Report for Blue Marine Foundation

Developing ecological long-term monitoring of the Berwickshire Marine Reserve and surrounding area

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Prepared by the University of Plymouth

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Executive summary

The Berwickshire coastline is known as a biodiversity hotspot attracting both commercial and recreational marine activities. The waters off Berwickshire are some of the most productive in the UK where cold and warm water currents converge in a habitat of rocky reefs, kelp forests and soft corals. The Berwickshire Marine Reserve (BMR), set up in 1984, is a registered charity and is Scotland's only voluntary marine reserve. Its' main aim is to make sure the waters inside the reserve are protected and remain so for years to come (adhttps://www.berwickshiremarinereserve.org.uk). This voluntary marine reserve sits inside an area introduced to resolve gear conflict between local static gear and mobile gear fishers, referred to as the 'Static Gear Reserve', inside of which the use of mobile or active gear is prohibited year round (Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 2004). The voluntary marine reserve is also located inside a wider Scotland/England Special Area of Conservation (SAC), the Berwickshire and Northumberland SAC. Both statutory designations contribute to the Scotland Marine Protected Area (MPA) network. Currently, not much is known about the ecological status of the sensitive benthic environment and associated animals that exist along this stretch of coast. Blue Marine Foundation (BLUE) formed a partnership with the BMR in 2018. BLUE has experience in implementing bottom-up approaches to management (developed in Lyme Bay), working with the local fishing communities, regulators, scientists, and conservationists to create a regional management plan for each area it works in. A key part in supporting BLUE's conservation strategy was to develop robust, research programmes to help better understand the marine environments of the BMR and its surrounds. A necessary first step was to gather a baseline against which ecological changes can be monitored over time, underpinning a long-term project aimed at protecting and improving key marine habitats and species and to promote sustainable exploitation by working with local stakeholders and the local community. In 2021 the University of Plymouth undertook a comprehensive research programme to establish an ecological baseline within of each of the statutory designations (Treatments) in Berwickshire. These treatments were in the Static Gear Reserve (SGR), the Special Area of Conservation (SAC) and in open controls (OC) which were areas located outside of the SAC. Within each treatment towed underwater video surveys to quantify sessile and sedentary benthic species combined with baited remote underwater video surveys that quantified benthic associated

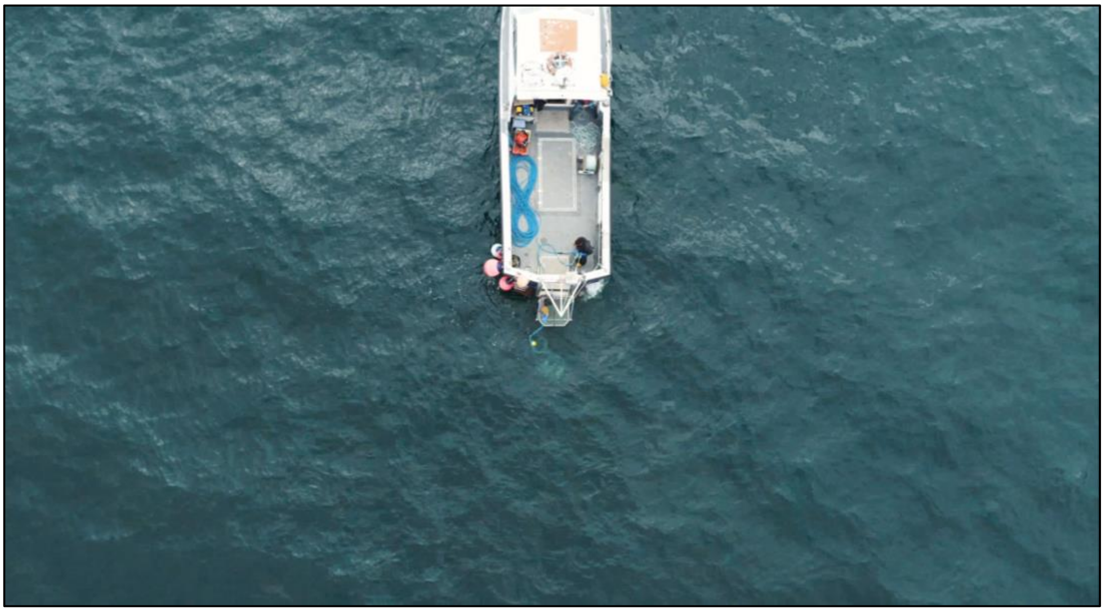
mobile nekton species were carried out in May 2021, on board a local diver vessel. Results from these surveys are presented in this report. Results show that the overall abundance of animals, the species richness and the assemblage composition were significantly similar in each treatment. Abundances of some individual species were, however, significantly greater inside the Static Gear Reserve, including Dead Mans' Fingers (*Alcyonium digitatum*); Edible sea urchins (*Echinus esculentus*); and common starfish (*Asteria rubens*). There were no differences observed for the reef associated mobile nekton assemblages between treatments for response variables abundance and species richness. Abundances remained low throughout the entire survey for reef associated mobile species. There was a significant difference in assemblage composition between the SGR and OC driven by high abundances of Dab (*Limanda limanda*) in the OC.

In 2014, the Scottish government identified and adopted 81 Priority Marine Features (from hereon in referred to as PMFs) (Natural Heritage, 2016). These features cover a variety of habitats that are considered a priority for conservation in Scotland's seas. Within the Berwickshire survey site, the SAC protects rocky reefs, sea caves and grey seals which fall under European Habitats Directive. Presence of PMFs, their extent and ecological status within this survey were examined through the underwater video surveys but no PMFs were seen.

In summary the treatments did not differ to each other significantly in either overall abundance or species richness for sessile and sedentary (towed) and mobile (baited) species. Individual species (*Alcyonium digitatum*; *Echinus esculentus*; *Asteria rubens*) were significantly higher in the SGR when looked at separately and high abundances of Dab drove differences in assemblage composition between the OC and SGR treatments. We suggest that to build on this baseline, repeat annual monitoring is required. With time series data further analysis with a focus on the ecosystem functioning roles that species (and groups of species) play in Berwickshire would be of value. Continued monitoring of the recovery of site with lower biodiversity is also important moving forward.

We suggest increasing the coverage of the survey by identifying and surveying an additional number of comparable sites within the OC treatment, in particular, while keeping the survey design balanced. More sites were surveyed in May 2021 (56) than are included in analysis (45) so this survey could be widened without adding more time to the survey period. Further individual species abundances may provide more information when combined with repeat surveys and future work. Nevertheless, this study provides a comprehensive assessment of the Berwickshire benthic marine ecosystem and provides baseline data to assess the efficacy of existing and future management at this site. It is hoped that annual sampling of the benthos in Berwickshire will continue with a view to establishing conclusive evidence of ecological change.

Other things to note: 2021 was an unprecedented year due to the global pandemic. This study provides an opportunity to begin to understand the potential positive and negative impacts this change in human activity might have on the marine environment and what lessons can be learned from this in terms of future management. It also contributes to the global call for knowledge on the long-term environmental impacts of COVID-19; the full extent of which are unlikely to be fully realised for some years. January 2021 also saw the UK's departure from the European Union, and while it is yet to be seen what the impacts on the U.K fishing industry will be, continuation of the long-term data set can provide evidence of any knock-on effects to the marine environment.



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Project background

The waters off the coast of Berwickshire, southeast Scotland, are some of the most biodiverse and productive in the UK. An area where cold and warm water currents converge in a habitat of rocky reefs, kelp forests and soft corals. In 1984 the charity the Berwickshire Marine Reserve (BMR) was formed, establishing an area of 10.3km^2 as a voluntary marine reserve, a paradise attracting divers and others from around the world. The oceanographic conditions along the coast of Berwickshire help to support species such as the Devonshire cup coral (*Caryophyllia smithii*), alongside cold water arctic wolffish (*Anarhichas lupus*). This unique environment also provides nursery grounds for commercially important species such as the brown crab (*Cancer pagurus*), European lobster (*Homarus gammarus*) and, together with Atlantic mackerel (*Scomber scombrus*) in the summer, are important for supporting the local fishing communities along this coast.

The BMR intersects two other levels of spatial management (Figure 1), the Berwickshire and North Northumberland marine Special Area of Conservation (SAC) and a Static Gear Reserve, highlighting the national and international importance of this coastline. The Berwickshire and North Northumberland marine SAC was designated to protect the following Annex I habitats and Annex II species as listed in the EU Habitats Directive:

- Shallow inlets & bays
- Reefs
- Submerged or partially submerged sea caves
- Mudflats and sandflats not covered by water at low tide
- Grey seals (*Halichoerus grypus*)

The majority of the BMR spatially overlaps with the Static Gear Reserve (Figure 1) inside which the Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 2004 prohibits the use of mobile or active gear for the period 1 January to 31 December (inclusive) in each year. The Static Gear Reserve was introduced to reduce gear conflict between the static and mobile commercial fishing sectors and this is currently the only fisheries management designation in place for the wider SAC. It covers 26 km2 and extends one nautical mile offshore from St Abbs Head in the north to the Scotland - England Border in the south and prohibits mobile or active fishing gear and is protected under the Scottish Inshore Fishing Order 2000.

Recently, Berwickshire's Marine Protected Areas and surrounds have been subject to illegal forms of fishing as well as increasing levels of commercial and recreational activities, the effects of which lack adequate monitoring. Following concerns from the community, Blue Marine Foundation (BLUE) formed a partnership with the BMR in 2018. BLUE has experience in implementing bottom-up approaches to management (developed in Lyme Bay), working with the local fishing communities, regulators, scientists, and conservationists to create a regional management plan for each area it works in. In Lyme Bay, this approach was underpinned by robust science, central to which was long term ecological monitoring. In Berwickshire, BLUE aims to work with the community to create a template for well protected and sustainably managed marine protected areas in Scotland. To assess the efficacy of such interventions, BLUE and the University of Plymouth are undertaking a long-term ecological monitoring programme to record spatial and temporal variation of the epibenthic communities. Here we report the year 1 baseline data.

The University of Plymouth team have developed several non-destructive, cost-effective ecological monitoring methods to quantify marine epibenthic and nektonic reef communities (Stevens *et al.* 2014, Sheehan *et al.* 2016). Sessile and sedentary benthic species were monitored using High Definition (HD) video on a towed flying array, while nekton and mobile benthic fauna were monitored using Baited Remote Underwater Video Systems (BRUVS). Data collected was used to compare the ecological status between areas managed through different marine conservation statutory designations (Static Gear Reserve, Special Area of Conservation) and suitable control areas. The long term aims of this work is to provide a baseline to assess the recovery of Berwickshire's sensitive ecosystems in response to improved local management:

1. To quantify the recovery of the identified species within the MPAs (Static gear reserve (SGR), SAC) compared to appropriate control areas. As this is the first study of its kind in this area, control sites will be identified using available data to ensure comparability and continuity.

2. To quantify changes in reef-associated nekton (free-swimming fish and invertebrates) within the BMR compared to appropriate control areas.

3. To identify and quantify Priority Marine Features (PMFs) within the survey sites (SGR, SAC, and open control areas)

Priority Marine Features

In 2014, the Scottish government identified and adopted 81 Priority Marine Features (from hereon in referred to as PMFs) (Natural Heritage, 2016). These features cover a variety of habitats that are considered a priority for conservation in Scotland's seas. Within the Berwickshire survey site, the SAC protects rocky reefs, sea caves and grey seals which fall under European Habitats Directive. Control sites that fell outside of spatial management were scrutinized for PMFs, to highlight any features that were not currently protected by the SAC. Identification of any PMFs, their extent and ecological status out with current protection will be quantified through the underwater video surveys.

This 1st year report will present data on the variation of epibenthic communities between existing management measures, highlight any PMFs rare species or areas of interest or damage and provide conclusions and next steps.

Methods

Berwickshire hosts a diverse range of benthic habitats, from rocky and cobble reefs to mixed pebbly sand (veneers), gravel sediments and muddy, soft substrata. This study was the first year, part of a long-term monitoring study to assess differences in benthic biodiversity between different 'treatments'. These treatments were defined as:

Static Gear Reserve (SGR) = sites inside the area closed to bottom trawling (static gear reserve; Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 2004). *These sites also fall within the SAC*.

Special Area of Conservation (SAC) = sites inside the Berwickshire and North Northumberland Coast Special Area of Conservation *only*, and,

Open Controls (OC) = controls sites *outside* of both these designations which remain open to all fishing.

During this first field season, survey sites within each treatment were identified using local knowledge and supported by geophysical survey data collected in 2018/2019. This survey included remote sensing with a SwathPlus bathymetric sonar and a sidescan sonar with ground truth provided by drop-down camera, Remotely Operated Vehicle (ROV) and grab samples. A preliminary interpretation of the data was made for benthic habitat (St Andrews Unpublished report).

