



Centre for Environment  
Fisheries & Aquaculture  
Science



**Cefas**

# **Assessment of king scallop stock status for selected waters around the English coast 2020/2021 – Annexe**

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# 1. Scallop biological sampling procedure

## 1.1. Methodology

The fishing industry proposed a methodology for the sampling procedure, which is a modification of an earlier scheme:

1. Cefas identifies sampling opportunities based on regular reports of the positions of participating vessels from the Vessel Monitoring Scheme (VMS) and requests a length or age sample from the processor.
2. The processor contacts the vessel operator by phone or internet-based messaging and requests a sample to be collected from the next haul.
3. The vessel crew collect a bag of scallops in a labelled and coloured bag (to aid identification at the processor) and land it along with the rest of the catch. Length samples are retained in red bags, and those for age determination are retained in a blue bag.
4. At the processors, the industry staff measure the length samples (height of round shell perpendicular to hinge) and return the size distributions along with sample weight and sample details to Cefas. Age samples are processed at the factory as per the usual procedure, but flat shells are sent to Cefas for age determination.

5. A supplementary and opportunistic method was introduced, where samples are pre-ordered by the processor contacts in consideration of target shortfalls.

In the laboratory, low power microscopes are used to confirm age, as growth rings observed with the naked eye have shown to be unreliable in the English Channel. Initial ages are checked and, where discrepancies exist between readers, are determined by consensus.

## **1.2. Sampling targets**

The spatial distribution of fishing effort and catches within each fishing season can be difficult to predict and appears to be influenced by irregular recruitment events. VMS data were used to define ICES statistical rectangles where fishing activity had occurred over the past 8 years and warranted sampling. Sampling targets in the first year (2017) were set at 5 length samples per rectangle per quarter year, where one of the length samples is retained for subsequent age determination to facilitate the construction of an age-length key for each rectangle. From 2018, sampling targets were revised to better reflect fishing patterns as defined by reported landings. One sample was requested for a threshold of 1 tonne of scallop landed per rectangle and then another for each subsequent 50 tonnes. To provide an improved estimation of age structure, two age samples were requested for every 3 length samples.

In a process parallel to that used by finfish stock assessments, estimates of the age composition of landings were obtained from length distributions through conversion to ages by means of an age-length key.

Given the limited mobility of scallops, together with pre-existing knowledge on the patchiness of scallop settlement and variability in growth rates, the sampling strata employed for scallops are much smaller than those for finfish.

The basic strata for the targeting of age and length are ICES statistical rectangles and reported landings. Samples are requested from a vessel when it is observed to be fishing in an area on a given day (using VMS data). The unit of sampling is therefore a combination of vessel, rectangle and day.

## **1.3. Data raising process**

### **Age-length key (ALK)**

1. From the age samples (blue-bag), 5 shells per 5-mm length class are retained for age-determination.
2. Within each 5-mm length class, the proportion of each age was determined to give an ALK for each rectangle-quarter stratum.
3. To fill any strata for which there were missing ALKs, all age (blue-bag) samples were pooled to the quarter - assessment area level to generate an ALK for each un-sampled rectangle within that assessment area.

## **Length distribution**

4. Sample length distributions (LDs) were raised to the reported catch of the vessel within the day, using the ratio of reported sample weight to landings.
5. Sample LDs and weights from step 4 were aggregated to the level of rectangle and quarter.
6. The pooled LDs from step 5 were raised to the total UK landings for that rectangle and quarter using the ratio of the sampled weight to total landings.
7. Not all strata with landings records had length samples. Missing strata were assumed to come from the same length distribution as the aggregate quarter – assessment area. The LDs from step 6 were pooled and then raised to each missing stratum using the ratio of sampled weight to strata landings.
8. Numbers in each size class from step 7 were summed within each stock assessment area and sampling season (quarter 4 of the previous calendar year plus quarters 1-3 of the current year) to give total numbers in each size class per assessment area and sampling season.

## **Age distribution**

9. For directly sampled strata, the raised rectangle-quarter numbers-at-length were multiplied by the corresponding ALK and then summed to give the total numbers-at-age per rectangle-quarter
10. For un-sampled strata, the in-fill LDs (step 7) were multiplied by the in-fill ALK (step 3) and summed to give numbers-at-age per un-sampled rectangle-quarter.
11. These numbers-at-age were summed over all quarters and rectangles within each stock assessment area and for each sampling season to give total removals-at-age per assessment area and sampling season.

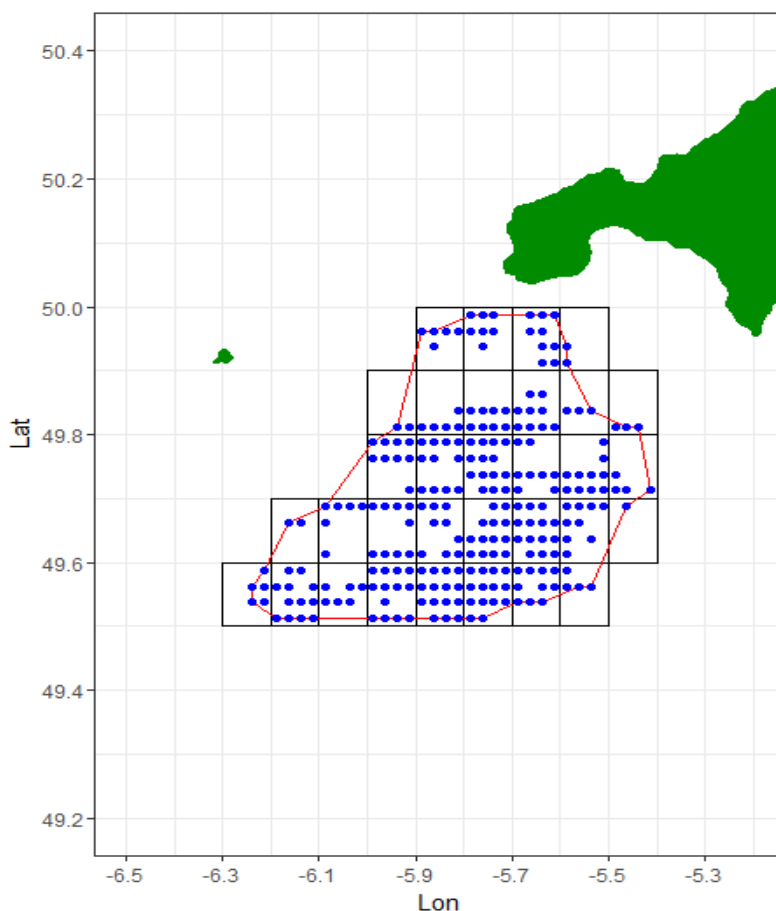
# **2. Dredge survey design**

## **2.1. Terminology**

The following spatial areas were used during the survey design process:

- **Bed** – An irregular outline representing a fished scallop ground, identified using Vessel Monitoring System (VMS) data.
- **Block** – A regular coordinate grid of 0.1-by-0.1-degree rectangles, with an approximate area of 80 km<sup>2</sup>.
- **Cell** – A regular coordinate grid of 0.025-by-0.025-degree rectangles, with an approximate area of 5 km<sup>2</sup>, and a maximum of 16 cells per block (4 by 4). This is the scale to which VMS data are aggregated as part of the survey design methodology. Mid-points of cells are used as potential sampling positions, randomly selected as part of the dredge survey design. This also forms the grid over which the data are raised to calculate the bed biomass and age-length population structure.
- **Valid cell** – A cell for which fishing activity has been identified based on VMS data.
- **Valid block** – A block with a specific minimum number of valid cells.

