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## Abbreviations and Acronyms

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CPUE	Catch per unit effort
DDV	Drop-down video
EIA	Environmental Impact Assessment
EIA Report	Environmental Impact Assessment Report
EUNIS	The European Nature Information System
HAWG	Herring Assessment Working Group
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
ICOL	Inch Cape Offshore Limited
IHLS	International Herring Larvae Survey
inds./m <sup>2</sup>	Individuals per metre squared
MMO	Marine Management Organisation
Nm	Nautical mile
STW	Scottish Territorial Waters

## **9A Herring Spawning Study**

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### **9A.1 Introduction**

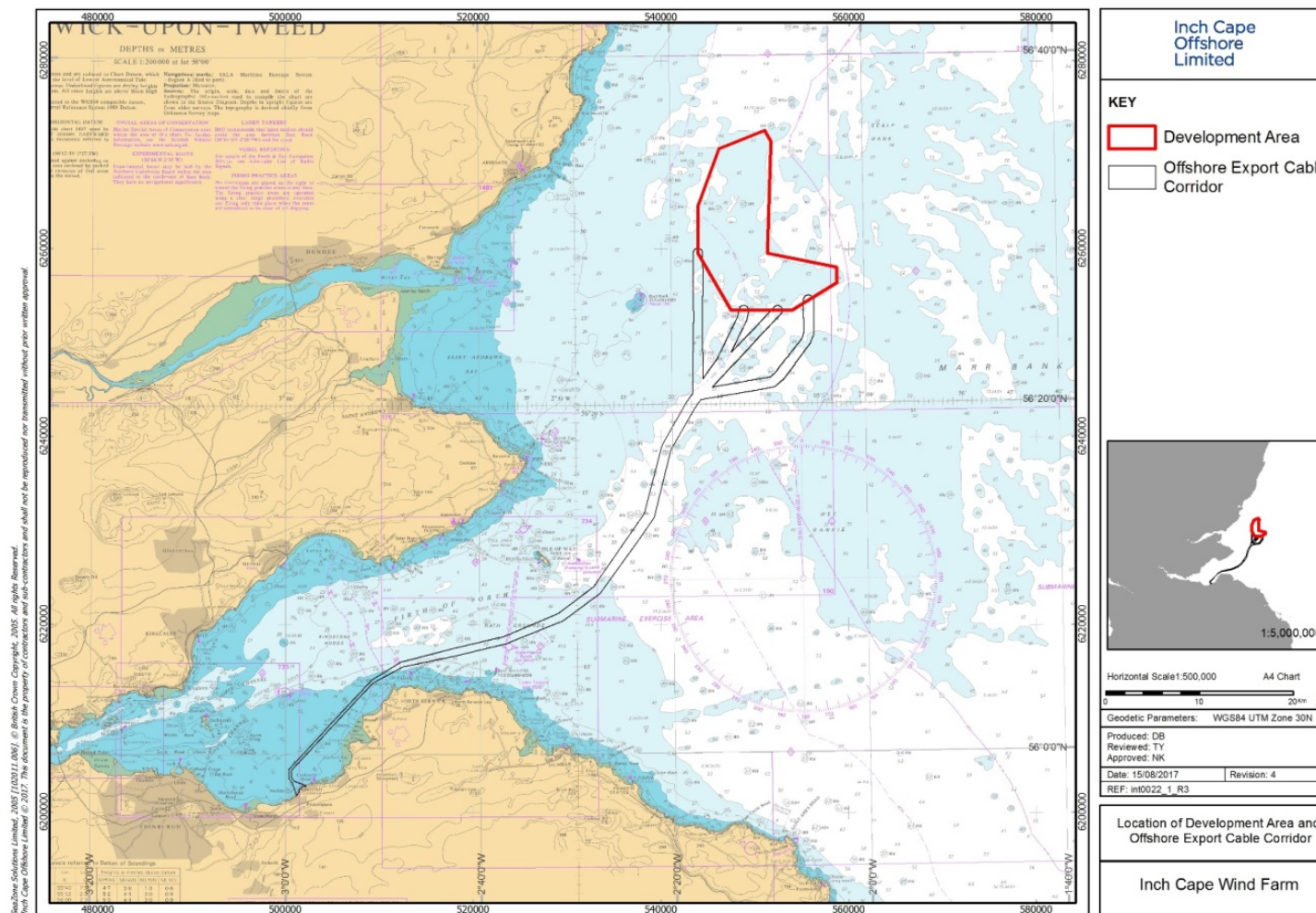
- 1 Inch Cape Offshore Limited (ICOL) are developers of the Inch Cape Wind Farm and associated Offshore Transmission Works (OfTW) in the outer Firth of Tay, Scotland. The Wind Farm is situated approximately 15 km to the east of the Angus coastline in Scottish territorial waters (STW). Export Cables are proposed to run from the southern end of the wind farm to an onshore site along the southern Firth of Forth coastline within the Offshore Export Cable Corridor (Figure 9A.1).
- 2 Atlantic herring (*Clupea harengus*) (from herein referred to as herring) are a demersal spawning species that lay eggs on clean gravel habitats where there are fast bottom currents. Herring are also known to have anatomical adaptations which increase the hearing ability of the species. Due to these specific life history traits, herring are considered to be at greater risk from subsea noise impacts from offshore developments than most other fish species.
- 3 This report reviews the most up to date information from the International Council for the Exploration of the Seas (ICES) International Herring Larvae Surveys (IHLS), the International Bottom Trawl Surveys (IBTS), and ICES commercial fishing data, along with information on spawning grounds, and site specific benthic and fish surveys, to present an up to date baseline for herring, relevant to the Inch Cape Wind Farm.
- 4 This report was prepared by The Natural Power Consultants Ltd on behalf of ICOL.

#### **9A.1.1 Objectives of this Report**

- 5 The report aims to address the following objectives:
  - Determine the level of spawning activity in and around the Inch Cape Development Area; and
  - Identify the likely presence of adult herring in and around the Development Area.

The outcome of the report has then been used in *Chapter 9: Natural Fish and Shellfish* of the Environmental Impact Assessment (EIA Report) to assess the potential impacts from the construction of Inch Cape Wind Farm on herring.

Figure 9A.1: The Inch Cape Wind Farm



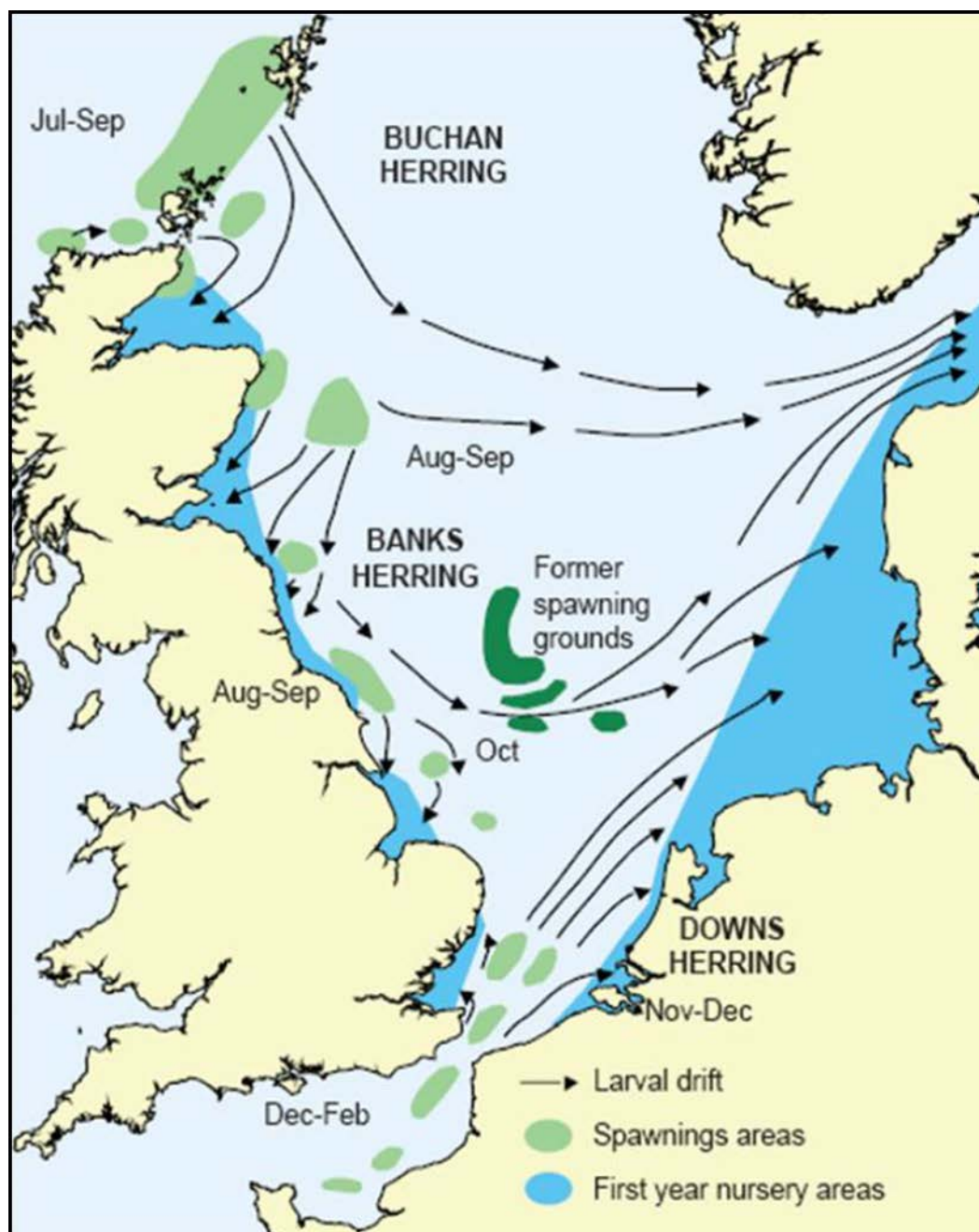
## **9A.2 Introduction to North Sea Herring**

### **9A.2.1 North Sea Herring Ecology**

- 6 Herring are a pelagic fish that utilise specific benthic habitats during spawning. As such herring spawning habitats are spatially restricted and can be vulnerable to activities impacting on the seabed. During spawning periods, as herring migrate to spawning grounds, separate groups of herring become reproductively isolated. This results in a number of sub-populations or 'races' exhibiting variations in spawning period and location (ICES, 2006). The majority of herring in the North Sea are spawned from one of three distinct races of autumn spawners that return to the same spawning grounds each year.
- 7 The three main races of adult herring that leave feeding grounds in autumn for North Sea spawning grounds are:
- Buchan/Shetland herring spawn off the north-east coasts of Scotland and Shetland commencing in August until September;
  - Banks or Dogger herring spawn in the central North Sea off the north-east England coast from August to October; and
  - Southern Bight/Downs herring spawn in the Southern Bight of the North Sea and the English Channel from November to January.
- 8 Of the three races, only the Buchan/Shetland herring are of relevance to the Inch Cape Wind Farm, and as such this report focusses on this autumn spawning group only.
- 9 At the Shetland and Buchan spawning grounds in the northern North Sea, herring spawning peaks in September. Hatched larvae from the Shetland spawning ground are transported to nursery grounds within the Moray Firth or on currents across the North Sea along the Danish coastline in the western Baltic (Figure 9A.2). Whereas herring hatching in coastal waters east of the Aberdeenshire coast are transported southwards to reside in nursery areas along the Scottish and English east coast (Figure 9A.2).



Figure 9A.2: The spawning areas and periods of the three autumn spawning North Sea sub-populations showing larval drift to known nursery grounds (taken from Nichols, 1999)



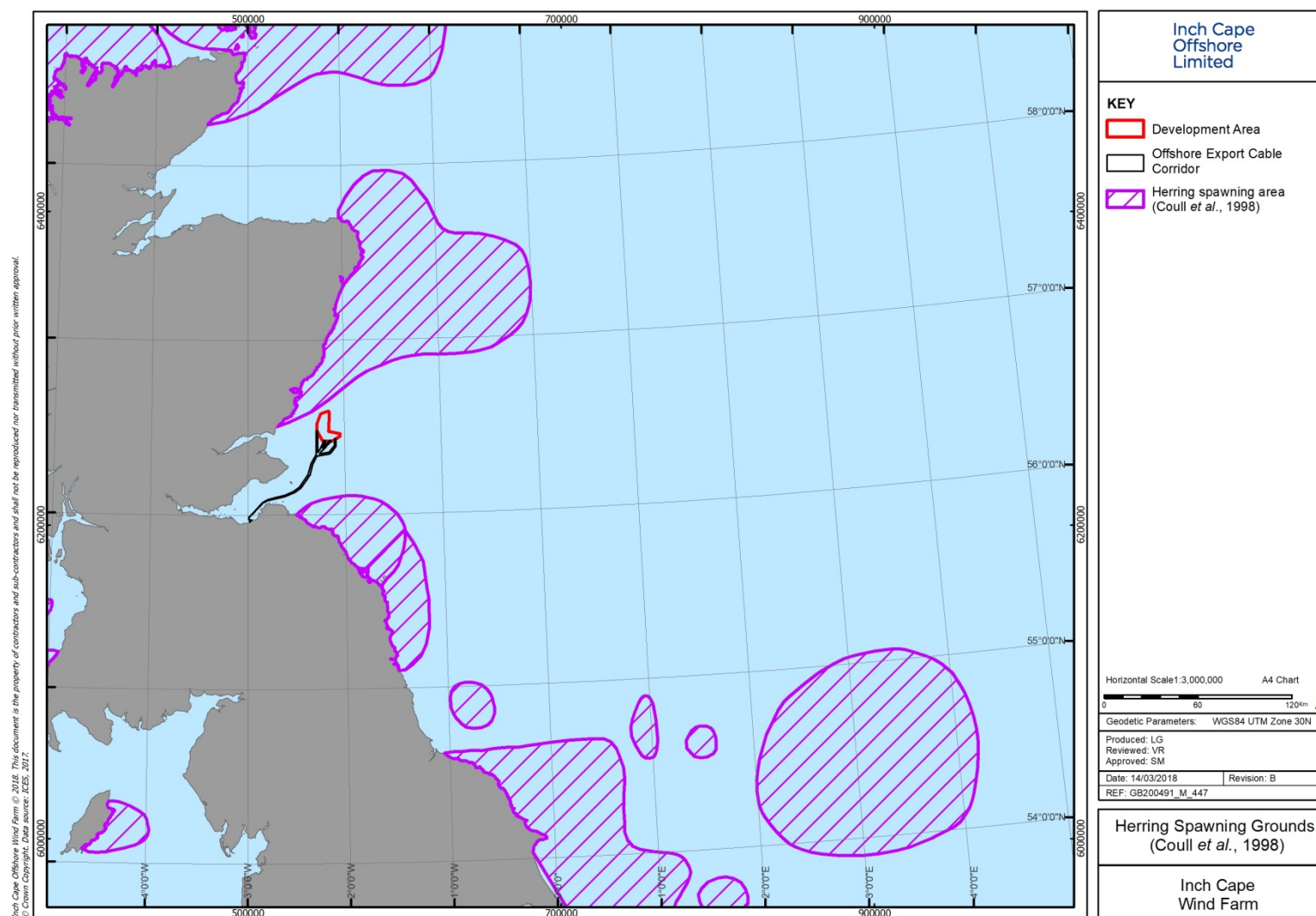
- 10 During Spawning, shoals of herring congregate in shallow waters ranging from 15 – 40 m and deposit egg masses on coarse gravels, sands, shells, maerl and small stones where there is fast flowing highly oxygenated water (Marvelias, 2001; Reid *et al.*, 1999; Marvelias, 1997). Due to the specific habitat requirements for herring spawning, suitable substrate types are limited in the North Sea and thus, spawning grounds are reasonably well defined.
- 11 The intensity of spawning at known spawning grounds can be highly variable between years and in some cases, such as the Dogger Bank, herring spawning has disappeared completely in recent years (Ellis *et al.*, 2012; Corten, 1988). This ability to shift between spawning



grounds over generations may act as a buffer against short term and localised environmental variability (Dickey-Collas *et al.*, 2010).

