Falmouth Cruise Project EIA - Marine Ecological Survey

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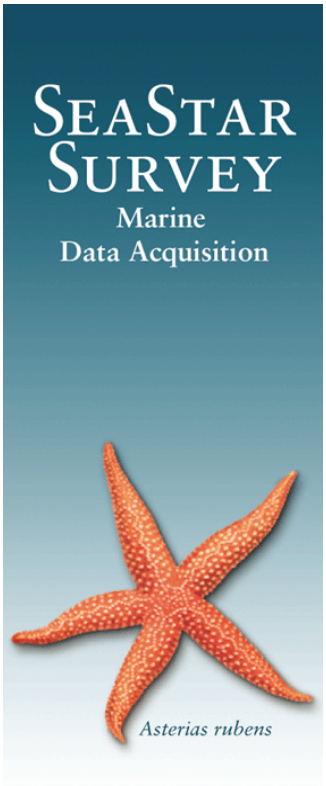

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Falmouth Docks EIA - Marine Ecological Survey

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1. Introduction

During August and September 2007 SeaStar Survey carried out a Marine Ecological Survey in Falmouth Harbour (figure 1 and 1a) for Royal Haskoning on behalf of Falmouth Harbour Commissioners and Falmouth Docks and Engineering Co. Ltd. The survey consisted of diver video transects, in situ habitat observations and diver sediment coring. The purpose of the survey was to inform the EIA associated with the development of the Northern Wharf and Queens Wharf areas of Falmouth Docks and proposed capital dredging. Within the project were three main aims:-

- To assess the environmental impact of the proposed expansion of the docks with particular focus on the effect of major dredging of the channel on the benthic habitat and sensitive species. The site lies within the Fal and Helford Special Area of Conservation (SAC) with one of the primary features of importance being the reef forming calcareous algae (*Phymatolithon calcareum* and *Lithothamnion corallioides*) that form **maerl beds**.

- To assess an area identified as a possible site for the placement of the dredged material. Criteria for this site are:-
1. An area with habitats not deemed to be of conservation value.
2. An area with habitats that could benefit from the introduced material with particular regard to the promotion of new **maerl** bed formation.

- To revisit a number of previously sampled stations in areas historically subjected to commercial dredging in order to inform the EIA on recovery rates of **maerl** communities.

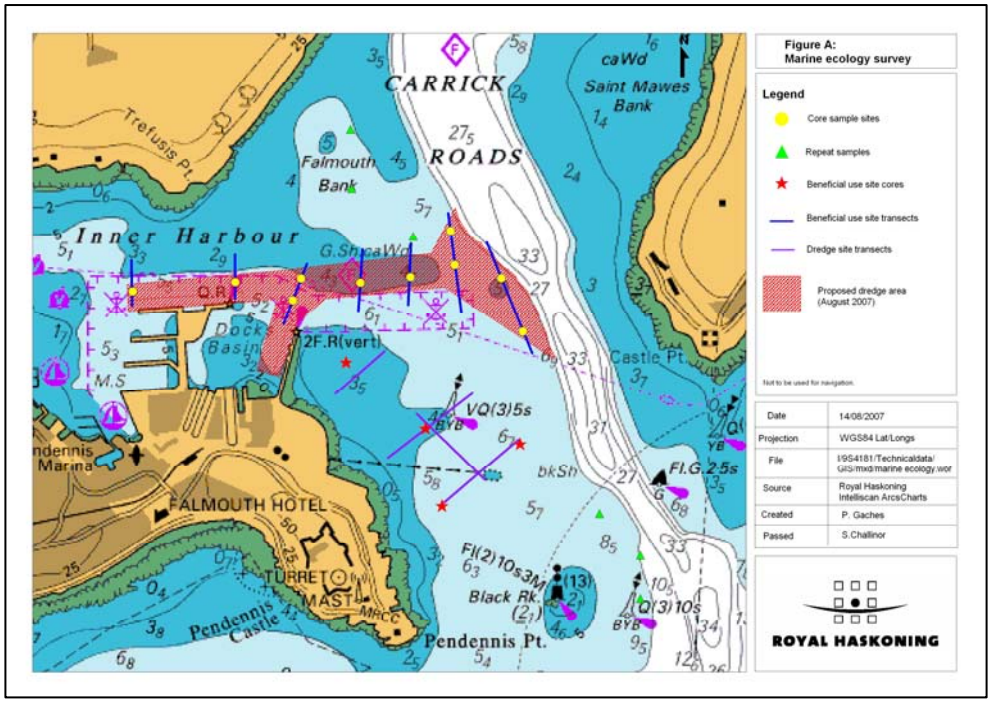


Figure 1: Survey area showing diver transects and sediment core locations

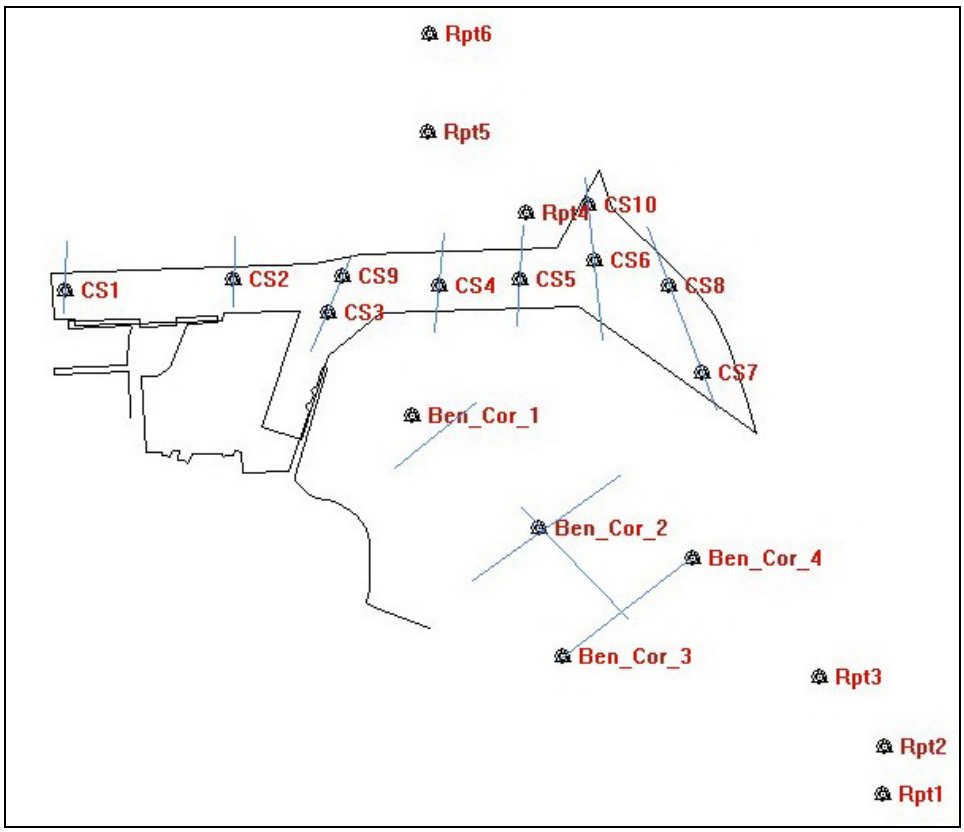


Figure 1a. Diver transects and sediment core locations

2. Maerl

Maerl habitats comprise loose-lying coralline algae (Corallinales, Rhodophyta) that can build-up over millennia to create carbonate-rich gravel deposits that form isolated habitats of high benthic biodiversity (Hall-Spencer 1998, Foster 2001, Grall & Hall-Spencer 2003). Maerl growth requires light for photosynthesis and usually occurs in areas with clear water and strong currents.

