

The logo for Moray East Offshore Windfarm features a large, stylized circular graphic in the background, composed of several light blue segments arranged in a ring. The text 'MORAY EAST' is written in a bold, dark blue, sans-serif font, with the 'O' in 'MORAY' containing a small white circle. Below it, 'OFFSHORE WINDFARM' is written in a smaller, light blue, sans-serif font.

# MORAY EAST

## OFFSHORE WINDFARM

A series of overlapping, wavy lines in shades of light blue and white, creating a sense of movement and depth, positioned above the dark teal background.

### Herring Larvae Annual Review

January 2018

Moray Offshore Windfarm (East) Limited

Produced by Brown & May Marine on behalf of Moray Offshore Windfarm (East) Limited <b>Brown &amp; May Marine Ltd.</b>	
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## List of Abbreviations

BGS	British geological survey
BMML	Brown and May Marine Limited
BOWL	Beatrice Offshore Wind limited
HAWG	Herring Assessment Working Group
ICES	International Council for Exploration of the Sea
IHLS	International Herring Larval Survey
MMO	Marine Management Organisation
MS-LOT	Marine Scotland Licensing Operations Team
VMS	Vessel Monitoring System

## Glossary of Project Terminology

Moray Offshore Windfarm (East) Limited (Moray East)	The company developing the Moray East Offshore Wind Farm (formerly known as Moray Offshore Renewables Limited).
Moray East Offshore Wind Farm	The wind farm to be developed in the Moray East Site.
Moray East Site	The area of the Zone in which the Moray East Offshore Wind Farm will be located. Formally known as “Eastern Development Area” and where the consented Telford, Stevenson and MacColl Offshore Wind Farms are located.
The Project	Combined Moray East offshore wind farm, transmission infrastructure and onshore transmission infrastructure.
The Development	Offshore component of the project.
Study area	Area surrounding the development associated with ICES rectangles 44E6, 44E7, 45E6 & 45E7.

## Executive Summary

Evaluation of the peer reviewed scientific literature, International Herring Larval Survey (IHLS) data, and Marine Management Organisation (MMO) commercial landing data as well as BOWL survey results suggests that significant herring spawning activity does not occur within the vicinity of the Moray East Site.

The findings of both the IHLS surveys and the BOWL herring larval surveys (in respect of larval abundance, length distribution and age back-calculation) indicates that larvae caught during the survey were most likely to have hatched from spawning grounds further to the north, around the Orkney Isles and then have drifted south into Moray Firth.

In the higher resolution survey conducted for BOWL (2014, 2015), no larvae were caught during the firsts three weeks of August. The majority of the larvae caught after this time period were at least 6 days old, again suggesting that they are transported from spawning grounds to the north into the Moray East Site by southerly currents to reach the Moray Firth by mid to late August. The multiple data sources all support the suggesting that the main spawning grounds occurs in waters around the Orkney Isle, with the main period of egg hatching commencing in early August.

## 1 Introduction

The following report constitutes a desktop Supplementary Baseline Report on herring spawning in areas relevant to the Moray East Site comprising the Telford, Stevenson and MacColl Offshore Wind Farms (Figure 1). Site specific larval sampling surveys will be undertaken in 2018 ahead of construction.

As described in the letter and accompanying proposal to Scottish Ministers on 9 January 2017, the principal objectives of the report are to provide a preliminary description of herring spawning and larval abundance within the vicinity of the Moray East Site with particular reference to:

- The spatial distribution and density of larvae by length and its inference on age;
- The influences of larval transport; and
- The timing of main spawning.

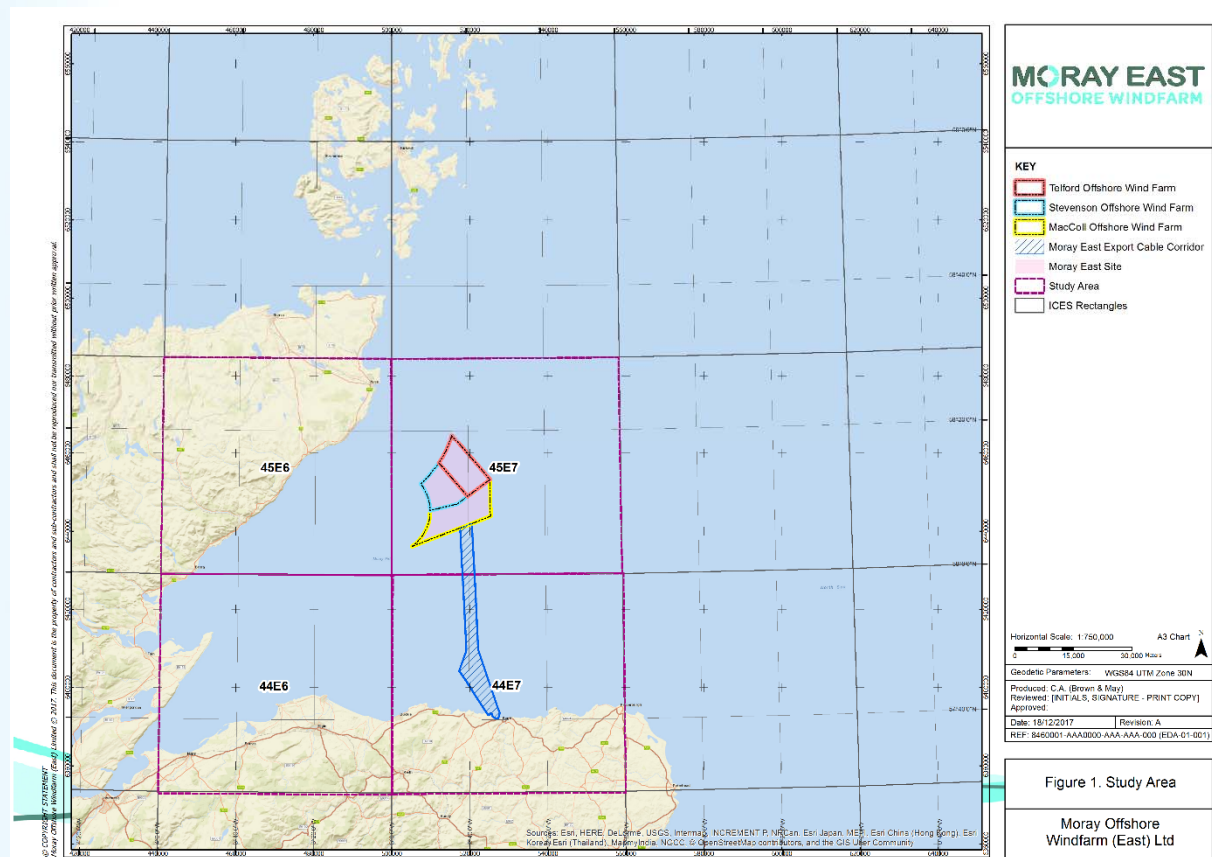


Figure 1. The project area of Telford, Stevenson and MacColl Offshore Wind Farms in Moray Firth, Scotland.



## 2 Background Information

### 2.1 North Sea Herring (*Clupea harengus*)

In the North Sea, herring (*Clupea harengus*) and herring eggs constitute an important food source for upper trophic predators (Rankine and Morrison, 1989; Ellis, 2012) as well as being a commercially important species (Nichols, 2001).

The North Sea Herring autumn spawning stocks have been estimated to have biomass between 2.34 - 2.6 million tonnes (2012 - 2016) (ICES, 2012; ICES, 2017). There have however been sequential years of low recruitment, for example between 2002 and 2011, which have led to concerns in respect of future management strategies (ICES, 2012; Payne *et al.*, 2010).

It is generally considered that North Sea herring is comprised of four stocks; Orkney/Shetlands, Buchan, Banks and Downs based on areas used for spawning (Figure 2). These stocks exhibit differences in spawning times, growth rates, migration routes and recruitment patterns (Dickey-Collas *et al.*, 2010). The stock in close proximity to the Moray East Site are Orkney/Shetland and Buchan stocks. However, as discussed below due to the tidal current regime the spawning of the Buchan stock is not directly relevant to the project.

Herring are seasonally migratory and travel considerable distances in large shoals between spawning, over-wintering and feeding grounds (Munro *et al.*, 1998). Adults from these two reproductively distinct stocks are considered to migrate from spawning grounds to wintering grounds in the Skagerrak and Kattegat. This is followed by a spring migration to feeding grounds in the Fladden Ground and Viking Bank (Munro *et al.*, 1998). Juveniles often remain in shallower nursery areas for up to two years (MacKenzie, 1985) before following the migration patterns of adults.

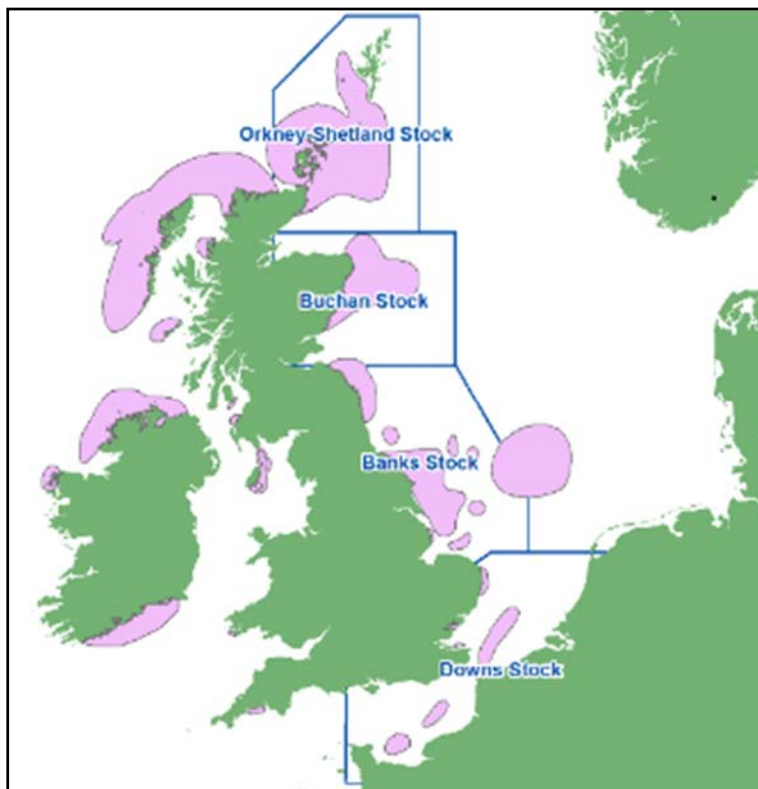


Figure 2. The four stocks of North Sea herring spawning areas of the UK.

## 2.2 Spawning Season

North Sea herring are synchronous batch spawners which show a preference for well-oxygenated environments with coarse sediment and fast flowing water when selecting their spawning grounds (Keltz & Bailey, 2010; Groot, 1980; Munro *et al.*, 1998, Parrish *et al.*, 1959; Blaxter, 1985). Females deposit eggs with adhesive membranes in single batches directly onto the seabed in areas of coarse sand, maerl, gravel and small stones with a low proportion of fine sediment at depths between 15-40m (Keltz & Bailey, 2010; Munro *et al.*, 1998; Geffen, 2009). Due to the specific habitat requirements, spawning grounds are reasonably well defined, although spawning intensity varies between years (Blaxter, 1985; Keltz & Bailey, 2010; Rockmann *et al.*, 2011).

According to Coull *et al.*, (1998), the Orkney/Shetland stock's peak spawning activity is usually between August and September. Herring congregate at traditional spawning grounds, with the larger, older fish arriving earlier than the smaller, younger fish (Lambert, 1987). Peak spawning periods are primarily influenced by temperature and stock structure (size and age). Sea temperature affects the onset of gonad development for spawning (Ware and Tanasichuk, 1989). The age and size of shoals influences the peak spawning phase. A shoal comprising mainly of older, larger fish usually spawns towards the beginning of the overall spawning period, whereas the opposite is usually the case with shoals being comprised of smaller, younger fish (Lambert, 1987).

## 2.3 Larvae

Herring larvae hatch approximately three weeks after spawning, depending on sea temperature (Keltz & Bailey, 2010, Munro *et al.*, 1998, Hodgson, 1957). Newly hatched larvae are normally 5-8mm in length and grow at a rate of approximately 0.28mm per day (Kiorboe *et al.*, 1988). The early stage larvae (<10mm in length) are lecithotrophic being dependent on their yolk-sac for 6-10 days until the yolk is reabsorbed. Following the lecithotrophic stage, the larvae become planktotrophic (late-stage), feeding on small zooplankton and reaching a length greater than 10mm (Blaxter, 1968; Fassler *et al.*, 2011; Heath, 1993; Hodgson, 1957; Dickey-Collas, *et al.*, 2010). During the planktonic phase the larvae metamorphose into juveniles (Gamble *et al.*, 1985).

### 2.3.1 Larval Drift

Herring larvae have limited swimming ability, so their spatial distribution is primarily determined by current flow rates (Urho & Hilden, 1990; Norcross *et al.*, 2001). In the northern North Sea around Scotland, the coastal currents are predominantly southerly and easterly (Figure 3). Therefore, only spawning activity around or north of Moray East Site will potentially be affected by the offshore wind farm development. Hence, this report focuses on the Orkney/Shetland stock, as the Buchan Stock larvae will drift south and eastwards away from the projects construction.

Herring larvae drift in this same pattern with distance drifted being dependant on time in the water column as a consequence of age and the current velocity (Guerin *et al.*, 2014). Larger larvae have been found to have been transported further distances from spawning sites as a consequence of spending more time in the water column. For the Orkney/Shetland stock, larval drift is predominantly influenced by two Fair Isle currents: the West of Orkney (current 4) and the North Sea (current 5) (Figure 3). These currents have been measured to have residual velocities of 7cm/second (current 4) and 10cm/second (current 5), which is equivalent to 6.0 km/day and 8.6 km/day respectively (Baxter *et al.*, 2011).

Larval drift varies considerably depending on the larvae location relative to the core current. Nichols (1999) considers that larvae hatched on the Orkney/Shetland spawning grounds are either transported south into the Moray Firth or eastwards towards the Danish coast (Figure 4).

In the centre of the Fair Isle currents, inflow larval drift is understood to be at maximum rate of 36km/day, whereas larvae in other areas the North Sea current have been recorded to drift at a rate of 6-8.6 km/day (Heath & Rankine, 1988; Baxter *et al.*, 2011). The vertical migration of fully developed planktonic phase (late-stage) larvae in the water column can also act as a mechanism to minimise horizontal drift due to opposing tidal flow directions (Stephenson & Power, 1985).

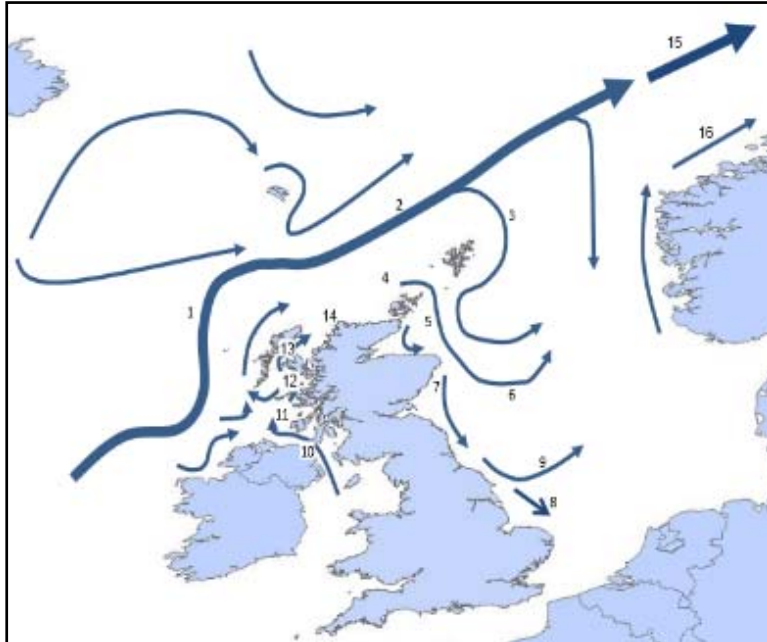


Figure 3. Schematic representation of the major oceanic and coastal currents in the North East Atlantic and the North Sea (Baxter *et al.*, 2011).



Figure 4. The spawning areas and spawning periods of the North Sea autumn spawning sub-populations showing larval drift to nursery grounds (Nichols, 1999).

### 3 Data and Information Sources

The following data sources have been used to inform this report:

- International herring larval survey (IHLS);
- Commercial herring catch reports and Vessel Monitoring Data (VMS) data;
- Site specific herring larval survey undertaken for the Beatrice Offshore Wind Farm;
- Current literature on herring larvae life history; and
- Hydrodynamics of the area.

#### 3.1 International Herring Larval Survey

The ICES program of International herring larval survey (IHLS) in the North Sea has been in operation since 1972. The findings are used to provide an estimate of herring larval abundance and spatial distribution which in turn contributes to management measures and policies. The survey methodology involves sampling 9 stations within each ICES rectangle. The sampling stations are numbered sequentially from west to east beginning in the northern most row (labelled alphabetically from “a” to “i”). In the Moray Firth area, sampling was typically undertaken in the last two weeks of September, although it has occurred in October, December and January, largely due to logistical reasons.

The equipment used has varied between GULF III, GULF IV and Nackthai high speed samplers. This report has considered the results of surveys from 2000 to 2015, as the 2016 survey did not collect samples in Moray Firth due to technical problems (ICES, 2017). The results of 2017 surveys are not yet available.

IHLS data does not report individual lengths of larvae. Larvae lengths are recorded into three categories; Absmall (<10mm in length), Abmedium (10-15mm in length) and Ablarge (>15mm in length), therefore undertaking back-calculations on one length (<10mm) will not be useful or accurate. Back calculations were carried out on the BOWL herring larval survey data as individual larvae lengths were reported. The larval length of interest are those <10mm.

For the following assessment, the raw IHLS data provided was screened and duplicated samples removed. If a value was missing in the raw data it was replaced with zero values, as it was assumed that no herring larvae were caught in that sample. The identification codes of the samples locations were referenced using ArcGIS, to verify the ICES sub-rectangles codes used. In cases where the ICES sub-rectangle codes did not match the ArcGIS positions, it was assumed that the latitude and longitude coordinates were correct and new ICES rectangle codes was given to the samples. The number of early-stage larvae herring (Absmall) collected in each ICES sub-rectangle code was averaged per year, as some years contained more than one sample. These averages were then used to calculate the average number of early-stage larvae caught over the 15 years.