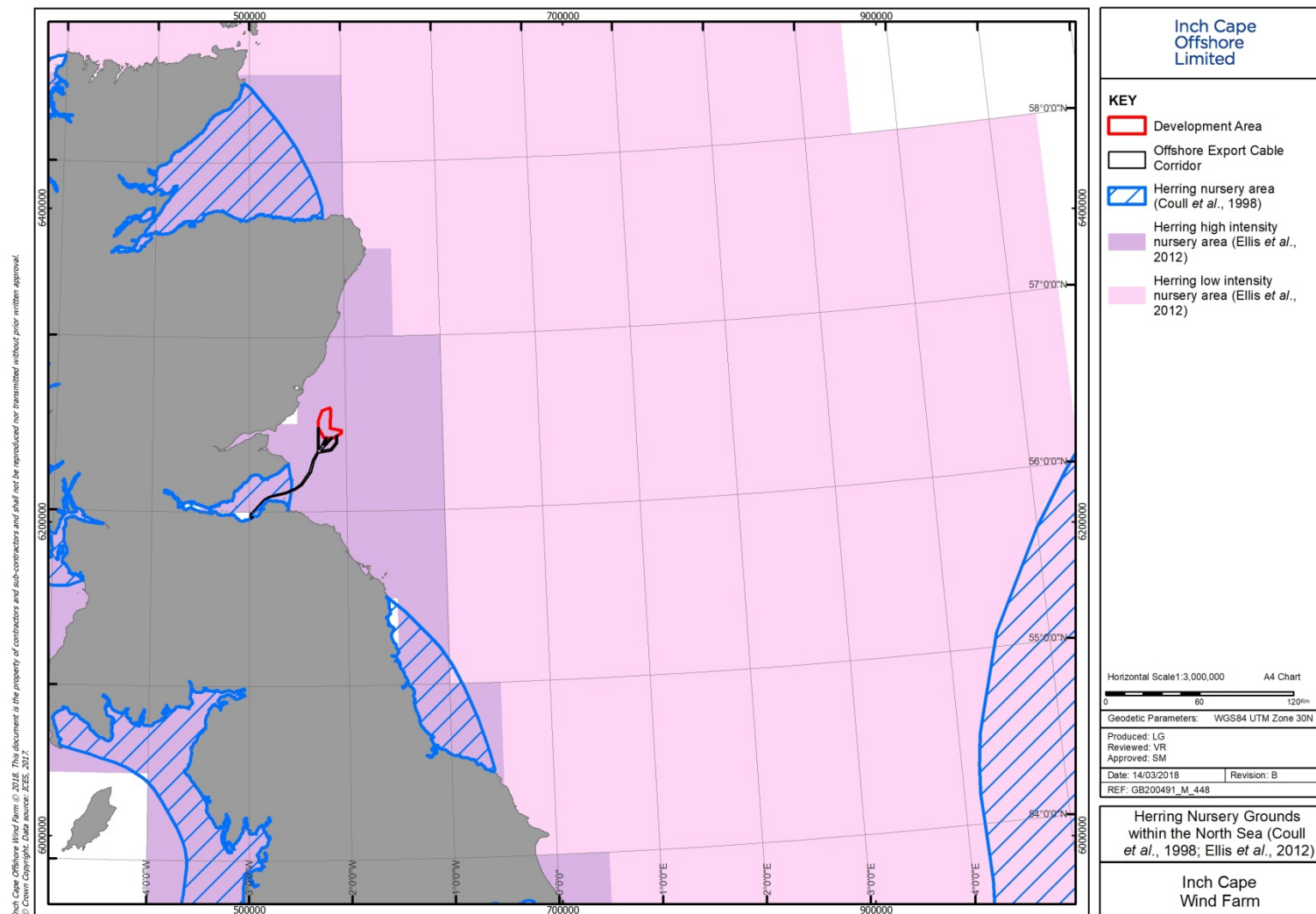
- 12 In the area of interest within the north North Sea, spawning areas are located along the Aberdeenshire, Berwickshire, and Northumberland coasts (Figure 9A.3).

Figure 9A.3: Herring spawning grounds adjacent to the Inch Cape Wind Farm Development Area (Coull *et al.*, 1998)



- 13 Once laid, the eggs take between one to three weeks to hatch at which point herring larvae rise to surface waters and are transported passively on currents (Dragesund *et al.*, 1980). Larval drift is highly variable and it has been reported that in some years, much of the hatched larvae may never make it to nursery grounds due to hydrographical and environmental parameters (Corten, 1988).
- 14 Juvenile herring spend the first two years in coastal nursery grounds in water depths of less than 100 m along the east coast of the UK, in the south-east North Sea and in the Kattegat. Sexually mature adult herring usually comprising of 3+ group fish (i.e. fish that were spawned over three years ago), are distributed predominately in deeper offshore waters in a band along the western North Sea from the southern Bight to the northern North Sea where they feed (MacKenzie, 1985). Because of the mixing of the sub-populations during this period, landings cannot be attributed to specific races and so the North Sea herring population is managed as a single stock (ICES, 2006). Migration patterns developed as juveniles remain throughout an individual's lifecycle (Corten, 2001).
- 15 Ellis *et al.* (2012) reported that herring nursery grounds are widespread along the Scottish and Northumberland coastlines (Figure 9A.4). 0 to 2 group fish (i.e. post-larvae juveniles up to sub-adults that are yet to reach sexual maturity) feed here until migrating to feeding grounds further offshore where they remain until reaching sexual maturity (ICES, 2006).
- 16 Coull *et al.* (1998) identified areas of potential nursery areas for a range of species in the North Sea based on available larvae, egg and benthic habitat survey data. Ellis *et al.* (2012) reviewed this nursery ground data of a number of fin fish species in the North Sea, including herring, and provided updated maps including areas of low and high intensity nursery grounds.
- 17 The revised herring nursery grounds produced by Ellis *et al.* (2012) are far more ubiquitous than those originally proposed by Coull *et al.* (1998). In the area of interest, high intensity nursery grounds are prevalent along the entire east coast of Scotland and the north-east coast of England (Figure 9A.4).

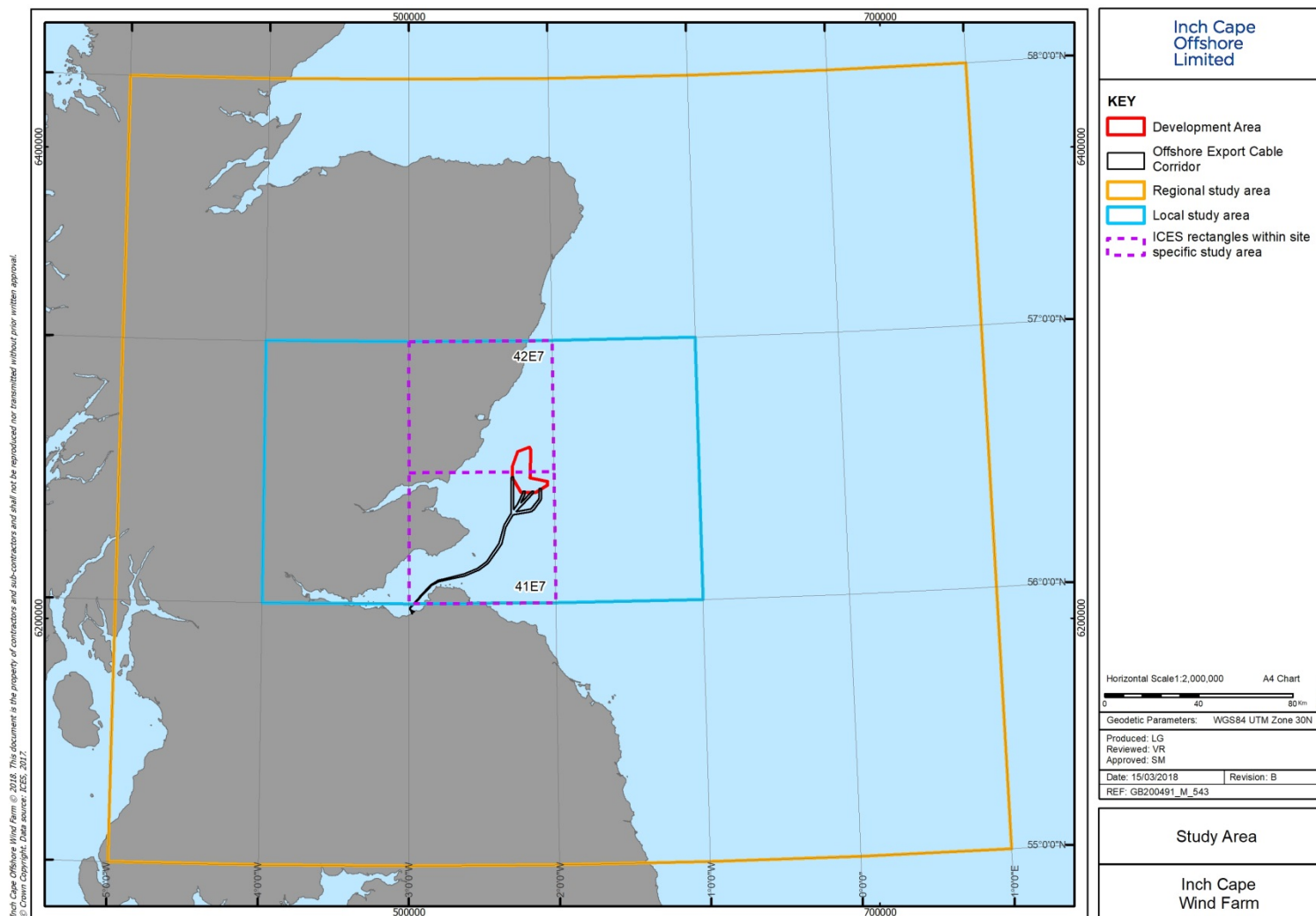
Figure 9A.4: Herring nursery grounds within the North Sea (Coull *et al.*, 1998; Ellis *et al.*, 2012)



### 9A.3 Study Methodology

- 18 In order to meet the aims of this study, data has been reviewed in order to define the following:
- Habitat suitability of the Development Area for herring spawning;
  - Herring larvae distribution in relation to the Development Area; and
  - Adult herring distribution in relation to the Development Area.
- 19 The study area mirrors, as far as data allows, the regional study area described in the EIA Report (Figure 9.1 in *Chapter 9*). This area encompasses ICES Rectangles 39-44 (south to north) E7 to F0 (east to west) (Figure 9A.5). Any variations to the study area due to data availability are highlighted below.

Figure 9A.5: Study area



**9A.3.1 Data Analysis Methods**

20 The following data sources have been reviewed as part of this study, with analysis methods outlined below:

- Site specific benthic and fish characterisation survey reports (AMEC, 2012a, b);
- IHLS herring larvae distribution data (ICES);
- IBTS data (ICES); and
- Commercial herring catch data (ICES; and reported by the ICES Herring Assessment Work Group (HAWG)).

**Site Specific Baseline Survey Data**

- 21 Site specific benthic baseline surveys were undertaken in 2012 encompassing the Development Area, an area extending for one tidal excursion outside of the Development Area, as well as discreet reference stations outside of these areas. At each sampling station a combination of drop-down video (DDV) and benthic grab sampling were undertaken, with the DDV deployed prior to the grab sampler. The sampling strategy represented a random stratified approach with a minimum of three stations within each habitat type, except for discrete features where only a single sample was proposed. This approach was agreed with Marine Scotland and their advisors in 2012 and allows for an accurate and robust ground truthing of the habitat maps produced from the geophysical data (including multibeam bathymetry and sidescan data to characterise the physical structure of the seabed).
- 22 In order to assess fish presence and distribution in the Development Area, four separate trawl surveys of 10 sampling stations were undertaken in 2012 using a local fishing vessel deploying a commercial otter trawl. The survey methodology was agreed with Marine Scotland and their advisors prior to the commencement of the survey. Locations were specified to provide a representative, but not exhaustive, coverage of the different areas and ground conditions, as defined by geophysical survey data and build upon desk-based information. Trawl surveys were conducted quarterly over a 12 month period, in order to try and identify any broad-scale variation in species distribution and abundance in the wind farm area.

**International Herring Larvae Survey Data**

- 23 Since 1967 ICES have coordinated a program of surveys where participating nations conduct larval surveys during herring spawning periods. Surveys are carried out using a Gulf III or Gulf IV high speed plankton sampler to catch herring larvae. The current report considers the most recent 25 years of data from 1991 to 2016 collected as part of the IHLS program. For the purposes of this review, data collected around the central North Sea off the east coast of Scotland (from just north of Fraserburgh), southwards to the Northumberland coastline has been incorporated into this review.
- 24 In order to allow mapping of point source data at an appropriate resolution, the standard 30 x 30 nautical mile (Nm) ICES rectangles are split into sub-squares of 10 x 10 nm. For ease of



reference throughout this report sampling squares have been numbered sequentially from the west to east beginning with the northernmost row (Figure 9A.6). The survey grid captures those IHLS sampling stations within the regional study area, with some slight variation to the southeast where additional data is available in ICES rectangles 39F1 and 39F2.

#### **International Bottom Trawl Survey Data**

- 25 ICES coordinate the International Bottom Trawl Survey (IBTS) Working Group which targets a number of commercial finfish species including herring. The main objective of the IBTS is to provide recruitment and distributional data of target species within the ICES study area. The IBTS surveys began in 1991 with quarterly semi-pelagic bottom trawl surveys conducted across ICES Area IV (the North Sea) until 1996 using a semi-pelagic bottom trawl. From 1997 survey effort was reduced and conducted biannually with only quarter 1 and quarter 3 surveys being undertaken. The current review incorporates the most recent data collected during quarter 3 between 2012 and 2016 within the regional study area.

#### **Commercial Herring Catch Data**

- 26 Commercial landings data is collected and freely distributed by the Marine Management Organisation (MMO) (and Marine Scotland) for each species per ICES rectangle. This data was downloaded and the results from quarter 3 each year between 2012 and 2016 analysed to provide a measure of adult herring activity in the vicinity of the Development Area.

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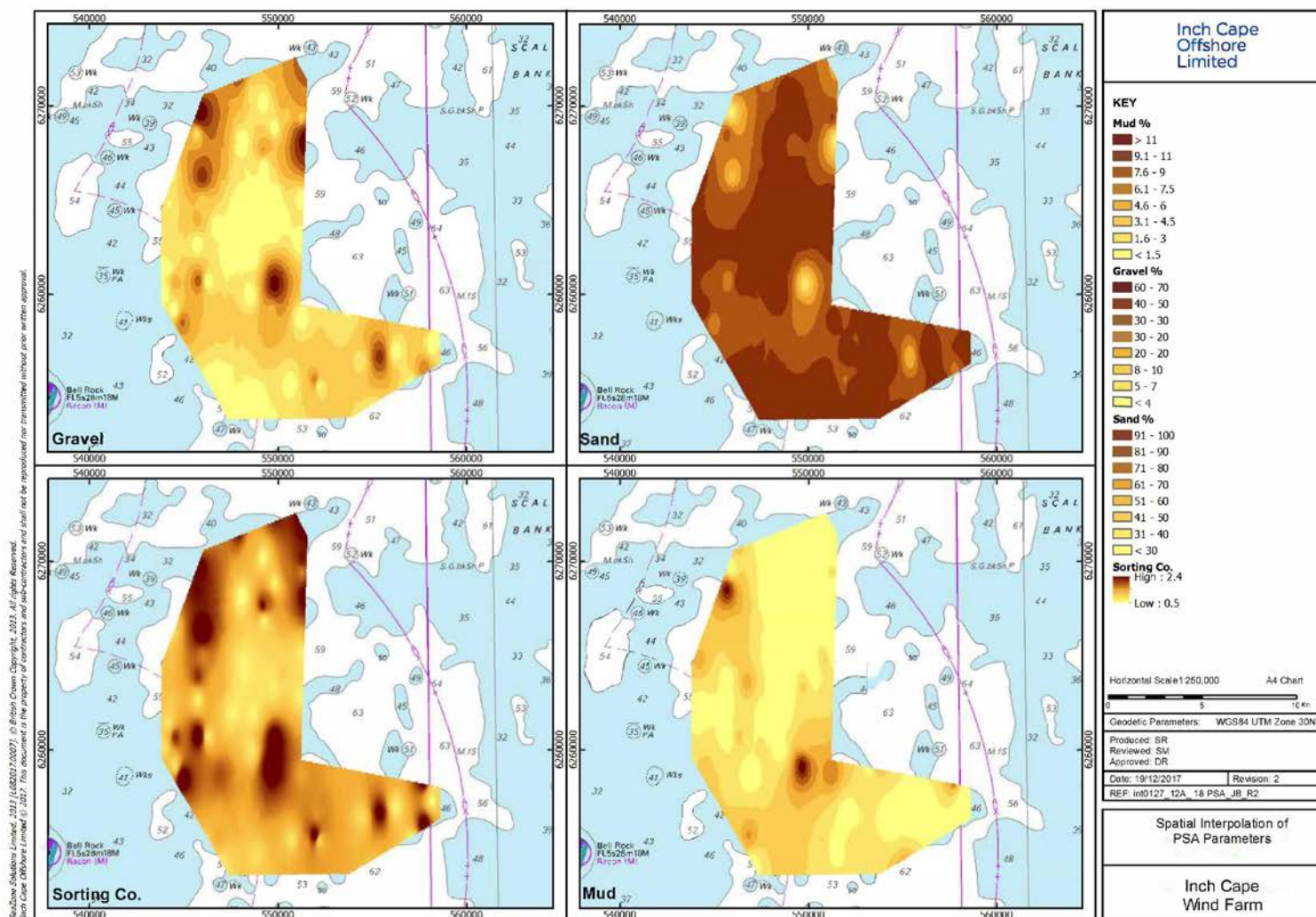


## **9A.4 Study Findings**

### **9A.4.1 Habitat Suitability**

- 27 As spawning grounds in the region may be highly variable, benthic characterisation data has been reviewed to determine the spawning potential within the Development Area. The Development Area is characterised by a heterogeneous sediment distribution ranging from fine muddy sand to coarse gravel with pebbles and boulders, but is dominated by fine and medium sands. (Figure 9A.7) (AMEC, 2012a). Fine sediment components comprising of very fine sand and mud and coarser components of coarse sands, gravels and pebbles are also variable across the area (AMEC, 2012a). Areas within the Development Area where there are low mud fractions and higher gravel fractions may be suitable for spawning herring. However, these habitat types are not widespread within the wind farm boundary and are instead spatially restricted to small discrete areas (Figure 9A.7). The majority of sampling stations can be assigned to the four classes; slightly gravelly muddy sand, slightly gravelly sandy mud, and the European Nature Information System (EUNIS) biotopes, circalittoral mud and deep circalittoral sand. The substrate within the Development Area are therefore unlikely to support spawning herring, which prefer coarse gravels, sands, shells, maerl and small stones where there is fast flowing highly oxygenated water.

