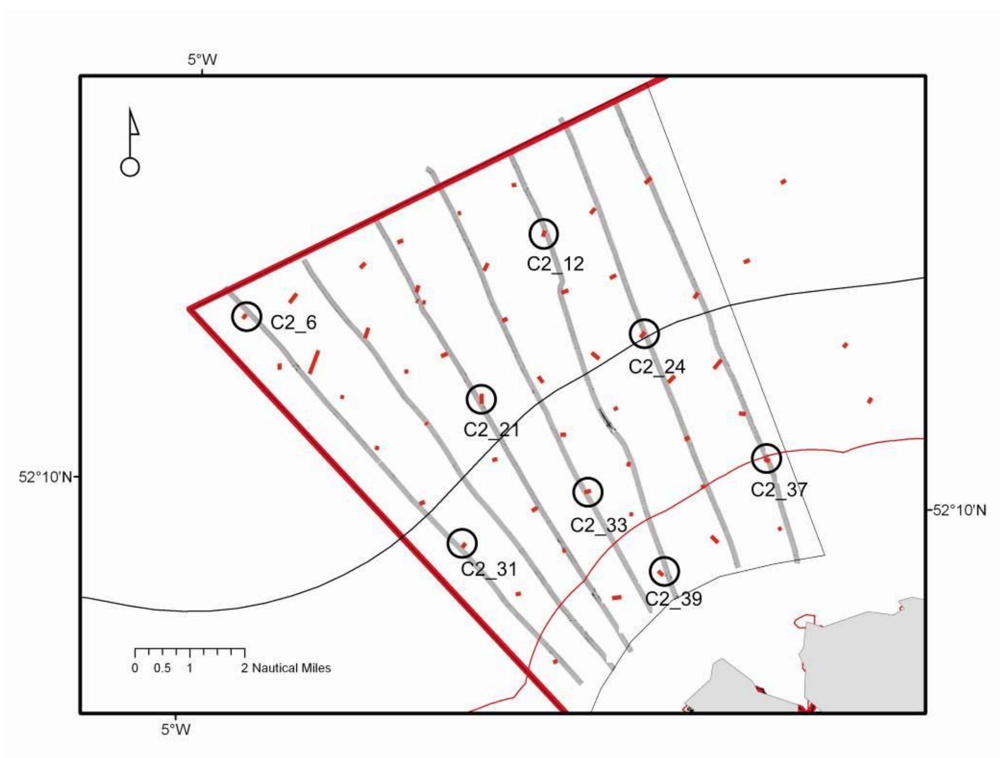

Fig. 9. Location of side scan sonar swath lines and camera tows. Encircled stations were used for ground truthing side scan images.

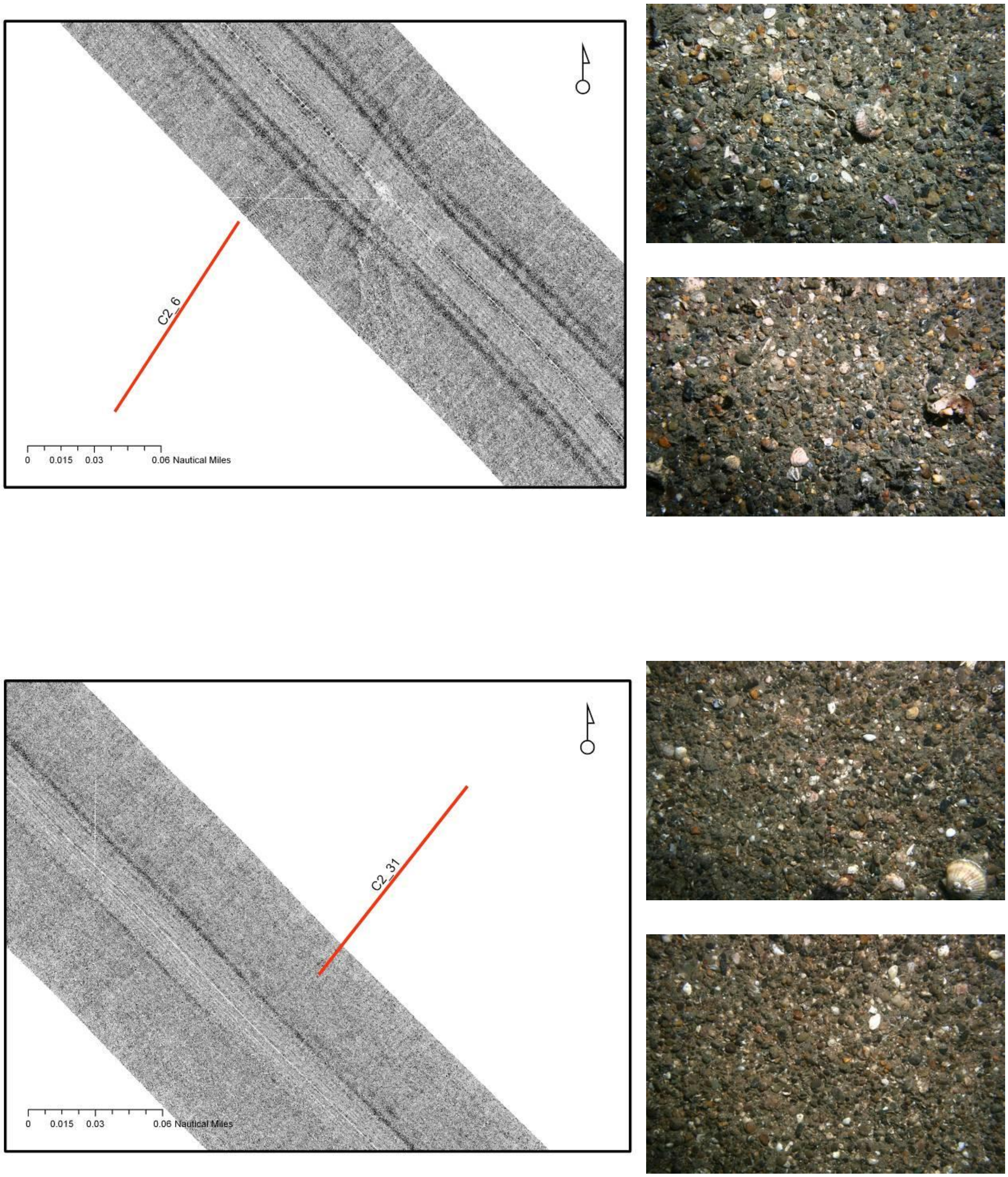

Fig. 10. Side scan line, position of camera tow and example images of Station C2_6 and station C2_31.

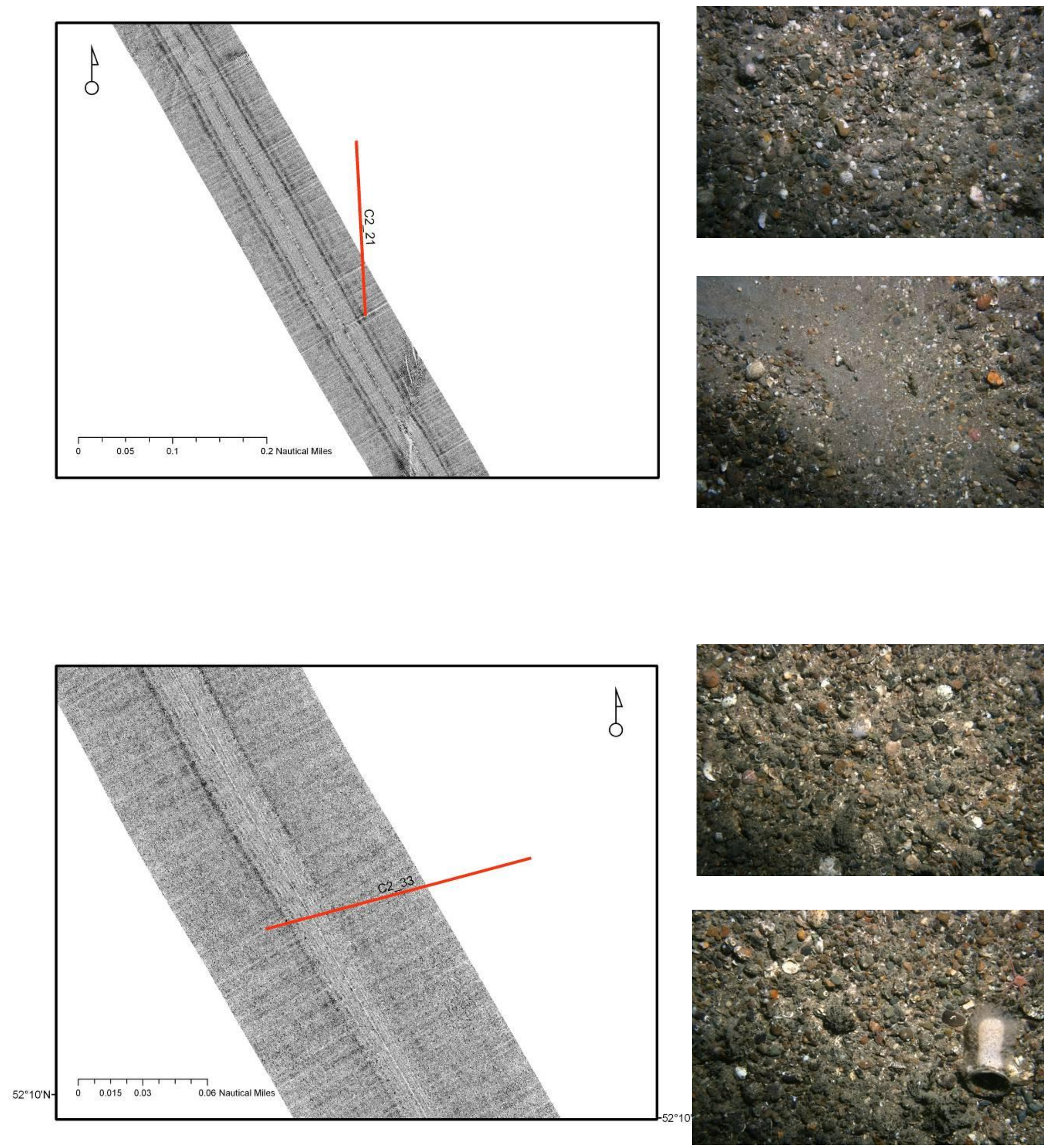

Fig. 11. Side-scan line, position of camera tow and example images of Station C2_21 and station C2_33.