#### 3.2 Vessel monitoring system (VMS) and landings data

The commercial fisheries data for pelagic fishing vessels in north-east of Scotland (IVa(W) see Appendix 1) was obtained between 2006 and 2016 from the Marine Management Organisation (MMO) VMS database. Landings data is given for UK registered vessels by species and ICES rectangle, averaged over a 10-year period. However, it is important to note that in respect of spawning aggregations, other factors such as quotas and market forces affect fish landing and as such fisheries data may not necessarily fully illustrate spawning adult abundance and distribution.

### 3.3 BOWL herring larval survey

In 2014 and 2015, Brown & May Marine Ltd undertook herring larval surveys specified as part of BOWL's consent pre-construction obligations.

The survey was conducted just north of the Moray East Site, providing high resolution of herring larvae data for the North East of Moray Firth.

The survey methodology was agreed with Marine Scotland Science (MSS) and Marine Scotland Licensing Operations Team (MS-LOT) in July 2014 (Meeting at Marine Scotland, Aberdeen). The survey was undertaken using a Gulf VII high speed plankton sampler (following the best practice methodology which is similar to IHLS methodology). Herring larvae was sampled at 25 stations (Figure 26) every week in the 8-week period, weather permitting. The analysis data was used to undertake back-calculations using methodology approved by MSS.

The primary objectives of the BOWL surveys were to:

- 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 within the BOWL development area and wider Moray Firth Area;
- Determine the level of spawning activity in and around the BOWL development area and wider Moray Firth.

The 2014 survey was undertaken between 4<sup>th</sup> August and 27<sup>th</sup> September and the 2015 survey between 3<sup>rd</sup> August and 27<sup>th</sup> September.

The BOWL survey data provides high-resolution data on the size and age of herring larvae that have been recorded in the immediate vicinity of the Moray East Site.



## 4 Research Findings

### 4.1 Spawning and Nursery grounds

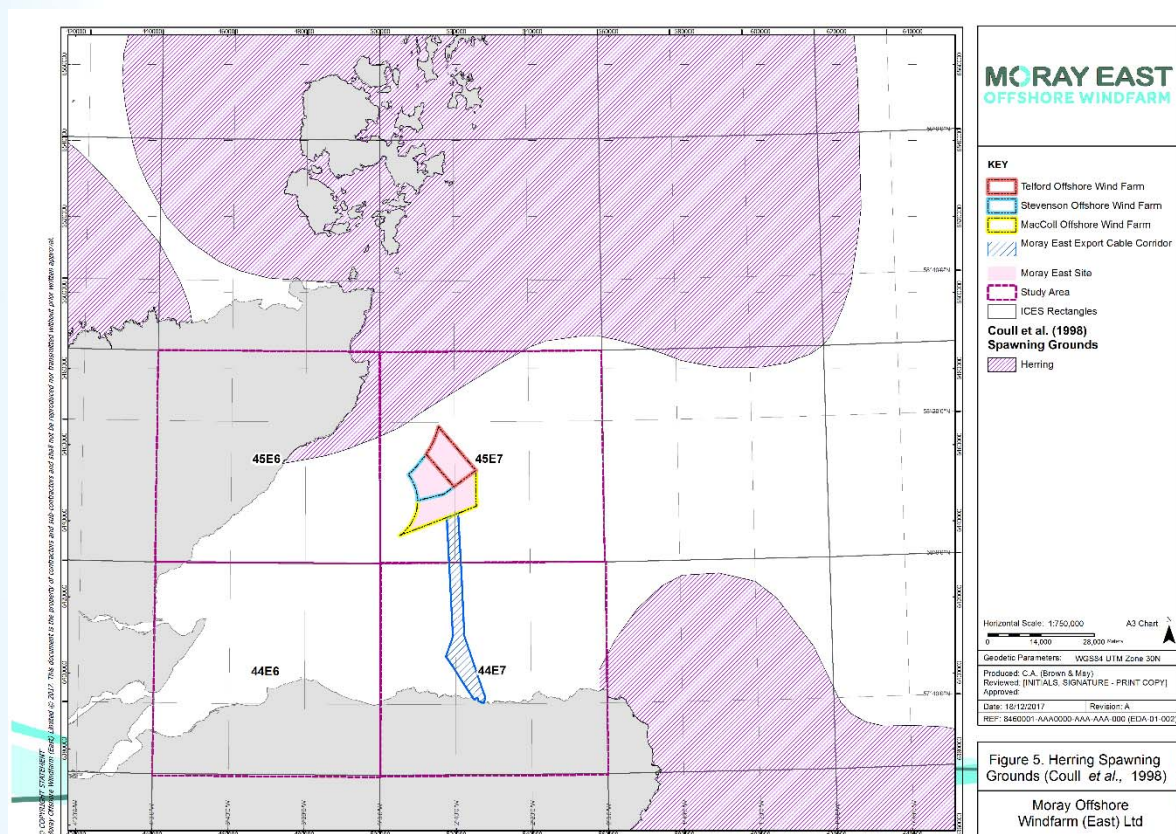
#### 4.1.1 Background data

Herring spawning activity requires specific habitat substrates, which have been identified as coarse sand, gravel coarse sand, maerl, gravel and small stones. North Sea herring spawning and nursery grounds have been identified by the widely used standard references of Coull *et al.*, (1998) (**Figure 5**) and Ellis *et al.*, (2010) (Figure 6).

Both Coull *et al.*, (1998) and Ellis *et al.*, (2010) indicate that the herring spawning grounds are to the north and south of the development (**Figure 5**; Figure 6).

According to British geological survey (BGS) data, the Moray Firth benthic substrate is predominantly muddy sand, sand and slightly gravelly sand with areas of sandy gravel and gravelly sand (Figure 7). The substrate preferable for herring spawning are coarse sand (sandy gravel, slightly gravelly sand and gravelly sand) and gravel sediment types; which are indicated by pink and orange colours in Figure 7.

The Moray East site is not located within the herring spawning reference site of Coull *et al.*, (1998) but within the referenced nursery grounds. The benthic substrate of the Moray East site are sand, sandy gravel and slightly gravelly sand (FIG). Whilst the Moray Firth may contain substrates considered suitable for herring spawning, as with many other areas in the North Sea. Substrate suitability alone does not determine the location of spawning activity.



**Figure 5. The spawning grounds of herring larvae in Moray Firth region defined by Coull *et al.*, (1998).**

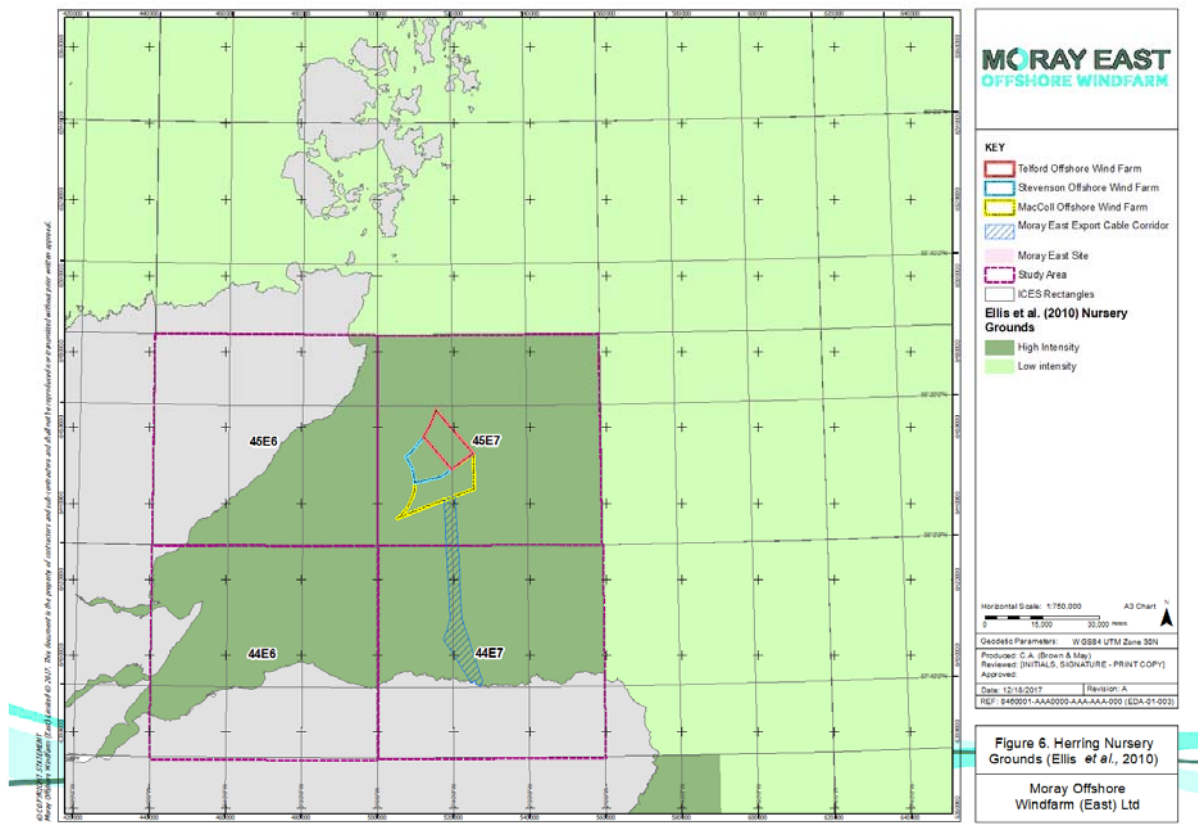


Figure 6. The nursery grounds of herring juveniles in Moray Firth region defined by Ellis *et al.*, (2010).

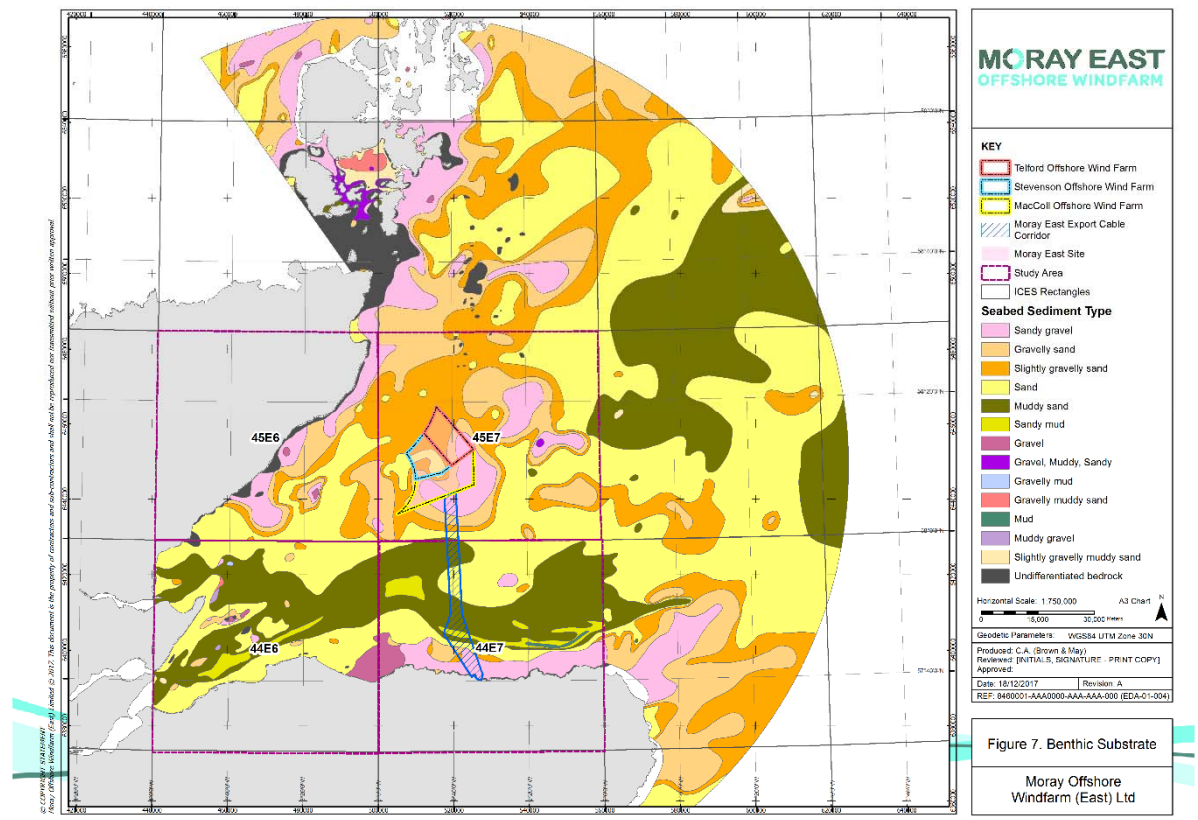


Figure 7. Benthic substrates the Moray Firth region.

#### 4.2 Larval Distribution and Abundance

The results from 2000-2015 show that the abundance of early stage larvae was much lower in the study area of Moray Firth than that found to the east and north-east of the Orkney Isles (Figure 8).

It is also apparent that the abundance of early-stage larvae varies considerably between years as shown by Figure 9 to Figure 12 (Appendices 2 to 13). In 2014 (Figure 11), early-stage larval abundance was low compared to other years, whereas in 2013, it was higher (Figure 10).

The results of the series of IHLS surveys in respect of early stage larval abundance corresponds with the findings of Coull *et al.*, (1998), both indicating that the main spawning areas of the Orkney/Shetland stock are north of the Moray Firth, being located to the east and north of the Orkney Isles (Figure 13).

The late-stage larvae distribution (Figure 14) further confirms this assumption by showing larger older larvae which have spent longer in the water column and are therefore being carried further into the Moray Firth from their site of spawning.

Figure 15 further implies that the main location of the Orkney/Shetland spawning ground is north-east of the Orkney Isles. It should be noted that the IHLS data does not state whether the eggs are herring eggs, however due to the time of the survey it is assumed that majority of the eggs caught will be herring eggs. It should be noted that the eggs were collected through high speed plankton sampling and were therefore found in the water column. It is therefore possible that they may be dead or unfertilized.

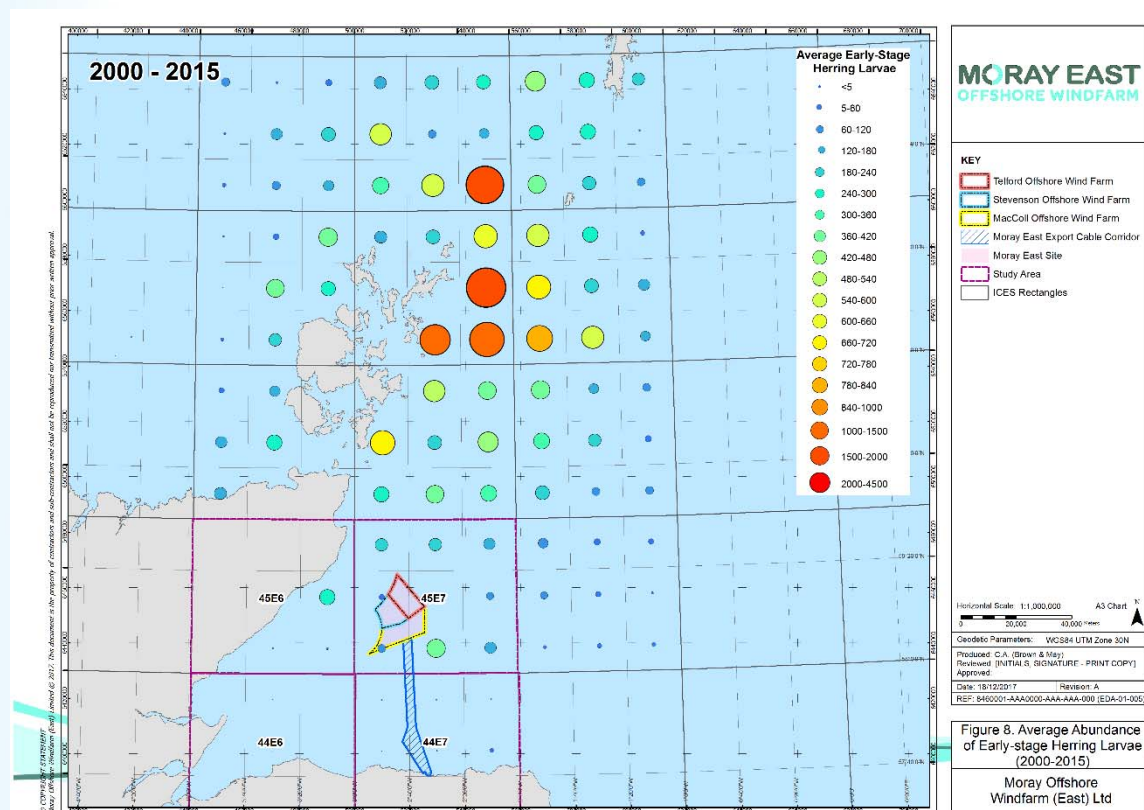


Figure 8. Average abundance and distribution of herring larvae (early-stage) around Moray Firth and along the north-eastern coast of Scotland (IHLS, 2000-2015).



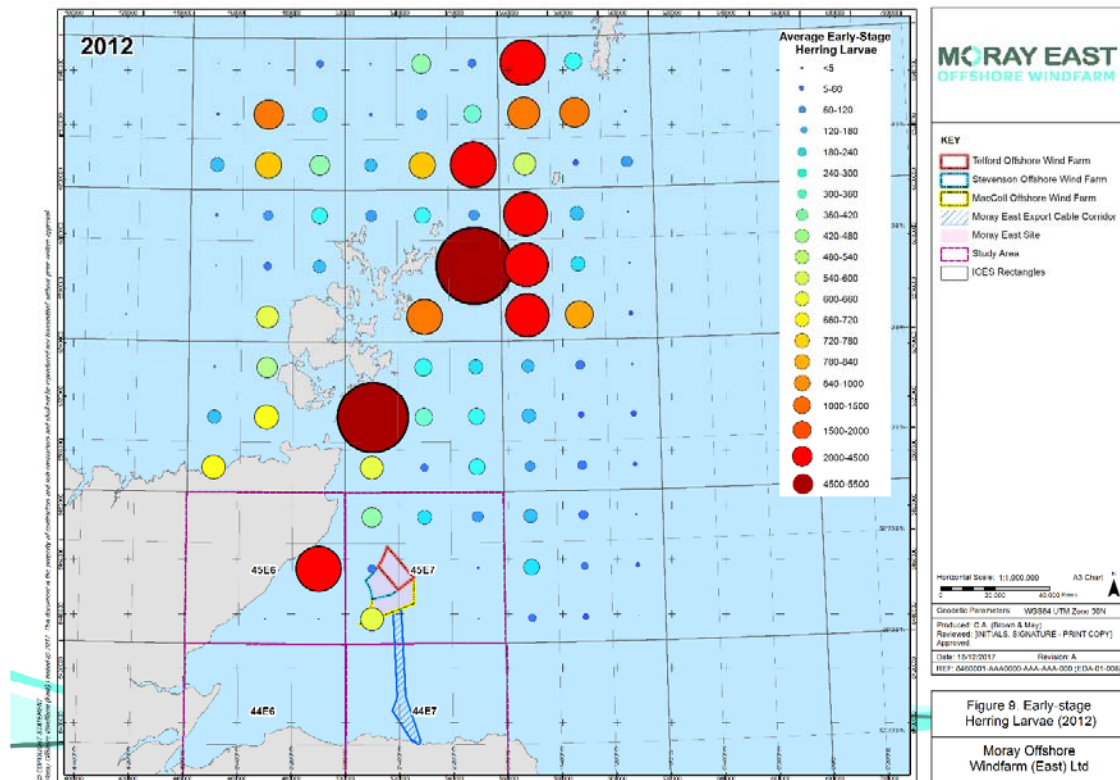


Figure 9. Abundance and distribution of herring larvae (early-stage) for 2012 around Moray Firth and the along the north-eastern coast of Scotland (IHLS, 2012).