Figure 9A.7: Sediment distribution (values as % contribution) across the Development Area as recorded from the site specific baseline surveys



### 9A.4.2 Herring Larvae Distribution

- 28 The IHLS survey systematically samples specified stations every year to record herring larvae concentrations across the North Sea. Data coverage in the vicinity of the Development Area is good, both temporally and spatially, and provides an indication of larval drift across the site. Herring larvae data collected between 1991 and 2016 has been reviewed to identify the regularity with which large numbers of herring larvae (defined as over 50 individuals/m<sup>2</sup>) are recorded around the Buchan spawning grounds south to the Northumberland coast (Figure 9A.8). This determines the consistency in the use of spawning grounds associated with the Shetland/Buchan spawning population. The most active IHLS survey squares with regards to herring larvae presence coincides with those proposed by Coull *et al.* (1998) as spawning grounds. High densities of herring larvae have also been regularly recorded in a band south east of the Development Area towards the Northumberland coast. Again on the Northumberland coast regular high densities of herring larvae coincide with reported spawning grounds (Coull *et al.*, 1998).
- 29 Data from the most recent years of survey work indicate that the greatest larval abundance consistently occurs to the north of the Development Area east of the Aberdeenshire coast (Figure 9A.9 to Figure 9A.13). Larval abundances were lowest in 2014 (Figure 9A.11) and greatest in 2016 (Figure 9A.13).
- 30 In 2015 (Figure 9A.10) and 2016 (Figure 9A.13) abundances east of the Northumbrian coast increased year on year compared to previous years data.



Figure 9A.8: IHLS survey grid with herring larvae concentrations exceeding 50 individuals per metre squared (inds/m<sup>2</sup>) (1991 – 2016)

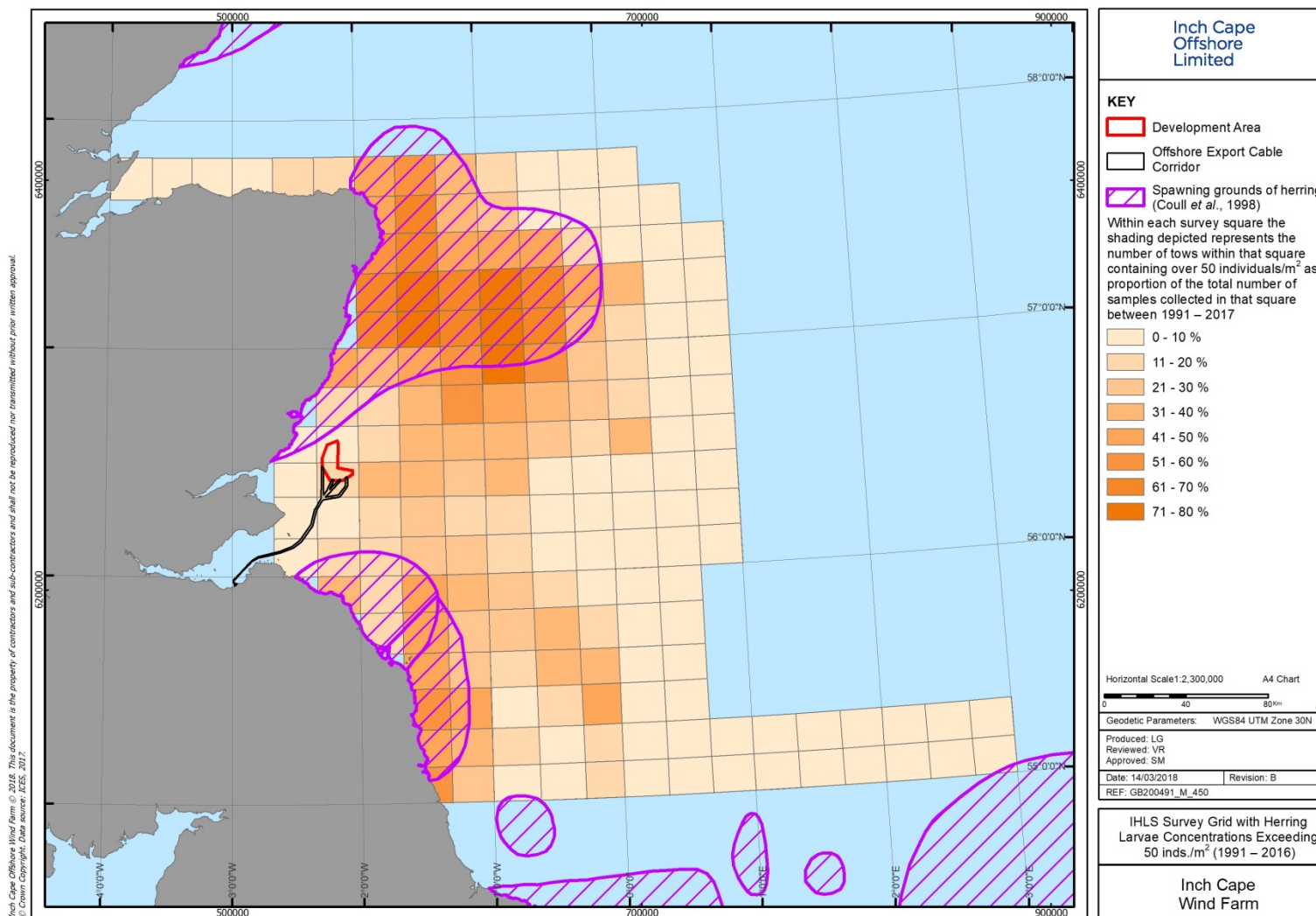


Figure 9A.9: Herring larval abundance data recorded during IHLS tows 2012 (inds/m<sup>2</sup>)

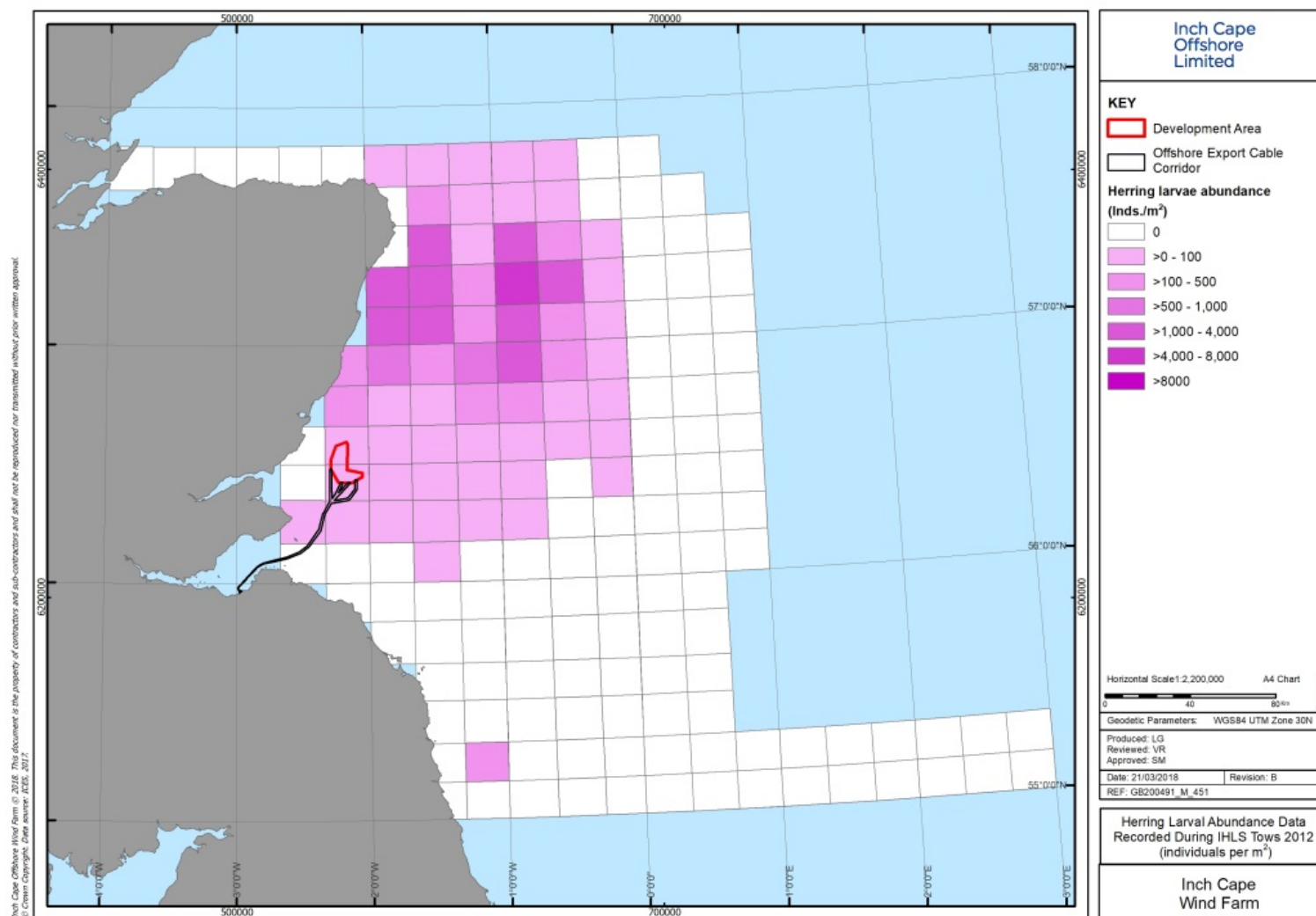




Figure 9A.10: Herring larval abundance data recorded during IHLS tows 2013 (inds/m<sup>2</sup>)

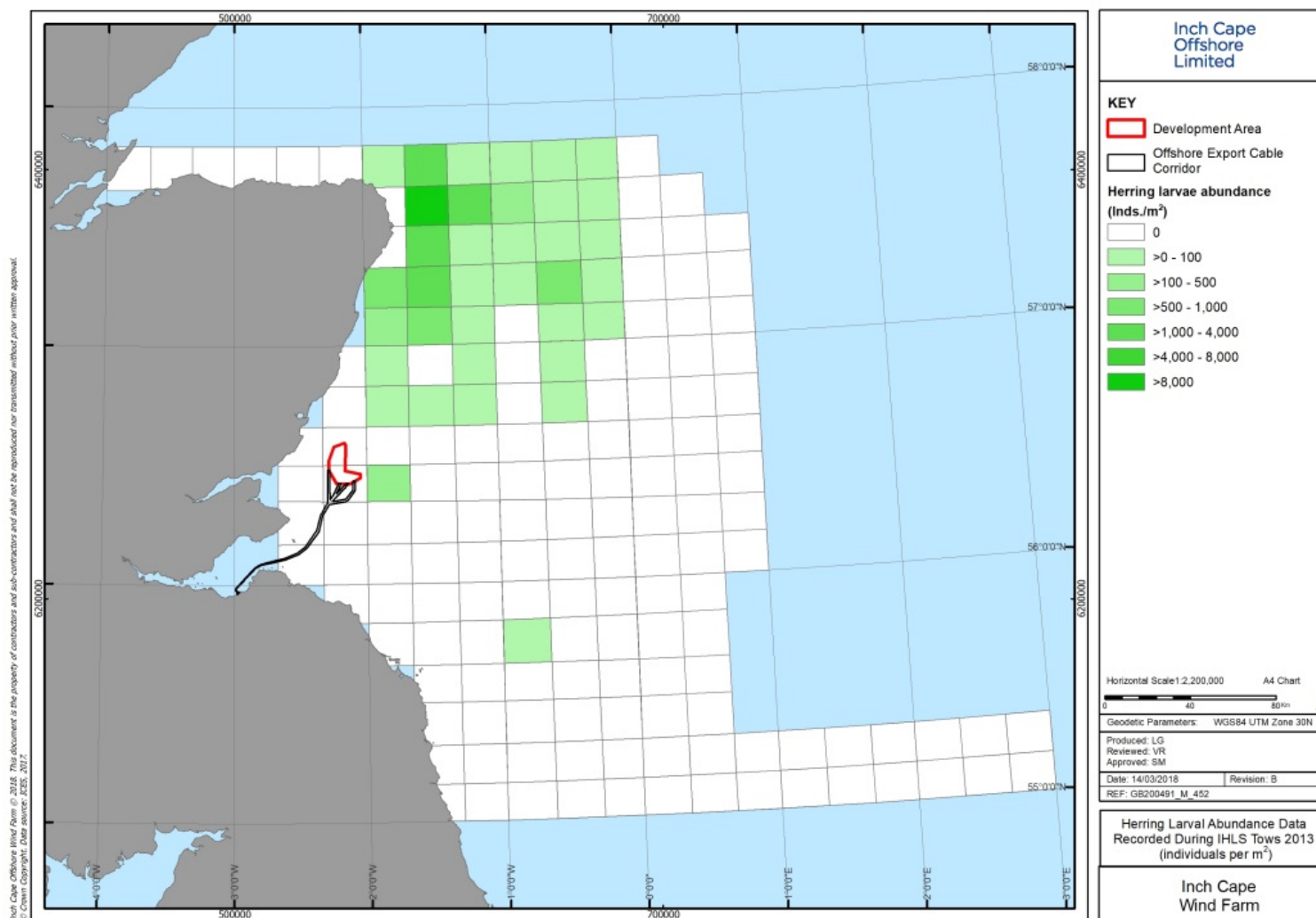


Figure 9A.11: Herring larval abundance data recorded during IHLS tows 2014 (inds/m<sup>2</sup>)

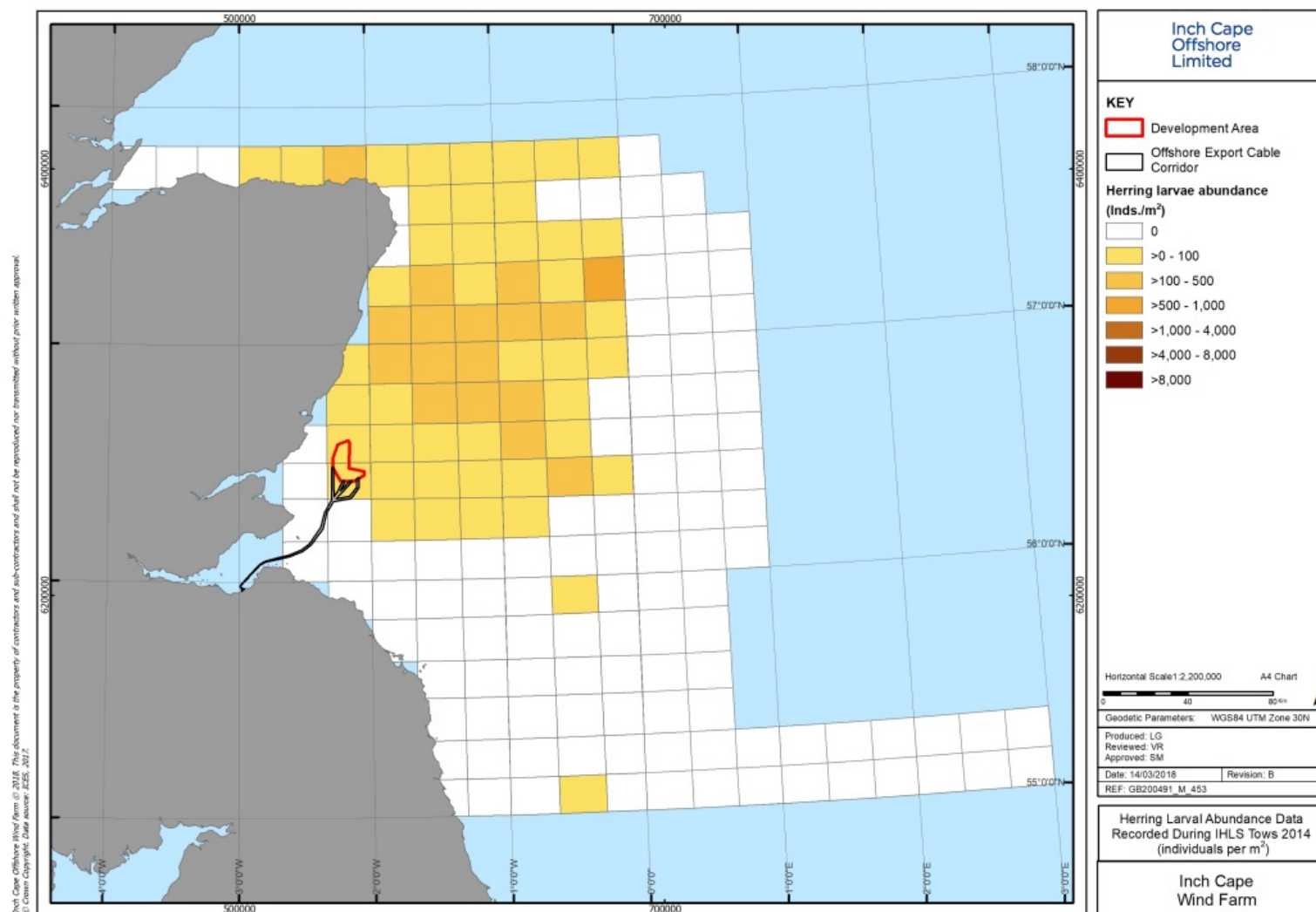


Figure 9A.12: Herring larval abundance data recorded during IHLS tows 2015 (inds/m<sup>2</sup>)