These concepts are graphically presented in Figure 2.1.



**Figure 2.1: An example scallop dredge bed (red outline) with 0.1-degree blocks (black) and 0.025-degree cells (blue).**



## 2.2. Identification of scallop beds

VMS data for fishing trips during the 2009-2016 period, during which scallop dredges were deployed, were used to identify the location of scallop grounds targeted by the commercial scallop dredge fleet in the English Channel. For the first four years of data, only vessels with lengths of at least 15 m were available, but changes to the VMS scheme enabled all vessels with lengths of 12 m and above to be included from 2013.

VMS data were processed as follows:

- Vessels were assumed to be fishing when the reported speed was between 1 and 5 knots. This speed range was used to remove records where vessels were likely to be transiting between grounds, or in harbour.
- VMS data were aggregated to cell level (on a 0.025-degree grid). Cells with less than 10 reported positions over the full-time series were removed.
- A measure of landings per unit effort (LPUE) was derived for each VMS position by dividing the reported trip landings for the relevant combination of vessel-day-rectangle by the fishing hours estimated from VMS data for the same strata.

Bed boundary polygons were created using the R function `ashape` from the `alphahull` package. This function uses the algorithm defined by (Edelsbrunner, et al., 1983) to construct an  $\alpha$ -shape around a set of points, in this case VMS points (cells), based upon the Delaunay triangulation.

The resulting  $\alpha$ -shape was converted to a polygon (bed outline) representing a scallop fishing ground. Within each bed are patches where VMS data are absent. These are represented as areas without valid cells (Figure 2.1). When aggregating the survey results within each scallop bed, only those cells with scallop-related VMS points are used. The assumption is that no commercial fishing (at least by vessels that are part of the VMS scheme) takes place in these cells, and that therefore there are no scallops in those cells that are accessible to standard fishing gear.

For the 2017 survey season, eight scallop beds within ICES Division 27.7.e, and one scallop bed within Division 27.7.d were defined using the above approach. In 2018 three additional scallop beds were identified using the same time series of VMS data, one in Division 27.7.f and two in Division 27.4.b. Following expansion of the fishery in Division 27.7.d., a further bed (7.d.2.) was identified by including 2017 fishing activity in the VMS time series. For the 2021 survey season, five beds in the Dogger Bank area (Division 27.4.b) were defined based on 2020 VMS data.

## 2.3. Station selection

A random stratified sampling design was used. As it is not clear if scallop density is randomly distributed across the whole bed, it was considered important to ensure broad spatial coverage of the sampling design. Therefore, within each bed, blocks were used to represent the different strata. Broad spatial coverage is provided by ensuring that most blocks are sampled. Within each block, one valid cell was selected at random, the midpoint of which is a potential sampling position. This procedure ensures that stations are only placed in areas commercially fished for scallops, and generates mean tow position separations in line with those suggested by earlier scoping work carried out in 2016 (Lawler, 2017; unpublished).

For the available survey time, it is not possible to sample each block which intersects the bed boundary. Many blocks, particularly around the boundary have very few valid cells contained within them (Figure 2.2, Figure 2.3, Figure 2.4, and Figure 2.5). A protocol was therefore developed to ensure that the sampled blocks represent as many of the valid cells as possible within the sampling time frame. For each bed, a threshold number of valid cells per block was established such that around 85% of the cells within each bed fell inside the sampled blocks. Table 2.1 gives the minimum number of valid cells per bed. This ensures that the main fishing areas are sampled within each bed, and the number of stations are consistent with the optimal tow separation suggested by the earlier scoping work. However, it does also mean that densities around the boundary of each bed are less well sampled, which could introduce bias into the approach, if there is a steeper gradient of density along bed boundaries than in the main fishing grounds.

**Table 2.1: Minimum number of cells used to determine whether a block is deemed valid for being surveyed.**

Bed	Total Number of Intersecting Blocks	Cell Threshold	Blocks Dropped	Cells Dropped	% Cells Dropped	Number of Stations
4.b.1	38	4	15	33	11	23
4.b.2	8	2	4	6	20	4
7.d.1	100	8	31	91	8	69
7.e.1	32	5	11	36	14	21
7.e.2	47	9	13	60	11	34
7.e.3	3	2	1	2	13	2
7.e.4	46	6	15	65	14	31

Bed	Total Number of Intersecting Blocks	Cell Threshold	Blocks Dropped	Cells Dropped	% Cells Dropped	Number of Stations
7.e.5	30	4	11	27	11	19
7.e.6	5	2	2	3	11	3
7.e.7	11	3	4	9	11	7
7.e.8	37	6	15	47	13	22
7.f.1	21	5	8	19	12	13