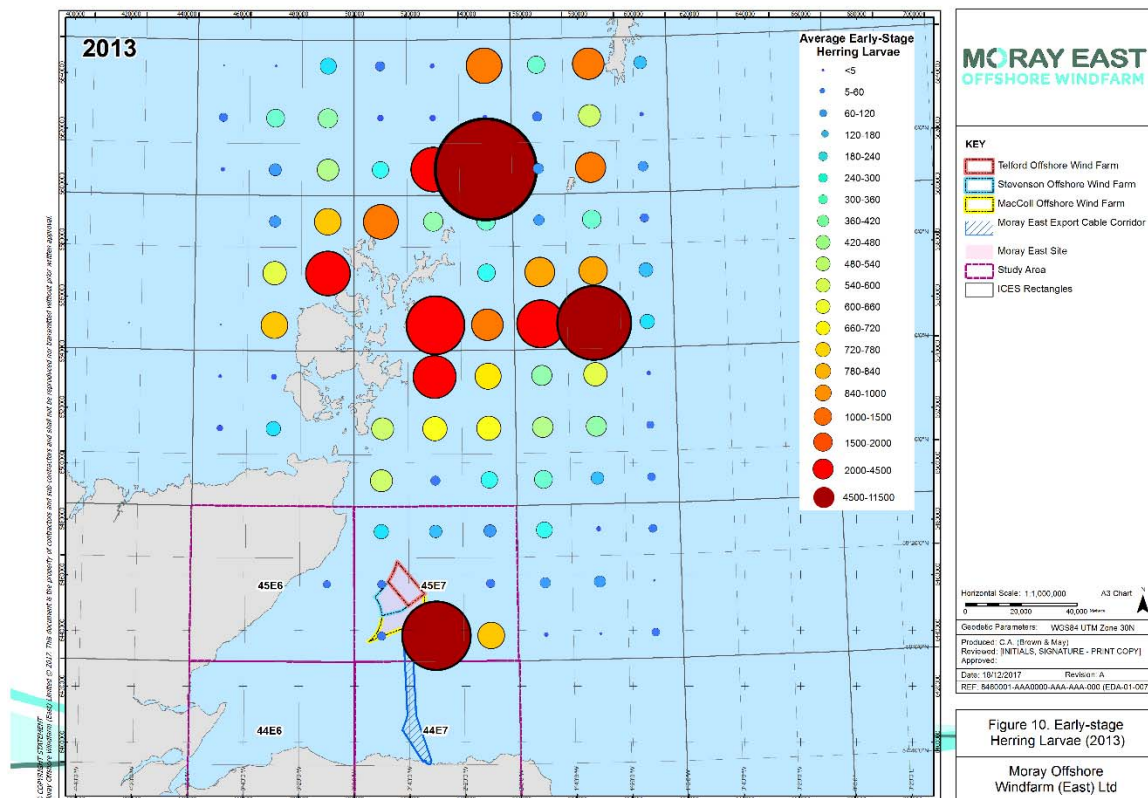
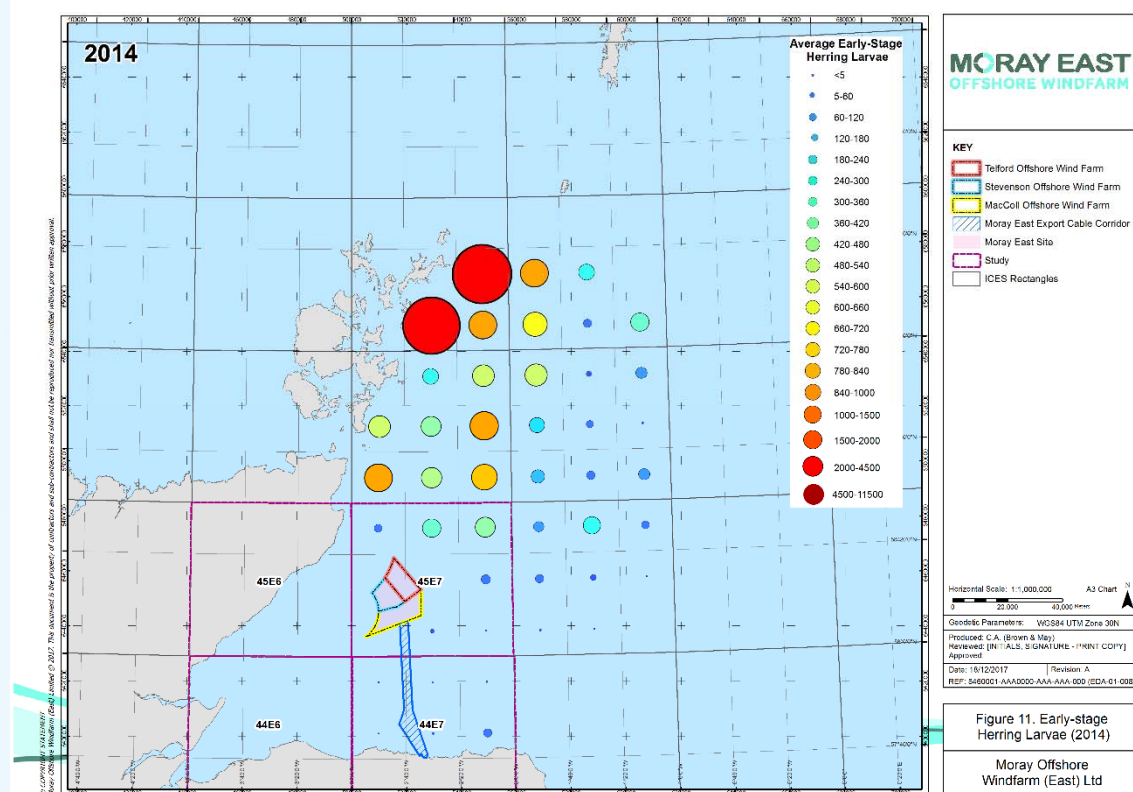
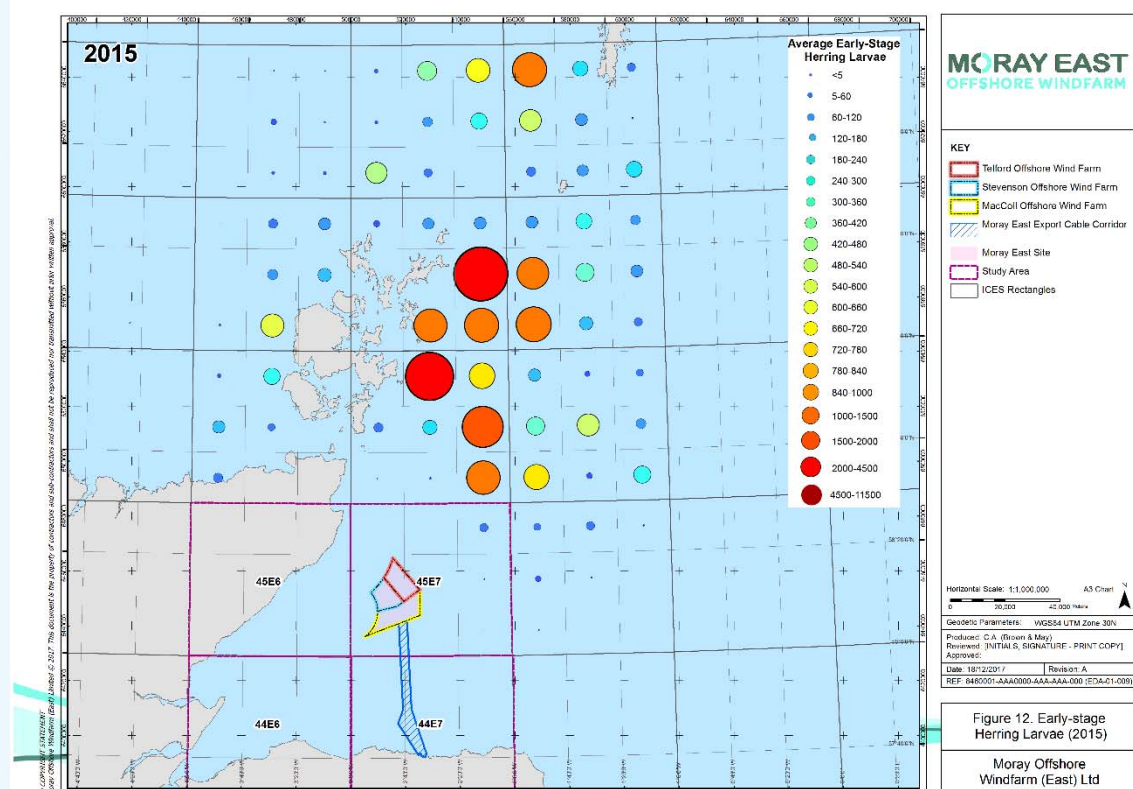


Figure 10. Abundance and distribution of herring larvae (early-stage) for 2013 around Moray Firth and the along the north-eastern coast of Scotland (IHLS, 2013).

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**Figure 11. Abundance and distribution of herring larvae (early-stage) for 2014 around Moray Firth and the along the north-eastern coast of Scotland (IHLS, 2014).**



**Figure 12. Abundance and distribution of herring larvae (early-stage) for 2015 around Moray Firth and the along the north-eastern coast of Scotland (IHLS, 2015).**



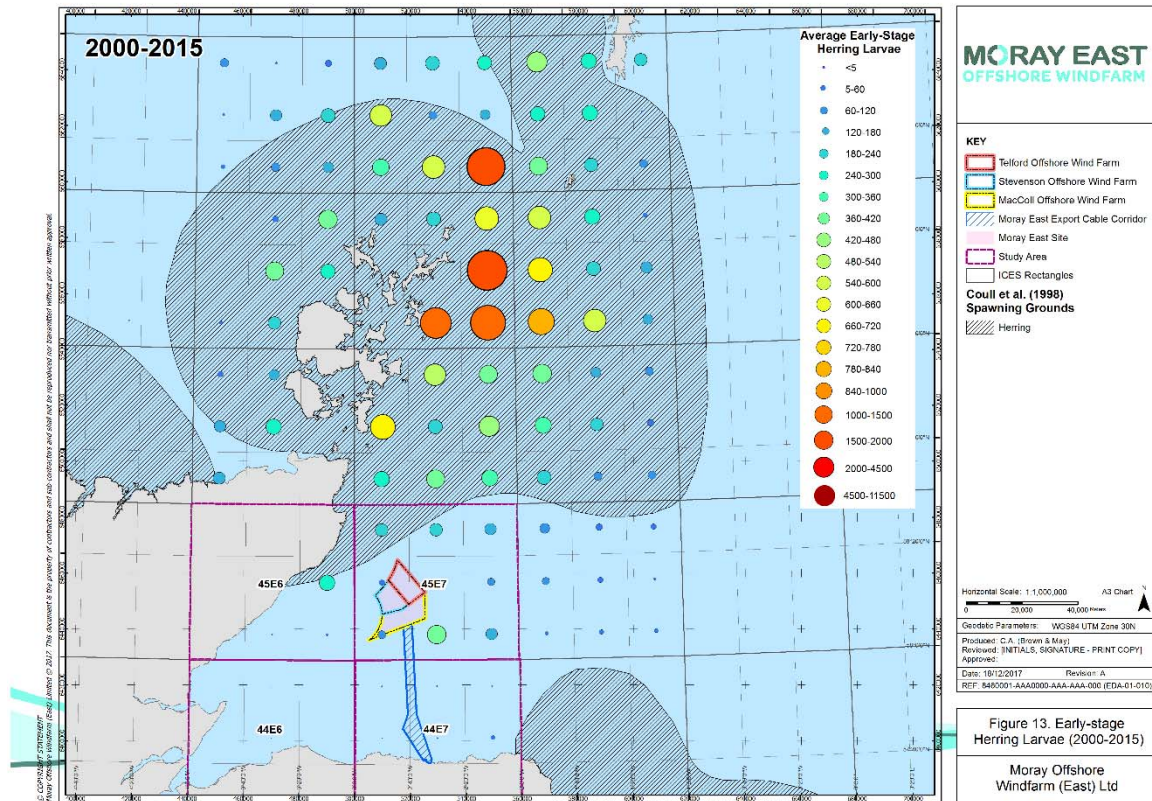


Figure 13. Abundance and distribution of early-stage herring larvae (<10mm length) showing Coull et al., (1998) referenced spawning area in the North Sea around Moray Firth (IHLS, 2000-2015).

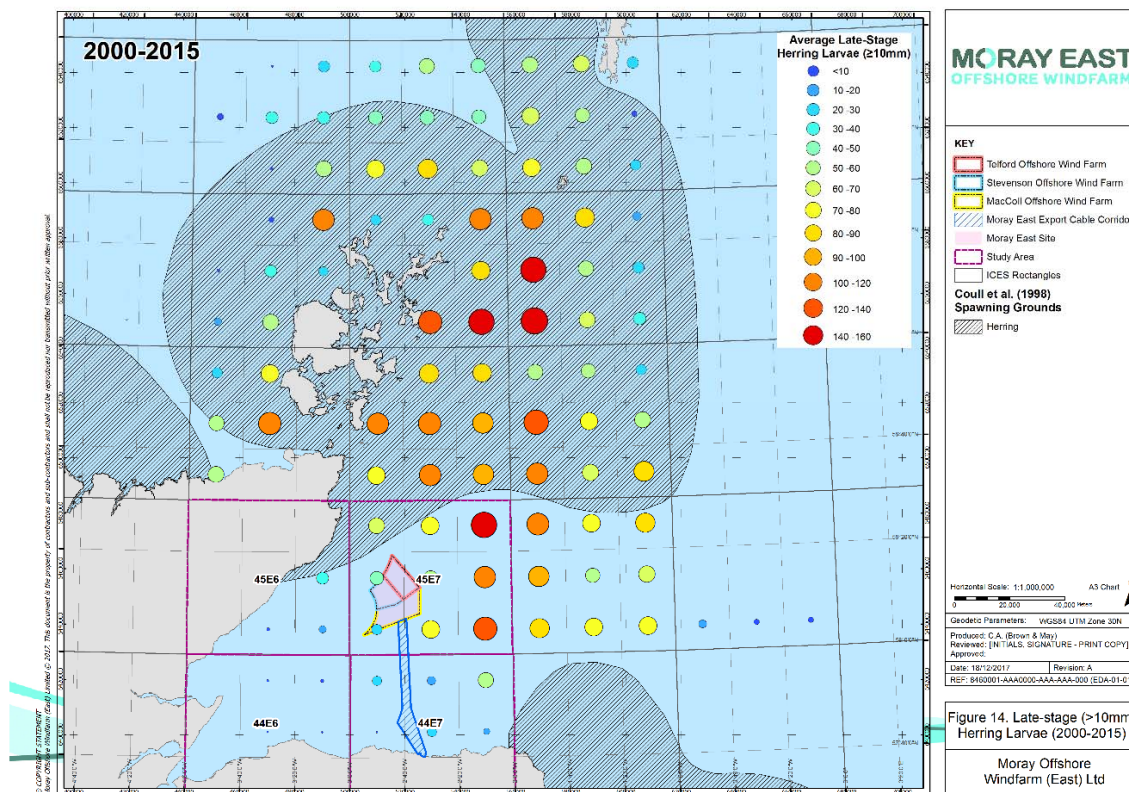
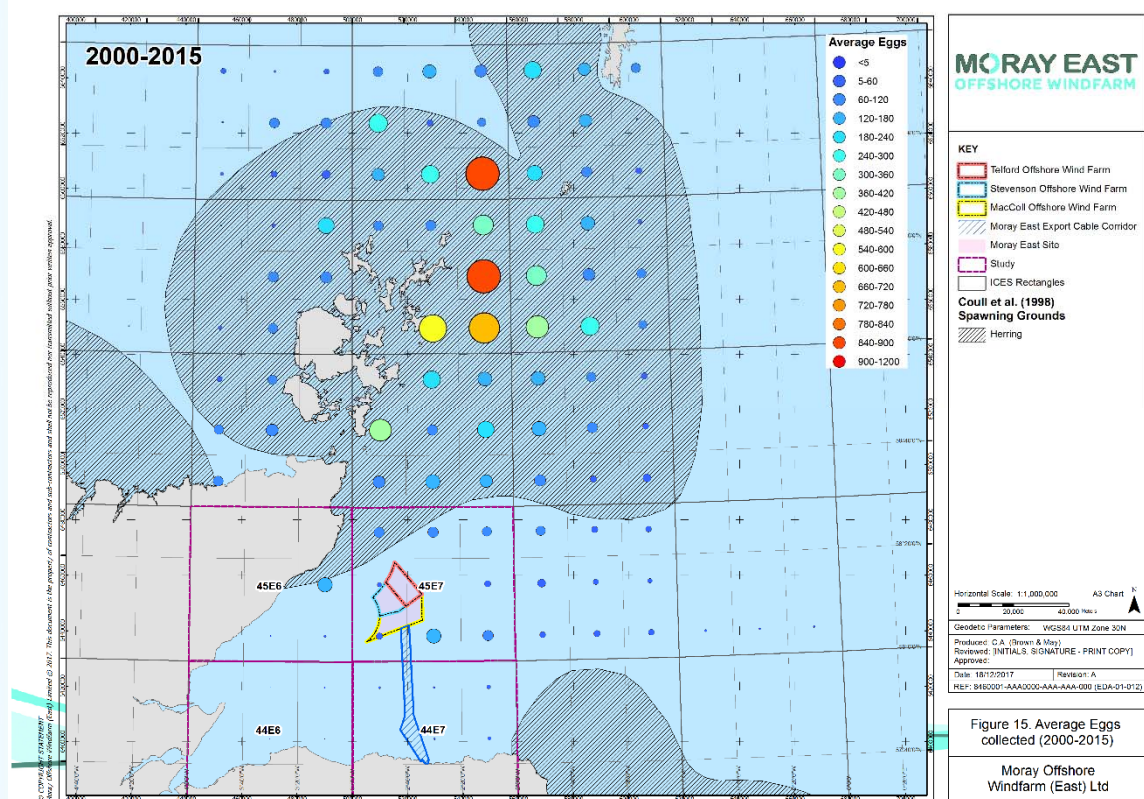


Figure 14. Abundance and distribution of late-stage herring larvae (≥10mm length) showing Coull et al., (1998) referenced spawning area in the North Sea around Moray Firth (IHLS, 2000-2015).



