Inch Cape Offshore Wind Farm

New Energy for Scotland

Offshore Environmental Statement:
VOLUME 2E
Appendix 13D: Herring Spawning Study

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Abbreviations and Acronyms

CPUE	Catch per unit effort
EIA	Environmental Impact Assessment
ES	Environment Statement
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
STW	Scottish Territorial Waters
TAC	Total Allowable Catch

List of Units

dB	decibels
dB_{ht}	decibels hearing threshold
inds./m^2	individuals per metre squared
km^2	kilometre squared
m	metre
mm	millimetre
t	tonnes
µPA	micro Pascal

13D Herring Spawning Study

13D.1 Introduction

Inch Cape Offshore Limited (ICOL) are developers of the Inch Cape Offshore Wind Farm and associated Offshore Transmission Works (OfTW) in the outer Firth of Tay, Scotland. The Offshore 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 one of two possible sites along the southern Firth of Forth coastline within the Offshore Export Cable Corridor.

Atlantic herring (*Clupea harengus*) are susceptible to pressures resulting from construction and operation of offshore wind farms. Herring are demersal spawners that lay eggs on clean gravel habitats where there are fast bottom currents. Impacts on benthic habitats which are known to constitute herring spawning grounds can result in a reduction in recruitment success of the stock (ICES, 2012). Herring are also known to have anatomical adaptations which increase the hearing ability of the species. There is therefore potential for the construction and operation of the Inch Cape Offshore Wind Farm to effect the distribution and success of autumn spawning herring off the east coast of Scotland.

This report reviews information on spawning grounds, data collected as part of the ICES International Herring Larvae Surveys (IHLS) and International Bottom Trawl Surveys (IBTS), ICES commercial fishing data, and site specific benthic and fish surveys to determine the likelihood and magnitude of any potential effects on herring stocks in the North Sea arising from the Inch Cape Offshore Wind Farm and OfTW.

This report was prepared by The Natural Power Consultants Ltd on behalf of ICOL.

13D.1.1 Objectives of this Report

The report will append the ES and provide a detailed description on the level of interaction between North Sea herring stocks and activities associated with the. In particular the report aims to address the following objectives:

- Determine the level of spawning activity in and around the Inch Cape Development Area and Offshore Export Cable Corridor;
- Identify the likely presence of adult herring in and around the Development Area and Offshore Export Cable Corridor; and
- Discuss the level of interaction between the construction and operation of Inch Cape Offshore Wind Farm and OfTW and herring.

13D.1.2 Introduction to North Sea Herring

13D.1.2.1 North Sea Herring Fishery

Herring in the north east Atlantic have a ubiquitous distribution from the Bay of Biscay to Greenland and east into the Barents Sea. Consequently, they have been the target of extensive exploitation since the 1940s. Within the North Sea, European fleets continue to land herring throughout the year. Currently, there are a number of fleets that target herring in the North Sea using mid-water, pair and otter trawls and smaller inshore fleets that operate drift nets (Nichols, 2001).

Following the Second World War, herring landings in the North Sea experienced a continual increase peaking at over 1 million tonnes in 1965. Subsequent over fishing caused the stock to collapse in the mid 1970s and as a result, there was a moratorium on fishing imposed between 1977 and 1981 (Saville and Bailey, 1980). The fishery continued throughout the 1980s but experienced a sharp decline in landings in the mid 1990s. In response to this decline, the implementation of a stock recovery plan was introduced with associated harvest controls in 1996 (Simmonds, 2005). The herring recovery plan appears to have been largely effective with stocks showing an increase in recent years.

The North Sea herring spawning stock was estimated at 2.34 million tonnes or 12,033 million herring in 2012 (ICES, 2012). The most recent report from the ICES Herring Assessment Working Group reports that the stock is harvested sustainably at full reproductive capacity (ICES, 2012). In 2007 herring stocks were reported to have reached an all time high (Simmonds, 2007). In contrast, herring exploitation is at a record low with harvesting of juveniles almost completely eradicated through current management plans (Payne *et al.,* 2010). However, concerns have been raised as a result of sequential years of low recruitment between 2002 and 2011. This has resulted in recruits per spawner numbers falling to a third of that recorded in the 1990's. Recommendations have been made to consider this in future management of the stock (ICES, 2012; Payne *et al.*, 2010).

13D.1.2.2 Atlantic Herring Ecology

Atlantic herring are a pelagic fish that utilise benthic habitats during spawning. As such herring spawning habitats are spatially restricted in the North Sea 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 contributing to a single North Sea stock (ICES Fish Map, URL1). The majority of herring in the North Sea are spawned from one of three distinct races of autumn spawners that return to traditional spawning grounds each year.

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), herring 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 Fish Map). When it is time to spawn each sub-population migrates back to traditional spawning grounds (Daan *et al*, 1990). Migration patterns developed as juveniles remain constant throughout the species lifecycle (Corten, 2001).

There are three main races of adult herring that leave feeding grounds in autumn for spawning grounds (Figure 13D.1):

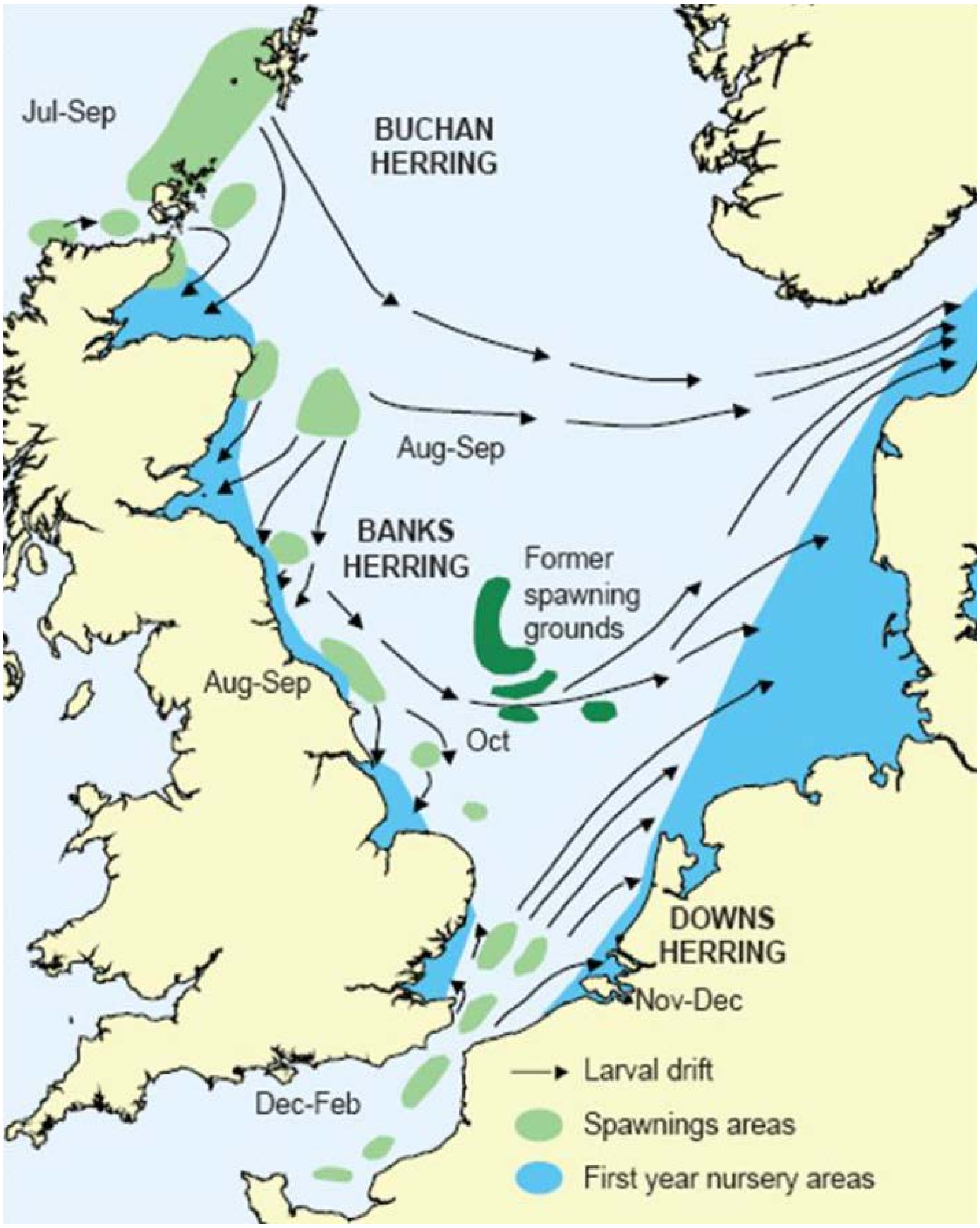
- Buchan/Shetland herring spawn off the north-east coasts of Scotland and Shetland commencing in August until September;
- Banks or Dogger herring spawn in the central North Sea off the north-east England coast from August to October; and
- Southern Bight/Downs herring spawn in the Southern Bight of the North Sea and the English Channel from November to January.

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 (Marvelius, 1997; Marvelius, 2001; Reid *et al.*, 1999). 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. 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 (Corten, 1988; Ellis *et al.*, 2012). It is postulated the ability to shift between spawning grounds between generations acts as a buffer against short term and localised environmental variability (Dickey-Collas *et al.,* 2001).

The eggs take between one to three weeks to hatch at which point herring larvae rises 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. It is hypothesised that this is a result of hydrographical and environmental parameters affecting prey distribution (Corten, 1988). For autumn spawning herring it is during this overwintering period between the early and late stage larval phase where increased mortality has resulted in poor recruitment success between 2001 and 2011 (Payne *et al.,* 2009). Payne *et al.* (2009) reports that this correlates with oceanic climate events and subsequent shifts in plankton communities in the North Sea which could be responsible for reduced larval survival.

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 13D.1). Whereas herring hatching in coastal waters east of the Aberdeenshire coast (Figure 13D.2) are transported southwards to reside in nursery areas along the Scottish and English east coast. Ellis *et al.* (2012) reported that herring nursery grounds are widespread along the Scottish and Northumberland coastlines. 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 (URL1: ICES FishMap).

Figure 13D.1. 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)



13D.2 Potential Interaction with Inch Cape Offshore Wind Farm

13D.2.1 Impacts of Offshore Wind Farms on Atlantic Herring

13D.2.1.1 Acoustic Impacts

Herring are a physostomic (i.e. have a duct connecting a swim bladder to the alimentary canal) clupeid that are considered a hearing specialist (Enger *et al.*, 1993; Kastelein *et al*., 2008). The diverticula (a slim protruding hollow) of the swim bladder extends into the skull and is connected to the inner ear; this aids transmission of acoustic vibrations from the swim bladder to the ear, thus increasing the hearing capabilities of the species (Allen *et al*., 1976). As such, there are concerns over the potential effects of noise on herring relating to wind farm construction and operation particularly in areas where greater densities of a species congregate for spawning. A variety of sources of noise from the Wind Farm and OfTW construction and operation activities, including drilling, rock placement, vessel traffic, piling and dredging may elevate noise levels and cause adverse effects on herring. However, the effects of piling have received particular attention because of concerns regarding the very high sound levels generated, at a relatively broad bandwidth (Nedwell and Howell, 2004).

13D.2.1.2 Physical Disturbance of Spawning Grounds

ICES (2010) describe physical disturbance from marine aggregate extraction and offshore wind farm construction as a major pressure on herring spawning grounds. Where herring spawning grounds are directly affected by construction and operation activities such as installation and operation of WTGs, OSPs, met mast, cable installation and associated works there is a risk of a reduction in the spatial distribution of suitable spawning habitats. This will only occur where there is a direct overlap between the development area or cable corridor of a wind farm project and herring spawning grounds.

