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East Douglas Experimental Research Area: Baseline Status (2017/2018)

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Report to Isle of Man Government, Department of Environment, Food and Agriculture

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1 | Introduction

An Experimental Research Area (ERA) off the east coast of the Island was introduced as a closed area to fishing of king and queen scallops (*Pecten maximus* and *Aequipecten opercularis*) in July 2017. The position of the ERA was recommended by the Scallop Management Board (SMB) and encompassed a region where scallop densities have declined considerably in recent years (Figure 1). The purpose of the ERA is to test the performance of artificial spat receptors, in the absence of fishing pressure, as a means of increasing scallop recruitment in the area.

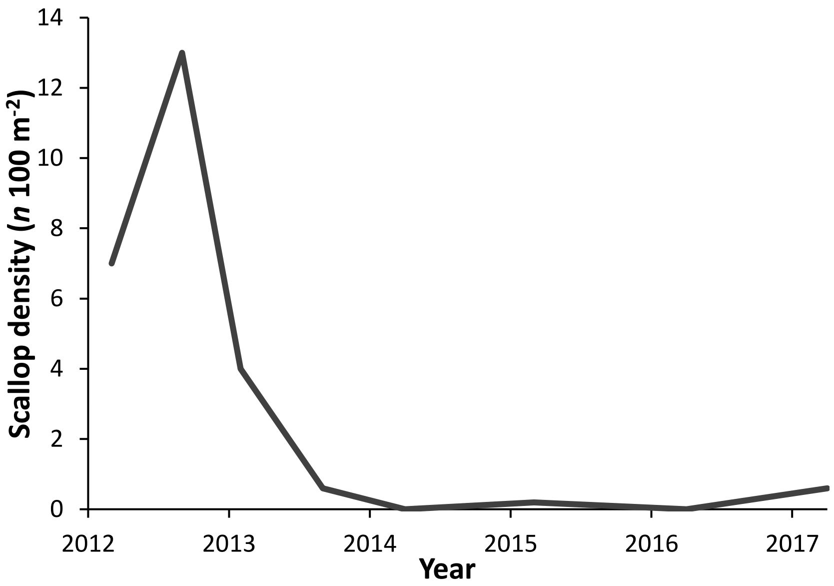

Figure 1. *Density of queen scallops (number of individuals per 100 m^2 of seabed) recorded in dredge catches at an annual stock assessment station (Station 29) within the ERA.*

Since its creation, a number of surveys have been completed within the ERA with the aim of assessing the baseline status of the area prior to the instalment of artificial spat receptors, with regard to scallop density, size and age, and bycatch diversity, and to examine the distribution of sediment types within the area. By providing a baseline, any changes in the area over time can be detected and quantified. In addition to these surveys, a successful 6-week trial deployment of a spat collector in the area was accomplished, before a full fieldwork programme deploying spat collectors and artificial spat receptors will be launched in 2019.

2 | Methods

The ERA, located just north of Laxey within the 0 - 3 nm limit, was split into four survey areas: two inshore areas (A1, B1) and two offshore areas (A2, B2) (Figure 2). A grid of 80 sampling stations was evenly distributed throughout the four areas, with the aim of establishing whether there were any important differences between the “A” areas and “B” areas, which will later be designated as treatment or control areas for deployment of artificial spat receptors (benthic settlement structures). It is intended that 12 artificial receptors (4 replicates of 3 designs) will be deployed on the seabed at random stations in each of the two treatment areas.

