# Beatrice Offshore Wind Farm

## Pre-construction Baseline Herring Larval Surveys
## Summary Technical Report

February 2016

Beatrice
Offshore Windfarm Ltd

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# Pre-Construction Baseline Herring Larval Surveys – Summary Report



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# 1 Introduction

This report was commissioned by Beatrice Offshore Windfarm Ltd (BOWL) and was prepared by Brown and May Marine Ltd (BMM). The report summarises and compares the results of the 2014 and 2015 herring larval surveys undertaken by BOWL. The surveys were undertaken to inform the Project Environmental Monitoring Programme (PEMP) required as part of the wind farm Section 36 Consent (condition 27) to discharge the pre-construction element of this condition as far as it relates to herring, and to fully discharge s36 condition 34 (requirement for herring surveys).

S36 condition 34 sets out the following requirements: *The results of the herring surveys will be used to better inform the knowledge of spawning behaviour / characteristics of the Orkney / Shetland herring stock, thus allowing the Company to devise mitigation options to minimise noise impacts from piling activity on all life stages of herring and to inform the Company's PS (if a PS is required). Following the results of the herring surveys undertaken in the last August and September prior to the Commencement of the Development, the Company must submit, in writing, its mitigation strategy to minimise the noise impacts on herring from piling activity, to the Scottish Ministers for their written approval. Once the Scottish Ministers have provided their written approval, the mitigation must be deployed during the annual herring spawning period (August and September) in any year of construction involving piling. Failing any agreement on mitigation, a piling restriction not exceeding sixteen (16) days within the months of August and September will take place across the whole Development in any year of construction involving piling.*

The BOWL Piling Strategy (LF000005-PLN-142) was approved by Marine Scotland Licensing on behalf of Scottish ministers on 2nd November 2015. The Piling Strategy states:

*10.3.2 Should the herring spawning surveys completed by BOWL in September 2015 (for which results are not yet available) resemble those of the surveys completed in 2014, BOWL proposes that mitigation for herring will not be required. However, final decisions on mitigation requirements for herring will be agreed with MSS and MS-LOT once the results of the 2015 herring spawning surveys are available.*

The purpose of this report is to summarise the findings of the two herring larval surveys undertaken in 2014 and 2015 over an eight week sampling period during August and September (BOWL, 2014; BOWL, 2015), and to compare the results to inform the piling mitigation requirements for herring. Agreement between the two survey data sets is further supported by comparison with the long term International Herring Survey (IHLS) data. This report should be read in conjunction with the 2014 and 2015 survey reports (BOWL, 2014; BOWL, 2015).

Based on the comparisons made, the report concludes that there is no requirement for mitigation of piling noise for herring as the 2015 survey results resemble those of the surveys completed in 2014.

## 2 Survey outcomes

The survey methodology (LF000005-REP-147 - BOWL Herring Larval Survey Methodology) was agreed with MSS and MS-LOT in July 2014. The sampling area was defined by the predicted 90 dBht ranges for a maximum hammer energy of 2300kJ modelled for herring.

A summary and comparison of the results from the BOWL 2014 and 2015 herring larval surveys are given below. The 2014 technical report was signed off by MSS (I. Davies, 07/01/2015) with the request for the second survey to be undertaken in 2015. The 2015 technical report is currently with MSS for approval.

### 2.1 Herring abundance and distribution

Herring larvae <10mm are categorised as newly hatched and considered to more accurately reflect 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 2014 and 2015 surveys is given in Table 2.1. A total of 18,544 herring larvae were recorded in 2014 compared to a significantly smaller total of 603 herring larvae caught in 2015. However, such large inter-annual variation in larval abundance is not uncommon, as demonstrated by the long term data set provided by the IHLS results, which are further discussed in Section 2.2 of this report.

Herring larvae were not found over all eight sampling weeks in 2014 and 2015. In 2014, no herring larvae were caught in weeks 1 and 2 and in 2015, the first herring larvae were caught in week 4. The majority of herring larvae in both 2014 and 2015 were caught in sampling weeks 6, 7 and 8.

There was variation in the size of herring larvae caught between the two surveys with the majority of larvae caught in 2014 measuring <10mm in length, whilst the majority in 2015 were ≥10mm, which are not considered to have been newly hatched. It should be noted that no herring larvae caught in 2014 or 2015 were recorded with yolk sacs, indicating that the larvae were at least 6 days old.

In line with ICES IHLS methodology, herring larval abundance below a square meter of sea surface at each station was also calculated (see Table 2.2). Details of the formula and method are described in the BOWL technical reports (BOWL, 2014; BOWL, 2015).

Comparative spatial distribution plots showing the abundance (no/$m^2$) of herring larvae <10mm were produced for every station sampled for each survey week in which herring larvae were recorded in both 2014 and 2015 (weeks 4, 6, 7 and 8; Figure 2.1 to Figure 2.4). The circle size corresponds to the abundance i.e. larger circles indicate higher abundances.

Although larval abundance was significantly higher in 2014, the spatial patterns of where herring larvae were caught is similar between the two surveys. Larvae were first observed in the most northerly stations of the survey area, by the Pentland Firth, before being recorded further south into the survey area in each progressive sampling week, indicating that larvae are transported into the survey area from the north rather than there being any significant spawning activity within the survey area.

**Table 2.1 Number of herring larvae of <10mm and ≥10mm recorded by sampling week in 2014 and 2015**

| Week | 2014 | | 2015 | |
|---|---|---|---|---|
| | <10mm | ≥10mm | <10mm | ≥10mm |
| 1 | - | - | - | - |
| 2 | - | - | - | - |
| 3 | 21 | 61 | - | - |
| 4 | 13 | 168 | 53 | 39 |
| 5 | 122 | 306 | * | * |
| 6 | 4,993 | 512 | 67 | 140 |
| 7 | 5,896 | 1,180 | 15 | 104 |
| 8 | 3,447 | 1,825 | 38 | 147 |
| Total | 14,492 | 4,052 | 173 | 430 |

- no herring larvae were recorded

* no samples were taken during week 5 due to poor weather

**Table 2.2 Herring larvae (no/m$^2$) of <10mm and ≥10mm recorded by sampling week in 2014 and 2015**

| Week | 2014 | | 2015 | |
|---|---|---|---|---|
| | <10mm | ≥10mm | <10mm | ≥10mm |
| 1 | - | - | - | - |
| 2 | - | - | - | - |
| 3 | 19.3 | 54.0 | - | - |
| 4 | 11.5 | 156.6 | 46.5 | 37.7 |
| 5 | 97.4 | 279.9 | - | - |
| 6 | 5,029.3 | 488.4 | 84.4 | 165.2 |
| 7 | 6,034.7 | 1,207.9 | 12.4 | 92.8 |
| 8 | 3,683.7 | 2,139.9 | 47.5 | 162.7 |
| Total | 14,876.1 | 4,326.9 | 190.8 | 458.4 |