13D.2.2 Potential Interaction with Inch Cape Offshore Wind Farm and Offshore Transmission Works

13D.2.2.1 Modelling Outputs

Nedwell *et al.* (2007) has reported weighted hearing thresholds for herring which have been applied to noise models to determine the distance at which individuals of a species are likely to detect and respond to sound. Noise modelling conducted by Subacoustech Environment Ltd. (hereafter referred to as Subacoustech) was conducted to inform the EIA process for the Inch Cape Offshore Wind Farm with 90 dB_{ht} indicating an area of significant avoidance and a 75 dB_{ht} contour indicating an area mild avoidance.

Noise modelling was undertaken using the INSPIRE model to determine the geographical extent of noise propagation which has the potential to affect the distribution and spawning success of herring during construction of the Inch Cape offshore wind farm. Full details of the noise modelling undertaken is presented in *Chapter 11: Underwater noise*. The assessment of effects on herring focuses on two behavioural response metrics: strong avoidance and mild avoidance (Table 13D.1). Note additional noise impact thresholds for other activities were also modelled however, the spatial extent of the resultant noise contours occur in the immediate vicinity of the installation location and so have not been considered further.

Table 13D.1. Herring Avoidance Thresholds and Behavioural Effects Used to Model any Potential Areas of Disturbance

Level in dB_{ht} (*Herring*)	Effect
75 and above	Mild avoidance reaction by the majority of individuals.
90 and above	Strong avoidance reaction by virtually all individuals.
Source: Nedwell *et al.* (2007)	

Two piling scenarios have been considered to determine the potential effects on the North Sea herring stock. Simultaneous piling at two locations within the Inch Cape Development Area and simultaneous piling at two locations within the Inch Cape Offshore Development Area cumulatively with simultaneous piling at two locations within Neart na Gaiothe and two locations with the Firth of Forth offshore wind farm projects. These scenarios have been identified to determine the likely worst case scenario and full geographical extent of any impacts to the North Sea herring population. It should however be noted that if this scenario does arise it will not persist for the duration of the construction periods. The full details of the input parameters are presented in Chapter 11: Underwater Noise.

Construction operations will result in an area of potential exclusion (90 dB_{ht}) during piling and a greater area of potential mild avoidance (70 dB_{ht}) (Table 13D.2). Piling within the Inch Cape Development Area is likely to take up to approximately 82 days but a worst case scenario considering more challenging ground conditions may take up to 167 days. It is anticipated that piling will be carried out over a 2 year period.

Table 13D.2. The Alone and Cumulative Noise Impact Scenarios Used for Modelling Potential Impact Zones and Associated Exclusion Areas

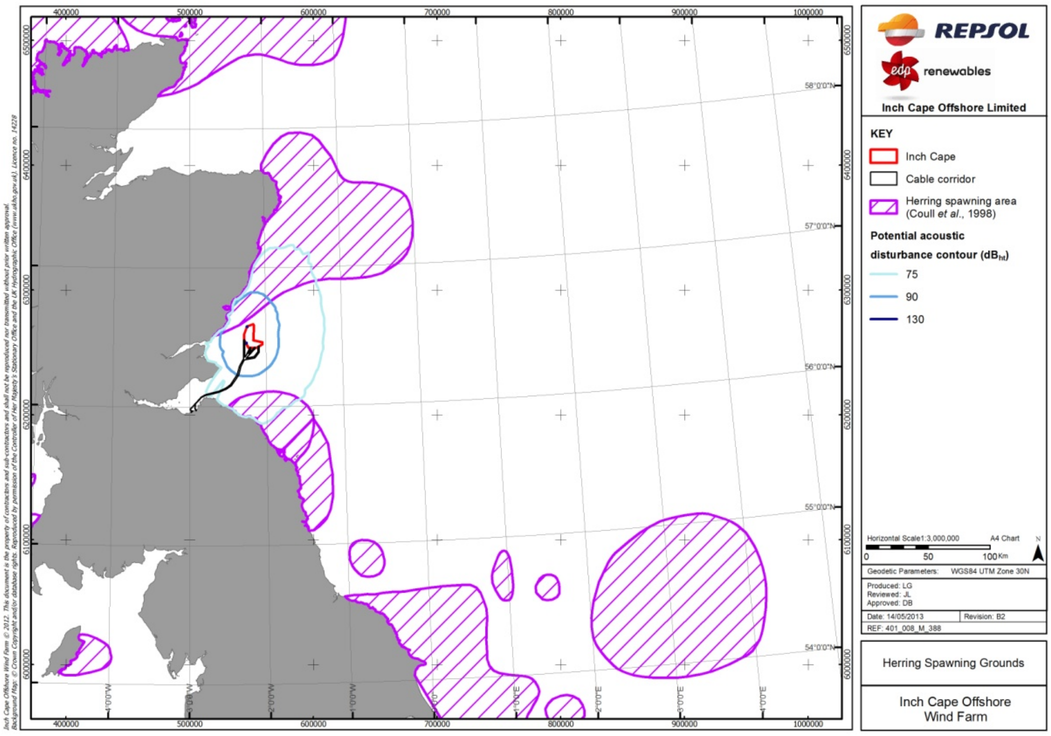
Scenario	Area of Strong Avoidance 90 dB_{ht} (km^2)	Area of Mild Avoidance 70 dB_{ht} (km^2)
Piling within Inch Cape (2 piling locations)	2473	9223
Simultaneous piling at Inch Cape, Neart na Gaiothe and Firth of Forth (6 piling locations)	4731	13192

13D.2.2.2 Overlap with Spawning Areas

Herring spawning grounds are not themselves affected by noise. However, they are limited in their spatial extent within the North Sea and during the spawning season large numbers of adult herring congregate to lay and fertilise eggs on the seabed. Any behavioural effects that could displace adult herring during spawning could result in reduced breeding success and recruitment to the adult stock. Therefore determination of spawning sites and the potential area of acoustic disturbance is necessary to quantify and assess any potential impacts resulting from construction.

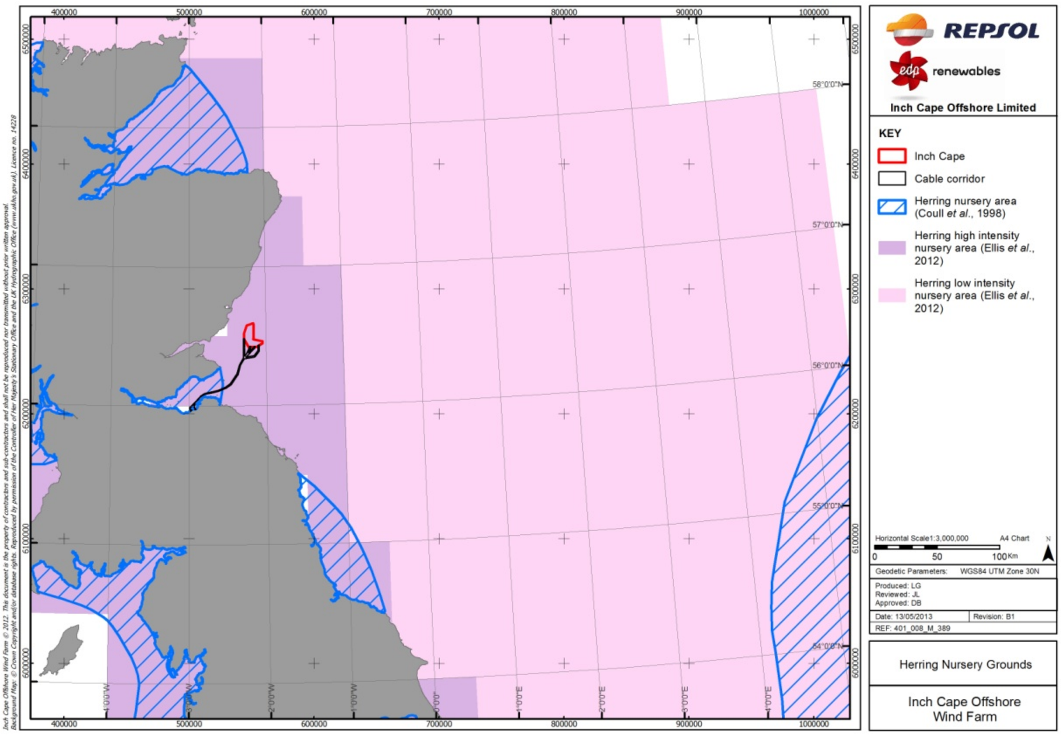
Coull *et al.* (1998) identified areas of potential spawning and nursery areas for a range of species in the North Sea based on available larvae, egg and benthic habitat survey data. The resultant maps indicate that the southern extent of spawning grounds associated with the Buchan sub-population does not overlap with the Inch Cape Development Area or Offshore Export Cable Corridor (Figure 13D.2). However, noise modelling conducted for piling activities during construction indicate that areas of potential disturbance associated with both the 90 dbht and 75 dbht noise contours could overlap with herring spawning grounds. Whilst Coull *et al.* (1998) reports that herring grounds may vary any overlap would be minimal and effects a peripheral area of the spawning grounds. Ellis *et al.* (2012) reviewed nursery and spawning grounds of a number of fin fish species in the North Sea, however, they did not provide revised spawning grounds for herring.

Figure 13D.2. Herring Spawning Grounds Adjacent to the Inch Cape Offshore Wind Farm Development Area (Coull *et al.*, 1998)



The revised herring nursery grounds produced by Ellis *et al.* (2012) are far more ubiquitous than those originally proposed by Coull *et al.* (1998). High intensity nursery grounds are prevalent along the entire east coast of Scotland and the north-east coast of England (Figure 13D.3).

Figure 13D.3. Herring Nursery Grounds Within the North Sea



13D.3 Methods

13D.3.1 Data Acquisition and Processing

In order to assess the potential impact of construction noise from Inch Cape Offshore Wind Farm and OfTW on the North Sea herring stock a review of extant data has been undertaken to determine the level of interaction. An evaluation on the level of use of the Inch Cape Development Area and Offshore Export Cable Corridor and the wider region has been undertaken and informed by the following data sources:

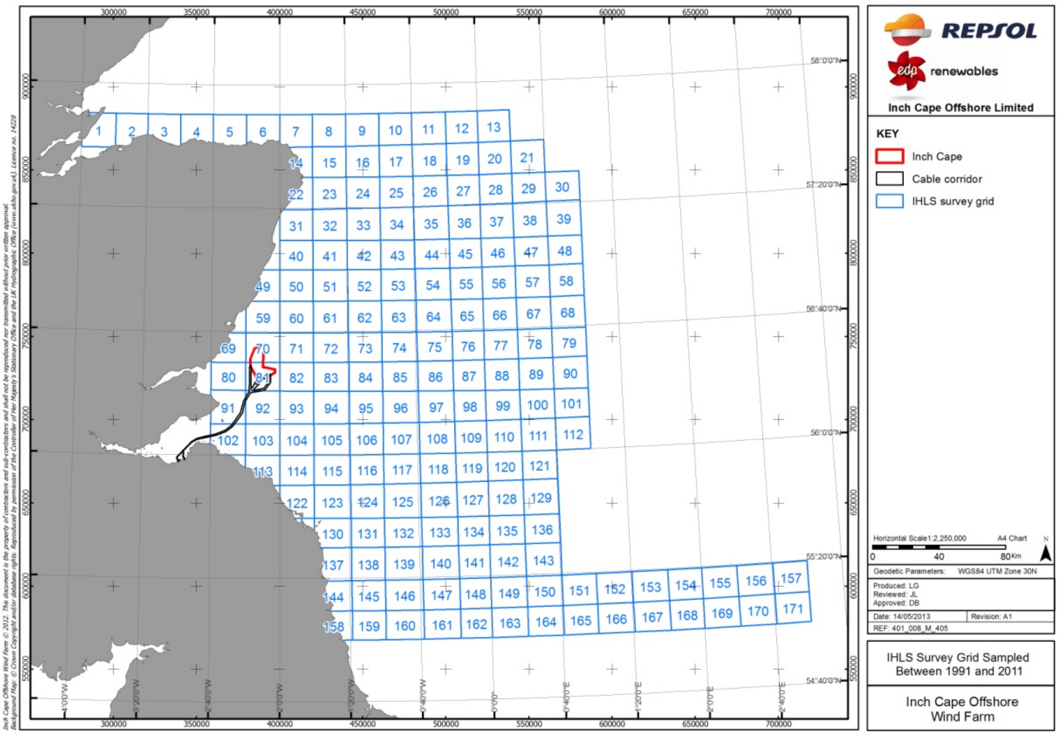
- Site specific benthic baseline (AMEC, 2012a) and fish (AMEC, 2012b) characterisation survey reports;
- International Herring Larvae Survey (IHLS) herring larvae distribution data;
- International Bottom Trawl Survey (IBTS) data; and
- Commercial herring catch reported by the ICES Herring Assessment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

13D.3.1.1 International Herring Larvae Survey

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 20 years of data from 1991 to 2011 collected as part of the IHLS program. For the proposes of this review data collected around the central North Sea off the east coast of Scotland just north of Fraserburgh southwards to the Northumberland coastline has been incorporated into the analysis.