**Figure 15. Abundance and distribution of eggs collected around Moray Firth and the along the north-eastern coast of Scotland (IHLS, 2000-2015).**

### 4.3 Commercial Fishing

MMO data has been used to describe herring fishing patterns within the general area under consideration. The VMS data on pelagic activity indicates that effort and landings values of pelagic fishing within the Moray Firth are very low in comparison to adjacent areas (Figure 16).

A similar pattern can be identified from the MMO herring landings data by ICES rectangle (for the last 5 years for which data is available). Figure 17 to

Figure 21 show negligible herring fishing activity within the Moray Firth. Also shown on Figures 16 to 20 are the spawning grounds as defined by Coull *et al.*, (1998), which indicate higher levels of herring fishing activity occurring in the herring spawning grounds around the Orkney Isles.

The main spawning of the Orkney/Shetland stock normally occurs between August and September, with September being the key month.

Figure 22, Figure 23 and Figure 24 show the five-year averaged landings (2012-2016) by ICES rectangle, again overlaid with the Coull *et al.*, spawning areas. Comparison of the three months suggests that greatest targeting of herring in the Orkney spawning area occurs in August, during the pre-spawning aggregation phase. A noticeable reduction in landings occurs in September however, possibly due to the low market value of late running, ripe and spent herring.

Figure 25 further confirms that landings are highest just before spawning in August, but that the combined landings within the four ICES rectangles under consideration are proportionally lower.



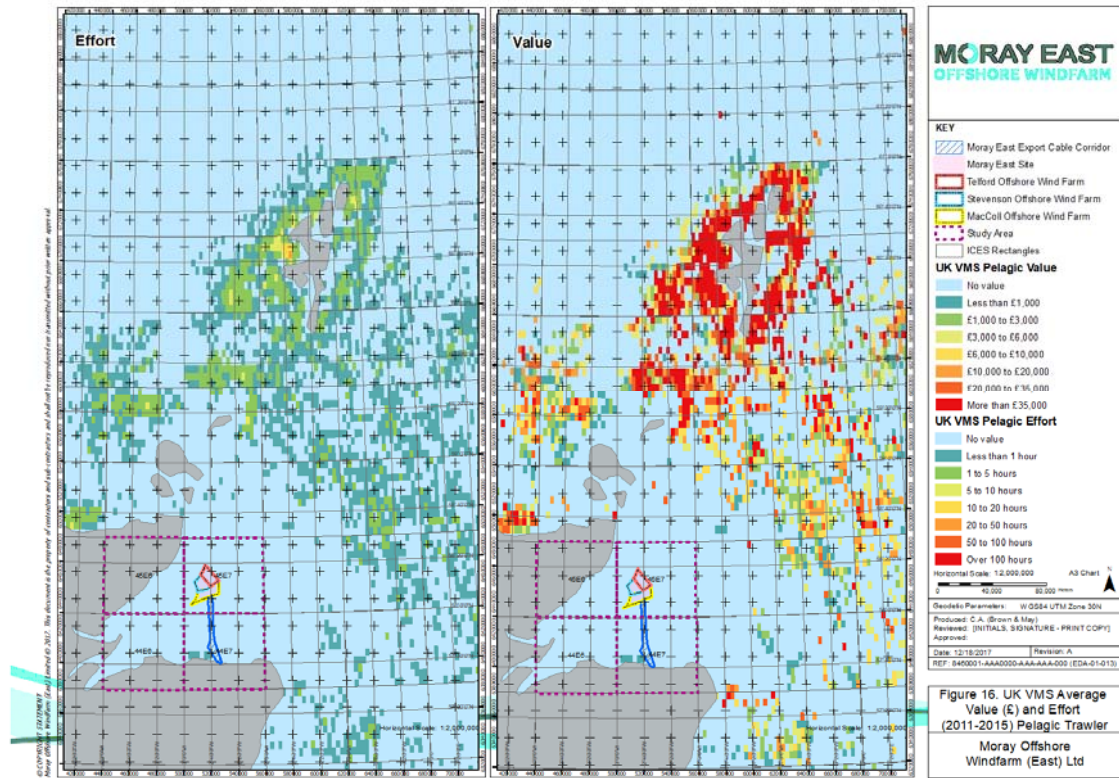


Figure 16. The average fishing value and effort of pelagic fishing (2011-2015).

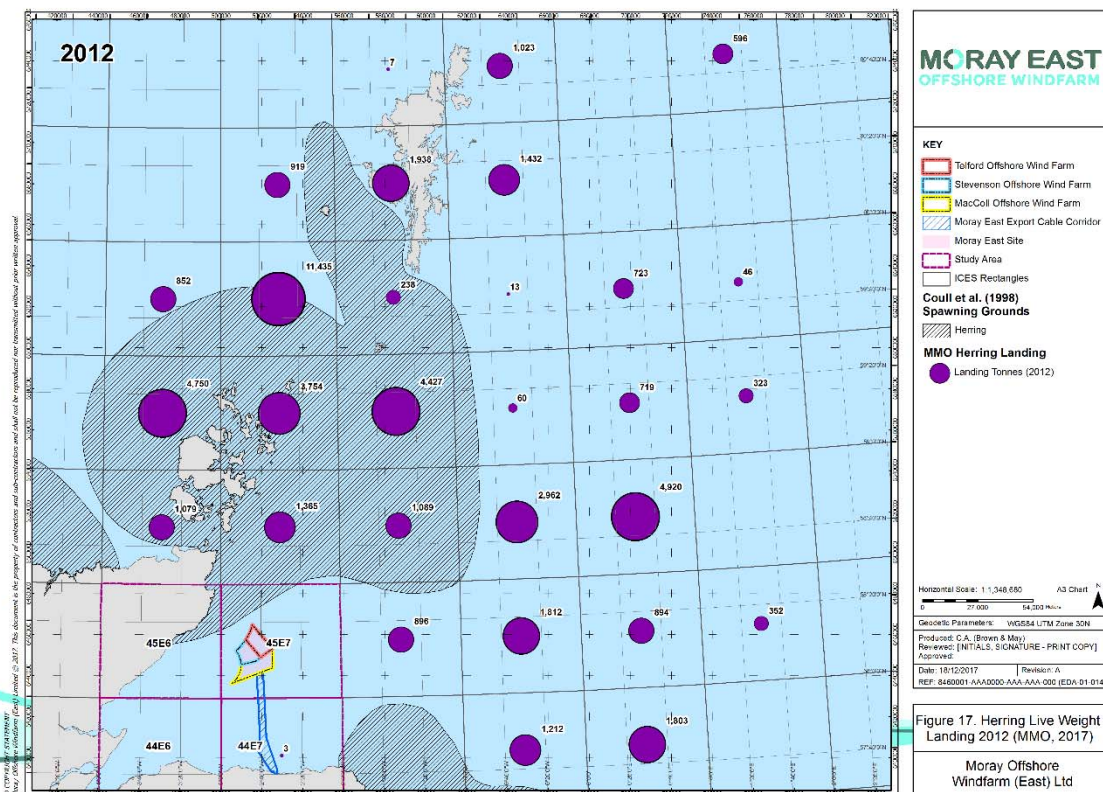


Figure 17. MMO landings data for herring in tonnes for 2012 with reference to Coull et al., (1998) spawning area.

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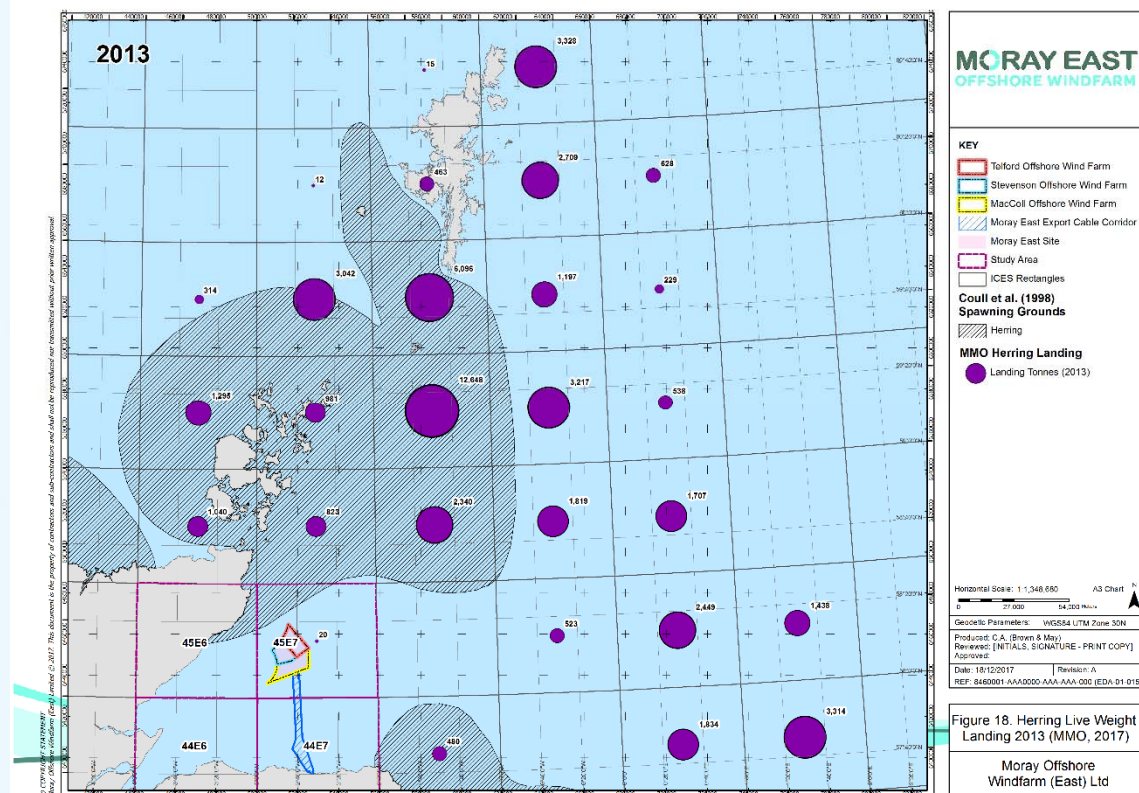


Figure 18. MMO landings data for herring in tonnes for 2013 with reference to Coull et al., (1998) spawning area.

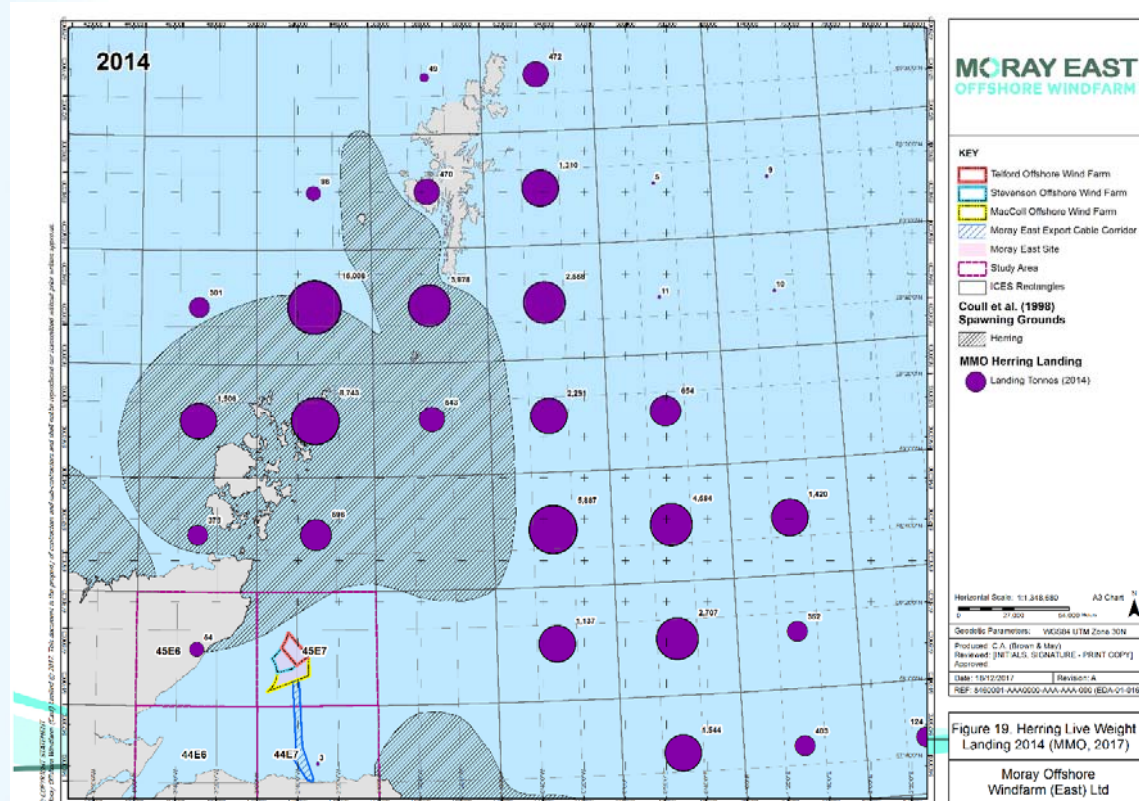


Figure 19. MMO landings data for herring in tonnes for 2014 with reference to Coull et al., (1998) spawning area.



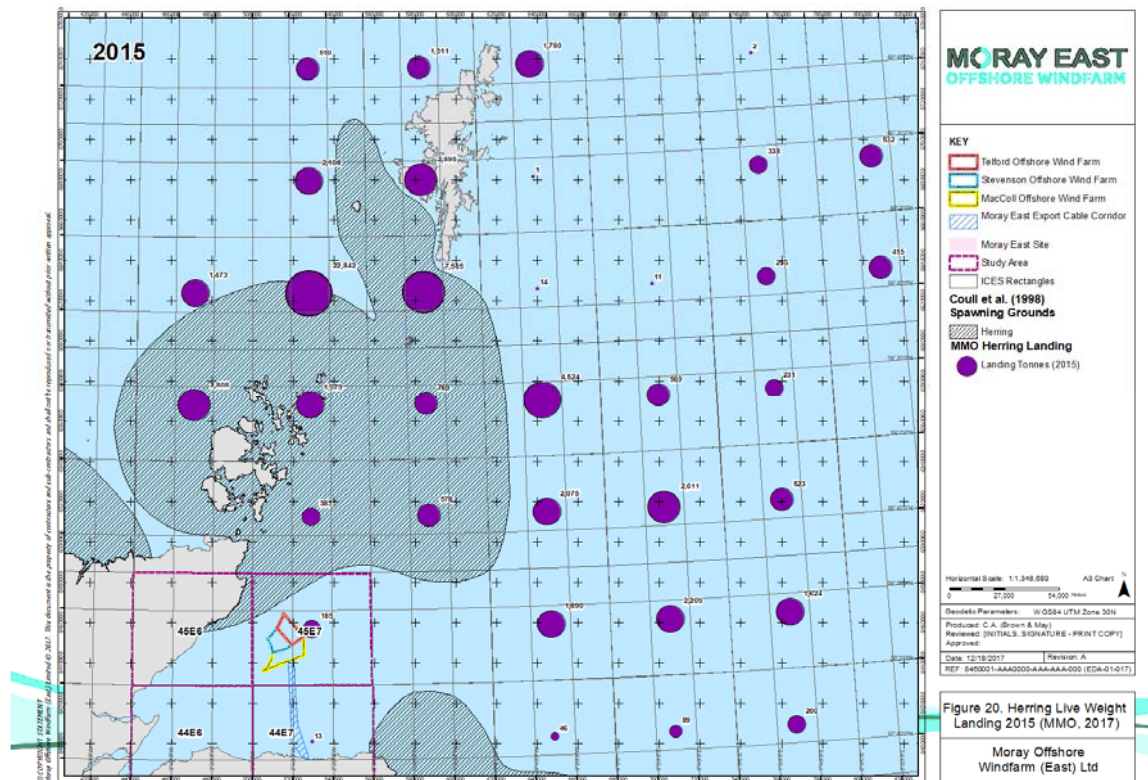


Figure 20. MMO landings data for herring in tonnes for 2015 with reference to Coull et al., (1998) spawning area.

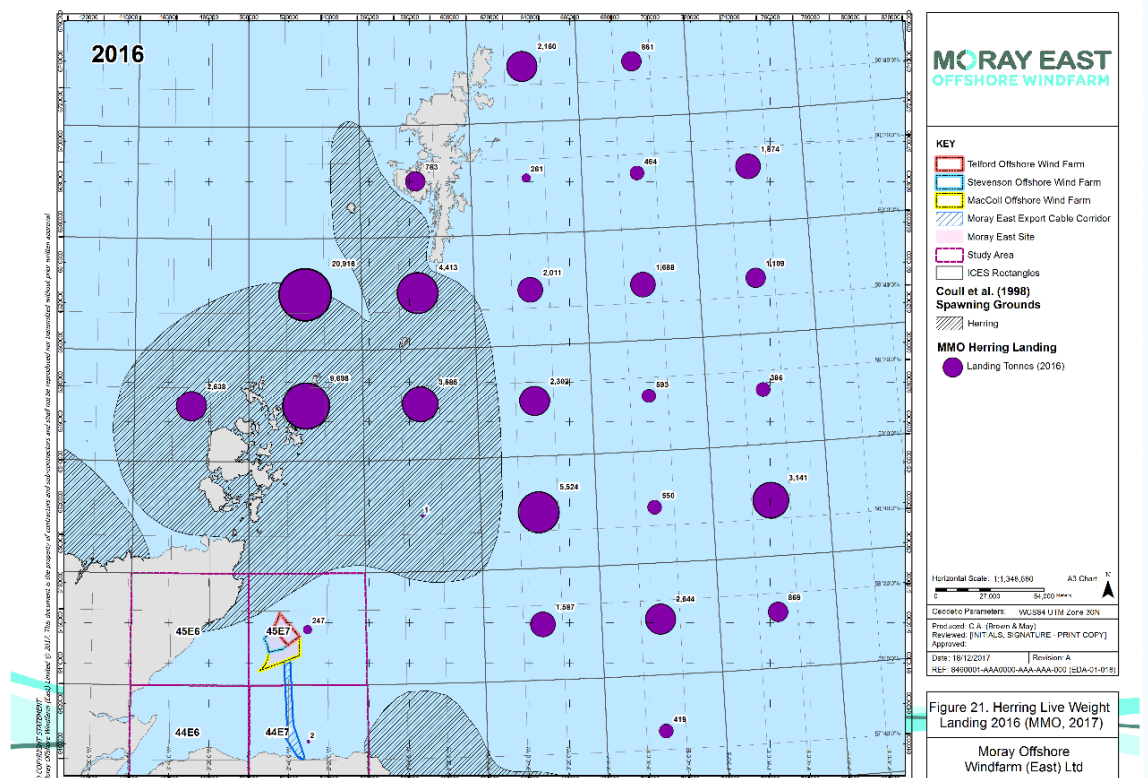


Figure 21. MMO landings data for herring in tonnes for 2016 with reference to Coull et al., (1998) spawning area.