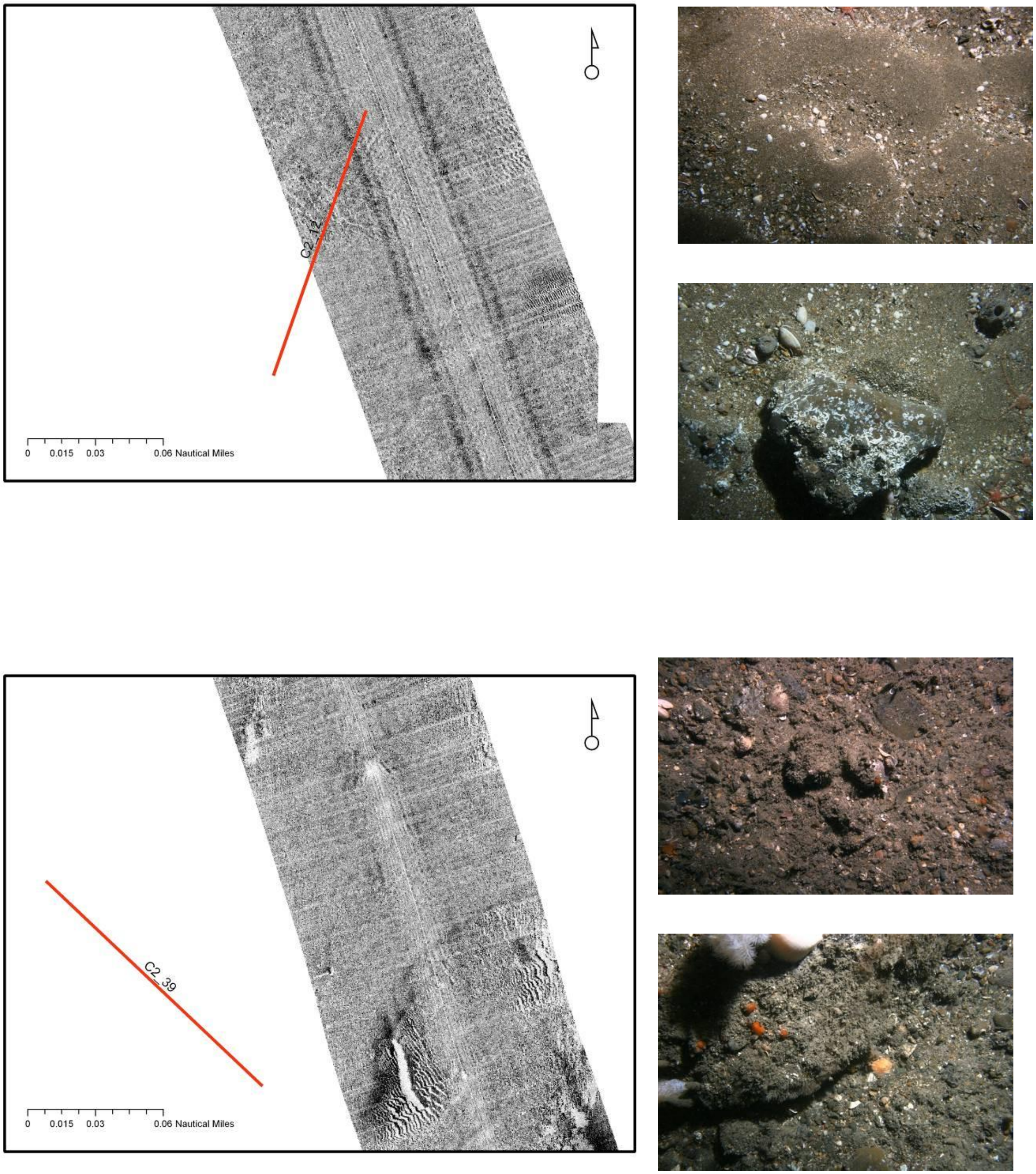

Fig. 12. Side scan line, position of camera tow and example images of Station C2_12 and station C2_39.

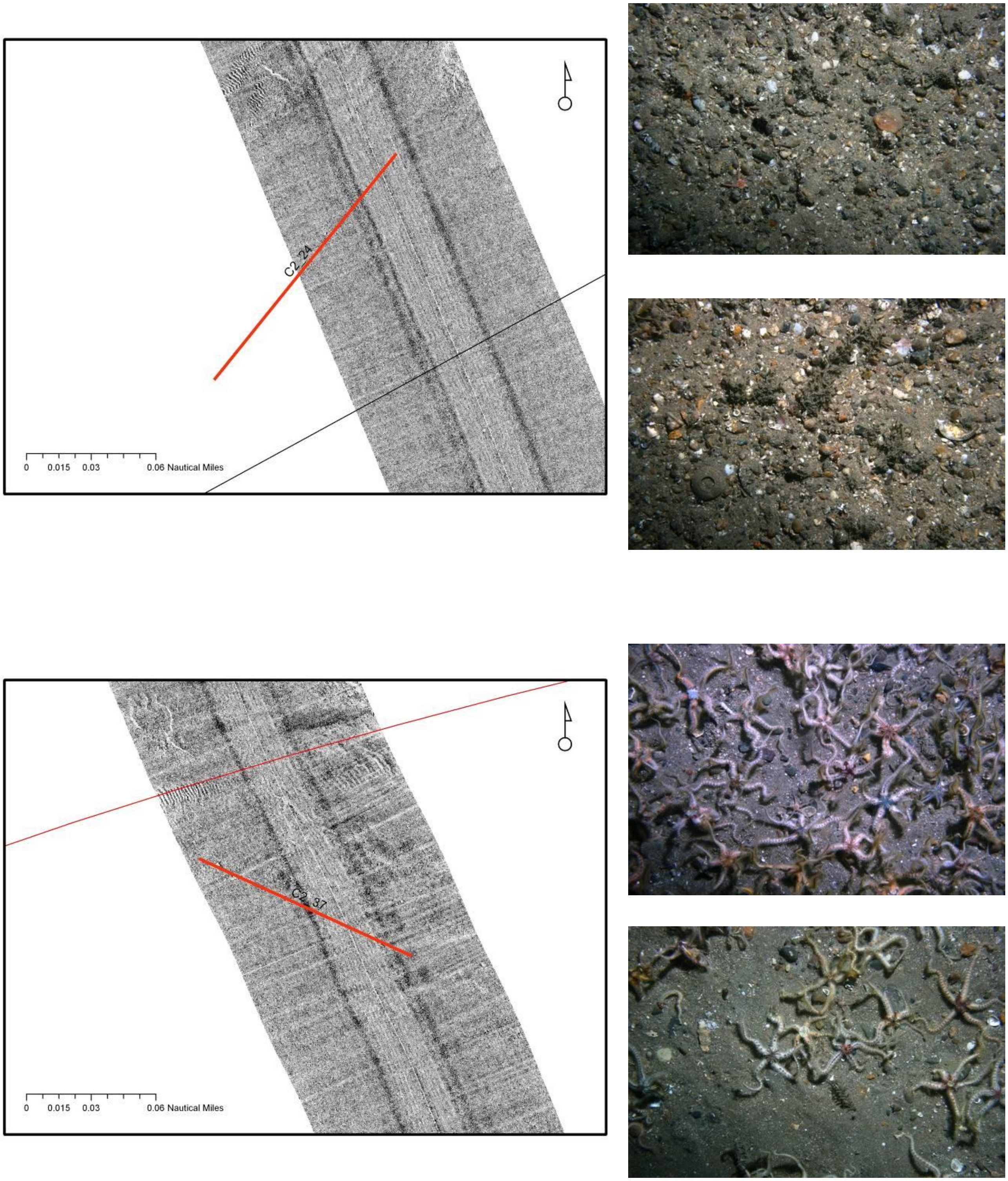

Fig. 13. Side scan line, position of camera tow and example images of Station C2_24 and station C2_37.