- no herring larvae were recorded

* no samples were taken during week 5 due to poor weather

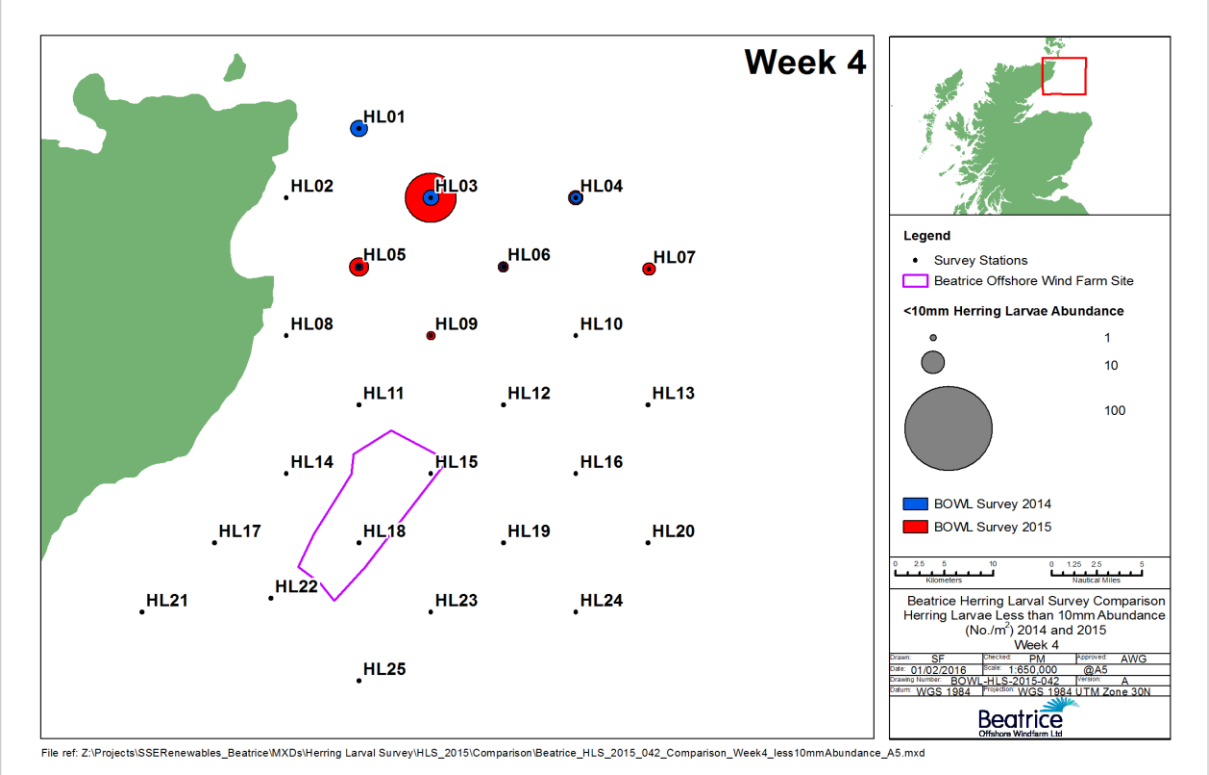


**Figure 2.1 Herring larvae abundance (no/m$^2$) in week 4 for 2014 and 2015**

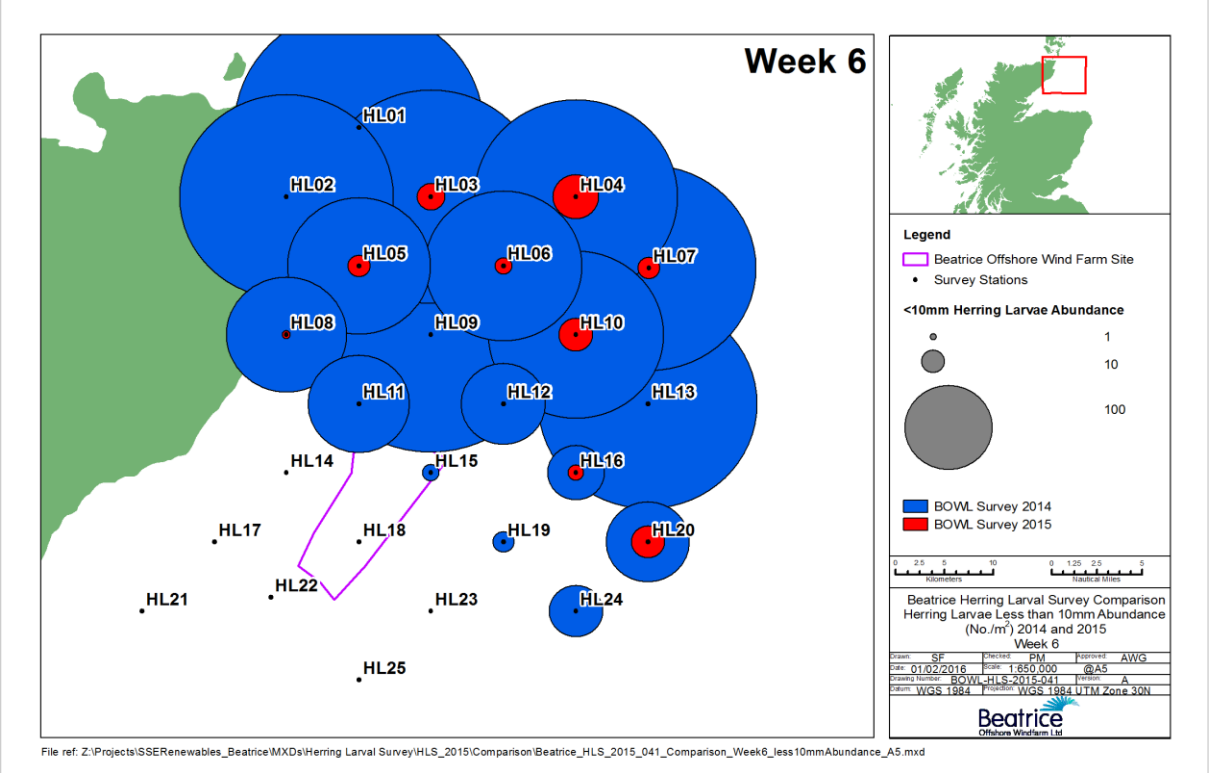


**Figure 2.2 Herring larvae abundance (no/m$^2$) in week 6 for 2014 and 2015**

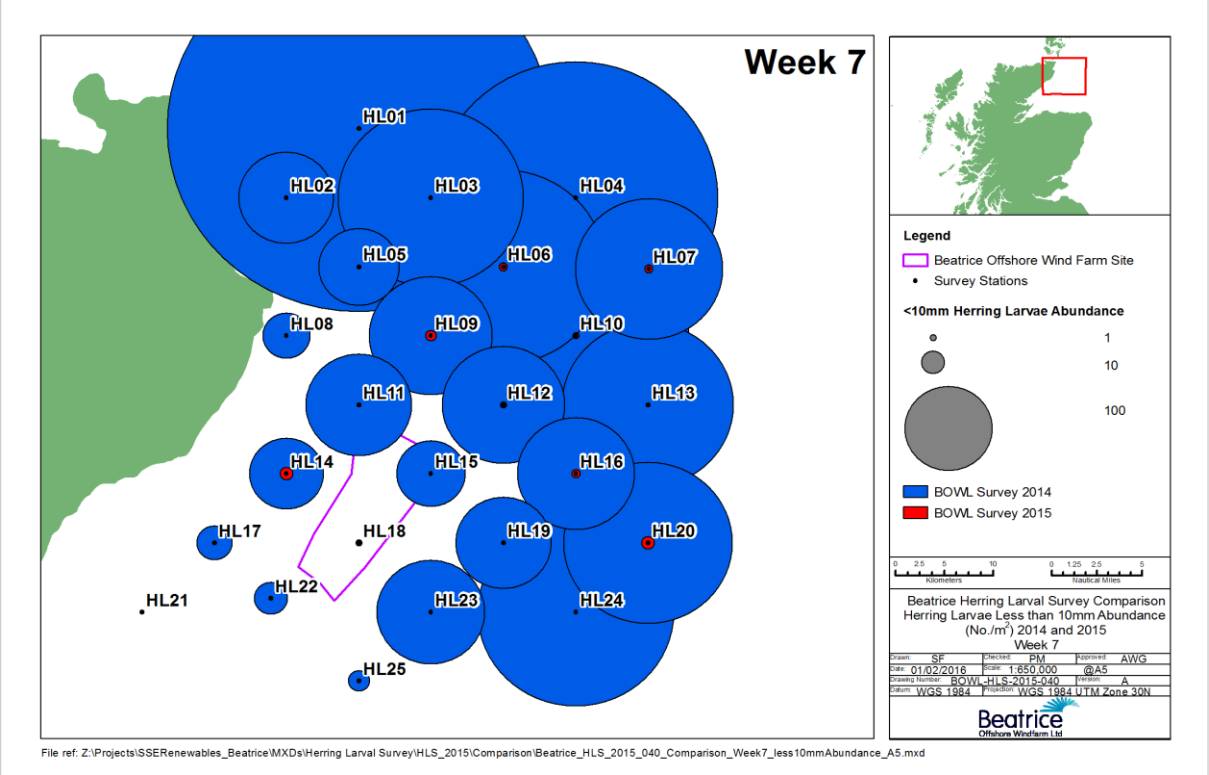


**Figure 2.3 Herring larvae abundance (no/m$^2$) in week 7 for 2014 and 2015**

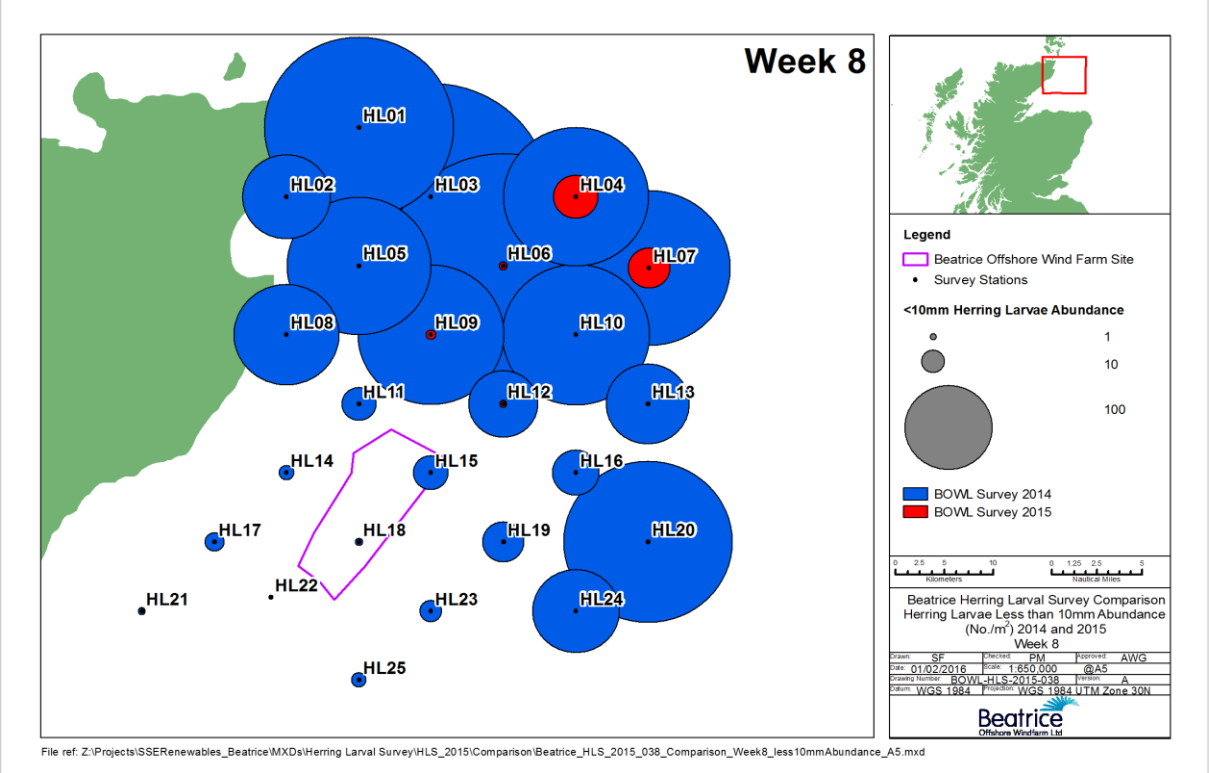


**Figure 2.4 Herring larvae abundance (no/m$^2$) in week 8 for 2014 and 2015**

## 2.2 Comparison with 2015 IHLS results

The ICES programme of IHLS surveys in the North Sea has been in operation since 1967. The surveys are undertaken to provide quantitative estimates of herring larval abundance (ICES, 2013). These annual surveys show that there is high inter-annual variability in larval abundance but consistently demonstrate that the majority of herring spawning occurs east of Orkney. In the 2015 IHLS cruise report it was stated that the spatial distribution of herring larvae was found to show the "typical pattern with most larvae hatched east of the Orkneys" (Rohlf, 2015). This is supported by the Sinclair & Power (2015) study that indicated that the spatial patterns of <10 mm herring larvae were consistent across decades (Figure 2.6).