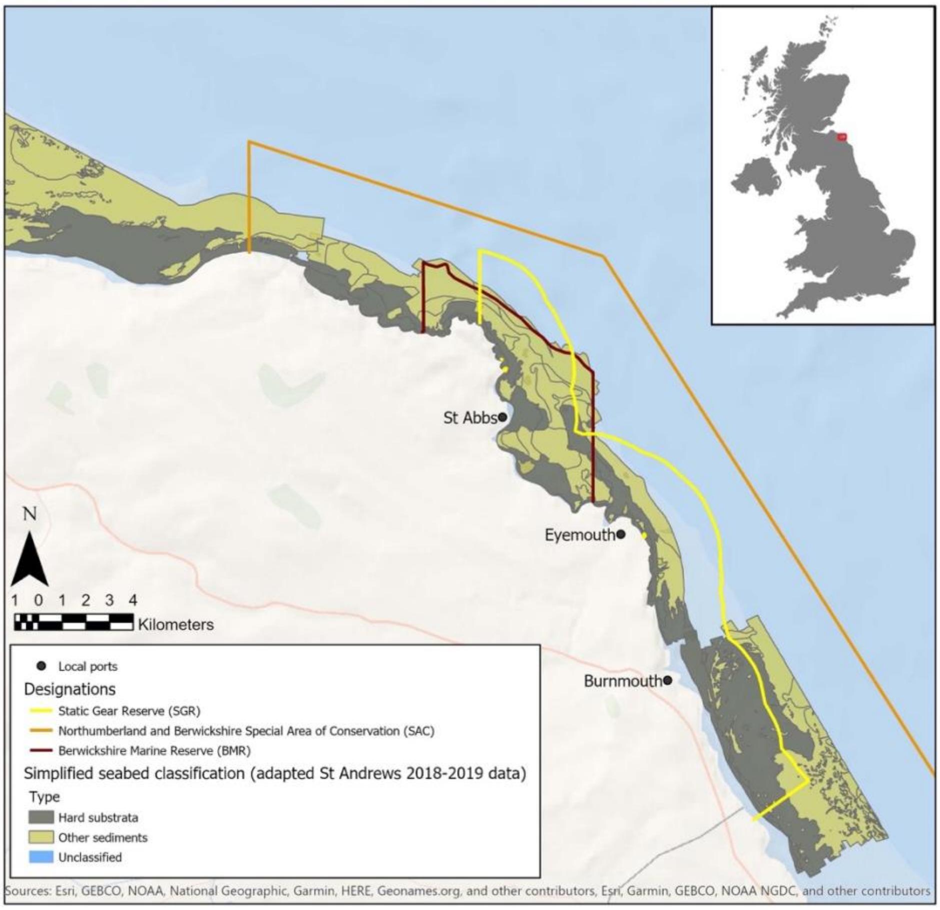

***Figure 1**. Simplified seabed habitat map of Berwickshire out to 50 m depth contour, adapted from St Andrews unpublished data. Hard substrata identified. Selected designations overlaid.*

In 2018 geophysical surveys were conducted inside BMR out to a limit of the 50 m depth contour which runs parallel to the coast, about 1.5 km from shore. This extent proved appropriate for mapping the inshore rocky-reef areas and further offshore sandy areas. In May 2019 this geophysical survey was extended North and South of the BMR to the limits of the Scottish Borders local authority from Dunglass in the north to the Scottish Border in the south, encompassing the whole of the Scottish section of the Berwickshire and North Northumberland marine Special Area of Conservation (SAC), also to 50m depth. Results were processed and preliminary analyses were performed to classify major seafloor types.

Sites were focused on areas of hard substrata using the geophysical survey data. For the purposes of this study, we define 'hard substrata' as a combination of the following seafloor bathymetry types as identified in the St Andrews geophysical survey (See St Andrews Unpublished report):

- 'Rocky reef'
- 'Hard base with sediment veneer'
- 'Exposed bedrock'
- 'Areas of boulders'

Underwater video

To remotely sample epibenthic reef fauna, two methods were employed using High Definition (HD) video. Firstly, a towed flying array was developed to fly the camera over the seabed to sample the sessile and sedentary species (Sheehan, Stevens and Attrill, 2010; Rees *et al.*, 2016; Sheehan *et al.*, 2016). Secondly, cameras were deployed on baited, static frames to sample the reef-associated nekton and mobile benthic fauna.

Towed Video

To quantify changes in the abundance of sessile and sedentary benthic species, a HD video camera was mounted on a flying array (Sheehan *et al.*, 2010) (Figure 2). This HD video system comprises of a camera (Surveyor-HD-J12 colour zoom titanium, 720p) with an umbilical, connected the video system topside (Bowtech System power supply/control unit), allowing for direct control of light intensity, camera focus, camera zoom and camera aperture. The camera was positioned at an oblique angle to the seabed, with three lights (Bowtech Products limited, LED-1600-13) fixed in front and below the camera to provide improved image definition and colour. Two green laser pointers lasers were positioned parallel to each other at a distance of 30 cm apart and used to quantify field of view (Freese *et al.*, 1999). A GoPro Hero5 black camera was also mounted at an oblique angle to the seabed on the front of the towed video array (*red dot in figure 2*). Videos were recorded on the GoPro for analysis and frame grab extraction. Videos were recorded at 60 FPS in 1080p, using the 'Medium' field of view setting to reduce image distortion. This method is particularly suitable for rapidly surveying large areas and is relatively low impact which is very applicable when sampling in areas of high conservation importance. The gear was deployed at the starting position using the wind and tide to select a unique transect.

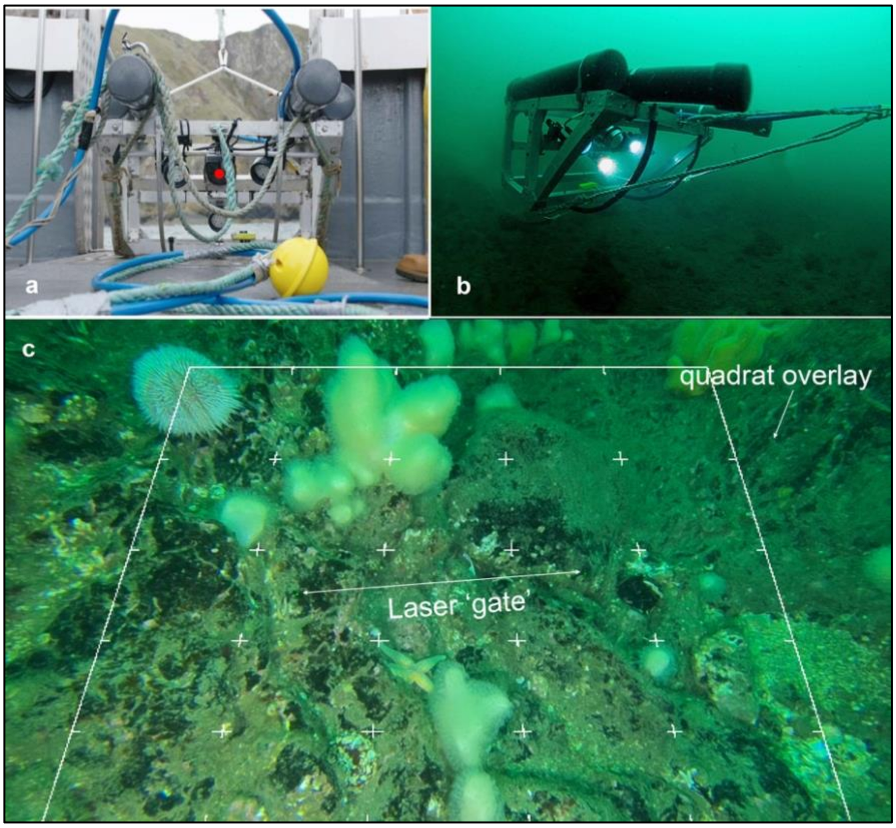

Figure 2*. Towed video flying array and frame grab example (quadrat overlaid). (a) Towed video flying array in Berwickshire (red dot = location of GoPro); (b) Towed flying array underwater (c) Berwickshire survey example frame grab taken from a 150 m transect of video with digital quadrat overlaid and scaling lasers.*

Baited Remote Underwater Videos (BRUVs)

To determine whether the closure affected reef-associated nekton species and mobile benthic fauna, Baited Remote Underwater Video (BRUV) was used. The remote deployment of cameras on static frames increased sampling efficiency and statistical independence. Six static frames (Greenaway Marine Ltd.) each housed a Panasonic HDC-SD60 full HD video camera and a battery-operated LED light mounted on the frame (Figure 3). Two 15 kg weights attached to the housing and a 1 m pole extended out from the centre of the camera's field of view held a 13 cm wide wire cage bait box (Figure 3) with 100 g fresh mackerel bait, which was replenished at the start of each deployment. At each site, three cameras were deployed from the side of the boat approximately 100 m away from each other, with a surface marker buoy attached.

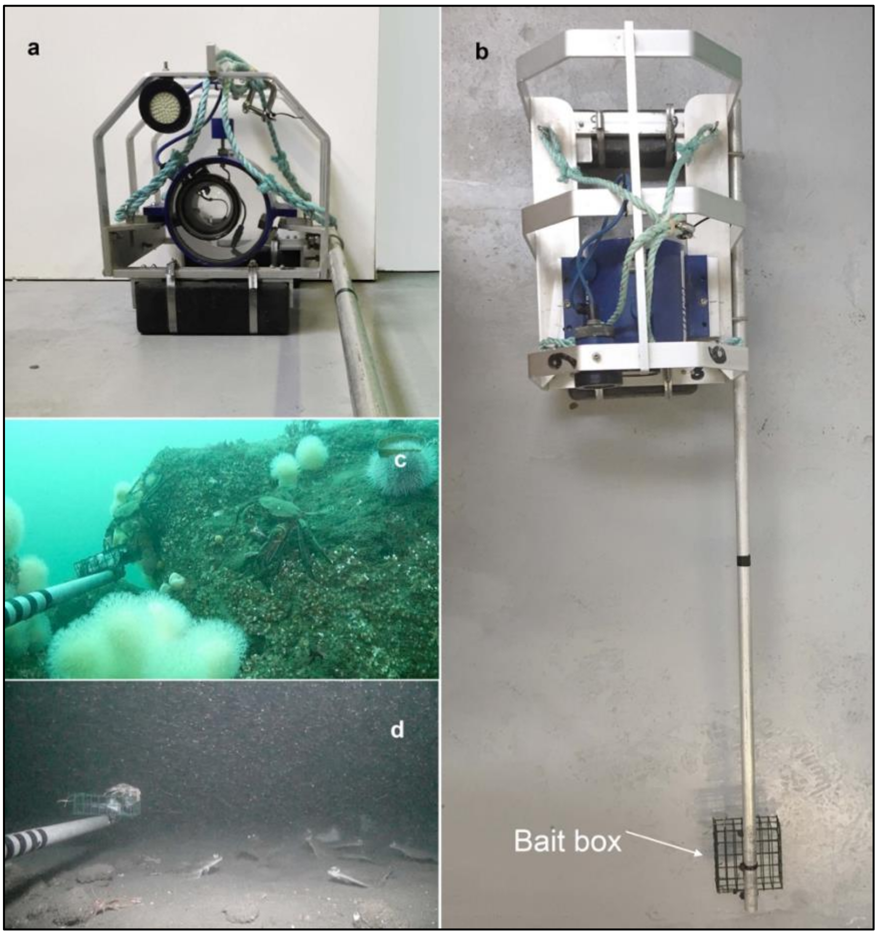

Figure 3. *a&b = Baited Remote Underwater Video static frames b = with bait box c&d = sample screenshots from 2021 BRUV survey in Berwickshire showing Necora puber, Echinus esculentus and Limanda limanda.*

Sampling Design

A structured selection of survey sites was undertaken pre survey and survey sites were distributed to account for spatial variation within each treatment. This resulted in 3 replicate Sites being sampled within 4-5 distinct Areas within each Treatment, equalling 45 survey Sites (Figures 4 & 5).