Analysis of benthic community data from stills images for the new area

Species numbers of the newly surveyed area were considerably higher compared to the previous area surveyed in December 2009. The average number of species was 21 (S.D. ±9.8) as opposed to 7 species (S.D. ±4) found over the previous survey area to the East (see Hinz et al. 2010). The maximum number of species recorded from the new survey was 49. Overall highest species numbers were found at near shore sites that had the highest percentage of cobbles and boulder habitat (see Fig 4 and 14). In contrast, stations with a high percentage of sand habitat generally had low numbers of species (Fig 4 and 14).

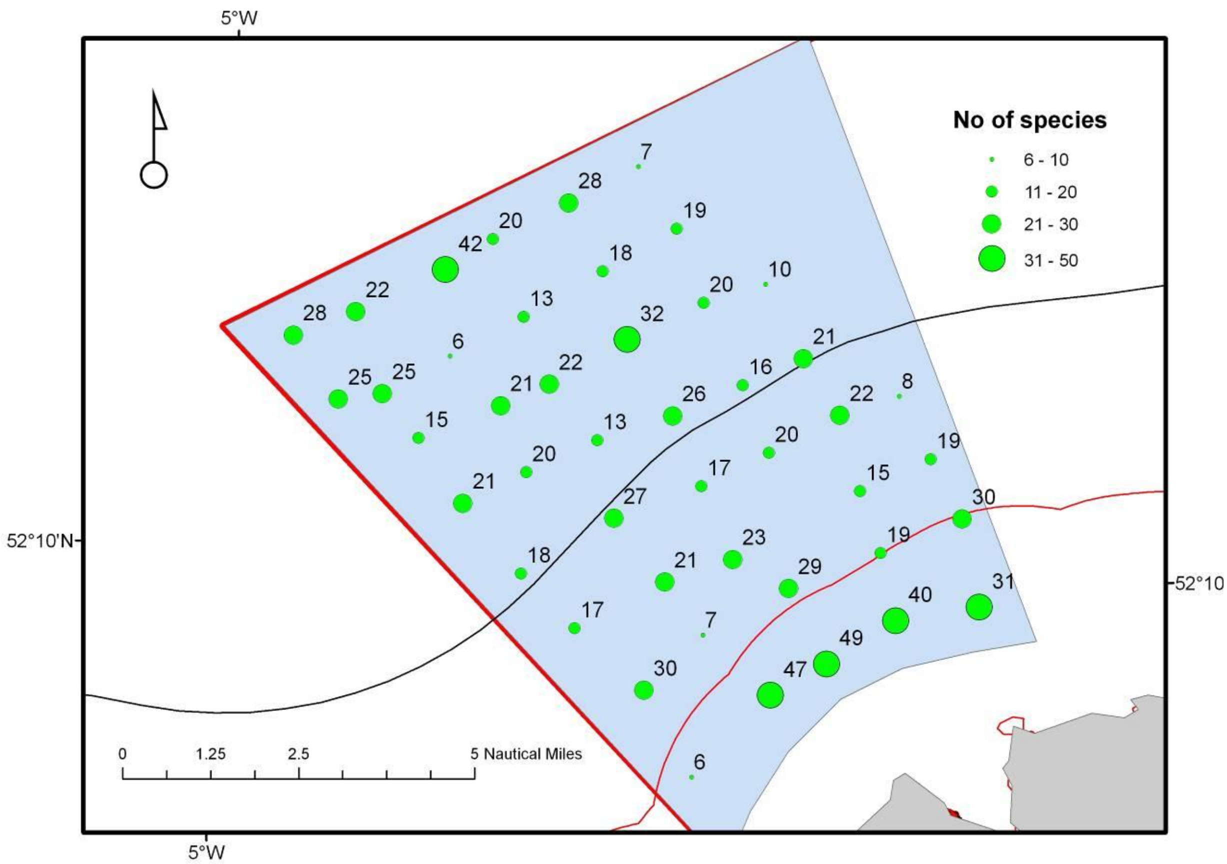

Fig. 14. Number of species per camera tow for the new survey are. Numbers are absolute values.

Abundances of emergent epifauna, generally associated with hard substrates, were found to be highest at stations located near the coast reflecting the distribution of the of cobble and boulder habitats (see Fig 15). Abundance of emergent epifauna were also high in the north western corner of the newly surveyed area, an area dominated by gravel and to a lesser extend by cobbles and boulders (see Fig 15). The average abundances was 106 individuals (individual colonies e.g. in case of hydroids or similar) per 10 m^2 (S.D. ±94). This was considerably higher than to the previously surveyed area that had an average abundance of emergent fauna of 8 individuals (S.D. ±11) per 10 m^2. The dominant emergent epifaunal groups were hydrozoans and anthozoans while other groups were less important (Fig 16).

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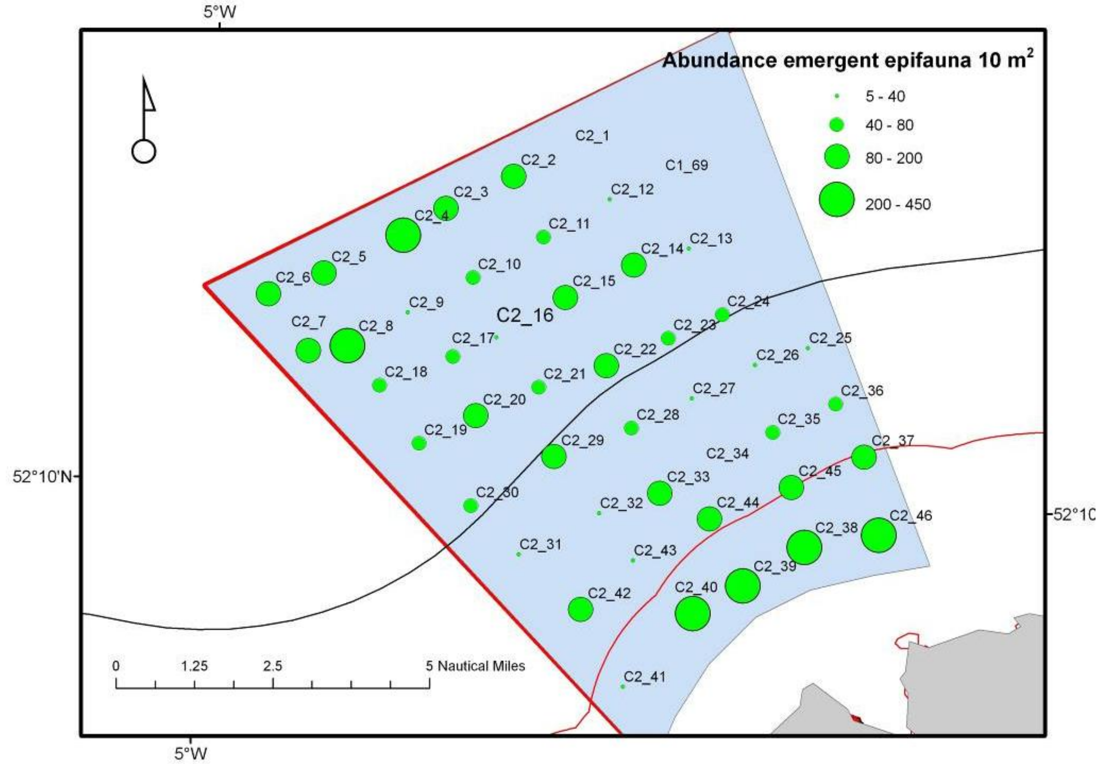

Fig 15 Abundance (number of individuals per 10m^2)of emergent epifauna including Hydroids at each station.

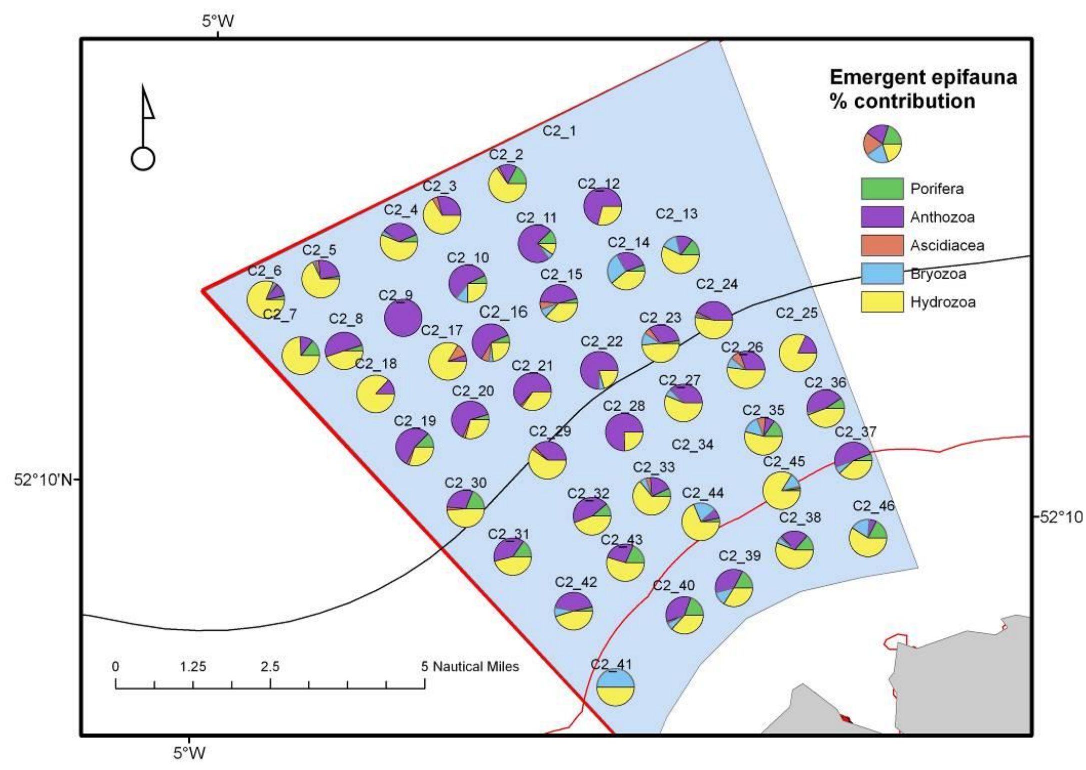

Fig 16 Percentage contribution of different emergent epifauna groups to the total abundance at each station.