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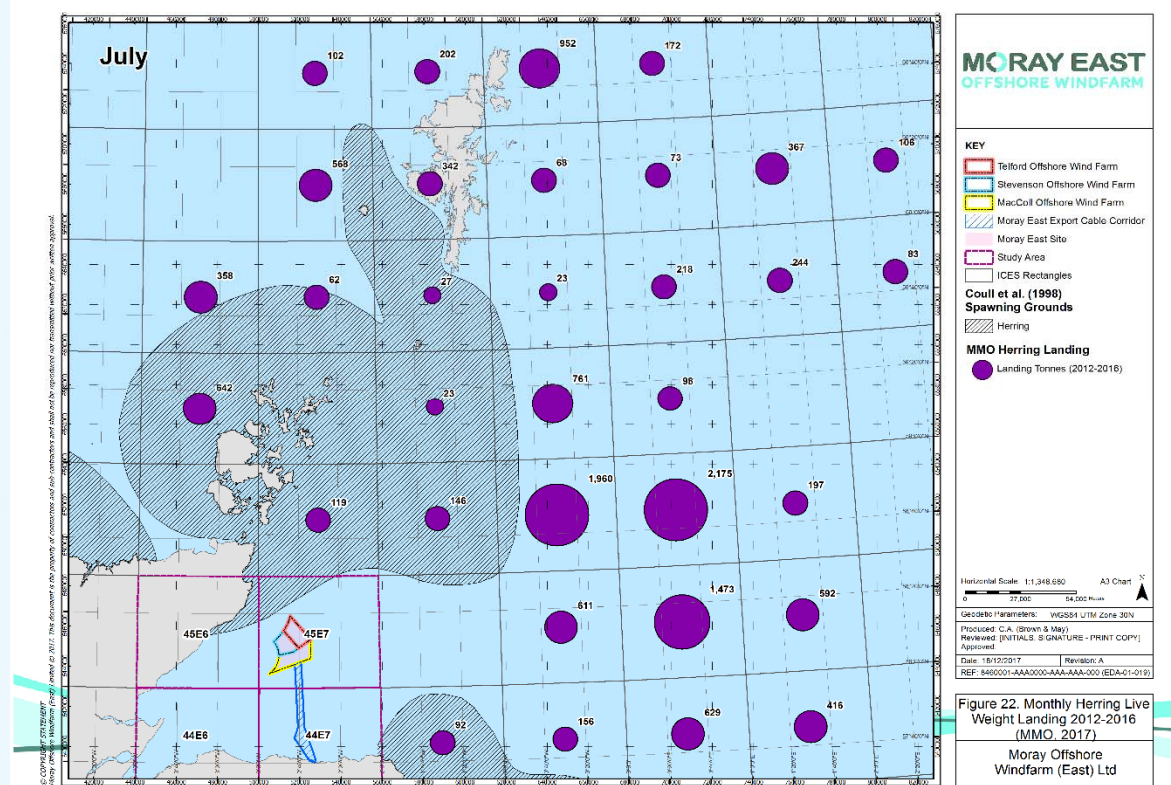


Figure 22. Average MMO landings for herring in tonnes for July (2012-2016) with reference to Coull et al., (1998) spawning area.

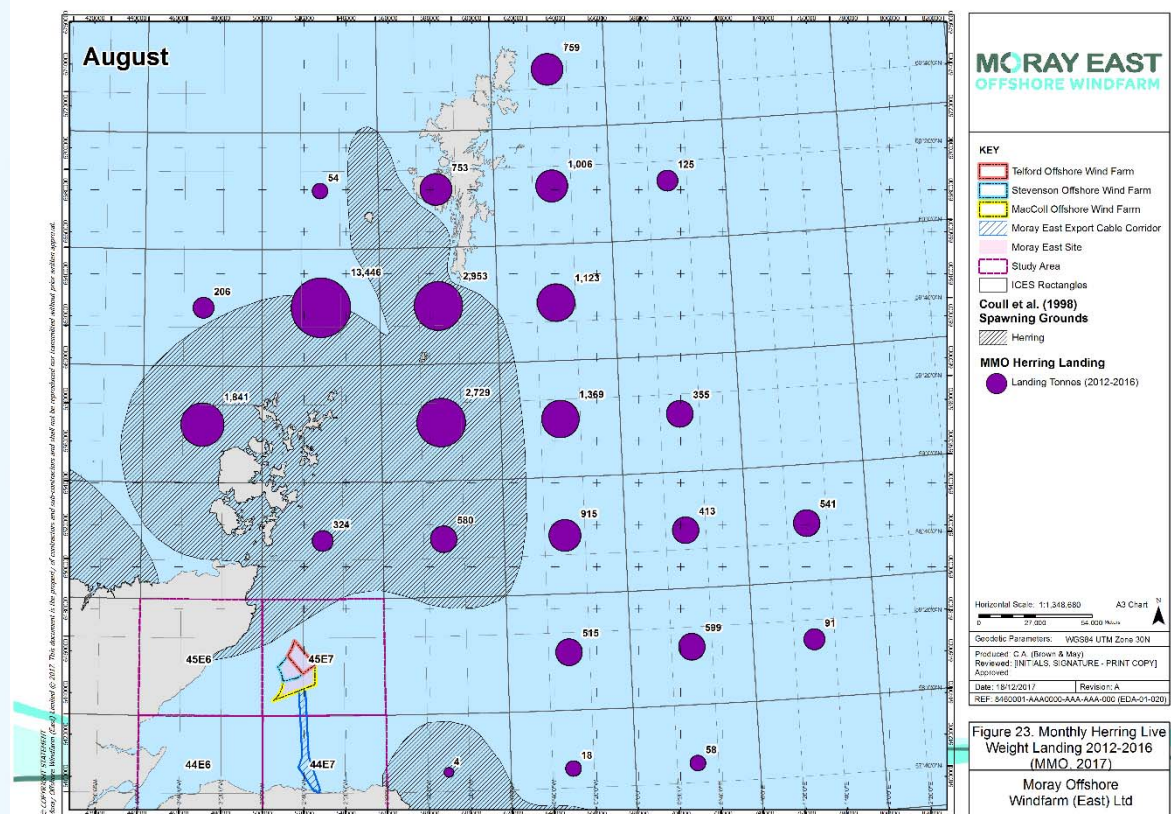


Figure 23. Average MMO landings for herring in tonnes for August (2012-2016) with reference to Coull et al., (1998) spawning area.



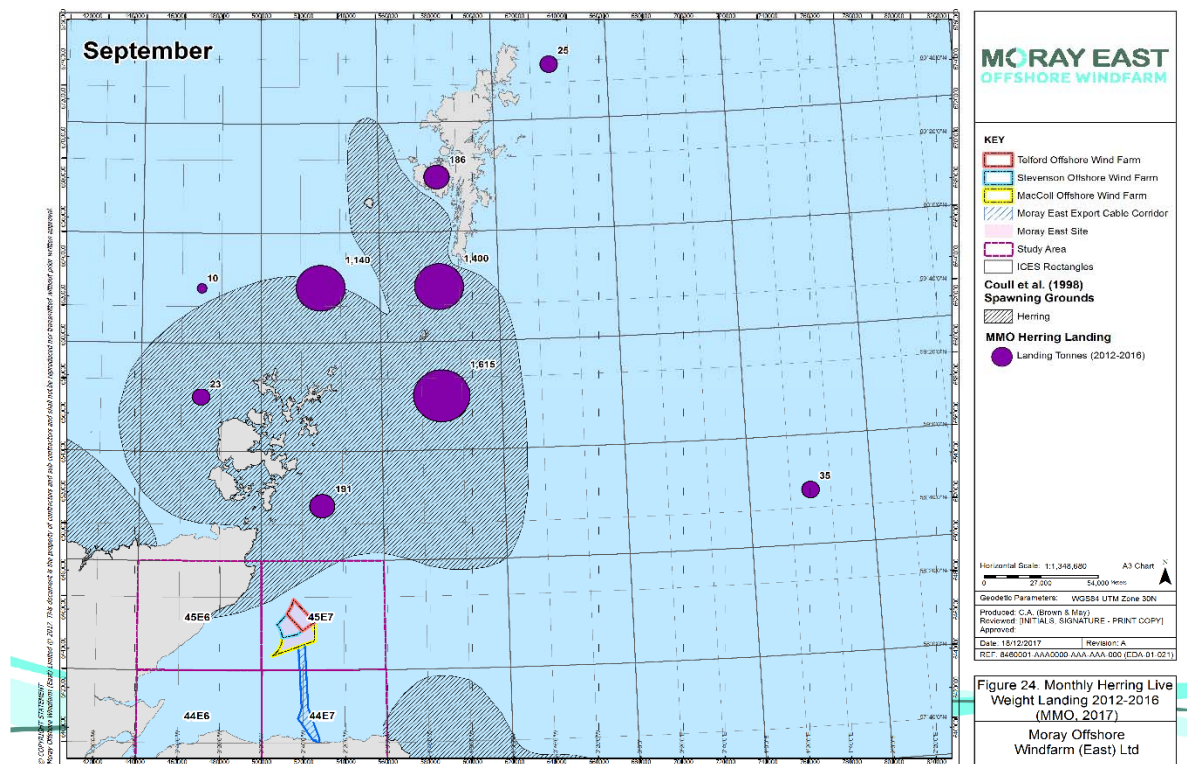
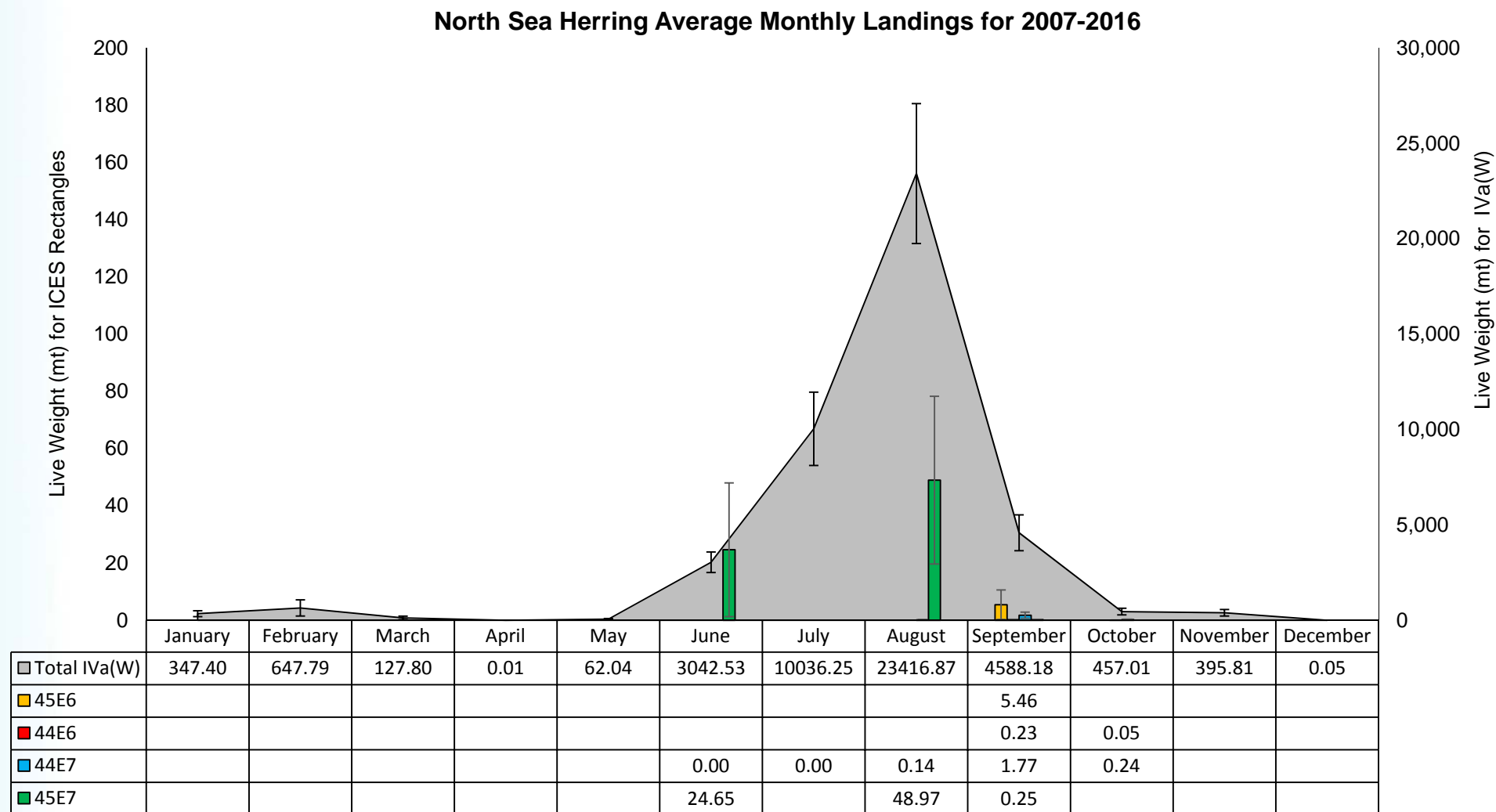


Figure 24. Average MMO landings for herring in tonnes for September (2012-2016) with reference to Coull et al., (1998) spawning area.



**Figure 25. Average monthly landings (tonnes) for herring for ICES rectangles within the study area of the Moray East Offshore Wind Farm (2007-2016) and the total average monthly landings of North Sea Herring for the ICES area IVa(W) (with error bars representing  $\pm$ SE).**

#### 4.4 BOWL Larval Surveys

The BOWL herring survey provides a high-resolution data set for herring larvae collected just north and within the northern region of the Moray East Site, for 8 weeks during August and September for both the 2014 and 2015 surveys.

The BOWL surveys collected no herring larvae during the first two weeks in 2014 (4th August – 17th August) or during the first three weeks in 2015 (3rd August – 23rd August).

Due to the scheduling and frequency of the IHLS sampling program, only one week of a BOWL survey had overlapping dates with IHLS. The herring larvae samples were compared in 2015 for 21st September to 27th September (Figure 26). This comparison indicated that larvae abundances found by the IHLS sampling in the northern Moray Firth area were similar to that found in BOWL survey (Figure 26). Figure 26 also shows higher concentrations of larvae further north of Moray Firth near Orkney Isles.

The length-frequency of the total number of herring larvae recorded during the BOWL 2014 and 2015 surveys is shown in Figure 27. As is apparent, in 2014, most herring larvae were <10mm with over 25% of the larvae caught being between 7.0 - 7.9mm in length. In 2015, the majority of herring larvae were ≥10mm with over 20% of the catch larvae being 10.0 - 10.9mm.

The difference of 3mm in the lengths at which the highest proportion of the catch was recorded suggests that a greater proportion of the catch was 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 spatial distribution of the abundance of herring larvae in 1 mm size classes for every station sampled for each sampling week in which herring larvae were recorded (4 out of 8 weeks) for the 2014 and 2015 surveys are shown in Figure 28, Figure 29, Figure 30 and Figure 31. The pie chart diameters have 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 further north. In sampling weeks 6, 7 and 8, smaller size classes were observed in the 2014 sampling. 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 however remains consistent across the two surveys.

The potential distances that the most prevalent larval size classes of larvae found in the 2014 and 2015 surveys that could be transported, was calculated using the residual velocity data. Using the estimated ages, 7.0 - 7.9mm larvae could be transported a minimum of 6 to 18km, using highly conservative estimates, and maximum distances of 52 to 72km for the time period (6.11-8.47days), whilst the most prevalent size class larvae caught in 2015 (10.0 - 10.9mm) could travel up to as much as 189 km. This further suggests that the majority of the larvae caught during both surveys drifted southwards from the well-established spawning grounds off Orkney and Shetland. This is in line with studies examining patterns of larval drift which 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 (Corten, 2013; Nichols, 1999).

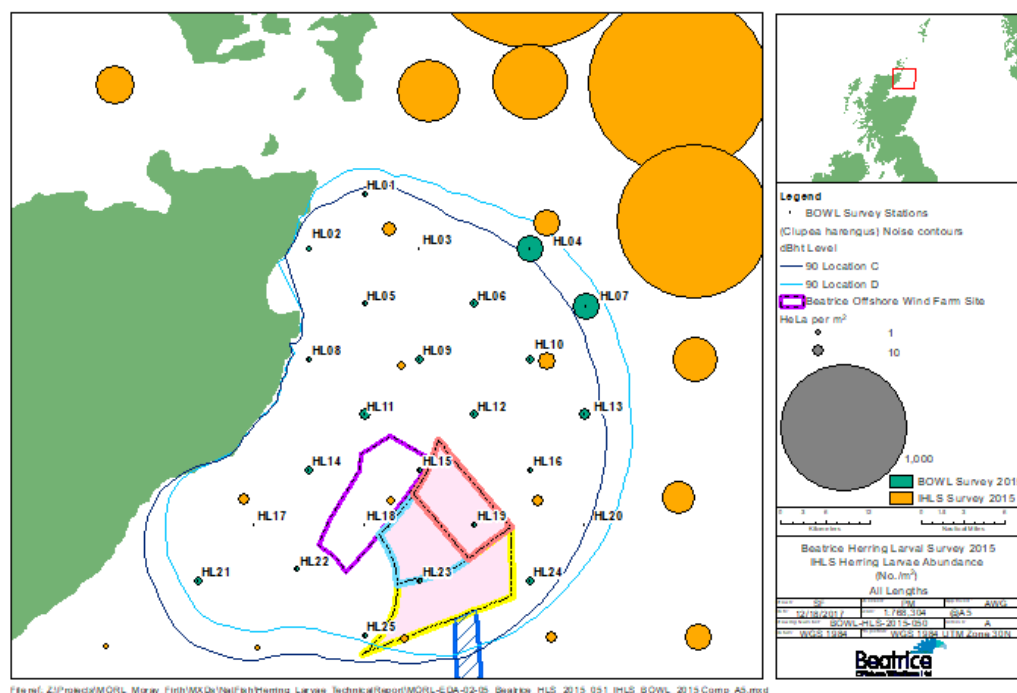


Figure 26. Herring larval abundance (all sizes) recorded during the IHLS 2015 and week 8 of the BOWL 2015 survey (no/m<sup>2</sup>) (BOWL, 2016).

