Beatrice Offshore Wind Farm

Pre-construction Baseline Herring Larval Survey - Technical Report

January 2016

Beatrice
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Beatrice Offshore Wind Farm

Herring Larval Survey Results – Technical Report

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1 Executive Summary

This pre-construction Monitoring Report has been prepared by Brown and May Marine Ltd (BMM) on behalf of Beatrice Offshore Windfarm Ltd (BOWL) to inform the Project Environmental Monitoring Programme (PEMP) required as part of the Section 36 Consent. This report describes the pre-construction element of s36 condition 27 in relation to herring and will be used to part discharge this condition, and fully discharge s36 condition 34 (requirement for herring surveys).

The herring larvae survey methodology was designed in consultation with Marine Scotland Science (MSS) and Marine Scotland Licensing and Operations Team (MS-LOT) and replicated the BOWL herring larvae survey undertaken in 2014. 25 stations were sampled every week, weather permitting, for 8 weeks (3rd August to 27th September 2015), using a Gulf VII high speed plankton sampler.

A total of 603 herring larvae were recorded during the survey. No herring larvae were caught in sampling weeks 1, 2 and 3 and no sampling was undertaken in week 5 due to adverse weather. The lowest abundance of herring larvae occurred in sampling week 4, and the highest occurred in weeks 6 and 8 (34.3% and 30.7% of the total catch, respectively) with 84.7% of the total catch recorded in weeks 6, 7 and 8 combined, indicating a distinct spawning period. The back-calculation of larval hatch date and spawning stock indicate that peak spawning period (in respect to hatching larvae) occurs in the first two weeks of September, with the highest hatching intensity estimated to be at the beginning of the second week of September. Based on these dates, the peak in adult herring spawning occurred at the end of August.

The majority of herring larvae caught over the period of the survey were ≥10mm (71.3%) with over 20% of the total catch in the size class 10.0 - 10.9 mm. This size class is not considered to be early stage larvae, indicating that larvae have drifted down from the well established spawning grounds in Orkney and Shetland waters. The spatial distribution of larvae by length shows that smaller larvae were caught in the north of the sampling area whereas larger larvae were in the south, indicating that larvae are being transported in a southerly direction from north of the sampling area.

The stations where the highest abundances of larvae were caught were to the north and to the east of the development area. The data from five years of International Herring Larvae Surveys (IHLS) found comparatively low numbers of herring larvae <10mm (n/m^2) in the vicinity of the BOWL development area. The highest larval densities recorded by IHLS surveys were found north of the survey area, in and around Orkney and Shetland.

The smallest larvae caught during the survey were in the size class 7.0 - 7.9 mm. The back-calculation of larval age from length indicates that the mean age for this size class was calclulated as 6.11 to 8.47 days (incorporating the 6 day yolk sac absorption time). Using the residual velocity data, larvae in this size class could travel a minimum distance of 6 – 18 km in that time period, using conservative estimates, and a maximum of 52 - 72 km. This suggests that even the smallest larvae caught during the survey may have drifted down from the Orkney and Shetland spawning grounds.

2 Introduction

This pre-construction Technical Report has been commissioned by Beatrice Offshore Windfarm Ltd (BOWL) to inform the Project Environmental Monitoring Programme (PEMP) required as part of BOWL's Section 36 Consent.

This report describes the pre-construction element of s36 condition 27 (PEMP) in relation to herring and will be used to part discharge this condition and fully discharge s36 condition 34 (requirement for herring surveys). This report has been prepared by Brown and May Marine Ltd (BMM).

The report details the findings of the herring larval survey undertaken between 3rd August and 27th September 2015 within the 90 dBht ranges modelled for herring for the BOWL development area. A previous survey was undertaken in August and September 2014 following the same methodology (BOWL, 2014).

The report addresses the following objectives:

- Collect data comparable with that produced by the ICES International Herring Larvae Surveys (IHLS; ICES, 2008);
- Collect data on the spatial and temporal distribution of herring larvae in the vicinity of the BOWL development area;
- Determine the level of spawning activity in and around the BOWL development area; and
- Collect data to inform a potential mitigation strategy for piling noise effects on spawning herring

The survey methodology (LF000005-REP-147 - BOWL Herring Larval Survey Methodology) was agreed with MSS and MS-LOT in July 2014 (Meeting at Marine Scotland, Aberdeen. A. Ford, E. Hatfield 15/07/2014). It was agreed with MSS that the data analysis would be supported by relevant published examples (S. Lusseau, 07/11/2014) with the back-calculation methodology, as given in the 2014 report, approved by MSS (I. Davies, 07/01/2015). In line with best practise, the survey was undertaken using a Gulf VII high speed plankton sampler at 25 sampling locations each week for 8 weeks, weather permitting.

A dispensation from MSS, in accordance with the terms of Section 9 of the Sea Fish Conservation Act 1967 and Article 43 of Council Regulation No. 850/98 related to days at sea, was obtained prior to commencement of this survey.

A summary of the Health and Safety performance of the survey is provided in the Appendix (section 9.1).

3 Background

The North Sea herring stock is comprised of four sub-stocks based on areas used for spawning (Figure 3.1), characterised by different spawning times, growth rates, migration routes and recruitment patterns (Dickey-Collas *et al.*, 2010). The sub-stock relevant to the Moray Firth is the Orkney/Shetland stock, which spawns in Shetland/Orkney waters and off the north-east coast of Scotland.

3.1 Life History

According to Coull *et al.* (1998) the Orkney/Shetland stock spawns between August and September. Herring shoals are considered to arrive at traditional spawning grounds in a series of waves (Lambert, 1987). The physical characteristics of herring spawning grounds are well documented, being characterised by coarse substrates in high energy environments. Due to the substrate specific habitat requirements, spawning grounds are reasonably well defined (Blaxter, 1985; Keltz & Bailey, 2010; Rockmann *et al*., 2011). However, spawning intensity can be highly variable between years.

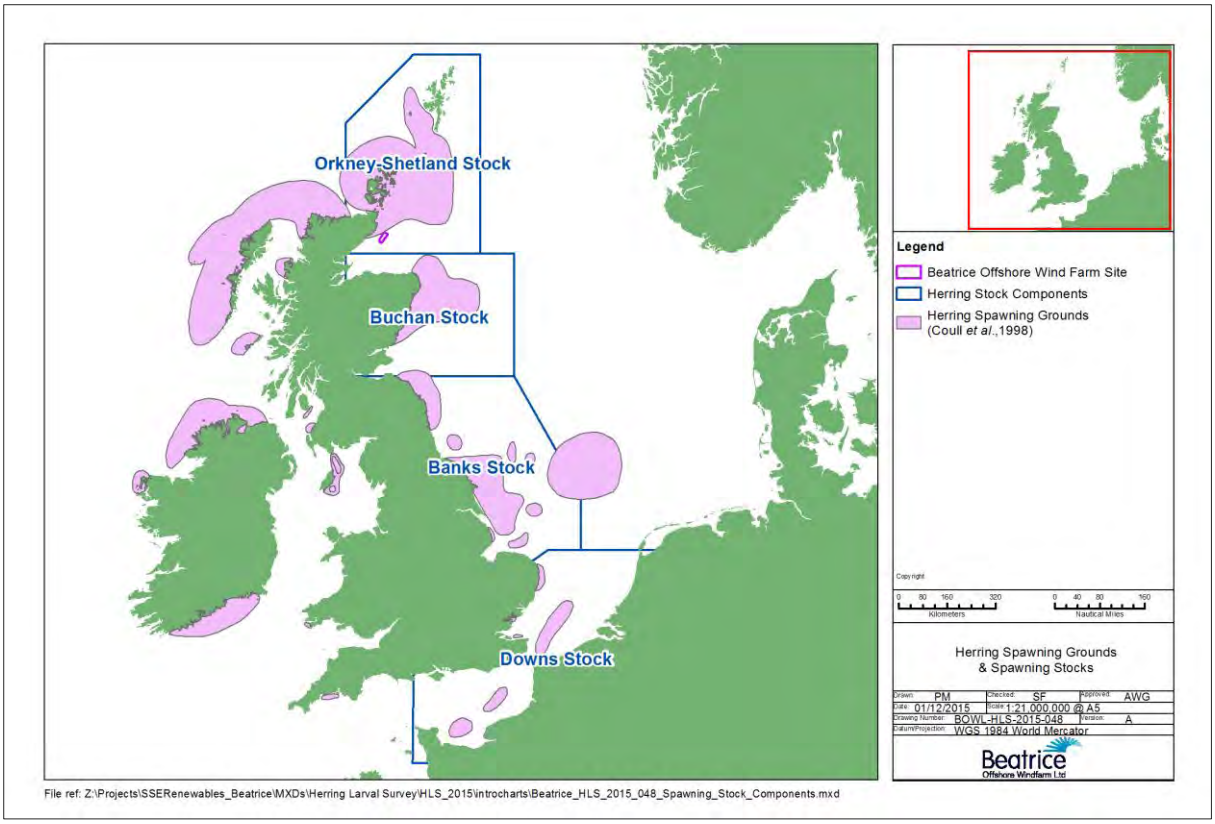

Figure 3.1 Spawning components of North Sea herring stock

North Sea herring are synchronous batch spawners where the females lay mats of benthic sticky eggs directly onto the seabed in areas of coarse sand, gravel, small stones or rocks (Geffen, 2009; Keltz & Bailey, 2010). Herring larvae hatch 10 – 20 days after fertilisation, depending on sea temperature (Hodgson, 1957; ICES, 2014; Kiorboe *et al*., 1985; Keltz & Bailey, 2010). Newly hatched larvae from the Orkney/Shetland stock are considered to

measure between 6 - 8 mm and are dependent on their yolk-sac for 6 - 10 days until the yolk is reabsorbed and the larvae begin to feed on small zooplankton (Blaxter, 1968; Fassler *et al*., 2011; Heath, 1993; Hodgson, 1957).

The distribution of early stage larvae determined from herring larval surveys is used to infer the spatial and temporal coverage of herring spawning grounds in active use (Ellis *et al*., 2012). The IHLS surveys have been regularly undertaken in the North Sea since 1972.

Charts of herring spawning grounds are presented in Ellis *et al*. (2010, 2012) and Coull *et al*. (1998). These are the standard references frequently used for the impact assessment of offshore developments on fish spawning in UK waters (Figure 3.2). It should be noted that the spatial distribution of larval densities in the North Sea, described in Ellis *et al*. (2010, 2012) is based on a single year of 2008 IHLS survey data for all herring larvae up to 24 mm in length. The data does show lower larval densities in the vicinity of the BOWL development area in comparison to larval abundances recorded to the north and east of Orkney and Shetland. This is supported by a review on larval distribution carried out by Sinclair & Power (2015) where the ICES IHLS data was used to analyse the observations on the distribution of different sizes of larvae (Figure 3.3). The spatial distribution of abundance of different length classes were used to estimate a centre of mass (CoM) for each year. The results of the study indicated that the spatial patterns of <10 mm herring larvae were relatively consistent across decades (Sinclair & Power, 2015).

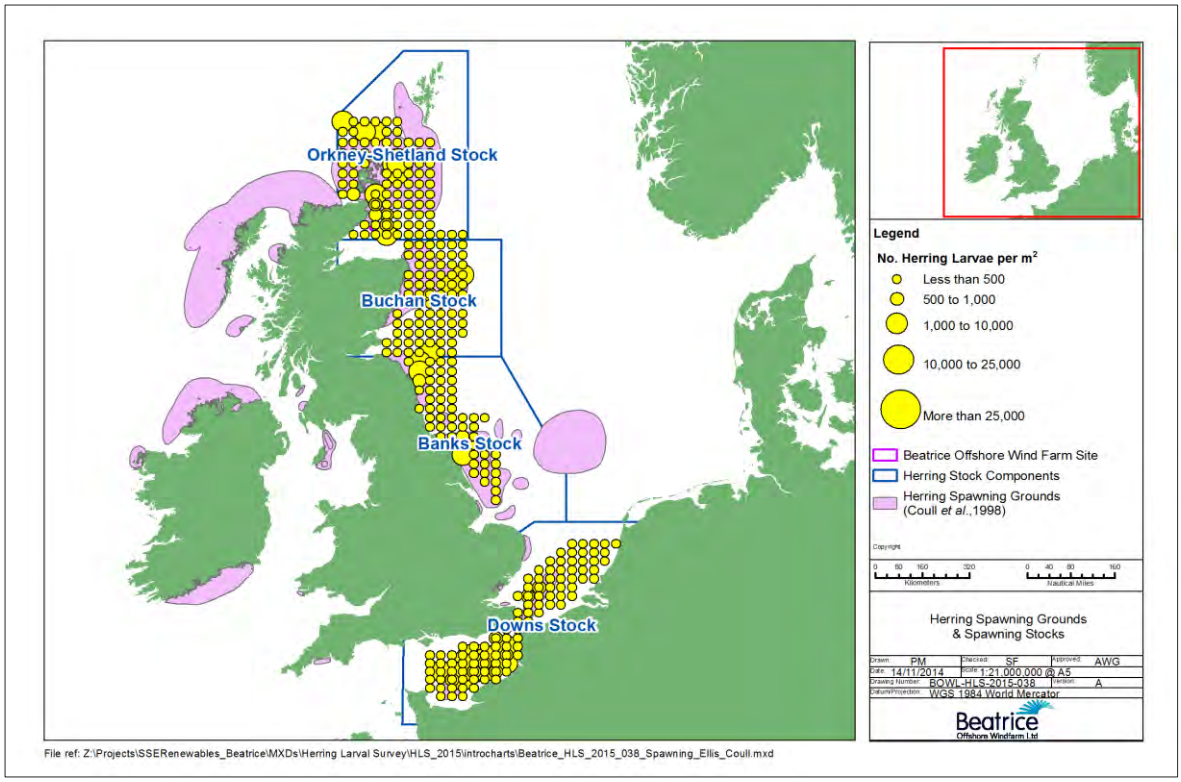

Figure 3.2 Herring spawning grounds presented in Coull *et al*. (1998) and Ellis *et al*. (2010)

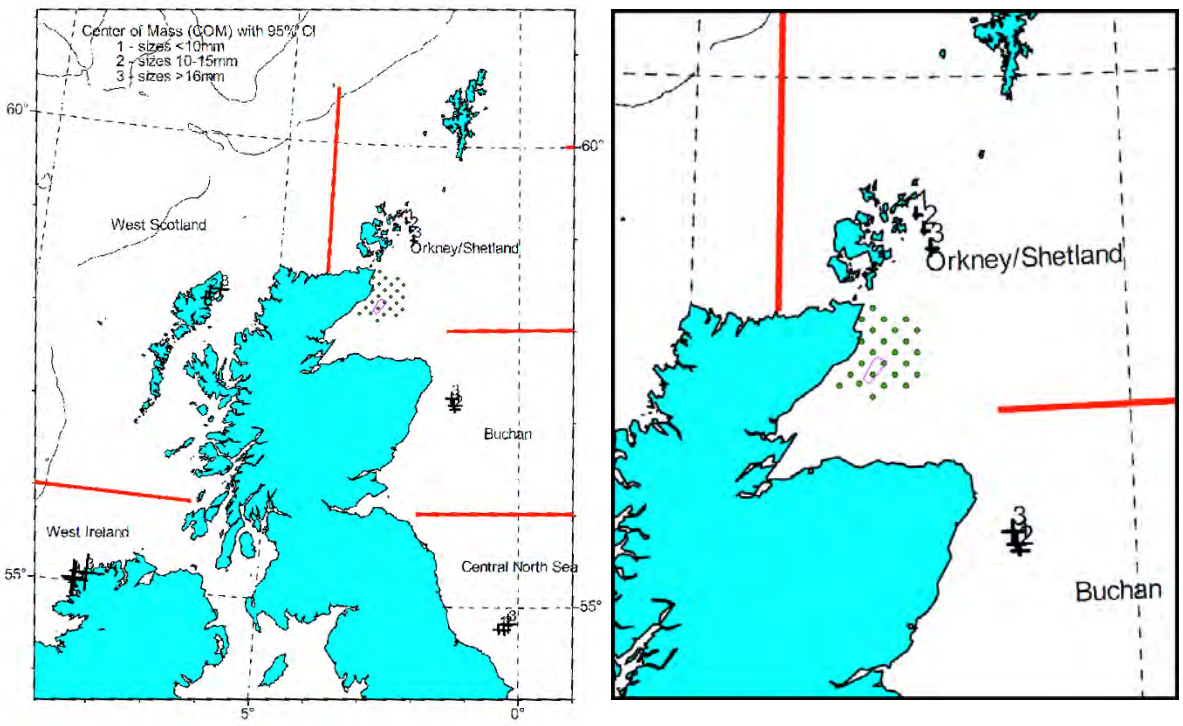

Figure 3.3 Mean locations of the annual CoMs for length classes of larvae from spawinng areas within the North Sea (with 95% confidence limits shown) with the BOWL development area and survey locations overlaid (Source: Sinclair & Power, 2015)

3.2 Hydrodynamics

Studies examining patterns of larval drift have shown that herring larvae from the Orkney/Shetland stock drift south into nursery grounds in the Moray Firth and east into nursery grounds in the Skagerrak and Kattegat (Figure 3.4, Nichols, 1999). Heath *et al.* (1989) found that herring larvae from a spawning site at Clythness in the Moray Firth had drifted from the spawning grounds at a rate of 1-2 km/day. This is a conservative value in comparison to estimates from a recent hydrodynamic study by Guerin *et al*. (2014). As part of the study an overview of the major oceanic and coastal currents in the North-east Atlantic and the North Sea was produced (Figure 3.5), with approximate mid-range estimates of residual current velocity derived from the literature (Baxter *et al*., 2011; UKMMAS, 2014; Turrell *et al*., 1990).

The currents relevant to the BOWL development area are currents 4 (Fair Isle current - West of Orkney) and 5 (Fair Isle current – North Sea) in Figure 3.5, with residual velocities of 7 cm/second and 10 cm/second respectively. This is equivalent to 6.0 km/day (current 4) and 8.6 km/day (current 5).

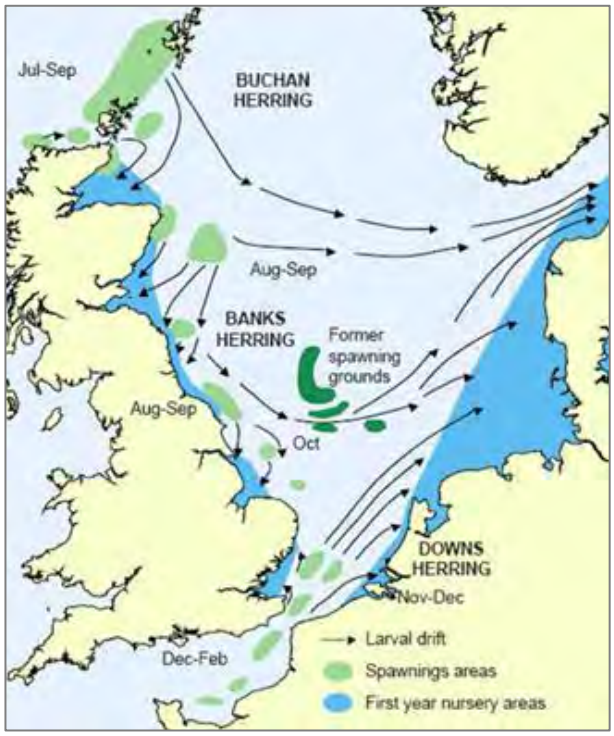

Figure 3.4 The spawning areas and spawning periods of the North Sea autumn spawning sub-populations showing larval drift to nursery grounds (Source: Nichols, 1999)

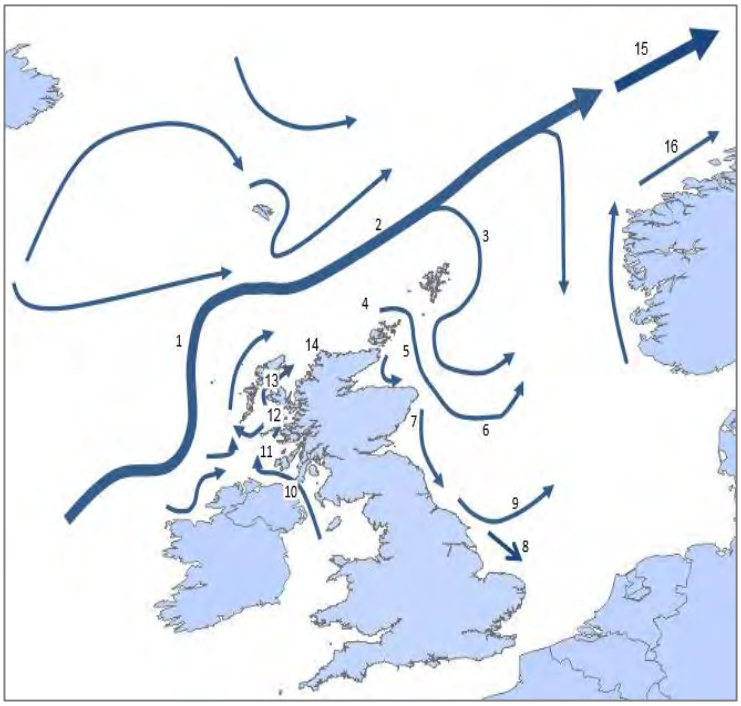

Figure 3.5 Schematic representation of the major oceanic or coastal currents in the North East Atlantic and the North Sea, modified from Baxter *et al*. 2011.

3.3 International Herring Larval Survey (IHLS)

The ICES programme of IHLS surveys in the North Sea has been in operation since 1967. The IHLS surveys are undertaken to provide quantitative estimates of herring larval abundance in order to inform the herring spawning stock biomass assessment (ICES, 2013). Sampling stations are allocated in a 10 by 10 nautical mile grid resulting in 9 smaller grid squares (labelled alphabetically from “a” to “i”) within each ICES rectangle. Further details of survey procedures can be found in the IHLS manual (ICES, 2008). It should be noted that the North Sea IHLS surveys are subject to variable coverage, with some spawning areas undertaken only once per year.

The IHLS surveys only give an indication of herring larval abundance in the first two weeks or last two weeks of September and for the past 20 years data has predominantly been collected from only the last two weeks of September in the Moray Firth. The distribution of herring larvae in recent years (2006-2008) is provided in Schmidt *et al*. (2007, 2008) and Rohlf & Groger (2009). IHLS findings for the previous five years (2010 – 2014) are given in Figure 3.7 to Figure 3.11. The IHLS data suggest that spawning activity in the Moray Firth is at significantly lower levels than that recorded further north off Orkney and Shetland, where the bulk of spawning of the Buchan stock takes place most years.