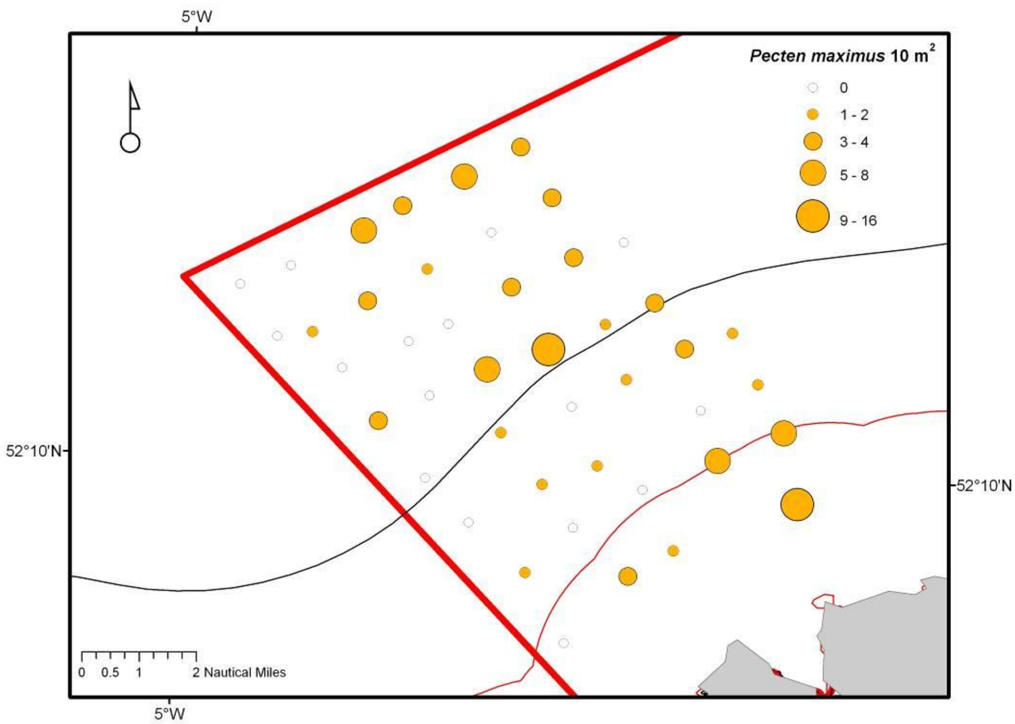

Fig. 17. Number of scallops *P. maximus* recorded from in still images per 10 m^2

The king scallop *Pecten maximus* was found throughout the survey area (Fig. 17) and had an average abundances of 2.5 individuals per 10 m^2 (S.D. $\pm$3) which was slightly lower compared to the 3 individuals per 10 m^2 (S.D. $\pm$5) found over the eastern areas surveyed in December 2009. Abundances where slightly higher in the northern part of the survey area. The maximum abundance recorded was 18 individuals per 10 m^2.

Cluster analysis together with the SIMPROF procedure identified seven significantly different clusters (a, c-h) of sites (alpha = 0.05). The similarity of clusters was relatively high with values ranging between 27-64% similarity among site groups (see Fig. 18 and Table 2).

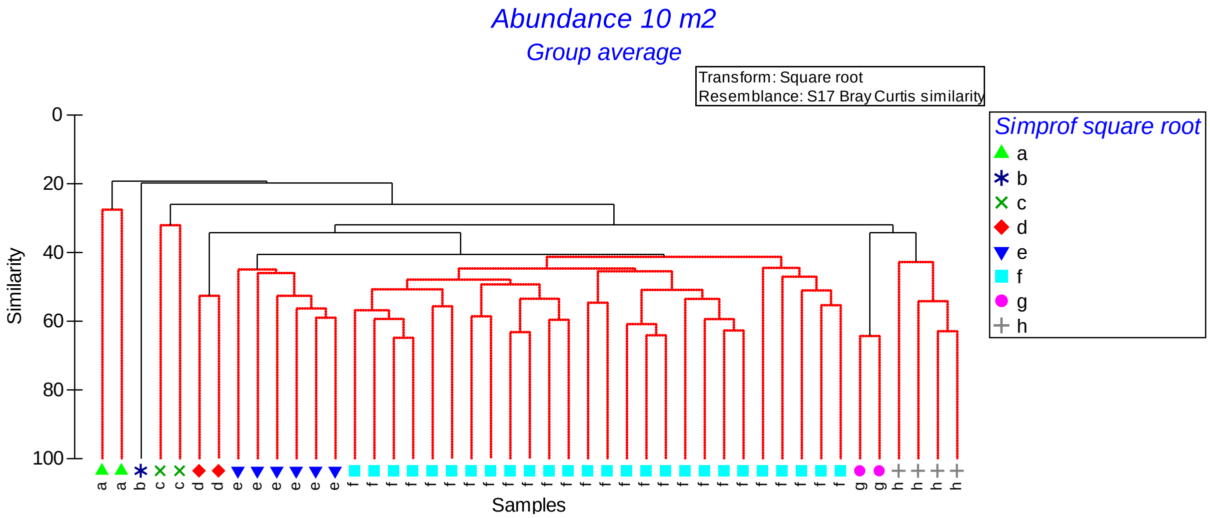

Fig. 18. Cluster analysis with statistically significant site groups identified by the SIMPROF routine

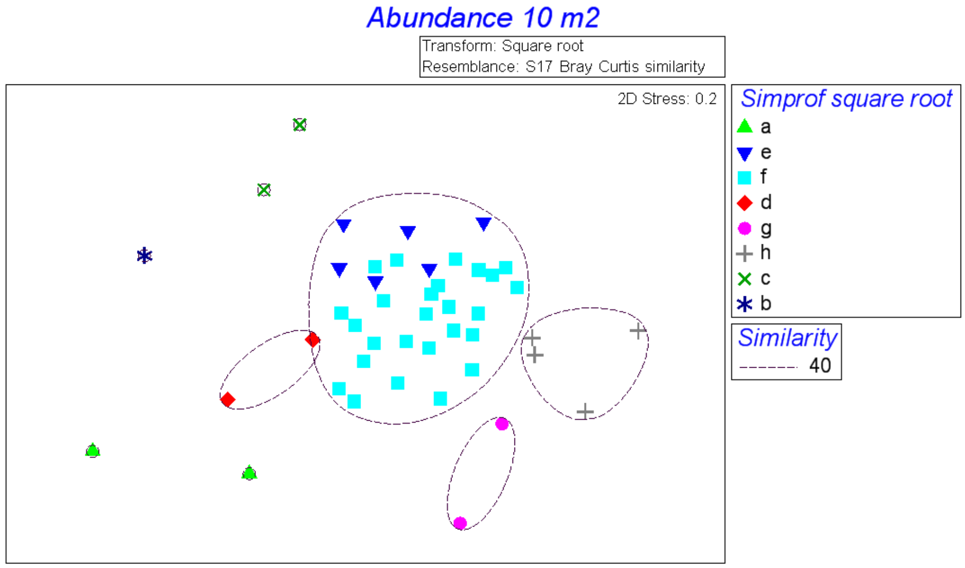

Fig 19 MDS plot of site groups identified by the SIMPROF routine

The largest station grouping was cluster **f** consisting of 26 stations (Fig 19). The community at these sites was mainly dominated by the brittlestar *Ophiura albida* and Hydrozoans (Table 2). Stations of this clusters occurred from the 3 nm limit out to the outer perimeter of the SAC (Fig 20). The second largest grouping was cluster **e** with six stations, which had a relatively high similarity with stations of cluster **f** and was similarly dominated by *Ophiura albida*. Both station grouping **e** and **f** were characterized by the same species with only the percentage contribution of each species varying slightly between the two clusters (Table 2). Cluster **e** was located in between the 6 nm limit and the outer perimeter of the SAC.

Table 2. SiIMPER analysis showing the 5 top ranking species for each of the identified stations groups. Values shown are the % contributions of a species to a particular station grouping. Species with the highest values were highlighted in bold.