The conservation importance of maerl beds is increasingly recognised, not only owing to their longevity and high biodiversity, but also owing to potential benefits for commercial fisheries. Maerl beds can harbour high densities of broodstock bivalves and act as nursery areas for the juvenile stages of commercial species such as cod (*Gadus morhua*), crabs (*Cancer pagurus*) and scallops (*Aequipecten opercularis*), which are attracted to the complex three-dimensional sediment structure (Hall-Spencer *et al*. 2003, Kamenos *et al*. 2004a,b).

The European Union's Habitats Directive provides legislative protection to maerl which is now a key habitat within a number of UK Special Areas of Conservation, and subject to a UK Habitat Action Plan which aims to maintain the extent, variety and quality of maerl beds and associated plant and animal communities (Wilson *et al*. 2004).

3. Survey Design

In order to gain the necessary information to advise the EIA an ecological diver survey was commissioned. This survey comprised three main survey techniques: diver video transects; in situ diver observations; and diver sediment push-cores for infauna and sediment analysis.

The survey design comprised three distinct areas of interest:

1. Proposed Dredge Area
2. Potential Beneficiary Use Area
3. Repeat Sites (Recovery Sites)

The sampling plan for each area is described below.

2.1 Proposed Dredge Survey Area:

- 6 transects measuring 300 – 500 metres along which seabed video was to be taken in conjunction with in situ diver observations.
- 10 Sediment core sites. Each core site consisting of 3 biological replicates and 1 sediment sample for Particle Size Analysis.

2.2 Potential Beneficial Use Area:

- 4 transects measuring 300 – 500 metres along which seabed video was to be taken in conjunction with in situ diver observations.
- 4 Sediment core sites. Each site consisting of 1 biological replicates and 1 sample for Particle Size Analysis.

2.3 Recovery Sites

- 6 Sediment core sites. Each site consisted of 5 biological replicates and 1 sediment sample for Particle Size Analysis (This method repeated the methodology used in 203 and 2004 and therefore the results will be comparable to the previous surveys).

See figure 1 and 1a for diver transects and sediment core locations

4. Survey personnel

All survey activities were carried out from SeaStar Survey's vessel *Mariner* (see attached information sheet in appendix 8) with a 4 metre tender used for diver support.

The survey team consisted of:-

Stephen Duke:	Vessel Skipper
Simon Bradburn:	Dive Supervisor
Sarah Chaddock	HSE Diver - videography and core extraction
Laura Plastow	HSE Diver - in situ observations, videography and core extraction
Emma Collins	HSE Diver: in situ observations, videography and core extraction
Roger Hollies	Vessel mate & Marine biologist: sample processing and diver support

5. Survey Methodology

5.1 Positioning control and Geodetics

The required geodetic parameters for the survey were UTM zone 30 WGS84. The horizontal control for the survey was achieved using a Leica MX412B DGPS logged using HYPACK survey software.

5.2 HSE and Diver safety

All diver operations followed HSC Scientific and Archaeological Diving Projects Diving at Work Regulations 1997.

Owing to the high level of boat activity in the survey area by both recreational and commercial vessels a Notice to Mariners was issued informing all users of the Falmouth Roads area of our operations and close communications were kept with the harbour office, dock master and pilot boats active in the area. Whenever divers were in the water the diver-support vessel was actively diverting ignorant traffic away from the work area.

5.3 Diver video transects and in situ biological survey

Diver survey video acquisition and in situ observation methodologies were based on the following Marine Monitoring Handbook Procedural Guidelines.
No. 3-3. In situ survey of subtidal (epibiota) biotopes and species using diving techniques
No. 3 -14. In situ survey of sublittoral epibiota using hand-held video

Video footage was acquired using a Cannon XM2 video camera in a Ikelite 6042 housing.

Diver video transects were carried out using a ground line on the seabed laid along the transect path. The ground line was made up using negatively buoyant high visibility rope with a 20kg sinker weight and a surface marker buoy at either end. Where possible a 10m or 25m extension was included at the start of the line as a run-in (this prevented the weight from disturbing the survey area seabed and allowed a short period for the divers to become adjusted to the conditions before the start of line) Blue polyprop rope markers were spliced into the line every 5 metres and different coloured plastic balls were attached to the rope every 25 metres to indicate distance travelled along the line. The colour sequence was as follows: yellow, orange, blue, and purple. The direction in which the line was swum varied due to tidal variations and the surrounding environment.

The ground line was laid by positioning the vessel over the start location; the shot line was then deployed along with the surface marker buoy. The shot line length was adjusted to the measured water depth allowing for tidal change. The vessel then ran along the line (guided via the DGPS and survey computer) while paying out the ground line. This ensured accuracy of the ground line regardless of tidal activity. Enough tension was applied to the rope to maintain a true line on the seabed whilst not enough to move the sinker weight. The required length of line was laid before the end of line sinker and buoy were dropped. The vessel then confirmed the correct position of the start and end of line markers.

Three divers then prepared for the operation, roles and equipment allocated to each diver are described below:-

Diver	Role	Equipment
1	Videographer	Underwater video camera, delayed SMB
2	Biologist	Observation slate, pencil, SMB (inflated), buddy line to diver 1.
3	Stand-by	None

10 seconds of clapper board footage was filmed showing transect name, date and project title. The observation slate was labelled with similar information. The diver support boat was launched and flag A (divers in the water) was raised on both vessels. Divers 1 and 2 then entered the water whilst diver 3 stayed on the main survey vessel. Divers descended the shot line to the seabed. The camera was started and divers began swimming the line using the run-in to assess and acclimatise to the conditions. The video was shot at a slightly oblique angle around 50 cm from the seabed keeping the ground line in shot at all times unless something of potential interest to the EIA was observed off line. A constant pace of approx 0.5 knots was maintained along the transect. Diver 2 swam ahead or behind (depending on conditions) noting species present and their extent using the DAFOR scale (as described in Appendix 9), sediment type, evidence of bioturbation (tracks or burrows) and evidence of tidal or current effects (sand waves etc), building up an overall picture of the environment along the transect.

Above water *Mariner* and the tender tracked the operation using Diver 2's SMB (Surface Marker Buoy) and protected the divers by diverting traffic away from the divers' path.

At the end of the line, the video camera was stopped and the shot line ascended by both divers who were recovered to the deck where post-dive checks were carried out and noted by the dive supervisor. The video footage was then immediately viewed on a monitor, logged and checked for quality. Once the footage was deemed to be satisfactory the ground line was recovered.

5.3.1 White balance:

Colour balance trials were carried out in the area of survey and it was decided to use the auto white balance setting in order to account for changes in water depth, cloud cover variation and nearby vessel activity.

5.4 Sediment Core Sampling

Sediment coring methodology was based on the Marine Monitoring Handbook Procedural Guideline Number 3–8. Quantitative sampling of subtidal sediment biotopes and species using diver-operated cores

Coring operations proved challenging due to the dense nature of the sediment. To recover the minimum biological core depth as defined by the work scope (15cm) a club hammer, striking plate (to prevent damage to the core) and a large amount of effort were required.