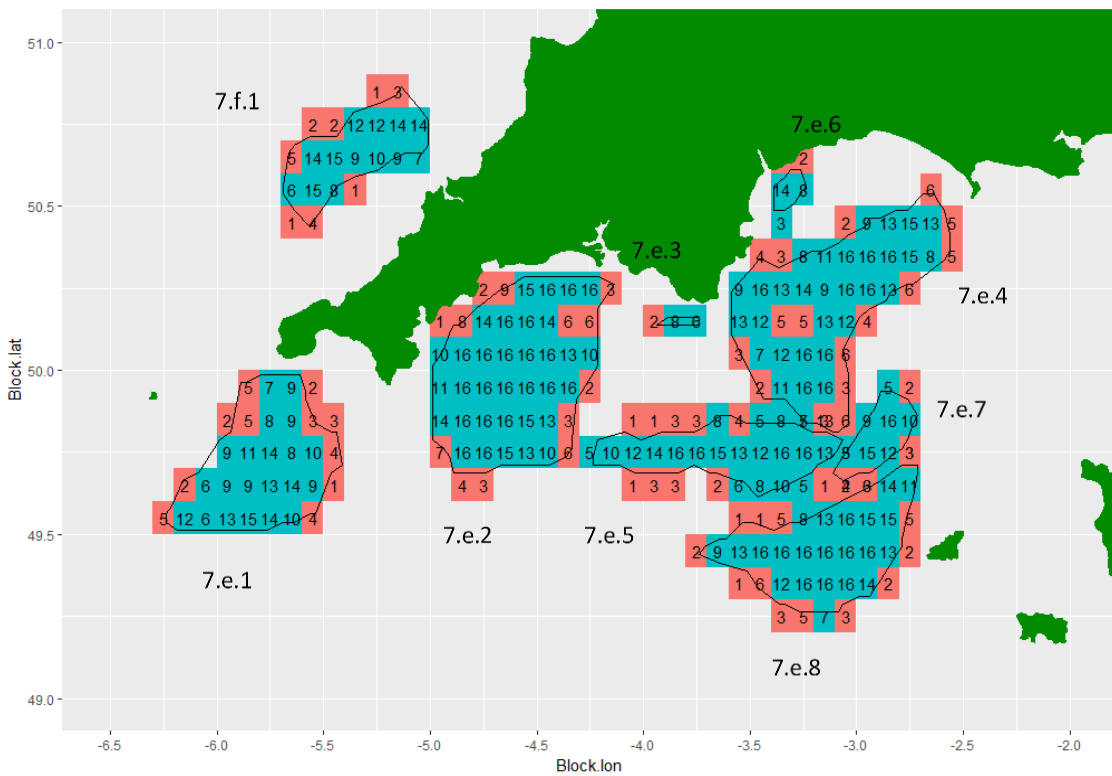
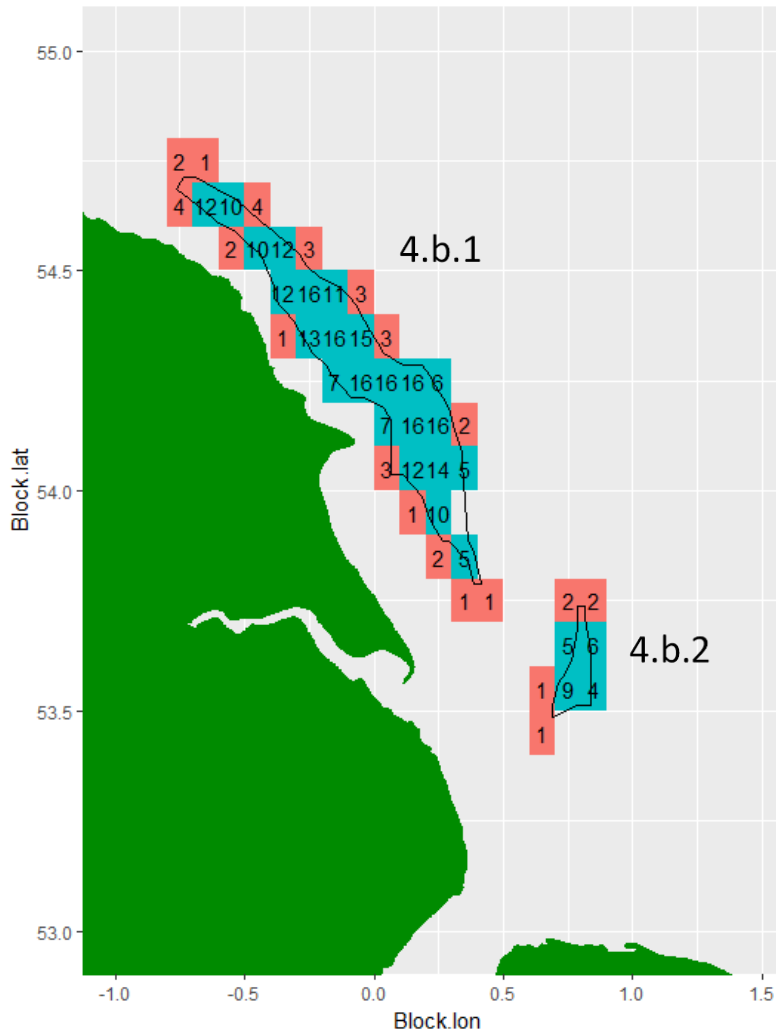
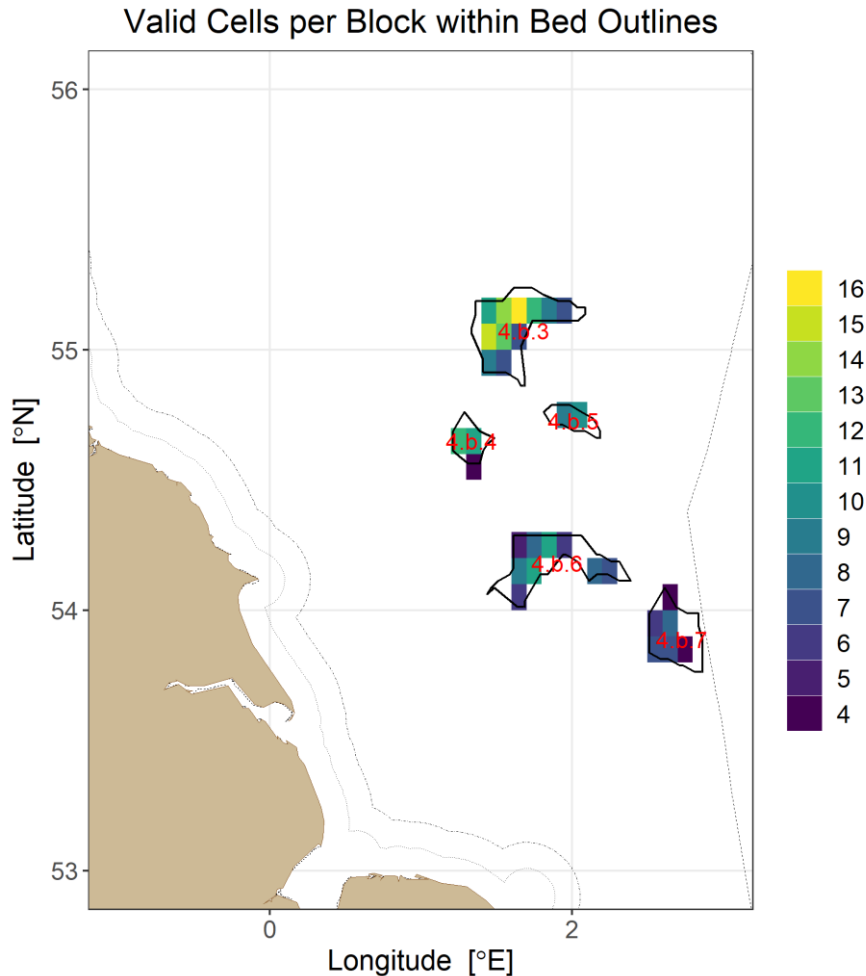


Figure 2.2: Valid (blue) and invalid (red) blocks in Beds 7.e.1-8 ( ICES Division 27.7.e), and Bed 7.f.1 (Division 27.7.f), along with the number of cells within each block.