As part of the survey design sampling stations are targeted within 3 x 3 nautical mile squares within the standard 9 x 9 nautical mile ICES statistical rectangles. For ease of reference throughout this report sampling squares have been numbered sequentially from the west to east beginning with the northernmost row (Figure 13D.4).

Figure 13D.4. IHLS Survey Grid and Square Numbers Assigned to Each Grid during Data Interpretation



13D.3.1.2 International Bottom Trawl Survey

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 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 data collected during quarter 3 between 2009 – 2012.

Catch data from the IHLS and IBTS surveys have been processed and presented in relation to the 90 dB_{ht} and 75 dB_{ht} noise contours to determine the likely level of interaction between construction operations and herring individuals.

13D.4 Results

13D.4.1 The Development Area and Offshore Export Cable Corridor

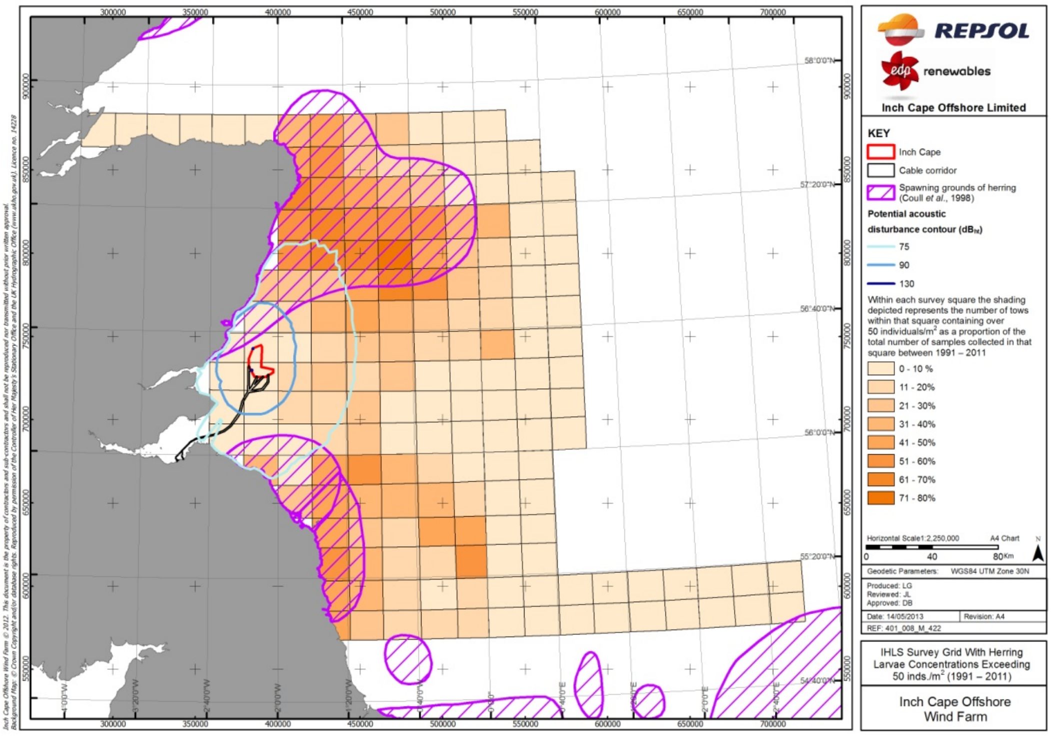
As spawning grounds in the region may be highly variable, benthic characterisation data has been reviewed to determine the spawning potential of the area within the Inch Cape Development Area. The Development Area is characterised by a heterogeneous distribution of subtidal sedimentary habitats ranging from fine muddy sand to coarse gravel with pebbles and boulders (*Appendix 12A – Benthic Ecology Baseline Development Area*). The area is however dominated by fine and medium sands. Fine sediment components comprising of very fine sand and mud and coarser components of coarse sands, gravels and pebbles are variable across the area (*Appendix 12A – Benthic Ecology Baseline Development Area*). 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. Similarly, survey work conducted along the Export Cable Corridor to the south of the Development Area indicates that the substrate is dominated by sediments with large mud fractions (*Appendix 12C – Benthic Baseline Offshore Export Cable Corridor*). The majority of sampling stations were assigned to the folk classes slightly gravelly muddy sand and slightly gravelly sandy mud and the Eunis biotopes Circalittoral mud and deep circalittoral sand. The substrate within the Development Area and the Export Cable Corridor are therefore unlikely to support a significant proportion of autumn spawning herring associated with the Shetland/Buchan component of the North Sea herring stock. This is supported by Coull *et al. (1998*) spawning grounds chart which do not report spawning grounds within the Development Area or Offshore Export Cable Corridor.

Further impacts resulting from physical disturbance during construction and habitat loss from WTG, OSPs, met mast and cable installation will occur across a relatively small area *(Chapter 13 Section 13.3)*. Therefore impacts during construction will not be significant. As such, disturbance to spawning grounds resulting from habitat disturbance or habitat loss has not been considered further within this report. Assessment of impact of temporary and permanent disturbance from construction and operation activities are further considered in *Chapter 13 Sections 13.5-13.9*.

13D.4.2 Herring Larvae Distribution

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 Inch Cape Project is good, both temporally and spatially, and provides an indication of larval drift across the site. Herring larvae data collected between 1991 and 2011 has been reviewed to identify the regularity with which large numbers of herring larvae (defined as over 50 individuals/m^2) are recorded around the Buchan spawning grounds south to the Northumberland coast (Figure 13D.5). 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 east of the site south towards the Northumberland coast. Again on the Northumberland coast regular high densities of herring larvae coincide with reported spawning grounds (Coull *et al.*, 1998).

Figure 13D.5. IHLS Survey Grid with Herring Larvae Concentrations Exceeding 50 inds./m^2 (1991 - 2011)

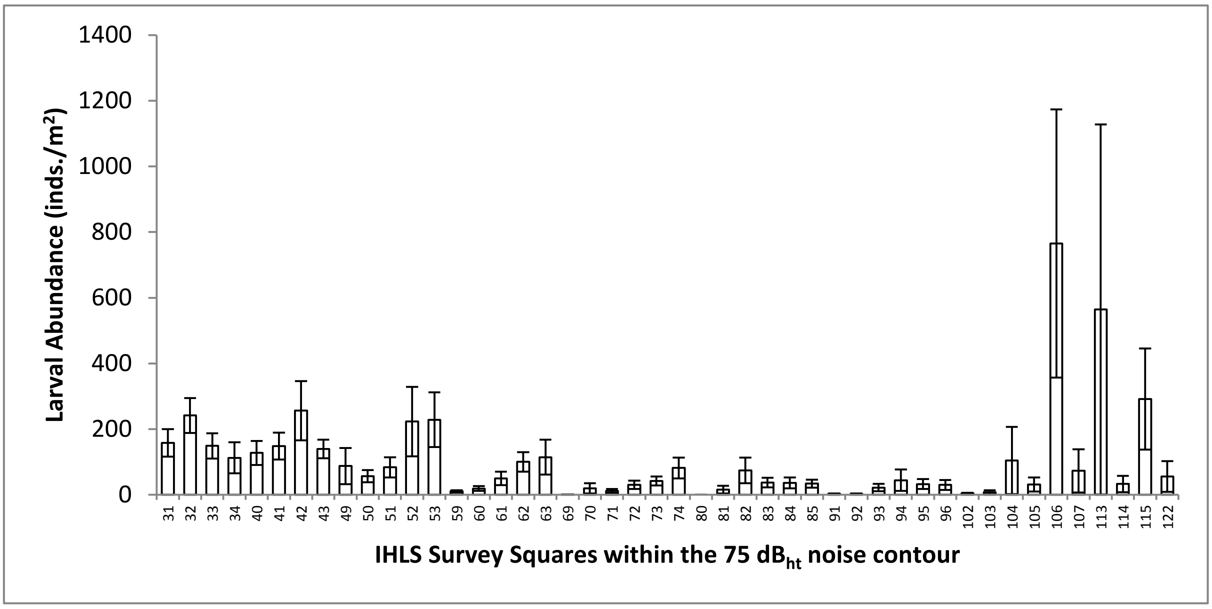


The North Sea herring stock is currently experiencing a phase of unprecedented low productivity which was first recorded in 2002 and recent data suggests that there is still no recovery (ICES, 2012; Payne *et al.,* 2009). Data from the most recent four years of survey work indicate that the greatest larval abundance consistently occurs to the north of the Inch Cape Development Area east of the Aberdeenshire coast (Figure 13D.7 to Figure 13D.10). Larval abundances were lowest in 2008 (Figure 13D.7) and greatest in 2011 (Figure 13D.10).

In 2009 (Figure 13D.8) and 2010 (Figure 13D.9) high abundances were recorded to the east and south east of the Inch Cape site at the edge of the 75 dB_{ht} noise contour.

Across the survey area there is a large variation in densities between years and between sampling squares. Means within the 75 dB_{ht} noise contour area have a high variability in larvae abundance, reflected by highly variable standard error bars (Figure 13D.6).

Figure 13D.6. Mean Larvae Abundance Recorded at Each IHLS Survey Square between 1991 - 2011. Error Bars Represent the SE of the Mean



While the IHLS data demonstrates the presence of low densities of herring larvae in the vicinity of the Inch Cape Project (within the 90 and 70 dB_{ht} noise contour) 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). Yolk sac presence often gives a good indication of proximity to hatching location, however, the IHLS data sheets acquired from the ICES data portal did not have yolk sac data for all tows across all years. Therefore this could not be used to identify newly hatched herring larvae. 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. In 2009 larvae smaller than 10 mm were almost completely absent from the area within the 90 dB_{ht} noise contour and greatly reduced within the 75dB_{ht} noise contour (Figure 13D.8). This would suggest that spawning grounds are distributed further to the north of the site. During 2008 (Figure 13D.7), 2010 (Figure 13D.9) and 2011 (Figure 13D.10) very few stations show a reduction in abundance of larvae smaller than 10 mm.