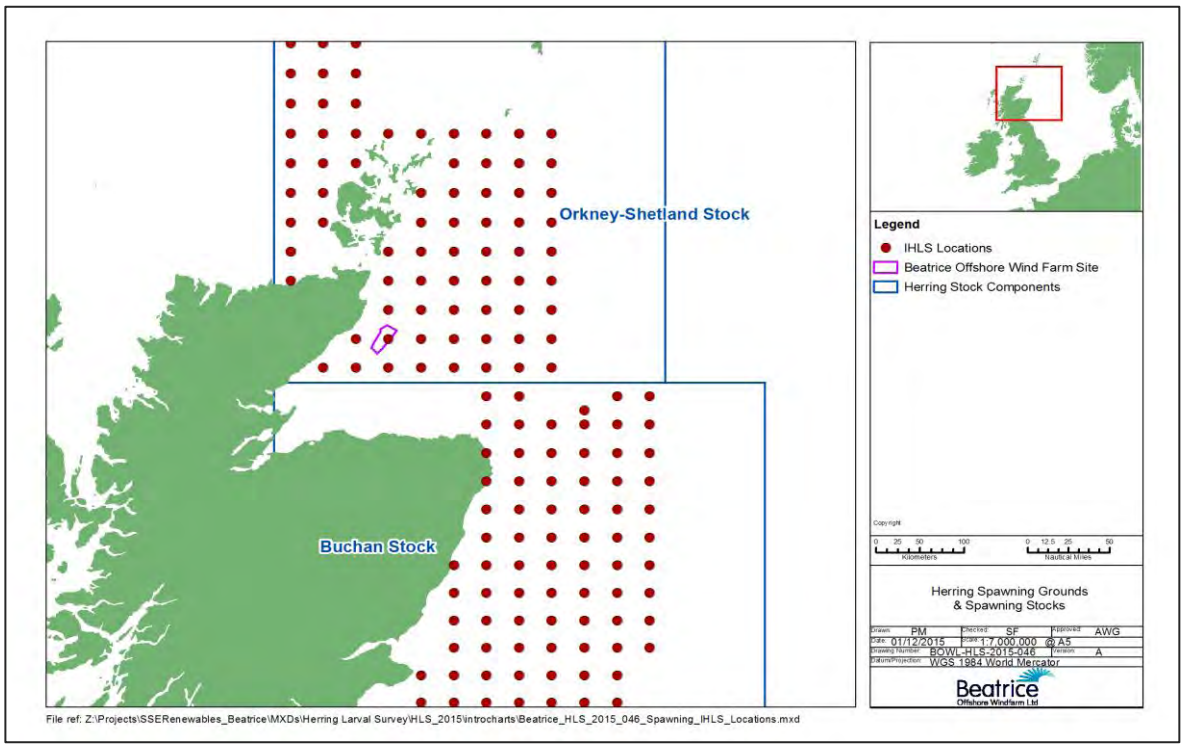

Figure 3.6 IHLS stations in the vicinity of the BOWL development area

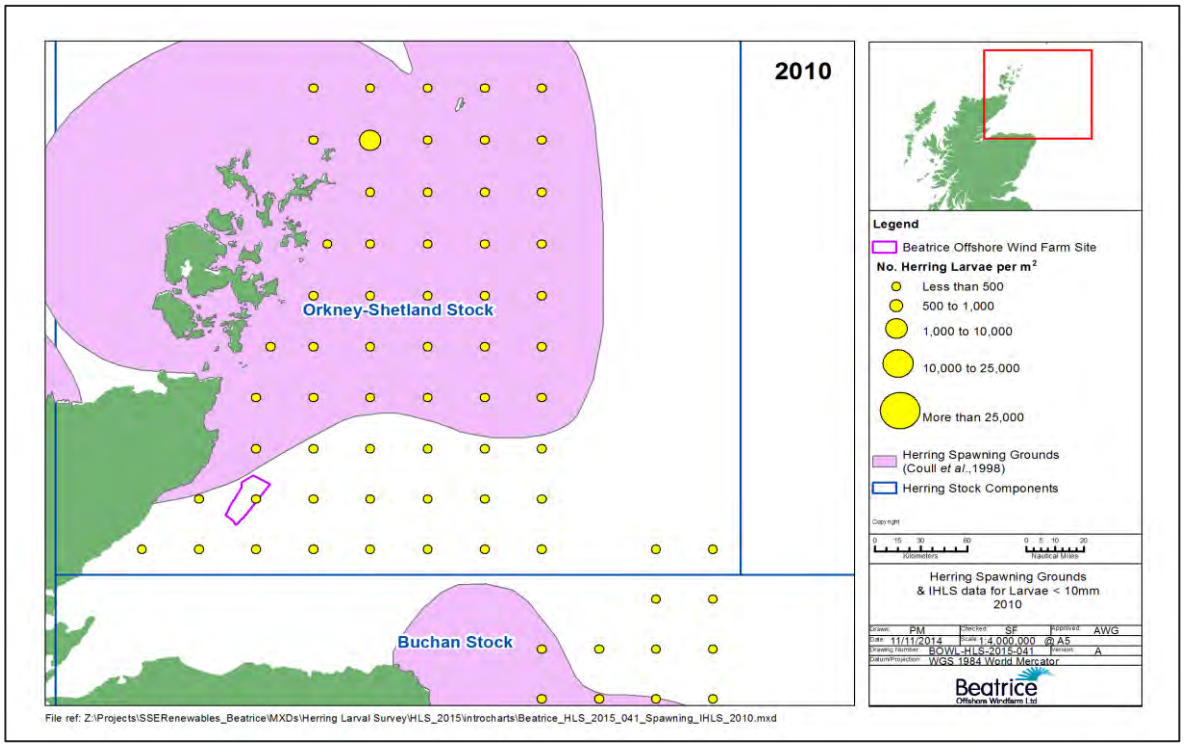

Figure 3.7 IHLS herring larvae (<10mm) abundance (n/m^2) 2010

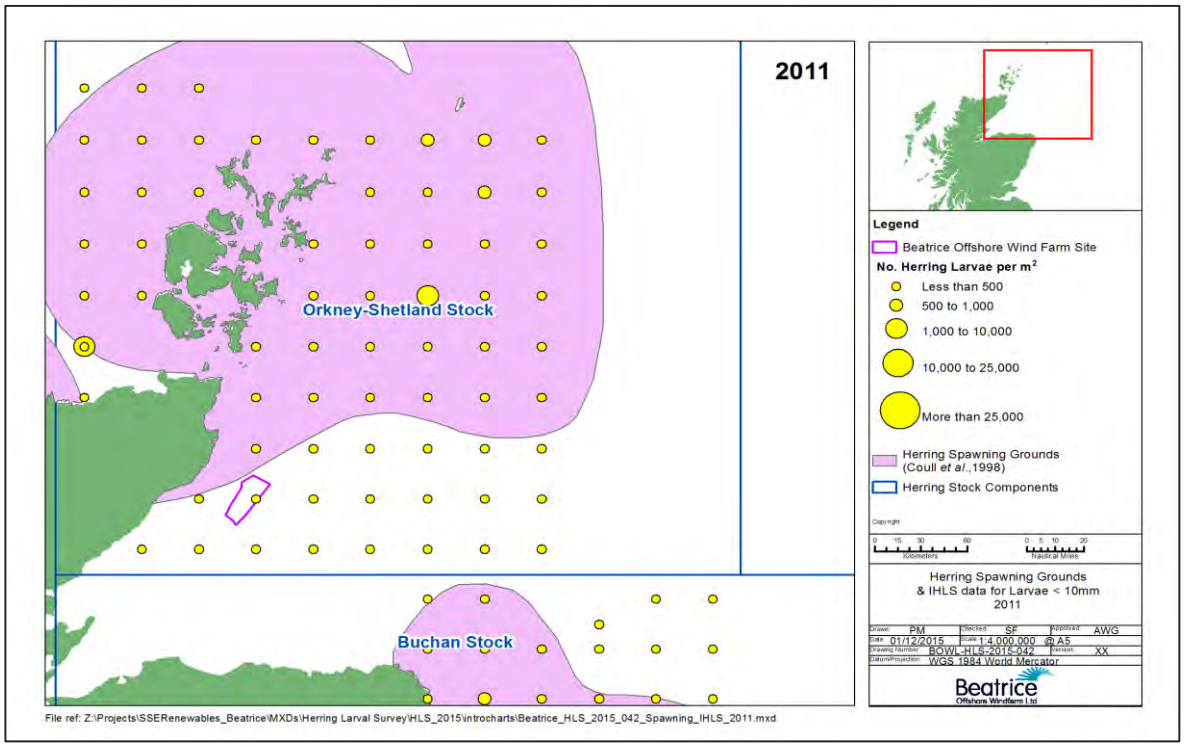

Figure 3.8 IHLS herring larvae (<10mm) abundance (n/m^2) 2011

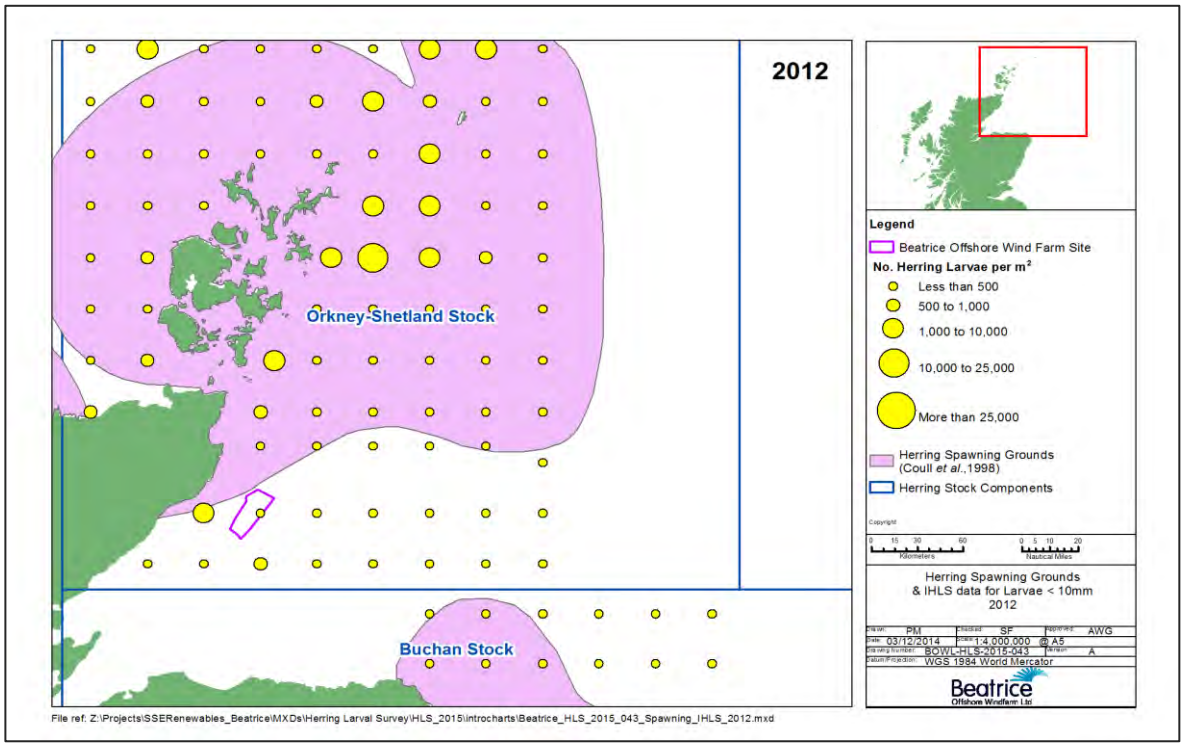

Figure 3.9 IHLS herring larvae (<10mm) abundance (n/m^2) 2012

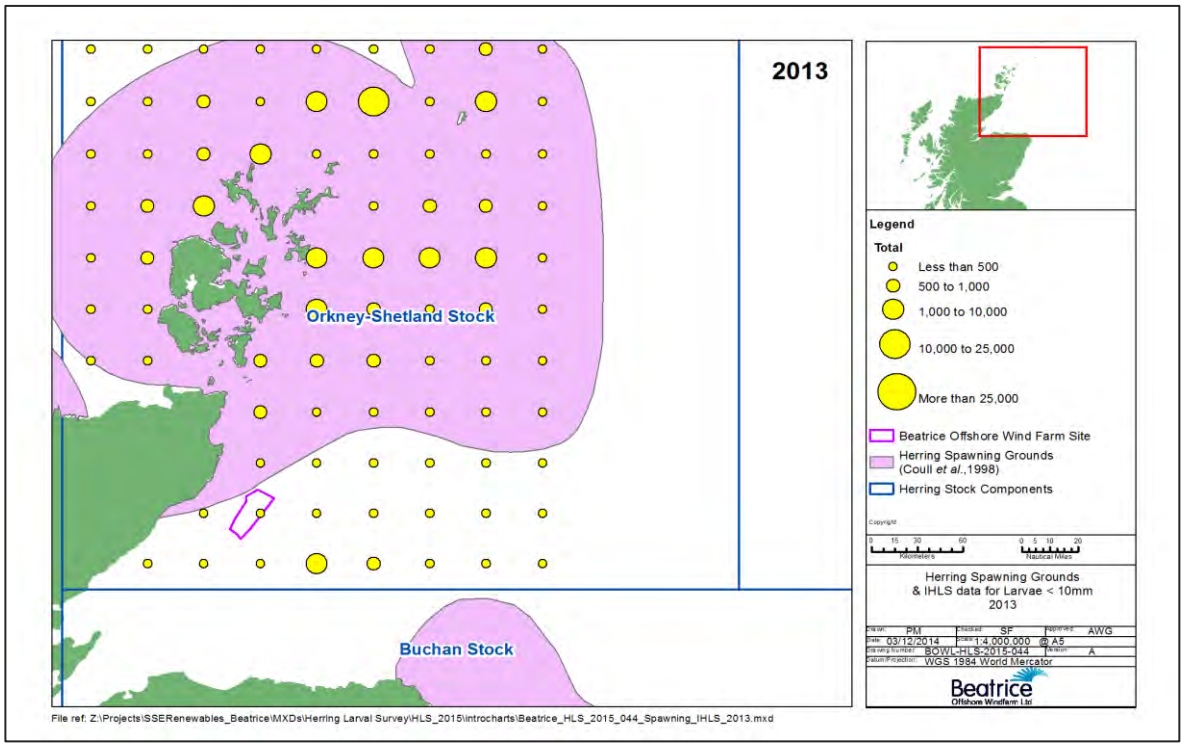

Figure 3.10 IHLS herring larvae (<10mm) abundance (n/m^2) 2013

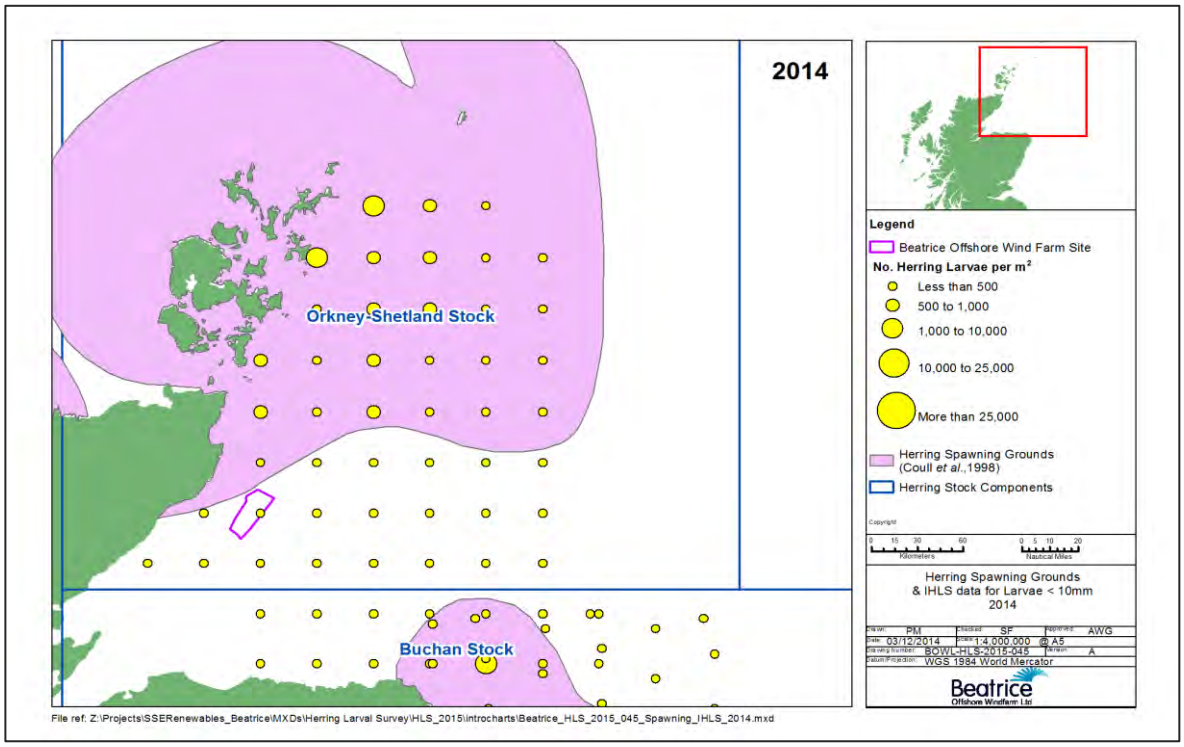

Figure 3.11 IHLS herring larvae (<10mm) abundance (n/m^2) 2014

4 Scope of Works

The scope of works for the BOWL herring larval survey are detailed below with the sampling stations illustrated in Figure 4.1. A grid formation was used to provide 25 sampling locations encompassed within the 90 dBht ranges modelled for herring and cross referenced with previous IHLS results and the area defined by Coull *et al.* (1998) as the Moray Firth herring spawning ground.

Accepting weather constraints, the objective was for sampling to be carried out during eight separate trips of four days duration, the first commencing 3rd August and continuing until 27th September 2015. A consistent sampling pattern was undertaken with the stations being sampled in the same order each week. A summary of the sampling design is provided below:

- Gulf VII high speed plankton sampler
  - 25 tows per week carried out in the same order for 8 weeks
- Sample analysis
  - Number of individuals by species
  - Length
- Data analysis
  - Sampling effort targeted at producing estimates of various life stages up to 10mm
  - Back calculations from length distributions will be undertaken to approximately determine peak spawning periods

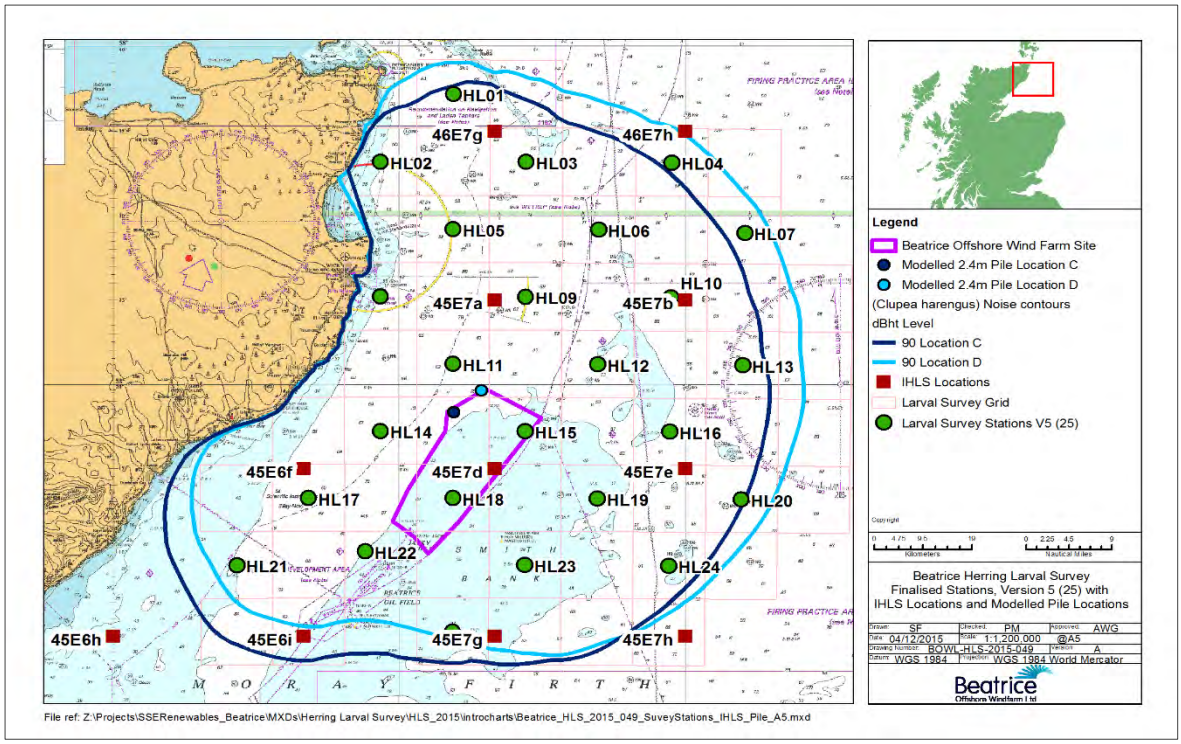

Figure 4.1 Sampling locations

5 Survey Methodology

The survey was undertaken from 3rd August to 27th September 2015. A summarised log of events is given in the Appendix (section 9.4).

The survey methodology was designed in consultation with MSS, using the IHLS standard methodology, to ensure adequate coverage of known spawning areas.

A dispensation from MSS, in accordance with the terms of Section 9 of the Sea Fish Conservation Act 1967 and Article 43 of Council Regulation No. 850/98, to fish in Area IVab related to days at sea was obtained prior to commencement of this survey.

5.1 Survey Vessels

Two vessels were chartered for the survey following discussions with Scottish Fishermen's Federation Services Ltd. (SFF). The fishing vessels Antaries (BF27; Figure 5.1) and Pleiades (BF155; Figure 5.2) undertook the sampling on a four week rotation.

5.1.1 Antaries (BF27)

Antaries (Figure 5.1) is a steel hulled, 16.70 metre, Fraserburgh based trawler. The specifications of the vessel are given below in Table 5.1.

Figure 5.1 Survey vessel Antaries

Table 5.1 Antaries vessel specifications

Survey Vessel Specifications	
Length	16.70m
Beam	6.45m
Draft	2.76m
Main engine	Caterpillar 3408-DITA-JW 363KW
GPS	2x Koden KGP-913D
Radar	JRC 5200 series (ARPA) & Koden MD3441
Plotters	Fishmaster Plotter and Trax Plotter
Sounder	Koden CVS8841
Berths	6

5.1.2 Pleiades (BF155)

Pleiades (Figure 5.2) is a steel hulled, 17.50 metre, Fraserburgh based trawler. The specifications of the vessel are given below in Table 5.2.

Figure 5.2 Survey vessel Pleiades

Table 5.2 Pleiades vessel specifications

Survey Vessel Specifications	
Length	17.50m
Beam	6.65m
Draft	3.07m
Main engine	Caterpillar 3408-480HP
GPS	Furuno SC50
Radar	Furuno Navnet Vx2 (ARPA & Ais modules); Furuno Navnet Vx2
Plotters	Fishmaster Plotter and Trax Plotter
Sounder	JRc-JFC 130
Berths	8

5.2 Sampling Gear

A Gulf VII high speed plankton sampler was used for sampling herring larvae with a plankton net with mesh size of 270µm. The amount of water filtered during each haul was measured using a General Oceanics flowmeter mounted inside the nosecone. An external flowmeter was mounted on the frame of the sampler. The sampler was fitted with a SAIV A/S SD204 probe to record conductivity, temperature and depth (CTD) measurements. An Applied Acoustics transponder was also fitted to give a real time feed of the sampler depth using an Applied Acoustics Portable Acoustics Modem (PAM 35 10). The transducer was deployed below the water surface using an aluminium pole attached to the side of the vessel to allow a clear 'line of sight' between the transducer and transponder.

The specifications of the Gulf VII plankton sampler are given below in Table 5.3. The Gulf VII used during the survey is shown in Figure 5.3.

Table 5.3 Gulf VII plankton sampler specifications

Gulf VII Plankton Sampler Specifications	
Frame size	50cm frame with tail fin
Nose cone	20cm
Scripps type depressor	20kg bronze
Drogue	1 standard form
Net	270 micron
Cod ends	Screw fit type
Flow meter	General Oceanics mechanical flowmeters (internal and external)
Deployment cable	9mm 6x36 IWRC galv rho 1960 grade MBL:5.76t
CTD probe	SAIV- A/S SD204
Transducer Control Box	Applied Acoustics PAM 35-10
Dunker	Applied Acoustics PAM 3 MF 3910
Beacon	Applied Acoustics 1019D

Figure 5.3 BMM Gulf VII plankton sampler

5.3 Sampling Procedure

Accepting weather constraints, sampling was carried out during eight separate trips of four days duration, the first commencing early August and continuing until late September. The 25 sampling locations are given in Figure 4.1. The sampling locations were encompassed within the 90 dBht ranges modelled for herring and cross referenced with previous IHLS results and the area defined by Coull *et al*. (1998) as the Moray Firth herring spawning ground.

At each station the Gulf VII high speed plankton sampler was deployed in a double oblique tow (V-shaped haul through the water column) to 3 – 5 metres above the sea floor. The standard towing speed was between 4 - 5 knots, directed into the tide. The cable pay out speed when shooting and hauling the sampler was continuous to ensure representative sampling at all depths. The cable pay out speed was such that each 10 metres of the water column was sampled for at least 1 minute.

5.3.1 Positioning and Navigation

The position of the vessel was tracked at all times using a Garmin GPSMap 278 with an EGNOS differential connected to an external Garmin GA30 antenna. Tow start times and positions were taken when the sampler makes contact with the sea surface and tow end times and positions were taken when the sampler returned to the surface. The vessel tracks whilst towing the sampler for each of the eight weeks are illustrated in the Appendix (section 9.6). The start and end times, co-ordinates and duration of each plankton tow are given in the Appendix (section 9.5).

For each station, information was logged on the station number, position, date and time, haul duration, internal and external flowmeter revolutions, bottom and sampler depth, water

bottom temperature and vessel direction of tow. The sampler depth was monitored continuously throughout the tow.

Due to weather constraints, it was was not always possible to undertake sampling at all stations each week. A summary of the number of stations completed each week is given in Table 5.4.

Table 5.4 Summary of Survey Stations Completed

Week	Stations completed	No. stations completed	Reason
1	24, 23, 25, 22, 21, 17, 14, 18, 15, 19, 16, 12, 09, 11, 08, 05, 01, 03, 06, 04, 07, 10, 13, 20	24	Static gear at station HL02
2	24, 23, 25, 22, 21, 17, 14, 18, 15, 19, 16, 12, 09, 11, 08, 05, 02, 01, 03, 06, 04, 07, 10, 13, 20	25	
3	24, 23, 25, 22, 21, 17, 14, 18, 15, 11, 09, 05, 03, 04, 07	15	Static gear at station HL02 and adverse weather conditions
4	24, 23, 25, 22, 21, 17, 14, 18, 15, 19, 16, 12, 09, 11, 08, 05, 01, 03, 06, 04, 07	24	Static gear at station HL02
5	-	0	Consistently poor weather conditions throughout week
6	24, 23,18, 14, 11, 08, 05, 03, 06, 04, 07, 10, 12, 16, 19, 20	16	Static gear at station HL02 and adverse weather conditions
7	24, 23, 25, 22, 21, 17, 14, 18, 15, 19, 16, 12, 09, 11, 08, 05, 01, 03, 06, 04, 07, 10, 13, 20	24	Static gear at station HL02
8	24, 23, 25, 22, 21, 17, 14, 18, 15, 19, 16, 12, 09, 11, 08, 05, 02, 03, 01, 06, 04, 07, 10, 13, 20	25	

5.3.2 Sample Retrieval and Preservation

After recovery of the Gulf VII sampler, the front of the sampler was raised to ensure the contents of the net washed down into the cod-end. The cod-end with the initial catch was removed. A second cod end was fitted and the net was very gently washed down with seawater. The sample was retrieved from the cod ends and preserved in screw top jars using 4% borax buffered formalin in seawater. The plankton volume did not exceed 20% of the jar volume on the advice of Marine Scotland and additional jars were used if required.

5.3.3 Sample Analysis

Sample analysis was undertaken by Jacobs. Samples were drained and sorted under a low powered microscope. Any fish larvae, post-larvae and juveniles present were removed, measured (total length, mm) and speciated using appropriate keys and literature (e.g. Russell, 1976). A sub sample of 50 individuals was measured if high numbers of a particular species other than herring were encountered.

6 Herring Larval Results

6.1 Herring Abundance and Distribution

Herring larvae <10mm are categorised as newly hatched and considered to provide a more accurate reflection of proximity to active spawning grounds (Ellis *et al*., 2012; ICES, 2014). The total number of herring larvae and larvae <10mm and ≥10mm caught for each week of the survey is given in Table 6.1. A total of 603 herring larvae were recorded during the survey. No herring larvae were caught in sampling weeks 1, 2 and 3. The majority of herring larvae were ≥10mm (71.3%). The largest number of herring larvae were caught in week 6 (34.3% of the total catch), followed by week 8 (30.7%) with 84.7% of the total catch caught in weeks 6, 7 and 8 combined. It should be noted that no herring larvae caught were recorded with a yolk sac.

A total of 45 other fish species were caught during the survey. The number of individuals caught for each bycatch species by sampling week is given in Table 9.4 in the Appendix (section 9.3).

Table 6.1 Number of herring larvae of <10mm and ≥10mm recorded

Week	<10mm	≥10mm	Total
1	-	-	-
2	-	-	-
3	-	-	-
4	53	39	92
5*	-	-	-
6	67	140	207
7	15	104	119
8	38	147	185
Total	173	430	603

As the volume of water filtered was recorded for each tow, herring larvae abundance was calculated using the below formula, which is used for the IHLS surveys (Smith & Richardson, 1977).

Herring larval abundance below a square meter of sea surface at each station were calculated as:

$$n/m^2 = \frac{herring\ larvae\ per\ sample\ (n) * bottom\ depth\ (m)}{Volume\ filtered\ (m^3)}$$

The total herring larvae abundance (n/m^2) for herring larvae <10mm and ≥10mm for each week of the survey is given in Table 6.2. Total herring larvae abundance for each station is given in the Appendix (section 9.1).

Table 6.2 Herring larvae (n/m^2) of <10mm and ≥10mm recorded

Week	<10mm	≥10mm	Total
1	-	-	-
2	-	-	-
3	-	-	-
4	46.5	37.7	84.2
5*	-	-	-
6	84.4	165.2	249.6
7	12.4	92.8	105.3
8	47.5	162.7	210.2
Total	190.8	458.4	649.2

Spatial distribution plots showing the abundance of herring larvae <10mm were produced for every station sampled for each survey week in which herring larvae were recorded (4 out of 8 weeks). No herring larvae were recorded in weeks 1, 2 and 3, and no sampling was undertaken during week 5 due to adverse weather conditions. The spatial plots for weeks 4, 6, 7 and 8 are given in Figure 6.1 to **Error! Reference source not found.** The circle size corresponds to the abundance i.e. larger circles indicate higher abundances.

The lowest abundance (n/m^2) of early stage herring larvae (<10mm) was observed during week 7 (12.4 per m^2) with the largest abundance of <10mm larvae recorded in week 6 (84.4 per m^2).

Overall, the stations with the highest abundances recorded in the survey were to the north and to the east of the development area. Herring larvae were only caught in the north of the survey area in week 4, with the highest abundance of larvae recorded at HL03. In week 6, larvae were predominantly found in the north of the survey area, with some larvae recorded to the east of the BOWL development area. Week 7 found low abundances of larvae in the survey area, mainly to the north and east of the development area, and week 8 showed high abundances of larvae in the north east of the survey area.