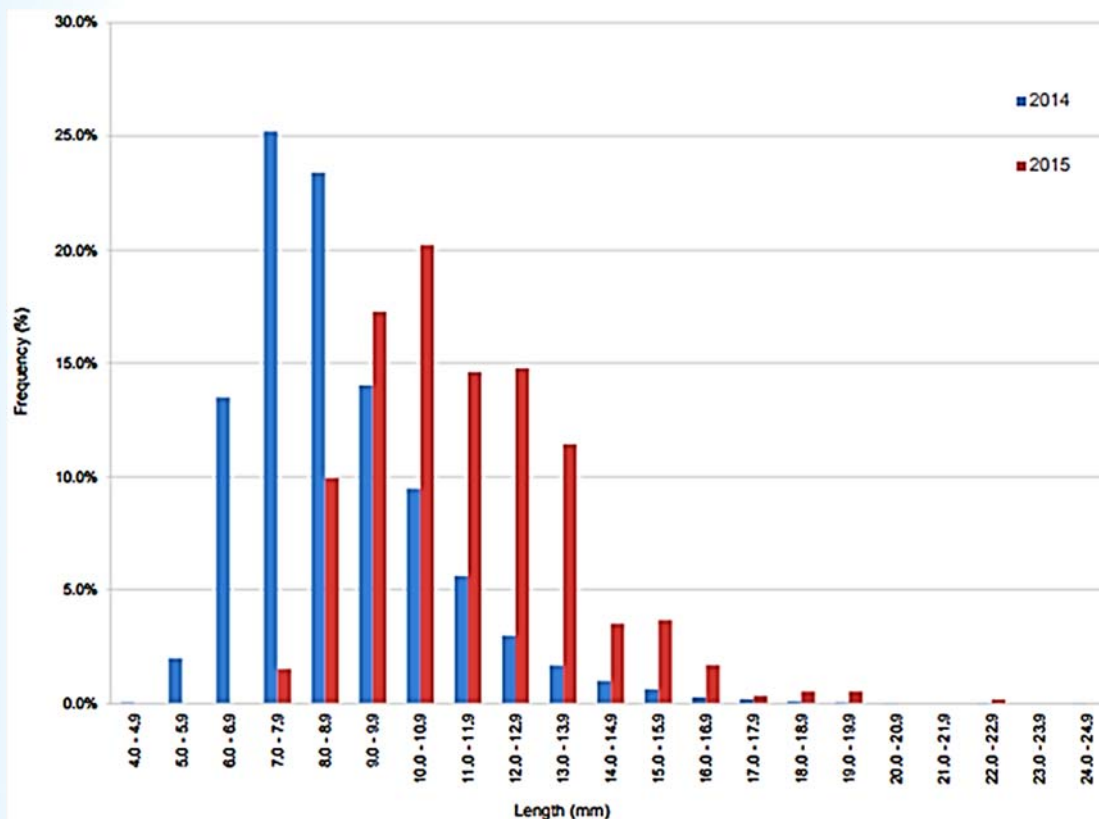


Figure 27. The frequency (%) of herring lengths recorded during the BOWL 2014 and 2015 surveys (BOWL, 2016).

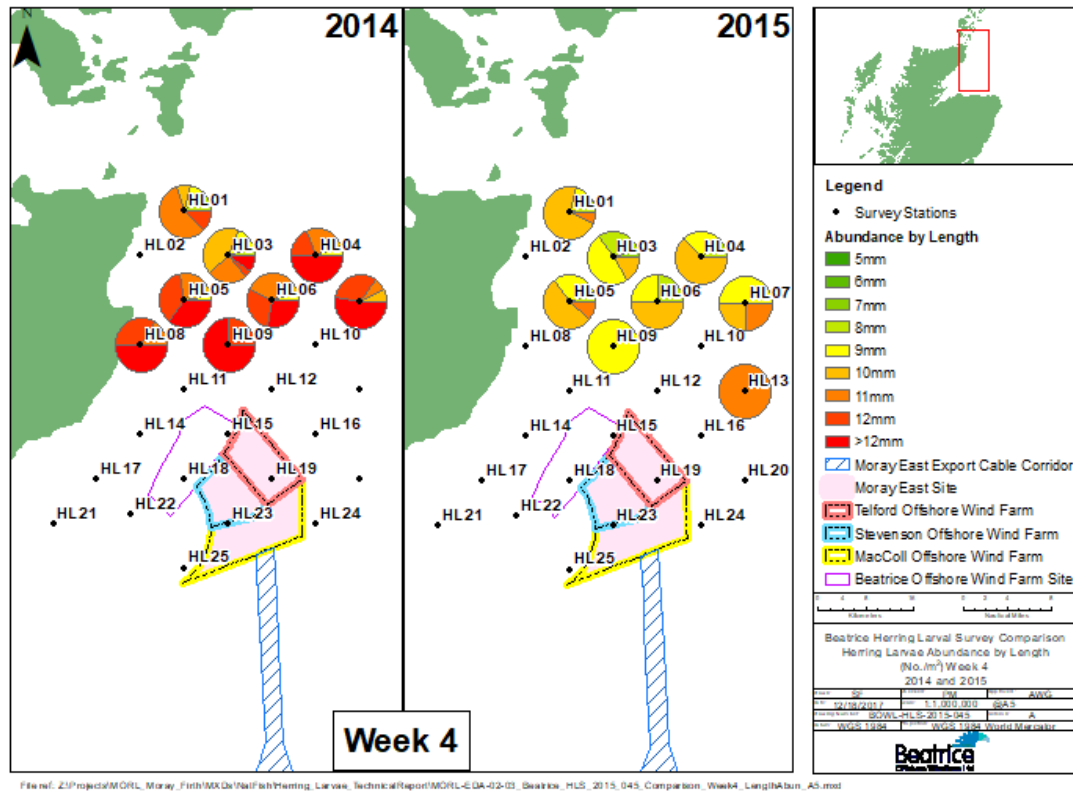


Figure 28. Herring larvae length distribution in week 4 for 2014 and 2015 surveys (24th August to 30th August) (BOWL, 2016).

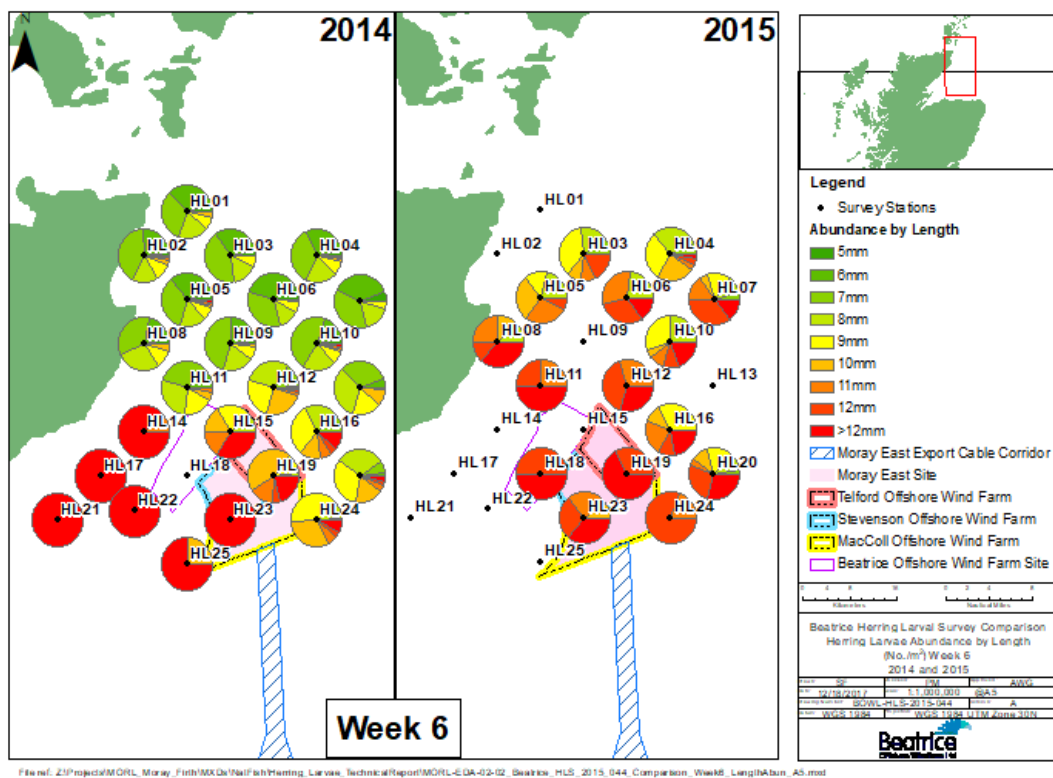


Figure 29. Herring larvae length distribution in week 6 for 2014 and 2015 surveys (31st August to 6th September) (BOWL, 2016).

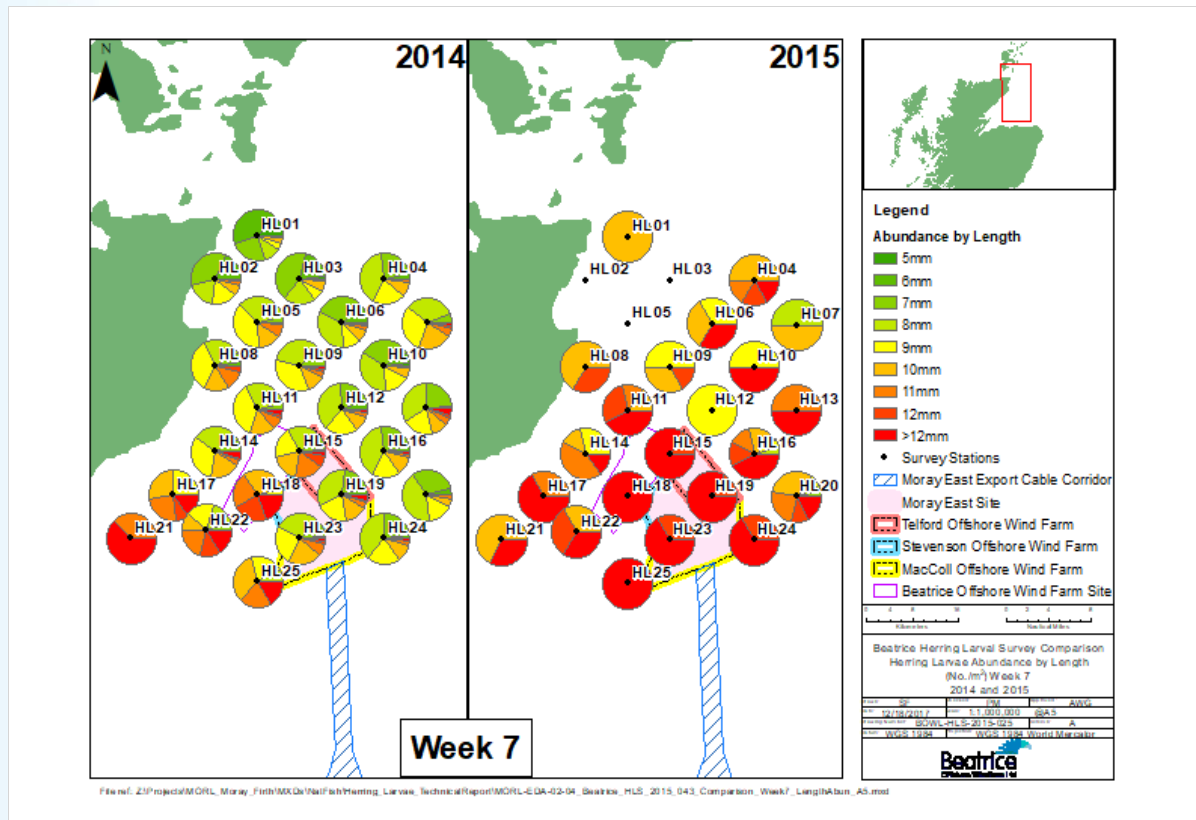


Figure 30. Herring larvae length distribution in week 7 for 2014 and 2015 surveys (7th September to 13th September) (BOWL, 2016).

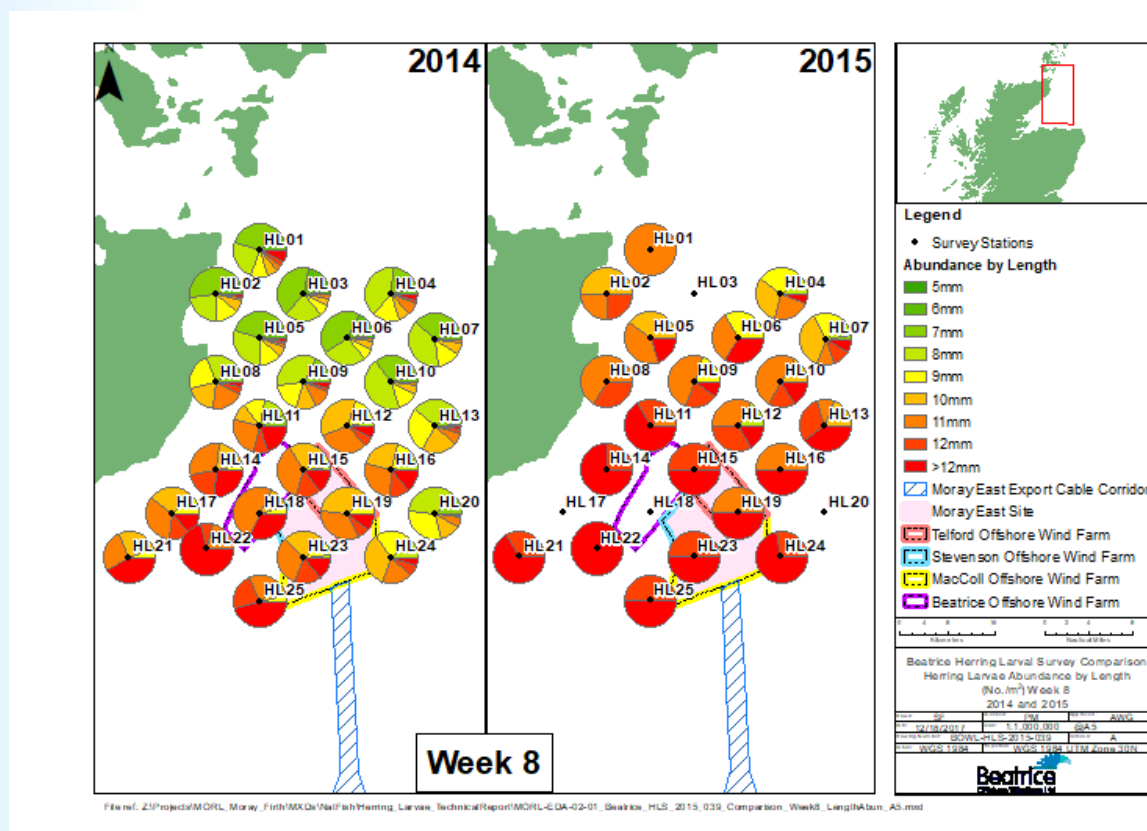


Figure 31. Herring larvae length distribution in week 8 for 2014 and 2015 surveys (14th September to 20th September) (BOWL, 2016).



## 5 Conclusion

The primary data sources used in the assessment of herring spawning were:

- Published Literature;
- International Herring Larvae Survey (IHLS);
- Commercial landing data (MMO); and
- BOWL survey data.

Published BGS literature indicates that some of the substrate within the Moray East Site may be suitable for spawning. However, it is recognised that substrate alone does not determine the location of spawning activity. Coull *et al.*, (1998) suggests that spawning does not occur over large areas of the Moray Firth where the substrate may be suitable.

The IHLS surveys (2000-2015) found very low concentrations of herring larvae in areas of the Moray Firth in which the project is located. Significantly higher levels of early stage larvae and eggs is in line with literature (Coull *et al.*, 1998; Corten, 2013; Schmidt *et al.*, 2008; Rohlf and Groger, 2009) who consider that the main spawning area of the Orkney/Shetland stock is to the north and east of the Orkney Isles. The presence of late-stage larvae found in the Moray Firth, suggests a south-eastward transportation of larvae from the Orkney spawning site, rather than actual spawning in the Moray Firth.

The commercial landing data (MMO, 2016) shows that fewer adults are landed within the Moray East Site and Moray Firth compared to waters around the Orkney and Shetland Isles. Herring landings in the north-east of Scotland (IVa(W)) were greatest between June and October, peaking in August around the Orkney Isles. This supports the assumption that spawning adult herring congregate around the north of Orkney in August, prior to spawning activities commencing in early September.

The BOWL survey's (2014, 2015) high-resolution data showed that the larvae in the immediate area of Moray East Site are not newly hatched as larvae weren't recorded during the first few weeks of sampling and older/larger larvae were more prevalent in the southern sampling sites in later weeks. Again, this supports the view of larvae drift south into the Moray East Sites from the main spawning grounds in the north.

