Port of Mostyn

Mostyn Energy Park Extension

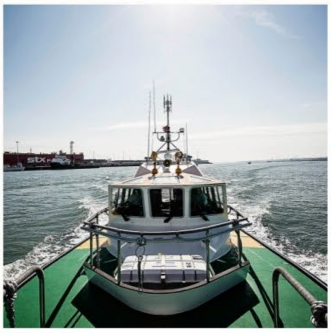
Environmental Statement

Appendix 8.2: Fish and Marine Mammal Summary

December 2022







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Port of Mostyn

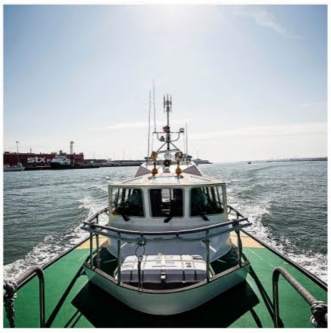
Port of Mostyn Fish and Marine Mammal Surveys

Summary Report

December 2022







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Port of Mostyn Fish and Marine Mammal Surveys

Summary Report

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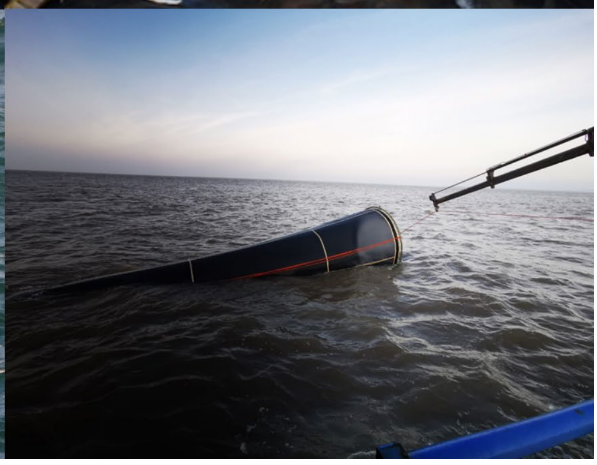

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Notice

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1 Introduction

1.1 Project background

ABPmer has been commissioned by the Port of Mostyn to coordinate a series of marine ecological surveys in the Dee Estuary. This report summarises the results of a baseline survey programme for fish and marine mammals (from October 2020 to December 2021) . These surveys are being used to inform a potential lagoon development but provide relevant information for the MEPE project. The surveys have involved the following elements:

1.1.1 Fish surveys

- **Quarterly Fish Surveys:** Intertidal (involving fyke nets, seine netting and a small 1.5 m scientific light weight beam trawl) and subtidal fish surveys (involving otter and beam trawls). The first quarterly surveys were undertaken in November/early December 2020 with the fourth quarterly survey in August 2021;
- **Monthly Ichthyoplankton Surveys:** Monthly fish plankton (trawl) surveys which started in November 2020;
- **Pelagic (Acoustic) Fish Surveys:** Surveys using a combination of echosounders to identify fish shoals and some trawl surveys to identify fish species) in May and August 2021; and
- **Environmental DNA (eDNA) Samples:** Ten water samples were collected throughout the outer Dee Estuary and approaches on the 25 August 2021 for Environmental deoxyribonucleic acid (eDNA) analysis.

1.1.2 Marine mammal surveys

- **Monthly Boat Surveys:** Monthly vessel based marine mammal surveys which involved four transects in the outer Dee Estuary (at 1.5 km spacing) and five transects in the approaches to the Dee Estuary within Liverpool Bay (at 2 km spacings). Surveys were undertaken between October 2020 and September 2021; and
- **Passive Acoustic Monitoring (PAM) using F-PODs:** These static acoustic detection devices are useful to record continuous long-term datasets at specific locations over extended periods. Four F-PODS were successfully deployed in November 2020 one off the Mostyn Deep, one in channel near Hilbre Island and two in the Dee approaches). The results of 12 months of deployment are summarised in this report.

The methods used in these surveys are described in more detail in Section 2 and the results are summarised in Section 3. Summary conclusions are then provided in Section 4.

2 Methods

2.1 Fish surveys

The methods for the fish surveys are described in more detail below in Sections 2.1.1 to 2.1.6:

- **Section 2.1.1:** Quarterly intertidal fish surveys;
- **Section 2.1.2:** Quarterly subtidal fish surveys;
- **Section 2.1.3:** Ichthyoplankton surveys;
- **Section 2.1.4:** Fish processing methods for the quarterly fish surveys and ichthyoplankton surveys;
- **Section 2.1.5:** Pelagic (acoustic) surveys; and
- **Section 2.1.6:** Environmental DNA (eDNA) surveys.

The dates for each of the surveys are shown in Table 1.

Table 1. Survey dates for each survey type.

Survey Type	Season	Dates	Survey method
Intertidal	Winter	1 December 2020	1.5 m beam trawl
	Winter	1-3 December 2020	Fyke and seine nets
	Spring	27 February 2021	1.5 m beam trawl
	Spring	27 February-1 March 2021	Fyke and seine nets
	Summer	27 May 2021	1.5 m beam trawl
	Summer	27-29 May 2021	Fyke and seine nets
	Autumn	24 August 2021	1.5 m beam trawl
	Autumn	24-26 August 2021	Fyke and seine nets
Subtidal	Winter	25-26 November 2020	Otter and beam trawls
	Spring	21-22 February 2021	Otter and beam trawls
	Summer	26-28 May 2021	Otter and beam trawls
	Autumn	27-29 August 2021	Otter and beam trawls
Ichthyoplankton	Monthly	25-26 November 2020	Plankton trawl
		10 December 2020	Plankton trawl
		15 January 2021	Plankton trawl
		22 February 2021	Plankton trawl
		31 March 2021	Plankton trawl
		25 April 2021	Plankton trawl
		28 May 2021	Plankton trawl
		17 June 2021	Plankton trawl
		22 July 2021	Plankton trawl
		29 August 2021	Plankton trawl
		20 September 2021	Plankton trawl
		8 November 2021	Plankton trawl
Pelagic (acoustic)	Spring	27 May 2021	Acoustic
	Summer	28 August 2021	Acoustic
eDNA samples		25 August 2021	eDNA

The raw data for the quarterly fish surveys and ichthyoplankton surveys is provided in Appendix A. The detailed survey report for the pelagic (acoustic) surveys is provided in Appendix B.

2.1.1 Quarterly intertidal fish surveys

Quarterly intertidal surveys were carried out during spring tides starting in November 2020 (referred to as the Winter survey) with subsequent surveys undertaken in February/early March 2021 (Spring survey), May 2021 (Summer survey) and August 2021 (Autumn survey). These surveys consisted of three different sampling gear types (seine nets, 1.5 m scientific light weight beam trawl and fyke nets). The sampling was carried out at predetermined sampling sites that were verified as suitable during a recce carried out prior to the first survey in November 2020. Figure 1 shows the location of the sampling sites for the intertidal surveys.

Fyke net

At eight sites within the estuary (Figure 1), two pairs of double-ended fyke nets 53 cm high with approx. 5 m leader, 10 mm mesh, 8 mm and 6.5 mm cod end mesh size were set by hand at low water. The nets were fitted with otter guards, net tags issued by the Environment Agency and Natural Resources Wales. Canes were used to stabilise the nets and secured with cable ties. The cod ends were tied and anchors attached to ensure the nets were fixed in position. The nets were left in position over two tidal cycles (24 hours); however, the nets were checked and the catch removed and processed after each cycle (12 hours). Where possible the catch was processed on site and fish and invertebrates returned to the water body alive. An Aqua TROLL 200 was attached to Nets F1, F2, F3, F4, F5, and F8, and a Solinst Levelogger 5 was attached to Net F7 to record continuous water quality data during net deployment. Although the sondes were left *in situ* over two tidal cycles, data was only recorded when the Sondes Levelogger was submerged. Where possible the catch was processed on site and fish and invertebrates returned to the water body alive.

Seine net

Seine netting was originally to be carried out at up to eight stations adjacent to the fyke net sites with up to three repetitions at each site. During the recce of the area and the first survey in November 2020 viable sites for the netting were identified in areas next to fyke net sites F1, F3, F5 and F8 as shown on Figure 1. More than three replicate samples were taken at these sites with the total amount being limited by time, space or weather. A single sample was attempted at site 4 during the Autumn survey of 2020, but due to the sediment characteristics it was deemed unsuitable. This site was then removed from the sampling programme for the subsequent surveys.

Netting was carried out at high tide or when there was suitable intertidal area for the net to be landed. At each sampling site a 'juvenile' seine net, 25 m in length by 2.7 m in depth, rigged with 4 mm knotless fry mesh with a single no. 4 lead-line was set from the shore by two members of staff in accordance with Joint Nature Conservation Committee (JNCC) procedural guidelines (Davies *et al*., 2001). One operative retained the end of the net while the other deployed the net by wading in an arc with the prevailing current and then walking upstream parallel to the shore creating an encompassing U-shape. Lead and float-lines were then simultaneously drawn to the shore to haul the net and contents. All fish and crustaceans were then placed in a holding container with water prior to processing then returned to the estuary.

1.5 m beam trawl

At nine pre-determined sites (Figure 1) a small scientific light weight 1.5 m beam trawl with 10 mm knot-to-knot mesh in the main body and 5 mm knot-to-knot mesh at the cod end, was deployed from the Ultramarine Powerboat Services Ltd's rigid inflatable boat (RIB). The trawling was carried out over high tide with the trawl being towed at a constant low speed, approximately 1 to 1.5 kts, for 300 m.

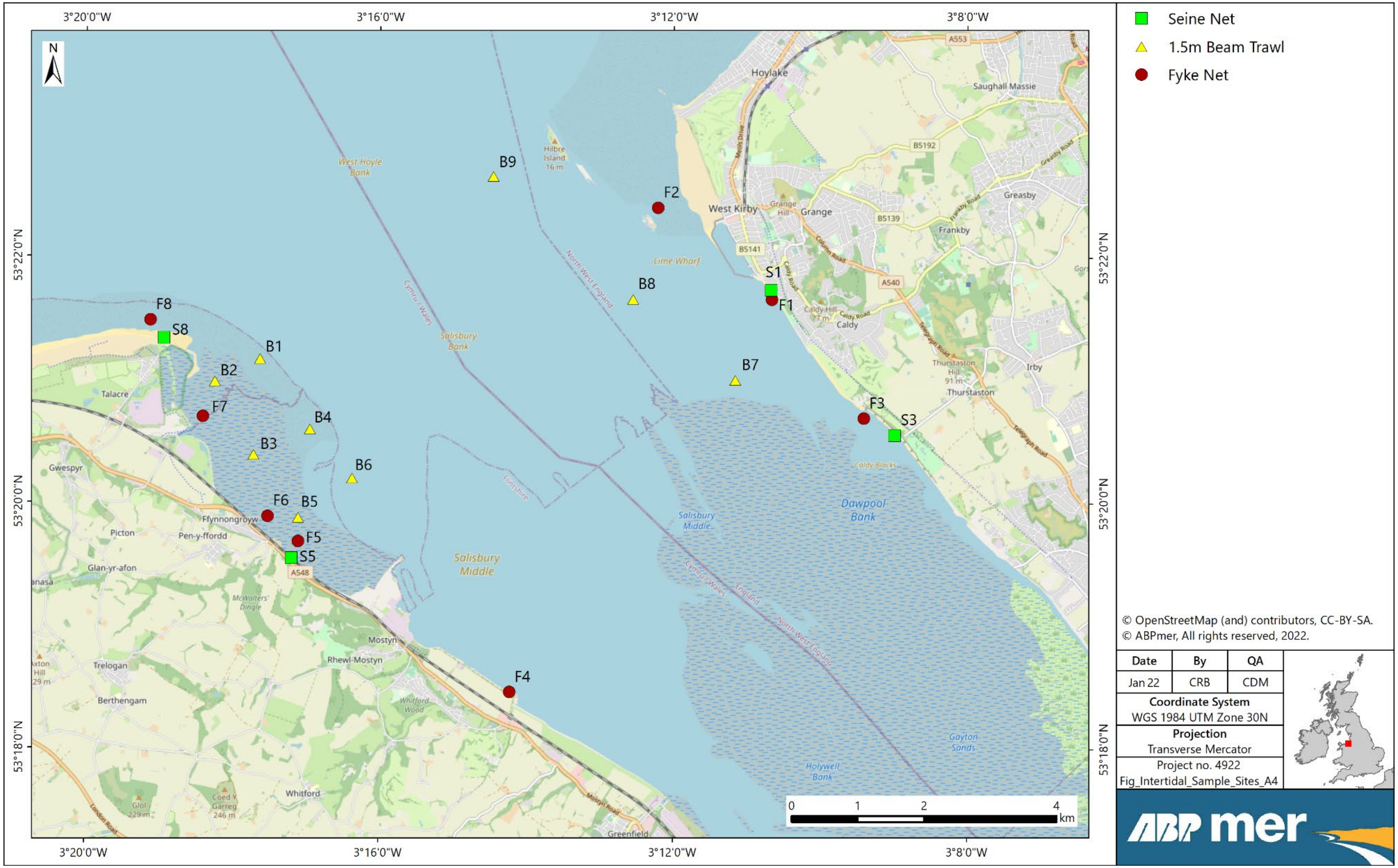


Figure 1. **Intertidal fish survey sites**

The coordinates of each trawl line were recorded using a hand-held Global Positioning System (GPS). At the end of each line the trawl was hauled on board by two survey staff, the cod end untied and the catch emptied into a holding container. The catches were processed on the boat and returned to the water.

2.1.2 Quarterly subtidal fish surveys

Quarterly intertidal surveys were carried out during spring tides starting in November 2020 (referred to as the Winter survey) with subsequent surveys undertaken in February 2021 (Spring survey), May 2021 (Summer survey) and August 2021 (Autumn survey). Six trawl lines were proposed in the approaches to the Dee Estuary (Figure 2). Along these lines otter trawling and beam trawling were carried out as part of the quarterly surveys. The surveys were carried out using the Briggs Marine boats *Mersey Guardian* and *Severn Guardian*. The monthly plankton surveys were carried out using the Port of Mostyn workboat *Eileen* and Carmet Tugs workboat *Vixen*.

Otter trawl

A Water Framework Directive (WFD) compliant otter trawl was deployed from the survey vessel, Mersey Guardian or Severn Guardian, along six predefined transects. The trawl had a 9 m footrope, a knotted 40 mm wing mesh fitted with a knotless 10 mm mesh lined cod end. The trawl was towed for 15 minutes in the Autumn and Winter surveys, which was increases to 20 minutes for the Spring and Summer surveys. The operation of the trawl was carried out by the boat's crew. During the trawls the start and end position, seabed depth and boat speed was recorded. The trawl was then recovered onto the deck and the catch placed into plastic containers for processing.

Beam trawl

A WFD compliant single beam trawl was deployed from the survey vessel, Mersey Guardian/Severn Guardian, along six predefined transects. The beam trawl consisted of a trawl 2 m in width with a mouth height of 0.45 m and mesh of 10 mm. A tickler chain was also positioned 15 cm in from of the footrope between the shoes. The trawl was towed for 15 minutes in the Autumn and Winter surveys, which was increases to 20 minutes for the Spring and Summer surveys. The operation of the trawl was carried out by the boat's crew. During the trawls the start and end position, seabed depth and boat speed was recorded. The trawl was then recovered onto the deck and the catch placed into plastic containers for processing

2.1.3 Ichthyoplankton surveys

Ichthyoplankton trawls were conducted using the same lines as the subtidal trawls (Figure 2) on a monthly basis from November 2020 to October 2021. The surveys used the survey vessel Mersey Guardian or Severn Guardian during the quarterly surveys and the work boats Eileen or Vixen during the other monthly surveys.

The trawls were carried out using a Gulf III high speed plankton trawl with 280 µm mesh cod end. The net was fished in an oblique, 'V' tow profile, along the six predefined transects for 15 minutes. The net was lowered and raised through the water column to sample the entire water column from the surface to within 1 m of the seabed. The net was fitted with a flow meter to enable quantification of the volume of water sampled. A Valeport CTD was attached to the trawl frame to give real time depth readings during the trawl's deployment. During the deployment the start and end position, seabed depth and boat speed were recorded. The trawl was then recovered onto the deck of the boat and the flow meter reading recorded. The cod end was removed and the catch transferred to a labelled plastic bucket and fixed with buffered 10 % formalin (4 % formaldehyde) solution. The samples were then returned to Hull Marine Laboratory for sorting and identification.

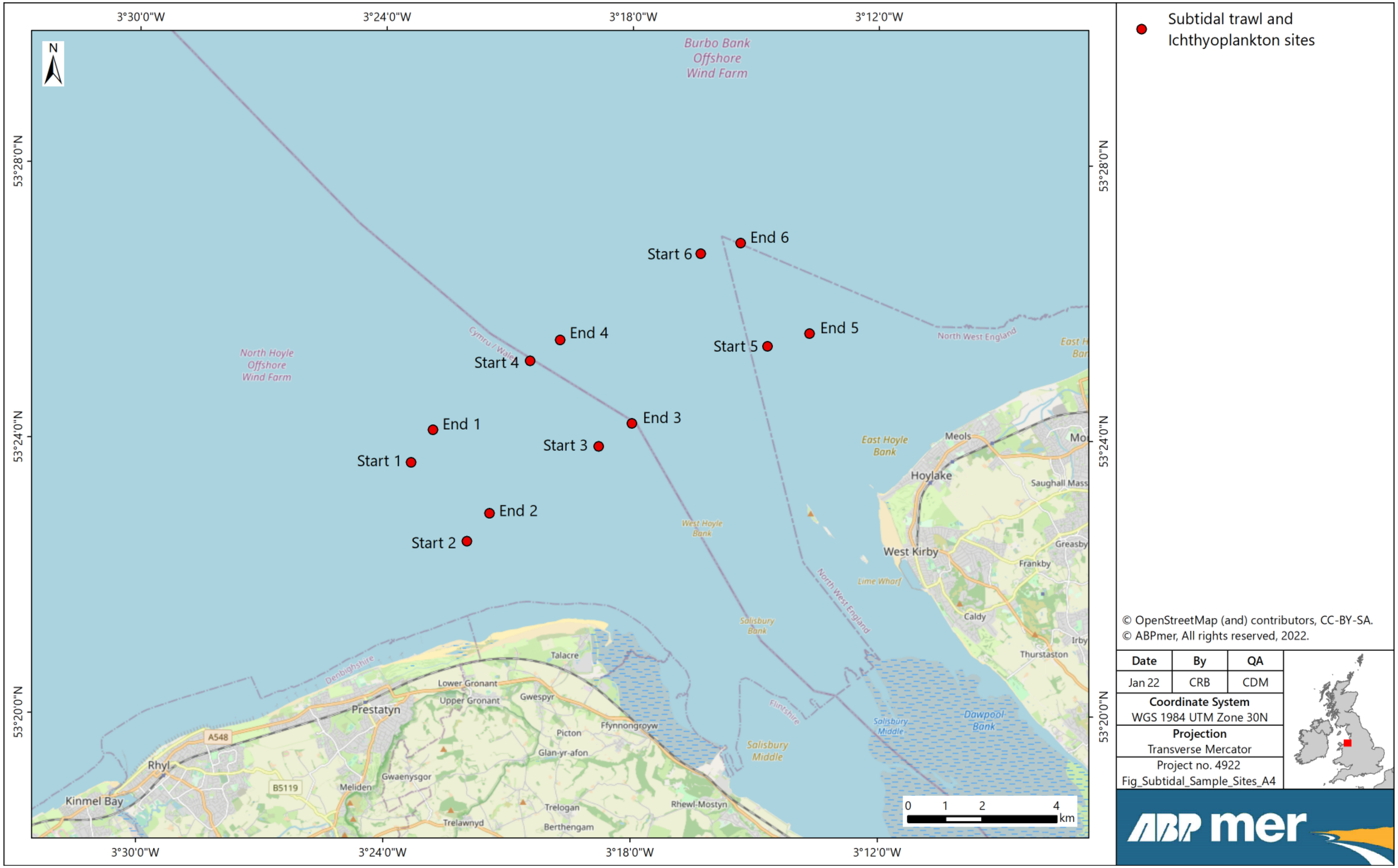


Figure 2. Subtidal and ichthyoplankton fish survey sites

2.1.4 Fish processing methods for the quarterly fish surveys and ichthyoplankton surveys

Fish were identified, measured to the nearest mm (total length, TL) and released in the vicinity of each sampling location, ensuring released individuals did not affect future sample replicates. Fish were identified to species level according to the Environment Agency's 'Key to the Marine and Freshwater Fishes of Britain and Ireland' (Maitland and Herdson, 2009). Where high numbers of one species of fish were present in a sample, 50 randomly selected individuals were measured. The remaining individuals of the species were then enumerated and recorded.

The length ranges presented in Ellis *et al.,* (2012), Pawson *et al.,* (1987) and Langan (2012) were used to identify the proportion of measured fish that are considered juvenile size classes.

Macroinvertebrates were identified to the lowest taxonomic level possible in the field and abundance recorded. Species were recorded as present where enumeration was not possible, or practical, due to high numbers, for example, in the case of ctenophores during the Spring intertidal survey or where colonial animals were caught, such as the soft coral *Alcyonium digitatum*.

Where samples consisted of large amounts of material caught in the net the samples were sorted through and the fish removed. The rest of the sample was then mixed and a suitable subsample taken, this was then sorted and the species identified and counted.

Ichthyoplankton samples were returned to Hull Marine Laboratory for sorting and identification. Where possible fish were recorded to species level and the eggs measured.

2.1.5 Pelagic fish (acoustic) surveys

This section summarises the survey methods for the acoustic fish surveys. The methods and analysis are described in more detail in Appendix B.

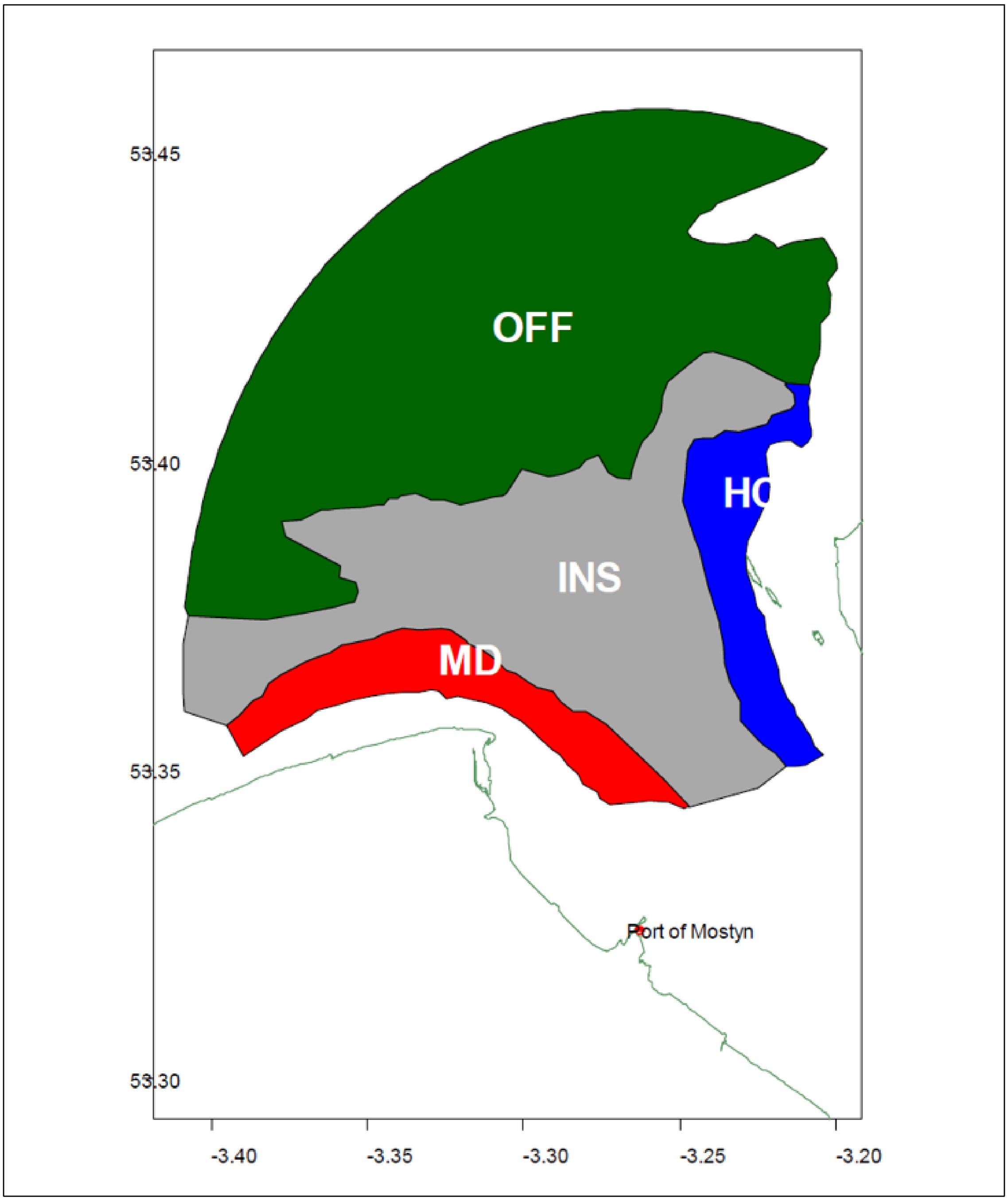
Acoustic fish surveys to detect pelagic fish shoals were conducted at four defined sites within the Dee Estuary, each of which possessed a distinct stratum:

- Mostyn Deep (MD);
- Hilbre Channel (HC);
- The shallow inshore region of the Dee Estuary which is predominately intertidal (INS); and
- The approaches to the Dee Estuary (OFF).

The survey areas are shown in Figure 3. These were undertaken by the University of Aberdeen on two occasions, one during May 2021 and one in August 2021.

Acoustic surveys were undertaken along zig-zag configurated transects at each site within the survey area. However, during the August 2021 survey, the INS stratum was not surveyed due to unforeseen circumstances. Otter trawls and a live underwater video system were deployed when fish aggregations were detected as echo traces via the echo sounder.

A Simrad Wideband Transceiver (WBT) portable echosounder, connected to a Simrad ES38-18_200-7c dual frequency transducer, was used for acoustic data collection. The instrument transmitted narrowband (continuous wave (CW)) signals at 38 kHZ and 200 kHZ simultaneously, at 0.512 ms^{-1} pulse lengths and a ping rate of 4 Hz. Operation of the instrument was controlled using Simrad EK80 computer software.



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Coordinate System n/a		
Projection n/a		
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Figure 3. Acoustic survey area

The acoustic system was calibrated in a 5 x 5 x 5 m tank at the National Decommissioning Centre, University of Aberdeen. Prior to returning to port, on both surveys, a calibration sphere was suspended beneath the transducer to confirm calibration settings (within 0.5 dB of former calibration values).

Otter trawls were deployed to identify and enumerate pelagic fish species during each survey. Trawls were undertaken when fish aggregations were detected as echo traces via the echo sounder and were deployed for 20 minutes at a time. Fish caught during each trawl haul were measured to the nearest 0.1 cm (TL). Three trawls were carried out on the May 2021 survey and five trawl hauls during the August 2021 survey. Data from associated seasonal bottom trawl surveys, that had been conducted around the same time as each pelagic survey, were also examined. These comprised a further six trawls for the May 2021 survey and four trawls for the August 2021 survey. Data for invertebrates, along with demersal and benthic fish species (such as dab *Limanda limanda*, Dover sole *Solea solea* and flounder *Paralichthys dentatus*) was excluded.

A PRO SQUID live underwater video system was also deployed, on three occasions, during both surveys.

2.1.6 Environmental DNA (eDNA)

Environmental deoxyribonucleic acid (eDNA) refers to DNA deposited in the environment through excretion, shedding, mucous secretions, saliva etc. This can be collected in environmental samples and used to identify the organisms that it originated from.

A total of ten water samples were collected throughout the outer Dee Estuary and approaches on the 25 August 2021 based on a standardised data collection methodology provided by NatureMetrics. The location of the sample stations is shown in Figure 4.

All samples were collected on site from the vessel *Eileen* using a 2L Niskin sampler, at various water depths aiming to capture variability in fish species (i.e. demersal, pelagic species etc.). The locations and timings of each water sample are provided in Table 2. Depths of each sample relative to the indicated water depth (provided by the vessel echo-sounder) are also provided.

Table 2. Locations and timings of water samples for eDNA analysis

Sample ID	WGS84 Latitude (°)	WGS84 Longitude (°)	Sample Time (GMT)	Water Depth (m)	Sample Depth (m)
1	053° 21.406′ N	003° 17.669′ W	06:47	14.5	13.0
2	053° 22.978′ N	003° 14.072′ W	13:22	20.0	10.0
3	053° 25.864′ N	003° 24.002′ W	09:20	12.0	6.0
4	053° 26.858′ N	003° 15.629′ W	11:15	17.3	15.0
5	053° 24.165′ N	003° 13.697′ W	11:37	8.6	2.0
6	053° 23.139′ N	003° 21.633′ W	07:20	1.7	1.0
7	053° 20.760′ N	003° 16.626′ W	05:03	4.3	3.0
8	053° 20.999′ N	003° 12.593′ W	13:45	6.0	2.0
9	053° 19.622′ N	003° 15.975′ W	14:10	3.0	3.0
10	053° 18.522′ N	003° 14.153′ W	14:30	5.0	1.0

Immediately following collection, each sample was processed using preservative kits provided by the laboratory. Disposable surgical gloves were worn during the preservation process of each sample to minimise both contamination of human DNA and contamination between each water sample. Samples were filtered until each filter clogged, or a full 2 L of each sample was used.

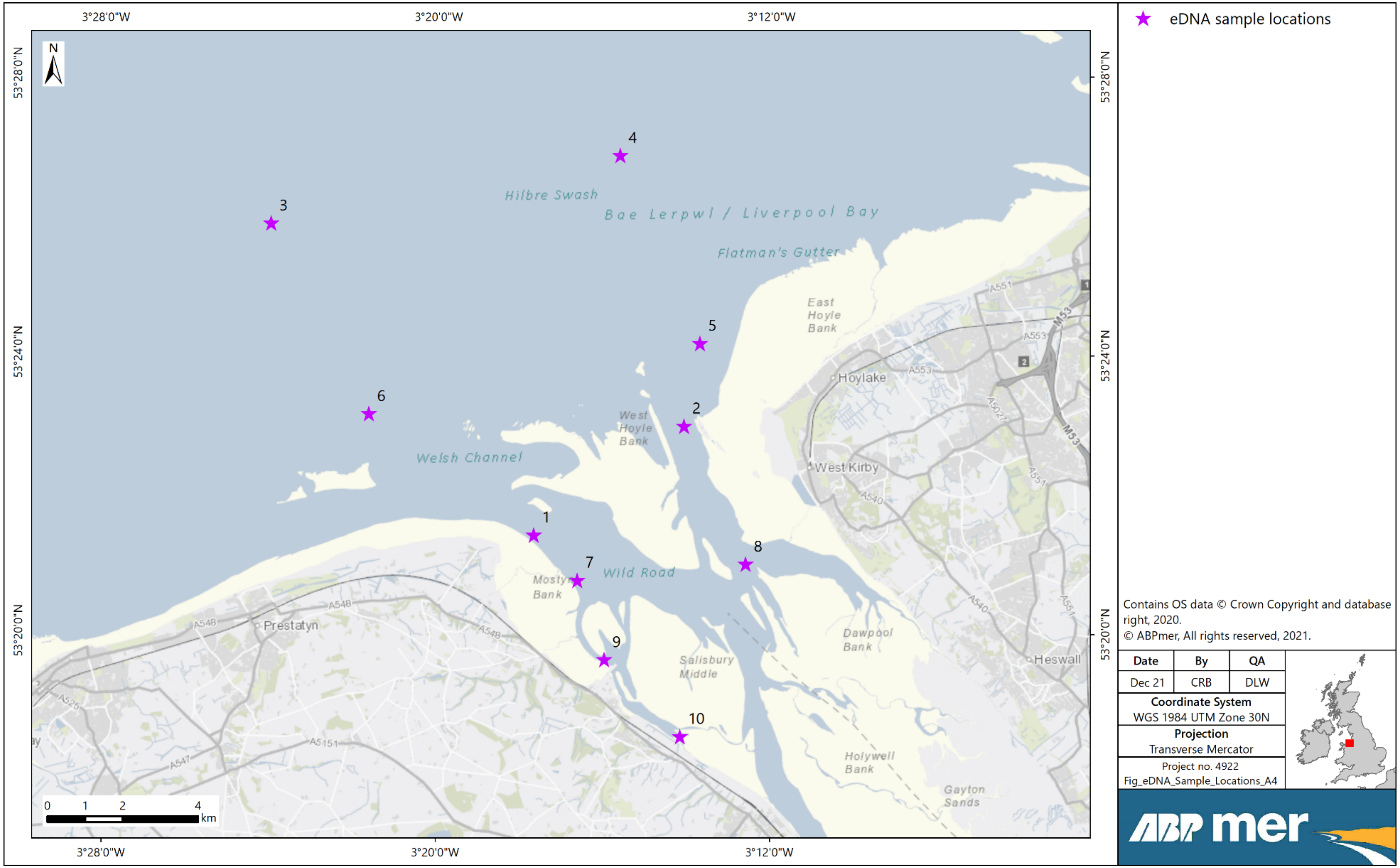


Figure 4. eDNA sample locations

Laboratory results

The laboratory analysis was undertaken by NatureMetrics. DNA from each filter was extracted using a commercial DNA extraction kit with a protocol modified to increase DNA yields. An extraction blank was also processed for the extraction batch. DNA was purified to remove Polymerase Chain Reaction (PCR)[1] inhibitors (naturally occurring chemicals/compounds that cause DNA amplification to fail, potentially resulting in false negative results) using a commercial purification kit.

The DNA was then tested with a 16S bacterial Polymerase Chain Reaction (PCR) to determine the presence of PCR inhibitors and/or DNA degradation in the samples. The samples were successfully amplified, indicating no inhibition or degradation. Purified DNAs were then amplified with PCR for a hypervariable region of the 12S rRNA gene to target fish.

All PCRs were performed in the presence of both a negative control and a positive control sample (a mock community with a known composition). Amplification success was determined by gel electrophoresis[2]. PCR reactions were successful for 8 of the 10 samples. PCR replicates were pooled and purified, and sequencing adapters were added.

Sequence data were processed using a custom bioinformatics pipeline. Bioinformatics refers to a data processing pipeline that takes the raw sequence data from high-throughput sequencing (often 20 million sequences or more) and transforms it into usable ecological data. Key steps for metabarcoding pipelines included quality filtering, trimming, merging paired ends, removal of sequencing errors, clustering of similar sequences into molecular Operational Taxonomic Units (OTUs) each of which approximately represents a species), and matching one sequence from each cluster against a reference database. The output was a species-by-sample table showing how many sequences from each sample were identified as each species.