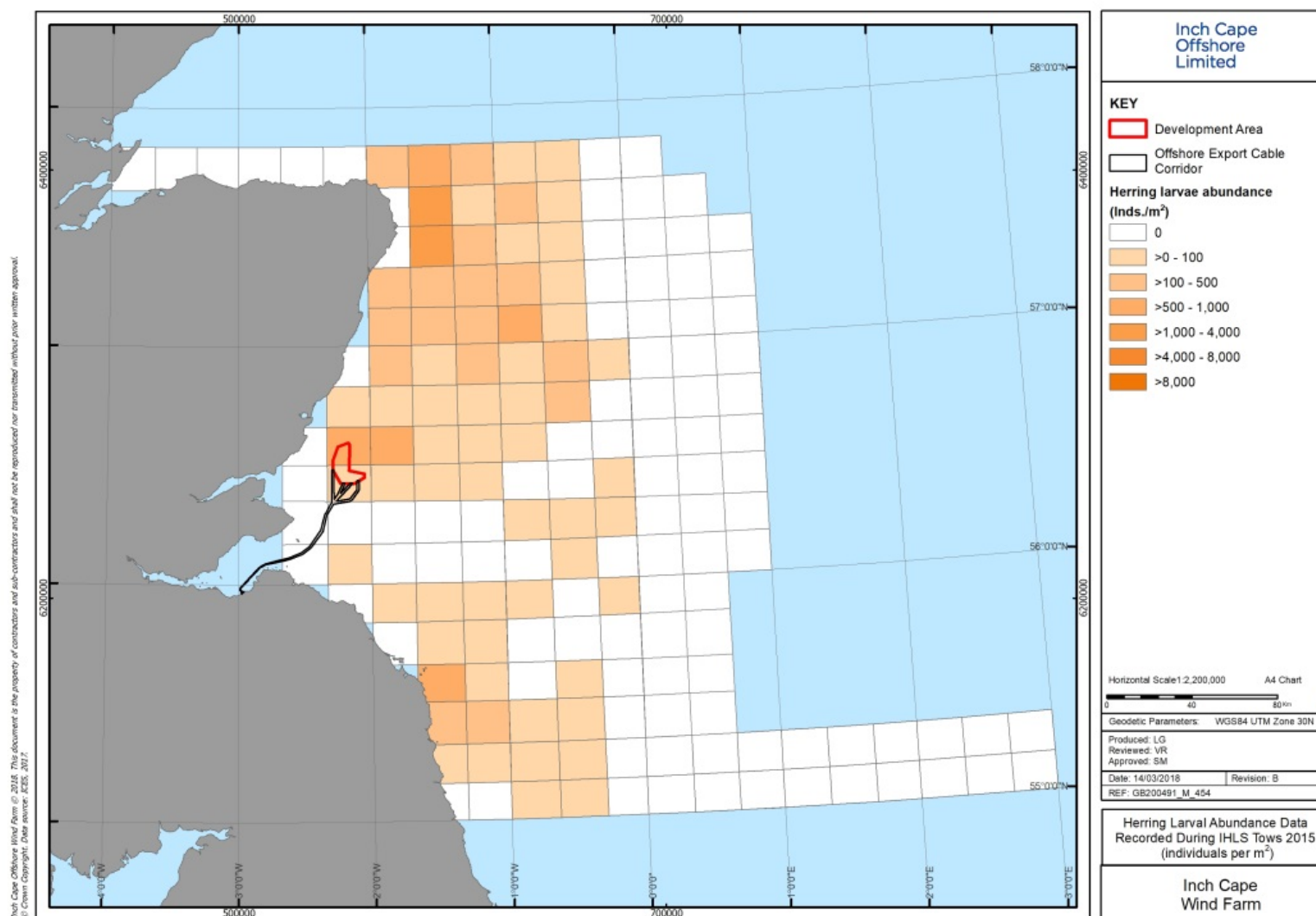
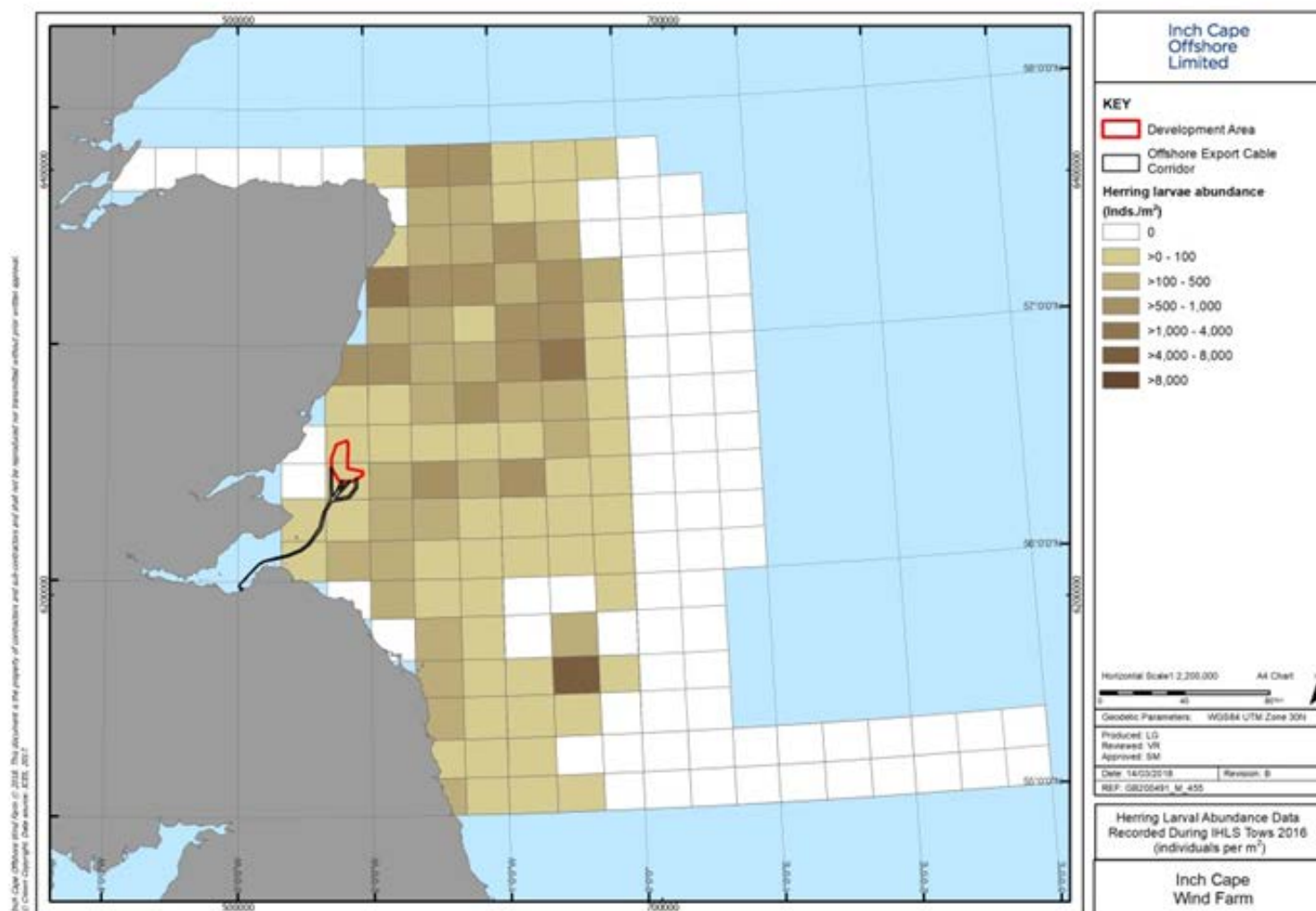


Figure 9A.13: Herring larval abundance data recorded during IHLS tows 2016 (inds/m<sup>2</sup>)



- 31 Across the area from which data was collected there is a large variation in densities between years and between sampling squares. While the IHLS data demonstrates the presence of low densities of herring larvae in the vicinity of the Development Area the presence of larvae does not necessarily reflect the presence of spawning grounds. Larvae drift passively on currents after hatching and it is likely that larvae recorded around the site have drifted from spawning grounds further to the north. Studies completed east of the Aberdeenshire coast report a larval drift rate of approximately 4.4 km/day (Munk *et al.*, 1986). It has been reported that herring larvae generally hatch at around 6 – 7 mm (Henderson *et al.*, 1984) but can range between 4 – 10 mm (Russell, 1976). Therefore, in line with the approach used in the most recent HAWG report young larvae less than 10 mm in length have been presented in isolation to provide a more accurate reflection of proximity to active spawning grounds (Figures 9A.14 – 9A.18). The distribution of the high concentrations of larvae less than 10 mm indicates that the main spawning grounds are to the north of the Development Area off the Aberdeenshire coast. In more recent years, there appears to be a shift with high densities present to the north east of the site, and with an increase in abundance along the Northumberland coast. Larvae smaller than 10 mm were present in some years within the Development Area but these levels were always low and never reached the densities in the more northern location, indicative that these areas are not used as primary spawning habitat.

Figure 9A.14: Herring larvae less than 10 mm recorded during IHLS tows 2012 (inds/m<sup>2</sup>)

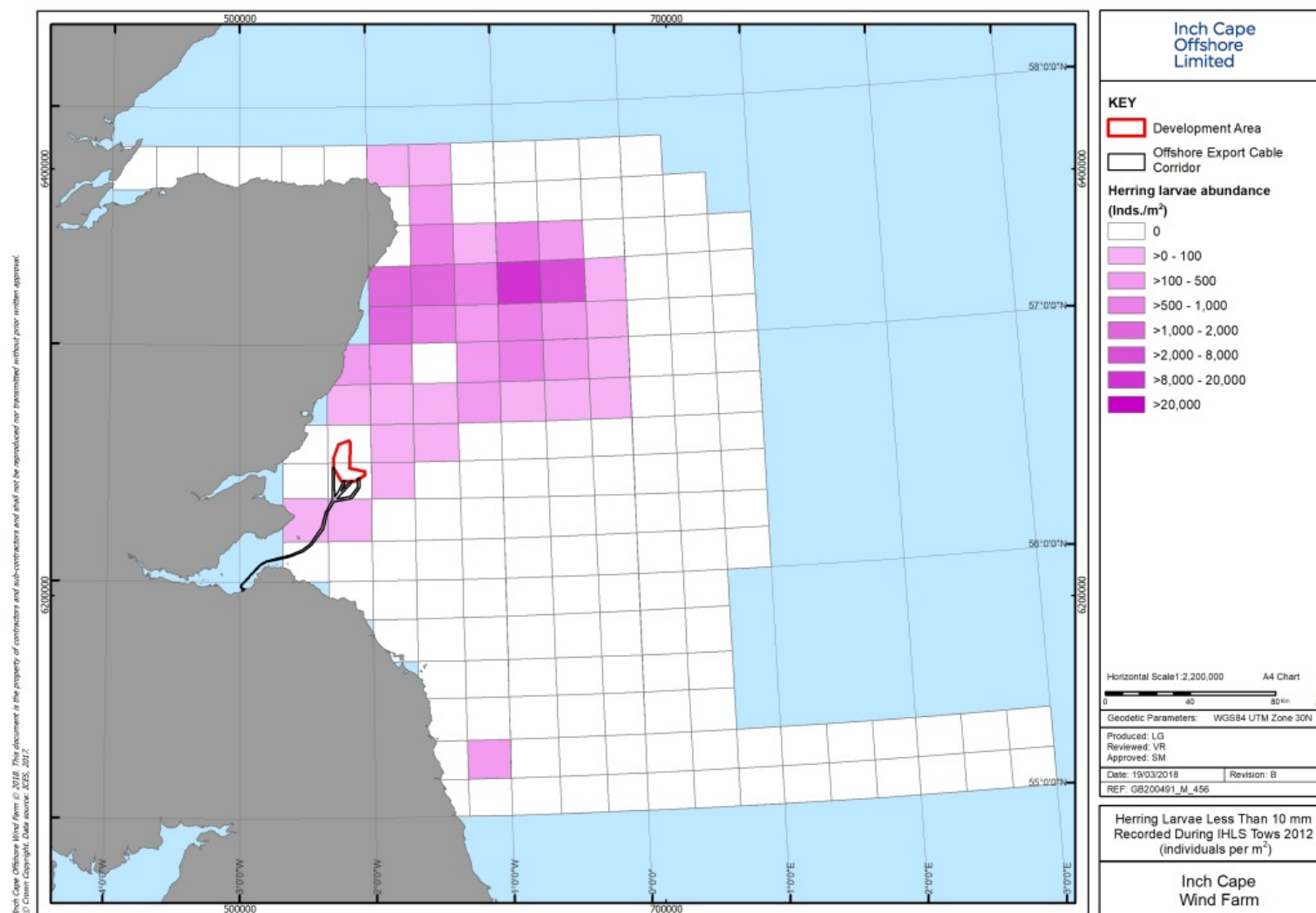




Figure 9A.15: Herring larvae less than 10 mm recorded during IHLS tows 2013 (inds/m<sup>2</sup>)

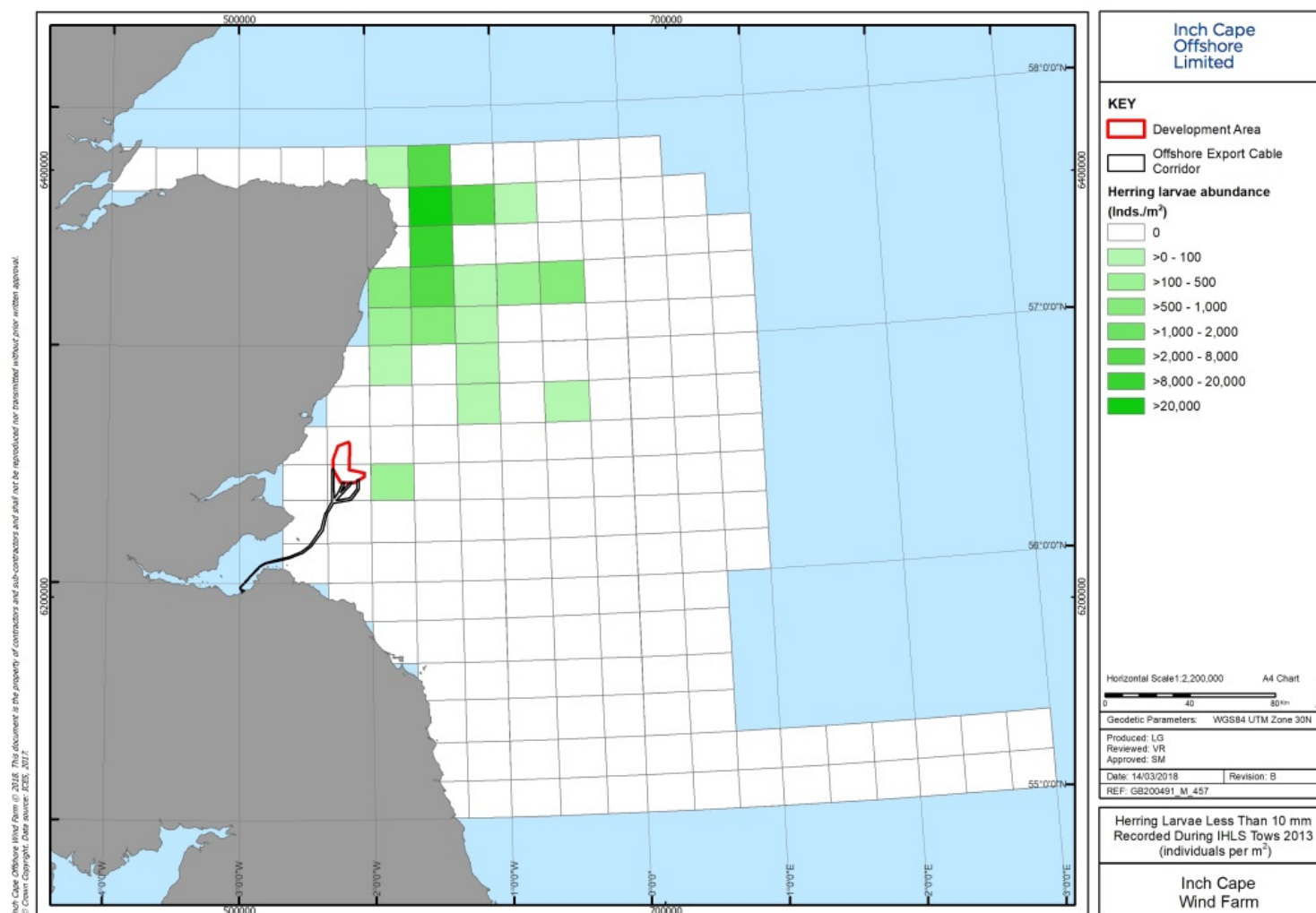




Figure 9A.16: Herring larvae less than 10 mm recorded during IHLS tows 2014 (inds/m<sup>2</sup>)

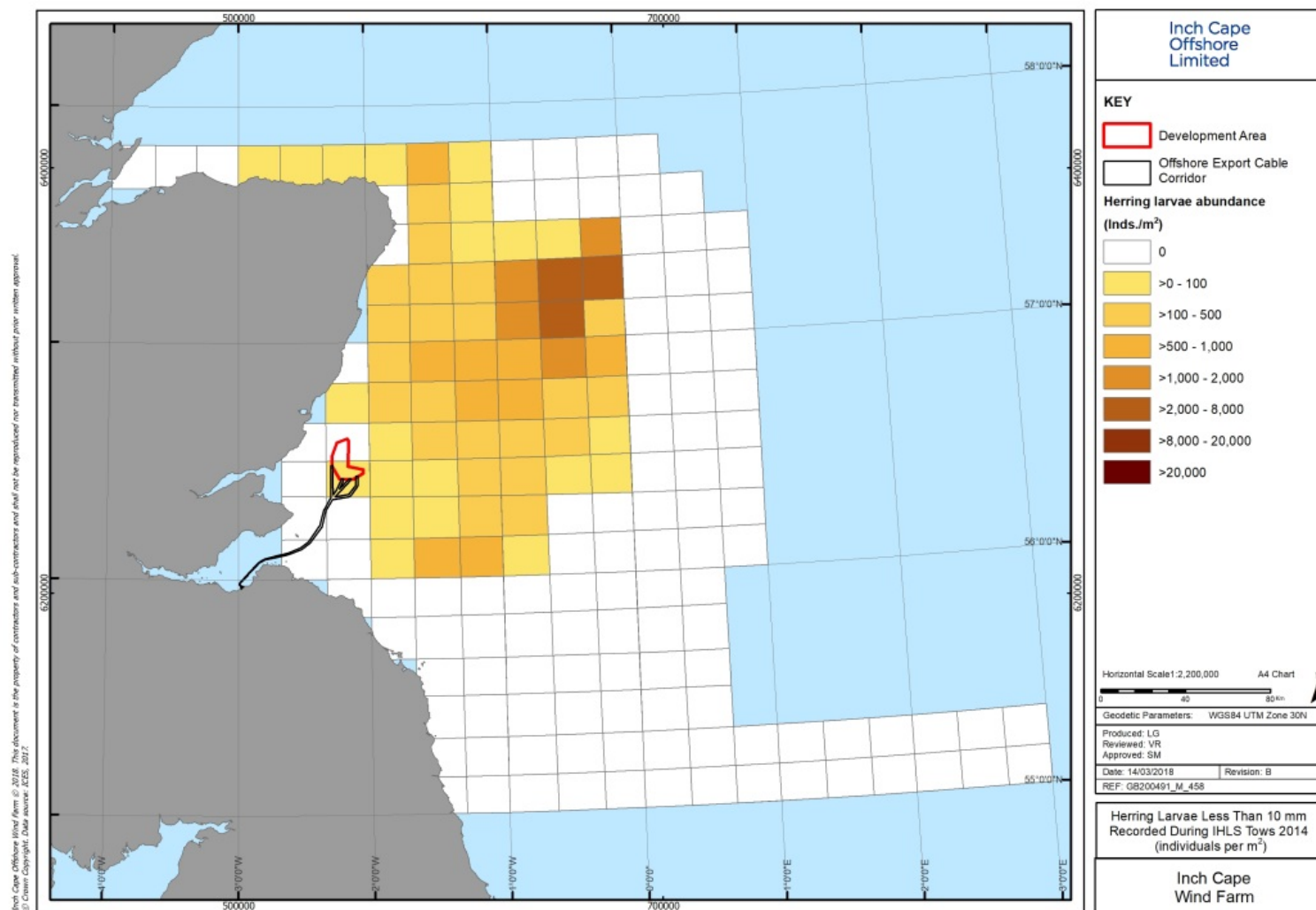


Figure 9A.17: Herring larvae less than 10 mm recorded during IHLS tows 2015 (inds/m<sup>2</sup>)