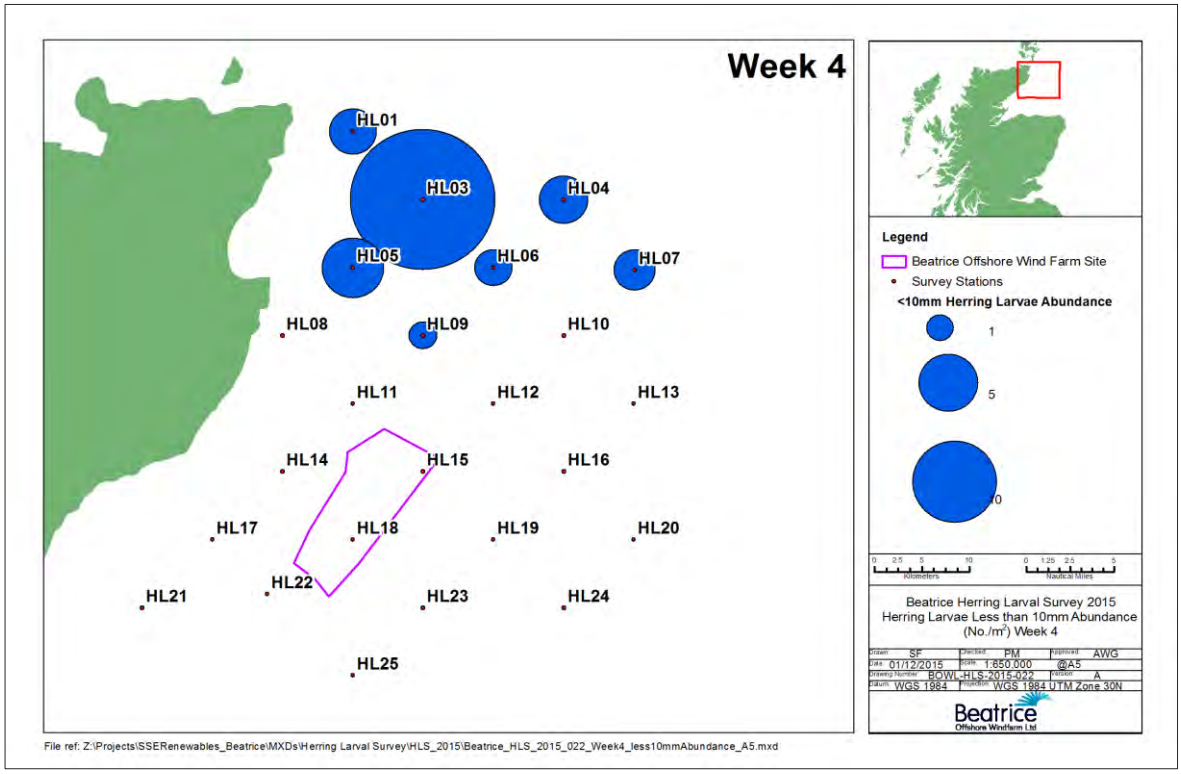

Figure 6.1 Herring larvae abundance (n/m^2) in week 4

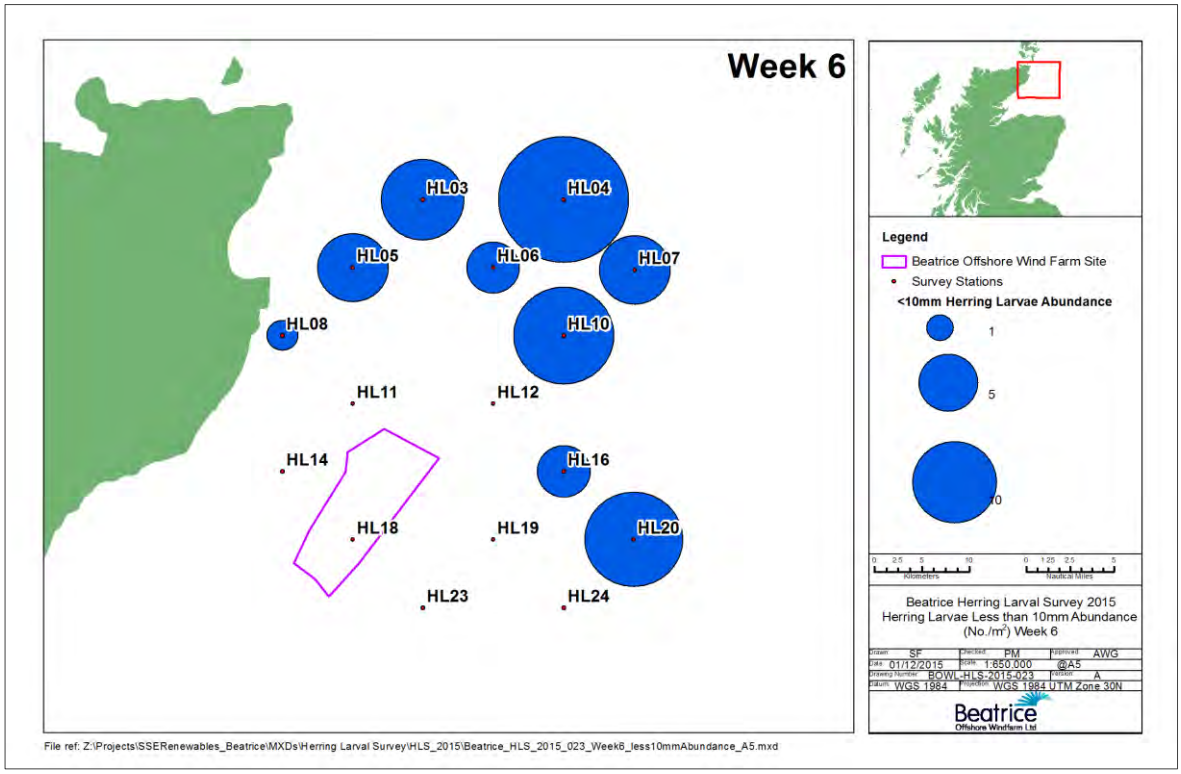

Figure 6.2 Herring larvae abundance (n/m^2) in week 6

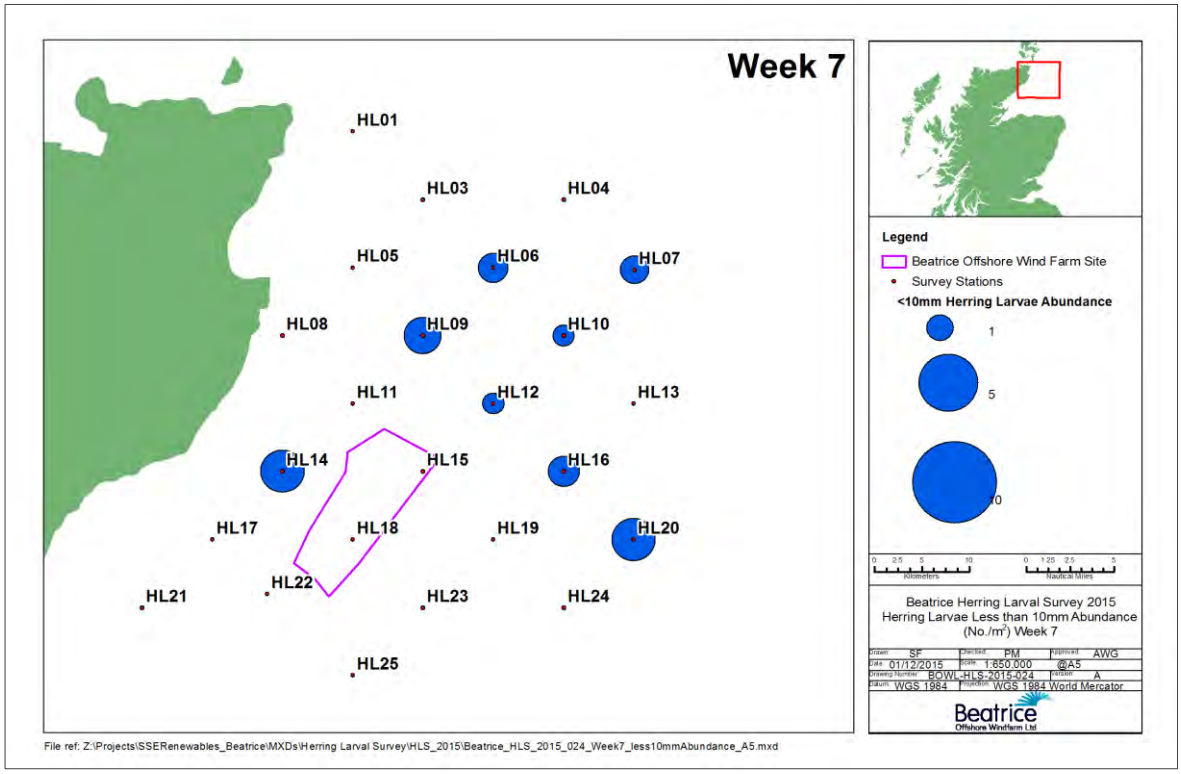

Figure 6.3 Herring larvae abundance (n/m^2) in week 7

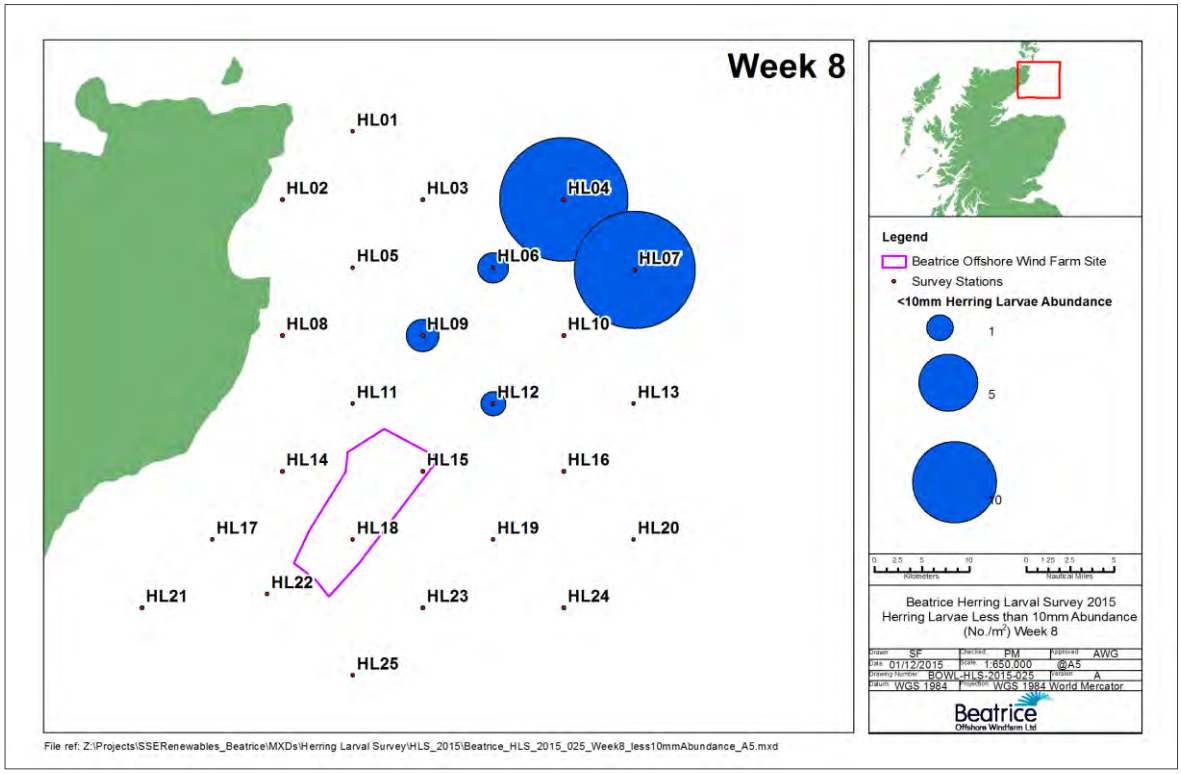

Figure 6.4 Herring larvae abundance (n/m^2) in week 8

6.2 Comparison with IHLS data

In order to compare between data obtained from the IHLS survey and the BOWL survey data, the IHLS abundance data (herring larvae <10 mm) was extracted for the same dates surveyed from 2010 to 2014. The 2015 data have not yet been made available from ICES. Whilst there were IHLS data for 2010-2014, after cross-referencing the sampling dates there were only comparable data for 2012 in week 7 (Figure 6.5 and Figure 6.6) and for 2011 and 2013 in week 8 (Figure 6.7 to Figure 6.10). Two sets of charts have been produced for each comparison in order to provide the abundance values in addition to a visual representation of the larval abundance data.

Low numbers of herring larvae <10 mm (n/m^2) were caught during the 2015 BOWL survey compared to the 2012 IHLS comparable data. However, in the context of the full 2012 IHLS survey (given in section 3.3), the largest abundances were still recorded north of the survey area, in and around Orkney and Shetland.

Larval abundances observed in the 2011 IHLS data and week 8 of the 2015 BOWL survey, showed a similar distribution, with higher abundances observed to the north and east of the development area.

Large abundances were recorded in the 2013 IHLS survey compared to week 8 (2015 BOWL survey), with the highest numbers of larvae found north of the survey area, in and around Orkney and Shetland. It should be noted that ICES reported that total numbers of <10 mm larvae had increased markedly in September 2013, resulting in the largest ever observed estimate in the Shetland/Orkney area in 40 years of sampling (ICES, 2014).

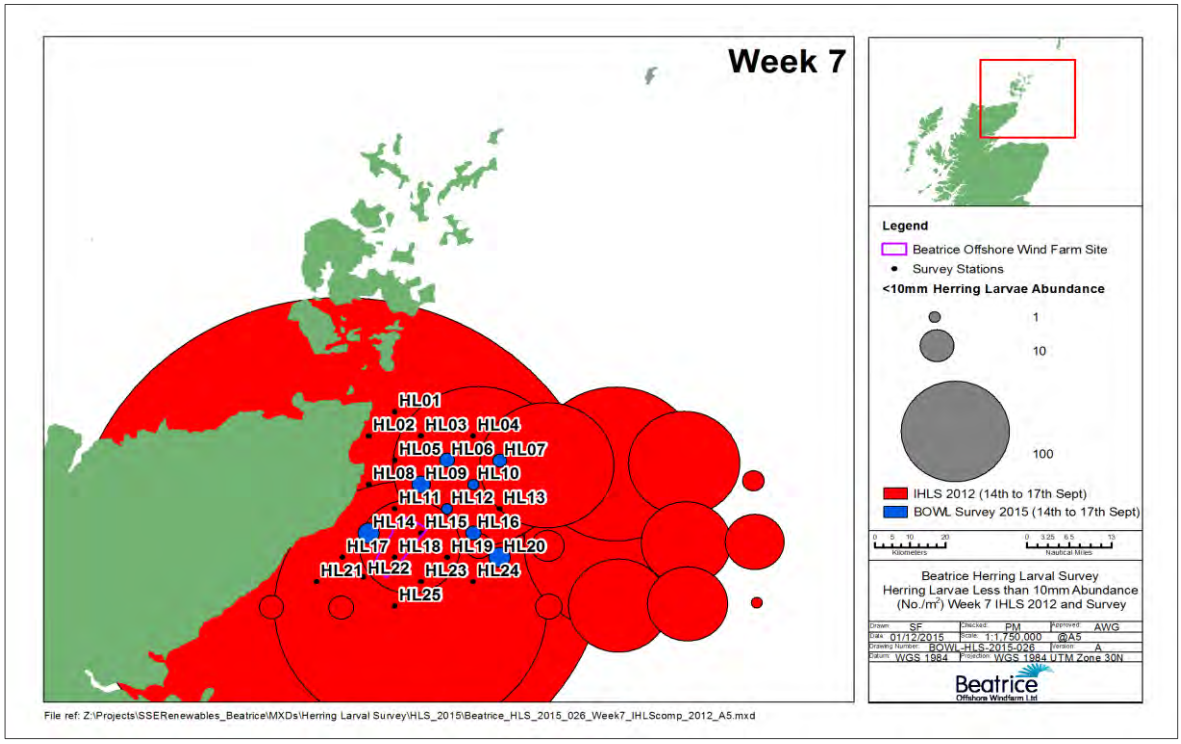

Figure 6.5 Herring larvae abundances recorded during the IHLS 2012 and week 7 of the BOWL 2015 survey for comparable dates

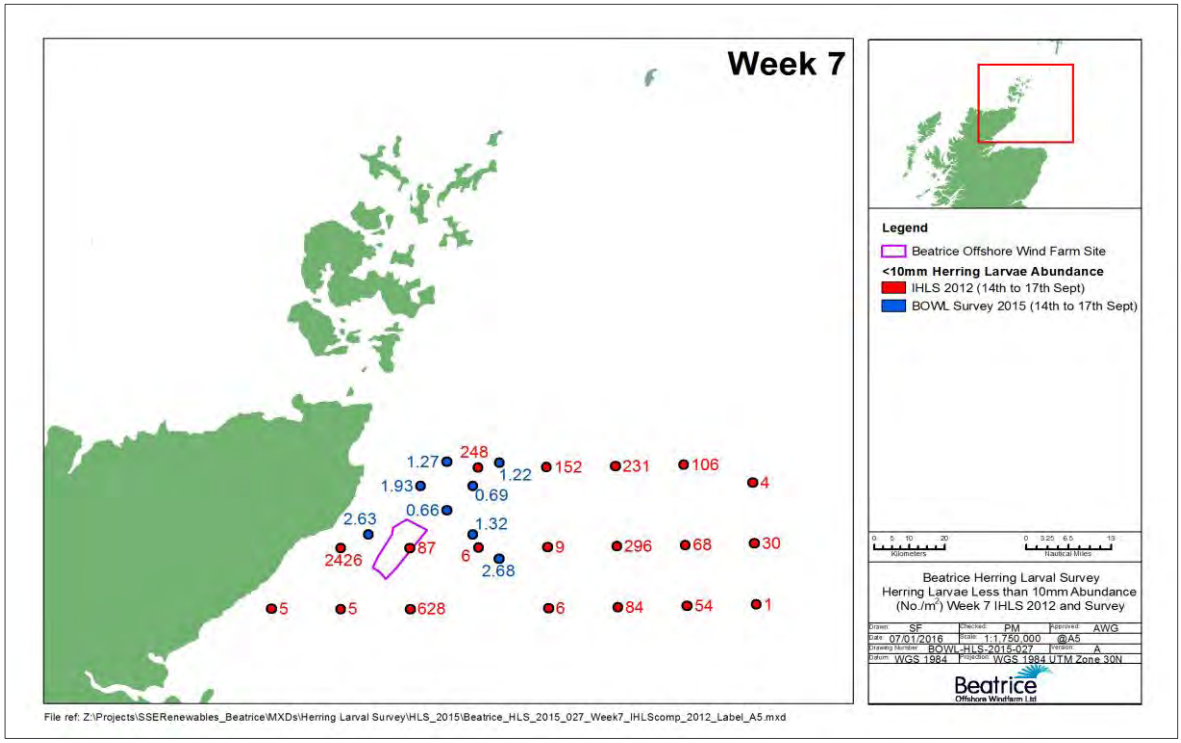

Figure 6.6 Herring larvae abundances recorded during the IHLS 2012 and week 7 of the BOWL 2015 survey for comparable dates (values)

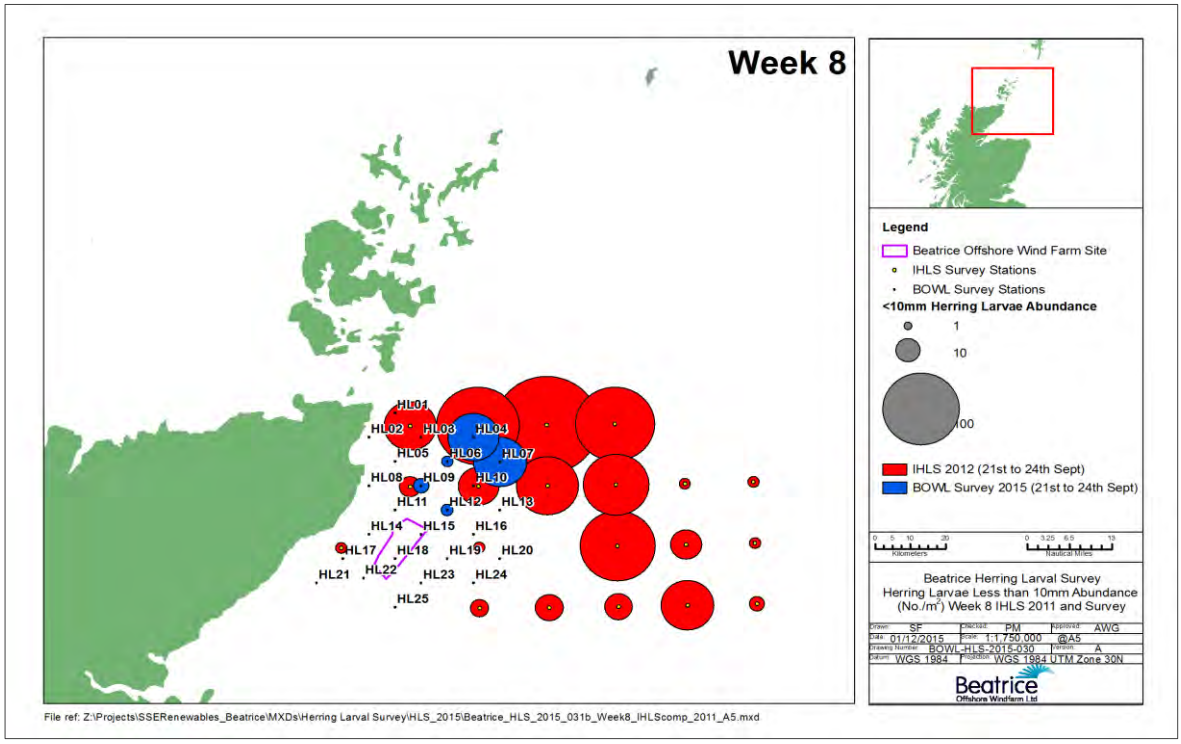

Figure 6.7 Herring larvae abundances recorded during the IHLS 2011 and week 8 of the BOWL 2015 survey for comparable dates

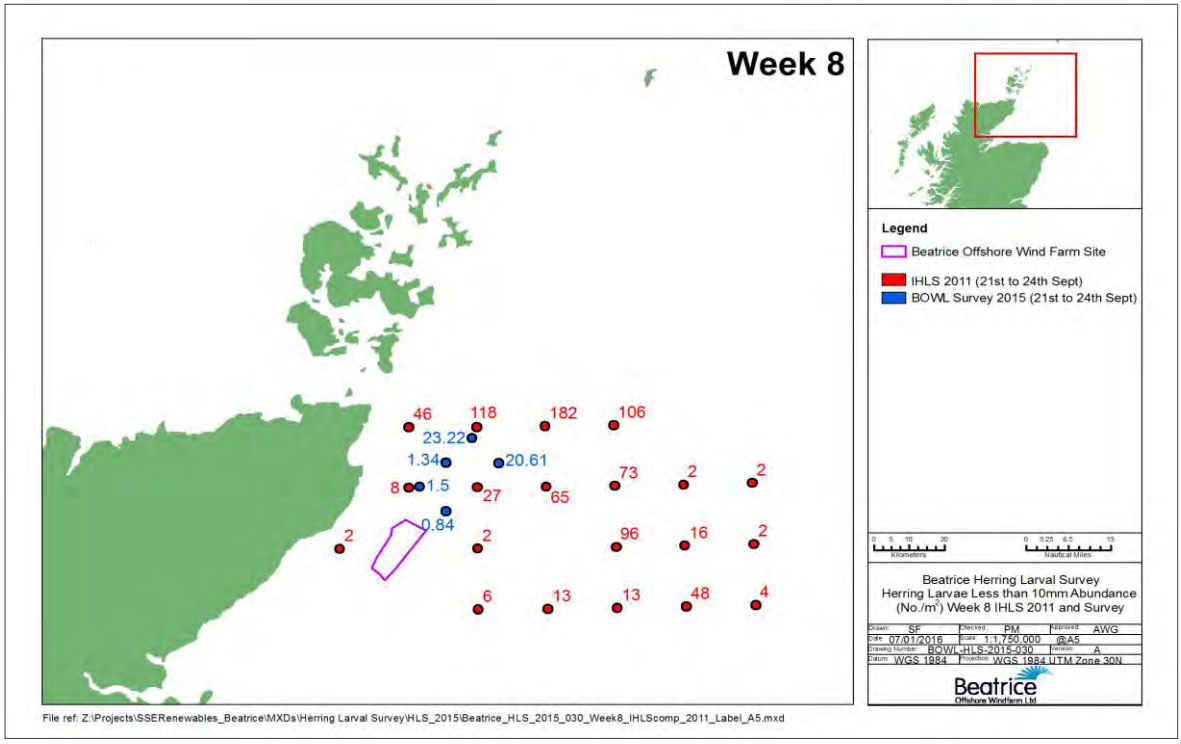

Figure 6.8 Herring larvae abundances recorded during the IHLS 2011 and week 8 of the BOWL 2015 survey for comparable dates (values)

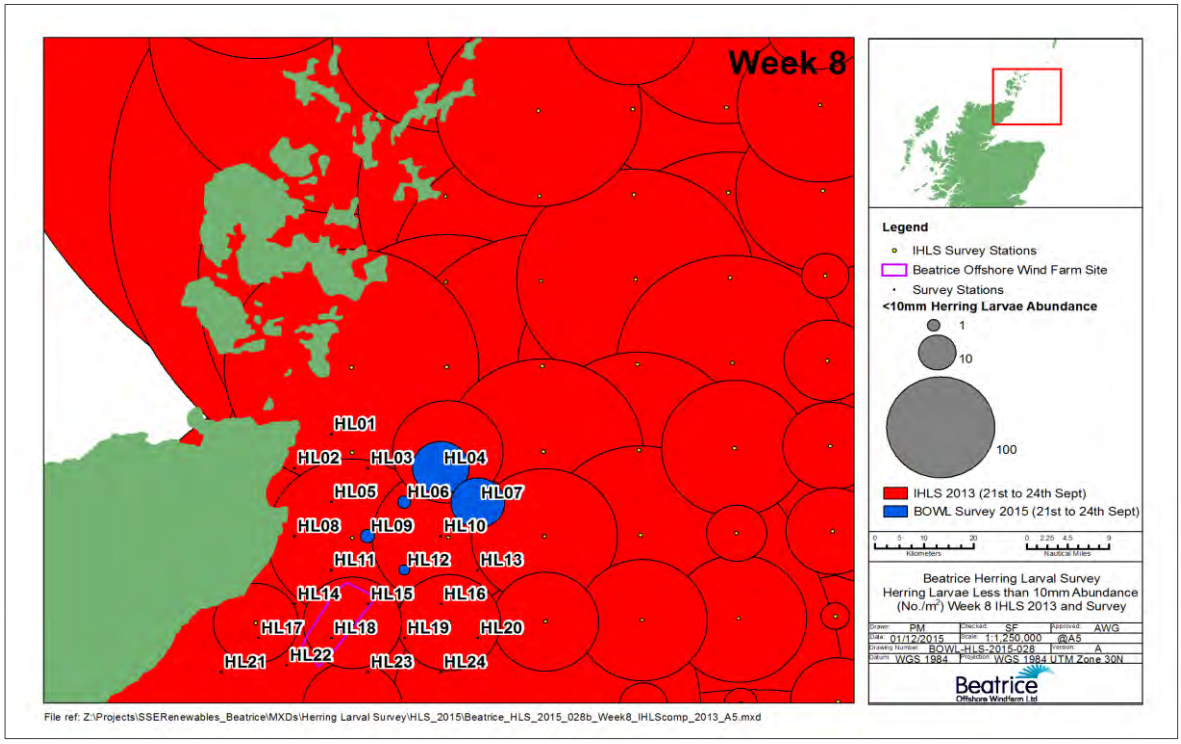

Figure 6.9 Herring larvae abundances recorded during the IHLS 2013 and week 8 of the BOWL 2015 survey for comparable dates

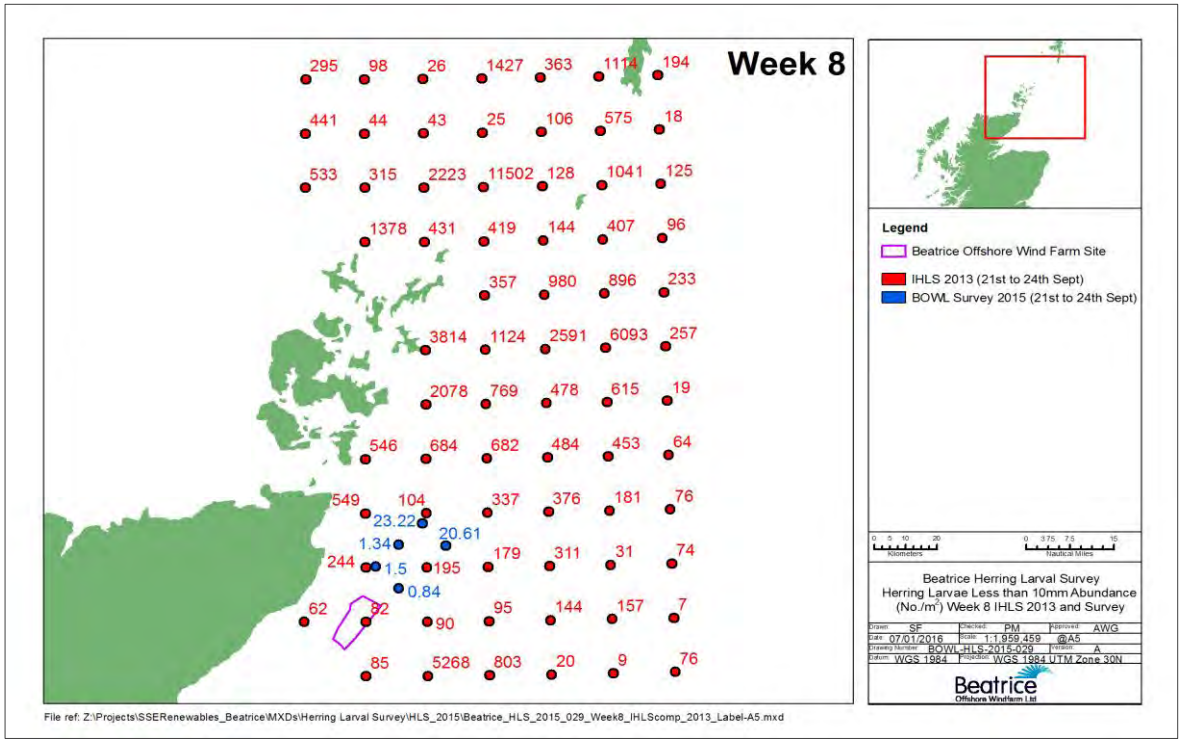

Figure 6.10 Herring larvae abundances recorded during the IHLS 2013 and week 8 of the BOWL 2015 survey for comparable dates (values)

6.3 Herring larvae length distributions

The length distributions of the total number of herring larvae recorded for each sampling week in the BOWL 2015 survey are given in Figure 6.11. The x-axis gives the 1 mm length intervals and the y-axis shows the number of individuals caught.

Figure 6.12 gives the length-frequency of the total number herring larvae recorded during the survey. The majority of herring larvae were ≥10 mm with over 20% of the catch recorded in the length interval 10.0 - 10.9 mm.

The least variation in larvae length was observed in week 4 (7.0 – 11.5 mm), with the greatest size range recorded in week 8 (7.5 – 22.9 mm).

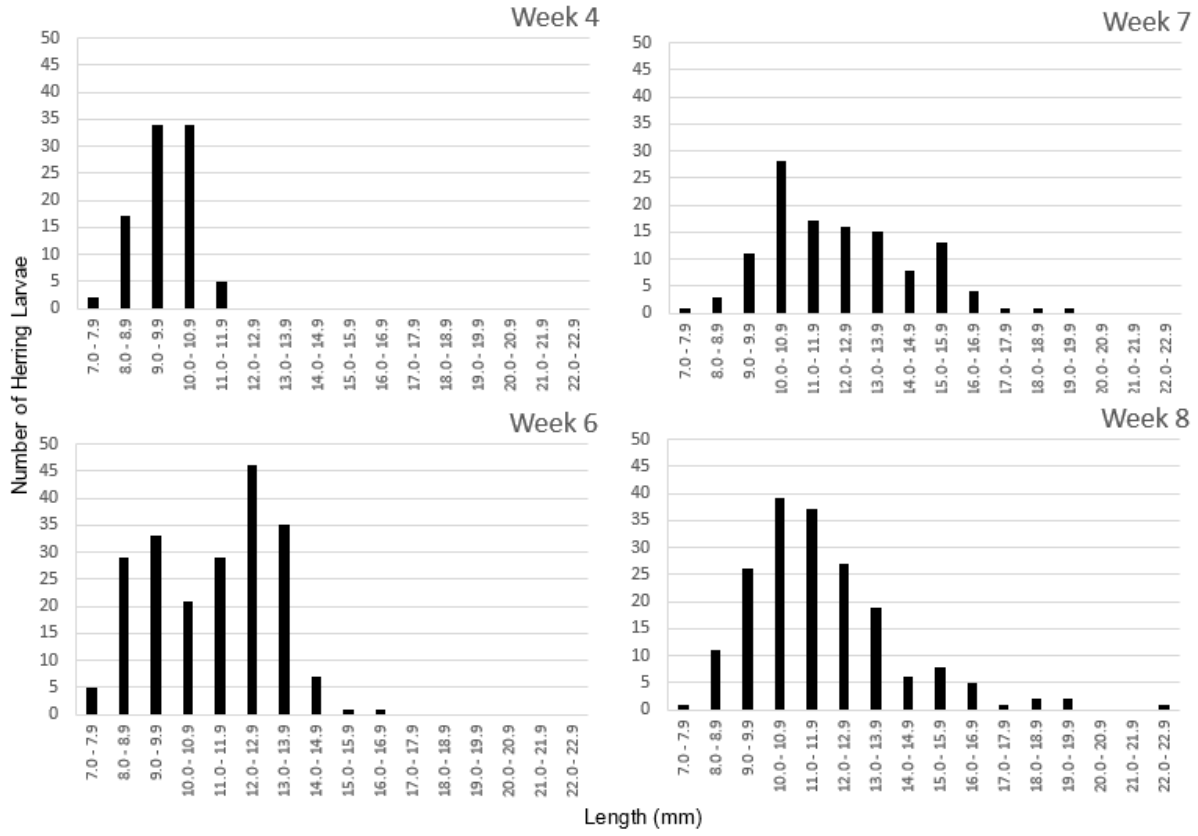

Figure 6.11 Length distributions of the total number of herring larvae recorded in each sampling week

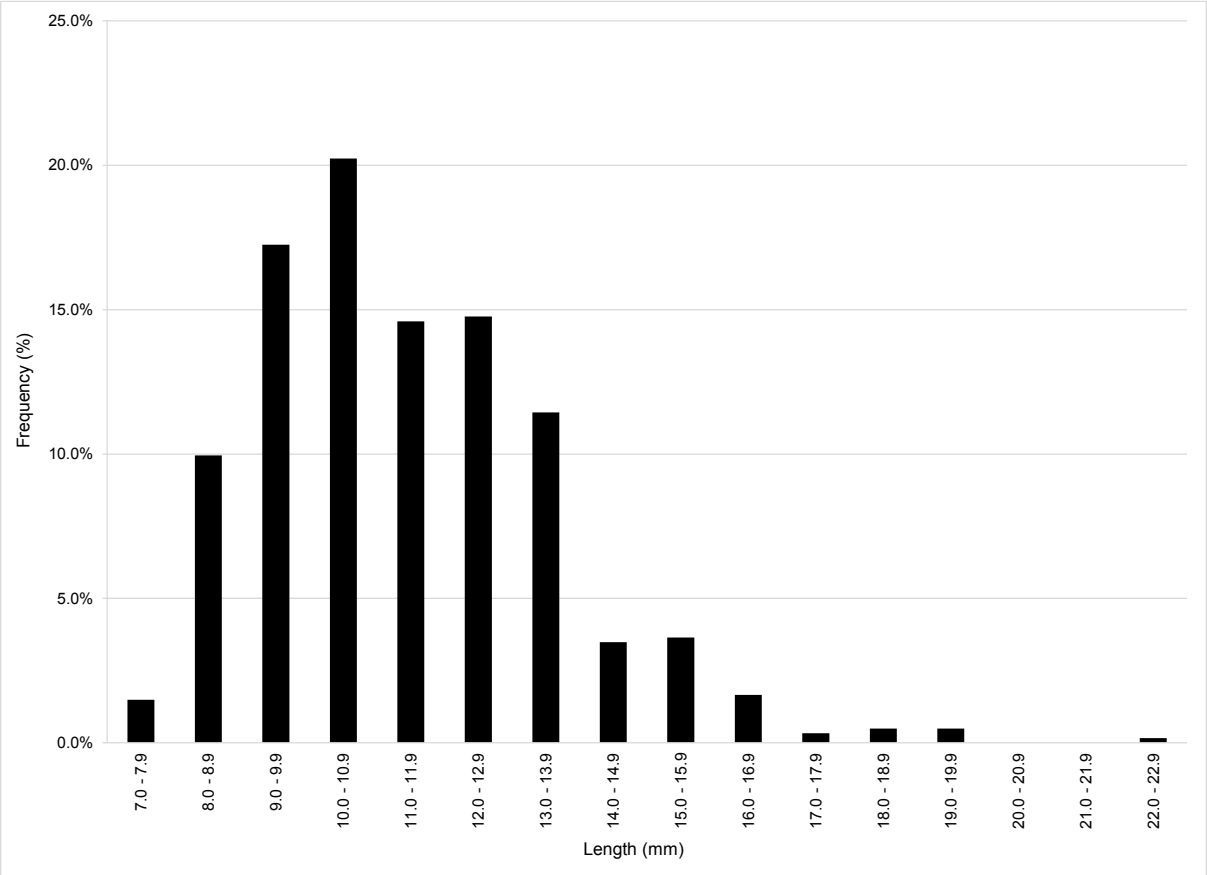

Figure 6.12 Length-frequency plot of total number of herring larvae (mm) recorded

6.4 Spatial distribution of herring larvae by length

Spatial distribution plots showing the abundance of herring larvae in 1 mm size classes have been produced for every station sampled for each survey week in which herring larvae were recorded (4 out of 8 weeks). No herring larvae were recorded in weeks 1, 2 and 3 and no sampling was undertaken in week 5. The spatial plots for weeks 4, 6, 7 and 8 are given in Figure 6.13 to Figure 6.16. The circle size has been standardised and shows only the proportion of each size class recorded at each station.

