Report on Razor Clam Surveys in the Sound of Harris and the Ayrshire Coast of the Clyde (Girvan to North Bay)

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This report presents the results of marine and freshwater scientific work carried out for Marine Scotland under external commission.

Report on razor clam surveys in the Sound of Harris and the Ayrshire coast of the Clyde (Girvan to North Bay)

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This report consists of two sections – Part 1: A description of the materials and methods, results of analysing the video data collected at sea and discussion; Part 2: An appendix of preliminary observations made at sea while collecting the video.

Executive Summary

This report describes surveys carried out in the Sound of Harris and Ayrshire coast, Clyde in late August and early September 2017. A combination of commercial electrofishing rig and towed video rig was deployed at potential razor clam grounds using the fishing vessel '*Nicola Jane'*. Recorded video was analysed for the number and sizes of razor clams forced to the surface by the electrofishing equipment. Data were converted to area densities (numbers of razor clams m^{-2}) based on estimates of the area swept (m^2) by the video recording.

Fifteen tows were completed in the Sound of Harris and all razor clams observed were *Ensis siliqua*. Generally low densities of clams were found varying from zero to 0.215 m^{-2}. Most of the area surveyed was likely too exposed to favour razor clams with clean, largely featureless sand occupied by the occasional crab or small fish. The only tows with higher densities of razor clams (>0.1 m^{-2}) were in, or adjacent to, the more sheltered Sound of Berneray.

Forty-two tows were completed along the Ayrshire coast between Irvine and Girvan and again all clams were identified as *E. siliqua*. A few areas had densities above one razor clam m^{-2}, for example some tows between Girvan and Turnberry Point. For all other tows in Culzean Bay (north of Turnberry Point), Meikle Bay (just south of Troon) and North Bay (just north of Troon) densities were in the range 0.023 to 1 razor clam m^{-2}.

The size distributions of razor clams (*E. siliqua*) across all sites appeared rather similar with two modes, one at around 120-130 mm and the other around 175 mm.

These modes possibly represent two age groups but there was little evidence of large numbers of smaller recruiting clams at any of the sites.

The use of the combined electrofishing and towed video rigs to assess razor clam stock abundance worked well with 9 to 13 tows being completed each day when weather permitted surveying. Recorded video was generally of sufficient quality to allow identification of objects with only a few tows having sections partially obscured by macroalgae, sea-grass or sediment kicked up by the sled.

Part 1 – Materials and Methods

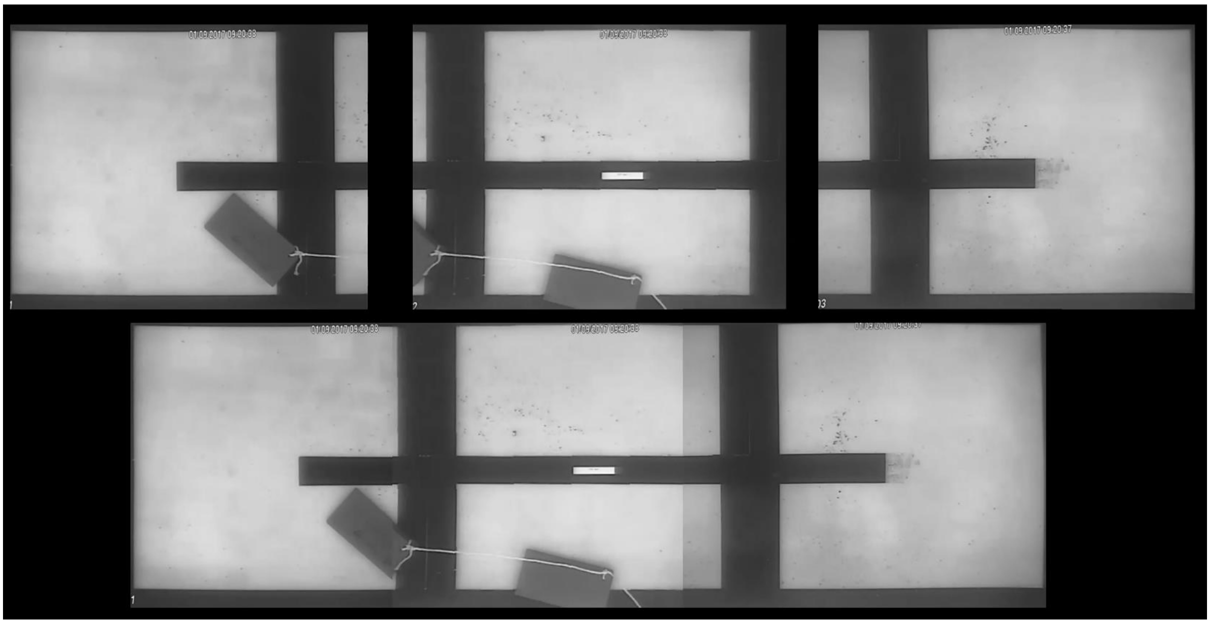
Introduction

The aim of this project was to use a combination of electrofishing with towed video to assess the quantities and sizes of razor clams (*Ensis* sp.) across a number of grounds on the west of Scotland. The results are intended to inform Marine Scotland in the setting of catch limits for potential commercial-scale fisheries on razor clams using the electrofishing technique.

Materials and Methods

Surveys were conducted using the video equipment described in Fox (2017). Prior to the surveys the video cameras were calibrated in seawater using the test-tank facility at SAMS. The conversion factor from video pixels to mm was estimated to be 1 pixel = 1.076555 mm and the error in the central calibration bar (Figure 1) which measures 1 m in length was estimated to be 1 mm.

Figure 1: Plastic calibration blocks imaged in the SAMS test-tank on top of the calibration targets, each block is 15 cm in length, each square is 45 cm internal and the horizontal bar is 1 m in length.



As a check on the accuracy of reconstructed lengths of objects from the video, 15 cm long plastic test blocks were imaged in the test tank at various locations within the field of view (Figure 1). Thirty measurements were collected from the post-processed video. The reconstructed lengths showed a small positive bias of

1.8 mm, close to that reported in Fox (2017). Reconstructed measurements were within 1 cm of the actual block length (the mean being 151.8 mm, std dev 3.59 mm, n=30). The impact of varying object distance from the cameras was considered in Fox (2017) who concluded that major errors in reconstructed razor clam lengths were unlikely, unless there were large undulations (>5 cm) in the seabed. Reconstructed razor clam lengths from field collected video are, therefore, expected to have an accuracy of within +/-1 cm of their true length.

One modification made prior to the Clyde surveys was that the laser pointers described in Fox (2017) were removed and replaced with a forward looking camera. This modification proved extremely useful in checking that the equipment had deployed correctly behind the electrofishing rig (Figure 2). The laser pointers originally acted as a check on the horizontally merged video frame separations but this was considered unnecessary with the additional test-tank calibrations undertaken prior to the field deployments. In addition, actual measurements of razor clams are made on the separate video frames rather than the merged frame. Minor horizontal merging errors may thus slightly affect the swept area in view but not the reconstructed measurements of individual razor clam lengths.

The live video was also used at the start of each tow to assess whether any seagrass or maerl was present in which case the tow was stopped, the gear recovered and the tow location moved.

Figure 2: Images from the forward looking camera showing the deployment of the electrofishing gear in North Bay, Clyde. The bar to which the electrodes are fixed is just visible in the left-hand panel as the tow ropes begin to tighten (left-hand panel); the rig fully deployed and being towed behind the electrodes (right-hand panel); several emerged razor clams and the tracks caused by the electrodes are visible.

Surveys were conducted from the fishing vessel '*Nicola Jane'* (OB1043; registry A16424) skippered by Robbie Grieve (Loch Leven Shellfish Ltd.). All experimental fishing took place under derogations issued by Marine Scotland Licencing because use of electricity in fishing remains illegal at the time of the surveys under Article 31 of EU regulations 850/98 “unconventional fishing methods”. The video rig was towed 3 m behind a 5 m wide plastic spreader bar which was fitted with three pairs of brass electrodes each 2.6 m in length with 1 m separation between positive and negative electrodes. Power was supplied using an inverter box identical in design to that described in Murray et al. (2014). Power was supplied to the electrodes as 24 V AC at around 50-60 amps per pair. The power outputs from the inverter-box were monitored using a close-circuit camera run to a display in the wheelhouse (Figure 3). This proved extremely useful in detecting the few occasions when rods ended up touching each other just after deployment by allowing a check for excessively high currents. In these cases the gear was raised, rods disentangled and the equipment redeployed.

Figure 3: The blue inverter box sitting in the hold next to the generator (red painted equipment), the power outputs were monitored continuously in the bridge during fishing.

Tows were undertaken in the Sound of Harris and off the Ayr coast at sites selected by Marine Scotland with advice from Marine Scotland Science and Scottish Natural Heritage. Originally it had been proposed to use a stratified random survey design but in practice this proved impossible. Most of the pre-selected random locations proved unsuitable being either too deep or on rocky ground. Tow locations were, therefore, selected on an *ad hoc* basis in the field, attempting to sample a range of water depths whilst avoiding rocky ground which was identified using the ship’s sounder (Figure 4).

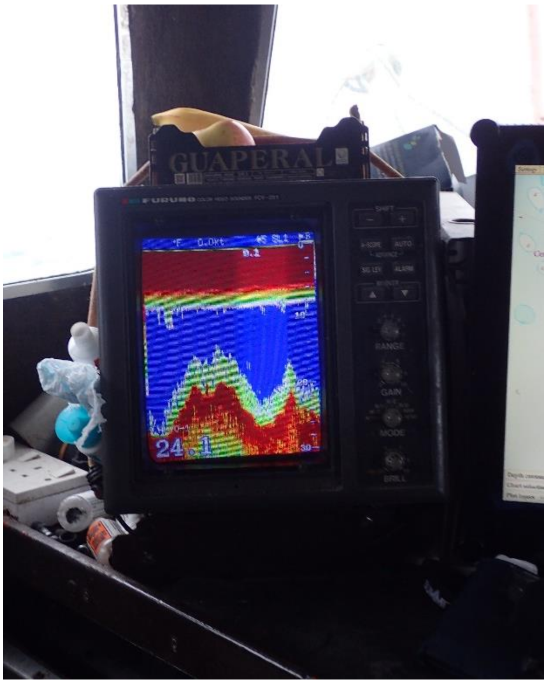
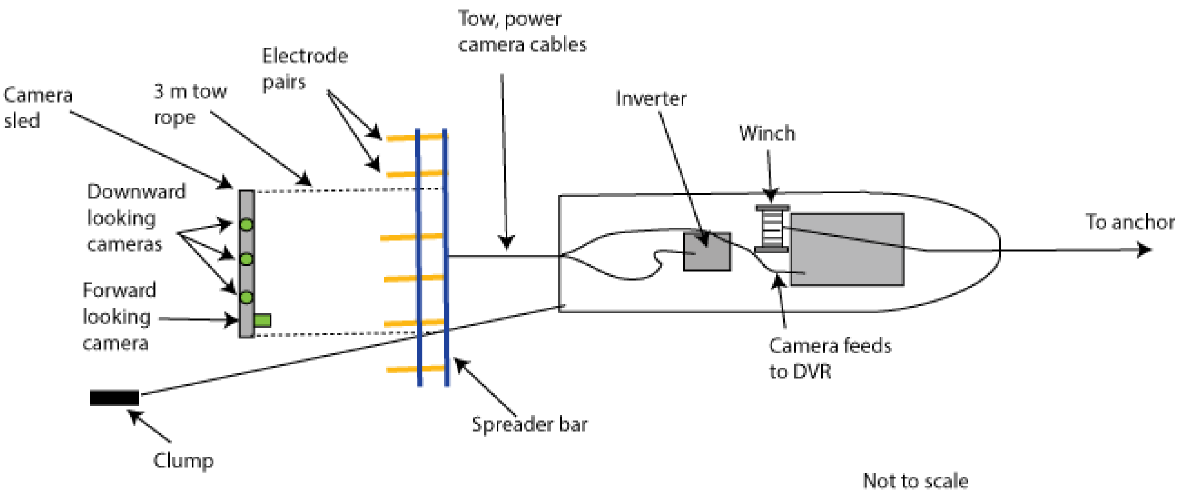


Figure 4: Example of rough ground from the vessel sounder.

At the start of each tow an anchor was deployed and the vessel then steamed backwards whilst paying out around 150 m of tow line. A clump weight was then dropped and the towing line slowly wound in using the winch thus drawing the vessel slowly towards the anchor. The camera rig was lowered to the seabed followed by the electrofishing rig (Figure 5). Once correct deployment was confirmed from the forward looking underwater video (Figures 2 and 6), the power to the electrofishing rig was turned on and the tow commenced.

Figure 5: The video-rig being lowered off the back of the vessel, the blue bars are the electrode spreaders.

Figure 6: Diagram illustrating how the electrofishing gear and towed camera sled were deployed.



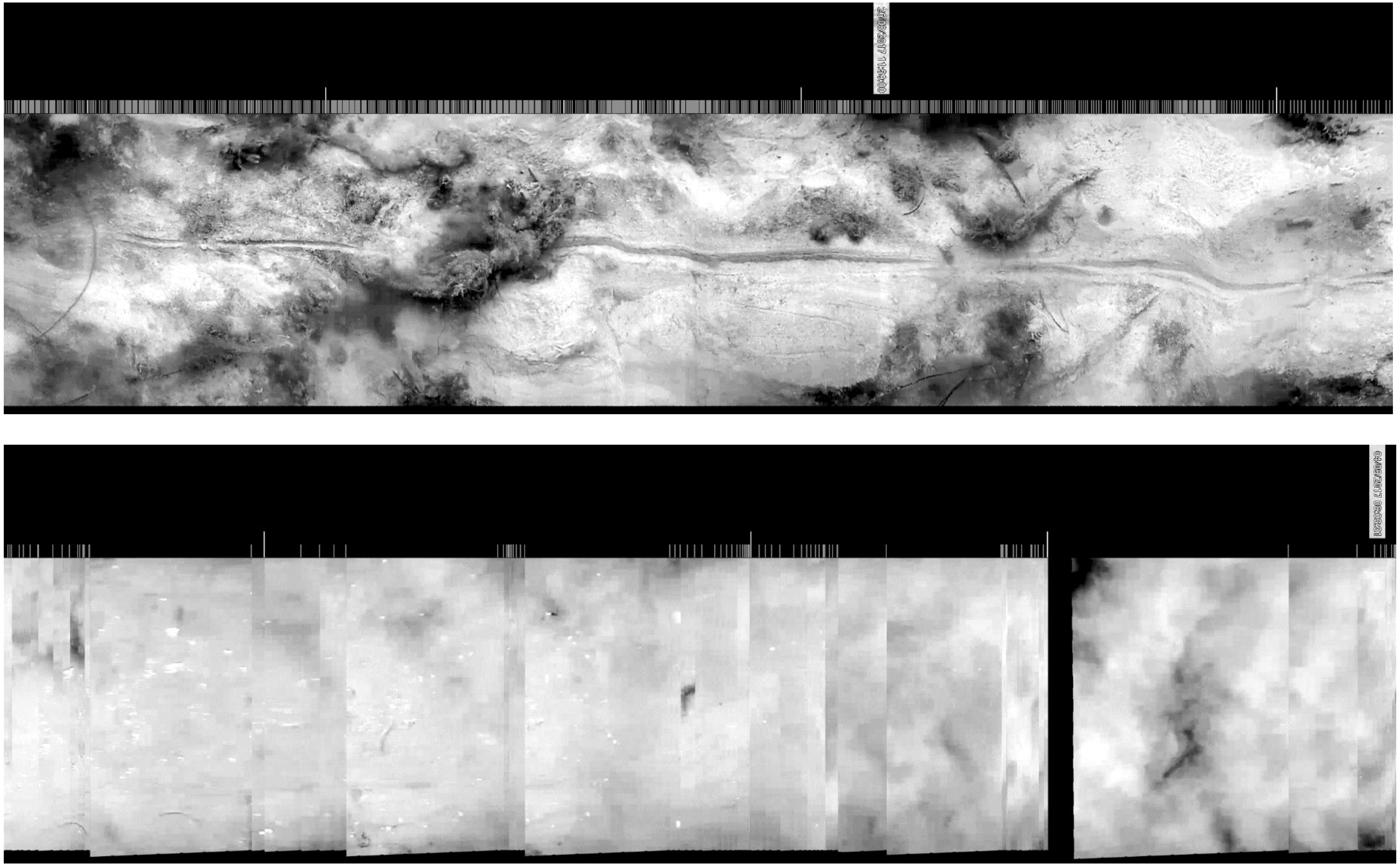
Video was monitored continuously during the tow (Figure 7) and recorded for the three downward looking and single forward looking underwater cameras using a digital video recorder (Hawk D1/960H AHD RF3089, RF Concepts, Belfast UK).

Figure 7: Video data being collected by the author on *Nicola Jane*, the monitoring screen with the live pictures is visible in front of the logsheet folder.

Recorded video was downloaded as .avi files and processed using the Matlab scripts described in Fox (2017) but with the lens distortion calibrations updated based on the test-tank calibrations undertaken just before the surveys. The lengths of razor clams on the processed video were recorded using the interactive Matlab program described in Fox (2017). Additional notes were made of any other organisms seen, such as seagrass, crabs and fish.

In order to convert counts of objects to area-based densities, estimates of tow length are required. There are two methods available for estimating tow lengths. Firstly, they can be calculated from the start and end positions of the tow recorded on the vessel's GPS chart plotter. The distance between the two points was calculated using the Haversine formula; secondly tow lengths can be estimated by vertically stitching the video from one of the camera feeds as described in Fox (2017). Both approaches were applied and the results compared. The quality of vertical stitching was also qualitatively evaluated as 'High', 'Medium' or 'Low' based on visual inspection of the vertically stitched montages. High quality stitching is characterised by an almost continuous grey band down the left hand side of the montage indicating that the montage has been constructed from pixel-height, or near pixel-height frame shifts. In addition, the resulting montage should show strong continuity of visual features (Figure 8). In contrast, poor stitching was characterised by large jumps in the frames, indicated by large gaps in the grey frame-shift index on the left edge of the montage and obvious jumps, breaks or repeats in visual features. Poor stitching can result from several factors such as (i) too few identifiable stationary features on the seabed (ii) obscuring of the seabed by moving objects such as silt being kicked up by the sled or weed being moved by the tide and (iii) poor contrast between features due to low light or features having similar reflectance to the sediment. Poor stitching tended to result in large over-estimates of the tow length compared with the GPS-based estimates.

Figure 8: Example of high quality vertical stitching (top panel, Sound Harris Tow 4) and poor quality vertical stitching (bottom panel, Meikle Bay Tow 10).



The camera alignments and video processing were set up so that the total imaged swath was 1.5 m wide and thus the swept areas (m^2) were estimated as tow lengths multiplied by 1.5. Razor clams on the video were assigned to one of six classes: Class 1 - whole *Ensis siliqua* lying flat on the seabed; Class 2 - *E. siliqua* lying flat on the seabed but overlapping the edge of the field of view so that only part of the shell was visible; Class 3 - *Ensis* tops where the clam had not fully emerged but was completely within the video frame; Class 4 - whole *Ensis arcuata* lying flat on the seabed but overlapping the edge of the field of view so that only part of the shell was visible; Class 5 - partial *E. arcuata* overlapping the edge of video frame; Class 6 – un-used. For Classes 2 and 5 it was assumed that each individual count would represent half an individual (since on average half an individual count would lie in the adjacent area outside the field of view). The measurement data for Classes 2 and 5 were not used further. For Class 3 each record was counted as one individual but the measurement data were not used further.