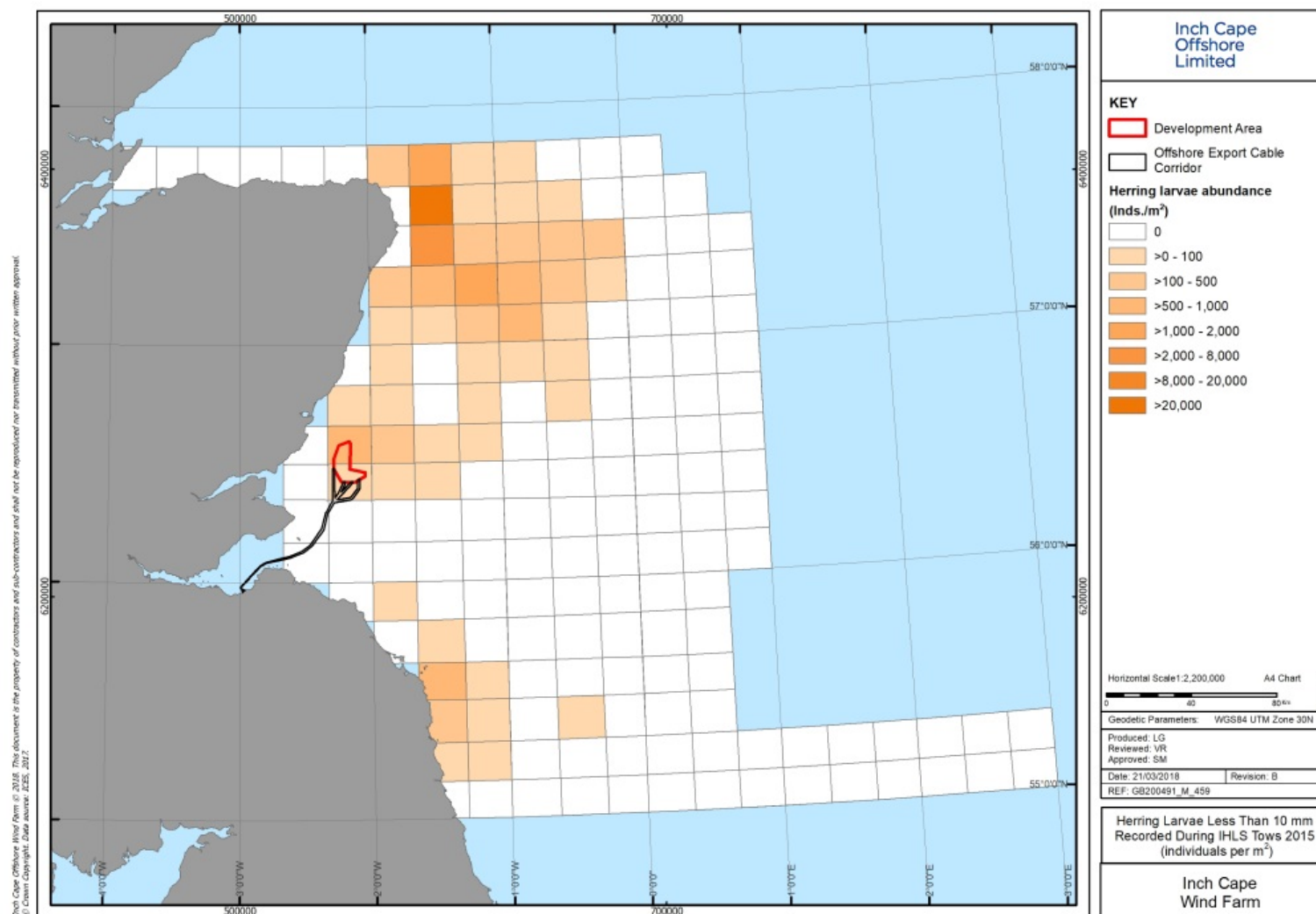
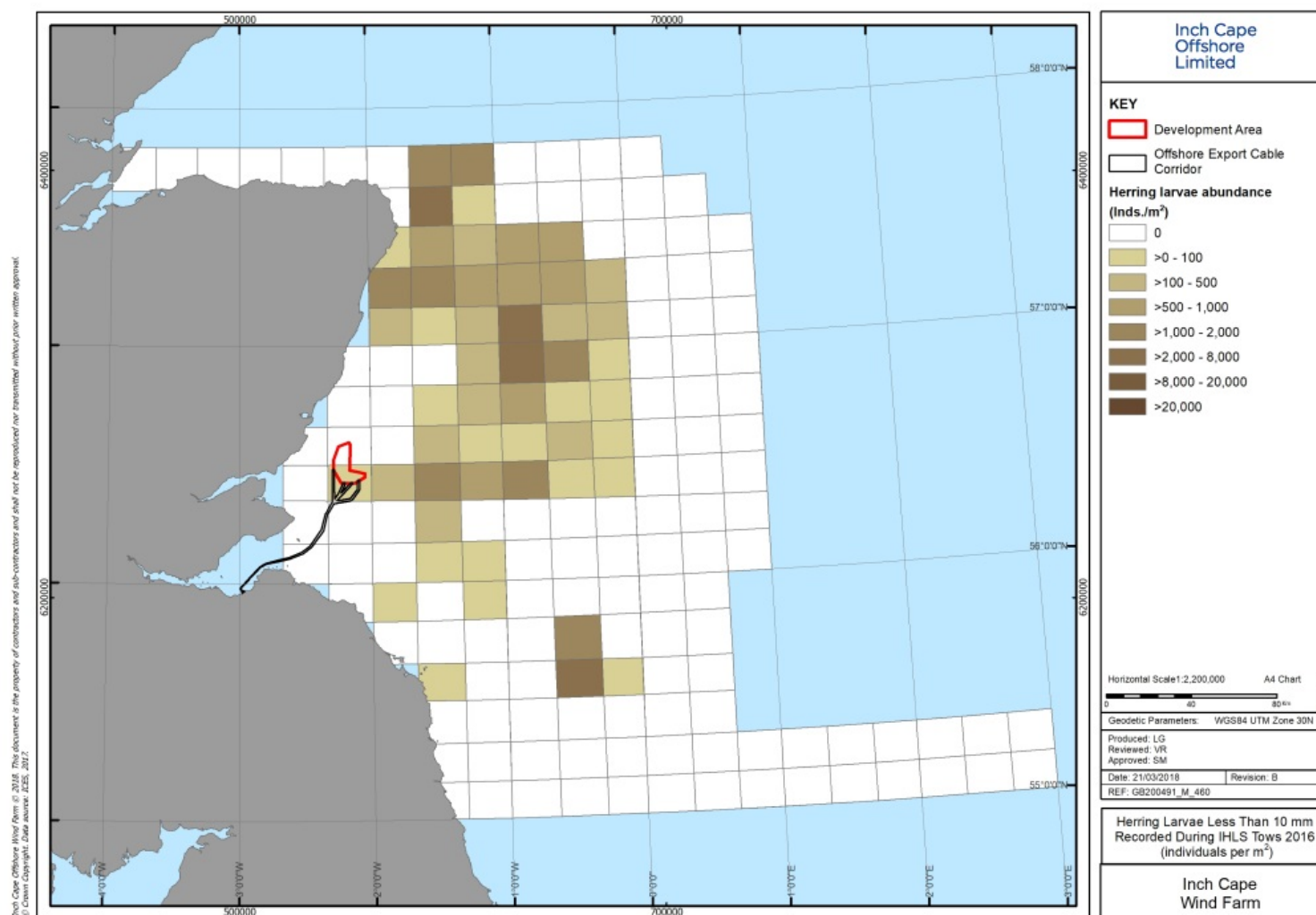


Figure 9A.18: Herring larvae less than 10 mm recorded during IHLS tows 2016 (inds/m<sup>2</sup>)



**9A.4.3 Adult Herring Distribution****International Bottom Trawl Survey Data**

- 32 IBTS data was collected for years 2012 to 2016 (Table 9.1) over the notable ICES rectangles, as well as the Local and Regional Study Areas.
- 33 The greatest catch rates are generally recorded further offshore with coastal waters recording consistently low catch rates, particularly those stations closest to the Development Area. The exception is 2015, where marginally higher numbers (less than 1000 individuals) were captured closer to the Development Area. The highest Catch per Unit Effort (CPUE) values were much further offshore (Figure 9A.19 to Figure 9A.23). Of the four years considered, higher CPUE values were recorded in stations to the north and east of the site, however there was no observable pattern.

**Table 9.1: IBTS Catch (CPUE) (ICES, Datas) of Herring within the study areas (2012 – 2016)**

Species	ICES Rectangle/ Study Area			
	ICES Rectangle 41E7	ICES Rectangle 42E7	Local Study Area	Regional Study Area
Herring (CPUE)	88.7	32.4	59.7	66.6

Figure 9A.19: Herring CPUE recorded during the 2012 IBTS Quarter 3 trawls, by trawl location

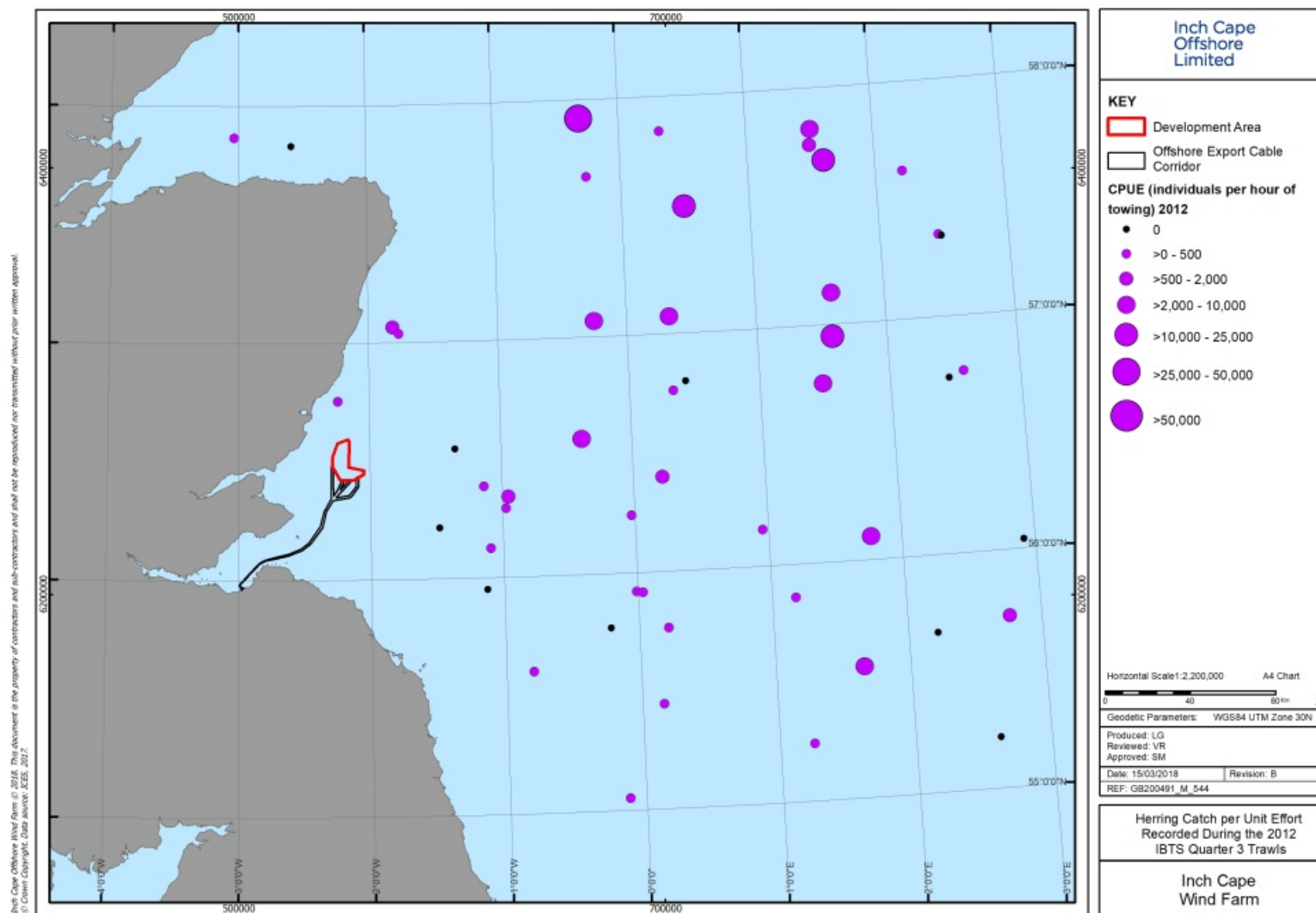


Figure 9A.20: Herring CPUE recorded during the 2013 IBTS Quarter 3 trawls, by trawl location

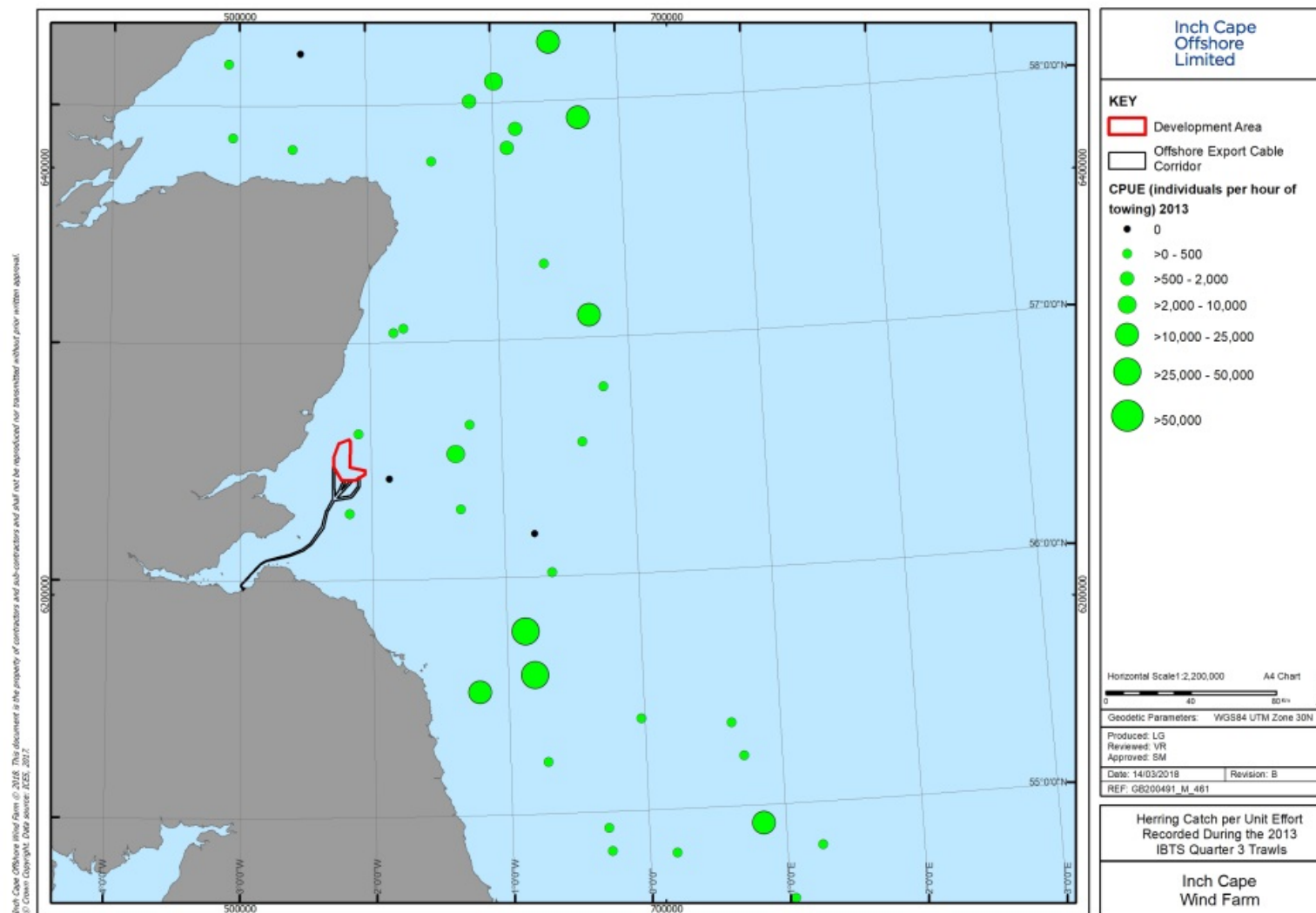




Figure 9A.21: Herring CPUE recorded during the 2014 IBTS Quarter 3 trawls, by trawl location