Groups	**a**	**c**	**d**	**e**	**f**	**g**	**h**
Overall % similarity	27.5	31.9	52.1	49.1	45.4	64.2	49.8
Alcyonium digitatum			10.16	18.02	8.43		
Asterias rubens		21.09		7.93	4.3		
Bivalvia unid.			17.6				
Burrow small	28.2					3.26	
Cerianthus lloydii						8.3	
Epizoanthus couchii							7.01
Hydrozoa			10.16	10.62	18.56	8.47	**18.39**
Nemertesia antennina			**21.83**	6.02	5.44	5.75	5.06
Ophiothrix fragilis						**55.79**	
Ophiura albida	**43.6**	**78.91**	20.32	**21.52**	**25.35**	7.43	
Ophiura ophiura	28.2						
Porifera							5.18
Scypha ciliata						3.99	4.43
% contribution of the top 5 species	127.5	100	80.07	113.2	107.5	157.2	89.87

Station group **h** consisted of four stations located in the near shore area between the 1.5 nm and 3nm limit. These stations were dominated by Hydrozoa, including *Nemertesia antennina* and encrusting anemones, *Epizoanthus couchii*. Additionally sponges including *Scypha ciliata* characterized this station grouping. Clusters **a**, **c**, **d** and **g** all consisted of only two stations each. Clusters **a** and **c** had very low overall similarities (Fig 20 and Table 2), both being characterized by *Ophiura albida* (Table 2). Stations of cluster **d** were dominated by the hydrozoan *Nemertesia antennina* as well as by an unidentified bivalve species (Table 2). Stations of cluster **g** were characterized by the brittlestar *Ophiotrix fragilis* (Table 2).

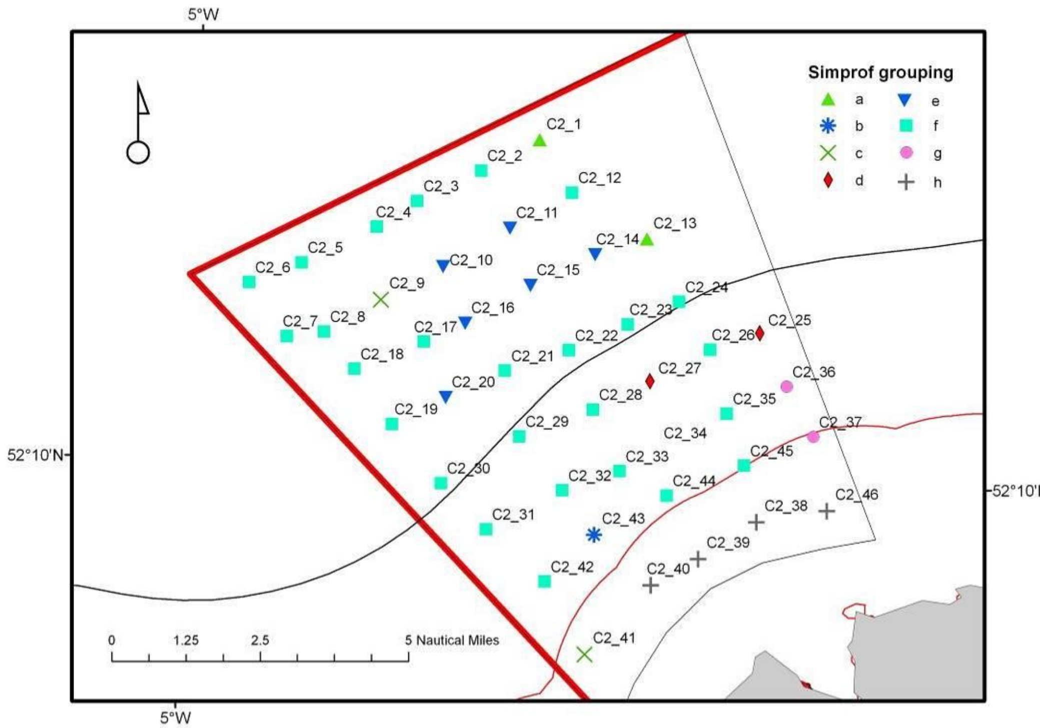

Fig. 20. Spatial distribution of station grouping identified by the SIMPOF routine.

Status of habitats resurveyed within the eastern part of the SAC

Habitat classification from camera tows

The thirteen sites resampled in June 2010 did not show any considerable changes in the percentage cover of the sediment types over time (Fig. 21). Most stations showed roughly the same percentage contribution of sediment types. Nevertheless, at stations 25, 32, 35, 58, and 59 a slight, but consistent change could be detected, with the percentage of sand increasing from December to June. This could be an indication that mobile sands move into these sites, a possible reflection of the dynamic character of the study area discussed here and in the previous report (Hinz et al 2010).

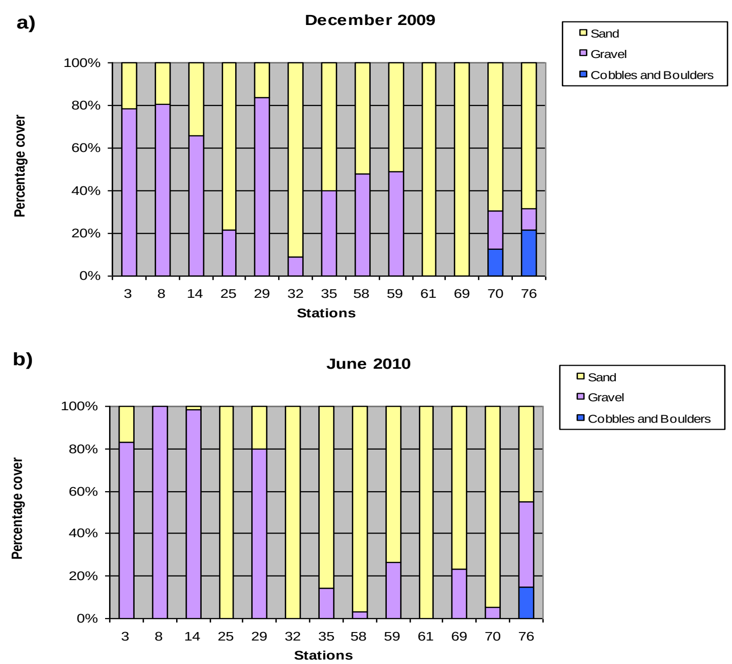

Fig 21 Sediment classes identified at resurveyed sites in December 09 and June 2010.

Comparison of side scan sonar swath from December 2009 and June 2010 data.

Three and a half side scan survey lines (B, D, E and half of F) were resurveyed in the area opened to scallop dredging. Comparison between survey lines recorded in December 2009 and June 2010 is complicated by the fact that the surveys were performed at different resolutions (the 2009 survey used mainly a sonar range of 200m for these lines while the 2010 survey employed a sonar range of 100m). Although survey lines did not coincide entirely between the two surveys, there was sufficient overlap to make some general observations (Fig. 22). Line B seemed to show the most considerable change in bedform. Fig. 23 and 24 indicate that the ribbons of small sand waves observed in December were transformed into larger bedforms by June.

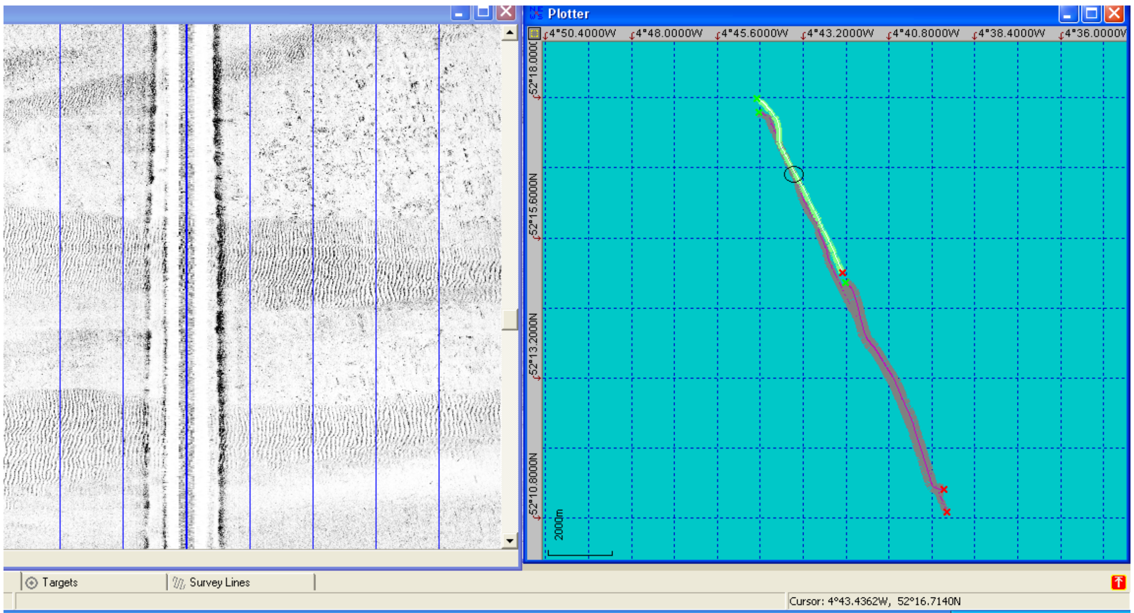

Fig. 22. Location of overlapping survey on line B (blue circle). Side scan image on the left from December 2009.