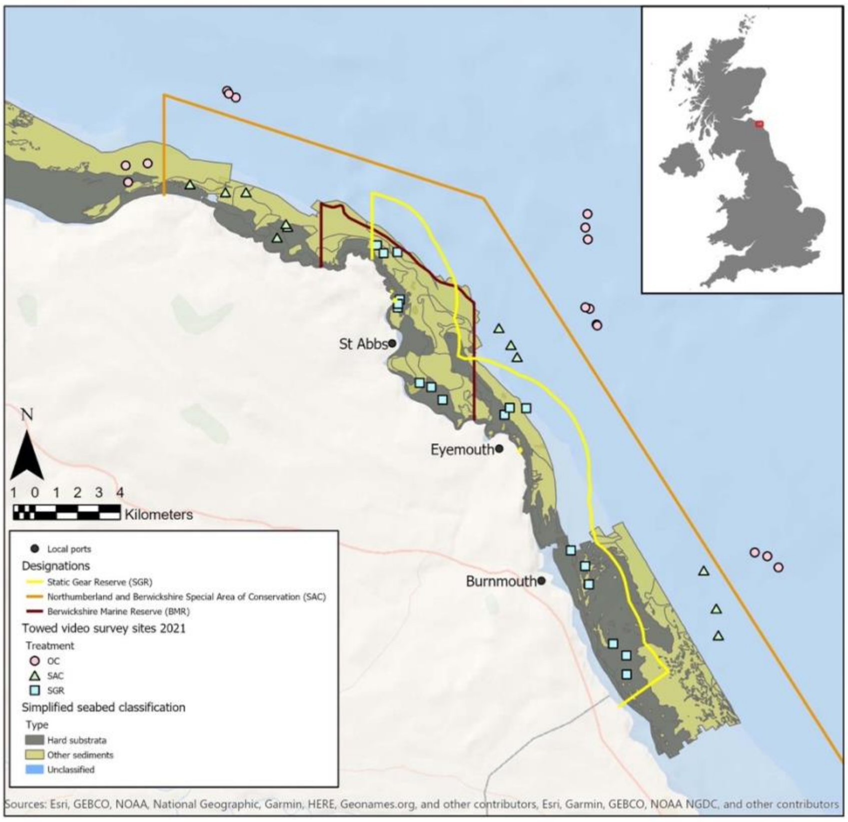

***Figure 4**. Locations of towed video survey sites (start points) in Berwickshire across all treatments (OC = Open Control, SAC = Berwickshire and Northumberland Special Area of Conservation (Orange line), SGR = Static Gear Reserve (Yellow line)). Some symbols overlap at this scale. The BMR has been outlined (Brown line) for illustrative purposes only and is not part of the sampling design for this study.*

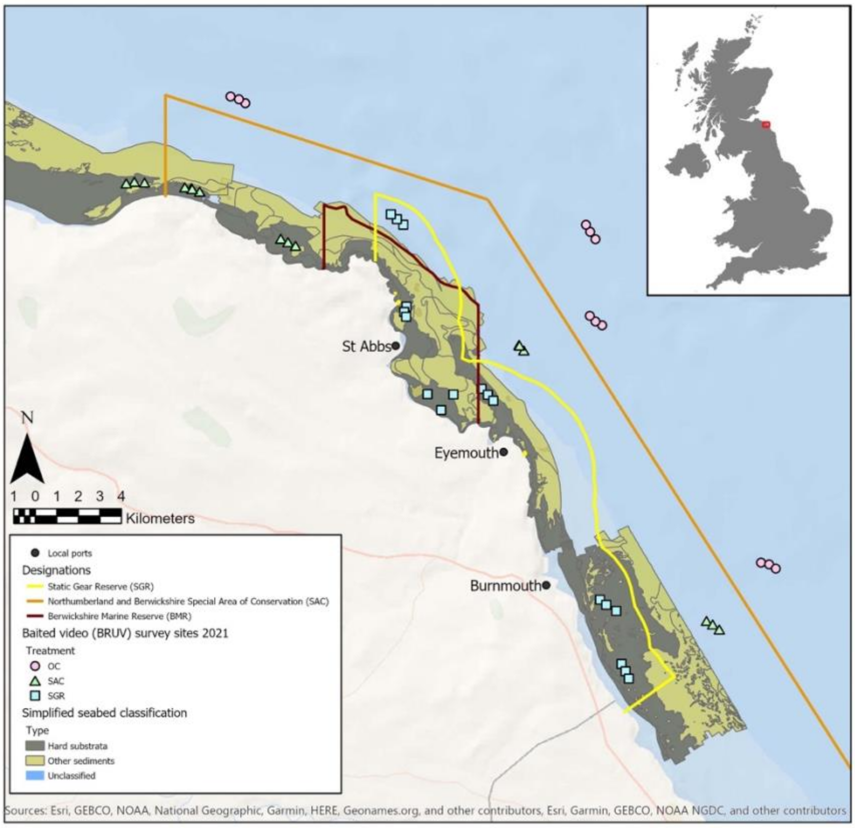

***Figure 5**. Locations of baited video survey sites in Berwickshire across all treatments (OC = Open Control, SAC = Berwickshire and Northumberland Special Area of Conservation (Orange line), SGR = Static Gear Reserve (Yellow line)). Some symbols overlap at this scale. The BMR has been outlined (Brown line) for illustrative purposes only and is not part of the sampling design for this study.*

For towed video a Site sample comprises a ~150 m video transect. For BRUVs a Site sample is a ~45-minute video to allow the extraction of a 30-minute video sample for analysis (Table 1).

***Table 1.** Description of terms used in the Berwickshire survey sampling design*

Term	Definition
Site	Replicate ~150 m transect (towed) or 30-minute BRUV video
Area	A group of 3 sites
Treatment	An experimental condition: ‘SGR’, ‘SAC’ or ‘OC’.

In 2021 fieldwork was carried out from the vessel 'Silver Sky', a local dive boat. Sampling took place from the 6th May to 19th May 2021. The average water temperature was 12.7 °C salinity was 34.1 ppt (at ~2 m depth) and the depth range of the survey was 14.5 m (Site 10, Appendix C Figure 1) – 67 m (Site 6, Appendix C Figure 1) (bsl).

Video Analysis

Extraction of quantitative data from HD video transect

Analysis of the video transects (n = 45) was conducted in two stages:

i. Species counts were made from each entire video transect by counting individuals that passed through the 'gate' formed by the two laser dots for infrequent organisms (all mobile species), and conspicuous sessile fauna (Appendix A Table 1). Dominant substrate type (R = Rock; BCPS =Boulders, cobbles, pebbles, sand; PS= pebbly sand; CS = coarse sand; SS = silty sand/mud) was also recorded. When substrate type changed, a new record was created allowing substrate extent to be calculated if required.

Species were recorded as density per m^{-2} for the species counts from video.

i. 20 randomly selected frame grabs were extracted from each video transect (see Sheehan *et al*. 2013, Stevens *et al*. 2013, Appendix D Figure1 (n = 898 frames in total)) and overlaid with a GoPro field of view calibrated digital quadrat to quantify the encrusting, sessile species, and some abundant, free-living fauna. The grid identifies the area of species to be enumerated. The quadrat overlay contained 16 dots. Cover-forming colonial taxa were quantified as percent cover by dividing the number of dots overlying that taxon by the total number of dots for the quadrat. The area sampled was corrected for every frame based on the apparent position of the laser dots. The position of the selected was then located in the GoPro video and use this in conjunction with the frame grab. This was to ensure that species identification can be made to the highest resolution possible. For each frame, the dominant substrate type was recorded. Frames where visibility was poor, or the array was not in the correct orientation or distance from the seafloor were removed. Dominant substrate type (R = Rock; BCPS =Boulders, cobbles, pebbles, sand; PS= pebbly sand; CS = coarse sand; SS = silty sand/mud) was also recorded for each frame.

Species were recorded as density per m^{-2} for the species counts and either density (Towed video and frames = Individuals per m^2) or percent cover as appropriate for the frame grabs (Appendix A Table 1, Appendix D).

Extraction of quantitative data from Baited Remote Underwater Video (BRUV)

Quantitative data were extracted from the BRUV samples (n = 45) by counting the maximum number of individuals on screen (MaxN) for each species that was recorded during a 30-minute period. MaxN is considered a conservative estimate of relative abundance of mobile species attracted to the bait, as it decreases the chance of an individual being repeatedly recorded (Cappo, Harvey and Shortis, 2006). Organisms were identified to the lowest taxonomic rank possible (Appendix A Table 1), and the counts were expressed as MaxN (± SE) per species, per replicate.

Groupings

For towed and baited video, all species observed were identified and their abundance recorded. A full species list used for analysis is presented in Appendix A Table 1. Identification was made to the highest taxonomic level deemed possible. Some groupings still occur due to between-species similarities, as outlined below:

i. All branching sponges, such as *Axinella dissimilis*, and *Haliclona oculata,* were grouped as “Branching sponges”;
ii. The hydroid species *Halecium halicinium, Hydrallmania falcata, Nemertesia antennina, Nemertesia ramosa, Dynamena pumila* and *Sertularia cupressina* were grouped as “Hydroids”;
iii. The brittlestar species *Ophiocomina nigra*, *Ophiothrix fragilis* and *Ophiura ophiura* were grouped as “Brittlestars”;
iv. The anemone species Sagartia spp. (only identifiable to genus level) and *Sagartia elegans* were grouped as “Sagartia spp.”;
v. The anemone species *Urticina eques* and *Urticina felina* were grouped as “Large anemones”;

vi. The bryozoans *Bugulina flabellata*, *Chartella papyracea* and *Flustra foliacea* were grouped as "Tufted bryozoans";

vii. The spider crabs Inachus spp. and Macropodia spp. were identified to genus level.

viii. Sponges that were not identifiable to species level were described and then identified as e.g., Red encrusting sponge, massive sponge 1 (Appendix A, Table 1), ensuring taxonomic resolution was maximised;

ix. The term "turf" incorporated hydroid and bryozoan turf that projected less than 1 cm above the seabed surface;

x. *Pagarus bernhardus* and *Pagarus prideaux* were grouped as "Pagurus spp.";

xi. Indistinguishable Palaemon species were grouped as "Palaemon spp.";

xii. Species that were not able to be identified were assigned to a descriptive group that described their morphology, e.g., Unidentified Juvenile fish species (screenshots of these species have been recorded for future requirements)

xiii. Lepadogaster spp., was identified to family level;

xiv. Gaidropsarus spp., was identified to family level;

xv. Loligo spp., was identified to family level;

xvi. Triakidae spp., was identified to family level;

xvii. The goby species were grouped as "Gobiinae spp."

While species might have been recorded in one or more methods described, species included in analyses were enumerated using one of these methods only. A full species list, and their enumeration method is provided in Appendix A, Table 1.

Data analysis

For towed video, the response variables Abundance, Species Richness and Assemblage Composition were tested between treatments. The abundances of appropriate individual species were also looked at. SIMPER (Similarity Percentage analysis) was used to explain which species contributed most to differences between assemblages. The factor Treatment was fixed and had three levels (Treatment: SGR, SAC, OC). Area was random and nested in Treatment (SGR = 6 areas, SAC = 4 areas, OC = 5 Areas). All Areas comprised of three replicate sites sampled in May 2021. A subset of the frames only data, collected on hard substrata only, was also tested on this dataset, as above. This data set looked at frames classified as either

Rock (R) or as Boulders, Cobbles, Pebbles, Sand (BCPS) as the dominant substrate only. This resulted in the following replication: OC = 7 sites (3 Areas) n= 140 frames; SAC = 5 sites (3 Areas) n= 100 frames, SGR = 16 sites (6 Areas) n = 320 frames. PERMANOVA analyses are robust to the unbalanced sample design.

Univariate and multivariate analyses were conducted using Permutational Multivariate Analysis of Variance (PERMANOVA, (Anderson, 2001; Clarke and Warwick, 2001)) based on similarity matrices (univariate = Euclidean, multivariate = Bray Curtis similarity). Prior to analysis, univariate data were 4^{th} root transformed and multivariate were square root transformed (Anderson & Millar, 2004). For abundance of each individual species, univariate analyses were used. For our baseline we consider all treatments to be fished equally so the null hypothesis of no difference among species assemblages between protected and fished treatments, that is consistent over temporal and spatial scales, was examined. Analyses were done using PRIMER 6 (Clarke and Warwick, 2001), with PERMANOVA + For PRIMER. Each term in the analysis used 9999 unrestricted permutations of raw data.

The same design and analysis principles were used to test for differences between treatments in the baited video. However, as joint species absences were important to consider between treatments, baited data were 'zero-adjusted; by adding a dummy value of 1 (Clarke *et al.*, 2006).

Results

Towed video results

In 2021 a total of 50 taxa from 10 phyla were recorded in towed video surveys in Berwickshire and included in analysis (Appendix A Table 1). Species included those commonly associated with rocky habitats, such as: Dead Man's Fingers (*Alcyonium digitatum*), Common starfish (*Asterias rubens*), high numbers of the Edible sea urchin (*Echinus esculentus*) and other starfish including sunstars (*Crossaster papposus*). On softer sediments large anemones (Urticina spp.) were common, as were rugose squat lobsters (*Munida rugosa*) and in some areas slender (*Virgularia mirabilis*) and phosphorescent (*Pennatula phosphorea*) sea pens. Rare species include the curled octopus (*Eledone cirrhosa*), nephrops (*Nephrops norvegicus*) and plumose anemones (*Metridium dianthus*).