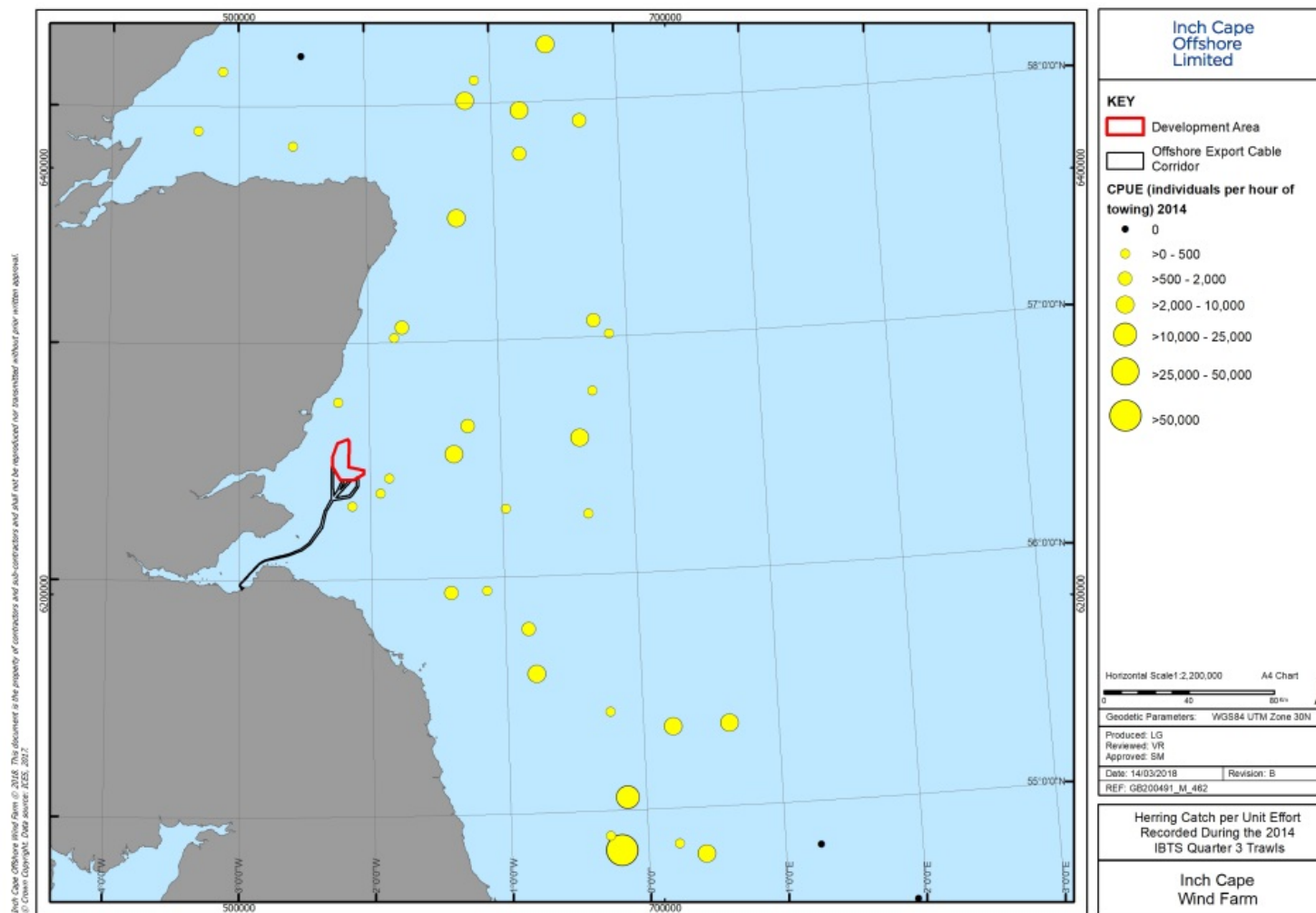


Figure 9A.22: Herring CPUE recorded during the 2015 IBTS Quarter 3 trawls, by trawl location

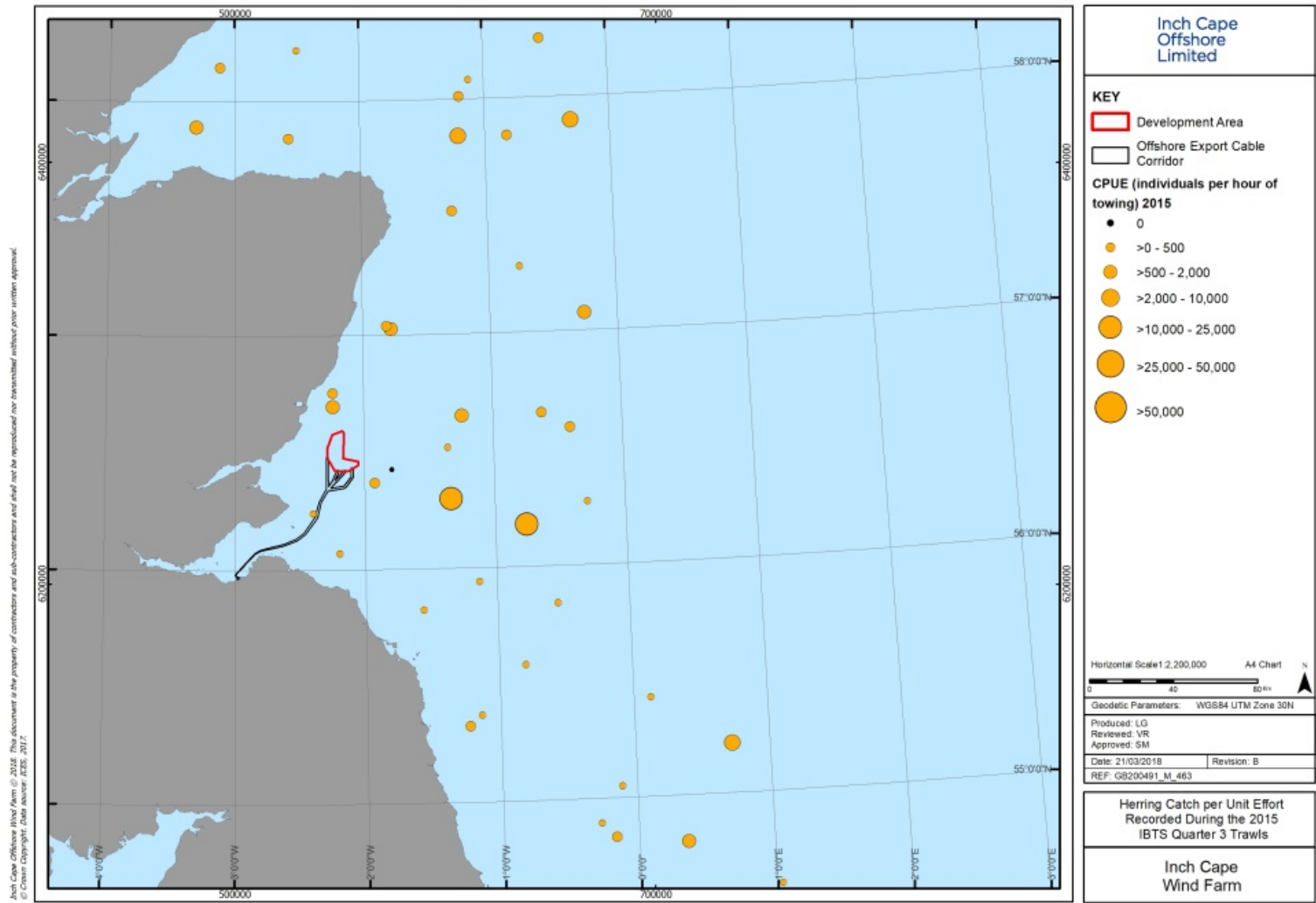
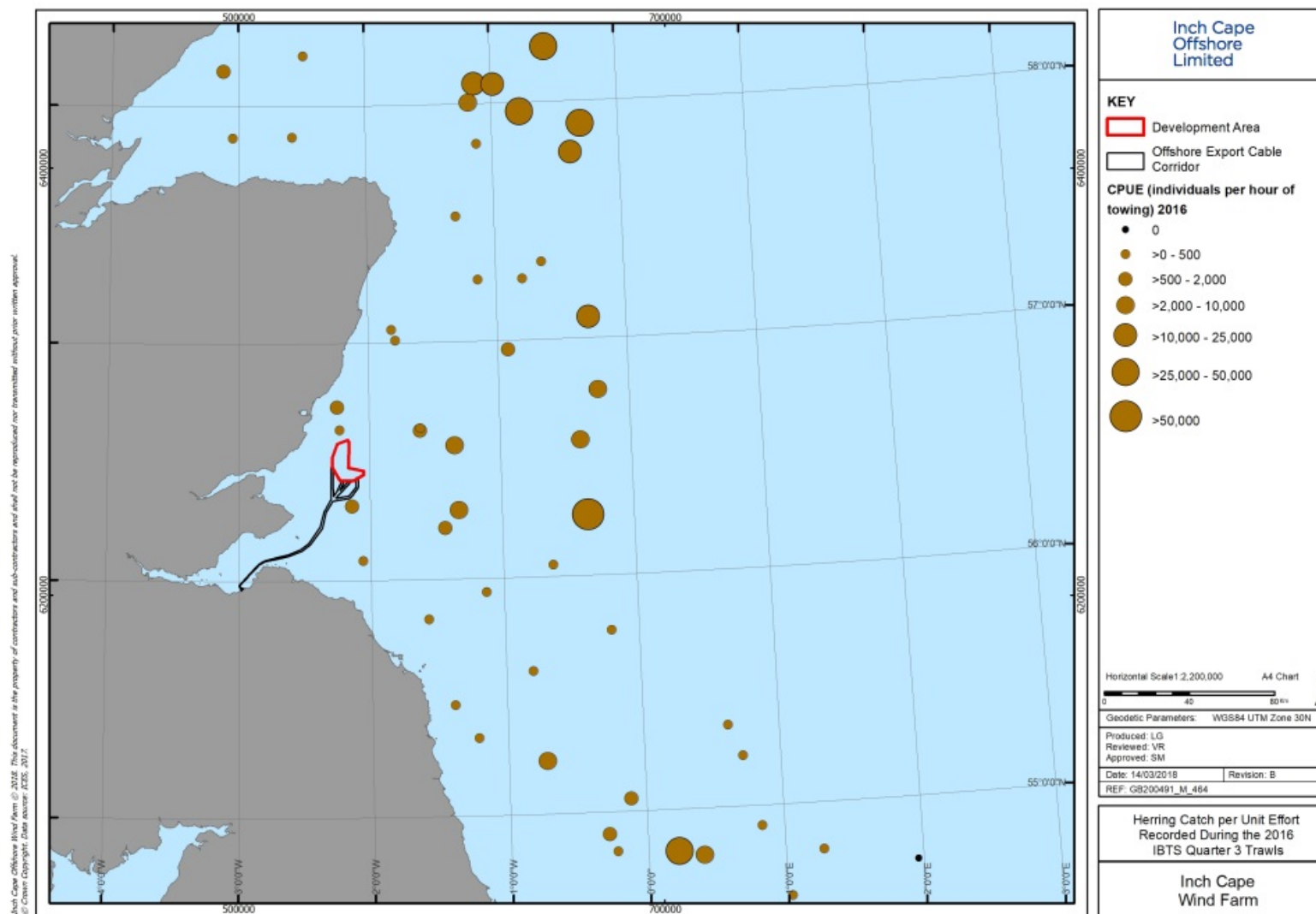


Figure 9A.23: Herring CPUE recorded during the 2016 IBTS Quarter 3 trawls, by trawl location



**Commercial Landings Data**

- 34 Herring catch data was collected for years 2012 – 2016 (Table 9.2) over the notable ICES rectangles, as well as the Local and Regional Study Areas.
- 35 The reported catch values reflect the CPUE data collected as part of the IBTS with the greatest tonnage reported in deeper offshore waters. In line with previous years, the greatest catch values have been reported east of the Caithness coastline in the northern North Sea and east of the Northumberland coastline in the central North Sea (Figure 9A.24).

**Table 9.2: Average Annual UK Fleet Landings (Tonnes) (MMO) of Herring within the study area (2012 – 2016)**

Species	ICES Rectangle/ Study Area			
	41E7	42E7	Local Study Area	Regional Study Area
Herring (Tonnes)	0.1	3.5	3.6	856.0

Figure 9A.24: Herring catches in the North Sea in the 3rd quarter of 2012 (in tonnes) by statistical rectangle