Figure 13D.7. Herring Larval Abundance Data Recorded during IHLS Tows 2008 (Individuals per m^2)

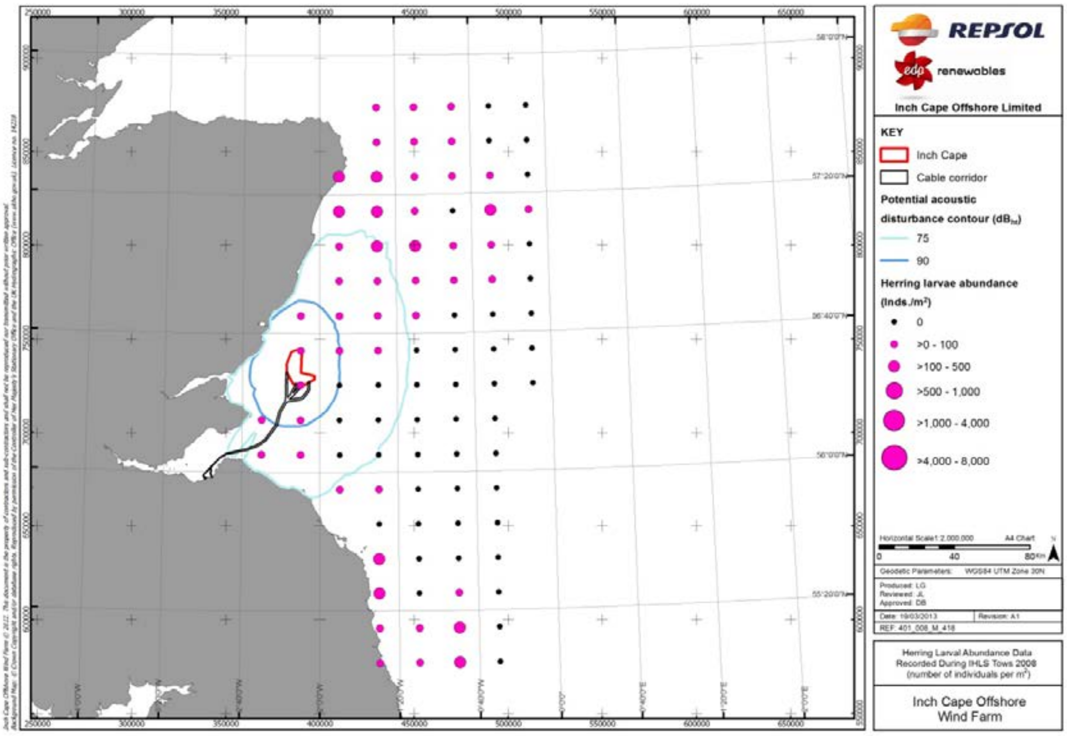


Figure 13D.8. Herring Larval Abundance Data Recorded during IHLS Tows 2009 (Individuals per m^2)

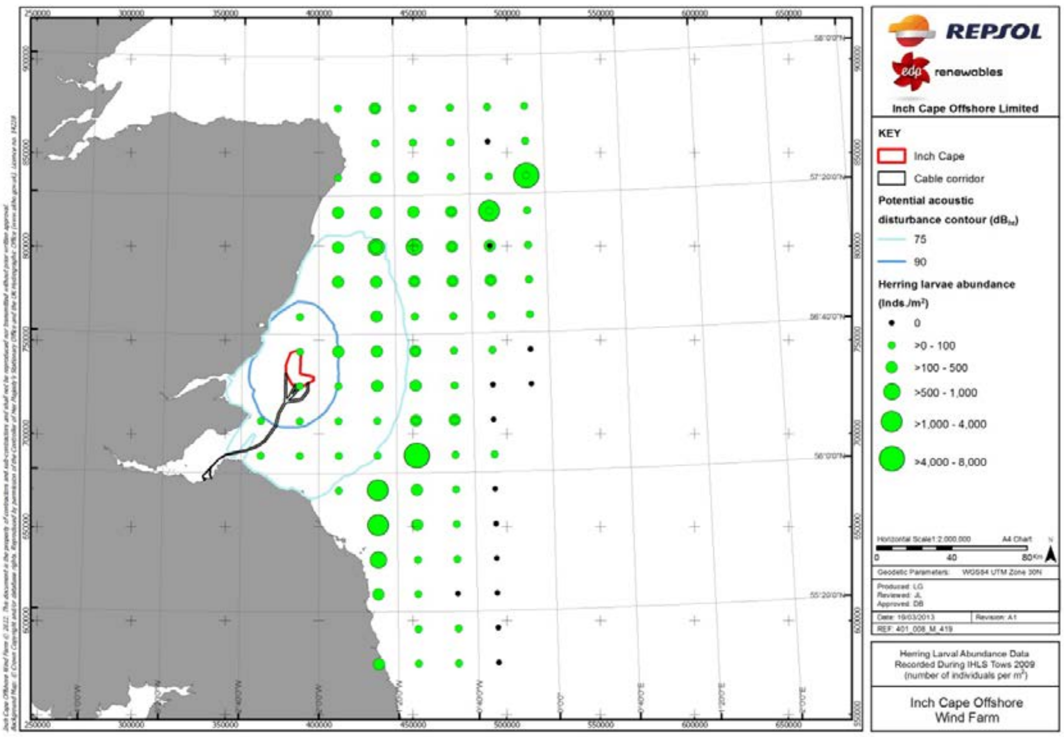


Figure 13D.9. Herring Larval Abundance Data Recorded during IHLS Tows 2010 (Individuals per m^2)

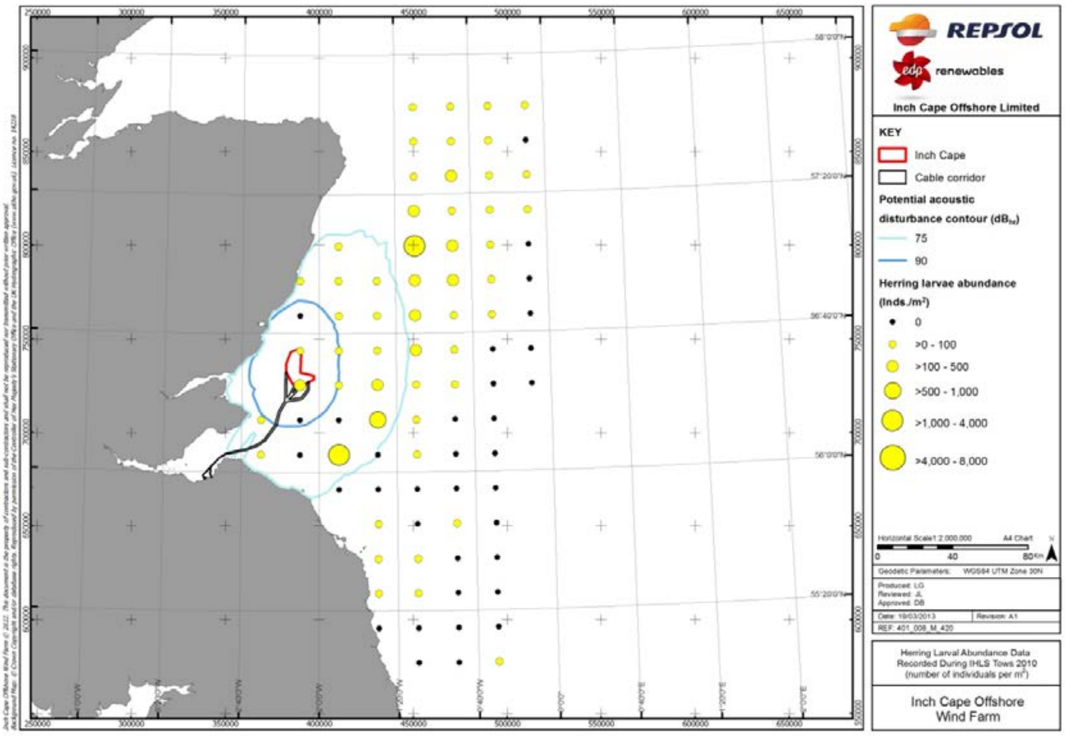


Figure 13D.10. Herring Larval Abundance Data Recorded during IHLS Tows 2011 (Individuals per m^2)

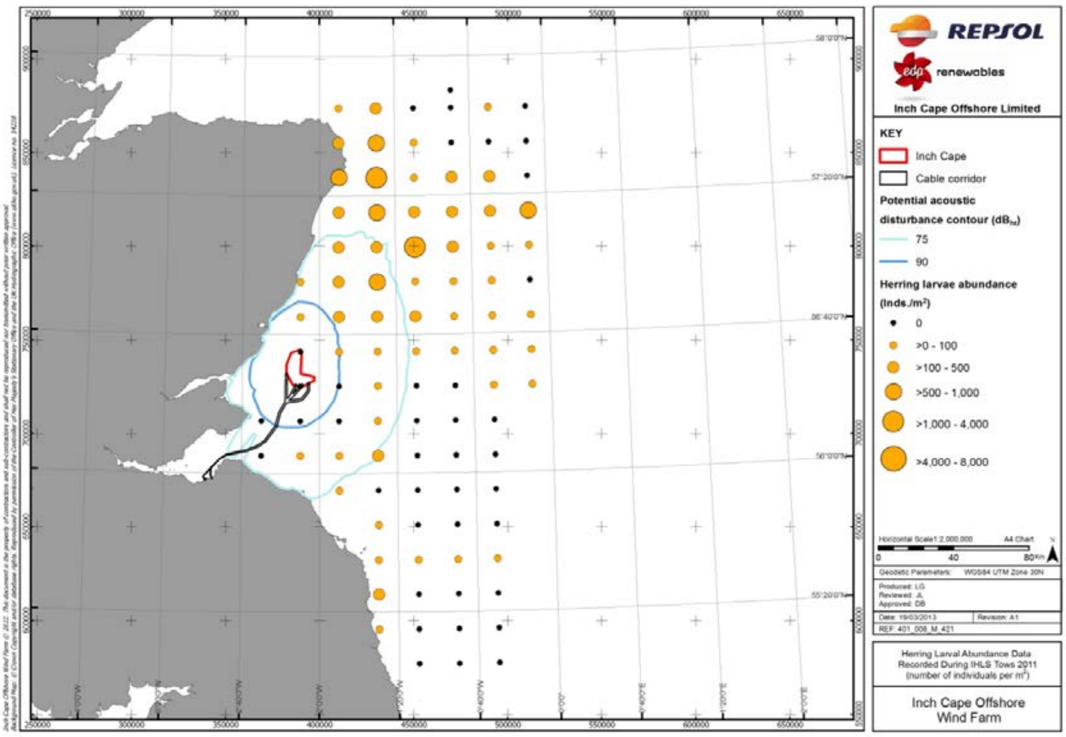


Figure 13D.11. Herring Larvae Less than 10 mm Recorded during IHLS Tows 2008 (Individuals per m^2)

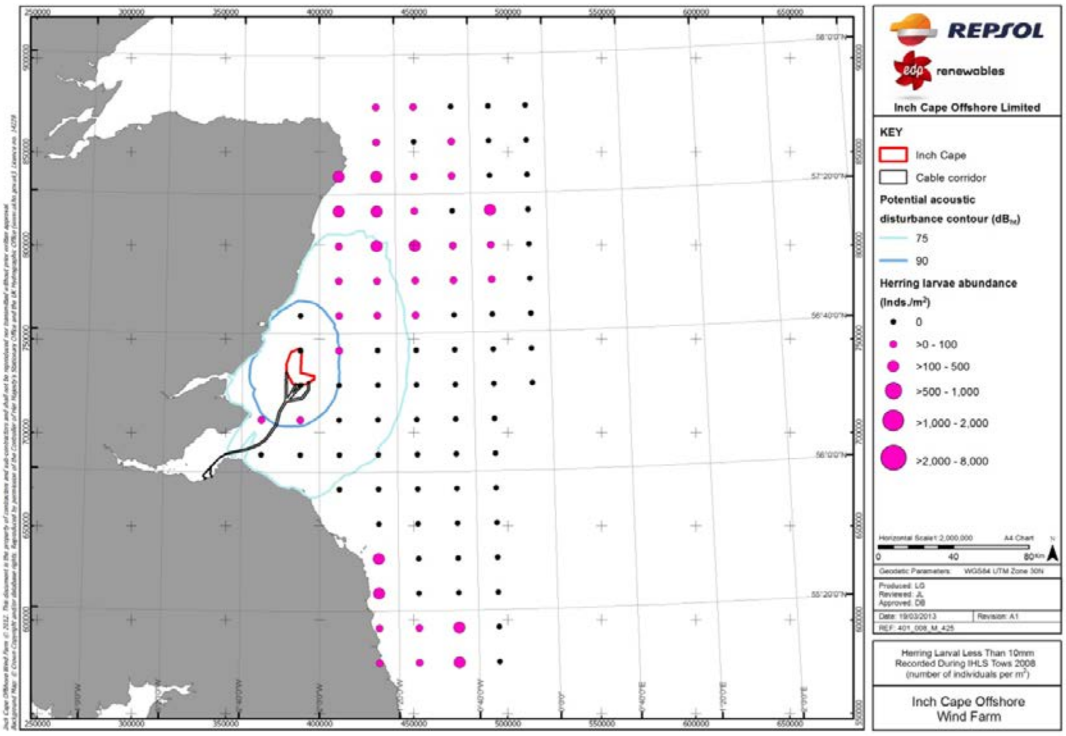


Figure 13D.12. Herring Larvae Less than 10 mm Recorded during IHLS Tows 2009 (Individuals per m^2)