Core sites were marked using a shot line and marker buoy accurately located by positioning the vessel above the site and dropping the weight to the seabed with the shot line adjusted to water depth. A survey basket was prepared for the site with contents as listed below:-

Item	Number
10cm diameter Biology core tubes (30cm length)	1 per core sample plus 2 spare.
Large core bags	2 per core sample plus 4 spare.
5 cm diameter PSA core tube (10 cm length)	2
Small PSA Bags	4
Mesh sack for bags	1
Hammer	1
Striking plate	1
Biological observations slate	1
Pencil	2
Core extractors (trowels)	3
Set square (labelled with Station ID)	1
Lift bag (deflated)	1
Lift bag pony cylinder	1
Tether line reel	1

a. core survey equipment

b. packed survey basket

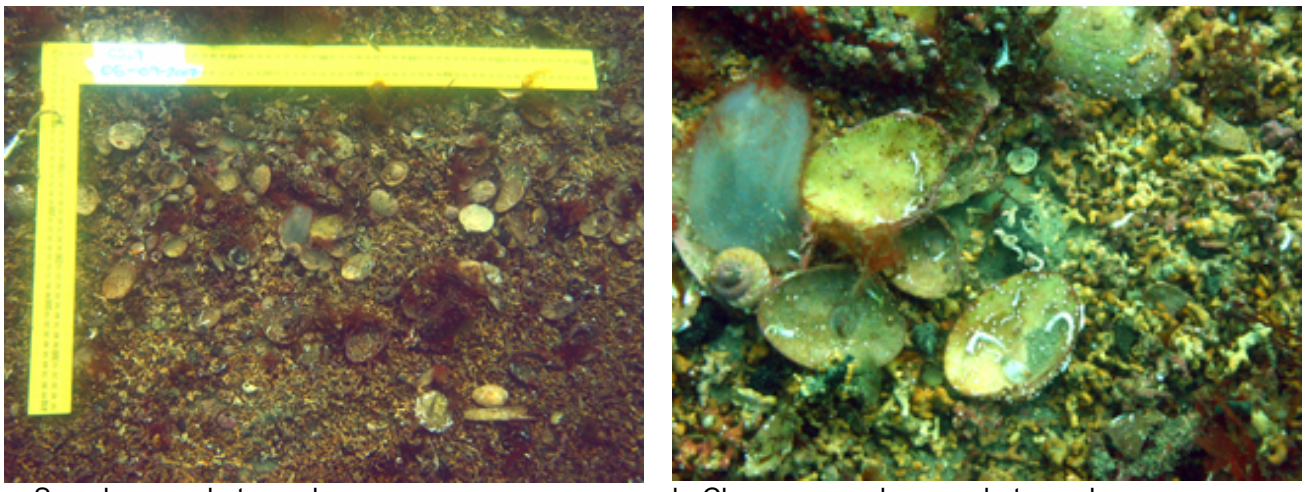
Figure 2. Photographs of survey basket with items loose and stowed (note: mesh bag, biological observation slate and pony bottle not in picture)

All tools were fitted with lanyards and clipped to the basket then made fast with elastic strapping. The basket was then clipped to the shot line with a Karabiner and lowered to the seabed.

Roles and equipment allocated to each diver are described below:-

Diver	Role	Equipment
1	Photographer	Camera, delayed SMB
2	Biologist	Observation slate, pencil, tether to shot line
3	Stand-by	None

The divers descended the shot line to the sea bed where the survey basket was checked. A representative sampling location within a few metres of the shot line was selected and a minimum of two photographs were taken, one at a distance 0.5 m -1 m (depending on conditions) and one in close (<20cm) to provide fine detail of the sediment (figure 3). Biological observations were taken of species present and their extent using the DAFOR scale, sediment type, evidence of bioturbation (tracks or burrows) and evidence of tidal or current effects (sand waves etc) within the immediate area of the shot weight.



a. Sample area photograph b. Close up sample area photograph

Figure 3. Examples of diver sediment photographs

The camera and slate were then stowed in the basket. The coring equipment (hammer, striking plate and trowels) were unclipped from the basket and clipped onto either the divers BCD (Buoyancy Control Device) or the shot line tether (visibility became very poor at times so this was a vital precaution in order to retain all equipment).

The small PSA core was pushed all the way into the seabed. A small bag was placed over the tube and the entire tube dug out and both tube and sediment sealed into the bag. This was then double bagged and stowed in the mesh sack in the survey basket.

Biological core tubes were located in position then inserted into the seabed to the required depth (15-25cm). A large sealable sample bag was placed over the core to retain surface material and the sediment/water interface. The core was then dug out of the sediment using the trowels and sealed in the bag. This was then double bagged and stowed in the basket. This was repeated until the required number of samples was collected.

All sampling equipment was then carefully stowed in the basket. The lift bag was then inflated using the pony cylinder and the basket ascended up the shot line to the surface. The divers then ascended the line to the surface.

During the dive operations the survey and diver support vessel maintained a position a safe distance away from the marker buoy and diverted traffic away from the area. Once the divers were on the surface they were recovered to the deck along with the survey basket. Once the samples were checked the marker buoy and shot were recovered to the deck and the vessel made its way to the next sample location.

Samples were processed on deck by the marine biologist. The PSA sample was carefully drained to remove excess water (unless the water was thick with sediment/mud in which case the entire sample was retained). Then both bags were labelled with the project name, date and station number. The sample was stored in a plastic tub for protection.

The biological samples were emptied from the bags and plastic core tubes into a 500µm sieve. If there was any vertical stratification present in the sample a photograph was taken before processing (figure 4). The sample was then gently sieved. Once completed the samples were photographed twice, one of the entire sample and one of a close up of the sediment. All photographs included a tag labelled with the station number and date (figure 4).

a. Unprocessed sample showing stratification of sediment

b. Processed sample

c. Processed sample close-up

Figure 4. Deck photographs of sieved samples.

The samples were then transferred into labelled 5 litre plastic sample tubs and preserved in 4% Formaldehyde. When handling the preservative, full PPE was worn (protective eyewear, long sleeve gloves etc) The tub was then taped up to prevent any leaks before processing and also to colour code the samples to sample area: Red tape- Recovery sites, Blue tape- Proposed Dredge Area and White tape- Proposed Beneficial Site.

6. Macroinfaunal Community Sample Processing and Analysis

In the laboratory, samples were gently washed across a 0.5 mm sieve to remove excess fines and preservative. The retained material was then hand sorted under the binocular microscope to extract all macrofauna from the sample. Elutriates from the sample residues were examined further under the binocular microscope. The organisms were identified and counted to produce a species list for each sample. Sample residues were checked by a second individual to provide a degree of quality control.

All species retained on the sieve were recorded. All taxa were distinguished to species level and identified to at least family level where possible.

Number of individuals (N) was calculated as an average per sample for each station, in order to relate the CS stations (3 replicates) and RPT stations (5 replicates). Number of species (S) was the total number of species recorded at that station. Community diversity was calculated as species richness (Margalef's "d": $(S-1)/(\log_e N)$), Shannon-Weiner H' (Shannon and Weaver, 1949: $\Sigma pi\ Log_2 pi$), and a measure of evenness (equitability: J') derived from the Shannon-Weiner diversity function, which expresses the degree of dominance between the species. This index of equitability ranges between 0 and 1, with low values indicating high dominance and 1 indicating an even distribution of individuals between species (i.e. low dominance). H' integrates the number of species and individual abundance to provide a summary value reflecting the diversity of fauna at a station. This index of diversity is influenced by both species richness (i.e. the number of species) and equitability.

Multivariate analysis was based on Bray-Curtis similarity analysis (%). Initially, the raw data were analyzed; owing to the influence of the dominant amphipod species, a better interpretation was enabled by using log-transformed data to reduce the over-influence of these taxa. Nearest-neighbour group-averaged cluster analysis from the similarity matrix allowed interpretation of community distinctions between groups of stations. A 2-dimensional interpretation was enabled using non-parametric multidimensional scaling (MDS); the values per station for the first two MDS axes were compared with environmental parameters (see below) using Spearman's Rank-correlation analysis, in order to determine which factors may be responsible for influencing the community trends.

Stepwise correlations were used to distinguish the influences of individual environmental parameters where these were auto-correlated, but in the event gave no further information, and are not discussed further.

Biomass (blotted wet weight, bww) was analyzed as grams of five major taxa: worms, crustaceans, molluscs, echinoderms and "others" (sipunculans, nemerteans, phoronids, hemichordates, cephalochordates, pycnogonids, flatworms, echiurans, chaetognaths), plus total, in each case as an average per sample per station, similar to the treatment of individual numbers per station. Single large individuals, such as venerupid bivalves, which would disproportionately bias the analysis, were excluded from statistical analyses.

Presence of live maerl, dead maerl and red/green algae were quantified from the DAFOR scale as D=5, A=4, F=3, O=2, R=1, absent = 0. Sediment was analyzed as the percentages of four fractions, silt & clay, sand, granule and pebble. As statistical interpretations were based on Spearman Rank-Correlation, no transformation of these data was necessary.