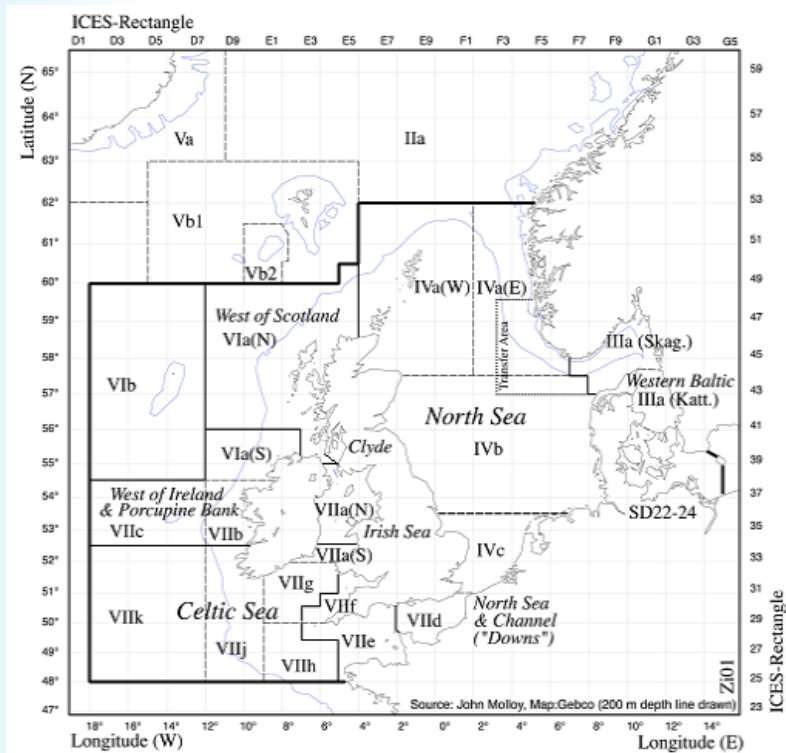
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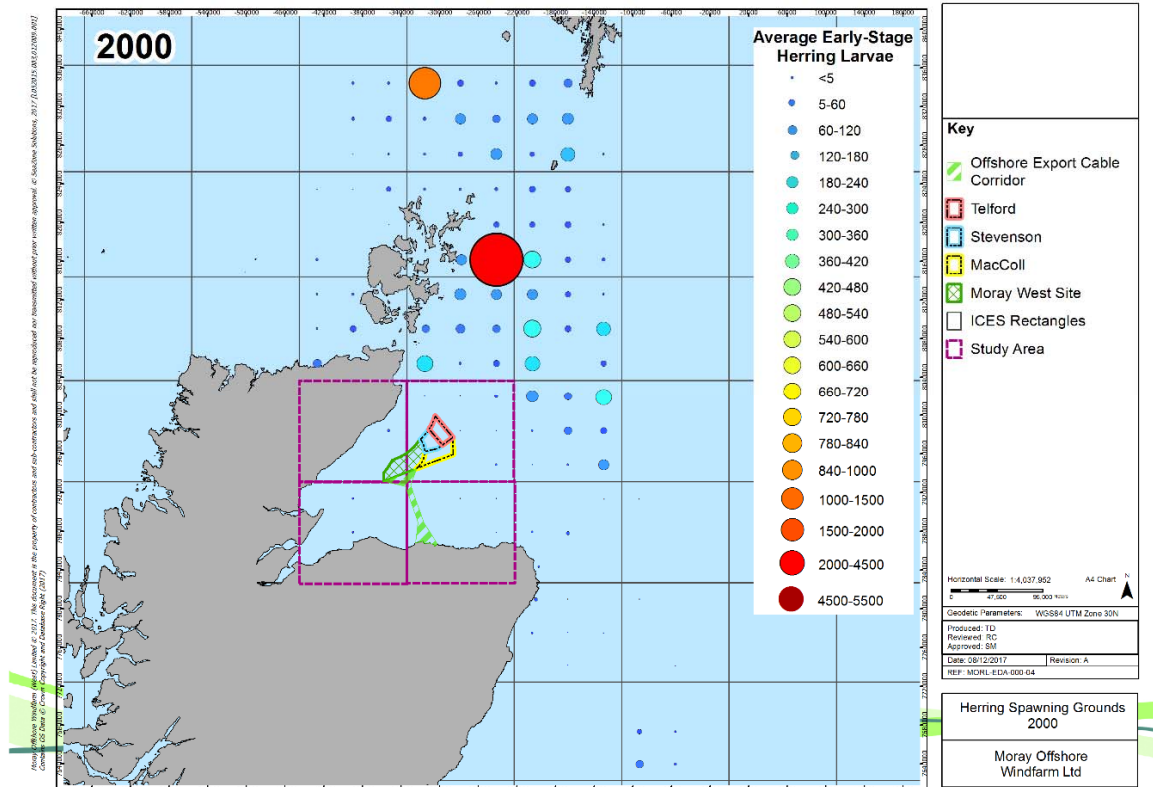


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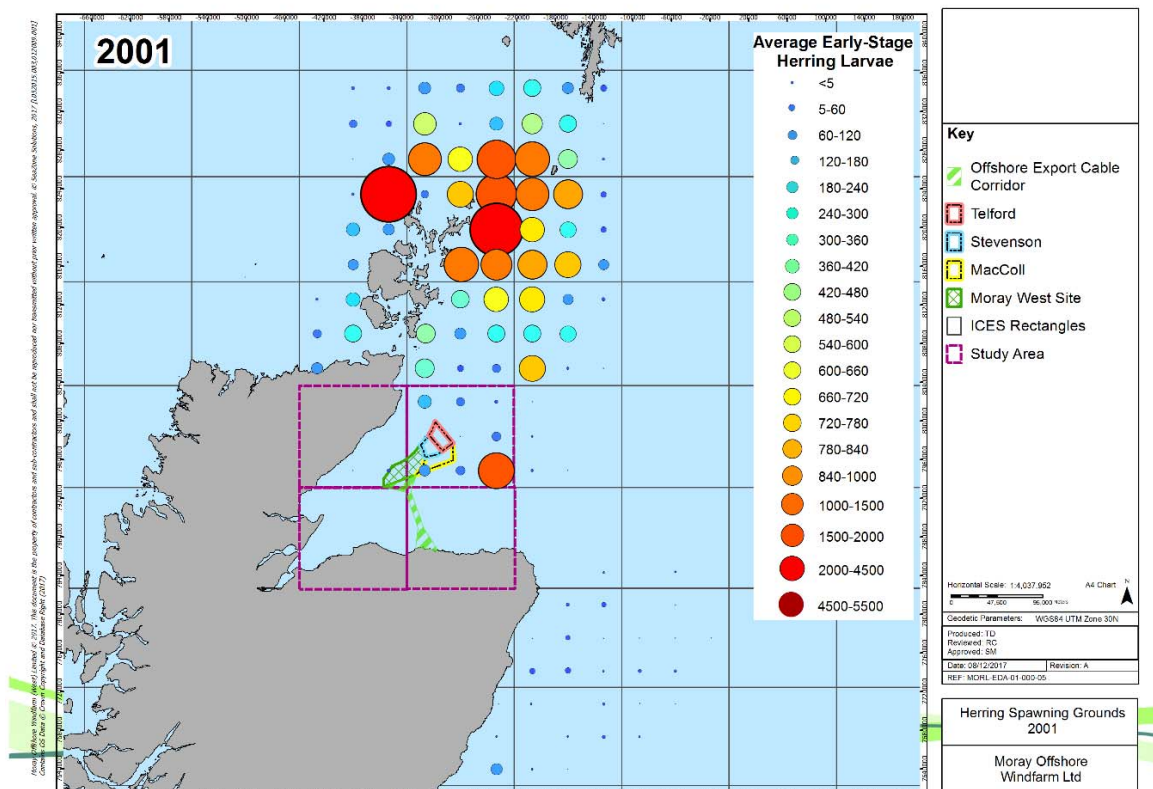
## 7 Appendices



**Appendix 1.** ICES areas as used for the assessment of herring stock south of 62N. Area names in *italics* indicates the area separation applied to the commercial catch and sampling data kept in long term storage. "Transfer area" refers to the transfer of western Baltic spring spawners caught in the North Sea to the Baltic Assessment (ICES, 2017).

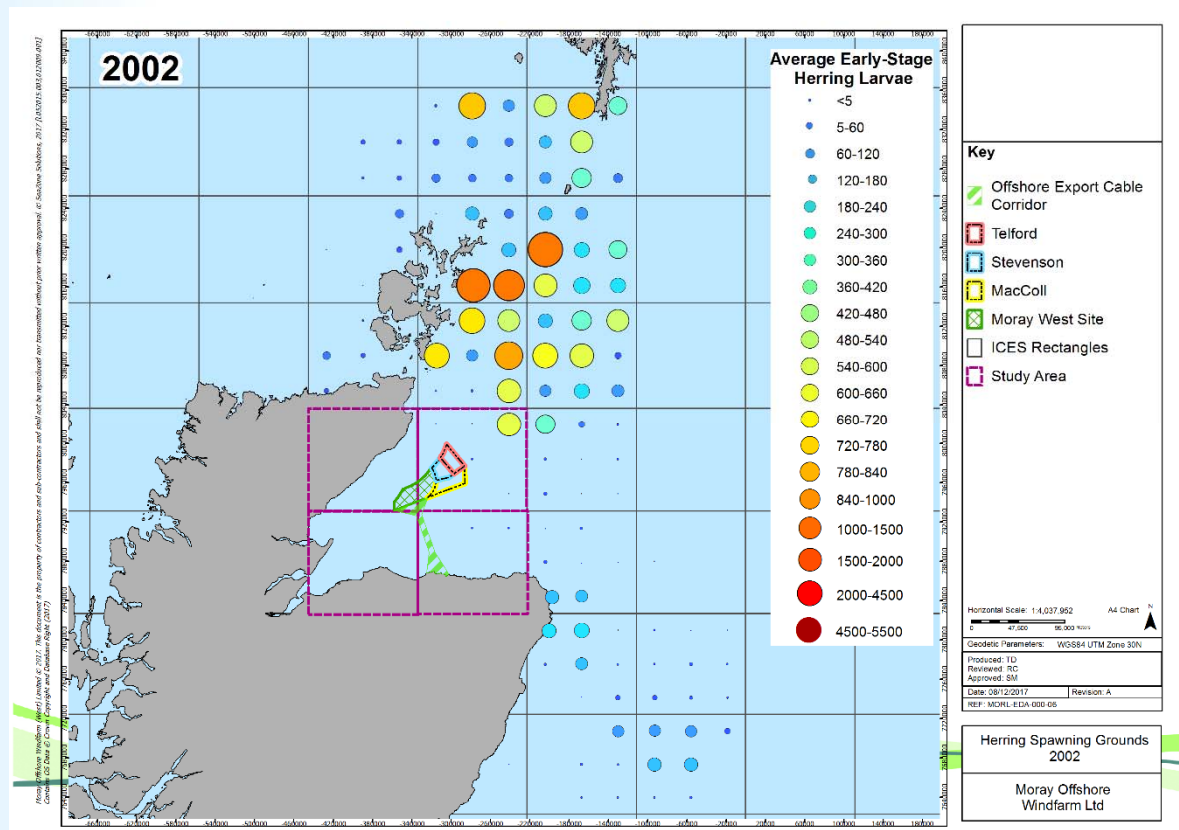


**Appendix 2 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).**

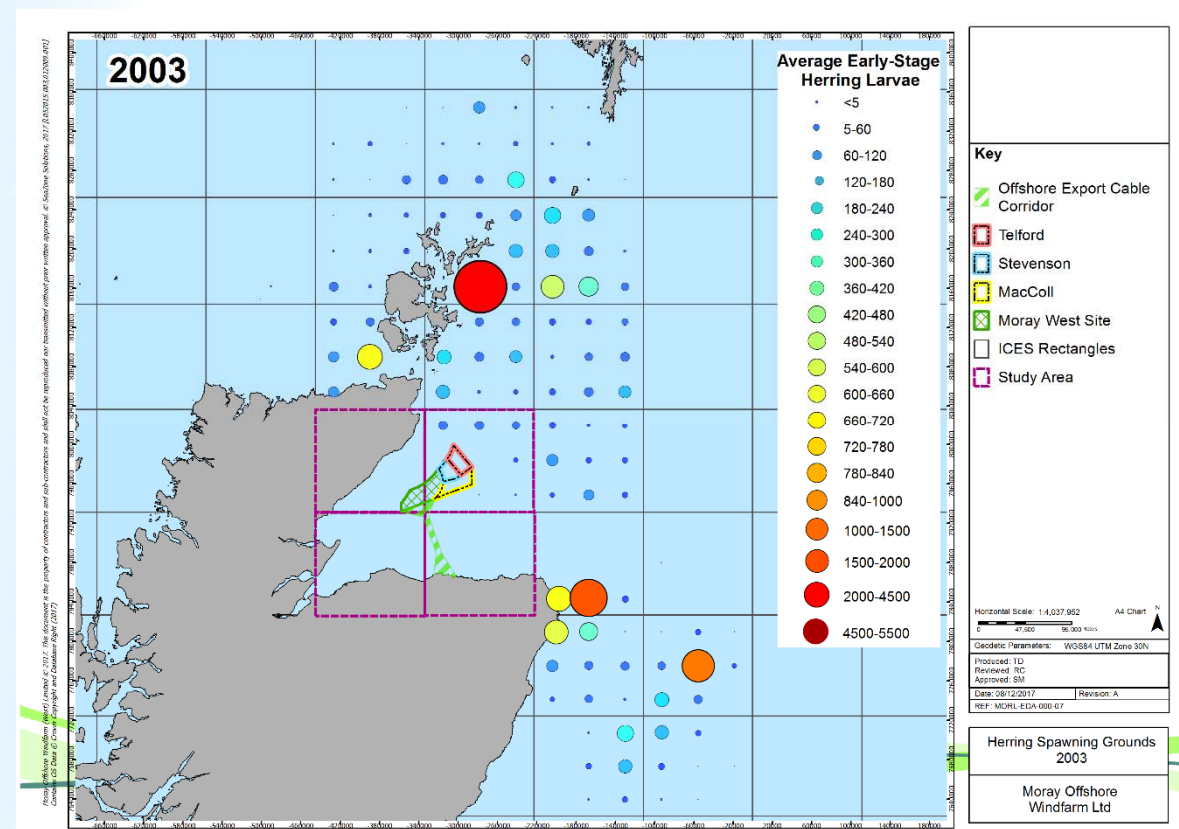


**Appendix 3 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).**

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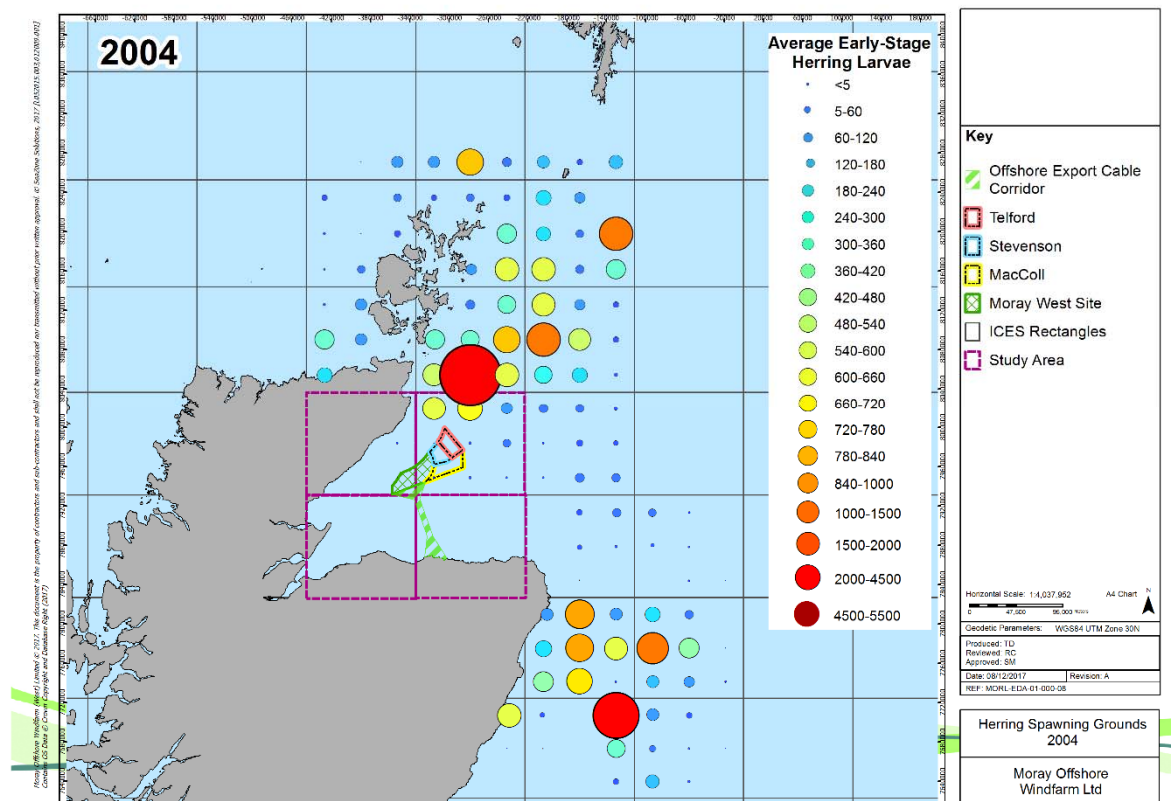