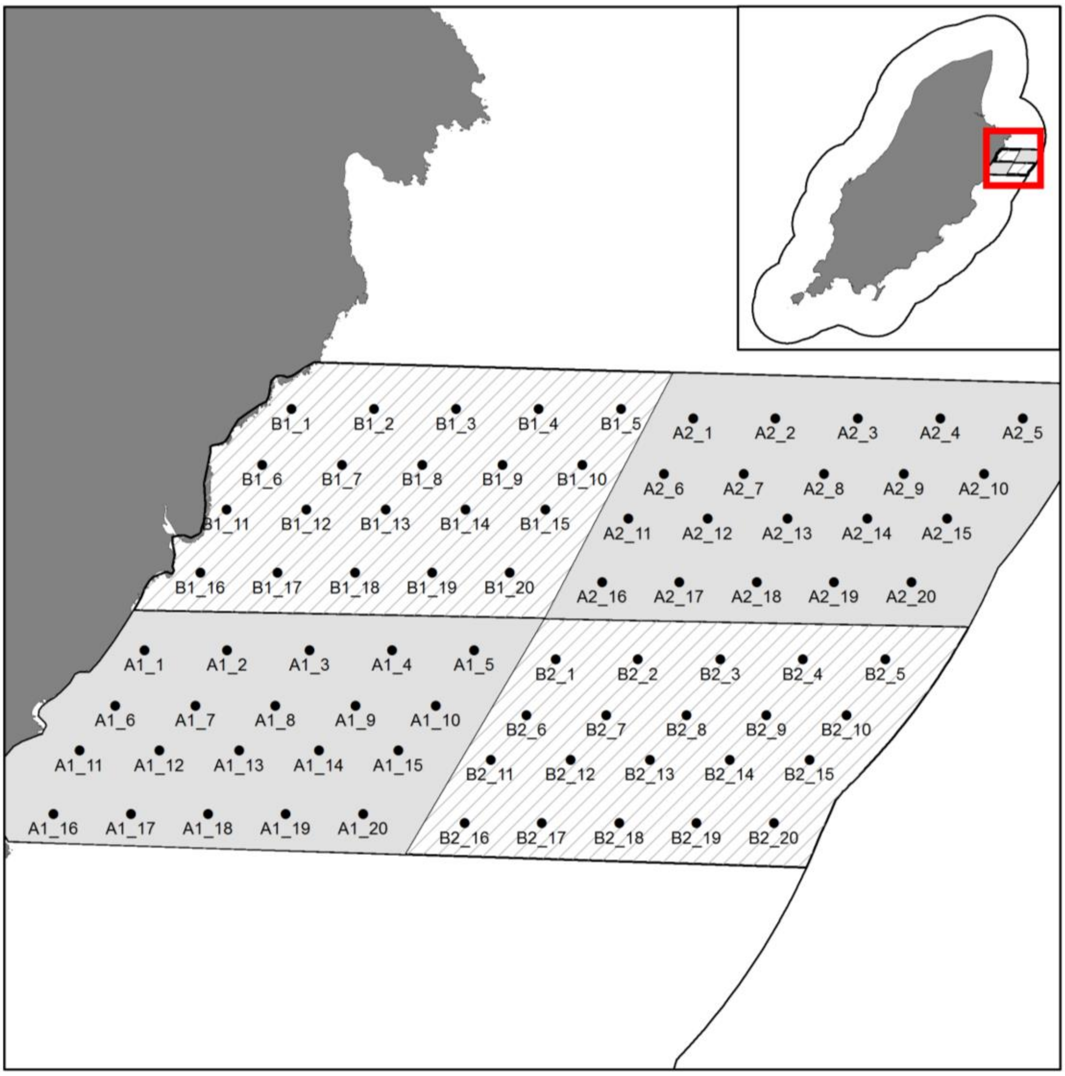

Figure 2. *Map showing the location of the ERA and the survey design, consisting of 20 stations in each area: A1 (inshore south); B1 (inshore north); A2 (offshore north); B2 (offshore south).*

The baseline surveys, which were carried out from the Isle of Man Government's fisheries protection vessel (F.P.V.) Barrule, included demersal fishing surveys to sample scallops and bycatch, and a drop-down camera survey to visually examine the benthic habitat. Demersal sampling was undertaken in the area using two approaches: beam trawling and dredging – although trawling has a higher sampling efficiency for queen scallops, dredges are required to catch king scallops. Beam trawl surveys were completed in October 2017 and October 2018, using comparable methods, in order to examine any initial changes in the epibenthic community (queen scallops and bycatch) that occurred over the year the area has been closed. Following this, the dredge survey and drop-down camera survey took place in October 2018, accounting for king scallops and seabed habitat type. Throughout the baseline surveys, a GPS logger was used to record the track of the vessel.

2.1 | Beam Trawl

Beam trawl surveys consisted of a series of 5-minute tows aimed to sample 16 randomly selected stations of the ERA (Figure 3), with the goal of sampling an even number of stations in each of the four areas. To achieve comparability, a 2 m beam trawl was used both years and each tow was 150 - 200 m in length, achieved by towing for 5 minutes at a speed of 1 - 1.5 knots. All tows were aimed to be in a straight line, against the tide whenever practical, and to pass through the station coordinate.

After each tow, the gear was retrieved for examination, and if the tow was deemed successful, the entire catch was emptied into a fish box ready for sorting. All live queen scallops were then removed from the catch and measured by shell height, with the remainder of the catch (bycatch) carefully sorted into taxonomic groups and the abundance of each species recorded.

2.2 | Dredge

The dredge survey consisted of eight 1.5 km tows, two in each area of the ERA (Figure 3), achieved by towing for 20 minutes at a speed of 2.5 knots. Because the sampling efficiency of dredges are lower than beam trawls, it was necessary to tow for longer and to pass through a sequence of stations in a straight line, rather than a single station as was executed in the beam trawl surveys. The gear consisted of 2 king scallop dredges (K) and 2 queen scallop dredges (Q) in configuration K, Q, Q, K.

In the same manner as the beam trawl survey, the gear was examined and the catch retrieved if the tow was successful. All live king scallops in the catches were measured by shell width, and aged by counting the number of growth rings, and queen scallops were measured by shell height. Bycatch was not captured in sufficient abundance for an analysis.

2.2 | Drop-down Camera

The drop-down camera gear consisted of a metal frame with two GoPros attached, which could then be lowered by a cable to rest on the seafloor. Footage of the seabed was taken at stations that had been sampled during the beam trawl surveys (Figure 3), with sediment type/habitat complexity expected to be important factors in determining the density and recruitment of scallops (Kostylev et al., 2003; Howarth et al. 2011). Stations that were captured during both beam trawl surveys were prioritised, and then stations sampled once in 2018 were randomly selected for the remaining time available. Lights were fitted to the frame to illuminate the seabed while the GoPros took 1 photo per second and continuous video footage, and the frame was moved to a different spot at least 3 times per station (determined by the boats drift), thereby capturing a larger area and ensuring the initial drop-down location did not have anomalous benthic characteristics.