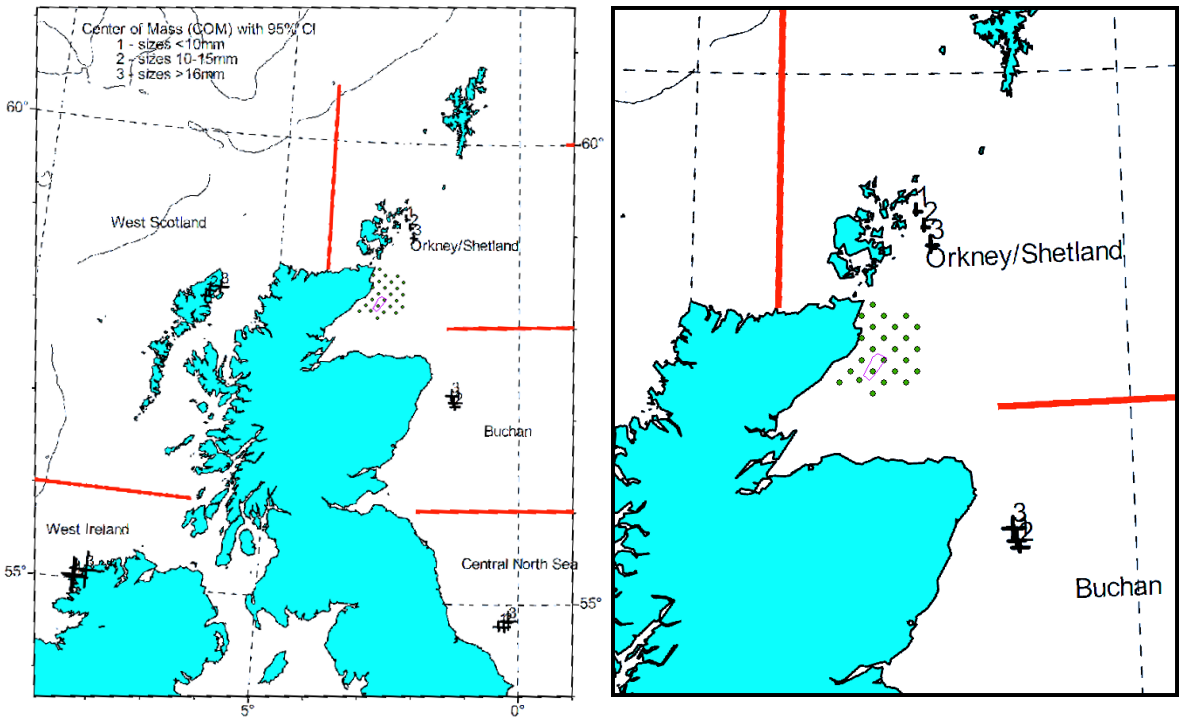


**Figure 2.5 Mean locations of the annual CoMs for length classes of larvae from spawning areas within the North Sea with the BOWL development area and survey locations overlaid (Source: Sinclair & Power, 2015)**

Provisional herring larval abundance data (all sizes) from the 2015 IHLS survey was published in the survey cruise report (Rohlf, 2015). Figure 2.7 shows the IHLS survey locations and the reported herring larvae abundances, showing the significantly higher values recorded to the north of the survey area, east of Orkney.

BOWL 2015 herring larvae abundance data from week 8 was compared to the 2015 IHLS results. Figure 2.7 shows the good agreement between abundances recorded by BOWL and IHLS within BOWL's survey area, and supports the low herring larvae numbers recorded during the BOWL 2015 survey. As stated previously, large inter-annual variations in larval abundanceare a feature of the long term IHLS data.

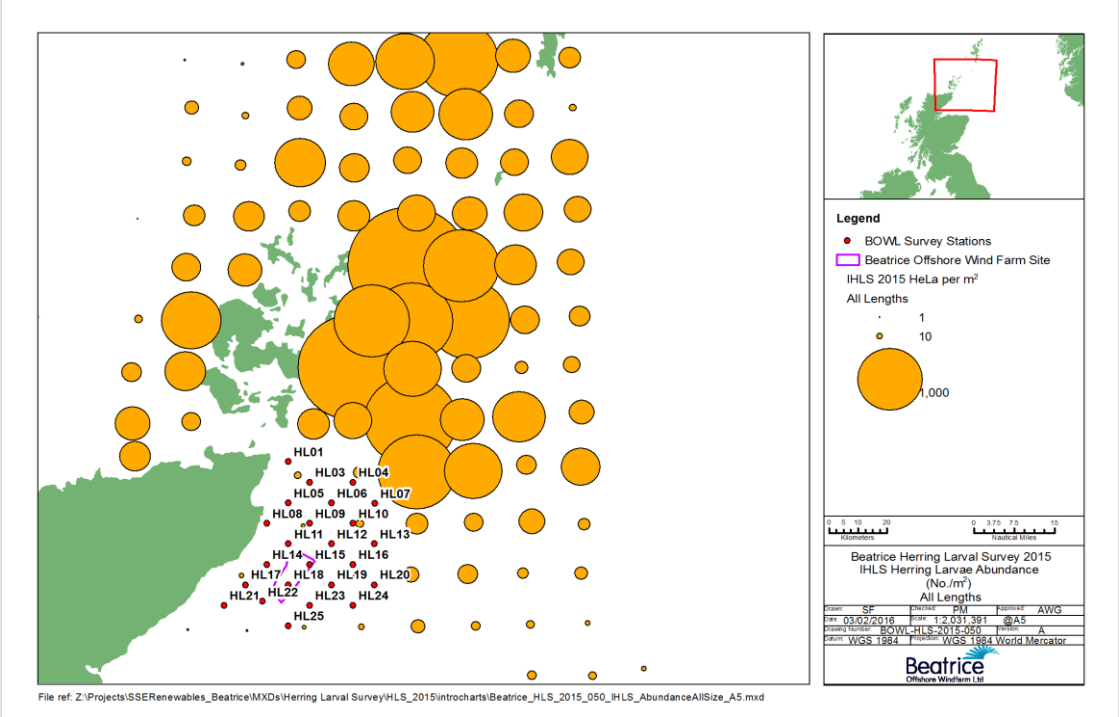


**Figure 2.6 Herring larvae abundances (no/m$^2$, all sizes) recorded during the 2015 IHLS sampling 24$^{th}$ to 27$^{th}$ September 2015**