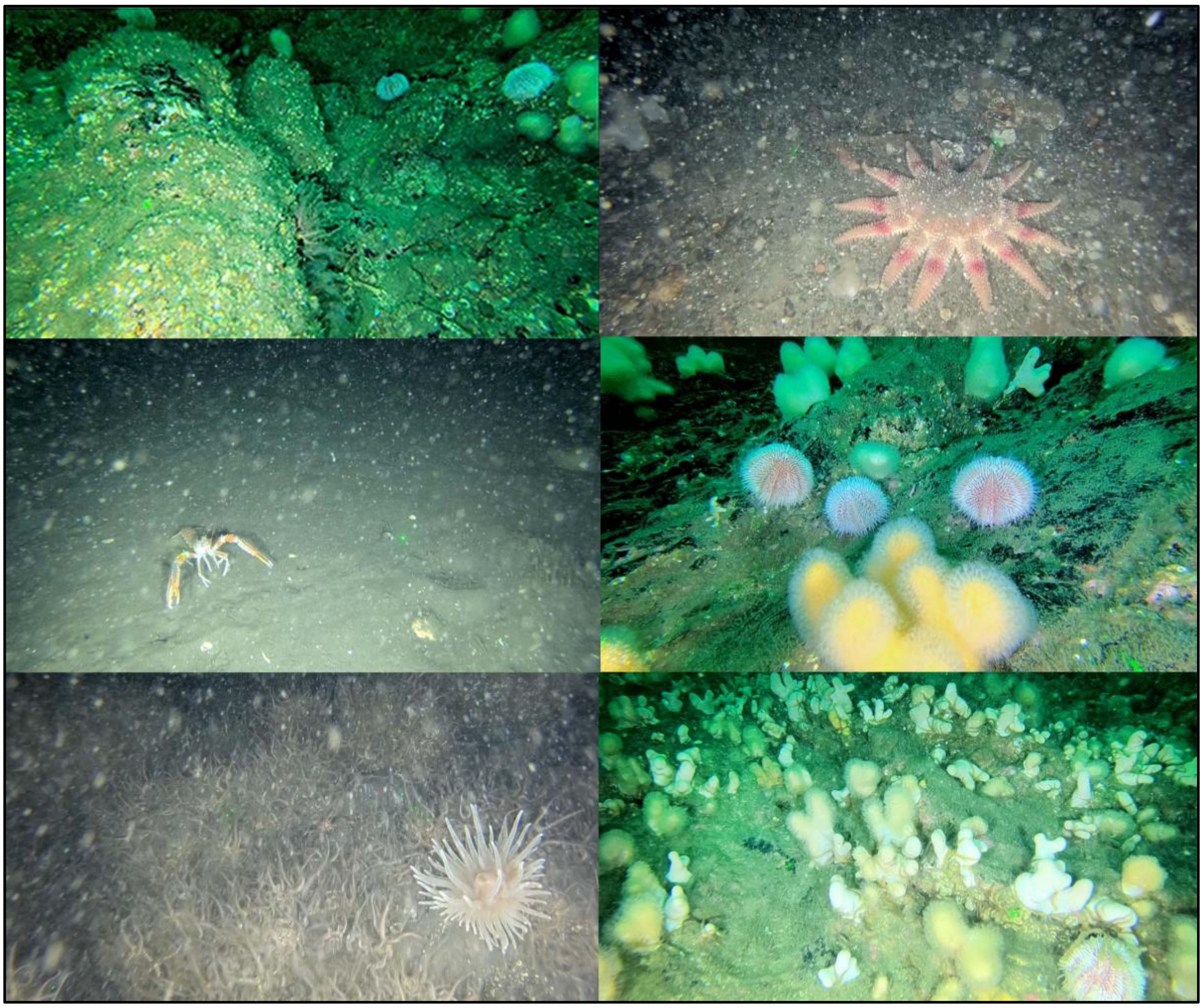

***Figure 6**. Example screenshots taken from towed video (video) survey. Top left = Antedon bifida in foreground, Top right = Crossaster papposus, Middle left = Nephrops norvegicus, Middle right = Alcyonium digitatum and Echinus esculentus, Bottom left = Urticina feline, Bottom right = large amounts of Alcyonium digitatum.*

Abundance

Overall abundance (number of individuals) was compared between all treatments in 2021 (Appendix B, Table 1). Abundance was highest in the SGR treatment (Mean = 2.22 indiv. M^{-2} ± 0.1 SE) compared to the other treatments. Abundance in the SAC treatment was slightly higher than the that of OC (SAC Mean = 1.63 indiv. M^{-2} ± 0.28 SE; OC Mean = 1.43 indiv. M^{-2} ± 0.13 SE) (Figure 7). However, there were no significant differences observed between treatments (Figure 7, Appendix B, Table 1).

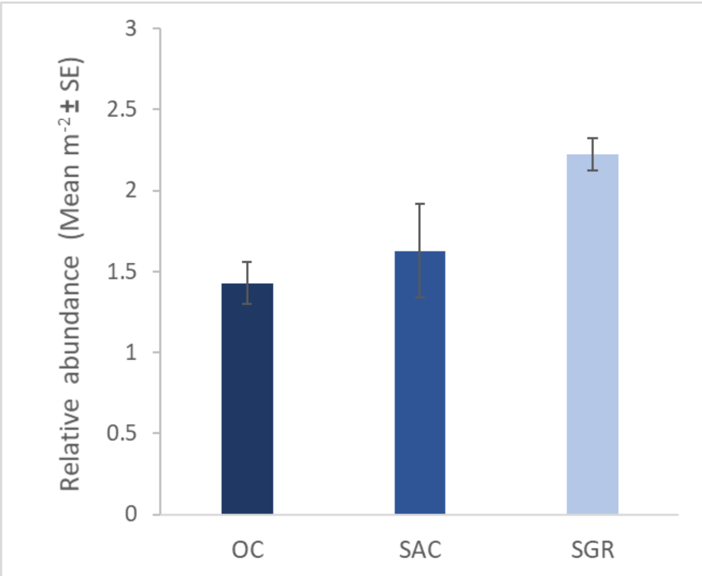

***Figure 7**. Overall Abundance (Mean m^{-2} ± SE) of species identified using towed video, for each Treatment (OC = Open Control, SAC = Berwickshire & Northumberland Special Area of Conservation, SGR = Static Gear Reserve)*

Species richness

Species Richness was compared between all treatment in 2021. There were no significant differences observed between treatments (Appendix B, Table 1). All treatments were similar to each other (OC Mean Sp. Rich. = 1.62 m^{-2}; SAC Mean Sp. Rich. = 1.64 m^{-2}; SGR Mean Sp. Rich. = 1.78 m^{-2}) (Figure 8).

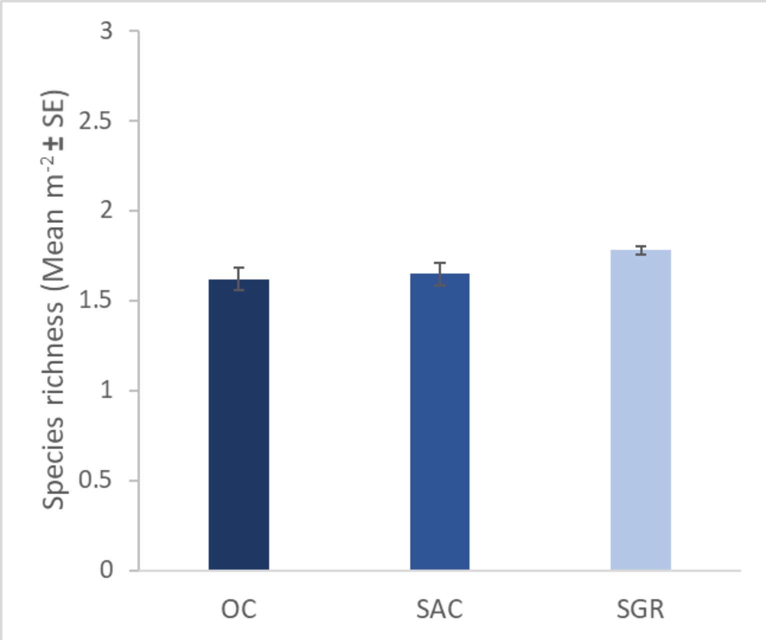

Figure 8*. Species Richness (Mean m^{-2} ± SE) for each Treatment (OC = Open Control, SAC = Berwickshire & Northumberland Special Area of Conservation, SGR = Static Gear Reserve)*

Assemblage composition

Assemblage compositions for each treatment were largely similar and there were no significant differences observed. The nMDS shows some grouping for the assemblage composition of sites within each treatment, but there is also a high degree of overlap between treatments (PERMANOVA main test P =0.0562, Appendix B, Table 1; Figure 9). SIMPER analyses showed 'Hydroids' were the most abundant species group in all treatments (Table 2, Appendix B Table 2). In the SGR treatment SIMPER analysis (Table 2) shows this assemblage to be driven by high abundances of Hydroids, Turf and *Alcyonium digitatum*. In the SAC treatment, in addition to Hydroids and *Alcyonium digitatum*, Brittlestars were extremely abundant. In the OC *Alcyonium digitatum* had lower abundances while large anemones contributed much more to the assemblage of this treatment. Abundances of these species identified through SIMPER analyses were selected for comparison (Figure 10).

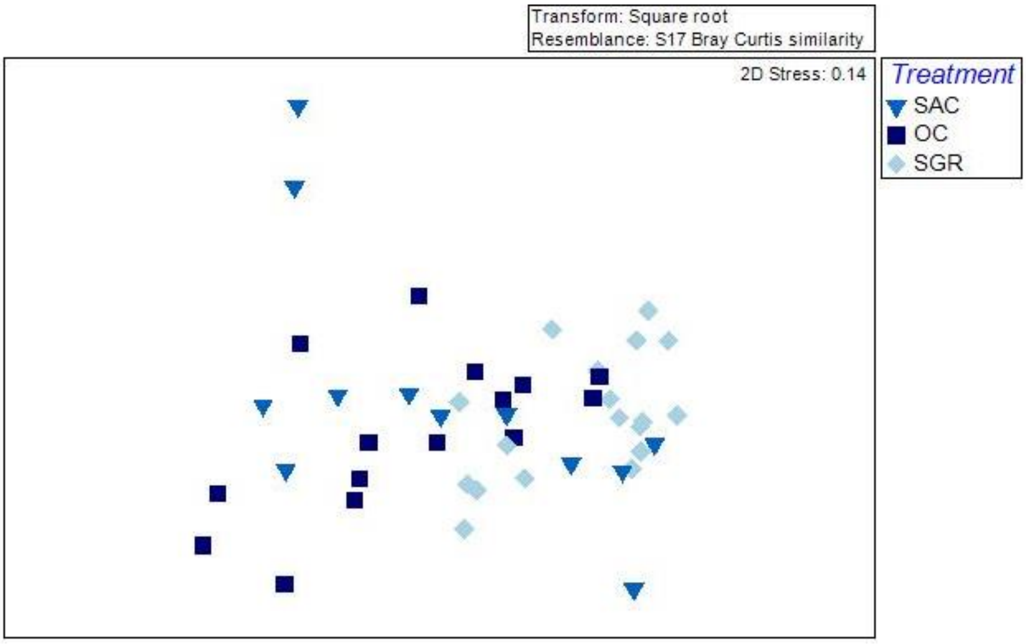

Figure 9. *nMDS plot illustrating similarities in species assemblages between Treatments*

Table 2. *Results of SIMPER analyses for each treatment. Species that contributed to cumulative abundance up to 90% in any treatment have been included. Average abundances of each species within each treatment and their contribution percentage area displayed*

	Average abundance (Mean m^{-2})			Contribution (%)		
SIMPER results	**SGR**	**SAC**	**OC**	**SGR**	**SAC**	**OC**
Hydroids	1.91	0.94	1.23	23.57	26.52	45.21
Turf	2.48	0.72	*na*	23.39	4.63	*na*
Alcyonium digitatum	1.83	0.92	0.56	20.88	19.85	12.44
Asterias rubens	0.46	0.2	0.23	6.36	11	4.61
Brittlestars	1.39	2.52	*na*	4.92	13.75	*na*
Encrusting sponges	0.62	*na*	*na*	4.82	*na*	*na*
Echinus esculentus	0.45	*na*	*na*	4.36	*na*	*na*
Large anemones	0.33	*na*	0.46	2.27	*na*	10.83
Munida rugosa	*na*	0.47	0.43	*na*	5.03	4.29
Lanice conchilega	*na*	0.25	0.28	*na*	11.17	9.92