2.2 Marine mammal surveys

2.2.1 Boat based surveys

Dedicated line transect surveys were undertaken on a monthly basis by the Sea Watch Foundation and ABPmer staff from October 2020 to September 2021. The surveys were undertaken from the vessel the MV *Patricia*.

Four surveys (November, February, June and September) had to be shortened, two due to weather conditions and two due to issues with the vessel's engine which would have resulted in unsafe conditions fservers and crew. Marine mammals are best observed in calm conditions ( ) but due to scheduling restrictions, surveys carried out in July and September 2020 were primarily conducted in sea state 4 or above.

Line transect methods

The surveys comprised nine transect lines, with four transects in the outer Dee Estuary (at 1.5 km spacing) and five transects in the approaches to the Dee Estuary within Liverpool Bay (at 2 km spacings) (Figure 5). Due to the significant tidal range in the estuary, transects were not undertaken in a set order but completed depending on which lines provided sufficient depth for the vessel to traverse them safely.

1 Polymerase chain reaction. A process by which millions of copies of a particular DNA segment are produced through a series of heating and cooling steps. Known as an 'amplification' process.

2 The process in which DNA is separated according to size and electrical charge via an electric current, while in a gel. The process is used to confirm the successful amplification of a specific size fragment of DNA.

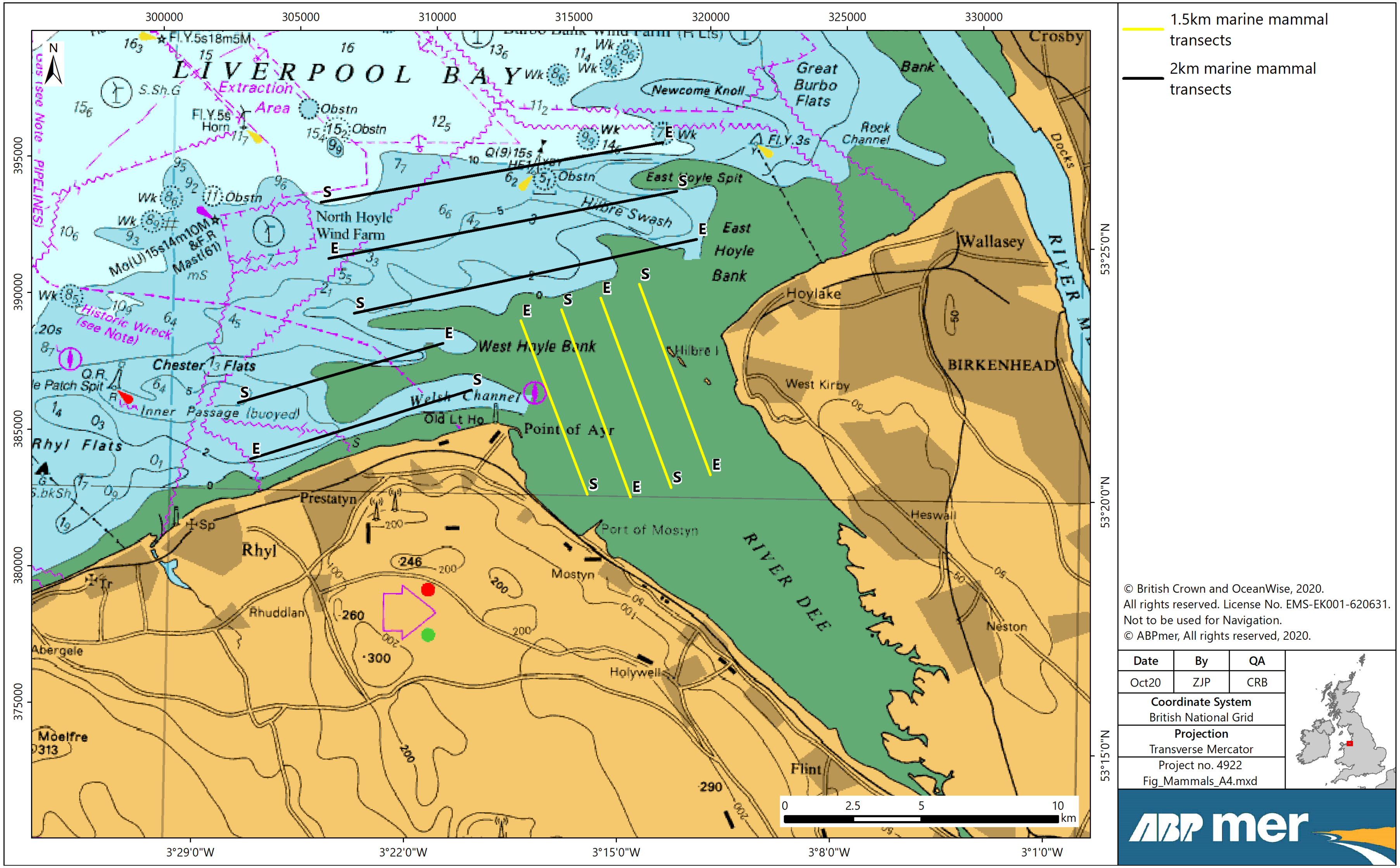


Figure 5. **Marine mammal transects**

Every survey was carried out by three experienced cetacean observers with two people functioning as 'primary observers (POs)', recording cetacean sightings, and the third recording effort data. While on survey, the vessel travelled at a constant speed of 10 knots, although on occasions this had to be reduced due to environmental conditions.

The POs were situated on the roof of the vessel, each scanning from abeam (90°) on their side to 10° on the opposite side. Scans were conducted primarily using the naked eye but binoculars were provided to confirm sightings and species ID when necessary. On sighting an animal, POs immediately recorded the boat position (using a handheld GPS), angle and distance to the animal.

Environmental conditions were recorded by the third person at 15-minute intervals throughout the survey. Additional lines of effort were taken when there was a significant change in environmental variables or vessel course. A GPS unit was used to record vessel position, course and speed. Additionally, the number and type of boats active in the survey area were recorded with every record as well as the type of survey effort. Four different types of survey effort were recorded:

- **Line transect (LT):** The vessel was on one of the predefined survey lines;
- **Dedicated search (DS):** The POs were in position and recording data while the boat was transiting between survey lines or on return to port;
- **Casual watch (CW):** The POs were not in position but sightings were recorded opportunistically; and
- **Photo-ID (ID):** The survey was interrupted to take photoidentification images of bottlenose dolphins.

Photo-identification methods

Photo-identification images of bottlenose dolphins were taken opportunistically using a Canon Electro-Optical System (EOS) 7D Mark II SLR with 70-300 mm lens. Photo-ID images were matched by eye to the Cardigan Bay photo identification catalogue, and matches were then confirmed by an experienced observer.

2.2.2 Passive acoustic monitoring

The F-POD (and predecessors T-PODs and C-PODs) are widely used instruments for passive acoustic monitoring of cetaceans and can provide high-temporal resolution data over long periods at discrete locations. F-PODS are a self-contained submersible ultrasound monitoring unit that includes a hydrophone element, an amplifier, a digital processor, as well as a battery pack and memory. These devices use digital characterisation of click waveform data (time domain data) to log all clicks that are similar to cetacean clicks. Cetacean detection is performed in post-processing in the F-POD app (v1.0.2.05 Chelonia Ltd, UK) by the detection and classification of coherent sequences i.e., trains of clicks found within the raw data. These devices have been used in a number of studies to assess the distribution of harbour porpoises and other cetaceans in the context of monitoring marine renewable energy developments (Clarke *et al.*, 2021; Benjamins *et al.*, 2017; Sparling *et al.*, 2015).

F-PODs have a maximum detection range for porpoises of approximately 400 m and dolphins may be detected over 1 km away. The F-POD is almost omnidirectional except for the small blindspot created by the air cavity around the batteries along the tube.

The units log continuously for up to four months with data typically downloaded every three months.

Deployment and services

Four F-PODs were successfully deployed in November 2020 one off the Mostyn Deep, one in the channel near Hilbre Island and two in the Dee Estuary approaches (Figure 6).

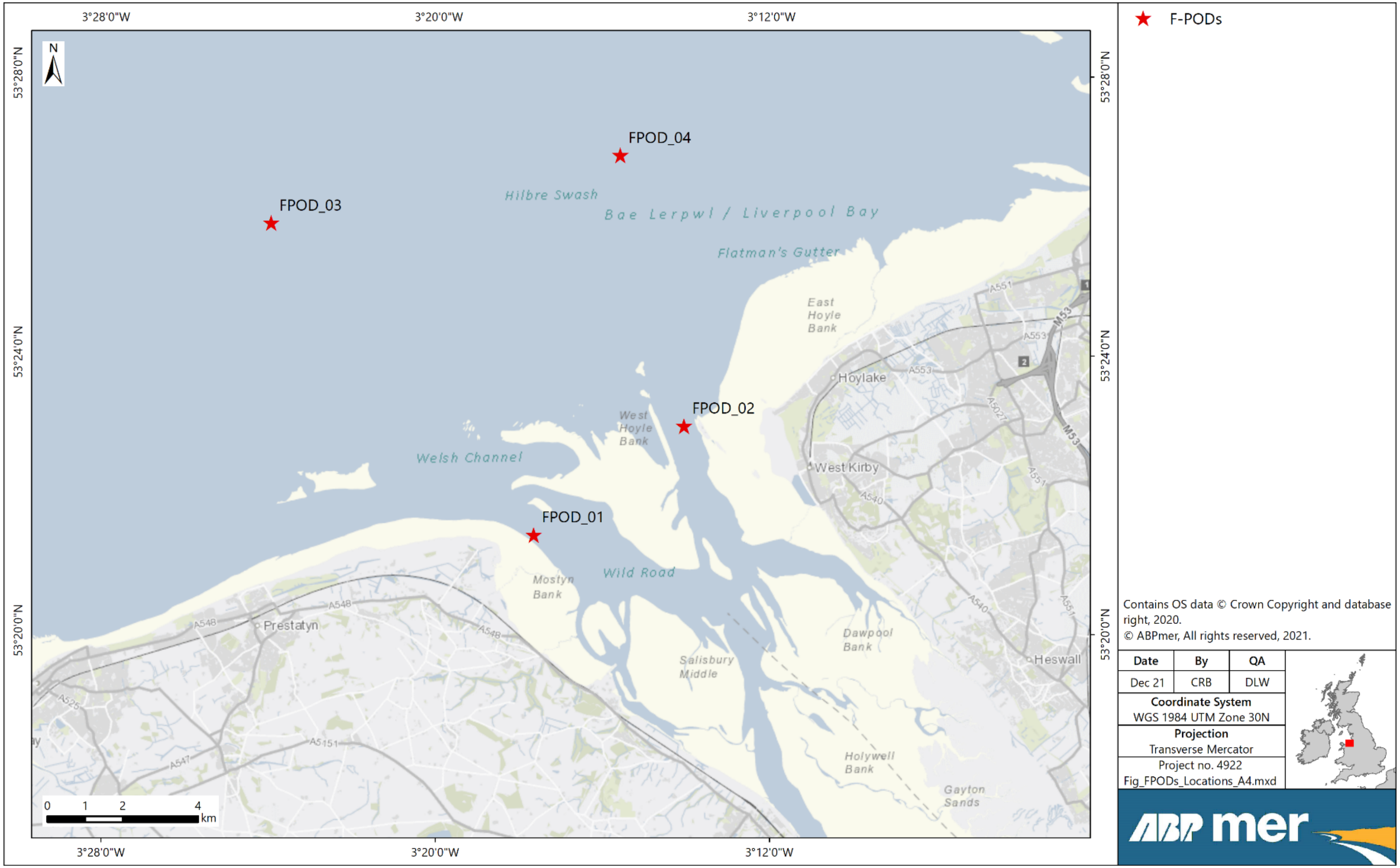


Figure 6. F-POD locations

The F-PODs were attached to a ~20 kg clump weight. The clump weight ran to a 1-tonne sinker via a weighted groundline, with each sinker marked using a lit buoy. A schematisation of this is provided in Figure 7. A seabed licence was obtained from the Crown Estate prior to deployments, with a local Notice to Mariners issued by the harbour authorities (Port of Mostyn and Port of Liverpool). Appropriate permissions were also obtained from the Marine Management Organisation (MMO), Natural Resource Wales (NRW), Dee Conservancy and Trinity House.

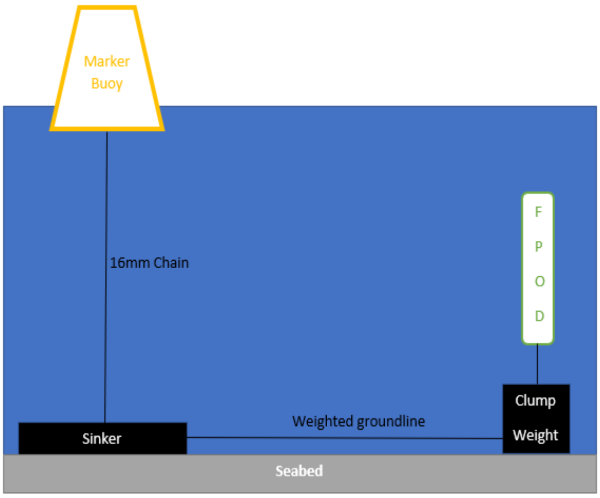


Figure 7. Schematisation (left) and deployment (right) of fixed acoustic mooring

All devices were deployed on 05 November 2020 from the vessel *Eileen*, with deployment coordinates provided below in Table 3. Subsequent services of the fixed moorings were conducted at *circa* 3–4-month intervals from the same vessel (see Table 3 for service timings). During each service visit the mooring chains, groundlines and shackles were visually inspected and replaced if necessary. The marker buoys and F-POD devices were cleaned of biofouling, data downloaded from each F-POD, and the internal batteries of each F-POD were replaced.

Table 3. Locations and deployment timings of acoustic monitoring devices

Site ID	WGS84 Latitude (°)	WGS84 Longitude (°)	Deployment Start (GMT)	Deployment End (GMT)
F-POD_01	053° 21.406′ N	003° 17.669′ W	04/11/2020 13:07	09/02/2021 17:20
			09/02/2021 17:45	28/05/2021 04:49
			28/05/2021 05:36	26/08/2021 05:58
			26/08/2021 06:30	16/12/2021 15:28
F-POD_02	053° 22.978′ N	003° 14.072′ W	04/11/2020 11:27	09/02/2021 10:09
			09/02/2021 10:52	28/05/2021 11:36
			28/05/2021 11:59	26/08/2021 12:38
			26/08/2021 13:05	16/12/2021 09:29
F-POD_03	053° 25.864′ N	003° 24.002′ W	05/11/2020 16:10	09/02/2021 14:45
			09/02/2021 15:21	28/05/2021 07:33
			28/05/2021 08:14	26/08/2021 08:36
			26/08/2021 08:59	16/12/2021 13:25
F-POD_04	053° 26.858′ N	003° 15.629′ W	05/11/2020 15:06	09/02/2021 12:16
			09/02/2021 13:23	28/05/2021 09:44
			28/05/2021 10:20	26/08/2021 10:26
			26/08/2021 10:57	16/12/2021 11:29

It should be noted that following retrieval and subsequent analysis of F-POD_02 at the end of the third period of deployment it was discovered that the F-POD was at times experiencing incorrect operation (recording electronic noise and only clicks sporadically). Further investigation found this was due to a faulty circuit board. This is likely to have caused the much lower number of Detection Positive Minutes detected during the third period of deployment. Analysis suggested the F-POD was working correctly in the fourth period.

Data analysis

Digital time domain waveform analysis (using duration (5 s resolution), frequenc , amplitude, number of cycles, bandwidth, amplitude profile, frequency profile and Narrow Band High Frequency Index) was used to select possible cetacean clicks in the range 20-160 kHz. Coherent click trains were extracted and classified in the F-POD app (v1.0.2.05 Chelonia Ltd, UK) using the KERNO-F classifier (Chelonia's automated classifier for data from the F-POD). This classifier is a fixed component of the process to give long term uniformity of performance.

After porpoise and dolphin click trains have been filtered in the F-POD app by creating the FP3 files, detection positive minutes (DPM) per day and DPM per hour were exported. These were then imported in Microsoft Access where queries were used to extract activity over the deployment (DPM per day) and to show the diel patterns i.e., total DPM per hour over-all 24-hour periods.

3 Results

3.1 Fish surveys

The results of the intertidal surveys (seine nets, 1.5 m scientific beam trawl and fyke nets) and subtidal surveys (otter and beam trawls) are summarised in Section 3.1.1 and 3.1.2 respectively). The ichthyoplankton results are presented in Section 3.1.3 The raw data from these surveys is provided in Appendix A.

Section 3.1.4 summarises the results of the pelagic (acoustic) surveys with the results of the eDNA surveys provided in Section 3.1.5.

3.1.1 Intertidal demersal fish surveys

Seine net

The total number of fish caught using this fishing method during each of the quarterly surveys is summarised in Table 4 with summary information on the fish and macrofauna assemblage recorded at each site shown in Table 5. Figure 8 shows the abundance of fish species recorded at each site during each quarter.

The abundance and number of fish caught during the seine net surveys was highest in the Spring survey (Table 4). This was mainly due to the large numbers of clupeids (herring *Clupea harengus* or sprats *Sprattus sprattus*) recorded with a total 1,665 juveniles/larval clupeids which couldn't be identified to species level as well as 93 herring *Clupea harengus* which could be identified to species level. Almost all the herring *Clupea harengus* captured during both the Spring and the other quarterly surveys were juveniles (Table 4). Other species recorded included European plaice *Pleuronectes platessa* (all juvenile size class), flounder *Platichthys flesus*, gobies and mullet species.

There was a lot of variability in the seine net catches between sites Table 5). Higher numbers of fish were observed at Site 1 during the Autumn and Winter surveys in comparison to the other sites. For the Winter survey, these higher numbers were mainly due to the large number of juvenile European pilchard *Sardina pilchardus*.

Invertebrates caught during the surveys were also identified and enumerated. Brown shrimp *Crangon crangon*, were abundant during the Summer survey (132 shrimp). Several shore crabs *Carcinus maenas*, were also caught during the Winter and Summer surveys, and a single barrel jellyfish *Rhizostoma octopus* was also observed during the Summer survey (Table 4 and Table 5).

Table 4. Seine net species abundance for each quarter for all sites

Seine Net	Species	Common Name	Survey Quarter			
			Autumn	Winter	Spring	Summer
Fish	*Ammodytes sp.*	Sandeel		1	3	
	Chelon labrosus	Thick-lipped grey mullet			1	
	Chelon ramada	Thin-lipped grey mullet				7
	Clupea harengus	Atlantic herring	27	19	93	13
	Clupeidae				1665	
	Dicentrarchus labrax	European bass				4
	Gadidae				3	
	Gasterosteus aculeatus	Three-spined stickleback			1	
	Mugilidae				3	
	Platichthys flesus	European flounder			2	9
	Pleuronectes platessa	European plaice				15
	Pleuronectidae				4	
	Pomatoschistus microps	Common goby			1	6
	Pomatoschistus minutus	Sand goby	2	6		24
	Sardina pilchardus	European pilchard		50		
	Scophthalmus maximus	Turbot				1
	Soleidae				2	
	Sprattus sprattus	European sprat				6
	Syngnathus rostellatus	Lesser pipefish				1
No. of fish species			2	4	11	10
Total fish abundance			29	76	1778	86
Macrofauna	*Carcinus maenas*	Shore crab		2		1
	Crangon crangon	Brown shrimp	4	1	3	132
	Rhizostoma octopus	Barrel jellyfish		1		
No. of macrofauna species			1	3	1	2
Total macrofauna abundance			4	4	3	133

Table 5. Summary of seine net data by site for each quarter showing the total number of fish species and macrofauna species and a description of the fish assemblages present

Site	Autumn	Winter	Spring	Summer	Summary
Number of Fish Species					
1	1	2	6	4	Atlantic herring, *Clupea harengus,* and sardines, *Sardina pilchardus*, were the most abundant species at this site (a total of 90 and 49 fish recorded respectively). Other commonly recorded species included European bass *Dicentrarchus labrax*, Thin-lipped greymullet *Chelon labrosus* and Common Goby *Pomatoschistus microps*. The Winter and Spring surveys had the highest abundances recorded and the Summer survey had the lowest.
3	0	1	4	3	At Site S3, Atlantic herring, *Clupea harengus,* and Sand gobies *Pomatoschistus minutus* were the species recorded in the highest abundances (a total of 53 and 47 fish recorded respectively). Thin-lipped grey mullet, *Chelon labrosus,* were also recorded at this site, although in lower abundances (a total of 13 fish recorded). The Spring and Summer surveys had the highest abundances recorded. No fish species were recorded during the Winter survey at this site.
5	2	3	2	4	Atlantic herring *Clupea harengus*, Flounder *Platichthys flesus,* and sand gobies *Pomatoschistus minutus* were the most abundant species at Site S5 (a total of 21, 15 and nine fish recorded respectively). Sand eels *Ammodytes sp*, Sardines and European bass, *Dicentrarchus labrax,* were also recorded at this site. The number of fish recorded was highest during the Spring survey (with a total of 24 fish recorded) and was lowest in the Autumn and Winter surveys (with a total of three fish recorded during both seasons).
8	0	0	6	6	Plaice, *Pleuronectes platessa*, and sprat, *Sprattus sprattus*, were the two species recorded in the highest numbers (a total of 45 and 12 fish were recorded respectively at this site). Other species recorded at this site included common goby *Pomatoschistus microps*, flounder *Platichthys flesus*, grey mullet, sand eel *Ammodytes sp*., turbot *Scophthalmus maximus* and lesser pipefish *Syngnathus rostellatus*. Fish abundances were highest during the Spring survey, with a total number of 89 fish recorded. No fish were recorded at this site during the Autumn or Winter surveys.

Site	Autumn	Winter	Spring	Summer	Summary
Number of Macrofauna Species					
1	1	1	0	0	At this site, three brown shrimp *Crangon crangon,* were recorded during the Autumn survey and an individual shore crab *Carcinus maenas* recorded during the Winter survey. No macrofauna species were recorded during the Spring or Summer survey.
3	0	2	0	2	Brown shrimp, *Crangon crangon*, were the most abundant species at this site (a total of 133 individuals recorded, with 132 of these during Summer and one during Winter). A single shore crab, *Carcinus maenas*, was also recorded on two occasions, during the Summer and Winter surveys. No macrofauna species were recorded in the Autumn or Spring surveys.
5	1	0	0	0	One brown shrimp, *Crangon crangon*, was recorded in the Autumn survey.
8	0	1	1	0	A single brown shrimp, *Crangon crangon*, and barrel jellyfish, *Rhizostoma octopus,* were the only species recorded at this site. Three brown shrimp were recorded in the Spring survey and a single barrel jellyfish was recorded during the Winter survey. No macrofauna species were recorded in the Autumn or Summer surveys.

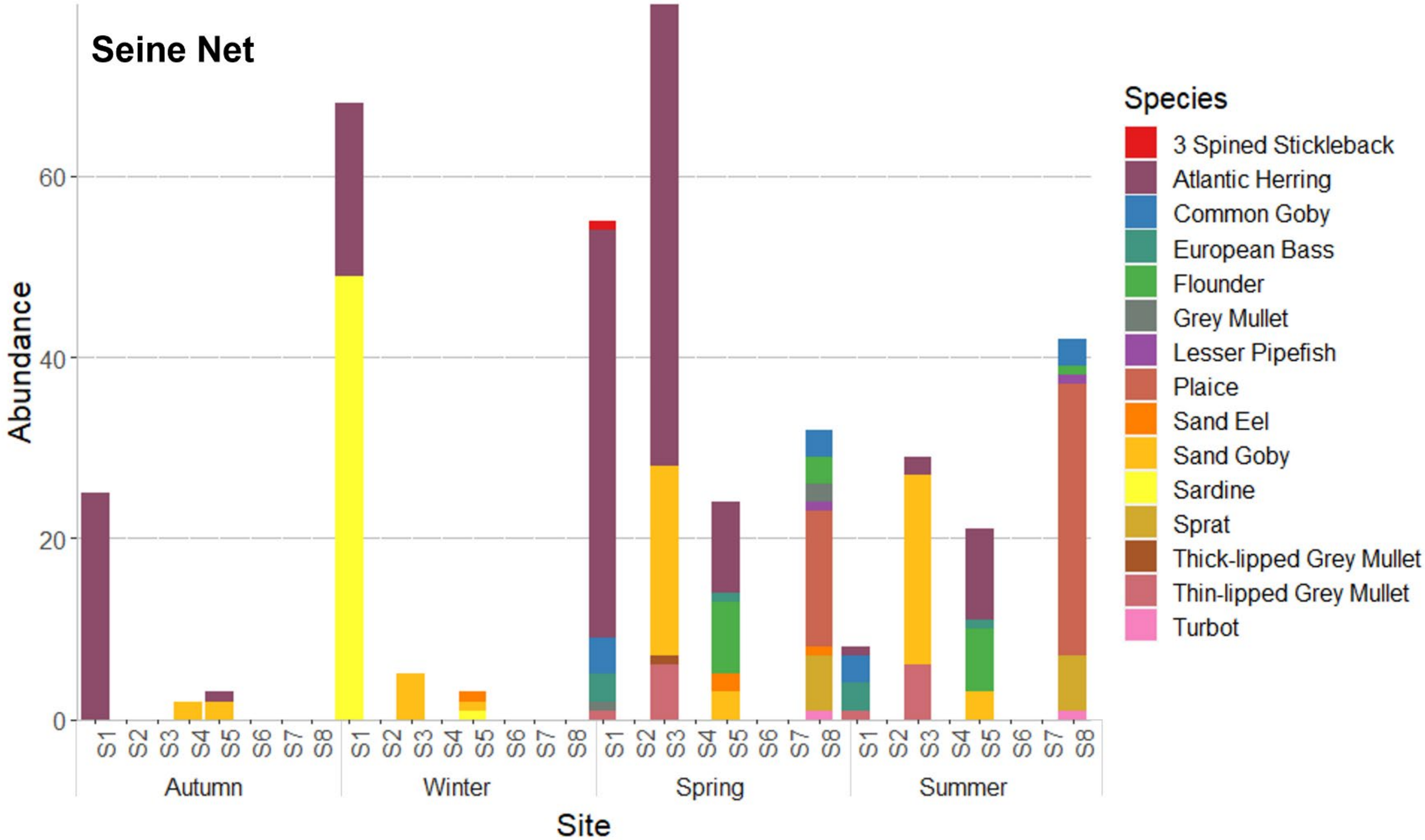


Figure 8. **Seine net species abundance for each site during each quarter**

1.5 m beam trawl

The total number of fish caught using this fishing method during each of the quarterly surveys is summarised in Table 6 with summary information on the fish and macrofauna assemblage recorded at each site shown in Table 7 Figure 9 shows the abundance of fish species recorded at each site during each quarter.

Low catches of fish were recorded in all the 1.5 m beam trawl surveys (Table 6), with no fish caught during the Winter survey. European plaice, *Pleuronectes platessa,* was the most frequently caught species throughout the survey period, caught during 3 out of 4 of the survey quarters (Table 6) Whiting *Merlangius merlangus* were the most abundant species caught during a single survey quarter, with three caught during the Autumn survey (Table 6 and Table 7). Hooknose *Agonus cataphractus*, Atlantic herring *Clupea harengus,* and Dover sole *Solea solea*, constituted the few other species caught during the 1.5 m beam trawl surveys Table 6 and Table 7).

Very high numbers of ctenophores were recorded at all sites during the Spring survey, likely due to prevailing weather conditions of strong on shore winds prior to and during the survey. Due to the high numbers caught during the survey, these were recorded as present and not enumerated (Table 6).

Table 6. 1.5 m beam trawl net species abundance for each quarter for all sites

1.5 m Beam Trawl	Species	Common Name	Survey Quarter			
			Autumn	Winter	Spring	Summer
Fish	*Agonus cataphractus*	Hooknose	1			
	Clupea harengus	Atlantic herring	1			2
	Merlangius merlangus	Whiting	3			
	Pleuronectes platessa	European plaice	2		2	1
	Solea solea	Dover sole			1	
No. of fish species			4	0	2	2
Total fish abundance			7	0	3	3
Macrofauna	*Carcinus maenas*	Shore crab		1		
	Crangon crangon	Brown shrimp	7	3	2	20
	CTENOPHORA			3	P	10
No. of macrofauna species			1	3	2	2
Total macrofauna abundance			7	7	2	30

Table 7. Summary of the 1.5 m beam trawl data by site for each quarter showing the total number of fish species and macrofauna species and a description of the fish assemblages present.

Site	Autumn	Winter	Spring	Summer	Summary
Number of Fish Species					
1	0	0	2	0	Dover sole *Solea solea* and plaice *Pleuronectes platessa* were the only species recorded at this site, with only one individual recorded for each species in the Spring survey.
2	0	0	0	0	No fish were recorded at this site during any survey.
3	0	0	1	0	Only one plaice, *Pleuronectes platessa,* was recorded at this site during the entire survey period (in the Spring survey).
4	0	0	0	0	No fish were recorded at this site during any survey.
5	2	0	0	1	Abundances were low across all species at this site however, Whiting *Merlangius merlangus* was the most abundant species recorded (a total abundance of three fish recorded during Autumn). A single Atlantic herring *Clupea harengus,* was also recorded on two occasions, during the Summer and Autumn surveys. No fish species were recorded during the Winter or Spring surveys.
6	0	0	0	0	No fish were recorded at this site during any survey.
7	0	0	0	2	Atlantic herring *Clupea harengus,* and plaice *Pleuronectes platessa* were the only species recorded at this site, both with a single individual recorded in the Summer survey. No fish were recorded during the Autumn, Winter or Spring surveys.
8	0	0	0	0	No fish were recorded at this site during any survey.
9	2	0	0	0	A low number of species were recorded at this site with plaice, *Pleuronectes platessa,* being the most numerous species, albeit with a low abundance of two fish recorded in the Autumn survey. A single pogge *Agonus cataphractus* was also recorded during the Autumn survey.
Number of Macrofauna Species					
1	1	2	2	1	At this site, brown shrimp *Crangon crangon*, and comb jellies Ctenophora, were the only macrofauna species recorded. Brown shrimp had a total abundance of 19, with most individuals being recorded during Summer. A single comb jelly was recorded in Winter however, comb jellies in Spring were recorded as present (P), due to high abundance.
2	0	1	1	1	Brown shrimp *Crangon crangon*, were recorded during the Winter and Summer surveys with abundances of one and two individuals recorded, respectively. Comb jellies, Ctenophora, were recorded as P in Spring. No macrofauna species were recorded in the Autumn survey.

Site	Autumn	Winter	Spring	Summer	Summary
3	1	1	1	1	At this site, brown shrimp *Crangon crangon* and comb jellies Ctenophora were the only macrofauna species recorded with comb jellies being recorded as P and a total of three brown shrimp recorded.
4	1	2	1	1	Comb jellies, Ctenophora, were the most abundantly recorded species at Site B4, being recorded as P during the Spring survey and having a total of 11 individuals recorded in the Summer and Winter surveys. Brown shrimp *Crangon crangon*, and shore crabs, *Carcinus maenas,* constitute the other macrofauna species recorded at this site with total abundances of seven and one respectively. Macrofauna abundance was highest in the Spring and Summer surveys, and lowest during the Winter survey.
5	1	0	1	0	At this site, comb jellies, Ctenophora, were recorded as P in the Spring survey and two brown shrimp *Crangon crangon*, were recorded during the Autumn survey. No macrofauna species were recorded during the Winter and Summer surveys.
6	1	0	1	1	A single brown shrimp, *Crangon crangon*, was recorded on two occasions during the Autumn and Summer surveys. Comb jellies, Ctenophora, were recorded as P during the Spring survey. No macrofauna were recorded in Winter at this site.
7	0	1	2	0	At this site, macrofauna abundance was highest in Spring with comb jellies, Ctenophora, being recorded as P and with one brown shrimp *Crangon crangon*, recorded. A single comb jelly was also recorded during the Winter survey. No macrofauna species were recorded during the Autumn or Summer surveys at this site.
8	1	0	1	1	Comb jellies, Ctenophora, were recorded as P during Spring, due to high abundance. A single brown shrimp *Crangon crangon*, was recorded on two occasions, during the Summer and Autumn surveys. No macrofauna species were recorded during the Winter surveys.
9	1	0	1	0	Comb jellies Ctenophora and brown shrimp *Crangon crangon,* were the only species recorded at this site with recorded abundances of P (in the Spring survey) and five (in the Autumn survey), respectively. No macrofauna species were recorded during the Winter or Summer surveys at this site.