7. Results

Of the 194 taxa recorded from the core samples, 74 species were annelids (71 polychaetes, three oligochaetes), 50 crustaceans (including seven decapods), 48 molluscs and seven echinoderms. Cnidarians, flatworms, chaetognaths, sipunculans, echiurans, nemerteans, pycnogonids, phoronids, cephalochordates and hemichordates made up a further 15 taxa.

The macrofaunal community was relatively consistent across the area. The dominant species were peracarid crustaceans, notably the amphipods *Leptocheirus pectinatus*, *Caprella linearis*, *Gammarella fucicola*, *Parametaphoxus fultoni* and *Socarnes erythrophthalmus*, as well as the isopod *Janira maculosa*, these species forming the top six ranked species by mean abundance per sample, and the first four occurring at every station, the last two being absent from station CS03. The only other species present at all stations was the syllid polychaete *Syllis* sp. A (*sensu* Garwood, unpubl.), while a second syllid, *Exogone verugera*, and the amphipod *Ceradocus semiserratus* was present at all stations other than CS03 and RPT12 respectively. Other dominant species were the brittle-star *Amphipholis squamata*, the gastropod *Cerithiopsis tuberculatus* and the amphipod *Megamphopus cornutus*.

These are mostly species of coarse substrata, exploiting the interstices of gravels, shell-breccia and maerl, although *Gammarella fucicola* is normally associated with algae and *Exogone verugera* is part of the sedimentary infauna.

The dominance of peracarid crustaceans in the fauna is demonstrated by the fact that, of the top 24 ranked species (by average abundance or by frequency of occurrence), 13 are amphipods, two are cumaceans, one is an isopod and one a tanaidacean.

Univariate community parameters are shown in table F1. Number of species per station ranged from 52 to 88, except at station CS03 where only 37 species were recorded. Average numbers of individuals per core was more variable, ranging mainly between 111 and 519, but as low as 41 at station CS03 and 69 at station CS07. Species richness (Margalef's "d") was high at all stations. Evenness ranged from comparatively low values (J'<0.9) across the area owing to high dominance of a few species, to particularly low at stations where the top-ranked amphipods were particularly numerous (dominant), e.g. CS10 and RPT, where J'<0.6). The Shannon-Weiner diversity was relatively consistent across the area, but depressed at stations with high dominance, being influenced by the evenness.

Table F1: Univariate community parameters by sampling station

Station	Species	Individuals	Species richness	Evenness	Shannon-Weiner diversity
CS01	57	206	10.51	0.778	4.539
CS02	73	178	13.89	0.816	5.051
CS03	37	41	9.673	0.886	4.613
CS04	65	308	11.17	0.751	4.523
CS05	71	516	11.21	0.656	4.035
CS06	60	111	12.52	0.829	4.895
CS07	52	69	12.06	0.886	5.050
CS08	83	312	14.28	0.726	4.631
CS09	66	348	11.11	0.673	4.065
CS10	60	519	9.437	0.551	3.255
RPT1	80	182	15.18	0.791	5.002
RPT2	88	370	14.71	0.697	4.501
RPT3	84	499	13.36	0.565	3.608
RPT4	73	169	14.04	0.761	4.711
RPT5	75	185	14.18	0.731	4.552
RPT6	70	184	13.23	0.709	4.347

The dendrogram from the community similarity analysis by sample is shown as figure F1. The majority of replicates cluster closely by station, confirming that they are representative of the sampling station, and that between-station-variation is greater than within-station-variation, and thus that small-scale (within-station) patchiness is not relevant in the analysis of this community.

The dendrogram of similarity by station is shown as figure F2. At 50% similarity, two stations, CS07 and CS03, are isolated, as are two station-pairs, stations CS09 and CS10 (cluster A) and CS01 and CS02 (cluster C); The remaining ten of the stations form a main cluster (B), subdividing at 53% similarity into subclusters B1 and B2, which largely separate CS stations from RPT stations. These associations do not reflect well the proximate spatial relationship of stations other than the southern cluster of RPT stations (1 to 3) and the inner-harbour couplet of the cluster C stations, although the eastern CS stations CS04 to CS08 are associated.

Figure F3 shows the MDS ordination of the stations, with the major clusters from figure F2 indicated, confirming the association of stations within clusters, and the isolation of stations CS03 and CS07. The resolution is good, with a stress of 0.08 for the MDS analysis.

The dominant taxa by cluster are shown in table F2.

The community of cluster B reflects the general amphipod-dominated structure described above. Subcluster B1 is distinguished by the greater densities of some infaunal taxa, notably the polychaete *Exogone verugera*, while the cumaceans *Cumella pygmaea* and *Nannastacus unguiculatus* are surface-sediment dwellers, as is the tubicolous tanaidacean *Typhlotanais brevicornis*. The distinction between these two subclusters is subtle, and regarded as minor variations on the same theme.

***Table F2: Dominant taxa per major cluster of figure F2, based on average numerical abundance, together with the average density of individuals and biomass per cluster*.**

A	B1	B2	C
Caprella linearis	*Leptocheirus pectinatus*		*Cerithiopsis tubercularis*
Leptocheirus pectinatus	*Caprella linearis*		*Mediomastus fragilis*
Janira maculosa	*Exogone verugera*	*Socarnes erythrophthalmus*	*Chaetozone christei*
Gammarella fucicola	*Amphipholis squamata*	*Parametaphoxus fultoni*	*Chaetozone gibber*
Ericthonius sp.	*Socarnes erythrophthalmus*	*Janira maculosa*	*Cirratulus filiformis*
Socarnes erythrophthalmus	*Cumella pygmaea*	*Apseudes latreilli*	*Tubificoides insularis*
Bathyporeia sp.	*Nannastacus unguiculatus*	*Gammarella fucicola*	*Leptocheirus pectinatus*
	Typhlotanais brevicornis	*Megamphopus cornutus*	
Mean no. of individuals			
413	293	328	213
Mean biomass, g			
2.36	0.70	0.78	2.84

Cluster A stations, spatially widely separated, represent a greater variation on the basic community shown by cluster B, largely distinguished by the absence of some species common in cluster B (the cumaceans, the brittle-star *Amphipholis squamata*) and the presence of two amphipods scarcely recorded elsewhere, the algal-associated *Ericthonius* sp. (not identifiable to species as only females were taken) and the sand-associated *Bathyporeia* sp. (none of good-enough condition to identify to species). These stations are again regarded as a minor variation on the basic community of cluster B.

The two stations of cluster C support a number of infaunal species normally associated with high organic loading in the sediment, notably the cirratulid polychaetes *Chaetozone christei*, *C. gibber* and *Cirratulus filiformis*, the capitellid *Mediomastus fragilis*, and the oligochaete *Tubificoides insularis*, although the latter is known to be an associate of maerl-communities. The gastropod *Cerithiopsis tubercularis* is normally associated with sponges, but also feeds on other epiphytic or epizooic detritus. The dominant amphipods were very sparse at these stations, and the brittle star *Amphipholis squamata* absent.

The isolated stations CS03 and CS07 are markedly impoverished (mean numbers of individuals per sample 41 and 69 respectively), and in particular the dominant peracarids of the 'typical' community are very sparse; as can be seen from table F1, the number of species overall is also very low in comparison to all other stations.

7.1 Infaunal biomass

The biomass per station is shown in table F3. The excess weight from larger specimens (e.g. stations CS06, CS07, CS10) was predominantly caused by large bivalve mollusc specimens (*Paphia rhomboids*; *Lutraria lutraria*). The residual total biomass was largely influenced by polychaetes, and varied greatly between stations, from < 1 g at most to > 2 g at stations where molluscs were numerous (e.g. CS01, CS02). Echinoderms had little influence, as most were juvenile, and the dominant brittle-star, *Amphipholis squamata*, is a small species.

Table F3: Biomass (blotted-wet-weight, g) per station by major taxon (without large individuals) and total, averaged per sample.

