Annex 1: Scallop biological sampling procedure

1 Methodology

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

1. Cefas identify sampling opportunities based on regular reports of the positions of participating vessels from the Vessel Monitoring Scheme (VMS) and contact industry contacts at the processors.
2. The processor contacts the vessel by phone or internet-based messaging and request a length sample or age 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 processors) 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 (shell height round shell) and return the size distributions along with sample weight and sample details to Cefas. Age samples are processed at the factory as per usual procedure, but the flat shells are sent to Cefas for age determination.
5. In addition, a supplementary and opportunistic method where samples were pre-ordered by the processor contacts in consideration of target shortfalls communicated by Cefas is also used.

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, further validated by consensus.

1.1 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 rectangles where fishing activity had occurred over the past 8 years and warranted sampling. Sampling targets in the first year were set at 5 length samples per ICES rectangle per quarter where one of the length samples is retained for subsequent age determination to facilitate the construction of an age-length key for each ICES rectangle.

In a process parallel to that used by the fin-fish stock assessments, estimates of age composition were obtained by obtaining Length Distributions (LD) of landings and then converting to ages using an age-length key.

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

The basic strata for the targeting of age and length are ICES rectangle and quarter, with a nominal target of *5* samples per strata for lengths and 1 sample per strata for an age sample. Samples are requested from named vessels when it is observed that they are fishing in an area on a given day. The unit of sampling is therefore a combination of vessel, rectangle and day.

1.2 Data raising process

1.2.1 Age-length key (ALK)

1. From the age samples (blue-bag), 5 shells per 5mm length class were retained for age-determination
2. Within each 5mm length class, the proportion at 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.

1.2.2 Length Distribution

4. Sample LD were raised to the reported catch of the vessel within the day using the ratio of reported sample weight to landings.
5. Samples from step 4 were pooled to the level of rectangle and quarter, and the sampled weights summed.
6. The pooled LD 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. Missing strata. 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.

1.2.3 Age distribution

8. 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
9. For un-sampled strata, the in-fill LD (step 7) were multiplied by the in-fill ALK (step 3) and summed to give numbers at age per un-sampled rectangle-quarter.
10. These numbers at age were summed over all quarters and rectangles within each stock area to give total annual removals at age per assessment area.

Annex 2: Dredge survey design

2 Terminology

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

- Bed – A polygon representing a fished scallop ground, identified using Vessel Monitoring System data (VMS)
- Block – A grid of 0.1-degree (latitude/longitude) rectangles within a bed. A full block is approximately 80 km^2.
- Cell – A grid of points separated by 0.025 degrees, with a maximum of 16 cell positions per block (4 by 4). Each cell is approximately 5 km^2. This is the scale to which the VMS data were aggregated as part of the survey design methodology. Mid points of cells are used as potential sampling positions, randomly selecting cells to sample as part of the dredge survey. This also forms the grid over which the data are raised to calculate the bed raised biomass and age-length population structure.
- Valid cell – A cell with VMS data reported within.
- Valid block – A block with a specific number (threshold) of valid cells within.

These concepts are graphically presented in Figure 2.1.

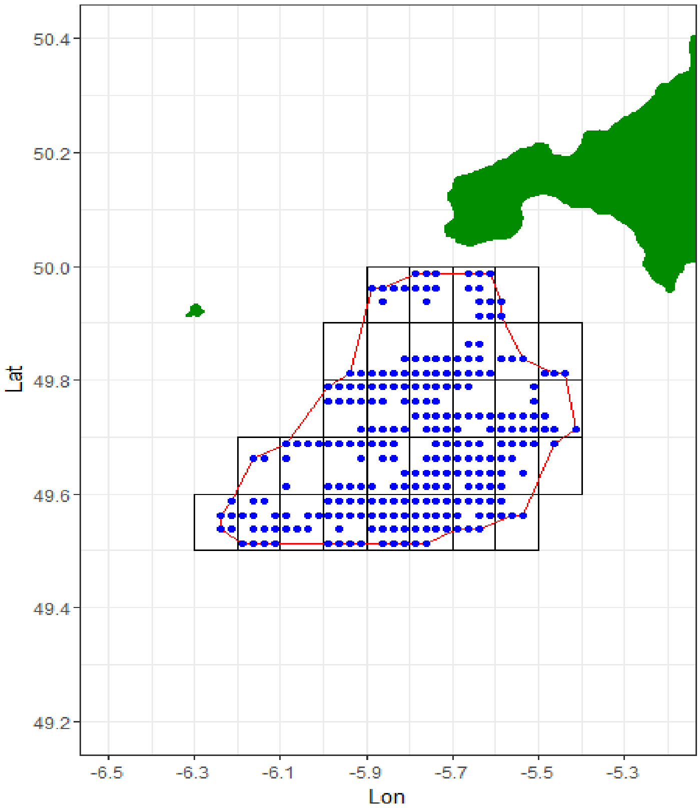

Figure 2.1. An example scallop dredge bed (red outline) with 0.1-degree blocks (black) and 0.025-degree cells (blue).