**Figure 2.4: Valid (blue) and invalid (red) blocks in Bed 4.b.1-2 (Area 27.4.b.S), along with the number of cells within each block.**



**Figure 2.5: Number of valid cells per block within the bed outlines of the Dogger Bank assessment area (Area 27.4.b.D).**

For the 2017 survey season, Industry collaborators were keen to contribute to the tow position selection process in line with some other collaborative surveys. It was agreed that industry could select 25% of the tow positions per bed. Therefore, 75% of the valid blocks were selected at random, from which a suite of scientifically derived station tow positions was selected by randomly choosing valid cells from the selected block. No rationale behind the choice of industry location was sought or provided, but the basic assumption was that these were not selected at random, but rather on prior knowledge. The inclusion of subjectively chosen station points has the potential to bias the result. If positions of known high density are selected, then high-density locations will be over-represented and are likely to bias the total population estimate upwards. Conversely over-representation of low-density areas will lead to an under-estimate of the population. Such bias is likely to be realised most strongly if all stations are pooled together to generate an average density per bed. Indeed, this approach would violate the statistical integrity of any abundance estimate. From 2018 onwards, tow selection was entirely by random selection, although the focus is still on the main fishing areas.

## 3. Dredge survey data processing

### 3.1. Scallop density raising

The stratified random design dictated that the data were processed by block as the sampling strata. The density estimate from stations within a block were considered representative of the surface area of the block, and the block mean density was used if more than one station was in a single block. The valid surface area of each block is the sum of the surface area of all valid cells. Total block abundance (in numbers) is then given by

$$N = \sum_c \rho_c A_c ,$$

where  $c$  are the valid cells,  $\rho_c$  is the areal number density, and  $A_c$  is the surface area of each cell.

There were however un-sampled blocks which had a surface area defined by the valid cells within that block. The stock lying within the un-sampled blocks was estimated by applying the bed-averaged density from the survey stations to the total valid surface area of the un-sampled blocks.

For the 2017 survey, the remaining issue was how to incorporate the industry-selected stations within this approach. As we could not guarantee that the industry station locations had been chosen at random, statistically speaking they could not be used to represent the mean density for the whole block. Because they were chosen specifically for a site, the Industry-selected stations could only be used as observations for that specific site (cell). The science-derived estimate of scallop abundance was used for all cells except for those where an industry selected station occurred, where the abundance was replaced by that observed at the industry selected station.

### 3.2. Sample processing

Sampling was carried out from the dredges on only one side of the vessel, which provided adequate sampling levels throughout the surveys. As such, samples were raised only to the catches and area swept by sampled dredges, avoiding the need to consider any potential bias between starboard and port gears.

The following raising procedure was carried out on the survey data for the commercial dredge gear:

1. The sampled length distribution (LD) was raised to the total catch per station, using the raising factor calculated as caught weight or numbers over sampled weight or numbers for the two catch components, discards (below minimum landing size, MLS) and retained.
2. The catch components were aggregated to get total raised numbers at size by station.
3. The catch density (number m<sup>-2</sup>) for each station was calculated by dividing the count by the swept area of the gear.
4. The station catch densities from step 3 were raised using the appropriate substrate-specific gear efficiency factor to estimate scallop density on the seabed.
5. For randomly allocated stations, and for blocks which had one or more sampled cells, the block mean density per length class was calculated.
6. For randomly allocated stations, the bed mean density per length class was calculated.
7. Block mean densities were applied to all cells within blocks, where there was at least one sampled cell.
8. Bed mean densities were applied to all cells in all un-sampled blocks.
9. For the 2017 survey, densities in cells where an industry selected station was available were substituted with the density generated for that industry station.
10. Cell densities were raised to the area of each cell.
11. Number densities from step 10 were summed within each assessment area to generate raised numbers-at-size.

Steps 3 to 11 were repeated with the age converted data, using the sample ALKs to generate the age profile of the population. The harvestable biomass was calculated for each assessment area by using the length-weight conversion parameters to calculate weight-at-length for scallops larger than the MLS. For assessment areas in ICES Divisions 27.4.b and 27.7.e, the MLS is 100 mm round shell length, whilst for ICES Divisions 27.7.d it is 110 mm.

### **3.3. Swept area estimation**

Internally logging data storage tags (Cefas G5) recording depth and time were attached to the bridles on the dredges to provide depth profiles and an accurate indication of the time of deployment. GPS receivers (RoyalTech MBT1100) recorded ship positions. These loggers provided the positions of the tow tracks with depth profiles of the gear and allowed the calculation of distance run at each tow position. This integrated method is a more accurate measure of tow distance than calculating straight line distances between start and end points, and eliminates potential data recording errors. From 2018, a smooth line (tensor line) was fitted through the positional information to provide a more accurate interpretation of the distance run.



For some tows, GPS data failed to log. For these, distance run was calculated as the product of mean tow speed (2.7 knots) and intended tow duration (15 min). The swept area was then calculated as the sum of all individual dredge widths (75 cm times the number of dredges), multiplied by the tow distance (2.7 knots times 15 min = 1.25 km). As the data were only raised to the dredges on one side of the vessel, the number of dredges used in this calculation of swept area only includes sampled dredges.

### 3.4. Substrate-specific dredge efficiency

The vessel skipper reports ground type at each survey tow location based on acoustic information in the wheelhouse and the contents of the dredges. The distribution of these ground types by bed and survey year is presented in Table 3.1. The skipper-reported ground types were related to two ground types described by historic depletion studies carried out by Cefas in the English Channel. These substrate-specific gear efficiencies are listed in the main part of the report, individually for each assessment area. The data were therefore adjusted for gear efficiency at each station based upon the skipper-determined ground type, prior to the raising procedure. The assumption of this method is that the ground types encountered at each tow position were representative of the wider area (block).