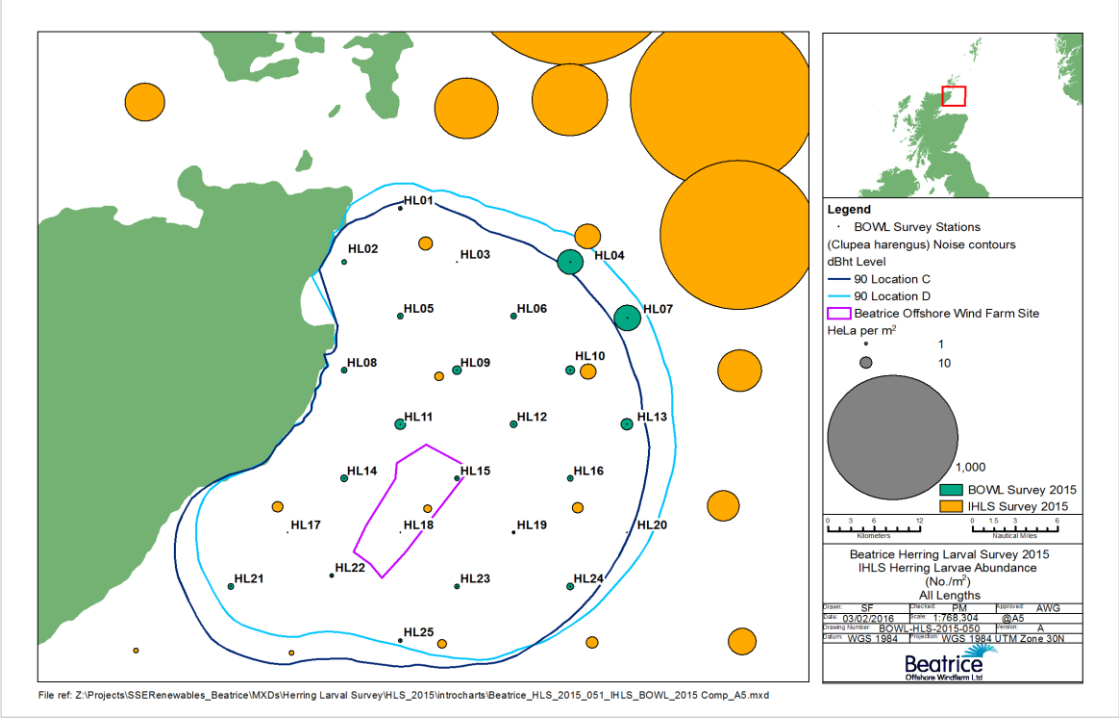


**Figure 2.7 Herring larvae abundances (all sizes) recorded during the IHLS 2015 and week 8 of the BOWL 2015 survey (no/m$^2$)**

## 2.3 Herring larvae length distributions

The length-frequency of the total number of herring larvae recorded during the BOWL 2014 and 2015 surveys is shown in Figure 2.8. In 2014, the majority of herring larvae were <10 mm with over 25% of the catch recorded in the length interval 7.0 - 7.9 mm. In 2015, 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 difference of 3 mm in the lengths at which the highest proportion of the catch was recorded indicates that a greater proportion of the catch is older with smaller larvae absent from the area in 2015. However, as no herring larvae were caught in the first four sampling weeks in 2015 it is unlikely that sampling missed the beginning of the hatching period. The absence of smaller larvae indicates that the path of larval drift may have moved to the east, with larvae possibly transported away from the sampling area.

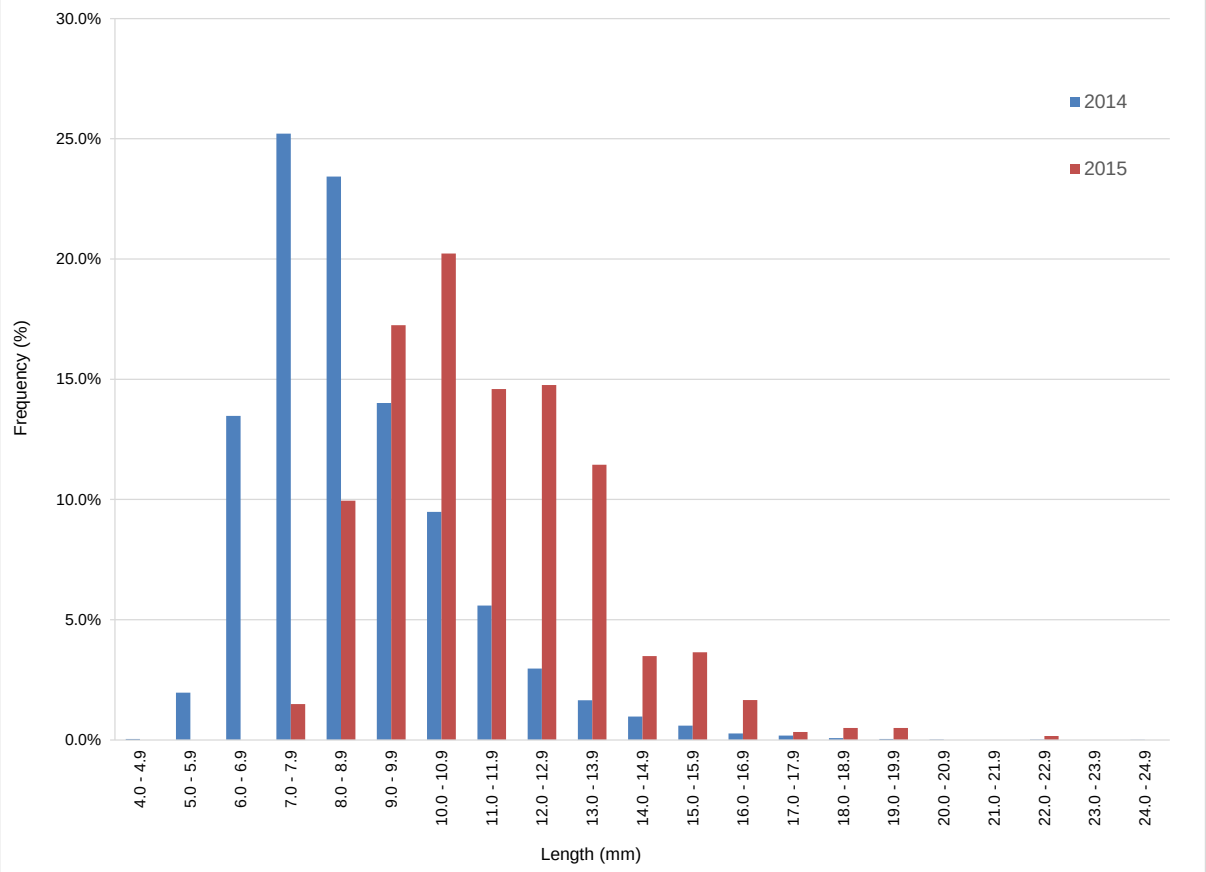


**Figure 2.8 Length-frequency plot of total number of herring larvae recorded for the BOWL 2014 and 2015 surveys**

## 2.4 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 sampling week in which herring larvae were recorded in both 2014 and 2015 (4 out of 8 weeks). The spatial plots for weeks 4, 6, 7 and 8 are given in Figure 2.9 to Figure 2.12. The circle size has been standardised and shows only the proportion of each size class recorded at each station.

In week 4 the presence of larger size classes of herring larvae recorded at northerly stations in both the 2014 and 2015 surveys indicate larval transport into the survey area from the north. In sampling weeks 6, 7 and 8, smaller size classes were observed in the 2014 data, however the spatial pattern of smaller size classes in the north of the sampling area with larger larvae recorded in the south of the sampling area remains consistent across the two surveys.