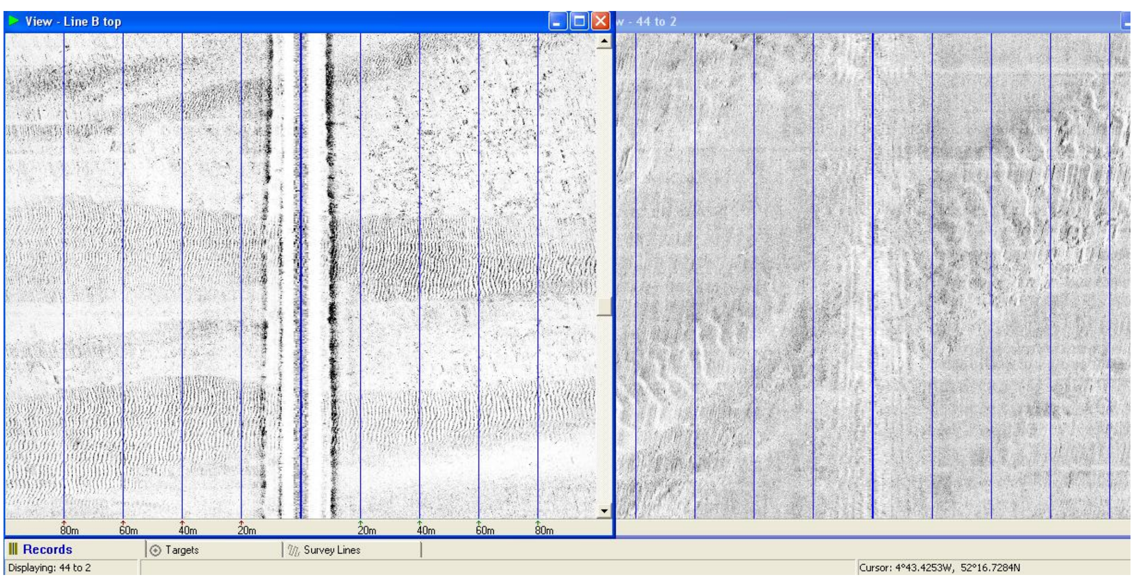

Fig. 23. Line B at latitude 52˚16.73'N. Left image taken from the 2009 survey (100m range) and right image taken from the 2010 survey (also 100m range).

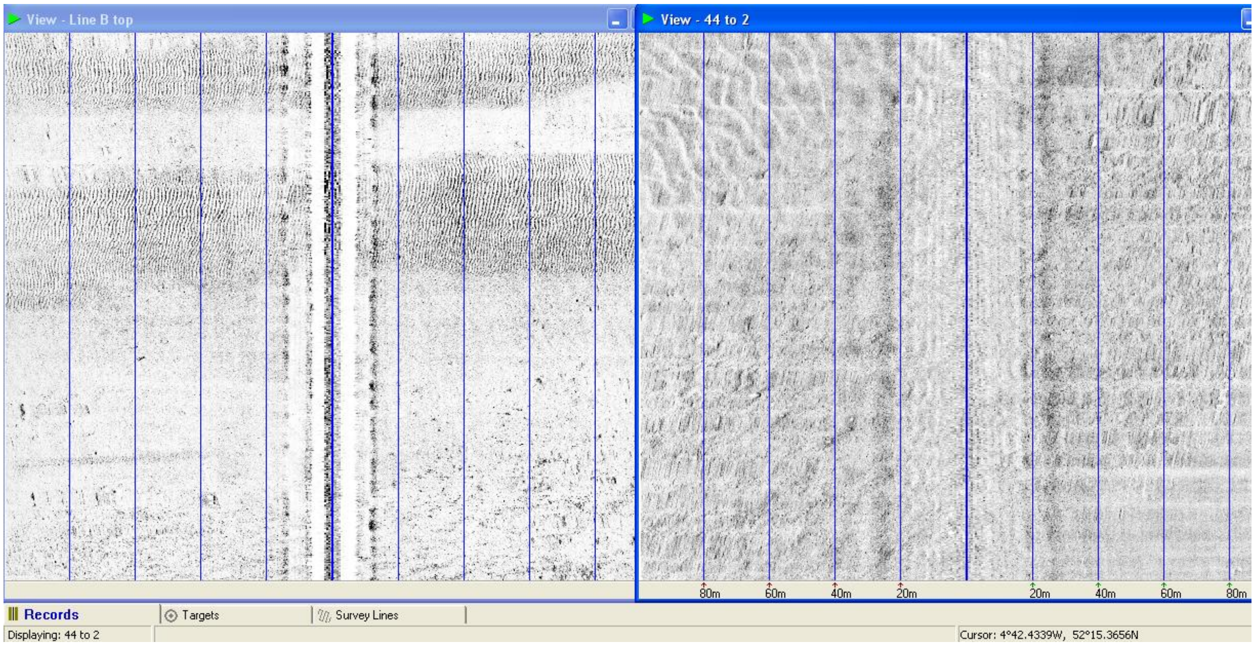

Fig. 24. Line B at latitude 52˚ 15.366'N. Left image taken from the 2009 survey (100m range) and right image taken from the 2010 survey (also 100m range)

The other repeated lines showed less change in the seabed features since the 2009 survey (e.g. Fig 25). There were similar sand ribbon features crossing a coarser gravely substrate with some rougher boulder fields in between. In fact the main change seems to be the presence of large numbers of dredge scars crossing the natural features.

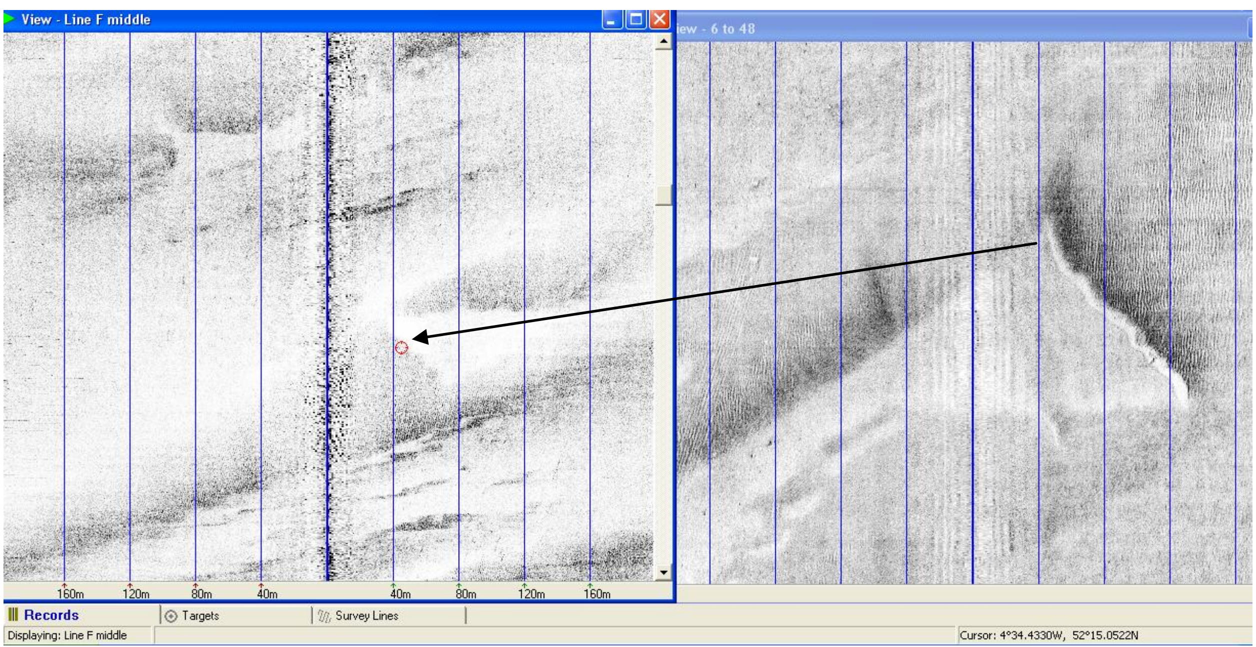

Fig. 25. Line F, latitude 52˚ 15.0508'N. Left image taken from the 2009 survey (200m range) and right image taken from the 2010 survey (100m range). Position of the same sand wave feature indicated by an arrow.

Analysis of dredge marks within areas open and closed to fishing

The side scan data was inspected for scallop dredge marks to ensure that areas closed to dredging functioned as valid control sites to assess changes related to scallop dredging within the open area. Start and end position of scallop dredge marks along side scan sonar swaths were marked within a GIS. Fig. 26 shows the location of dredge marks within areas that were open or closed to scallop dredging. Some dredge marks were less clear and were therefore marked as possible dredge marks. No scallop dredge marks were found within the newly surveyed western area. Most scallop dredge marks as expected occurred within the area that was opened to scallop dredging between March and June 2010 (Fig 26). However, dredge marks were found within the eastern part of the closed area indicating that fishermen did scallop dredge this area despite its closure (Fig 26). Although, only very few scallop dredge marks were found within this area and only three of the six control camera tows conducted were located here, the possibility that this may have biased results of the faunal analysis can not be excluded. Dredge marks within this area of Cardigan Bay are almost certainly short lived and are thought to last only a few weeks due to the dynamic character of the area. Their short life span is evident in the fact that during the December 2009 survey no dredge marks were detected despite the previous heavy scalloping effort.