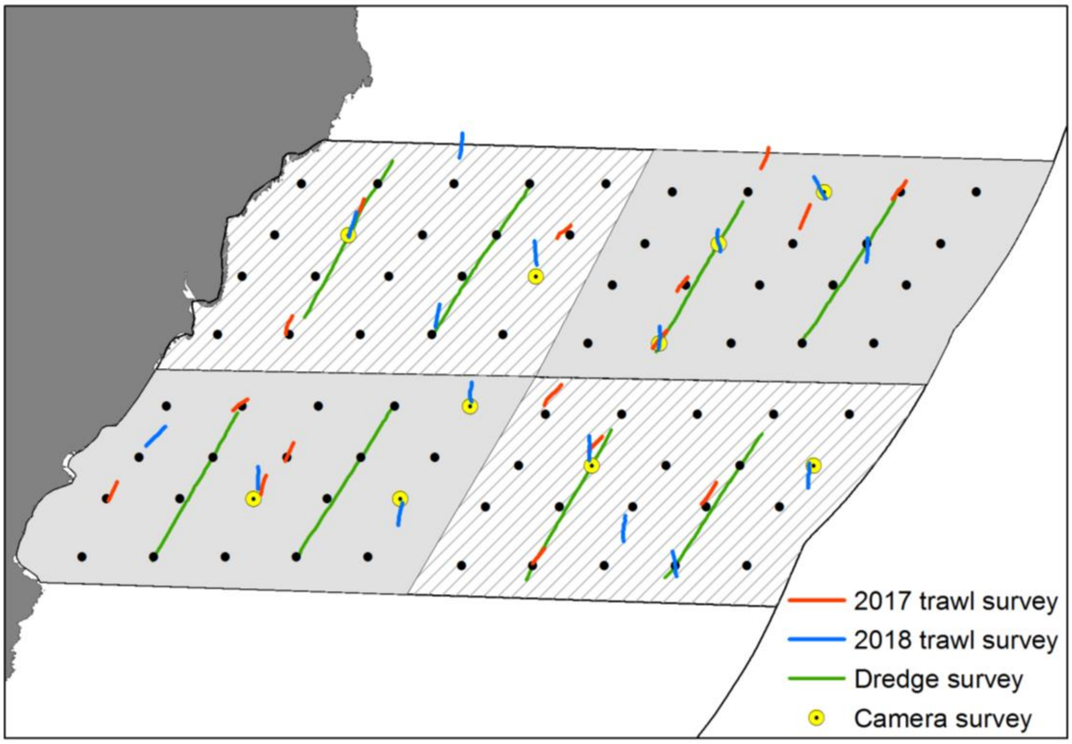

Figure 3. *Map displaying trawl and dredge tows, and drop-down camera locations (refer to Figure 1 for station names).*

2.3 | Data Analysis

Scallop densities from trawls and dredges were calculated by dividing the number of individuals (*n*) in each catch by the area of the tow: *n* / area; where area (m^2) = tow distance (m) x gear width (m). Tow distances were calculated using the data from the GPS logger, using ArcGIS (points to line) to determine the distance of the vessel track between the start and end times of each tow. Scallop size and age frequency distributions were created using R (CRAN: ggplot2), from which cohorts were visually defined and analysed separately. The densities of bycatch species in beam trawl catches were calculated in the same manner as the scallop densities, and the Shannon-Wiener diversity of bycatch from each tow was determined using R (diversity, CRAN: vegan).

Beam trawl data was analysed using two-way ANOVAs, testing the first and second order effects of area (A or B) and year (2017 or 2018) on the density and size cohorts of queen scallops, and the total density, species richness and diversity of bycatch. Dredge data was only collected once, and therefore t-tests were used to individually compare the densities and sizes of king and queen scallops between "A" and "B" areas in 2018 only. Queen scallop densities were calculated from Q dredges only as K dredges are not designed to catch queenies.

The drop-down camera footage was carefully examined and one image from each station selected as characteristic of that location. Stations were grouped into three main habitat types based on the sedimentary composition of the seabed, and a one-way ANOVA was used to determine whether queen scallop density (2018 beam trawl data) was significantly affected by sediment type. Finally, ArcGIS was used to create maps of sediment type and scallop densities measured in 2017 and 2018 in order to explore spatial patterns.

3 | Results

3.1 | Beam Trawl

In 2017, queen scallop densities ranged from 0.5 to 34.0 individuals per 100 m^2 (Table 1), with the overall mean density being 14.1 (refer to Figure 10 for spatial distributions). In 2018, densities ranged from 0.4 to 42.3 (Table 1), with an overall mean of 17.2, slightly higher than was found the previous year. However, this change in mean density from 2017 to 2018 was not statistically significant, and no difference was found between the "A" and "B" areas (Figure 4) (Table 3).

Table 1. *Seabed density estimates for queen scallops within the four areas of the ERA, caught in beam trawl tows during the two baseline surveys.*

Area	Station	Scallop density (*n* 100 m^{-2})	
		October 2017	***October 2018***
A1: Inshore south	A1_2	13.2	
	A1_5		21.9
	A1_6		1.2
	A1_11	0.5	
	A1_13	13.8	20.4
	A1_15		42.3
B1: Inshore north	B1_3		17.9
	B1_7	10.8	1.5
	B1_10	26.4	
	B1_15		25.9
	B1_17	14.5	
	B1_19		25.1
A2: Offshore north	A2_2	34.0	
	A2_3		29.1
	A2_4	10.2	
	A2_7		25.4
	A2_8	5.4	
	A2_9		15.9
	A2_12	25.1	
	A2_17	23.2	15.4
B2: Offshore south	B2_1	11.0	
	B2_7	5.6	11.3
	B2_10		4.3
	B2_13		0.4
	B2_14	3.8	
	B2_17	13.4	
	B2_19		17.1

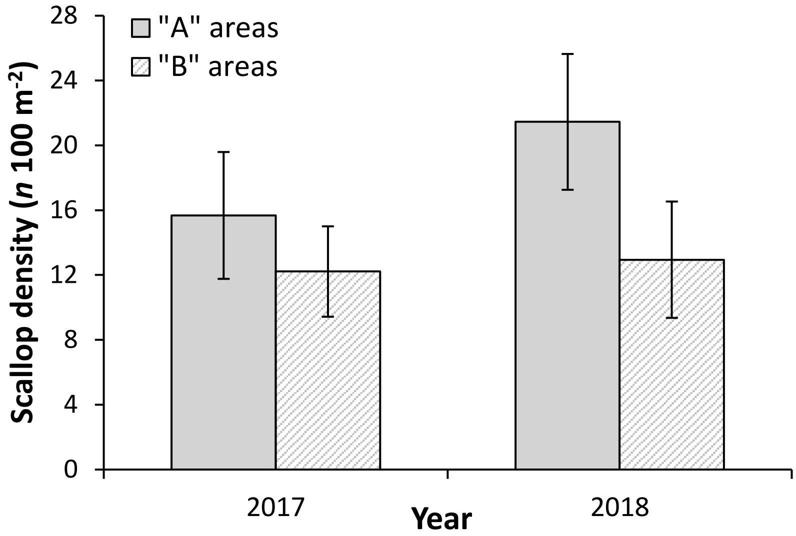

Figure 4. *Mean (± S.E.) density of queen scallops from trawls in the "A" and "B" areas of the ERA, sampled during baseline surveys in October 2017 and October 2018.*

The sizes of queen scallops (shell height) ranged from 8 to 73 mm and were distributed between two main size cohorts with median shell lengths of 21 and 51 mm (Figure 5). Although these cohorts were present regardless of area or year, significant differences in scallop sizes were detected in the smaller cohort (<38 mm) between years, and the larger cohort (≥38 mm) between areas and years (Table 3). The smaller cohort decreased in median size from 21 to 19 mm, due to some smaller new recruits being found, and the median size of the larger cohort also decreased slightly from 52 to 51 mm, possibly influenced by the growth of the smaller cohort from 2017 which became part of the larger cohort in 2018.