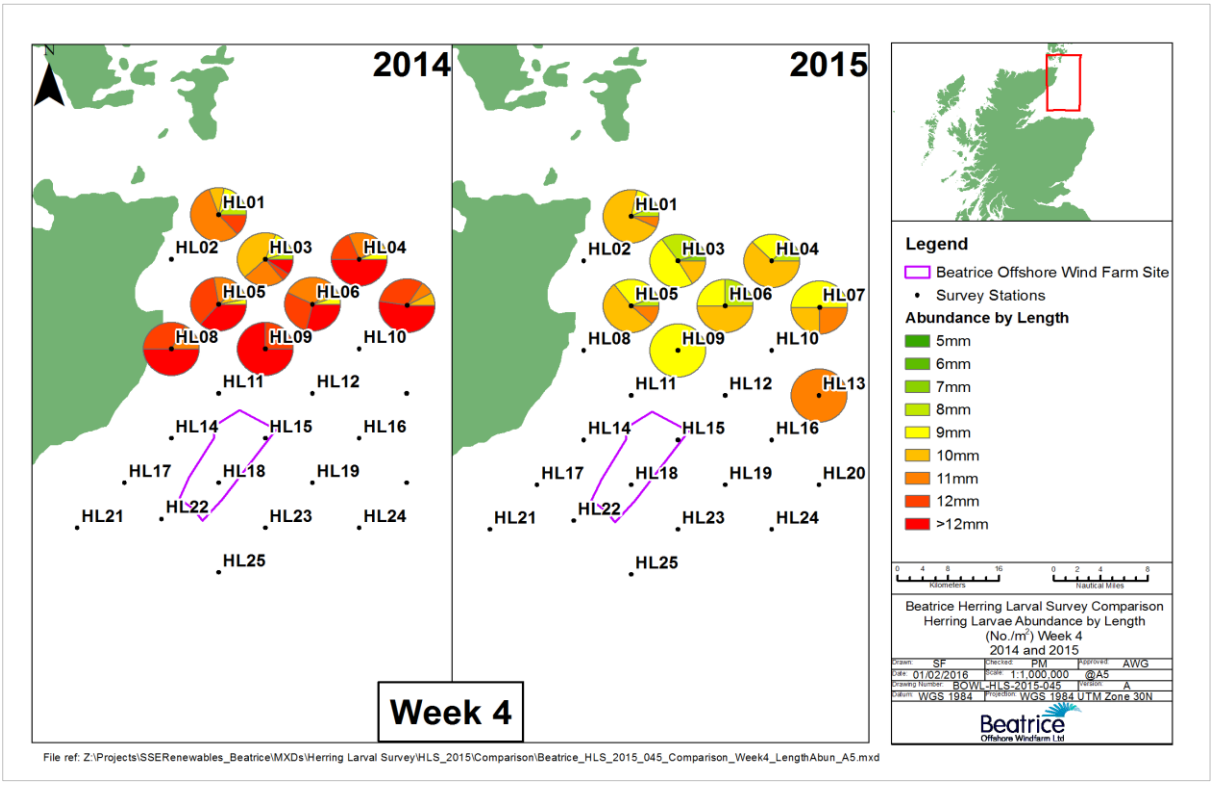


**Figure 2.9 Herring larvae length distribution in week 4 for 2014 and 2015 surveys**

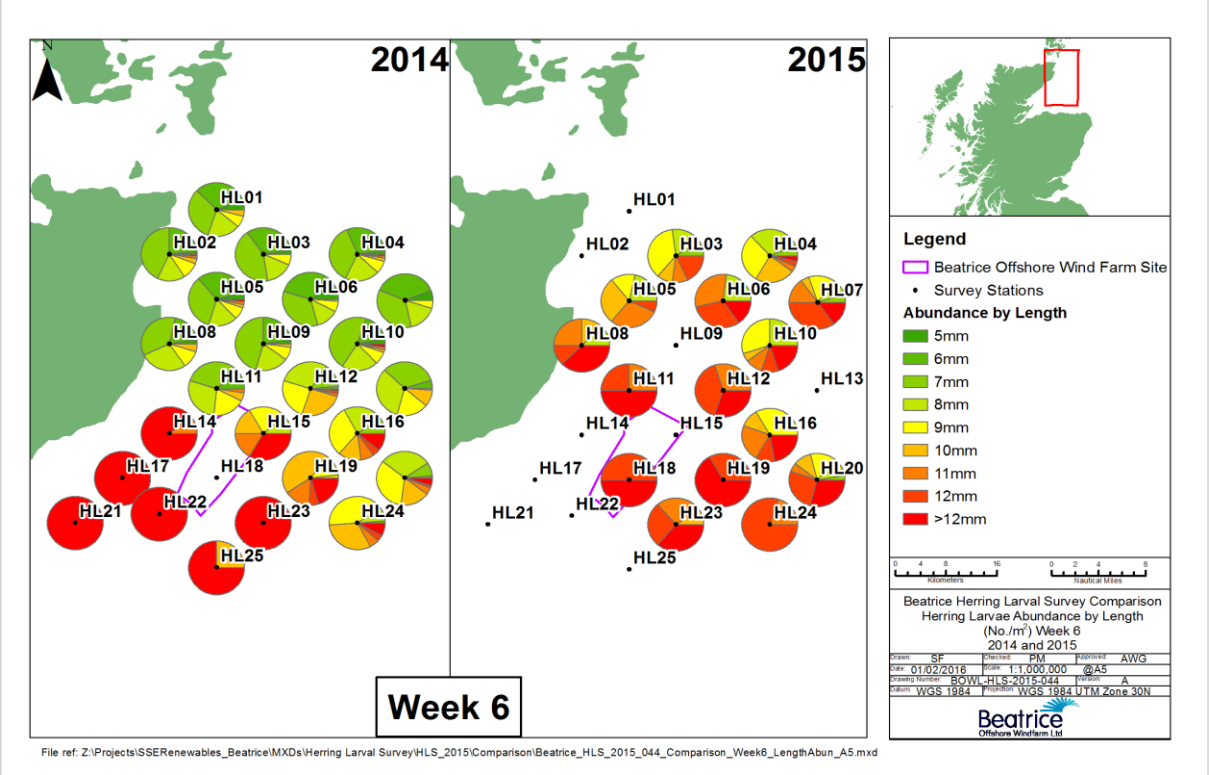


**Figure 2.10 Herring larvae length distribution in week 6 for 2014 and 2015 surveys**

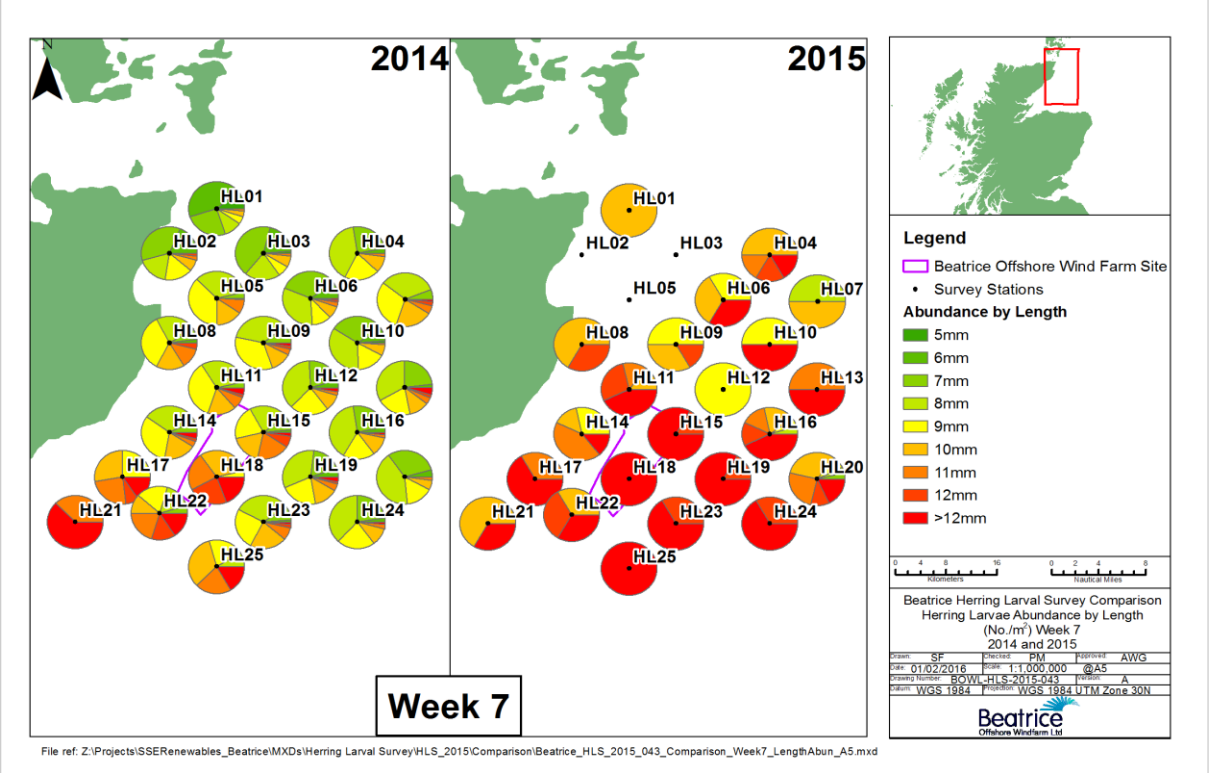


**Figure 2.11 Herring larvae length distribution in week 7 for 2014 and 2015 surveys**

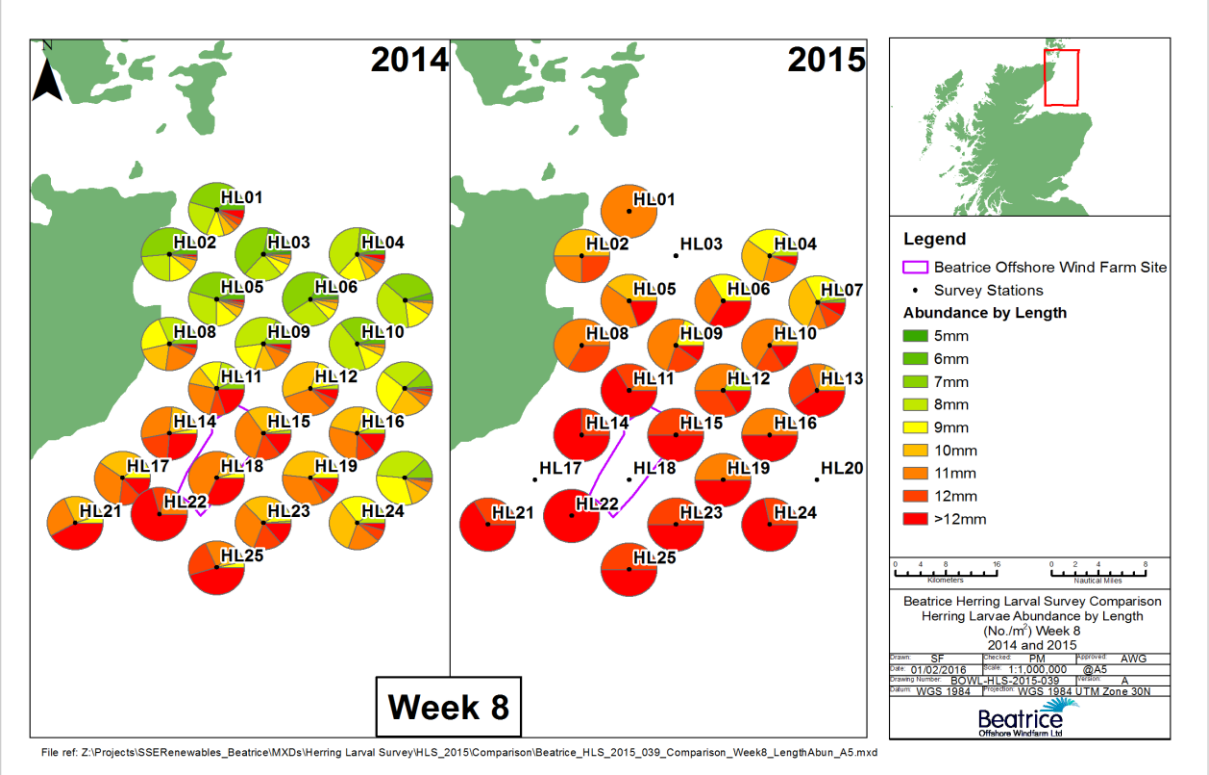


**Figure 2.12 Herring larvae length distribution in week 8 for 2014 and 2015 surveys**

## 2.5 Herring larvae age

As specified by MSS, published values of growth and mortality rates and hatch sizes were used to estimate age from length, in order to back-calculate approximate hatch dates and spawning dates. Published lengths and ages were also used to cross-reference the back calculation of age from length (DARD, 2003; Dickey-Collas *et al*., 2001; Fassler *et al*., 2011; Heath, 1993; Hufnagl & Peck, 2011; ICES, 2009; Johannessen *et al*., 2000; Lough *et al*., 1982; Lazzari & Stevenson, 1992; Maneja *et al*., 2015; Munk *et al*., 1986; Payne *et al*., 2013).

The mean age of the most prevalent size classes recorded for both surveys ranged between 6.11 and 9.28 days for the larvae size class of 7.0 - 7.9 mm, and 19.41 to 22.17 days for the size class 10.0 – 10.9 mm.

Estimated larvae ages were then applied to hydrodynamic data to determine potential drift distances and also used to back-calculate hatch dates. Similar mean peak larvae hatching times were estimated for both surveys with the main hatch period occurring in the first two weeks of September. Mean peak hatching was estimated to occur at the end of the first week of September in 2014 and at the beginning of the second week of September in 2015 (BOWL 2014; BOWL, 2015).