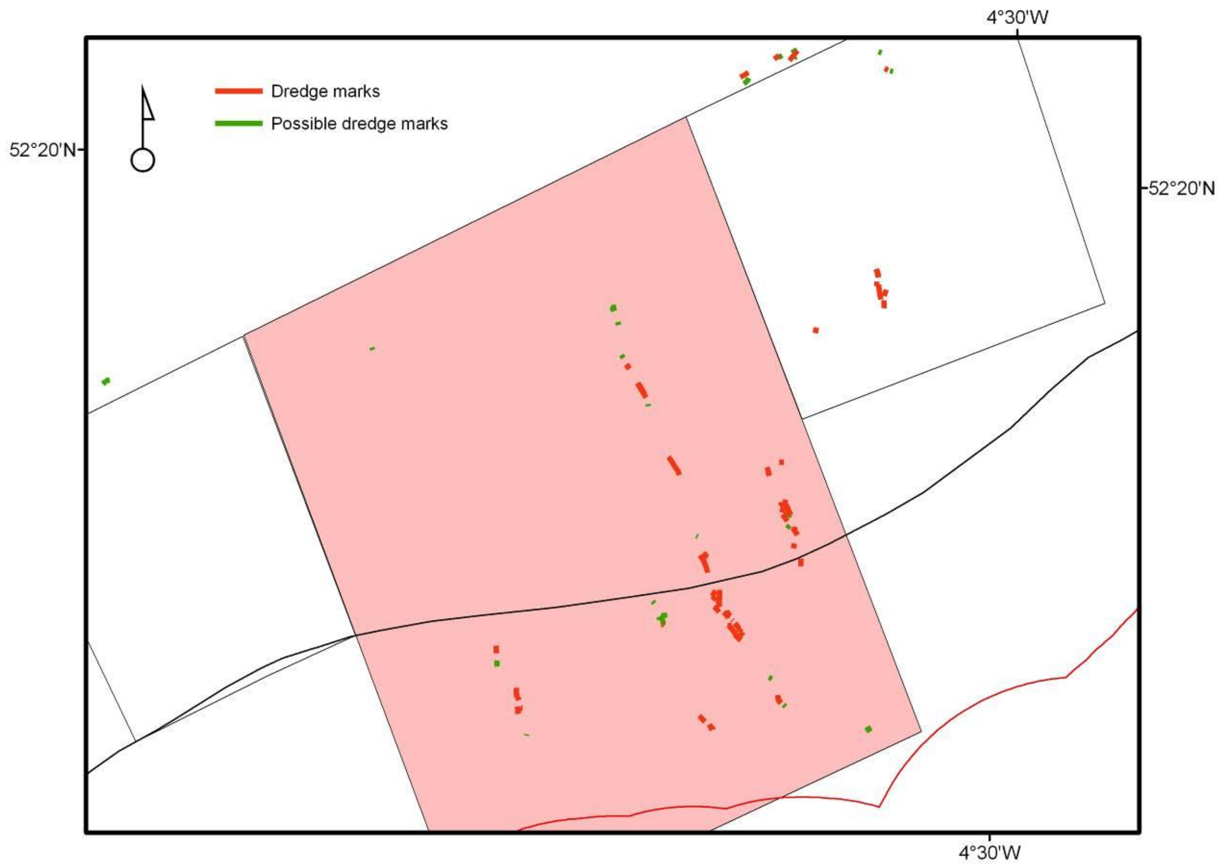

Fig. 26. Location of scallop dredge marks recoded by the side scan sonar. Red area was open to scallop dredging between March to the end of May 2010. Red lines indicate marks identified with certainty while green lines indicate possible dredge marks.

Analysis of benthic community data from the resurveyed sites

Of the thirteen stations resampled in June 2010 seven fell within an area that was subsequently reopened to fishing, while six stations were located in areas closed to fishing (Fig. 3). The benthic community data from the stills camera survey were analysed to ascertain whether there were differences in abundance, species richness and community composition between the 'open' and 'closed' area (Protection) between December 2009 and June 2010. Furthermore seasonal differences were also examined (Season).

The 2-way ANOVA analysis of the abundance data showed that there was a significant effect of Season, but no effect of Protection (Table 3, Fig 27). Thus, there was no difference in the abundance of fauna at sites that were open to fishing compare to sites that were closed. Equally the interaction term was not significant indicating that seasonal differences were consistent at sites open and closed to fishing. (Table 3, Fig 27). Abundances of fauna observed in the camera tows were significantly higher in June 2010 compared to December 2009 (Fig 27).

Table 3. Test for differences in total abundance of benthic organisms per 10 m² testing for the effects season (Decembe and June) and level of protection (open and closed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.696(a)	3	.899	4.272	.016
Intercept	18.038	1	18.038	85.740	.000
Season	2.499	1	2.499	11.878	**.002**
Protection	.163	1	.163	.774	.389
Season * Protection	.004	1	.004	.019	.892
Error	4.628	22	.210		
Total	25.736	26			
Corrected Total	7.324	25			

a R Squared = .368 (Adjusted R Squared = .282)

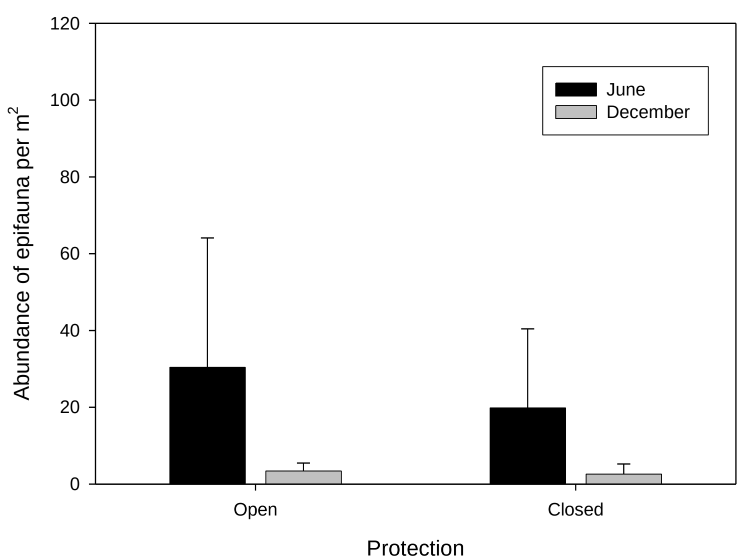

Fig. 27. Abundance of epifauna per m² during the December 2009 and June 2010 survey in the resurveyed areas open and closed to scallop dredging.

Similarly the number of species recorded per tow showed a significant difference between December 2009 and June 2010 (Season; Table 4), while no significant difference could be detected for areas closed or open to scallop dredging (Protection; Table 4). The interaction term of Season and Protection was not significant indicating that the seasonal differences were similar across open and closed sites (Table 4). The number of species recorded was higher in June compared to December across both open and close sites (Fig 28).

Table 4. Test for differences in total number of species of benthic organisms per tow testing for the effects of season (December and June) and level of protection (open and closed).

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.088(a)	3	.363	3.340	.038
Intercept	26.020	1	26.020	239.663	.000
Season	.793	1	.793	7.306	**.013**
Protection	.243	1	.243	2.238	.149
Season * Protection	.025	1	.025	.229	.637
Error	2.388	22	.109		
Total	30.041	26			
Corrected Total	3.476	25			

a R Squared = .313 (Adjusted R Squared = .219)

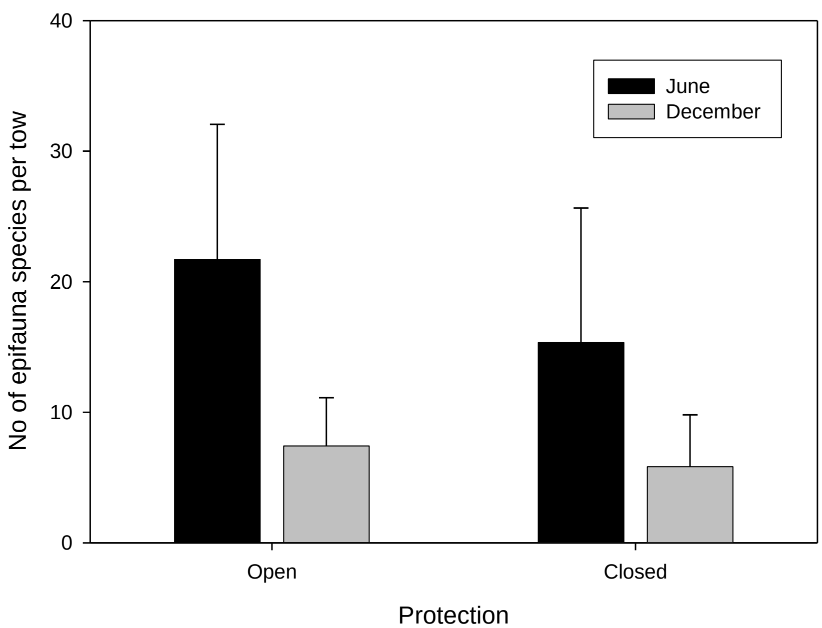

Fig. 28. Number of species per tow during the December 2009 and June 2010 survey in the resurveyed areas open and closed to scallop dredging.