As no *E. arcuata* were identified from the videos only data for object Classes 1-3 were analysed further. The total counts of whole *E. siliqua* (object Class 1) were added to the number of clams overlying the edges of the field of view and partially emerged clams (Class 2 counts * 0.5 + Class 3 counts) and then partitioned into the number of *Ensis* larger than and smaller than the current legal minimum conservation size (MCS) limit of 100 mm. These numbers were then converted to densities per unit area (nos m^{-2}) by dividing the raised counts by the estimated swept area of each tow (m^2).

For each site a histogram of the frequency distribution of measured whole *Ensis siliqua* (Class 1) was also produced.

All statistical analyses were conducted using R3.3.2.

Results

The equipment generally worked well although problems with corruption of video files were experienced on four tows from the Sound of Harris. For these tows the counts of *Ensis* noted on-board the survey vessel from monitoring the live video were used. On most tows the equipment settled into the correct configuration (Figure 6) as a result of tension on the ropes connecting the spreader bar and camera rig (Figure 2) but on some occasions the equipment became tangled and had to be re-deployed. Tows lasted around 15-20 minutes covering an average of around 62 m, equivalent to 93 m^2 swept area. One tow in the Sound of Harris (Tow 2) had to be stopped early due to running into an area of muddy silt.

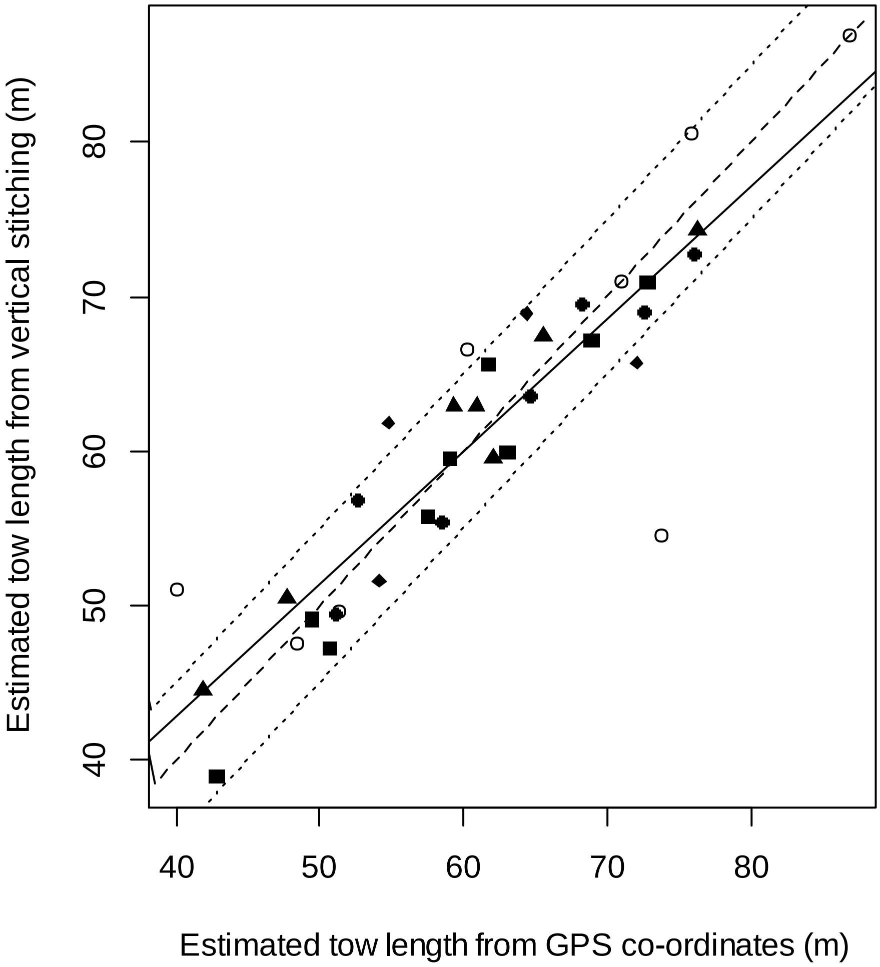
The accuracy of the ship's GPS plotter was not known. However, it is important to remember that typical accuracy of an uncorrected GPS unit may be around 5 m (https://www.gps.gov/systems/gps/performance/accuracy/). While this will not make much difference when working at larger scales this represents a potential error of up to 8% in estimating the length of a 60 m tow. This potential error will feed into the estimates of razor clam density because tow length is used to estimate the swept area.

An alternate measure of estimating tow length was developed by Fox (2017) and relies on automatically aligning sequential frames from one of the downward-looking camera feeds creating a composite of the seabed along the entire tow length. Because the relationship between the number of pixels each frame needs to be shifted by to align it with the previous frame and the true length of the frame shift is known, the length of the final composite image in pixels can be converted to an estimate of total tow length in meters. However, for the technique to work well there needs to be sufficient identifiable stationary objects within each video frame to estimate its spatial shift relative to the previous frame. The quality of the vertical stitching can be judged by visual inspection of the vertically stitched composite (Figure 8).

Vertical stitching of the videos collected in this study produced more variable results than achieved with video collected in the western Isles during method development in 2016 (Fox 2017). Comparing the appearance of videos from 2016 and 2017 suggests a lower level of identifiable objects in some of the 2017 tows, particularly in areas such as Turnberry Bay. In other areas, such as North Bay, all the videos stitched with a medium or high quality. The level of contrast in the video also affects the ability of the software to identify registration objects in adjacent frames. On a few tows the sled tended to move forward in a jerky manner due to swell causing the vessel to jerk the towing cables. In these cases the video moved forward fast enough to cause some blurring of identifiable features on the seabed or kicked up sediment which would also affect the automatic image reconstruction. In terms of stitching results, 22 tows were classified as ‘high quality’, 13 as ‘medium quality’ and 18 as ‘low quality’ while one tow failed to stitch.

Comparing tow lengths estimated from video-stitching (‘high’ and ‘medium’ quality tows only) with the lengths estimated from the tow start and end GPS co-ordinates showed generally good agreement (Figure 9). Two tows appeared as outliers and both were from the Sound of Harris (Tows 1 and 3). The reasons for the larger difference comparing the two estimation methods for these two tows are unclear. It is possible that the GPS co-ordinates at the start or end of these tows could have been mis-transcribed as vertical stitching produced similar length estimates when repeated using video from camera 3. Overall there was a strong correlation (0.90, n=35) between GPS-based and vertically-stitched estimates of tow length suggesting that tow length estimates from GPS were accurate to within 5 m.

Figure 9: Comparison of tow length estimates from vertically-stitching images along the tow versus tow length estimates based on recorded tow start and end positions from the ship's GPS. The slope of the relationship (solid line) was not significantly different (p=0.065) from 1 (dashed line). A difference of +/- 5 m are indicated by the dotted lines.



Because of the high proportion (34%) of tows where visual inspection of the vertically stitched images suggested there were problems with image processing, it was decided to use the GPS-based estimates of tow length to estimate swept areas for all the tows.

Average tow speeds varied between 2.1 and 6.3 m min^{-1}. A higher speed of 7.1 m s^{-1} occurred on one tow (Sound of Harris Tow 10) due to the direction of tow and sea state requiring a faster hauling speed to stabilise the vessel. Estimated swept areas were between 51 to 159 m^2 with the average being 93 m^2 (Figure 10).

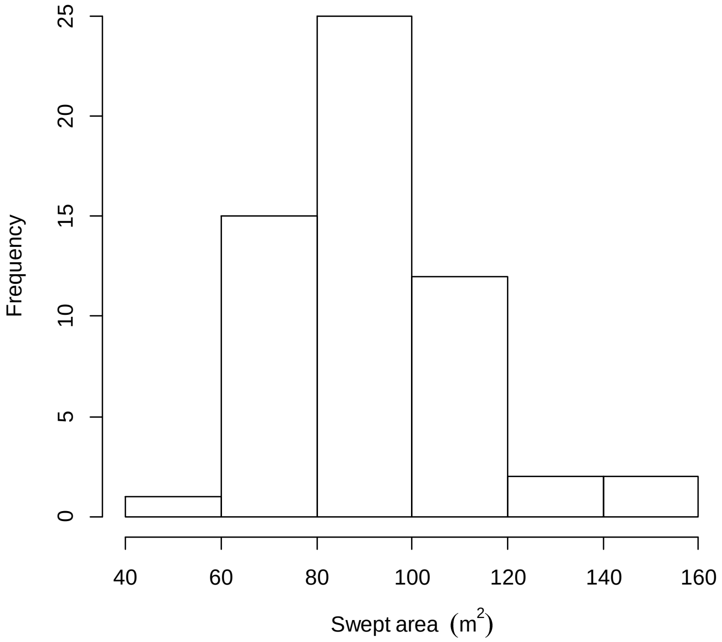


Figure 10: Distribution of swept areas across the 57 tows undertaken in the Sound of Harris and Clyde surveys.

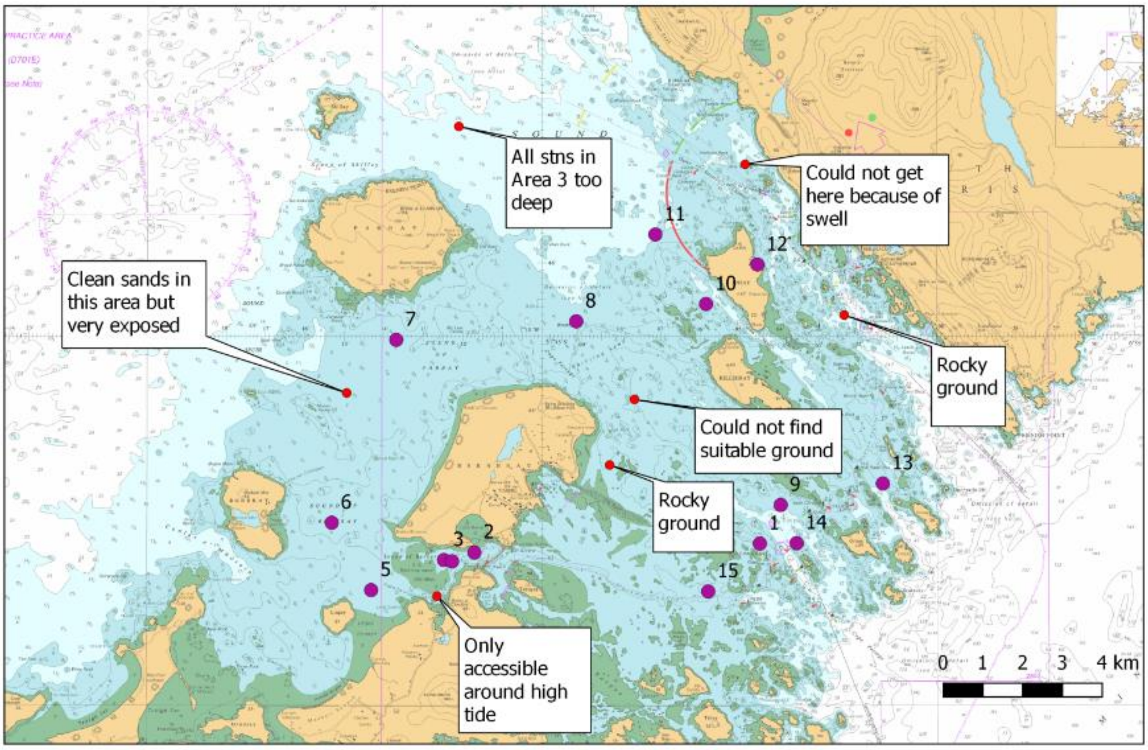
Western Isles Surveys

The area surveyed in the Western Isles was the Sound of Harris.

Sound of Harris

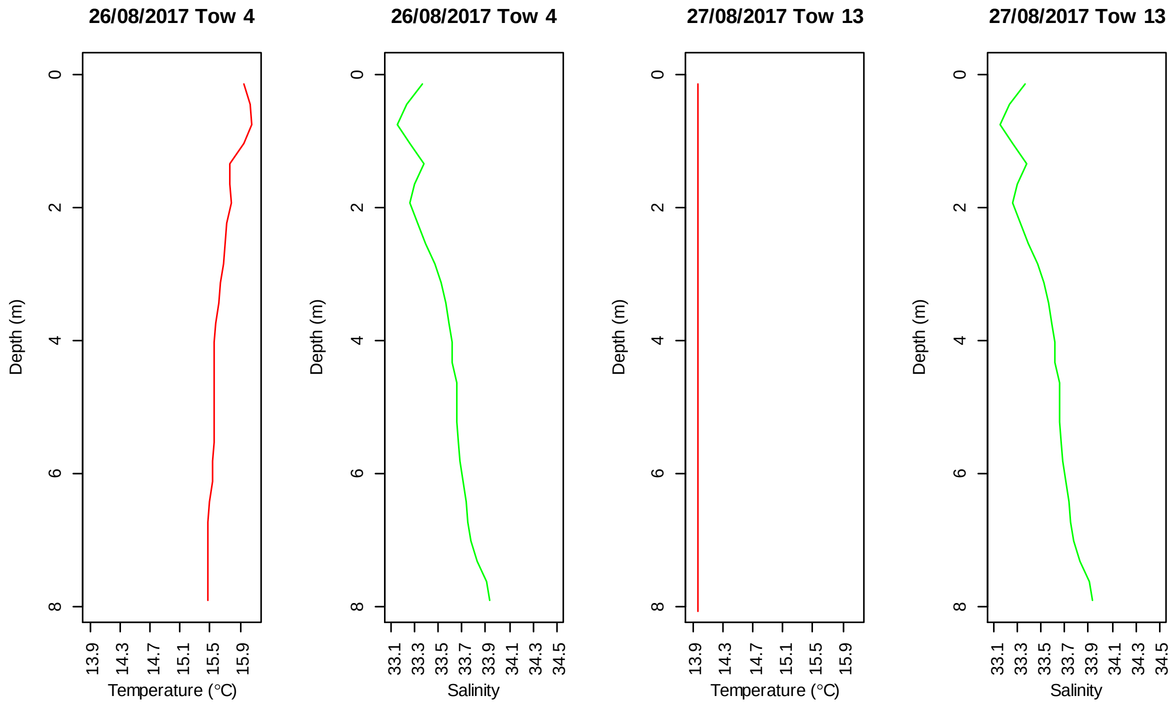
Fifteen stations were completed on 26 and 27 August 2017 at water depths between 5 and 15 m (Figure 11). It proved difficult to find suitable tow locations because the area consists of sandy patches interspersed with rocks and reefs. Considerable time was spent steaming to find suitable tows based on the appearance of the seabed on the vessel's sounder (Figure 4).

Figure 11: Worked tows in the Sound of Harris. Purple dots, worked stations; Red dots – initial observations made on board survey vessel. Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.



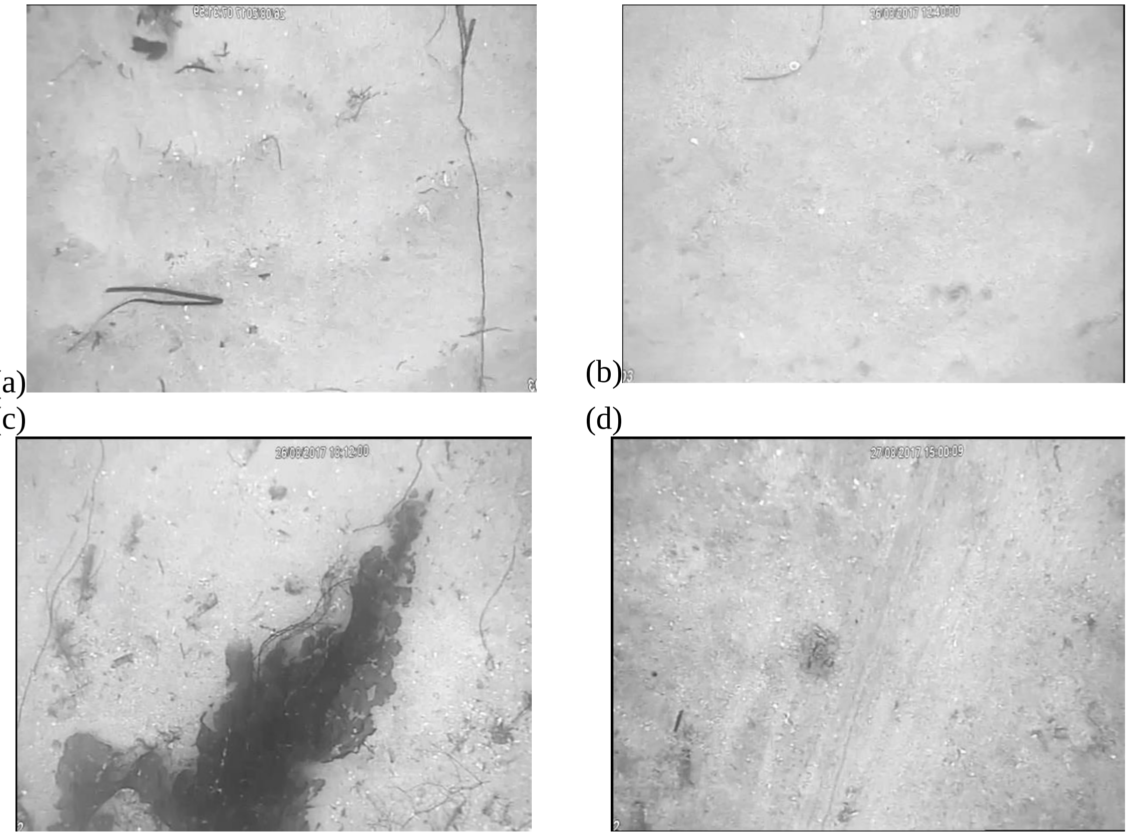
Water temperatures were between 13.9 and 16.1°C and salinities were between 33.1 and 34.5. There was little variation in temperature with depth but salinities were slightly lower at the surface than at depth (Figure 12).

Figure 12: CTD profiles for Sound of Harris.



The sediment consisted mainly of clean fine sand with occasional small patches of macroalgae and isolated strands of seagrass (Figure 13).

Figure 13: Representative images of the seabed in the Sound of Harris (a) Tow 1, (b) Tow 5, (c) Tow 9, (d) Tow 15.



Shore crabs were the most common incidental organisms identified along with a few fish including gobies, sandeels and small gadoids (Table 1).

Table 1: Incidental records from Sound of Harris tows. * indicates probable identity from video but where key features were obscured or unclear.

Object (s)	Tow									
	1	2	3	4	5	7	8	9	14	15
Crab (shore crab)	0	0	13	2	2	12	5	2	2	11
Crab (shore crab*)	0	0	2	4	0	0	4	10	1	3
Fish (gadoids*)	0	0	0	2	0	0	0	2	0	0
Fish (goby)	3	0	1	0	0	0	0	0	3	0
Fish (sandeel)	0	0	1	0	0	3	1	0	1	0
Fish (sandeel*)	0	0	1	0	0	0	0	0	0	0
Fish (spp*)	0	0	0	1	0	0	0	0	0	0
Gaper (*Mya* spp.)*	0	0	1	0	0	0	0	0	0	0

When downloaded it was found that video files for Tows 10-13 had become corrupted. However, only five razor clams were observed on the live video monitor while these tows were being undertaken. The problem of corrupted video files did not occur again.