As shown, there is a general trend of smaller size classes found at the north of the sampling area with larger size classes found in the south. Fish larvae caught in week 4 were recorded at stations only in the north of the survey area. The smallest larvae recorded during the week (7 mm) were found in one of the most northern stations (HL03) with larger larvae (11 mm) found in the sourthernmost station.

Larvae >11 mm were recorded for the first time in week 6. The larger larvae were found predominantly in the south and west of the survey area and the smaller larvae were found mainly in the north. This trend in larval size spatial distribution was also observed in sampling weeks 7 and 8.

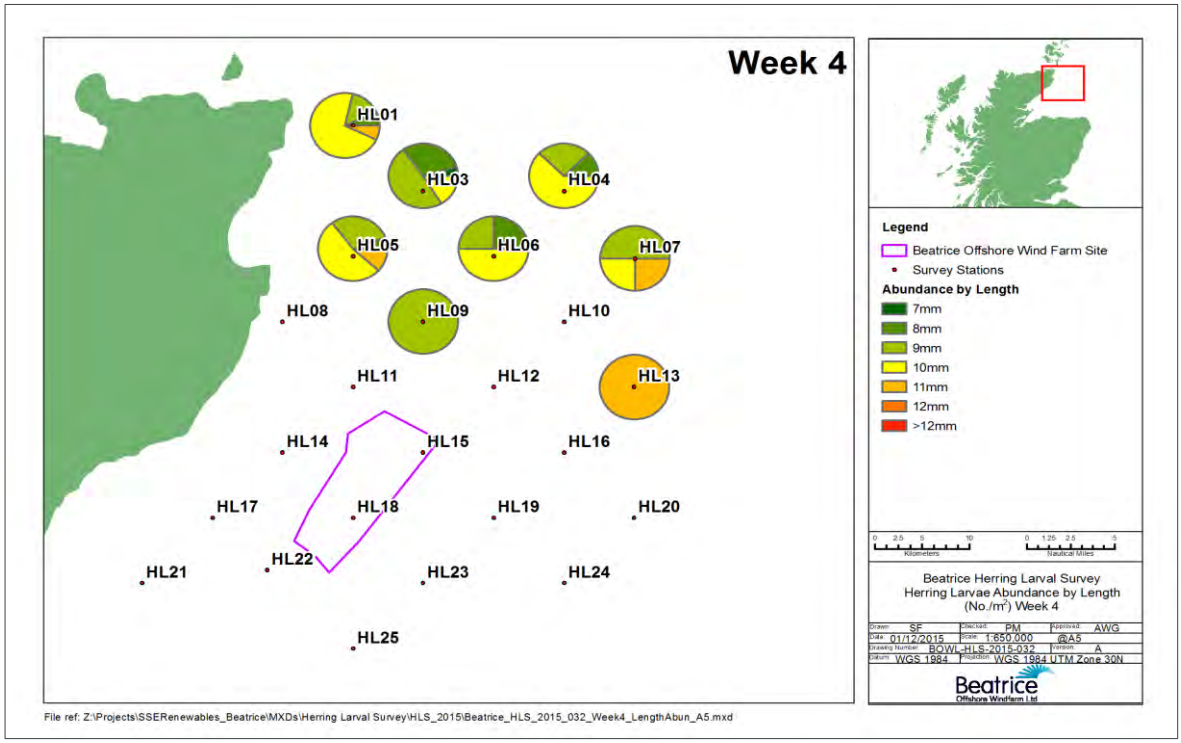

Figure 6.13 Herring larvae length distribution in week 4

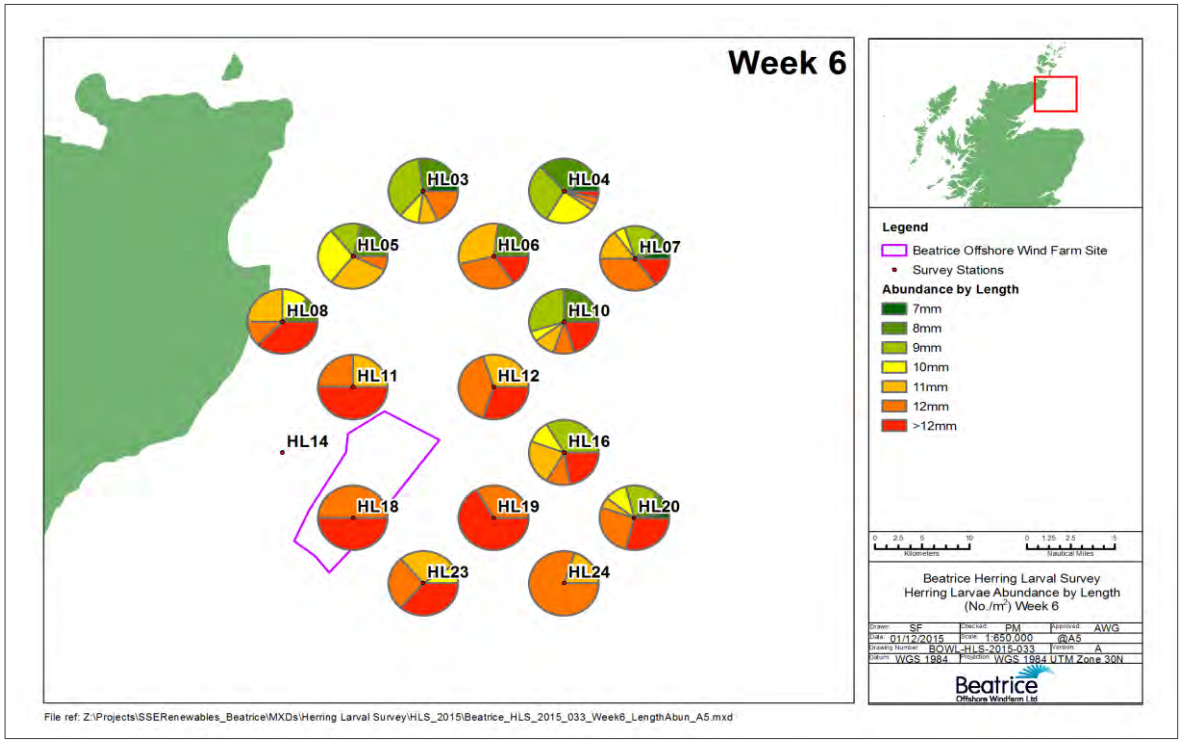

Figure 6.14 Herring larvae length distribution in week 6

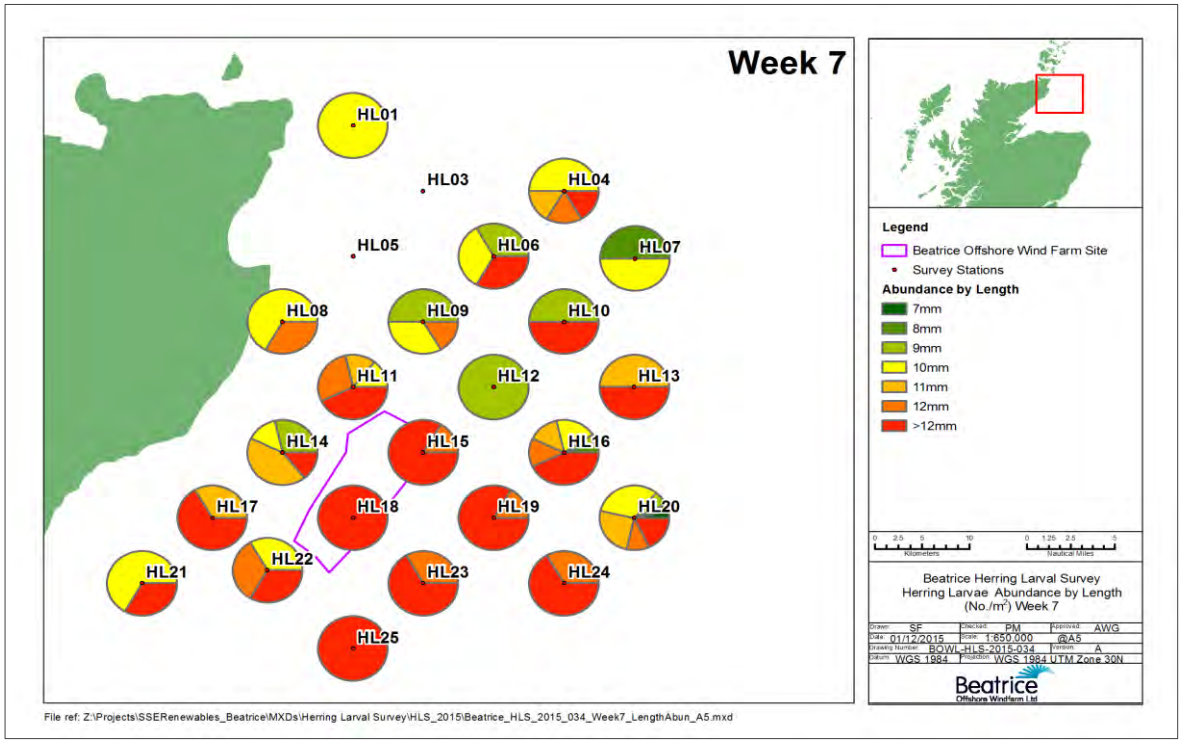

Figure 6.15 Herring larvae length distribution in week 7

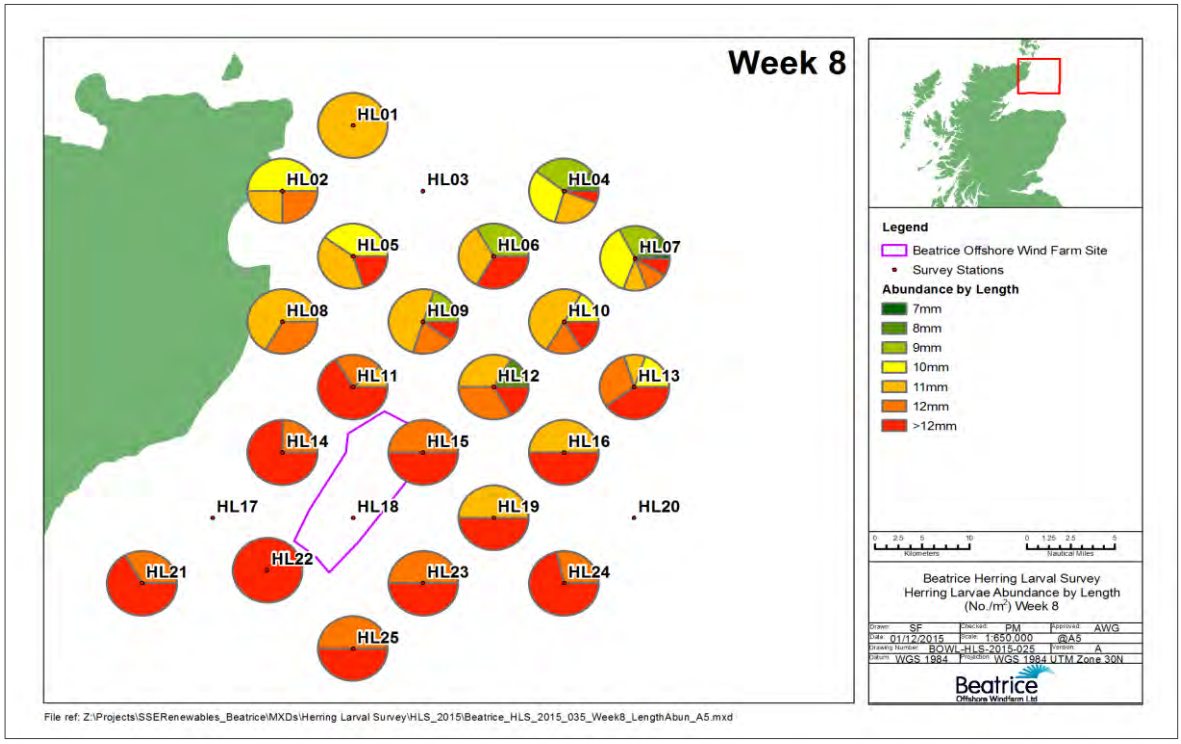

Figure 6.16 Herring larvae length distribution in week 8

6.5 Temperature and Salinity

Salinity (ppt) and temperature (°C) were recorded throughout each tow using a CTD probe on the Gulf VII high speed sampler. Salinity and temperature data were taken from the deepest part of the plankton tow (bottom salinity and temperature) at each station for each survey week and will vary in depth depending on station depth. Surface salinities and temperatures were taken from a standardised 1 metre below surface depth. Bottom temperature and bottom salinity are used in the IHLS reports and have been spatially plotted for each survey week. Bottom salinity and bottom temperature for each sampling week are shown in the Appendix (section 9.7 and 9.8) in Figure 9.8 to Figure 9.14 and Figure 9.15 to Figure 9.21, respectively.

6.5.1 Salinity

Bottom salinities for each sampling week are shown in Figure 9.8 to Figure 9.14. The range of surface and bottom salinities observed during each week are summarised in Table 6.3.

Surface salinity varied between 35.1 ppt and 35.8 ppt over the survey and bottom salinity ranged between 35.4 ppt and 36.0 ppt.

Table 6.3 Surface and bottom salinity range by sampling week (ppt)

Week	Salinity (ppt)					
	Surface			Bottom		
	Min.	Max.	Average	Min.	Max.	Average
1	35.4	35.8	35.6	35.6	35.9	35.7
2	35.3	35.8	35.6	35.6	35.9	35.7
3	35.5	35.8	35.6	35.6	36.0	35.7
4	35.1	35.8	35.6	35.5	35.9	35.7
5	-	-	-	-	-	-
6	35.5	35.7	35.6	35.6	35.8	35.7
7	35.3	35.8	35.6	35.4	35.7	35.6
8	35.4	35.8	35.7	35.7	35.9	35.8

6.5.2 Temperature

Bottom temperatures for each sampling week are shown in Figure 9.15 to Figure 9.21. The range of surface and bottom temperatures observed during each week are summarised in Table 6.4.

Surface temperature varied between 11.6°C and 13.5°C over the survey with the highest temperature observed in week 2. Bottom temperature ranged between 10.8°C and 12.7°C.

There is some limited indication of a thermal gradient during weeks 1 to 4, but this is absent in weeks 6 to 8. This breakdown of possible thermal stratification may have resulted from the adverse weather conditions in week 5.

Table 6.4 Surface and bottom temperature ranges by sampling week (°C)

Week	Temperature (°C)					
	Surface			Bottom		
	Min.	Max.	Average	Min.	Max.	Average
1	11.6	12.6	11.9	10.8	11.8	11.5
2	11.9	13.5	12.3	10.9	11.9	11.7
3	12.2	13.4	12.7	11.3	12.2	11.9
4	12.4	13.2	12.8	11.7	12.4	12.2
5	-	-	-	-	-	-
6	12.3	12.5	12.4	11.9	12.4	12.3
7	12.4	12.7	12.5	12.3	12.5	12.5
8	12.3	12.9	12.5	12.1	12.7	12.5

6.6 Back calculation of larval age, spawning date and intensity

Herring larvae <10mm are considered to provide a more accurate reflection of proximity to active spawning grounds (Ellis *et al*., 2012). Herring larvae in the Moray Firth have been attributed a hatch size of 6-7 mm but can range from 4-10 mm (Russel, 1976).

Published values of growth and mortality rates and hatch sizes have been used for this analysis (Dard, 2003; Dickey-Collas *et al*., 2001; Fassler *et al*., 2011; Heath, 1993; Heath *et al*., 1997; Hufnagl & Peck, 2011; ICES, 2009; Johannessen *et al*., 2000; Lazzari & Stevenson, 1992; Munk *et al*., 1986; Payne *et al*., 2013). Published lengths and ages were also used to cross-reference the back calculation of age from length (Lough *et al*., 1982; Maneja *et al*., 2015).

It should be noted when using back calculations a study by Geffen (2002) found that “age at hatching determines the hatching length rather than length determining the age at hatching”.

6.6.1 Estimated Ages

Histograms were plotted of the length distribution of herring on each day that herring larvae were caught (Figure 6.17). Ages of herring larvae, in days, were calculated using published values of growth rates and hatch sizes (Dard, 2003; Dickey-Collas *et al*., 2001; Fassler *et al*., 2011; Heath, 1993; Heath *et al*., 1997; Hufnagl & Peck, 2011; ICES, 2009; Johannessen *et al*., 2000; Lazzari & Stevenson, 1992; Munk *et al*., 1986; Payne *et al*., 2013).

Published hatch sizes (here defined as L_0) varied between 6 and 7 mm for the Moray Firth, while growth rates, *g,* varied between 0.2 and 0.35 mm^{-d}. To reflect the variation in these parameters, ages were estimated using the mean of these values. Additionally, the maximum and minimum possible ages were estimated based on the upper and lower 95% quartiles of the range of published values (Table 6.5, Figure 6.18). Minimum ages were estimated by using a larger hatch size (7 mm) and faster growth rates (0.35 mm^{-d}) while maximum ages were estimated using the small hatch size (6 mm) and slower growth rate (0.2 mm^{-d}).

In the literature, studies have found that herring larvae take 6-10 days to absorb the yolk sac after hatching. As no yolk sacs were observed on any of the larvae caught it is proposed that the minimum of 6 days be added to the age back-calculation results. In Table 6.5, the 6 days was added to the mean estimates of herring age.

The mean, lower and upper 95% confidence intervals for the hatch dates of herring larvae recorded on each day of the survey were plotted (Figure 6.19). The standard approach in the literature (in the absence of data on temperature values experienced by larvae) is to assume linear growth rates for newly hatched larvae, therefore the below formula was applied

$$Age = \frac{L_i - L_0}{g}$$

where L_i is the measured size of individual i, L_0 the hatch size and g, the growth rate.

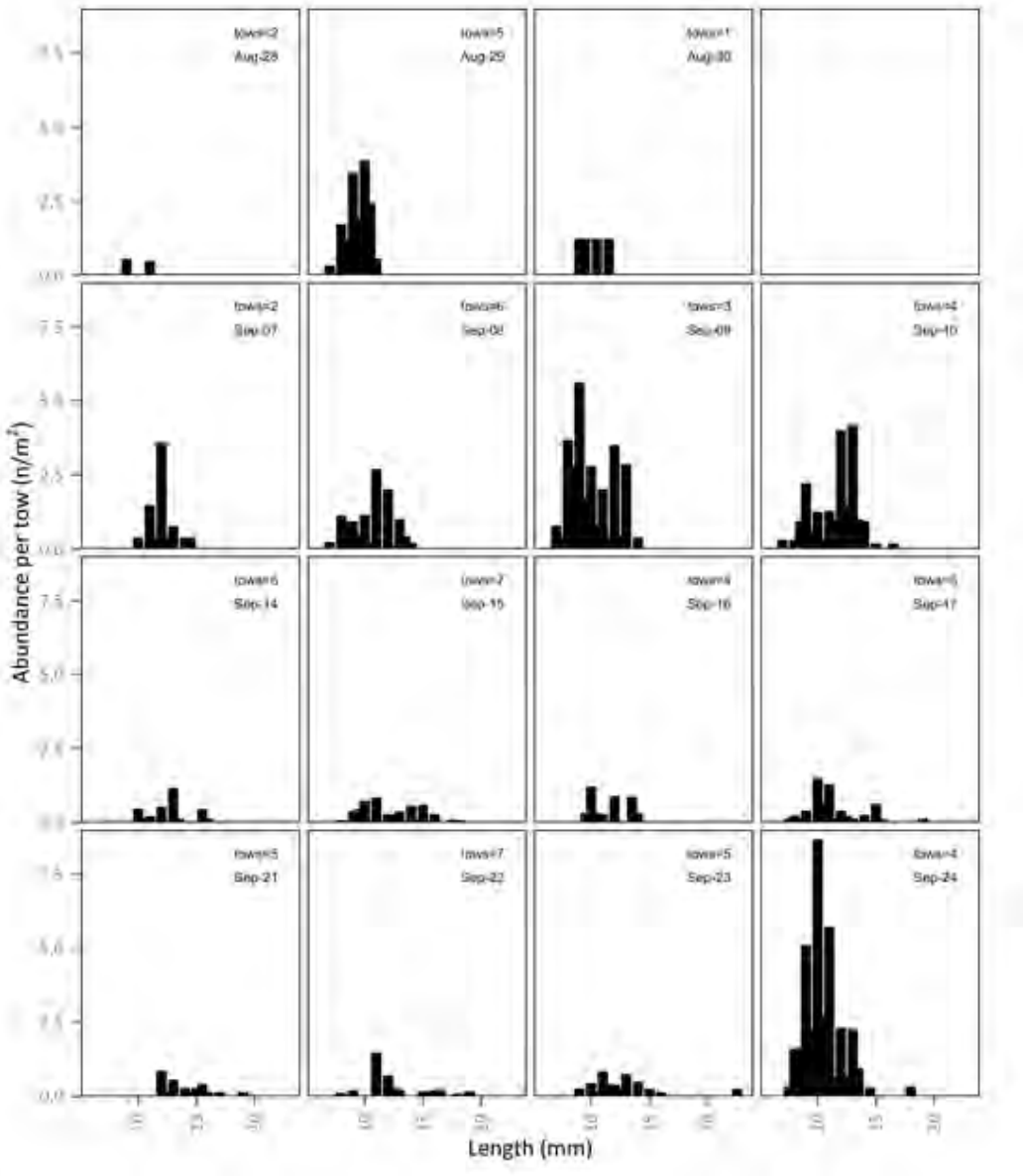

Figure 6.17 Daily histograms of larval herring lengths (mm). Each grid cell gives the daily aggregate samples from all tows in a day, while each row corresponds to one sampling week.

Table 6.5 Mean, min. and max. estimated ages (in days) for each length of herring larvae encountered in all tows. Min. age is based on the larger hatch size and faster growth rate, while max. age is based on the reverse. Age +6 days is the mean herring larvae age incorporating the absorption time of the yolk sac

Length (mm)	No. larvae	Herring larvae age (days)			
		Mean age	Min. age	Max. age	Age +6 days
7.0	6	0.11	0.00	2.93	6.11
7.5	3	2.47	1.44	5.41	8.47
8.0	33	5.30	3.63	7.97	11.30
8.5	27	7.24	5.72	10.58	13.24
9.0	73	9.28	7.70	13.19	15.28
9.5	31	11.57	9.65	15.83	17.57
10.0	89	13.87	11.60	18.70	19.87
10.5	33	16.17	13.55	21.87	22.17
11.0	77	18.47	15.51	25.04	24.47
11.5	11	20.77	17.46	28.21	26.77
12.0	70	23.06	19.41	31.38	29.06
12.5	19	25.36	21.36	34.55	31.36
13.0	56	27.66	23.31	37.72	33.66
13.5	13	29.96	25.27	40.89	35.96
14.0	17	32.25	27.22	44.06	38.25
14.5	4	34.55	29.17	47.23	40.55
15.0	15	36.85	31.12	50.40	42.85
15.5	7	39.15	33.07	53.57	45.15
16.0	8	41.45	35.03	56.74	47.45
16.5	2	43.74	36.98	59.91	49.74
17.0	1	46.04	38.93	63.08	52.04
17.5	1	48.34	40.88	66.25	54.34
18.0	3	50.64	42.83	69.42	56.64
19.0	3	55.23	46.74	75.76	61.23
22.5	1	71.24	60.40	97.95	77.24

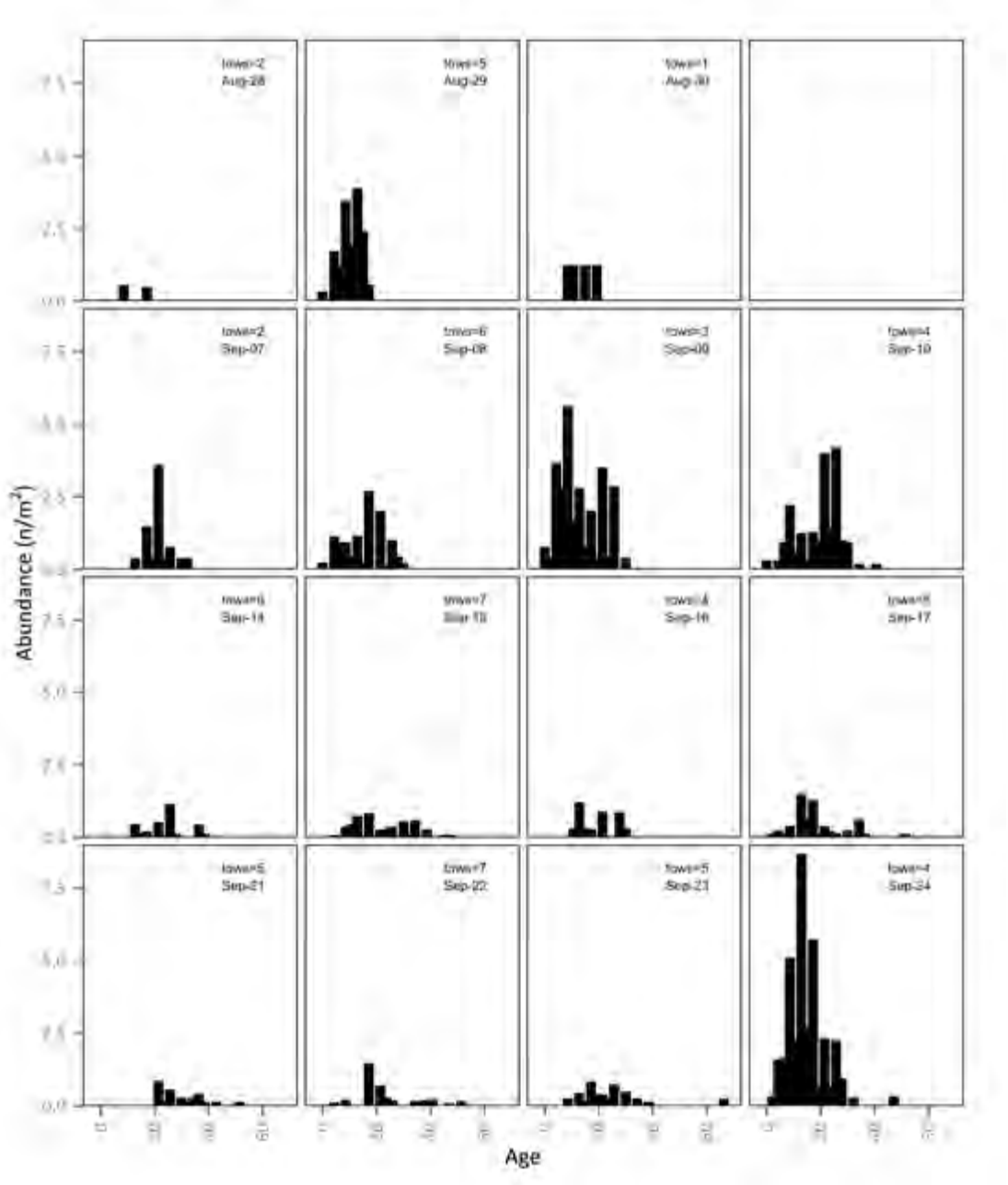

Figure 6.18 Histograms of mean estimated ages (in days) for sampled herring larvae on each day of sampling. Each row indicates the sampling weeks in which herring were caught.

6.6.2 Estimated Hatch Dates

The mean, lower 2.5% and upper 97.5% quartiles of the estimated hatch dates for each size of fish were then calculated and plotted (Figure 6.19). The larvae ages (Table 6.5) were used to back-calculate the hatch dates of the herring larvae from each sample.

Estimated mean peak hatching occurred during the second week of September. The charts indicate that there may have been a smaller peak in spawning in the third week of August, based on estimated hatch dates. However, this pattern is likely due to the absence of data in sampling week 5.