2.1. Identification of scallop beds

VMS data from 2009 to 2016 for trips where 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 15m and above were available but changes to the VMS scheme enabled all vessels 12m and above to be included from 2013.

2.1.1 VMS data were processed as follows:

- Vessels were assumed to be fishing when the reported speed was between 1 and 5 knots to remove records where vessels were more likely transiting between grounds or in harbour.

- VMS data were aggregated to the cell level (0.025-degree grid). Cells with less than 10 reported positions over the full-time series were removed.
- 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 by the VMS 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 α-shape around a set of points, in this case VMS points (cells), based upon the Delaunay triangulation.

The resulting α-shape was converted to a polygon (bed) representing a scallop fishing ground. Within each bed there are patches where VMS data are absent, these are represented as areas without valid cells (Figure 2.1). When raising the survey results up to each scallop bed only those cells identified 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 therefore that there are no scallops in those cells.

Eight scallop beds within ICES SubDivision 27.7.e and 1 scallop bed within 27.7.d were defined using the above approach.

2.2. 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 and by ensuring that most blocks are sampled this gives broad spatial coverage. Within each block, one valid cell was selected at random, the midpoint of which was a potential sampling position. This procedure ensured stations were only placed in areas commercially fished for scallops and generated 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 was not possible to sample each block which intersected the bed boundary. Many blocks, particularly around the boundary had very few valid cells contained within them (Figures 2.2 & 2.3). A procedure was therefore developed to ensure that the sampled blocks represented 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 >85% of the cells within each bed fell inside the sampled blocks. Table 2.1 gives the threshold per bed. This ensured that the main fishing areas are sampled within each bed and ensured the number of stations were 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 were less well sampled which could introduce bias into the approach if there is a steeper gradient of density at boundary edges than in the main fishing grounds.

Table 2.1 – The cell thresholds used to determine whether a block was deemed valid.

Bed	Total number of blocks that intersect bed	Cell threshold	Blocks dropped	Cells dropped	% Cells Dropped	No. Stations per bed (no. valid blocks)
1	32	5	11	36	14	21
2	47	9	13	60	11	34
3	3	2	1	2	13	2
4	46	6	15	65	14	31
5	30	4	11	27	11	19
6	5	2	2	3	11	3
7	11	3	4	9	11	7
8	37	6	15	47	13	22
9	100	8	31	91	8	69

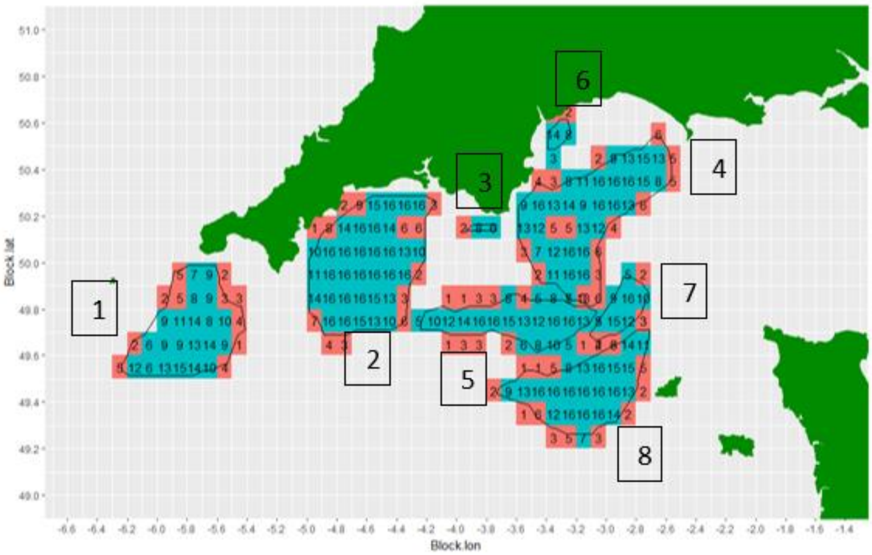

Figure 2.2 – Valid (blue) and invalid (red) blocks for beds 1-8 in 27.7.e along with the number of cells within each block.