Observations recorded on board the survey vessel suggested that moderate numbers of razor clams were only observed at two sites in the Sound of Berneray. Detailed analysis of the videos confirmed the impression reached on board the survey vessel that there was a paucity of razor clams with no tow having a density exceeding 0.25 razor clams m^{-2} (Table 2). All records were identified as *E. siliqua* and no *E. arcuata* were seen. Because of the low number of clams lengths were only measured on 59 whole *E. siliqua*. The majority (83%) were above the MCS of 100 mm (Figure 14).

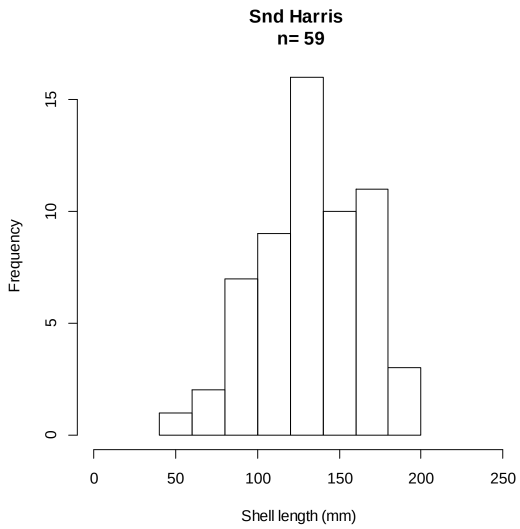


Figure 14: Histogram of measured E. siliqua from Sound of Harris surveys.

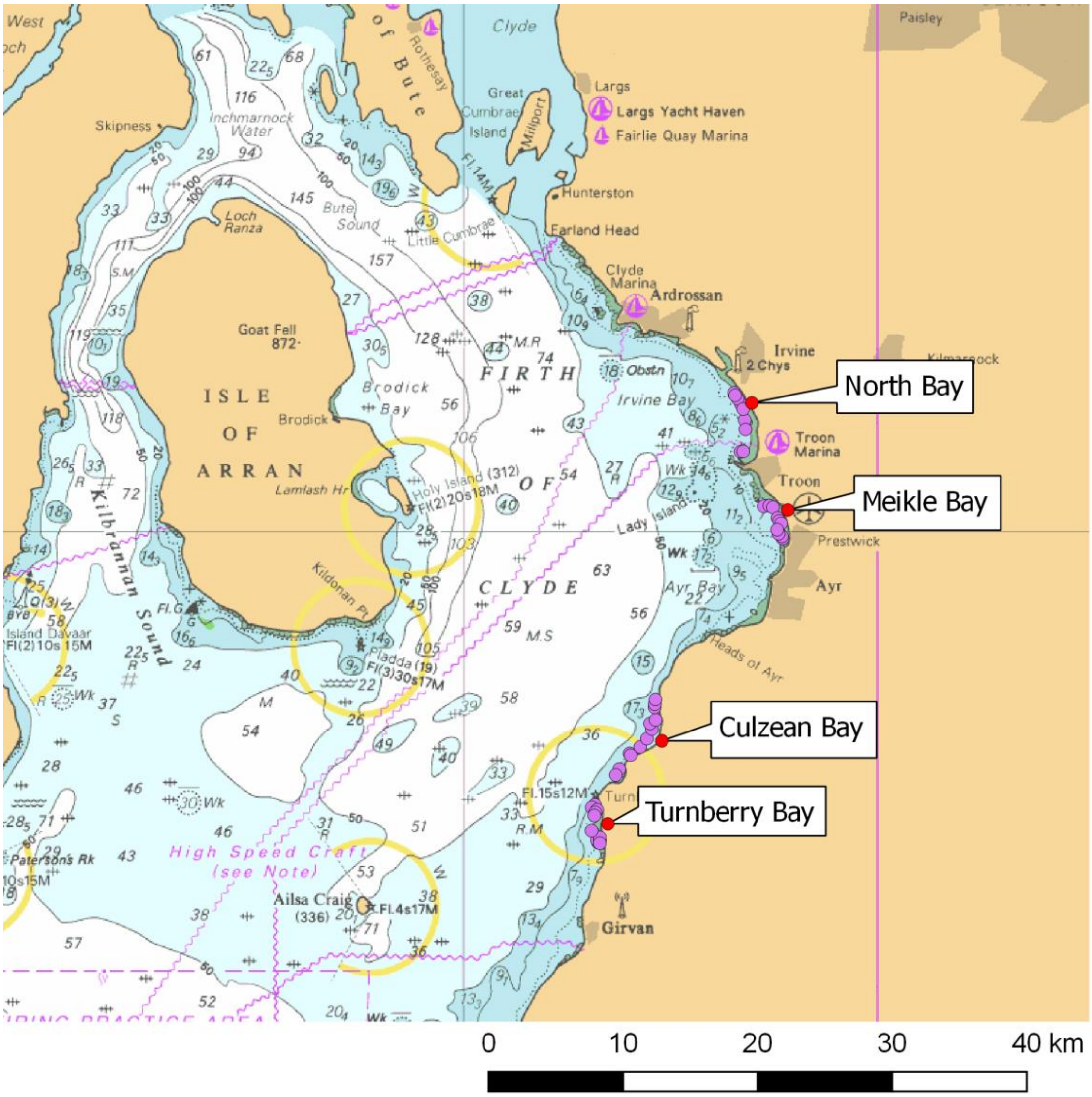
Table 2: Summary results for *E. siliqua* from the video tows undertaken in the Sound of Harris. Shading indicates tows which were not analysed from recorded video as these files were corrupted so the counts were based on counts recorded from monitoring the live video on board the survey vessel.

Tow	Average depth (m)	UTC Start	Lat Start (degrees)	Lon Start (degrees)	UTC End	Lat End (degrees)	Lon End (degrees)	Tow Len (mins)	Tow Len GPS (m)	Tow Len Vertical Stitched (m)	Quality Vertical Stitching	Average speed GPS-based (m^{-1})	Swept area GPS-based (m^2)	Raised count *E. siliqua*<100mm length	Raised count *E. siliqua*>100mm length	Density *E. siliqua*<100mm length (m^{-2})	Density E. siliqua>100mm length (m^{-2})
1	7	07:32	57.7032	-7.0749	07:47	57.7030	-7.0744	00:15	40	51	Medium	2.7	60	2.0	0.0	0.033	0.000
2	7	10:01	57.7012	-7.1953	10:12	57.7012	-7.1948	00:11	34	33	Low	3.1	51	0.0	0.0	0.000	0.000
3	11	10:44	57.6995	-7.2081	11:00	57.6997	-7.2069	00:16	74	55	High	4.6	111	3.8	23.8	0.034	0.215
4	5	11:40	57.6992	-7.2047	12:00	57.6993	-7.2035	00:20	71	71	High	3.6	107	0.0	1.5	0.000	0.014
5	5	12:40	57.6927	-7.2388	13:00	57.6922	-7.2379	00:20	76	81	High	3.8	114	5.9	20.6	0.052	0.181
6	7	14:26	57.7079	-7.2554	14:39	57.7082	-7.2561	00:13	51	50	High	3.9	77	0.0	3.0	0.000	0.039
7	8	15:42	57.7492	-7.2283	15:57	57.7492	-7.2272	00:15	87	87	Medium	5.8	130	1.0	2.0	0.008	0.015
8	12	16:47	57.7534	-7.1523	17:02	57.7539	-7.1535	00:15	95	89	Low	6.3	143	0.0	1.0	0.000	0.007
9	15	18:12	57.7119	-7.0661	18:27	57.7123	-7.0667	00:15	60	69	Low	4.0	90	0.0	0.0	0.000	0.000
10	12	08:13	57.7573	-7.0975	08:28	57.7571	-7.0958	00:15	106			7.1	159			0.000	0.000
11	15	09:06	57.7730	-7.1189	09:17	57.7727	-7.1190	00:11	43			3.9	64			0.000	0.000
12	7	10:23	57.7662	-7.0758	10:39	57.7669	-7.0755	00:16	86			5.4	129			0.000	0.020
13	15	11:57	57.7167	-7.0230	12:12	57.7162	-7.0227	00:15	54			3.6	81			0.000	0.040
14	9	14:04	57.7033	-7.0594	14:19	57.7029	-7.0595	00:15	48	48	Medium	3.2	73	0.0	3.0	0.000	0.041
15	10	15:00	57.6924	-7.0967	15:15	57.6919	-7.0968	00:15	60	67	Medium	4.0	90	1.1	7.9	0.012	0.087

Clyde Surveys

The Ayrshire coast was surveyed between Irvine and Girvan (Figure 15). Tows were undertaken in four blocks: North Bay (Tows 1-9), Meikle Bay (Tows 10-19), Turnberry Bay (Tows 20-32) and Culzean Bay (Tows 32-42). It should be noted that some of these blocks consist of smaller areas of sandy ground separated by rocky outcrops e.g. in the Turnberry Bay block Tows 30 and 31 were off the smaller Maidenhead Bay which is separated from Turnberry Bay proper by a rocky spur.

Figure 15: Worked tows in the Clyde (Purple dots). Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.



North Bay, Clyde

Nine tows were completed to the north of Troon in water depths between 2 and 17 m (Figure 16). It was noted that even in areas where the chart indicated sand this was not always accurate and several stations had to be moved once the bottom conditions had been observed on the video cameras just after deployment of the equipment.

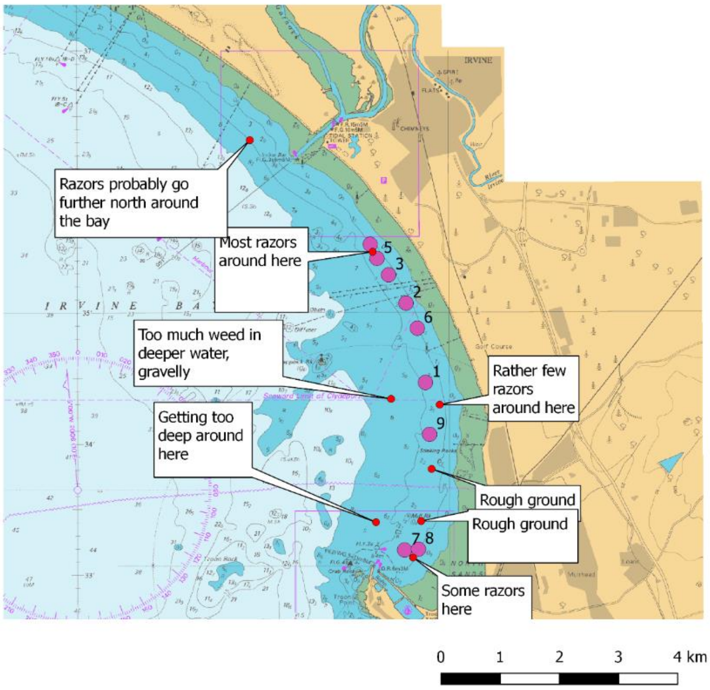


Figure 16: Worked tows in North Bay, Clyde. Purple dots, worked stations; Red dots – initial observations made on board survey vessel. Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.

Water temperatures were between 15.1 and 15.6°C and salinities were between 31.5 and 32.7. Temperatures were slightly warmer and salinities slightly lower at the surface than at depth (Figure 17).

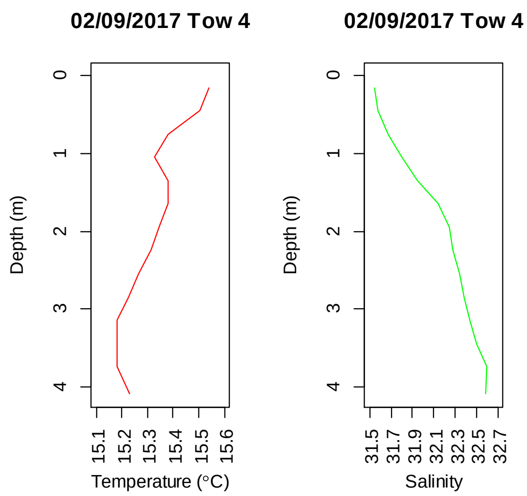
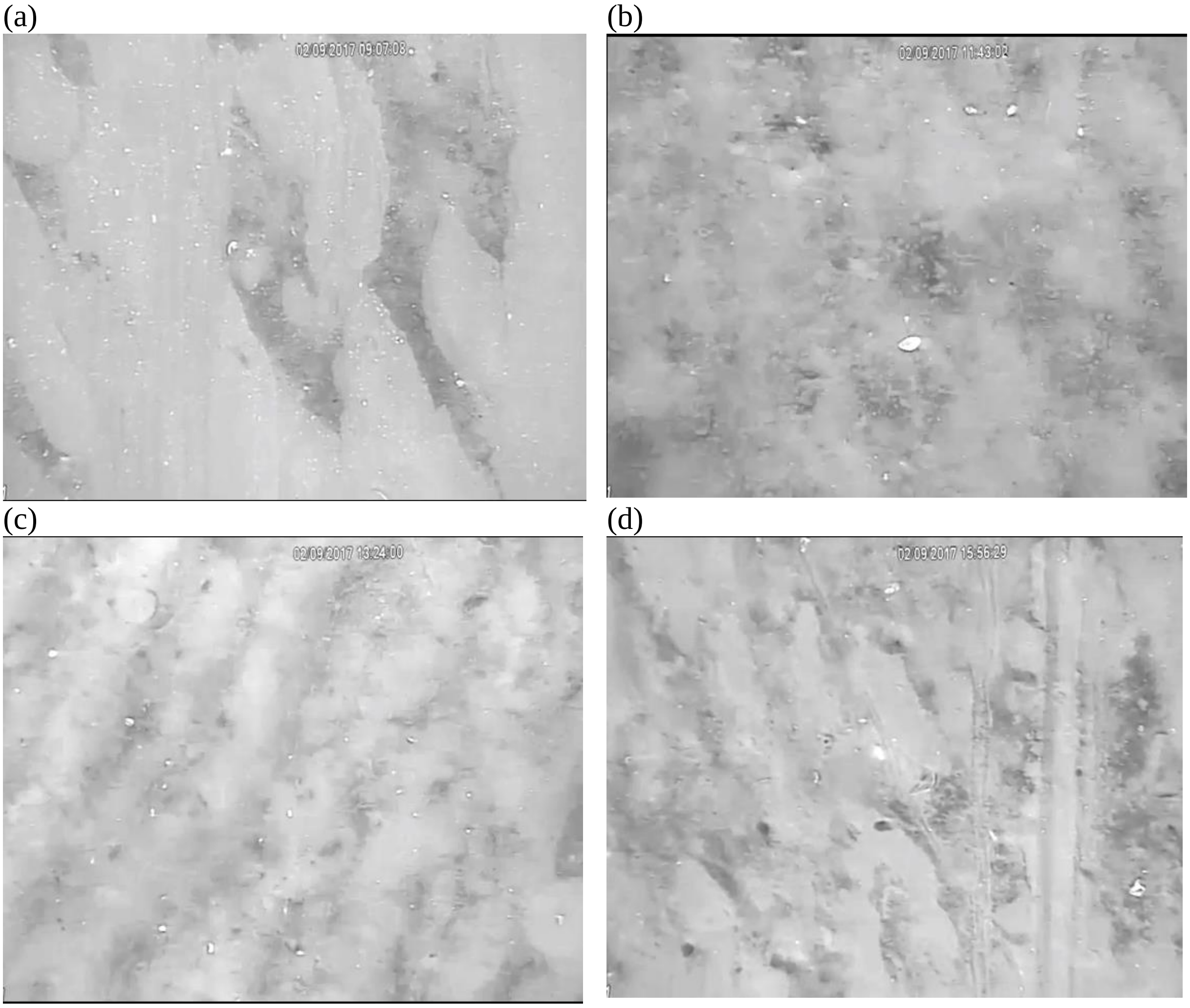


Figure 17: CTD profile for North Bay, Clyde.

The sediment consisted of slightly silty sand mingled with shell fragments, rippled sand on some tows and patches of benthic phytoplankton (Figure 18).

Figure 18: Representative images of the seabed in North Bay, Clyde (a) Tow 1, (b) Tow 3, (c) Tow 5, (d) Tow 7.



The most common incidental organisms observed were shore crabs along with occasional fish (a single sandeel and several small flatfish). Patches of macroalgae were recorded on tow 9 (Table 3).

Table 3: Incidental records from North Bay, Clyde. * indicates probable identity from video but where key features were obscured or unclear.

Object	Tow								
	1	2	3	4	5	6	7	8	9
Crab (shore crab)	3	0	3	12	3	6	1	3	3
Fish (flatfish)	1	2	0	0	0	1	0	0	1
Fish (sandeel*)	0	1	0	0	0	0	0	0	0
Kelp	0	0	0	0	0	0	0	0	3

Observations on board the survey vessel suggested that there were reasonable densities of razors (>0.5 m^{-2}) on a few stations in North Bay. The area with reasonable densities was however less than the total area of the 2-10 m depth zone because of rocky outcrops, especially closer to Troon harbour. These outcrops are all marked on the Admiralty chart. Detailed analysis of the video confirmed the on-board observations with densities above 0.5 *E. siliqua* m^{-2} only being found on Tows 4, 7 and 8 (Table 4).

A total of 249 whole *E. siliqua* were measured (Figure 19) with all being above the MCS of 100 mm length.

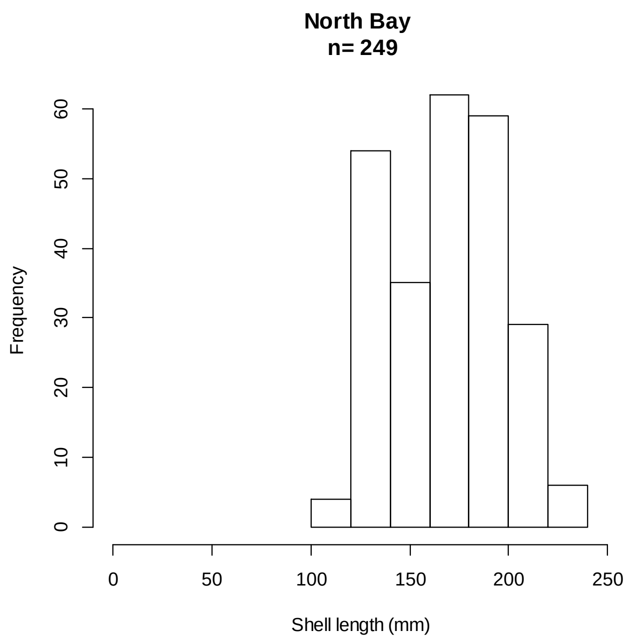


Figure 19: Histogram of measured *E. siliqua* from North Bay surveys.

Table 4: Summary results for *E. siliqua* from the video tows undertaken in North Bay, Clyde.