Station	Annelid Worms	Crustacea	Mollusca	Echinoderms	Others	Total	Total plus large specimens
CS01	0.594	0.036	2.831	0	0.040	3.501	3.501
CS02	0.652	0.104	1.309	0	0.114	2.178	2.178
CS03	0.288	0.027	0	0	0	0.315	0.315
CS04	0.528	0.113	0.247	0.013	0	0.901	2.568
CS05	0.159	0.267	0.212	0.012	0.022	0.673	0.740
CS06	0.146	0.037	0.268	0.007	0	0.457	25.933
CS07	0.353	0.021	0.076	0.004	0.010	0.465	24.418
CS08	0.532	0.198	0.497	0.027	0.001	1.254	2.985
CS09	1.137	0.223	0.559	0.005	0.016	1.940	1.940
CS10	0.295	0.300	2.181	0.014	0	2.789	18.626
RPT1	0.228	0.039	0.421	0.019	0.051	0.758	1.367
RPT2	0.225	0.080	0.538	0.033	0.024	0.900	14.406
RPT3	0.269	0.208	0.163	0.047	0.007	0.695	0.695
RPT4	0.396	0.023	0.203	0.017	0.030	0.669	13.659
RPT5	0.301	0.114	0.192	0.006	0.022	0.635	0.635
RPT6	0.203	0.022	0.235	0.013	0.002	0.475	16.798

At a community level, the mean biomass for stations in community clusters A and C is markedly higher than in cluster B, owing to the greater density of molluscs at these stations; there is also a higher faunal density in cluster A, and a predominance of annelids (individually heavier than peracarids) in cluster C. The biomass of the isolated stations CS03 and CS07 is very low, reflecting their impoverished communities.

7.2 Relation to environmental parameters

Environmental parameters used in the community analysis are shown in table F4. Site depth was relatively consistent across the area, at between 4.8 and 8 m (uncorrected data). Generally, as would be expected from maerl beds, the sediments were gravelly sands to sandy gravels. Highest silt/clay contents (>4%) were found at the stations furthest into the inner harbour (CS01, 02, 03 and 09); CS10 supported a particularly coarse sediment, with a 95% coarse fraction (>2 mm diameter). Other than station CS08, where no maerl or algae were recorded, dead maerl was common at all sites, while live maerl and algae were patchy, both being most abundant at stations CS03 and CS09.

Table F4: Environmental parameters of sediment granulometry, and the presence of live and dead maerl and red/green algae used in statistical analyses (abundance based on the DAFOR scale as D=5, A=4, F=3, O=2, R=1 and absent = 0).

Station	Silt & Clay %	Sand %	Granule %	Pebble %	Depth	Live maerl	Dead maerl	Algae
CS01	4.8	28.51	36.89	29.81	5.5	2	4	0
CS02	6.92	44.09	27.58	21.4	6.3	0	3	0
CS03	4.04	56.55	30.31	9.12	5.5	4	3	3
CS04	1.92	25.34	38.35	34.4	4.8	1	5	2
CS05	1.76	16.03	40.98	41.22	4.8	1	5	0
CS06	1.62	33.94	34.22	30.21	6	1	5	2
CS07	3.58	56.77	25.43	14.23	6.5	2	4	3
CS08	2.71	65.65	20.46	11.18	8	0	0	0
CS09	5.2	31.63	33.24	29.92	5	4	5	3
CS10	1.26	3.8	26.25	68.68	7.2	2	4	1
RPT1	2.25	36.68	37.48	23.59	7.5	1	4	1
RPT2	2.69	30.24	51.53	15.54	8	1	4	3
RPT3	2.94	12.44	52.74	31.88	7.7	1	5	2
RPT4	1.29	28.2	27.84	42.67	6	1	4	2
RPT5	2.52	41.27	30.52	25.69	5.4	2	4	2
RPT6	1.68	41.9	37.83	18.59	5.2	1	5	3

The MDS station coordinates from the community analysis were compared with these environmental parameters by Spearman rank-correlation. MDS1 is the horizontal axis in figure F3, MDS2 the vertical axis. The significant results ($p<0.05$) are shown in table F5.

Table F5: significant correlations (Spearman's rho; p<0.05) between station coordinates on MDS axes 1 and 2 and environmental parameters.

	MDS1		MDS2	
	rho	p	rho	p
% silt/clay	-0.635	0.008		
Number of species	0.645	0.007		
Number of individuals			-0.735	<0.001
Species richness	0.588	0.017		
Evenness			0.585	0.017
biomass of worms	-0.606	0.013	-0.456	0.076
biomass of echinoderms	0.799	<0.001		
biomass of crustaceans			-0.765	<0.001
biomass of molluscs			-0.788	<0.001
Total biomass			-0.912	<0.001
Algal presence			0.558	0.025

The correlation with silt/clay% relates to the highest proportion of this fraction occurring in the stations towards the inner harbour (CS01, 02, 03 and 09), including stations of cluster C, with their organically-associated infaunal-annelid community, and the impoverished station CS03.

Correlations with numbers of species and of individuals are biased by, in the former case the very low diversity at station CS03, and in the latter case the low faunal densities at the

impoverished isolated stations CS03 and CS07, and the high faunal densities at stations of cluster A. The species richness follows number of species, while evenness trends are not considered realistic, being an artefact of the high level in CS03 owing to the sparsity of fauna and lack of dominance.

Correlations with biomass reflect the highest levels of worm biomass occurring in cluster C stations (low on axis MDS1), of echinoderm biomass at stations of cluster B1 (high on MDS1), and of crustaceans and molluscs, and thus of total biomass, in stations of clusters C and A, low on axis MDS2. These data repeat the findings of the annelid dominance in cluster C, and the comparative restriction to peracarid crustaceans in cluster A stations.

The correlation with algal presence is caused by the absence of algae from cluster C stations, and its low presence in stations CS05, CS08 and CS10, all low on axis MDS2. These stations support the highest densities of the top-dominant amphipods and *Gammarella fucicola*, and the weed presence does appear to be having a secondary influence on the community structure.

7.3 Analysis of epifauna and flora from diver transect surveys

In order to aid interpretation of the above data, the information from the diver surveys of the core sites, of the proposed dredged zone (CS01 to 10), the repeat survey zone (RPT1-6) and the beneficial use zone (BEN1-4), was analyzed using the "DAFOR" scale information converted as described above for the analysis of maerl. Clustering from the Bray-Curtis similarity index gave the dendrogram shown in figure F4.

There is clear separation of the two muddier inner harbour sites CS01 and CS02; subsequently, three of the BEN sites are isolated as a cluster, while the remaining stations cluster together, indicating little community variation between the RPT and CS core sites (other than CS01 and CS02). MDS ordination of these data (figure F5) does show some grouping by zone three zones. The dominant taxa for the three zones are shown in table F6. Using SIMPER analysis from the Primer package (Warwick & Clarke, 1991), the distinctions between these zones were confirmed.

Table F6: taxa comprising 70% of the diver-reported community at core sites in the three zones; taxa above the heavy line are those averaging at least "Frequent" in the "DAFOR" scale.

Proposed Dredge sites	Recovery sites	Beneficial Use sites
Pomatoceros lamarcki	*Pomatoschistus minutus*	*Phymatolithon purpureum*
Pomatoschistus minutus	Red/Green Algae	Red/Green Algae
Phymatolithon purpureum	*Phymatolithon purpureum*	*Membranipora membranacea*
Phymatolithon calcareum	*Phymatolithon calcareum*	*Laminaria saccharina*
Ascidiella aspersa	*Pomatoceros lamarcki*	*Pomatoschistus minutus*
		Phymatolithon calcareum

The proposed dredging zone and the recovery sites had a similar community, as was discovered for the infauna, although the former had slightly more dense populations of some larger sessile invertebrates, while macroalgal cover was more conspicuous at the recovery sites. In terms of these large errant species, macroalgae and epifaunal taxa, the recovery sites were more sparsely covered: the average number of taxa per transect was 8.2, compared with 8.6 in the dredging zone. However, the distinction between these two is not considered significant.