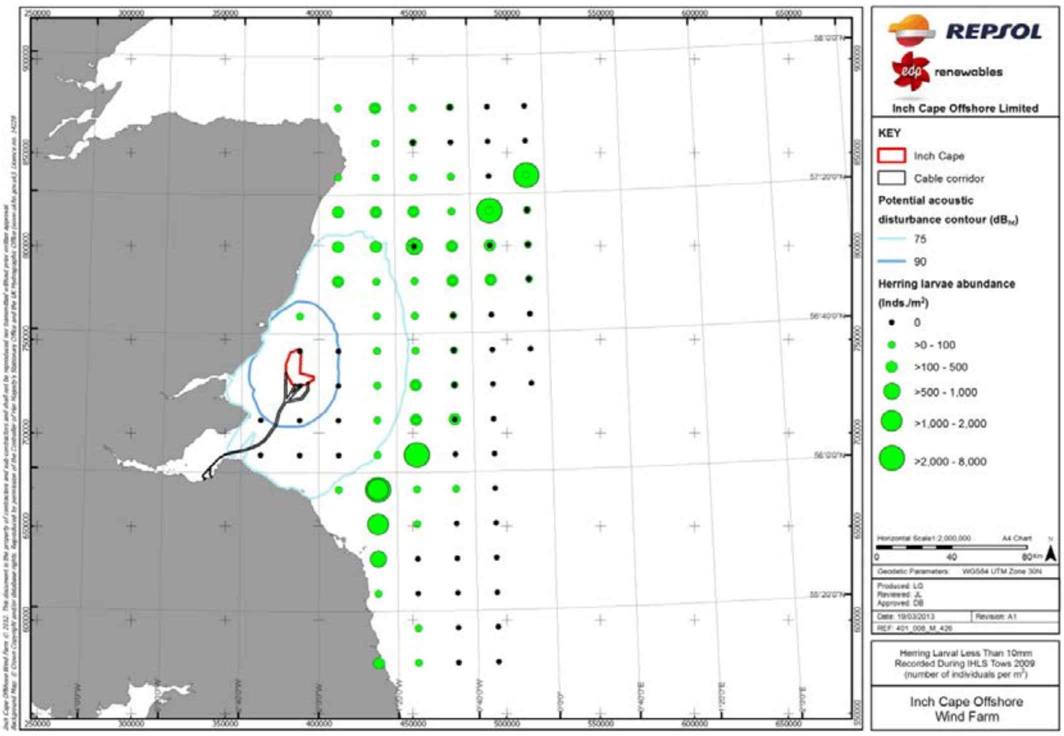


Figure 13D.13. Herring Larvae Less than 10 mm Recorded during IHLS Tows 2010 (Individuals per m²)

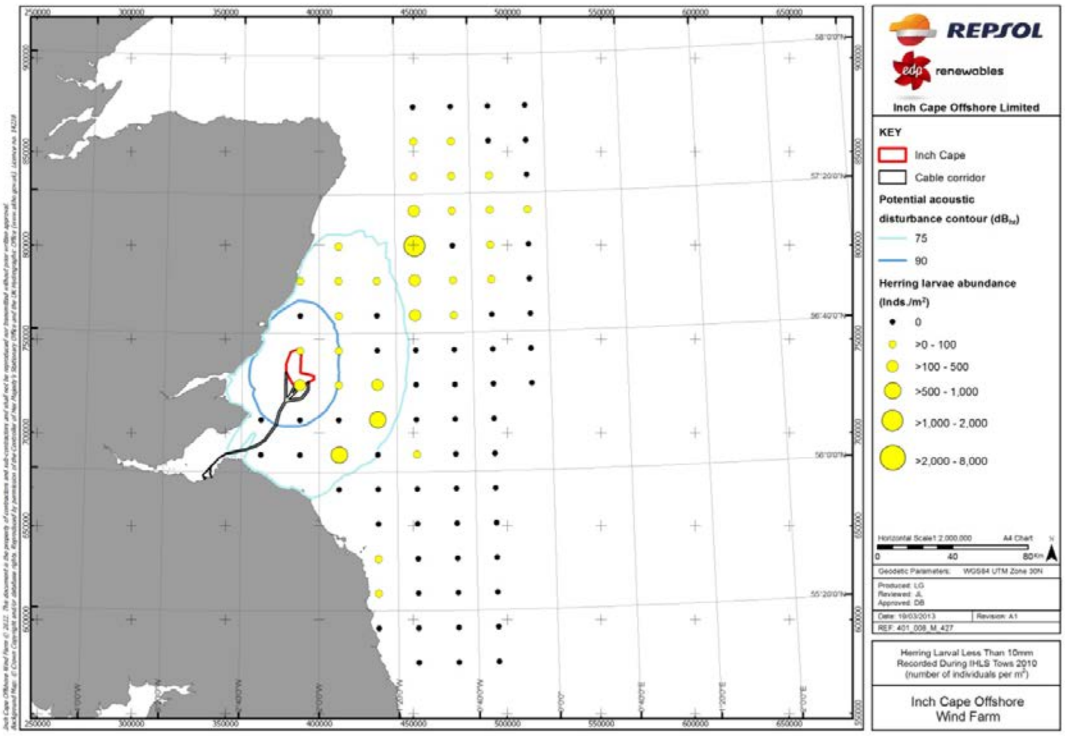
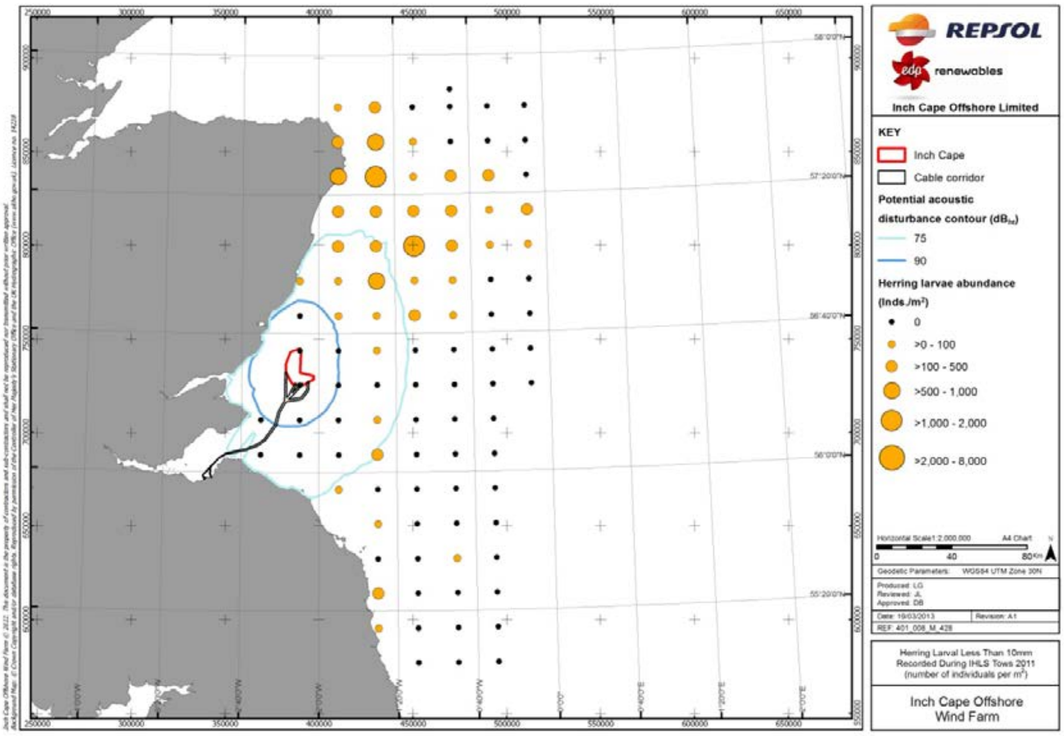


Figure 13D.14. Herring Larvae Less than 10 mm Recorded during IHLS Tows 2011 (Individuals per m²)



13D.4.3 Adult Herring Distribution

13D.4.3.1 Site specific surveys

ICOL commissioned fish surveys using demersal otter trawl gear across the Inch Cape Development Area. Surveys were conducted quarterly and comprised of ten one hour tows to determine fish assemblages during each season. Although this survey methodology is likely to under record the numbers of herring present, herring were captured providing an indication of the usage of the area by this species. Very low herring numbers were identified during all surveys with peak numbers recorded in winter followed by spring (Appendix 13A: Natural Fish Baseline Development Area). The majority of herring sampled were smaller than the minimum landing size during all seasons and are therefore unlikely to be sexually mature. Fish that are smaller than 200 mm are likely to be less than 2 years old (URL1: ICES FishMap) and therefore supports Ellis *et al.'s* (2012) conclusion that the area is a nursery ground for herring.

Table 13D.3. Inch Cape Site Specific Quarterly Fish Survey Data Summary

Survey	**Survey Dates**	**Proportion of tows with adult herring (%)**	**Total number of herring recorded**	**Proportion over minimum landing size of 200 mm (%)**
Spring	16th and 17th May 2012	80	59	8
Summer	25th and 26th July 2012	20	5	40
Autumn	04th and 5th October 2012	50	19	0.5
Winter	27th and 28th January 2012	90	77	14.75

13D.4.3.2 International Bottom Trawl Survey Data

Semi-pelagic bottom trawls conducted as part of the IBTS survey have been conducted across the central and southern North Sea consistently since the early 1990s. For the purposes of the current assessment the most recent four years data has been reviewed to assess the catch per unit effort (CPUE) standardised as number of individuals per hour of towing at sampling stations around the Inch Cape Project. Only data from quarter 3 surveys were used as these stations were sampled most consistently year on year and also coincide with the spawning season when herring numbers are expected to be greatest in coastal waters.

The greatest catch rates are generally recorded further offshore with coastal waters recording consistently low catch rates particularly those stations closest to the Inch Cape Project. The highest CPUE values were generally beyond the 75 dB_{ht} hearing threshold noise contour for herring (Figure 13D.15 to Figure 13D.18). Of the four years considered higher CPUE values were recorded in stations to the north of the site within the 90 and 75 dB_{ht} noise contours in 2009 (Figure 13D.15). There was also a very large catch at one station within the 75 dB_{ht} noise contour in 2011 (Figure 13D.17). These values may indicate the annual variation in spawning herring numbers or the temporal variation in spawning herring within one season during spawning events. The greatest CPUE recorded offshore were consistently beyond the 75 dB_{ht} hearing threshold noise contour.