Tow	Average depth (m)	UTC Start	Lat Start (degrees)	Lon Start (degrees)	UTC End	Lat End (degrees)	Lon End (degrees)	Tow Len (mins)	Tow Len GPS (m)	Tow Length Vertical Stitched (m)	Quality Vertical Stitching	Average speed GPS-based (m^{-1})	Swept area GPS-based (m^2)	Raised count *E. siliqua*<100mm length	Raised count *E. siliqua*>100mm length	Density *E. siliqua*<100mm length (m^{-2})	Density *E. siliqua*>100mm length (m^{-2})
1	8	09:02	55.5741	-4.6720	09:22	55.5737	-4.6719	00:20	43	39	High	2.1	64	0.0	14.0	0.000	0.218
2	17	10:28	55.5845	-4.6763	10:48	55.5839	-4.6762	00:20	63	61	High	3.2	95	0.0	26.5	0.000	0.280
3	6	11:43	55.5881	-4.6802	12:03	55.5886	-4.6807	00:20	62	66	High	3.1	93	0.0	37.0	0.000	0.400
4	15	12:34	55.5920	-4.6843	12:54	55.5916	-4.6834	00:20	69	67	High	3.4	103	0.0	82.5	0.000	0.799
5	5	13:24	55.5903	-4.6830	13:39	55.5901	-4.6823	00:15	49	49	High	3.3	74	0.0	25.0	0.000	0.337
6	4	14:40	55.5813	-4.6738	14:55	55.5806	-4.6739	00:15	73	71	High	4.9	109	0.0	44.5	0.000	0.408
7	4	15:54	55.5531	-4.6768	16:09	55.5527	-4.6771	00:15	51	47	High	3.4	76	0.0	45.5	0.000	0.598
8	4	16:50	55.5532	-4.6737	17:05	55.5526	-4.6738	00:15	58	56	High	3.8	86	0.0	52.0	0.000	0.603
9	6	17:55	55.5678	-4.6711	18:10	55.5673	-4.6714	00:15	59	60	Medium	3.9	89	0.0	2.0	0.000	0.023

Meikle Bay, Clyde

Ten tows were completed in Meikle Bay in water depths between 4.5 and 9.5 m (Figure 20).

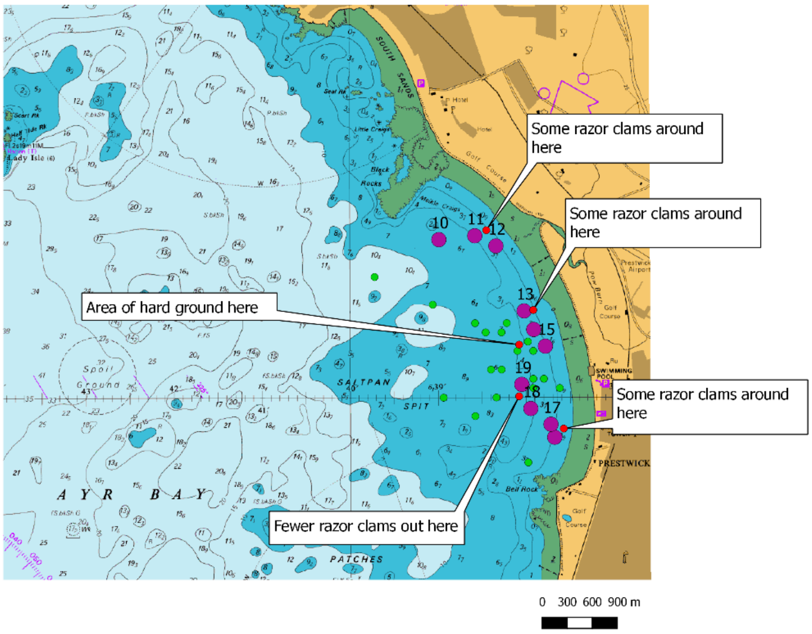


Figure 20: Worked tows in Meikle Bay, Clyde. Purple dots, worked stations; Green dots, spots noted as unsuitable on sounder or video; Red dots – initial observations made on board survey vessel. Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.

Water temperatures were between 15.4 and 15.5 C and salinities were between 32.4 and 32.5 with hardly any variation with depth (Figure 21).

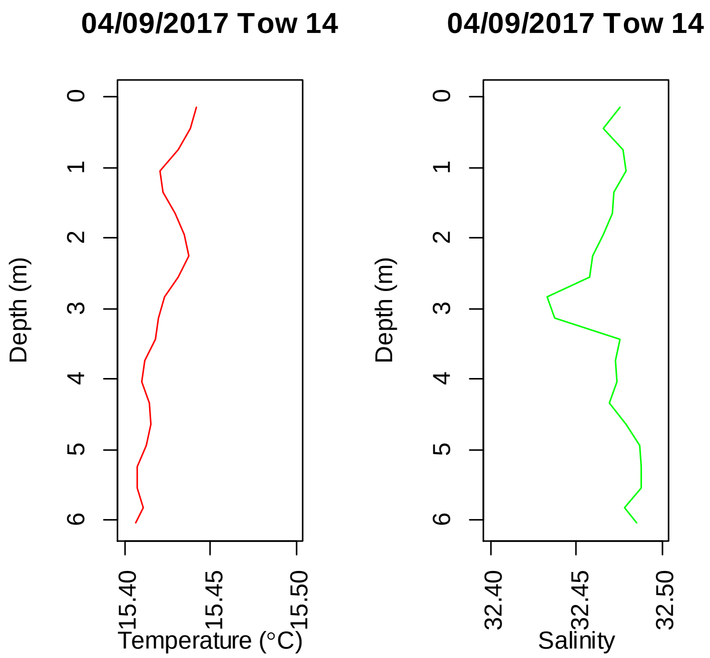
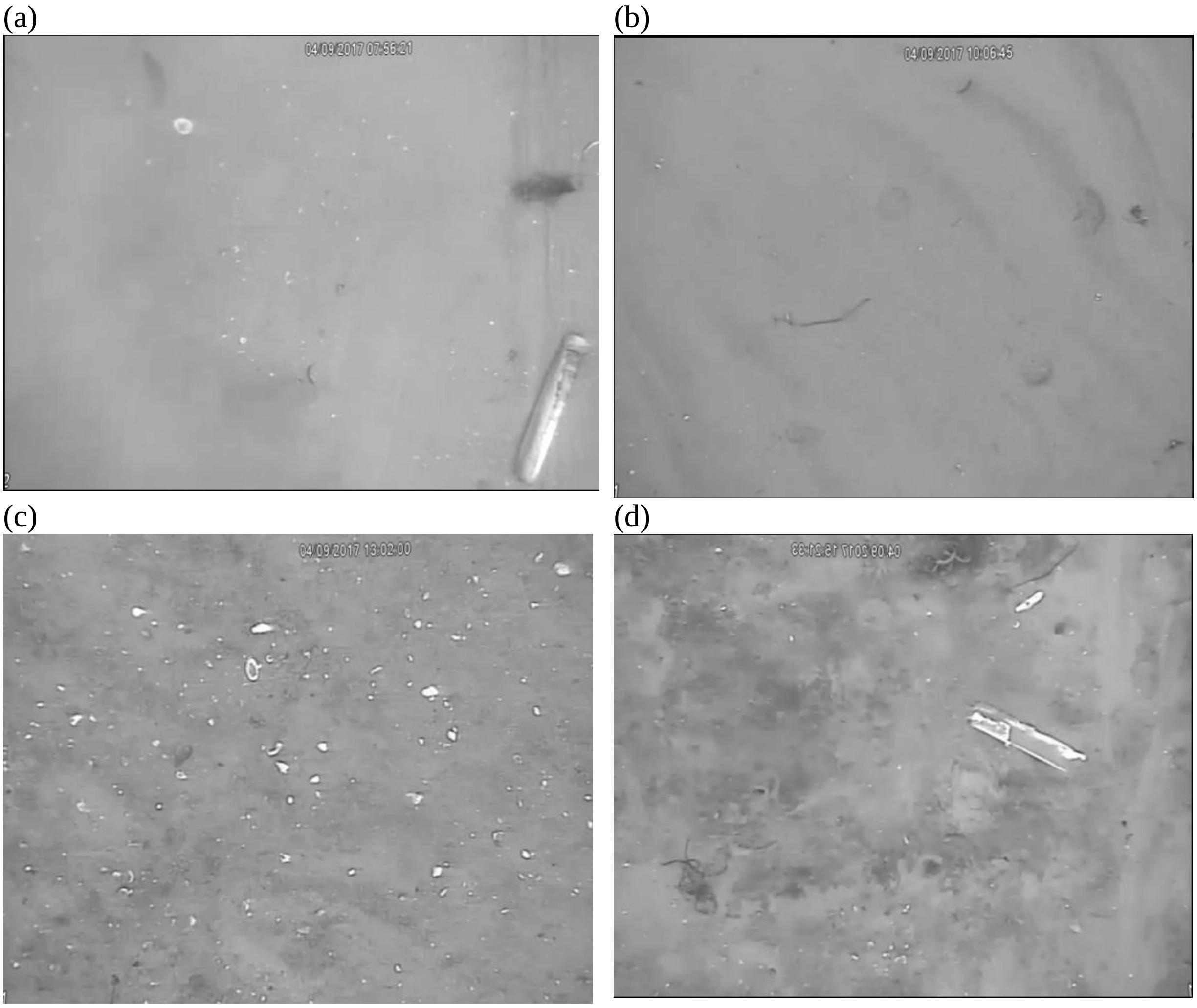


Figure 21: CTD profile for Meikle Bay, Clyde

The appearance of the seabed for representative tows is shown in Figure 22. Sediments were fine sand with small ripples at the northern tows (10-15) becoming mingled with more shell fragments moving southwards (16-19).

Figure 22: Representative images of the seabed in Meikle Bay, Clyde (a) tow 10, (b) tow 13, (c) tow 16, (d) tow 19.



Shore crabs were the most common incidental organisms seen and one was observed attacking an emerged razor clam. Other records included occasional small flatfish and a single sandeel (Table 5).

Table 5: Incidental records from Meikle Bay, Clyde. * indicates probable identity from video but where key features were obscured or unclear.

Object	Tow									
	10	11	12	13	14	15	16	17	18	19
Crab (shore crab) attacking razor clam	0	0	0	0	1	0	0	0	0	0
Crab (shore crab*)	5	3	7	2	1	0	0	1	1	0
Crab (shore crab)	0	0	0	0	0	0	2	2	6	1
Fish (flatfish)	0	0	0	1	2	0	0	1	0	1
Fish (sandeel)	0	0	0	0	0	0	0	1	0	0

Observations made on board the survey vessel indicated reasonable densities of razor clams (> 0.5 m^{-2}) in this block. It was noted that the main area of sand runs in a band between the chart datum and 5 m chart contour. This corresponds roughly to water depths of 2 to 8 m taking account of the mean tidal elevation. Although razor clams were present at some of the deeper tows their abundance appeared to be less than at the inshore tows. Further offshore the ground also became rougher as evidenced by the presence of buoys marking the location of lobster and crab creels. Detailed analysis of the video confirmed the impressions recorded on-board with 60% of tows having densities between 0.5 and 1.0 *E. siliqua* m^{-2} (Table 6).

A total of 386 whole *E. siliqua* were measured (Figure 23) with all but a few above the MCS of 100 mm length.

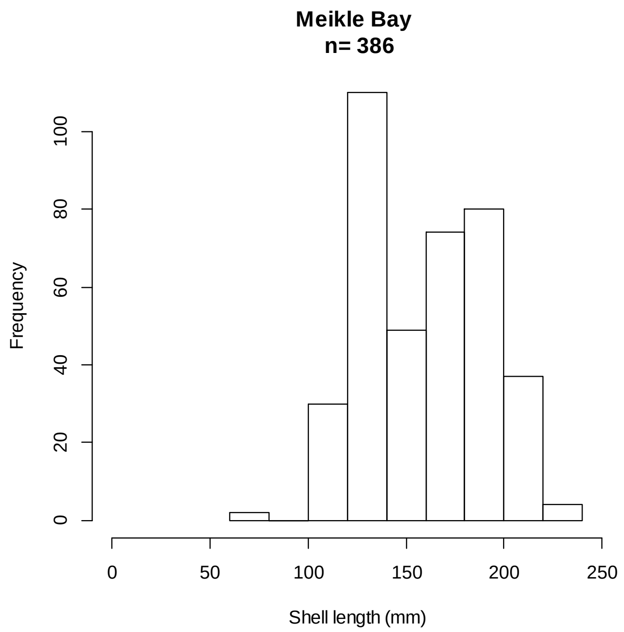


Figure 23: Histogram of measured *E. siliqua* from Meikle Bay surveys.

Table 6: Summary results for *E. siliqua* from the video tows undertaken in Meikle Bay, Clyde.

Tow	Average depth (m)	UTC Start	Lat Start (degrees)	Lon Start (degrees)	UTC End	Lat End (degrees)	Lon End (degrees)	Tow Len (mins)	Tow Len GPS (m)	Tow Length Vertical Stitched (m)	Quality Vertical Stitching	Average speed GPS-based (m^{-1})	Swept area GPS-based (m^2)	Raised count *E. siliqua*<100mm length	Raised count *E. siliqua*>100mm length	Density *E. siliqua*<100mm length (m^{-2})	Density *E. siliqua*>100mm length (m^{-2})
10	10	07:54	55.5170	-4.6498	08:10	55.5169	-4.6505	00:16	45	61	Low	2.8	68	0.0	29.0	0.000	0.425
11	8	08:45	55.5174	-4.6430	09:00	55.5169	-4.6437	00:15	65	68	Low	4.3	97	0.0	91.5	0.000	0.944
12	5	09:24	55.5163	-4.6390	09:39	55.5156	-4.6389	00:15	72	69	Medium	4.8	109	0.0	65.0	0.000	0.598
13	6	10:06	55.5093	-4.6337	10:21	55.5087	-4.6334	00:15	76	73	High	5.1	114	0.0	60.5	0.000	0.531
14	10	11:20	55.5073	-4.6319	11:30	55.5069	-4.6321	00:10	53	57	Medium	5.3	79	1.4	49.1	0.017	0.623
15	4	12:06	55.5055	-4.6297	12:21	55.5059	-4.6291	00:15	58	55	Medium	3.9	88	0.0	53.0	0.000	0.605
16	4	13:02	55.4957	-4.6280	13:17	55.4953	-4.6284	00:15	51	50	Medium	3.4	77	0.0	32.5	0.000	0.424
17	5	13:40	55.4971	-4.6287	13:55	55.4966	-4.6294	00:15	64		Failed	4.3	96	0.0	63.0	0.000	0.656
18	7	14:25	55.4988	-4.6325	14:45	55.4984	-4.6334	00:20	68	70	Medium	3.4	102	1.3	40.2	0.013	0.393
19	7	15:20	55.5014	-4.6342	15:35	55.5009	-4.6348	00:15	65			4.3	97	0.0	43.0	0.000	0.444

Culzean Bay

Ten tows were undertaken in Culzean Bay in water depths between 5 and 12 m (Figure 24).

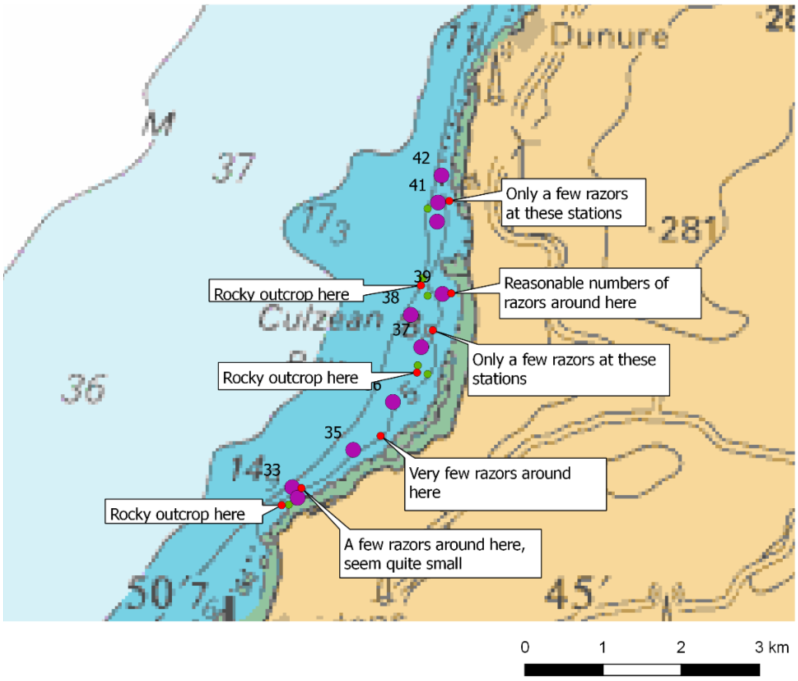


Figure 24: Worked tows in Culzean Bay, Clyde. Purple dots, worked stations; Green dots, spots noted as unsuitable on sounder or video; Red dots – initial observations made on board survey vessel. Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.

Water temperatures were between 14.7 and 14.8°C and salinity between 32.7 and 32.9. There was very little difference in temperature or salinity with depth (Figure 25).