The beneficial use transects had a well-developed and mature epibiota, particularly dominated by red/green and larger algae (*Laminaria saccharina*, *Saccorhiza polyschides*) but also associated epizooites (the hydroid *Obelia geniculata*, the bryozoan *Membranipora membranacea*) , as well as a similar density of live maerl. The average number of taxa present per beneficial-use-transect was 9.3.

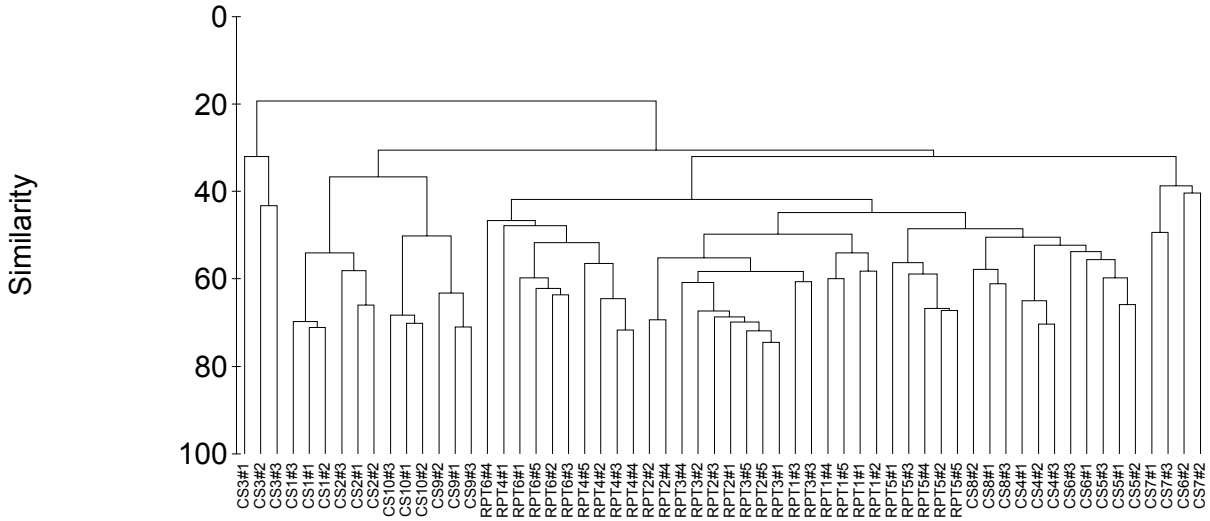


Figure F1. Dendrogram based on Bray-Curtis similarity (%; log-transformed data) for all sample replicates

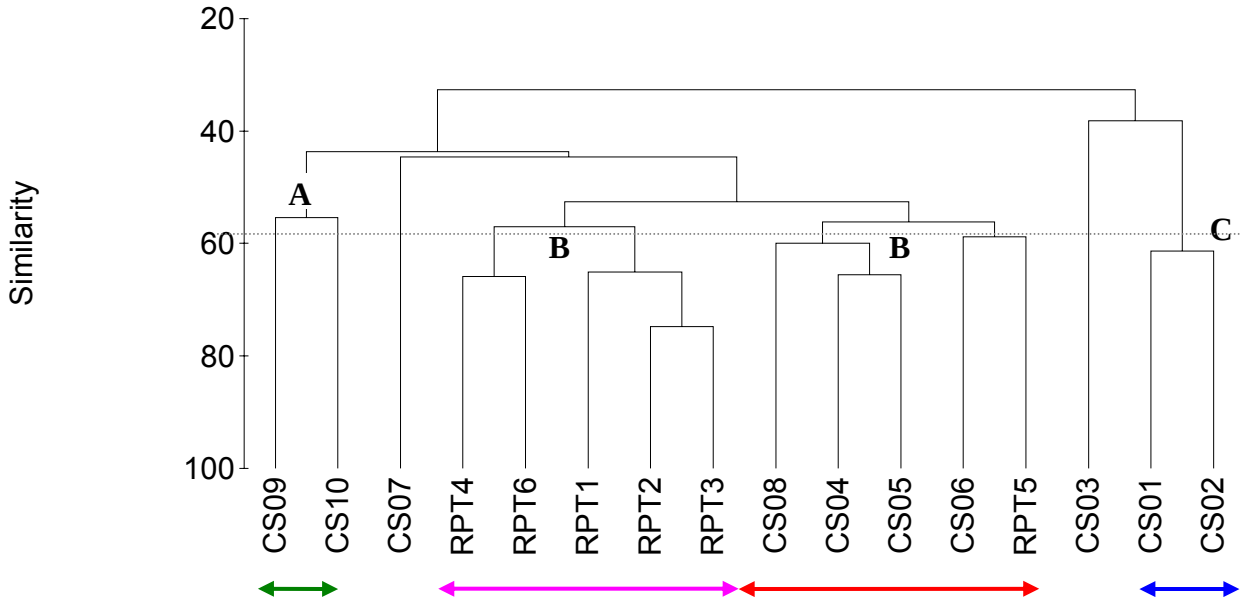


Figure F2. Dendrogram based on Bray-Curtis similarity (%; log-transformed data) for all stations, with clusters distinguished at 50% similarity indicated.

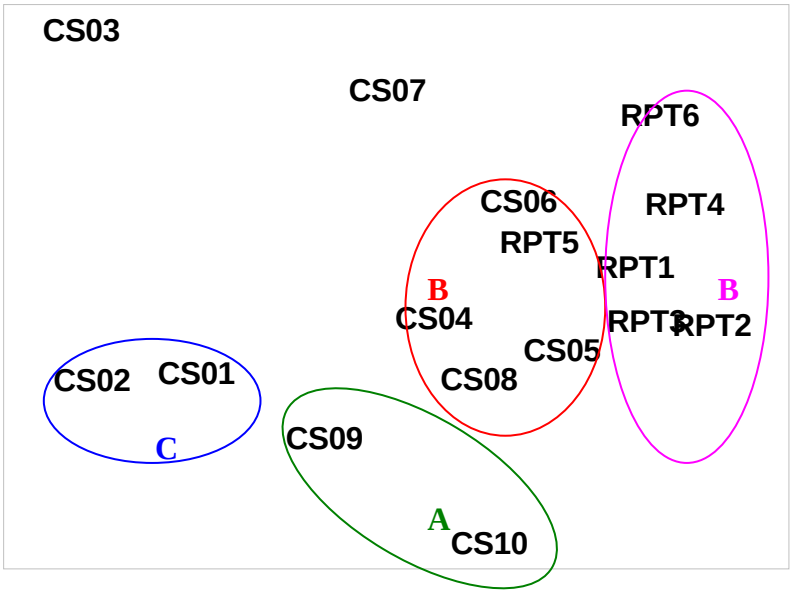


Figure F3. MDS ordination for all stations (log-transformed data), with major clusters distinguished in figure F2 indicated.

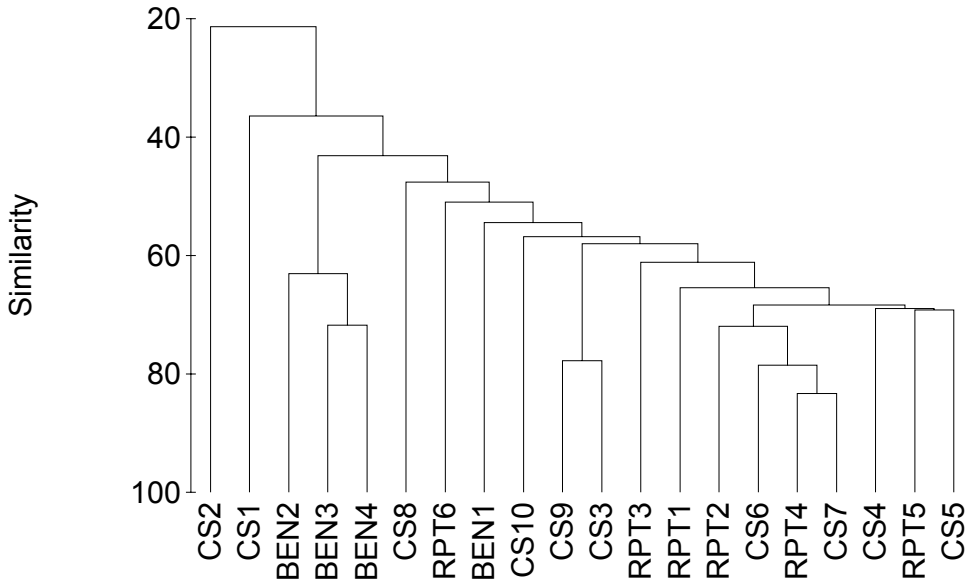


Figure F4. Dendrogram from the Bray-Curtis similarity analysis (%) for all diver-survey core sites, based on converted DAFOR data.