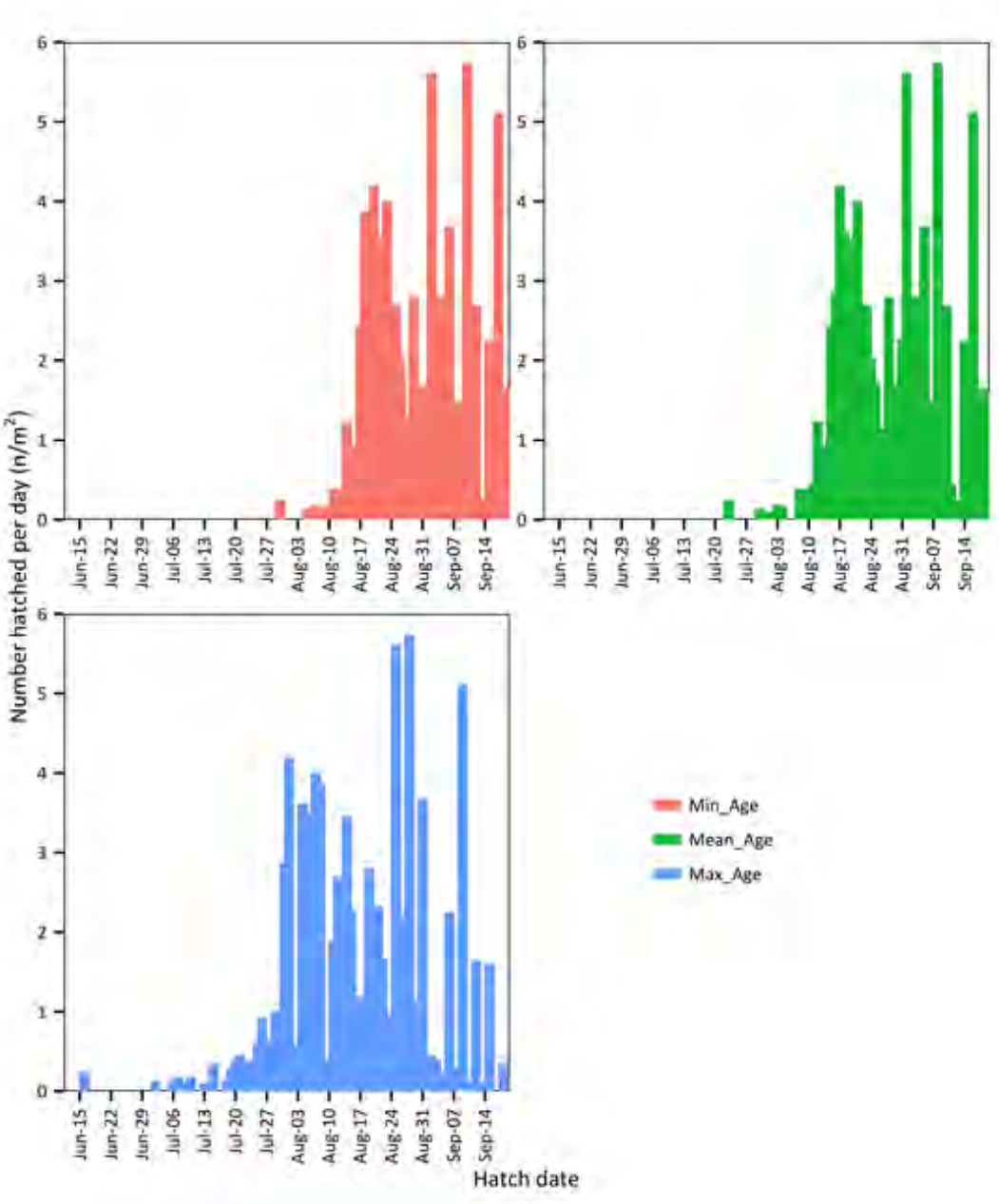

Figure 6.19 Histogram of mean, lower (slow growth) and upper (fast growth) confidence intervals of estimated hatch dates for sampled larvae

6.6.3 Estimated Spawning Intensity

Published growth rates were used to back-calculate an estimate of the mean spawning stock at the time of hatching for each hatch-date (Figure 6.20). Larval lengths were aggregated into bins of 0.5 mm for each day and standardised by the number of tows on each day. Spawning intensity was then estimated from the survey dates using the formula

$$P_i = N * e^{(Lt - L0)^{Z/k}}$$

where P_i is the number of larvae hatching on day i, N is the number of larvae in each length category at time t (L_t), L_0 is the hatching size, Z is the mortality rate and k is the growth rate.

Peak spawning intensity is estimated to have occurred during the second week of September (mean). The data appears to be indicate a small peak prior to this, however, this is likely due to the absence of week 5 sampling data.

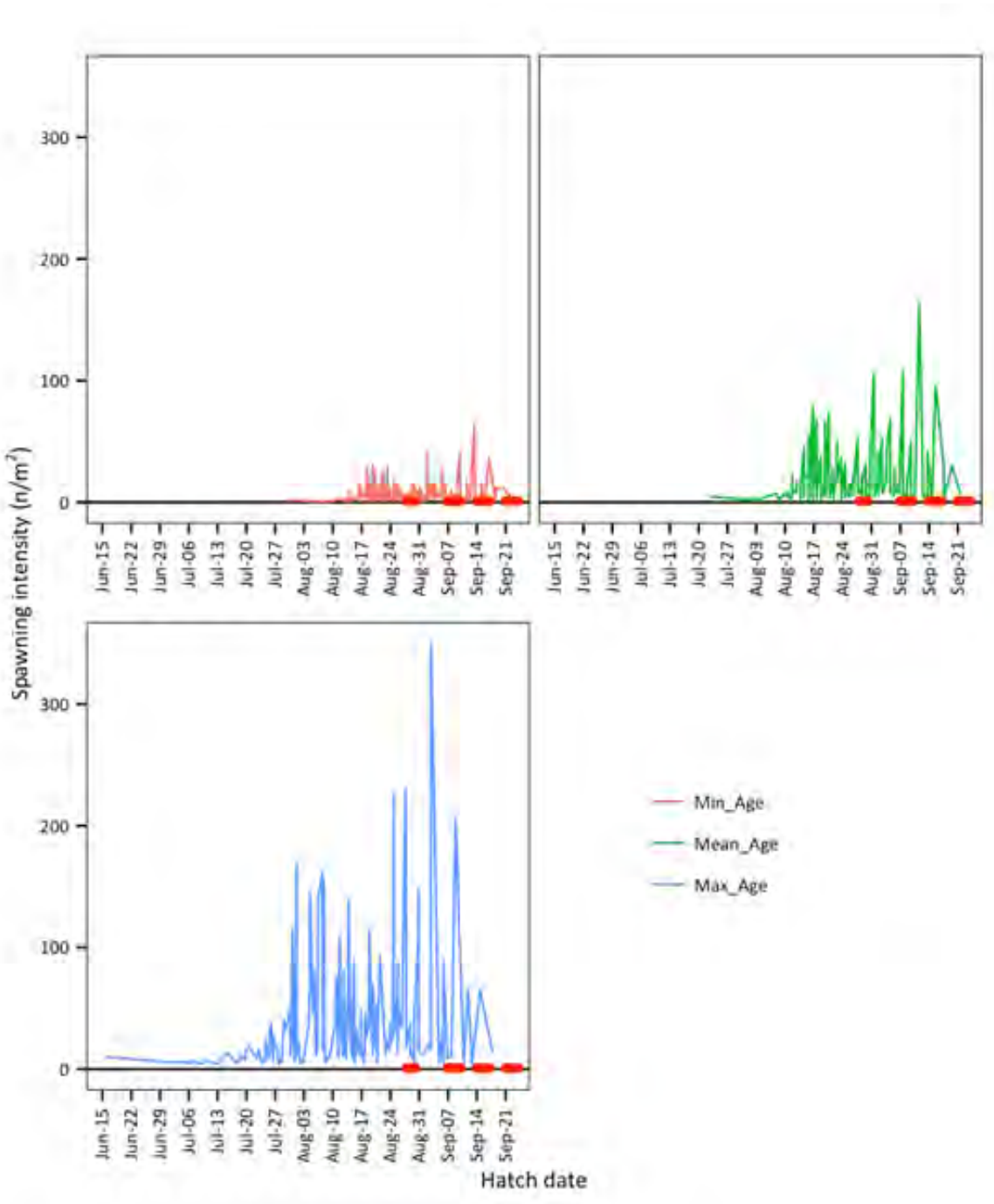

Figure 6.20 Estimated spawning intensity (number of hatching larvae). Red dots indicate dates of sampling. Mean, Max and Min lines refer to estimates of spawning intensity based on lower, mean and upper growth rates

7 Conclusion

The 2015 herring larval survey conducted in line with s36 conditions 27 (PEMP) and 34 (requirement for herring surveys) is the second of two herring larval surveys, the first of which was undertaken in August and September 2014.

The IHLS data confirms that herring larvae abundance in the Moray Firth between years is variable, but that the main spawning areas have remained consistent. The duration and high resolution sampling of the BOWL survey design provides robust data that show the temporal duration of herring spawning in the vicinity of the BOWL development area for August and September in 2015.

The survey has indicated a peak spawning period for herring, with higher larval abundances recorded during sampling weeks 6, 7 and 8 of the survey. The back-calculation of larval hatch date and spawning stock indicated the mean peak spawning period occurred in the first two weeks of September, with the highest mean spawning intensity (in relation to hatched larvae) estimated to be at the beginning of the second week of September. Herring eggs take 10- 20 days to hatch after fertilisation, therefore, based on these dates, peak abundance of adult spawners, occurred at the end of August.

The majority of herring larvae caught during the survey were ≥10 mm, with the greatest percentage of larvae between 10.0 mm and 10.9 mm in length. This size class is not considered to be early stage larvae, indicating that larvae have drifted down from the well established spawning grounds in Orkney and Shetland waters.

The back-calculation of age from larvae length estimated the mean age for the most prevalent size class (10.0 – 10.9 mm) to be between 13.87 and 16.17 days. The mean age for the smallest size class recorded (7.0 - 7.9 mm) was estimated as 0.11 to 2.47 days. However, no yolk sacs were observed on any herring larvae in the samples and studies have found that absorption of the yolk sac after hatching takes a minimum of 6 days. In order to incorporate the time for yolk sac absorption, the 6 days were used as a base age, to which the back-calculation age was then added to. For the larvae size class of 7.0 - 7.9 mm, this resulted in a mean age of between 6.11 days to 8.47 days. The mean age of the most prevalent size class (10.0 – 10.9 mm) was calculated to be 19.87 to 22.17 days old.

Hydrodynamic data for the area, derived from the literature, has produced estimates of residual current velocity ranging from 1-2 km/day to 7.0 and 8.6 km/day. Using the residual velocity data, 7.0 - 7.9 mm larvae could be transported, in 6.11 days to 8.47 days, a minumum of 6 - 18 km, using conservative estimates, up to 52 to 72 km. The most prevalent size class larvae (10.0 - 10.9 mm) could travel, in 19.87 days to 22.17 days, from 19 km to 189 km. This suggests that the majority of the larvae caught during the survey have drifted down from the well established spawning grounds in the Orkneys and Shetlands.

The higher larval densities found in the north of the survey area and the size distribution of larvae recorded during this survey further support the theory that the larvae are transported to the survey area from the main spawning grounds further north in the vicinity of Orkney and Shetland. Similarly, the findings of the IHLS surveys suggest that the highest larval densities occur to the east of Orkney and Shetland. The results of the 2015 survey should be interpreted in the context of the spatial and temporal variation of environmental factors that may influence patterns of herring spawning.

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9 Appendix

9.1 Health and Safety

9.1.1 Personnel

Brown and May Marine (BMM) staff followed the standard health and safety protocol outlined in the BMM "Offshore Operational Procedures for Surveys using Commercial Fishing Vessels".

All BMM staff have completed a Sea Survival course approved by the Maritime and Coastguard Agency, meeting the requirements laid down in: **STCW 95 Regulation VI/1 para 2.1.1 and STCW Code section A- VI/1** before boarding any vessel conducting works for the company. Employees are also required to have valid medical certificates (ENG1), Safety Awareness, Basic Fire Fighting and Basic First Aid certificates before participating in offshore works.

9.1.2 Vessel Induction

Before boarding the survey team were shown how to safely board and disembark the vessel. Prior to departure the skipper briefed surveyors on the whereabouts of the safety equipment, including the life raft, emergency flares and fire extinguishers, and the location of the emergency muster point. The safe deck areas, man-overboard procedures and emergency alarms were also discussed. The survey team was warned about the possible hazards, such as slippery decks and obstructions whilst aboard. Surveyors were briefed about trawling operations and the need to keep clear of all winches when operational. All hazards were assessed prior to the survey in the BMM health and safety risk assessment.

9.1.3 Daily Safety Checks

The condition of the life jackets, EPIRB's, and life raft were inspected daily. Also checked were the survey team working areas, including the fish room and the wheelhouse to ensure these areas were clear of hazards such as clutter and obstructions.

9.1.4 Post Trip Survey Review

Upon completion of the survey a "Post Trip Survey Review" was filled, see Table 9.1 below.

Table 9.1 Post trip survey review

Project: BOWL Herring Larvae Survey 2015	**Vessel:** Pleiades / Antaries
Surveyors: Alex Winrow-Giffin / Sophie Farenden / Courtney French / Jake Laws / Antoine Fry	**Skipper:** P. Hepburn / J. Hepburn / G. Hepburn
Survey Area: Moray Firth	**Total Time at Sea:** 7 sampling weeks
Dates at Sea: 03/08/15 –27/09/15	

	Comments	Actions
Did vessel comply with pre trip safety audits?	Yes (IMCA audits undertaken prior to survey and all items closed out)	N/A
Skipper and crew attitude to safety?	Good – safety glasses worn	N/A
Vessel machinery failures?	None	N/A
Safety equipment failures?	None	N/A
Accidents?	None	No
Injuries?	None	No

9.2 Herring larvae data

The data used to calculate the number of herring larvae below a square meter of water (no./m^2) for each station is given in Table 9.2, with herring larvae abundance (no./m^2) for larvae <10mm and ≥10mm by station and week given in Table 9.3. The first 3 weeks of sampling has been omitted as no herring larvae were caught.

Table 9.2 Herring larvae abundance and volume filtered data by station

Week	Station	Tow duration (mm:ss)	Water depth (m)	Volume filtered (m^2)	No. herring larvae	Herrring larvae (no./m^2)
4	HL01	18:25	74.9	72.5	14	14.5
	HL03	20:15	67.2	82.7	43	34.9
	HL04	16:48	71.3	62.7	8	9.1
	HL05	17:02	59.4	68.3	17	14.8
	HL06	17:53	67.4	68.6	4	3.9
	HL07	15:55	69.2	56.0	4	4.9
	HL09	09:07	64.0	58.6	1	1.1
	HL13	16:23	65.6	67.9	1	1.0
6	HL03	13:11	65.3	46.7	11	15.4
	HL04	15:35	72.4	60.7	30	35.8
	HL05	12:06	61.3	44.3	14	19.4
	HL06	13:36	67.5	50.5	13	17.4
	HL07	16:24	74.6	64.6	20	23.1
	HL08	12:03	59.8	44.7	8	10.7
	HL10	12:07	58.1	45.4	20	25.6
	HL11	16:51	74.7	60.9	4	4.9
	HL12	11:24	57.9	44.8	10	12.9
	HL16	11:41	59.4	45.3	9	11.8
	HL18	14:49	41.8	59.4	2	1.4
	HL19	19:57	53.6	72.4	12	8.9
	HL20	14:47	66.8	54.3	38	46.7
	HL23	14:53	43.9	56.9	11	8.5
	HL24	12:27	56.2	39.5	5	7.1
7	HL01	16:37	76.2	64.7	1	1.2
	HL04	16:05	75.0	65.0	6	6.9
	HL06	14:40	68.9	54.1	3	3.8
	HL07	14:47	71.5	58.8	2	2.4
	HL08	12:35	63.0	49.9	3	3.8
	HL09	25:37	64.2	99.8	6	3.9
	HL10	26:11	64.7	94.3	2	1.4
	HL11	15:41	73.7	63.4	7	8.1

Week	Station	Tow duration (mm:ss)	Water depth (m)	Volume filtered (m^2)	No. herring larvae	Herrring larvae (no./m^2)
	HL12	20:43	56.9	85.6	1	0.7
	HL13	16:18	78.6	61.8	2	2.5
	HL14	16:20	79.5	60.4	7	9.2
	HL15	18:24	50.3	72.8	6	4.1
	HL16	20:30	55.9	84.7	21	13.9
	HL17	12:23	62.0	46.9	3	4.0
	HL18	13:16	40.7	46.7	1	0.9
	HL19	19:43	54.2	79.0	6	4.1
	HL20	14:34	63.9	95.3	28	18.8
	HL21	11:49	55.2	38.8	3	4.3
	HL22	17:34	52.6	62.6	3	2.5
	HL23	13:57	42.7	54.3	3	2.4
	HL24	10:08	55.2	34.4	3	4.8
	HL25	15:04	45.0	54.6	2	1.6
8	HL01	13:57	75.7	51.5	1	1.5
	HL02	17:09	51.9	69.9	4	3.0
	HL04	15:27	72.8	59.6	48	58.7
	HL05	21:51	62.7	82.9	5	3.8
	HL06	14:22	68.4	50.9	3	4.0
	HL07	14:55	75.0	54.6	46	63.2
	HL08	12:55	63.4	48.4	3	3.9
	HL09	21:58	64.5	85.6	10	7.5
	HL10	16:03	73.8	56.5	6	7.8
	HL11	16:53	74.6	59.8	9	11.2
	HL12	18:18	57.3	68.0	6	5.1
	HL13	16:15	80.4	63.9	10	12.6
	HL14	18:01	81.4	67.6	4	4.8
	HL15	18:04	48.7	69.7	4	2.8
	HL16	11:05	55.9	35.4	2	3.2
	HL19	20:58	52.5	75.4	2	1.4
	HL21	20:47	55.5	80.1	6	4.2
	HL22	18:14	52.0	72.2	3	2.2
	HL23	14:27	42.0	56.2	4	3.0
	HL24	20:42	54.8	77.1	7	5.0
	HL25	16:04	43.6	59.1	2	1.5

Table 9.3 Herring larvae abundance (no./m^2) for larvae <10mm and ≥10mm by station and week

Week	Station	<10mm	≥10mm	Total
4	HL01	3.1	11.4	14.5
	HL03	29.2	5.7	34.9
	HL04	3.4	5.7	9.1
	HL05	5.2	9.6	14.8
	HL06	2.0	2.0	3.9
	HL07	2.5	2.5	4.9
	HL09	1.1	0.0	1.1
	HL13	0.0	1.0	1.0
6	HL03	9.8	5.6	15.4
	HL04	23.9	11.9	35.8
	HL05	6.9	12.5	19.4
	HL06	4.0	13.4	17.4
	HL07	6.9	16.2	23.1
	HL08	1.3	9.4	10.7
	HL10	14.1	11.5	25.6
	HL11	0.0	4.9	4.9
	HL12	0.0	12.9	12.9
	HL16	3.9	7.9	11.8
	HL18	0.0	1.4	1.4
	HL19	0.0	8.9	8.9
	HL20	13.5	33.2	46.7
	HL23	0.0	8.5	8.5
	HL24	0.0	7.1	7.1
7	HL01	0.0	1.2	1.2
	HL04	0.0	6.9	6.9
	HL06	1.3	2.5	3.8
	HL07	1.2	1.2	2.4
	HL08	0.0	3.8	3.8
	HL09	1.9	1.9	3.9
	HL10	0.7	0.7	1.4
	HL11	0.0	8.1	8.1
	HL12	0.7	0.0	0.7
	HL13	0.0	2.5	2.5
	HL14	2.6	6.6	9.2
	HL15	0.0	4.1	4.1
	HL16	1.3	12.5	13.9
	HL17	0.0	4.0	4.0
	HL18	0.0	0.9	0.9

Week	Station	<10mm	≥10mm	Total
	HL19	0.0	4.1	4.1
	HL20	2.7	16.1	18.8
	HL21	0.0	4.3	4.3
	HL22	0.0	2.5	2.5
	HL23	0.0	2.4	2.4
	HL24	0.0	4.8	4.8
	HL25	0.0	1.6	1.6
8	HL01	0.0	1.5	1.5
	HL02	0.0	3.0	3.0
	HL04	23.2	35.4	58.7
	HL05	0.0	3.8	3.8
	HL06	1.3	2.7	4.0
	HL07	20.6	42.6	63.2
	HL08	0.0	3.9	3.9
	HL09	1.5	6.0	7.5
	HL10	0.0	7.8	7.8
	HL11	0.0	11.2	11.2
	HL12	0.8	4.2	5.1
	HL13	0.0	12.6	12.6
	HL14	0.0	4.8	4.8
	HL15	0.0	2.8	2.8
	HL16	0.0	3.2	3.2
	HL19	0.0	1.4	1.4
	HL21	0.0	4.2	4.2
	HL22	0.0	2.2	2.2
	HL23	0.0	3.0	3.0
	HL24	0.0	5.0	5.0
	HL25	0.0	1.5	1.5

9.3 Bycatch data

A total of 45 other fish species were caught during the survey. The number of individuals caught for each species by sampling week is given in Table 9.4. The most abundant by-catch species were gobies (Goby family, 2,951). Week 1 had the greatest total number of individuals caught (1,322 individuals).

Table 9.4 Number of individuals for by-catch fish species by sampling week

Common Name	Species	Sampling Week							Grand Total
		1	2	3	4	6	7	8	
Goby family	Gobiidae	783	438	337	419	143	492	339	2,951
Goby sp.	*Lebetus* sp.	53	35	26	46	35	55	38	288
Lemon sole	*Microstomus kitt*	99	82	40	22	9	24	11	287
Smooth sandeel	*Gymnammodytes semisquamatus*	65	51	15	21	20	39	18	229
Sprat	*Sprattus sprattus*	74	46	16	8	4	5	1	154
Sandeel	*Ammodytidae*	40	27	17	48	8	5	3	148
Herring family	Clupeidae	3	0	2	15	50	56	16	142
Two-spot clingfish	*Diplecogaster bimaculata*	19	7	9	26	4	12	3	80
Crystal goby	*Crystallogobius linearis*	76	0	1	0	0	0	0	77
Dragonet sp.	*Callionymidae*	14	14	1	5	6	5	0	45
Sole family	Soleidae	8	12	9	8	2	5	0	44
Montagu's seasnail	*Liparis montagui*	15	8	3	6	4	4	2	42
Rockling family	Lotidae	5	3	1	6	11	12	4	42
Gurnard family	Triglidae	13	8	1	5	3	1	2	33
Greater sandeel	*Hyperoplus lanceolatus*	6	1	3	1	2	3	0	16
Norway bullhead	*Taurulus lilljeborgi*	6	6	2	1	0	0	0	15
Common dragonet	*Callionymus lyra*	5	4	2	1	1	0	1	14
Indet	Indetermined	3	3	3	4	1	0	0	14
Solenette	*Buglossidium luteum*	13	0	0	0	0	1	0	14
Dab	*Limanda limanda*	4	4	2	0	0	0	0	10
Hake	*Merluccius merluccius*	0	0	0	1	3	2	0	6
Lesser weever	*Echiichthys vipera*	0	0	0	2	2	1	1	6
Reticulated dragonet	*Callionymus reticulatus*	1	2	1	1	1	0	0	6
Argentine	*Argentina sphyraena*	3	0	0	1	0	1	0	5
Corkwing wrasse	*Symphodus melops*	0	3	1	0	1	0	0	5
Tadpole fish	*Raniceps raninus*	0	0	0	3	1	0	1	5
Worm pipefish	*Nerophis lumbriciformis*	1	0	0	1	0	2	1	5
Ballan wrasse	*Labrus bergylta*	1	1	0	0	1	1	0	4
Common ling	*Molva molva*	1	0	0	1	1	1	0	4
Common seasnail	*Liparis liparis*	1	0	0	0	1	1	1	4
Grey gurnard	*Eutrigla gurnardus*	3	0	0	0	0	0	0	3
Long-spined sea scorpion	*Taurulus bubalis*	1	1	0	1	0	0	0	3
Norway topknot	*Phrynorhombus norvegicus*	2	1	0	0	0	0	0	3
Shanny	*Lipophrys pholis*	0	1	0	0	1	1	0	3
Straight-nosed pipefish	*Nerophis ophidion*	0	1	0	0	0	1	1	3
Goldsinny wrasse	*Ctenolabrus rupestris*	0	0	0	0	0	2	0	2
Whiting	*Merlangius merlangus*	1	0	1	0	0	0	0	2
Witch	*Glyptocephalus cynoglossus*	0	1	0	1	0	0	0	2
Cuckoo wrasse	*Labrus mixtus*	0	0	1	0	0	0	0	1
Scaldfish	*Arnoglossus laterna*	0	0	0	0	0	0	1	1
Scaldfish sp.	*Arnoglossus* sp.	0	0	0	0	0	0	1	1
Scorpionfish family	Cottidae	1	0	0	0	0	0	0	1
Scorpionfish genus	*Taurulus* sp.	0	0	0	1	0	0	0	1
Thickback sole	*Microchirus variegatus*	1	0	0	0	0	0	0	1

Common Name	Species	Sampling Week							Grand Total
		1	2	3	4	6	7	8	
Topknot	*Zeugopterus punctatus*	1	0	0	0	0	0	0	1
Grand Total		1,322	760	494	655	315	732	445	4,723

9.4 Log of events

The survey was undertaken from the 1st August to the 27th September 2015, aiming to undertake 25 stations each week for 8 weeks weather permitting. A summarised log of events is given in Table 9.5.

Large numbers of static gear markers were observed at station HL02 and it was only possible to sample at this location twice over the 8 week survey (week 2 and week 8).

Due to poor weather conditions experienced during week 3 and week 6, only 15 stations and 16 stations (out of 25), respectively were sampled. Contingency stations were chosen that covered the area and the potential herring spawning grounds.

No sampling occurred during week 5 due to consistently poor weather conditions throughout the week.

Table 9.5 Summarised log of events

Saturday 1st August 2015 (Day 1 – Week 1)
BMM surveyors travel from office to Edinburgh
Sunday 2nd August 2015 (Day 2 – Week 1)
BMM surveyors travel from Edinburgh to Fraserburgh
Equipment loaded onto vessel (Antaries) and stowed away
Monday 3rd August 2015 (Day 3 – Week 1)
Mobilisation day - Antaries
Survey kick off meeting and HSE briefing and induction with reps from SSE (Nick Brockie & David Johnston) and SFF (Peter West)
Vessel remained in port due to poor weather conditions
Tuesday 4th August 2015 (Day 4 – Week 1)
Weather day in port
Wednesday 5th August 2015 (Day 5 – Week 1)
Vessel departed Fraserburgh at 1000 and steamed to survey area
Delayed sampling until 1400 due to swell
Undertook herring larval sampling at stations: 24, 23, 25
Weather: BF 4-5 SE to SSW, slight to moderate
Overnight at sea
Thursday 6th August 2015 (Day 6 – Week 1)
Undertook herring larval sampling at stations: 22, 21, 17, 14, 18, 15, 19
Weather: BF 2-4 SSW to NW, slight to moderate
Overnight at sea
Friday 7th August 2015 (Day 7 – Week 1)
Undertook herring larval sampling at stations: 16, 12, 09, 11, 08, 05

HL02 omitted due to high density of static gear in the vicinity
Weather: BF 2-4 SSW to NW, slight to moderate
Overnight at sea
Saturday 8th August 2015 (Day 8 – Week 1)
Undertook herring larval sampling at stations: 01, 03, 06, 04, 07, 10, 13, 20 – week 1 sampling completed
Vessel steamed to Fraserburgh, arrived in port at 2130
Weather: BF 2-3 SSE to NW, slight to moderate
Overnight on vessel
Sunday 9th August 2015 (Day 9 – Week 1)
Vessel crew change – Michael Sangster on for John Hepburn
Vessel departed Fraserburgh at 2300 to steam overnight to survey area
Overnight at sea
Monday 10th August 2015 (Day 10 – Week 2)
Undertook herring larval sampling at stations: 24, 23, 25, 22, 21, 17
Weather: BF 1-5 S to SE, slight to moderate
Overnight at sea
Tuesday 11th August 2015 (Day 11 – Week 2)
Undertook herring larval sampling at stations: 14, 18, 15, 19, 16, 12, 09
Weather: BF 2 W to NE, slight
Overnight at sea
Wednesday 12th August 2015 (Day 12 – Week 2)
Undertook herring larval sampling at stations: 11, 08, 05, 02, 01, 03
Weather: BF 2 SW to S, slight
Overnight at sea
Thursday 13th August 2015 (Day 13 – Week 2)
Undertook herring larval sampling at stations: 06, 04, 07, 10, 13, 20 - week 2 sampling completed
Vessel steamed to Fraserburgh, arrived in port at 2130
Weather: BF 2-5 SW to S to SE, slight to moderate
Overnight on vessel
Friday 14th August 2015 (Day 14 – Week 2)
Vessel on standby in port until week 3 sampling commences
Saturday 15th August 2015 (Day 15 – Week 2)
Vessel on standby in port until week 3 sampling commences
Surveyor crew change – Courtney French on for Sophie Farenden
Sunday 16th August 2015 (Day 16 – Week 2)
Vessel crew change – John Hepburn on for Michael Sangster
Vessel departed port at 2300 and steamed overnight to survey area
Overnight at sea
Monday 17th August 2015 (Day 17 – Week 3)
Undertook herring larval sampling at stations: 24, 23, 25, 22, 21, 17
Weather: BF 2 NW to N, slight
Overnight at sea
Tuesday 18th August 2015 (Day 18 – Week 3)