Figure 13D.15. Herring Catch per Unit Effort Recorded during the 2009 IBTS Quarter 3 Trawls

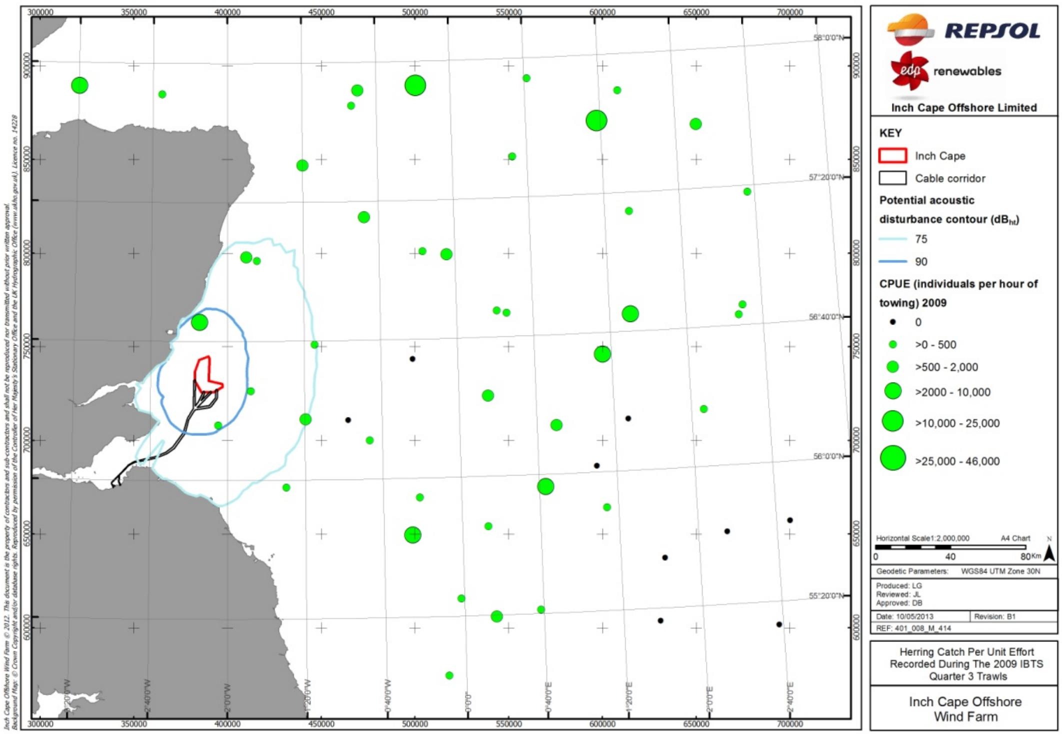


Figure 13D.16. Herring Catch per Unit Effort Recorded during the 2010 IBTS Quarter 3 Trawls

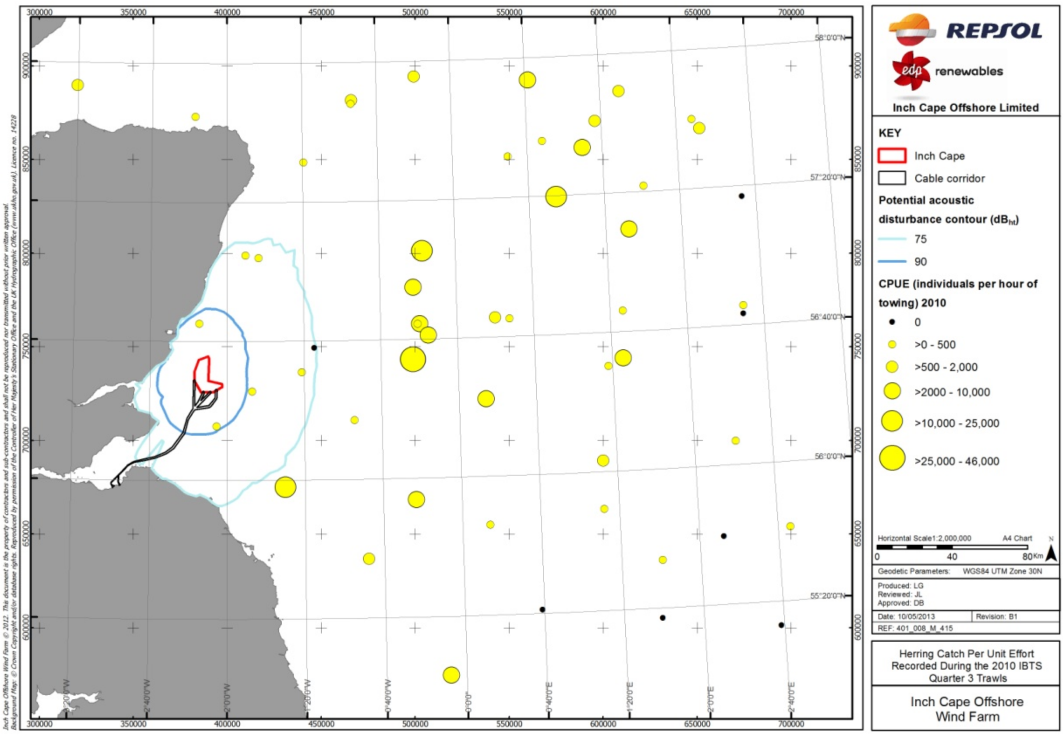


Figure 13D.17. Herring Catch per Unit Effort Recorded during 2011 IBTS Quarter 3 Trawls

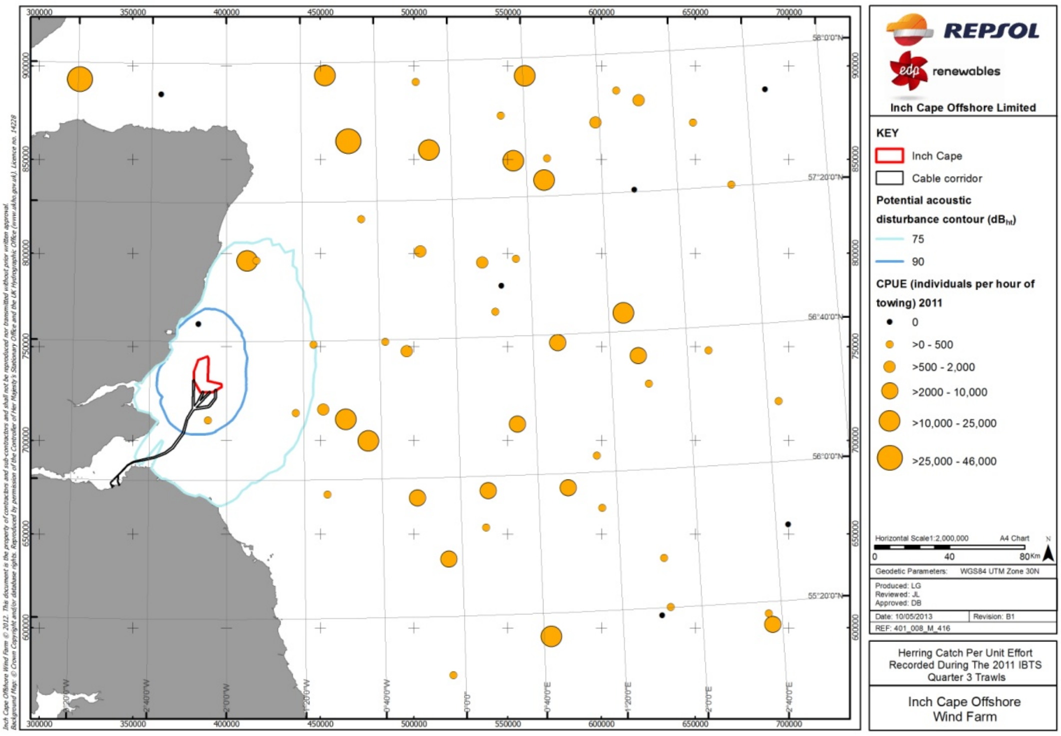
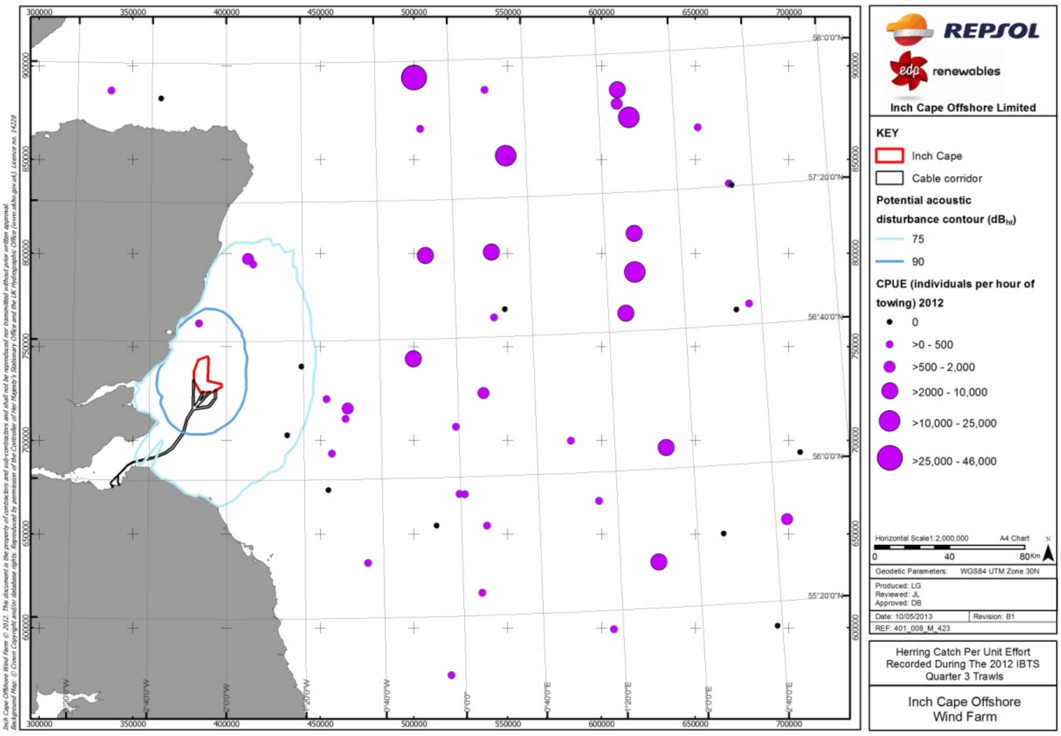


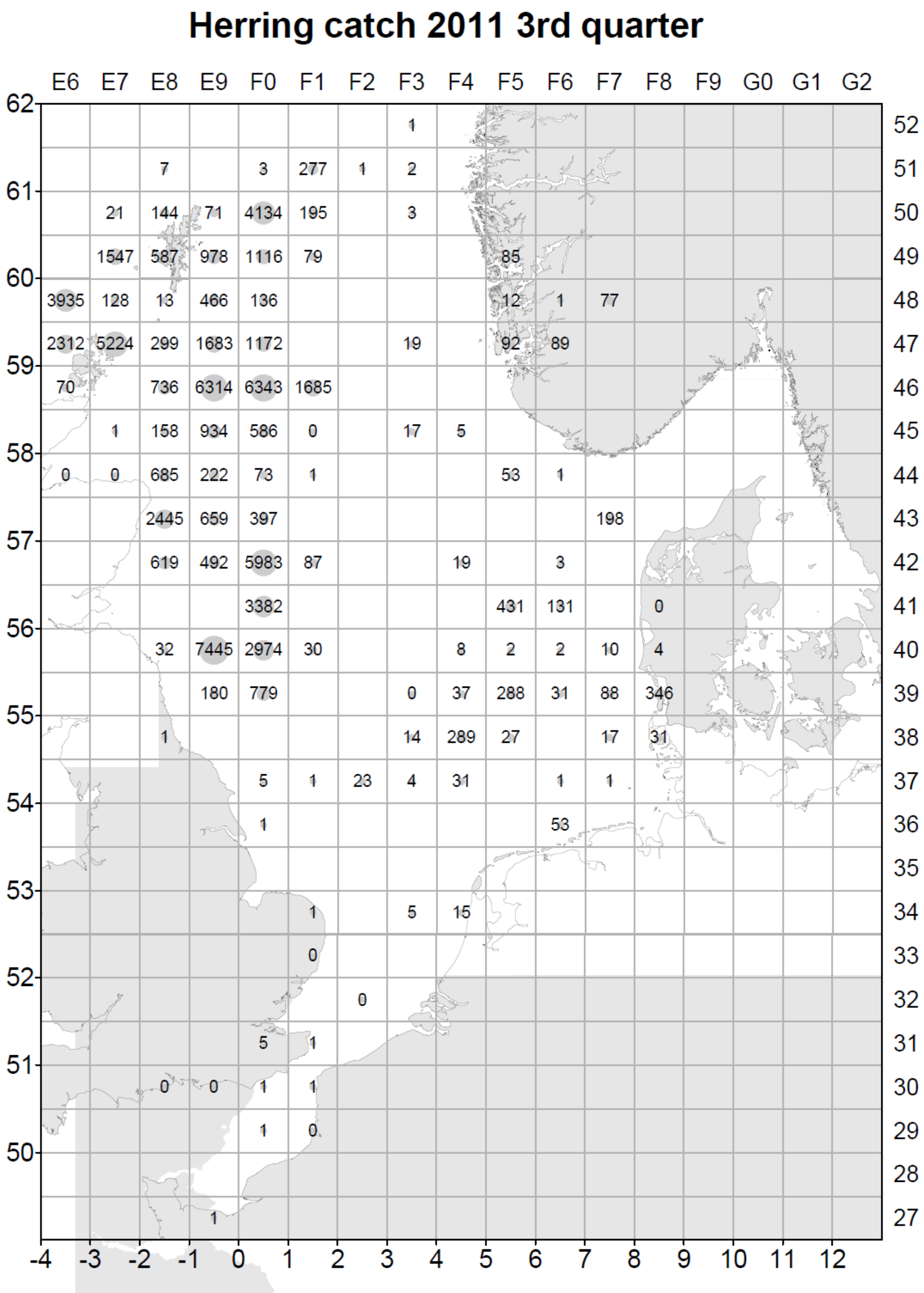
Figure 13D.17. Herring Catch per Unit Effort Recorded during the 2012 IBTS Quarter 3 Trawls