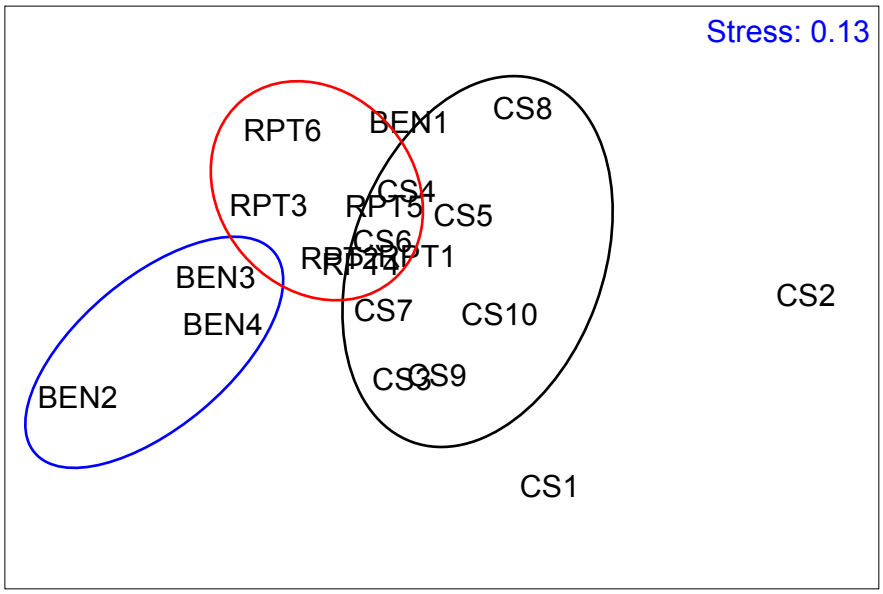
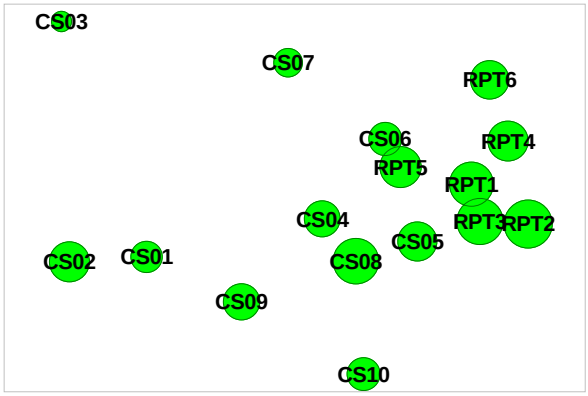
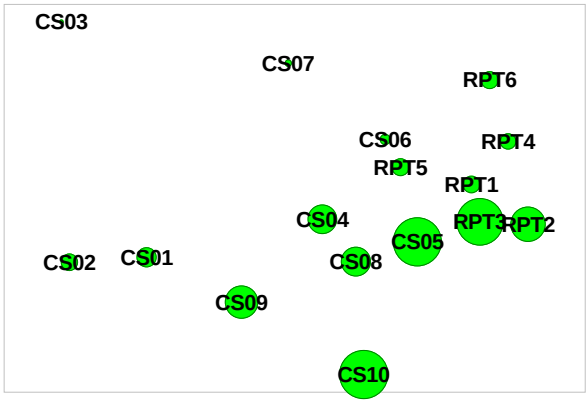


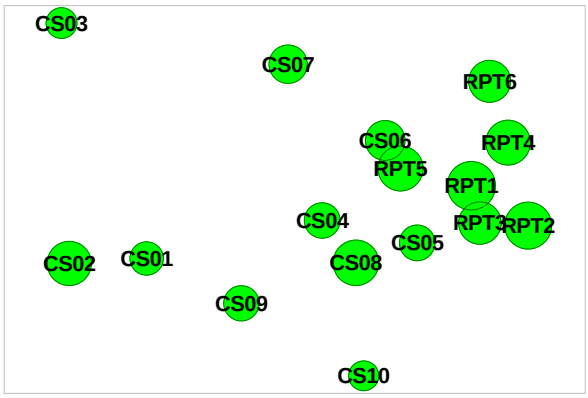
Figure F5. MDS ordination for all diver-survey core sites, based on converted DAFOR data, with the three survey zones distinguished.