Undertook herring larval sampling at stations: 14, 18, 15, after which sea state became unsuitable for sampling
Weather: BF 4 NE slight to moderate
Weather forecasts poor for the next day. Vessel steamed to Fraserburgh, arrived in port at 1730.
Wednesday 19th August 2015 (Day 19 – Week 3)
Weather day in port. Forecasted wave heights unsuitable for sampling.
Thursday 20th August 2015 (Day 20 – Week 3)
Weather day in port. Forecasted wave heights unsuitable for sampling.
Friday 21st August 2015 (Day 21 – Week 3)
Weather day in port. Forecasted wave heights unsuitable for sampling.
Vessel departed port at 2215 and steamed overnight to survey area to continue week 3 sampling on Saturday morning
Overnight at sea
Saturday 22nd August 2015 (Day 22 – Week 3)
Undertook herring larval sampling at stations identified in 1 day contingency plan: 11, 09, 05, 03, 04, 07 – this concludes week 3 sampling due to poor conditions forecasted for Sunday
Vessel steamed to port, arrived at 2245
Weather: BF 3-4 SE, slight to moderate
Overnight on vessel
Sunday 23rd August 2015 (Day 23 – Week 3)
Weather day in port
Surveyor crew transfer – Jake Laws on for Courtney French
Monday 24th August 2015 (Day 24 – Week 4)
Weather day in port
Tuesday 25th August 2015 (Day 25 – Week 4)
Weather day in port
Vessel departed port at 2200 and steamed overnight to survey area
Overnight at sea
Wednesday 26th August 2015 (Day 26 – Week 4)
Beacon malfunction. Replacement beacon couriered up same day.
Vessel steamed to Fraserburgh to collect replacement beacon, arrived in port at 1330.
Vessel departed port at 2230 and steamed overnight to survey area
Overnight at sea
Thursday 27th August 2015 (Day 27 – Week 4)
Undertook herring larval sampling at stations: 24, 23, 25, 22, 21, 17
Weather: BF 3-4 SW, slight
Overnight at sea
Friday 28th August 2015 (Day 28 – Week 4)
Undertook herring larval sampling at stations: 14, 18, 15, 19, 16, 12, 09
Weather: BF 3-4 SW, slight
Overnight at sea
Saturday 29th August 2015 (Day 29 – Week 4)
Undertook herring larval sampling at stations: 11, 08, 05, 01, 03, 06
Weather: BF 4-5 SW, slight to moderate

Overnight at sea
Sunday 30th August 2015 (Day 30 – Week 4)
Undertook herring larval sampling at stations: 04, 07, 10, 13, 20 – week 4 sampling
Vessel steamed to Fraserburgh, arrived in port at 1730.
Weather: BF 4-5 SW, slight to moderate
Monday 31st August 2015 (Day 31 – Week 5)
Mobilisation day - Pleiades
Vessel changeover – equipment unloaded from Antaries and loaded onto Pleiades
Survey kick off meeting and HSE briefing and induction with reps from SSE (Nick Brockie) and SFF (Peter West)
Vessel departed port at 1415 to undertake trial tows with the Gulf VII 1 mile offshore. Vessel returned to port at 1530.
Weather day in port
Tuesday 1st September 2015 (Day 32 – Week 5)
Weather day in port
Wednesday 2nd September 2015 (Day 33 – Week 5)
Weather day in port
Thursday 3rd September 2015 (Day 34 – Week 5)
Weather day in port
Friday 4th September 2015 (Day 35 – Week 5)
Weather day in port
Saturday 5th September 2015 (Day 36 – Week 5)
Weather day in port
Sunday 6th September 2015 (Day 37 – Week 5)
Weather day in port
Monday 7th September 2015 (Day 38 – Week 6)
Vessel departed Fraserburgh at 1000 and steamed to survey area.
Undertook herring larval sampling at stations: 24, 23
Weather: BF 4 NW, slight
Overnight at sea
Tuesday 8th September 2015 (Day 39 – Week 6)
Undertook herring larval sampling at stations: 18, 14, 11, 08, 05, 03, 06
Weather: BF 2-4 SW, slight
Overnight at sea
Wednesday 9th September 2015 (Day 40 – Week 6)
Undertook herring larval sampling at stations: 04, 07, 10
Weather: BF 4, SW, slight to moderate
Overnight at sea
Thursday 10th September 2015 (Day 41 – Week 6)
Undertook herring larval sampling at stations:12, 16, 20, 19
Poor weather forecasted, vessel steamed to Fraserburgh, arrived in port at 2115
Weather: BF 4, SW, slight to moderate
Overnight on vessel
Friday 11th September 2015 (Day 42 – Week 6)
Weather day in port

Saturday 12th September 2015 (Day 43 – Week 6)
Weather day in port
Sunday 13th September 2015 (Day 44 – Week 6)
Vessel on standby in port
Departed Fraserburgh at 2200 and steamed overnight to survey area
Overnight at sea
Monday 14th September 2015 (Day 45 – Week 7)
Undertook herring larval sampling at stations: 24, 23, 25, 22, 21, 17
Weather: BF 4-5 NE, slight to moderate
Overnight at sea
Tuesday 15th September 2015 (Day 46 – Week 7)
Undertook herring larval sampling at stations: 14, 18, 15, 19, 16, 12, 09
Weather: BF 2-3, SE to SW, slight to moderate
Overnight at sea
Wednesday 16th September 2015 (Day 47 – Week 7)
Undertook herring larval sampling at stations: 11, 08, 05, 01, 03, 06
Weather: BF 2-3, NW, slight
Overnight at sea
Thursday 17th September 2015 (Day 48 – Week 7)
Undertook herring larval sampling at stations: 04, 07, 10, 13, 20.
Vessel steamed to Fraserburgh, arrived in port at 2000
Weather: BF 2-3 NW, slight
Overnight on vessel
Friday 18th September 2015 (Day 49 – Week 7)
Vessel on standby in port
Saturday 19th September 2015 (Day 50 – Week 7)
Vessel on standby in port
Sunday 20th September 2015 (Day 51 – Week 7)
Vessel on standby in port
Departed Fraserburgh at 2300 and steamed overnight to survey area
Overnight at sea
Monday 21st September 2015 (Day 52 – Week 8)
Undertook herring larval sampling at stations: 24, 23, 25, 22, 21, 17
Weather: BF 2 – 3, SE to NW, slight
Overnight at sea
Tuesday 22nd September 2015 (Day 53 – Week 8)
Undertook herring larval sampling at stations: 14, 18, 15, 19, 16, 12, 09
Weather: BF 4 NNW, slight to moderate
Overnight at sea
Wednesday 23rd September 2015 (Day 54 – Week 8)
Undertook herring larval sampling at stations: 11, 08, 05, 02, 01, 03, 06
Weather: BF 2-4 SW, slight to moderate
Overnight at sea
Thursday 24th September 2015 (Day 55 – Week 8)
Undertook herring larval sampling at stations: 04, 07, 10, 13, 20

Weather: BF 4 SW, slight to moderate
Vessel steamed to Fraserburgh, arrived in port at 2000
Overnight on vessel
Friday 25th September 2015 (Day 56 – Week 8)
Vessel demob and survey demob - equipment unloaded from vessel and onto van
Saturday 26th September 2015 (Day 57 – Week 8)
BMM surveyors return to office. Samples transported to office.

9.5 Times and Coordinates

The times and coordinates of each Gulf VII plankton tow are given for each survey week in Table 9.6 to Table 9.12.

Table 9.6 Week 1 Gulf VII plankton tow times and coordinates

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL01	08/08/2015	06:49:52	58° 35.994	-02° 54.211	82.7	07:03:55	58° 36.804	-02° 54.947	73.5	14:03
HL03	08/08/2015	07:51:03	58° 34.340	-02° 48.792	69.9	08:03:47	58° 33.767	-02° 47.480	65.9	12:44
HL04	08/08/2015	10:16:34	58° 33.171	-02° 32.249	66.2	10:33:17	58° 32.828	-02° 30.088	71.0	16:43
HL05	08/08/2015	14:34:47	58° 28.520	-02° 55.026	65.1	14:50:04	58° 29.468	-02° 54.638	67.2	15:17
HL06	08/08/2015	09:04:17	58° 29.867	-02° 40.379	67.4	09:21:57	58° 29.298	-02° 38.119	62.7	17:40
HL07	08/08/2015	11:27:51	58° 29.487	-02° 24.765	71.0	11:44:02	58° 28.469	-02° 24.697	66.9	16:11
HL08	07/08/2015	13:14:03	58° 24.398	-03° 01.184	62.9	13:28:45	58° 25.323	-03° 01.833	73.5	14:42
HL09	07/08/2015	10:13:29	58° 25.148	-02° 46.365	60.9	10:34:46	58° 25.232	-02° 49.312	63.7	21:17
HL10	07/08/2015	12:35:26	58° 25.976	-02° 30.450	63.6	12:51:25	58° 24.882	-02° 31.213	62.7	15:59
HL11	07/08/2015	11:29:48	58° 22.206	-02° 53.433	69.9	11:46:05	58° 21.299	-02° 54.634	73.5	16:17
HL12	07/08/2015	08:52:15	58° 21.052	-02° 38.823	54.5	09:08:32	58° 21.920	-02° 40.398	55.7	16:17
HL13	08/08/2015	13:34:47	58° 22.593	-02° 24.559	67.1	13:49:23	58° 21.513	-02° 24.295	76.3	14:36
HL14	06/08/2015	11:31:07	58° 16.858	-03° 03.275	73.8	11:49:22	58° 16.660	-03° 00.508	71.7	18:15
HL15	06/08/2015	14:09:31	58° 16.558	-02° 47.882	47.8	14:22:48	58° 16.856	-02° 46.219	46.4	13:17
HL16	07/08/2015	07:23:41	58° 17.993	-02° 31.701	53.1	07:38:56	58° 16.964	-02° 31.950	53.9	15:15
HL17	06/08/2015	10:08:53	58° 13.090	-03° 10.025	59.8	10:37:49	58° 14.687	-03° 07.223	64.0	28:56
HL18	06/08/2015	12:49:40	58° 13.219	-02° 54.563	39.4	13:08:42	58° 13.785	-02° 52.651	40.5	19:02
HL19	06/08/2015	15:22:12	58° 12.987	-02° 40.413	50.6	15:35:00	58° 13.041	-02° 38.681	53.9	12:48
HL20	08/08/2015	15:00:56	58° 14.304	-02° 23.906	59.9	15:13:58	58° 13.367	-02° 23.869	62.5	13:02
HL21	06/08/2015	08:46:24	58° 09.655	-03° 15.052	55.9	09:03:37	58° 09.274	-03° 17.264	51.1	17:13
HL22	06/08/2015	07:21:16	58° 10.296	-03° 03.812	53.4	07:35:40	58° 09.295	-03° 04.196	48.1	14:24
HL23	05/08/2015	16:54:08	58° 09.362	-02° 46.272	42.7	17:13:30	58° 08.836	-02° 48.739	36.5	19:22
HL24	05/08/2015	15:01:51	58° 08.378	-02° 31.592	50.9	15:31:23	58° 09.984	-02° 33.502	56.7	29:32
HL25	05/08/2015	18:00:15	58° 06.127	-02° 53.347	37.4	18:16:03	58° 05.322	-02° 54.657	41.3	15:48

Table 9.7 Week 2 Gulf VII plankton tow times and coordinates

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL01	12/08/2015	16:29:15	58° 37.580	-02° 54.539	73.6	16:46:58	58° 36.294	-02° 53.868	74.1	17:43
HL02	12/08/2015	13:37:10	58° 34.233	-03° 02.161	41.5	13:48:59	58° 33.540	-03° 02.042	42.6	11:49
HL03	12/08/2015	17:47:29	58° 32.847	-02° 46.147	59.0	18:05:24	58° 33.946	-02° 47.433	66.7	17:55
HL04	13/08/2015	08:24:50	58° 32.485	-02° 31.329	69.5	08:46:35	58° 33.998	-02° 32.043	70.3	21:45
HL05	12/08/2015	11:47:49	58° 29.715	-02° 54.585	60.8	12:04:33	58° 28.525	-02° 53.918	63.4	16:44
HL06	13/08/2015	07:07:34	58° 28.462	-02° 38.999	63.9	07:26:12	58° 29.643	-02° 40.011	66.1	18:38
HL07	13/08/2015	10:05:40	58° 28.336	-02° 23.673	72.1	10:23:31	58° 29.565	-02° 24.314	70.8	17:51
HL08	12/08/2015	10:13:58	58° 24.677	-03° 02.283	54.8	10:29:46	58° 25.822	-03° 01.867	44.1	15:48
HL09	11/08/2015	15:56:37	58° 25.541	-02° 46.731	63.4	16:13:07	58° 24.375	-02° 47.176	60.4	16:30
HL10	13/08/2015	11:30:57	58° 24.713	-02° 31.071	62.5	11:47:45	58° 25.901	-02° 31.470	71.4	16:48
HL11	12/08/2015	08:51:43	58° 20.468	-02° 54.744	75.0	09:12:12	58° 21.867	-02° 54.214	73.5	20:29
HL12	11/08/2015	14:26:34	58° 21.723	-02° 38.925	52.4	14:44:38	58° 20.467	-02° 39.753	57.3	18:04
HL13	13/08/2015	13:09:50	58° 20.708	-02° 24.019	77.3	13:27:44	58° 22.107	-02° 24.044	64.3	17:54
HL14	11/08/2015	07:07:45	58° 16.585	-03° 02.581	77.1	07:25:39	58° 17.668	-03° 01.521	79.0	17:54
HL15	11/08/2015	09:53:03	58° 16.825	-02° 47.012	47.5	10:07:52	58° 17.940	-02° 46.895	50.7	14:49

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL16	11/08/2015	12:52:06	58° 17.606	-02° 31.764	53.2	13:10:28	58° 16.276	-02° 31.887	52.8	18:22
HL17	10/08/2015	15:43:47	58° 14.002	-03° 10.375	59.8	15:56:33	58° 13.176	-03° 09.576	60.5	12:46
HL18	11/08/2015	08:37:34	58° 12.728	-02° 55.000	41.6	08:50:42	58° 13.511	-02° 53.930	39.1	13:08
HL19	11/08/2015	11:21:26	58° 13.481	-02° 38.769	51.4	11:36:34	58° 13.068	-02° 40.771	48.6	15:08
HL20	13/08/2015	14:52:10	58° 14.274	-02° 24.047	59.7	15:06:45	58° 13.207	-02° 24.243	63.4	14:35
HL21	10/08/2015	14:16:10	58° 10.048	-03° 14.871	55.3	14:32:22	58° 09.154	-03° 16.330	53.9	16:12
HL22	10/08/2015	12:47:24	58° 10.760	-03° 02.887	52.8	13:03:21	58° 09.968	-03° 04.374	53.5	15:57
HL23	10/08/2015	09:20:47	58° 08.935	-02° 46.226	43.6	09:37:38	58° 10.077	-02° 47.072	40.9	16:51
HL24	10/08/2015	07:32:22	58° 08.540	-02° 31.479	52.0	07:48:42	58° 09.824	-02° 31.300	54.1	16:20
HL25	10/08/2015	10:57:26	58° 05.606	-02° 54.056	40.2	11:18:12	58° 04.366	-02° 55.961	46.4	20:46

Table 9.8 Week 3 Gulf VII plankton tow times and coordinates

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL03	22/08/2015	11:25:41	58° 32.969	-02° 46.707	66.5	11:41:00	58° 34.124	-02° 46.641	62.6	15:19
HL04	22/08/2015	13:05:42	58° 32.073	-02° 33.003	71.1	13:20:52	58° 32.793	-02° 31.324	71.5	15:10
HL05	22/08/2015	09:54:42	58° 29.877	-02° 53.299	61.3	10:11:53	58° 29.233	-02° 55.334	58.8	17:11
HL07	22/08/2015	14:25:03	58° 28.286	-02° 25.184	68.9	14:41:38	58° 29.229	-02° 24.073	71.3	16:35
HL09	22/08/2015	08:30:29	58° 25.644	-02° 48.389	63.2	08:46:44	58° 25.378	-02° 46.248	60.6	16:15
HL11	21/08/2015	07:05:58	58° 22.064	-02° 54.158	69.6	07:24:09	58° 20.776	-02° 53.588	70.4	18:11
HL14	18/08/2015	05:02:47	58° 17.968	-03° 01.641	76.9	05:19:27	58° 16.986	-03° 00.484	74.1	16:40
HL15	18/08/2015	07:57:06	58° 17.809	-02° 47.471	47.4	08:13:36	58° 16.846	-02° 46.119	45.7	16:30
HL17	17/08/2015	14:56:14	58° 13.538	-03° 08.986	62.0	15:11:53	58° 12.567	-03° 10.220	60.8	15:39
HL18	18/08/2015	06:21:29	58° 14.191	-02° 54.874	41.2	06:34:52	58° 13.398	-02° 53.791	37.4	13:23
HL21	17/08/2015	13:21:54	58° 09.124	-03° 17.975	52.4	13:37:21	58° 09.847	-03° 16.279	54.1	15:27
HL22	17/08/2015	11:48:18	58° 09.602	-03° 03.715	47.6	12:04:24	58° 10.426	-03° 04.738	60.5	16:06
HL23	17/08/2015	09:13:43	58° 09.312	-02° 45.802	41.8	09:30:11	58° 08.964	-02° 47.959	39.0	16:28
HL24	17/08/2015	07:42:21	58° 09.231	-02° 31.060	52.1	07:55:54	58° 09.232	-02° 32.873	53.8	13:33
HL25	17/08/2015	10:22:04	58° 05.586	-02° 54.389	40.1	10:42:13	58° 05.678	-02° 57.207	44.7	20:09

Table 9.9 Week 4 Gulf VII plankton tow times and coordinates

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL01	29/08/2015	11:32:18	58° 36.507	-02° 54.745	78.1	11:50:43	58° 37.542	-02° 54.067	79.0	18:25
HL03	29/08/2015	13:13:54	58° 33.690	-02° 47.178	66.5	13:34:09	58° 32.528	-02° 47.499	72.0	20:15
HL04	30/08/2015	06:12:18	58° 33.848	-02° 31.052	73.6	06:29:06	58° 32.748	-02° 31.077	69.7	16:48
HL05	29/08/2015	08:28:42	58° 28.459	-02° 55.273	63.3	08:55:44	58° 29.334	-02° 54.715	60.2	27:02
HL06	29/08/2015	14:55:05	58° 29.181	-02° 40.966	68.2	15:12:58	58° 29.593	-02° 38.377	62.7	17:53
HL07	30/08/2015	07:13:25	58° 30.015	-02° 24.995	72.0	07:29:20	58° 29.156	-02° 23.435	71.3	15:55
HL08	29/08/2015	07:14:44	58° 24.333	-03° 00.789	64.1	07:33:03	58° 25.366	-03° 01.360	57.0	18:19
HL09	28/08/2015	15:23:13	58° 25.860	-02° 46.142	58.1	15:39:51	58° 25.331	-02° 47.834	63.3	16:38
HL10	30/08/2015	08:33:24	58° 25.391	-02° 30.135	65.8	08:52:52	58° 24.774	-02° 32.561	69.7	19:28
HL11	29/08/2015	06:03:59	58° 22.031	-02° 53.103	71.0	06:20:09	58° 22.154	-02° 55.317	66.5	16:10
HL12	28/08/2015	14:00:21	58° 20.514	-02° 38.342	53.9	14:14:05	58° 21.451	-02° 38.904	54.5	13:44
HL13	30/08/2015	09:54:16	58° 21.034	-02° 24.054	77.6	10:10:39	58° 22.048	-02° 22.826	62.9	16:23
HL14	28/08/2015	07:09:28	58° 16.529	-03° 02.456	78.4	07:28:21	58° 17.645	-03° 01.210	78.5	18:53
HL15	28/08/2015	09:52:09	58° 16.509	-02° 47.378	47.8	10:08:27	58° 17.492	-02° 46.354	49.3	16:18

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL16	28/08/2015	12:45:07	58° 16.811	-02° 30.918	54.8	13:00:55	58° 17.758	-02° 32.354	50.6	15:48
HL17	27/08/2015	14:50:42	58° 13.638	-03° 10.200	59.2	15:06:35	58° 12.671	-03° 08.903	63.6	15:53
HL18	28/08/2015	08:39:58	58° 12.331	-02° 54.773	39.9	08:57:15	58° 13.400	-02° 53.614	39.1	17:17
HL19	28/08/2015	11:21:05	58° 12.761	-02° 40.078	51.1	11:36:10	58° 13.514	-02° 38.891	51.4	15:05
HL20	30/08/2015	11:44:14	58° 13.422	-02° 22.578	64.0	12:00:09	58° 13.559	-02° 24.752	61.3	15:55
HL21	27/08/2015	13:30:42	58° 09.676	-03° 14.955	56.7	13:47:45	58° 09.551	-03° 17.228	51.1	17:03
HL22	27/08/2015	12:05:58	58° 10.135	-03° 02.456	40.9	12:20:17	58° 10.095	-03° 04.417	55.7	14:19
HL23	27/08/2015	09:13:09	58° 08.471	-02° 45.734	47.9	09:29:35	58° 09.664	-02° 46.055	43.2	16:26
HL24	27/08/2015	07:29:00	58° 08.416	-02° 31.523	50.8	07:45:22	58° 09.507	-02° 31.943	55.5	16:22
HL25	27/08/2015	10:39:47	58° 05.280	-02° 53.618	43.0	10:53:39	58° 05.428	-02° 55.616	42.0	13:52

Table 9.10 Week 6 Gulf VII plankton tow times and coordinates

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL03	08/09/2015	14:15:30	58° 33.573	-02° 46.722	63.7	14:28:41	58° 32.751	-02° 46.663	71.0	13:11
HL04	09/09/2015	07:17:30	58° 32.602	-02° 31.101	73.4	07:33:04	58° 33.657	-02° 31.269	76.6	15:34
HL05	08/09/2015	12:50:20	58° 29.672	-02° 54.414	62.5	13:02:26	58° 28.972	-02° 54.548	60.6	12:06
HL06	08/09/2015	15:25:14	58° 29.670	-02° 39.182	67.5	15:38:50	58° 28.707	-02° 39.273	68.0	13:36
HL07	09/09/2015	09:18:07	58° 28.279	-02° 23.630	73.6	09:34:31	58° 29.428	-02° 24.100	74.2	16:24
HL08	08/09/2015	11:29:05	58° 25.613	-03° 01.185	58.1	11:41:08	58° 24.885	-03° 01.430	62.0	12:03
HL10	09/09/2015	11:18:27	58° 24.703	-02° 31.867	65.5	11:30:35	58° 25.582	-02° 31.824	73.6	12:08
HL11	08/09/2015	10:03:45	58° 21.376	-02° 54.309	72.9	10:20:36	58° 22.620	-02° 53.961	73.7	16:51
HL12	10/09/2015	07:11:44	58° 20.429	-02° 38.953	60.4	07:23:08	58° 21.193	-02° 39.214	58.1	11:24
HL14	08/09/2015	08:37:51	58° 16.540	-03° 01.658	79.3	08:55:51	58° 17.829	-03° 01.769	80.0	18:00
HL16	10/09/2015	09:08:35	58° 16.633	-02° 31.175	57.8	09:20:16	58° 17.404	-02° 31.294	56.3	11:41
HL18	08/09/2015	07:29:23	58° 12.364	-02° 52.902	43.1	07:44:12	58° 13.105	-02° 54.386	42.2	14:49
HL19	10/09/2015	12:45:52	58° 13.240	-02° 37.846	53.6	13:05:49	58° 12.832	-02° 40.211	51.8	19:57
HL20	10/09/2015	11:10:22	58° 12.748	-02° 23.880	66.0	11:25:09	58° 13.618	-02° 24.785	62.1	14:47
HL23	07/09/2015	04:25:55	58° 08.704	-02° 46.502	44.7	04:40:52	58° 09.707	-02° 46.261	43.6	14:57
HL24	07/09/2015	02:37:13	58° 09.562	-02° 32.154	56.2	02:49:40	58° 08.900	-02° 31.335	53.7	12:27

Table 9.11 Week 7 Gulf VII plankton tow times and coordinates

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL01	16/09/2015	14:17:01	58° 37.569	-02° 54.580	77.0	14:33:38	58° 36.583	-02° 53.527	88.7	16:37
HL03	16/09/2015	15:20:10	58° 33.750	-02° 47.807	68.1	15:34:18	58° 33.122	-02° 46.439	61.8	14:08
HL04	17/09/2015	07:03:21	58° 34.039	-02° 31.220	76.7	07:19:26	58° 32.886	-02° 31.122	72.1	16:05
HL05	16/09/2015	10:32:55	58° 28.491	-02° 54.830	65.0	10:44:59	58° 29.189	-02° 55.126	60.7	12:04
HL06	16/09/2015	16:27:55	58° 29.488	-02° 39.929	70.1	16:42:35	58° 28.867	-02° 38.493	63.3	14:40
HL07	17/09/2015	08:13:06	58° 29.336	-02° 24.324	72.9	08:27:53	58° 28.401	-02° 25.302	68.9	14:47
HL08	16/09/2015	09:21:02	58° 24.245	-03° 01.618	63.8	09:33:37	58° 25.077	-03° 01.397	60.2	12:35
HL09	15/09/2015	14:54:12	58° 24.926	-02° 46.004	62.0	15:19:49	58° 24.069	-02° 49.087	62.2	25:37
HL10	17/09/2015	09:11:14	58° 25.350	-02° 30.705	68.7	09:37:35	58° 23.662	-02° 28.681	70.1	26:21
HL11	16/09/2015	08:09:46	58° 22.413	-02° 53.515	74.0	08:25:27	58° 21.339	-02° 54.788	72.2	15:41
HL12	15/09/2015	13:42:03	58° 20.681	-02° 37.856	54.8	14:02:46	58° 21.821	-02° 40.293	61.3	20:43
HL13	17/09/2015	10:27:06	58° 20.060	-02° 23.413	73.4	10:43:24	58° 21.080	-02° 24.370	80.6	16:18
HL14	15/09/2015	07:32:27	58° 17.986	-03° 02.127	74.5	07:48:47	58° 16.815	-03° 01.743	79.2	16:20

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL15	15/09/2015	10:09:34	58° 16.885	-02° 47.926	50.1	10:27:58	58° 17.602	-02° 45.881	50.9	18:24
HL16	15/09/2015	12:38:36	58° 16.667	-02° 32.376	57.6	12:59:06	58° 18.187	-02° 31.727	56.3	20:30
HL17	14/09/2015	16:21:07	58° 13.419	-03° 08.708	62.6	16:33:30	58° 13.184	-03° 10.170	62.6	12:23
HL18	15/09/2015	08:45:45	58° 13.616	-02° 54.500	41.0	08:59:01	58° 12.634	-02° 54.831	42.3	13:16
HL19	15/09/2015	11:28:36	58° 12.828	-02° 40.389	53.3	11:48:19	58° 13.752	-02° 38.269	53.1	19:43
HL20	17/09/2015	12:09:39	58° 12.202	-02° 24.647	62.6	12:34:13	58° 13.768	-02° 24.430	63.1	24:34
HL21	14/09/2015	14:45:26	58° 09.204	-03° 16.566	56.2	14:57:15	58° 09.095	-03° 17.973	53.6	11:49
HL22	14/09/2015	13:08:17	58° 09.281	-03° 03.331	49.0	13:25:51	58° 10.437	-03° 03.599	57.3	17:34
HL23	14/09/2015	10:11:55	58° 08.733	-02° 47.517	42.8	10:25:52	58° 09.605	-02° 47.336	43.3	13:57
HL24	14/09/2015	08:18:51	58° 09.148	-02° 32.246	55.5	08:28:59	58° 09.248	-02° 30.963	54.8	10:08
HL25	14/09/2015	11:40:00	58° 04.812	-02° 54.270	47.3	11:55:04	58° 05.709	-02° 54.970	43.3	15:04

Table 9.12 Week 8 Gulf VII plankton tow times and coordinates

Station	Date	Gulf VII Plankton Tow Start				Gulf VII Plankton Tow End				Duration (mm:ss)
		Time (GMT)	WGS84 DDM		Depth (m)	Time (GMT)	WGS84 DDM		Depth (m)	
			Latitude	Longitude			Latitude	Longitude		
HL01	23/09/2015	13:36:54	58° 37.526	-02° 53.870	76.9	13:50:51	58° 36.612	-02° 54.549	77.1	13:57
HL02	23/09/2015	11:39:31	58° 34.465	-03° 01.644	51.5	11:56:40	58° 33.328	-03° 01.737	50.3	17:09
HL03	23/09/2015	14:56:41	58° 32.736	-02° 46.941	77.0	15:10:48	58° 33.640	-02° 46.360	61.2	14:07
HL04	24/09/2015	06:19:58	58° 32.264	-02° 31.579	73.2	06:35:25	58° 33.300	-02° 31.302	75.1	15:27
HL05	23/09/2015	09:05:48	58° 29.696	-02° 54.063	62.6	09:27:39	58° 28.333	-02° 54.566	66.0	21:51
HL06	23/09/2015	16:12:16	58° 29.054	-02° 39.403	70.8	16:26:38	58° 29.898	-02° 38.731	66.8	14:22
HL07	24/09/2015	07:41:13	58° 28.474	-02° 23.762	75.3	07:56:08	58° 29.389	-02° 23.965	74.6	14:55
HL08	23/09/2015	07:46:33	58° 24.474	-03° 01.278	64.9	07:59:28	58° 25.378	-03° 01.281	60.1	12:55
HL09	22/09/2015	16:09:43	58° 24.722	-02° 46.244	62.1	16:31:41	58° 26.157	-02° 46.652	61.9	21:58
HL10	24/09/2015	09:12:03	58° 24.892	-02° 31.175	68.1	09:28:06	58° 25.957	-02° 31.132	71.0	16:03
HL11	23/09/2015	06:44:56	58° 21.309	-02° 54.157	73.4	07:01:03	58° 22.370	-02° 54.642	71.4	16:07
HL12	22/09/2015	14:48:35	58° 20.761	-02° 39.063	57.6	15:06:53	58° 21.907	-02° 39.145	53.2	18:18
HL13	24/09/2015	10:29:08	58° 21.380	-02° 25.082	77.9	10:45:23	58° 20.504	-02° 23.574	76.8	16:15
HL14	22/09/2015	07:13:21	58° 17.593	-03° 01.553	80.7	07:31:22	58° 16.618	-03° 02.999	78.5	18:01
HL15	22/09/2015	10:20:23	58° 17.656	-02° 46.859	50.6	10:38:27	58° 16.484	-02° 46.468	46.8	18:04
HL16	22/09/2015	13:16:57	58° 17.222	-02° 32.472	54.4	13:28:02	58° 17.177	-02° 31.116	58.4	11:05
HL17	21/09/2015	15:58:39	58° 12.724	-03° 10.362	62.8	16:11:04	58° 13.418	-03° 09.510	65.0	12:25
HL18	22/09/2015	08:36:11	58° 13.783	-02° 54.310	39.6	08:50:45	58° 12.756	-02° 54.120	32.0	14:34
HL19	22/09/2015	11:32:41	58° 13.826	-02° 39.552	51.6	11:53:39	58° 12.438	-02° 39.214	53.8	20:58
HL20	24/09/2015	12:17:54	58° 13.289	-02° 24.166	65.8	12:30:31	58° 12.474	-02° 24.017	65.4	12:37
HL21	21/09/2015	14:49:48	58° 08.949	-03° 17.764	54.6	15:10:33	58° 09.903	-03° 15.864	56.8	20:45
HL22	21/09/2015	12:58:00	58° 09.510	-03° 04.308	52.3	13:16:14	58° 10.385	-03° 02.484	52.0	18:14
HL23	21/09/2015	09:45:36	58° 09.930	-02° 46.747	41.9	10:00:03	58° 08.908	-02° 47.045	41.3	14:27
HL24	21/09/2015	07:55:39	58° 09.713	-02° 31.698	56.1	08:16:21	58° 08.280	-02° 31.786	51.8	20:42
HL25	21/09/2015	11:16:03	58° 05.640	-02° 54.458	41.9	11:32:07	58° 04.527	-02° 54.679	49.7	16:04

9.6 Tow and Vessel Track charts

The Gulf VII plankton sampler tow locations and vessel tracks for each survey week is shown in Figure 9.1 to Figure 9.7.