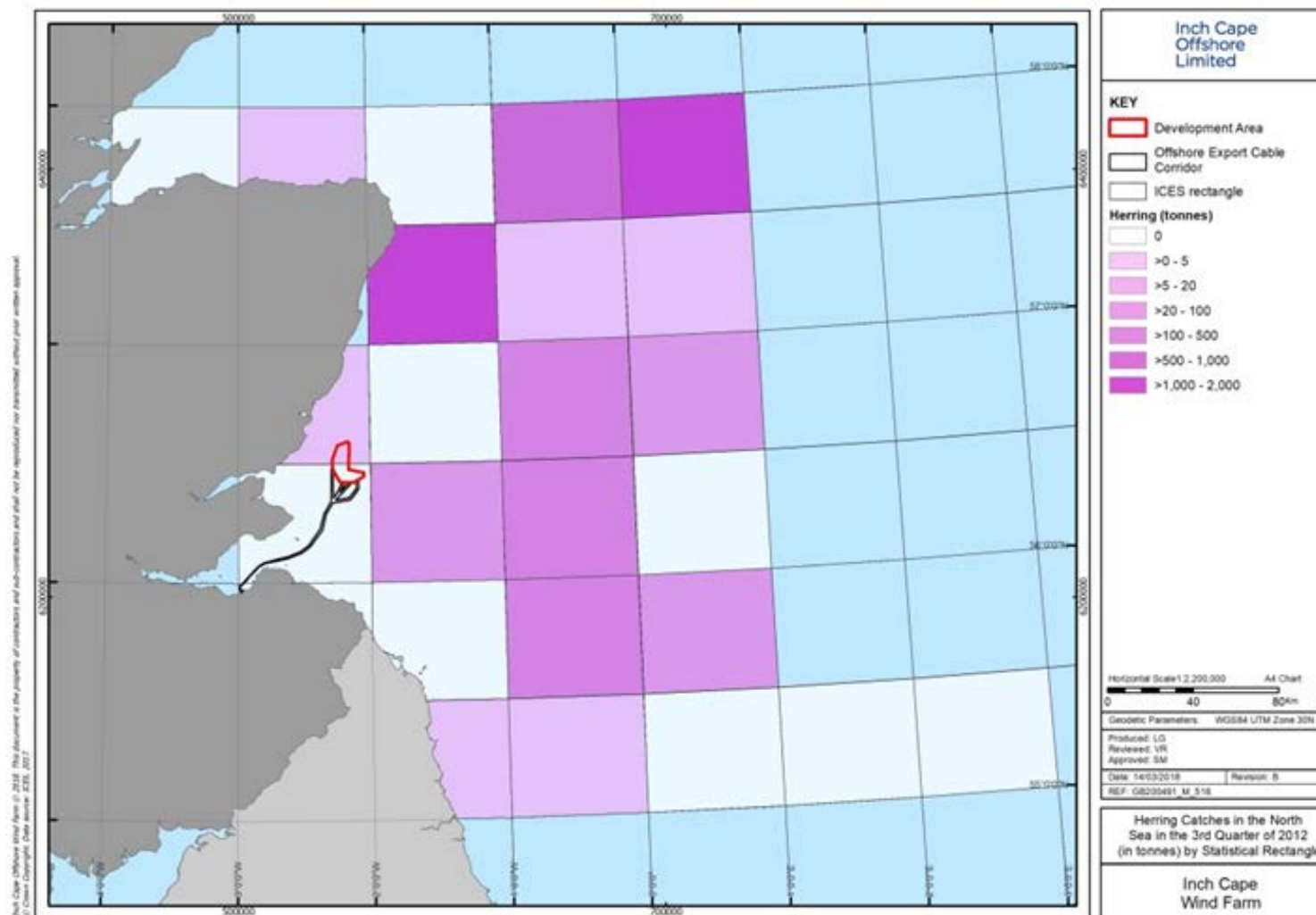
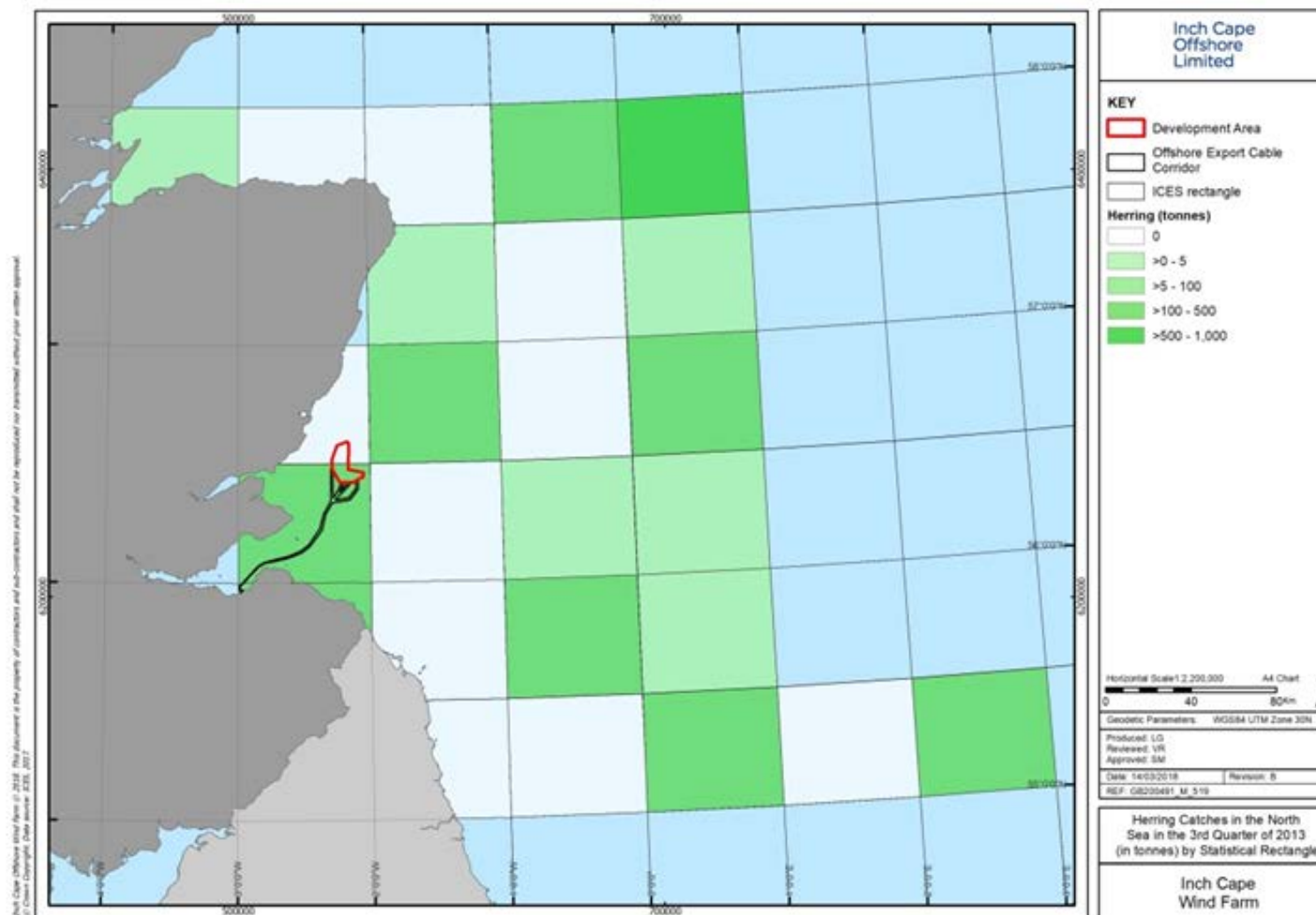
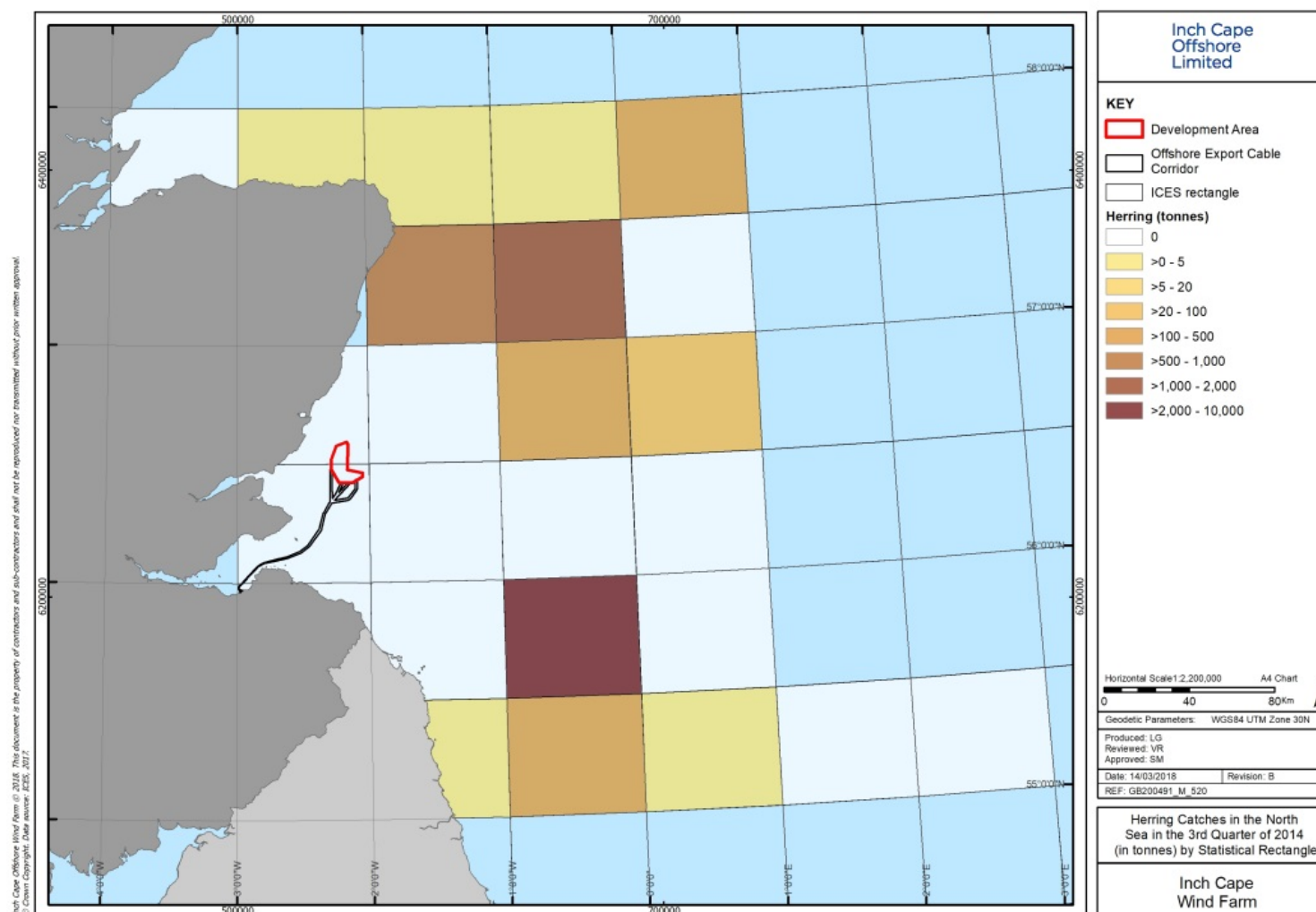


Figure 9A.25: Herring catches in the North Sea in the 3rd quarter of 2013 (in tonnes) by statistical rectangle





**Figure 9A.26: Herring catches in the North Sea in the 3rd quarter of 2014 (in tonnes) by statistical rectangle**



**Figure 9A.27: Herring catches in the North Sea in the 3rd quarter of 2015 (in tonnes) by statistical rectangle**

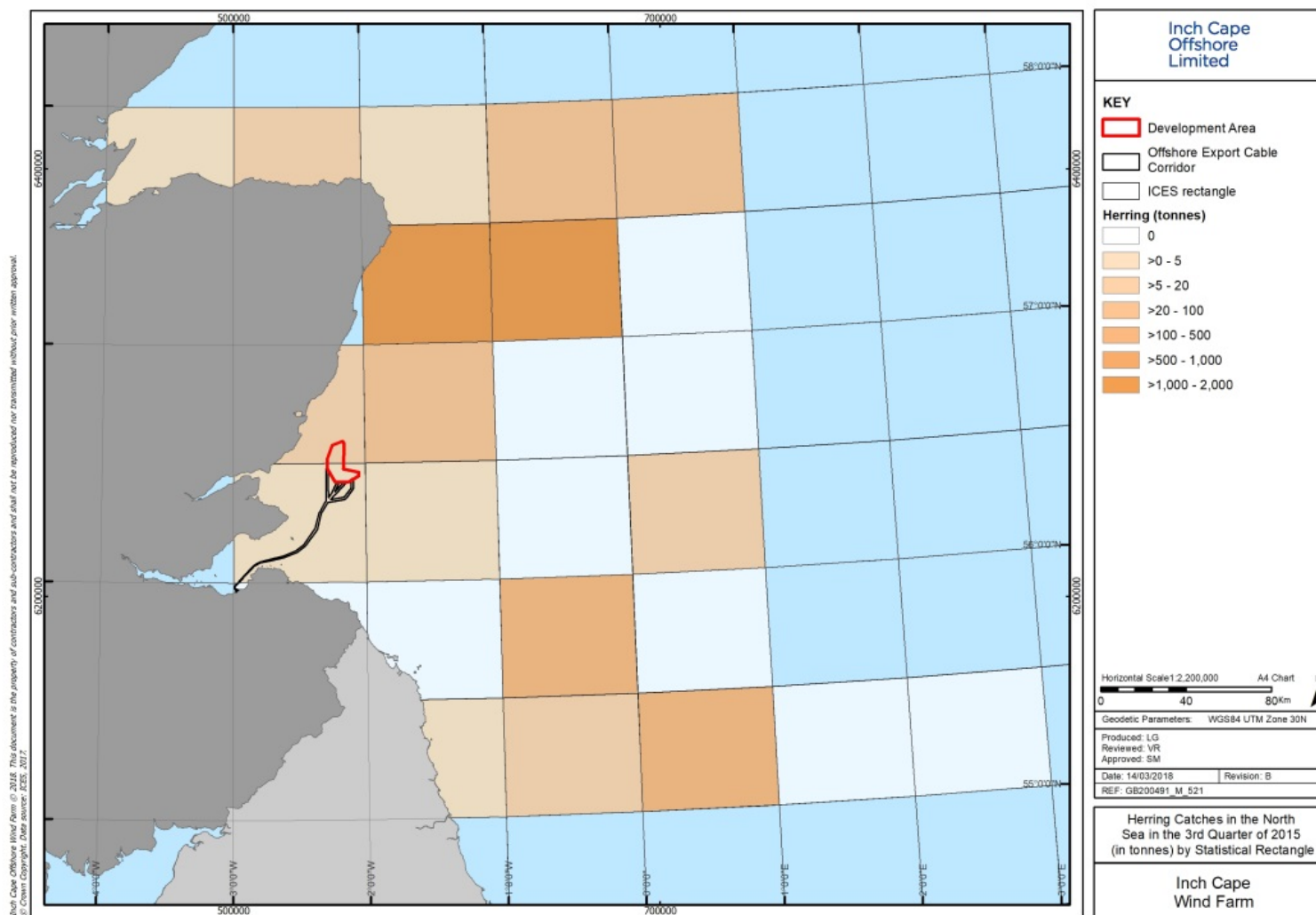


Figure 9A.28: Herring catches in the North Sea in the 3rd quarter of 2016 (in tonnes) by statistical rectangle

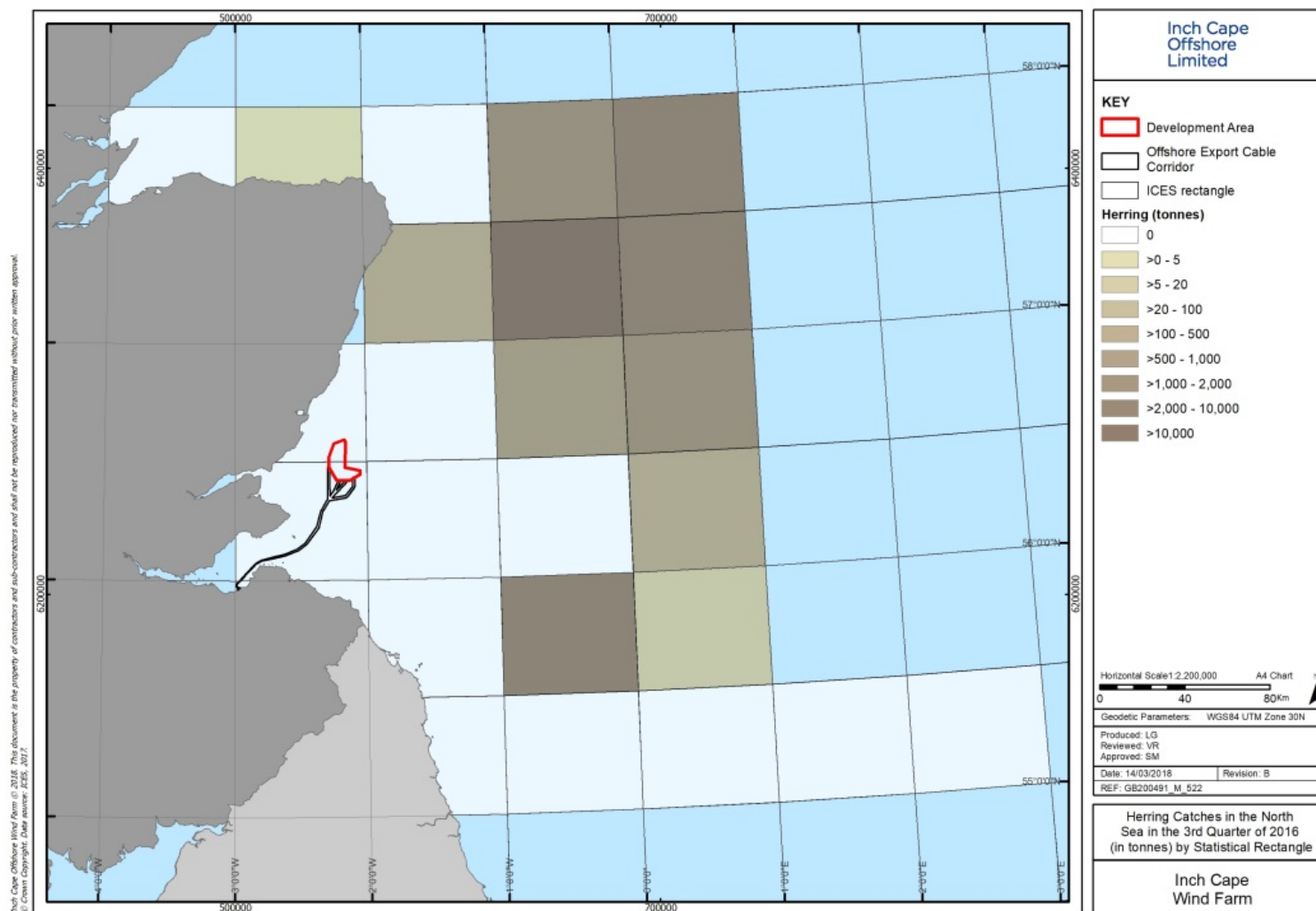


Figure 9A.24: Herring catches in the North Sea in the 3rd quarter of 2012 (in tonnes) by statistical rectangle