**Table 3.1: Number of tows by ground type in each bed with proportion described by the survey vessel skipper as having significant amounts of flint or cobbles.**

Bed	Year	Ground Type		Total	Tows with Flint Cobbles (%)
		Clean, Some Stones	Flint or Cobbles		
4.b.1	2018	8	15	23	65
	2019	19	3	22	14
	2020	22	0	22	0
	2021	17	0	17	0
4.b.2	2018	2	2	4	50
	2019	1	0	1	0
	2020	2	0	2	0
	2021	2	0	2	0
7.d.1	2017	49	14	63	22

Bed	Year	Ground Type		Total	Tows with Flint Cobbles (%)
		Clean, Some Stones	Flint or Cobbles		
	2018	38	28	66	42
	2019	50	17	67	25
	2020	49	2	51	4
	2021	35	12	47	26
<b>7.d.2</b>	2018	1	3	4	75
	2019	-	-	-	-
	2020	-	-	-	-
	2021	-	-	-	-
<b>7.e.1</b>	2017	20	1	21	5
	2018	18	2	20	10
	2019	20	0	20	0
	2020	19	0	19	0
	2021	23	0	23	0
<b>7.e.2</b>	2017	32	3	35	9
	2018	29	3	32	9
	2019	32	0	32	0
	2020	33	0	33	0
	2021	33	0	33	0
<b>7.e.4</b>	2017	31	0	31	0
	2018	31	0	31	0
	2019	29	0	29	0
	2020	31	0	31	0
	2021	31	0	31	0
<b>7.e.5</b>	2017	16	8	24	33
	2018	18	2	20	10
	2019	18	0	18	0
	2020	20	0	20	0
	2021	16	0	16	0
<b>7.e.7</b>	2017	7	2	9	22

Bed	Year	Ground Type		Total	Tows with Flint Cobbles (%)
		Clean, Some Stones	Flint or Cobbles		
	2018	6	2	8	25
	2019	4	0	4	0
	2020	4	0	4	0
	2021	7	0	7	0
<b>7.e.8</b>	2017	13	8	21	38
	2018	9	10	19	53
	2019	5	3	8	38
	2020	8	0	8	0
	2021	20	1	21	5
<b>7.f.1</b>	2018	8	6	14	43
	2019	12	0	12	0
	2020	13	0	13	0
	2021	-	-	-	-

## 4. Underwater television survey

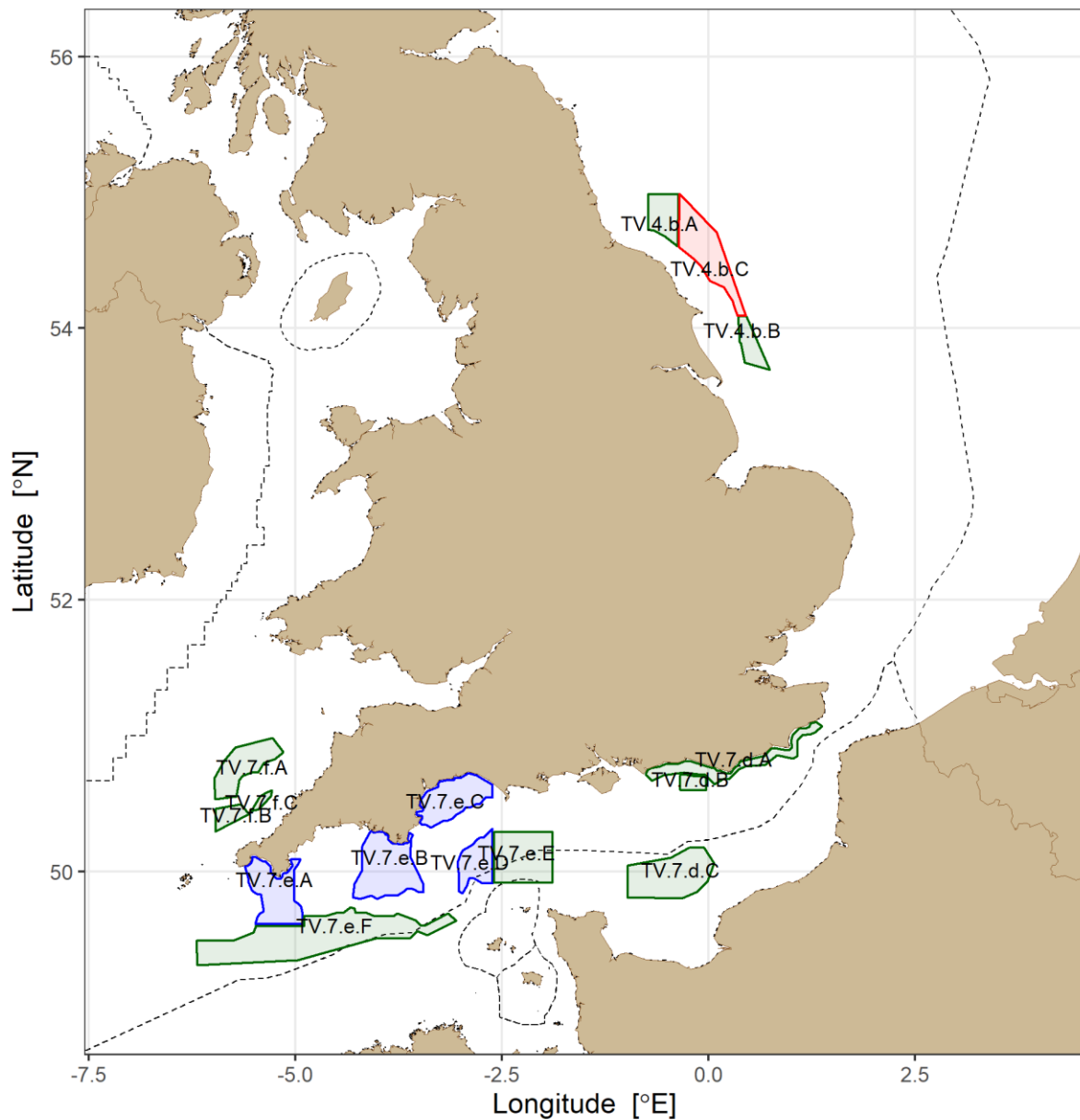
### 4.1. Methodology

#### 4.1.1. Survey design

Beds where scallop fishing takes place had already been defined for the scallop dredge surveys. For the underwater television (UWTV) survey areas, boundaries were defined around likely scallop ground (from habitat modelling), as well as around areas that are considered by industry to contain scallop populations but cannot be fished due to unsuitable ground type, conservation management, or gear conflict issues. Four zones adjacent to current fishing grounds that are typically not fished by scallop dredgers were defined in 2017 (TV.7.e.A-D, Figure 4.1). Ten further un-dredged zones were defined in 2019, and another zone in the North Sea was defined in 2021.

Once the un-dredged zones had been determined, random positions were selected using the same procedure as for the dredge surveys (Section 2.3).