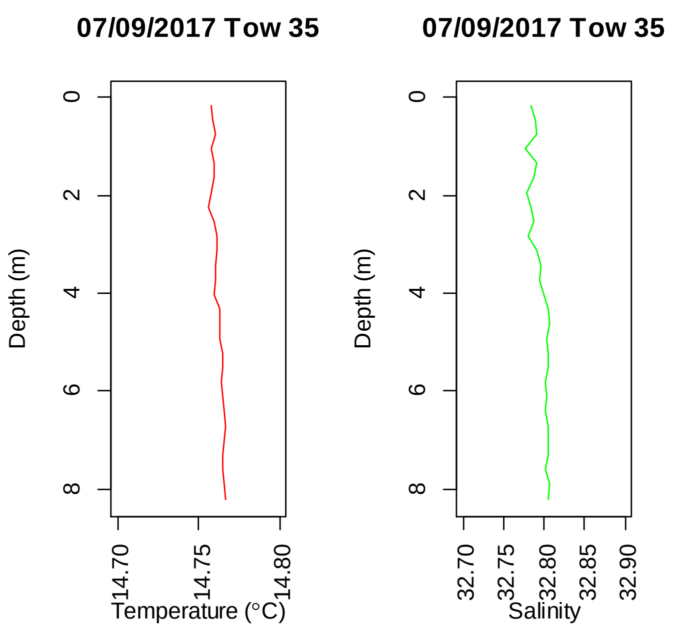
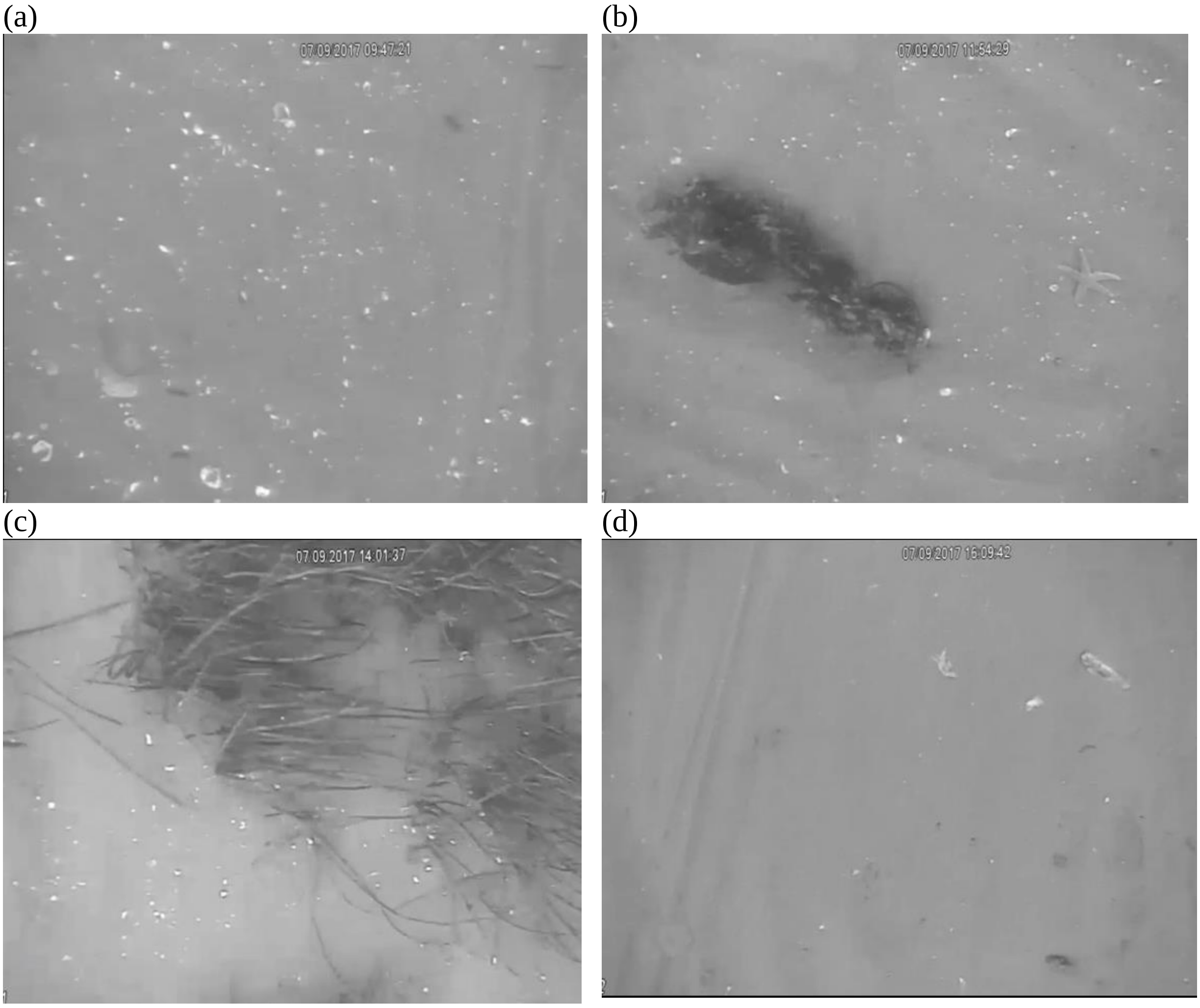


Figure 25: CTD profile for Culzean Bay, Clyde.

Sediments were mainly fine sand mingled with shell fragments with occasional isolated patches of sea grass. At the middle stations there were many sand marks typical of sand or blunt gaper, *Mya spp*. (Figure 26). According to the skipper these clams do not react to electrical stimulation, in contrast to *Ensis*.

Figure 26: Representative images of the seabed in Culzean Bay, Clyde (a) Tow 33, (b) Tow 36, (c) Tow 39, (d) Tow 42.



The most common incidental organisms observed in were shore crabs but a few edible (brown) crabs were also seen (Table 7). This probably reflects the closeness of the rocky reefs to some of the tows as flags marking creels were also seen in this area (Tows 37-39). Occasional fish were also observed, gobies, juvenile flatfish and sandeels. Starfish were also quite common on Tows 34-36.

Table 7: Incidental records from Culzean Bay, Clyde. * indicates probable identity from video but where key features were obscured or unclear.

Object	Tow										
	32	33	34	35	36	37	38	39	40	41	42
Crab (brown crab)	0	0	0	0	0	1	2	1	0	0	0
Crab (shore crab)	4	4	2	6	8	6	3	9	7	7	2
Crab (hermit)	0	1	1	0	0	0	0	0	0	0	0
Fish (flatfish)	1	0	1	0	0	0	0	0	1	0	0
Fish (goby*)	0	1	0	0	0	0	0	0	0	0	0
Fish (sandeel)	0	0	0	0	0	0	0	1	0	0	0
Fish (sole*)	0	0	0	0	0	0	0	0	0	1	0
Seagrass	0	0	0	0	0	0	0	2	0	0	0
Starfish	2	0	12	4	8	7	2	0	3	2	0

Observations made on board the survey vessel suggested very few razors at the southerly stations with moderate numbers at one or two of the more northerly tows. Detailed analysis of the videos largely confirmed these observations although the south to north difference was less apparent in final density estimates which were nearly all less than 0.5 *E. siliqua* m^{-2} (Table 8).

A total of 160 whole *E. siliqua* were measured (Figure 27) with all but one above the MCS of 100 mm length.

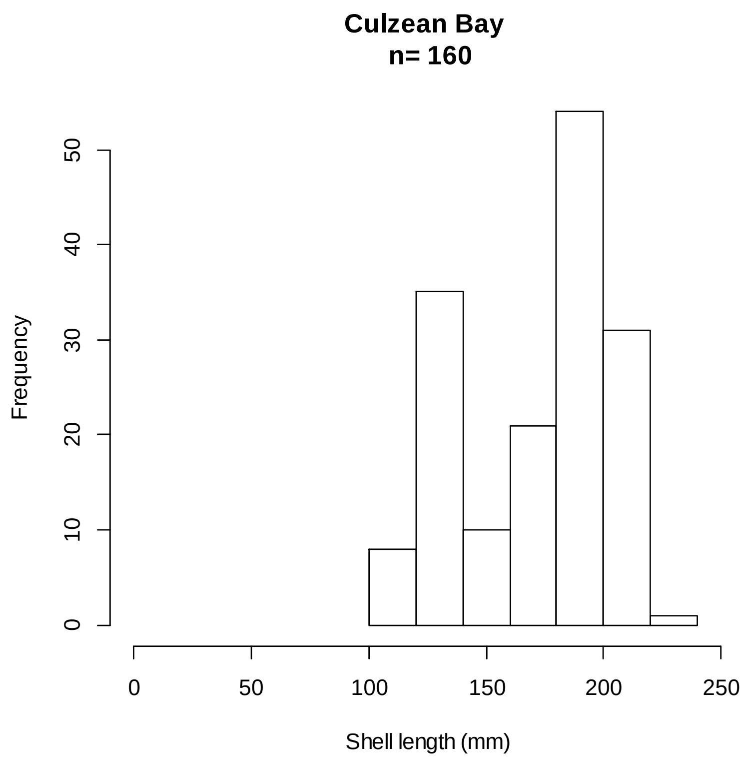


Figure 27: Histogram of measured *E. siliqua* from Culzean Bay surveys.

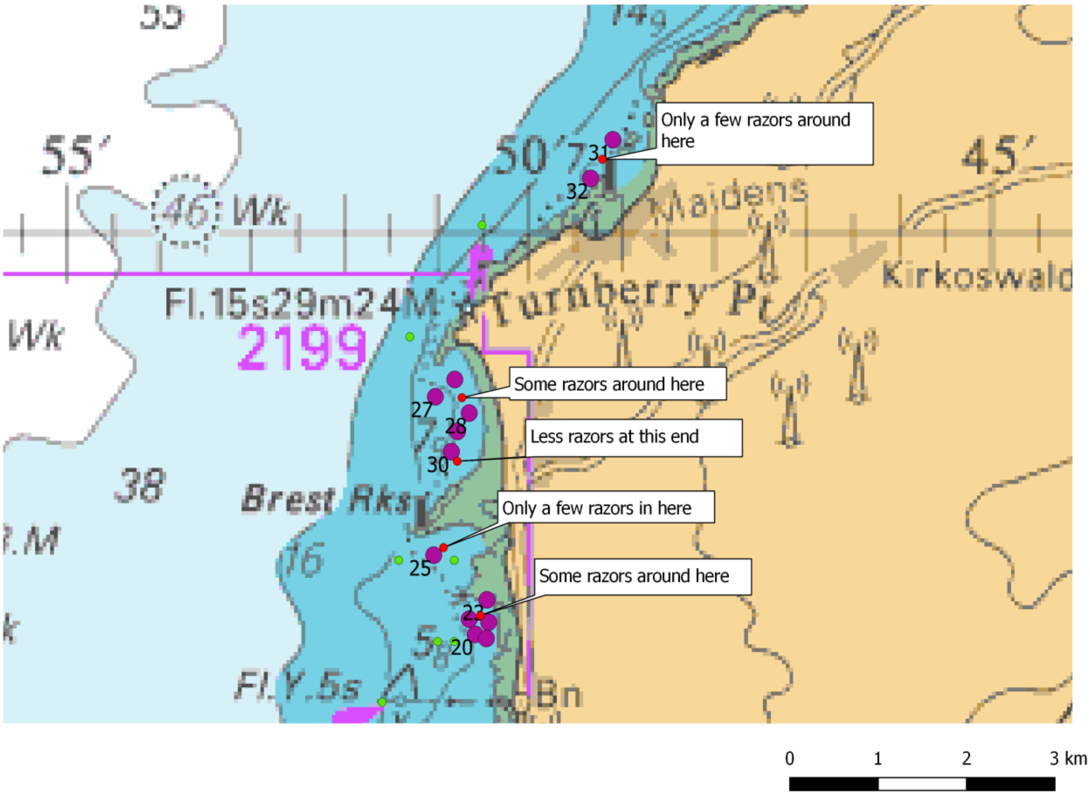
Table 8: Summary results for *E. siliqua* from the video tows undertaken in Culzean Bay, Clyde.

Tow	Average depth (m)	UTC Start	Lat Start (degrees)	Lon Start (degrees)	UTC End	Lat End (degrees)	Lon End (degrees)	Tow Len (mins)	Tow Len GPS (m)	Tow Length Vertical Stitched (m)	Quality Vertical Stitching	Average speed GPS-based (m^{-1})	Swept area GPS-based (m^2)	Raised count *E. siliqua*<100mm length	Raised count *E. siliqua*>100mm length	Density *E. siliqua*<100mm length (m^{-2})	Density *E. siliqua*>100mm length (m^{-2})
33	10	09:47	55.3530	-4.8063	10:02	55.3526	-4.8070	00:15	54	52	High	3.6	81	0.0	20.0	0.000	0.246
34	7	10:30	55.3518	-4.8052	10:45	55.3518	-4.8061	00:15	55	62	Medium	3.7	82	0.0	37.0	0.000	0.450
35	10	11:10	55.3573	-4.7940	11:25	55.3573	-4.7950	00:15	64	69	High	4.3	97	0.0	7.0	0.000	0.072
36	11	11:54	55.3628	-4.7860	12:09	55.3625	-4.7869	00:15	66	77	Low	4.4	100	0.0	18.0	0.000	0.181
37	10	12:38	55.3691	-4.7803	12:53	55.3685	-4.7807	00:15	72	66	Medium	4.8	108	0.0	8.5	0.000	0.079
38	12	13:22	55.3728	-4.7824	13:37	55.3723	-4.7830	00:15	61	71	Low	4.1	92	0.0	19.5	0.000	0.212
39	5	14:01	55.3752	-4.7760	14:16	55.3746	-4.7756	00:15	76	64	Low	5.1	114	1.2	77.3	0.011	0.676
40	7	14:44	55.3835	-4.7771	14:59	55.3829	-4.7769	00:15	64	45	Low	4.3	96	0.0	29.0	0.000	0.303
41	9	15:22	55.3857	-4.7769	15:37	55.3854	-4.7778	00:15	68	85	Low	4.5	102	0.0	14.0	0.000	0.137
42	8	16:09	55.3888	-4.7762	16:24	55.3883	-4.7762	00:15	54	51	Low	3.6	81	0.0	29.0	0.000	0.359

Turnberry Bay

Thirteen tows were undertaken in the area notionally called Turnberry Bay. However, this area consists of several smaller areas of sandy ground separated by rocky outcrops (Figure 28). The sandy areas to the north of Girvan (Tows 20-25) are separated from Turnberry Bay by the Brest Rocks. Turnberry Bay proper (Tows 26-30) lies between the Brest Rocks and Turnberry Point and north of Turnberry Point there is another small area of sandy ground, Maidens Head Bay (Tows 31 and 32).

Figure 28: Worked tows in Turnberry Bay, Clyde. Purple dots, worked stations; Green dots, spots noted as unsuitable on sounder or video; Red dots – initial observations made on board survey vessel. Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.



Water temperatures were between 14.9 and 15.0°C and salinities between 32.3 and 32.5. Temperature varied little with depth although salinity decreased slightly below 5 m (Figure 29).

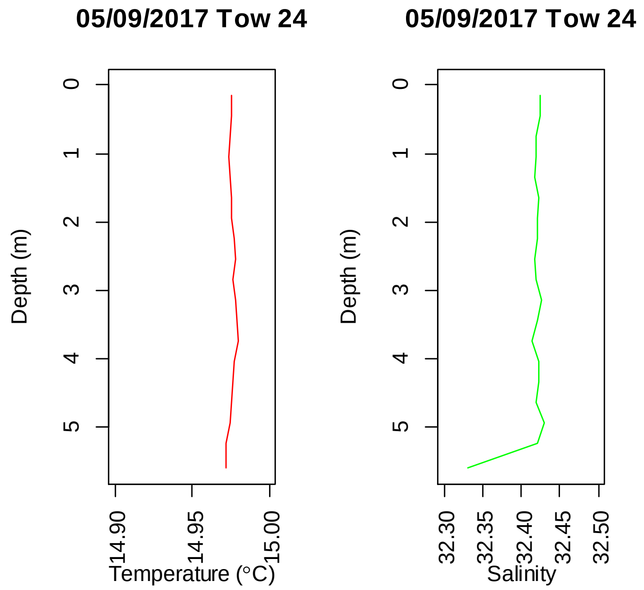
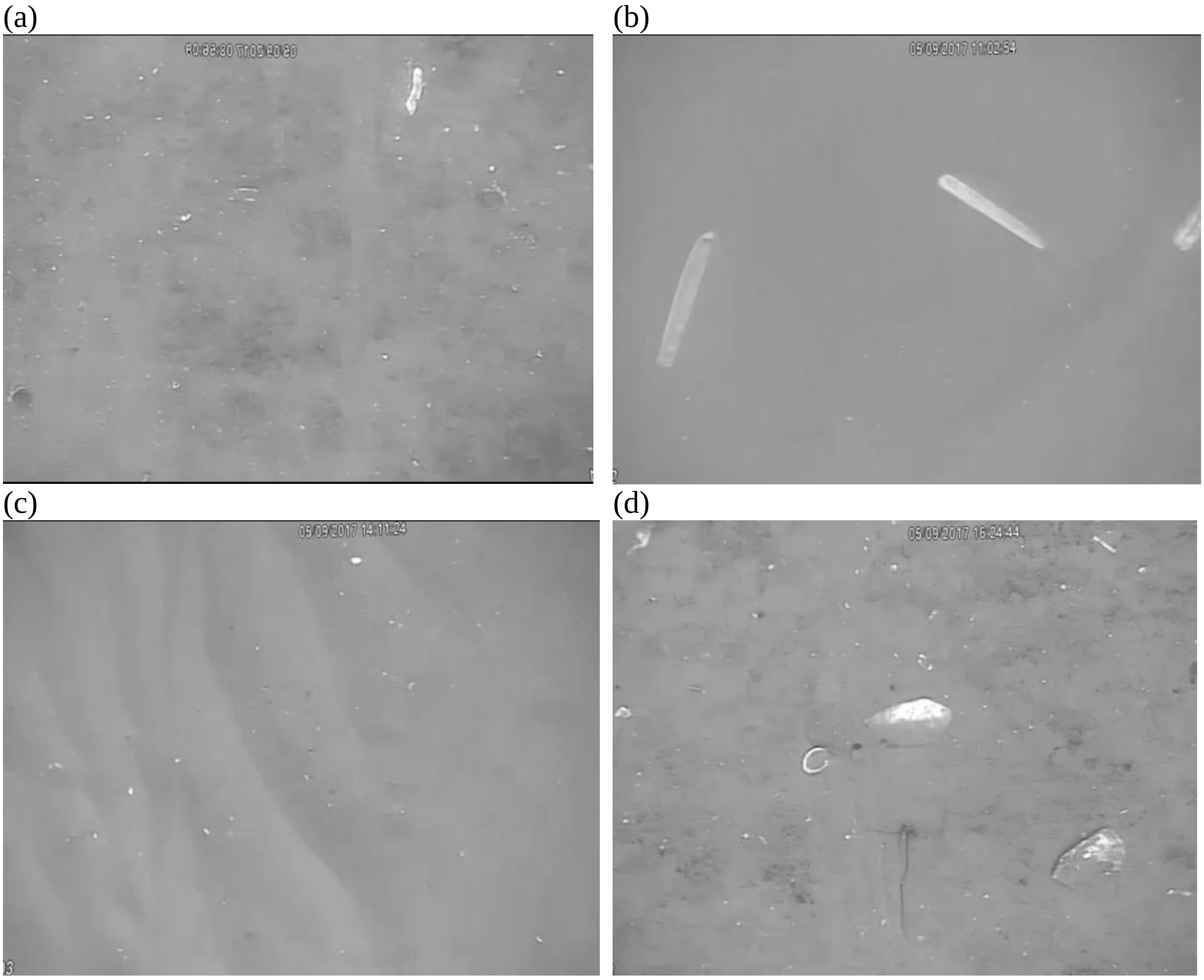


Figure 29: CTD profile for Matthews Harbour in the Turnberry Bay block of tows.

Sediments were fine clean sand sometimes mingled with shell fragments with slight rippling on some tows (Figure 30). Quite a lot of empty bivalve shells were seen on the more northern tows which were probably the remains of sand or blunt gaper, *Mya* spp.

Figure 30: Representative images of the seabed in Turnberry Bay, Clyde (a) Tow 21, (b) Tow 24, (c) Tow 28, (d) Tow 31.



Shore crabs were the most common incidental organism recorded along with occasional fish (Table 9). Starfish were quite common on some tows, particularly those adjacent to the Brest Rocks.

Table 9: Incidental records from Turnberry Bay, Clyde. * indicates probable identity from video but where key features were obscured or unclear.

Object	Tow											
	20	21	22	23	24	25	26	27	28	29	30	31
Crab (shore crab)	5	4	3	1	1	2	5	4	2	2	5	4
Fish (flatfish)	1	1	1	0	0	0	2	0	1	1	0	0
Fish (goby)	0	0	1	1	0	0	0	0	0	0	0	0
Fish (goby*)	0	0	1	0	1	1	0	0	0	0	0	0
Fish (sandeel)	0	0	0	0	0	0	0	0	2	0	0	0
Fish (sandeel*)	0	0	0	0	0	0	0	0	2	0	0	0
Fish (scorpion fish)	0	0	1	0	0	0	0	0	0	0	0	0
Starfish	0	0	0	0	0	15	4	9	0	2	10	3

Observations recorded on board the survey vessel suggested reasonable quantities of razor clams at the southern sites. Only a few razor clams were observed to the south-west of the Brest Rocks and the sandy patch here is rather small in extent. Reasonable densities of razor clams (> 0.5 m^{-2}) were seen on the videos in Turnberry Bay itself but mainly on the more northern tows. Detailed analysis of the videos largely confirmed these impressions with 38% of tows having densities between 0.5 and 1.0 *E. siliqua* m^{-2} and 23% having densities exceeding 1.0 *E. siliqua* m^{-2} (Table 10).