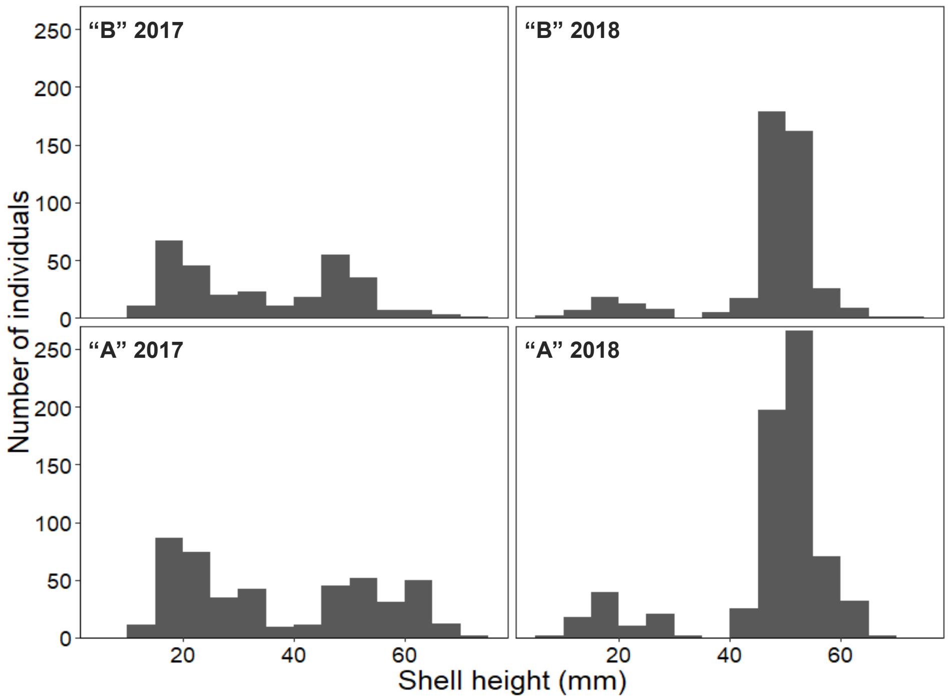

Figure 5. *Size distribution (shell height in mm) of all queen scallops caught in the "A" and "B" areas of the ERA during the 2017 and 2018 beam trawl surveys.*

During the 2017 beam trawl survey, the mean density of bycatch was 42 individuals per 100 m^2, with an average of 15 species per tow. The most common taxa were echinoderms (65%) and crustaceans (22%), with the most abundant species being *Ophiura ophiura* (Table 2), which made up on average 30% of the catch. The subsequent survey in 2018 yielded similar results, with an average density of 51 individuals per 100 m^2 and 16 species per tow. The most common taxa continued to be echinoderms (60%) and crustaceans (27%), and the most abundant species was *Psammechinus miliaris*, closely followed by *Ophiothrix fragilis* (Table 2). No significant differences were found in total bycatch density, species richness or Shannon's diversity between 2017 and 2018, nor between "A" and "B" areas (Table 3, Figure 6).

Table 2. *Mean densities of the most common bycatch species found during the 2017 and 2018 beam trawl surveys, defined as those whose abundance collectively added to at least 1 n 100 m^{-2}.*

Species	**Mean density (*n* 100 m^{-2})**	
	October 2017	***October 2018***
Serpent star (*Ophiura ophiura*)	12.5	6.6
Green sea urchin (*Psammechinus miliaris*)	4.6	13.4
Common brittle star (*Ophiothrix fragilis*)	4.4	11.1
Cloaked hermit crab (*Pagurus prideaux*)	5.6	6.9
Common starfish (*Asterias rubens*)	3.2	1.2
Serpent's table brittle star (*Ophiura albida*)	-	2.8
Common dragonet (*Callionymus lyra*)	1.5	0.9
Spider crab (*Inachus* spp.)	2.2	-
Dead man's fingers (*Alcyonium digitatum*)	0.1	1.8
Black brittle star (*Ophiocomina nigra*)	1.4	0.2
Sea squirt (*Ciona intestinalis*)	1.4	0.2
Hermit crab (*Pagurus bernhardus*)	0.6	0.9
Long-legged spider crab (*Macropodia* sp.)	0.4	0.9
Common whelk (*Buccinum undatum*)	0.9	0.2
Sand star (*Astropecten irregularis*)	0.7	0.3

Table 3. *Results of two-way ANOVAs on beam trawl survey data (queen scallops and bycatch), testing the first and second order effects of area (A, B) and year (2017, 2018). "Cohort 1": <38 mm; "cohort 2": ≥38 mm.*

Response		**Area**		**Year**		**Area:Year**	
	d.f.	*F*	*p*	*F*	*P*	*F*	*p*
Sallop density (*n* 100 m^{-2})	1, 27	2.53	0.12	0.78	0.38	0.47	0.50
Scallop size (mm) cohort 1	1, 561	0.57	0.45	33.50	<0.001*	0.11	0.74
Scallop size (mm) cohort 2	1, 1325	71.66	<0.001*	35.09	<0.001*	36.85	<0.001*
Bycatch density (*n* 100 m^{-2})	1, 26	1.05	0.32	0.62	0.44	0.16	0.69
Bycatch species richness	1, 26	4.22	0.50 .	0.82	0.37	0.27	0.61
Bycatch diversity (H')	1, 26	1.43	0.24	0.95	0.34	0.22	0.64