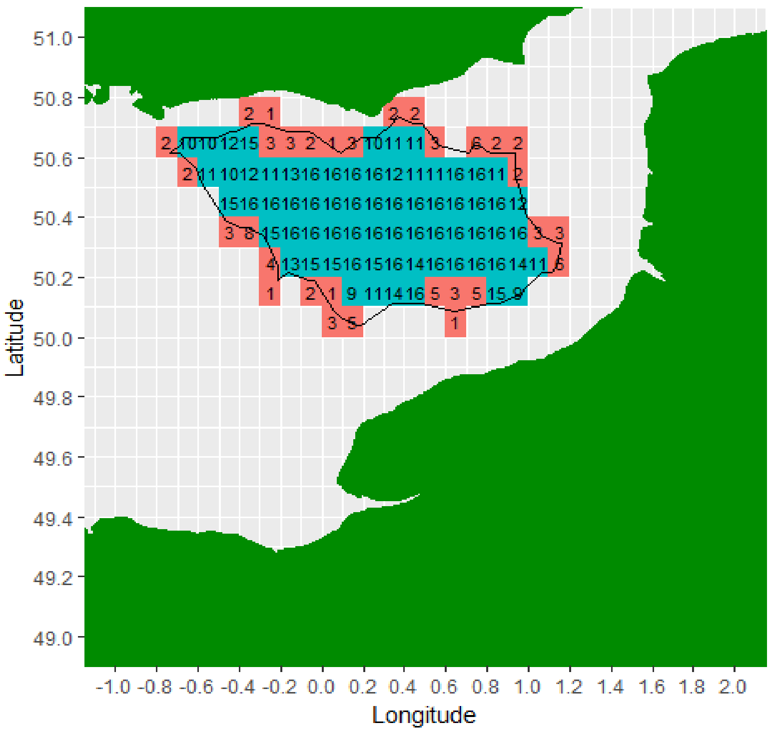

Figure 2.3 – Valid (blue) and invalid (red) blocks for bed 9 in 27.7.d.N along with the number of cells within each block.

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. 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. Industry partners then chose the remaining 25% of stations (per bed). No rationale behind the choice of industry location was sought or provided, but the basic assumption must be 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, and indeed this approach would violate the statistical integrity of any abundance estimate.

Annex 3: Dredge Survey data processing

3.1 Scallop density raising - Arithmetic approach

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 median density was used if more than one station was in a single block. Within each block there were a limited number of valid cells, as defined by the VMS data, so the valid surface area of the block was the sum of the surface area of the valid cells. Total block abundance was therefore

$$N = \sum_{C} density \times A_c$$

Where C are the valid cells and A is the surface area of each cell.

There were however, unsampled blocks which had a surface area defined by the valid cells within that block. The estimate of stock lying within the unsampled blocks was estimated by applying the median density from the survey stations (bed median densities) to the total valid surface area of the unsampled blocks.

The remaining issue was how to incorporate the industry selected stations within this approach. As we cannot guarantee that the industry station locations have been chosen at random, statistically speaking they cannot be used to represent the mean density for the whole block. Because they are chosen specifically for a site, the Industry selected stations can 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 were an industry selected station occurred where the abundance was replaced by that observed at the industry selected station.

3.2 Sample Processing

Sampling was exclusively carried out on the starboard set of gear which provided adequate sampling levels throughout the surveys. As such samples were raised to the catches and area swept by the starboard dredges alone, 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 on the starboard side only:

1. The sampled length distribution (LD) was raised to total caught per station, using the raising factor calculated as Caught weight / Sampled weight for the catch components (discards and retained).
2. The components were collapsed to get total raised numbers at size by station.
3. The density (number/m^2) for each station was calculated by dividing the count by the swept area of the gear.
4. The station densities were adjusted to allow for the scallop gear efficiency.
5. For the randomly allocated stations and for blocks which had one or more sampled cells, the block median density per length class was calculated.
6. For the randomly allocated stations the bed median density per length class was calculated.
7. Block median densities were applied to all cells within blocks where there was at least one sampled cell.
8. Bed median densities were applied to all cells in all unsampled blocks.
9. Densities in cells where an industry selected station was available were substituted with the density generated for that industry station.
10. Cell densities was raised to the area (m^2) of each cell.
11. Numbers per m^2 from step 10 were summed within each Assessment Area to generate the raised numbers at size for each.

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 the assessment area by using the length-weight conversion parameters to calculate weight at length for the scallops over the minimum landing size. For assessment areas in ICES subdivision 27.7e the MLS is 100mm shell length, whilst for ICES subdivision 27.7d it is 110mm.

3.2.1. Swept area estimation

For the dredge survey in 27.7.d.N 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 deployments. GPS receivers (RoyalTech MBT1100) provided ships position at a given time. These loggers provided the positions of the tow tracks with depth profiles of the gear and allowed for calculation of distance run at each tow position. This integrated method is a more accurate measure of distance towed than calculating straight line distance between start and end points of the tow and eliminates potential data recording errors. For the dredge survey in 27.7.e the DSTs were not available and distance run was estimated as the straight-line distance between the start and end of tow from the skipper logbook. The swept area was then calculated as sum of the dredge width (0.75*number of dredges) multiplied by the tow distance. As the data were only raised to the dredges on the starboard side the number of dredges used in the calculation of swept area only represented this side (11 commercial dredges in this case).