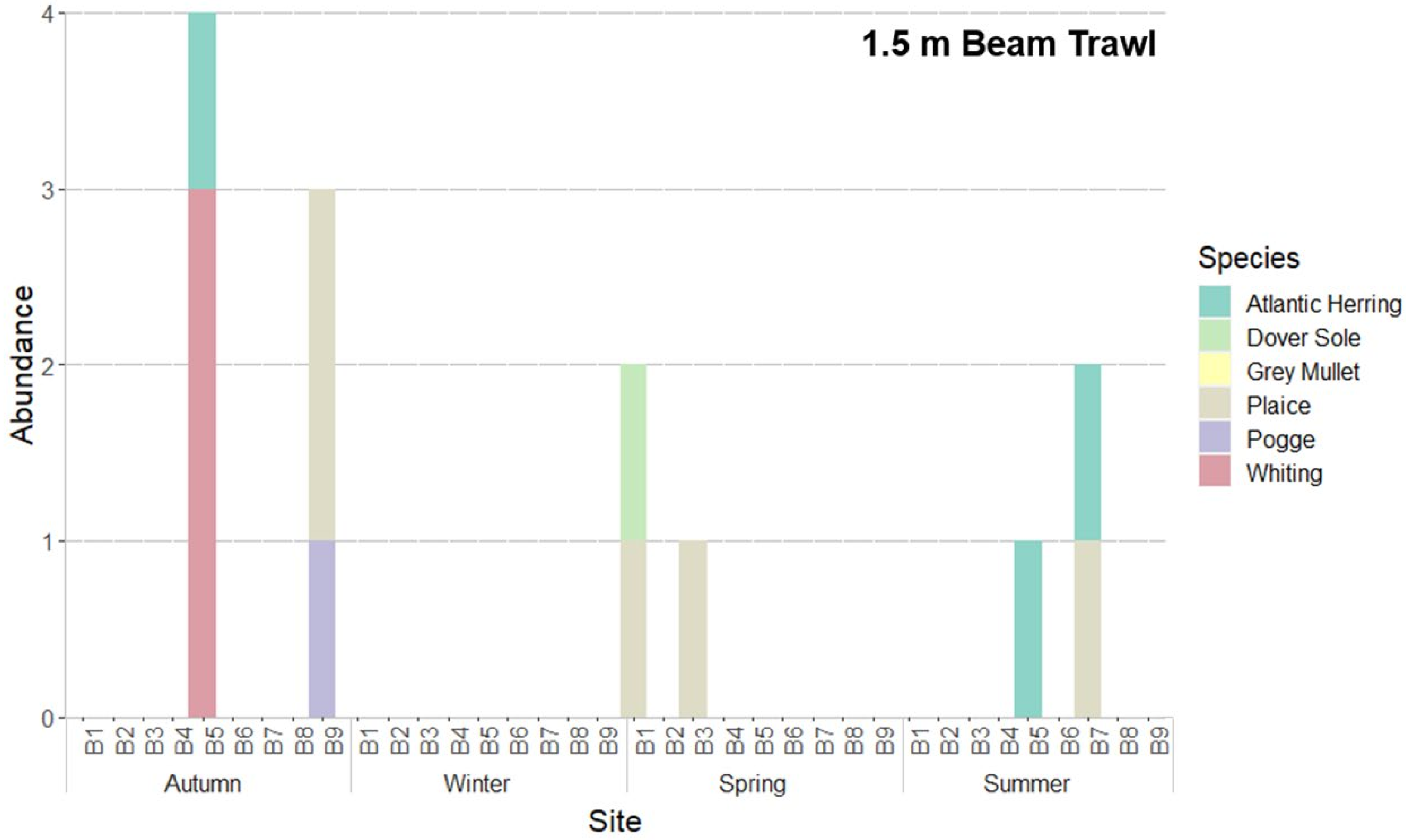


Figure 9. 1.5 m beam trawl species abundance for each site during each quarter

Fyke net

The total number of fish caught using this fishing method during each of the quarterly surveys is summarised in Table 8 with summary information on the fish and macrofauna assemblage recorded at each site shown in Table 9. Figure 10 shows the abundance of fish species recorded at each site during each quarter.

The continuous water quality data recorded with Aqua TROLLs which were left *in situ* (attached to Nets F1, F2, F3, F4, F5, and F8) and the Solinst Levelogger 5 that was attached to Net F7, are provided in Appendix A.

The number of species caught in the fyke nets was low across all quarterly surveys, reaching a maximum of seven species in the Winter and Summer surveys (Table 8). The total number of fish caught of each species was also typically low, with the exception of flounder *Platichthys flesus*. This species was recorded in the highest numbers in the Summer survey with a total of 77 captured (from mainly Sites 1, 3 and 6) (Table 9). The fish captured consisted of a mixture of juvenile and adult size classes. Other species recorded in lower numbers included European eel *Anguilla anguilla*, European plaice *Pleuronectes platessa* (the majority which were juveniles) and sea bass *Dicentrarchus labrax*. Hooknose *Agonus cataphractus*, Atlantic herring *Clupea harengus*, lesser weever *Echiichthys viper*, common dab *Limanda limanda*, whiting *Merlangius merlangus*, mullet and longspined bullhead *Taurulus bubalis* were the species with the lowest abundance, with only one individual caught over the entire survey period (Table 8 and Table 9).

The diversity of macrofaunal species caught was low across all quarterly surveys. Abundance was also low, with the exception of shore crab *Carcinus maenas* which was caught in high numbers at during the Spring and Summer surveys (Table 8). Most shore crabs *Carcinus maenas* were recorded from Site 4. Brown shrimp was also recorded year round and the common prawn, *Palaemon serratus,* was also caught during the Winter and Spring survey (Table 8 and Table 9).

Table 8. Fyke net total species abundance for each quarter for all sites

Fyke Net	Species	Common Name	Survey Quarter			
			Autumn	Winter	Spring	Summer
Fish	*Agonus cataphractus*	Hooknose		1		
	Anguilla anguilla	European eel			5	11
	Ciliata mustela	Five-bearded rockling	3	2		
	Clupea harengus	Atlantic herring		1		
	Dicentrarchus labrax	European bass			2	4
	Echiichthys vipera	Lesser weever				1
	Limanda	Common dab			1	
	Liparis montagui	Montagu's seasnail		2		
	Merlangius merlangus	Whiting	1			2
	Mugilidae	Mullet	1			
	Platichthys flesus	European flounder	3	10	15	77
	Pleuronectes platessa	European plaice	3	2	4	9
	Solea solea	Dover sole			2	2
	Taurulus bubalis	Longspined bullhead		1		
No. of fish species			5	7	6	7
Total fish abundance			11	19	29	106
Macrofauna	*Carcinus maenas*	Shore crab	29	44	745	449
	Cnidaria					3
	Crangon crangon	Brown shrimp	10	16	1	15
	CTENOPHORA			39	P	
	Cyanea capillata	Lion's mane jellyfish				1
	Eriocheir sinensis	Chinese mitten crab			1	
	Liocarcinus depurator	Harbour crab				5
	Liocarcinus holsatus	Flying crab			1	
	Palaemon serratus	Common prawn			29	26
No. of macrofauna species			2	3	6	6
Total macrofauna abundance			39	99	777	499

Table 9. Summary of the fyke net data by site for each quarter showing the total number of fish species and macrofauna species and a description of the fish assemblages present

Site	Autumn	Winter	Spring	Summer	Summary
Number of Fish Species					
1	0	1	3	3	Flounder, *Platichthys flesus,* were the most abundant species at this site (a total of 42 fish recorded). Other species recorded, albeit in low abundances (<3), included European eel *Anguilla anguilla*, European bass *Dicentrarchus labrax*, lesser weaver *Echiichthys vipera*, and dover sole *Solea solea*. The Summer and Spring surveys had the highest abundances recorded. No fish were recorded during the Autumn survey at this site.
2	0	0	0	1	No fish were recorded at this site during the Autumn, Winter or Spring surveys but low numbers of flounder, *Platichthys flesus,* (a total of 2 fish) were recorded during the Summer survey.
3	0	2	0	2	At this site, flounder, *Platichthys flesus,* were the most abundant species recorded with 16 fish recorded during the Summer survey and a single individual recorded during the Winter survey. Low numbers of Atlantic herring *Clupea harengus* and European eel *Anguilla anguilla* were also observed during the Winter survey. No fish were recorded at this site during the Autumn and Spring surveys.
4	3	2	3	4	Flounder *Platichthys flesus* and European eel *Anguilla anguilla* were the most abundant species record at this site (a total of fish 7 and 4 fish, respectively). Other species recorded at this site, although in low abundances, included five-bearded rockling *Ciliata mustela*, plaice *Pleuronectes platessa*, dover sole *Solea solea,* and whiting *Merlangius merlangus*. Abundances were highest during the Summer and Spring surveys.
5	1	2	1	2	At this site, a low number of species were recorded including dover sole *Solea solea*, European eel, *Anguilla anguilla,* and flounder, *Platichthys flesus* (with a total of one, one and 10 fish recorded respectively, with most fish recorded during Summer). Abundances were lowest in the Autumn and Spring surveys with only a single fish being recorded during each season.
6	1	2	2	3	Flounder *Platichthys flesus,* European eel *Anguilla anguilla* and European bass *Dicentrarchus labrax* were the only species recorded at this site with total abundances of 16, eight and two fish recorded respectively, with most fish being recorded during the Summer survey.
7	1	2	1	2	At this site, flounder *Platichthys flesus* and plaice *Pleuronectes platessa* were the only species recorded (a total abundance of 9 and 3 fish recorded respectively). The Spring and Summer surveys had the highest abundances.

Site	Autumn	Winter	Spring	Summer	Summary
8	3	4	4	3	Plaice, *Pleuronectes platessa,* and five-bearded rockling, *Ciliata mustela,* were the most abundantly recorded species at this site (a total of 14 and 3 fish recorded respectively). Other recorded species included Montagu's seasnail *Liparis montagui*, whiting *Merlangius merlangus*, European bass *Dicentrarchus labrax*, pogge *Agonus cataphractus*, dab *Limanda limanda* and dover sole *Solea solea*. The Summer and Spring surveys had the highest abundances recorded with a total of nine and six fish respectively.
Number of Macrofauna Species					
1	0	2	1	1	Shore crabs *Carcinus maenas* and comb jellies Ctenophora were the only macrofauna species recorded at this site. Shore crabs *Carcinus maenas* were the most abundantly recorded species (a total of 56 recorded, with the highest numbers recorded in the Spring surveys). Only two comb jellies, Ctenophora, were recorded throughout the entire survey period during the Winter survey.
2	0	2	0	2	No macrofauna were recorded at this site during Autumn or Spring but a low number of brown shrimp *Crangon crangon,* and comb jellies, Ctenophora, were recorded (a total of 16 and 5 individuals recorded respectively). The Winter survey had the highest abundances recorded.
3	1	3	2	2	At this site, shore crabs *Carcinus maenas* were the most abundant species recorded with a total of 85 individuals recorded. Other species recorded at this site, although in low abundances, included brown shrimp *Crangon crangon*, common prawns *Palaemon serratus* and comb jellies Ctenophora with a total number of 13, two and one induvial recorded respectively. The Spring and Summer surveys had the highest abundances recorded.
4	2	1	4	2	Shore crabs *Carcinus maenas* and common prawn, *Palaemon serratus*, were the most abundant species recorded at this site (a total of 1,099 and 50 individuals recorded respectively, with most individuals recorded in the Spring and Summer surveys). Brown shrimp *Crangon crangon*, comb jellies Ctenophora and the invasive Chinese mitten crabs *Eriocheir sinensis* constitute the other species recorded at this site.
5	0	0	3	1	Macrofauna were only recorded at this site during the Spring and Summer surveys. Comb jellies, Ctenophora, were recorded as present (P) during a Spring survey. Shore crabs *Carcinus maenas,* and common prawns *Palaemon serratus,* were also recorded at this site, albeit in low abundances, with a total of six and two individuals recorded respectively.

Site	Autumn	Winter	Spring	Summer	Summary
6	1	0	1	1	Shore crabs *Carcinus maenas* and brown shrimp *Crangon crangon* were the only species recorded at this site, although in low abundances, with a total of four and one individual recorded respectively. No macrofauna was recorded during the Winter survey at this site.
7	1	1	1	3	The abundance of macrofauna recorded at this site was highest in the Summer survey and lowest during the Autumn survey. Shore crabs *Carcinus maenas* were the most abundant species at this site, albeit with a relatively low abundance, with a total of six individuals recorded. Other species recorded included comb jellies Ctenophora, brown shrimp *Crangon crangon* and lion's mane jellyfish *Cyanea capillata*.
8	1	3	3	5	At this site, comb jellies Ctenophora, shore crab *Carcinus maenas* and brown shrimp *Crangon crangon* were the most abundantly recorded species (a total of 14, 11 and eight individuals recorded respectively). Other species recorded at this site included common prawns *Palaemon serratus*, flying crabs *Liocarcinus holsatus* and harbour crabs *Liocarcinus depurator.* Abundances were highest during the Summer and Winter surveys.

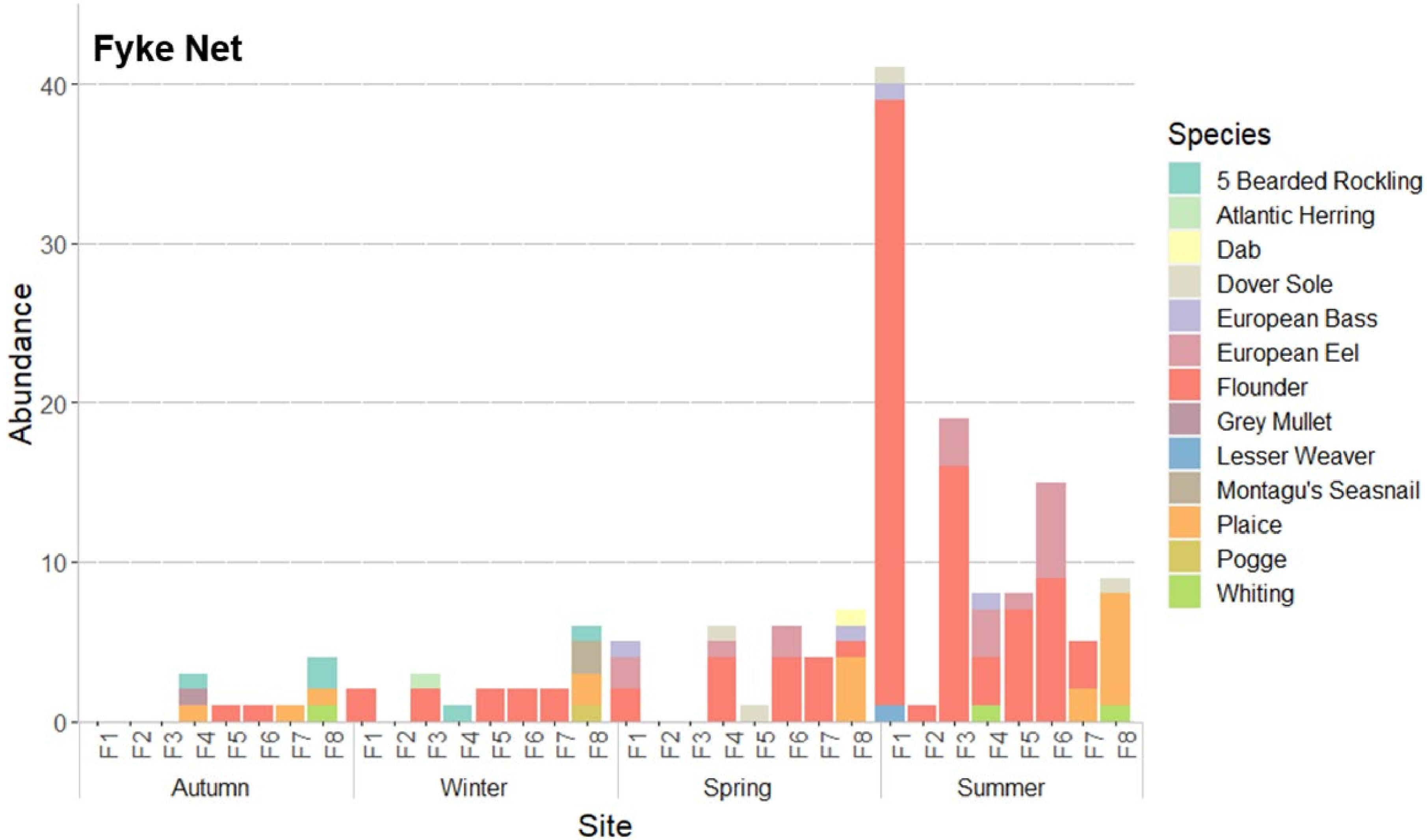


Figure 10. Fyke net species abundance for each site during each quarter

3.1.2 Subtidal demersal fish surveys

Otter trawl

The total number of fish caught using this fishing method during each of the quarterly surveys is summarised in Table 10 with summary information on the fish and macrofauna assemblage recorded at each site shown in Table 11. Figure 11 shows the abundance of fish species recorded at each site during each quarter.

The total number of fish species caught during the otter trawling was relatively consistent across the quarterly surveys. Total fish abundance was highest during Spring survey and lowest during the Winter survey with values of 1,433 and 331, respectively (Table 10). The high numbers fish recorded in the Spring survey was largely attributable to large catches of dab *Limanda limanda* and whiting *Merlangius merlangus*) (which consisted predominantly of adult fish). These species were also two of the most numerous species recorded during other quarterly surveys (with a much high proportion of juvenile whiting *Merlangius merlangus* recorded in the other quarterly surveys). Other commonly recorded species included lesser weaver *Echiichthys viper*, European plaice *Pleuronectes platessa*, sand goby *Pomatoschistus minutus* and sandeel *Ammodyte*s spp. Elasmobranchs recorded included thornback ray *Raja clavata*, small-spotted catshark *Scyliorhinus canicular* and starry smooth-hound *Mustelus asterias* (Table 10 and Table 11).

Image 1. Otter trawl catches (Site 3 in Autumn (left) and Spring (right))

With respect to macrofauna, large numbers of common starfish *Asterias rubens* were recorded during the surveys which dominated the epifaunal assemblage recorded, particularly at site 5 which had consistently high numbers over all of the surveys (Table 11). Other commonly recorded macrofaunal species recorded included the common heart urchin *Echinocardium cordatum,* brittlestar *Ophiura ophiura*, green sea urchin *Psammechinus miliaris*, hermit crabs *Pagurus bernhardus* and brown shrimps *Crangon crangon* (Table 10).

Table 10. Otter trawl species abundance for each quarter for all sites

Otter trawl	Species	Common Name	Survey Quarter			
			Autumn	Winter	Spring	Summer
Fish	*Agonus cataphractus*	Hooknose	34	4	2	13
	Ammodytes sp.	Sand lance	2	3	22	13
	Aphia minuta	Transparent goby		1		
	Arnoglossus laterna	Mediterranean scaldfish	7	2	3	
	Buglossidium luteum	Yellow sole	5		1	9
	Callionymus lyra	Common dragonet	11		2	3
	Chelidonichthys lucerna	Tub gurnard			28	27
	Clupea harengus	Atlantic herring	6	6		9
	Echiichthys vipera	Lesser weaver	121	12	105	230
	Eutrigla gurnardus	Grey gurnard	24			1
	Hyperoplus lanceolatus	Greater sandeel			66	
	Limanda limanda	Common dab	152	47	654	127
	Merlangius merlangus	Whiting	142	17	441	75
	Mustelus asterias	Starry smooth-hound			11	3
	Myoxocephalus scorpius	Shorthorn sculpin		1		1
	Platichthys flesus	European flounder	3		18	1
	Pleuronectes platessa	European plaice	33	41	45	84
	Pomatoschistus minutus	Sand goby	25	42	3	58
	Raja clavata	Thornback ray	19	12	11	10
	Scomber scombrus	Atlantic mackerel	2		4	
	Scyliorhinus canicula	Small-spotted catshark			10	1
	Solea solea	Dover sole	4		5	36
	Sprattus sprattus	Sprat	45	142		
	Syngnathus acus	Greater pipefish			2	
	Syngnathus rostellatus	Lesser pipefish	1	1		5
	Trisopterus luscus	Whiting-pout	2			
No. of fish species			19	14	19	19
Total fish abundance			638	331	1433	706

Otter trawl	Species	Common Name	Survey Quarter			
			Autumn	Winter	Spring	Summer
Macrofauna	*Asterias rubens*	Common starfish	4679	4806	1743	2888
	Alcyonium digitatum	Dead man's fingers		P	P	
	Astropecten irregularis	Sand sea star	73		154	12
	Buccinum undatum	Common whelk	53	5	4	11
	Cancer pagurus	Edible crab			2	1
	Carcinus maenas	Shore crab	1	2		
	Corystes cassivelaunus	Helmet crab	2	21	11	
	Crangon crangon	Brown shrimp	196	18	3	294
	Echinocardium cordatum	Common heart urchin	182	151	2196	178
	Ensis sp.	Razor clam	5	71	43	
	Euspira catena	Necklace shell		4	4	
	Hyas araneus	Great spider crab		4	1	
	Liocarcinus holsatus	Flying crab	44	6	25	136
	Loligo vulgaris	European squid	2		1	8
	Lutraria sp.	Otter shell			8	3
	Mytilus sp.	Blue mussel	32			
	Ophiura ophiura	Serpent star	1041	286	1492	20
	Pagurus bernhardus	Common hermit crab	181	48	378	16
	Psammechinus miliaris	Green sea urchin	161	40	46	23
No. of macrofauna species			14	14	17	12
Total macrofauna abundance			6652	5462	6111	3590

Table 11. Summary of the otter trawl data by site for each quarter showing the total number of fish species and macrofauna species and a description of the fish assemblages present

Site	Autumn	Winter	Spring	Summer	Summary
Number of Fish Species					
1	10	11	8	14	Dab *Limanda limanda,* and sprat *Sprattus sprattus*, were the most abundant species at this site (a total of 122 and 64 fish recorded respectively). Other commonly recorded species included lesser weaver *Echiichthys vipera*, whiting *Merlangius merlangus*, sand goby *Pomatoschistus minutus* and plaice *Pleuronectes platessa*. The Summer and Autumn surveys had the highest abundances recorded, whilst Winter had the lowest abundances.
2	12	8	8	14	Dab *Limanda limanda,* was the most abundant species recorded with a total of 166 fish recorded. Whiting *Merlangius merlangus*, sprat *Sprattus sprattus*, lesser weaver *Echiichthys vipera* and plaice *Pleuronectes platessa* constitute some of the other species that were commonly observed at this site (with total abundances of 82, 72, 70 and 70 fish recorded respectively). Abundances at this site during the Autumn survey were the highest out of all sites and seasons.
3	11	6	9	10	Lesser weaver *Echiichthys vipera* and sprat *Sprattus sprattus* were the species with the highest recorded abundances (a total of 135 and 47 respectively). Other species recorded at the site included sand gobies *Pomatoschistus minutus*, grey gurnard, dab *Limanda limanda* and lesser sand eels *Ammodytes spp*. The Autumn and Summer surveys had the highest recorded abundances.
4	6	4	12	12	At this site, lesser weaver *Echiichthys vipera* and greater sand eels *Hyperoplus lanceolatus* were the species with the highest abundance, with a total of 148 and 62 fish recorded respectively. Other species recorded at this site, with relatively high abundances, include dab *Limanda limanda*, whiting *Merlangius merlangus* and plaice *Pleuronectes platessa* with total abundances of 39, 25 and 17 fish recorded, respectively. Abundances were highest during the Summer and Spring surveys and lowest in the Winter survey.
5	12	9	7	12	The abundance of fish recorded at this site was highest in the Autumn and lowest during the Winter surveys. Dab *Limanda limanda* was the species with the highest abundance recorded at Site 5, with a total of 138 fish recorded. This was closely followed by whiting *Merlangius merlangus* with a total of 114 fish recorded. Plaice *Pleuronectes platessa*, thornback rays *Raja clavata* and lesser weaver *Echiichthys vipera* were some of the other species also recorded at this site.

Site	Autumn	Winter	Spring	Summer	Summary
6	8	7	10	11	Dab *Limanda limanda* was the species recorded in the highest abundances at Site 6, with a total of 89 fish recorded. Lesser weaver *Echiichthys vipera*, whiting *Merlangius merlangus* and sand gobies *Pomatoschistus minutus* were also recorded at relatively high abundances, with a total of 58, 37 and 17 fish recorded, respectively. Overall, abundances were highest in the Spring and lowest in the Autumn surveys.
Number of Macrofauna Species					
1	9	6	8	7	Common starfish *Asterias rubens*, brown shrimp *Crangon crangon*, and sea potatoes *Echinocardium cordatum* were the most abundant species at this site (a total of 437, 291 and 174 individuals recorded respectively). Some of the other macrofauna species recorded at this site included flying crabs *Liocarcinus holsatus*, brittle stars *Ophiura ophiura*, common hermit crabs *Pagurus bernhardus*, otter shells *Lutraria sp.* and razor clams *Ensis sp.* Abundances were highest in the Summer survey and lowest in Spring survey with total abundances of 398 and 102 individuals recorded respectively.
2	6	7	2	8	The abundance of macrofauna recorded at Site 2 was highest in the Winter survey, due to the large number of common starfish *Asterias rubens* recorded. Common starfish *Asterias rubens* were the most abundant species overall, with a total of 229 individuals recorded. In addition, soft coral *Alcyonium digitatum* was recorded as present (P) during the Winter survey. Brown shrimp C*rangon cragon* and brittle stars *Ophiura ophiura* were also found in relatively high abundances, with a total of 129 and 64 individuals recorded respectively.
3	11	8	7	4	Abundances at Site 3 were highest in the Winter survey, driven by the large number (373) of common starfish *Asterias rubens* recorded. Overall, common starfish *Asterias rubens* were the most abundantly recorded species at this site with a total of 455 individuals recorded. Brown shrimp *Crangon crangon*, sand stars *Astropecten irregularis* and common hermit crabs *Pagurus bernhardus* constitute some of the other species recorded at this site in relatively high abundances (a total of 103, 28 and 28 individuals recorded respectively).
4	7	9	10	7	The total abundance of all macrofauna species combined was highest in the Spring survey and lowest in the Autumn survey, with abundances of 697 and 8 respectively. Common starfish *Asterias rubens* and brittle stars *Ophiura ophiura* were the most abundantly recorded species at this site with a total abundance of 571 and 164 individuals recorded respectively. Soft coral, *Alcyonium digitatum*, was recorded as P during the Spring survey.

Site	Autumn	Winter	Spring	Summer	Summary
					Some of the other species recorded at this site, albeit in lower abundances, included brown shrimp *Crangon crangon*, flying crab *Liocarcinus holsatus*, common hermit crab *Pagurus bernhardus* and sand stars *Astropecten irregularis*.
5	9	9	7	5	Common starfish *Asterias rubens* was the most abundant species of macrofauna at this site with a total abundance of 9,764 individuals recorded with the majority (3,888) of these recorded during the Autumn survey. Consequently, overall, Autumn had the highest recorded abundance of macrofauna, whilst winter had the lowest. Other species recorded in high abundances at this site included sea potatoes *Echinocardium cordatum*, brittle stars *Ophiura ophiura* and common hermit crabs *Pagurus bernhardus* (total abundances of 2,518, 2,180 and 434 respectively).
6	9	10	12	8	At this site, common starfish *Asterias rubens* and brittle stars *Ophiura ophiura* were the species recorded in the highest abundances (a total of 2,646 and 112 individuals recorded respectively). Examples of other species recorded at this site include razor clams *Ensis sp*., flying crabs *Liocarcinus holsatus*, sand stars *Astropecten irregularis* and green sea urchins *Psammechinus miliaris.*

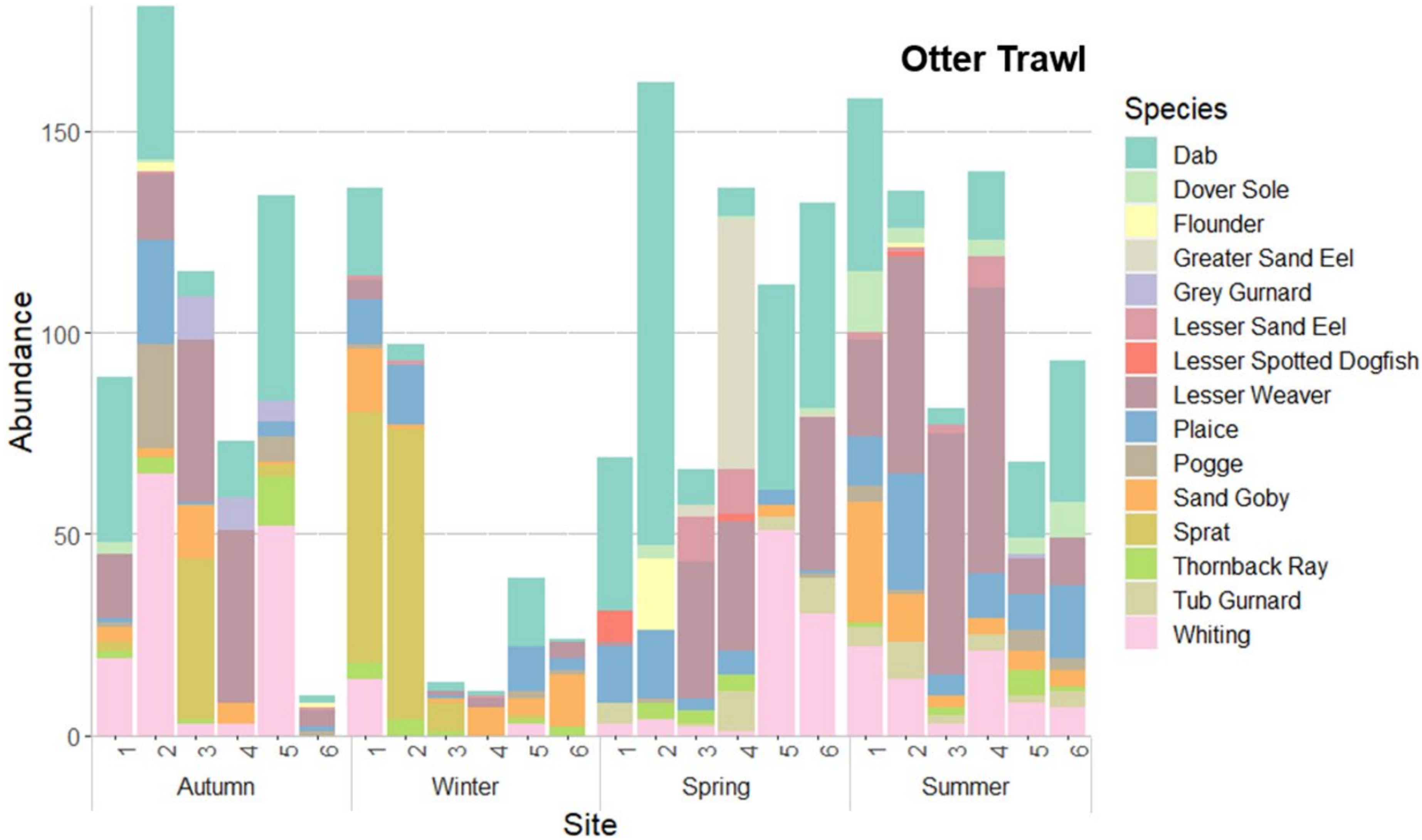


Figure 11. Otter trawl species abundance for each site during each quarter

Beam trawl

The total number of fish caught using this fishing method during each of the quarterly surveys is summarised in Table 12 with summary information on the fish and macrofauna assemblage recorded at each site shown in Table 13. Figure 12 shows the abundance of fish species recorded at each site during each quarter.

Image 2. Beam trawl catches (Site 6, Autumn (left) and Spring (right))

The greatest abundance of fish was recorded in the Spring survey (which was largely attributable to large catches of adult dab *Limanda limanda*) (Table 12). Other commonly recorded species during the surveys included whiting *Merlangius merlangus* (the majority of the catches being juveniles), hooknose *Agonus cataphractus*, lesser weaver *Echiichthys viper*, European plaice *Pleuronectes platessa* and sand goby *Pomatoschistus minutus*. Elasmobranchs recorded included thornback ray *Raja clavata*, small-spotted catshark *Scyliorhinus canicular* and a single starry smooth-hound *Mustelus asterias*.

During the Spring survey all sites recorded higher diversity as well as higher abundance than the other quarters with the exception of Site 1 which had a higher abundance in the Autumn survey (Table 13). This was due to large numbers of Dab *Limanda limanda* being caught as well as higher numbers of fish overall (Table 12). Total fish species diversity and total fish abundance were correspondingly highest during Spring with values of 20 and 642 respectively (Table 12).

The macrofauna diversity across the site was variable with low numbers recorded in the Summer survey (Table 12). Overall, numbers were similar with low numbers recorded during Summer. Site 5 had high numbers across the surveys due to high numbers of common starfish *Asterias rubens* (Table 13).