Individual species

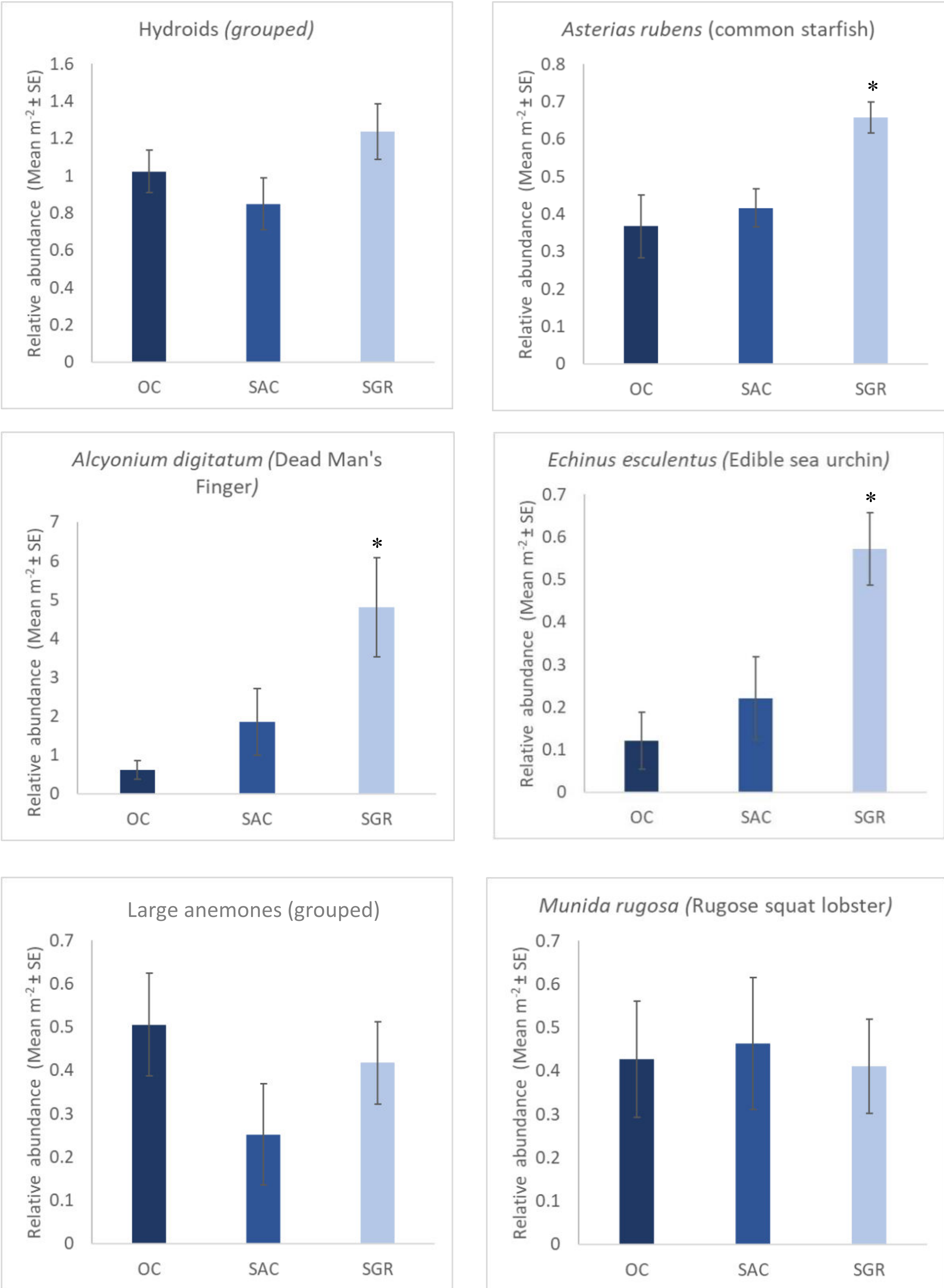

Figure 10*. Relative abundances of 'most abundant' species identified through SIMPER analyses, between each treatment, (Mean m^{-2} ± SE). Asterisk denotes pairwise testing significance. Note difference in scales on y-axis.*

Abundances were formally compared between treatments for each individual species. The abundances of species common Starfish (*Asterias rubens*), Dead Man's Finger (*Alcyonium digitatum*) and edible sea urchin (*Echinus esculentus*) were all significantly higher (PERMANOVA main test result P=<0.05, Appendix B, Table 1) in the SGR compared to SAC and OC treatments (which were not significantly different to each other) (Pairwise comparisons P=<0.05, Appendix B, Table 3) (Figure 11). There were no significant differences between treatments for the other species tested here (Appendix B, Table 3).

Figure 11. *Example screenshot from SGR site showing Atlantic cod (Gadus morhua) interrogating BRUV bait box*

Baited video

In 2021 a total of 15 species (or groups of species) from 2 phyla were recorded in baited video (BRUV) surveys in Berwickshire and included in analysis (Appendix A Table 1). Overall abundance (number of individuals) was compared between all treatments in 2021 (Appendix B, Table 4). There was no significant difference between treatment. Figure 12 shows that abundances in the SGR (SGR Mean = 0.98 indiv. m^{-2} ± 0.14 SE) were lower than other treatments (OC Mean = 1.3 indiv. m^{-2} ± 0.16 SE; SAC Mean = 1.28 indiv. m^{-2} ± 0.14 SE) but this was not significant. Species richness did not differ significantly between treatments (Figure 14). However, assemblage composition did differ significantly between the SGR treatment when compared to the OC and SAC treatments (PERMANOVA main test P =0.0267, pairwise test SAC, OC P = 0.0279, Appendix B, Table 4; Figure 12).

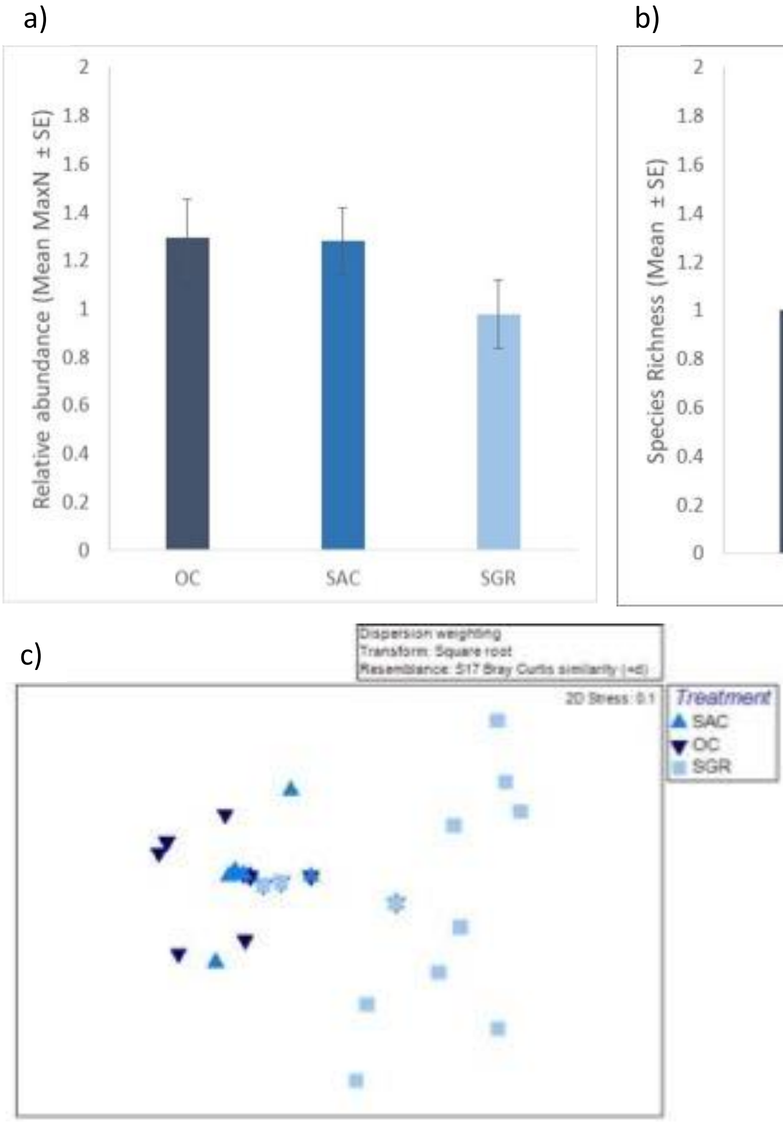

__Figure 12__.a) Relative abundance and b) species richness for mobile species compared between Treatment (OC = Open Control, SAC = Berwickshire & Northumberland Special Area of Conservation, SGR = Static Gear Reserve), and c) mobile species assemblage composition nMDS for each treatment

However, SIMPER analyses confirmed that this difference was driven by the lower abundances of Dab (*Limanda limanda*) recorded in the SGR. SAC and OC treatments were dominated by the presence of this species (Appendix B Table 5). Abundances were extremely low in all treatments and so any results drawn from this data should be carefully considered.

Discussion and conclusions

The surveys carried out in 2021 were the first in a long-term monitoring project for Berwickshire. The data presented here represents ecological baseline against which, using the same response variables, changes in the benthic ecosystem (sessile and sedentary species), and reef-associated nekton and mobile benthic fauna species, can be measured against over time. 45 sites across three treatments were surveyed to assess changes between different management regimes (for commercial fishing) in place in this area of Berwickshire and to assess the effect of these regimes on benthic ecosystem health.

Towed video

None of the response variables tested for the entire towed video dataset showed significant differences between treatments. Overall, the abundance was lowest in the OC and highest in the SGR treatment. There was some weak evidence showing assemblages in the SGR were diverging away from the other treatments. This was likely due to the higher presence of hard substrata being present within SGR sites. Open controls were typically deeper and contained less rocky reefs and more soft sediment habitat. The SAC comprised a mix of habitats including, bedrock, mixed sediments (BCPS) and soft sandy sediments. Typically, OC sites were located >1.5km from the shore and so bathymetry data were not available. Using local knowledge efforts were made to try and find sites with harder substrata in Open Control areas (total sites surveys = 56), however, hard substrata was still hard to find. Some hard substrata were identified in OC areas surveyed in the south (near Burnmouth, site 14, Appendix C, Figure 1) and in the site just north of Fast Castle Head (site 2, Appendix C, Figure 1).

The greater abundances observed inside the SGR were driven by the presence of large numbers of Dead Man's Fingers (*Alcyonium digitatum*). This slow growing, soft-coral proliferates on hard rock, boulder and sediment veneers overlying hard bedrock (Sheehan *et al.* 2013, Picton and Morrow 2016). Our results show that this species was significantly higher inside the SGR compared to the other two treatments. This species is indicative of healthy reef habitats and is considered a key contributing species to biogenic reef habitats (Sheehan *et al.* 2013). The lower abundances Dead Man's Fingers seen in the other treatments could indicate increased disturbance in these treatments, or a lack of suitable constituent habitat, The common starfish (*Asterias rubens*) and the edible sea urchin (*Echinus esculentus*) were also significantly more abundant inside the SGR. Areas of rock dominated by these three species were prolific particularly in areas to the south of St Abbs head (SGR sites 9 & 10 Appendix C, Figure 1) and to the south near Burnmouth (SGR sites 15 & 17 (Appendix C, Figure 1)) (Figure 13).