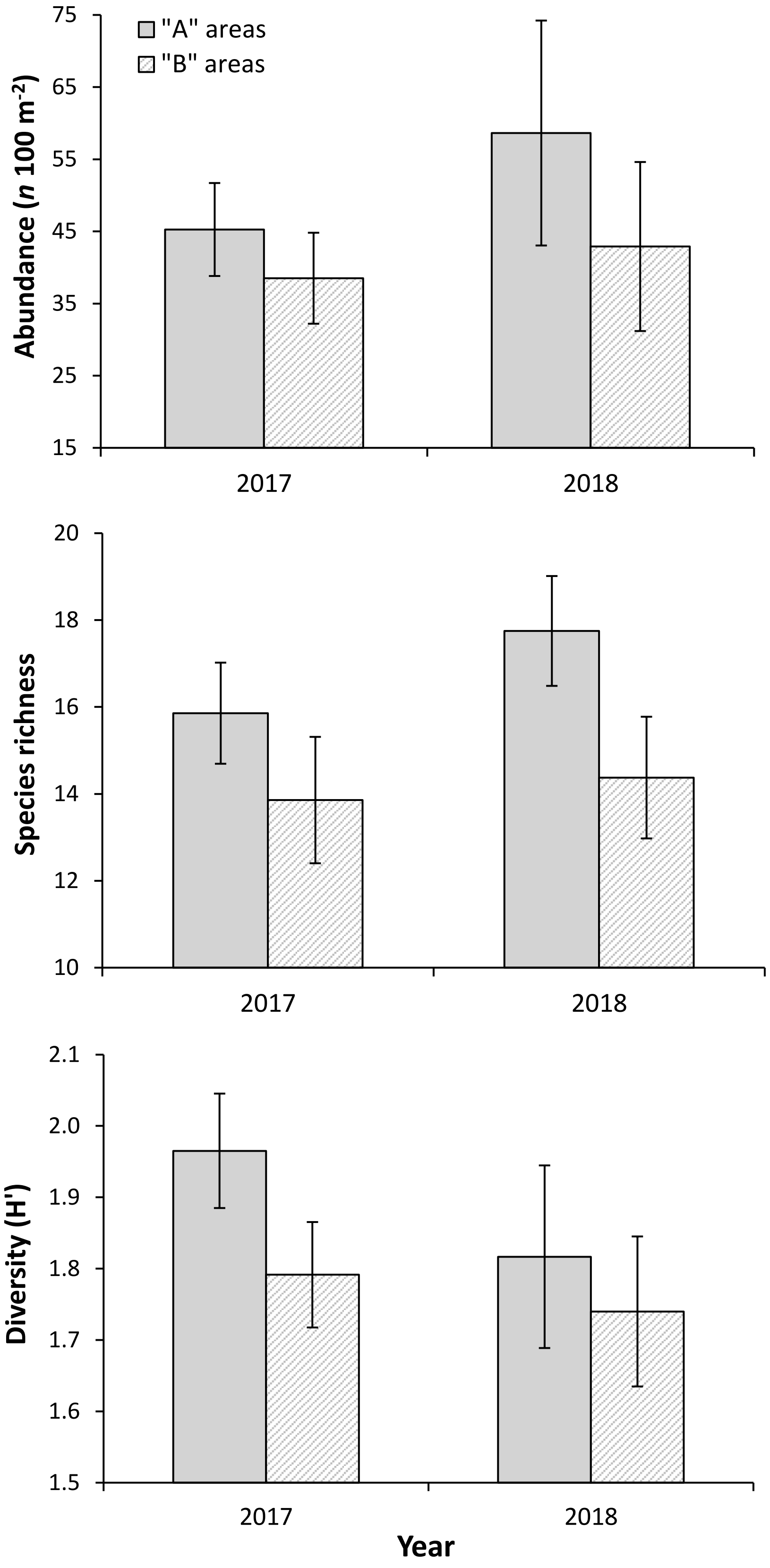

Figure 6. *Mean (± S.E.) abundance (total number of individuals per 100 m^2 of seabed), species richness (total number of species) and Shannon's diversity (H') of the bycatch community caught in the "A" and "B" areas of the ERA during the 2017 and 2018 beam trawl surveys.*

3.2 | Dredge

The scallop composition of dredge catches was 37% king scallops and 63% queen scallops on average. King scallop densities ranged from 0.1 to 0.7 individuals per 100 m^2, while queen scallop densities ranged from 0.1 to 7.9, with the overall mean densities being 0.3 and 1.8 for kings and queens respectively. The mean density of king scallops did not significantly differ between “A” and “B” areas ($t_{(4.9)}$ = -1.13, p = 0.31), and although the mean density of queen scallops was greater in “A” areas (Figure 7), this difference was not significant ($t_{(3.1)}$ = -1.44, p = 0.24) as it was driven predominately by a single tow, where abundance was nearly 3 times greater than any other.

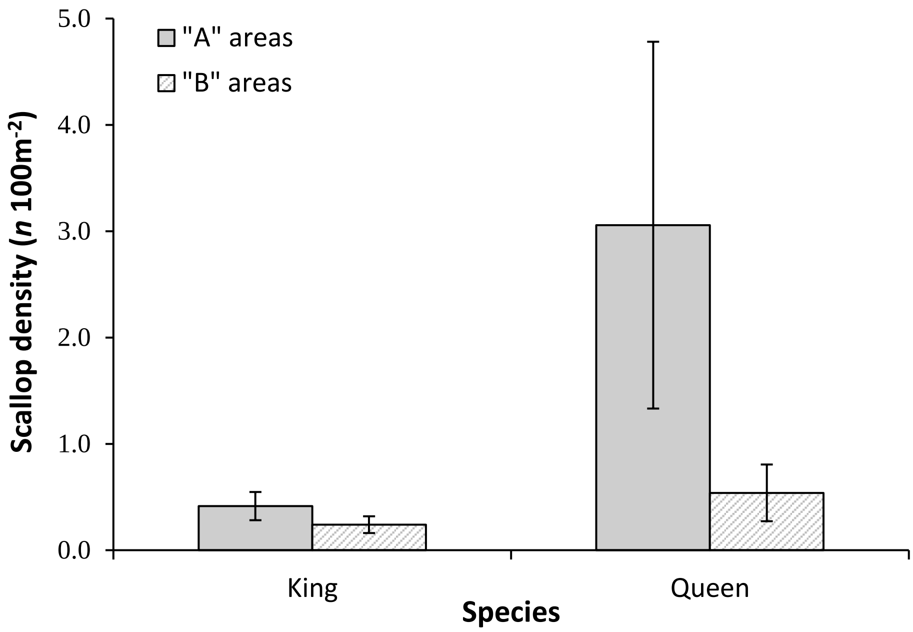

Figure 7. *Mean (± S.E.) densities of king and queen scallops from dredges within the “A” and “B” areas of the ERA, sampled October 2018. King scallops – all dredges; queen scallops – queen dredges only.*