## 2.6 Residual currents and larval drift

Studies examining patterns of larval drift have shown that herring larvae from the Orkney/Shetland stock drift southwards into nursery grounds in the Moray Firth and

eastwards with the Atlantic inflow, into nursery grounds in the Skagerrak and Kattegat (Figure 2.13; Corten, 2013; Nichols, 1999).

A conservative larval dispersal speed of 1-2 km/day was taken from Heath *et al.* (1989) in addition to mid-range estimates of residual current velocity (6.0 km/day to 8.6 km/day) derived from the literature for the major oceanic and coastal currents in the North-east Atlantic and the North Sea (Figure 2.14; Baxter *et al*., 2011; Guerin *et al*., 2014; UKMMAS, 2014; Turrell *et al*., 1990).

The potential distances that the most prevalent size classes of larvae found in 2014 and 2015 could be transported was calculated using the residual velocity data. Using the estimated ages, 7.0 - 7.9 mm larvae could be transported, a minimum of 6 to 18 km, using highly conservative estimates, and maximum distances of 52 to 72 km, whilst the most prevalent size class larvae in 2015 (10.0 - 10.9 mm) could travel from 19 km to 189 km. This further suggests that the majority of the larvae caught during both surveys drifted down from the well established spawning grounds off Orkney and Shetland.

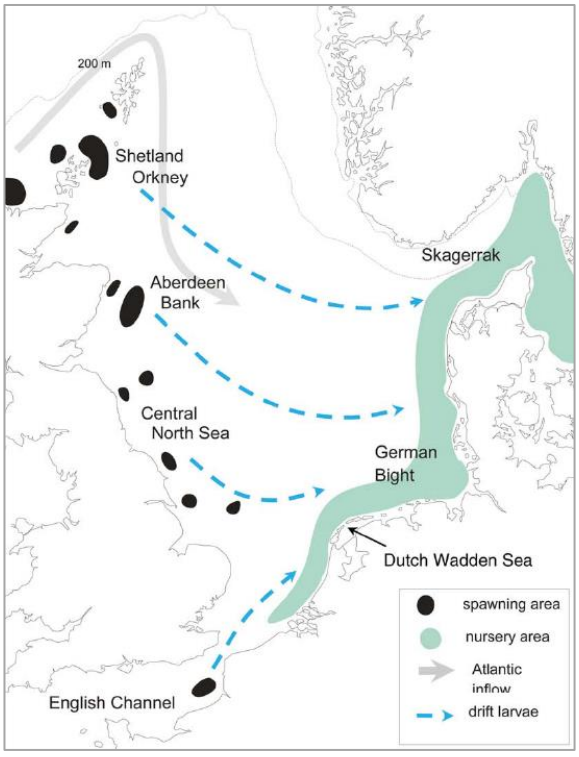


**Figure 2.13 Drift routes of herring larvae from spawning areas in the North Sea (source: Corten, 2013)**

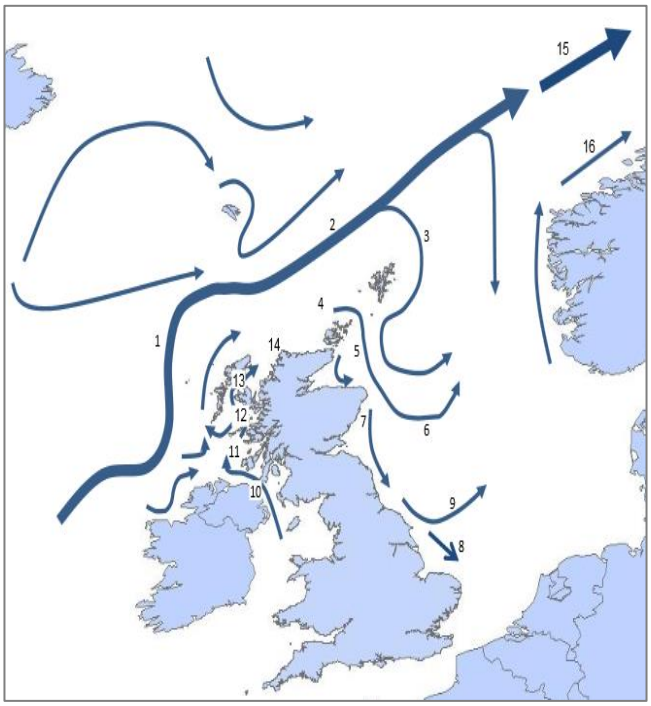


**Figure 2.14 Schematic representation of the major oceanic or coastal currents in the North East Atlantic and the North Sea, modified from Baxter *et al*., 2011.**

## 3 Requirement for Mitigation

As set out in the introduction, the purpose of this report is to compare the results of BOWL's 2014 and 2015 herring larval surveys, and to compare these results with IHLS surveys completed in 2015, to inform any piling noise mitigation requirements for herring (as required by S36 condition 34).

The IHLS data confirms that herring larvae abundance in the Moray Firth between years is highly variable, but that the main spawning areas have remained consistent. The duration and high resolution sampling of the BOWL survey design has provided robust data that show the temporal duration of herring spawning in the vicinity of the BOWL development area for August and September in 2014 and 2015.

The two BOWL surveys have indicated a peak spawning period for herring, with higher larval abundances recorded during sampling weeks 6, 7 and 8 of the surveys. The total abundance of herring larvae recorded in 2014 was significantly greater than that recorded in 2015, however such inter-annual variation is consistent with that recorded by the IHLS. The abundances recorded in 2015 were corroborated by the IHLS 2015 preliminary abundance data.

The back-calculation of larval hatch date and spawning date 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 from the end of the first week of September. The residual current velocities and estimated hatch dates indicate actual spawning areas well to the north of the development area, east of Orkney.

The spatial patterns of where herring larvae were caught were also similar between the two surveys with larvae first observed in the most northerly stations of the survey area before being recorded further south in the survey area in the following sampling weeks. The observation of smaller size classes in the north of the sampling area with larger larvae recorded in the south of the sampling area also remained consistent across the two surveys, adding further support that larvae are transported in to the survey area from the spawning grounds to the east of Orkney and Shetland and therefore outside the predicted underwater noise contours.

This report provides strong evidence that the main herring spawning grounds are at some distance beyond the area of potential effect from piling noise and it is therefore concluded that the planned piling installation activities will not adversely impact spawning of the Orkney-Shetland herring stock.

The summary and comparison of BOWL's 2014 and 2015 herring survey data provided in this report demonstrates that the survey results from the 2015 herring surveys resemble those of the 2014 surveys, and therefore that mitigation of piling noise is not required. Further to this, a piling restriction not exceeding 16 days within the months of August and September will not be required.

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## 5 ISO Accreditation

Brown & May Marine Ltd. utilises 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.