Limited survey vessel time necessitated prioritisation of the survey areas. Three zones were surveyed in 2017 (TV.7.e.A, C and D). In 2019, two un-dredged zones were surveyed in the western English Channel (TV.7.e.B and E), and another in the eastern English Channel (TV.7.d.A). In 2021, zones TV.4.b.A-C were surveyed.



**Figure 4.1: The UWTV survey un-dredged zones as defined in 2017 (blue outlines), 2019 (green outlines), and 2021 (red outline). The dashed lines are EEZ boundaries.**

The research vessel (RV) Cefas Endeavour was used to survey a grid of randomly selected positions in the identified un-dredged zones. During the 2017 survey, at each

position, an STR High Definition (HD) video camera and an SLR stills camera were deployed on an STR drop frame system for an 11-min track. Tow direction and speed were with the tide at 0.3 knots, controlled by the ships dynamic positioning system and equated to a distance run typically of just over 100 m. During the 2nd UWTV survey in 2019, the tow speed of the drop frame was increased to 0.4 knots, and track duration was increased to 20 minutes to increase the distance covered to just under 250 m. An altimeter on the drop frame enabled it to be maintained at a relatively consistent height of 0.5 m above the seabed. Field of view was determined by the view within the drop frame (about 1.35 m), and determination of scale was facilitated by point lasers fitted to the camera mounts to mark a consistent distance on the seabed. For the 2021 survey, the field of view was also determined to be 1.35 m. As during the previous survey, the track duration was 20 minutes, and the average track length was just under 250 m.

Video images were viewed live on board the RV and all observed scallops were counted. Digital stills were manually taken when scallops or indications of scallops were observed to provide more detailed images for subsequent count confirmation.

As is standard practice for other UWTV surveys, video footage was reviewed later by trained staff for additional verification, and the median count per transect standardised to area. For the Cefas Nephrops UWTV survey, Lin's Concordance Correlation Coefficient (CCC) methodology is used to measure inter-observer reliability, i.e., the agreement between burrow counts by different scientists. However, this is not considered to be suitable for the scallop survey footage due to the very low counts and resulting integer artefacts (~ 1 per minute, compared to ~ 30 for Nephrops). When Nephrops stations get to similarly low densities, the CCC criterion is waived.

#### **4.1.2. Video processing**

Arithmetic methods were used to raise observed counts to survey areas using a similar methodology as that used for the dredge surveys. As with the dredge survey, the conversion of the relative density of scallops to absolute abundance indices requires an assumption about the relative efficiency of the camera gear, in this case the proportion of observed scallops. Again, this is likely to be dependent upon the ground type, with scallops on softer ground being more difficult to identify when they are partially buried. At present there are no data available for the specific gear configuration being used, and a coefficient of 1.0 (i.e., 100% efficiency) is used. There is, as yet, no information on the size range of animals observed. It is assumed that scallops become detectable on UWTV footage at 80 mm shell height, which is at the low end of the range of mature sizes.

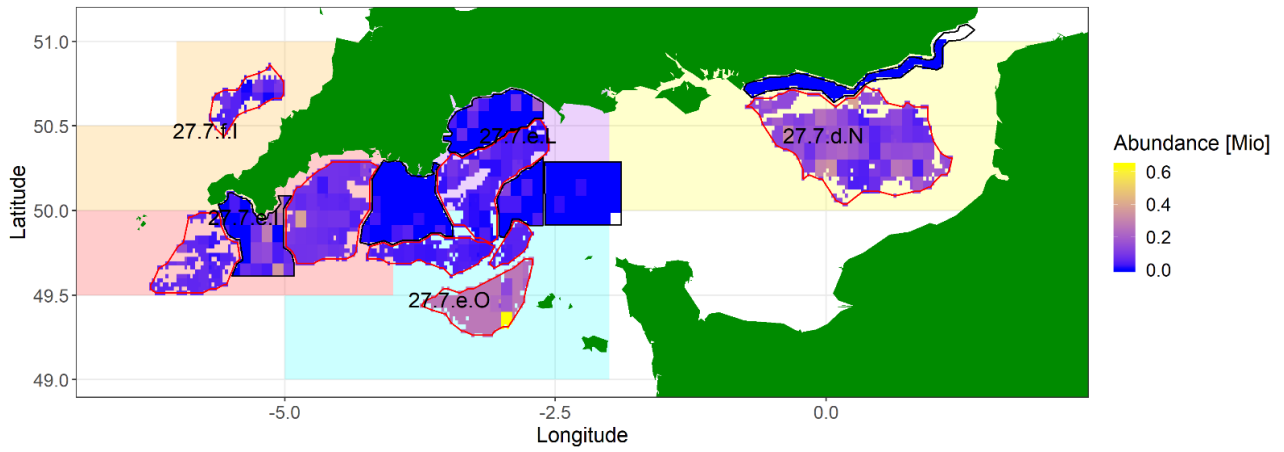
## 4.2. Results

The density estimates from the 2017 survey have been reworked to enable improved assignment to each assessment area. A summary of these results, together with those from the 2019 and 2021 surveys, is presented in Table 4.1.