The size distribution of queen scallops displayed a single cohort with a median shell height of 51 mm (Figure 8), regardless of area ($t_{(77.0)}$ = -0.42, p = 0.68), and corresponding exactly to the larger size cohort in the beam trawl data (Figure 5). The smaller cohort (recruits) that was present in beam trawl catches was not captured by dredging, which is designed to target larger individuals.

King scallops, however, did display a bimodal distribution, in shell width (Figure 8) and also arguably in age (Figure 9), although the older age cohort was less well-represented in catches from “B” areas. The median sizes (shell width) of the king scallop cohorts were 90 and 125 mm, with median ages of 2^+ and 5^+.

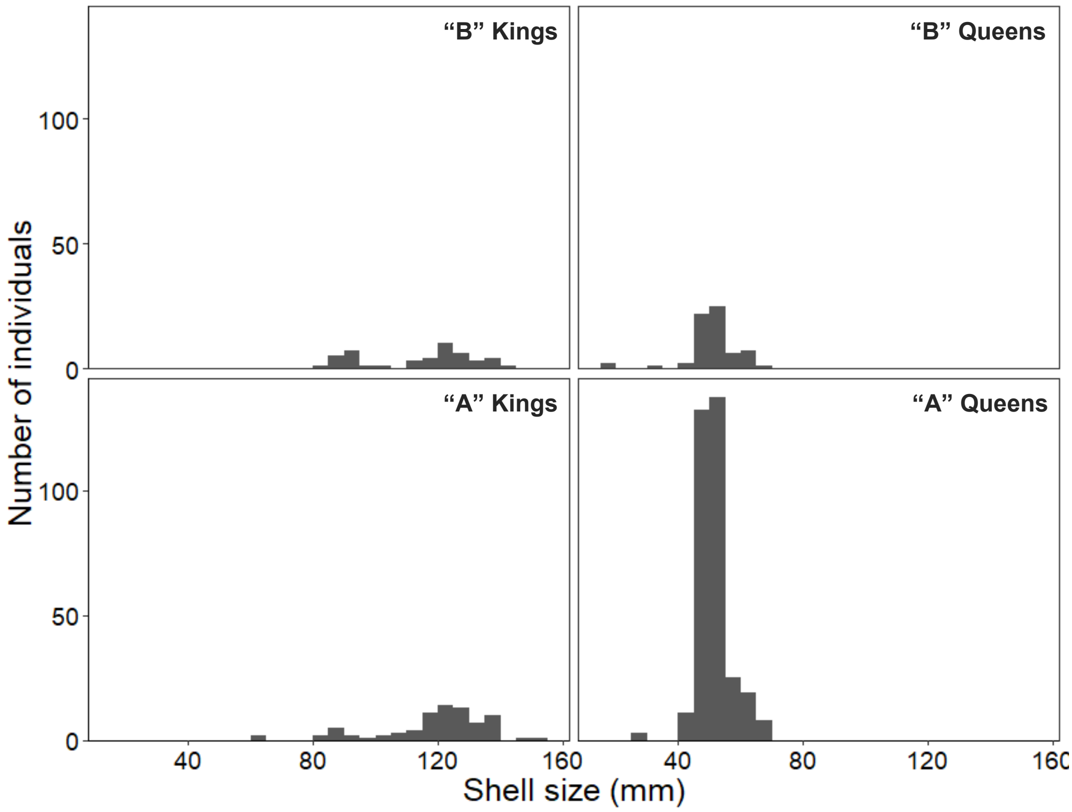

Figure 8. *Size distribution of all king scallops (shell width) and queen scallops (shell height) caught in the "A" and "B" areas of the ERA during the dredge survey.*

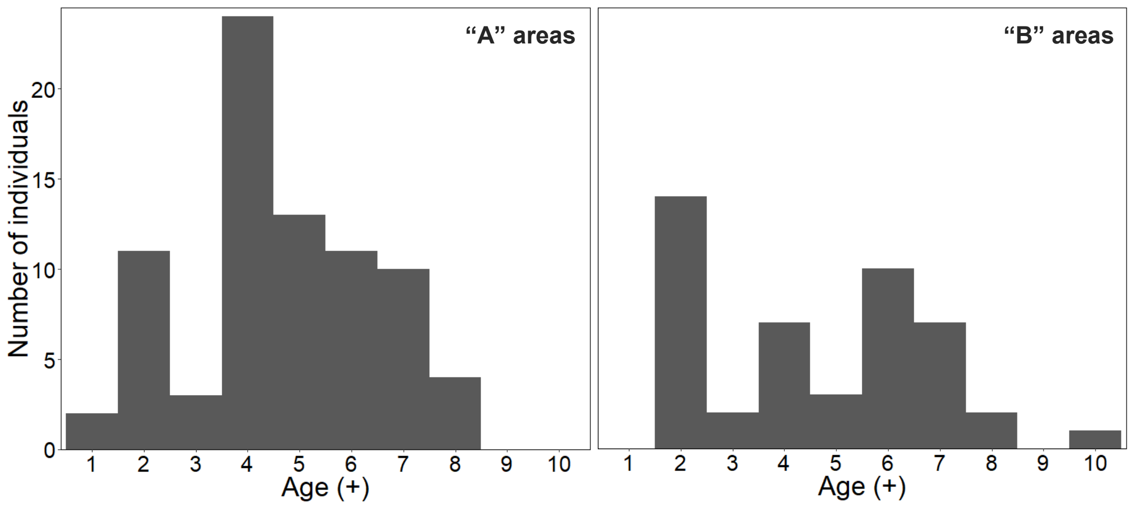

Figure 9. *Age distribution of king scallops caught in the "A" and "B" areas of the ERA during the dredge survey.*