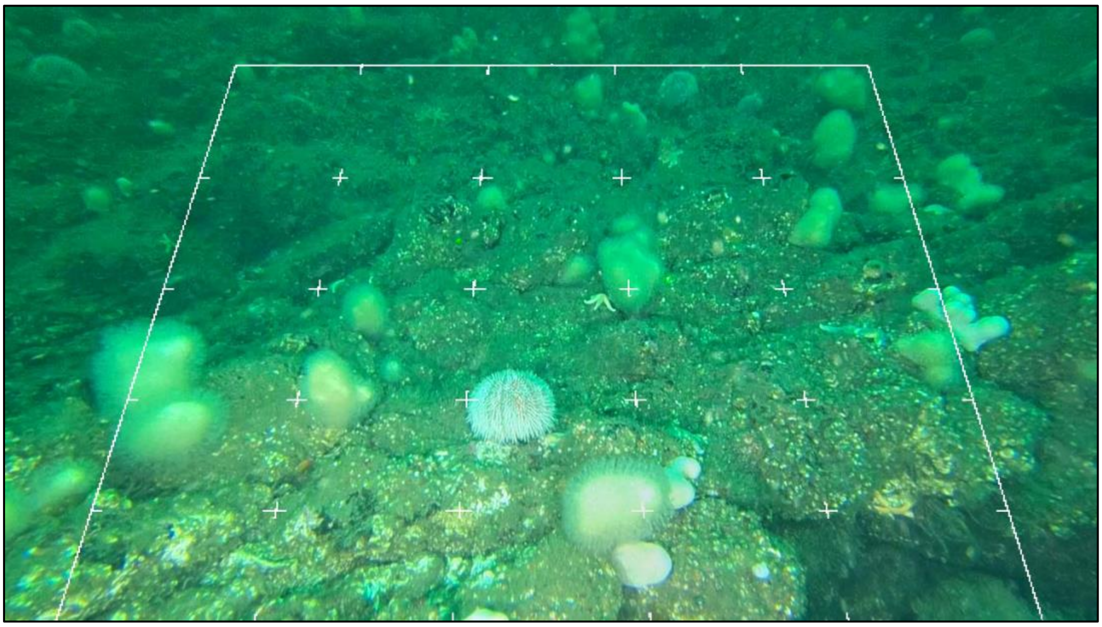

***Figure 13**. Frame grab example of common habitat - rock covered in Alcyonium digitatum, Echinus esculentus and Asterias rubens. Frame taken from site 10.*

Baited video

Abundances of the species attracted to the baited video units were unexpectedly low in all treatments. This makes it difficult to undertake statistical analyses and draw meaningful conclusions about the existing management. In some of the SAC and OC sites there were large numbers of *Limanda limanda,* a scavenging flatfish species. They were mostly observed in areas of soft sediment and so it was not surprising that they were not seen in large numbers inside the SGR where there was less soft sediment habitat.

The habitats were surveyed following large storms and early spring when sea temperatures are still low. Such environmental factors may be responsible for the low numbers of fish observed. We would therefore advise that surveys were also repeated in the summer months in future years for comparison.

Next steps and further research

Further effort is required to identify areas of hard substrata in the SAC and OC treatments. We suggest increasing the coverage of the survey by identifying and surveying an additional number of comparable sites within the OC treatment in particular, while keeping the survey design balanced.

There are further analyses in terms of functional diversity, functional groupings, and ecosystem functionality that different species (or groups of species) may contribute to in Berwickshire. These could be examined with time series data collected from future annual monitoring. In addition, there are several historical surveys that have been undertaken by divers and other survey methods against which the data collected here could be compared to better understand temporal changes that might have occurred.

To complement the towed and baited video surveys, diver surveys were carried out in 2021 and area planned for 2022. These surveys focussed on areas where the towed video would encounter operational difficulties, i.e., wreck sites with substantial ship infrastructure present. Video and species records data were collected, but not analysed. Analysis of this data in combination with the data provided in this study would be beneficial to compare benthic assemblages between wreck sites, expected to be relatively unimpacted by direct anthropogenic impacts, and the reef assemblages surveyed in this study around Berwickshire. It would also add to the overall baseline dataset.

There were no identified Priority Marine Features (PMFs) in either the towed or baited surveys from the list of 81 identified by Scottish Government. Priority marine features (PMFs) are habitats and species considered to be marine nature conservation priorities in Scottish waters. It should not be concluded that these features do not exists in the study site, but more targeted surveys may be required in areas of expected/historical/anecdotal occurrence. The available diver data should be interrogated for the presence of PMFs.

Notes of interest

The survey took place ~14 months into the COVID-19 pandemic. Enforced lockdowns, 'stay at home' instructions and reduced tourism could have had significant knock-on impacts for local fishermen due to closure of direct markets for seafood selling, disrupted supply chains and safety concerns operating vessels with crew. Anecdotal reports are that fishing activities and fishing effort was reduced within the inshore fishing sector during this time (Local Scottish and English fishermen, pers. comm.). This change in behaviour may have potentially alleviated some fishing pressure on habitats and species around Berwickshire.

The baited video survey was carried out in May. This was based on available capacity and input from local stakeholders suggesting the clarity of the water was highest during this time, important for video surveys. The abundances recorded during the surveys were lower than expected. Water temperature may have influenced the behaviour of reef-associated nekton species and mobile benthic fauna, particularly mobile fish, around Berwickshire, potentially amplified by Berwickshire's unique oceanography. We suggest that any repeat surveys should also be carried out later in the year for comparison.

In towed video survey transects from sites in southern Areas of the SGR, around Burnmouth, some areas of seabed were recorded as 'sand', despite sites located on 'hard substrata' based on bathymetry data. The accuracy of the bathymetry data (Figure 1) should be noted.
Parallel light and dark patterns within the sand were observed in some of these areas. These patterns may have been caused by bottom towed fishing gear due to their regularity and distinct, indiscriminate appearance (Figure 14), however, this has not been confirmed and has only been suggested by the authors of this report. Large areas of burrowed mud were observed on the towed video surveys. Organisms in burrows were counted but there were many more burrows than organisms observed. Infauna are not sampled using the methods outlined here so determining between active and extinct burrows is difficult and therefore not recorded. Burrowed mud[1] is however a Priority Marine Feature and may be of interest to the reader (Figure 15).

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[1] * Qualifying component for burrowed mud

- Seapens and burrowing megafauna in circalittoral fine mud
- Burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud
- Tall seapen *Funiculina quadrangularis*
- Fireworks anemone Pachycerianthus multiplicatus
- Mud burrowing amphipod

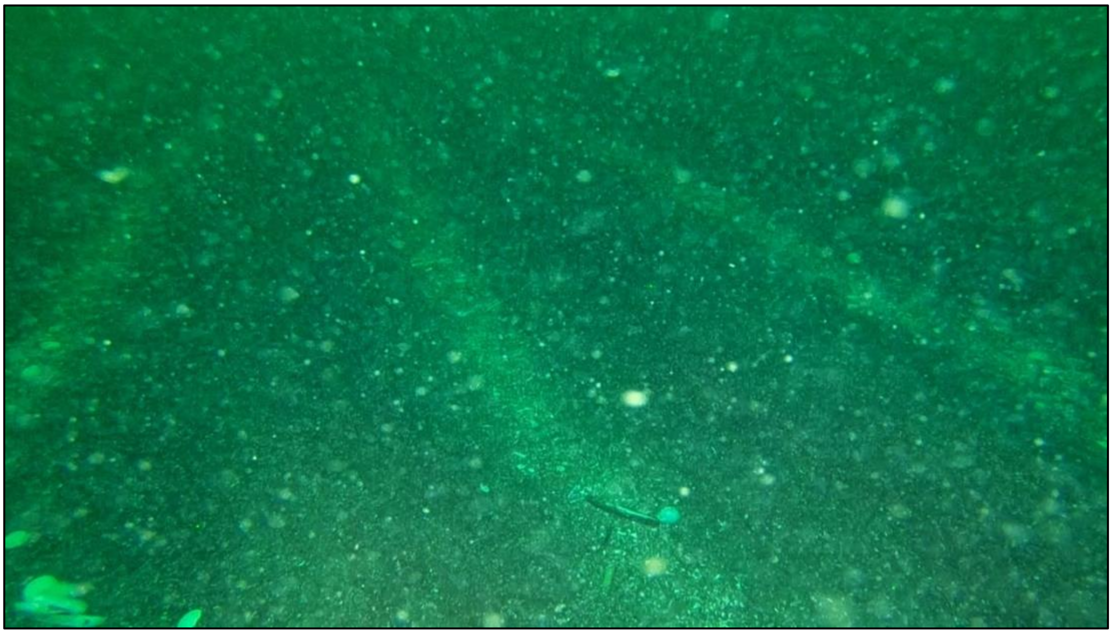

Figure 14. *Example screenshot taken from towed video transect (Site 17, SGR, Appendix 3, Figure 1) showing patterns potentially from anthropogenic activity (unverified).*

Figure 15. *Example of 'burrowed mud' observed from towed video, 2021*

An interesting observation from the towed video which may not be expressed by the data was the apparent interconnectivity between the squat lobsters (*Munida rugosa, Galathea squamifera*) and Dead Man's Fingers (*Alcyonium digitatum*). Squat lobster, although regularly seen in multiple habitats, were observed many times situated at the base of Dead Man's Fingers, either hidden or submerged in scoured sediment (Figure 16).

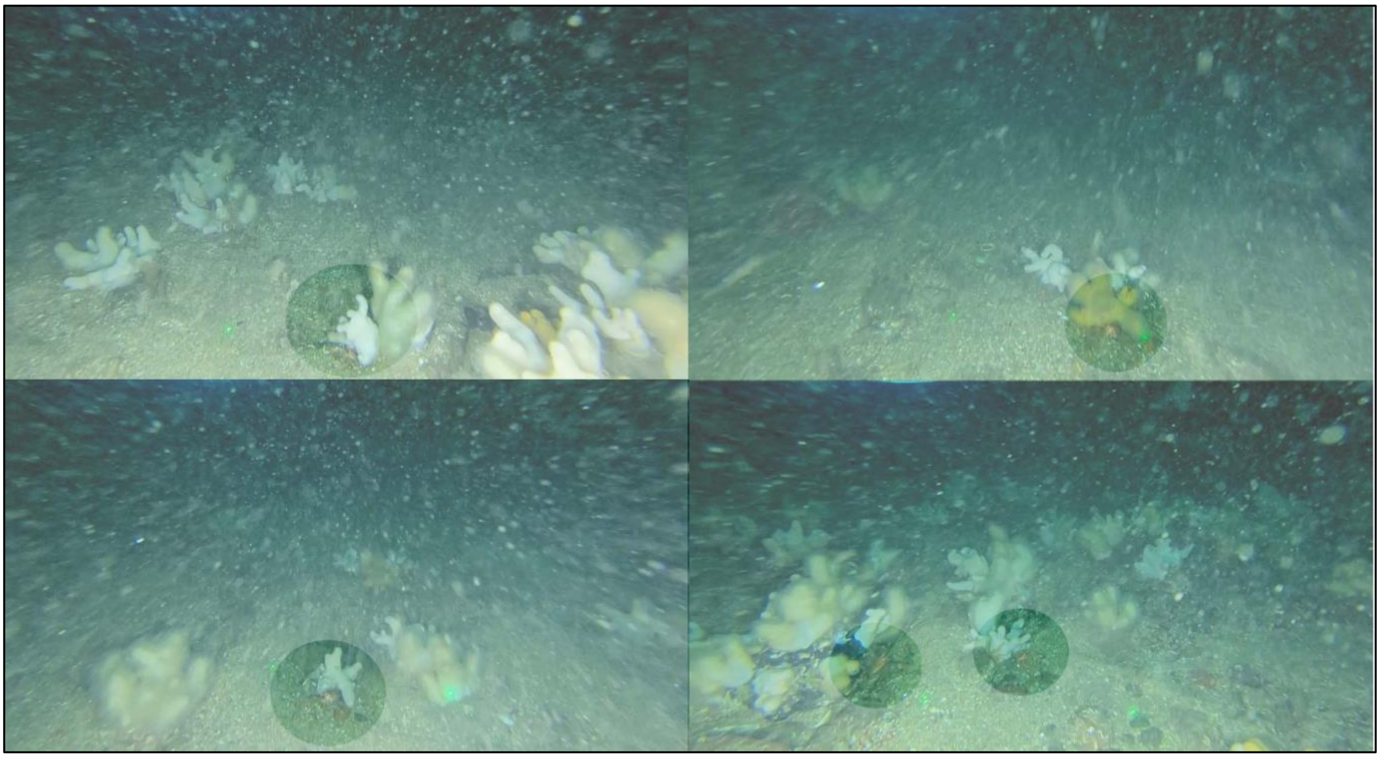

Figure 16. *Example screenshots from towed video transect (~10 seconds of video) showing Munida rugosa hiding under Alcyonium digitatum*

There remained a few unidentified organisms despite best efforts and consultation with local experts. They have been included here for reference (Figure 17):

a)

b)

c)

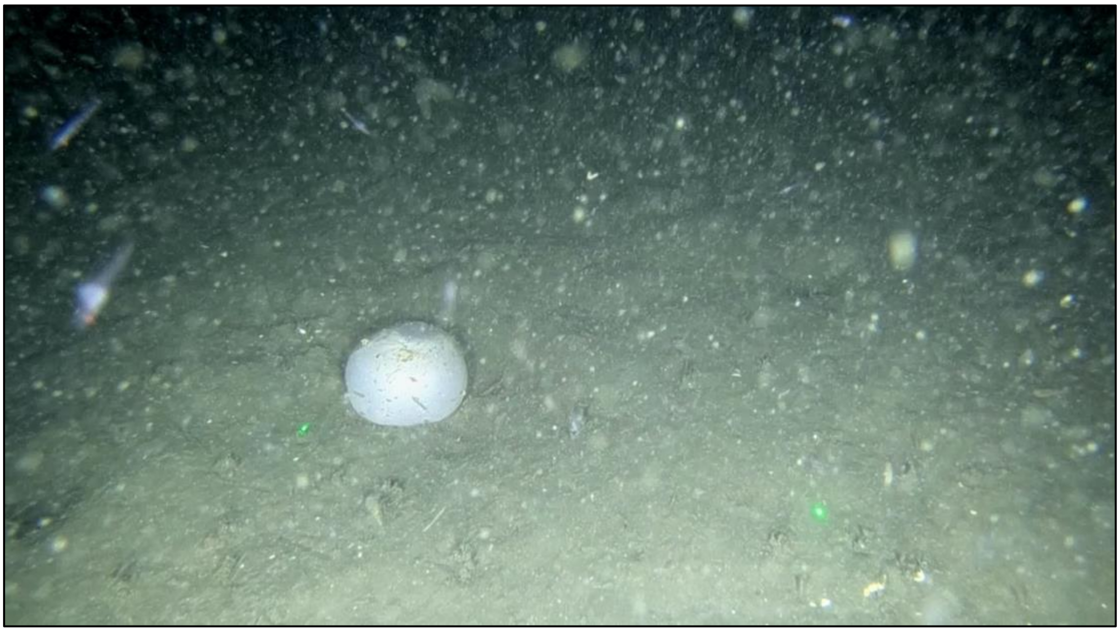

Figure 17. *Screen shot of unidentified organisms from towed video survey 2021, a) potentially Alcyonium digitatum, b) potentially an anemone or branching sponge, c) potentially retracted anemone.*

Curled octopus (*Eledone cirrhosa*) were spotted (n=2) on different occasions and included in the data. A screenshot is provided below (Figure 18).