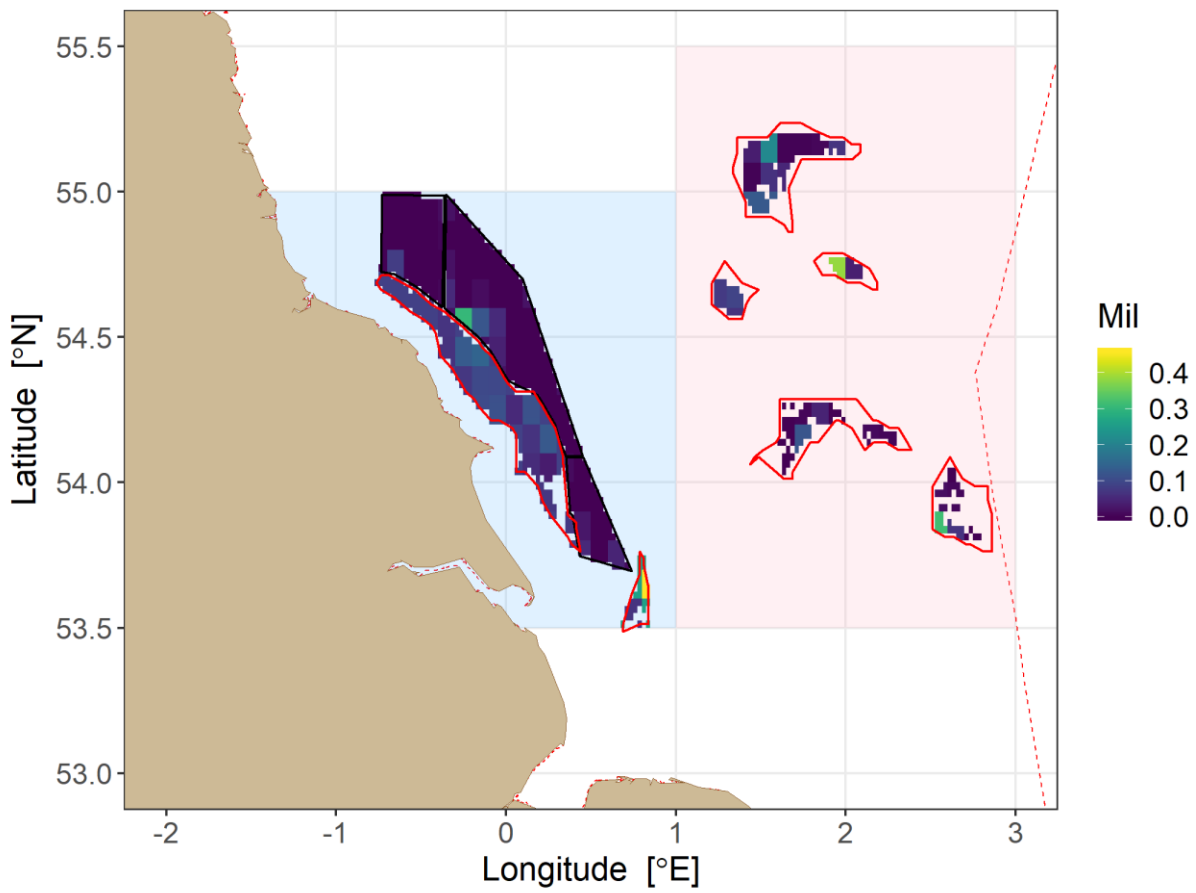
**Table 4.1: Summary of the 2017, 2019, 2021 UWTV survey results. Densities are given as numbers per 100 m<sup>2</sup>.**

Un-Dredged Zone	Number of Transects	Mean Density	Min Density	Max Density	Number of Zero Counts
TV.7.e.A (2017)	25	1.71	0	7.01	9
TV.7.e.C (2017)	26	0.53	0	3.71	19
TV.7.e.D (2017)	12	0.43	0	2.42	7
TV.7.e.B (2019)	21	0.17	0	0.94	14
TV.7.e.E (2019)	11	0.05	0	0.30	9
TV.7.d.A (2019)	15	0	0	0	15
TV.4.b.A (2021)	16	0.13	0	1.80	14
TV.4.b.B (2021)	10	0.27	0	1.14	7
TV.4.b.C (2021)	31	0.44	0	6.78	24

Estimated harvestable abundance in millions of scallops presented by block in the 2017 and 2019 surveyed un-dredged zones show that highest numbers of scallops were observed in the eastern side of Zone TV.7.e.A (Figure 4.2). The corresponding results from the 2021 UWTV survey are shown in Figure 4.3.



**Figure 4.2: Estimated harvestable abundance in millions from the 2017 and 2019 UWTV surveys in un-dredged zones (black outlines) of the assessment areas, together with the abundance estimates from the 2019 dredge surveys in commercially dredged areas (red outlines).**



**Figure 4.3: Estimated harvestable abundance in millions from the 2021 UWTV survey in un-dredged zones (black outlines) of the assessment areas, together with the abundance estimates from the 2021 dredge survey in commercially dredged areas (red outlines).**

Zone abundances in un-dredged areas, estimated based on the results from the 2017, 2019, and 2021 UWTV surveys, are presented in Table 4.2, together with estimates of harvestable biomass and spawning stock biomass. The survey estimate is obtained by using all survey tracks. Median and inter-quartile range are obtained from random resampling with replacement (“bootstrapping”, 5000 iterations), following the same procedure as for the dredge surveys. The spawning stock biomass is estimated from the area-aggregated length distributions by assuming a logistic maturity curve, with L25 = 80 mm, and L50 = 90 mm.



**Table 4.2: Abundance of scallops in un-dredged zones surveyed by UWTV (2017, 2019, 2021), together with estimates of harvestable biomass and spawning stock biomass.**

Area	UWTV Zone	25th Perc. (mil)	Median Abund. (mil)	Survey Estimate (mil)	75th Perc. (mil)	Harv. Biomass (tonnes)	Spawn. Stock Biomass (tonnes)
27.7.d.N	TV.7.d.A	0	0	0	0	0	0
27.7.d.N	TV.7.e.E	0.05	0.1	0.1	0.15	29	28
27.7.e.I	TV.7.e.A	24.0	27.9	28.3	31.5	4559	4264
27.7.e.I	TV.7.e.B	0.7	0.9	0.8	1.1	124	116
27.7.e.L	TV.7.e.B	0.9	1.1	1.1	1.4	245	229
27.7.e.L	TV.7.e.C	6.2	8.0	7.3	9.8	1610	1506
27.7.e.L	TV.7.e.D	1.9	3.0	2.9	3.6	628	587
27.7.e.L	TV.7.e.E	0.5	0.7	0.8	1.1	166	155
27.7.e.O	TV.7.e.B	1.3	1.8	2.0	2.2	372	343
27.7.e.O	TV.7.e.D	0.9	1.2	1.1	1.5	194	178
27.7.e.O	TV.7.e.E	0.2	0.3	0.3	0.4	54	50
27.7.f.I	TV.7.e.A	1.7	2.3	1.7	3.1	375	351
27.4.b.S	TV.4.b.A	0.1	1.5	1.2	1.7	207	193
27.4.b.S	TV.4.b.B	1.0	1.4	1.5	1.9	248	231
27.4.b.S	TV.4.b.C	5.1	7.9	7.5	9.9	1281	1195

## 5. Supporting research and development

Additional research would enable refinement of our current stock assessment methodology. Some of our main priorities are discussed below.

### 5.1. Dredge efficiency estimates

These are required to relate dredge survey catch rates to absolute abundance. Biomass estimates are generated using substrate-specific estimates of dredge efficiency derived from earlier work by Palmer and others at Cefas (2001; unpublished). Although these efficiency estimates are in line with some other work, a method to determine the dredge efficiency, in particular on the dredge survey vessel, is required to further refine the efficiency estimates we use. Historically, depletion studies or diver surveys have been

used to estimate dredge efficiency, but results can be inconsistent or logistically problematic. In 2017, a Defra funded R&D project was started to determine if novel technology (Radio Frequency Identification, RFID) could provide a solution.