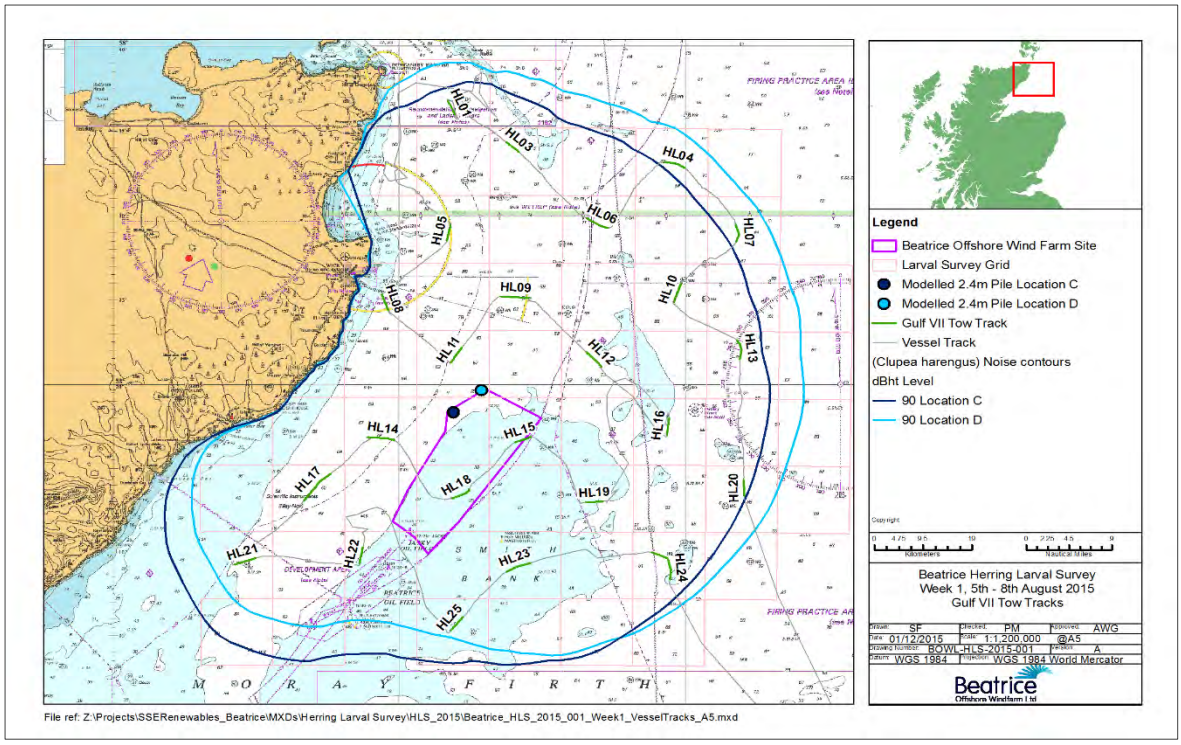

Figure 9.1 Week 1 tow and vessel tracks

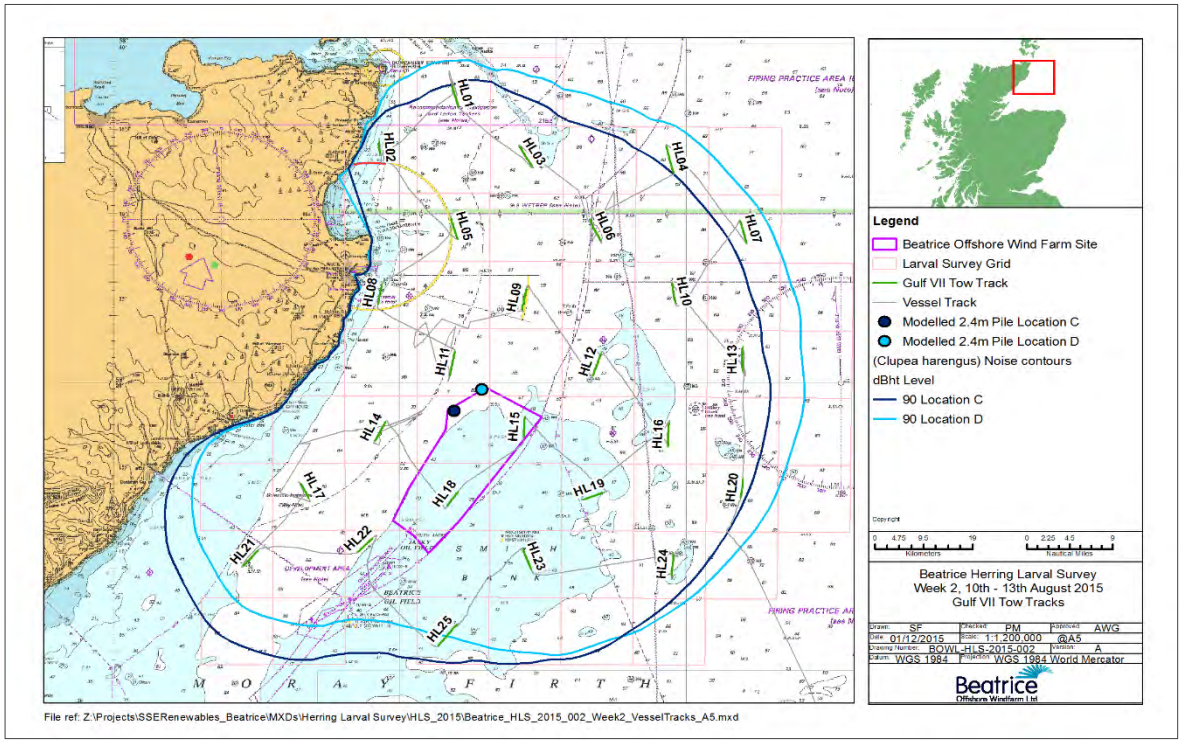

Figure 9.2 Week 2 tow and vessel tracks

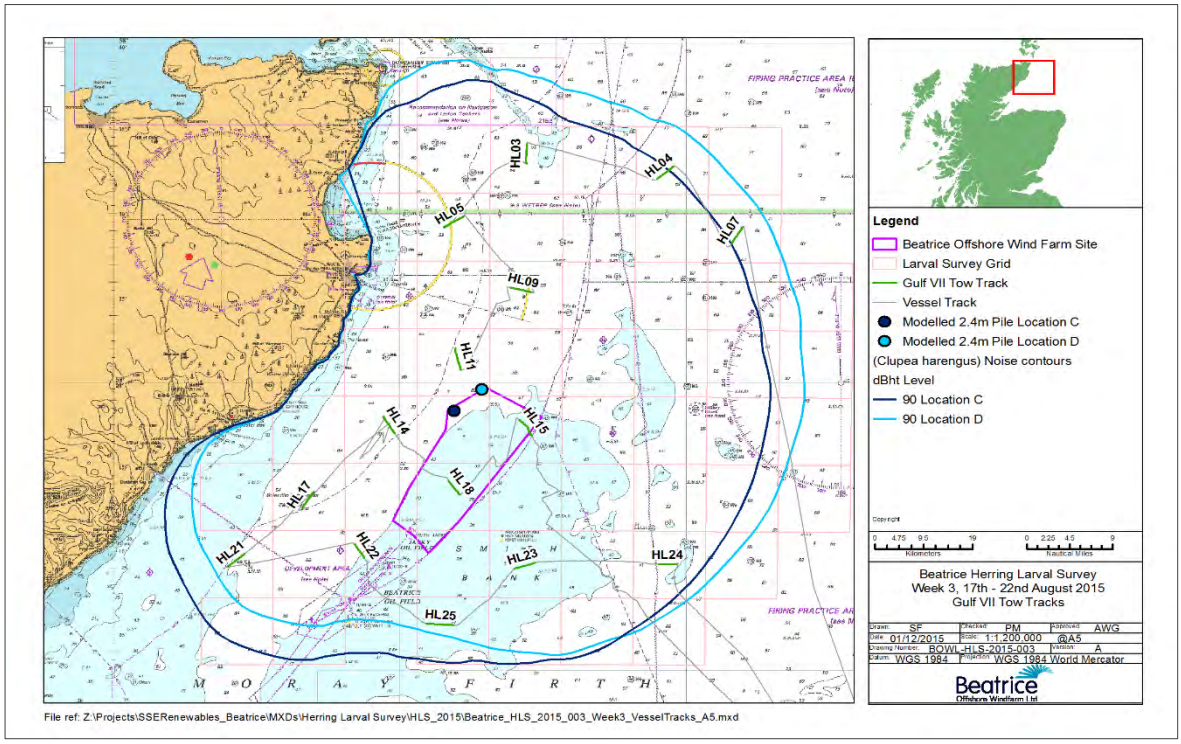

Figure 9.3 Week 3 tow and vessel tracks

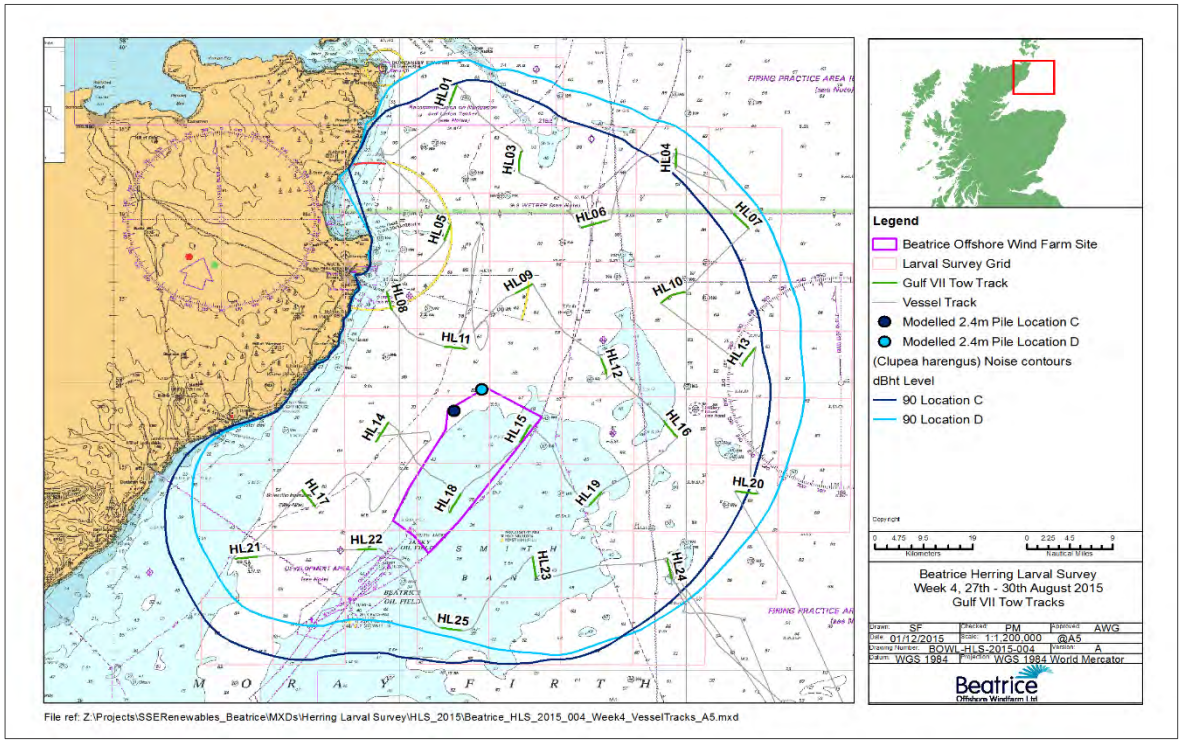

Figure 9.4 Week 4 tow and vessel tracks

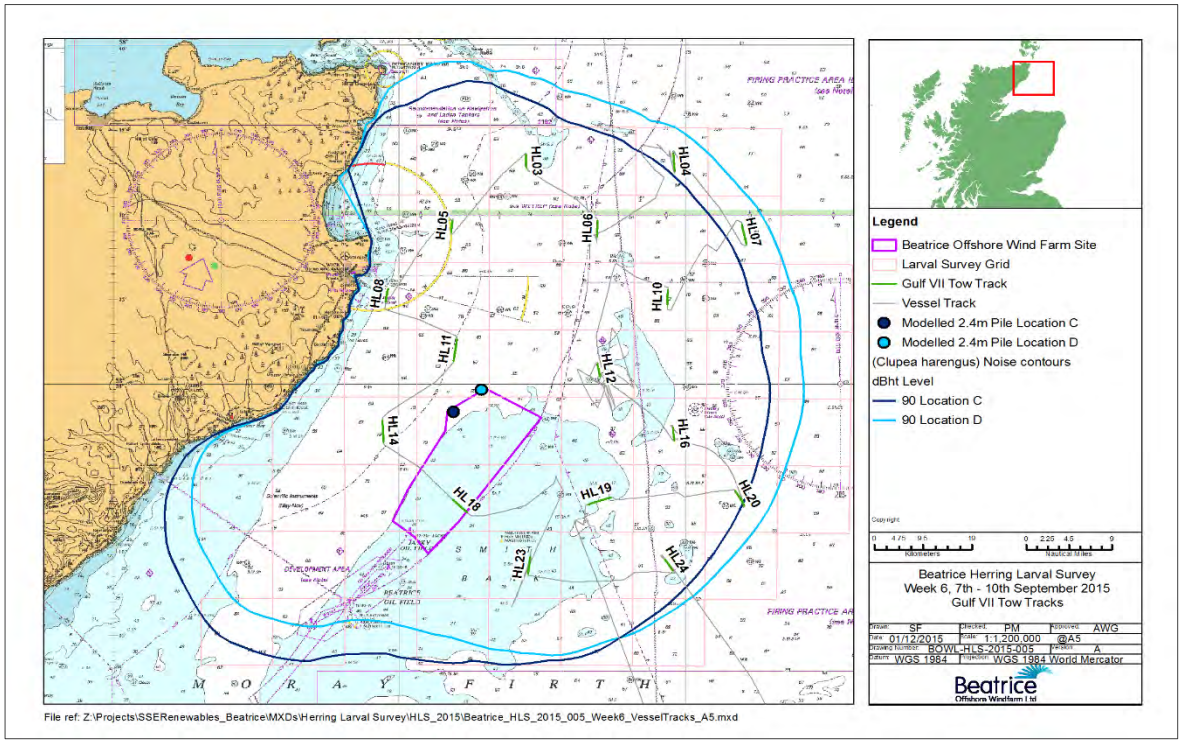

Figure 9.5 Week 6 tow and vessel tracks

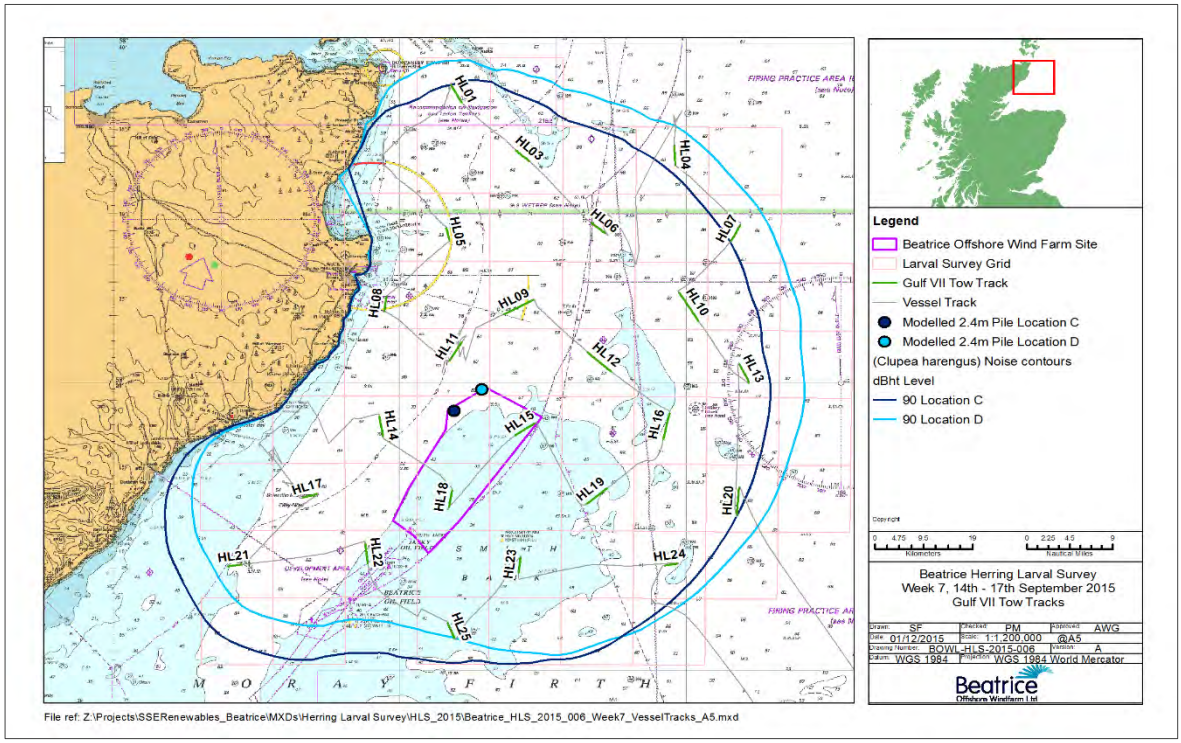

Figure 9.6 Week 7 tow and vessel tracks

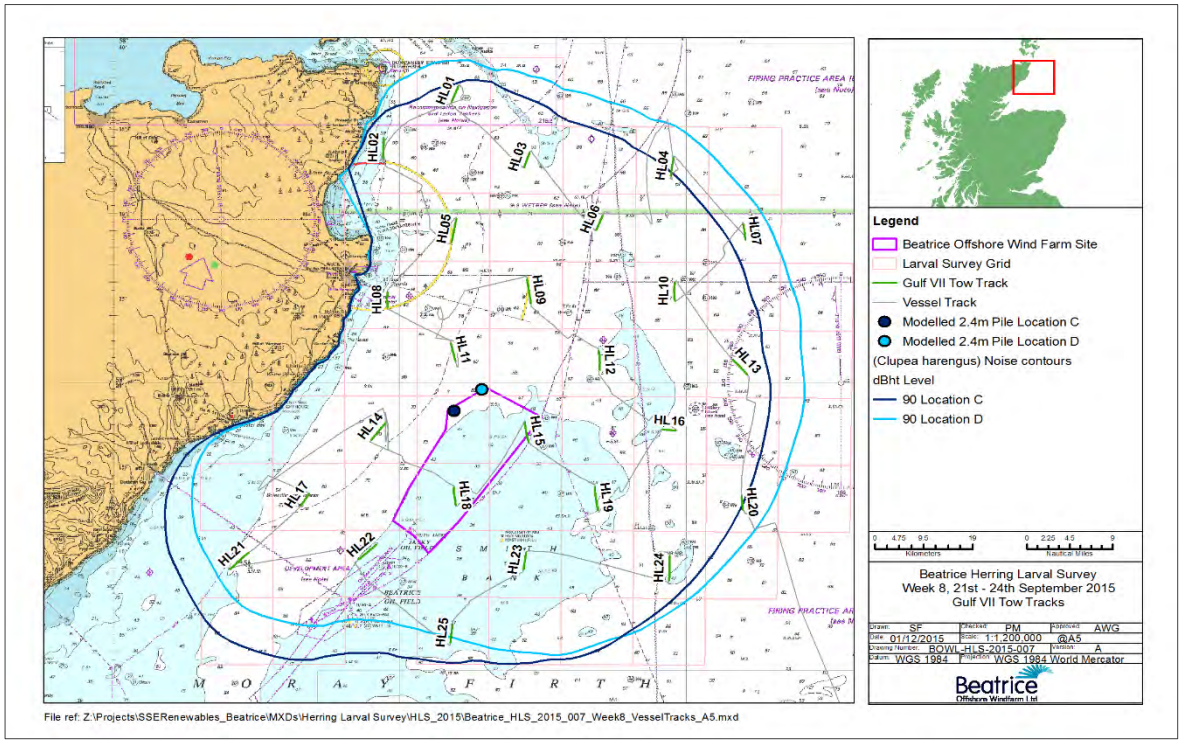

Figure 9.7 Week 8 tow and vessel tracks

9.7 Bottom Salinity

Bottom salinities for the survey weeks are shown in Figure 9.8 to Figure 9.14.

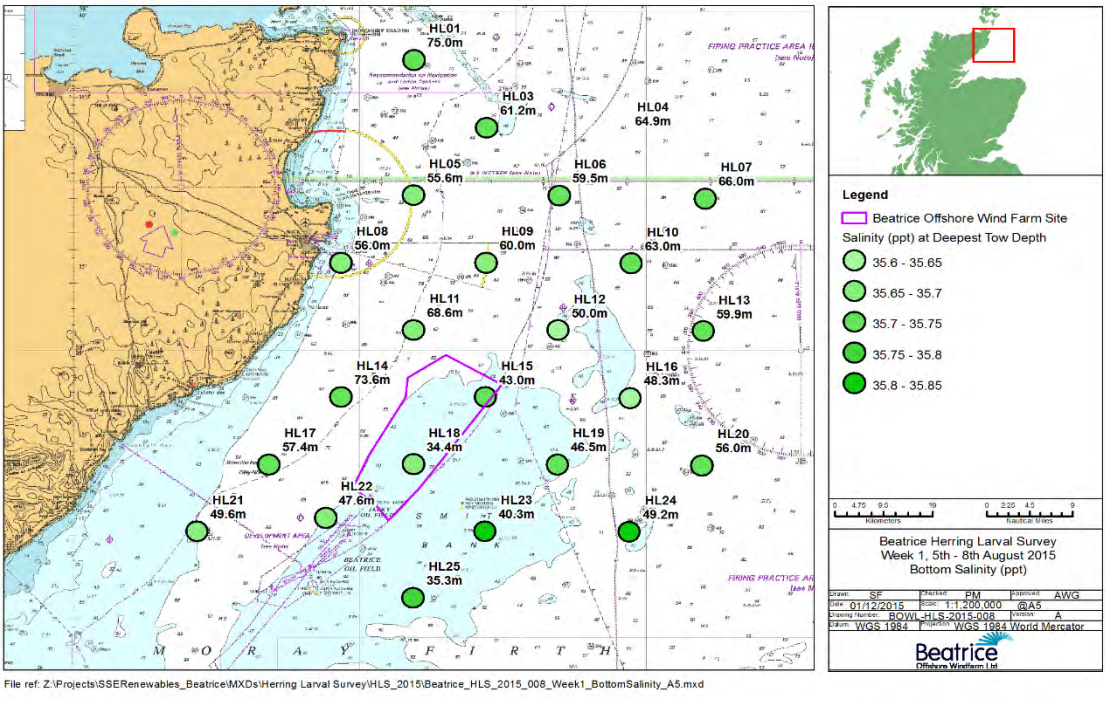

Figure 9.8 Week 1 bottom salinity (ppt)

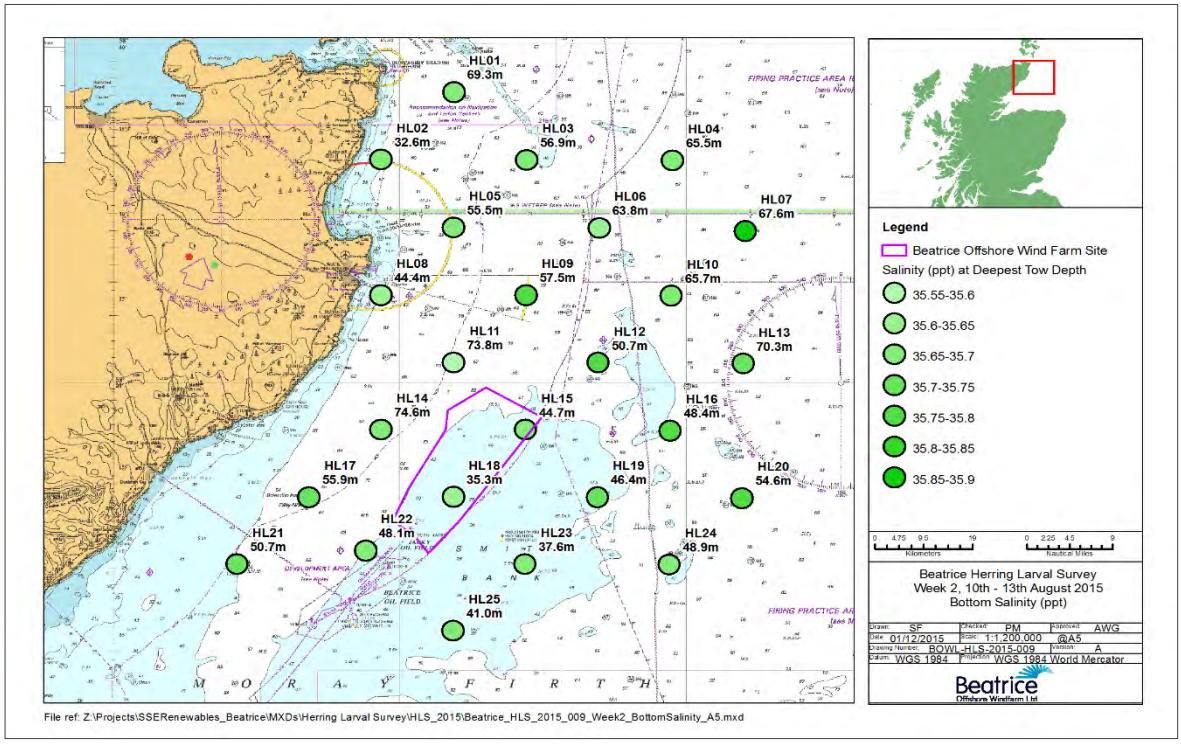

Figure 9.9 Week 2 bottom salinity (ppt)

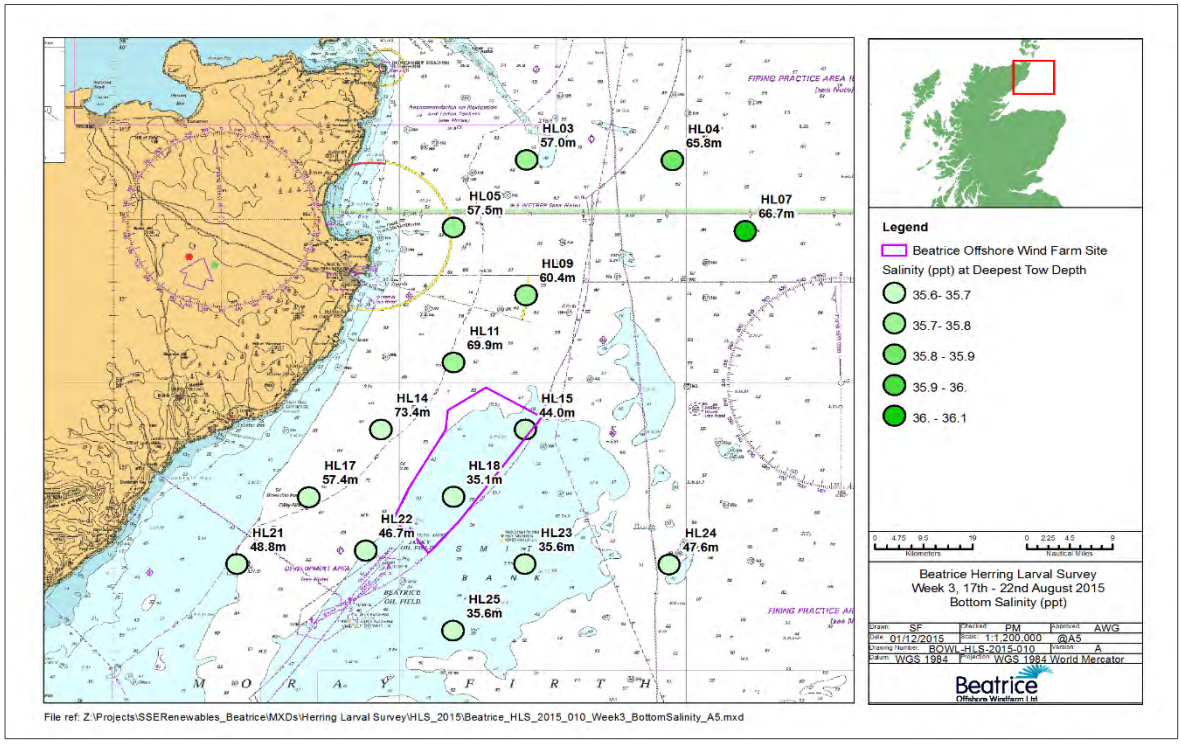

Figure 9.10 Week 3 bottom salinity (ppt)