3.3 | Drop-down Camera

Six "A" stations and four "B" stations were visited during the camera survey, with a minimum of two stations in each of the four areas (Figure 10). Seabed sediment type varied noticeably between areas, and also between stations within an area (Figure 10). The southern inshore area (A1) was the most gravelly, also containing lots of shell fragments and brittlestars and frequent sea urchins. The northern offshore area (A2) contained finer sediment, also with some shell fragments and echinoderms, although the gravel was absent. The northern inshore area (B1) contained lots of shells but no gravel patches, and the southern offshore area (B2) contained finer sediment and frequent brittlestars, and was similar in appearance to the other offshore area (Figure 11).

Based on the footage, three main habitat types were identified: gravelly sand (sand with gravel); mixed sand (large particles present e.g. whole shells, but no or very little gravel); and clean sand (sand without large particles such as shells or gravel, although shell fragments may still be common). Although there is a correlation between the distribution of sediment types and scallop densities (Figure 10), with gravelly areas containing the highest mean densities of scallops (Figure 12), the effect of sediment type was not statistically significant ($F_{(2,7)}$ = 1.48, p = 0.29).

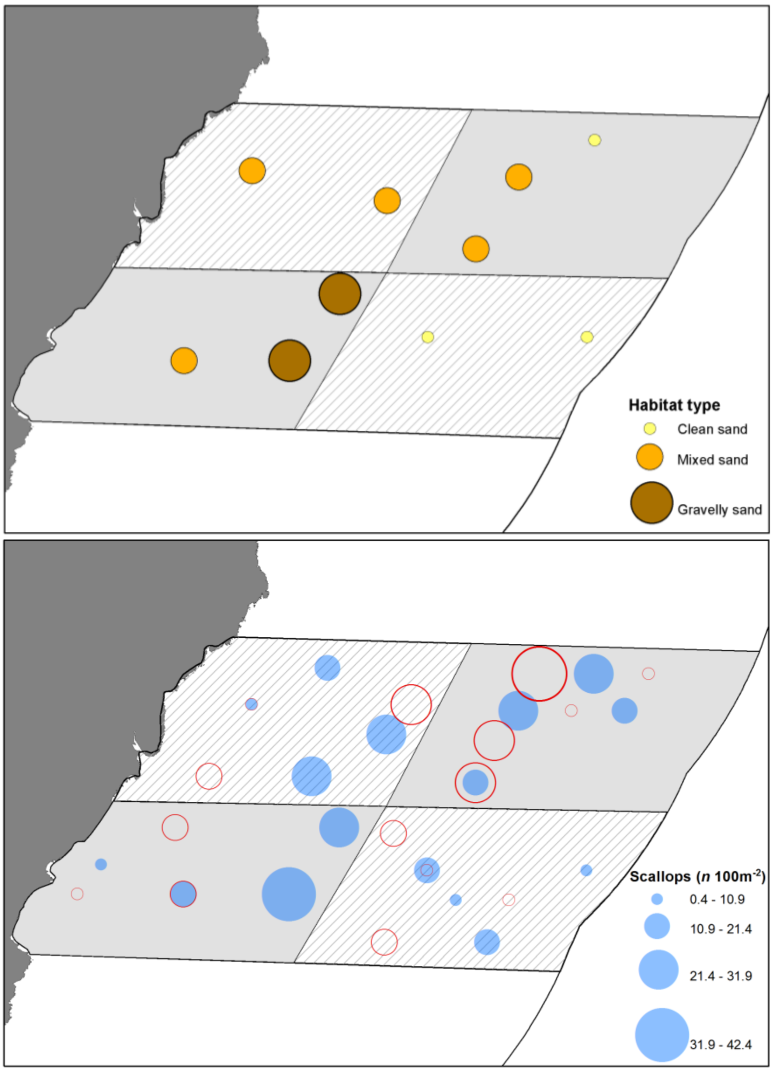

Figure 10. *General distribution of sediment types in the ERA based on data from drop-down camera footage, compared to queen scallop densities from beam trawl surveys in 2018 (blue circle) and 2017 (red outline).*