Figure 18. *Curled octopus (Eledone cirrhosa) observed on towed video (Site 11, Treatment = SAC (Appendix 3, Figure 1)).*

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Disclaimer

Photoshop was used to finalise the composition of images for presentation purposes in the report only. Image processing was basic and included auto colour curve correction and sharpening.

Appendices

Appendix A: Species Lists

***Table 1** Complete species list identified and used in analysis from 2021 surveys, in all methods (Towed video, BRUVs). Method used enumeration is indicated along with units abundances are expressed in.*

UoP Scientific name	Method	Abundance Units	UoP common name	UoP code	AphialD	Genus	Family	Order	Class	Phylum
Aequipecten opercularis	video	m2	Queen scallop	Aeqope	140687	Aequipecten	Pectinidae	Pectinida	Bivalvia	Mollusca
Alcyonium digitatum	video	m2	Dead man's fingers	Alcdig	125333	Alcyonium	Alcyoniidae	Alcyonacea	Anthozoa	Cnidaria
Asterias rubens	video	m2	Common starfish	Astrub	123776	Asterias	Asteriidae	Forcipulatida	Asteroidea	Echinodermata
Astropecten irregularis	video	m2	Sand sea star	Astirr	123867	Astropecten	Astropectinidae	Paxillosida	Asteroidea	Echinodermata
Callionymus lyra	video	m2	Common dragonet	Callyr	126792	Callionymus	Callionymidae	Perciformes	Actinopterygii	Chordata
Cancer pagurus	video	m2	Brown crab	Canpag	107276	Cancer	Cancridae	Decapoda	Malacostraca	Arthropoda
Chelidonichthys cuculus	video	m2	Red gurnard	Checuc	127259	Chelidonichthys	Triglidae	Scorpaeniformes	Actinopterygii	Chordata
Crossaster papposus	video	m2	Common sunstar	Cropap	124154	Crossaster	Solasteridae	Valvatida	Asteroidea	Echinodermata
Echinus esculentus	video	m2	Edible sea urchin	Echesc	124287	Echinus	Echinidae	Camarodonta	Echinoidea	Echinodermata
Eledone cirrhosa	video	m2	Curled octopus	Elecir	140600	Eledone	Eledonidae	Octopoda	Cephalopoda	Mollusca
Henricia oculata	video	m2	Bloody henry	Henocu	123970	Henricia	Echinasteridae	Spinulosida	Asteroidea	Echinodermata
Luidia ciliaris	video	m2	Seven-armed starfish	Luicil	123920	Luidia	Luidiidae	Paxillosida	Asteroidea	Echinodermata
Metridium dianthus	video	m2	Plumose anemone	Metdia	158251	Metridium	Metridiidae	Actiniaria	Anthozoa	Cnidaria
Metridium senile	video	m2	Plumose anemone	Metsen	100982	Metridium	Metridiidae	Actiniaria	Anthozoa	Cnidaria
Nephrops norvegicus	video	m2	Nephrops	Nepnor	na	Nephrops	Decapoda	na	na	Crustacea
Pecten maximus	video	m2	King scallop	Pecmax	140712	Pecten	Pectinidae	Pectinida	Bivalvia	Mollusca
Pholis gunnellus	video	m2	Rock gunnel	Phogun	126996	Pholis	Pholidae	Perciformes	Actinopterygii	Chordata
Agonus cataphractus	frames	m2	Scorpion fish (Pogge)	Agocat	127190	Agonus	Agonidae	Perciformes	Actinopteri	Chordata
Alcyonidium diaphanum	frames	m2	Sea chervil	Alcdia	111597	Alcyonidium	Alcyonidiidae	Ctenostomatida	Gymnolaemata	Bryozoa
Antedon bifida	frames	m2	Feather star	Antbif	124201	Antedon	Antedonidae	Comatulida	Crinoidea	Echinodermata
Asterina gibbosa	frames	m2	Cushion star	Astgib	123987	Asterina	Asterinidae	Valvatida	Asteroidea	Echinodermata
Buccinum undatum	frames	m2	Common whelk	Bucund	138878	Buccinum	Buccinidae	Neogastropoda	Gastropoda	Mollusca
Calliostoma zizyphinum	frames	m2	Painted top shell	Calziz	141767	Calliostoma	Calliostomatidae	Trochida	Gastropoda	Mollusca
Chaetopterus variopedatus	frames	m2	Parchment worm	Chavar	129914	Chaetopterus	Chaetopteridae	NA	Polychaeta	Annelida
Cliona celata	frames	m2	Boring sponge	Clicel	134121	Cliona	Clionaidae	Clionaida	Demospongiae	Porifera
Corystes cassivelaunus	frames	m2	Masked crab	Corcas	107277	Corystes	Corystidae	Decapoda	Malacostraca	Arthropoda
Galathea dispersa	frames	m2	A squat lobster	Galdis	107148	Galathea	Galatheidae	Decapoda	Malacostraca	Arthropoda
Lanice conchilega	frames	m2	Sand mason	Lancon	131495	Lanice	Terebellidae	Terebellida	Polychaeta	Annelida
Liocarcinus depurator	frames	m2	Harbour crab	Liodep	107387	Liocarcinus	Polybiidae	Decapoda	Malacostraca	Arthropoda
Munida rugosa	frames	m2	Rugose squat lobster	Munrug	107160	Munida	Munididae	Decapoda	Malacostraca	Arthropoda
Necora puber	frames	m2	Velvet swimming crab	Necpub	107398	Necora	Polybiidae	Decapoda	Malacostraca	Arthropoda
Pagurus spp.	frames	m2	Common hermit crab	Pagber	107232	Pagurus	Paguridae	Decapoda	Malacostraca	Arthropoda
Palaemon spp.	frames	m2	Palaemon species	Palspp	na	Palaemon	Palaemonidae	Decapoda	Malacostraca	Arthropoda
Pennatula phosphorea	frames	m2	Phosphorescent sea pen	Penpho	na	Pennatula	Pennatulacea	na	na	Cnidaria
Pyura squamulosa	frames	m2	A sea squirt	Pyusqu	103852	Pyura	Pyuridae	Stolidobranchia	Ascidiacea	Chordata
Stolonica socialis	frames	m2	Orange sea grapes	Stosoc	103921	Stolonica	Styelidae	Stolidobranchia	Ascidiacea	Chordata
Sycon ciliatum	frames	m2	A sponge	Syccil	132251	Sycon	Sycettidae	Leucosolenida	Calcarea	Porifera
Tonicella rubra	frames	m2	Northern Red Chiton	Tonrub	na	Tonicella	Chitonida	na	na	Mollusca
Tubularia indivisa	frames	m2	A hydroid	Tubind	117994	Tubularia	Tubulariidae	Anthoathecata	Hydrozoa	Cnidaria
Unidentified blobs	frames	m2	Unidentified	Unknown	na	na	na	na	na	na
Unidentified red algae	frames	m2	Red algae	Redalg	na	na	na	na	na	Rhodophyta

Virgularia mirabilis	frames	m2	Slender sea pen	Virmir	na	Virgularia	Pennatulacea	na	na	Cnidaria
Zoarces viviparous	frames	m2	Viviparoius blenny	Zoaviv	na	Zoarces	Perciformes	na	na	Chordata
Branching sponges	frames	m2	Grouped branching sponges	na	na	na	na	na	na	Porifera
Hydroids	frames	m2	Grouped hydroids	na	na	na	na	na	na	Cnidaria
Brittlestars	frames	m2	Grouped brittlestars	na	na	na	na	na	na	Echinodermata
Large anemones	frames	m2	Grouped large anemones	na	na	na	na	na	na	Cnidaria
Tufted bryozoans	frames	m2	Grouped bryozoans	na	na	na	na	na	na	Bryozoa
Turf	cover	percent_cover	Turf	Turf	na	na	na	na	na	na
Encrusting sponges	cover	percent_cover	Encrusting sponge	Spoenc*	na	na	na	na	na	Porifera
Ctenolabrus rupestris	BRUV	MaxN	Goldsinny wrasse	Cterup	126964	Ctenolabrus	Labridae	Perciformes	Actinopterygii	Chordata
Gadus morhua	BRUV	MaxN	Cod	Gadmor	126436	Gadus	Gadidae	Gadiformes	Actinopterygii	Chordata
Gaidropsarus.spp.	BRUV	MaxN	na	na	na	Gaidropsarus	Lotidae	Gadiformes	Actinopterygii	Chordata
Gobiinae.spp.	BRUV	MaxN	na	na	105820	Galeorhinus	Triakidae	Carcharhiniformes	Elasmobranchii	Chordata
Homarus gammarus	BRUV	MaxN	European lobster	Homgam	107253	Homarus	Nephropidae	Decapoda	Malacostraca	Arthropoda
Labrus bergylta	BRUV	MaxN	Ballan wrasse	Labber	126965	Labrus	Labridae	Perciformes	Actinopterygii	Chordata
Limanda limanda	BRUV	MaxN	Dab	Limlim	127139	Limanda	Pleuronectidae	Pleuronectiformes	Actinopterygii	Chordata
Merlangius merlangus	BRUV	MaxN	Whiting	Merlamer	126438	Merlangius	Gadidae	Gadiformes	Actinopterygii	Chordata
Merluccius merluccius	BRUV	MaxN	European Hake	Merlumer	126484	Merluccius	Merlucciinae	Gadiformes	Actinopteri	Chordata
Molva molva	BRUV	MaxN	Ling	Molmol	126461	Molva	Lotidae	Gadiformes	Actinopterygii	Chordata
Myxine glutinosa	BRUV	MaxN	Atlantic hagfish	Myxglu	101170	Myxine	Myxinidae	Myxiniformes	Myxini	Chordata
Pollachius pollachius	BRUV	MaxN	Pollack	Polpol	126440	Pollachius	Gadidae	Gadiformes	Actinopterygii	Chordata
Thorogobius ephippiatus	BRUV	MaxN	Leopard goby	Thoeph	126937	Thorogobius	Gobiidae	Perciformes	Actinopterygii	Chordata
Trisopterus luscus	BRUV	MaxN	Pouting	Trilus	126445	Trisopterus	Gadidae	Gadiformes	Actinopterygii	Chordata
Trisopterus minutus	BRUV	MaxN	Poor cod	Trimin	126446	Trisopterus	Gadidae	Gadiformes	Actinopterygii	Chordata

Appendix B: PERMANOVA tables

Table 1. *Results of PERMANOVA main test for the response variables Abundance, Species Richness and Assemblage composition (all towed video data), in response to the fixed factor Treatment (Tr). Bold type denotes statistical significance*

Source	df	SS	MS	*F*	P
Abundance					
Tr	2	5.6881	2.844	3.3945	0.06889
Area (Tr)	12	10.054	0.8378	3.3568	**0.0044**
Res	30	7.4879	0.2496		
Total	44	23.23			
Species Richness					
Tr	2	0.2432	0.1216	1.6578	0.2173
Area (Tr)	12	0.8804	0.0073	3.6352	**0.0035**
Res	30	0.6054	0.002		
Total	44	1.7292			
Assemblage Composition					
Tr	2	18346	9172.9	1.9566	0.0562
Area (Tr)	12	56258	4688.2	3.613	**0.0001**
Res	30	38928	1297.6		
Total	44	1.135			