A total of 586 whole *E. siliqua* were measured (Figure 31) with the majority being above the MCS of 100 mm shell length.

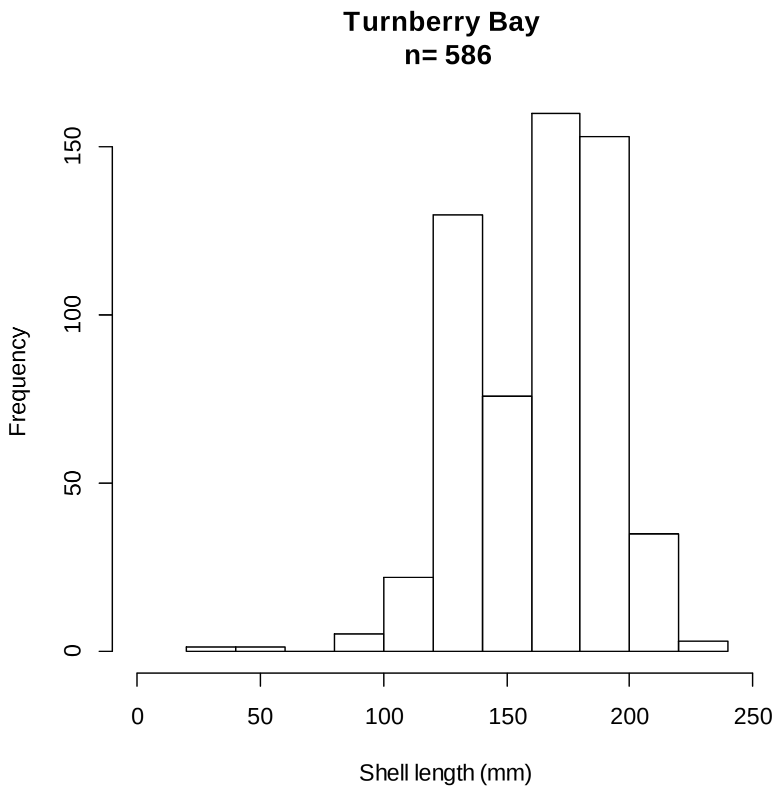


Figure 31: Histogram of measured *E. siliqua* from Turnberry Bay surveys.

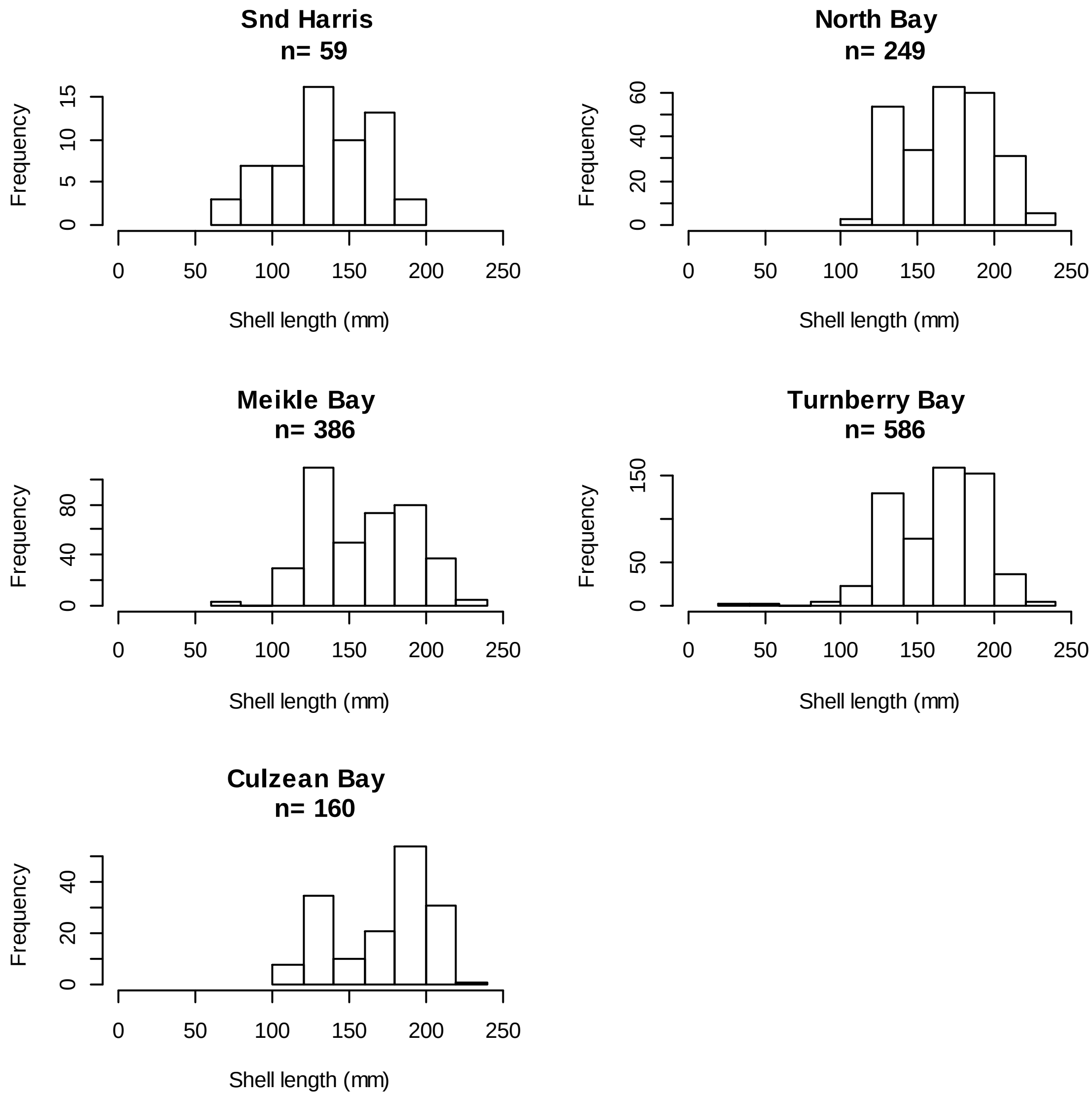
Table 10: Summary results for *E. siliqua* from the video tows undertaken in Turnberry Bay block, Clyde.

Tow	Average depth (m)	UTC Start	Lat Start (degrees)	Lon Start (degrees)	UTC End	Lat End (degrees)	Lon End (degrees)	Tow Len (mins)	Tow Len GPS (m)	Tow Length Vertical Stitched (m)	Quality Vertical Stitching	Average speed GPS-based (m^{-1})	Swept area GPS-based (m^2)	Raised count *E. siliqua*<100mm length	Raised count *E. siliqua*>100mm length	Density *E. siliqua*<100mm length (m^{-2})	Density *E. siliqua*>100mm length (m^{-2})
20	7	08:14	55.2937	-4.8432	08:29	55.2932	-4.8433	00:15	56	61	Low	3.7	84	0.0	118.5	0.000	1.409
21	7	08:54	55.2952	-4.8443	09:09	55.2946	-4.8444	00:15	66	67	Medium	4.4	98	1.3	98.2	0.013	0.998
22	5	09:40	55.2949	-4.8408	09:55	55.2945	-4.8407	00:15	48	44	Low	3.2	73	1.4	43.6	0.019	0.600
23	4	10:19	55.2971	-4.8411	10:34	55.2969	-4.8417	00:15	46	49	Low	3.1	69	0.0	20.5	0.000	0.298
24	6	11:01	55.2933	-4.8412	11:16	55.2929	-4.8406	00:15	63	52	Low	4.2	94	0.0	70.5	0.000	0.750
25	10	11:51	55.3015	-4.8507	12:06	55.3012	-4.8512	00:15	46	32	Low	3.0	69	3.0	103.5	0.044	1.509
26	6	12:43	55.3188	-4.8469	12:58	55.3183	-4.8470	00:15	63	64	Low	4.2	95	0.0	111.5	0.000	1.176
27	10	13:34	55.3171	-4.8504	13:49	55.3167	-4.8510	00:15	62	60	Medium	4.1	93	2.5	70.5	0.027	0.758
28	2	14:10	55.3155	-4.8443	14:25	55.3150	-4.8445	00:15	61	63	High	4.1	91	0.0	39.0	0.000	0.427
29	5	14:44	55.3137	-4.8464	14:59	55.3137	-4.8473	00:15	59	63	High	4.0	89	1.4	47.1	0.016	0.529
30	6	15:21	55.3117	-4.8475	15:36	55.3111	-4.8481	00:15	76	74	High	5.1	114	0.0	41.5	0.000	0.363
31	7	16:24	55.3424	-4.8184	16:39	55.3422	-4.8190	00:15	48	51	High	3.2	71	0.0	13.0	0.000	0.182
32	7	17:12	55.3395	-4.8224	17:27	55.3392	-4.8228	00:15	42	45	High	2.8	63	0.0	27.5	0.000	0.438

Razor Clam Size Distributions

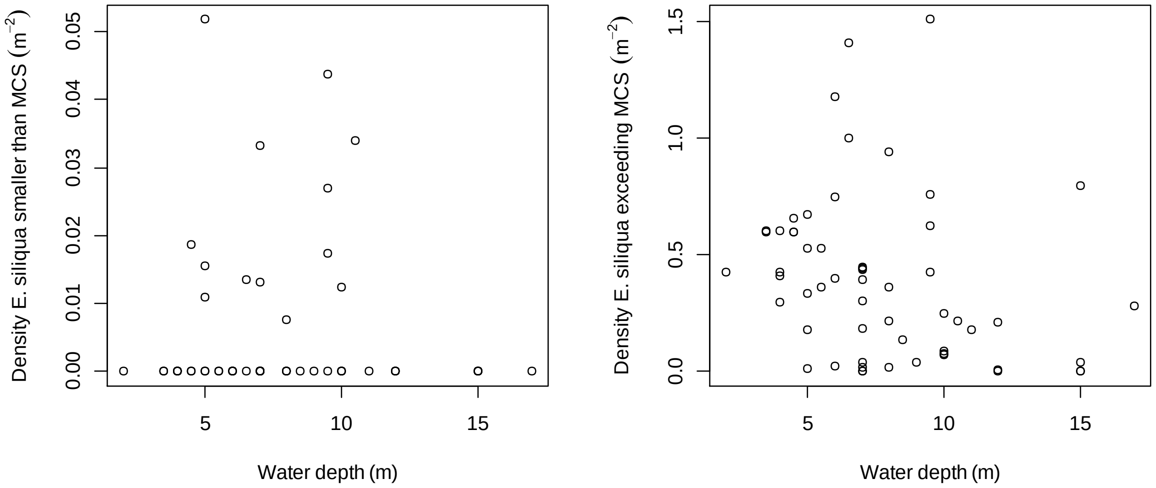
Comparing the sizes of razor clams (*E. siliqua*) across all sites (Figure 32) suggests rather similar patterns along the Ayr coast and perhaps even for the Sound of Harris. There seem to be two modes, one around 120-130 mm and the other around 175 mm. These possibly represent two age/size groups but there was little evidence of large numbers of smaller recruiting clams at any of the sites.

Figure 32: Histogram of measured *E. siliqua* from all sites.



There was a tendency for lower densities of razor clams to be found in deeper water (Figure 33) although this impression is based on very few tows in depths exceeding 10 m.

Figure 33: Relationship between densities of *E. siliqua* below the MCS (left panel) and above the MCS (right panel) and water depth at time of sampling (note water depths have not been corrected for tidal elevation at time of sampling).



There was also no obvious relationship between *E. siliqua* size and water depth (Figure 34) although this result is based on very few tows in depths exceeding 10 m.

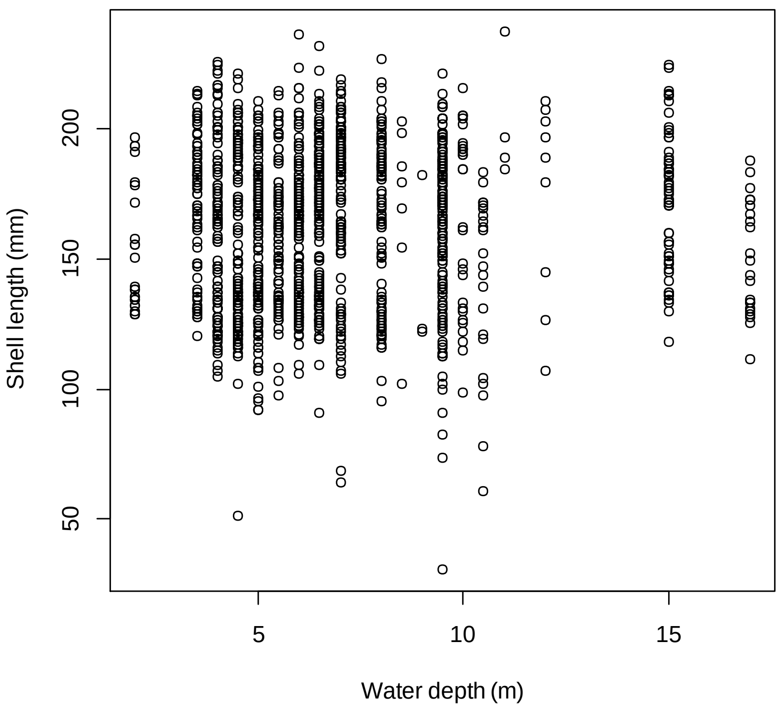


Figure 34: Relationship between individual *E. siliqua* shell lengths as estimated from the videos and average water depth at time of sampling.

Discussion and Conclusions

There are a limited number of historical estimates of razor clam densities with which to compare the present findings. McKay (1992) conducted surveys for a variety of shellfish using a suction dredge around Scotland, but not in the Clyde. *Ensis siliqua* were recorded, particularly around Orkney and the Outer Hebrides, but catches were expressed as number of clams per hour of fishing so cannot be easily compared with area-based densities. Local density estimates for *Ensis* (both species combined) made by divers in Loch Nevis, Scotland were reported to be up to 17 clams m^{-2}. The mean density was not reported but may have been about 5-6 m^{-2} based on Figure 10 in Murray et al. (2014). Based on a limited number of tows using electrofishing gear average densities for *E. siliqua* to the north of Barra were between 1.4 to 2.3 m^{-2} and were 1.5 m^{-2} in the Sound of Eriskay (Fox 2017). Hauton et al. (2007) surveyed Irvine Bay in the early 2000s using a hydraulic dredge and recorded densities of *E. siliqua* of around 5.5 clams m^{-2}. The densities found in the present study for the Sound of Harris and off the Ayr coast appear to be low with only a few tows exceeding 1.0 m^{-2}. The lack of *E. siliqua* in the Sound of Harris likely reflects unsuitable conditions with many of the locations being too exposed to favour razor clams. It is notable that the only tows with moderate densities were in more sheltered areas, such as the Sound of Berneray. Because of the lack of historical stock assessments it is difficult to say whether present razor clam densities along the Ayr coast are substantially less than historical abundances. However, anecdotal evidence (skipper pers. comm.) suggests that harvesting of razor clams has taken place, at least at some of these sites, over recent years.

Tow speeds (2-7 m min^{-1}) in the present surveys were higher than reported in Fox (2017) using the fishing vessel '*Lizanna'*. The reason for the difference between the two vessels is due to the method of moving the vessel whilst towing. On '*Lizanna'* the warp was paid out gradually by-hand over the pot-hauling drum with the vessel being moved backwards from the anchor point by the wind and tide. On '*Nicola Jane'* the vessel deployed a clump and was then drawn towards the anchor warping in by the hydraulic winch (Figure 6). Use of the winch results in faster speeds over the ground compared with relying on wind and tide to move the vessel. It does, however, allow working in slightly poorer weather conditions and allows more control on the direction of the tow. Although faster speed over the ground will result in shorter exposure times to the electricity, the tow speeds in the present study were within the range reported for previous trials of electrofishing (Murray et al. 2014).

The efficiency of the gear in forcing razor clams completely out of the sediment in the present study did seem to vary between tows, as evidenced by the ratio of Class 1 (fully emerged *Ensis*) versus Class 3 (partially emerged *Ensis*) counts. This was probably a result of differences in sediment type although the depth clams bury is also thought to change in response to environmental factors, such as winds from certain directions (skipper pers. observation). Low water temperatures are also supposed to affect the efficiency of electrofishing but the water temperatures in the present study were above those recorded in Murray et al. (2014).

Data from the forward-looking camera, plus the fact that the power outputs from the inverter were continuously monitored, did not give any reason to think that the electrofishing equipment was not performing well throughout. The low abundances observed are, therefore, thought to genuinely reflect the stocks of razor clams at these sites.

In future surveys carrying an additional small drop-down camera would help speed-up initial evaluations of the seabed condition and help confirm the impressions of the seabed type from the ship's sounder. Although seabed type was evaluated using the depth-plotter and from the towed video at the start of each tow, the deployment of the full electrofishing-video rig took some time. This is because before the video rig is lowered to the seabed the main anchor has to be dropped, the vessel reversed as the warp is paid out and the clump dropped. In a few cases the tow had to be abandoned at this stage, because of the presence of hard ground on the video.

Accurate estimation of tow lengths remains another area which could be improved. Although the accuracy of the vessel's GPS used in this study is unknown, values of +/-5 m are often quoted (https://www.gps.gov/systems/gps/performance/accuracy/). Fixed errors in tow length, such as might be expected from GPS-based navigation systems, will have proportionally more impact when the total tow length is small. An accuracy of +/-5 m could result in tow length errors of up to 5% on a 100 m long tow but 10% on a 50 m long tow. On the other hand when razor clam densities are around 1 m^{-2} tow lengths longer than 50-60 m will not substantially increase the precision of the final density estimations (Fox 2017). Longer tows will however increase both survey time and the amount of video processing and data analysis needed so there is a trade-off between using longer versus shorter tows. As an alternative to relying on manual recording of the tow start and end positions, Fox (2017) developed a method of vertically stitching sequential video frames to generate a composite image of the whole tow from which the tow length could be estimated. However, in the present study about 33% of tows failed to generate good quality stitched images so tow length estimates were based on the GPS co-ordinates at the start and end of each tow. Comparing the GPS-based tow length estimates with those from vertically stitching the videos suggested generally good agreement. Tow length estimates should be accurate within +/-5 m.

One final difference between the present surveys and those described in Fox (2017) was that divers were not used in 2017. The method of deploying the equipment was successfully modified resulting in lower overall survey costs. However, the lack of divers on the survey meant that razor clams could not be collected for additional length-weight measurements or maturity scoring but sampling from the commercial fishery should allow additional samples to be collected for this purpose in future.

Acknowledgements

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Appendix I
Preliminary Observations Collected During the Surveys

Narrative

Surveys were conducted for razor clams (*Ensis siliqua* and *Ensis arcuata*) in late August and early September 2017 in the the Sound of Harris and along the Clyde (Ayrshire) coast. This preliminary report relates to the Sound of Harris and North Bay. Surveys were conducted from a commercial shellfish harvesting vessel, the Nicola Jane, deploying a combination of electrofishing equipment and towed video cameras.