**Appendix 4 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).**

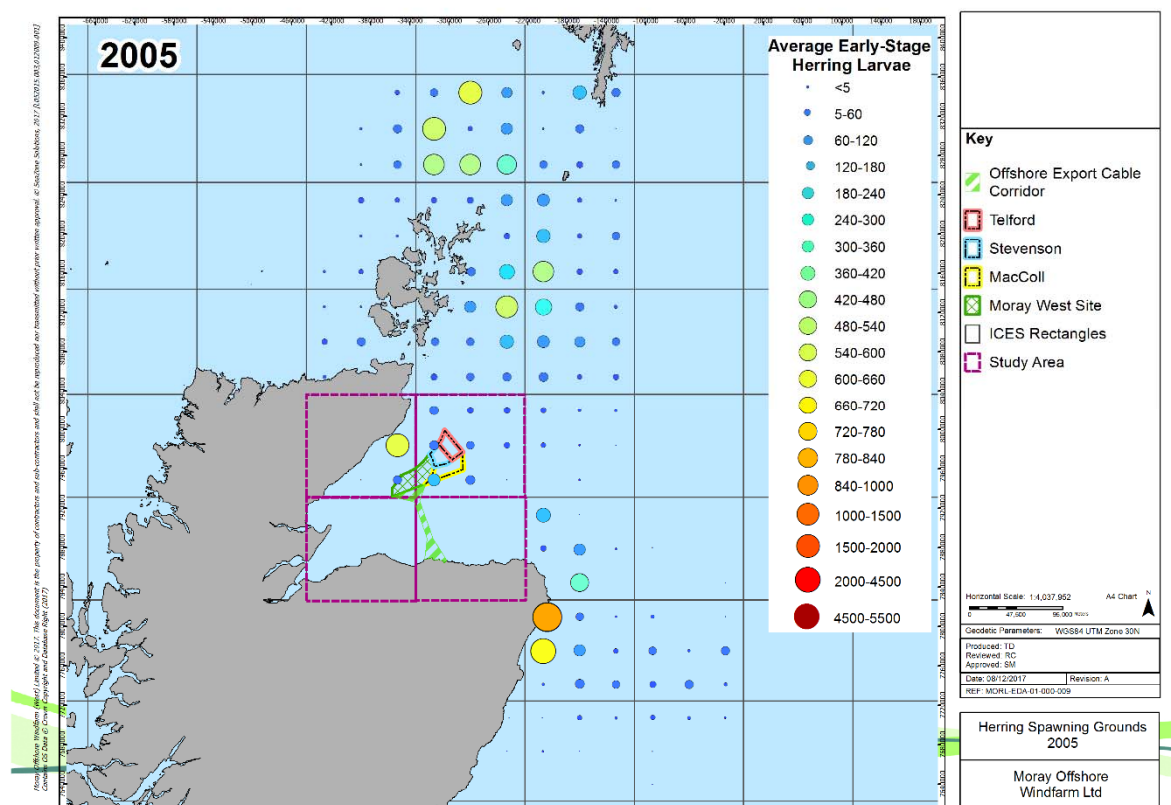


**Appendix 5: Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).**

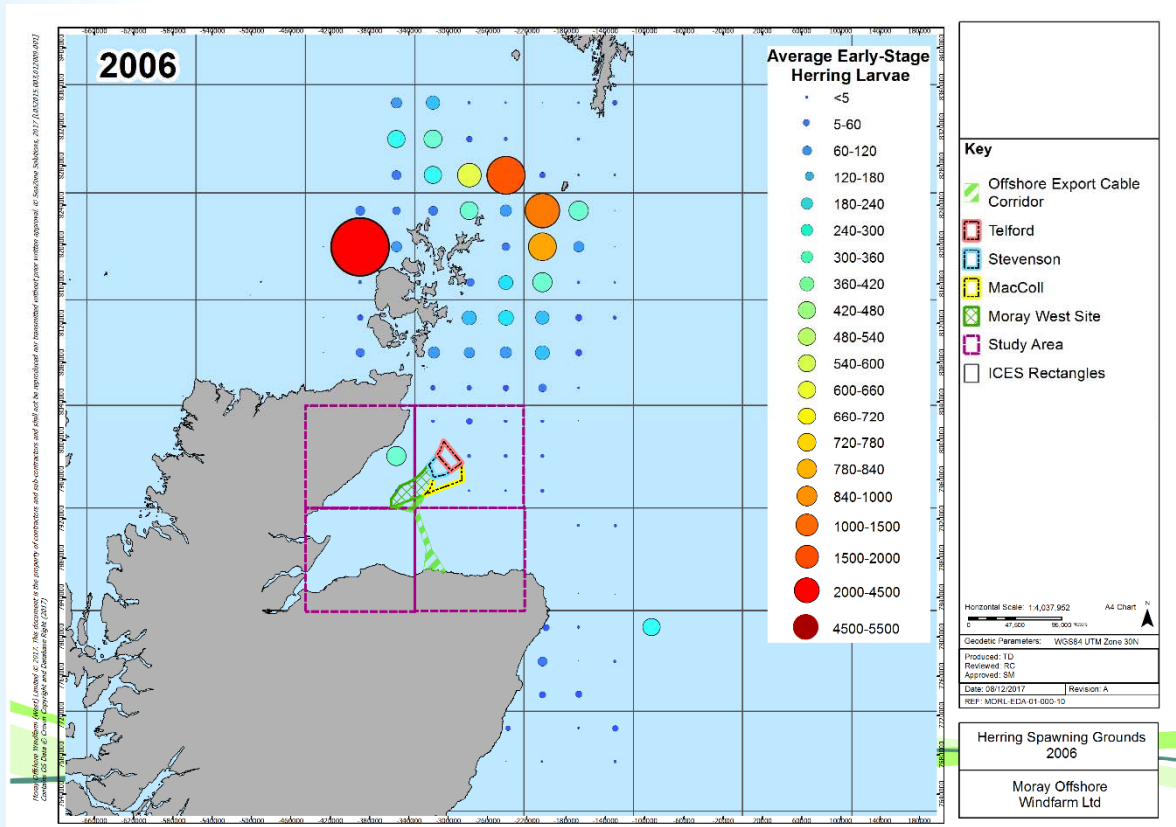




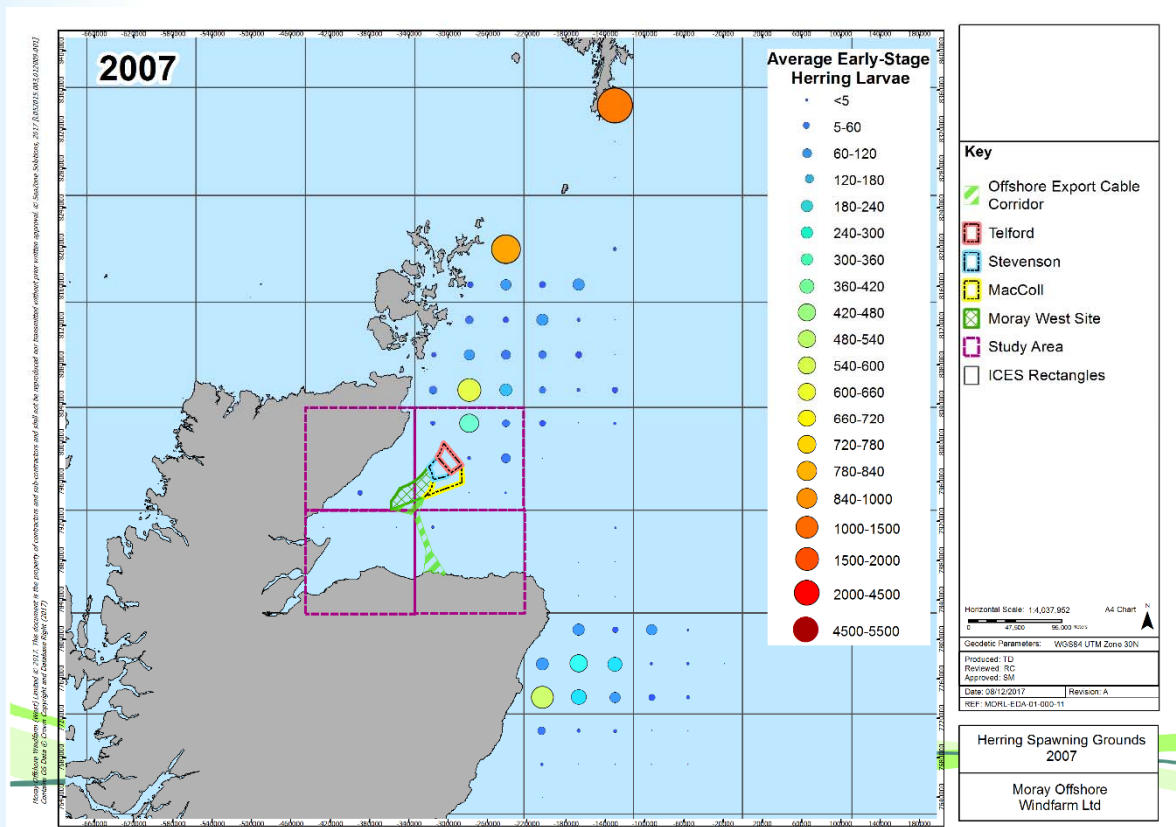
**Appendix 6 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).**



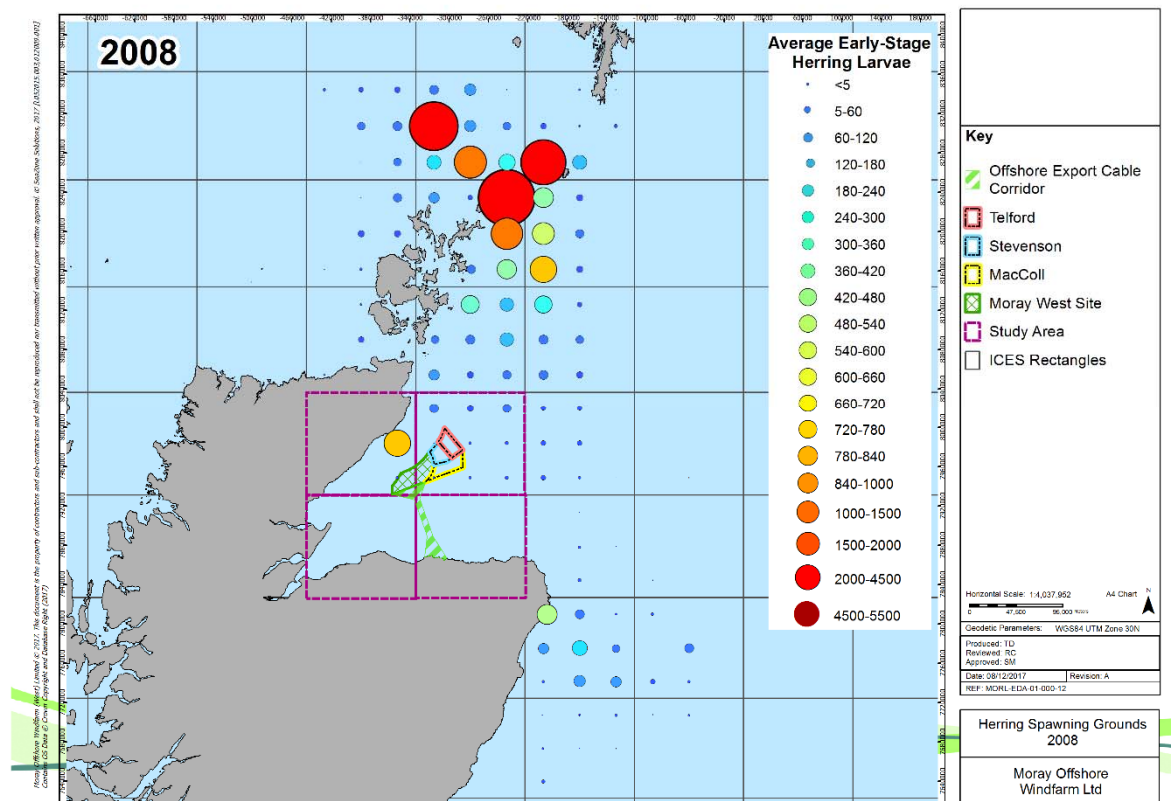
**Appendix 7 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).**



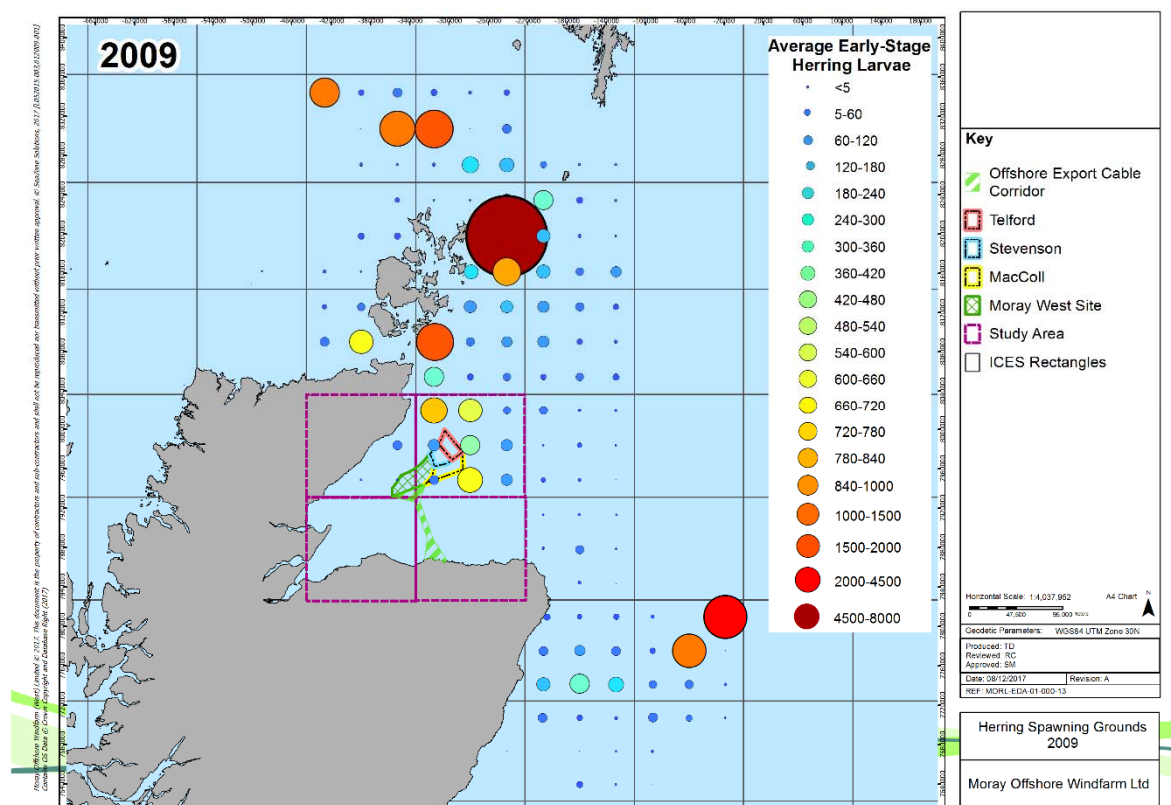
**Appendix 8 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).**



**Appendix 9 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).**



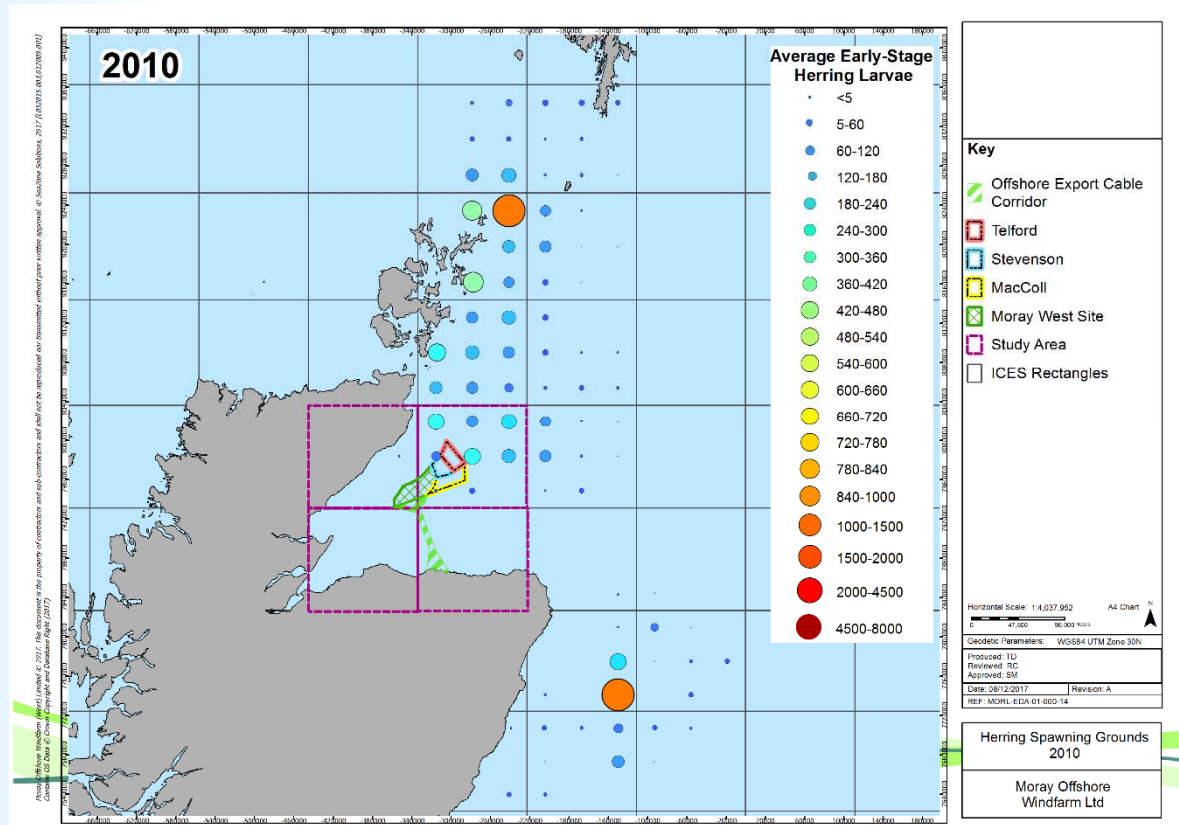
Appendix 10 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).



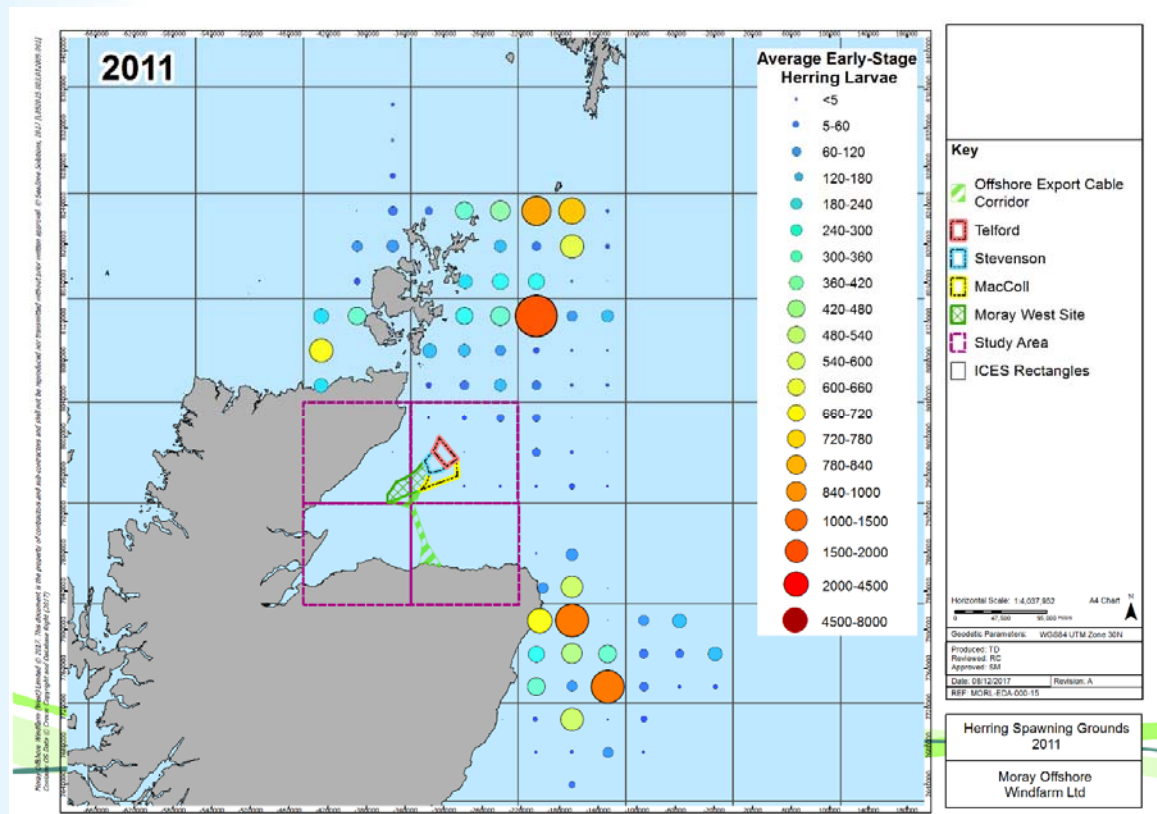
Appendix 11 Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).



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**Appendix 12** Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).



**Appendix 13** Abundance and distribution of North Sea Herring larvae (early-stage) around Moray Firth and the along the north eastern coast of Scotland (IHLS, 2016).





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