Table 12. Beam trawl species abundance for each quarter for all sites

Beam trawl	Species	Common Name	Survey Quarter			
			Autumn	Winter	Spring	Summer
Fish	*Agonus cataphractus*	Hooknose	20	1	23	
	Ammodytes sp.	Sand lance	1	1	8	14
	Arnoglossus laterna	Mediterranean scaldfish			4	
	Buglossidium luteum	Yellow sole	6		5	
	Callionymus lyra	Common dragonet	4		5	3
	Chelidonichthys lucerna	Tub gurnard			20	
	Clupea harengus	Atlantic herring				4
	Echiichthys vipera	Lesser weaver	26	12	44	9
	Hyperoplus lanceolatus	Greater sandeel	3		4	
	Limanda limanda	Common dab	48	6	428	3
	Merlangius merlangus	Whiting	66	15	14	3
	Mustelus asterias	Starry smooth-hound			1	
	Platichthys flesus	European flounder		2	24	
	Pleuronectes platessa	European plaice	7	29	18	2
	Pomatoschistus minutus	Sand goby	8	19	3	8
	Raja clavata	Thornback ray	3	9	14	
	Scyliorhinus canicula	Small-spotted catshark			8	1
	Solea solea	Dover sole	1	1	16	2
	Sprattus sprattus	European sprat		15		8
	Syngnathus acus	Greater pipefish			1	
	Syngnathus rostellatus	Lesser pipefish		2		1
	Trisopterus luscus	Pout			1	
	Zeus faber	John Dory			1	
No. of fish species			12	12	20	12
Total fish abundance			203	112	642	58

Beam trawl	Species	Common Name	Survey Quarter			
			Autumn	Winter	Spring	Summer
Macrofauna	ACTINIARIA		1	1		
	Alcyonium digitatum	Dead man's fingers	P	P		
	Aphrodita aculeata	Sea mouse	1			
	Asterias rubens	Common starfish	1271	1974	845	3
	Astropecten irregularis	Sand sea star	20	55	11	
	Buccinum undatum	Common whelk	21	7	6	
	Carcinus maenas	Shore crab	18	1		
	Corystes cassivelaunus	Helmet crab	3	2	20	
	Crangon crangon	Brown shrimp	315	80	65	22
	CTENOPHORA			42		
	Echinocardium cordatum	Common heart urchin	101	2	4	806
	Ensis sp.	Razor clam	7	23	9	
	Euspira catena	Necklace shell	4			1
	Hyas araneus	Great spider crab		2	1	
	Liocarcinus holsatus	Flying crab	31	4	12	2
	Loligo vulgaris	Common squid				1
	Lutraria sp.	Common otter shell	1	2	1	
	Ophiothrix fragilis	Common brittle star	1			
	Ophiura ophiura	Serpent star	281	150	169	1
	Pagurus bernhardus	Common hermit crab	42	40	45	1
	Psammechinus miliaris	Green sea urchin	12	7	8	1
No. of macrofauna species			18	17	13	9
Total macrofauna abundance			2130	2392	1196	838

Table 13. Summary of the beam trawl data by site for each quarter showing the total number of fish species and macrofauna species and a description of the fish assemblages present

Site	Autumn	Winter	Spring	Summer	Summary
Beam Trawls Number of Fish Species					
1	11	6	14	3	Abundances at this site were highest in the Autumn survey and lowest during the Summer survey. Whiting, *Merlangius merlangus,* was the most abundant species recorded with a total abundance of 70 fish recorded. This was closely followed by dab, *Limanda limanda,* with a total abundance of 54 fish recorded. Other commonly observed species at this site included lesser weaver *Echiichthys vipera,* sprat *Sprattus sprattus*, pogge *Agonus cataphractu,* dover sole *Solea solea* and thornback rays *Raja clavata.*
2	9	2	9	7	At this site, dab *Limanda limanda* and plaice *Pleuronectes platessa* were the most abundant species (a total of 78 and 29 fish recorded respectively). Lesser weaver *Echiichthys vipera*, pogge *Agonus cataphractus,* whiting *Merlangius merlangus* and flounder *Platichthys flesus* were also found in relatively high abundances with a total of 19, 18, 15 and 10 fish recorded respectively. Abundances were highest in the Spring survey and lowest during the Winter survey.
3	2	4	6	3	Dab *Limanda limanda* was the species recorded with the highest abundance, at Site 3, with a total of 61 fish recorded. Other species recorded at this site include thornback ray *Raja clavata*, lesser weaver *Echiichthys vipera*, lesser and greater sand eels *Ammodytes sp*, tub gurnard *Chelidonichthys lucerna*, whiting *Merlangius merlangus* and sand gobies *Pomatoschistus minutus*. Overall abundances at this site were relatively low in the Autumn, Winter and Summer surveys. Abundances were much higher during the Spring due to the large number of dab, *Limanda limanda,* recorded.
4	4	4	11	3	At this site, abundances were relatively low across all seasons but were overall highest during the Spring survey. Lesser weaver *Echiichthys vipera* and dab *Limanda limanda* were the most abundant species, albeit with a relatively low number of fish recorded (a total of 15 and 11 respectively). Some other species commonly recorded at this site included thornback ray *Raja clavata*, plaice, *Pleuronectes platessa* and sand eels *Ammodytes sp*.
5	1	8	10	3	Abundances at Site 5 were highest in the Spring survey due to the large number of dab *Limanda limanda* recorded. Given this, dab *Limanda limanda* were the most abundant species with a total abundance of 228 fish recorded. Some other species recorded, albeit

Site	Autumn	Winter	Spring	Summer	Summary
					in lower abundances, included plaice, *Pleuronectes platessa,* whiting *Merlangius merlangus*, pogge *Agonus cataphractus* and tub gurnard *Chelidonichthys lucerna*.
6	3	7	13	5	No species were recorded during the Summer survey at this site. The total abundance of all fish species combined at Site 6 was highest in the Spring survey, likely driven by the large number of dab, *Limanda limanda,* and lesser weaver *Echiichthys vipera* recorded. Overall, these were the species with the highest abundance, with a total of 67 and 40 fish recorded respectively. Examples of other species recorded at Site 6 include sand eels *Ammodytes sp*, sand gobies *Pomatoschistus minutus*, flounder *Platichthys flesus* and plaice *Pleuronectes platessa*.
Beam Trawls Number of Macrofauna Species					
1	5	6	6	3	Abundances at this site ere highest in the Autumn survey and lowest in the Summer survey. Common starfish *Asterias rubens*, brittle stars *Ophiura ophiura* and brown shrimp *Crangon crangon* were the most abundant species recorded (with a total abundance of 214, 133 and 127 individuals recorded respectively). Some other species recorded at this site included common hermit crabs *Pagurus bernhardus*, comb jellies Ctenophora and flying crabs *Liocarcinus holsatus*.
2	7	6	4	2	At this site, abundances were relatively low across all seasons but were overall highest during the Autumn survey. Brown shrimp, *Crangon crangon*, was the most abundant macrofauna species with a total abundance of 266 individuals recorded. Other relatively abundant macrofauna species included common starfish *Asterias rubens* and comb jellies Ctenophora, with total abundances of 78 and 34 individuals recorded respectively.
3	8	7	6	2	Common starfish was the species with the highest abundance at Site 4 with a total of 538 individuals recorded. Examples of other species recorded at this site include brittle stars *Ophiura ophiura*, common hermit crabs *Pagurus bernhardus* and sand stars *Astropecten irregularis*. Overall abundances were highest in the Autumn survey and lowest in the Winter survey with values of 223 and 3 respectively.
4	7	7	6	1	At this site, abundances were relatively low across all species in comparison to other sites. Common starfish *Asterias rubens* and sand stars *Astropecten irregularis* were the most abundant species (a total of 72 and 47 individuals recorded respectively). Soft coral, *Alcyonium digitatum*, was recorded as present (P) in the Winter survey. Some of

Site	Autumn	Winter	Spring	Summer	Summary
					the other species recorded at this site included brown shrimp *Crangon crangon*, brittle stars *Ophiura ophiura* and common whelks *Buccinum undatum*.
5	15	6	9	2	At this site, abundances were relatively high across all seasons due to the large number of common starfish *Asterias rubens* recorded but were highest during the Winter survey. Common starfish *Asterias rubens* was the species with the highest recorded abundance, with a total of 2,615 individuals recorded. Sea potatoes *Echinocardium cordatum* and brittle stars *Ophiura ophiura* were other species recorded with relatively high abundances (a total of 905 and 184 individuals recorded respectively).
6	12	10	9	5	Common whelk eggs, *Buccinum undatum* eggs, and soft coral, *Alcyonium digitatum*, were recorded as P in the Winter survey. Common starfish, *Asterias rubens,* was the most abundant species, with a total of 766 individuals recorded. Other species recorded at this site included brittle stars *Ophiura ophiura*, razor clams *Ensis sp*., common hermit crabs *Pagurus bernhardus* and common whelks *Buccinum undatum*.

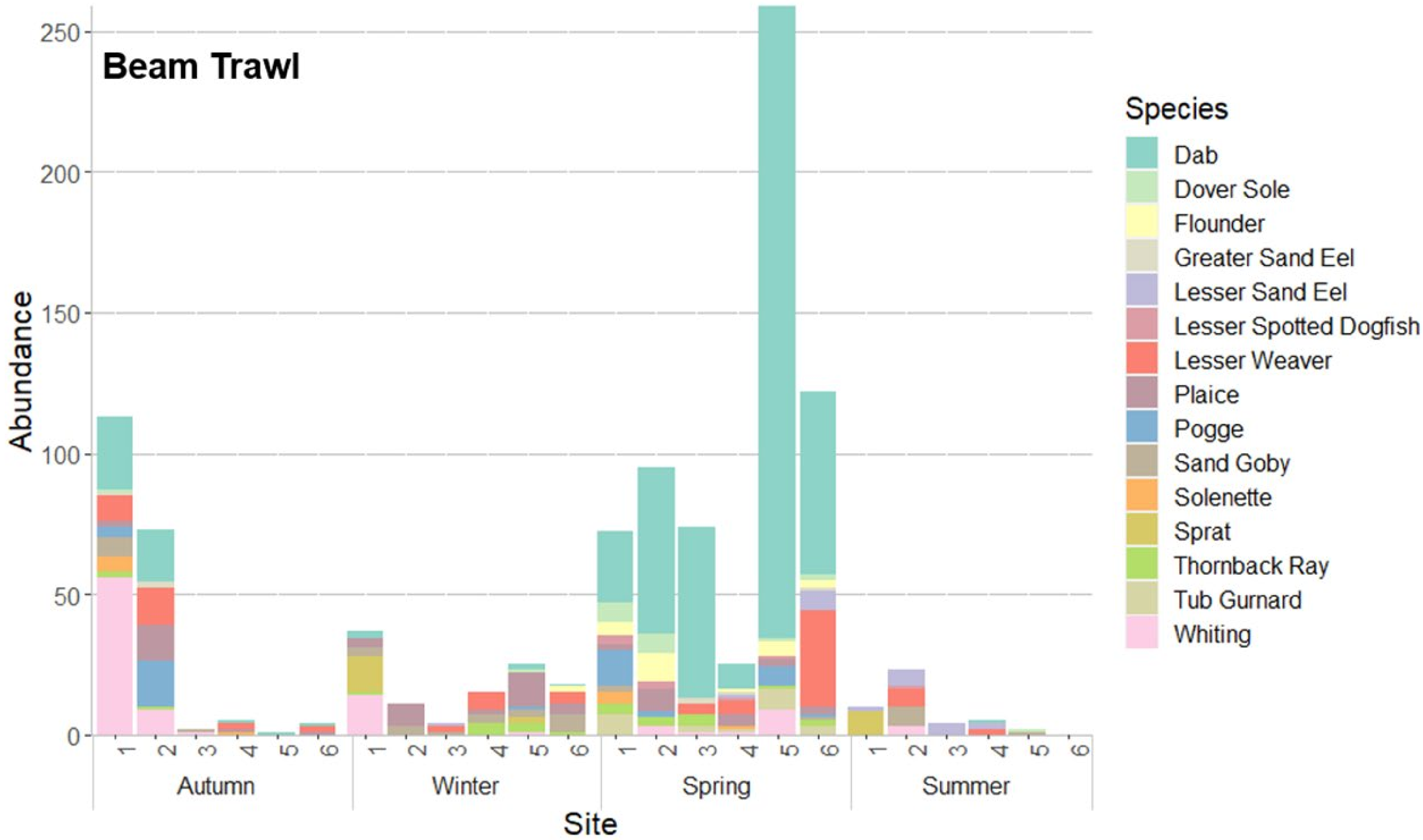


Figure 12. Beam trawl species abundance for each site during each quarter

3.1.3 Ichthyoplankton surveys

Ichthyoplankton are the eggs and larvae of fish and form part of the plankton assemblages during their development. Ichthyoplankton samples can provide useful information on spawning stocks in an area.

The ichthyoplankton data presented in Table 14 presents larval fish identification to the lowest possible taxonomic level. It shows the abundances of the species caught by month. The potential continuation of the monthly surveys in 2022 will allow for the dataset to be further refined, as more specimens are gathered. During the survey in March, the trawl was lost during the survey and therefore no result is presented for Site 2 for that month.

The diversity of ichthyoplankton fish species caught and total fish abundance were both highest during the March 2021 survey with values of 15 and 893, respectively. Large numbers of sandeel *Ammodyte*s spp, sprat *Sprattus sprattus* and clupeids (sprat or herring *Clupea harengus* which couldn't be identified to species level), caught during this survey largely contributed to this high total abundance (Table 14). Sprat *Sprattus sprattus* larvae was also recorded in similar abundance levels in April and May to that recorded in March. Sandeels *Ammodyte*s spp typically hatch from eggs during February or March with sprat *Sprattus sprattus* spawning known to occur through the late spring/early summer months (Green, 2017; Coombs, 1992). The data is therefore broadly consistent with spawning information for the wider region. The larvae of other species such as whiting *Merlangius merlangus*, dab *Limanda limanda*, sole *Solea solea* and gobies were also recorded in the spring/early summer months (March to June) which overlaps with the main spawning periods for these species (DECC, 2016: Ellis *et al*., 2012).

Herring *Clupea harengus* larvae was mainly recorded in November 2020. This species is known to spawn from September to November in the Irish Sea region with eggs hatching in 1-3 weeks (ICES, 2013; DECC, 2016).

Table 14. Fish species and abundance caught per month for all sites

Species Name	Common Name	Survey Date											
		Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Nov-21
Clupeidae					1	204	24	5	3				
Clupea harengus	Atlantic herring	207	3	4									
Sprattus sprattus	European sprat					71	79	84	17				
Gadidae						17	10	1					
Ciliata mustela	Five-bearded rockling					5	2						
Merlangius merlangus	Whiting						54						
Syngnathus rostellatus	Lesser pipefish									2	1		1
Triglidae	Gurnard									1			
Trigla lucerna	Tub gurnard								1				
Cottidae	Sculpins						2						
Liparis	Snailfish					1							
Blenniidae	Blennies									2			
Ammodytidae	Sandeels				18	429	3	5	1	3			
Ammodytes marinus	Raitt's sandeel					1							
Ammodytes tobianus	Lesser sandeel						4						
Callionymidae	Dragonnet							3	3	2			
Gobiidae	Gobies					4	10	11	141	1	1	1	
Pleuronectidae	Dabs					5	11						
Platichthys flesus	European flounder					8	18						
Pleuronectes platessa	European plaice							1					
Soleidae	Flatfishes					4	37	49	237	21			
Soleidae	Flatfishes							1	13				
Buglossidium luteum	Solenette							1					1
No. of fish species		1	1	2	3	15	14	11	9	7	2	1	2
Total fish abundance		207	3	5	20	893	285	166	460	32	2	1	2

3.1.4 Pelagic (acoustic) fish surveys

This section summarises the results of the acoustic fish surveys with a more detailed description of the results provided in the acoustic survey report (Appendix B).

May 2021 survey

A total of 740 schools were detected during the May 2021 survey, although, the distribution of these within each stratum was sensitive to the number of samples taken in each stratum. Therefore, the number of schools per km was taken as a measure of school density within each stratum. It is important to note that this metric may not relate to the density and abundance of fish since schools vary in size and density.

Fish schools were most prevalent in the Hilbre Channel stratum (~17 schools km^{-1}), followed by the Mostyn deep stratum (~11.2 schools km^{-1}) The inshore stratum possessed the lowest number of schools with approximately 3.7 per km. 'Other' fish were also abundant in the two channels, Hilbre Channel and the Mostyn Deep, but occurred in highest densities within the northern region of the offshore stratum.

The total abundance of fish within the survey area was estimated at 114 million and comprised of 109 million clupeids and 5 million 'other' fish (mainly whiting *Merlangius merlangus* and lesser weever *Echiichthys vipera,* but also with small numbers of starry smooth-hounds *Mustelus asterias* and lesser spotted dogfish *Scyliorhinus canicula*).

The estimated biomass was 980 tonnes (821 tonnes of Clupeids and 159 tonnes of 'other' fish). Table 15 provides a breakdown of these estimates by stratum.

Table 15. Estimates of fish abundance from the Dee estuary acoustic survey in May 2021

Stratum	Area (m^2)	Density ($N.m^{-2}$)	N (millions)	Dens ($kg.m^{-2}$)	Biomass (t)
Clupeidae (sprat Sprattus sprattus and herring Clupea harengus)					
Mostyn Deep	9258854	1.57198	14.6	0.01179	109.2
Hilbre Channel	7949060	1.77907	14.1	0.01334	106.1
Inshore area	39937888	0.84380	33.7	0.00633	252.8
Offshore area	67104700	0.70478	47.3	0.00529	354.7
		Total	**109.7**		**822.7**
Other Fish (unidentified fish)					
Mostyn Deep	9258854	0.053520	0.50	0.004784	44.3
Hilbre Channel	7949060	0.059688	0.47	0.002794	22.2
Inshore area	39937888	0.026154	1.04	0.000534	21.3
Offshore area	67104700	0.038175	2.56	0.001216	81.6
		Total	**4.57**		**169.4**

Abundance and biomass were highest in the offshore stratum for clupeids (abundance: 47.3, biomass 354.7 tonnes) and 'other fish' (abundance: 2.56, biomass: 81.6 tonnes), followed by the inshore stratum (Table 15). The Mostyn Deep and Hilbre Channel also possessed a relatively high abundance and biomass of fish, despite being a fraction of the size of the offshore and inshore strata, as reflected by density estimates (see Table 15).

Fish abundances comprised mainly of fish <12.5 cm, likely to have been whiting *Merlangius merlangus* or lesser weever *Echiichthys vipera*. Biomass estimates, on the other hand, were highest for fish between 12.5 cm and 30 cm, likely to have been whiting *Merlangius merlangus*. Biomass estimates were also relatively high for fish >30 cm (possibly comprising of starry smooth-hounds *Mustelus asterias* and lesser spotted dogfish *Scyliorhinus canicula*).

August 2021 survey

Overall, a total of 349 schools of fish were detected during the August 2021 survey. Again, the distribution of these schools in each stratum was sensitive to the number of samples taken in each one, so the number of schools per km was taken as a measurement of school density within each stratum. Schools were most prevalent in the Hilbre Channel, followed by the offshore stratum, with 26 and 5 schools km^{-1}, respectively. The lowest number of schools were recorded within the Mostyn Deep (2 schools km^{-1}).

The total abundance of fish within the survey area was 398 million, comprising 394 million Clupeidae and 4 million 'other' fish (mainly whiting *Merlangius merlangus* and lesser weever *Echiichthys vipera*). Total biomass was estimated at 1,264 tonnes (1,014 tonnes of Clupeidae and 250 tonnes of 'other' fish; Table 16).

Clupeidae abundance and biomass were highest in the offshore stratum, due to its size (abundance: 238.4, biomass: 613.6 tonnes). The Hilbre Channel possessed a relatively high abundance of Clupeidae, whereas in Mostyn Deep, Clupeidae abundance was low (Table 16).

The offshore stratum also possessed the highest abundance and biomass of 'Other' fish abundance (abundance: 1.27, biomass: 114.9 tonnes). However, unlike for clupeids, biomass was higher (more than double) in Mostyn Deep compared to Hilbre Channel (Table 16). Numbers of 'other' fish were dominated by smaller fish (<12.5 cm), likely whiting *Merlangius merlangus* and lesser weever *Echiichthys vipera*. Biomass possessed two peaks: (1) fish between 7.5 cm and 27.5 cm (likely whiting and lesser weever) and (2) fish >30 cm (likely starry smooth-hounds *Mustelus asterias* and lesser spotted dogfish *Scyliorhinus canicula*).

Table 16. Estimates of fish abundance from the Dee Estuary acoustic survey in August 2021

Stratum	Area (m^2)	Density ($N.m^{-2}$)	N (millions)	Dens ($kg.m^{-2}$)	Biomass (t)
Clupeidae (sprat Sprattus sprattus and herring Clupea harengus)					
Mostyn Deep	9258854	0.243799	2.3	0.000628	5.8
Hilbre Channel	7949060	19.281009	153.3	0.049637	394.6
Inshore area	39937888				
Offshore area	67104700	3.551978	238.4	0.009144	613.6
		Total	**394.0**		**1014.0**
Other Fish (unidentified fish)					
Mostyn Deep	9258854	0.22323	2.07	0.009959	92.2
Hilbre Channel	7949060	0.096222	0.76	0.00539	42.8
Inshore area	39937888				
Offshore area	67104700	0.018949	1.27	0.001712	114.9
		Total	**4.1**		**249.9**

Discussion

The pelagic survey estimates of abundance and biomass were dominated by clupeids. Both sprat *Sprattus sprattus* and herring *Clupea harengus* were caught in the trawl hauls, albeit in low abundances but the acoustically detected schools were very characteristic of these fish species. This suggests that detected schools mainly comprised these species. Trawls were directed towards acoustically detected schools however, since schools were positioned at an average depth of approximately 8 m, the bottom trawl was unable to obtain a large catch.

Additionally, due to poor visibility no data was obtained from the deployment of the PRO SQUID live underwater video system. A similar study conducted in the Irish Sea (ICES, 2021), estimated the biomass of sprat and herring to be 156,200 tonnes and 101,253 tonnes, respectively. The area surveyed encompassed approximately 3,086 km^2, meaning the average biomass of Clupeids was approximately 0.01 kg m^{-2}. This is comparable to the biomass density in Mostyn Deep and Hilbre Channel in May and to a lesser extent to the higher densities in Hilbre Channel in August.

'Other' fish in the bottom trawl mainly comprised whiting *Merlangius merlangus* and lesser weever *Echiichthys vipera*. However, since lesser weever do not possess a swim bladder, they are unlikely to scatter much sound. This suggests that most fish detected, that were <30 cm, were whiting *Merlangius merlangus*.

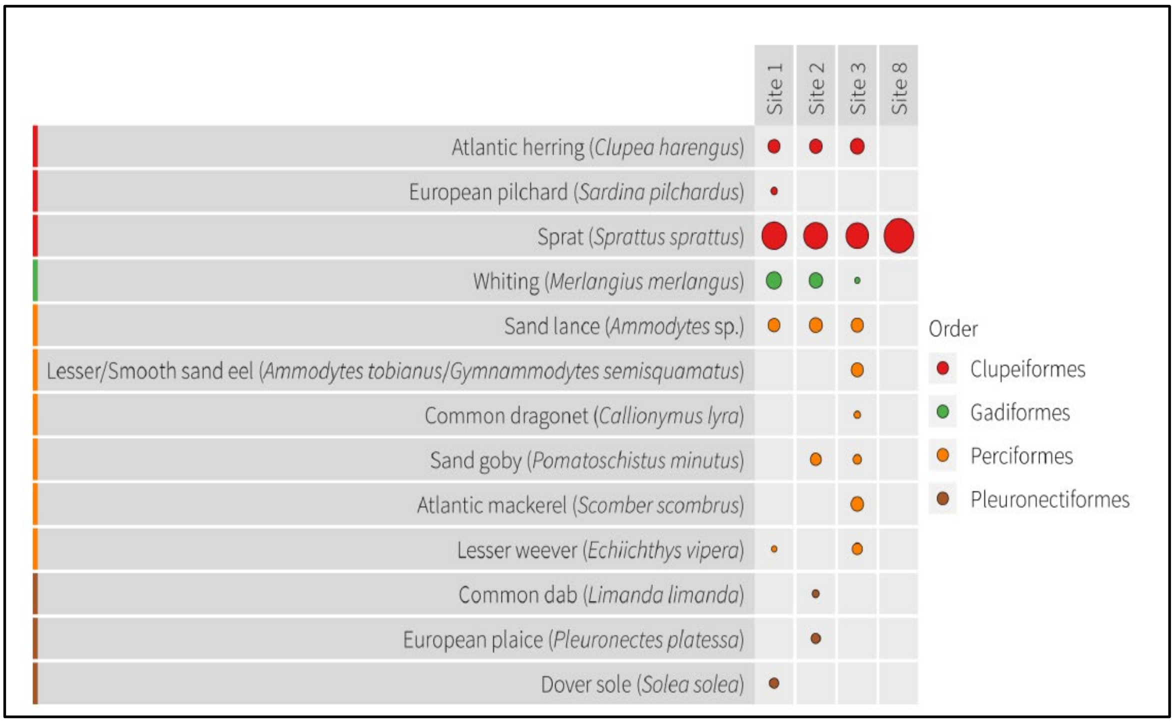
All fish >30 cm were starry smooth-hounds *Mustelus asterias* or lesser spotted dogfish *Scyliorhinus canicular*. Data from several international surveys suggest smooth-hound *Mustelus asterias* abundance has been on an increasing trajectory since 1997 (ICES, 2019a), although no absolute estimate is provided. Lesser spotted dogfish *Scyliorhinus canicular* abundance has also been shown to have increased in the North Sea and Irish Sea (ICES, 2019b; 2019c).

3.1.5 eDNA

In total 13 taxa were detected in the eDNA samples (Figure 13). The average species richness was six and ranged from one (Site 8) to nine (Site 3). Sprat *Sprattus sprattus*, which accounted for 68 % of the total sequence reads, was the most abundant in terms of sequences[3]. Among the most commonly detected and abundant species were the sprat *Sprattus sprattus*, Atlantic herring *Clupea harengus,* and whiting *Merlangius merlangus*, which were detected in 4, 3, and 3 of the samples, respectively.

Other species detected included sandeels *Ammodyte*s spp, Atlantic mackerel *Scomber scombrus*, lesser weaver *Echiichthys viper*, sole *Solea solea*, dab *Limanda limanda* and plaice *Pleuronectes platessa*. All these species recorded are considered commonly occurring species in the region and were some of the main characterising species recorded in the other fish surveys.

[3] The abundance of taxa cannot be directly inferred from the proportion of total sequence reads. While the proportion of sequence reads is a consequence of abundance, it is also impacted by biomass, activity, surface area, condition, distance from the physical sample, primer bias, and species-specific variation in the genome.



Each bubble per sample represents the proportion of DNA for each taxon for that sample.
The size of the bubble is relative to the number of sequences from all taxa for that sample

Figure 13. The proportion of the sequencing output allocated to the different taxa (rows) within each sample (columns)

3.2 Marine mammal surveys

3.2.1 Boat based surveys

Marine mammal sightings

A total of 1,221 km of survey effort were completed over the course of 12 months, resulting in 162 marine mammal sightings (Figure 14a-c). In total, three marine mammal species were recorded. The most frequently sighted marine mammal species which accounted for 83 % of all sightings and was observed on every trip, was grey seal *Halichoerus grypus* (135 sightings), followed by harbour porpoise *Phocoena phocoena* which accounted for 15 % of sightings (25 in total). Finally, bottlenose dolphins *Tursiops truncatus* made up 2 % of sightings with two sightings (both made on the same survey) (Figure 14a-c).

Grey seal *Halichoerus grypus* sighting rates over 12 months averaged at 0.111 sightings/km, with the highest monthly rates being recorded in August (0.508 sightings/km), November (0.263 sightings/km) July (0.156) and October (0.131 sightings/km). Grey seals *Halichoerus grypus*, were widely distributed throughout the survey area with the highest sighting rates from the transects within the Dee Estuary (Figure 14a). Harbour porpoise *Phocoena phocoena* was sighted on 67 % of survey trips with comparatively lower sightings rates to grey seals *Halichoerus grypus*, with a peak of 0.068 sightings/km in February. Sightings were recorded throughout both the outer Dee Estuary and approaches Figure 14b). Bottlenose dolphins *Tursiops truncatus* were only sighted on one survey in December 2020 when the same group was encountered twice within the span of two hours outside of the Dee Estuary (Figure 14c). Group size was estimated at 12 individuals, including two calves.

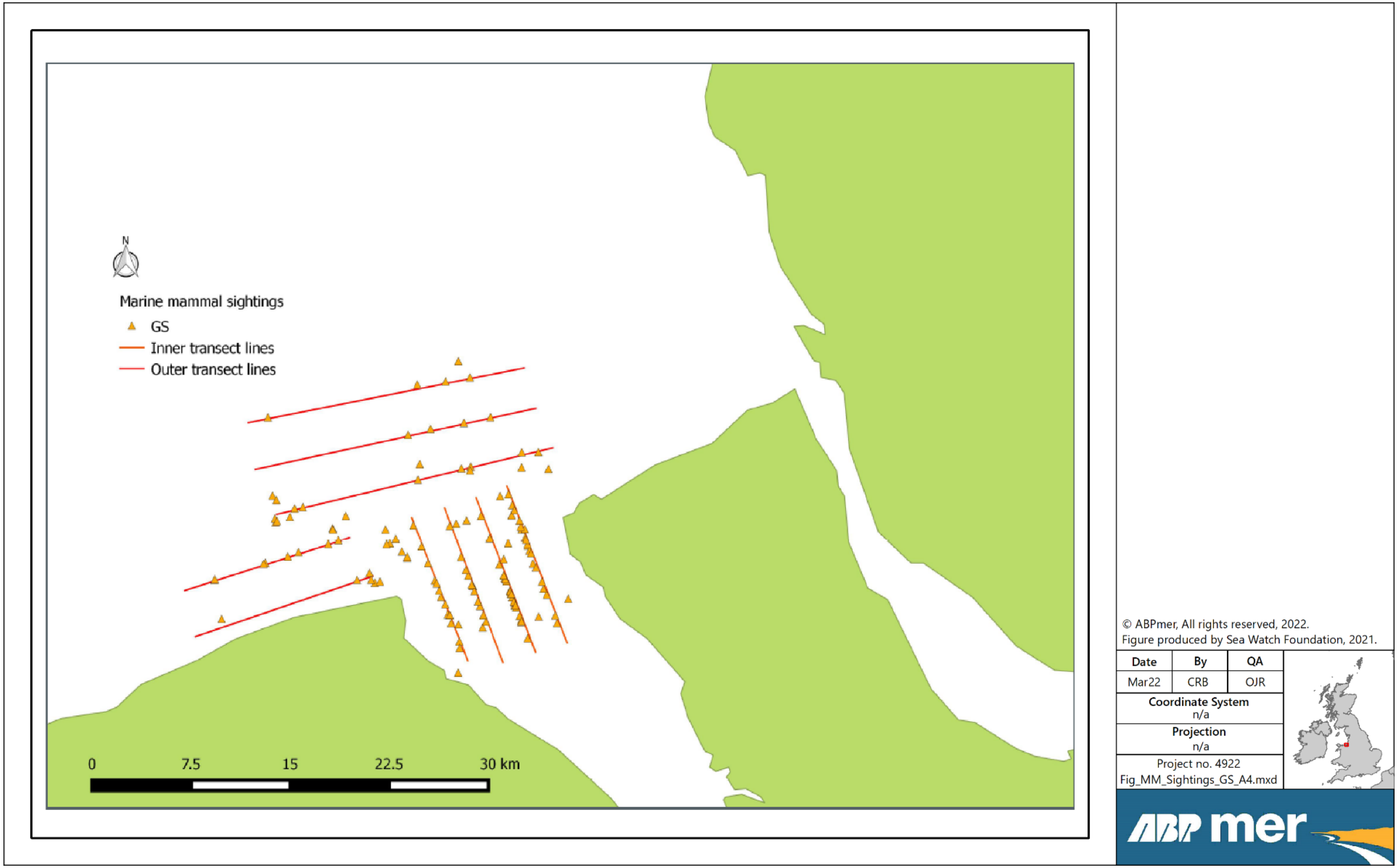


Figure 14a. **Marine mammal sightings (grey seal-GS)**

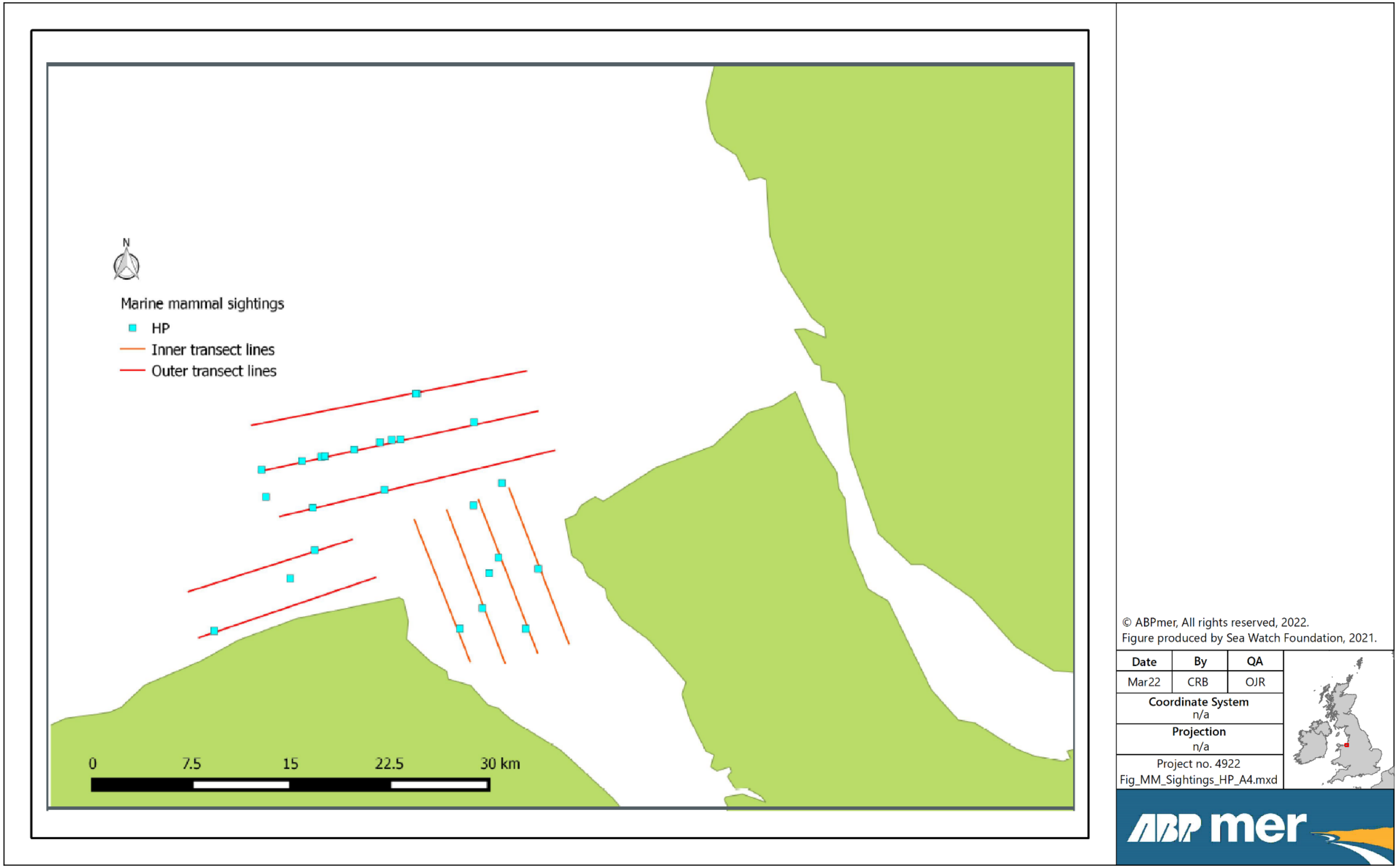


Figure 14b. Marine mammal sightings (harbour porpoise-HP)

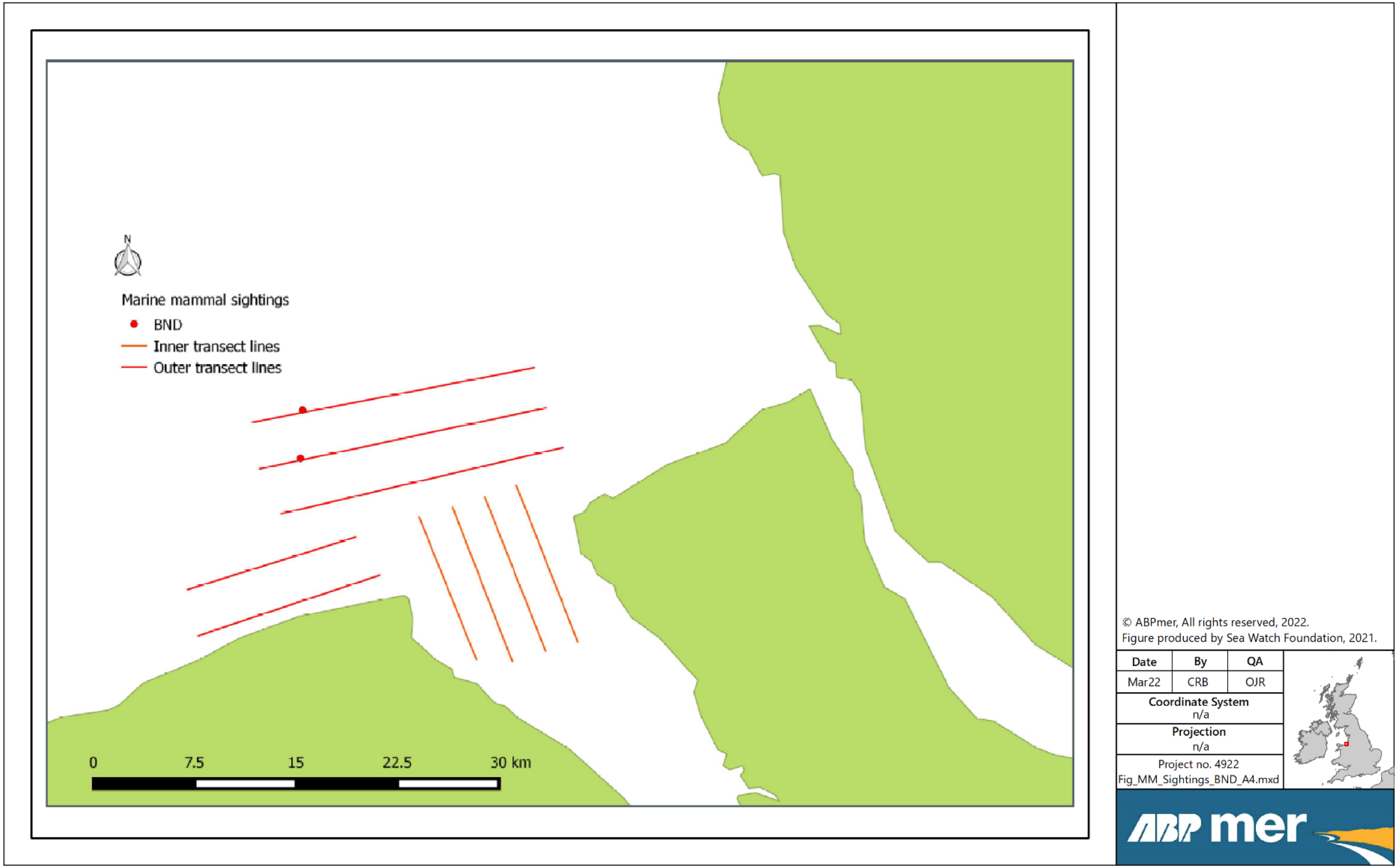


Figure 14c. Marine mammal sightings (bottlenose dolphin-BND)

Photo-identification

Of the 12 bottlenose dolphins encountered during December, eight had probable or possible matches in the Cardigan Bay photo-identification catalogue. Images were compared to the Cardigan Bay photo identification catalogue and resulted in four probable and four possible matches (Image 3 and Image 4 respectively).