Sound of Harris

The survey team met the vessel at Berneray jetty on the morning of 25 August but problems with the electrofishing inverter meant that the *Nicola Jane* had to return to the mainland to collect a spare inverter unit. The actual work commenced on 26 August at 08:00. Surveying on day one targeted the proposed production area in the Sound of Berneray plus stations on the steam around to that site. Reaching the proposed production area took 2.5 hours due to the requirement to steam around Berneray to reach the access channel. This area is rather small and proved to be only accessible at high tide. Only three stations could be worked in the proposed production area in the Sound of Berneray before the falling tide meant the vessel had to exit the area. Very few razor clams were seen close to the Berneray-North Uist causeway although slightly higher numbers were seen at the site further to the west. On the second day further stations in Area 1 and 2 of the original sampling plan were surveyed. All stations in Area 3 were considered to be too deep. Grounds in the wider Sound of Harris proved difficult to work as they consist of patchy rock and reef which could not be sampled. Considerable time was spent steaming around trying to find suitable fishing locations based on the appearance of the seabed on the vessel's sounder. Other larger sandy areas in the Sound of Harris seemed very exposed to the Atlantic and few razor clams were seen on the video. These results conformed with the skippers assertion that razor clams require less exposed conditions. Overall 15 stations were completed with moderate numbers of razor clams only been observed at one site in the Sound of Berneray.

See Table 11 and Figure 35.

North Bay, Clyde

Following work in the Sound of Harris an additional forward looking video camera was installed on the towed rig. This modification was made in order to confirm that the rig was tracking the centre of the electrofishing gear. It also proved extremely useful in monitoring conditions ahead of the video gear and in observing the behaviour of clams as the electrofishing rig passed over them.

The survey team met the *Nicola Jane* at 08:00 on 2 September at Troon harbour. After loading, and setting up the equipment, the vessel proceeded to the North Bay at 09:00 heading to proposed site NB1. However, even this relatively inshore location proved to be around 20 m depth which was considered too deep to survey. Only two of the sampling locations proposed by Marine Scotland proved workable with the majority of the originally proposed locations being either too deep, or on gravel or rocky areas. Discussions with the skipper suggested that razor clams are only found in the Clyde between around 2 m to a maximum of 15 m water depth. Beyond this depth the sediment tends to become too muddy. The skipper also stated that he would only work in waters <15 m because allowable dive time would be too limited at greater depths for harvesting razor clams.

The orientation of the survey sites was thus changed to be parallel to the shore, in the depth zone 2-10 m with a few deeper stations. Locations were selected on the basis of the bottom appearance on the vessel's sounder. Although this means the survey did not follow a truly statistically random design, it seemed the only practical approach on the basis of conditions found on the ground. It was noted that even in areas where the chart indicated sand, this was not always accurate and several stations had to be moved once the bottom conditions had been observed on the video cameras just after deployment. Overall nine stations were completed in the North Bay (Clyde) before freshening breeze and increasing swell stopped work around 19:30. Moderate numbers of razor clams were observed at several locations. It was noted that reasonable densities (> 0.5 clams m 2) of razors were only found on a few stations and that the area where reasonable densities (> 0.5 clams m 2) were found is less than the total area of the 2-10 m zone because of rocky outcrops, not all well marked on the chart, especially closer to Troon harbour.

Weather conditions were poor on 3 September so survey is planned to continue on Monday 4 September working to the south of Troon. Based on experience so far it will probably be necessary to concentrate on stations in the shallower (<15 m) depths and to drop planned stations in deeper water.

See Table 12 and Figure 36.

Meikle Bay, Clyde

The *Nicola Jane* left Troon harbour at 07:15 on 4 September and proceeded south into Meikle Bay. Work started at location MC12 from the original survey plan. Ten video tows were completed, many close to the original proposed survey locations, or being moved slightly to avoid unsuitable ground as identified from the vessel sounder. Reasonable densities (> 0.5 clams m 2) of razor clams were observed within the bay. It was noted that the main area of sand appears to run in a band between the chart datum and 5 m chart contour. This corresponds roughly to depths below the water of between 2 to 8 m taking account of the tidal elevation. Although razor clams were present at some of the deeper tows their abundance appeared to be less than at the inshore tows. Further offshore the ground appeared to become rougher as evidenced by the presence of creel buoys at some locations. After completing work in Meikle Bay the *Nicola Jane* steamed to Girvan Harbour to reduce transit time to the stations to the south of the survey plan.

See Table 13 and Figure 37.

Turnberry Bay (Girvan to Maidenhead Bay), Clyde

The *Nicola Jane* left Girvan harbour around 07:30 on 5 September and proceeded towards the planned station CB43. The sounder indicated rough and rocky ground so the vessel continued north-east until suitable ground was indicated where video sampling commenced. Five stations were worked in Matthews Harbour area with reasonable quantities of razor clams being observed. A single station was then worked off Brest Rocks close to the planned station CB19. Only a few razor clams were observed here and the sandy patch was very small in extent. The *Nicola Jane* then moved to Turnberry Bay where a further five stations were completed. Reasonable densities (> 0.5 clams m 2) of razor clams were seen on the video but mainly on the more northern tows. The vessel was then moved around the rocky headland and two stations completed off Maidenhead Bay but very few razor clams were observed. The Nicola Jane then returned to Girvan and docked around 18:30 UTC (19:30 local time).

See Table 14 and Figure 38.

Weather conditions on 6 September were too poor to work with strong westerly winds causing a large amount of swell.

Culzean Bay, Clyde

Winds had lessened and swung to the south on 7 September allowing *Nicola Jane* to exit Girvan harbour around 08:00 by which time there was sufficient water depth to exit this tidal harbour. The vessel proceeded around to Culzean Bay and began sampling at 09:47. Ten stations were worked moving northwards and attempting to sample a range of depths. Very few razors were observed at the southerly stations. Moderate numbers were observed at one or two of the more northerly tows but overall the impression was of a rather depleted ground.

According to the skipper and the charts the area between worked station 42 and Ayr, off Dunure, is all rocky ground. *Nicola Jane,* therefore, returned to Girvan through heavy swell docking at around 20:00 UTC (21:00 local time). Electrofishing equipment was unloaded and returned to storage that night. Video survey equipment was unloaded and returned to SAMS the following day.

See Table 15 and Figure 39.

Overnight winds increased in strength and shifted to the west so that no further survey work was possible. However, all the original planned locations had been sampled so the survey was ended at this point. In total 42 stations were worked in the Clyde.

Operational issues

- The deployment of the video rig and electrofishing rig generally worked well, even without diver support. On some occasions the equipment became tangled while being deployed but was recovered and redeployed reasonably quickly (5-10 minutes) and no damage to the equipment occurred.
- The addition of a forward looking video camera to the towed rig was very helpful in monitoring that the equipment had deployed correctly and in checking whether razors were being forced out of the substrate.
- In future surveys carrying an additional small drop-down camera would help speed-up initial evaluations of the seabed and help confirm the impressions of the seabed type from the ship's sounder. Although seabed type was evaluated at the start of a tow from the towed video, the deployment takes some time. This is because before the video camera rig is lowered to the seabed the main anchor has to be dropped, the vessel reversed as the cable is paid out over 100 m or so and the clump dropped. In a few cases the tow

had to be abandoned at this stage, because of the presence of hard ground on the video.

- The lack of divers did mean that razor clams could not be collected for additional length-weight measurements. However, when a commercial fishery is established it should be relatively easy to get samples collected for this purpose.

Summaries and Charts for Stations Worked

Table 11: Station details for Sound of Harris survey.

Date	Site	Stn	Av Depth (m)	UTCStart	LatStart (dec deg)	LonStart (dec deg)	UTCEnd	LatEnd (dec deg)	LonEnd (dec deg)	TowLen (mins)	TowLenGPS (m)	CTD	Notes
26/08/2017	SndHarris	1	7	07:32	57.7032	-7.0749	07:47	57.7030	-7.0744	00:15	40		Hard to find suitable ground; Few bits seagrass; No razors seen on video
26/08/2017	SndHarris	2	7	10:01	57.7012	-7.1953	10:12	57.7012	-7.1948	00:11	28		Bit silty; Muddy at end of tow; No razors seen on video
26/08/2017	SndHarris	3	10.5	10:44	57.6995	-7.2081	11:00	57.6997	-7.2069	00:16	74		Course sand; Lots dead shells; Some razor clams seen on video
26/08/2017	SndHarris	4	5	11:40	57.6992	-7.2047	12:00	57.6993	-7.2035	00:20	73	Yes	Muddy sand; Very few razors
26/08/2017	SndHarris	5	5	12:40	57.6927	-7.2388	13:00	57.6922	-7.2379	00:20	76		Course sand; Rather exposed; A few razors seen on video
26/08/2017	SndHarris	6	7	14:26	57.7079	-7.2554	14:39	57.7082	-7.2561	00:13	52		Only a few razors seen at start on video
26/08/2017	SndHarris	7	8	15:42	57.7492	-7.2283	15:57	57.7492	-7.2272	00:15	70		Clean sand; One or two razors; Couple of sandeels;
26/08/2017	SndHarris	8	12	16:47	57.7534	-7.1523	17:02	57.7539	-7.1535	00:15	95		Clean sand; Sandeel; Few crabs
26/08/2017	SndHarris	9	15	18:12	57.7119	-7.0661	18:27	57.7123	-7.0667	00:15	60		Some macroalgae
27/08/2017	SndHarris	10	12	08:13	57.7573	-7.0975	08:28	57.7571	-7.0958	00:15	106		Course sand; No razors seen on video
27/08/2017	SndHarris	11	15	09:06	57.7730	-7.1189	09:17	57.7727	-7.1190	00:11	43		Finer sand; No razors seen on video
27/08/2017	SndHarris	12	7	10:23	57.7662	-7.0758	10:39	57.7669	-7.0755	00:16	86		Three razors seen on video; Few crabs
27/08/2017	SndHarris	13	15	11:57	57.7167	-7.0230	12:12	57.7162	-7.0227	00:15	54	Yes	Two razors seen on video
27/08/2017	SndHarris	14	9	14:04	57.7033	-7.0594	14:19	57.7029	-7.0595	00:15	48		Two razors seen on video
27/08/2017	SndHarris	15	10	15:00	57.6924	-7.0967	15:15	57.6919	-7.0968	00:15	60		About 6-8 razor clams seen on video; Swell increasing to point where further sampling not possible

Figure 35: Sound of Harris. Planned stations (left panel); Planned stations (left panel); Purple dots, worked stations; Red dots – comments (right panel). Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.

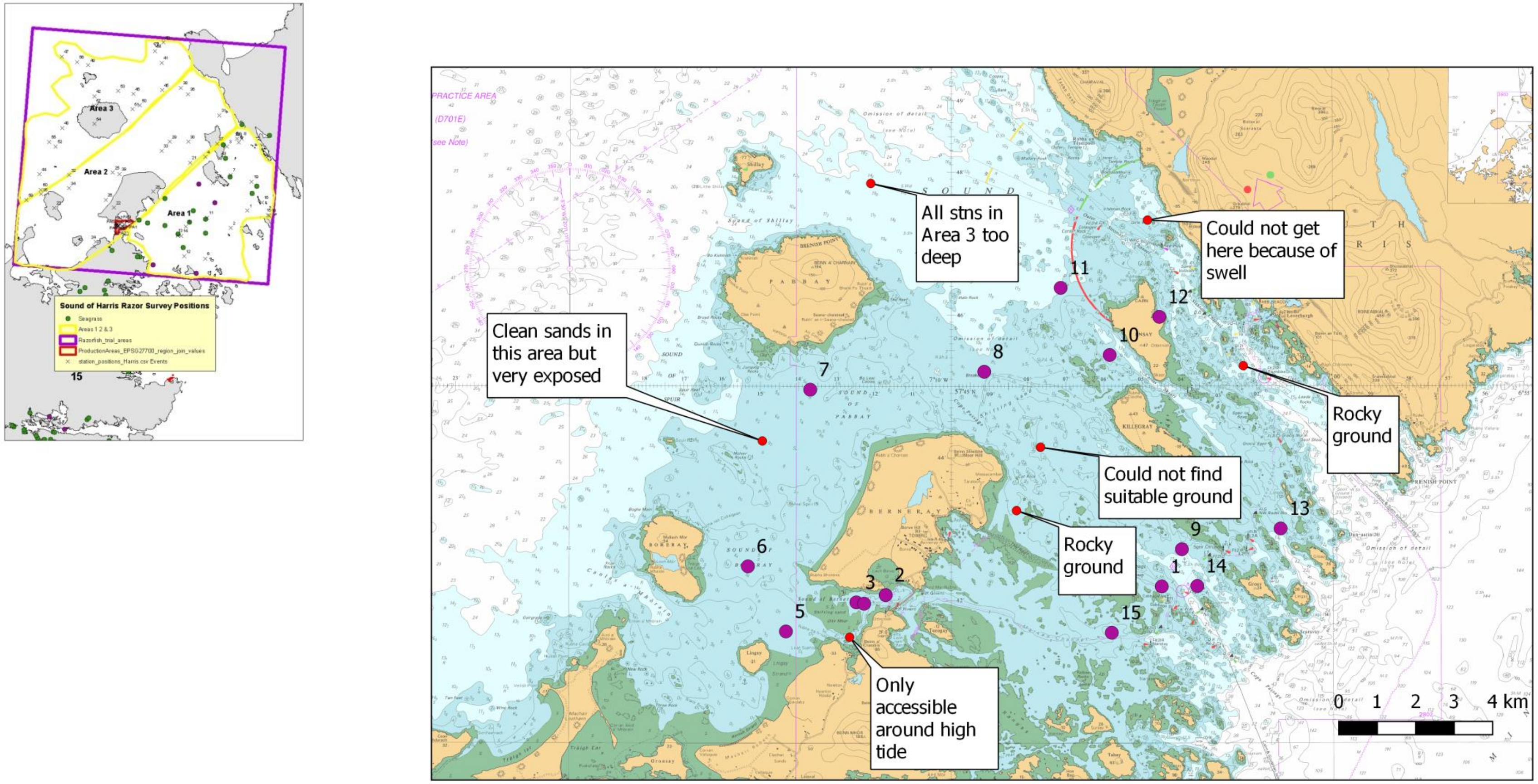


Table 12: Station details for North Bay, Clyde survey.

Date	Site	Stn	Av Depth (m)	UTCStart	LatStart (dec deg)	LonStart (dec deg)	UTCEnd	LatEnd (dec deg)	LonEnd (dec deg)	TowLen (mins)	TowLenGPS (m)	CTD	Notes
2/09/2017	NorthBay	1	8	09:02	55.5744	-4.6720	09:22	55.5737	-4.6719	00:20	80		About 6-8 razor clams seen on video; Swell increasing to point where further sampling not possible
02/09/2017	NorthBay	2	17	10:28	55.5845	-4.6763	10:48	55.5839	-4.6762	00:20	63		Video rig slightly offset - changed towing arrangement so connected to spreader bar; A few razors here
02/09/2017	NorthBay	3	6	11:43	55.5881	-4.6802	12:03	55.5886	-4.6807	00:20	61		Course sand; A few razors here
02/09/2017	NorthBay	4	15	12:34	55.5920	-4.6843	12:54	55.5916	-4.6834	00:20	67	Yes	Reasonable densities (> 0.5 clams m 2) of razors here; Video sled well aligned
02/09/2017	NorthBay	5	5	13:30	55.5902	-4.6828	13:39	55.5901	-4.6823	00:09	32		Some razor clams here
02/09/2017	NorthBay	6	4	14:40	55.5813	-4.6738	14:55	55.5806	-4.6739	00:15	73		Lot of macroalgae further offshore (5 m depth) so moved in a bit; Some razors here
02/09/2017	NorthBay	7	3.5	15:54	55.5531	-4.6768	16:09	55.5527	-4.6771	00:15	50		Muddy sand; A few razors here
02/09/2017	NorthBay	8	3.5	16:50	55.5532	-4.6737	17:05	55.5526	-4.6738	00:15	58		Breeze strenthening; Swell increasing; A few razors here
02/09/2017	NorthBay	9	6	17:55	55.5678	-4.6711	18:10	55.5673	-4.6714	00:15	59		Breeze and swell quite strong; One or two clams only; Ground getting harder;

Figure 36: Clyde, North Bay. Planned stations (left panel); Purple dots, worked stations; Red dots – comments (right panel). Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.

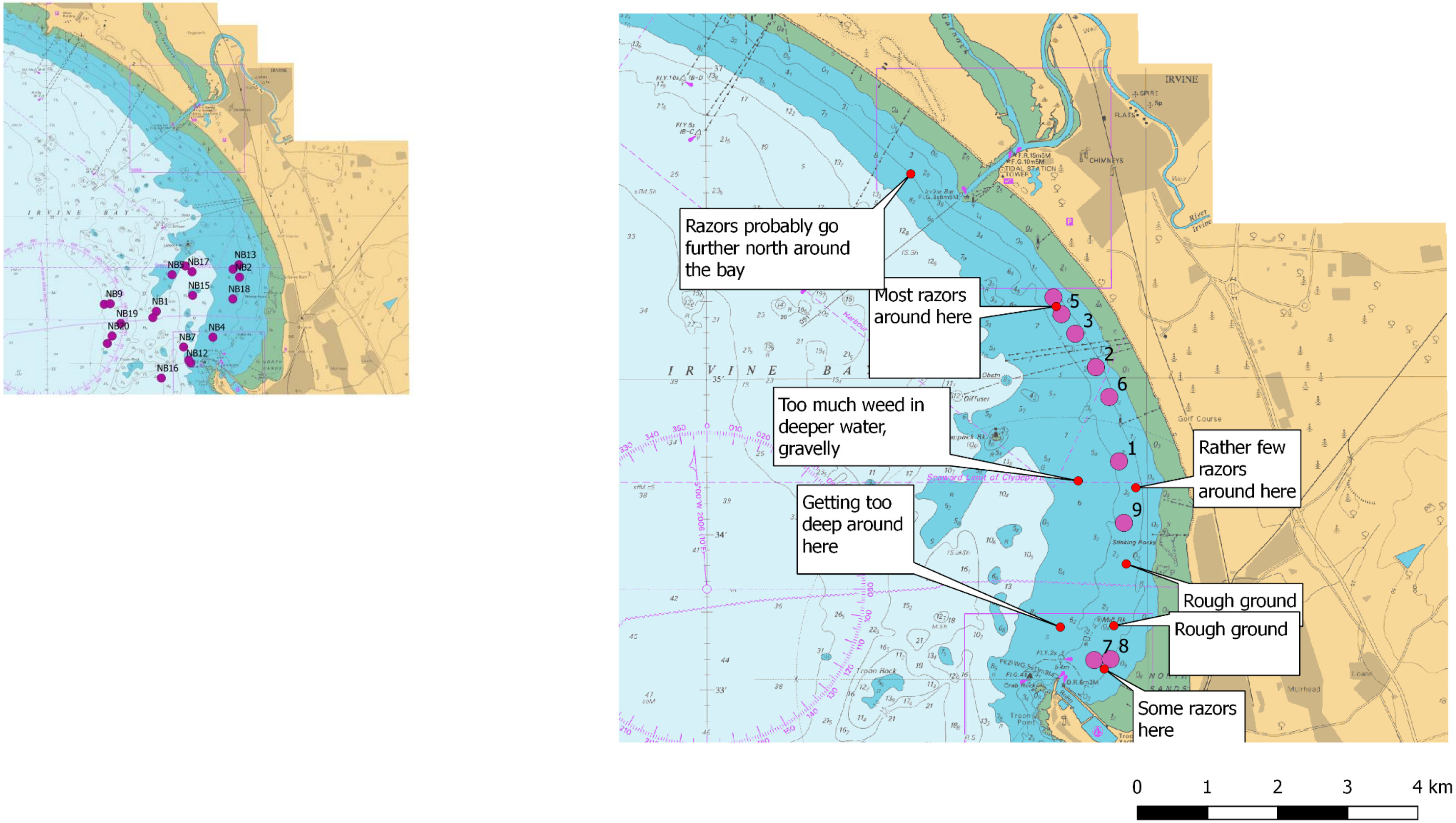
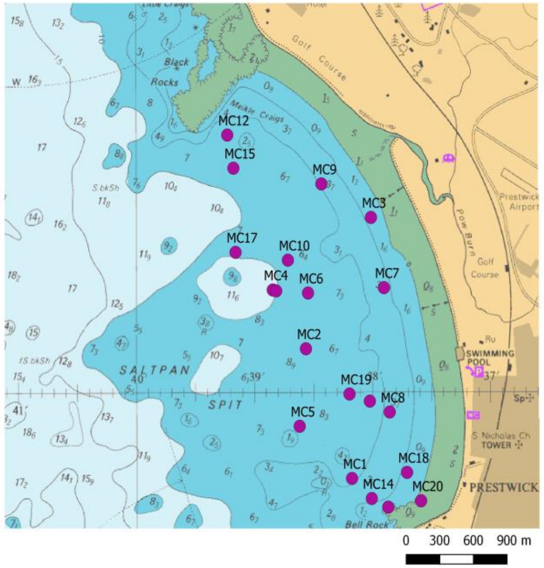


Table 13: Station details for Meikle Bay, Clyde survey.