13D.4.3.3 Commercial Landings Data

Commercial catch data reported by the Herring Assessment Working Group (HAWG) indicate higher catches during quarter 3 in ICES statistical rectangles to the north and north east of the site (ICES, 2012). This increase in quarter 3 at these locations is most likely a result of exploitation of herring migrating to spawning grounds (Figure 13D.19). The reported catch values reflects the CPUE data collected as part of the IBTS with the greatest tonnage reported in deeper offshore waters. 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 13D.19).

Figure 13D.18. Herring Catches in the North Sea in the 3rd Quarter (in tonnes) by Statistical Rectangle (ICES, 2012: Herring Assessment Work Group Report)



Note: Catches in Division IIIa (the Baltic Sea subdivision) are not included in this figure.

13D.5 Discussion

13D.5.1 Noise Impacts on the Herring Spawning Stock

Previous reports have suggested that the area to the north of the Inch Cape Development Area could potentially represent an important spawning resource for the Buchan/Shetland herring sub-population (Coull *et al.,* 1998). This spawning area coincides with the 90 dB_{ht} and 75 dB_{ht} noise contours (Figure 13D.5). Exclusion of adult herring from these areas could have adverse effects on the herring population by reducing suitable available spawning habitats.

A review of data in the area confirms that the Buchan spawning ground is likely to overlap with the area of mild disturbance and a small area of the significant disturbance noise contour. However, the Buchan/Shetland sub-population utilise extensive spawning grounds around the Shetland Islands, the Orkney Islands around the Caithness coast and east of the Aberdeenshire coast. The overlap of the noise contours and the Buchan spawning grounds represent a relatively small area of potential spawning habitat. Similarly, there is a small overlap between the area of potential mild avoidance and the northern periphery of the Banks spawning component. The Banks spawning component extends across a series of banks off the south west coast of Scotland and north-east coast of England. The area of overlap represents only a small spawning resource available to the Banks component of the herring stock and will therefore not exclude adult herring from an area of spawning resource that would constitute a significant effect on the Banks sub-population. Furthermore, exclusion during the course of a single spawning season from such a small area is unlikely to persist the following season following cessation of piling as herring have been reported to recolonise recently unused spawning habitats (Corten, 1999; Dickey-Collas *et al.*, 2010).

In the absence of more recent specific herring spawning data Ellis *et al.* (2012) recommend considering more extensive areas where spawning could potentially occur than that originally proposed by Coull *et al*. (1998). The current approach considering the more limited spawning resource is considered to be more conservative since it assumes there is a smaller area available as suitable spawning resource to support the population. Spawning grounds could therefore be more extensive than those considered within this assessment, although IHLS data generally supports findings of Coull *et al.* (1998) in terms of the geographical distribution of spawning areas within the study area.

Little is known of the migration routes used by herring during the spawning season. During this period adults migrating to spawning grounds may interact with piling at the site. This could result in increased energy expenditure to avoid areas of piling disturbance. However, adult herring densities are greatest to the east of the spawning grounds and Inch Cape Development Area. Assuming that herring migrate across a broad front from areas where herring densities are greatest the predominant direction of migrations is likely to be from the east. Although there is potential for autumn spawners to migrate from a more southerly direction these are not likely to constitute a significant proportion of the spawning stock. Furthermore, it is likely to delay and perhaps affect the fitness of spawners arriving at a spawning ground rather than causing a barrier to those fish from reaching the site. Effects of piling will be temporary and are unlikely to be constant throughout the spawning season. Only a small proportion of the spawning stock will be affected and will therefore not significantly affect the North Sea adult herring population during construction.

Herring landings from the six ICES statistical rectangles that coincide with the Buchan spawning grounds (Coull *et al.,* 1998) to the north of the Inch Cape site during the spawning season (quarter 3) of 2011 was 5122 tonnes. Within the ICES Area IV (the North Sea) and Division VIId (the Southern Bight) the 2012 total allowable catch (TAC) was set at 422,850 tonnes. This constitutes approximately 18% of the North Sea autumn spawning herring stock. At present ICES conclude that the herring stock is currently being harvested sustainable and is at full reproductive capacity. Whilst there is insufficient data to estimate the tonnage of herring that has the potential to be disturbed as a result of construction noise at Inch Cape Offshore Wind Farm increased mortality will be negligible in the context of fishing mortality.

13D.5.2 Impacts on Juvenile Herring at Nursery Grounds

No data is available to identify the number of juvenile herring that utilise the Firth of Forth nursery grounds and wider nursery grounds along the east coast of Scotland. The footprint of the 75 dB_{ht} falls within high intensity nursery grounds along the east coast of Scotland and within the Firth of Forth. Herring are highly mobile and temporary disturbance during piling may evoke an avoidance response and displace herring juveniles to other suitable nursery grounds along the east coast of Scotland and England. Upon cessation of piling herring juveniles are likely to redistribute and utilise all available nursery grounds. Any effects resulting from piling will therefore not result in a significant impact to the juvenile population and recruitment to the spawning stock.

13D.5.3 Noise Impacts on Herring Larvae

The ability of herring larvae to detect noise from piling coincides with the development of the auditory bullae (Fuiman, 1989). At this stage, herring larvae start to swallow air which fills the swim bladder and the auditory bullae with gas which increases sensitivity to changes in hydrostatic pressure and thus, acoustic energy (Blaxter *et al.*, 1981). This has been reported to occur in older larvae when they reach between 26 and 30 mm in length (Blaxter *et al.*, 1981; Fuiman, 1989). Growth rates for herring in the Buchan area varies with length between 0.13 mm/day to 0.26 mm/day (Munk *et al.*, 1986). A larvae hatching at 6 mm (Henderson *et al.,* 1984) would therefore take over 76 days to reach a length at which it is likely to develop based on the fastest growth rate recorded. It is therefore unlikely that herring larvae from the Buchan stock will be significantly affected by the production of construction noise during the breeding season.

Payne *et al.* (2010) observed that since 2002 when there was a noticeable reduction in recruitment success to the adult population early stage larvae densities have remained high as have the adult spawning stock. However, it is during the early stage and late stage larval development period that increased mortality appears to have affected recruitment success. This occurs during the first overwintering period. Any additive affects caused by piling noise on overwintering larvae will be minimal as larvae drifting past the site will have limited hearing abilities at this stage in their lifecycle.

The effects of behavioural responses on later stage larvae are unknown, however, the level of recruitment success varies year on year, partly as a result of large changes in prey. In some cases, effects of environmental and hydrographical variation results in herring larvae not reaching important nursery grounds (Corten, 1988). Information on avoidance behavior of herring larvae to large scale disturbance such as that associated with piling noise is extremely limited. Bolle *et al.* (2012) found no significant effects of piling noise on common sole (*Solea solea*) larvae at levels around 206 dB re. 1µPA. However, these findings cannot be directly applied to herring larvae. The response of herring larvae to piling noise is therefore unknown. Effects on later stage larvae that utilize spawning grounds in the outer Firth of Forth region may be more exposed to piling. However, herring nursery grounds are extensive along the east coast of Scotland and the north east coast of England. Therefore any potential displacement may result in increased energy expenditure and thus survival rates in larval herring, this will not be of a magnitude to significantly affect the overall recruitment success of the stock given the limited proportion of larvae that are likely to be exposed.

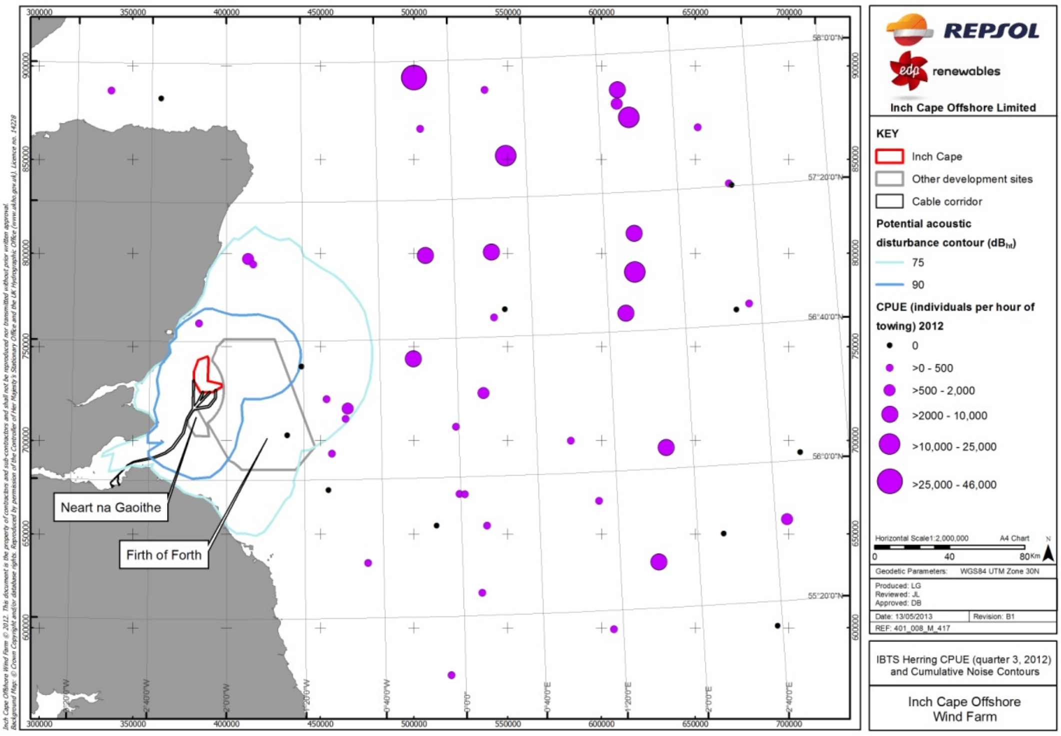
13D.5.4 Cumulative Impacts

Inch Cape Offshore Project lies east in close proximity to the Neart na Gaithe STW site and the Firth of Forth Round 3 offshore projects. Due to the proximity of the three sites to each other and the likely overlap in construction timetables the simultaneous piling at two locations within all three sites has been considered to assess any cumulative effects arising from construction noise.