This project was designed to derive a method that could generate vessel specific efficiency rates. The ultimate aim is to design a method that can be replicated on a commercial scallop dredging vessel to provide robust efficiency coefficients of direct relevance to the vessel and ground types surveyed. The equipment counts the number of uniquely tagged scallops in the path of a dredge using an antenna mounted in front of the scallop dredge. This total is then compared to the actual number of tagged scallops caught by the dredge.

The initial phases included land, aquaria and beach trials of the technology. The resulting rig was then mounted to scallop dredging gear and tested at sea on the RV Cefas Endeavour in the Western Channel in June 2018. These at-sea trials aimed to determine several factors: a) how to achieve a dispersal pattern that was dense enough to re-locate tags, yet sufficiently dispersed to avoid “tag-clash” (detection errors when tags are too close together); b) the time required for tagged scallops to reacclimatise and behave “normally” on release; c) how the antennae performed at depth; and d) how the antenna mount performed in front of the dredge.

A satisfactory dispersal pattern was achieved by hand-releasing scallops from the deck (as opposed to cage-borne releases in mid-water). The released scallops typically took longer than 24 hours to commence “normal” behaviour, although the length of time between initial capture and final release is considered to have been highly influential. The antennae worked at depth although with a reduced range compared to that experienced on land. The prototype electronics also require further development to be sufficiently robust. The antennae mounting mechanism (a wooden trolley in front of the dredge) appeared to work well in the water but was prone to damage (principally on retrieval).

These initial trials have prompted further work planned in 2021 and early 2022 following substantial delays incurred as a result of the Covid pandemic. A shorter time between initial capture and release should reduce the time scallops take to behave “normally” on re-release and avoid the survival issues encountered (survival in the tanks deteriorated after 24 hours).

Further development to the electronics has occurred to provide additional reliability and practicality.

Further work will establish the settlement period of freshly caught tagged scallops. Further testing of the RFID equipment will also be carried out. The equipment has been re-configured to improve efficiency and maximise read range.

The equipment is due to be deployed on the FV Evening Star early in 2022, the first deployment on a commercial fishing vessel.

## 5.2. Biomass estimates from UWTV

UWTV surveys are used to determine abundance of scallop populations in un-dredged areas. This is important as we would expect populations in some of these areas to contribute to recruitment to adjacent exploited populations by larval dispersal.

### 5.2.1. Camera system

A non-contact camera system is used, as ground types may not be suitable for camera platforms that are towed along the seabed (sledges). Such towed systems may not be appropriate for sensitive habitats. However, the non-contact system currently used from the Cefas research vessel (STR SeaSpyder drop frame with HD video and stills) is limited to low tow speed deployment. This system does not cover much ground and there is a risk of under-sampling scallops which are distributed at relatively low densities. In addition, scallops can be cryptic by recessing into the substrate and covering themselves with a fine layer of sediment. Alternative camera platforms have been investigated and some trialled for suitability.

1. Devon and Severn IFCA “flying array” (a device originally developed by Plymouth Marine Laboratory) which was deployed from both an inshore vessel (D&SIFCA) and the Cefas RV with dynamic positioning.
2. Cornwall IFCA STR SeaSpyder drop frame system (more compact than the Cefas system and suitable for small vessel deployments) deployed from CIFCA RV.
3. Videoray Pro4 mini ROV deployed from CIFCA RV.
4. The Marine Scotland “Sea Chariot” was investigated but not deployed.

Further optimisations of the current Cefas STR SeaSpyder drop frame system has been carried out to provide more ground coverage without compromising scallop visibility, and to maximise the potential of the captured imagery.

Development of a high-speed, non-contact camera platform with a camera system optimised for scallop surveys is ongoing, as resources allow.

A new video camera (Rayfin by SubC Imaging) which provides high-definition video imagery and facilitates capture of multiple high resolution stills images was trialled in May 2021. These images are taken at high frequency by means of strobe lighting. The stills images compliment the video footage by enabling digital enhancement and zooming in on scallop shells that may require confirmation that they are alive or for finding the more cryptic animals. Multiple stills images may lend themselves to automated image analysis in the future, although many problems of using machine learning algorithms to achieve this require resolution.

### **5.2.2. Camera efficiency**

The cryptic behaviour of scallop means that in some circumstances not all of the scallops in the field of view of the video camera will be observed. The video camera and human observer combination has an efficiency that, analogous to the scallop dredges, is likely dependent on substrate type. As yet, there are no data available for the specific gear configuration used. Therefore, a coefficient of 1.0 is used, assuming that all scallops in the camera field of view are identified. The same RFID technology used to determine dredge efficiency is currently also being developed to determine camera/human observer efficiency on various substrates (see Section 5.1 above).

### **5.2.3. Population structure**

Relating video observations of scallops in the un-dredged areas directly to the harvestable biomass of the population is not straightforward. In our assessment we have assumed that the camera has a knife edge selection at 80 mm shell height, which is at the low end of the range of mature sizes. Automated image analysis software has been considered as an alternative to manual methods of determining scallop size from video and stills images. However, application of this technology to scallop species is relatively new and in the early stages of development. The potential application of any new developments in video or still image analysis and machine learning, both at Cefas and at external agencies, will be considered as resources allow.

### **5.2.4. Connectivity between dredged and un-dredged areas**

To enable appropriate incorporation of biomass estimates from un-dredged beds into the assessment process, we need to determine the level of linkage between scallop populations in un-dredged zones and fished beds. This might best be achieved by calculating harvest ratios that incorporate a proportion of the biomass estimated in un-dredged areas derived from UWTV, with biomass estimated in the dredged beds derived from the dredge surveys. These proportions could be defined by the levels of recruitment to the dredged beds which are derived from those un-dredged beds.

Recent work by (Nicolle, et al., 2017) used particle dispersal modelling in the English Channel to provide some answers as to the level of linkage between fished areas but does not describe the specific connectivity between most of the un-dredged beds with the dredged beds defined for Cefas scallop stock assessments. Further oceanographic modelling was carried out by colleagues at Cefas in 2021 to determine levels of connectivity. Results from North Sea modelling show no connectivity to the inshore exploited beds. For the Channel region, the modelling data are presently being analysed.

## 6. References

**Edelsbrunner, H., Kirkpatrick, D. G. and Seidel, R. 1983.** On the Shape of a Set of Points in the Plane. *IEEE Trans. Inform. Theory.* 1983, Vol. 29, 4, pp. 551–559.

**Nicolle, A., et al. 2017.** Modelling larval dispersal of *Pecten maximus* in the English Channel: a tool for the spatial management of the stocks. *ICES Journal of Marine Science.* 2017, Vol. 74, 6, pp. 1812-1825.



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