3.2.2. Substrate specific dredge efficiency

British Geographical Survey (BGS) sediment data were reviewed and compared to the skipper reported ground type at each survey tow location (Figures 3.1 and 3.2). It was noted that the BGS data did not relate to observations encountered during the surveys. 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). These ground types were related to some of those described by historic depletion studies carried out by Cefas in the English Channel and those substrate specific gear efficiencies are presented in the parameter Tables 2.5 and 3.4 of the main report.

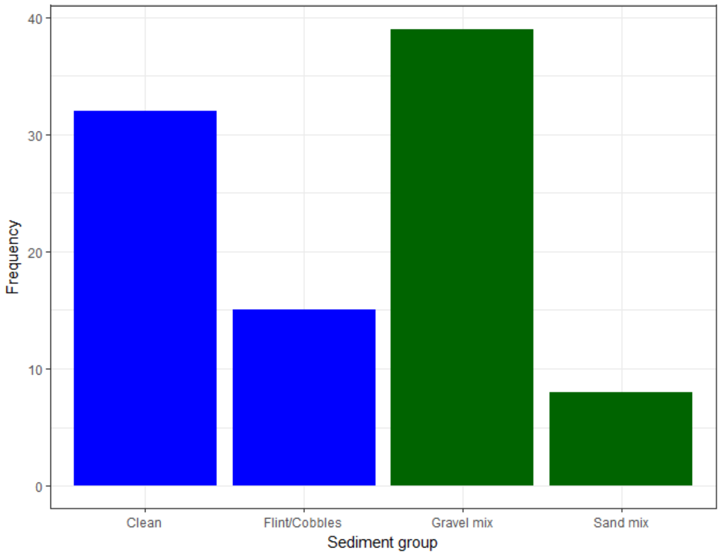

Figure 3.1 Ground types encountered on the dredge surveys as defined by the vessel skipper (blue) and British Geological Survey data (green) in bed 9, 27.7.d.N.

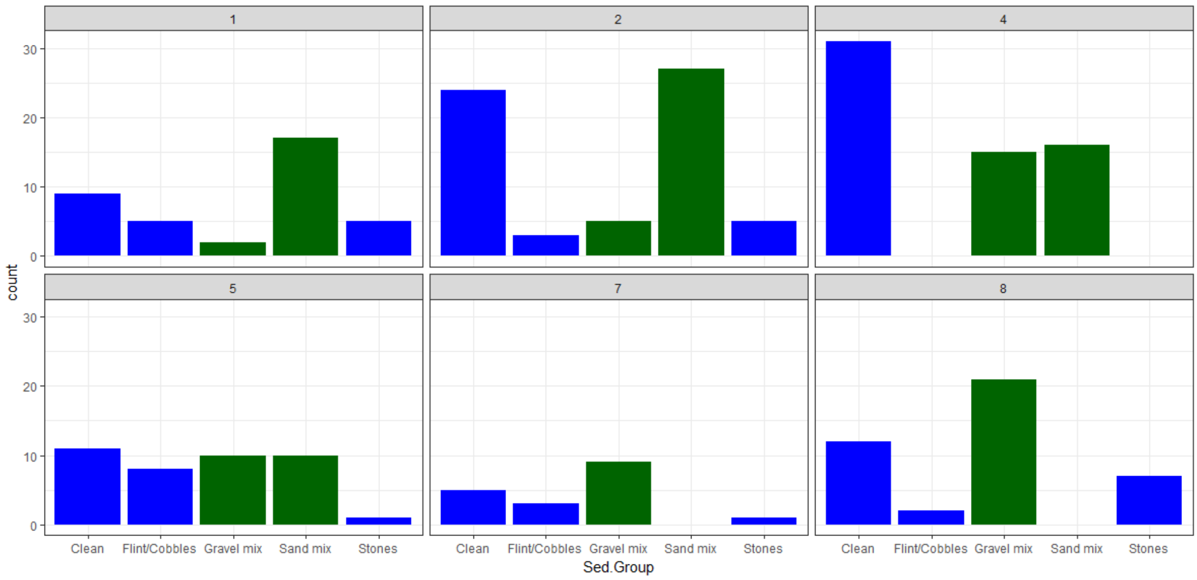

Figure 3.2 Ground types encountered on the dredge surveys as defined by the vessel skipper (blue) and British Geological Survey data (green) in beds 1-8, 27.7.e.