13D.5.4.1 Cumulative Impacts on the Herring Spawning Stock

Cumulative impacts resulting from simultaneous piling operations within the Neart na Gaoithe and Firth of Forth project boundaries will not result in significant changes to outputs of the impact assessment. Increases in the area of mild avoidance are minor to the north of the Inch Cape project. To the south and east the maximum extent of mild avoidance increases, however, the IBTS data and ICES catch data provide no evidence of significant aggregations of herring that may be affected as a result of simultaneous piling at these projects. Distribution of larvae <10 mm suggests that spawning grounds are distributed further to the north in line with Coull *et al.*'s (1998) predictions. Whilst there is the potential for displacement effects at the southern periphery of the spawning grounds this is not likely to result in reduced spawning success since there are extensive alternative spawning grounds supporting the Shetland/Buchan sub-population.

Figure 13D.19. Herring Catch per Unit Effort Recorded during the 2012 IBTS Quarter 3 Trawls with Cumulative Noise Contours from Simultaneous Piling at Adjacent Projects



Furthermore catch data to the east and south east of the area of impact during the spawning season during quarter 3 is beyond the 75 dB_{ht} (Figure 13D.19; Figure 13D.20). Any displacement effects are therefore likely to temporarily displace herring into more common areas of usage and not exclude individuals from key areas.

13D.5.4.2 Cumulative Impacts on Juvenile Herring at Nursery Grounds

The area from the Fraserburgh to the Northumberland coast encompassing the Outer Forth Estuary has been reported as a high intensity nursery ground for juvenile herring. Low intensity nursery grounds have also been identified across much of the North Sea. Any temporary displacement effects resulting from construction noise may result in juvenile herring utilising additional nursery ground resources. Nursery grounds are ubiquitous in the region and so temporary displacement from part of this area will not result in a significant effect in recruitment to the spawning stock. Furthermore, as herring are a highly mobile species it is highly likely that juveniles will recolonise previously unavailable nursery grounds following the cessation of piling.

Figure 13D.20. Herring Larval Abundance Data Recorded during IHLS Tows 2011 with Cumulative Noise Contours from Simultaneous Piling at Adjacent Projects (Individuals per m^2)

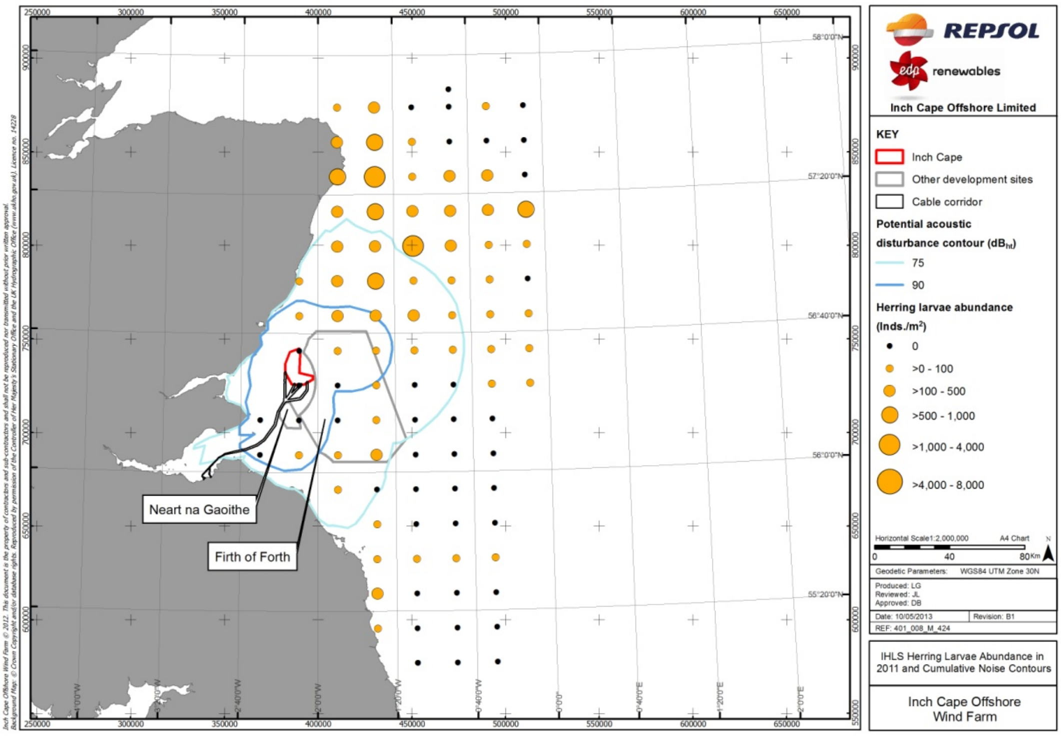
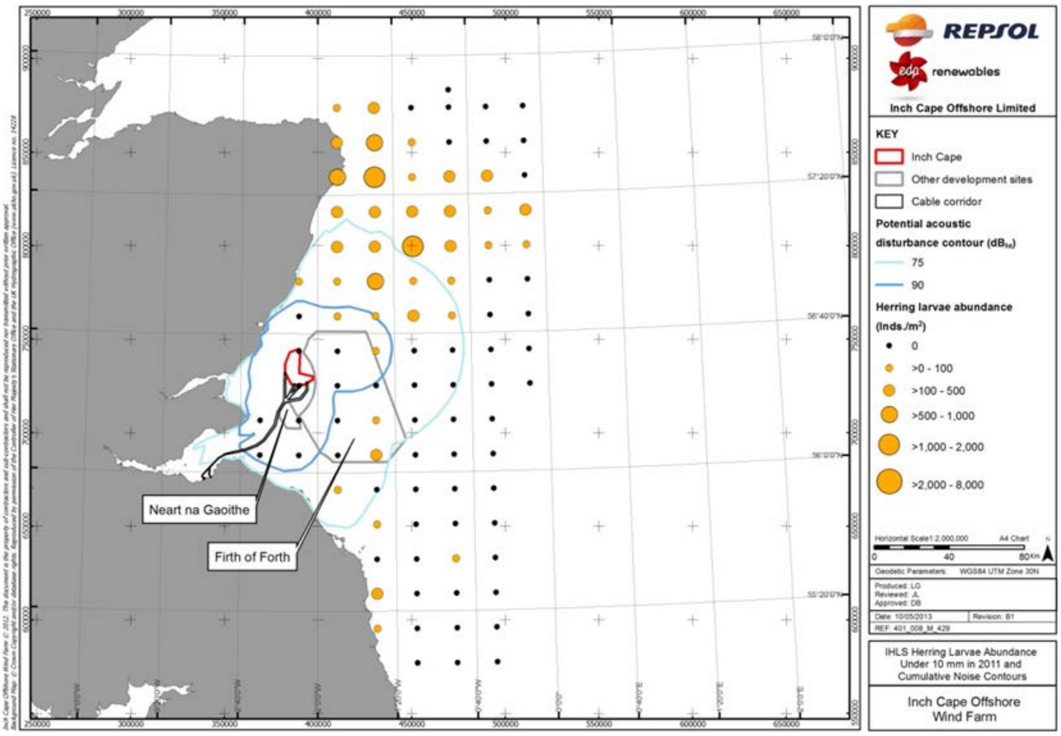


Figure 13D.21. Herring Larvae Less than 10 mm Recorded During IHLS Tows 2011 with Cumulative Noise Contours from Simultaneous Piling at Adjacent Projects (individuals per m^2)

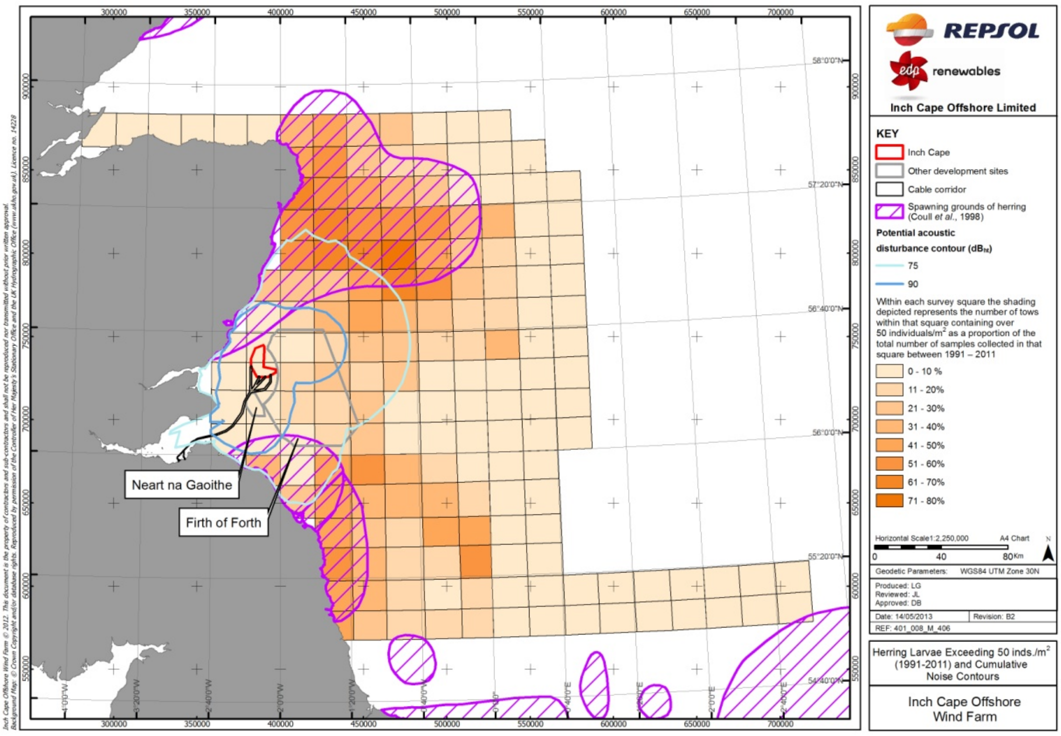


13D.5.4.3 Cumulative Impacts on Larvae from Piling Noise

The impact assessment describing the effects of piling at two simultaneous piling locations for Inch Cape alone is still applicable to the cumulative assessment. Whilst the areas of potential disturbance extend further east and south where high densities of larvae have been recorded (Figure 13D.21; Figure 13D.22; Figure 13D.23) most consistently over the last twenty years the majority of larvae will pass the site prior to the development of hearing sensory organs.

Larvae that reside around the Firth of Forth may be exposed to a disturbance effect that could evoke an avoidance response during late stage larval development. However, Ellis *et al.* (2012) have identified extensive suitable nursery grounds along almost the entire east coast of Scotland and northeast coast of England. Therefore, any temporary displacement effects will not result in any deleterious effects to a significant proportion of the larval population.

Figure 13D.22. IHLS Survey Grid with Herring Larvae Concentrations Exceeding 50 ind./m^2 with Cumulative Noise Contours from Simultaneous Piling at Adjacent Projects (1991 - 2011)



13D.6 Conclusions

Piling noise has the potential to exclude hearing specialists such as herring from significant areas during construction activities at an offshore wind farm. The area around the Inch Cape Project lies to the south of what has historically been considered as important spawning grounds. Data collected as part of ICES coordinated survey work and catch data from commercial fishery support the continued importance of these spawning grounds. Whilst there is some overlap between the southern periphery of spawning grounds to the north of the Inch Cape Project and two adjacent wind farm projects effects of noise will not significantly reduce the extent of spawning resource available to adult herring.

In fact the area around the site appears to be of little importance to adult herring with commercial fisheries focusing on areas to the North and the East during the spawning season. This is reflected in the relatively low quantities of herring recorded at Inch Cape site specific surveys and through the lack of commercial landings.

Juvenile herring have the potential to be exposed to construction noise from piling at nursery grounds around the Firth of Forth. As there is a widespread area of suitable nursery habitats along the east coast of Scotland and northern England any temporarily displaced fish are likely to utilise these spawning grounds and are likely to return upon cessation of piling.

The herring stock is currently reported to be at full reproductive capacity and harvested sustainably with increases of over 95% in the TAC for 2012. Any minor temporary displacement effects resulting from piling will not result in a significant increase in mortality that would be detrimental to the Shetland/Buchan sub-population or to the North Sea herring stock as a whole.

13D.7 References

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