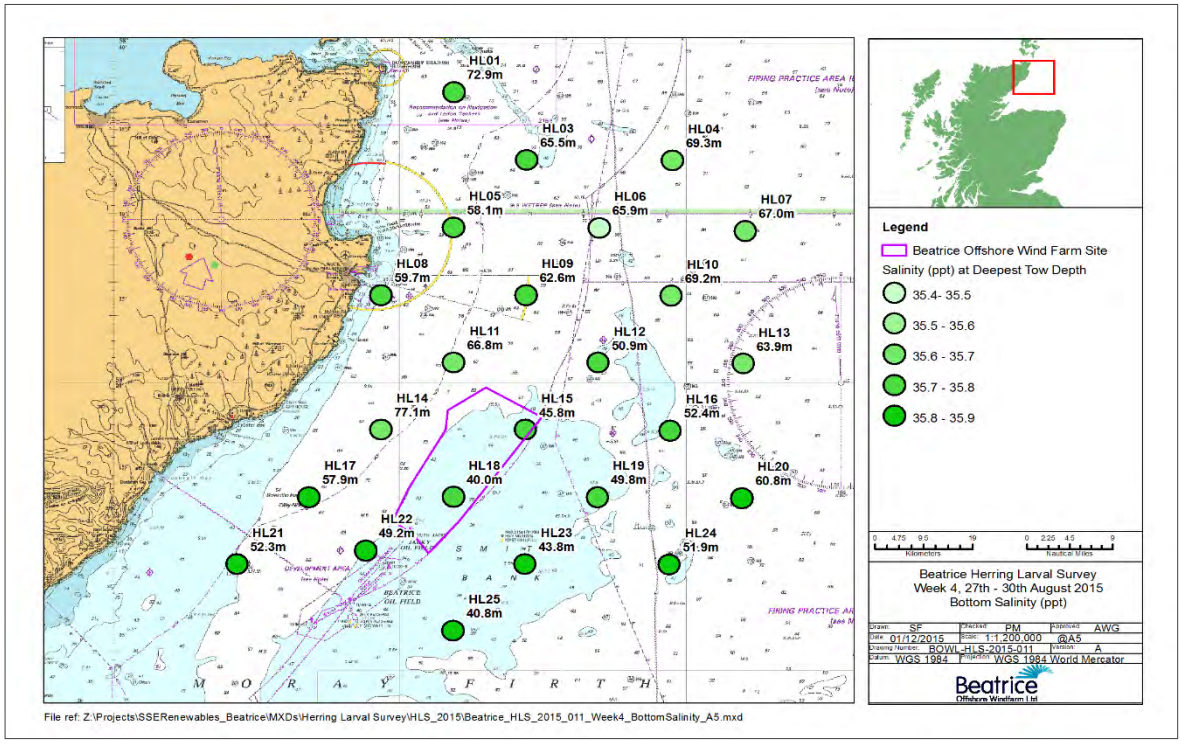

Figure 9.11 Week 4 bottom salinity (ppt)

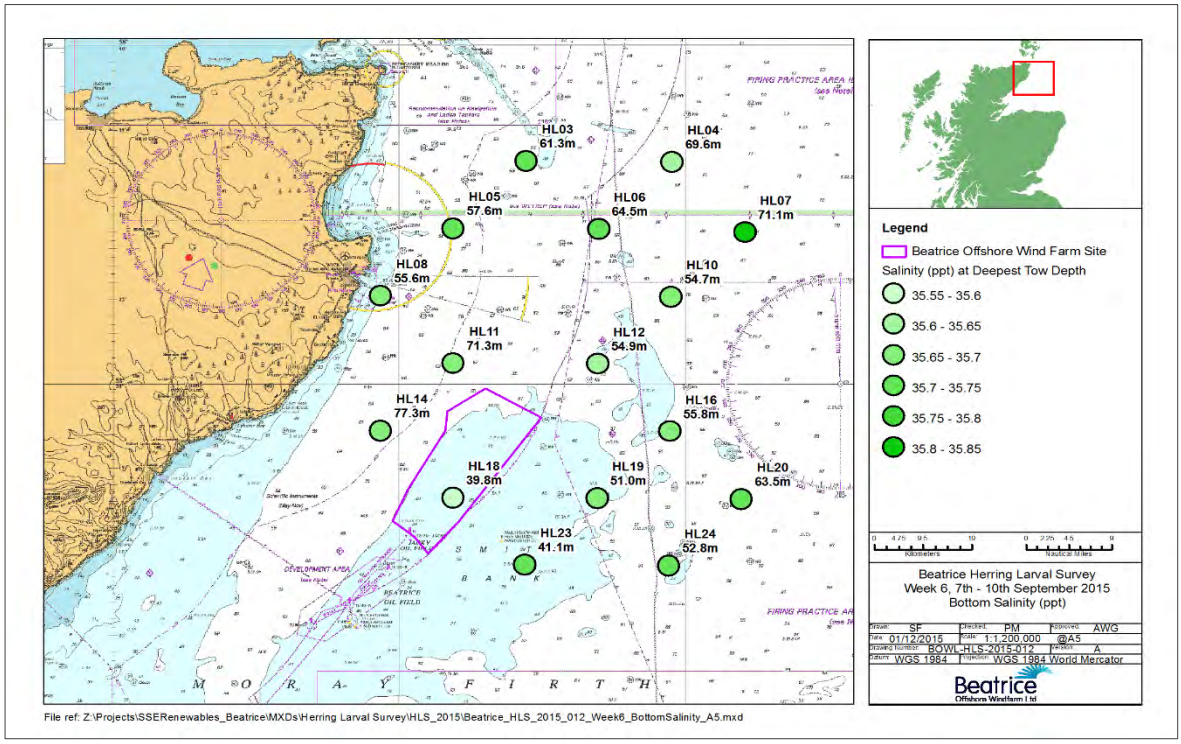

Figure 9.12 Week 6 bottom salinity (ppt)

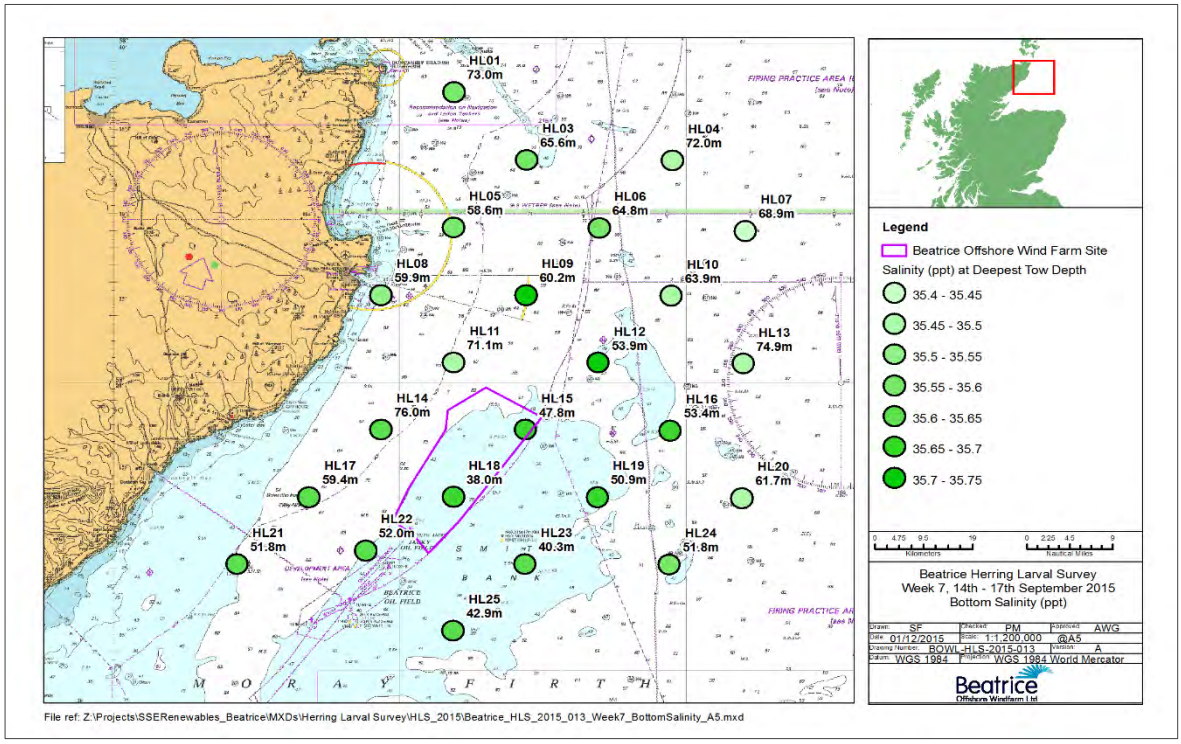

Figure 9.13 Week 7 bottom salinity (ppt)

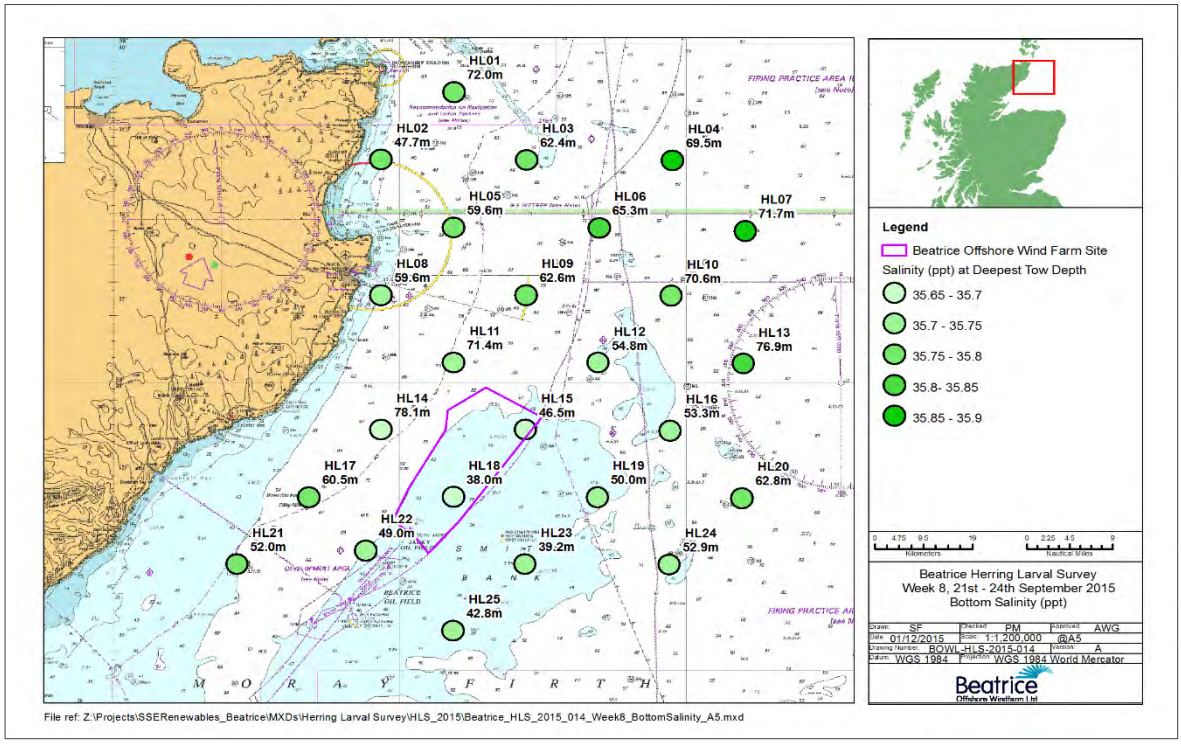

Figure 9.14 Week 8 bottom salinity (ppt)

9.8 Bottom Temperature

Bottom temperatures for the survey weeks are shown in Figure 9.15 to Figure 9.21.

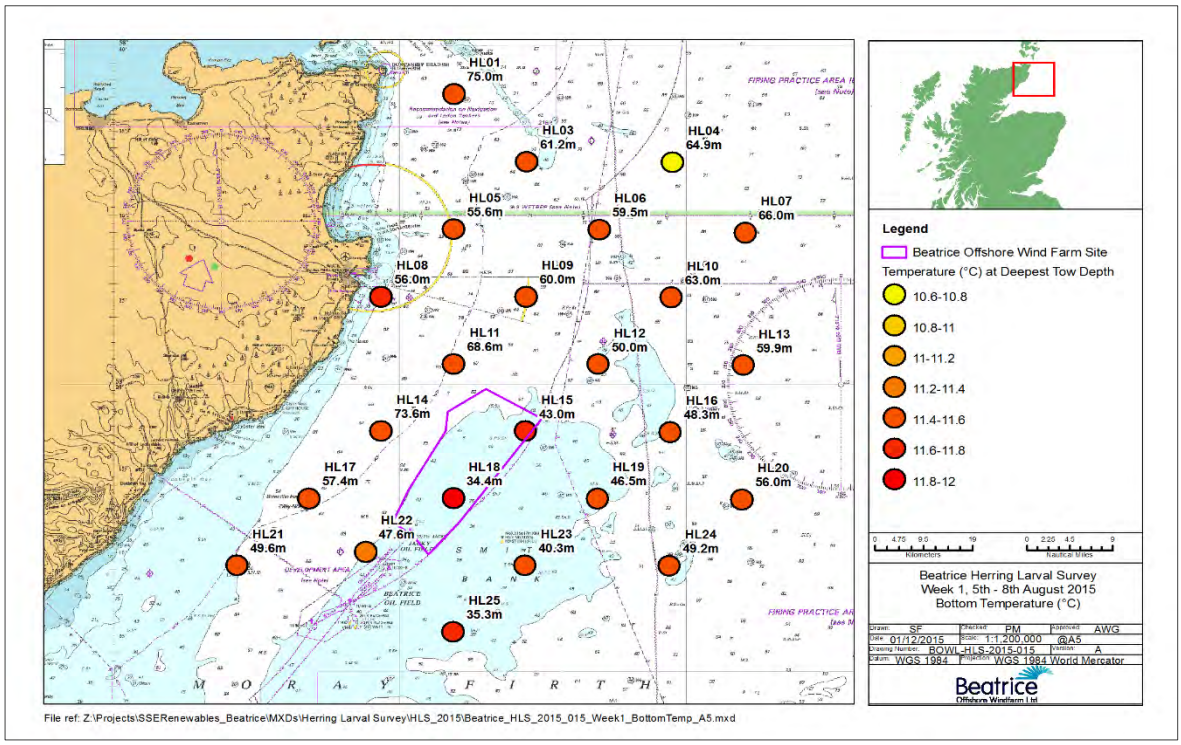

Figure 9.15 Week 1 bottom temperature (°C)

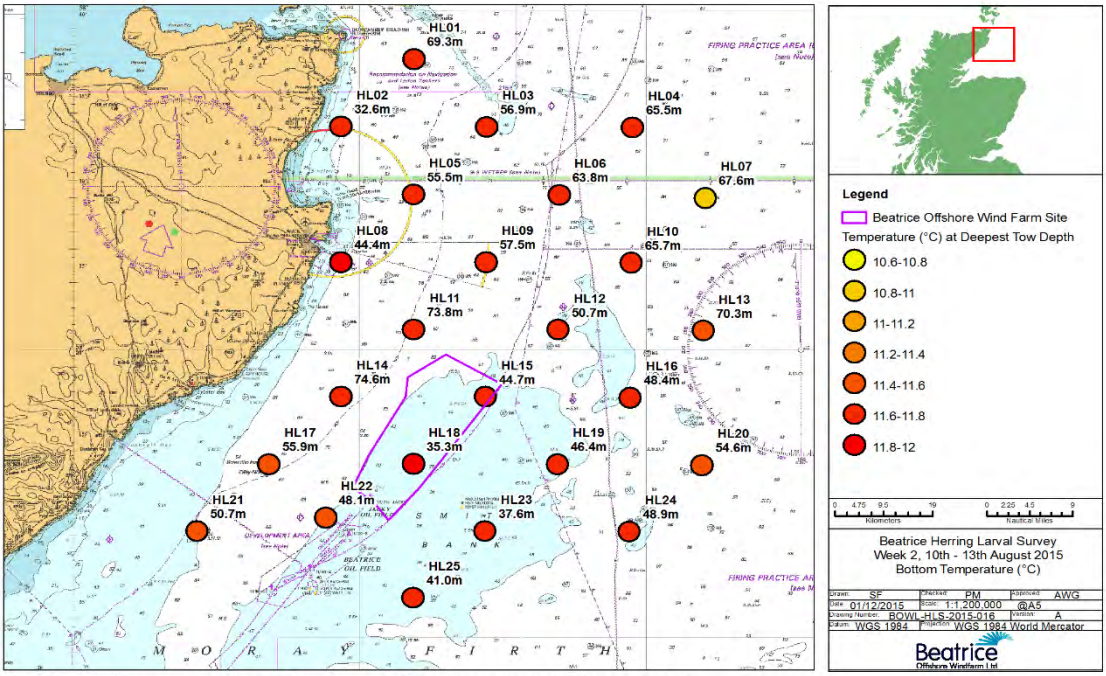

Figure 9.16 Week 2 bottom temperature (°C)

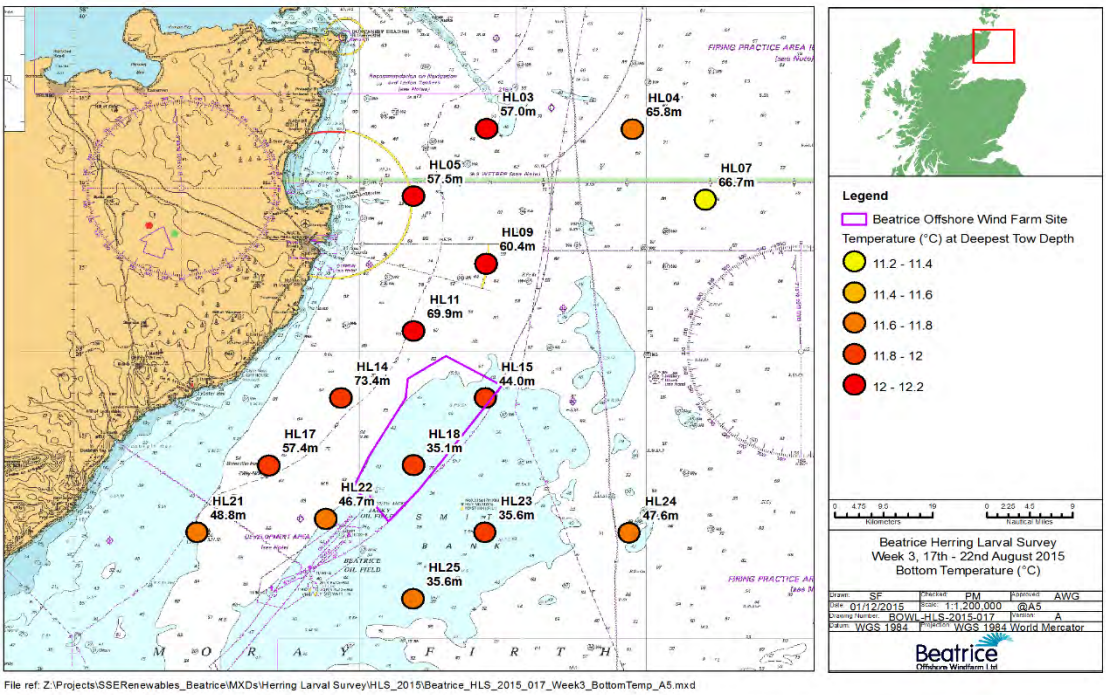

Figure 9.17 Week 3 bottom temperature (°C)

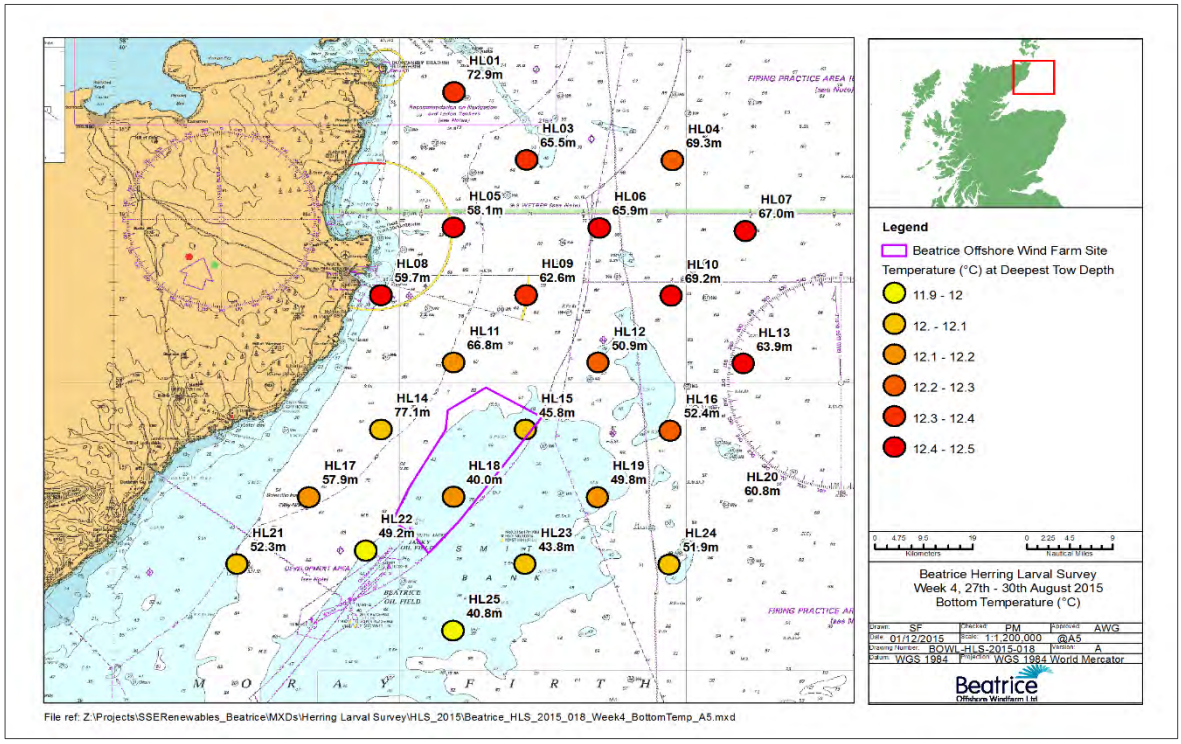

Figure 9.18 Week 4 bottom temperature (°C)

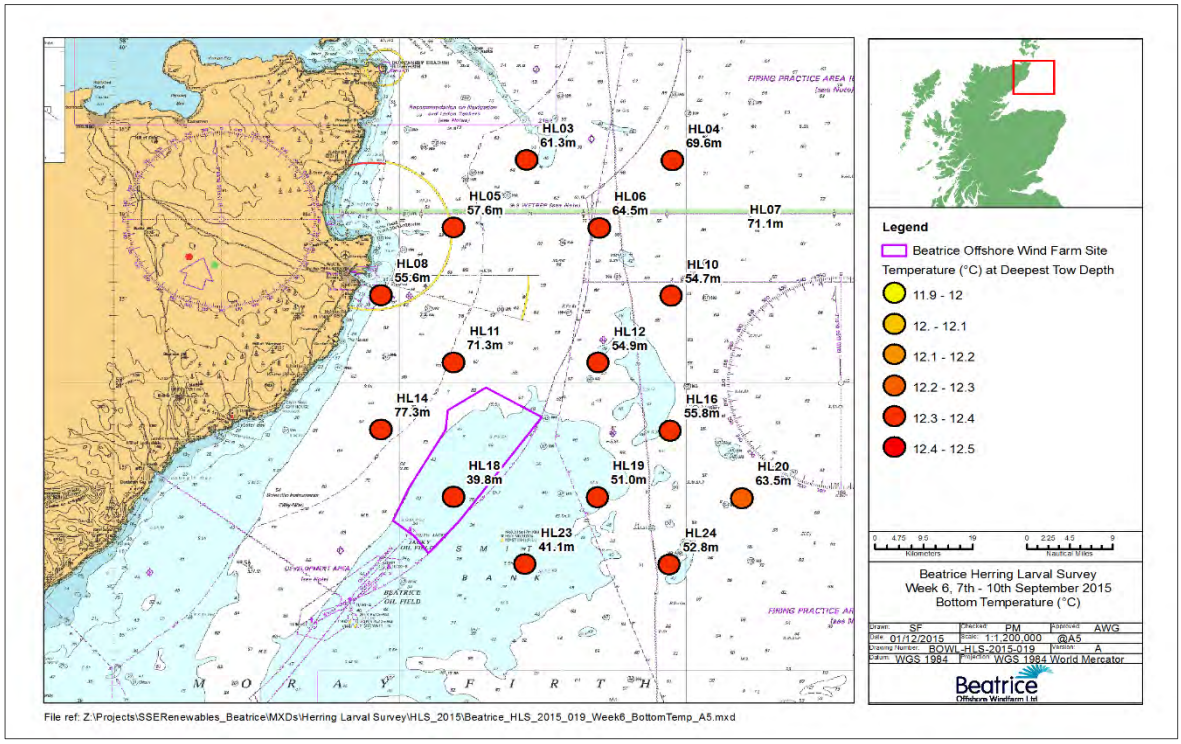

Figure 9.19 Week 6 bottom temperature (°C)

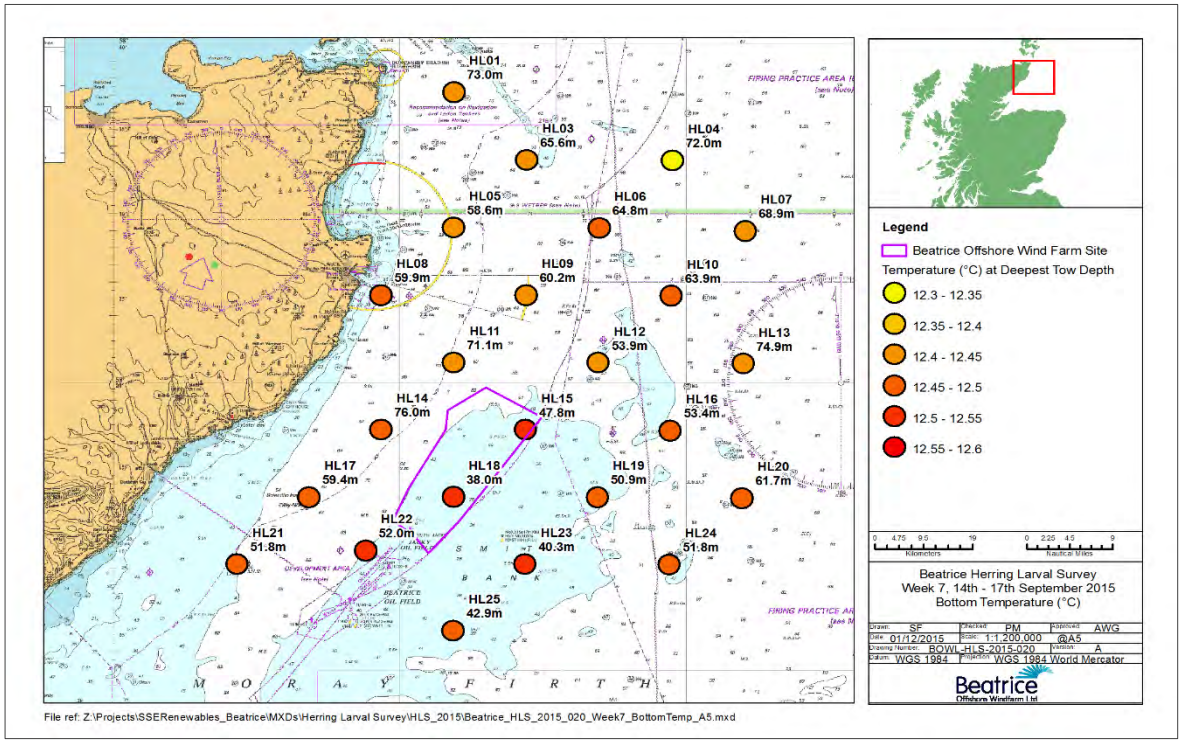

Figure 9.20 Week 7 bottom temperature (°C)

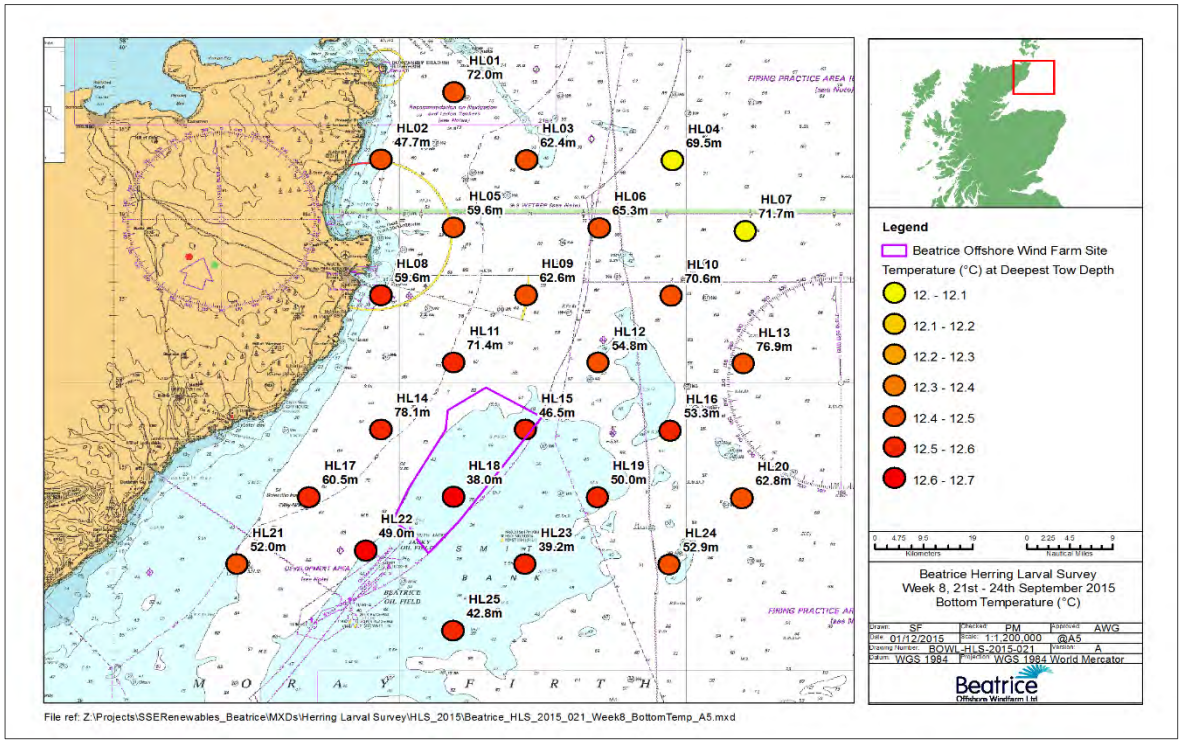

Figure 9.21 Week 8 bottom temperature (°C)

10 ISO Accreditation

Brown & May Marine Ltd. utislises an ISO 9001: 2008, ISO 14001: 2004 and OHSAS 18001: 2007 certified quality management system (certificate number: 11957). This certificate is valid until 22nd July 2017. The certification was issued by ISOQAR Ltd., Alcumus Certification.