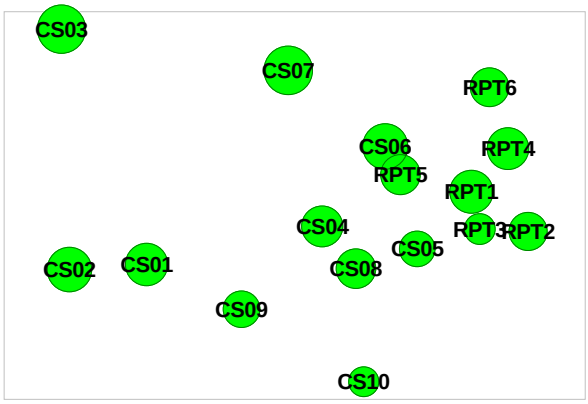
Species



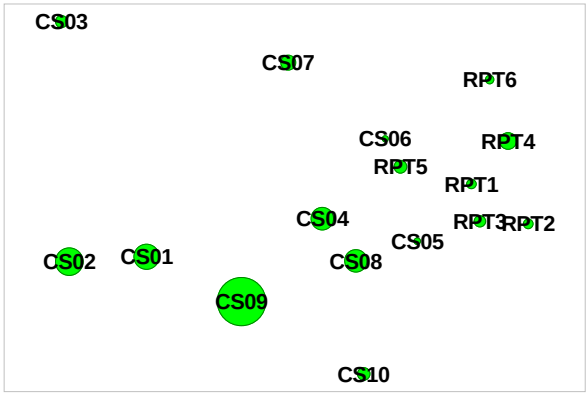
Individuals



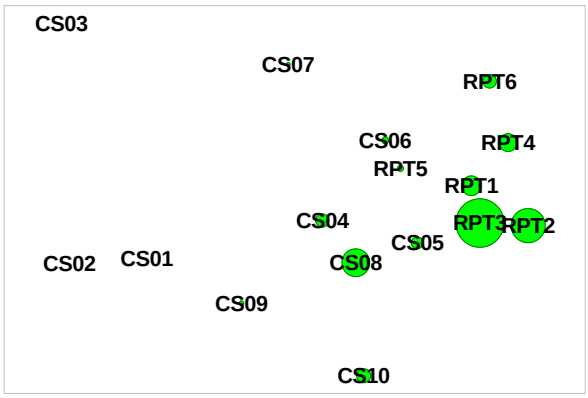
Species richness



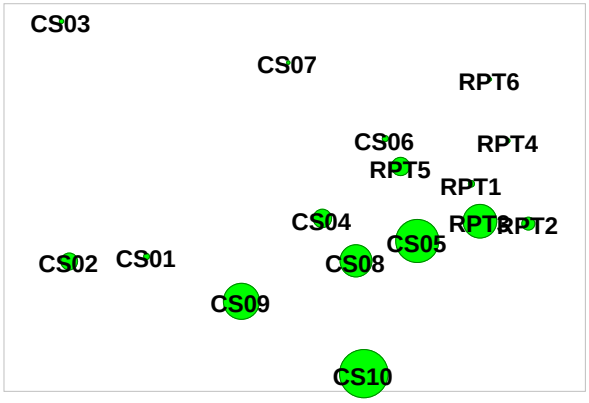
Evenness



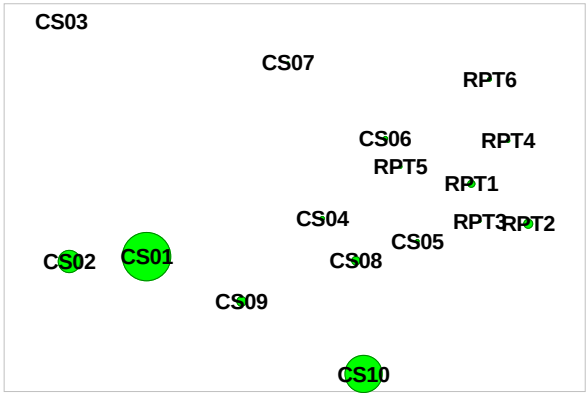
Worm biomass



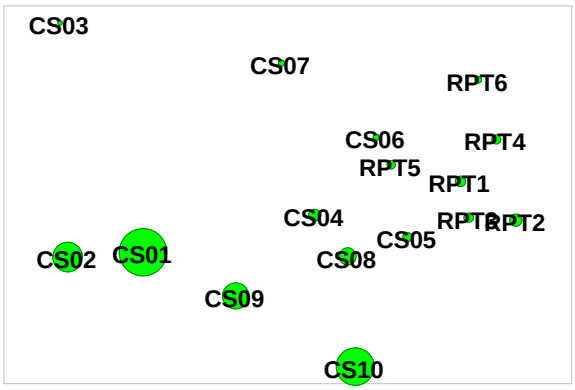
Echinoderms biomass



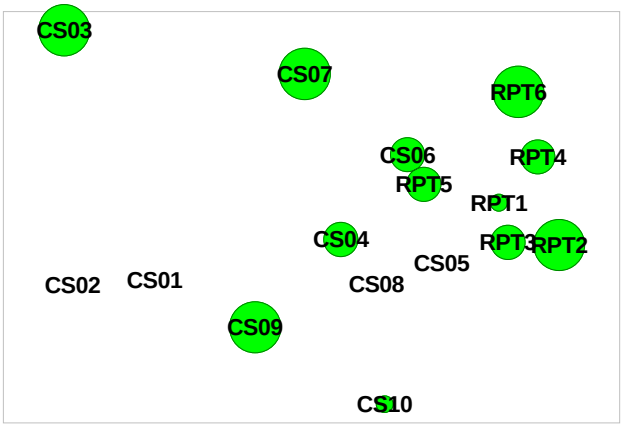
Crustacean biomass



Mollusc biomass



Total biomass



Algal presence

8. Discussion

The infaunal community of this area is comparatively diverse, with high species richness, and, except towards the inner harbour, dominated by peracarid crustaceans, as is typical of maerl-associated communities (e.g. Hall-Spencer & Bamber, 2007).

No scheduled or otherwise conservation-significant species were recorded, other than the maerl itself. One notable species, previously rarely recorded, but present across the area at cluster B stations, was the tanaidacean *Leptognathia paramanca*. This species was known previously only from six specimens off Brittany (the types) and sparse numbers in the Irish Sea (Lang, 1958; Bruce *et al.*, 1963; Bamber, in press), and is being considered for statutory conservation-protection. A number of the other species are distinctly Lusitanian in distribution (*Guernea coalita*, *Apseudes latreilli*, *Anthura gracilis* and *Arcopagia crassa*) and some are particularly associated with maerl habitats (*Microjaera anisopoda*, *Tubificoides insularis*).

The community gives some clear indications of differences between parts of the survey area. The stations of the inner harbour (CS01, CS02, cluster C) have a community reflecting a greater fine fraction to the sediment, and potentially higher organic loading, with an atypical dominance of infaunal annelids, until at station CS03 the fauna is severely

impoverished and uncharacterized in comparison with the surrounding stations. These are the stations nearest to the Falmouth marinas and Dock Basin. The diver survey of Dredged Site Transect 1 confirmed the substratum to be predominantly of mud, and that of transect 2 as sand. Paradoxically, station CS03, and the adjacent CS09, also supported high densities of live maerl; heterogeneity of habitat along transect 3, which includes these two sampling stations, was observed by the diving survey.

Stations CS09 and CS10, both with good live-maerl cover, supported a denser community of peracarid crustaceans of lower species richness, with lower presence of infaunal species, in the case of CS10 likely to be related to the coarseness of the sediment. There is no common environmental cause between these two stations. CS10, as well as CS06, lies on diver transect 6, where coarse gravels were observed along with coarse sand as mounds and in depressions.

Station CS07, close to the deeper channel of Carrick Roads, has an impoverished community, and despite the good presence of maerl, has a smaller coarse fraction. There is no other apparent environmental cause for this impoverishment.

The remaining stations support a relatively consistent and diverse community, dominated by species which are consistent with a habitat of gravel, shell breccia and maerl. There is some isolation of the RPT stations from the CS stations, the former having a greater proportion of sediment-associated species (despite the granulometry data not showing any significant distinction).

9. Conclusions

The proposed dredge area includes the two most impoverished stations, inshore muddier stations, and a range of stations supporting a species-rich maerl-associated community, entirely comparable to that of many of the repeat-survey stations both alongside and further seaward (the cluster B infaunal community). However, the epibiota recorded during the dive-survey was far more dense and diverse in this zone than at the recovery-site-zone.

The community structure at the inner, softer sediment, stations is attributed to the influence of reduced hydrodynamics as well as potential impacts from the adjacent marinas and docks, and would be likely to revert to a similar status after dredging, rather than recover to a species-rich cluster-B-type infaunal community. Relatively high water flow is considered essential to good maerl growth and survival, as well as maintaining cleaner interstices for the associated fauna (in particular, the dominant and diverse peracarids).

The evidence from the repeat stations is that recovery has been successful to the point that distinctions in the infaunal community are minor and insignificant. A similar response may therefore be expected at the outer proposed-dredged-area stations on dredge-transects 4 to 7. However, the longer-lived taxa of the epibiota are clearly taking longer to recover, and, as a result, so are their associated epizooite species.

While there was insufficient core-data to analyze the infauna, it is evident that the epibiota at the beneficial-use-zone was densest and most mature of the three zones, and also that live maerl was as abundant in this zone. It is therefore likely that the infauna would also be more stable and diverse, and of a similar community to the cluster B community described above.

To relate to the three aims of the survey:

1. Dredging of the CS zone area would result in the removal of the present community. While the infaunal community would be expected to recover in time along the lines of that at the RPT stations, the larger epifauna and algae will take longer to recover, as will the epifauna and epiflora associated with these taxa. The area nearest the marinas and docks is unlikely ever to revert to a species-rich maerl-associated community.
2. The BEN zone, proposed as a site for the placement of dredged material for the purpose of enhancing the habitat to promote new maerl bed formation, already supports a mature and species-rich community, and is not considered an appropriate area for this activity.
3. The recovery of the community at the RPT zone has progressed satisfactorily with regard to the infaunal and epibiotic community, which are both similar to those found within the outer part of the proposed dredge zone. Given more time, it is anticipated that the community here would approach that of the more mature community at the beneficial-use-zone.

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- No. 3 – 8 Quantitative sampling of sub tidal sediment biotopes and species using diver-operated cores
- No. 3-3 In *situ* survey of subtidal (epibiota) biotopes and species using diving techniques
- No. 3 -14 In *situ* survey of sublittoral epibiota using hand-held video

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