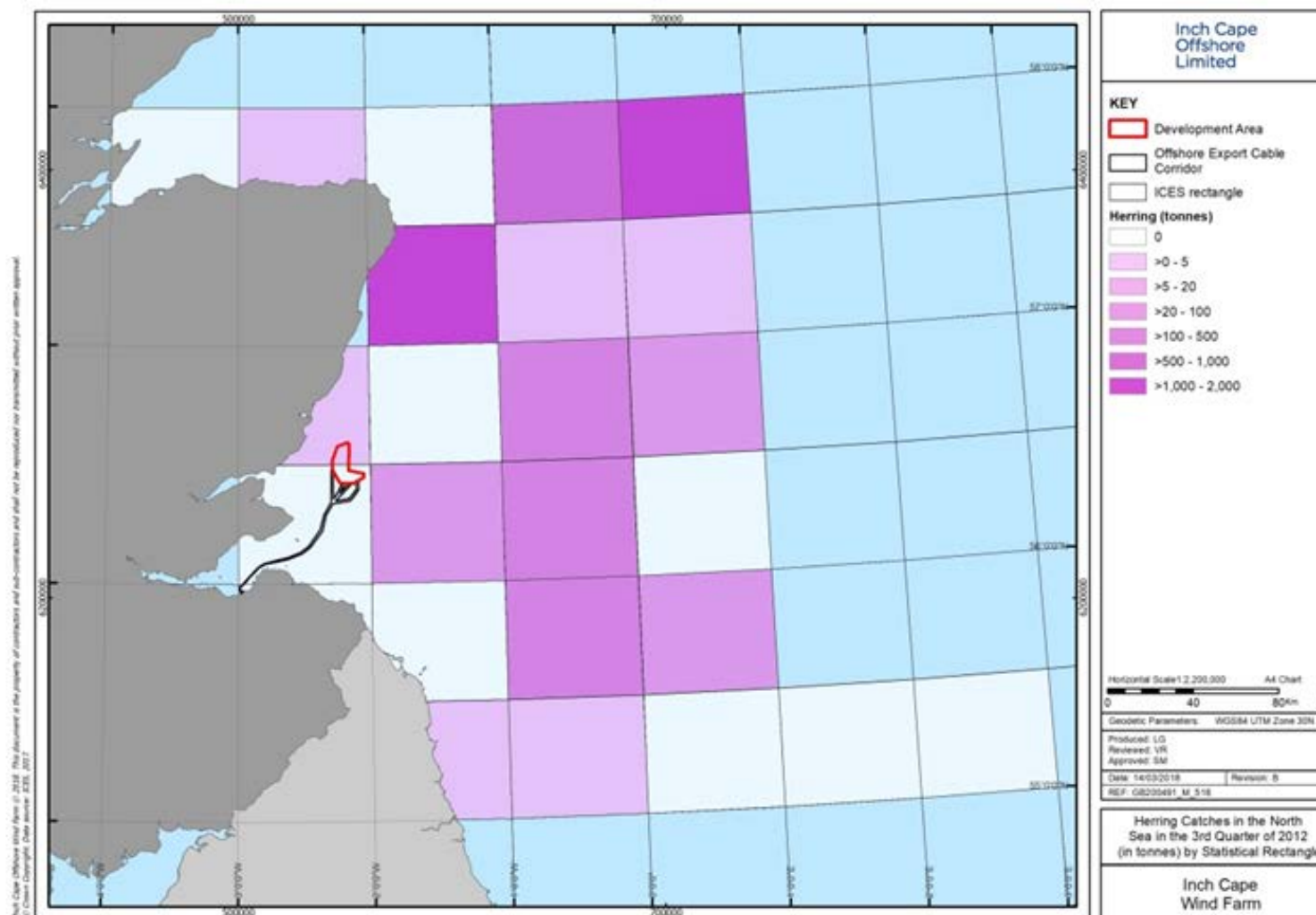
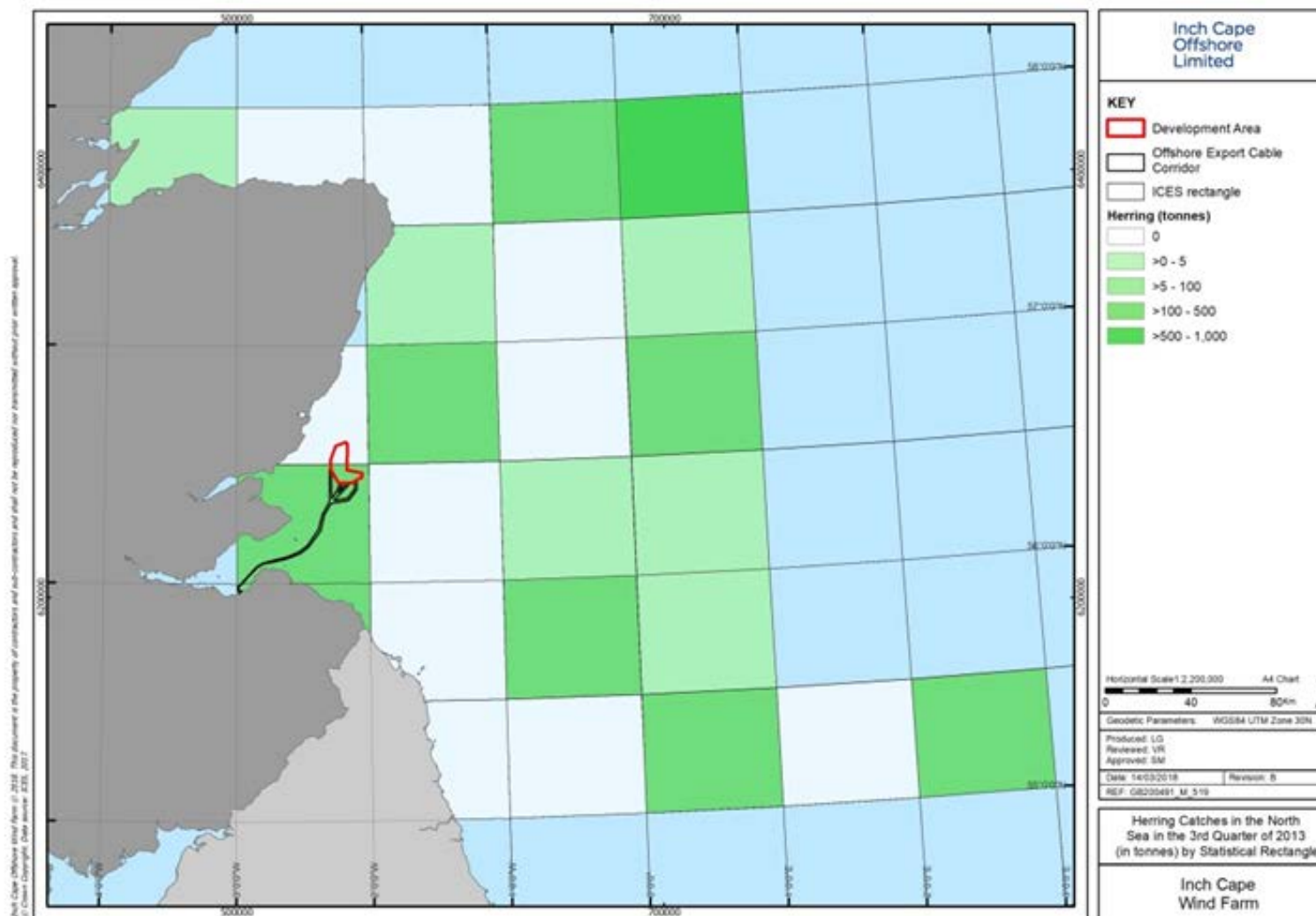


Figure 9A.25: Herring catches in the North Sea in the 3rd quarter of 2013 (in tonnes) by statistical rectangle



**Figure 9A.26: Herring catches in the North Sea in the 3rd quarter of 2014 (in tonnes) by statistical rectangle**

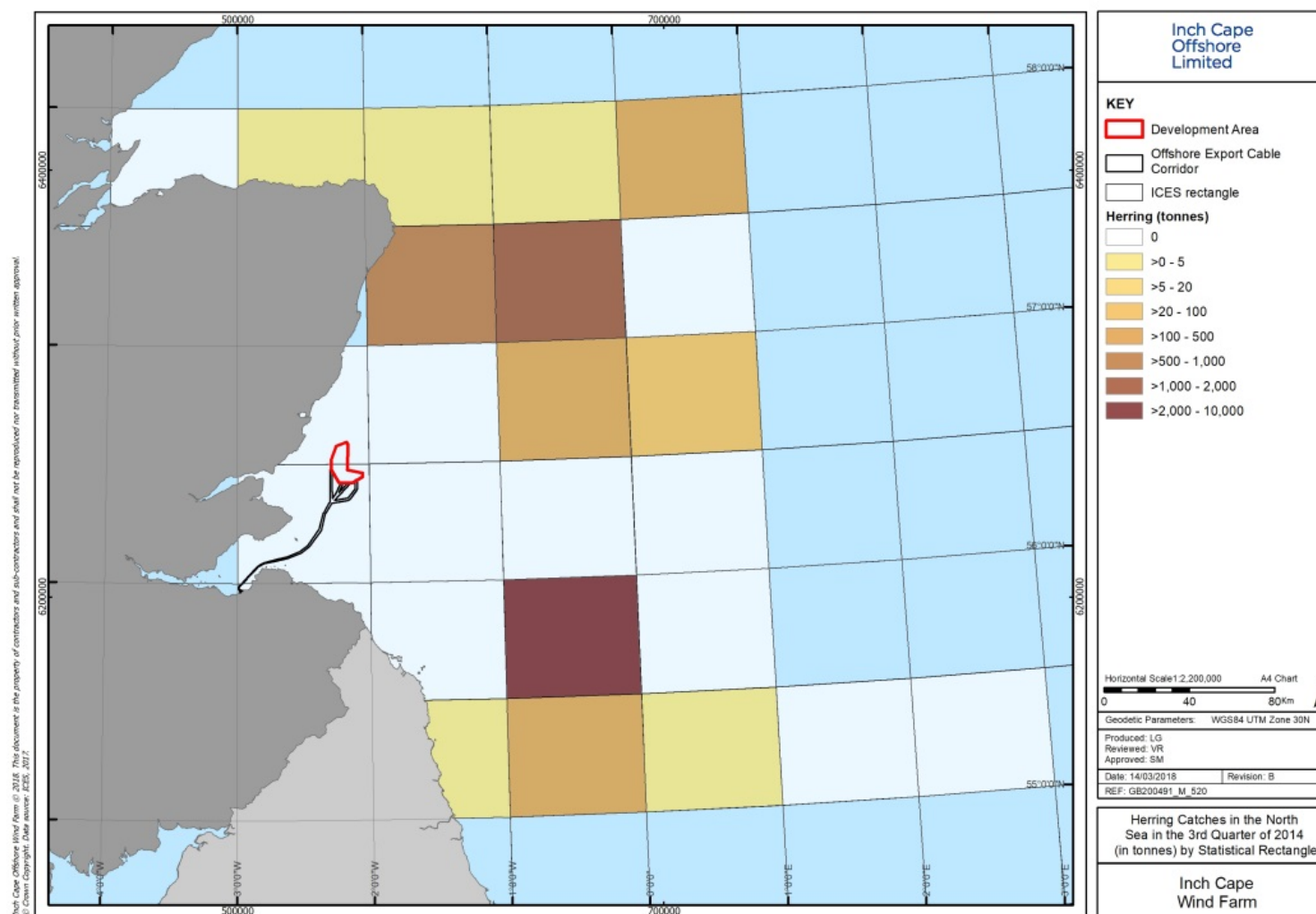
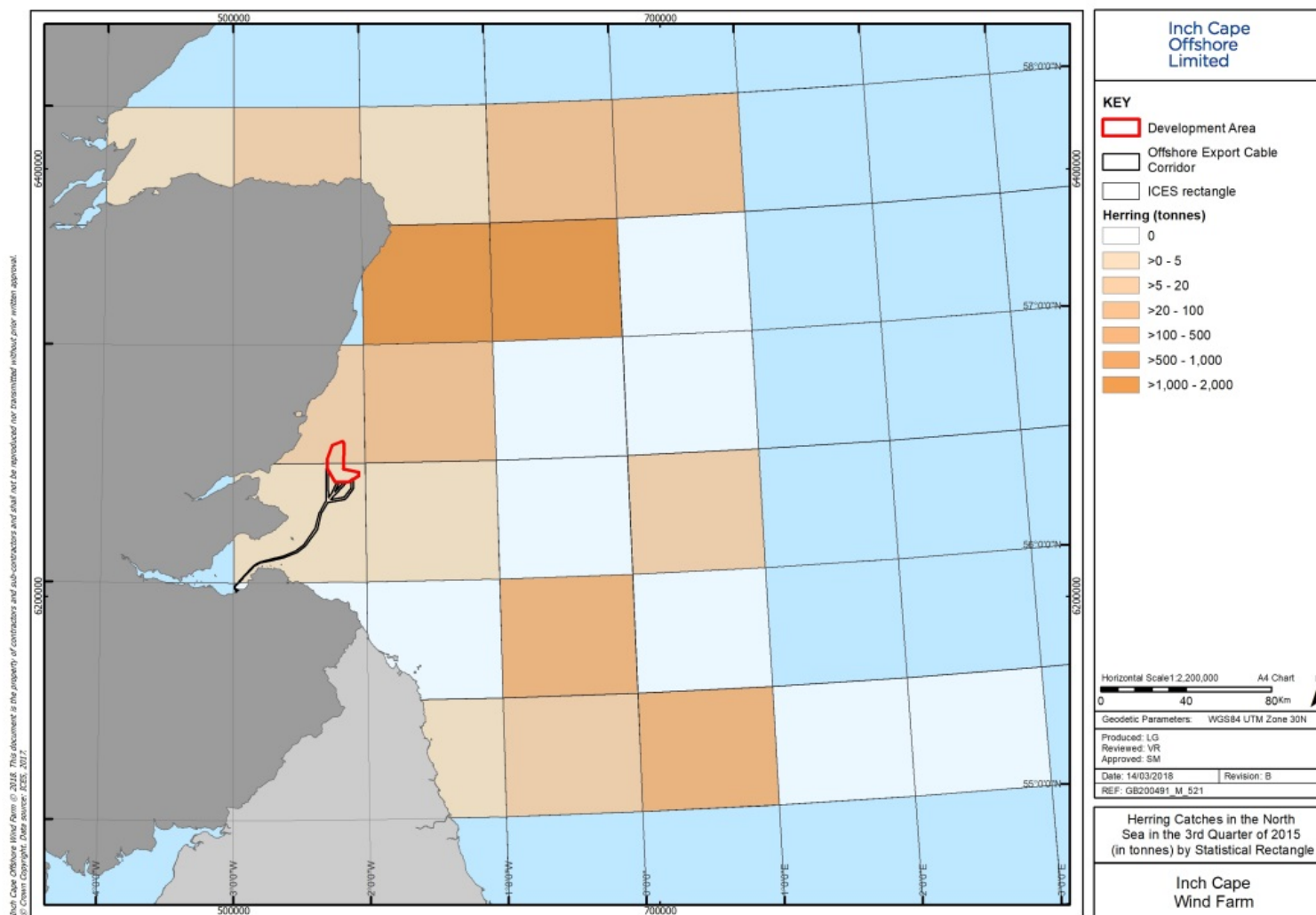
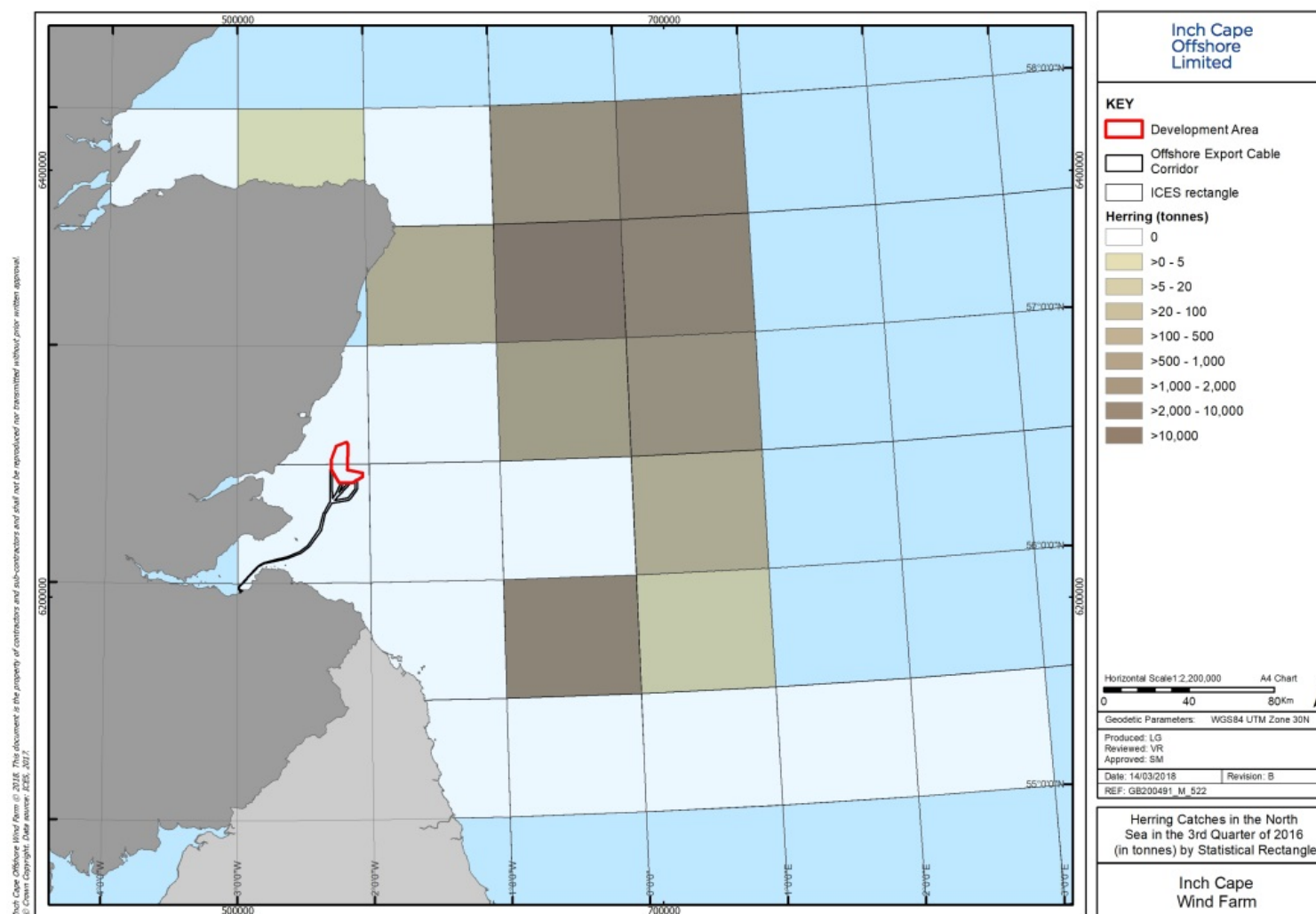




Figure 9A.27: Herring catches in the North Sea in the 3rd quarter of 2015 (in tonnes) by statistical rectangle



**Figure 9A.28: Herring catches in the North Sea in the 3rd quarter of 2016 (in tonnes) by statistical rectangle**



**Site Specific Fish Surveys**

- 36 Very low herring numbers (161 fish in total) were identified during all surveys with peak numbers recorded in winter (77) followed by spring (61). The majority of herring sampled were smaller than the minimum landing size (200 mm) during all seasons and are therefore unlikely to be sexually mature. The mean landing sizes during the winter and spring surveys were 166 and 161 mm respectively, whilst in autumn the mean landing size was 141 mm (19 fish). Fish that are smaller than 200 mm are likely to be less than 2 years old (ICES, 2006).

**9A.5 Conclusion**

- 37 Although the Development Area does not lie within any mapped spawning grounds for Herring, it is located within a high intensity nursery area according to Ellis *et al.* (2012) and is in relatively close proximity to a known spawning ground for the Buchan spawning population.
- 38 A number of patches within the Development Area may have sediment characteristics suitable for spawning herring however these habitat types are isolated within the Development Area in discrete areas and do not therefore indicate prime spawning habitat.
- 39 IHLS data collected as part of this study indicates that the majority of spawning activity occurs to the north of the site, in the north of the area identified by Coull *et al.* (1998), and that the southern area of the defined spawning area is used rarely, if at all.
- 40 The IBTS and commercial catch data indicates that abundances of adult herring are generally greatest further offshore, with coastal waters recording consistently low catch rates, particularly at those stations closest to the Development Area. This is also reflected in the relatively low numbers of adult herring recorded at Inch Cape site specific surveys. Such low catches in and around the Development Area suggest that it does not form a key part of any migration route from the offshore feeding areas to the spawning grounds.
- 41 Overall, and based on current studies, the Development Area appears to be of little importance to adult or larval herring with spawning focusing on areas to the North of the Development Area, and adult distribution generally further offshore. Larval catch was relatively low in the vicinity of the Development Area indicating that it is also of relatively low importance as a nursery area.

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