Table 2. *Results of SIMPER analyses of towed video assemblages within each Treatment. 90% cumulative contribution percentage cut off.*

Treatment	Av.Abund	Contrib%	Cum.%
SGR			
Hydroids	1.91	23.57	23.57
Turf	2.48	23.39	46.95
Alcyonium digitatum	1.83	20.88	67.84
Asterias rubens	0.46	6.36	74.19
Brittlestars	1.39	4.92	79.12
Encrusting sponges	0.62	4.82	83.94
Echinus esculentus	0.45	4.36	88.31
Large anemones	0.33	2.27	90.58
SAC			
Hydroids	0.94	26.52	26.52
Alcyonium digitatum	0.92	19.85	46.36
Brittlestars	2.52	13.75	60.12
Lanice conchilega	0.25	11.17	71.29
Asterias rubens	0.2	11	82.29
Munida rugosa	0.47	5.03	87.32
Turf	0.72	4.63	91.94
OC			
Hydroids	1.23	45.21	45.21
Alcyonium digitatum	0.56	12.44	57.65
Large anemones	0.46	10.83	68.48
Lanice conchilega	0.28	9.92	78.4
Turf	0.83	5.03	83.43
Asterias rubens	0.23	4.61	88.04
Munida rugosa	0.43	4.29	92.33

Table 3. *Results of PERMANOVA main test, and pairwise comparisons where applicable, for the response variable Abundance (Individual species), in response to the fixed factor Treatment (Tr). Bold type denotes statistical significance*

Source	df	SS	MS	*F*	P		
Hydroids							
Tr	2	1.126	0.563	1.0933	0.3558		
Area (Tr)	12	6.1794	0.5149	2.5775	**0.0164**		
Res	30	5.9935	0.1998				
Total	44	13.299					
Asterias rubens							
Tr	2	0.7921	0.3961	4.0789	**0.0482**	**pairwise**	**P**
Area (Tr)	12	1.1652	0.0097	2.5096	**0.0187**	SGR, SAC	**0.0314**
Res	30	1.1608	3.869			SGR, OC	**0.032**
Total	44	3.1181				OC,SAC	0.375
Alcyonium digitatum							
Tr	2	3.634	1.817	3.01	**0.0084**	**pairwise**	**P**
Area (Tr)	12	7.2437	0.6036	6.9747	**0.0001**	SGR, SAC	**0.038**
Res	30	2.5964	0.0086			SGR, OC	**0.0129**
Total	44	13.474				OC,SAC	0.835
Echinus esculentus							
Tr	2	1.8573	0.9286	2.9096	**0.0101**	**pairwise**	**P**
Area (Tr)	12	3.83	0.3191	16.357	**0.0001**	SGR, SAC	**0.0012**
Res	30	0.5853	0.0019			SGR, OC	**0.048**
Total	44	6.2726				OC,SAC	0.3928
Large anemones							
Tr	2	0.4356	0.2178	0.8254	0.4581		

Area (Tr)	12	3.1665	0.2638	1.8069	0.0963
Res	30	4.3747	0.1458		
Total	44	7.9769			
Munida rugosa					
Tr	2	0.0027	0.001	0.002	0.9808
Area (Tr)	12	5.8595	0.4883	3.2098	**0.005**
Res	30	4.5638	15.214		
Total	44	10.443			

Table 4. *Results of PERMANOVA main test and pairwise testing for the response variables Abundance, Species Richness and Assemblage composition (all baited video data), in response to the fixed factor Treatment (Tr). Bold type in P coloumn denotes statistical significance*

Source	**df**	**SS**	**MS**	***F***	**P**		
Abundance							
Tr	2	0.854	0.427	1.2395	0.3263		
Area (Tr)	12	4.1473	0.3456	2.1535	**0.049**		
Res	28	4.4937	0.1605				
Total	42	9.6397					
Species Richness							
Tr	2	0.0097	0.0048	0.2753	0.7996		
Area (Tr)	12	2.1222	0.1769	1.6021	0.1297		
Res	28	3.0908	0.1104				
Total	42	5.3362					
Assemblage Composition							
Tr	2	8225.4	4112.7	3.2803	**0.0267**	**pairwise**	**P**
Area (Tr)	12	15101	1258.4	2.5719	**0.0006**	SGR, SAC	0.0624
Res	28	13994	499.77			SGR, OC	**0.0279**
Total	42	37190				OC,SAC	0.9034

Table 5. *Results of SIMPER analyses of baited video assemblages within each Treatment. 90% cumulative contribution percentage cut off.*

Treatment	**Av.Abund**	**Contrib%**	**Cum.%**
SGR			
Limanda limanda	0.37	70.34	70.34
Gadus morhua	0.26	25.12	95.74
SAC			
Limanda limanda	1.26	100	100
OC			
Limanda limanda	1.23	98.82	98.82

Appendix C: Study site

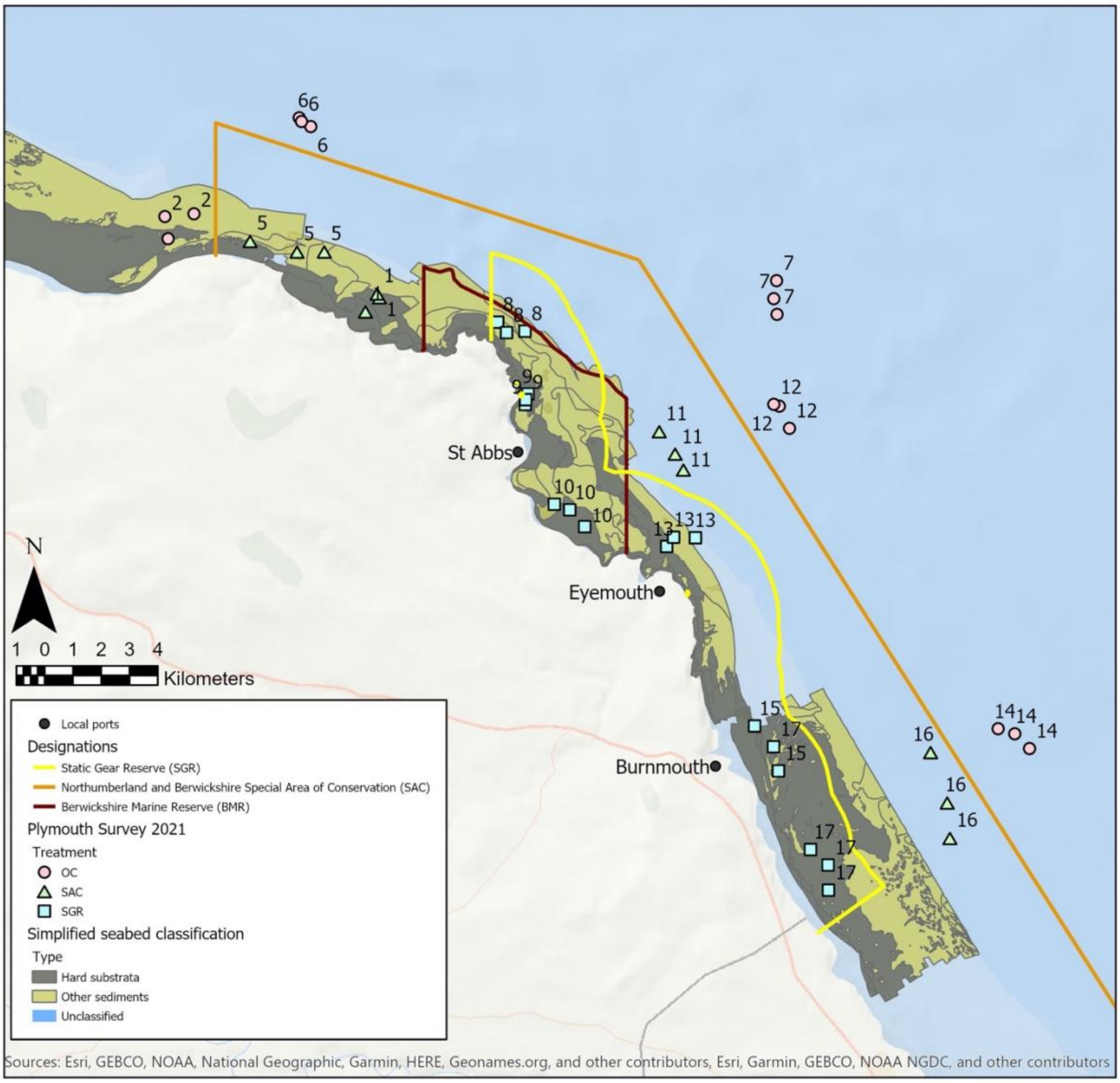

Figure 1. *UoP survey site locations in Berwickshire, coded by treatment (OC = Open Control, SAC = Berwickshire and Northumberland Special Area of Conservation, SGR = Static Gear Reserve), with 'site number' labelled.*

Appendix D: Species accumulation

20 replicate frames were chosen based on similar methods tested and used in a previous, similar, study (Stevens *et al.* 2014). In this previous study a series of analyses were undertaken to determine the number of frames per transect needed to provide robust biological information without sacrificing accuracy. These results showed that 33% of frames was a suitable number to accept. In this current study a 15 minute transect allowed ~63 (mean) frames to be extracted from each sample. 33% of 66 = 20.79 so we therefore determined that

a minimum of 20 frames per transect should be used to extract data for the whole study. A small subset of transects (those with highest species richness) were analysed for 30 frames and compared to results from the results of the samples using 20 frames. Cumulative species richness was calculated (Appendix D Figure 1). Here we show that for the dataset used for Berwickshire an additional 10 frames analysed equates to 0.075 (~4% of total species richness) additional species being identified (see unfilled circles in Appendix D Figure 1). This analysis validated the decision to extract 20 frames per transect.

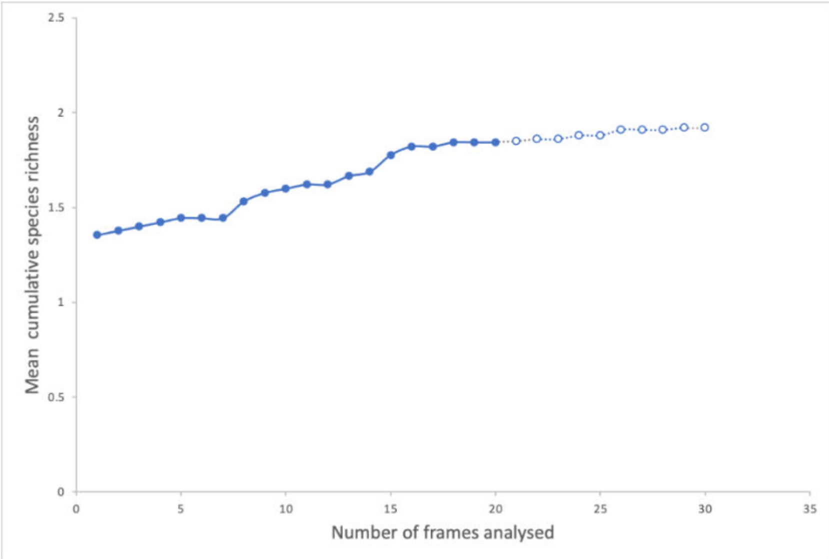

Figure 1. *Species accumulation curve (cumulative mean species richness per frame analysed) based on entire dataset extracted from frame grab analysis. Solid circles = first 20 frames, unfilled circles = additional subset of replicated analysed to 30 frames.*

General comments:

Treatments - I understand why you haven't included a BMR treatment (all the survey sites in the BMR lie within the SGR) but I think it's important to have BMR as a treatment for this baseline. There are areas inside the BMR that fall outside the SGR that we will have comparable dive data from, and I think important to have BMR treatment baseline to monitor any future BMR interventions against change etc

Can we make any observation about the health of the ecosystems in this survey? Do the results from SGR indicate healthy benthic ecosystem? Or is the fact that there is no significant difference suggest that current management isn't effective? I know not directly comparable, but can we draw some comparison or highlight what results look like from healthy benthic ecosystems, on rocky reef in MPAs where mobile fishing is banned? I.e Lyme?

The narrative of the exc summary needs edited slightly to move focus away fromthe BMR and more focus on understanding spatial differences from different marine designations- SGR, SAC and wider MPA etc

Be great to get all the raw data, can this include all GIS files so that we can add as layer to all our data for Beriwickshire?