Photo-identification in this area has been limited. However, of the two encounters prior to these, 41 % of animals were matched to the Cardigan Bay catalogue (Sea Watch Foundation, unpublished data). The probable and possible matches recorded in December were all of animals that had not been recorded for several years and their last sightings fell into the northern part of Cardigan Bay, North Wales or Anglesey. Within Cardigan Bay, different individuals show distinct home range preferences, some remaining local to the Cardigan Bay Special Area of Conservation (SAC) throughout the year, others migrating north in the winter, ranging from Anglesey to the Isle of Man (Feingold & Evans, 2014).

Dee Estuary Image	Catalogue Image
	
Temporary ID: A Marked: Slightly marked	SWF Catalogue ID: 206-07S Likelihood of Match: Probable Last seen: 2012 Area last seen: Pen Llyn a'r Sarnau SAC
	
Temporary ID: D Marked: Slightly marked With calf	SWF Catalogue ID: 087-13S Likelihood of Match: Probable Last seen: 2015 Area last seen: North Wales

Image 3. Probable matches between individuals photographed during the Dee estuary encounter (left) and the SWF catalogue (right) for Cardigan Bay.

	
Temporary ID: G Marked: Slightly marked	SWF Catalogue ID: 182-06S Likelihood of match: Possible Last seen:2008 Area last seen: Pen Llyn a'r Sarnau SAC
	
Temporary ID: F Marked: Slightly marked	SWF Catalogue ID: 187-07S Likelihood of match: Possible Last seen: 2015 Area last seen: Anglesey

Image 4. Possible matches between individuals photographed during the Dee estuary encounter (left) and the SWF catalogue (right) for Cardigan Bay

3.2.2 Passive acoustic monitoring

This section summarises the results of the F-POD deployments between November 2020 and December 2021. The data was downloaded approximately every 3-4 months and analysed for each of the deployment periods:

- **Period 1**: 5 November 2020-9 February 2021;
- **Period 2:** 9 February-28 May 2021;
- **Period 3:** 28 May-26 August 2021; and
- **Period 4**: 26 August-16 December 2021.

As highlighted in the methods section, the F-POD does not record sound but works by logging the start and end of echolocation clicks of porpoises and dolphins. Using custom software data is processed to group sequences of clicks into 'trains' and classify these click-trains by their most likely source (e.g. harbour porpoise *Phocoena phocoena*, dolphin species, boat sonar etc.).

The basic metric generated is porpoise Detection Positive Minutes (DPMs) (also known as Porpoise Positive Minutes) and dolphin DPMs which are defined as any minute in which a cetacean click train is detected for these two broad groups of cetaceans.

Summary analysis for each F-POD using the following DPM parameters is shown in Table 17 to Table 20:

- Percentage of days with DPM detections;
- Mean DPM per day: and
- Standard Deviation of DPM per day.

During the monitoring, relatively high levels of harbour porpoise *Phocoena phocoena*, activity were detected in all monitoring periods.

The surveys recorded harbour porpoise DPMs every day over the monitoring period at F-POD_04 (100 % of the days with positive detections) and almost every day at F-POD_03 (99 % or 100 % of days with positive detections during each period). Both of these F-PODS were deployed in Liverpool Bay (in the approaches to the Dee Estuary) (Figure 6). F-POD_04 had the highest mean DPM per day ranging from 72 (Period 3-28 May-26 August 2021) to 176 (Period 2-9 February-28 May 2021) depending on the survey period (Table 20). Detections were lower at F-POD_04 staying around 30 DPM per day throughout the survey period.

Harbour porpoise activity was also regularly recorded at F-POD_01 located in the Mostyn Deep near to the Point of Ayr (Figure 6) with harbour porpoise detected on between 62 % and 98 % of days. Mean DPM per day at this site ranged from 20 to 54.

F-POD_02 located near Hilbre Island recorded high levels of activity in Period 1 (5 November 2020-9 February 2021) and Period 2 (9 February-28 May 2021) with 90 % and 98 % of days positive respectively. It should be noted that following retrieval and subsequent analysis of F-POD_02 at the end of the third period of deployment it was discovered that the F-POD was at times experiencing incorrect operation (recording electronic noise and only clicks sporadically). Further investigation found this was due to a faulty circuit board. This is likely to have caused the much lower number of DPMs detected during Period 3 (28 May-26 August 2021) with harbour porpoise only recorded on 31 % of days. Activity was again higher in Period 4 (26 August and 16 December 2021) with DPMs on 77 % of days[4]. Mean DPM per day at this site was high in in Period 2 (9 February-28 May 2021) at 156 but lower in other periods.

With respect to dolphin activity, the highest levels of activity were recorded at F-POD_03 and F-POD_04 in the approaches to the Dee Estuary. Activity was highest in the summer period from 28 May to 26 August where 41 % and 30 % of days had positive dolphin detections at F-POD_03 and F-POD_04 respectively. While it is not possible to identify dolphins to species level with F-PODS, based on an understanding of dolphin abundance and distribution in the area, these records are most likely to be bottlenose dolphin *Tursiops truncatus*.

[4] Analysis suggested the F-POD was working correctly in the fourth period but.

Table 17. The results of the data analysis for F-POD_01 showing the % of days with DPM detections, mean DPM per day and Standard Deviation of DPM per day

Parameter	4 November 2020-9 February 2021		9 February-28 May 2021		28 May-26 August 2021		26 August-16 December 2021	
	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise
Percentage of days with DPM detections		98 %		93 %		62 %	0.88	84 %
Mean DPM per day:		54		42		4	0.14	20
Standard Deviation of DPM per day:		62		53		7	1.4	27

Table 18. The results of the data analysis for F-POD_02 showing the % of days with DPM detections, mean DPM per day and Standard Deviation of DPM per day

Parameter	4 November 2020-9 February 2021		9 February-28 May 2021		28 May-26 August 2021*		26 August-16 December 2021	
	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise
Percentage of days with DPM detections		90 %		98 %		31 %		77 %
Mean DPM per day:		30		194		8		12
Standard Deviation of DPM per day:		35		156		18		27

* On retrieval and subsequent analysis of F-POD_02 at the end of the third period of deployment it was discovered that the F-POD was at times experiencing incorrect operation (recording electronic noise and only clicks sporadically). Further investigation found this was due to a faulty circuit board. This is likely to have caused the much lower number of DPMs detected during the third period of deployment. Analysis suggested the F-POD was working correctly in the fourth period.

Table 19. The results of the data analysis for F-POD_03 showing the % of days with DPM detections, mean DPM per day and Standard Deviation of DPM per day.

Parameter	5 November 2020-9 February 2021		9 February-28 May 2021		28 May-26 August 2021		26 August-16 December 2021	
	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise
Percentage of days with DPM detections		100 %	3 %	99 %	41 %	100 %	9 %	100 %
Mean DPM per day:		29	>0.3	38	8	29	1.5	31
Standard Deviation of DPM per day:		39	2	39	17	31	4.3	21

Table 20. The results of the data analysis for F-POD_04 showing the % of days with DPM detections, mean DPM per day and Standard Deviation of DPM per day.

Parameter	5 November 2020-9 February 2021		9 February-28 May 2021		28 May-26 August 2021		26 August-16 December 2021	
	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise	Dolphin species	Harbour porpoise
Percentage of days with detections		100 %		100 %	30 %	100 %	6 %	100 %
Mean DPM per day:		122		176	5	72	>0.3	150
Standard Deviation of DPM per day:		79		119	13	45	6	85

4 Conclusions

This report provides a summary the results baseline fish and marine mammal surveys undertaken on behalf of the Port of Mostyn. These surveys have provided a large amount of data with the results of the surveys summarised below.

4.1 Fish

The quarterly intertidal and subtidal fish surveys recorded a range of fish and epifaunal species with the assemblage considered typical to inshore waters and outer estuaries in the region. The most abundant species recorded in the quarterly intertidal surveys were clupeids (particularly herring *Clupea harengus*), flatfish (such as founder *Platichthys flesus* and plaice *Pleuronectes platessa*) and gobies. European eel *Anguilla anguilla* were also recorded in these surveys. Epifaunal species recorded consisted mainly of mobile scavengers such as shore crabs *Carcinus maenas* and brown shrimps *Crangon crangon*. Larger catches of fish were recorded in the subtidal demersal trawls surveys with the flatfish dab *Limanda limanda*, commercially important whiting *Merlangius merlangus* and lesser weaver *Echiichthys viper* typically the most abundant. The largest numbers of these species were generally recorded in the Spring surveys. The flatfish species flounder *Platichthys flesus* and plaice *Pleuronectes platessa*, thornback ray *Raja clavata*, sand goby *Pomatoschistus minutus* and sprats *Sprattus sprattus* were also some of the most abundant species recorded. Macrofauna recorded included large numbers of common starfish *Asterias rubens*, brown shrimp *Crangon crangon* and brittlestars, which can all occur in large densities in suitable sandy habitats.

The quarterly fish surveys also recorded a large proportion of juvenile fish, particularly during the intertidal surveys (including commercially important species such as herring *Clupea harengus*, whiting *Merlangius merlangus*, plaice *Pleuronectes platessa* and sole *Solea solea*) which suggests the Dee Estuary and approaches provides nursery habitat for these fish. This is consistent with other data for the region which has found that the area provides an important nursery function for these species (Ellis *et al*., 2012).

The ichthyoplankton surveys recorded the largest abundances of fish larvae in the spring and early summer months for sprat *Sprattus sprattus*, sandeels *Ammodyte*s spp, whiting *Merlangius merlangus*, gobies and flatfish (such as sole species and dab *Limanda limanda*) and in the winter (November) for herring *Clupea harengus*. The months with the largest abundances of larvae for these species is consistent with broad known spawning/larval periods for these species in the region.

The acoustic fish surveys recorded large shoals of clupeids (herring *Clupea harengus* and sprat *Sprattus sprattus*). While the total amount of clupeids were similar between months, in May they were recorded both in the Mostyn Deep and Hilbre Channel but in August they were almost entirely absent from the Mostyn Deep and largely contained in the Hilbre Channel. The biomass density of clupeids recorded in the Mostyn Deep and Hilbre Channel in and to a lesser extent to the higher densities in Hilbre Channel in August were broadly comparable to the approximate mean biomass density of clupeids found more widely in the Irish Sea.

The eDNA surveys recorded a similar assemblage of fish to that recorded using more traditional survey methods including herring *Clupea harengus*, sprat *Sprattus sprattus*, whiting *Merlangius merlangus* and sandeel *Ammodyte*s spp and provided a useful additional technique for surveying fish populations.

4.2 Marine mammals

The vessel based transect surveys regularly recorded grey seals *Halichoerus grypus* foraging throughout the outer Dee Estuary and approaches to the estuary in Liverpool Bay. This would be expected given that on the eastern (English) side of the Dee Estuary a large grey seal haul out of 300 to 800 individuals can be found on the West Hoyle sandbank adjacent to Hilbre Island (Westcott and Stringell, 2004; CCW/NE, 2010; Baines and Evans, 2012). Grey seals do not breed at this site as it is used solely for moulting and during feeding trips (Baines and Evans, 2012). Individual seals identified in the Dee Estuary by means of photo-identification have been re-sighted around the Skerries, North Wales, as well as in Cardigan Bay and at Skomer Island, West Wales (Langley *et al*., 2018), suggesting that this population probably breeds in West Wales. Specific tagging studies of seals from the West Hoyle Bank colony has shown foraging to occur almost exclusively within the Liverpool Bay and Irish Sea area including the Dee Estuary (Baines and Evans, 2012; Carter *et al*., 2020). This is reflected in high predicted at-sea densities of grey seals in Liverpool Bay (Carter *et al*., 2020).

The F-PODs record high levels of daily harbour porpoise *Phocoena phocoena* activity year-round at the deployment locations in Liverpool Bay (in the approaches to the Dee Estuary) and also relatively high levels at the deployment locations within the outer Dee Estuary. Harbour porpoises were also frequently sighted (and widely distributed) in Liverpool Bay and the outer Dee Estuary during the vessel-based surveys. The data suggests that Liverpool Bay and the outer Dee Estuary region provides an important foraging habitat for this species year-round. Within Wales, harbour porpoise is the most numerous and commonly recorded species (Baines and Evans, 2012; Hammond *et al*., 2021). Harbour porpoises *Phocoena phocoena* are widespread across much of the Irish Sea, with high densities recorded within Cardigan Bay, Pembrokeshire and offshore from North Anglesey (Heinänen and Skov, 2015; Evans *et al*., 2015; DECC. 2016). High densities have also been recorded within Liverpool Bay (Heinänen and Skov, 2015; DECC, 2016).

Bottlenose dolphin *Tursiops truncates* were recorded during one of the vessel-based surveys (in December 2020) in in the approaches to the Dee Estuary. The individuals observed had probable or possible matches in the Cardigan Bay photo-identification catalogue suggesting the dolphins are part of this population. Individuals from the Cardigan Bay population have previously been recorded in Liverpool Bay. Dolphin activity was also recorded on the F-PODS located in the approaches to the Dee Estuary. Activity was highest in the summer period but were recorded during winter, spring and autumn also. While it is not possible to identify dolphins to species level with F-PODS, based on an understanding of dolphin abundance and distribution in the area, these records are most likely to be bottlenose dolphin *Tursiops truncatus*.

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6 Abbreviations/Acronyms

BND	Bottlenose Dolphin
CCW	Countryside Council for Wales
CTD	Conductivity, Temperature and Depth instrument
CW	Casual Watch
DECC	Department of Energy and Climate Change
DNA	Deoxyribonucleic Acid
DPM	Detection Positive Minutes
DS	Dedicated Search
eDNA	Environmental Deoxyribonucleic Acid
EIRPHOT	Grey seal photo-identification database
EOS	Electro-Optical System
GMT	Greenwich Mean Time
GPS	Global Positioning System
GS	Grey Seal
HAWG	The Herring Assessment Working Group
HC	Hilbre Channel Survey Area
HP	Harbour Porpoise
ICES	International Council for the Exploration of the Sea
ID	Identity
INS	Shallow Inshore Region Survey Area
JNCC	Joint Nature Conservation Committee
kHZ	kilohertz
LT	Line Transect
MD	Mostyn Deep Survey Area
s	Microsecond
MMO	Marine Management Organisation
MV	Motor Vessel
NE	Natural England
NRW	Natural Resources Wales
OESEA	Offshore Energy Strategic Environmental Assessment
OFF	Approaches to the Dee Estuary Survey Area
OTU	Operational Taxonomic Unit
PAM	Passive Acoustic Monitoring
PCR	Polymerase Chain Reaction
POs	Primary Observers
RIB	Rigid Inflatable Boat
rRNA	Ribosomal Ribonucleic Acid
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SLR	Single-Lens Reflex (camera)

SWF	Sea Watch Foundation
TL	Total Length
UK	United Kingdom
WBT	Simrad Wideband Transceiver
WFD	Water Framework Directive
WGIPS	Working Group of International Pelagic Survey
WGS84	World Geodetic System 84

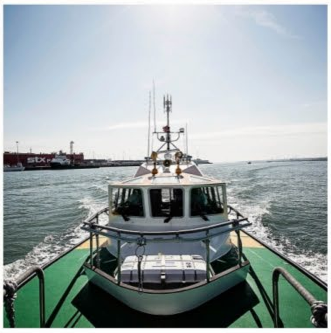
Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendices







Innovative Thinking - Sustainable Solutions

A Quarterly Fish Surveys and Ichthyoplankton Data

Click here to view Microsoft Excel *.xls spreadsheet attachment:

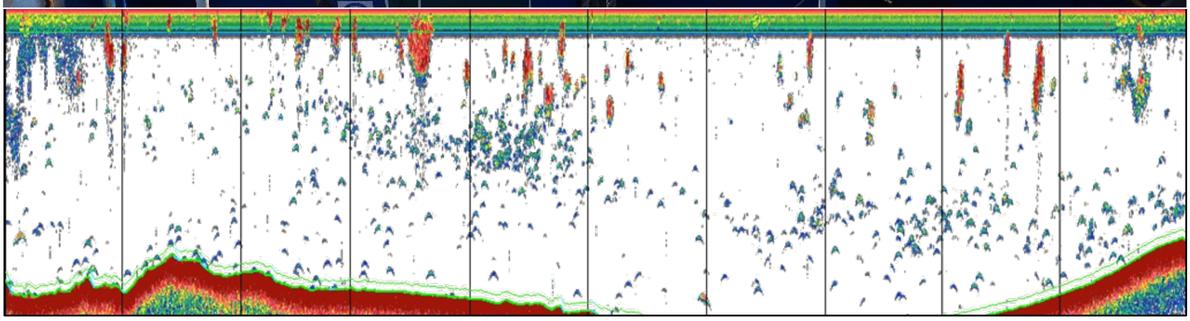
- Final data sheets 2020-2021.xlsx

NB. Spreadsheets are available on request if required, as some pdf applications have permissions to view disabled.

B Pelagic (Acoustic) Fish Survey Report

Pelagic fish of the Dee estuary: a report of acoustic surveys in May & August 2021



1495 UNIVERSITY OF ABERDEEN

PAUL G. FERNANDES
25 FEBRUARY 2022
ABERDEEN, SCOTLAND, UK

Declaration: The data, analyses and results presented in this report are entirely the work of the lead author, Professor Paul G Fernandes.

Acknowledgements: Thanks are due to Edward Sibley PhD candidate from the University of Aberdeen, who assisted with the May survey; and Joshua Lawrence, postdoctoral research assistant from the University of Aberdeen, who assisted with the August survey. Dr Rodney Forster, and his sampling team from the University of Hull, also provided assistance and support on both surveys. Thanks are also due to the skippers and crews of the Mersey Guardian and Severn Guardian for their assistance and efforts to complete the surveys under difficult tidal conditions.

Front cover: *Images taken during the acoustic surveys of pelagic fish in 2021: top left – captures of small herring in August 2021; top right - the Dee estuary showing a tidal foam line, taken on 27 May 2021; the acoustic transducer mounted on a pole in its out of water position prior to deployment from the vessel Severn Guardian (note the extremely calm sea conditions experienced on 22 August 2021); an echogram section from August 2021 in the Hilbre Channel (see Figure 17 for details).*

Contents

Executive summary

1. This report presents the results of two surveys of pelagic fish in the Dee estuary, near Merseyside, UK, on 27 May 2021 and 28 August 2021.

2. A scientific echosounder, operating at two frequencies (38 kHz and 200 kHz) was used to survey the Mostyn Deeps, the Hilbre Channel, the shallow inshore area between these two deeper channels, and an offshore area within a 10 km radius of the estuary. The area is very challenging to survey due to the large tidal range and shallow banks: in the August survey, for example, it was considered too dangerous to include the shallow inshore area.

3. Two techniques, based on echo integration, were applied to estimate the abundance, biomass, and distribution of fish. Signal processing allowed for the separation of fish schools from other fish targets detected in midwater. Other fish targets were resolved by length to provide estimates of fish abundance and biomass by length class.

4. In addition to acoustic data, information relating to fish species composition and size was obtained from the deployment of a bottom trawl. Trawl hauls taken within one day of the survey at fixed locations from the accompanying bottom trawl survey were examined, as well as dedicated trawl hauls targeted at areas of high backscatter. Species caught in these hauls, which were likely to be present in midwater included: sprat, herring, whiting, starry smooth-hound, and lesser spotted dogfish.

5. In May, over 750 fish schools were detected, and these were characteristic of the clupeid fish, sprat, and herring, which are abundant in the adjacent Irish Sea. They occurred in high densities in the Mostyn Deeps and Hilbre Channel. The mean depth of schools was 8 m. In August fewer schools were detected (349), and these were almost absent from the Mostyn Deeps.

6. Other fish, most likely whiting & lesser weever (< 30cm) were numerous in the deep channels, but also in the northern part of the offshore area. Larger other fish, most likely starry smooth-hound, and lesser spotted dogfish (> 30 cm), although not particularly numerous, accounted for a significant proportion of the biomass in both deep channels in both months.

7. The biomass of clupeid fish (sprat and herring) was estimated at 821 t in the whole area in May, and 1014 t in August. The Mostyn Deeps contained 109 t of clupeids in May and only 6 t in August, whereas the Hilbre Channel had 106 t in May and 394 t in August. The inshore and offshore areas had even larger biomass, despite lower densities, due to the larger area they occupy.

8. The biomass of other fish was estimated at 159 t in the whole area in May and 250 t in August. The Mostyn Deeps had 40 t of other fish in May and 92 t in August, and the Hilbre Channel has 21 t in May and 43 t in August.

9. The results are in keeping with other estimates of the abundance and biomass of sprat and herring the Irish Sea, where the total biomass of both populations is over 257,000 t. The latter was derived from an almost identical survey approach (an acoustic survey with the same assumptions about target strength).

1 Introduction

The Dee estuary sits at the mouth of the river Dee as it flows into Liverpool Bay in the eastern Irish Sea, hosting the boundary between England and Wales (Figure 1). It is an important area for nature conservation, with 13 sites designated as either Special Area of Conservation (SAC) or Special Protection Areas (SPA) under the UK national site network of European sites (Natura 2000), or other UK designations. The estuary is characterized by strong tides and large areas of mudflats and sandbanks which become exposed at low tide. The high tidal range makes the area opportune for the development of a tidal lagoon, which is proposed close to the Port of Mostyn, which lies on the Welsh side adjacent to Bug Bank (Figure 1).

In preparation for the proposed tidal lagoon a series of environmental surveys are being carried out to determine the abundance and distribution of marine fauna in the estuary. This report provides results of an acoustic survey of the pelagic environment. Acoustic surveys are used throughout the world to survey pelagic fish and other marine fauna such as krill (Simmonds and MacLennan, 2005). Scientific echosounders are used to collect backscatter data, which are processed to detect objects of interest, such as fish schools (Fernandes, 2009). These can then be processed quantitatively to determine abundance and biomass, although alternative evidence of the species composition, and biological characteristics, may be required to be obtained simultaneously (McClatchie *et al*., 2000). Alternative evidence is usually obtained from net samples, such as pelagic trawls, but under the right conditions, other tools can be used such as rod and lines, or cameras (Fernandes *et al*., 2016).

Acoustic surveys were carried out in the Dee estuary in May and August 2021 to determine the abundance, biomass, and distribution of pelagic fish. This report presents the results of both the May & August 2021 surveys.

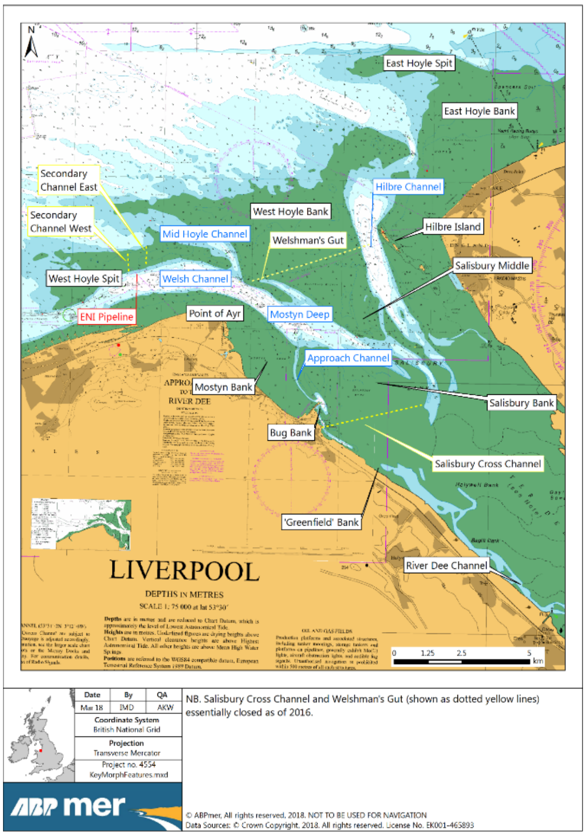
2 Methods

2.1 Survey design

The bathymetry of the estuary is very diverse, with two deep channels, the Mostyn Deeps, and the Hilbre Channel, on either side of a shallow bank which extends out to sea (Figure 1). This allowed for the designation of four distinct strata for the survey design (Figure 2a): the Mostyn Deeps (MD), to the west of the estuary, with water depths up to 30 m; the Hilbre Channel (HC), with similar water depths to the east; the very shallow inshore area (INS), which at low tide becomes completely exposed; and an offshore area (OFF) which was defined as an outer arc of radius 10 km out from a point in the centre of the mouth of the estuary, limited inshore by the borders of land or the other strata.

Acoustic surveys collect data continuously along transects. In this case, the transects were arranged in a zig-zag configuration due to the shapes of the strata (Figure 2b). Such designs are optimal when strata are irregularly shaped, or when they do not conform to rectangular areas with ratios of length to width greater than two (Rivoirard *et al*., 2000). The survey design was further complicated by the logistics of covering the area in the time available due to changes in the tide. Not only is the port of Mostyn restricted in the times at which vessels can leave or depart, but the large inshore area (INS, Figure 2) is completely exposed at low tide. This makes synoptic navigation of the entire survey area very difficult, particularly the inshore area which is only submerged for a few hours either side of high tide.

a)



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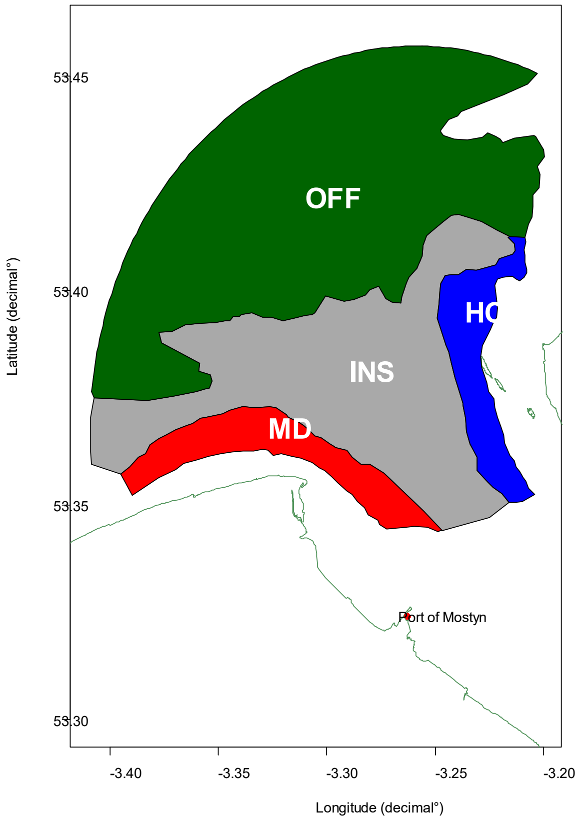

Figure 1. Maps of the survey area. a) Nautical chart of the Dee estuary. The location of the estuary is indicated by the red dot on the map of the British Isles (bottom left). Areas exposed by low tide are shown in green. Points of interest are labelled. b) Strata used for the design of the acoustic surveys carried out in May & August 2021: "MD" is the area of the Mostyn Deeps which has depths of up to 30 m; "HC" is the Hilbre Channel which has similar depths; "INS" is the inshore area which is very shallow and completely exposed at low tide; and "OFF" is the offshore region which is subtidal.

2.2 Survey narrative – May 2021

The Survey was carried out by the survey vessel, Mersey Guardian, an 18.3 m long catamaran operated by Briggs Marine (Figure 3). The vessel departed from the Port of Mostyn at 09:10 GMT and headed to the south-east of the Mostyn Deeps. Zig zag transects then proceeded towards the northwest, criss-crossing the Mostyn Deeps to as shallow as navigably possible. At 10:43, the vessel traversed across the inshore stratum, heading north north-east. On entering the Hilbre channel at 11:30, a long transect traversed the channel heading south-east, followed by shorter zigzag transects traversing the Hilbre channel proceeding north. A bottom trawl was deployed at 12:30 for 10 mins, returning to the survey pattern at 12:45. The vessel exited the Hilbre channel at 13:40. Long zig zag transects were then deployed in the offshore stratum. The vessel stopped to deploy a live viewing underwater camera at 14:35 for 14 minutes. A second trawl haul was deployed at 15:00 for 11 minutes, returning to the survey track at 15:20. The final transect in the offshore region was completed at 17:00 and the vessel headed back to port. On the way, another trial with the camera was undertaken at 18:27 and a further trawl was deployed at 19:30 for 9 minutes. A calibration sphere was suspended beneath the transducer at 18:50 to confirm calibration settings. The vessel returned to port at approximately 20:00. Survey speed was maintained at approximately 7 knots (3.6 ms^{-1}) throughout, and sea conditions were excellent, with calm water (Beaufort wind scale 1, see front cover).

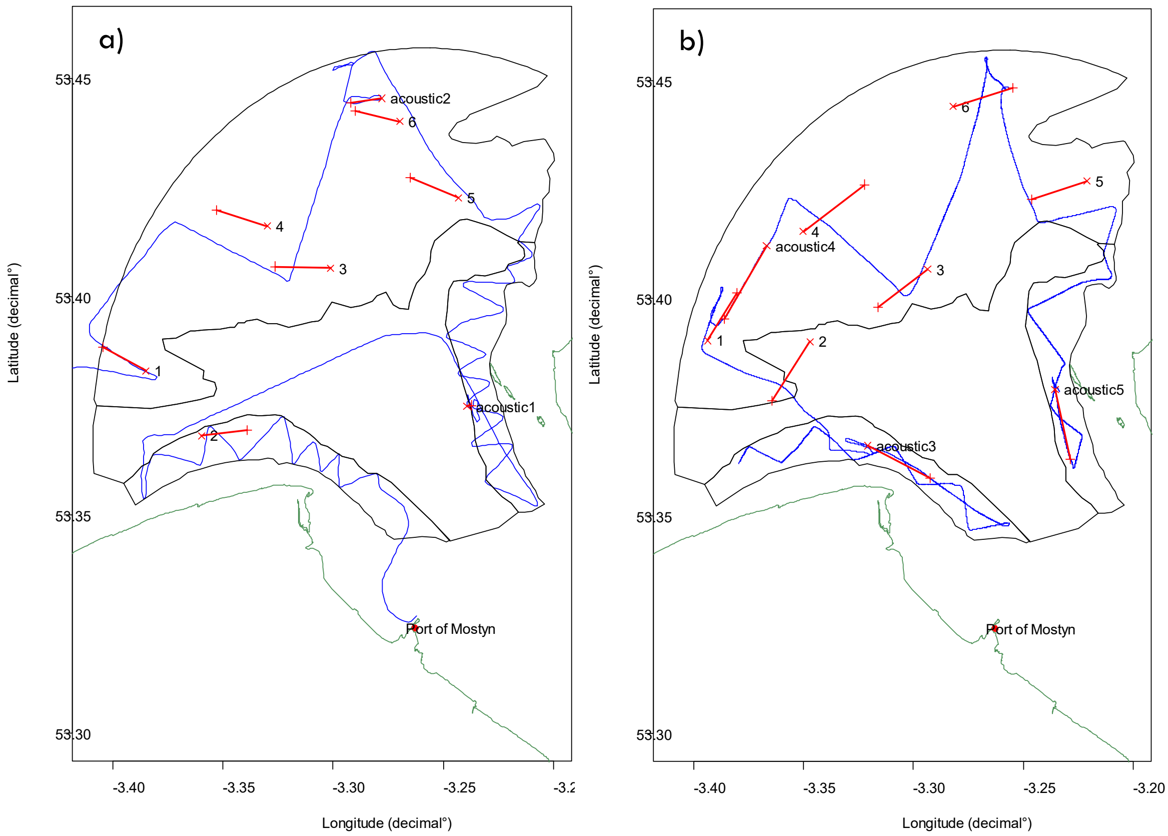

Figure 2. Survey track designs (blue lines) and positions (red lines) of the trawling stations (numbers indicate standard bottom trawl locations for the Hull University trawl survey, whilst those prefixed with "acoustic" are those specific to the acoustic survey). a) May 2021; b) August 2021

2.3 Survey narrative – August 2021

The Survey was carried out by the survey vessel, Severn Guardian, an 18.3 m long catamaran operated by Briggs Marine which is almost identical to the Mersey Guardian which carried out the May 2021 survey (Figure 3). The vessel departed from the Port of Mostyn at 05:00 GMT and headed to the south-west of the offshore stratum. Two demersal trawl hauls (Hull University hauls 1 and 2, Figure 2b) were then conducted whilst the sonar system was being set up. The vessel then headed to the north-west end of the Mostyn Deeps and then proceeded towards the south-east, criss-crossing the area to as shallow as navigably possible. At 09:01, the vessel traversed through the Mostyn Deeps, heading north-west. A trawl haul (Acoustic 3, was conducted at 09:16; and a video camera drop at 09:50). Given the nature of the tides, and his unfamiliarity of the area, the skipper of the vessel was not comfortable with traversing the inshore area as per the survey design, and so this area was not surveyed on this occasion. The vessel, therefore, headed to the offshore transects. A fourth trawl haul (Acoustic 4, Figure 2b) was conducted at 10:58 GMT. The vessel paused again at 12:30 to do a video camera drop. On entering the Hilbre channel at 13:21, zigzag transects were conducted traversing the channel proceeding south. A bottom trawl was deployed at the end of the Hilbre Channel at 14:05. A calibration sphere was suspended beneath the transducer at 14:31 to confirm calibration settings. The vessel returned to port at approximately 17:00. Survey speed was maintained at approximately 7 knots (3.6 ms^{-1}) throughout, and sea conditions were excellent, with flat calm water (Beaufort wind scale 0, see front cover).