Date	Site	Stn	Av Depth (m)	UTCStart	LatStart (dec deg)	LonStart (dec deg)	UTCEnd	LatEnd (dec deg)	LonEnd (dec deg)	TowLen (mins)	TowLenGPS (m)	CTD	Notes
04/09/2017	MeikleBay	10	9.5	07:54	55.5170	-4.6498	08:10	55.5169	-4.6505	00:16	45		Near MC12; Some razor clams; Ground looks bit silty
04/09/2017	MeikleBay	11	8.0	08:45	55.5174	-4.6430	09:00	55.5169	-4.6437	00:15	65		Quite lot of razor clams here
04/09/2017	MeikleBay	12	4.5	09:24	55.5163	-4.6390	09:39	55.5156	-4.6389	00:15	72		Reasonable nos clams but seem smaller
04/09/2017	MeikleBay	13	5.5	10:06	55.5093	-4.6337	10:21	55.5087	-4.6334	00:15	76		Some razors here
04/09/2017	MeikleBay	14	9.5	11:20	55.5073	-4.6319	11:30	55.5069	-4.6321	00:10	53	Yes	Rough ground offshore; Some razors here
04/09/2017	MeikleBay	15	4.0	12:06	55.5055	-4.6297	12:21	55.5059	-4.6291	00:15	58		Some razors here
04/09/2017	MeikleBay	16	4.0	13:02	55.4957	-4.6280	13:17	55.4953	-4.6284	00:15	51		Quite a lot razors here but seem quite small
04/09/2017	MeikleBay	17	4.5	13:40	55.4971	-4.6287	13:55	55.4966	-4.6294	00:15	64		
04/09/2017	MeikleBay	18	7.0	14:25	55.4988	-4.6325	14:45	55.4984	-4.6334	00:20	68		A few razors here but not as much as inshore
04/09/2017	MeikleBay	19	7.0	15:20	55.5014	-4.6342	15:35	55.5009	-4.6348	00:15	65		A few razors here but not as much as inshore

Figure 37: Clyde, Meikle Bay. Planned stations (left panel); Purple dots, worked stations; Green dots, spots noted as unsuitable on sounder or video; Red dots – comments (right panel). Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.



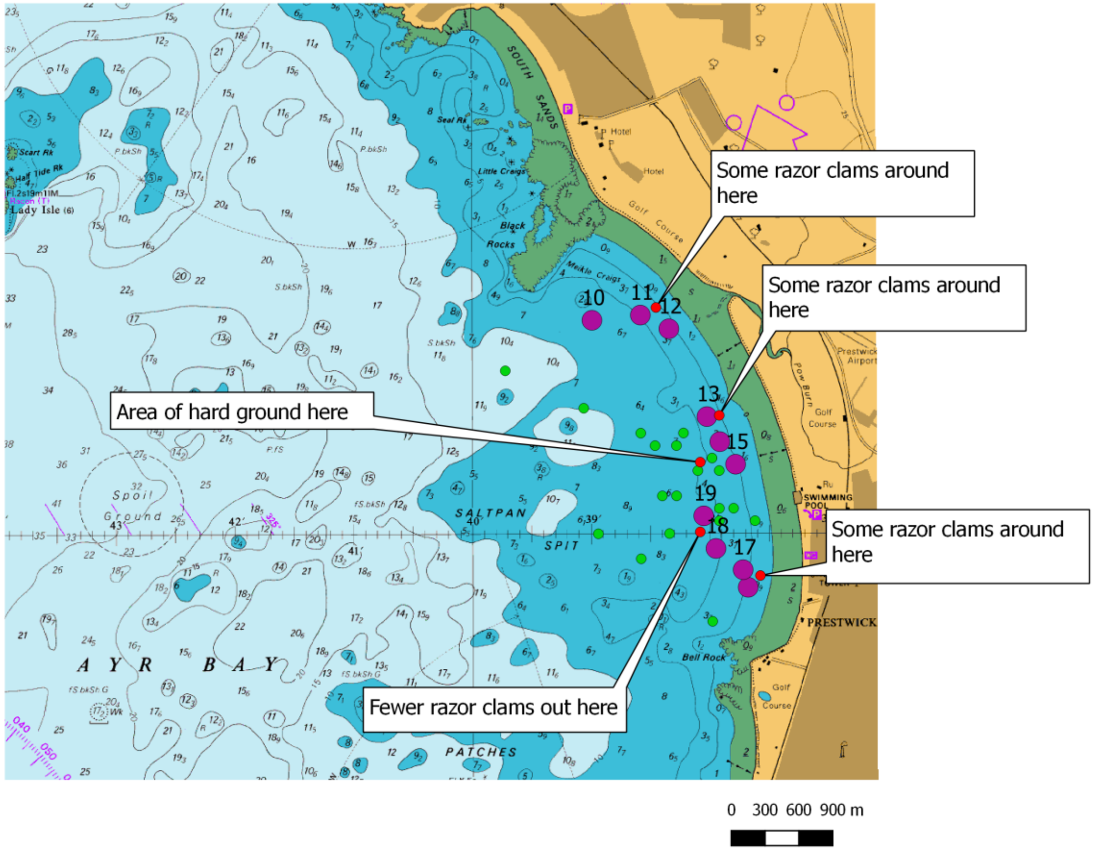


Table 14: Station details for Turnberry Bay (Girvan to Maidenhead Bay), Clyde survey.

Date	Site	Stn	Av Depth (m)	UTCStart	LatStart (dec deg)	LonStart (dec deg)	UTCEnd	LatEnd (dec deg)	LonEnd (dec deg)	TowLen (mins)	TowLenGPS (m)	CTD	Notes
05/09/2017	TurnberryBay	20	6.5	08:14	55.2937	-4.8432	08:29	55.2932	-4.8433	00:15	56		Some razors here
05/09/2017	TurnberryBay	21	6.5	08:54	55.2952	-4.8443	09:09	55.2946	-4.8444	00:15	66		Reasonable nos clams
05/09/2017	TurnberryBay	22	4.5	09:40	55.2949	-4.8408	09:55	55.2945	-4.8407	00:15	48		
05/09/2017	TurnberryBay	23	4.0	10:19	55.2971	-4.8411	10:34	55.2969	-4.8417	00:15	46		
05/09/2017	TurnberryBay	24	6.0	11:01	55.2933	-4.8412	11:16	55.2929	-4.8406	00:15	63	Yes	Some razors here
05/09/2017	TurnberryBay	25	9.5	11:51	55.3015	-4.8507	12:06	55.3012	-4.8512	00:15	46		A few razors here
05/09/2017	TurnberryBay	26	6.0	12:43	55.3188	-4.8469	12:58	55.3183	-4.8470	00:15	63		
05/09/2017	TurnberryBay	27	9.5	13:34	55.3171	-4.8504	13:49	55.3167	-4.8510	00:15	62		Some razors here, quite a few starfish
05/09/2017	TurnberryBay	28	2.0	14:10	55.3155	-4.8443	14:25	55.3150	-4.8445	00:15	61		Some razors here
05/09/2017	TurnberryBay	29	5.0	14:44	55.3137	-4.8464	14:59	55.3137	-4.8473	00:15	59		Only few razors here
05/09/2017	TurnberryBay	30	5.5	15:21	55.3117	-4.8475	15:36	55.3111	-4.8481	00:15	76		A few razors towards end of tow
05/09/2017	TurnberryBay	31	7.0	16:24	55.3424	-4.8184	16:39	55.3422	-4.8190	00:15	48		Not many razors here
05/09/2017	TurnberryBay	32	7.0	17:12	55.3386	-4.8224	17:27	55.3392	-4.8228	00:15	70		Only a few razors here; Lot of broken shell

Figure 38: Clyde, Turnberry Bay (Girvan to Maidenhead Bay). Planned stations (left panel); Purple dots, worked stations; Green dots, spots noted as unsuitable on sounder or video; Red dots – comments (right panel). Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.

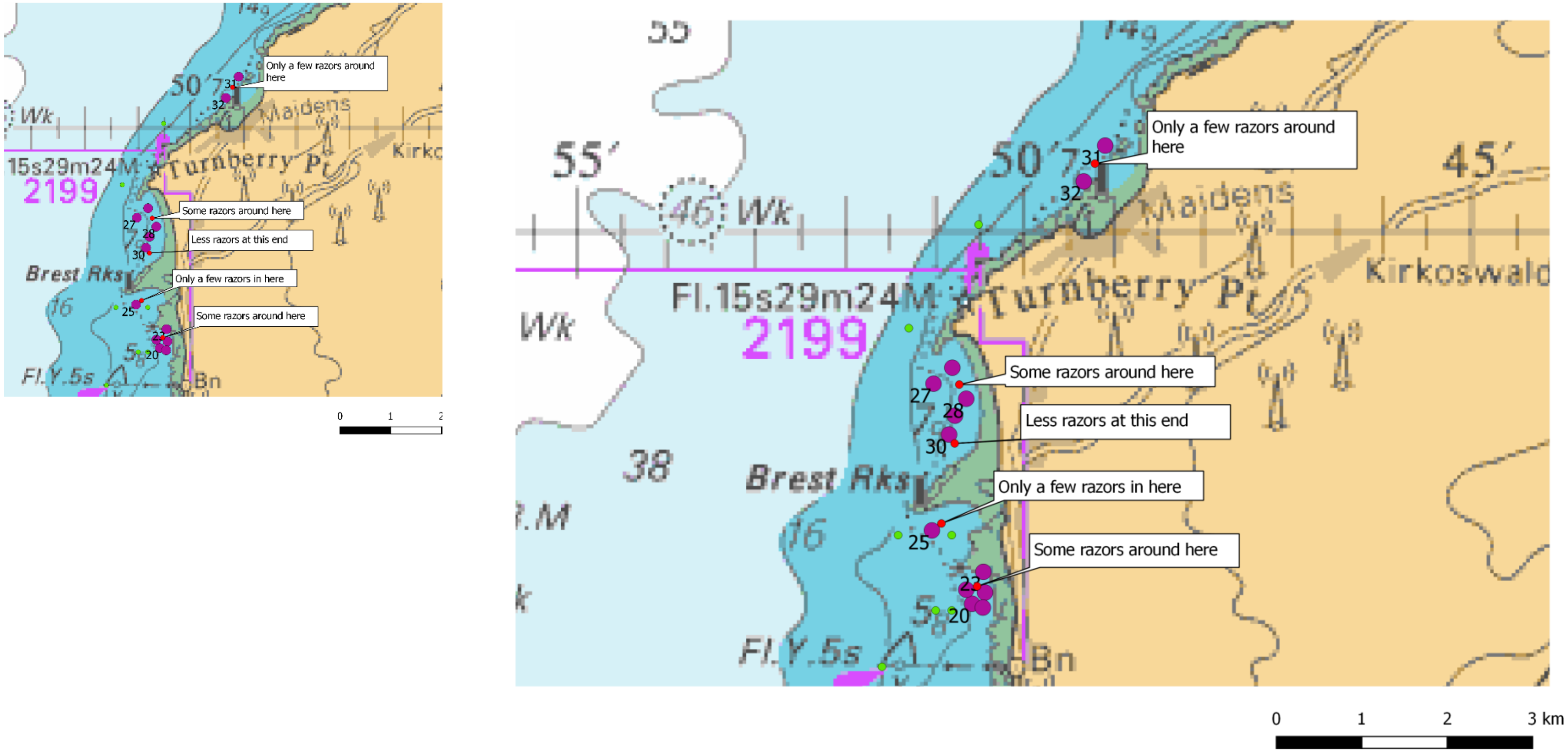
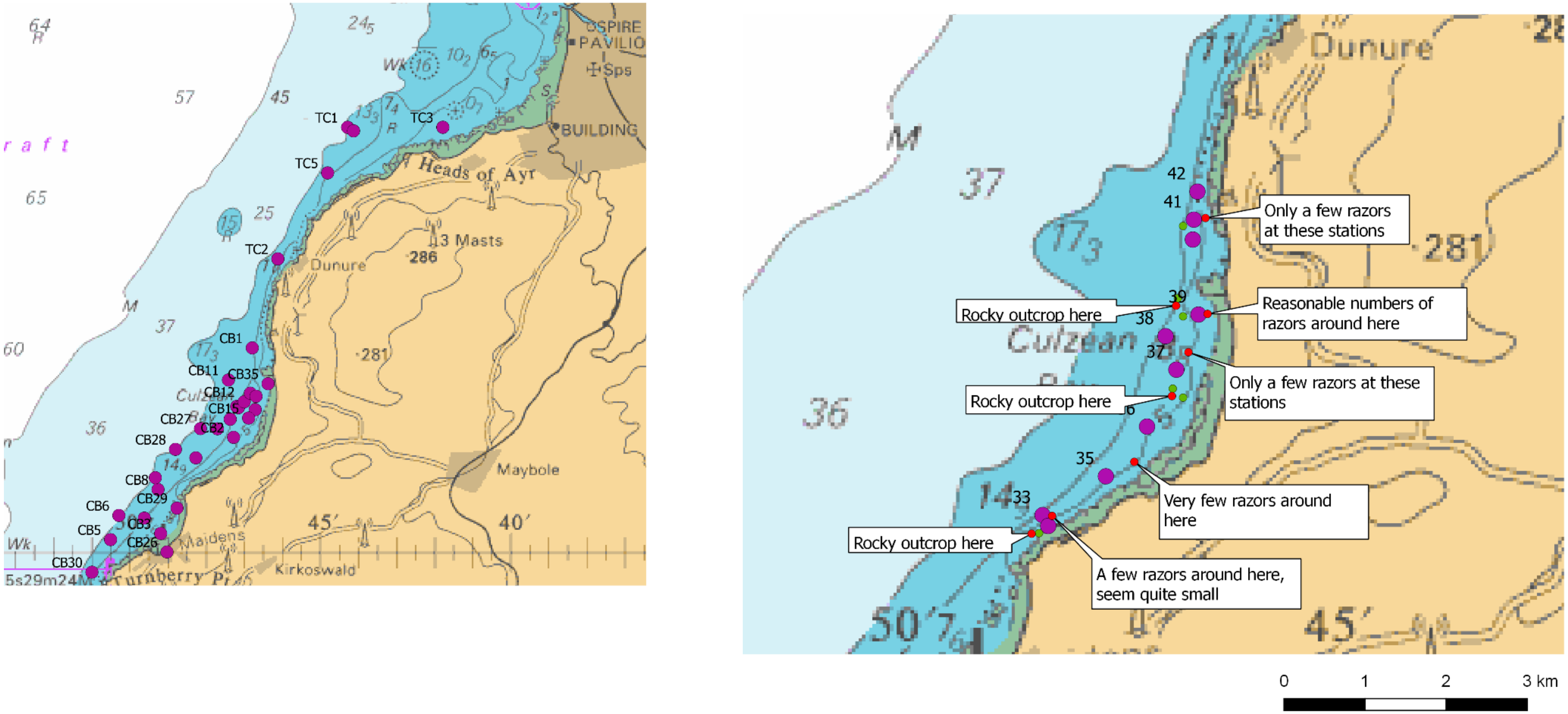


Table 15: Station details for Culzean Bay, Clyde survey.

Date	Site	Stn	Av Depth (m)	UTCStart	LatStart (dec deg)	LonStart (dec deg)	UTCEnd	LatEnd (dec deg)	LonEnd (dec deg)	TowLen (mins)	TowLenGPS (m)	CTD	Notes
07/09/2017	CulzeanBay	33	10.0	09:47	55.3530	-4.8063	10:02	55.3526	-4.8070	00:15:00	54		A few razors here, quite small; Lots of broken shell
07/09/2017	CulzeanBay	34	7.0	10:30	55.3518	-4.8052	10:45	55.3518	-4.8061	00:15:00	55		Only few razors here; Some starfish
07/09/2017	CulzeanBay	35	10.0	11:10	55.3573	-4.7940	11:25	55.3573	-4.7950	00:15:00	64	Yes	Very few razors; Some starfish
07/09/2017	CulzeanBay	36	11.0	11:54	55.3628	-4.7860	12:09	55.3625	-4.7869	00:15:00	66		Only a few razors here
07/09/2017	CulzeanBay	37	10.0	12:38	55.3691	-4.7803	12:53	55.3685	-4.7807	00:15:00	72		Only a few razors here
07/09/2017	CulzeanBay	38	12.0	13:22	55.3728	-4.7824	13:37	55.3723	-4.7830	00:15:00	61		A few razors here; Marks in sand probably *Mya* (Sand or blunt gaper) which does not seem to react to the electricity
07/09/2017	CulzeanBay	39	5.0	14:01	55.3752	-4.7760	14:16	55.3746	-4.7756	00:15:00	76		A few clumps of seagrass at start; Reasonable densities (> 0.5 clams m 2) of razors later on
07/09/2017	CulzeanBay	40	7.0	14:44	55.3835	-4.7771	14:59	55.3829	-4.7769	00:15:00	64		Some razors here; Rocky reef inshore
07/09/2017	CulzeanBay	41	8.5	15:22	55.3857	-4.7769	15:37	55.3854	-4.7778	00:15:00	68		Only a few razors here
07/09/2017	CulzeanBay	42	8.0	16:09	55.3888	-4.7762	16:24	55.3883	-4.7762	00:15:00	54		A few razors here

Figure 39: Clyde, Culzean Bay. Planned stations (left panel); Purple dots, worked stations; Green dots, spots noted as unsuitable on sounder or video; Red dots – comments (right panel). Underlying chart © Crown Copyright/HR Wallingford Ltd. 2017. All Rights Reserved. Licence No. L012017.0001. Not to be Used for Navigation.



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