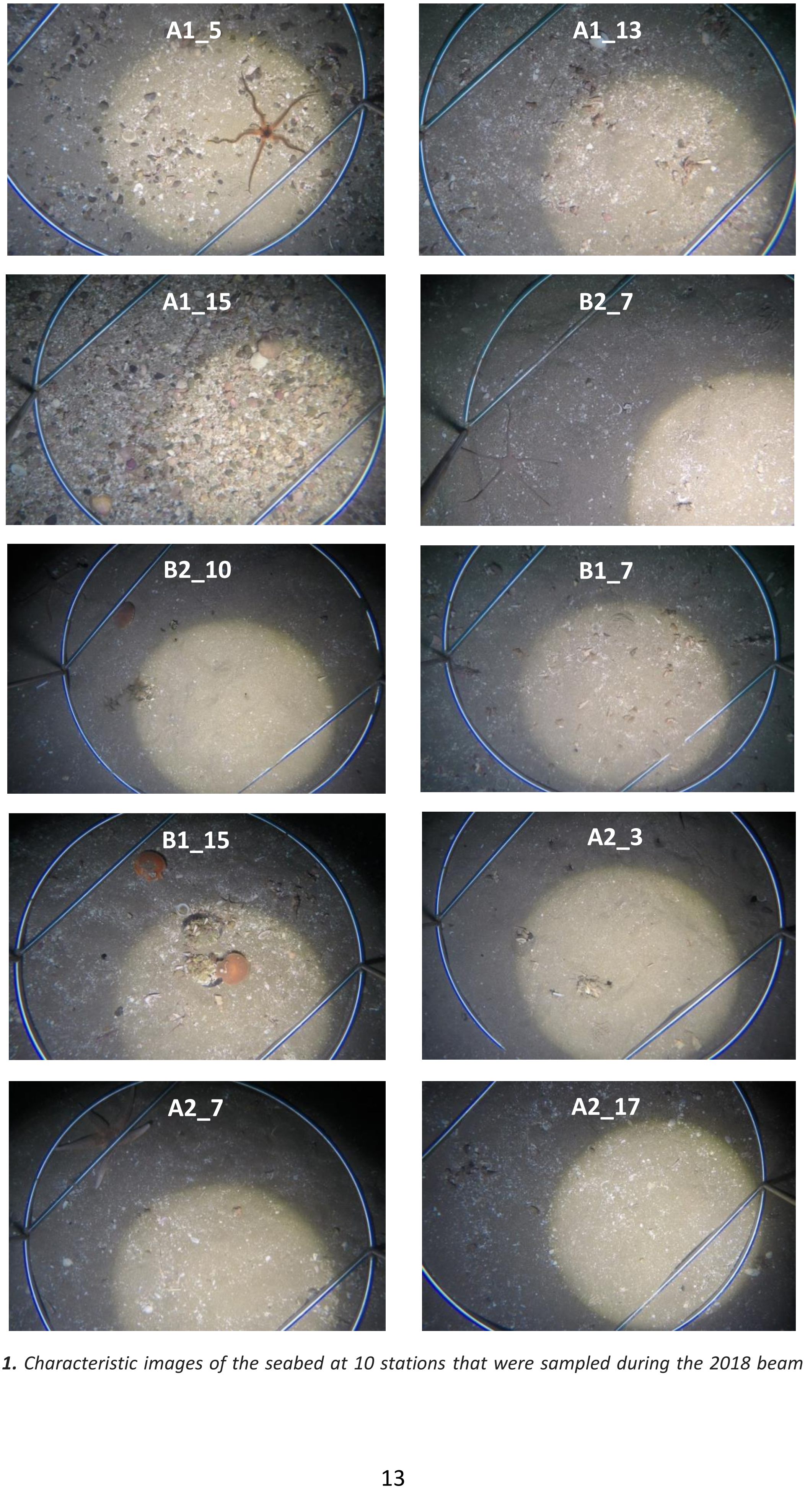

Figure 11. *Characteristic images of the seabed at 10 stations that were sampled during the 2018 beam trawl survey.*

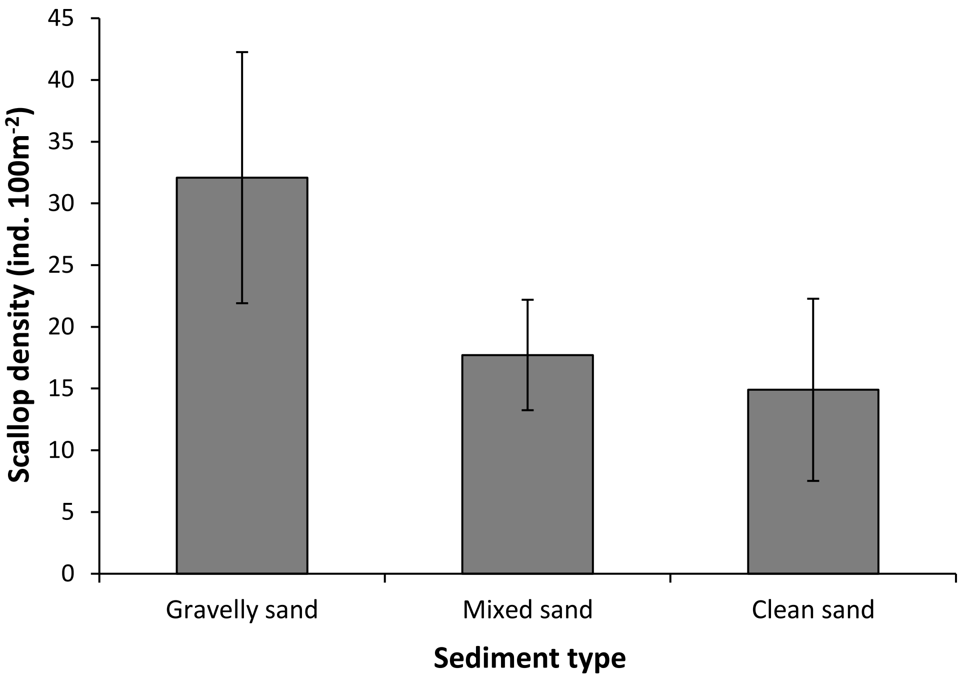

Figure 12. *Mean (± S.E.) densities of queen scallops from beam trawl catches (2018 data) at stations for which camera footage of the seabed was available.*

4 | Future Work

The results from these initial surveys provide important data regarding scallop densities, their size, age and spatial distributions, the composition of bycatch, and an insight into the distribution of different sediment types within the ERA. This data will be used in formulating a suitable strategy for deploying artificial spat receptors in the area, with the aim of increasing scallop recruitment, and will be used as a baseline in order to detect resulting changes and assess the success of the programme.

Although the baseline surveys found the potential treatment and control areas (A and B) to not be significantly different, there was a clear trend towards “A” areas containing higher mean abundances of queen scallops and bycatch, likely driven by the gravelly patch in area A1. Before artificial spat receptors are deployed, further camera footage will be collected (ideally of every sampling station in the ERA) in order to better understand any differences between areas and decide whether a modified approach is necessary.

Going forward, it is intended that three different types of benthic settlement strucutres, likely including an X-shaped mesh receptor (Fegley et al., 2009) and lobster pots with frayed ropes attached, will be trialled in the ERA, with 4 replicates of each design in each of the two treatment areas. Traditional spat collectors (suspended onion bags) will be deployed evenly in treatment and control areas to monitor spat abundance. This programme is expected to launch in 2019, after a separate project proposal is published detailing the final methods and rationale for the work.

5 | References

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