2.4 Acoustic data collection.

Acoustic data were collected with a Simrad Wideband Transceiver (WBT) portable scientific echosounder, connected to a Simrad ES38-18_200-7c dual frequency transducer. The transducer was mounted on the bottom of a pole which in May was suspended through the moon pool of the vessel and into the water to a depth of 1 m. In August the transducer was deployed on a sonar pole mount to the port side of the vessel. The instrument transmitted narrowband (continuous wave, CW) signals at 38 and 200 kHz simultaneously, at 0.512 ms pulse lengths and a ping rate of 4 Hz. Additional settings for each transducer were the same as those during calibration of the instrument (Table 1 and Table 2, and further details below), with the exception of the sound speed which was set to an estimated ambient value of 1506.4 ms^{-1}. Operation of the instrument was controlled using Simrad EK80 software on a laptop PC, and acoustic data were saved locally as *.raw files.

The acoustic system was calibrated in a 5 x 5 x 5 m tank at the National Decommissioning Centre at the University of Aberdeen on 6 May 2021. This ensured a controlled calibration of the system, which given the strong tidal streams and the logistics of operation, was not guaranteed on site. The settings and results of the calibration are given in Table 1and Table 2. The calibration sphere was suspended underneath the transducer at the end of each survey to check that the calibration was still valid. Processing of the latter data indicated that calibrated transducer gains were within 0.5 dB of the former calibrated values.

Figure 3. Image of the survey vessel, Mersey Guardian, which was used to carry out the acoustic survey of the Dee estuary on 27 May 2021. The Severn Guardian was used in the August survey and is almost identical. The major difference between the two vessels was the deployment of the sonar transducer: on the Mersey Guardian in May, the transducer was deployed on a pole mounted through the moon pool on the rear deck of the vessel; on the Severn Guardian in August, the pol was mounted on the port side in line with the foremost part of the aft deck.

Table 1. Parameters, settings, and results from the calibration of the Simrad WBT mini and Simrad ES38-18_200-7c dual frequency transducer at 38 kHz.

Platform:	NDC tank		Date:	06/05/2021	
Sonar type:	Simrad EK80 WBT mini		Previous calibration date:	None	
Location:	NDC, Newburgh				
Bottom Depth (m):	4.2				
Transducer name:	ES 38-18/200-18C		Transducer serial no.:	202	
Sonar EK80 firmware platform (PC):		Fernandes pc MD-053874			
Frequency (kHz):	**38**		Pulse type:	CW	
Sphere (material/size):		WC 38.1	Sphere id:	Towed body March 2009	
Temperature at sphere (°C) :		13.6	Salinity at sphere (PSU):	0	
Sound speed at sphere depth (m/s):		1463.8			
TS sphere* (dB):	**-42.4**	*From https://swfscdata.nmfs.noaa.gov/AST/SphereTS/			
Sphere range (m):	**3.15**		Theoretical s_A (m2/nmi2):	**4444.99**	
			$s_A = (\sigma_{sp}/r^2\psi).1852^2$	$\sigma_{sp} = 4.\pi.10^{TS/10}$	
			$s_A = (4.\pi.\sigma_{bs}/r^2\psi).1852^2$	$\sigma_{bs} = 10^{TS/10}$	
Harmonic mean of the sound speed between transducer and sphere depth (m/s):				Not measured	

Parameters				
Name	Unit	Current values	This cal values	Applied (yes/no)
Transducer depth, setting	(m)	0.3		
Transducer depth, actual	(m)	0		
Absorption coefficient	(dB/km)			
Nominal pulse duration	(ms)	0.512		
Receiver bandwidth	(kHz)			
Transmitter power	(W)	500		
Two-way beam angle (10 log ψ)	(dB)	-12.5		
Transducer gain	(dB)	18	**18.70**	No
s_A correction	(dB)	0	**-0.42**	No
Athwartship beam angle	(°)	17.1	16.91	No
Alongship beam angle	(°)	17.1	16.8	No
Athwartship offset angle	(°)	0	0	No
Alongship offset angle	(°)	0	0.66	No

Measured parameters **before** correction: (with sphere on acoustic axis)

Measured TSsphere (dB):	**-41.01**	Measured s_A (m2/nmi2):	**5041.3**
Sphere echo times corresponding to measurements. Start:	**12:24:24**	End:	**12:42:51**
Source:	Echoview, single target detection split beam (method 2)		
s_A after gain adjustment (m2/nmi2):			

Comments	Hybrid approach: echoview calibration assistant used to determine TS and beam pattern, then measured NASC taken from Echoview and entered here.
Raw data filenames	D20210506-T122424.raw-D20210506-T124246.raw
Calibration results filename	DEE.calibration.May.2021.ecs, NDC.calibration.May.2021.v1_Dee.xlsx
Weather conditions	NA
Wind speed (m/s)	NA
Responsible persons	Paul Fernandes

Table 2. Parameters, settings, and results from the calibration of the Simrad WBT mini and Simrad ES38-18_200-7c dual frequency transducer at 200 kHz. This is a single beam transducer so the beam pattern was not calibrated but taken as default factory settings.

Platform:	NDC tank	Date:	06/05/2021
Sonar type:	Simrad EK80 WBT mini	Previous calibration date:	None
Location:	NDC, Newburgh		
Bottom Depth (m):	4.2		
Transducer name:	ES 38-18/200-18C	Transducer serial no.:	202
Sonar EK80 firmware platform (PC name):	Fernandes pc MD-053874		
Frequency (kHz):	**200**	Pulse type:	CW
Sphere (material/size):	WC 38.1	Sphere id:	Towed body March 2009
Temperature at sphere (°C) :	14.4	Salinity at sphere (PSU):	0
Sound speed at sphere depth (m/s):	1463.8		
TS sphere* (dB):	**-39.54**	*From:	https://swfscdata.nmfs.noaa.gov/AST/SphereTS/
Sphere range (m):	**3.25**	Theoretical s_A (m2/nmi2):	**8255.15**
		$s_A = (\sigma_{sp}/r^2\psi).1852^2$	$\sigma_{sp} = 4.\pi.10^{TS/10}$
		$s_A = (4.\pi.\sigma_{bs}/r^2\psi).1852^2$	$\sigma_{bs} = 10^{TS/10}$
Harmonic mean of the sound speed between transducer and sphere depth (m/s):			Not measured

Parameters				
Name	Unit	Current values	This cal values	Applied (yes/no)
Transducer depth, setting	(m)	0.3		
Transducer depth, actual	(m)	0		
Absorption coefficient	(dB/km)			
Nominal pulse duration	(ms)	0.512		
Receiver bandwidth	(kHz)			
Transmitter power	(W)	250		
Two-way beam angle (10 log ψ)	(dB)	-12.6		
Transducer gain	(dB)	18.7	**19.27**	No
s_A correction	(dB)	0	**-0.06**	No
Athwartship beam angle	(°)	17.3		
Alongship beam angle	(°)	16.9		
Athwartship offset angle	(°)	0		
Alongship offset angle	(°)	0		

Measured parameters **before** correction: (with sphere on acoustic axis)

Measured TSsphere (dB):	**-38.40**	Measured s_A (m2/nmi2):	**10423.0**
Sphere echo times corresponding to measurements. Start:	**12:24:24**	End:	**12:25:24**
Source:	Echoview, single target detection - single beam (method 2)		
s_A after gain adjustment (m2/nmi2):			

Comments	Single beam calibration based on echoview single target detection module
Raw data filenames	D20210506-T125022.raw
Calibration results filename	NA
Weather conditions	NA
Wind speed (m/s)	NA
Responsible persons	Paul Fernandes, Joshua Lawrence

2.5 Biological data – fishing trawls & video casts

2.5.1 May 2021

Three trawl hauls were carried out during the survey on schools and fish aggregations detected as denser echo traces (Figure 2a). The fishing gear used throughout the survey was a bottom otter trawl, deployed for 20 minutes. The catch from each haul was sampled for length of all individual fish. Lengths were recorded to the nearest 0.1 cm. Data from the associated seasonal bottom trawl survey, comprising a further six trawl hauls (Figure 2a), carried out in the days around the pelagic survey, were also examined. Several species were excluded from consideration because they were either invertebrates, or fish considered to be demersal or benthic (e.g., dab, dover sole, flounder, plaice, sand goby, tub gurnard, thornback ray).

A pro-squid live underwater viewing video camera, equipped with a red light, was deployed into the water column on three occasions. However, the visibility was so poor, due largely to sediment and marine snow, that no animals were seen.

2.5.2 August 2021

Five trawl hauls were carried out during the survey on schools and fish aggregations detected as denser echo traces (Figure 2b); two of these (trawls 1 and 2, Figure 2b) were in the locations of the associated seasonal bottom trawl survey. The fishing gear used throughout the survey was a bottom otter trawl, deployed for 20 minutes. The catch from each haul was sampled for length of all individual fish. Lengths were recorded to the nearest 0.1 cm. Data from the associated seasonal bottom trawl survey, comprising a further four trawl hauls (Figure 2b), carried out in the days around the pelagic survey, were also examined. Several species were excluded from consideration because they were either invertebrates, or fish considered to be demersal or benthic (e.g., dab, dover sole, flounder, plaice, sand goby, tub gurnard, thornback ray). As in May 2021, no animals were seen with the underwater viewing video camera, which was deployed three times.

2.6 Acoustic signal processing

Acoustic signal processing was carried out with Echoview Software Pty Ltd (2021) version 11.1.23. The following processing steps were carried out:

1. Identify bad data regions where, for example, the vessel was on passage, trawling or turning. These were excluded from survey dataset.
2. Examine the seabed and correct the sounder detected seabed line to include strong fish echoes close to the seabed and exclude seabed intrusions.
3. Create a new seabed offset line at 0.5 m above the corrected detected seabed to act as a buffer to ensure no seabed is integrated.
4. Mask out seabed with a line bitmap masked on the corrected sounder detected bottom.
5. Identify and remove sea surface turbulence associated with wave action. This requires top slicing at e.g., 5 m, median filtering noise, identifying and labelling as a region, and masking out on region bitmap. A copy of the surface turbulence removed echogram was then made and multiplied by 0.1 to create the type of high backscatter values typically associated with the surface. Scrutinise this by eye to adjust any additional turbulence associated with topographical features.
6. Develop a dual frequency fish school filter adapted from (Fernandes, 2009), with the summed dual frequency threshold (38+200) set to -115 dB. Detect fish schools, create a fish school region mask over the 38 kHz raw data and threshold at -70 dB for echo integration of fish (clupeid) schools with a horizontal grid of 100 m Equivalent Distance Sampling Units (EDSUs).

7. Detect single targets using the Split beam method 2, with a -60 dB threshold, a pulse length determination level of 6 dB, a minimum normalised pulse length of 0.7 and a maximum of 1.5.
8. Generate Sv echograms at 38 kHz masked out to remove seabed and surface noise. Threshold at -60 dB. Overlay 10 m (horizontal) x 2 m (vertical) cells.
9. Calculate the two indices of fish density in each cell of (8) above: i) the number of fish in the effective reverberation volume (Nv) and the percentage of multiple echoes (M) from Sawada *et al*. (1993).
10. Create echogram of valid Single Echo Detections (SED's) by setting thresholds of Nv<0.04 and M<0.7 (Sawada *et al*., 1993) and masking the single target detection echogram (7, above) by all cells which exceed these thresholds and masking all fish school regions.
11. Create echogram of other fish, masking out fish schools and setting a range dependent Sv threshold of -66 dB (Rudstam *et al*., 2009) and an overall Sv threshold of -52 dB.
12. Export valid Single Echo Detections (SEDs).
13. Export integrated EDSUs from fish school echogram (clupeid fish) by cells.
14. Export integrated EDSUs from other fish echogram (other fish) by cells.

2.7 Data analysis

The analysis was divided into two major categories: schooling fish, assumed to be the clupeids sprat (*Sprattus sprattus*) and herring (*Clupea harengus*); and other fish (made up of potentially pelagic fish species, see Table 4). SEDs were used to scale the echo integral of the other fish according to an adapted method of Sv/TS scaling (Parker-Stetter *et al*., 2009).

2.7.1 Estimation of the abundance and biomass of schooling fish (clupeids).

To calculate integrator conversion factors the Target Strengths (TS) for herring & sprat were estimated using the TS/length relationship recommended by the International Council of the Sea's (ICES) Working Group of the International Pelagic Surveys (ICES, 2021):

$$\text{Clupeid TS} = 20\log_{10}L - b_{20} \text{ dB per individual} \qquad \textit{Equation 1}$$

where L is the fish length in cm, and b_{20} was 71.2 for clupeids (herring and sprat). The backscattering cross-section σ_{bs} (m^2) is related to TS and L by the equation:

$$\sigma_{bs} = 10^{\frac{TS}{10}} = 10^{\frac{-b20}{10}} L^2 \qquad \textit{Equation 2}$$

However, to account for the length distributions encountered in the trawl hauls, the mean backscattering cross section (m^2) for clupeids (herring and sprat) was estimated from the total numbers at length of herring and sprat caught as:

$$\bar{\sigma}_{bs} = 10^{\frac{-b20}{10}} \frac{\sum_j p_{ij}(L_j^2)}{\sum_j p_{ij}} \qquad \textit{Equation 3}$$

Where L_j was the length in cm (at size class j) and P_{ij} was the number in size class j in haul i. The weight of clupeid fish at length was determined according to the length weight relationship:

$$w = aL^b \qquad \textit{Equation 4}$$

Where the parameters, a=0.00465 and b=3.1915 for sprat in the Irish Sea, were taken from Coull *et al*. (1989). To account for the length distributions encountered in the trawl hauls, the mean weight, in grammes, of clupeids in all trawl hauls was estimated as:

$$\overline{w} = a\frac{\sum_j p_{ij}(L_j^b)}{\sum_j p_{ij}}$$ Equation 5

Where L_j was the length in cm (at size class j) and P_{ij} = number in size class j in haul i. Estimates of clupeid fish density were obtained using standard methods from echo integration as described in Simmonds and MacLennan (2005). All backscatter from the isolated clupeid fish schools was integrated and exported as Nautical Area Scattering Coefficients (NASCs, symbol s_A, in m^2.n.mi^{-2}, see Maclennan *et al.*, 2002) at 100 m EDSU intervals. Fish density, in numbers per square metre at each EDSU, was then estimated according to:

$$\rho_E = \frac{s_{A_E}}{4\pi(1852^2)\bar{\sigma}_{bs}}$$ Equation 6

Where s_{AE} is the NASC of clupeid fish schools at each EDSU (E). Clupeid biomass density (kg.m^{-2}) at each EDSU was then estimated as the number density (Equation 6) times the mean weight (Equation 5) divided by 1000. Density estimates (ρ_E) were then averaged by stratum, and the $\bar{\rho}_E$ was multiplied by the area of the stratum (m^2), to obtain abundance and biomass for each stratum. The total abundance and biomass of clupeids for the survey was then summed over the four strata.

2.7.2 Estimation of the abundance and biomass of other fish

Other fish were assumed to have the generic TS to length relationship for physoclists (including most gadoids) used by the International Council of the Sea's (ICES) Working Group of the International Pelagic Surveys (ICES, 2021), where b20 (Equation 1) was 67.5 dB. However, unlike the case, above, where clupeid σ_{bs} were estimated from the length compositions from the trawl hauls (Equation 3), in the case of the other fish, the TS was taken from the distribution of SEDs measured in each stratum. Histograms of SED in each stratum were created with σ_{bs} bins equivalent to 5 cm length classes from 0 to 90 cm to create proportions of σ_{bs} at each length class. The NASC from other fish was then apportioned according to these proportions at σ_{bs} to estimate NASC at the length class and EDSU (s_{AEj}) according to:

$$s_{A_{Ej}} = \frac{s_{A_E} p_{Ej} \sigma_{bsj}}{\sum_E p_{Ej} \sigma_{bsj}}$$ Equation 7

Where j was the 5 cm length class and p the proportion of σ_{bs} at that length class in EDSU E. Fish density at length, in numbers per square metre, then followed as:

$$\rho_{Ej} = \frac{s_{A_{Ej}}}{4\pi(1852^2)\bar{\sigma}_{bsj}}$$ Equation 8

Fish biomass density at length (kg.m^{-2}), was then estimated as fish density at length multiplied by the weight at the midpoint of the length class (divided by 1000), according to the weight length relationship (Equation 4) for whiting (*Merlangius merlangus*) from (Coull *et al.*, 1989), where a=0.0093 and b=2.9456. Density estimates at length (ρ_{Ej}) were then averaged by stratum, and the $\bar{\rho}_{Ej}$ were multiplied by the area of the stratum (m^2), to obtain abundance and biomass at length for each stratum. The total abundance and biomass of other fish for the survey were then summed over lengths and strata.

3 Results of the May 2021 survey

3.1 Fish distribution in May 2021

3.1.1 Spatial distribution

Fish schools were present throughout the area but were most prevalent in the Mostyn Deeps and Hilbre Channel (Figure 4). Although there were fish schools detected offshore, they were far more numerous in the two channels and densities there were higher than in all other strata. Other fish were also very prevalent in the two channels, but also occurred in high densities in the northern part of the offshore area. The inshore area had the lowest densities of schooling and other fish, but fish schools were present there too.

A total of 740 schools were detected, but the distribution of these in each stratum is sensitive to the number of samples taken in each stratum. The number of schools per kilometre was, therefore, taken as a measure of school density per stratum. Note that this metric may not relate to the density and abundance of fish because schools may vary in size and in [internal] density. The Hilbre channel had the highest number of schools per km, followed by the Mostyn Deeps, and the offshore stratum, with the inshore stratum having the lowest number of schools per km (Table 3).

3.1.2 Depth distributions

The mean depths of fish schools were similar in all strata (overall mean of 8.1 m), with only the Hilbre channel having slightly deeper schools (9.0 m). However, the schools in the inshore area, although less dense, had higher backscatter (NASC) inferring a higher packing density (Table 3). The depth distribution of schools and other fish are given in Figure 5. Other fish were more evenly distributed over depths than fish schools, occurring both shallower and deeper, with a slightly deeper average depth in all strata except the inshore one (Table 3). Example echograms of the types of fish detected, in schools and as individuals, are given in Figure 6 - Figure 9.

3.1.3 Length distributions

A total of 3066 single echoes (detections of individual fish) were detected in areas considered to be low enough in density for valid measurements to be made. The target strengths of these SED's were converted to lengths (Equation 1, but with a b_{20} of 67.5). The distribution of lengths in each stratum is given in Figure 10. The Mostyn Deeps and Hilbre channel had the broadest range of inferred fish lengths, with fish up to 90 cm and many fish greater than 25 cm. Inshore and offshore areas were dominated by small fish.

3.1.4 Biological data from the trawls

A total of 9 trawl hauls were carried out in the area (Table 4): one on the day before the survey as part of accompanying the bottom trawl survey (Station 2, in the Mostyn Deeps); three on the day of the survey (Acoustic 1-3); and five on the day after the survey (remaining complement from the bottom trawl survey, Stations 1, and 3-6). Table 4 provides the numerical catch composition of what were considered to be the species that may occur in pelagic realm. Very little was caught in the two channels (Mostyn Deeps and Hilbre Channel), and only 7 sprats were caught in the Hilbre Channel (trawl "Acoustic 1"). The length distributions of pelagic fish from the trawls (Figure 11) were quite similar to the distribution of lengths inferred from the acoustic data (SEDs, Figure 10). The offshore area was dominated by small fish, mostly whiting, but there were some large fish (up to 60 cm) in the offshore area too.

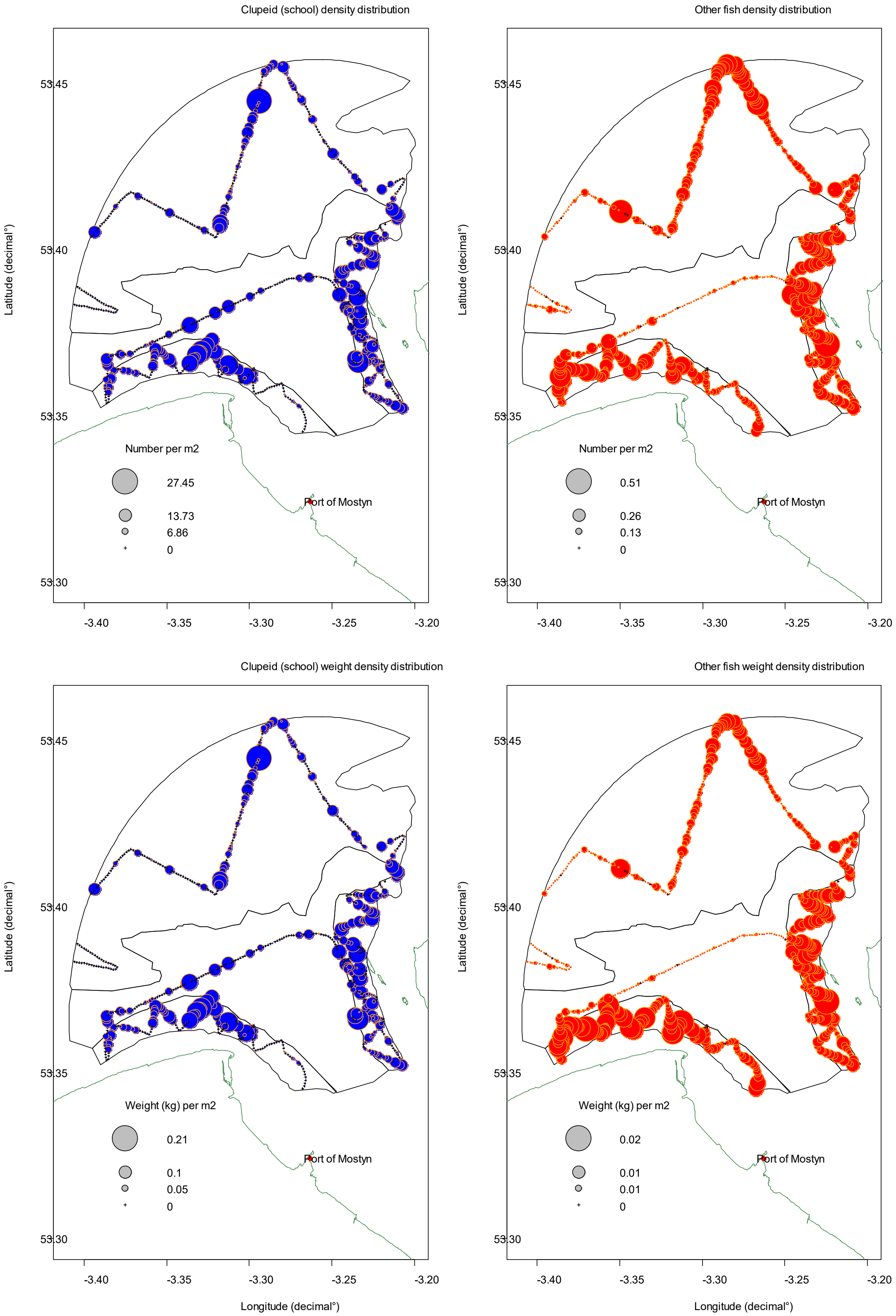

Figure 4. Maps of the Dee estuary showing the distributions of fish density with circles proportional to density (upper figures numeric density, m^{-2}; lower figures weight density, kg.m^{-2}) at each 100 m EDSU, according to the legend. Left column (blue circles) are schooling fish (clupeids), right (red) are other fish.

Table 3. Statistics of fish schools detected during the acoustic survey of the Dee estuary in May 2021 in each stratum (see Figure 2a).

Stratum	Schools.km^{-1}	Mean school depth (m)	School NASC (m^2.nmi^{-2})	Mean depth of other fish (m)
MD	11.2	7.18	447	8.40
HC	17.0	9.00	335	9.87
INS	3.7	7.51	663	6.25
OFF	7.3	7.17	303	9.10
Overall	10.2	8.05	374	9.10

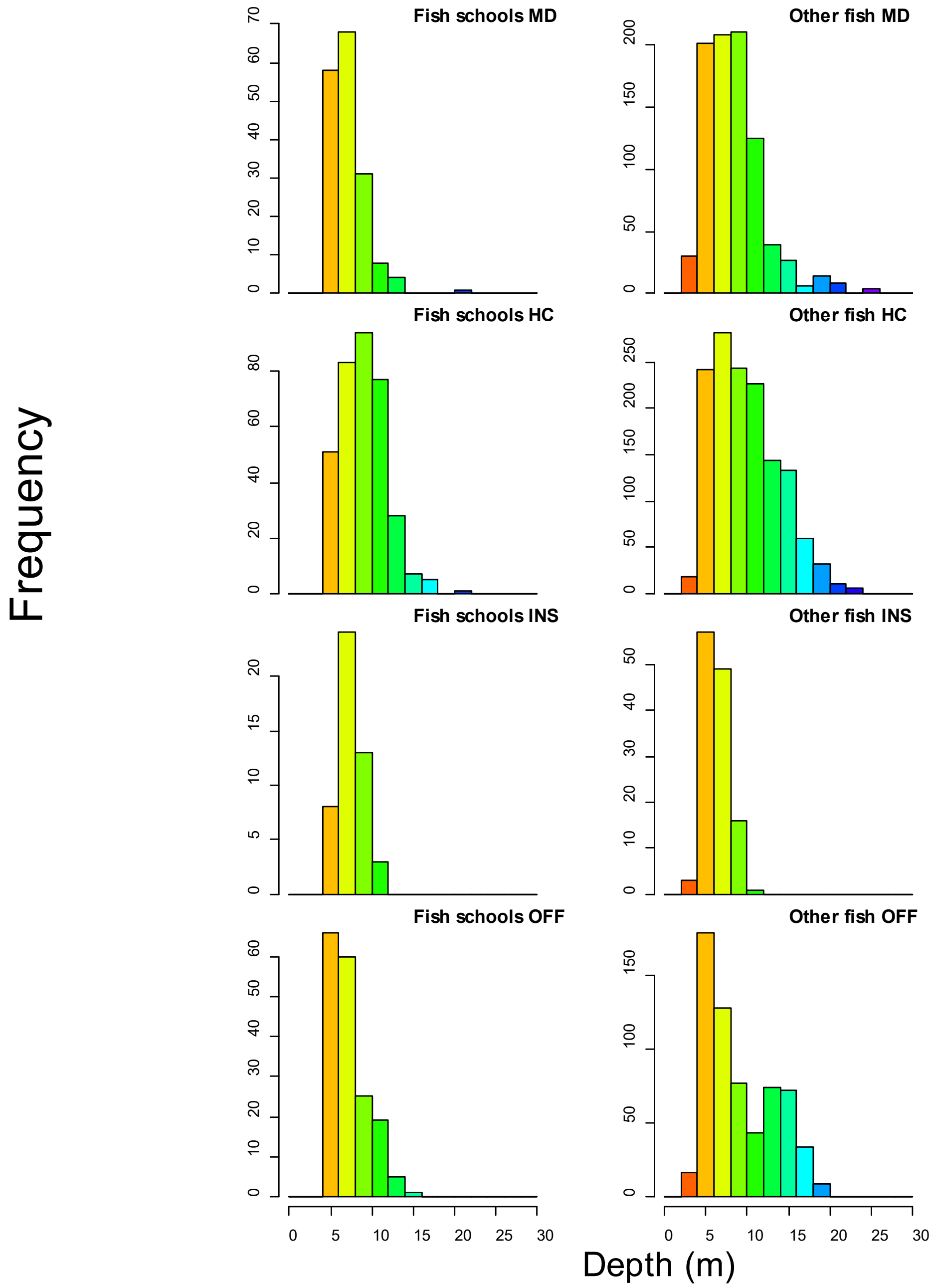

Figure 5. Depth distribution of fish schools (left column) and other fish (right column) in each of the strata from the acoustic survey of the Dee estuary carried out in May 2021.

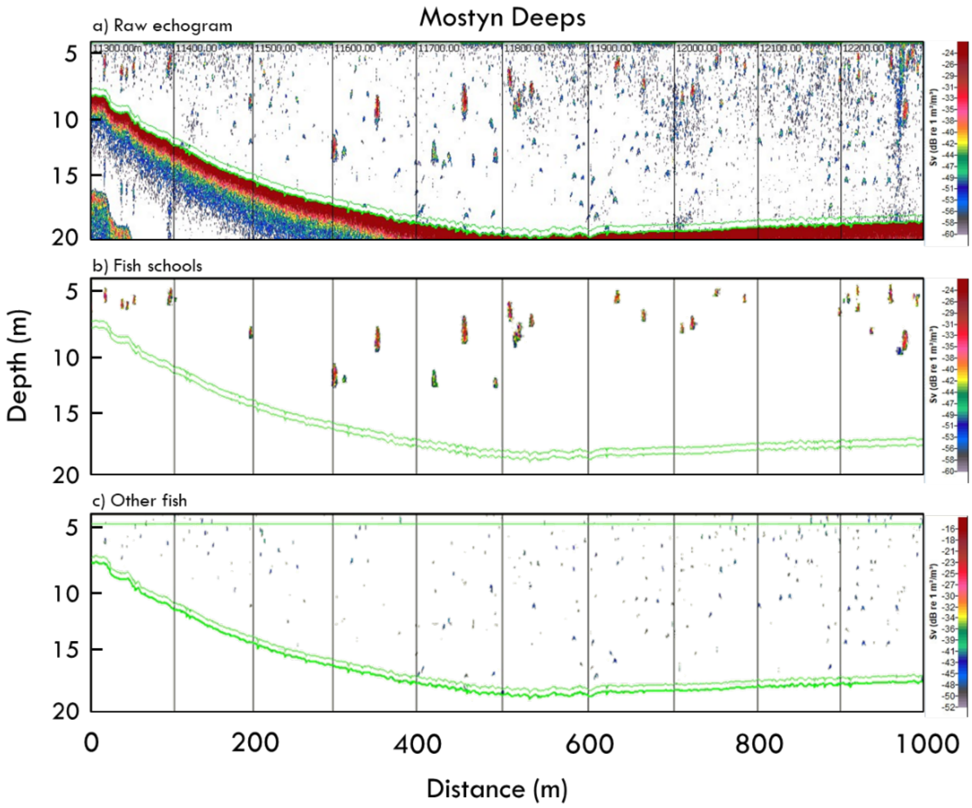

Figure 6. Example echograms from the Mostyn Deeps of the Dee estuary acoustic survey in May 2021. a) raw data; b) data processed to extract fish schools; c) other fish. Colour coding is according to legend on the right with the threshold set at the lowest value. Thick green line is the seabed, thin line is a 0.5 m buffer.

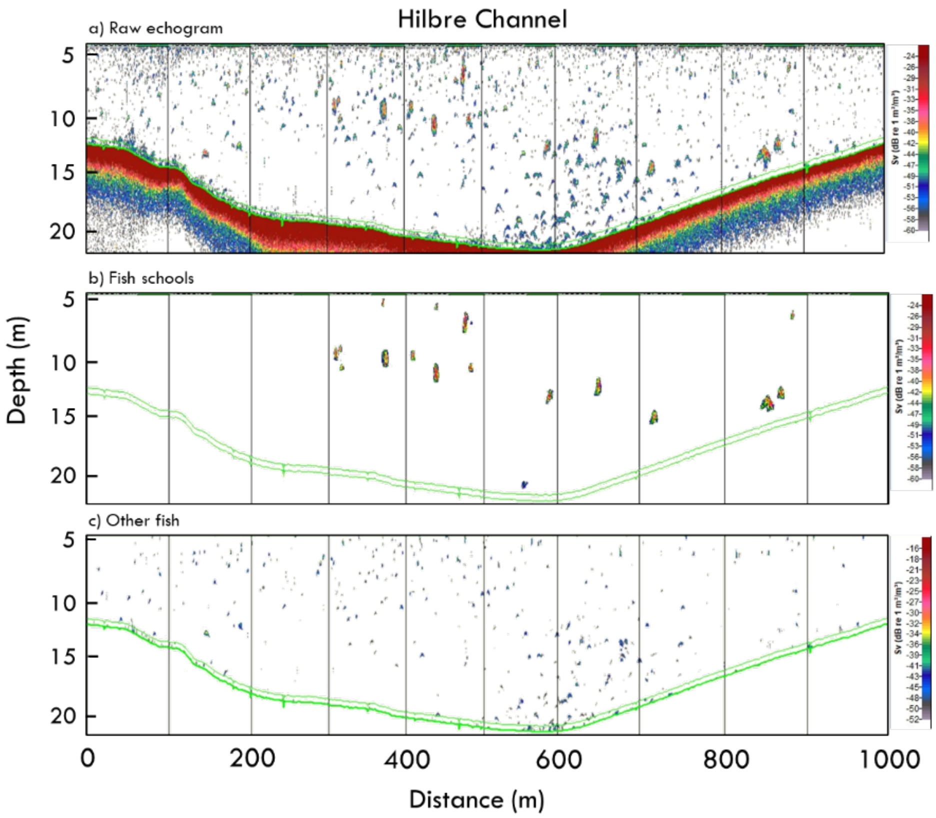

Figure 7. Example echograms from the Hilbre Channel, Dee estuary (see Figure 6 caption for details).