The community structure was analysed by multivariate statistics. The output of the multidimensional scaling plot (Fig. 29), each point represents the community data from a still camera tow, showed that December samples cluster to the right of the plot while the June sample cluster separately to the left of the plot. Accordingly, a PERMANOVA statistical test showed that there was a strong seasonal difference in community structure (Table 5). The MDS also showed that there was no clear pattern in the positioning of stations open or closed to fishing within the plot (Fig. 29). The PERMANOVA results verified this absence of pattern by showing that there was no significant difference in the species composition across protection levels. This means that species compositions of areas open or closed to fishing were indistinguishable. Likewise the interaction term was not significant indicating that seasonal differences were consistent in open and closed areas.

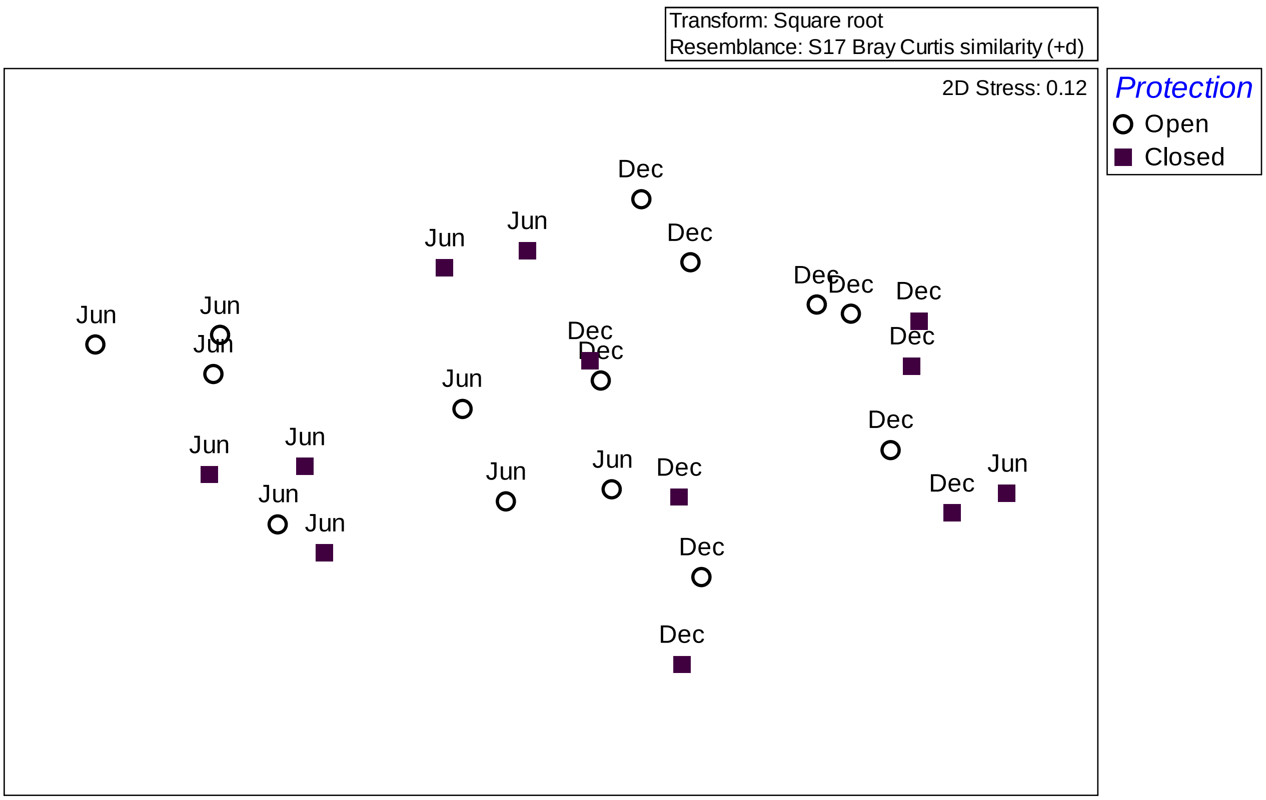

Fig. 29. MDS ordination plot of the same sites sampled in December 2009 and June 2010 from the 'open' and 'closed' areas in Cardigan Bay SAC.

Table 5. The output of the PERMANOVA analysis for the effect of protection from fishing (open vs closed) and the effect of season (December vs June) on the community characteristics.

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Season (December v. June)	1	13176	13176	7.0702	**0.001**	999
Protection (open v. closed)	1	1973.3	1973.3	1.0589	0.370	999
Season x Protection	1	1030.0	1030.0	0.5527	0.841	997
Res	22	40998	1863.6			
Total	25	57421				

An analysis of those species that contributed most to the seasonal differences (SIMPER routine) showed that these were characterized by species that typically senesce in the winter with regrowth in the summer such as Hydroids including Nemertesia (Table 6). Recruitment and growth of juveniles will have occurred in the late spring and summer explaining increases of several species including the brittlestar *Ophiura albida*, soft corals *Alcyonium digitatum* or encrusting anemones such as *Epizoanthus couchii*. This increase occurred irrespective of whether the sites had been protected from fishing or not. Both target species of the fisheries *Pecten maximus* and *Aequipecten opercularis* interestingly showed a reduction in abundance from December to June which could be related to fishing mortality.

Table 6. Average abundance m^2 of those species that contributed most to the seasonal changes observed in the benthic community.

Average dissimilarity = 84.19			
Species	**December 2009** Av.Abund.	**June 2010** Av.Abund.	Contrib%
Hydroid turf	0.18	1.87	9.66
Porifera unid.	0.22	1.57	8.87
Ophiura albida	0.43	1.18	6.86
Pecten maximus	0.67	0.49	5.36
Nemertesia spp.	0.03	0.96	5.31
Alcyonium digitatum	0.22	0.86	5.31
Epizoanthus couchii	0	1.09	4.76
Aequipecten opercularis	0.47	0.22	4.01
Bivalve unid.	0.12	0.48	3.59
Cellaria spp.	0.34	0.32	2.97
Alcyonidium diaphanum	0	0.45	2
Cerianthus lloydii	0.04	0.51	2

Discussion and conclusion

The new survey area located in the western parts of the Cardigan Bay SAC showed a dominance of gravel dominated habitats. Fields of sand waves were still visible but to a lesser extent compared to the area surveyed in the East during the December 2009 survey. Gravel dominated habitats were in the main characterized by the brittlestars *Ophiura albida* (*Ophiotrix fragilis* at some sites) and Hydrozoan species including *Nemertesia* spp. Other species that were also common were small colonies of dead man's fingers *Alcyonium digitatum*, emergent Bryozoan colonies such as *Cellaria* and the star fish *Asterias rubens*. Overall abundances of epifauna were considerably higher in the western area compared to the previous survey area. While this will partly be a reflection of the different substratum type observed in the new area i.e. gravely substrates, compared to the eastern area which was mainly dominated by sand that tends to hold low abundance and a less diverse fauna, it is most likely a result of seasonal new growth and recruitment. This notion was supported by the data from the resurveyed stations from the eastern areas which showed a significant increase in abundance and diversity of epibenthic species between the two sampling events in December 2009 and June 2010.

Besides the gravel dominated stations described above four sites located in the near shore area, between the 1.5 and 3 nm limit, showed percentages of cobble and boulder substrates above 50%, resembling most closely ‘stony reef’ like habitat characteristics. The multivariate analysis of the community structure also underlined the different faunal make up of theses sites as they formed their own station grouping within the analysis. The sites were mainly dominated by high abundances of Hydrozoa and several sponge species including *Scypha ciliata* and the encrusting anemone species *Epizoanthus couchii*. All these species are typical for hard substrates habitats.

Overall thirteen sites were resurveyed to assess the status of faunal communities in the area which was open to scallop dredging between March and the end of May 2010. Seven sites were surveyed within the open area, while six were surveyed within areas that remained closed to fishing. Based on the statistical analysis there was no significant difference in the abundance, species numbers and community composition between the two areas. However, a strong seasonal difference could be detected with higher abundances and species numbers in June 2010 compared to December 2009. Similarly species composition changed significantly between the two sampling events reflecting new growth and recruitment processes which generally occur during spring synchronised with the higher food availability from phytoplankton blooms. This suggests the assertion that the area is subject to natural disturbance levels that outweigh any effects of fishing disturbance was a valid conclusion. This conclusion is however dependent on the assumption that no infringement of the areas that remained closed to fishing occurred. Side-scan sonar data showed the numerous and widespread occurrence of scallop dredge in the open area confirming that the area was intensively fished. However, a small number of dredge marks were also visible within the eastern area that was closed to fishing. Three of the resurveyed stations were located within this area and thus a potential bias of the resulting data has to be acknowledged. Nevertheless, inspection of the results showed that average abundance and species numbers were similar in both areas, in fact values were slightly higher in the open area which evidently received far higher fishing pressure compared to the closed area. This observation thus vindicates the initial conclusion that natural processes outweighed the negative effects associated with scallop dredging within this highly dynamic area.

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