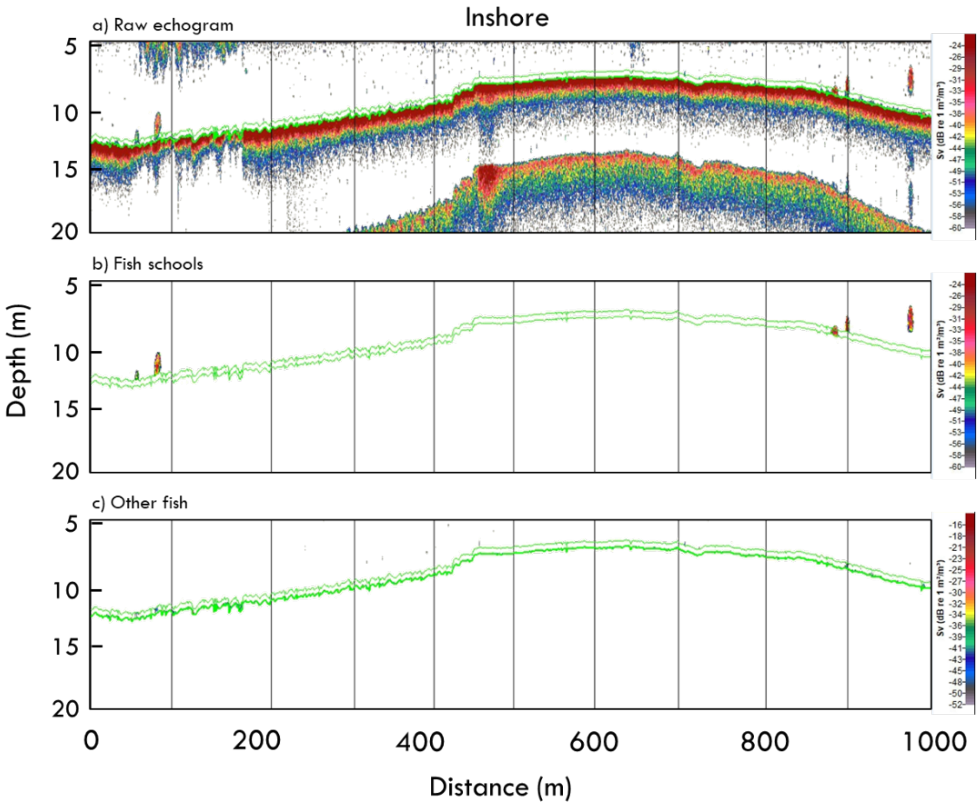

Figure 8. Example echograms from the Inshore stratum, Dee estuary (see Figure 6 caption for details).

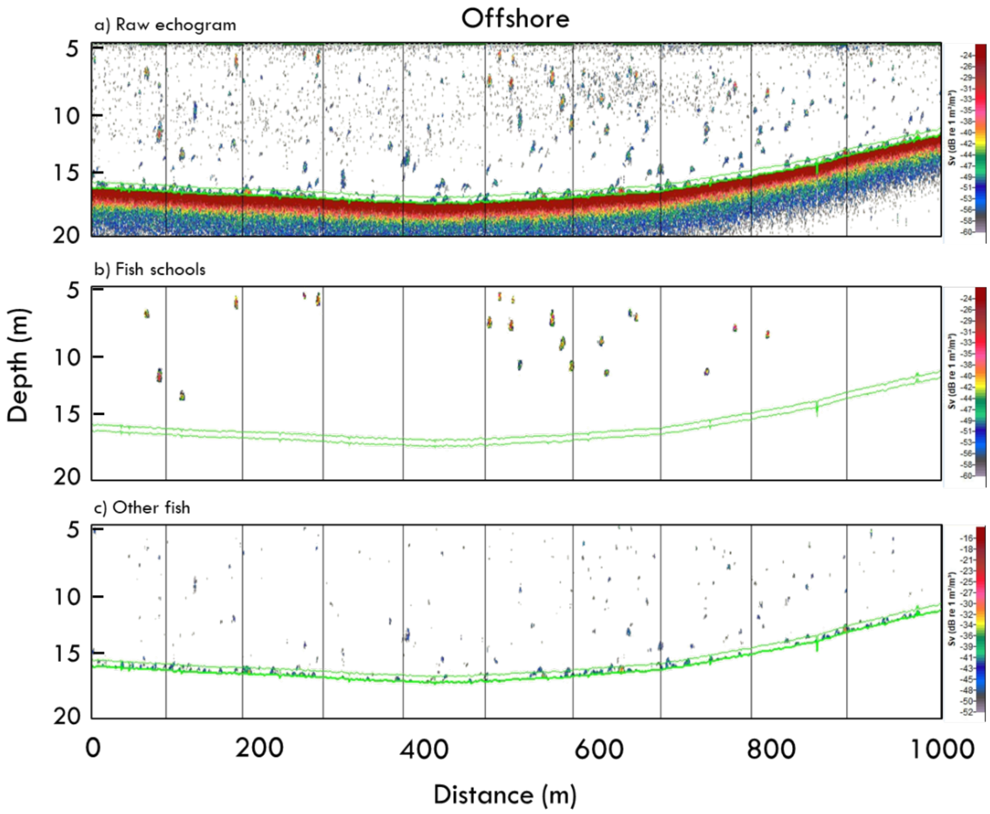

Figure 9. Example echograms from the offshore stratum, Dee estuary (see Figure 6 caption for details).

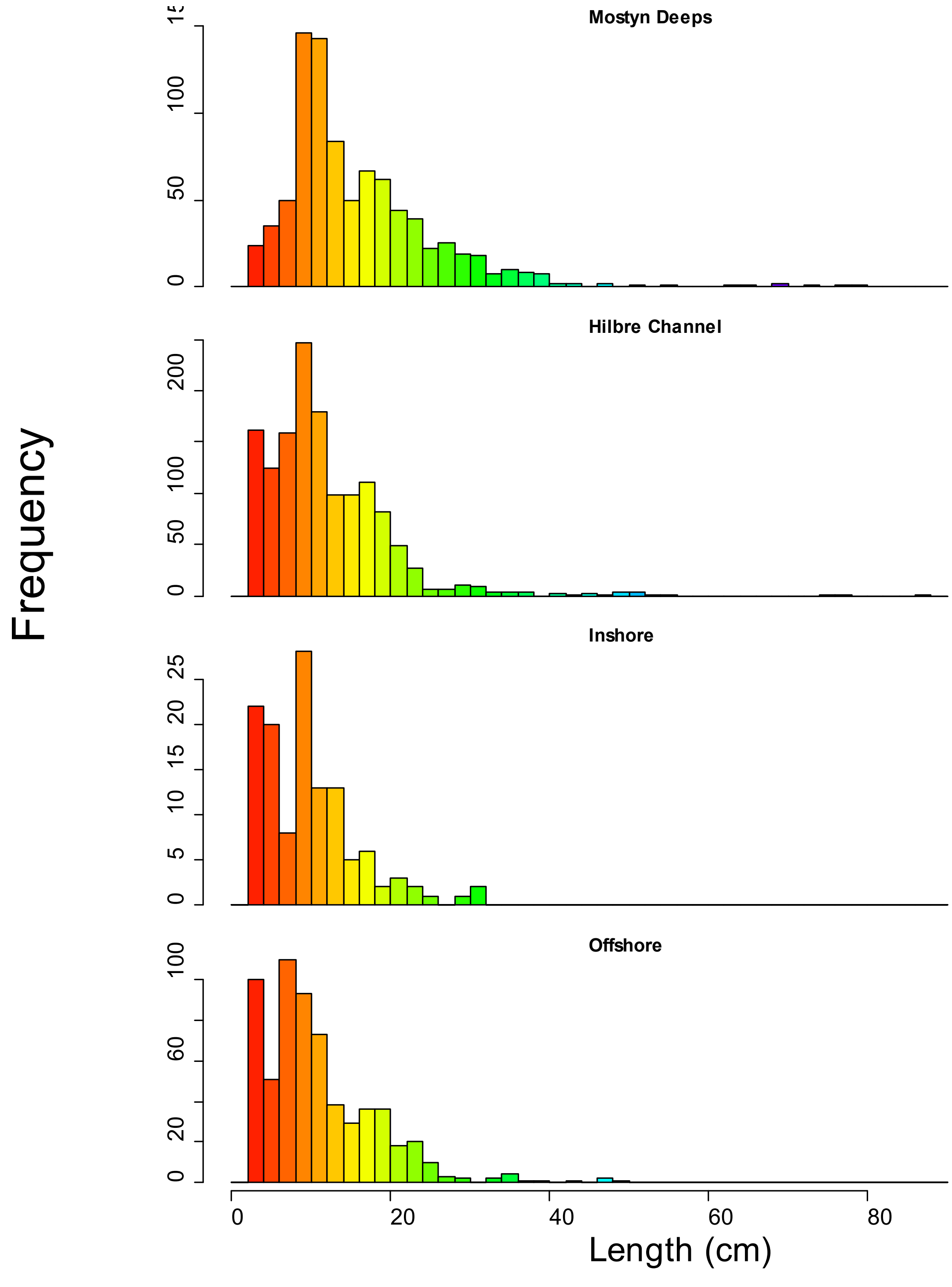

Figure 10. Inferred fish length (L) distributions by stratum in the Dee acoustic survey May 2021, converted from measured Target Strengths (TS) from single echo detections and assuming a TS/L relationship (Equation 1) where b_{20}=67.5.

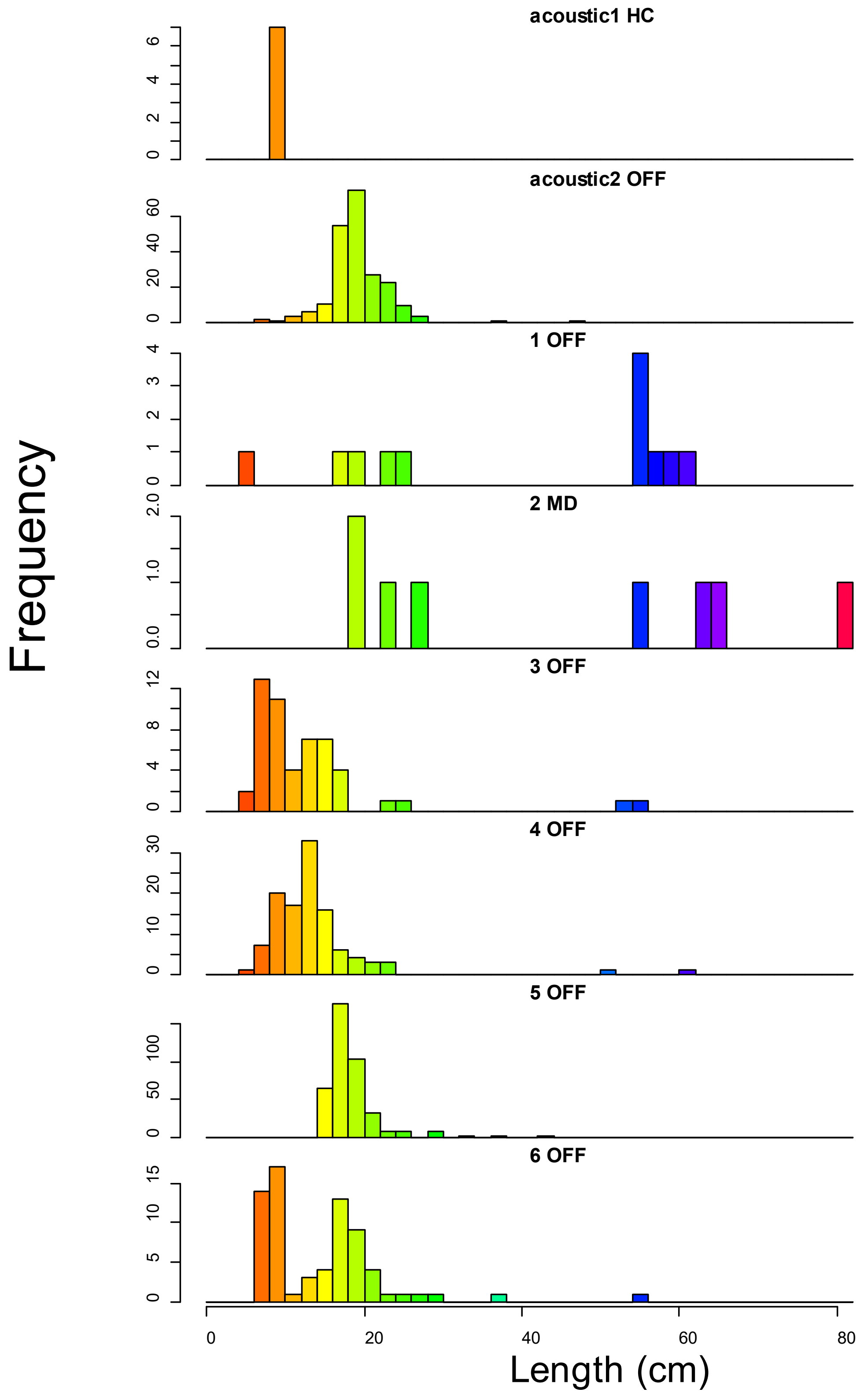

Figure 11. Length distributions of measured pelagic fish by trawl haul and stratum in the Dee acoustic survey May 2021.

Table 4. Trawl haul information from the Dee estuary acoustic and trawl surveys conducted in May 2021, with numbers of fish species caught that were considered to be potentially pelagic.

Station	Date	Start time (BST)	End time (BST)	Longitude (decimal°)	Latitude (decimal°)	Depth (m)	Stratum	Atlantic Herring	Atlantic Mackerel	Greater Sand Eel	Lesser Sand Eel	Lesser Spotted Dogfish	Lesser Weaver	Sprat	Starry Smooth Hound	Whiting
1	28/05/2021	14:03	14:23	-3.395	53.386	12.4	OFF	0	0	0	0	8	1	0	0	3
2	26/05/2021	19:54	20:14	-3.350	53.369	6.9	MD	0	0	0	0	0	0	0	4	4
3	28/05/2021	15:17	15:37	-3.314	53.407	8.8	OFF	0	0	3	11	0	34	0	2	2
4	28/05/2021	14:48	15:08	-3.341	53.418	16.6	OFF	0	4	59	14	2	32	0	0	1
5	28/05/2021	15:53	16:13	-3.254	53.425	13.3	OFF	0	0	0	0	0	0	0	3	751
6	28/05/2021	16:37	16:57	-3.280	53.441	12	OFF	0	0	0	1	0	38	0	2	30
Acoustic 1	27/05/2021	13:30	13:50	-3.238	53.375	11	HC	0	0	0	0	0	0	7	0	0
Acoustic 2	27/05/2021	16:00	16:13	-3.285	53.445	8.6	OFF	1	0	0	0	0	1	1	2	317
Acoustic 3	27/05/2021	20:30	20:39	-3.304	53.362	13.0	MD	0	0	0	0	0	0	0	0	0

In keeping with the distributions of SED's (Figure 10), catches of the largest fish (up to 81 cm) were in the Mostyn Deeps. All fish larger than 30 cm (n=22) were either Lesser spotted dogfish or starry smooth-hound. Most of the fish between 25 and 30 cm were whiting.

Very little was caught in the Hilbre Channel (a total of 7 sprat, Table 4) and time constraints (due to tide) meant that there was no opportunity to trawl in the shallow inshore area.

3.2 Abundance & biomass estimates

The total abundance of fish in the area was 114 million fish, comprised of 109 million clupeids (sprat and herring) and 5 million other fish (mostly whiting, but a large number of lesser weaver fish, and a small number of dogfish and smooth-hounds). The estimate of biomass was 980 tonnes (t), 821 t of clupeids and 159 t of other fish. Table 5 provides a breakdown of these estimates by stratum. The abundance and biomass were highest in the offshore area by virtue of its large size, followed by the inshore area doe similar reasons. The smaller areas of the Mostyn Deeps and Hilbre Channel had significant quantities of fish despite being a fraction of the area, which is reflected in the estimates of density: the two channels had densities which were very similar (Table 5) and over double that of the other areas.

Estimates of numbers of other fish at length are given in Figure 12. Numbers were dominated by small fish less than 12.5 cm, which were probably dominated by whiting or lesser weaver. Estimates of biomass of other fish at length are given in Figure 13. The biomass was dominated by medium sized fish between 12.5 cm and 30 cm, which were probably whiting. There were reasonable amounts of biomass of larger fish, which were likely to be starry smooth-hound (*Mustelus asterias*) and lesser spotted dogfish (*Scyliorhinus canicula*).

Table 5. Estimates of fish abundance from the Dee estuary acoustic survey in May 2021, by species groups and strata (See Figure 2 for strata definitions). Clupeids represent sprat (Sprattus sprattus) and herring (Clupea harengus); other fish represent unidentified fish, likely candidates of which are the small gadoids such as whiting (Merlangius merlangus), the lesser weaver (Echiichthys vipera), and larger fish such as the starry smooth-hound (Mustelus asterias) and lesser spotted dogfish (Scyliorhinus canicula). Length compositions of these other fish are given in Figure 12 and Figure 13. Abundance is given in number (N in millions) and biomass (tonnes).

Clupeids (sprat and herring)					
Stratum	Area (m^2)	Density ($N.m^{-2}$)	N (millions)	Dens ($kg.m^{-2}$)	Biomass (t)
Mostyn Deeps	9258854	1.57198	14.6	0.01179	109.2
Hilbre Channel	7949060	1.77907	14.1	0.01334	106.1
Inshore area	39937888	0.84380	33.7	0.00633	252.8
Offshore area	67104700	0.70478	47.3	0.00529	354.7
Total			109.7		822.7

Other fish					
Stratum	Area (m^2)	Density ($N.m^{-2}$)	N (millions)	Dens ($kg.m^{-2}$)	Biomass (t)
Mostyn Deeps	9258854	0.053520	0.50	0.004784	44.3
Hilbre Channel	7949060	0.059688	0.47	0.002794	22.2
Inshore area	39937888	0.026154	1.04	0.000534	21.3
Offshore area	67104700	0.038175	2.56	0.001216	81.6
Total			4.57		169.4

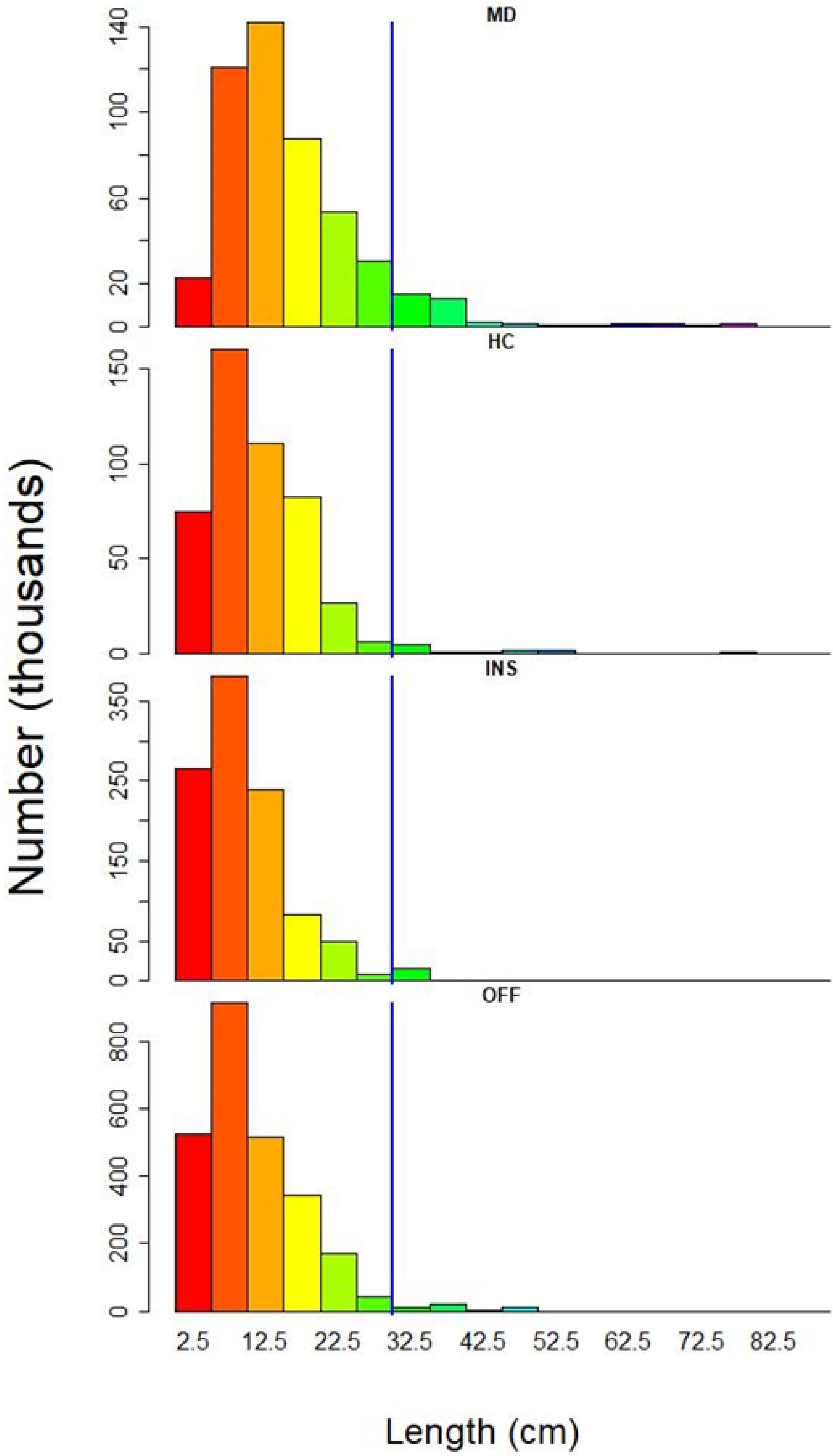

Figure 12. Estimates of total numbers of other fish at length by stratum. Blue vertical line is at 30 cm: all fish greater than this size caught in the trawls were either starry smooth-hound (Mustelus asterias) or lesser spotted dogfish (Scyliorhinus canicular).

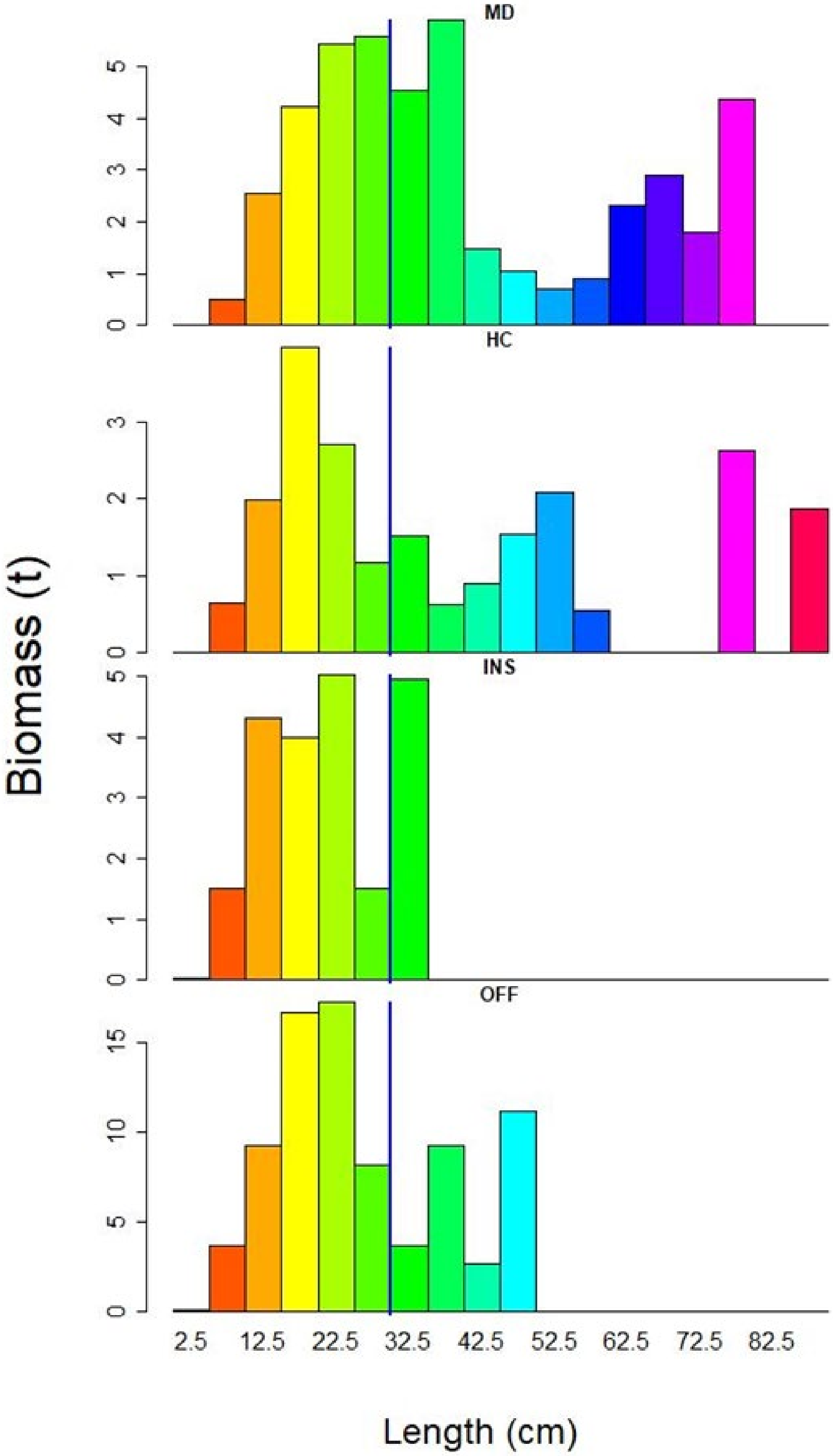

Figure 13. Estimates of total biomass of other fish at length by stratum. Blue vertical line is at 30 cm: all fish greater than this size caught in the trawls were either starry smooth-hound (Mustelus asterias) or lesser spotted dogfish (Scyliorhinus canicular).

4 Results of the August 2021 survey

4.1 Fish distribution in August 2021

4.1.1 Spatial distribution

Only a few very small fish schools were present in the Mostyn Deeps in August 2021. A few schools were detected in the offshore area, notably one very dense school, but schools were most prevalent in the Hilbre Channel (Figure 14). Other fish were very prevalent in both channels and occurred in low densities in the northern part of the offshore area. The inshore area was not surveyed at all on this occasion.

A total of 349 schools were detected, but the distribution of these in each stratum is sensitive to the number of samples taken in each stratum. The number of schools per kilometre was, therefore, taken as a measure of school density per stratum. Note that this metric may not relate to the density and abundance of fish because schools may vary in size and in [internal] density. For example, although there were fewer schools detected in the offshore area, the presence of one large dense school (at 8 m depth and 825 m distance on Figure 19) contributed to a high mean density in the offshore stratum (Table 6). The Hilbre channel had by far the highest number of schools per km (26), followed by the offshore stratum (4.8), with the Mostyn Deeps having the lowest number of schools per km (1.8, Table 6).

Other fish were more evenly distributed between the two channels: the Mostyn Deeps had the highest densities of other fish, followed by the Hilbre channel, with very little in the offshore stratum (Figure 14).

4.1.2 Depth distributions

The mean depths of fish schools were similar in all strata (overall mean of 7.4 m), with only the offshore stratum having slightly deeper schools (9.8 m). The depth distribution of schools and other fish are given in Figure 15. Other fish were more evenly distributed over depths than fish schools, occurring both shallower and deeper, with a deeper average depth in all strata (Table 6). Example echograms of the types of fish detected, in schools and as individuals, are given in Figure 16-Figure 19.

4.1.3 Length distributions

A total of 5002 single echoes (detections of individual fish) were detected in areas considered to be low enough in density for valid measurements to be made. The target strengths of these SED's were converted to lengths (Equation 1, but with a b_{20} of 67.5). The distribution of lengths in each stratum is given in Figure 20. All areas had a broad range of inferred fish lengths, with fish up to 90 cm and many fish greater than 25 cm. Offshore areas were dominated by small fish.

4.1.4 Biological data from the trawls

A total of 9 trawl hauls were carried out in the area (Table 7): four on the day after the survey as part of accompanying the bottom trawl survey (Stations 3-6, in the offshore area); 5 on the day of the survey: 3 dedicated to the acoustic survey (Acoustic 4-6), and two stations of the bottom trawl survey (Stations 1 and 2). Table 7 provides the numerical catch composition of what were considered to be the species that may occur in pelagic realm. Very little was caught overall, particularly in the two channels (Mostyn Deeps and Hilbre Channel). 18 sprats were caught in the Hilbre Channel (trawl "Acoustic 3"). The length distributions of pelagic fish from the trawls (Figure 21) were quite similar to the distribution of lengths inferred from the acoustic data (SEDs, Figure 20). The offshore area was dominated by small fish, mostly lesser weaver and whiting. Large fish (up to 90 cm) were constrained to the Hilbre Channel and Mostyn Deeps.

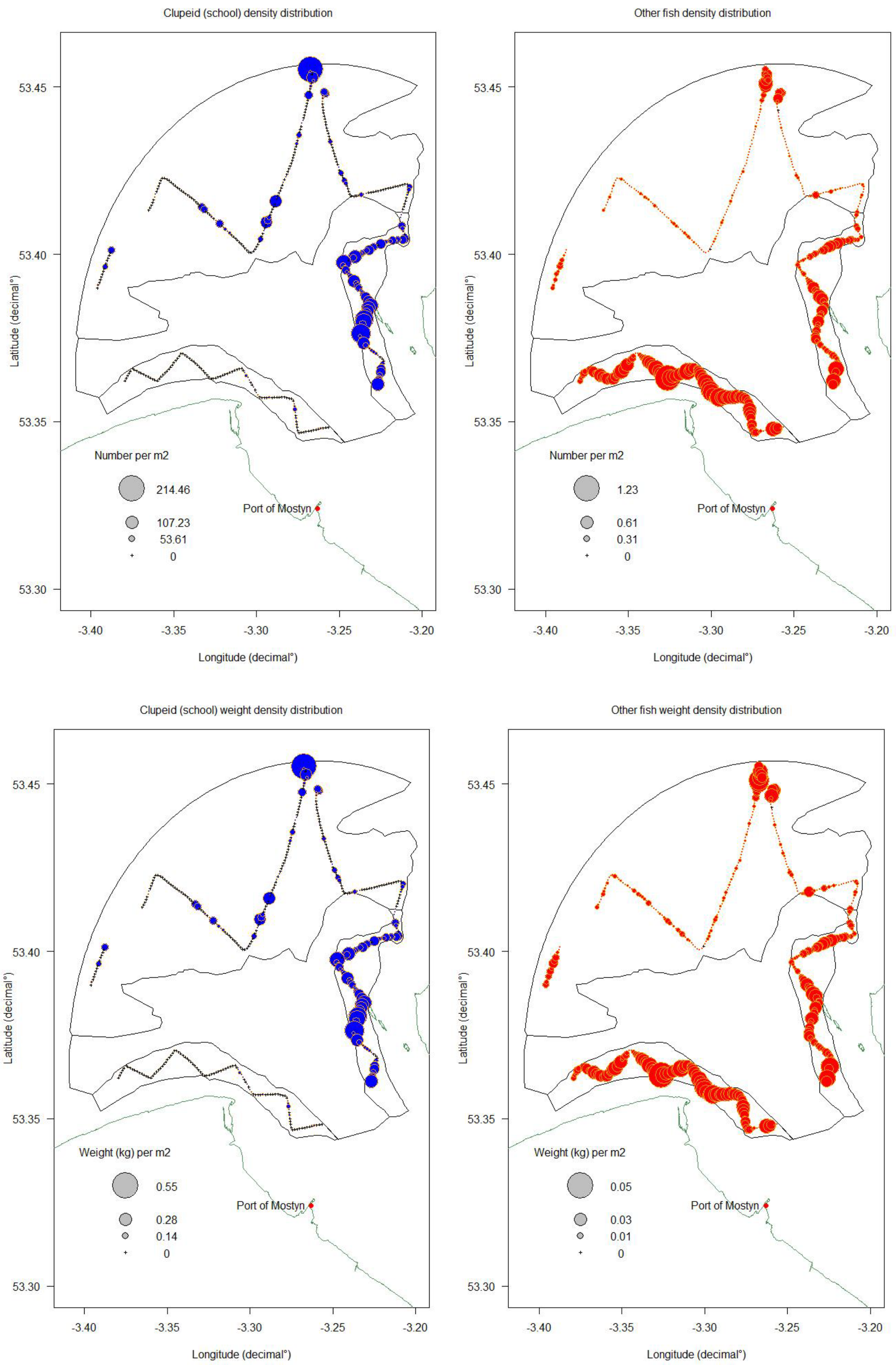

Figure 14. Maps of the Dee estuary showing the distributions of fish density with circles proportional to density (upper figures numeric density, m^{-2}; lower figures weight density, $kg.m^{-2}$) at each 100 m EDSU, according to the legend. Left column (blue circles) are schooling fish (clupeids), right (red) are other fish.

Table 6. Statistics of fish schools detected during the acoustic survey of the Dee estuary in August 2021 in each stratum (see Figure 2a).

Stratum	$Schools.km^{-1}$	Mean school depth (m)	School NASC ($m^2.nmi^{-2}$)	Mean depth of other fish (m)
MD	1.8	6.46	230	8.24
HC	26	6.42	1238	10.86
INS				
OFF	4.8	9.84	1239	10.69
Overall	8.5	7.44	1177	9.04

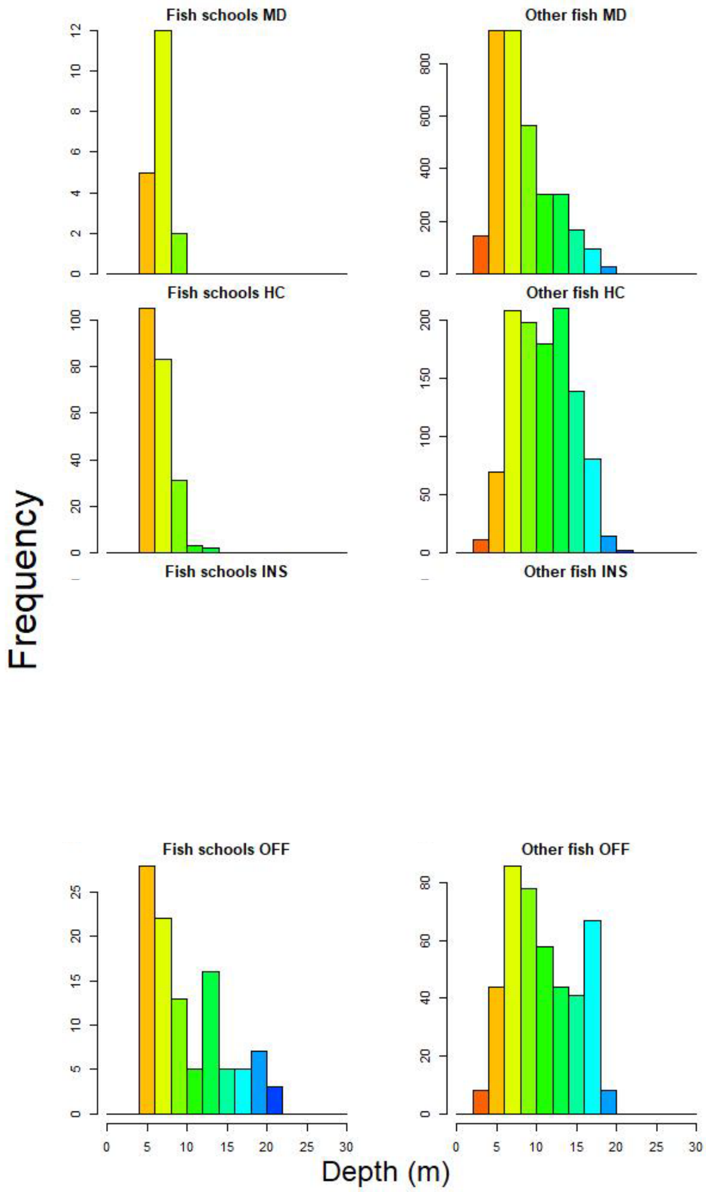

Figure 15. Depth distribution of fish schools (left column) and other fish (right column) in each of the strata from the acoustic survey of the Dee estuary carried out in August 2021.

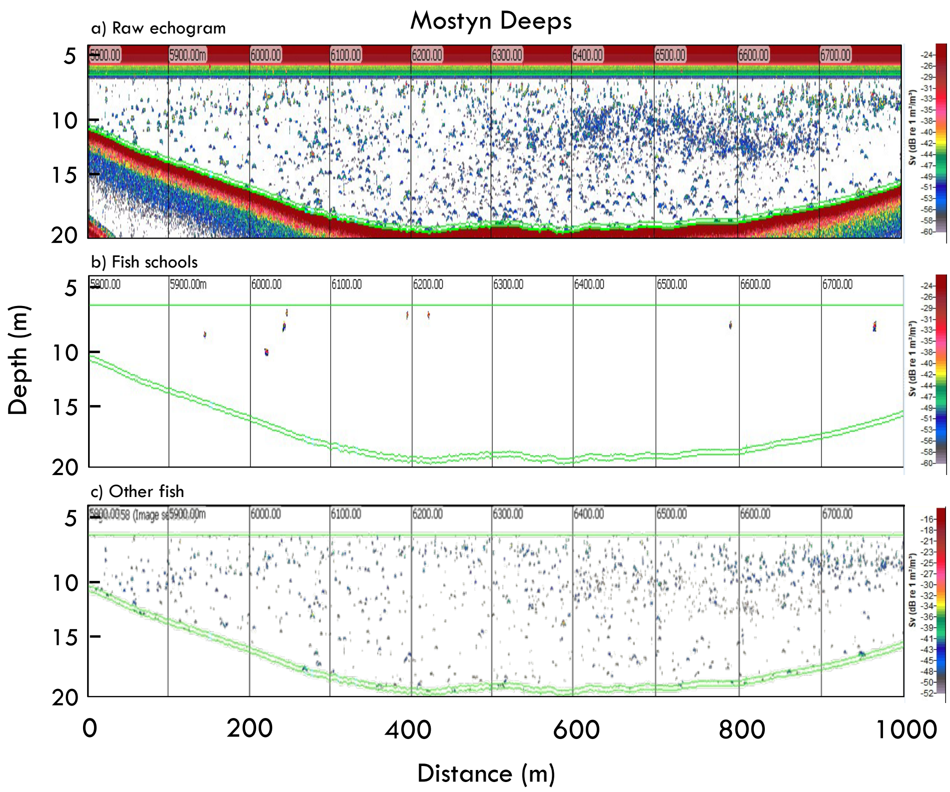

Figure 16. Example echograms from the Mostyn Deeps of the Dee estuary acoustic survey in August 2021. a) raw data; b) data processed to extract fish schools; c) other fish. Colour coding is according to legend on the right with the threshold set at the lowest value. Thick green line is the seabed, thin line is a 0.5 m buffer.

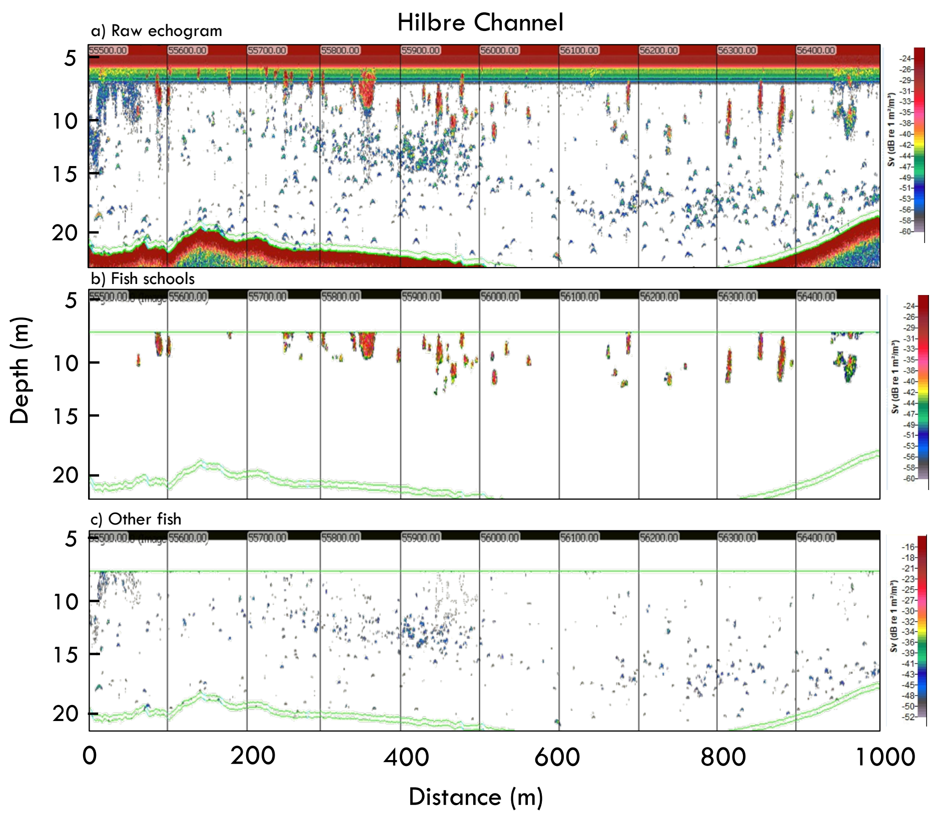

Figure 17. Example echograms from the Hilbre Channel, Dee estuary (see Figure 6 caption for details).

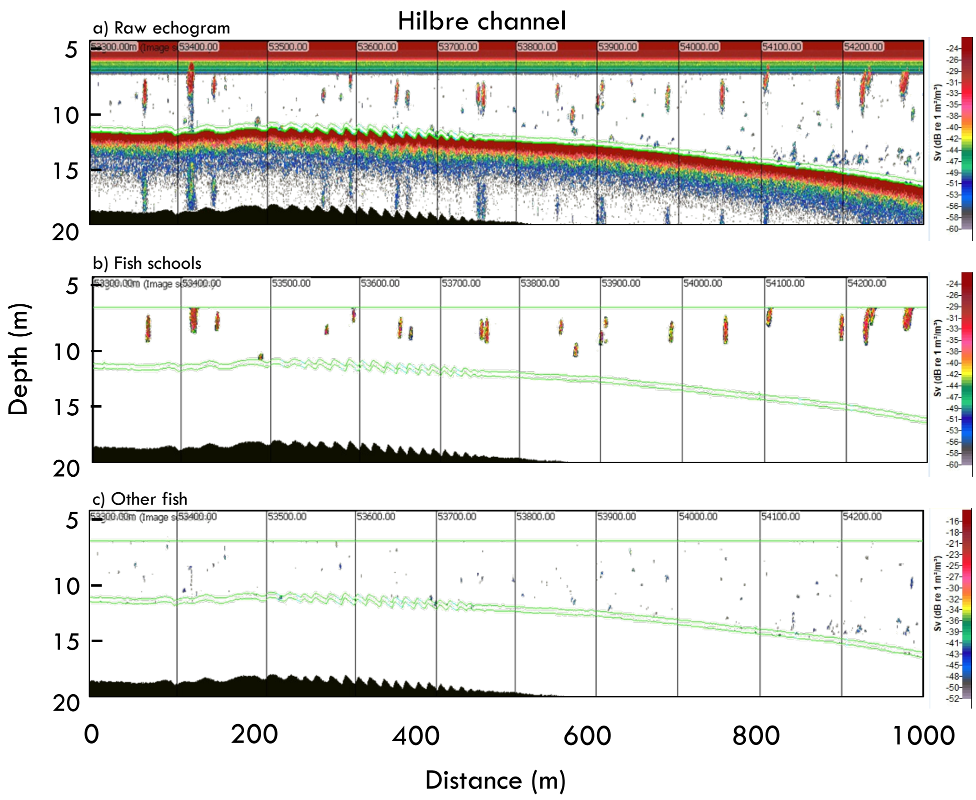

Figure 18. Example echograms from the Inshore stratum, Dee estuary (see Figure 6 caption for details).

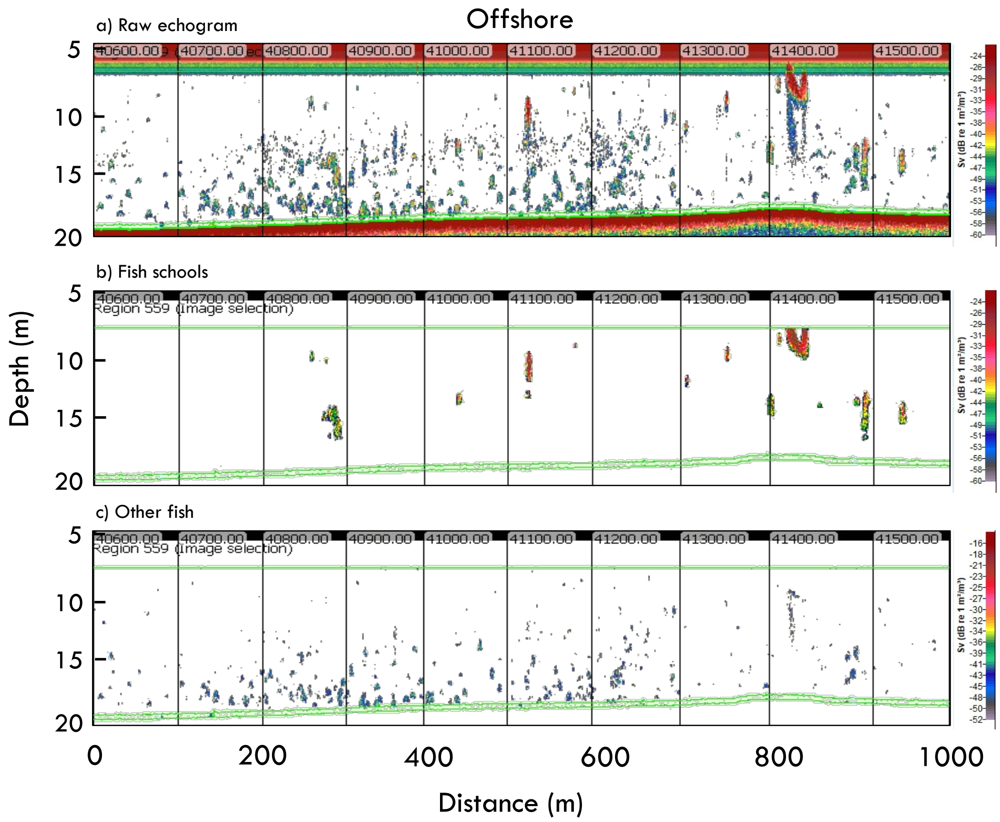

Figure 19. Example echograms from the offshore stratum, Dee estuary (see Figure 6 caption for details).

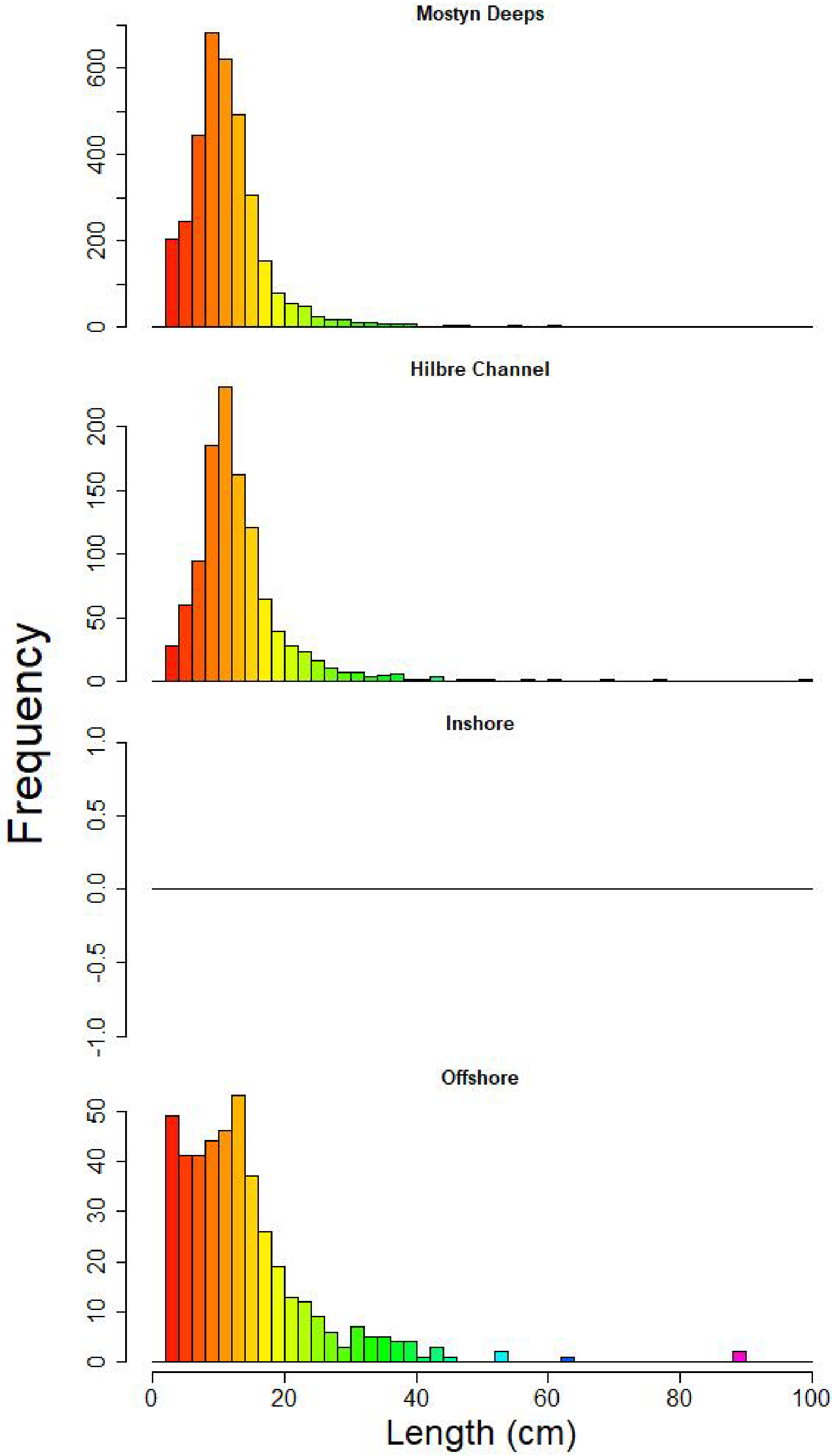

Figure 20. Inferred fish length (L) distributions by stratum in the Dee acoustic survey August 2021, converted from measured Target Strengths (TS) from single echo detections and assuming a TS/L relationship (Equation 1) where b_{20}=67.5.

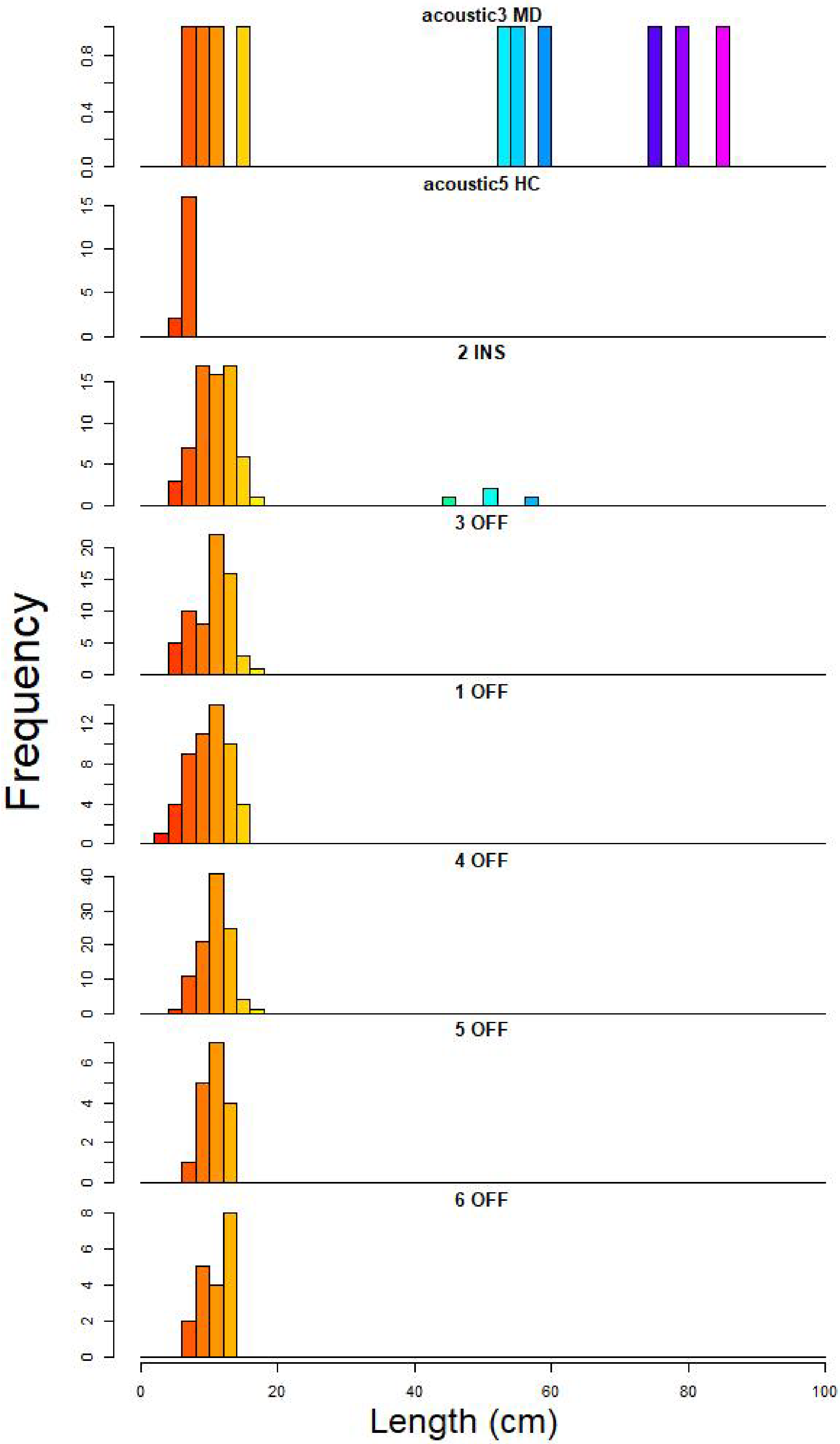

Figure 21. Length distributions of measured pelagic fish by trawl haul and stratum in the Dee acoustic survey August 2021.

Table 7. Trawl haul information from the Dee estuary acoustic and trawl surveys conducted in August 2021, with numbers of fish species caught that were considered to be potentially pelagic.

Station	Date	Start time (BST)	End time (BST)	Longitude (decimal°)	Latitude (decimal°)	Depth (m)	Stratum	Atlantic Herring	Atlantic Mackerel	Greater Sand Eel	Lesser Sand Eel	Lesser Spotted Dogfish	Lesser Weaver	Sprat	Starry Smooth Hound	Whiting
1	29/08/2021	10:41	11:01	-3.387	53.396	NA	OFF	5	0	0	2	0	24	0	0	22
2	28/08/2021	06:26	06:46	-3.356	53.383	5	INS	0	0	0	1	1	54	0	3	12
3	28/08/2021	07:13	07:36	-3.305	53.402	8	OFF	0	0	0	2	0	60	0	0	3
4	29/08/2021	09:55	10:16	-3.336	53.421	NA	OFF	4	0	0	8	0	71	0	0	21
5	29/08/2021	07:27	07:45	-3.234	53.425	NA	OFF	0	0	0	0	0	9	0	0	8
6	29/08/2021	08:35	08:56	-3.268	53.446	NA	OFF	0	0	0	0	0	12	0	0	7
Acoustic 3	28/08/2021	10:17	10:36	-3.307	53.362	17	MD	0	0	0	0	2	1	0	4	3
Acoustic 5	28/08/2021	15:05	15:25	-3.232	53.371	14	HC	0	0	0	0	0	0	18	0	0
Acoustic 4	28/08/2021	11:58	11:18	-3.404	53.375	5	OFF	0	0	0	0	0	0	0	0	0

In keeping with the distributions of SED's (Figure 20), catches of the largest fish (up to 85 cm) were in the Mostyn Deeps. All fish larger than 20 cm (n=10) were either Lesser spotted dogfish or starry smooth-hound.

4.2 Abundance & biomass estimates

The total abundance of fish in the area was 398 million fish, comprised of 394 million clupeids (sprat and herring) and 4 million other fish (mostly whiting and lesser weaver fish, and a number of dogfish and smooth-hounds). The estimate of biomass was 1,264 tonnes (t), 1,014 t of clupeids and 250 t of other fish. Table 8 provides a breakdown of these estimates by stratum. The abundance and biomass were highest in the offshore area by virtue of its large size. The smaller area of the Hilbre Channel had significant quantities of clupeids whereas the Mostyn Deeps had virtually none. Other fish were also more prevalent by weight in the Offshore area, but the Mostyn Deeps had significant quantities by weight (Table 8) and over double that of the Hilbre Channel.

Estimates of numbers of other fish at length are given in Figure 22. Numbers were dominated by small fish less than 12.5 cm, which were probably dominated by whiting or lesser weaver. Estimates of biomass of other fish at length are given in Figure 13. The biomass was had two peaks: small fish sized fish between 7.5 cm and 27.5 cm, which were probably lesser weaver and whiting; and large fish, greater than 30 cm almost certainly starry smooth-hound (*Mustelus asterias*) and lesser spotted dogfish (*Scyliorhinus canicula*).

Table 8. Estimates of fish abundance from the Dee estuary acoustic survey in August 2021, by species groups and strata (See Figure 2 for strata definitions). Clupeids represent sprat (Sprattus sprattus) and herring (Clupea harengus); other fish represent unidentified fish, likely candidates of which are the small gadoids such as whiting (Merlangius merlangus), the lesser weaver (Echiichthys vipera), and larger fish such as the starry smooth-hound (Mustelus asterias) and lesser spotted dogfish (Scyliorhinus canicula). Length compositions of these other fish are given in Figure 22 and Figure 23. Abundance is given in number (N in millions) and biomass (tonnes).

Clupeids (sprat and herring)					
Stratum	Area (m^2)	Density ($N.m^{-2}$)	N (millions)	Dens ($kg.m^{-2}$)	Biomass (t)
Mostyn Deeps	9258854	0.243799	2.3	0.000628	5.8
Hilbre Channel	7949060	19.281009	153.3	0.049637	394.6
Inshore area	39937888	Not surveyed in August 2021			
Offshore area	67104700	3.551978	238.4	0.009144	613.6
Total			394.0		1014.0

Other fish					
Stratum	Area (m^2)	Density ($N.m^{-2}$)	N (millions)	Dens ($kg.m^{-2}$)	Biomass (t)
Mostyn Deeps	9258854	0.22323	2.07	0.009959	92.2
Hilbre Channel	7949060	0.096222	0.76	0.00539	42.8
Inshore area	39937888	Not surveyed in August 2021			
Offshore area	67104700	0.018949	1.27	0.001712	114.9
Total			4.1		249.9

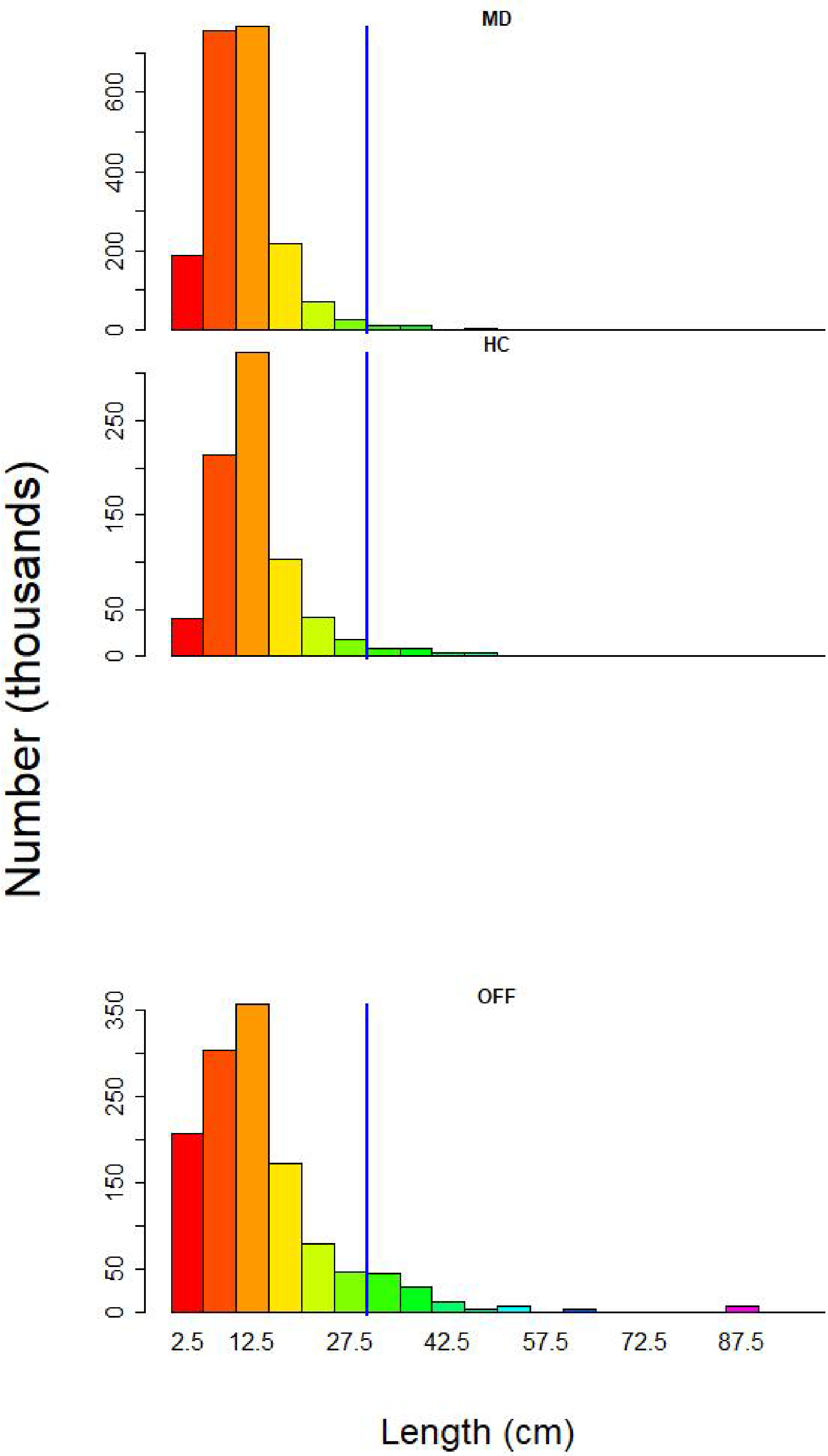

Figure 22. Estimates of total numbers of other fish at length by stratum. Blue vertical line is at 30 cm: all fish greater than this size caught in the trawls were either starry smooth-hound (Mustelus asterias) or lesser spotted dogfish (Scyliorhinus canicular).

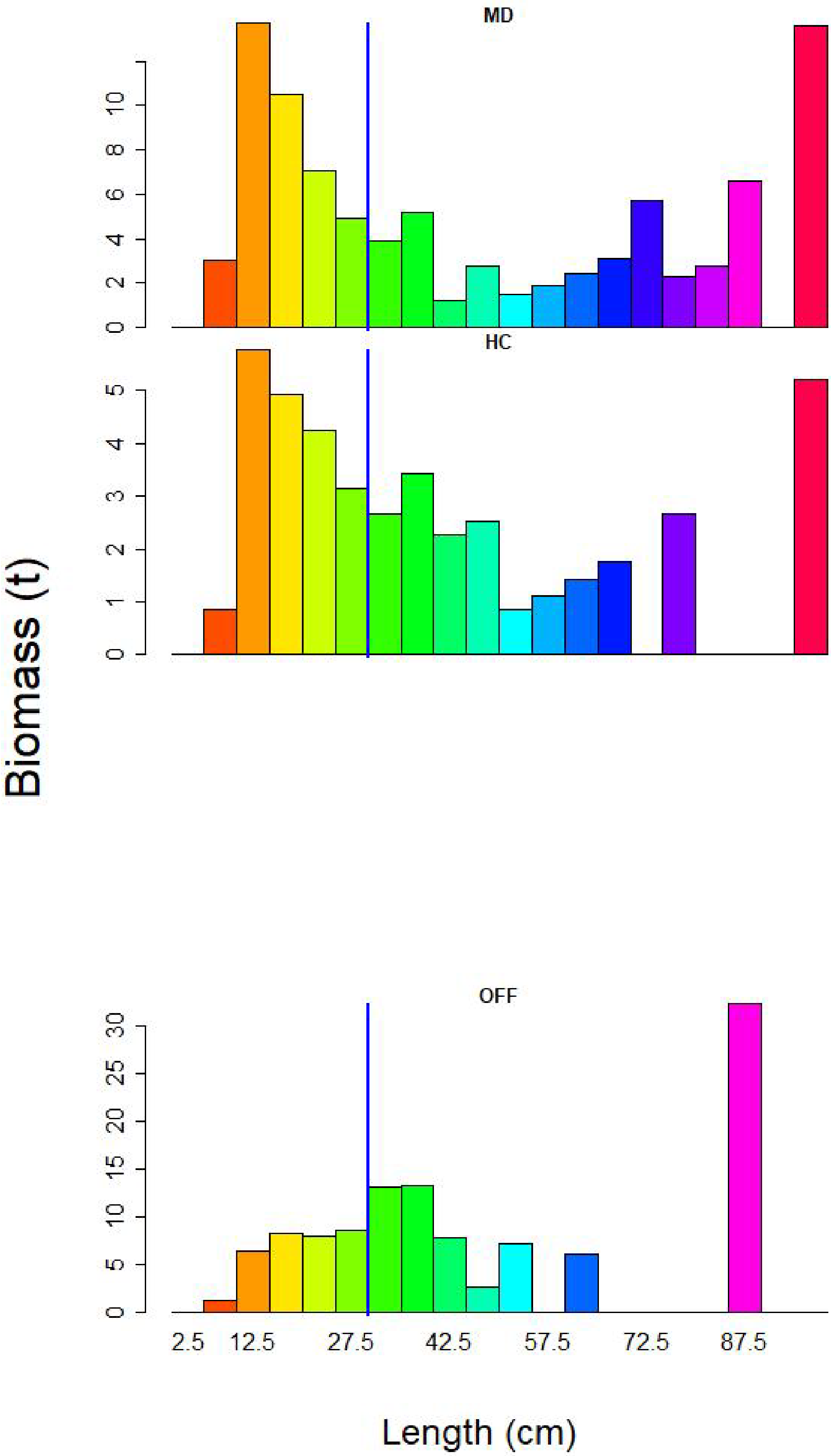

Figure 23. Estimates of total biomass of other fish at length by stratum. Blue vertical line is at 30 cm: all fish greater than this size caught in the trawls were either starry smooth-hound (Mustelus asterias) or lesser spotted dogfish (Scyliorhinus canicular).

5 Discussion

The survey estimates of number and biomass, in both May and August, were dominated by clupeids. Sprat and herring were caught in very small numbers in the trawl hauls, but the schools that were detected are very characteristic of these fish. Trawl hauls were directed towards the schools, but because the trawl was a bottom trawl, and the schools were, on average at about 8 m depth (Table 3 and Table 6), the chances of catching them were slim. Nonetheless, when the trawl was directed towards large concentrations, such as those in the Hilbre Channel, sprat, and virtually little else that could be pelagic, were caught (Table 4 and Table 7). A single Atlantic herring was also caught in May and five in August, so there was some alternative evidence that these were sprat and/or herring schools. Sadly, none of the visual methods deployed (live viewing underwater camera and under water video cameras) yielded any information due to the extreme turbidity and marine snow in the water. Alternative net sampling methods (pelagic trawl) are being sought for future surveys.

The Irish Sea contains a large population of sprat and herring. Using virtually identical methods (similar equipment, same assumptions about target strength to length and similar allocation of species to fish school echotraces), an acoustic survey of the Irish Sea, carried out in 2021, estimated the total biomass of herring to be 101,253 t and sprat to be 156,200 t (ICES, 2021). The area surveyed encompassed about 3086 km2, so the approximate mean biomass density of clupeids in the Irish Sea was about 0.01 kg.m-2. This is remarkably similar to the biomass density in the Mostyn Deeps and Hilbre Channel in May (Table 5), and to a lesser extent to the higher densities in Hilbre Channel in August (Table 8), which gives some confidence to the estimates here.

Other fish in the bottom trawl catches were dominated by whiting in May and by whiting and lesser weever in August. Whiting were once abundant in the Irish Sea, but the population has been at historically low levels for over 20 years now. The latest estimates put the population biomass at about 1393 t. Small whiting would be difficult to distinguish from other small fish such as the lesser weever, which was also caught in reasonable numbers and has been known to leave the seabed for feeding, despite being predominantly demersal (Vasconcelos *et al.*, 2004). However, the lesser weever has no swimbladder, so it was unlikely to scatter much sound relative to the whiting. Most of the fish detected here, less than 30 cm were probably whiting.

All fish greater than 30 cm, were either starry smooth-hounds or lesser spotted dogfish. The acoustic data suggest a reasonable biomass associated with larger targets consistent with fish greater than 30 cm (Figure 13 and Figure 23). Data from several international surveys, indicate that smooth-hound abundance has been steadily increasing since 1997 (ICES, 2019a), although no absolute estimate is provided. Similarly, abundance of the lesser spotted dogfish has also been increasing both in the North Sea (ICES, 2019b) and the Irish Sea (ICES, 2019c). So it is not unexpected to see low numbers but high biomass here.

Finally, there was a notable difference in the composition of fish in the Mostyn Deeps between the two surveys. In both months, other fish were prevalent in this particular deep channel, but fish schools, or clupeids, were almost entirely absent from there in August. However, the total amount of clupeids was similar between in the two months, but in August they were largely contained in the Hilbre Channel.

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